Thu. Jun 3, 2021

[J] Oral | U (Union)：Union

1:45 PM - 3:15 PM JST | 4:45 AM - 6:15 AM UTC | Ch.01 Zoom Room 01

[U-06] Science Council of Japan in one hour: How it supports international organizations

convener:Nobuko Saigusa(National Institute for Environmental Studies), Takuji Nakamura(National Institute of Polar Research), Shigeko Haruyama(Mie University .Emeritus Prof.), Eiichi Tajika(Department of Earth and Planetary Science, Graduate School of Science, The University of Tokyo), Chairperson:Takuji Nakamura(National Institute of Polar Research), Nobuko Saigusa(National Institute for Environmental Studies)

1:45 PM - 1:55 PM JST | 4:45 AM - 4:55 AM UTC

[U06-01] Introduction

1:55 PM - 2:00 PM JST | 4:55 AM - 5:00 AM UTC

[U06-02] Achievements and Prospects of the Committee on Space Research (COSPAR): Promoting International Activities through the Science Council of Japan (SCJ)

*Takuji Nakamura[1], Masaki Fujimoto[2], Akiko Nakamura[3], Hajime Yano[2] (1.National Institute of Polar Research, 2.Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency, 3.Graduate School of Science, Kobe University)

2:00 PM - 2:05 PM JST | 5:00 AM - 5:05 AM UTC

[U06-03] Achievements and Prospects of the Scientific Committee on Solar-Terrestrial Physics (SCOSTEP): Promoting International Activities through the Science Council of Japan (SCJ)

*Kazuo Shiokawa[1], Yoshizumi Miyoshi[1], Akimasa Yoshikawa[2], Takuji Nakamura[3] (1.Institute for Space-Earth Environmental Research, Nagoya University, 2.International Center for Space Weather Science and Education, Kyusyu University, 3.National Institute of Polar Research)

2:05 PM - 2:10 PM JST | 5:05 AM - 5:10 AM UTC

[U06-04] Achievements and Prospects of the Scientific Committee on Antarctic Research (SCAR): Promoting International Activities through the Science Council of Japan (SCJ)

*Takuji Nakamura[1,2], Satoshi Imura[1,2], Gen Hashida[1,2] (1.National Institute of Polar Research, 2.SOKENDAI, the Graduate University for Advanced Studies)

2:10 PM - 2:15 PM JST | 5:10 AM - 5:15 AM UTC

[U06-05] Achievements and Prospects of the International Arctic Science Committee (IASC): Promoting International Activities through the Science Council of Japan (SCJ)

*Hiroyuki Enomoto[1] (1.National Institute of Polar Research)

2:15 PM - 2:20 PM JST | 5:15 AM - 5:20 AM UTC

[U06-06] Elucidating mechanisms of the ocean and its variations and changes-Activities of the Scientific Committee on Oceanic Research (SCOR) and Japan's contribution-

*Yukio Masumoto[1], Naomi Harada[2] (1.Graduate School of Science, The University of Tokyo, 2.Japan Agency for Marine-Earth Science and Technology)

2:20 PM - 2:25 PM JST | 5:20 AM - 5:25 AM UTC

[U06-07] Achievements and Prospects of the World Climate Research Programme (WCRP): Promoting International Activities through the SCJ

*Nobuko Saigusa[1] (1.National Institute for Environmental Studies)

2:25 PM - 2:30 PM JST | 5:25 AM - 5:30 AM UTC

[U06-08] Achievements and Prospects of the International Cartographic Association (ICA): Promoting International Activities through the Science Council of Japan (SCJ)

*Kaori Ito[1], Takashi Morita[2] (1.Tokyo University of Science, 2.Hosei University)

2:30 PM - 2:35 PM JST | 5:30 AM - 5:35 AM UTC

[U06-09] Achievements and Prospects of the International Geographical Union (IGU): Promoting International Activities through the Science Council of Japan (SCJ)

*Yasuhiro Suzuki[1] (1.Nagoya University)

2:35 PM - 2:40 PM JST | 5:35 AM - 5:40 AM UTC

[U06-10] Activities of INQUA (International Union for Quaternary Research) and Contributions from Japan

*Yoshiki Saito[1] (1.Estuary Research Center, Shimane University)

2:40 PM - 2:45 PM JST | 5:40 AM - 5:45 AM UTC

[U06-11] Achievements and Prospects of the International Mineralogical Association (IMA): Promoting International Activities through the Science Council of Japan (SCJ)

*Eiji Ohtani[1] (1.Department of Earth and Planetary Materials Science, Graduate School of Science, Tohoku University)

2:45 PM - 2:50 PM JST | 5:45 AM - 5:50 AM UTC

[U06-12] Activities and Roles of International Union of Geodesy and Geophysics (IUGG): Standardization of Earth Observation and Models

*Kenji Satake[1], Kumiko Goto-Azuma[2], Masato Furuya[3], Takuji Nakamura[2], Toshio Koike[4], Maki Tsujimura[5], Hisashi Nakamura[6], Toshiyuki Hibiya[7], Keiko Kuge[8], Setsuya Nakada[9] (1.Earthquake Research Institute, University of Tokyo, 2.National Institute of Polar Research & SOKENDAI, 3.Earth and Planetary Science, Hokkaido University, 4.ICHARM, Public Works Research Institute, 5.Faculty of Life and Environmental Sciences, University of Tsukuba, 6.RCAST, University of Tokyo, 7.Earth and Planetary Science, The University of Tokyo , 8.Dept. of Geophysics, Kyoto University, 9.National Research Institute for Earth Science and Disaster Resilience)

2:50 PM - 2:55 PM JST | 5:50 AM - 5:55 AM UTC

[U06-13] International Union of Geological Sciences: its activities and social contributions

*Hiroshi Kitazato[1], Hiroshi Nishi[2] (1.Tokyo University of Marine Science and Technology (TUMSAT), 2.Fukui Prefectural University, Institute of Dinosaur Research)

2:55 PM - 3:15 PM JST | 5:55 AM - 6:15 AM UTC

[U06-14] Discussion

[J] Oral | U (Union)：Union

3:30 PM - 5:00 PM JST | 6:30 AM - 8:00 AM UTC | Ch.01 Zoom Room 01

[U-07] Open Science and Open Data in Academic Publishing from Japan

convener:Hirokuni Oda(Institute of Geology and Geoinformation, Geological Survey of Japan, AIST), Hodaka Kawahata(Atmosphere Ocean Research Institute, the University of Tokyo), Chairperson:Hirokuni Oda(Institute of Geology and Geoinformation, Geological Survey of Japan, AIST), Hodaka Kawahata(Atmosphere Ocean Research Institute, the University of Tokyo)

3:30 PM - 3:45 PM JST | 6:30 AM - 6:45 AM UTC

[U07-01] Advanced publication of scientific journals by JpGU and the related academic societies

★Invited Papers

*Hodaka Kawahata[1] (1.Atmosphere Ocean Research Institute, the University of Tokyo)

3:45 PM - 4:00 PM JST | 6:45 AM - 7:00 AM UTC

[U07-02] Current status and issues of PEPS journal

★Invited Papers

*Eiji Ohtani[1] (1.Department of Earth and Planetary Materials Science, Graduate School of Science, Tohoku University)

4:00 PM - 4:15 PM JST | 7:00 AM - 7:15 AM UTC

[U07-03] ”Earth, Planets and Space": The current status

★Invited Papers

*Takeshi Sagiya[1] (1.Disaster Mitigation Research Center, Nagoya University)

4:15 PM - 4:30 PM JST | 7:15 AM - 7:30 AM UTC

[U07-04] STAM and STAM-M : Open Data and Open Science with Open Access Journal from Japan

★Invited Papers

*Masanobu NAITO[1] (1.National Institute for Materials Science)

4:30 PM - 4:45 PM JST | 7:30 AM - 7:45 AM UTC

[U07-05] Research data repository for journals “J-STAGE Data” launching

★Invited Papers

*Ritsuko Nakajima[1] (1.Japan Science and Technology Agency)

4:45 PM - 5:00 PM JST | 7:45 AM - 8:00 AM UTC

[U07-06] Norms in scholarly communication: changes brought by open science

★Invited Papers

*Nobuko Miyairi

[J] Oral | P (Space and Planetary Sciences)：P-PS Planetary Sciences

1:45 PM - 3:15 PM JST | 4:45 AM - 6:15 AM UTC | Ch.04 Zoom Room 04

[P-PS06] Planetary Sciences

convener:Yusuke Nakauchi(Japan Aerospace Exploration Agency), Hiroshi Kikuchi(Japan Aerospace Exploration Agency), Chairperson:Yuri Fujii(Graduate School of Human and Environmental Studies, Kyoto University), Haruka Hoshino(Department of Astronomy, Graduate School of Science, The University of Tokyo)

1:45 PM - 2:00 PM JST | 4:45 AM - 5:00 AM UTC

[PPS06-01] Size evolution of close-in super-Earths: effects of giant impacts and photoevaporation

*Yuji Matsumoto[1], Eiichiro Kokubo[2], Pin-Gao Gu[1], Kenji Kurosaki[3] (1.ASIAA, 2.NAOJ, 3.Nagoya Univ.)

2:00 PM - 2:15 PM JST | 5:00 AM - 5:15 AM UTC

[PPS06-02] Stellar mass dependence of planetary systems formed by giant impacts: minimum-mass exstrasolar nebula model and habitable planets

*Haruka Hoshino[1,2], Eiichiro Kokubo[2,1] (1.Department of Astronomy, Graduate School of Science, The University of Tokyo, 2.Division of Science, National Astronomical Observatory of Japan)

2:15 PM - 2:30 PM JST | 5:15 AM - 5:30 AM UTC

[PPS06-03] Collisional Growth and Fragmentation of Dust Aggregates with Low Mass Ratios

*Yukihiko Hasegawa[1], Takeru Suzuki[1], Hidekazu Tanaka[2], Hiroshi Kobayashi[3], Koji Wada[4] (1.The University of Tokyo, 2.Tohoku University, 3.Nagoya University, 4.Chiba Institute of Technology)

2:30 PM - 2:45 PM JST | 5:30 AM - 5:45 AM UTC

[PPS06-04] The amount of cosmic rays in protoplanetary disks and their effects on ionization degrees

*Yuri I. Fujii[1], Shigeo Kimura[2] (1.Kyoto University, 2.Tohoku University)

2:45 PM - 3:00 PM JST | 5:45 AM - 6:00 AM UTC

[PPS06-05] Suppression of the vertical shear instability in protoplanetary disks by dust growth : Implications for disk observations

*Yuya Fukuhara[1], Satoshi Okuzumi[1] (1.Department of Earth and Planetary Sciences, Tokyo Institute of Technology)

3:00 PM - 3:15 PM JST | 6:00 AM - 6:15 AM UTC

[PPS06-06] Constructing a model of metal accretion disks around white dwarf stars: toward understanding the evolution of remnant planetary systems

*Ayaka Okuya[1], Shigeru Ida[2], Ryuki Hyodo[3] (1.Department of Earth & Planetary Sciences, Tokyo Institute of Technology, 2.Earth-Life Science Institute, Tokyo Institute of Technology, 3.JAXA/ISAS)

[J] Oral | P (Space and Planetary Sciences)：P-PS Planetary Sciences

3:30 PM - 5:00 PM JST | 6:30 AM - 8:00 AM UTC | Ch.04 Zoom Room 04

[P-PS06] Planetary Sciences

convener:Yusuke Nakauchi(Japan Aerospace Exploration Agency), Hiroshi Kikuchi(Japan Aerospace Exploration Agency), Chairperson:Hiroshi Kikuchi(Japan Aerospace Exploration Agency), Yusuke Nakauchi(Japan Aerospace Exploration Agency)

3:30 PM - 3:45 PM JST | 6:30 AM - 6:45 AM UTC

[PPS06-07] ALMA high resolution observations of the transitional disk around SY Cha.

*Ryuta Orihara[1], Munetake Momose[1], Takayuki Muto[2], Jun Hashimoto[3], Hauyu Baobab Liu[4], Takashi Tsukagoshi[5], Tomoyuki Kudo[5], Sanemichi Takahashi[5], Yi Yang[5,6], Yasuhiro Hasegawa[7], Ruobing Dong[8], Mihoko Konisi[9], Eiji Akiyama[10], Masato Ishiduka[6] (1.Ibaraki University, 2.Kogakuin University, 3.Astrobiology Center, 4.Academia Sinica Institute of Astronomy and Astrophysics, 5.National Astronomical Observatory of Japan, 6.University of Tokyo, 7.NASA Jet Propulsion Laboratory, 8.University of Victoria, 9.Oita University, 10.Niigata institute of technology)

3:45 PM - 4:00 PM JST | 6:45 AM - 7:00 AM UTC

[PPS06-08] Model calculation of infrared and radio observations of the circumplanetary disks: Conditions for satellite formation

*Bochao Hu[1], Hideko Nomura[2] (1.Tokyo Institute of Technology/National Astronomical Observatory of Japan, 2.National Astronomical Observatory of Japan)

4:00 PM - 4:15 PM JST | 7:00 AM - 7:15 AM UTC

[PPS06-09] Development of a Hayabusa2 ONC image retrieval system with 2D/3D switchable maps in a web browser

*Hiroshi Kikuchi[1], Mitsuo Yamamoto[1], Yasuhiro Yokota[1], Hiroyuki Sato[1], Hisashi Otake[1], Rie Honda[2], Seiji Sugita[3], Tomokatsu Morota[3], Toru Ishikawa[4], Kazuya Imaki[4], Yasuyuki Watabe[4], Takeshi Konishi[5], Ryodo Hemmi[3], Hideaki Miyamoto[3], Yukio Yamamoto[1], Naru Hirata[6], Naoyuki Hirata[7], Sho Sasaki[8], Goro Komatsu[9], Hirohide Demura[6], Chikatoshi Honda[6], Manabu Yamada[10], ERI TATSUMI[11], Yuichiro Cho[3], Kazuo Yoshioka[3], Hirotaka Sawada[1], Naoya Sakatani[12], Masahiko Hayakawa[1], Moe Matsuoka[1], Toru Kouyama[13], Hidehiko Suzuki[14], Kazunori Ogawa[1] (1.JAXA, 2.Kochi Univ., 3.Univ. of Tokyo, 4.JAMSS, 5.Konniesystem, 6.Univ. of Aizu, 7.Kobe Univ., 8.Osaka Univ., 9.IRSPS, Università d'Annunzio, 10.Chiba Inst. Tech., 11.IAC, 12.Rikkyo Univ., 13.AIST, 14.Meiji Univ.)

4:15 PM - 4:30 PM JST | 7:15 AM - 7:30 AM UTC

[PPS06-10] Martian Moons eXploration MMX: Current Status Report 2021

*Kiyoshi Kuramoto[1,2], Yasuhiro Kawakatsu[2], Masaki Fujimoto[2], Maria Antonietta Barucci[3], Hidenori Genda[4], Naru Hirata[5], Takeshi Imamura[6], Jörn Helbert[7], Shingo Kameda[8], Masanori Kobayashi[9], Hiroki Kusano[10], David J. Lawrence[11], Koji Matsumoto[12], Patrick Michel[13], Hideaki Miyamoto[6], Hiromu Nakagawa[14], Tomoki Nakamura[14], Kazunori Ogawa[2], Hisashi Otake[2], Masanobu Ozaki[2], Sara Russell[15], Sho Sasaki[16], Hiroki Senshu[9], Naoki Terada[14], Stephan Ulamec[7], Tomohiro Usui[2], Koji Wada[9], Shoichiro Yokota[16] (1.Hokkaido University, 2.JAXA, 3.Paris Observatory, 4.Tokyo Institute of Technology, 5.Aizu University, 6.The University of Tokyo, 7.DLR, 8.Rikkyo University, 9.Chiba Institute of Technology, 10.QST, 11.Johns Hopkins University APL, 12.NAOJ, 13.Université Côte d'azur, 14.Tohoku University, 15.Natural History Museum, 16.Osaka University)

4:30 PM - 4:45 PM JST | 7:30 AM - 7:45 AM UTC

[PPS06-11] The orbital evolution of Phobos in the expanded atmosphere of early Mars under an intense solar EUV radiation

*Kohei Fujita[1], Naoki Terada[1], Shotaro Sakai[1], Kaori Terada[1] (1.Tohoku University)

4:45 PM - 5:00 PM JST | 7:45 AM - 8:00 AM UTC

[PPS06-12] Hydrodynamic escape of reduced proto-atmospheres: different consequences for surface volatile inventories between Mars and Earth

*Tatsuya Yoshida[1], Kiyoshi Kuramoto[1] (1.Hokkaido University)

[J] Oral | P (Space and Planetary Sciences)：P-CG Complex & General

9:00 AM - 10:30 AM JST | 12:00 AM - 1:30 AM UTC | Ch.04 Zoom Room 04

[P-CG18] Planetary Magnetosphere, Ionosphere, and Atmosphere

convener:Kanako Seki(Graduate School of Science, University of Tokyo), Hiroyuki Maezawa(Department of Physical Science Osaka Prefecture University), Takeshi Imamura(Graduate School of Frontier Sciences, The University of Tokyo), Naoki Terada(Graduate School of Science, Tohoku University), Chairperson:Tomoki Kimura(Tokyo University of Science), Hiroyuki Maezawa(Department of Physical Science Osaka Prefecture University), Kanako Seki(Graduate School of Science, University of Tokyo)

9:00 AM - 9:15 AM JST | 12:00 AM - 12:15 AM UTC

[PCG18-01] Current status, initial results, and upcoming observation plans during cruise of BepiColombo

*Go Murakami[1], Johannes Benkhoff[2] (1.Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency, 2.European Space Agency)

9:15 AM - 9:30 AM JST | 12:15 AM - 12:30 AM UTC

[PCG18-02] Revisiting Mariner-10 and MESSENGER observations: Anticipation for BepiColombo's Mercury flybys

*Sae Aizawa[1,2], Nicolas André[1], Ronan Modolo[3], James A. Slavin[4], Scott A. Boardsen[5] (1.Institute de Recherche en Astrophysique et Planetologie, 2.Graduate School of Science, Tohoku University, 3.LATMOS, 4.University of Michigan, 5.NASA/GSFC)

9:30 AM - 9:45 AM JST | 12:30 AM - 12:45 AM UTC

[PCG18-03] A belt-like distribution of gaseous hydrogen cyanide on Neptune's equatorial stratosphere detected by ALMA

*Takahiro IINO[1], Hideo Sagawa[2], Takashi Tsukagoshi[3], Satonori Nozawa[4] (1.Information Technology Center, the University of Tokyo, 2.Department of Science, Kyoto Sangyo University, 3.NAOJ, 4.ISEE, Nagoya University)

9:45 AM - 10:00 AM JST | 12:45 AM - 1:00 AM UTC

[PCG18-04] Estimation of the drift rate and intensity of Neptune's storm in 2018-2020 with Pirka Telescope

*Yuuki Sato[1], Yukihiro Takahashi[1], Mitsuteru Sato[1], Seiko Takagi[1], Masataka Imai[2], Tatsuharu Ono[1] (1.Graduate School of Science, Hokkaido University, 2.National Institute of Advanced Industrial Science and Technology)

10:00 AM - 10:15 AM JST | 1:00 AM - 1:15 AM UTC

[PCG18-05] Ion escape mechanism from a Mars-like planet under weak intrinsic magnetic field conditions: Dependence of IMF clock angle

*Shotaro Sakai[1,2], Kanako Seki[3], Naoki Terada[1], Hiroyuki Shinagawa[4], Ryoya Sakata[3], Takashi Tanaka[4,5], Yusuke Ebihara[6] (1.Department of Geophysics, Graduate School of Science, Tohoku University, 2.Planetary Plasma and Atmospheric Research Center, Graduate School of Science, Tohoku University, 3.Department of Earth and Planetary Science, Graduate School of Science, University of Tokyo, 4.National Institute of Information and Communications Technology, 5.International Center for Space Weather Science and Education, Kyushu University, 6.Research Institute for Sustainable Humanosphere, Kyoto University)

10:15 AM - 10:30 AM JST | 1:15 AM - 1:30 AM UTC

[PCG18-06] Dependences of ion escape from Mars on the intrinsic magnetic field strength under CME-like solar conditions at 3.5 Ga

*Ryoya Sakata[1], Kanako Seki[1], Shotaro Sakai[2], Naoki Terada[2], Hiroyuki Shinagawa[3], Takashi Tanaka[3,4] (1.Department of Earth and Planetary Science, Graduate School of Science, The University of Tokyo, 2.Department of Geophysics, Graduate School of Science, Tohoku University, 3.National Institute of Information and Communications Technology, 4.International Center for Space Weather Science and Education, Kyushu University)

[J] Oral | P (Space and Planetary Sciences)：P-CG Complex & General

10:45 AM - 12:15 PM JST | 1:45 AM - 3:15 AM UTC | Ch.04 Zoom Room 04

[P-CG18] Planetary Magnetosphere, Ionosphere, and Atmosphere

convener:Kanako Seki(Graduate School of Science, University of Tokyo), Hiroyuki Maezawa(Department of Physical Science Osaka Prefecture University), Takeshi Imamura(Graduate School of Frontier Sciences, The University of Tokyo), Naoki Terada(Graduate School of Science, Tohoku University), Chairperson:Yuki Harada(Kyoto University), Takeshi Imamura(Graduate School of Frontier Sciences, The University of Tokyo), Naoki Terada(Graduate School of Science, Tohoku University)

10:45 AM - 11:00 AM JST | 1:45 AM - 2:00 AM UTC

[PCG18-07] **Investigation of periodic electron injection observed in Martian crustal magnetic fields with MAVEN and MGS**

*Michio Kato[1], Yuki Harada[1], David L Mitchell[2], Christian Mazelle[3], Gina A DiBraccio[4], Jasper S Halekas[5], Suranga Ruhunusiri[5] (1.Department of Geophysics, Graduate School of Science, Kyoto University, 2.Space Sciences Laboratory, University of California, Berkeley, 3.RAP, University of Toulouse, CNRS, UPS, CNES , 4.NASA Goddard Space Flight Center, 5.Department of Physics and Astronomy, University of Iowa)

11:00 AM - 11:15 AM JST | 2:00 AM - 2:15 AM UTC

[PCG18-08] Modeling diffuse auroral emissions at Mars: Contribution of precipitating protons and mirror effects of crustal fields

*Yuki Nakamura[1,2], Naoki Terada[1], Francois Leblanc[2], Hiromu Nakagawa[1], Shotaro Sakai[1], Sayano Hiruba[1], Ryuho Kataoka[3], Kiyoka Murase[4] (1.Department of Geophysics, Graduate School of Science, Tohoku University, 2.LATMOS, Sorbonne University, 3.National Institute of Polar Research, 4.The Graduate University for Advanced Studies)

11:15 AM - 11:30 AM JST | 2:15 AM - 2:30 AM UTC

[PCG18-09] Effects of the magnetic field orientation on the vertical emission profile of Martian diffuse aurora: A Monte Carlo model development

*Taishin Okiyama[1], Kanako Seki[1], Nicholas M. Schneider[2], Sonal K. Jain[2] (1.Graduate School of Science, University of Tokyo, 2.LASP, University of Colorado, Boulder)

11:30 AM - 11:45 AM JST | 2:30 AM - 2:45 AM UTC

[PCG18-10] Extraction of Martian atmospheric fine structures by analyzing Mars Global Surveyor radio occultation data

*Ryutaro Sakurai[1], Takeshi Imamura[1] (1.Graduate School of Frontier Sciences, The University of Tokyo)

11:45 AM - 12:00 PM JST | 2:45 AM - 3:00 AM UTC

[PCG18-11] Variation of CO/CO_2 profile in the Martian middle atmosphere observed by TGO/NOMAD

*Nao Yoshida[1], Hiromu Nakagawa[1], Shohei Aoki[2,3], Justin Erwin[2], Ann Carine Vandaele[2], Isao Murata[1], Ian Thomas[2], Frank Daerden[2], Lori Neary[2], Shungo Koyama[1], Naoki Terada[1], Yasumasa Kasaba[1], Bojan Ristic[2], Manish R Patel[4], Giancarlo Bellucci[5], Jose-Juan Lopez-Moreno[6] (1.Dep. Geophysics Graduate School of Science Tohoku University, 2.Royal Belgian Institute for Space Aeronomy, BIRA-IASB, 3.LPAP, STAR Institute, Université de Liège, 4.School of Physical Sciences, The Open University, 5.Instituto di Astrofisica e Planetologia Spaziali (IAPS/INAF), 6.Instituto de Astrofisica de Andalucia (IAA/CSIC))

12:00 PM - 12:15 PM JST | 3:00 AM - 3:15 AM UTC

[PCG18-12] Periodic variations of hydrogen and oxygen airglow in the Martian upper atmosphere during a rapid growth of a regional dust storm

*Kei Masunaga[1], Naoki Terada[2], Nao Yoshida[2], Takeshi Kuroda[2], Kazuo Yoshioka[3], Tomoki Kimura[2], Fuminori Tsuchiya[2], Go Murakami[4], Atsushi Yamazaki[4], Ichiro Yoshikawa[3] (1.University of Colorado Boulder, 2.Tohoku University, 3.University of Tokyo, 4.Institute of Space and Astronautical Science)

[J] Oral | A (Atmospheric and Hydrospheric Sciences)：A-AS Atmospheric Sciences, Meteorology & Atmospheric Environment

9:00 AM - 10:30 AM JST | 12:00 AM - 1:30 AM UTC | Ch.06 Zoom Room 06

[A-AS06] Stratosphere-troposphere Processes And their Role in Climate

convener:Takenari Kinoshita(Japan Agency for Marine-Earth Science and Technology), Takatoshi Sakazaki(Graduate School of Science, Kyoto University), Masashi Kohma(Department of Earth and Planet Science, Graduate School of Science, The University of Tokyo), Nawo Eguchi(Kyushu University), Chairperson:Takenari Kinoshita(Japan Agency for Marine-Earth Science and Technology)

9:00 AM - 9:20 AM JST | 12:00 AM - 12:20 AM UTC

[AAS06-01] Updated atmospheric composition chemica reanalysis and emission estimates

★Invited Papers

*Kazuyuki Miyazaki[1] (1.NASA Jet Propulsion Laboratory)

9:20 AM - 9:40 AM JST | 12:20 AM - 12:40 AM UTC

[AAS06-02] Ozone variability associated with the dynamical fields during YMC-Sumatra2017 field campaign

★Invited Papers

*Junko Suzuki[1], Shin-Ya Ogino[1], Takenari Kinoshita[1], Ryuichi Shirooka[1], Suginori Iwasaki[2], Kunio Yoneyama[1] (1.Japan Agency for Marine-Earth Science and Technology, 2.National Defense Academy of Japan)

9:40 AM - 9:55 AM JST | 12:40 AM - 12:55 AM UTC

[AAS06-03] Tropical coastal bidirectional gravity waves robustizing QBO

*Manabu D. Yamanaka[1,2], Shin-Ya Ogino[2] (1.Research Institute for Humanity and Nature / Professor Emeritus of Kobe University, 2.Japan Agency for Marine-Earth Science and Technology)

9:55 AM - 10:10 AM JST | 12:55 AM - 1:10 AM UTC

[AAS06-04] Study for influence of temperature at TTL on evolution of deep convection and tropical cyclones

Kenta Kobayashi[1], *Nawo Eguchi[1], Tomoe Nasuno[2], Yohei Yamada[2], Kunihiko Kodera[3] (1.Kyushu University, 2.JAMSTEC, 3.Meteorological Research Institute)

10:10 AM - 10:25 AM JST | 1:10 AM - 1:25 AM UTC

[AAS06-05] Stratospheric Influence on the Troposphere During the Remarkably Strong Arctic Circumpolar Vortex Condition in 2019-2020 Winter

*Shunsuke Noguchi[1,2], Kunihiko Kodera[2], Ryo Mizuta[2], Seiji Yukimoto[2] (1.Japan Agency for Marine-Earth Science and Technology, 2.Meteorological Research Institute)

10:25 AM - 10:30 AM JST | 1:25 AM - 1:30 AM UTC

[AAS06-06] Discussion

[J] Oral | A (Atmospheric and Hydrospheric Sciences)：A-AS Atmospheric Sciences, Meteorology & Atmospheric Environment

10:45 AM - 12:15 PM JST | 1:45 AM - 3:15 AM UTC | Ch.06 Zoom Room 06

[A-AS06] Stratosphere-troposphere Processes And their Role in Climate

convener:Takenari Kinoshita(Japan Agency for Marine-Earth Science and Technology), Takatoshi Sakazaki(Graduate School of Science, Kyoto University), Masashi Kohma(Department of Earth and Planet Science, Graduate School of Science, The University of Tokyo), Nawo Eguchi(Kyushu University), Chairperson:Takatoshi Sakazaki(Graduate School of Science, Kyoto University)

10:45 AM - 11:05 AM JST | 1:45 AM - 2:05 AM UTC

[AAS06-07] Do sudden stratospheric warmings boost convective activity in the tropics?

★Invited Papers

*Kohei Yoshida[1], Ryo Mizuta[1] (1.Meteorological Research Institute)

11:05 AM - 11:20 AM JST | 2:05 AM - 2:20 AM UTC

[AAS06-08] Dynamical Features of Antarctic Sudden Stratospheric Warming in 2019

*Guangyu Liu[1], Toshihiko Hirooka[2], Nawo Eguchi[3], Kirstin Krüger[4] (1.Department of Earth and Planetary Sciences, Kyushu University, 2.Department of Earth and Planetary Sciences, Faculty of Science, Kyushu University, 3.Research Institute for Applied Mechanics, Kyushu University, 4.Department of Geosciences, University of Oslo)

11:20 AM - 11:40 AM JST | 2:20 AM - 2:40 AM UTC

[AAS06-09] Seasonal predictability of the persisted negative Antarctic oscillations after sudden stratospheric warming in the Southern Hemisphere in 2019

★Invited Papers

*Chiaki Kobayashi[1], Shuhei Maeda[2] (1.Meteorological Research Institute, 2.Japan Meteorological Agency)

11:40 AM - 11:55 AM JST | 2:40 AM - 2:55 AM UTC

[AAS06-10] **The stratospheric QBO affects Antarctic sea ice through the tropical convection in early austral winter**

*Koji Yamazaki[1], Tetsu Nakamura[1] (1.Hokkaido University)

11:55 AM - 12:10 PM JST | 2:55 AM - 3:10 AM UTC

[AAS06-11] A study of Kelvin-Helmholtz billow in the Antarctic troposphere and lower stratosphere based on the PANSY radar observation using a frequency domain interferometry technique

*Yuichi Minamihara[1], Kaoru Sato[1], Masaki Tsutsumi[2] (1.Department of Earth and Planetary Science, Graduate School of Science, The University of Tokyo, 2.National Institute of Polar Research)

12:10 PM - 12:15 PM JST | 3:10 AM - 3:15 AM UTC

[AAS06-12] Discussion

[J] Oral | A (Atmospheric and Hydrospheric Sciences)：A-AS Atmospheric Sciences, Meteorology & Atmospheric Environment

1:45 PM - 3:15 PM JST | 4:45 AM - 6:15 AM UTC | Ch.06 Zoom Room 06

[A-AS06] Stratosphere-troposphere Processes And their Role in Climate

convener:Takenari Kinoshita(Japan Agency for Marine-Earth Science and Technology), Takatoshi Sakazaki(Graduate School of Science, Kyoto University), Masashi Kohma(Department of Earth and Planet Science, Graduate School of Science, The University of Tokyo), Nawo Eguchi(Kyushu University), Chairperson:Masashi Kohma(Department of Earth and Planet Science, Graduate School of Science, The University of Tokyo)

1:45 PM - 2:00 PM JST | 4:45 AM - 5:00 AM UTC

[AAS06-13] LODEWAVE (LOng-Duration balloon Experiment of gravity WAVE over Antarctica)

*Yoshihiro Tomikawa[1,2], Kaoru Sato[3], Yoshitaka Saito[4], Isao Murata[5], Naohiko Hirasawa[1,2], Masashi Kohma[3], Kyoichi Nakashino[6], Daisuke Akita[7], Takuma Matsuo[8], Masatomo Fujiwara[9], Lihito Yoshida[2] (1.National Institute of Polar Research, 2.School of Multidisciplinary Sciences, The Graduate University for Advanced Studies, SOKENDAI, 3.Graduate School of Science, The University of Tokyo, 4.Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency, 5.Graduate school of Environmental Studies, Tohoku University, 6.School of Engineering, Tokai University, 7.School of Environment and Society, Tokyo Institute of Technology, 8.School of Science and Technology, Meiji University, 9.Faculty of Environmental Earth Science, Hokkaido University)

2:00 PM - 2:15 PM JST | 5:00 AM - 5:15 AM UTC

[AAS06-14] Sporadic, large gravity wave events over Syowa Station in summer -Comparison between the PANSY radar and the ERA5 reanalysis-

*Lihito Yoshida[1], Yoshihiro Tomikawa[2,1], Mitsumu K. Ejiri[2,1], Masashi Kohma[3], Kaoru Sato[3] (1.Department of Polar Science, School of Multidisciplinary Sciences, The Graduate University for Advanced Studies, 2.National Institute of Polar Research, 3.Department of Earth and Planetary Science, Graduate School of Science, The University of Tokyo)

2:15 PM - 2:35 PM JST | 5:15 AM - 5:35 AM UTC

[AAS06-15] Detection of a climatological short break in the polar night jet in early winter and its relation to cooling over Siberia

★Invited Papers

*Yuta Ando[1,2], Koji Yamazaki[3], Yoshihiro Tachibana[2], Masayo Ogi[3], Jinro Ukita[1] (1.Faculty of Science, Niigata University, 2.Weather and Climate Dynamics Division, Mie Univesity, 3.Hokkaido University)

2:35 PM - 2:55 PM JST | 5:35 AM - 5:55 AM UTC

[AAS06-16] Characteristics of planetary-wave packet propagation during a major sudden stratospheric warming event in January 2021

★Invited Papers

*Yayoi Harada[1], Takenari Kinoshita[2], Kaoru Sato[3], Toshihiko Hirooka[4] (1.Meteorological Research Institute, Japan Meteorological Agency, 2.The Japan Agency for Marine-Earth Science and Technology (JAMSTEC) , 3.Department of Earth and Planetary Sciences, University of Tokyo, 4.Department of Earth and Planetary Sciences, Kyushu University)

2:55 PM - 3:10 PM JST | 5:55 AM - 6:10 AM UTC

[AAS06-17] A Statistical Analysis of Downward Propagation of Planetary Wave Packets in the Stratosphere Using Large Ensemble Data

*Matsuyama Yuya[1], Toshihiko Hirooka[2] (1.Department of Earth and Planetary Sciences, Graduate School of Science, Kyushu University, 2.Department of Earth and Planetary Sciences, Faculty of Science, Kyushu University)

3:10 PM - 3:15 PM JST | 6:10 AM - 6:15 AM UTC

[AAS06-18] Discussion

[J] Oral | A (Atmospheric and Hydrospheric Sciences)：A-OS Ocean Sciences & Ocean Environment

3:30 PM - 5:00 PM JST | 6:30 AM - 8:00 AM UTC | Ch.07 Zoom Room 07

[A-OS18] Kuroshio Large Meander

convener:Toru Miyama(Japan Agency for Marine-Earth Science and Technology, Application Laboratory), Norihisa Usui(Meteorological Research Institute), Hidetaka Hirata(Rissho University), Takashi SETOU(Japan Fisheries Research and Education Agency), Chairperson:Hidetaka Hirata(Rissho University), Takashi Setou(Japan Fisheries Research and Education Agency)

3:30 PM - 3:45 PM JST | 6:30 AM - 6:45 AM UTC

[AOS18-01] Impact of the 2017 Kuroshio Large Meander on the Decadal Kuroshio Extension Variability

★Invited Papers

*Bo Qiu[1], Shuiming Chen[1], Niklas Schneider[1], Eitarou Oka[2], Shusaku Sugimoto[3] (1.University of Hawaii at Manoa, 2.University of Tokyo , 3.Tohoku University)

3:45 PM - 4:00 PM JST | 6:45 AM - 7:00 AM UTC

[AOS18-02] Subtropical Mode Water in a recent persisting Kuroshio large meander period. Part I: Formation and advection over the entire distribution region

*Eitarou Oka[1], Hatsumi Nishikawa[1], Shusaku Sugimoto[2], Bo Qiu[3], Niklas Schneider[3] (1.Atmosphere and Ocean Research Institute, The University of Tokyo, 2.Graduate School of Science, Tohoku University, 3.Department of Oceanography, University of Hawaii at Manoa)

4:00 PM - 4:15 PM JST | 7:00 AM - 7:15 AM UTC

[AOS18-03] Subtropical Mode Water in a recent persisting Kuroshio large meander period. Part II: Formation and temporal evolution in the recirculation gyre off Shikoku.

*Hatsumi Nishikawa[1], Shusaku Sugimoto[2], Eitarou Oka[1] (1.Atmosphere and Ocean Research Institute, University of Tokyo, 2.Graduate School of Science, Tohoku University)

4:15 PM - 4:30 PM JST | 7:15 AM - 7:30 AM UTC

[AOS18-04] Increase in summer surface air temperature at the Kanto district attributable to Kuroshio large meander

*Shusaku Sugimoto[1], Bo Qiu[2], Niklas Schneider[2] (1.Graduate School of Science, Tohoku University, 2.The University of Hawaii)

4:30 PM - 4:45 PM JST | 7:30 AM - 7:45 AM UTC

[AOS18-05] Comparison of the processes of their response to the Kuroshio Large Meander between explosive cyclones that differ in the development type

*Hidetaka Hirata[1], Ryuichi Kawamura[2], Masami Nonaka[3] (1.Rissho University, 2.Kyushu University, 3.Japan Agency for Marine-Earth Science and Technology)

4:45 PM - 5:00 PM JST | 7:45 AM - 8:00 AM UTC

[AOS18-06] Why has the 2017 Kuroshio large meander lasted so long?

*Norihisa Usui[1], Nariaki Hirose[1], Yosuke Fujii[1], Nadao Kohno[1] (1.Meteorological Research Institute)

[J] Oral | A (Atmospheric and Hydrospheric Sciences)：A-CC Cryospheric Sciences & Cold District Environment

9:00 AM - 10:30 AM JST | 12:00 AM - 1:30 AM UTC | Ch.13 Zoom Room 13

[A-CC25] Glaciology in the new normal

convener:Hiroto Nagai(Waseda Univ., School of Education), Kzutaka Tateyama(National University Corporation Kitami Institute of Technology), Ishikawa Mamoru(Hokkaido University), Keiko Konya(Japan Agency for Marine-Earth Science and Technology), Chairperson:Kzutaka Tateyama(National University Corporation Kitami Institute of Technology), Hiroto Nagai(Waseda Univ., School of Education)

9:00 AM - 9:15 AM JST | 12:00 AM - 12:15 AM UTC

[ACC25-01] Fieldwork under the COVID19 circumstances –Examples from Alaska and Siberia–

★Invited Papers

*Go Iwahana[1] (1.International Arctic Research Center, University of Alaska Fairbanks)

9:15 AM - 9:30 AM JST | 12:15 AM - 12:30 AM UTC

[ACC25-02] Mapping of permafrost distribution in mid-Amur basin by satellite data analysis and local vegetation research

*Yuto Tashiro[1], Muneoki Yoh[2], Takayuki Shiraiwa[3], Takeo Onishi[4] (1.Institute for Space Earth Environmental Research, Nagoya University, 2.Tokyo University of Agriculture and Technology, 3.Institute of Low Temperature Science, Hokkaido University, 4.Gifu University)

9:30 AM - 9:45 AM JST | 12:30 AM - 12:45 AM UTC

[ACC25-03] Observation at Ny-Alesund, Svalbard under the COVID-19 situation

★Invited Papers

*Junji Matsushita[1], Hiroshi Miyaoka[1] (1.National Institute of Polar Research)

9:45 AM - 10:00 AM JST | 12:45 AM - 1:00 AM UTC

[ACC25-04] Study of the formation of stratified firn on the snow surface near Dome Fuji, Antarctica, by multiple physicochemical analyses

*Ryo Inoue[1], Shuji Fujita[2,1], Kenji Kawamura[2,1,3], Jun Ogata[2], Motohiro Hirabayashi[2], Kaori Fukuda[2], Kyotaro Kitamura[2], Ayaka Yonekura[1], Kumiko Goto-Azuma[2,1], Fumio Nakazawa[2,1], Ikumi Oyabu[2], Hideaki Motoyama[2,1] (1.The Graduate University for Advanced Studies, 2.National Institute of Polar Research, 3.Japan Agency for Marine-Earth Science and Technology)

10:00 AM - 10:15 AM JST | 1:00 AM - 1:15 AM UTC

[ACC25-05] Evolution of supraglacial ponds at the southern Inylchek Glacier, Kyrgyz Republic

*Natsumi Homma[1], Chiyuki Narama[1], Naoki Sakurai[2] (1.Niigata Univ., 2.Aero Asahi Co.)

10:15 AM - 10:30 AM JST | 1:15 AM - 1:30 AM UTC

[ACC25-06] **The area fluctuations of short-lived glacial lake in the Teskey Range, Central Asia**

*Naho Yamada[1], Chiyuki Narama[1], Mirlan Daiyrov[2] (1.niigata university, 2.CAIAG)

[J] Oral | A (Atmospheric and Hydrospheric Sciences)：A-CC Cryospheric Sciences & Cold District Environment

10:45 AM - 12:15 PM JST | 1:45 AM - 3:15 AM UTC | Ch.13 Zoom Room 13

[A-CC25] Glaciology in the new normal

convener:Hiroto Nagai(Waseda Univ., School of Education), Kzutaka Tateyama(National University Corporation Kitami Institute of Technology), Ishikawa Mamoru(Hokkaido University), Keiko Konya(Japan Agency for Marine-Earth Science and Technology), Chairperson:Ishikawa Mamoru(Hokkaido University), Keiko Konya(Japan Agency for Marine-Earth Science and Technology)

10:45 AM - 11:00 AM JST | 1:45 AM - 2:00 AM UTC

[ACC25-07] The formation environment of glacier-derived rock glacier in the Tien Shan, Central Asia

*Shun Okuyama[1], Chiyuki Narama[2], Akiko Yamamura[3], Hideyuki Takadama[4], yamanokuti Tsutomu[5] (1.Graduate Student,Niigata Univ., 2.Niigata Univ., 3.Aero Asahi Co., 4.PASCO Co., 5.Remote Sensing Technology Center of Japan)

11:00 AM - 11:15 AM JST | 2:00 AM - 2:15 AM UTC

[ACC25-08] Collapse of snow patch in the Hakuba-Daisekkei, northern Japanese Alps

*Ryoji Yoshimura[1], Chiyuki Narama[1] (1.Niigata Univ.)

11:15 AM - 11:30 AM JST | 2:15 AM - 2:30 AM UTC

[ACC25-09] Characteristics of topography where glaciers can exist in the northern Japanese Alps

*Kenshiro Arie[1], Chiyuki Narama[1], Kotaro FUKUI[2], Hajime IIDA[2], Ryohei Yamamoto[3] (1.Niigata University, 2.Tateyama Caldera Sabo Museum, 3.Aero Asahi corporation)

11:30 AM - 11:45 AM JST | 2:30 AM - 2:45 AM UTC

[ACC25-10] Seasonal and altitudinal variations in snow algal bloomings in Mt. Gassan in Yamagata prefecture, Japan

*Takumi Suzuki[1], Nozomu Takeuchi[1] (1.Chiba University)

11:45 AM - 12:00 PM JST | 2:45 AM - 3:00 AM UTC

[ACC25-11] Research life under COVID19 in Colorado, USA

★Invited Papers

*Uetake Jun[1] (1.Field Science Center for Northern Biosphere, Hokkaido University)

12:00 PM - 12:15 PM JST | 3:00 AM - 3:15 AM UTC

[ACC25-12] Discussion

[J] Oral | A (Atmospheric and Hydrospheric Sciences)：A-CC Cryospheric Sciences & Cold District Environment

1:45 PM - 3:15 PM JST | 4:45 AM - 6:15 AM UTC | Ch.13 Zoom Room 13

[A-CC26] Ice cores and paleoenvironmental modeling

convener:Nozomu Takeuchi(Chiba University), Ayako Abe-Ouchi(Atmosphere and Ocean Research Institute, The University of Tokyo), Ryu Uemura(Nagoya University), Kenji Kawamura(National Institute of Polar Research, Research Organization of Information and Systems), Chairperson:Ayako Abe-Ouchi(Atmosphere and Ocean Research Institute, The University of Tokyo), Kenji Kawamura(National Institute of Polar Research, Research Organization of Information and Systems)

1:45 PM - 2:00 PM JST | 4:45 AM - 5:00 AM UTC

[ACC26-01] Fractionation of O_2/N_2 and Ar/N_2 in polar ice cores during bubble formation, bubble-clathrate hydrate transition, and gas loss during storage from precise gas measurements of the Dome Fuji ice core, Antarctica

★Invited Papers

*Ikumi Oyabu[1], Kenji Kawamura[1,2,3], Tsutomu Uchida[4], Shuji Fujita[1,2], Kyotaro Kitamura[1], Motohiro Hirabayashi[1], Jeffrey Severinghaus[5], Morgan Jacob[5] (1.National Institute of Polar Research, Research Organization of Information and Systems, 2.The Graduate University of Advanced Studies (SOKENDAI), 3.Japan Agency for Marine Science and Technology (JAMSTEC), 4.Hokkaido University, 5.Scripps Institution of Oceanography)

2:00 PM - 2:15 PM JST | 5:00 AM - 5:15 AM UTC

[ACC26-02] Analysis of Dome Fuji ice core fabric by dielectric tensor measurement

★Invited Papers

*Tomotaka Saruya[1], Shuji Fujita[1,2] (1.National Institute of Polar Research, 2.SOKENDAI (The Graduate University for Advanced Studies))

2:15 PM - 2:30 PM JST | 5:15 AM - 5:30 AM UTC

[ACC26-03] Methane concentration in Dome Fuji ice core measured with a continuous flow analysis system

*Ayaka Yonekura[1], Kenji Kawamura[1,2,3], Ikumi Oyabu[2], Kyotaro Kitamura[2], Jun Ogata[2], Motohiro Hirabayashi[2], Kaori Fukuda[2], Yoshimi Tsukagawa[2], Tomotaka Saruya[2], Fumio Nakazawa[1,2], Shuji Fujita[1,2], Kumiko Goto-Azuma[1,2], Hideaki Motoyama[1,2] (1.The Graduate University for Advanced Studies, SOKENDAI, 2.National Insutitute of Polar Research, 3.JAMSTEC)

2:30 PM - 2:45 PM JST | 5:30 AM - 5:45 AM UTC

[ACC26-04] The role of Southern warming on global ocean states and abrupt warming events during the last deglaciation

★Invited Papers

*Takashi Obase[1], Sam Sherriff-Tadano[1], Ayako Abe-Ouchi[1], Tristan Vadsaria[1], Christo Buizert[2] (1.Atmosphere and Ocean Research Institute, the University of Tokyo, 2.Oregon State University)

2:45 PM - 3:00 PM JST | 5:45 AM - 6:00 AM UTC

[ACC26-05] Climate model study on the driving mechanisms for abrupt climate changes during glacial periods and the effects of climatic precessions on the stability of the AMOC

*Yuta Kuniyoshi[1], Ayako Abe-Ouchi[1], Sam Sherriff-Tadano[2], Wing-Le Chan[1], Fuyuki SAITO[3] (1.The University of Tokyo, 2.University of Leeds, 3.JAMSTEC)

3:00 PM - 3:15 PM JST | 6:00 AM - 6:15 AM UTC

[ACC26-06] Comparative analysis of interglacial (MIS1, 5e, 11) climate responses to orbital elements and internal feedbacks

*Lynn Hirose[1], Ayako Abe-Ouchi[1], Wing-Le Chan[1] (1.the University of Tokyo)

[J] Oral | A (Atmospheric and Hydrospheric Sciences)：A-CC Cryospheric Sciences & Cold District Environment

3:30 PM - 5:00 PM JST | 6:30 AM - 8:00 AM UTC | Ch.13 Zoom Room 13

[A-CC26] Ice cores and paleoenvironmental modeling

convener:Nozomu Takeuchi(Chiba University), Ayako Abe-Ouchi(Atmosphere and Ocean Research Institute, The University of Tokyo), Ryu Uemura(Nagoya University), Kenji Kawamura(National Institute of Polar Research, Research Organization of Information and Systems), Chairperson:Nozomu Takeuchi(Chiba University), Ryu Uemura(Nagoya University)

3:30 PM - 3:45 PM JST | 6:30 AM - 6:45 AM UTC

[ACC26-07] Impacts of large scale atmospheric circulation on water isotopes of daily precipitation at Dome Fuji Station: A study with an isotope-enabled AGCM MIROC5-iso

*Kanon Kino[1,2], Okazaki Atsushi[3], Alexandre Cauquoin[2], Kei Yoshimura[2] (1.Atmosphere and Ocean Research Institute, the University of Tokyo, 2.Institute of Industrial Science, the University of Tokyo, 3.The Pennsylvania State University)

3:45 PM - 4:00 PM JST | 6:45 AM - 7:00 AM UTC

[ACC26-08] The correlations between cloud amount over Northern mid-high latitudes and aerosol proxies preserved in the SE-Dome ice core, Greenland

* AKIHISA WATARI[1], Iizuka Yoshinori[1], Koji Fujita[2], Hirohiko Masunaga[2], Kazuaki Kawamoto[3] (1.Hokkaido university, 2.Nagoya university, 3.Nagasaki university)

4:00 PM - 4:15 PM JST | 7:00 AM - 7:15 AM UTC

[ACC26-09] Possible albedo reduction of snow surface due to black carbon over the past 350 years on the Greenland Ice Sheet estimated from the SIGMA-D ice core

*Teruo Aoki[1,2], Kumiko Goto-Azuma[1,2], Sumito Matoba[3], Rigen Shimada[4], Yutaka Kondo[1], Nobuhiro Moteki[5], Makoto Koike[5], Koji Fujita[6], Hideaki Motoyama[1,2], Masahiro Hori[7] (1.National Institute of Polar Research, 2.SOKENDAI, 3.Institute of Low Temperature Science, Hokkaido University, 4.Earth Observation Research Center, Japan Aerospace Exploration Agency, 5.School of Science, University of Tokyo, 6.Graduate School of Environmental Studies, Nagoya University, 7.School of Sustainable Design, University of Toyama)

4:15 PM - 4:30 PM JST | 7:15 AM - 7:30 AM UTC

[ACC26-10] Intra-ice and intra-sediment cryopeg brine occurrence in permafrost near Utqiagvik (Barrow)

*Go Iwahana[1], Zachary S. Cooper[2], Shelly D. Carpenter[2], Jody W. Deming[2], Hajo Eicken[1] (1.International Arctic Research Center, University of Alaska Fairbanks, 2.School of Oceanography, University of Washington)

4:30 PM - 4:45 PM JST | 7:30 AM - 7:45 AM UTC

[ACC26-11] Ice core drilling on a high-elevation accumulation zone of Trambau Glacier in the Nepal Himalaya

*Nao Esashi[1], Akane Tsushima[2], Ryu Uemura[1], Yoshinori Iizuka[3], Sumito Matoba[3], Koji Fujita[1] (1.Graduate School of Environmental Studies, Nagoya University, 2.Graduate School of Science, Chiba University, 3.Institute of Low Temperature Science, Hokkaido University)

4:45 PM - 5:00 PM JST | 7:45 AM - 8:00 AM UTC

[ACC26-12] An attempt to reconstruct air temperature in the past using DNA information in ice core samples on Gregoriev Glacier, Kyrgyz Tienshan

★Invited Papers

*Segawa Takahiro[1], Koji Fujita[2], Ayumi Akiyoshi[3], Nozomu Takeuchi[4] (1.University of Yamanashi, 2.Nagoya University, 3.National Institute of Polar Research, 4.Chiba University)

[J] Oral | A (Atmospheric and Hydrospheric Sciences)：A-CG Complex & General

9:00 AM - 10:30 AM JST | 12:00 AM - 1:30 AM UTC | Ch.10 Zoom Room 10

[A-CG40] Coastal Ecosystems - 1. Water Cycle and Land-Ocean Interactions

convener:Masahiko Fujii(Faculty of Environmental Earth Science), Ryo Sugimoto(Faculty of Marine Biosciences, Fukui Prefectural University), Makoto Yamada(Faculty of Economics, Ryukoku University), Chairperson:Masahiko Fujii(Faculty of Environmental Earth Science), Ryo Sugimoto(Faculty of Marine Biosciences, Fukui Prefectural University), Makoto Yamada(Faculty of Economics, Ryukoku University)

9:00 AM - 9:15 AM JST | 12:00 AM - 12:15 AM UTC

[ACG40-01] Submarine groundwater discharge from Mt. Fuji in Suruga Bay(Ⅷ)

*Yasuhide Muranaka[1], Tomohide Kaneko[1], Tetsuhiro Watano[1], Tomoya Oka[1], Akira Ito[1], Masahiko Ono[2], Atsunao Marui[2] (1.Shizuoka Institute of Environment and Hygiene, 2.National Institute of Advanced Industrial Science and Technology)

9:15 AM - 9:30 AM JST | 12:15 AM - 12:30 AM UTC

[ACG40-02] Influence of groundwater-surface water exchange on riverine nutrient export to coastal seas: a comparative study at the six tide-less rivers in Wakasa Bay

*Toshimi Nakajima[1], Ryo Sugimoto[1] (1.Fukui Prefectural University)

9:30 AM - 9:45 AM JST | 12:30 AM - 12:45 AM UTC

[ACG40-03] Quantifying flux of groundwater-derived nutrients and phytoplankton assimilation rate of nutrients in a volcanic sandy beach

*Ryo Sugimoto[1], Ryoma Yagi[1], Toshimi Nakajima[1], Tatsuhiro Ishida[1], Makoto Yamada[2] (1.Faculty of Marine Biosciences, Fukui Prefectural University, 2.Faculty of Economics, Ryukoku University)

9:45 AM - 10:00 AM JST | 12:45 AM - 1:00 AM UTC

[ACG40-04] **Spatial and Temporal Patterns of the Physical and Biogeochemical Properties in the Nearshore Waters of Toyama Bay**

*Eligio de Raus Maure[1], Genki Terauchi[1], Yasuyuki Harada[1] (1.Northwest Pacific Region Environmental Cooperation Center)

10:00 AM - 10:15 AM JST | 1:00 AM - 1:15 AM UTC

[ACG40-05] The relationship between the timing and scale of *Karenia mikimotoi* bloom and environmental factors in the western Bungo Channel of Seto Inland Sea, Japan

*Yuma Hayashi[1], Naoki Yoshie[1], Goh Onitsuka[2] (1.Center for Marine Environmental Studies , Ehime University, 2.Japan Fisheries Research and Education Agency)

10:15 AM - 10:30 AM JST | 1:15 AM - 1:30 AM UTC

[ACG40-06] Continuous monitoring and future projection of ocean warming, acidification, and deoxygenation on the subarctic coast of Hokkaido, Japan

*Masahiko Fujii[1,2], Shintaro Takao[3], Takuto Yamaka[2], Tomoo Akamatsu[2], Yamato Fujita[2], Masahide Wakita[4], Akitomo Yamamoto[5], Tsuneo Ono[6] (1.Faculty of Environmental Earth Science, 2.Graduate School of Environmental Science, Hokkaido University, 3.National Institute for Environmental Studies, 4.Mutsu Institute for Oceanography, Japan Agency for Marine-Earth Science and Technology, 5.Japan Agency for Marine-Earth Science and Technology, 6.Japan Fisheries Research and Education Agency)

[J] Oral | A (Atmospheric and Hydrospheric Sciences)：A-CG Complex & General

10:45 AM - 12:15 PM JST | 1:45 AM - 3:15 AM UTC | Ch.10 Zoom Room 10

[A-CG41] Coastal Ecosystems -2. Coral reefs, seagrass and macroalgal beds, and mangroves

convener:Yu Umezawa(Tokyo University of Agriculture and Technology), Toshihiro Miyajima(Marine Biogeochemistry Group, Division of Ocean-Earth System Science, Atmosphere and Ocean Research Institute, The University of Tokyo), Atsushi Watanabe(The ocean policy research institute, The Sasakawa peace foundation), Tomihiko Higuchi(Atmosphere and Ocean Research Institute, The University of Tokyo), Chairperson:Yu Umezawa(Tokyo University of Agriculture and Technology), Toshihiro Miyajima(Marine Biogeochemistry Group, Division of Ocean-Earth System Science, Atmosphere and Ocean Research Institute, The University of Tokyo), Atsushi Watanabe(The ocean policy research institute, The Sasakawa peace foundation), Tomihiko Higuchi(Atmosphere and Ocean Research Institute, The University of Tokyo)

10:45 AM - 10:50 AM JST | 1:45 AM - 1:50 AM UTC

[ACG41-01] Introduction

10:50 AM - 11:10 AM JST | 1:50 AM - 2:10 AM UTC

[ACG41-02] Current status and future of ecosystem monitoring of seagrass beds in Japan and Asia: from basic field observation to the policy making and international planning.

★Invited Papers

*Takehisa Yamakita[1], Masakazu Hori[2], Yoshiyuki Tanaka[3], Misuzu Aoki[4], Masahiro Nakaoka[5] (1.Japan Agency for Marine-Earth Science and Technology, 2.Japan Fisheries Research and Education Agency , 3.Hachinohe Institute of Technology, 4.Wetlands International Japan, 5.Hokkaido Univ)

11:10 AM - 11:30 AM JST | 2:10 AM - 2:30 AM UTC

[ACG41-03] Seagrass distribution and adaptation in a turbid tropical estuary (Brunei Bay, Borneo)

★Invited Papers

*Yasuaki Tanaka[1], Nadhirah Lamit[1] (1.Universiti Brunei Darussalam)

11:30 AM - 11:45 AM JST | 2:30 AM - 2:45 AM UTC

[ACG41-04] Detection of seagrass habitat in Himi, Toyama Bay using Google Earth Engine

*Genki Terauchi[1], Eligio de Raus Maure[1], Yasuyuki Harada[1], Wataru Matsumura[2], Tsuneo Maeda[3] (1.Northwest Pacific Region Environmental Cooperation Center, 2.Fisheries Research Institute, Toyama Prefectural Agricultural Forestry and Fisheries Research Center, 3.Toyama Prefectural Fisheries and Fishing Ports Division)

11:45 AM - 12:00 PM JST | 2:45 AM - 3:00 AM UTC

[ACG41-05] **Assessment of mangrove regeneration in abandoned aquaculture ponds using multi-temporal satellite imagery**

Kriselda Anna Delos Santos[2], Ram Avtar[1,2], *Masahiko Fujii[1,2] (1.Faculty of Environmental Earth Science, 2.Graduate School of Environmental Science, Hokkaido University)

12:00 PM - 12:15 PM JST | 3:00 AM - 3:15 AM UTC

[ACG41-06] Quantification of drag force and material trapping ability of a planted mangrove forest in the Philippines

*Yoshikai Masaya[1], Takashi Nakamura[1], Dominic Bautista[2], Eugene Herrera[2], Takuya Okamoto[1], Rempei Suwa[3], Kazuo Nadaoka[1] (1.School of Environment and Society, Tokyo Institute of Technology, 2.Institute of Civil Engineering, University of the Philippines, 3.Forestry Division, Japan International Research Center for Agricultural Sciences)

[J] Oral | A (Atmospheric and Hydrospheric Sciences)：A-CG Complex & General

1:45 PM - 3:15 PM JST | 4:45 AM - 6:15 AM UTC | Ch.10 Zoom Room 10

[A-CG41] Coastal Ecosystems -2. Coral reefs, seagrass and macroalgal beds, and mangroves

convener:Yu Umezawa(Tokyo University of Agriculture and Technology), Toshihiro Miyajima(Marine Biogeochemistry Group, Division of Ocean-Earth System Science, Atmosphere and Ocean Research Institute, The University of Tokyo), Atsushi Watanabe(The ocean policy research institute, The Sasakawa peace foundation), Tomihiko Higuchi(Atmosphere and Ocean Research Institute, The University of Tokyo), Chairperson:Yu Umezawa(Tokyo University of Agriculture and Technology), Toshihiro Miyajima(Marine Biogeochemistry Group, Division of Ocean-Earth System Science, Atmosphere and Ocean Research Institute, The University of Tokyo), Atsushi Watanabe(The ocean policy research institute, The Sasakawa peace foundation), Tomihiko Higuchi(Atmosphere and Ocean Research Institute, The University of Tokyo)

1:45 PM - 2:00 PM JST | 4:45 AM - 5:00 AM UTC

[ACG41-07] **Photoinhibition as a strategy for corals to mitigate heat stress and resulting ROS production**

Reimi Terayama[1], *Agostini Sylvain[1], Takashi Nakamura[2], Tomihiko Higuchi[3], Ikuko Yuyama[5], Sung-Yin Yang[1], Toshihiro Miyajima[3], Hiroyuki Fujimura[4] (1.Shimoda Marine Research Center, University of Tsukuba, 2.Tokyo Institute of Technology, 3.AORI, University of Tokyo, 4.University of the Ryukyus, 5.Yamaguchi University)

2:00 PM - 2:15 PM JST | 5:00 AM - 5:15 AM UTC

[ACG41-08] Epizootiology of a temperate coral disease driven by thermal stress and macroalgal interactions

*Joshua Masataro Heitzman[1], Nicole Caputo[2], Sung-Yin Yang[1], Ben P Harvey[1], Sylvain Agostini[1] (1.Shimoda Marine Research Center, University of Tsukuba, 2.CIRI-FRAME, Alma Mater Studiorum, Università di Bologna)

2:15 PM - 2:30 PM JST | 5:15 AM - 5:30 AM UTC

[ACG41-09] Disease occurrence among various zonation: Status of Coral Reefs at Karimunjawa Island, Indonesia

*Dio Dirgantara[1], Rhesi Kristiana[2], Kuswadi bin Bunadi[3], Takashi Nakamura[1] (1.Faculty of Science, University of The Ryukyus, Nishihara, Okinawa 903-0213, Japan, 2.Marine Education and Research Organisation, Karangasem, Bali 80853, Indonesia, 3.Karimunjawa National Park Office, Semarang, Central Java 50273, Indonesia)

2:30 PM - 2:45 PM JST | 5:30 AM - 5:45 AM UTC

[ACG41-10] Degraded turf algal systems are ‘locked-in’ by ocean acidification

*Benjamin Paul Harvey[1], Ro Allen[2,3], Sylvain Agostini[1], Linn J Hoffmann[2], Koetsu Kon[1], Tina C Summerfield[2], Shigeki Wada[1], Jason M Hall-Spencer[1,4] (1.Shimoda Marine Research Center, University of Tsukuba, 5-10-1 Shimoda, Shizuoka 415-0025, Japan, 2.Department of Botany, University of Otago, Dunedin, New Zealand, 3.The Marine Biological Association, Plymouth, Devon PL1 2PB, UK, 4.School of Biological and Marine Sciences, University of Plymouth, Plymouth PL4 8AA, UK)

2:45 PM - 3:00 PM JST | 5:45 AM - 6:00 AM UTC

[ACG41-11] Development of Numerical Model for Dynamics of Partial Pressure of CO_2 in Seawater Considering Effects of Stratification in the Yatsushiro Sea

*Naoki Saito[1], Bing Xiong[2], Hiroto Komori[2], Shinichiro Yano[2], Keisuke Nakayama[3], Katsuaki Komai[4], Hiroshi Yajima[5] (1.National Institute of Advanced Industrial Science and Technology, 2.Kyushu University, 3.Kobe University, 4.Kitami Institute of Technology, 5.Shimane University)

3:00 PM - 3:15 PM JST | 6:00 AM - 6:15 AM UTC

[ACG41-12] Two-way nested blue carbon tracing simulation for elucidating fates of exported organic carbon from coastal ecosystems

*Takashi Nakamura[1], Faisal Amri[1], Lawrence Patrick Cases Bernardo[2], Kazuo Nadaoka[1], Masakazu Hori[3], Masami Hamaguchi[3], Toshihiro Miyajima[4] (1.School of Environment and Society, Tokyo Institute of Technology, 2.Graduate School of Environmental Science, Hokkaido University, 3. Japan Fisheries Research and Education Agency, 4.Atmosphere and Ocean Research Institute, The University of Tokyo)

[J] Oral | A (Atmospheric and Hydrospheric Sciences)：A-CG Complex & General

1:45 PM - 3:15 PM JST | 4:45 AM - 6:15 AM UTC | Ch.11 Zoom Room 11

[A-CG42] Water and sediment dynamics from land to coastal zones

convener:Shinichiro Kida(Research Institute for Applied Mechanics, Kyushu University), Yuko Asano(The University of Tokyo), Keiko Udo(International Research Institute of Disaster Science, Tohoku University), Dai Yamazaki(Institute of Industrial Sciences, The University of Tokyo), Chairperson:Dai Yamazaki(Institute of Industrial Sciences, The University of Tokyo), Keiko Udo(International Research Institute of Disaster Science, Tohoku University), Yuko Asano(The University of Tokyo), Shinichiro Kida(Research Institute for Applied Mechanics, Kyushu University)

1:45 PM - 2:00 PM JST | 4:45 AM - 5:00 AM UTC

[ACG42-01] The fate of riverine freshwater in the ocean

*Shinichiro Kida[1], Ryo Abe[2], Yosuke Alexandre Yamashiki[3] (1.Research Institute for Applied Mechanics, Kyushu University, 2.Interdisciplinary Graduate School of Engineering Sciences, 3.Graduate School of Advanced Integrated Studies in Human Survivability)

2:00 PM - 2:15 PM JST | 5:00 AM - 5:15 AM UTC

[ACG42-02] Interpreting the sediment dynamics from mountains to the sea in the Saru River souce-to-sink system using radionuclide tracers

★Invited Papers

*Shigeru Mizugaki[1], Junichi Otsuka[1], Yasuhiro Murakami[1], Keiko Iwakura[1] (1.Civil Engineering Research Institute for Cold Region, Public Works Research Institute)

2:15 PM - 2:30 PM JST | 5:15 AM - 5:30 AM UTC

[ACG42-03] River survey using airborne laser bathymetry (ALB) and its applications

★Invited Papers

*Keigo Nakamura[1] (1.Public Works Research Institute)

2:30 PM - 2:45 PM JST | 5:30 AM - 5:45 AM UTC

[ACG42-04] How much suspended sediment is transported from land to oceans globally?

*Misako Hatono[1], Kei Yoshimura[2] (1.Hiroshima University, 2.The University of Tokyo)

2:45 PM - 3:00 PM JST | 5:45 AM - 6:00 AM UTC

[ACG42-05] Estimation of coastal freshwater discharge using surface salinity of Nanao Bay

*Shiho Kobayashi[1], Satoshi Nakada[2], Kei Senbokuya[3], Jun-ichi Okuno [3] (1.Kyoto University, 2.National Institute for Environmental Studies, 3.Ishikawa Prefecture Fisheries Research Center)

3:00 PM - 3:15 PM JST | 6:00 AM - 6:15 AM UTC

[ACG42-06] Storm runoff at hillslopes and channels in mountain catchment

*Yuko Asano[1], Taro Uchida[2], Mitsuhide Tomomura[3], Naoko Miura[1] (1.The University of Tokyo, 2.University of Tsukuba, 3.Meteorological Engineering Center)

[J] Oral | A (Atmospheric and Hydrospheric Sciences)：A-CG Complex & General

3:30 PM - 5:00 PM JST | 6:30 AM - 8:00 AM UTC | Ch.11 Zoom Room 11

[A-CG42] Water and sediment dynamics from land to coastal zones

convener:Shinichiro Kida(Research Institute for Applied Mechanics, Kyushu University), Yuko Asano(The University of Tokyo), Keiko Udo(International Research Institute of Disaster Science, Tohoku University), Dai Yamazaki(Institute of Industrial Sciences, The University of Tokyo), Chairperson:Shinichiro Kida(Research Institute for Applied Mechanics, Kyushu University), Yuko Asano(The University of Tokyo), Dai Yamazaki(Institute of Industrial Sciences, The University of Tokyo), Keiko Udo(International Research Institute of Disaster Science, Tohoku University)

3:30 PM - 3:45 PM JST | 6:30 AM - 6:45 AM UTC

[ACG42-07] Sediment budget analysis and geomorphological evolution in alluvial river – Case study in the lower Yodo River –

★Invited Papers

*Ryoukei Azuma[1] (1.Osaka Institute of Technology)

3:45 PM - 4:00 PM JST | 6:45 AM - 7:00 AM UTC

[ACG42-08] Toward an improvement of river runoff in the Japanese Coastal Ocean Monitoring and Forecasting System

★Invited Papers

*Kei Sakamoto[1], Shogo Urakawa[1], Nariaki Hirose[1], Hideyuki Nakano[1], Takahiro Toyoda[1], Norihisa Usui[1], Goro Yamanaka[1] (1.Meteorological Research Institute)

4:00 PM - 4:15 PM JST | 7:00 AM - 7:15 AM UTC

[ACG42-09] Long river plume around Akkeshi Bay formed by snowmelt runoff

*Satoshi Nakada[1], Tomonori Isada[2] (1.National Institute for Environmental Studies, 2.Hokkaido University)

4:15 PM - 4:30 PM JST | 7:15 AM - 7:30 AM UTC

[ACG42-10] Application of suspended sediment and physical process interaction to river-plume simulations in the microtidal coastal region during a flood

*Yasuhiro Hoshiba[3], Yoshimasa Matsumura[2], Sachihiko Itoh[3], Hiroyasu Hasumi[1] (1.Division of Climate System Research, Atmosphere and Ocean Research Institute, University of Tokyo, 2.Division of Marine Life Science, Atmosphere and Ocean Research Institute, University of Tokyo, 3.Center for Earth Surface System Dynamics, Atmosphere and Ocean Research Institute, University of Tokyo)

4:30 PM - 4:45 PM JST | 7:30 AM - 7:45 AM UTC

[ACG42-11] Experimental study on the effect of vegetation cover and location by a forest floor model on reducing sediment transport

*Ako YAMAMOTO[1], Akira Kojima[2], Ryusei Shiotsuki[2], Keita Kawaharada[3], Makjoto Sotoyama[3], Tsuyoshi Tada[2], Yoshinori Shigihara[2], Yo Fukutani[3] (1.Forest of Research and Management Organization Forestry and Forest Products Research Institute, 2.National Defense Academy, 3.Kanto Gakuin University)

4:45 PM - 5:00 PM JST | 7:45 AM - 8:00 AM UTC

[ACG42-12] Sediment transport and morphology change in coastal areas

*Keiko Udo[1] (1.International Research Institute of Disaster Science, Tohoku University)

[J] Oral | A (Atmospheric and Hydrospheric Sciences)：A-CG Complex & General

1:45 PM - 3:15 PM JST | 4:45 AM - 6:15 AM UTC | Ch.07 Zoom Room 07

[A-CG43] Earth & Environmental Sciences and Artificial Intelligence/Machine Learning

convener:Tomohiko Tomita(Faculty of Advanced Science and Technology, Kumamoto University), Shigeki Hosoda(Japan Marine-Earth Science and Technology), Ken-ichi Fukui(Osaka University), Satoshi Ono(Kagoshima Univeristy), Chairperson:Tomohiko Tomita(Faculty of Advanced Science and Technology, Kumamoto University), Shigeki Hosoda(Japan Marine-Earth Science and Technology)

1:45 PM - 1:50 PM JST | 4:45 AM - 4:50 AM UTC

[ACG43-01] Introduction

1:50 PM - 2:10 PM JST | 4:50 AM - 5:10 AM UTC

[ACG43-02] Deep Learning that Ensures Laws of Physics and Other Constraints and Its Applications

★Invited Papers

*Takashi Matsubara[1] (1.Osaka University)

2:10 PM - 2:30 PM JST | 5:10 AM - 5:30 AM UTC

[ACG43-03] Recent trends in earth and environmental informatics

★Invited Papers

*Daisuke Matsuoka[1,2] (1.Japan Agency for Marine-Earth Science and Technology, 2.Japan Science and Technology Agency)

2:30 PM - 2:45 PM JST | 5:30 AM - 5:45 AM UTC

[ACG43-04] Adversarial Multi-task Learning Algorithm for Solving Partial Differential Equations

*Pongpisit Thanasutives[1], Masayuki Numao[1], Ken-ichi Fukui[1] (1.Osaka University)

2:45 PM - 3:00 PM JST | 5:45 AM - 6:00 AM UTC

[ACG43-05] Statistical Downscaling of Meteorological Fields from the Synoptic Scale to the Mesoscale Using Deep Convolutional Neural Networks

*Thomas Sekiyama[1] (1.Meteorological Research Institute)

3:00 PM - 3:15 PM JST | 6:00 AM - 6:15 AM UTC

[ACG43-06] Deep learning approach for rainfall forecasting using U-Net with data augmentation

*Ryo Kaneko[1], Shiho Onomura[2], Makoto Nakayoshi[2] (1.The University of Tokyo, 2.Tokyo University of Science)

[J] Oral | A (Atmospheric and Hydrospheric Sciences)：A-CG Complex & General

3:30 PM - 5:00 PM JST | 6:30 AM - 8:00 AM UTC | Ch.06 Zoom Room 06

[A-CG43] Earth & Environmental Sciences and Artificial Intelligence/Machine Learning

convener:Tomohiko Tomita(Faculty of Advanced Science and Technology, Kumamoto University), Shigeki Hosoda(Japan Marine-Earth Science and Technology), Ken-ichi Fukui(Osaka University), Satoshi Ono(Kagoshima Univeristy), Chairperson:Shigeki Hosoda(Japan Marine-Earth Science and Technology), Tomohiko Tomita(Faculty of Advanced Science and Technology, Kumamoto University)

3:30 PM - 3:50 PM JST | 6:30 AM - 6:50 AM UTC

[ACG43-07] Automated identification of tornadic vortex with Doppler radar data using deep learning approaches: Recent progress and challenges

★Invited Papers

*Kusunoki Kenichi[1], Naoki Ishitsu[2], Toru Adachi[1], Hanako Inoue[1], Osamu Suzuki[1], Ken-ichiro Arai[2], Chusei Fujiwara[3], Hiroto Suzuki[3] (1.Meteorological Research Institute, 2.Alpha-denshi Co., Ltd., 3.East Japan Railway Company)

3:50 PM - 4:10 PM JST | 6:50 AM - 7:10 AM UTC

[ACG43-08] **Estimation of cloud and meteorological state from satellite image by deep neural network**

★Invited Papers

*Hironobu Iwabuchi[1], Xinyue Wang[1], Hana Kato[1], Takaya Yamashita[1] (1.Graduate School of Science, Tohoku University)

4:10 PM - 4:25 PM JST | 7:10 AM - 7:25 AM UTC

[ACG43-09] Clustering global ocean profiles according to temperature-salinity structure

*Nozomi Sugiura[1] (1.Japan Agency for Marine-Earth Science and Technology)

4:25 PM - 4:40 PM JST | 7:25 AM - 7:40 AM UTC

[ACG43-10] **Automated Hybrid Machine Learning Approaches for Groundwater Level Forecasting in Kumamoto area, Japan**

*A T M Sakiur Rahman[1], Takahiro Hosono[4,5], John Quilty[2], Jayanta Das[3], Amiya Basak[3] (1.Postdoctoral researcher, Kumamoto University, 2.Department of Civil and Environmental Engineering , University of Waterloo, Waterloo, ON, Canada , 3.Department of Geography and Applied Geography, University of North Bengal, Darjeeling - 734013, India , 4.Faculty of Advanced Science and Technology, Kumamoto University, 2-39-1 Kurokami, Kumamoto 860-8555, Japan, 5.International Research Organization for Advanced Science and Technology, Kumamoto University, 2-39-1 Kurokami, Kumamoto 860-8555, Japan)

4:40 PM - 4:55 PM JST | 7:40 AM - 7:55 AM UTC

[ACG43-11] **Improving Detection of Tropical Cyclones by Deep Convolutional Neural Network through a Two-step Training**

*TAKERU TSUCHIYA[1], Shunji Kotsuki[2], Ryota Kikuchi[3], Takeshi Umezawa[4], Noritaka Osawa[4] (1.Department of Information Engineering, Chiba University, Chiba, Japan, 2.Center for Environmental Remote Sensing, Chiba University, Chiba, Japan, 3.Office of Society Academia Collaboration for Innovation, Kyoto University, Japan, 4.Graduate School & Faculty of Engineering, Chiba University, Chiba, Japan)

4:55 PM - 5:00 PM JST | 7:55 AM - 8:00 AM UTC

[ACG43-12] Discussion

[J] Oral | A (Atmospheric and Hydrospheric Sciences)：A-CG Complex & General

3:30 PM - 5:00 PM JST | 6:30 AM - 8:00 AM UTC | Ch.10 Zoom Room 10

[A-CG44] Biogeochemical linkages between the surface ocean and atmosphere

convener:Sohiko Kameyama(Hokkaido University), Yoko Iwamoto(Graduate School of Integrated Sciences for Life, Hiroshima University), Noguchi Maki Aita(Japan Agency for Marine-Earth Science and Technology), Daisuke Sasano(Japan Meteorological Agency), Chairperson:Sohiko Kameyama(Hokkaido University)

3:30 PM - 3:45 PM JST | 6:30 AM - 6:45 AM UTC

[ACG44-01] R/V Mirai cruise for IMPACT-SEA project 2021: Preliminary results

*Fumikazu Taketani[1], Kana Nagashima[1], Minoru Kitamura[1] (1.Japan Agency for Marine-Earth Science and Technology)

3:45 PM - 4:00 PM JST | 6:45 AM - 7:00 AM UTC

[ACG44-02] **Seasonal and interannual variations of surface water carbonate chemistry in the Indian sector of the Southern Ocean**

*Manami Tozawa[1], Daiki Nomura[1,2,3], Shin-ichiro Nakaoka[4], Masaaki Kiuchi[1], Daisuke Hirano[5], Shigeru Aoki[5], Hiroko Sasaki[6], Hiroto Murase[7] (1.Faculty of Fisheries Sciences, Hokkaido University, 2.Field Science Center for Northern Biosphere, Hokkaido University, 3.Arctic Research Center, Hokkaido University, 4.National Institute for Environmental Studies, 5.Institute of Low Temperature Science, Hokkaido University, 6.Fisheries Resources Institute, Japan Fisheries Research and Education Agency, 7.Tokyo University of Marine Science and Technology)

4:00 PM - 4:15 PM JST | 7:00 AM - 7:15 AM UTC

[ACG44-03] **Summer carbonate chemistry near the Totten Ice Shelf, Sabrina Coast, East Antarctica**

*Tetsuya Tamura[1], Daiki Nomura[1,2,3], Daisuke Hirano[3,4], Takeshi Tamura[5], Masaaki Kiuchi[1], Gen Hashida[5], Shigeru Aoki[4], Hiroko Sasaki[6], Hiroto Murase[7] (1.Faculty of Fisheries Science, Hokkaido University, 2.Field Science Center for Northern Biosphere, 3.Arctic Research Center, 4.Institute of Low Temperature Science, 5.National Institute of Polar Research, 6.Fisheries Resources Institute, Japan Fisheries Research and Education Agency, 7.Tokyo University of Marine Science and Technology)

4:15 PM - 4:30 PM JST | 7:15 AM - 7:30 AM UTC

[ACG44-04] Iodomethane and Iodoethane distributions in coastal seawater of subarctic Pacific and Northern Bering sea

*Atsushi Ooki[1], Keita Minamikawa[1], Fanxing Meng[1] (1.Hokkaido University)

4:30 PM - 4:45 PM JST | 7:30 AM - 7:45 AM UTC

[ACG44-05] Effects of marine nitrogen fixation on the formation of atmospheric water-soluble organic nitrogen revealed by a laboratory incubation experiment

*Tsukasa Dobashi[1,2], Koji Suzuki[2], Yuzo Miyazaki[1] (1. Institute of Low Temperature Science, Hokkaido Univ., 2.Graduate School of Env. Sci., Hokkaido Univ.)

4:45 PM - 5:00 PM JST | 7:45 AM - 8:00 AM UTC

[ACG44-06] Characterization of Adhesivity of marine organic aerosols by atomic force microscopy

*Kohei Ono[1], Ayumi Iwata[2], Takeshi Fukuma[3], Yoko Iwamoto[4], Koji Hamasaki[5], Atsushi Matsuki[6] (1.Graduate School of Natural Science and Technology, Kanazawa University, 2.Faculty of Science and Technology, Keio University, 3.Nano Life Science Institute, Kanazawa University, 4.Graduate School of Integrated Sciences for Life, Hiroshima University, 5.Atmosphere and Ocean Research Institute, The University of Tokyo, 6.Institute of Nature and Environmental Technology, Kanazawa University)

[J] Oral | H (Human Geosciences)：H-RE Resource and Engineering Geology

1:45 PM - 3:15 PM JST | 4:45 AM - 6:15 AM UTC | Ch.15 Zoom Room 15

[H-RE12] Resource Geology

convener:Tsubasa Otake(Division of Sustainable Resources Engineering, Faculty of Engineering, Hokkaido University), Kenzo Sanematsu(Mineral Resource Research Group, Institute for Geo-Resources and Environment, Geological Survey of Japan, National Institute of Advanced Industrial Science and Technology), Ryohei Takahashi(Graduate School of International Resource Sciences, Akita University), Tatsuo Nozaki(Submarine Resources Research Center, Research Institute for Marine Resources Utilization, Japan Agency for Marine-Earth Science and Technology), Chairperson:Tatsuo Nozaki(Submarine Resources Research Center, Research Institute for Marine Resources Utilization, Japan Agency for Marine-Earth Science and Technology), Ryohei Takahashi(Graduate School of International Resource Sciences, Akita University)

1:45 PM - 2:00 PM JST | 4:45 AM - 5:00 AM UTC

[HRE12-01] **Formation of various types of iron ore deposits in the Earth's surface environments: A review**

*Tsubasa Otake[1] (1.Division of Sustainable Resources Engineering, Faculty of Engineering, Hokkaido University)

2:00 PM - 2:15 PM JST | 5:00 AM - 5:15 AM UTC

[HRE12-02] A rapid analytical method of Re-Os isotope on sulfides by MC-ICP-MS and sparging method: Its application to the Kamaishi deposit in NE Japan

*Mizuki Ogasawara[1], Junichiro Ohta[1,2], Mizuki Ishida[1], Moei Yano[2,1], Ryota Maki[1], Tatsuo Nozaki[3,1,4,2], Yutaro Takaya[5,3,2], Koichiro Fujinaga[2,1], Kazutaka Yasukawa[1,2], Yasuhiro Kato[1,2] (1.School of Engineering, The University of Tokyo, 2.ORCeNG, Chiba Institute of Technology, 3.JAMSTEC, 4.Kobe University, 5.Waseda University)

2:15 PM - 2:30 PM JST | 5:15 AM - 5:30 AM UTC

[HRE12-03] Geochemical Characterization of Rivers Contaminated by Acid Mine Drainage from an Abandoned Mine in Northern Japan

*Sereyroith Tum[1], Tatsuya Matsui[1], Frances Chikanda[1], Ryosuke Kikuchi[2], Yoko Ohtomo[2], Tsubasa Otake[2], Susumu Norota[3], Tsutomu Sato[2] (1.Graduate School of Engineering, Hokkaido University, 060-8628, Sapporo, Japan , 2.Faculty of Engineering, Hokkaido University, 060-8628, Sapporo, Japan, 3.Geological Survey of Hokkaido, Hokkaido Research Organization, 060-0819, Sapporo, Japan)

2:30 PM - 2:45 PM JST | 5:30 AM - 5:45 AM UTC

[HRE12-04] **Utilizing isotopic Fe fractionations to trace the behaviour of dissolved and colloidal Fe in mine drainages**

*Frances Chikanda[1], Tsubasa Otake[2], Tatsuya Matsui[1], Sereyroith Tum[1], Tsutomu Sato[2] (1.Division of Sustainable Resources Engineering, Graduate School of Engineering, Hokkaido University, 2.Division of Sustainable Resources Engineering, Faculty of Engineering, Hokkaido University)

2:45 PM - 3:15 PM JST | 5:45 AM - 6:15 AM UTC

[HRE12-05] Discussion

[J] Oral | H (Human Geosciences)：H-TT Technology & Techniques

9:00 AM - 10:30 AM JST | 12:00 AM - 1:30 AM UTC | Ch.16 Zoom Room 16

[H-TT16] Development and application of environmental traceability methods

convener:Ichiro Tayasu(Research Institute for Humanity and Nature), Ki-Cheol Shin(Research Institute for Humanity and Nature), Nozomu Takeuchi(Chiba University), Chairperson:Nozomu Takeuchi(Chiba University)

9:00 AM - 9:15 AM JST | 12:00 AM - 12:15 AM UTC

[HTT16-01] Application of environmental traceability methodology by multi-isotopes

*Ichiro Tayasu[1], Ki-Cheol Shin[1] (1.Research Institute for Humanity and Nature)

9:15 AM - 9:30 AM JST | 12:15 AM - 12:30 AM UTC

[HTT16-02] Daily variation in winter precipitation isotopes over Hirosaki and associate atmospheric circulation - Case study of a winter season 2019/2020 -

*Akiyo Yatagai[1], Syota Nishioka[2], Kei Yoshimura[3] (1.Graduate School of Science and Technology, Hirosaki University, 2.Faculty of Science and Technology, Hirosaki University, 3.IIS Chiba Experimental Station, The University of Tokyo)

9:30 AM - 9:45 AM JST | 12:30 AM - 12:45 AM UTC

[HTT16-03] Identification of snow characteristics in the basin to applied chemical composition and meteorological hydrological data

*kawagoe seiki[1], shiho yabusaki[2] (1.Faculty of Symbiotic Systems science/Fukushima university, 2.Research institute for Humanity and Nature)

9:45 AM - 10:00 AM JST | 12:45 AM - 1:00 AM UTC

[HTT16-04] Distribution of trace element concentrations in groundwater and spring water near coastal and inland area of Fukushima prefecture

*Shiho Yabusaki[1] (1. Research Institute for Humanity and Nature・Faculty of Symbiotic Systems Science, Fukushima University)

10:00 AM - 10:15 AM JST | 1:00 AM - 1:15 AM UTC

[HTT16-05] Response of forest ecosystems to reduction of atmospheric sulfur deposition

*Hiroyuki Sase[1], Tsuyoshi Ohizumi[1], Yayoi Inomata[2], Naoyuki Yamashita[3], Toko Tanikawa[4], Masamichi Takahashi[3], Tatsuyoshi Saito[5], Masayuki Morohashi[1], Hiroki Yotsuyanagi[1] (1.Asia Center for Air Pollution Research, 2.Kanazawa University, 3.Forestry and Forest Products Research Institute, 4.Nagoya University, 5.Niigata Prefectural Government)

10:15 AM - 10:30 AM JST | 1:15 AM - 1:30 AM UTC

[HTT16-06] Estimate the origin of nutrients supplied to coastal areas using Ulva pertusa's nitrogen and carbon stable isotope ratios.

*Tatsuhiro Ishida[1], Osamu Tominaga[1], Ryo Sugimoto[1], Naoki Kisa[1], Keisuke Koba[2], Keitaro Fukushima[2] (1.Fukui Prefectural University, 2.Center for Ecological Research,Kyoto University)

[J] Oral | H (Human Geosciences)：H-TT Technology & Techniques

10:45 AM - 12:15 PM JST | 1:45 AM - 3:15 AM UTC | Ch.16 Zoom Room 16

[H-TT16] Development and application of environmental traceability methods

convener:Ichiro Tayasu(Research Institute for Humanity and Nature), Ki-Cheol Shin(Research Institute for Humanity and Nature), Nozomu Takeuchi(Chiba University), Chairperson:Ichiro Tayasu(Research Institute for Humanity and Nature)

10:45 AM - 11:00 AM JST | 1:45 AM - 2:00 AM UTC

[HTT16-07] A comparative study of diet of winged and wingless stoneflies on alpine snow in Mt. Gassan, Yamagata Prefecture, using carbon and nitrogen stable isotopes

*Nozomu Takeuchi[1], Risako Yonechi[1] (1.Chiba University)

11:00 AM - 11:15 AM JST | 2:00 AM - 2:15 AM UTC

[HTT16-08] The spatial variations in carbon and nitrogen stable isotopes of organic matter on the surface of Gulkana Glacier in Alaska

*Tsubasa Takahashi[1], MASATO ONO[1], Ayumi Kizawa[2], Nozomu Takeuchi[1] (1.Chiba University, 2.Chuo University)

11:15 AM - 11:30 AM JST | 2:15 AM - 2:30 AM UTC

[HTT16-09] Reconstructing lifetime isotope baselines of fish from eye lenses

*Yota Harada[1], Shin-ichi Ito[2], Chisato Yoshikawa[1], Nanako O. Ogawa[1], Naoto Ishikawa[1], Naohiko Ohkouchi[1] (1.Biogeochemistry Research Center, Japan Agency for Marine-Earth Science and Technology, 2.Atmosphere and Ocean Research Institute, The University of Tokyo)

11:30 AM - 11:45 AM JST | 2:30 AM - 2:45 AM UTC

[HTT16-10] Tracing habitat areas and migration of marine fishes from fish bone Pb isotopes

*Keiji Horikawa[1], Hinako Nishimura[2], Ki-Cheol Shin[3] (1.Faculty of Science, University of Toyama, 2.Graduate School of Engineering and Science for Education, University of Toyama, 3.Research Institute of Humanity and Nature)

11:45 AM - 12:00 PM JST | 2:45 AM - 3:00 AM UTC

[HTT16-11] Dietary evaluation through zinc isotope ratios of human skeletal remains from Yoshigo shell mound of Jomon period

*Soichiro Kusaka[1], Ki-Cheol Shin[2] (1.Tokai Univ., 2.RIHN)

12:00 PM - 12:15 PM JST | 3:00 AM - 3:15 AM UTC

[HTT16-12] Origin of prehistoric pottery clay deciphered from Sr-Nd-Pb isotope ratios

*Eriko Ishimaru[1], Ki-Cheol Shin[2], Makoto Tomii[3], Yoshiki Nobusato[4] (1.Hiroshima Univ., 2.RIHN, 3.Kyoto Univ., 4.Kagawa Mus.)

[J] Oral | H (Human Geosciences)：H-TT Technology & Techniques

9:00 AM - 10:30 AM JST | 12:00 AM - 1:30 AM UTC | Ch.15 Zoom Room 15

[H-TT17] New Developments in Shallow Geophysics

convener:Kyosuke Onishi(Public Works Research Institute), Kunio Aoike(Oyo corporation), Tishiyuki Yokota(National Institute of Advanced Industrial Science and Technology), Toru Takahashi(Fukada Geological Institute), Chairperson:Toru Takahashi(Fukada Geological Institute), Kunio Aoike(Oyo corporation)

9:00 AM - 9:05 AM JST | 12:00 AM - 12:05 AM UTC

[HTT17-01] Introduction

9:05 AM - 9:25 AM JST | 12:05 AM - 12:25 AM UTC

[HTT17-02] Accumulation pattern of near-seafloor methane gas revealed by a shallow seismic survey in the northern Tokyo Bay

*Tetsuro Tsuru[1], Kazuki Takanaka[1], Koichi Fujimoto[1], Osamu Takano[2], Yukio Nakagawa[3], Naoto Kumagai[1] (1.Tokyo University of Marine Science and Technology, 2.University of Tsukuba, 3.Tobako LLC)

9:25 AM - 9:45 AM JST | 12:25 AM - 12:45 AM UTC

[HTT17-03] Imaging of near surface structure beneath a coastal plain by means of high-resolution S-wave seismic reflection survey

*Tomio INAZAKI[1], Kyoko Kagohara[2], Shinsuke Okada[3], Takayuki Nakano[4], Nobuhisa Matta[5] (1.Research Institute of Geology and Geoinformation, AIST, 2.Yamaguchi Univ., 3.Iwate Univ., 4.GSI, 5.Okayama Univ.)

9:45 AM - 10:05 AM JST | 12:45 AM - 1:05 AM UTC

[HTT17-04] Differences in P-wave velocities due to velocity logging in overlapping sections of horizontal boring surveys in sedimentary rock tunnel ground

*Kenji OKAZAKI[1], Toshiyuki KURAHASHI[1] (1.Civil Engineering Research Institute for cold region, Public Works Research Institute)

10:05 AM - 10:25 AM JST | 1:05 AM - 1:25 AM UTC

[HTT17-05] Applicability of Distributed Acoustic Sensing (DAS) technology for surface wave measurement

*Hayato Nonaka[1], Peter Hubbard[2], Koichi Hayashi[3], Yasuhiro Yokota[1], Kensuke Date[1], Kazuhiko Masumoto[1], Kenichi Soga[2] (1.Kajima corporation, 2.University of California, Berkeley, 3.OYO Corporation)

10:25 AM - 10:30 AM JST | 1:25 AM - 1:30 AM UTC

[HTT17-06] Discussion

[J] Oral | H (Human Geosciences)：H-TT Technology & Techniques

10:45 AM - 12:15 PM JST | 1:45 AM - 3:15 AM UTC | Ch.15 Zoom Room 15

[H-TT17] New Developments in Shallow Geophysics

convener:Kyosuke Onishi(Public Works Research Institute), Kunio Aoike(Oyo corporation), Tishiyuki Yokota(National Institute of Advanced Industrial Science and Technology), Toru Takahashi(Fukada Geological Institute), Chairperson:Kyosuke Onishi(Public Works Research Institute), Tishiyuki Yokota(National Institute of Advanced Industrial Science and Technology)

10:45 AM - 10:50 AM JST | 1:45 AM - 1:50 AM UTC

[HTT17-07] Introduction

10:50 AM - 11:10 AM JST | 1:50 AM - 2:10 AM UTC

[HTT17-08] CCR survey using plate electrodes

*Chisato Konishi[1], Hiroshi Kisanuki[1], Dennis Wilkison (1.OYO Corporation)

11:10 AM - 11:30 AM JST | 2:10 AM - 2:30 AM UTC

[HTT17-09] Differential tomography of continuously repeated measurement data using electrical exploration method - Application to monitor changes in soil moisture content due to rainfall

*Ryota Watatani[1], Koichi Suzuki[2] (1.Cooperative Program for Resources Engineering, Graduate School of Engineering, Hokkaido University, 2.Research Group of Geoenvironmental Engineering, Division of Sustainable Resource Engineering, Faculty of Engineering, Hokkaido University)

11:30 AM - 11:50 AM JST | 2:30 AM - 2:50 AM UTC

[HTT17-10] Subsurface exploration by multifrequency electromagnetic portable senser GEM-2 at the Goshogake geothermal area

*Shin'ya Sakanaka[1], Keigo Tsuboe[1], Yuya Tada[1], Inoue Yusuke[2], Shura Taomote[3], Ritsu Sakiyama[1] (1.Graduate school of International Resource Sciences, Akita University, 2.OYO corporation, 3.Faculty of International Resource Sciences, Akita University)

11:50 AM - 12:10 PM JST | 2:50 AM - 3:10 AM UTC

[HTT17-11] Bayesian estimation method of near-surface density under irregular distribution of gravity network

*Yuanyuan Niu[1], Jiancang Zhuang[1] (1.Institute of Statistical Mathematics)

12:10 PM - 12:15 PM JST | 3:10 AM - 3:15 AM UTC

[HTT17-12] Discussion

[J] Oral | H (Human Geosciences)：H-CG Complex & General

1:45 PM - 3:15 PM JST | 4:45 AM - 6:15 AM UTC | Ch.14 Zoom Room 14

[H-CG28] Earth surface processes related to deposition, erosion and sediment transport

convener:Koji Seike(Geological Survey of Japan, AIST), Masayuki Ikeda(University of Tokyo), Hajime Naruse(Department of Geology and Mineralogy, Graduate School of Science, Kyoto University), Hideko Takayanagi(Institute of Geology and Paleontology, Graduate School of Science, Tohoku University), Chairperson:Koji Seike(Geological Survey of Japan, AIST), Masayuki Ikeda(University of Tokyo), Hajime Naruse(Department of Geology and Mineralogy, Graduate School of Science, Kyoto University), Hideko Takayanagi(Institute of Geology and Paleontology, Graduate School of Science, Tohoku University)

1:45 PM - 2:00 PM JST | 4:45 AM - 5:00 AM UTC

[HCG28-01] Sedimentary environment and earthquake history off Cape Muroto, SW Japan

*Juichiro Ashi[1], Toshiya Kanamatsu[2], Masafumi MURAYAMA[3] (1.The University of Tokyo, 2.JAMSTEC, 3.Kochi University)

2:00 PM - 2:15 PM JST | 5:00 AM - 5:15 AM UTC

[HCG28-02] Detrital Zircon and Provenance Analysis of Sedimentary Rock in the Nemuro and Urahoro Groups, Eastern Hokkaido, Northern Japan

*Harisma Harisma[1], Hisashi Asanuma[2], Takafumi Hirata[2], Hajime Naruse[1] (1.Kyoto University, 2.University of Tokyo)

2:15 PM - 2:30 PM JST | 5:15 AM - 5:30 AM UTC

[HCG28-03] Numerical study on formation mechanism of *shoal* and *cauldron* topographies on the seafloor in the eastern Seto Inland Sea

*Motoki Ubara[1], Yusuke Uchiyama[1], Taichi Kosako[2] (1.Graduate School of Engineering, Kobe University, 2.Coastal and Estuarine Environment Department, Port and Airport Research Institute)

2:30 PM - 2:45 PM JST | 5:30 AM - 5:45 AM UTC

[HCG28-04] Long-term perspectives on coastal changes of the Mekong delta, Vietnam

*Toru Tamura[1] (1.Institute of Geology and Geoinformation Geological Survey of Japan, AIST)

2:45 PM - 3:00 PM JST | 5:45 AM - 6:00 AM UTC

[HCG28-05] Ichnodiversity in the Upper Cretaceous submarine channel-levee deposits: examples from the northern and southwest Japan

*Kazuki Kikuchi[1], Hajime Naruse[1] (1.Division of Earth and Planetary Sciences, Guraduate School of Science, Kyoto University)

3:00 PM - 3:15 PM JST | 6:00 AM - 6:15 AM UTC

[HCG28-06] Behavior of plucking of bedrock with fully developed joints and its sensitivity to surface roughness

*Masahiro Ishizuka[1], Noritaka Endo[1] (1.Kanazawa University)

[J] Oral | S (Solid Earth Sciences)：S-SS Seismology

1:45 PM - 3:15 PM JST | 4:45 AM - 6:15 AM UTC | Ch.22 Zoom Room 22

[S-SS05] Crustal Deformation

convener:Masayuki Kano(Graduate school of science, Tohoku University), Tadafumi Ochi(Institute of Earthquake and Volcano Geology, Geological Survey of Japan, The National Institute of Advanced Industrial Science and Technology), Fumiaki Tomita(Japan Agency for Marine-Earth Science and Technology), Chairperson:Yoshiyuki Tanaka(Earth and Planetary Science, The University of Tokyo), Keisuke Yano(The Institute of Statistical Mathematics)

1:45 PM - 2:00 PM JST | 4:45 AM - 5:00 AM UTC

[SSS05-01] Formation simulation of imbrication and décollement under uniform compression based on the elasto-plastic soil mechanics

*Tomohiro Toyoda[1], Toshihiro Noda[1], Kazuya Onishi[2], Akira Asaoka[3] (1.Nagoya University, Disaster Mitigation Research Center, 2.Nagoya University, School of Engineering, 3.Association for the Development of Earthquake Prediction)

2:00 PM - 2:15 PM JST | 5:00 AM - 5:15 AM UTC

[SSS05-02] **Estimate of Strain Rate Field in Japan from GNSS Data: Comparison between Shen's Method and Basis Function Expansion**

*Tomohisa Okazaki[1], Yukitoshi Fukahata[2], Takuya NISHIMURA[2] (1.RIKEN Center for Advanced Intelligence Project, 2.Disaster Prevention Research Institute, Kyoto University)

2:15 PM - 2:30 PM JST | 5:15 AM - 5:30 AM UTC

[SSS05-03] A Bayesian approach to estimating the crustal strain-rate fields from GNSS data and application to data from Mainland China

*ZIYAO XIONG[1], Jiancang Zhuang[1] (1.Institute of Statistical Mathematics)

2:30 PM - 2:45 PM JST | 5:30 AM - 5:45 AM UTC

[SSS05-04] Effects of curvature and lateral heterogeneities in elasticity constants on coseismic deformation

*Yoshiyuki Tanaka[1] (1.Department of Earth and Planetary Science, The University of Tokyo)

2:45 PM - 3:00 PM JST | 5:45 AM - 6:00 AM UTC

[SSS05-05] Applicability of the Hamiltonian Monte Carlo method for single rectangular fault estimation

*Taisuke Yamada[1], Yusaku Ohta[1] (1.Research Center for Prediction of Earthquakes and Volcanic Eruptions, Graduate School of Science, Tohoku University)

3:00 PM - 3:15 PM JST | 6:00 AM - 6:15 AM UTC

[SSS05-06] Automatic detection of short-term slow slip events using GNSS data: An l1-trend filtering approach

*Keisuke Yano[1], Masayuki Kano[2] (1.The Institute of Statistical Mathematics, 2.Tohoku University)

[J] Oral | S (Solid Earth Sciences)：S-SS Seismology

3:30 PM - 5:00 PM JST | 6:30 AM - 8:00 AM UTC | Ch.22 Zoom Room 22

[S-SS05] Crustal Deformation

convener:Masayuki Kano(Graduate school of science, Tohoku University), Tadafumi Ochi(Institute of Earthquake and Volcano Geology, Geological Survey of Japan, The National Institute of Advanced Industrial Science and Technology), Fumiaki Tomita(Japan Agency for Marine-Earth Science and Technology), Chairperson:Yusaku Ohta(Research Center for Prediction of Earthquakes and Volcanic Eruptions, Graduate School of Science, Tohoku University), Yusuke Yokota(Institute of Industrial Science, The University of Tokyo)

3:30 PM - 3:45 PM JST | 6:30 AM - 6:45 AM UTC

[SSS05-07] New stable slip on the plate in a wide area after 2015 detected by postseismic deformation model of 2011 Tohoku-Oki Earthquake

*Satoshi Fujiwara[1], Mikio Tobita[1], Shinzaburo Ozawa[1] (1.Geospatial Information Authority of Japan)

3:45 PM - 4:00 PM JST | 6:45 AM - 7:00 AM UTC

[SSS05-08] Preliminary results of sea-floor crustal deformation measured by GNSS-Acoustic technique in Nemuro-Oki, southwestern part of Kuril Trench

*Yusaku Ohta[1], Motoyuki Kido[2], Chie Honsho[1], Yukiho Kimura[1], Makiko Sato[1], Syuichi Suzuki[1], Ryosuke Azuma[1], Mako Ohzono[3,5], Hiroki Aota[3], Hiroaki Takahashi[3], Fumiaki Tomita[4], Takeshi Iinuma[4], Masanao Shinohara[5], Ryota Hino[1] (1.Research Center for Prediction of Earthquakes and Volcanic Eruptions, Graduate School of Science, Tohoku University, 2.International Research Institute of Disaster Science, Tohoku University, 3. Institute of Seismology and Volcanology, Faculty of Science, Hokkaido University, 4.Japan Agency for Marine-Earth Science and Technology, 5.Earthquake Research Institute,The University of Tokyo)

4:00 PM - 4:15 PM JST | 7:00 AM - 7:15 AM UTC

[SSS05-09] Monitoring of the inter-plate coupling using GNSS-A seafloor geodesy along the Nankai trough

*Tadashi Ishikawa[1], Shun-ichi Watanabe[1], Yuto Nakamura[1], Yusuke Yokota[2] (1.Hydrographic and Oceanographic Department, Japan Coast Guard, 2.Institute of Industrial Science, the University of Tokyo)

4:15 PM - 4:30 PM JST | 7:15 AM - 7:30 AM UTC

[SSS05-10] Relationship between observation ability of GNSS-A and its detection ability for coupling condition and SSE

*Yusuke Yokota[1], Tadashi Ishikawa[2], Shun-ichi Watanabe[2], Yuto Nakamura[2] (1.Institute of Industrial Science, The University of Tokyo, 2.Hydrographic and Oceanographic Department, Japan Coast Guard)

4:30 PM - 4:45 PM JST | 7:30 AM - 7:45 AM UTC

[SSS05-11] **Estimation of Average Displacement Rate Vector Using GNSS Data in Yaeyama Islands**

*Aoi Ikeichi[1], Masayuki Kano[1], Hisashi Nakahara[1], Takeshi Nishimura[1], Kazuki Komano[2], Takuya NISHIMURA[3], SHINICHI MIYAZAKI[2] (1.Graduate School of Science, Tohoku University, 2.Graduate School of Science, Kyoto University, 3.Disaster Prevention Research Institute, Kyoto University)

4:45 PM - 5:00 PM JST | 7:45 AM - 8:00 AM UTC

[SSS05-12] **Possible overlap of coseismic slip and afterslip investigated by InSAR analysis**

*Kanami Sakamoto[1], Yo Fukushima[2] (1.Graduate School of Science, Tohoku University, 2.International Research Institute of Disaster Science, Tohoku University)

[J] Oral | S (Solid Earth Sciences)：S-SS Seismology

9:00 AM - 10:30 AM JST | 12:00 AM - 1:30 AM UTC | Ch.20 Zoom Room 20

[S-SS06] Statistical seismology and underlying physical processes

convener:Yasuhiro Yoshida(Meteorological Research Institute, Japan Meteorological Agency), Chairperson:Youichi Asano(National Research Institute for Earth Science and Disaster Prevention), Yohei Yukutake(Earthquake Research Institute, University of Tokyo)

9:00 AM - 9:15 AM JST | 12:00 AM - 12:15 AM UTC

[SSS06-01] Aseismic process driving the earthquake swarm, revealed by the dense seismic observation

*Yohei Yukutake[1], Keisuke Yoshida[2], Ryou Honda[1] (1.Hot Springs Research Institute of Kanagawa Prefecture, 2.Tohoku University)

9:15 AM - 9:30 AM JST | 12:15 AM - 12:30 AM UTC

[SSS06-02] Statistical analysis and its characteristics of the earthquake activity near the border of Nagano, Gifu and Fukui prefectures

*Takao Kumazawa[1], Yosihiko Ogata[2] (1.Earthquake Research Institute, The University of Tokyo, 2.The Institute of Statistical Mathematics)

9:30 AM - 9:45 AM JST | 12:30 AM - 12:45 AM UTC

[SSS06-03] Seismic activity around Kamikochi, Nagano Prefecture after the M5.5 earthquake on April 23, 2020

*Takayuki Kawabe[1] (1.Ex. Faculty of Education, Arts and Sciences, Yamagata University)

9:45 AM - 10:00 AM JST | 12:45 AM - 1:00 AM UTC

[SSS06-04] A simple way to distinguish rather shallow PAC-intraplate events from interplate ones around Japan

*Ritsuko S. Matsu'ura[1], Takeo Ishibe[1], Koji Iwasa[1] (1.Earthquake Research Center, Association for the Development of Earthquake Prediction)

10:00 AM - 10:15 AM JST | 1:00 AM - 1:15 AM UTC

[SSS06-05] Hypocenter determination assuming a 1-D velocity model with station corrections and its result for the Tohoku region

*Youichi Asano[1] (1.National Research Institute for Earth Science and Disaster Resilience)

10:15 AM - 10:30 AM JST | 1:15 AM - 1:30 AM UTC

[SSS06-06] Seismicity distribution in the Tonankai and Nankai seismogenic zones and its spatial relationship with interplate coupling and slow earthquakes

*Yojiro Yamamoto[1], Shuichiro Yada[1], Keisuke Ariyoshi[1], Takane Hori[1], Narumi Takahashi[2] (1.JAMSTEC, 2.NIED)

[J] Oral | S (Solid Earth Sciences)：S-SS Seismology

10:45 AM - 12:15 PM JST | 1:45 AM - 3:15 AM UTC | Ch.20 Zoom Room 20

[S-SS06] Statistical seismology and underlying physical processes

convener:Yasuhiro Yoshida(Meteorological Research Institute, Japan Meteorological Agency), Chairperson:Kohei Nagata(Meteorological Research Institute), Masatoshi Miyazawa(Disaster Prevention Research Institute, Kyoto University)

10:45 AM - 11:00 AM JST | 1:45 AM - 2:00 AM UTC

[SSS06-07] Toward the construction of an integrated assessment method of crustal activity - characterization of “normal” seismicity in Japan-

*Kohei Nagata[1], Koji Tamaribuchi[1], Fuyuki Hirose[1], Akemi Noda[1] (1.Meteorological Research Institute)

11:00 AM - 11:15 AM JST | 2:00 AM - 2:15 AM UTC

[SSS06-08] A hierarchical model of earthquake asperity

*Yoshio Fukao[1] (1.Center for Earthquake and Tsunami / Japan Agency for Marine-Earth Science & Technology)

11:15 AM - 11:30 AM JST | 2:15 AM - 2:30 AM UTC

[SSS06-09] Radiation-corrected empirical Green's function in slip inversion

*Ritsuya Shibata[1], Genki Oikawa[1], Naofumi Aso[1], Junichi Nakajima[1], Satoshi Ide[2] (1.Department of Earth and Planetary Sciences, Tokyo Institute of Technology, 2.Department of Earth and Planetary Science, The University of Tokyo)

11:30 AM - 11:45 AM JST | 2:30 AM - 2:45 AM UTC

[SSS06-10] Modeling dynamic rupture and statistical properties of earthquakes with cellular automaton models.

*Kota Fukuda[1], Takahiro Hatano[2], Kimihiro Mochizuki[1] (1.Earthquake Research Institute The University of Tokyo, 2.Department of Earth and Space Science Osaka University)

11:45 AM - 12:00 PM JST | 2:45 AM - 3:00 AM UTC

[SSS06-11] Dynamic earthquake triggering in Southern California in high resolution

*Masatoshi Miyazawa[1], Emily E Brodsky[2], Huiyun Guo[2] (1.Disaster Prevention Research Institute, Kyoto University, 2.University of California, Santa Cruz)

12:00 PM - 12:15 PM JST | 3:00 AM - 3:15 AM UTC

[SSS06-12] Discussion

[J] Oral | S (Solid Earth Sciences)：S-SS Seismology

10:45 AM - 11:45 AM JST | 1:45 AM - 2:45 AM UTC | Ch.19 Zoom Room 19

[S-SS07] Crustal Structure

convener:Mikiya Yamashita(National Institute of Advanced Industrial Science and Technology), Chairperson:Kazuya Shiraishi(Japan Agency for Marine-Earth Science and Technology)

10:45 AM - 11:00 AM JST | 1:45 AM - 2:00 AM UTC

[SSS07-01] Examination of applicability of seismic interferometry in exploration of underground structure under a volcanic body

*Hirofumi Kowari[1], Koji Yamada[1], Tatsuyuki Ueno[1] (1.Hanshin Consultants Co., Ltd.)

11:00 AM - 11:15 AM JST | 2:00 AM - 2:15 AM UTC

[SSS07-02] Deep seismic reflection profiling across the Tsugaru peninsula, northern Honshu, Japan

*Hiroshi Sato[1,2], Tatsuya Ishiyama[1], Hideo Saito[3], Mamoru Nakata[3], Naoko Kato[1], Susumu Abe[3] (1.Earthquake Research Institute, The University of Tokyo, 2.Center for integrated Research and Education of Natural Hazards, Shizuoka University, 3.JGI, Inc.)

11:15 AM - 11:30 AM JST | 2:15 AM - 2:30 AM UTC

[SSS07-03] Deep crustal seismic profiling from airgun-OBS surveys offshore Niigata-Yamagata: reflection imaging via reverse time migration

*Kazuya Shiraishi[1], Tetsuo No[1], Gou Fujie[1] (1.Japan Agency for Marine-Earth Science and Technology)

11:30 AM - 11:45 AM JST | 2:30 AM - 2:45 AM UTC

[SSS07-04] Revealing structures in the shallow crust beneath Botswana, southern Africa: considering dip and anisotropy

*Admore Phindani Mpuang[1,2], Takuo Shibutani[2] (1.Graduate School of Science, Kyoto University, 2.Research Center for Earthquake Prediction, Disaster Prevention Research Institute, Kyoto University)

[J] Oral | S (Solid Earth Sciences)：S-SS Seismology

3:30 PM - 5:00 PM JST | 6:30 AM - 8:00 AM UTC | Ch.20 Zoom Room 20

[S-SS08] Fault Rheology and Earthquake Physics

convener:Shunya Kaneki(Disaster Prevention Research Institute, Kyoto University), Makiko Ohtani(Earthquake Research Institute, the University of Tokyo), Keishi Okazaki(Japan Agency for Marine-Earth Science and Technology), Keisuke Yoshida(Tohoku University), Chairperson:Makiko Ohtani(Earthquake Research Institute, the University of Tokyo), Keisuke Yoshida(Tohoku University)

3:30 PM - 3:45 PM JST | 6:30 AM - 6:45 AM UTC

[SSS08-01] **Fault frictional heterogeneities can explain earthquakes with no foreshocks, accelerating foreshocks and earthquake swarms observed in central Alaska**

★Invited Papers

*Yoshihiro Kaneko[1], Nealey Sims[2], Carl Tape[2], Stephen Holtkamp[2], Andrea Perez[3] (1.Kyoto University, 2.University of Alaska - Fairbanks, 3.Victoria University of Wellington)

3:45 PM - 4:00 PM JST | 6:45 AM - 7:00 AM UTC

[SSS08-02] Rupture segmentation caused by fault bends in simulated earthquake sequences

*So Ozawa[1], Ryosuke Ando[1] (1.Graduate School of Science, the University of Tokyo)

4:00 PM - 4:15 PM JST | 7:00 AM - 7:15 AM UTC

[SSS08-03] Energy-based scenarios for the Nankai trough subduction earthquakes: Stress accumulation model taking historical earthquakes into account

*Akemi Noda[1], Tatsuhiko Saito[2] (1.Meteorological Research Institute, Japan Meteorological Agency, 2.National Research Institute for Earth Science and Disaster Resilience)

4:15 PM - 4:30 PM JST | 7:15 AM - 7:30 AM UTC

[SSS08-04] **Estimation of absolute shear stress in the source region of large earthquakes based on estimates of fault fracture energy**

*Nelson Pulido[1] (1.National Research Institute for Earth Science and Disaster Resilience)

4:30 PM - 4:45 PM JST | 7:30 AM - 7:45 AM UTC

[SSS08-05] Three-dimensional tectonic stress fields estimated from seismic data for long-term periods with direct prior information

*Toshiko Terakawa[1] (1.Earthquake and Volcano Research Center, Graduate School of Environmental Studies, Nagoya University)

4:45 PM - 5:00 PM JST | 7:45 AM - 8:00 AM UTC

[SSS08-06] Spatial and temporal change of stress field in the focal area of the 2016 Kaikoura earthquake, New Zealand (2)

Miu Matsuno[1], Ayaka Tagami[1], *Tomomi Okada[1], Satoshi Matsumoto[2], Yuta Kawamura[2], Yoshihisa Iio[3], Tadashi Sato[1], Takashi NAKAYAMA[1], Satoshi Hirahara[1], Stephen Bannister[4], John Ristau[4], Martha K Savage[5], Clifford H Thurber[6], Richard H Sibson[7] (1.Research Center for Prediction of Earthquakes and Volcanic Eruptions, Graduate School of Science, Tohoku University, 2.Institute of Seismology and Volcanology, Faculty of Science, Kyushu University, 3.Disaster Prevention Research Institute, Kyoto University, 4.GNS Science, New Zealand, 5.Victoria University of Wellington, New Zealand, 6.University of Wisconsin - Madison, United States of America, 7.University of Otago, New Zealand)

[J] Oral | S (Solid Earth Sciences)：S-EM Earth's Electromagnetism

9:00 AM - 10:30 AM JST | 12:00 AM - 1:30 AM UTC | Ch.23 Zoom Room 23

[S-EM14] Electromagnetic Induction in the Earth and Planetary Interiors, and Tectono-Electromagnetism

convener:Maki Hata(Earthquake Research Institute, the University of Tokyo), Mitsuru Utsugi(Aso Volcanological Laboratory, Institute for Geothermal Sciences, Graduate School of Science, Kyoto University), Chairperson:Takuto Minami(Division of Frontier Planetology, Department of Planetology, Graduate School of Science, Kobe University), Maki Hata(Earthquake Research Institute, the University of Tokyo)

9:00 AM - 9:15 AM JST | 12:00 AM - 12:15 AM UTC

[SEM14-01] Imaging the magma plumbing system of Mt. Meakandake volcano based on broadband magnetotellurics and three-dimensional resistivity modelling

*Tomohiro Inoue[1], Takeshi Hashimoto[1], Ryo Tanaka[1], Yusuke Yamaya[2], Hiroshi Ichihara[3] (1.Graduate School of Science,Hokkaido University, 2.National Institute of Advanced Industrial Science and Technology, 3.Graduate School of environmental Studies, Nagoya University)

9:15 AM - 9:30 AM JST | 12:15 AM - 12:30 AM UTC

[SEM14-02] Three-dimensional resistivity structure of the Tarumae volcanic region using MT data

*Takaya Yamagiwa[1], KENTARO AOYAMA[1], Koichi Suzuki[1], Toru Mogi[2], Yusuke Yamaya[3] (1.Hokkaido University, 2.Faculty of Science, Tokyo Institute of Technology, 3.National Institute of Advanced Industrial Science and Technology)

9:30 AM - 9:45 AM JST | 12:30 AM - 12:45 AM UTC

[SEM14-03] 3-D resistivity models beneath Aso caldera by new and old Network-MT dipole data arranged into reticular shapes

*Maki Hata[1], Makoto Uyeshima[1], Mitsuru Utsugi[2], Nobuo Matsushima[3], Yoshikazu Tanaka, Takeshi Hashimoto[4], Ryokei Yoshimura[5], Naoto Oshiman[5] (1.Earthquake Research Institute, the University of Tokyo , 2.Aso Volcanological Laboratory, Institute for Geothermal Sciences, Graduate School of Science, Kyoto University, 3.Geological Survey of Japan, 4.Institute of Seismology and Volcanology, Graduate School of Science, Hokkaido University, 5.Disaster Prevention Research Institute, Kyoto University)

9:45 AM - 10:00 AM JST | 12:45 AM - 1:00 AM UTC

[SEM14-04] Toward joint inversion of AMT and ACTIVE data sets for better understanding of the hydrothermal system of Aso volcano

*Takuto Minami[1], Mitsuru Utsugi[2], Wataru Kanda[3], Marceau Gresse[4] (1.Division of Frontier Planetology, Department of Planetology, Graduate School of Science, Kobe University, 2.Aso Volcanological Laboratory, Graduate School of Science, Kyoto University, 3.Volcanic Fluid Research Center, School of Science, Tokyo Institute of Technology, 4.Earthquake Research Institute, University of Tokyo)

10:00 AM - 10:15 AM JST | 1:00 AM - 1:15 AM UTC

[SEM14-05] Electromagnetic field fluctuations by infrasound during the eruption of Kirishima Shinmoe-dake in 2018

*Satoru ANIYA[1], Koki Aizawa[2], Takeshi Matsushima[2] (1.Department of Earth and Planetary Sciences,Graduate School of Sciences,Kyushu University, 2.Institute of Seismology and Volcanology, Faculty of Sciences, Kyushu University)

10:15 AM - 10:30 AM JST | 1:15 AM - 1:30 AM UTC

[SEM14-06] Time Series Analyses of EM-ACROSS Data

*Sohei Serita[1], Yasuo Ogawa[1], Kuo Hsuan Tseng[1], Keiichi Ishizu[1], Takahiro Kunitomo[2], Takuto Minami[3], Hiroshi Ichihara[2], T Grant Caldwell[4] (1.Tokyo Institute of Technology, 2.Nagoya University, 3.Kobe University, 4.GNS Science)

[J] Oral | S (Solid Earth Sciences)：S-EM Earth's Electromagnetism

10:45 AM - 12:15 PM JST | 1:45 AM - 3:15 AM UTC | Ch.23 Zoom Room 23

[S-EM14] Electromagnetic Induction in the Earth and Planetary Interiors, and Tectono-Electromagnetism

convener:Maki Hata(Earthquake Research Institute, the University of Tokyo), Mitsuru Utsugi(Aso Volcanological Laboratory, Institute for Geothermal Sciences, Graduate School of Science, Kyoto University), Chairperson:Ken'ichi Yamazaki(Disaster Prevention Research Institute, Kyoto University), Mitsuru Utsugi(Aso Volcanological Laboratory, Institute for Geothermal Sciences, Graduate School of Science, Kyoto University)

10:45 AM - 11:10 AM JST | 1:45 AM - 2:10 AM UTC

[SEM14-07] Accuracy and precision evaluation of the new method for the absolute magnetic measurements

★Invited Papers

*Hideyuki Hirahara[1], Junpei Oogi[1], Megumi Kaito[1], Seiki Asari[1] (1.Kakioka Magnetic Observatory, Japan Meteorological Agency.)

11:10 AM - 11:25 AM JST | 2:10 AM - 2:25 AM UTC

[SEM14-08] Piezomagnetic fields associated with a dislocation source in a layered elastic medium

*Ken'ichi Yamazaki[1] (1.Disaster Prevention Research Institute, Kyoto University)

11:25 AM - 11:40 AM JST | 2:25 AM - 2:40 AM UTC

[SEM14-09] Development and Application of Noise Reduction Method using two-stage MSSA (Multichannel Singular Spectrum Analysis) for MT data in Boso, Japan

*Shu Kaneko[1], Katsumi Hattori[2], Toru Mogi[2], Chie Yoshino[2] (1.Chiba University Graduate School of Science and Engineering, 2.Chiba University Graduate School of Science)

11:40 AM - 11:55 AM JST | 2:40 AM - 2:55 AM UTC

[SEM14-10] Understanding the spatial distribution characteristics of the MT response using Variogram

*Nagi Yamashita[1], Tada-nori Goto[1], Satoru Yamaguchi[2] (1.University of Hyogo, 2.Osaka City University)

11:55 AM - 12:10 PM JST | 2:55 AM - 3:10 AM UTC

[SEM14-11] Development of a 3D inversion code to consider ocean bottom magnetotelluric data including topographic distortion ~forward modeling part~

*Masamitsu Araki[1], Tetsuo Matsuno[1], Nobukazu Seama[1], Takuto Minami[1] (1.Department of Planetology, Graduate School of Science, Kobe University)

12:10 PM - 12:15 PM JST | 3:10 AM - 3:15 AM UTC

[SEM14-12] Discussion

[J] Oral | S (Solid Earth Sciences)：S-IT Science of the Earth's Interior & Techtonophysics

1:45 PM - 3:15 PM JST | 4:45 AM - 6:15 AM UTC | Ch.24 Zoom Room 24

[S-IT21] Innovation through the Integration of Solid Earth Science and Materials Science

convener:Kenji Kawai(Department of Earth and Planetary Science, School of Science, University of Tokyo), Jun Tsuchiya(Geodynamics Research Center, Ehime University), Ryuichi Nomura(Kyoto University), Satoshi Ohmura(Hiroshima Institute of Technology), Chairperson:Kenji Kawai(Department of Earth and Planetary Science, School of Science, University of Tokyo), Ryuichi Nomura(Kyoto University)

1:45 PM - 1:50 PM JST | 4:45 AM - 4:50 AM UTC

[SIT21-01] Introduction

1:50 PM - 2:20 PM JST | 4:50 AM - 5:20 AM UTC

[SIT21-02] Time-resolved transmission electron microscopy toward operando-measurement in geoscience

★Invited Papers

*Kuwahara Makoto[1] (1.Nagoya University)

2:20 PM - 2:35 PM JST | 5:20 AM - 5:35 AM UTC

[SIT21-03] Ab initio modeling of antigorite transported by subducting oceanic plates

*Jun Tsuchiya[1], Sayako Inoue[1] (1.Geodynamics Research Center, Ehime University)

2:35 PM - 3:05 PM JST | 5:35 AM - 6:05 AM UTC

[SIT21-04] Properties of liquid Fe mixtures under high-pressure conditions

★Invited Papers

*Satoshi Ohmura[1], Taku Tsuchiya[2] (1.Hiroshima Institute of Technology, 2.Ehime Univ.)

3:05 PM - 3:15 PM JST | 6:05 AM - 6:15 AM UTC

[SIT21-05] Discussion

[J] Oral | S (Solid Earth Sciences)：S-IT Science of the Earth's Interior & Techtonophysics

3:30 PM - 5:00 PM JST | 6:30 AM - 8:00 AM UTC | Ch.24 Zoom Room 24

[S-IT21] Innovation through the Integration of Solid Earth Science and Materials Science

convener:Kenji Kawai(Department of Earth and Planetary Science, School of Science, University of Tokyo), Jun Tsuchiya(Geodynamics Research Center, Ehime University), Ryuichi Nomura(Kyoto University), Satoshi Ohmura(Hiroshima Institute of Technology), Chairperson:Satoshi Ohmura(Hiroshima Institute of Technology), Jun Tsuchiya(Geodynamics Research Center, Ehime University)

3:30 PM - 4:00 PM JST | 6:30 AM - 7:00 AM UTC

[SIT21-06] High spatial resolution electronic structure analysis by scanning transmission electron microscopy and electron energy loss spectroscopy

★Invited Papers

*Mitsutaka Haruta[1] (1.Kyoto University)

4:00 PM - 4:30 PM JST | 7:00 AM - 7:30 AM UTC

[SIT21-07] Molecular Dynamics Simulation of Shock-Induced Structural Transformation of Silica Using Artificial Neural Network

★Invited Papers

*Masaaki Misawa[1], Kohei Shimamura[2], Fuyuki Shimojo[2] (1.Okayama Univ., 2.Kumamoto Univ.)

4:30 PM - 4:45 PM JST | 7:30 AM - 7:45 AM UTC

[SIT21-08] Deformation mechanisms maps of bridgmanite based on high pressure experiments

*Noriyoshi Tsujino[1], Daisuke Yamazaki[1] (1.Institute for Planetary Materials, Okayama University)

4:45 PM - 5:00 PM JST | 7:45 AM - 8:00 AM UTC

[SIT21-09] Waveform inversion for the structure of Earth's deep interior: Progress and Prospects

*Kenji Kawai[1] (1.Department of Earth and Planetary Science, School of Science, University of Tokyo)

[J] Oral | S (Solid Earth Sciences)：S-VC Volcanology

1:45 PM - 3:15 PM JST | 4:45 AM - 6:15 AM UTC | Ch.25 Zoom Room 25

[S-VC30] Volcanic and igneous activities, and these long-term forecasting

convener:Takeshi Hasegawa(Department of Earth Sciences, College of Science, Ibaraki University), Teruki Oikawa(GSJ, National Institute of Advanced Industrial Science and Technology), Daisuke MIURA(Department of Physical Science, Graduate School of Science, Osaka Prefecture University), Nobuo Geshi(Geological Survey of Japan, The National Institute of Advanced Industrial Science and Technology), Chairperson:Tomohiro Tsuji(Division of Earth Science The Graduate School of Science and Technology for Innovation Yamaguchi University), Chisato Anai(Aso Volcanological Laboratory, Institute for Geothermal Sciences, Graduate School of Science, Kyoto University)

1:45 PM - 2:00 PM JST | 4:45 AM - 5:00 AM UTC

[SVC30-01] Paleomagnetic evidence for polygenetic origin of Mamiyadake tephra ring, Ohachidaira maar-caldera complex, Hokkaido, Japan

*Yuki Yasuda[1] (1.Institute of Seismology and Volcanology, Faculty of Science, Hokkaido University)

2:00 PM - 2:15 PM JST | 5:00 AM - 5:15 AM UTC

[SVC30-02] Constraining residence times of plagioclase phenocrysts at the latest activity of Zao volcano

*Motohiro Sato[1], Masao Ban[1] (1.Graduate School of Science and Technology, Yamagata University)

2:15 PM - 2:30 PM JST | 5:15 AM - 5:30 AM UTC

[SVC30-03] Inverse crystallization order of phenocrysts in high-Mg basalt from Ryozen Formation, Fukushima prefecture

*Tsukasa Ohba[1], Tokiya Ando[1] (1.Faculty of International Resource Sciences, Akita University)

2:30 PM - 2:45 PM JST | 5:30 AM - 5:45 AM UTC

[SVC30-04] Discovery of new block and ash flow deposit from Azuma-kofuji volcano, Fukushima, Japan

*Takeshi Hasegawa[1], Suzuki Kazuma[1] (1.Department of Earth Sciences, College of Science, Ibaraki University)

2:45 PM - 3:00 PM JST | 5:45 AM - 6:00 AM UTC

[SVC30-05] Reexamination of the characteristics and eruption style of Haruna-Hakoda tephra found from the southern foot of Akagi Volcano to the eastern foot of Haruna Volcano in North Kanto, Northeast Japan

*Junichi Sato[1], Takehiko Suzuki[2] (1.Department of Geography, Graduate School of Urban Environmental Sciences, Tokyo Metropolitan University, 2.Faculty of Urban Environmental Sciences, Tokyo Metropolitan University)

3:00 PM - 3:15 PM JST | 6:00 AM - 6:15 AM UTC

[SVC30-06] What have been erupted from the 2020 eruption of Nishinoshima?

*Yoshihiko Tamura[1], Tomoki Sato[1], Kenta Yoshida[1], Fukashi Maeno[2], Osamu Ishizuka[1,3], Yasuhiro Hirai[1], Noriko Tada[1], Kiyoshi Baba[2], Daisuke Suetsugu[1], Maiko Miyoshi[4], Shigeaki Ono[1] (1.Research Institute for Marine Geodynamics, Japan Agency for Maine-Earth Science and Technology, 2.ERI, Univ. of Tokyo, 3.GSJ/AIST, 4.NHK)

[J] Oral | S (Solid Earth Sciences)：S-VC Volcanology

3:30 PM - 5:00 PM JST | 6:30 AM - 8:00 AM UTC | Ch.25 Zoom Room 25

[S-VC30] Volcanic and igneous activities, and these long-term forecasting

convener:Takeshi Hasegawa(Department of Earth Sciences, College of Science, Ibaraki University), Teruki Oikawa(GSJ, National Institute of Advanced Industrial Science and Technology), Daisuke MIURA(Department of Physical Science, Graduate School of Science, Osaka Prefecture University), Nobuo Geshi(Geological Survey of Japan, The National Institute of Advanced Industrial Science and Technology), Chairperson:Takeshi Hasegawa(Department of Earth Sciences, College of Science, Ibaraki University), Yuki Yasuda(Institute of Seismology and Volcanology, Faculty of Science, Hokkaido University)

3:30 PM - 3:45 PM JST | 6:30 AM - 6:45 AM UTC

[SVC30-07] Estimating magma flux from contact metamorphic aureoles

*Ken Yamaoka[1], Simon Richard Wallis[1], Akira Miyake[2], Catherine Annen[3] (1.The University of Tokyo, 2.Aichi University of Education, 3.University of Bristol)

3:45 PM - 4:00 PM JST | 6:45 AM - 7:00 AM UTC

[SVC30-08] Petrogenesis of Quaternary Yokota alkaline basalts, southwestern Japan

*Tetsuya Sakuyama[1], Izumi Kirishiki[1], Jun-Ichi Kimura[2] (1.Faculty of Science, Osaka City University, 2.JAMSTEC)

4:00 PM - 4:15 PM JST | 7:00 AM - 7:15 AM UTC

[SVC30-09] The history of 54 ka eruption of Kuju volcano

*Tomohiro Tsuji[1], Kishimoto Hiroshi[2], Koji Fujita[3], Chisato Nakamura[4], Tomohiro Nagata[4], Kazunari Kimura[4], Kozo Onishi[5], Michiharu Ikeda[6], Naoki Nishizaka[5] (1.Division of Earth Science The Graduate School of Science and Technology for Innovation Yamaguchi University, 2.kagoshima Meteorological Office, 3.Asia Air Survey Co. Ltd., 4.Naiba, 5.Shikoku Electric Power Co. Inc., 6.Shikoku Research Institute, Inc.)

4:15 PM - 4:30 PM JST | 7:15 AM - 7:30 AM UTC

[SVC30-10] Reappraising the Eruptive Age and Classification of Holocene Volcanic Products around Nakadake Crater, Aso Volcano Using Paleomagnetic and Rock Magnetic Methods

*Chisato Anai[1], Yasuo Miyabuchi[2], Mitsuru Utsugi[1], Shin Yoshikawa[1], Nobutatsu Mochizuki[3], Hidetoshi Shibuya[3], Takahiro Ohkura[1] (1.Aso Volcanological Laboratory, Institute for Geothermal Sciences, Graduate School of Science, Kyoto University, 2.Center for Water Cycle, Marine Environment and Disaster Management, Kumamoto University, 3.Department of Earth and Environmental Sciences, Faculty of Advanced Science and Technology, Kumamoto University)

4:30 PM - 4:45 PM JST | 7:30 AM - 7:45 AM UTC

[SVC30-11] Petrogenesis of Nekodake magma in Aso volcano

*Soko Kado[1], Katsuya Kaneko[1] (1.Department of Planetology, Graduate school of science, Kobe university)

4:45 PM - 5:00 PM JST | 7:45 AM - 8:00 AM UTC

[SVC30-12] Silicic magma formations in the Aira caldera region during the last 100,000 years inferred from geochemical characteristics of plagioclase

*Ayumu Nishihara[1,2], Katsuya Kaneko[1], Qing Chang[3], Nobuo Geshi[2] (1.Department of Planetology, Graduate School of Science , Kobe University, 2.Geological Survey of Japan, National Institute of Advanced Industrial Science and Technology., 3.Research Institute for Marine Geodynamics, Japan Agency for Marine-Earth Science and Technology)

[J] Oral | S (Solid Earth Sciences)：S-TT Technology & Techniques

3:30 PM - 5:00 PM JST | 6:30 AM - 8:00 AM UTC | Ch.23 Zoom Room 23

[S-TT34] Airborne surveys and monitoring of the Earth

convener:Shigekazu Kusumoto(Institute for Geothermal Sciences, Graduate School of Science, Kyoto University), Shigeo Okuma(Geological Survey of Japan, AIST), Takao Koyama(Earthquake Research Institute, The University of Tokyo), Yuji Mitsuhata(AdvancedIndustrial Science and Technology), Chairperson:Shigekazu Kusumoto(Institute for Geothermal Sciences, Graduate School of Science, Kyoto University), Takao Koyama(Earthquake Research Institute, The University of Tokyo), Shigeo Okuma(Geological Survey of Japan, AIST), Yuji Mitsuhata(AdvancedIndustrial Science and Technology)

3:30 PM - 3:45 PM JST | 6:30 AM - 6:45 AM UTC

[STT34-01] Introduction

3:45 PM - 4:00 PM JST | 6:45 AM - 7:00 AM UTC

[STT34-02] Comparison of airborne magnetic surveys by different types of aircrafts - A case of Izu-Oshima Volcano

*Shigeo Okuma[1], Tadashi Nakatsuka[1], Ayumu Miyakawa[1], Masahiko Makino[2], Shogo Komori[3], Takao Koyama[4], Takayuki Kaneko[4], Takao Ohminato[4], Atsushi Yasuda[4], Yoshiaki Honda[5] (1.Institute of Geology and Geoinformation, AIST, 2.Geological Survey of Japan, AIST, 3.Research Institute for Geo-Resources and Environment, AIST, 4.Earthquake Research Institute, Univ. of Tokyo, 5.Center for Environmental Remote Sensing, Chiba univ)

4:00 PM - 4:15 PM JST | 7:00 AM - 7:15 AM UTC

[STT34-03] Aeromagnetic survey in Kusatsu-Shirane volcano by unmanned helicopter

*Takao Koyama[1], Wataru Kanda[2], Mitsuru Utsugi[3], Takayuki Kaneko[1], Takao Ohminato[1], Atsushi Watanabe[1], Hiroshi Tsuji[1], taro nishimoto[1], Yoshiaki HONDA[4] (1.Earthquake Research Institute, The University of Tokyo, 2.Tokyo Institute of Technology, 3.Kyoto University, 4.Chiba University)

4:15 PM - 4:30 PM JST | 7:15 AM - 7:30 AM UTC

[STT34-04] Automatic estimation of regression curves indicating average depths of causative layers from power spectrum of gravity anomaly or gravity gradient (g_{zz}) data

*Shigekazu Kusumoto[1], Motonori Higashinaka[2] (1.Institute for Geothermal Sciences, Graduate School of Science, Kyoto University, 2.JGI, Inc.)

4:30 PM - 4:45 PM JST | 7:30 AM - 7:45 AM UTC

[STT34-05] Study on the behavior of the groundwater in the slope in the heavy rain using Drone Airborne TEM

*Atsuhiko Kinoshita[1,2], Suguru Shibata[2], Takao Yamakoshi[1], Hiroaki Nakaya[1], Atsuyoshi Jomori[3], Tetsuya Toyama[3], Akira Jomori[3], Kentaro Kanayama[4], Minoru Okumura[4], Katsushi Kawato[4], Muneki Mitamura[5], Tamotsu Matsui[6] (1.National Institute for Land and Infrastructure Management, 2.Sediment Disaster Prevention Technology Center, 3.NEOSCIENCE CO.LTD., 4.NIPPON ENGINEERING CONSULTANTS CO.,LTD., 5.Osaka City University, 6.Osaka University)

4:45 PM - 5:00 PM JST | 7:45 AM - 8:00 AM UTC

[STT34-06] Discussion

[J] Oral | S (Solid Earth Sciences)：S-TT Technology & Techniques

10:45 AM - 12:15 PM JST | 1:45 AM - 3:15 AM UTC | Ch.18 Zoom Room 18

[S-TT37] Seismic Big Data Analysis Based on the State-of-the-Art of Bayesian Statistics

convener:Hiromichi Nagao(Earthquake Research Institute, The University of Tokyo), Aitaro Kato(Earthquake Research Institute, the University of Tokyo), Keisuke Yano(The Institute of Statistical Mathematics), Takahiro Shiina(National Institute of Advanced Industrial Science and Technology), Chairperson:Ryo Kurihara(Earthquake Research Institute, The University of Tokyo), Takayuki Nagata(Tohoku University)

10:45 AM - 11:00 AM JST | 1:45 AM - 2:00 AM UTC

[STT37-01] Seismic noise reduction in MeSO-net during COVID-19 pandemic

★Invited Papers

*Suguru Yabe[1], Kazutoshi Imanishi[1], Kiwamu Nishida[2] (1.National Institute of Advanced Industrial Science and Technology, 2.Earthquake Research Institute, University of Tokyo)

11:00 AM - 11:15 AM JST | 2:00 AM - 2:15 AM UTC

[STT37-02] MCMC-based joint determination of earthquake hypocenters and 1-D velocity structures around a fault zone

*Takahiro Shiina[1], Masayuki Kano[2] (1.National Institute of Advanced Industrial Science and Technology (AIST), 2.Graduate School of Science, Tohoku University)

11:15 AM - 11:30 AM JST | 2:15 AM - 2:30 AM UTC

[STT37-03] Application of structured regularization to seismic tomography for adaptation to discontinuities

*Sumito Kurata[1], Yohta Yamanaka[1], Keisuke Yano[2], Fumiyasu Komaki[1], Takahiro Shiina[3], Aitaro Kato[1] (1.The University of Tokyo, 2.The Institute of Statistical Mathematics, 3.National Institute of Advanced Industrial Science and Technology)

11:30 AM - 11:45 AM JST | 2:30 AM - 2:45 AM UTC

[STT37-04] Bayesian Dynamic Mode Decomposition

★Invited Papers

*Hideitsu Hino[1] (1.The Institute of Statistical Mathematics)

11:45 AM - 12:00 PM JST | 2:45 AM - 3:00 AM UTC

[STT37-05] Sensor Selection for Seismic Wavefield Reconstruction based on Sparse Observation (Part I. Proposal and Evaluation on Method based on Linearized Model of Governing Equation)

*Kumi Nakai[1], Takayuki Nagata[1], Yuji Saito[1], Taku Nonomura[1], Masayuki Kano[1], Shin-ichi Ito[2], Hiromichi Nagao[2] (1.Tohoku University, 2.Earthquake Research Institute, The University of Tokyo)

12:00 PM - 12:15 PM JST | 3:00 AM - 3:15 AM UTC

[STT37-06] Modeling space-time heterogeneities of hypocenter catalog

*Yosihiko Ogata[1], Koiti Katsura[1] (1.Research Organization of Information and Systems, The Institute of Statistical Mathematics)

[J] Oral | S (Solid Earth Sciences)：S-CG Complex & General

9:00 AM - 10:30 AM JST | 12:00 AM - 1:30 AM UTC | Ch.21 Zoom Room 21

[S-CG50] Dynamics in mobile belts

convener:Yukitoshi Fukahata(Disaster Prevention Research Institute, Kyoto University), Hikaru Iwamori(Earthquake Research Institute, The University of Tokyo), Kiyokazu Oohashi(Graduate School of Sciences and Technology for Innovation, Yamaguchi University), Chairperson:Akinori Hashima(Japan Agency for Marine-Earth Science and Technology), Kiyokazu Oohashi(Graduate School of Sciences and Technology for Innovation, Yamaguchi University)

9:00 AM - 9:15 AM JST | 12:00 AM - 12:15 AM UTC

[SCG50-01] 3D numerical simulation of island arc deformation due to steady plate subduction: Effects of a bend along a trench axis

*Yutaro Mori[1], Yukitoshi Fukahata[2] (1.Graduate School of Science, Kyoto University, 2.Disaster Prevention Research Institute, Kyoto University)

9:15 AM - 9:30 AM JST | 12:15 AM - 12:30 AM UTC

[SCG50-02] Effect of the Philippine Sea slab–overriding plate contact on the stress field in the Southwest Japan arc

*Akinori Hashima[1], Takashi Iidaka[1] (1.Earthquake Research Institute, The University of Tokyo)

9:30 AM - 9:45 AM JST | 12:30 AM - 12:45 AM UTC

[SCG50-03] A Framework to Understand Deformation in Japanese Islands: Inter-arc Deformation and Intra-arc Deformation

*Yukitoshi Fukahata[1], Tomohisa Okazaki[2] (1.Disaster Prevention Research Institute, Kyoto University, 2.RIKEN)

9:45 AM - 10:00 AM JST | 12:45 AM - 1:00 AM UTC

[SCG50-04] Visualization of crustal deformation in a high-strain shear zone by geodetic, geomorphologic, and geologic approaches

★Invited Papers

*Masakazu Niwa[1], Koji Shimada[1], Tsuyoshi Watanabe[1], Akira Goto[1], Shinya Hiratsuka[1] (1.Tono Geoscience Center, Japan Atomic Energy Agency)

10:00 AM - 10:15 AM JST | 1:00 AM - 1:15 AM UTC

[SCG50-05] Deciphering 3-dimensional crustal movements before and after the 2011 Tohoku-oki earthquake using principal component analysis

Shuntaro Fukaya[2], *Takeshi Sagiya[1] (1.Disaster Mitigation Research Center, Nagoya University, 2.Graduate School of Environmental Studies, Nagoya University)

10:15 AM - 10:30 AM JST | 1:15 AM - 1:30 AM UTC

[SCG50-06] Effects of a crustal heterogeneity in the postseismic deformation of 2008 Iwate-Miyagi Nairiku Earthquake

*Youichiro Takada[1], Yoshiki Takei[2], James Daniel Paul Moore[3], Mako Ohzono[4] (1.Faculty of Science, Hokkaido University, 2.Graduate School of Science, Hokkaido University, 3.Nanyang Technological University, Earth Observatory of Singapore, 4.Earthquake Research Institute, University of Tokyo)

[J] Oral | S (Solid Earth Sciences)：S-CG Complex & General

10:45 AM - 12:15 PM JST | 1:45 AM - 3:15 AM UTC | Ch.21 Zoom Room 21

[S-CG50] Dynamics in mobile belts

convener:Yukitoshi Fukahata(Disaster Prevention Research Institute, Kyoto University), Hikaru Iwamori(Earthquake Research Institute, The University of Tokyo), Kiyokazu Oohashi(Graduate School of Sciences and Technology for Innovation, Yamaguchi University), Chairperson:Katsushi Sato(Division of Earth and Planetary Sciences, Graduate School of Science, Kyoto University), Hikaru Iwamori(Earthquake Research Institute, The University of Tokyo)

10:45 AM - 11:00 AM JST | 1:45 AM - 2:00 AM UTC

[SCG50-07] The evolving structure and material of normal fault in Yonaguni Island, Okinawa prefecture, Japan

*Kiyokazu Oohashi[1], Haruya Miyaki[1], Makoto Otsubo[2] (1.Graduate School of Sciences and Technology for Innovation, Yamaguchi University, 2.Geological Survey of Japan, Research Institute of Earthquake and Volcano Geology)

11:00 AM - 11:15 AM JST | 2:00 AM - 2:15 AM UTC

[SCG50-08] Tectonic development in the Median Tectonic Line and surrounding regions during the Late Cretaceous to Paleogene periods: Spatiotemporal development

★Invited Papers

*Toru Takeshita[1] (1.Department of Natural History Sciences, Graduate School of Science, Hokkaido University)

11:15 AM - 11:30 AM JST | 2:15 AM - 2:30 AM UTC

[SCG50-09] Relationship between the Northern Osaka Prefecture earthquake and the Arima-Takatsuki Tectonic Line estimated from dense aftershock observations

*Yoshihisa Iio[1], Satoshi Matsumoto[2], Joint aftershock observation group of the Northern Osaka Prefecture earthquake (1.Disater Prevention Research Institute, Kyoto University, 2.Institute of Seismology and Volcanoloty, Kyushu University)

11:30 AM - 11:45 AM JST | 2:30 AM - 2:45 AM UTC

[SCG50-10] Fracture as an electrical conduction path under pressure

*Tohru Watanabe[1], Arina Tomioka[2] (1.Faculty of Sustainable Design, University of Toyama, 2.Graduate school of science and engineering, University of Toyama)

11:45 AM - 12:00 PM JST | 2:45 AM - 3:00 AM UTC

[SCG50-11] Grain-boundary diffusion creep of olivine and the rheology of the oceanic upper mantle

★Invited Papers

*Kosuke Yabe[1], Takehiko Hiraga[1] (1.Earthquake Research Institute, the University of Tokyo)

12:00 PM - 12:15 PM JST | 3:00 AM - 3:15 AM UTC

[SCG50-12] An inversion method of fault-slip analysis to deteremine stress tensor and friction coefficient

*Katsushi Sato[1] (1.Division of Earth and Planetary Sciences, Graduate School of Science, Kyoto University)

[J] Oral | S (Solid Earth Sciences)：S-CG Complex & General

1:45 PM - 3:15 PM JST | 4:45 AM - 6:15 AM UTC | Ch.21 Zoom Room 21

[S-CG50] Dynamics in mobile belts

convener:Yukitoshi Fukahata(Disaster Prevention Research Institute, Kyoto University), Hikaru Iwamori(Earthquake Research Institute, The University of Tokyo), Kiyokazu Oohashi(Graduate School of Sciences and Technology for Innovation, Yamaguchi University), Chairperson:Keisuke Yoshida(Tohoku University), Yukitoshi Fukahata(Disaster Prevention Research Institute, Kyoto University)

1:45 PM - 2:00 PM JST | 4:45 AM - 5:00 AM UTC

[SCG50-13] Spatio-temporal patterns of inland stress field: Characteristics revealed by a new method using focal mechanisms and interseismic plate coupling, and its tectonic implication

★Invited Papers

*Kazutoshi Imanishi[1], Akemi Noda[2] (1.National Institute of Advanced Industrial Science and Technology, 2.Meteorological Research Institute)

2:00 PM - 2:15 PM JST | 5:00 AM - 5:15 AM UTC

[SCG50-14] **Effects of ETS on seismicity and stress in the subducting oceanic plate**

*Saeko Kita[1], Heidi Houston[2], Suguru Yabe[3], Sachiko Tanaka[4], Youichi Asano[4], Takuo Shibutani[5], Naoki Suda[6] (1.Building Research Institute, 2.University of California, 3.AIST, 4.NIED, 5.DPRI, Kyoto University, 6.Hiroshima University)

2:15 PM - 2:30 PM JST | 5:15 AM - 5:30 AM UTC

[SCG50-15] Prevailing updip ruptures in small interplate earthquakes along the Japan Trench revealed from land-based and offshore observations

*Keisuke Yoshida[1], Naoki Uchida[1], Hisahiko Kubo[2], Ryota Takagi[1], Shiqing Xu[3] (1.Tohoku University, 2.National Research Institute for Earth Science and Disaster Resilience, 3. Southern University of Science and Technology)

2:30 PM - 2:45 PM JST | 5:30 AM - 5:45 AM UTC

[SCG50-16] Spatiotemporal change in the inelastic strain rate due to aftershock activity of the 2016 Kumamoto earthquake sequence, in central Kyushu, Japan

*Ayaho Mitsuoka[1], Satoshi Matsumoto[2] (1.Department of Earth and Planetary Sciences, Graduate School of Science, Kyushu University, 2.Institute of Seismology and Volcanology, Faculty of Science, Kyushu University)

2:45 PM - 3:00 PM JST | 5:45 AM - 6:00 AM UTC

[SCG50-17] **Toward understanding earthquake mechanism based on theories of strain energy**

★Invited Papers

*Tatsuhiko Saito[1] (1.National Research Institute for Earth Science and Disaster Resilience)

3:00 PM - 3:15 PM JST | 6:00 AM - 6:15 AM UTC

[SCG50-18] Reconsideration of the energy balance in earthquake faulting - I: The origin of the background stress field

*Mitsuhiro Matsuura[1] (1.Institute of Statistical Mathematics)

[J] Oral | S (Solid Earth Sciences)：S-CG Complex & General

1:45 PM - 3:15 PM JST | 4:45 AM - 6:15 AM UTC | Ch.19 Zoom Room 19

[S-CG51] New perspectives of subduction zone earthquake dynamics through experiments across-scales

convener:Masataka Kinoshita(Earthquake Research Institute, University of Tokyo), Chairperson:Masataka Kinoshita(Earthquake Research Institute, University of Tokyo), Toshinori Kimura(Japan Agency for Marine-Earth Science and Technology)

1:45 PM - 2:00 PM JST | 4:45 AM - 5:00 AM UTC

[SCG51-01] Current status and future plan of deformation and fracture experiments at SPring-8/BL04B1

★Invited Papers

*Yuji Higo[1] (1.Japan Synchrotron Radiation Research Institute)

2:00 PM - 2:15 PM JST | 5:00 AM - 5:15 AM UTC

[SCG51-02] Ultrasonic elastic wave velocity measurement of antigorite at high pressures to 10 GPa

*Yoshio Kono[1], Riseno Nose[1], Nozomi Kondo[1], Ken-ichi Hirauchi[2] (1.Geodynamics Research Center, Ehime University, 2.Shizuoka University)

2:15 PM - 2:30 PM JST | 5:15 AM - 5:30 AM UTC

[SCG51-03] Depth-dependent frictional properties of mud gouge in the Nankai Trough accretionary prism

*Kyuichi Kanagawa[1], Tomohiro Ishii[2], Tomoya Funaki[2], Junya Fujimori[3], Michiyo Sawai[1] (1.Graduate School of Science, Chiba University, 2.Faculty of Science, Chiba University, 3.Graduate School of Science and Engineering, Chiba University)

2:30 PM - 2:45 PM JST | 5:30 AM - 5:45 AM UTC

[SCG51-04] Seafloor fiber optic strainmeter performance with different cable laying condition.

*Eiichiro Araki[1], Shuhei Nishida[1], Takashi Yokobiki[1], Matthew James Cook[1], Mark Zumberge[2], Toshinori Kimura[1], Yuya Machida[1], Shuichi Kodaira[1] (1.Japan Agency for Marine-Earth Science and Technology, 2.IGPP, Scripps Institution of Oceanography)

2:45 PM - 3:00 PM JST | 5:45 AM - 6:00 AM UTC

[SCG51-05] Real-time SSE monitoring by optical borehole tiltmeter in the Nankai Trough, Japan

*Toshinori Kimura[1], Eiichiro Araki[1], Takashi Yokobiki[1], Shuhei Nishida[1], Matthew J Cook[1], Mark Zumberge[2], Keisuke Takahashi[3], Takane Hori[1], Shuichi Kodaira[1] (1.Japan Agency for Marine-Earth Science and Technology, 2.Scripps Institution of Oceanography, 3.UBE Industries, Ltd.)

3:00 PM - 3:15 PM JST | 6:00 AM - 6:15 AM UTC

[SCG51-06] **Thermal maturity observations depend on the structural history of the wedge**

*Utsav Mannu[1], David Fernández-Blanco[2], Ayumu Miyakawa[3], Taras Gerya[4], Masataka Kinoshita[5] (1.Indian Institute of Science Education and Research Pune, 2.Barcelona Center of Subsurface Imaging, Institut de Ciències del Mar (ICM-CSIC), Barcelona, 3.Geological Survey of Japan, AIST, 4.Institute of Geophysics, ETHZ Zurich, 5.Earthquake and Volcano Information, Earthquake Research Institute, Tokyo-U)

[J] Oral | S (Solid Earth Sciences)：S-CG Complex & General

9:00 AM - 10:30 AM JST | 12:00 AM - 1:30 AM UTC | Ch.18 Zoom Room 18

[S-CG52] Driving Solid Earth Science through Machine Learning

convener:Hisahiko Kubo(National Research Institute for Earth Science and Disaster Resilience), Yuki Kodera(Meteorological Research Institute, Japan Meteorological Agency), Makoto Naoi(Kyoto University), Keisuke Yano(The Institute of Statistical Mathematics), Chairperson:Yuki Kodera(Meteorological Research Institute, Japan Meteorological Agency)

9:00 AM - 9:15 AM JST | 12:00 AM - 12:15 AM UTC

[SCG52-01] Crustal stress inferred from focal mechanism solutions based on P wave first-motion polarities picked using deep learning

*Takahiko Uchide[1], Takahiro Shiina[1], Kazutoshi Imanishi[1] (1.Research Institute of Earthquake and Volcano Geology, Geological Survey of Japan, National Institute of Advanced Industrial Science and Technology (AIST))

9:15 AM - 9:30 AM JST | 12:15 AM - 12:30 AM UTC

[SCG52-02] Automatic seismic arrival-time picking of seismogram sampled at 250 Hz using Deep Learning

*Shinya Kato[1], Yoshihisa Iio[2], Hiroshi Katao[2], Masayo Sawada[2], Kazuhide Tomisaka[2], Rie Mizushima[2] (1.Graduate School of Science, Kyoto University., 2.Disater Prevention Research Institute, Kyoto University)

9:30 AM - 9:45 AM JST | 12:30 AM - 12:45 AM UTC

[SCG52-03] Deep-neural-network-based arrival-time picking and earthquake location: application to S-net

*Rintaroh Suzuki[1], Naoki Uchida[1], Weiqiang Zhu[2], Takashi NAKAYAMA[1], Genti Toyokuni[1], Ryota Takagi[1], Ryosuke Azuma[1], Gregory C Beroza[2] (1.Graduate School of Science, Tohoku University, 2.Department of Geophysics, Stanford University)

9:45 AM - 10:00 AM JST | 12:45 AM - 1:00 AM UTC

[SCG52-04] Induced Earthquakes Before and After Cessation of Longterm Injections in Rongchang Gas Field, Sichuan, China

*Zhiwei Wang[1], Xinglin Lei[2], Jinrong Su[3], Shengli Ma[1], Yusuke Mukuhira[4] (1.Institute of Geology, China Earthquake Administration, 2.Geological Survey of Japan, AIST, 3.Earthquake Monitoring Centre, Sichuan Earthquake Administration, 4.Institute of Fluid Science, Tohoku University)

10:00 AM - 10:15 AM JST | 1:00 AM - 1:15 AM UTC

[SCG52-05] **Site Generalization Performance of Ground Motion Models: Application of Monotonic Neural Networks**

*Tomohisa Okazaki[1], Nobuyuki Morikawa[2], Hiroyuki Fujiwara[2], Naonori Ueda[1] (1.RIKEN Center for Advanced Intelligence Project, 2.National Research Institute for Earth Science and Disaster Resilience)

10:15 AM - 10:30 AM JST | 1:15 AM - 1:30 AM UTC

[SCG52-06] Prediction of natural disasters based on a hybrid approach of physics-driven and data-driven method

★Invited Papers

*Takashi Miyamoto[1] (1.University of Yamanashi)

[J] Oral | M (Multidisciplinary and Interdisciplinary)：M-IS Intersection

10:45 AM - 12:15 PM JST | 1:45 AM - 3:15 AM UTC | Ch.25 Zoom Room 25

[M-IS21] Chemosynthetic community and mud volcano: biology, geochemistry, and geophysics of fluid discharge

convener:Yusuke Miyajima(Geomicrobiology Research Group, Research Institute for Geo-Resources and Environment, Geological Survey of Japan, National Institute of Advanced Industrial Science and Technology), Kayama Hiromi WATANABE(Japan Agency for Marine-Earth Science and Technology), Akira Ijiri(Japan Agency for Marine-Earth Science and Technology), Tomohiro Toki(Faculty of Science, University of the Ryukyus), Chairperson:Yusuke Miyajima(Geomicrobiology Research Group, Research Institute for Geo-Resources and Environment, Geological Survey of Japan, National Institute of Advanced Industrial Science and Technology), Hiromi Kayama WATANABE(Japan Agency for Marine-Earth Science and Technology)

10:45 AM - 11:00 AM JST | 1:45 AM - 2:00 AM UTC

[MIS21-01] **Characteristic and Origin of erupted sediments in submarine mud volcanoes, off Tanegashima Island**

*Ryoma Setoguchi[1], Akira Ijiri[2], Takeyasu Yamagata[3], Hiroyuki Matsuzaki[3], Kyoko Hagino[1], Juichiro Ashi[4], Masafumi MURAYAMA[1] (1.Kochi University, 2.Japan Agency for Marine-Earth Science and Technology, 3.The University Museum, The University of Tokyo, 4.Atmosphere and Ocean Research Institute, The University of Tokyo)

11:00 AM - 11:15 AM JST | 2:00 AM - 2:15 AM UTC

[MIS21-02] Methanogenesis in deep subseafloor sediments −living methanogen diversity, distribution, physiology and activity−

★Invited Papers

*Taiki Katayama[1], Hideyoshi Yoshioka[1], Masanori Kaneko[1], Susumu Sakata[1], Miki Amo[2], Tetsuya Fujii[2] (1.National Institute of Advanced Industrial Science and Technology, 2.Japan Oil, Gas and Metals National Corporation)

11:15 AM - 11:30 AM JST | 2:15 AM - 2:30 AM UTC

[MIS21-03] Aerobic and anaerobic methanotrophs and their activity in methane-seep sediments of the northeastern Japan Sea offshore Sakata assessed by ^{13}C-labelling experiments

*Yusuke Miyajima[1], Hideyoshi Yoshioka[1], Tomo Aoyagi[2], Tomoyuki Hori[2], Hiroshi A Takahashi[3], Masahiro Suzumura[2] (1.Geomicrobiology Research Group, Research Institute for Geo-Resources and Environment, Geological Survey of Japan, National Institute of Advanced Industrial Science and Technology, 2.Environmental Management Research Institute, National Institute of Advanced Industrial Science and Technology (AIST), Japan, 3.Research Institute of Earthquake and Volcano Geology, Geological Survey of Japan, National Institute of Advanced Industrial Science and Technology (AIST), Japan)

11:30 AM - 11:45 AM JST | 2:30 AM - 2:45 AM UTC

[MIS21-04] Could listening underwater sounds reveal the dynamics of chemosynthetic ecosystems?

★Invited Papers

*Tzu-Hao Lin[1], Chong Chen[2], Hiromi Kayama Watanabe[2], Shinsuke Kawagucci[2], Yung-Che Tseng[3] (1.Biodiversity Research Center, Academia Sinica, 2.X-STAR, Japan Agency for Marine-Earth Science and Technology (JAMSTEC), 3.Marine Research Station, Institute of Cellular and organismic Biology, Academia Sinica)

11:45 AM - 12:00 PM JST | 2:45 AM - 3:00 AM UTC

[MIS21-05] The minor-yet-crucial roles of gut microbiomes in a deep-sea hydrothermal vent snail

*Yi YANG[1,2], Jin SUN[1,3], Chong CHEN[4], Yadong ZHOU[5], Cindy Lee Van Dover[6], Chunsheng WANG[5,7], Jian-Wen QIU[2,8], Pei-Yuan QIAN[1,2] (1.Department of Ocean Science and Hong Kong Branch of the Southern Marine Science and Engineering Guangdong Laboratory (Guangzhou), The Hong Kong University of Science and Technology, Hong Kong, China, 2.Southern Marine Science and Engineering Guangdong Laboratory (Guangzhou), Guangzhou, China, 3.Institute of Evolution & Marine Biodiversity, Ocean University of China, Qingdao 266003, China, 4.X-STAR, Japan Agency for Marine-Earth Science and Technology (JAMSTEC), 2-15 Natsushima-cho, Yokosuka, Kanagawa 237-0061, Japan, 5.Laboratory of Marine Ecosystem and Biogeochemistry, Second Institute of Oceanography, State Oceanic Administration, Hangzhou, China, 6.Division of Marine Science and Conservation, Nicholas School of the Environment, Duke University, Beaufort, NC, United States, 7.State Key Laboratory of Satellite Ocean Environment Dynamics, Second Institute of Oceanography, State Oceanic Administration, Hangzhou, China, 8.Department of Biology, Hong Kong Baptist University, Hong Kong, China)

12:00 PM - 12:15 PM JST | 3:00 AM - 3:15 AM UTC

[MIS21-06] Dual symbiosis in the deep-sea hydrothermal vent snail *Gigantopelta aegis* revealed by its hologenome

*Yi Lan[1], Jin Sun[1,2], Chong Chen[3], Jian-Wen Qiu[4], Pei-Yuan Qian[1] (1.Hong Kong University of Science and Technology, 2.Ocean University of China, 3.Japan Agency for Marine-Earth Science and Technology , 4.Hong Kong Baptist University)

[J] Oral | M (Multidisciplinary and Interdisciplinary)：M-GI General Geosciences, Information Geosciences & Simulations

1:45 PM - 3:15 PM JST | 4:45 AM - 6:15 AM UTC | Ch.18 Zoom Room 18

[M-GI33] Data-driven geosciences

convener:Tatsu Kuwatani(Japan Agency for Marine-Earth Science and Technology), Hiromichi Nagao(Earthquake Research Institute, The University of Tokyo), Kenta Ueki(Japan Agency for Marine-Earth Science and Technology), Shin-ichi Ito(The University of Tokyo), Chairperson:Kenta Ueki(Japan Agency for Marine-Earth Science and Technology), Tatsu Kuwatani(Japan Agency for Marine-Earth Science and Technology)

1:45 PM - 2:15 PM JST | 4:45 AM - 5:15 AM UTC

[MGI33-01] Data-driven low-dimensional model/sparse sensing of fluid dynamics and its application to seismic waves

★Invited Papers

*Taku Nonomura[1], Yuji Saito[1], Takayuki Nagata[1], Kumi Nakai[1], Keigo Yamada[1], Sayumi Kaneko[1] (1.Tohoku University)

2:15 PM - 2:30 PM JST | 5:15 AM - 5:30 AM UTC

[MGI33-02] Reclassification of oceanic intraplate basalts using trace element compositions of hotspots and petit-spots

*Yosuke Shimbo[1], Taku Yutani[1], Naoto Hirano[1] (1.Tohoku University)

2:30 PM - 2:45 PM JST | 5:30 AM - 5:45 AM UTC

[MGI33-03] Spatial distributions of source components for REY-rich mud based on independent component analysis on major- and trace-element composition

*Masahiro Hirako[1], Kazutaka Yasukawa[1,2], Erika Tanaka[1], Koichiro Fujinaga[2,1], Kentaro Nakamura[1], Yasuhiro Kato[1,2] (1.School of Engineering, The University of Tokyo, 2.Ocean Resources Research Center for Next Generation, Chiba Institute of Technology)

2:45 PM - 3:00 PM JST | 5:45 AM - 6:00 AM UTC

[MGI33-04] Independent Component Analysis of bulk chemical compositions of submarine hydrothermal deposits in the Okinawa Trough

*Akito Aichi[1], Kazutaka Yasukawa[1,2], Tatsuo Nozaki[3,1,4,2], Yutaro Takaya[5,3,2], Mizuki Ishida[1], Erika Tanaka[1], Kentaro Nakamura[1], Yasuhiro Kato[1,2] (1.School of Engineering, The University of Tokyo, 2.ORCeNG, Chiba Institute of Technology, 3.JAMSTEC, 4.Kobe University, 5.Waseda University)

3:00 PM - 3:15 PM JST | 6:00 AM - 6:15 AM UTC

[MGI33-05] Spatial resolution of Bayesian sensing

*Tatsu Kuwatani[1], Hideitsu Hino[2], Nagata Kenji[3], Takahiro Kawashima[4], mitsuhiro toriumi[1], Masato Okada[5] (1.Japan Agency for Marine-Earth Science and Technology, 2.The Institute of Statistical Mathematics, 3.National Institute for Materials Science, 4.Graduate University for Advanced Studies, 5.The University of Tokyo)

[J] Oral | M (Multidisciplinary and Interdisciplinary)：M-GI General Geosciences, Information Geosciences & Simulations

3:30 PM - 5:00 PM JST | 6:30 AM - 8:00 AM UTC | Ch.18 Zoom Room 18

[M-GI33] Data-driven geosciences

convener:Tatsu Kuwatani(Japan Agency for Marine-Earth Science and Technology), Hiromichi Nagao(Earthquake Research Institute, The University of Tokyo), Kenta Ueki(Japan Agency for Marine-Earth Science and Technology), Shin-ichi Ito(The University of Tokyo), Chairperson:Tatsu Kuwatani(Japan Agency for Marine-Earth Science and Technology), Kenta Ueki(Japan Agency for Marine-Earth Science and Technology)

3:30 PM - 4:00 PM JST | 6:30 AM - 7:00 AM UTC

[MGI33-06] Sedimentology as a science of reconstruction

★Invited Papers

*Hajime Naruse[1], Rimali Mitra[1], Zhirong Cai[1] (1.Department of Geology and Mineralogy, Graduate School of Science, Kyoto University)

4:00 PM - 4:15 PM JST | 7:00 AM - 7:15 AM UTC

[MGI33-07] Data-driven Analysis of Nonlinear Heterogeneous Reactions through Sparse Modeling and Bayesian Statistical Approaches

*Masaki Ito[1], Tatsu Kuwatani[2], Ryosuke Oyanagi[2], Toshiaki Omori[1] (1.Kobe University, 2.Japan Agency for Marine-Earth Science and Technology)

4:15 PM - 4:30 PM JST | 7:15 AM - 7:30 AM UTC

[MGI33-08] Development of a deep learning approach to estimate numerical simulation parameters of a hydrothermal system: Evaluation using a two-dimensional model

*Akihiro Shima[1], Kazuya Ishitsuka[1], Elvar Karl Bjarkason[2], Anna Suzuki[2], Weiren Lin[1] (1.Kyoto University, 2.Tohoku University)

4:30 PM - 4:45 PM JST | 7:30 AM - 7:45 AM UTC

[MGI33-09] Testing on Earthquake Prediction by Deep CNN-Labeling Model

*mitsuhiro toriumi[1] (1.Japan agency of marine science and technology)

4:45 PM - 5:00 PM JST | 7:45 AM - 8:00 AM UTC

[MGI33-10] Discussion

*Tatsu Kuwatani[1] (1.Japan Agency for Marine-Earth Science and Technology)

[J] Oral | M (Multidisciplinary and Interdisciplinary)：M-GI General Geosciences, Information Geosciences & Simulations

9:00 AM - 10:30 AM JST | 12:00 AM - 1:30 AM UTC | Ch.03 Zoom Room 03

[M-GI34] Earth and planetary informatics with huge data management

convener:Ken T. Murata(National Institute of Information and Communications Technology), Susumu Nonogaki(Geological Survey of Japan, National Institute of Advanced Industrial Science and Technology), Rie Honda(Department of Science and Technology, System of Natual Science, Kochi University), Keiichiro Fukazawa(Academic Center for Computing and Media Studies, Kyoto University), Chairperson:Keiichiro Fukazawa(Academic Center for Computing and Media Studies, Kyoto University), Ken T. Murata(National Institute of Information and Communications Technology)

9:00 AM - 9:15 AM JST | 12:00 AM - 12:15 AM UTC

[MGI34-01] Development of snow detection techniques by using visual IoT

*Yuki MURAKAMI[1], Ken T. Murata[1], Shigeto Watanabe[2] (1.National Institute of Information and Communications Technology, 2.Hokkaido Information University)

9:15 AM - 9:30 AM JST | 12:15 AM - 12:30 AM UTC

[MGI34-02] Environment Monitoring Using a Technology of Visual Internet of Things

*Tsutomu Nagatsuma[1], Ken T. Murata[1], Junji Tokairin[1], Kazunori Yamamoto[1], Yuki MURAKAMI[1], Takamichi Mizuhara[2] (1.National Institute of Information and Communications Technology, 2.CLEALINK TECHNOLOGY Co. Ltd.)

9:30 AM - 9:45 AM JST | 12:30 AM - 12:45 AM UTC

[MGI34-03] Release of three-dimensional geological map of central Tokyo

*Susumu Nonogaki[1], Tsutomu Nakazawa[1], Tomonori Naya[1], Junko Komatsubara[1], Yoshinori Miyachi[1], Masanori Ozaki[1], Toshio Nakayama[2] (1.Geological Survey of Japan, National Institute of Advanced Industrial Science and Technology, 2.Civil Engineering Support and Training Center, Tokyo Metropolitan Government)

9:45 AM - 10:00 AM JST | 12:45 AM - 1:00 AM UTC

[MGI34-04] Introduction of Ultra-large-scale Visualization Method for 3D Geographical Information Using a Web Browser-based Scalable Display System

Tomohiro Kawanabe[1], Kenji Ono[2], *Ken T. Murata[3], Atsushi Higuchi[4] (1.Institute of Physical and Chemical Research, 2.Kyushu University, 3.National Institute of Information and Communications Technology, 4.Chiba University)

10:00 AM - 10:15 AM JST | 1:00 AM - 1:15 AM UTC

[MGI34-05] Environmental Monitoring Experiment with the Sensor Network in Chikuma City

*Kohei Mizuani[1], Ken T. Murata[1], Kazunori Yamamoto[1], Yuki MURAKAMI[1], Kazuya Muranaga[2], Takamichi Mizuhara[3] (1.National Institute of Information and Communications Technology, 2.Systems Engineering Consultants Co., LTD., 3.CLEALINKTECHNOLOGY Co.,Ltd.)

10:15 AM - 10:30 AM JST | 1:15 AM - 1:30 AM UTC

[MGI34-06] Data Quality Control and Data Disclosure of Phased Array Weather Radar

*Shinsuke Satoh[1], Fusako Isoda[1], Hiroshi HANADO[1], Katsuhiro Nakagawa[1], Susumu Uchino[2], Kohei Yamashita[2], Kazuya Muranaga[2] (1.National Institute of Information and Communications Technology, 2.Systems Engineering Consultants (SEC))

[J] Oral | M (Multidisciplinary and Interdisciplinary)：M-GI General Geosciences, Information Geosciences & Simulations

10:45 AM - 12:15 PM JST | 1:45 AM - 3:15 AM UTC | Ch.03 Zoom Room 03

[M-GI34] Earth and planetary informatics with huge data management

convener:Ken T. Murata(National Institute of Information and Communications Technology), Susumu Nonogaki(Geological Survey of Japan, National Institute of Advanced Industrial Science and Technology), Rie Honda(Department of Science and Technology, System of Natual Science, Kochi University), Keiichiro Fukazawa(Academic Center for Computing and Media Studies, Kyoto University), Chairperson:Susumu Nonogaki(Geological Survey of Japan, National Institute of Advanced Industrial Science and Technology), Rie Honda(Department of Science and Technology, System of Natual Science, Kochi University)

10:45 AM - 11:05 AM JST | 1:45 AM - 2:05 AM UTC

[MGI34-07] Efforts of Aizu Research Center for Space Informatics, Univ. of Aizu as a Joint Usage / Research Center

★Invited Papers

*Hirohide Demura[1] (1.The University of Aizu)

11:05 AM - 11:20 AM JST | 2:05 AM - 2:20 AM UTC

[MGI34-08] Development of a Data Analysis Environment for Small Irregular-Shaped Bodies Centered on a 3D-GIS

*Naru Hirata[1,2], Takuma Furudate[1], Hiroshi Kikuchi[3], Hirohide Demura[1,2], Hiroyuki Sato[3], Koji Matsumoto[4], Naoto Nakasato[1], Fumiya Kono[1] (1.Dep. of Computer Science and Engineering, Univ. of Aizu, 2.ARC-Space, Univ. of Aizu, 3.Japan Aerospace Exploration Agency, 4.RISE Project, National Astronomical Observatory of Japan)

11:20 AM - 11:35 AM JST | 2:20 AM - 2:35 AM UTC

[MGI34-09] Practice, Application and Future Potential of High-Capacity Space Data Processing

*Junya Terazono[1], Ken T. Murata[1], Tomohiro Sato[1], YASUKO KASAI[1] (1.National Institute of Information and Communication Technology)

11:35 AM - 11:50 AM JST | 2:35 AM - 2:50 AM UTC

[MGI34-10] **Construction of hot spring database over Japan for clarifying thermal and fluid flow structures in the upper crust**

*Jacek Scibek[1], Katsuaki Koike[1], Koki Kashiwaya[1] (1.Kyoto University)

11:50 AM - 12:05 PM JST | 2:50 AM - 3:05 AM UTC

[MGI34-11] Detection of geothermal fluids paths in highly vegetated area through a vegetation stress index using hyperspectral satellite imagery

*Taiki Kubo[1], Hiroaki Gonnokami[1], Mohamad Nur Heriawan[2], Katsuaki Koike[1] (1.Graduate School of Engineering, Kyoto University, 2.Institut Teknologi Bandung)

12:05 PM - 12:15 PM JST | 3:05 AM - 3:15 AM UTC

[MGI34-12] Discussion

[J] Oral | M (Multidisciplinary and Interdisciplinary)：M-TT Technology & Techniques

9:00 AM - 10:30 AM JST | 12:00 AM - 1:30 AM UTC | Ch.17 Zoom Room 17

[M-TT42] Frontiers in Geochemistry

convener:Tsuyoshi Iizuka(University of Tokyo), Yoshio Takahashi(Department of Earth and Planetary Science, Graduate School of Science, The University of Tokyo), Urumu Tsunogai(Graduate School of Environmental Studies, Nagoya University), Chairperson:Tsuyoshi Iizuka(University of Tokyo), Aya Sakaguchi(Faculty of Pure and Applied Science)

9:00 AM - 9:15 AM JST | 12:00 AM - 12:15 AM UTC

[MTT42-01] High energy resolution fluorescence XAFS for the speciation of trace elements in environment

Yamaguchi Akiko[1,4], Hikaru Miura[3], Makoto Nagasawa[1], *Yoshio Takahashi[1,2] (1.Department of Earth and Planetary Science, Graduate School of Science, The University of Tokyo, 2.Photon Factory, 3.CRIEPI, 4.JAEA)

9:15 AM - 9:30 AM JST | 12:15 AM - 12:30 AM UTC

[MTT42-02] **Quantifying denitrification rate across water-sediment interface in aquatic areas by using triple oxygen isotopes as tracers**

*FEI CUIXIA[1], Fumiko Nakagawa[1], Urumu Tsunogai[1], Masanori Ito[1], Hiroka Mizuno (1.Nagoya University)

9:30 AM - 9:45 AM JST | 12:30 AM - 12:45 AM UTC

[MTT42-03] High-precision measurement of ^{17}O-excess in phosphate in hydrosphere

*Takashi Sambuichi[1], Urumu Tsunogai[1], Fumiko Nakagawa[1], Masanori Ito[1] (1.Graduate School of Environmental Studies, Nagoya university)

9:45 AM - 10:00 AM JST | 12:45 AM - 1:00 AM UTC

[MTT42-04] Development of iron stable isotope measurement for biological tissue and its application to the marine organisms

*Nanako Hasegawa[1], TAKAAKI ITAI[1], Yoshio Takahashi[1], Tatsuya Kunisue[2], Shinsuke Tanabe[2] (1.Department of Earth and Planetary Science, The University of Tokyo, 2.CMES, Ehime Univ.)

10:00 AM - 10:30 AM JST | 1:00 AM - 1:30 AM UTC

[MTT42-05] Interaction between Cerium and H_2O in Hydrous Rhyolitic Melts

★Invited Papers

*Nozomi Kondo[1], Yoshio Kono[1], Koji Ohara[2], Ryoichi Nakada[3], Toshiaki Ina[2], Etienne Skrzypek[4,7], Akihiro Yamada[5], Satoshi SAITO[6] (1.Geodynamics Research Center, Ehime University, 2.Center for Synchrotron Radiation Research, Japan Synchrotron Radiation Institute, 3.Kochi Institute for Core Sample Research, Japan Agency for Marin-Earth Science and Technology, 4.Graduate School of Science, Kyoto University, 5.Center of Glass Science and Technology, The University of Shiga Prefecture, 6.Department of Earth Science, Graduate School of Science and Engineering, Ehime University, 7.Institute of Earth Science, University of Graz)

[J] Oral | M (Multidisciplinary and Interdisciplinary)：M-TT Technology & Techniques

10:45 AM - 12:15 PM JST | 1:45 AM - 3:15 AM UTC | Ch.17 Zoom Room 17

[M-TT42] Frontiers in Geochemistry

convener:Tsuyoshi Iizuka(University of Tokyo), Yoshio Takahashi(Department of Earth and Planetary Science, Graduate School of Science, The University of Tokyo), Urumu Tsunogai(Graduate School of Environmental Studies, Nagoya University), Chairperson:Urumu Tsunogai(Graduate School of Environmental Studies, Nagoya University), Yoshio Takahashi(Department of Earth and Planetary Science, Graduate School of Science, The University of Tokyo)

10:45 AM - 11:00 AM JST | 1:45 AM - 2:00 AM UTC

[MTT42-06] High resolution mass spectrometry analysis of alkaline copper oxide degradation products from insoluble organic matter in carbonaceous chondrite

*Miho Shigenaka[1], Tomoko Amimoto[1], Hikaru Yabuta[1] (1.Hiroshima University)

11:00 AM - 11:15 AM JST | 2:00 AM - 2:15 AM UTC

[MTT42-07] Analysis of single platinum nanoparticles using high-time resolution multiple collector ICP-MS (HTR-MC-ICP-MS) and application to cosmochemical samples

*Norika Numa[1], Shuji Yamashita[1], Takafumi Hirata[1] (1.School of science, The University of Tokyo)

11:15 AM - 11:30 AM JST | 2:15 AM - 2:30 AM UTC

[MTT42-08] **On-site Magnetic Separation of Heterogeneous Geological Particles**

*Chiaki Uyeda[1] (1.Institute of earth and Space Science Graduate School of Science Osaka University)

11:30 AM - 11:45 AM JST | 2:30 AM - 2:45 AM UTC

[MTT42-09] **Towards quantitative evaluation of the chondritic Earth model: A combined geo-neutrino, -physics, and -chemistry study**

*Tsuyoshi Iizuka[1], Nozomu Takeuchi[1], Kenta Ueki[2], Akiko Tanaka[3], Sanshiro Enomoto[4], Hiroko Watanabe[5], Satoru Haraguchi[1] (1.University of Tokyo, 2.JAMSTEC, 3.AIST, 4.University of Washington, 5.Tohoku University)

11:45 AM - 12:00 PM JST | 2:45 AM - 3:00 AM UTC

[MTT42-10] Element abundance modeling method with the gamma distribution for quantitative balance calculations

*Sanshiro Enomoto[1,2], Kenta Ueki[3], Tsuyoshi Iizuka[4], Nozomu Takeuchi[5], Akiko Tanaka[6], Hiroko Watanabe[7], Satoru Haraguchi[5] (1.Kavli Institute for the Physics and Mathematics of the Universe, University of Tokyo, 2.University of Washington, 3.Japan Agency for Marine-Earth Science and Technology, 4.University of Tokyo, 5.Earthquake Research Institute, University of Tokyo, 6.National Institute of Advanced Industrial Science and Technology, 7.Research Center for Neutrino Science, Tohoku University)

12:00 PM - 12:15 PM JST | 3:00 AM - 3:15 AM UTC

[MTT42-11] Prospects of Ocean Bottom Geoneutrino Detector for direct observation of mantle radioactive element distribution

*Kenta Ueki[1], Natsue Abe[1], Hiroko Watanabe[2], Kunio Inoue[2], Taichi Sakai[2], William F McDonough[2,3,4], Eiichiro Araki[1], Takafumi Kasaya[1], Kyo Masanori[1], Noriaki Sakurai[1] (1.Japan Agency for Marine-Earth Science and Technology, 2.Tohoku University Research Center for Neutrino Science, 3.Graduate School of Science, Tohoku University, 4.University of Maryland)

[J] Oral | EVENT：EVENT

1:45 PM - 3:15 PM JST | 4:45 AM - 6:15 AM UTC | Ch.16 Zoom Room 16

[EV-13] Exhibitors' Pop-Up

1:45 PM - 3:15 PM JST | 4:45 AM - 6:15 AM UTC

[E-11-15] Exhibitors' Pop-Up

[J] Oral | U (Union)：Union

Thu. Jun 3, 2021 1:45 PM - 3:15 PM JST | Thu. Jun 3, 2021 4:45 AM - 6:15 AM UTC | Ch.01 Zoom Room 01

[U-06] Science Council of Japan in one hour: How it supports international organizations

convener:Nobuko Saigusa(National Institute for Environmental Studies), Takuji Nakamura(National Institute of Polar Research), Shigeko Haruyama(Mie University .Emeritus Prof.), Eiichi Tajika(Department of Earth and Planetary Science, Graduate School of Science, The University of Tokyo), Chairperson:Takuji Nakamura(National Institute of Polar Research), Nobuko Saigusa(National Institute for Environmental Studies)

The Science Council of Japan (SCJ) joins 46 international scientific organizations, including the International Science Council (ISC), as the representative organization of Japan for the promotion of science in cooperation with the global academic community. The SCJ supports 12 organizations in the field of earth and planetary sciences by providing financial contributions and dispatching representatives to the scientific steering committee, where long-term visions and research plans are discussed with the aim of pursuing the truth and realizing global sustainability. The SCJ also supports promotion of young scientists and international research exchanges. This session covers the 12 international organizations with the latest achievements and prospects in one hour and discusses the promotion of future international activities through the SCJ.

(*) in alphabetical order
Committee on Space Research (COSPAR); International Arctic Science Committee (IASC); International Cartographic Association (ICA); International Geographical Union (IGU); International Mineralogical Association (IMA); International Union for Quaternary Research (INQUA); International Union of Geodesy and Geophysics (IUGG); International Union of Geological Sciences (IUGS); Scientific Committee on Antarctic Research (SCAR); Scientific Committee on Oceanic Research (SCOR); Scientific Committee on Solar-Terrestial Physics (SCOSTEP); World Climate Research Programme (WCRP)

1:45 PM - 1:55 PM JST | 4:45 AM - 4:55 AM UTC

[U06-01] Introduction

1:55 PM - 2:00 PM JST | 4:55 AM - 5:00 AM UTC

[U06-02] Achievements and Prospects of the Committee on Space Research (COSPAR): Promoting International Activities through the Science Council of Japan (SCJ)

*Takuji Nakamura[1], Masaki Fujimoto[2], Akiko Nakamura[3], Hajime Yano[2] (1.National Institute of Polar Research, 2.Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency, 3.Graduate School of Science, Kobe University)

2:00 PM - 2:05 PM JST | 5:00 AM - 5:05 AM UTC

[U06-03] Achievements and Prospects of the Scientific Committee on Solar-Terrestrial Physics (SCOSTEP): Promoting International Activities through the Science Council of Japan (SCJ)

*Kazuo Shiokawa[1], Yoshizumi Miyoshi[1], Akimasa Yoshikawa[2], Takuji Nakamura[3] (1.Institute for Space-Earth Environmental Research, Nagoya University, 2.International Center for Space Weather Science and Education, Kyusyu University, 3.National Institute of Polar Research)

2:05 PM - 2:10 PM JST | 5:05 AM - 5:10 AM UTC

[U06-04] Achievements and Prospects of the Scientific Committee on Antarctic Research (SCAR): Promoting International Activities through the Science Council of Japan (SCJ)

*Takuji Nakamura[1,2], Satoshi Imura[1,2], Gen Hashida[1,2] (1.National Institute of Polar Research, 2.SOKENDAI, the Graduate University for Advanced Studies)

2:10 PM - 2:15 PM JST | 5:10 AM - 5:15 AM UTC

[U06-05] Achievements and Prospects of the International Arctic Science Committee (IASC): Promoting International Activities through the Science Council of Japan (SCJ)

*Hiroyuki Enomoto[1] (1.National Institute of Polar Research)

2:15 PM - 2:20 PM JST | 5:15 AM - 5:20 AM UTC

[U06-06] Elucidating mechanisms of the ocean and its variations and changes-Activities of the Scientific Committee on Oceanic Research (SCOR) and Japan's contribution-

*Yukio Masumoto[1], Naomi Harada[2] (1.Graduate School of Science, The University of Tokyo, 2.Japan Agency for Marine-Earth Science and Technology)

2:20 PM - 2:25 PM JST | 5:20 AM - 5:25 AM UTC

[U06-07] Achievements and Prospects of the World Climate Research Programme (WCRP): Promoting International Activities through the SCJ

*Nobuko Saigusa[1] (1.National Institute for Environmental Studies)

2:25 PM - 2:30 PM JST | 5:25 AM - 5:30 AM UTC

[U06-08] Achievements and Prospects of the International Cartographic Association (ICA): Promoting International Activities through the Science Council of Japan (SCJ)

*Kaori Ito[1], Takashi Morita[2] (1.Tokyo University of Science, 2.Hosei University)

2:30 PM - 2:35 PM JST | 5:30 AM - 5:35 AM UTC

[U06-09] Achievements and Prospects of the International Geographical Union (IGU): Promoting International Activities through the Science Council of Japan (SCJ)

*Yasuhiro Suzuki[1] (1.Nagoya University)

2:35 PM - 2:40 PM JST | 5:35 AM - 5:40 AM UTC

[U06-10] Activities of INQUA (International Union for Quaternary Research) and Contributions from Japan

*Yoshiki Saito[1] (1.Estuary Research Center, Shimane University)

2:40 PM - 2:45 PM JST | 5:40 AM - 5:45 AM UTC

[U06-11] Achievements and Prospects of the International Mineralogical Association (IMA): Promoting International Activities through the Science Council of Japan (SCJ)

*Eiji Ohtani[1] (1.Department of Earth and Planetary Materials Science, Graduate School of Science, Tohoku University)

2:45 PM - 2:50 PM JST | 5:45 AM - 5:50 AM UTC

[U06-12] Activities and Roles of International Union of Geodesy and Geophysics (IUGG): Standardization of Earth Observation and Models

*Kenji Satake[1], Kumiko Goto-Azuma[2], Masato Furuya[3], Takuji Nakamura[2], Toshio Koike[4], Maki Tsujimura[5], Hisashi Nakamura[6], Toshiyuki Hibiya[7], Keiko Kuge[8], Setsuya Nakada[9] (1.Earthquake Research Institute, University of Tokyo, 2.National Institute of Polar Research & SOKENDAI, 3.Earth and Planetary Science, Hokkaido University, 4.ICHARM, Public Works Research Institute, 5.Faculty of Life and Environmental Sciences, University of Tsukuba, 6.RCAST, University of Tokyo, 7.Earth and Planetary Science, The University of Tokyo , 8.Dept. of Geophysics, Kyoto University, 9.National Research Institute for Earth Science and Disaster Resilience)

2:50 PM - 2:55 PM JST | 5:50 AM - 5:55 AM UTC

[U06-13] International Union of Geological Sciences: its activities and social contributions

*Hiroshi Kitazato[1], Hiroshi Nishi[2] (1.Tokyo University of Marine Science and Technology (TUMSAT), 2.Fukui Prefectural University, Institute of Dinosaur Research)

2:55 PM - 3:15 PM JST | 5:55 AM - 6:15 AM UTC

[U06-14] Discussion

[J] Oral | U (Union) | Union

[U-06] Science Council of Japan in one hour: How it supports international organizations

convener:Nobuko Saigusa(National Institute for Environmental Studies), Takuji Nakamura(National Institute of Polar Research), Shigeko Haruyama(Mie University .Emeritus Prof.), Eiichi Tajika(Department of Earth and Planetary Science, Graduate School of Science, The University of Tokyo), Chairperson:Takuji Nakamura(National Institute of Polar Research), Nobuko Saigusa(National Institute for Environmental Studies)

Thu. Jun 3, 2021 1:45 PM - 3:15 PM Ch.01 (Zoom Room 01)

The Science Council of Japan (SCJ) joins 46 international scientific organizations, including the International Science Council (ISC), as the representative organization of Japan for the promotion of science in cooperation with the global academic community. The SCJ supports 12 organizations in the field of earth and planetary sciences by providing financial contributions and dispatching representatives to the scientific steering committee, where long-term visions and research plans are discussed with the aim of pursuing the truth and realizing global sustainability. The SCJ also supports promotion of young scientists and international research exchanges. This session covers the 12 international organizations with the latest achievements and prospects in one hour and discusses the promotion of future international activities through the SCJ.

(*) in alphabetical order
Committee on Space Research (COSPAR); International Arctic Science Committee (IASC); International Cartographic Association (ICA); International Geographical Union (IGU); International Mineralogical Association (IMA); International Union for Quaternary Research (INQUA); International Union of Geodesy and Geophysics (IUGG); International Union of Geological Sciences (IUGS); Scientific Committee on Antarctic Research (SCAR); Scientific Committee on Oceanic Research (SCOR); Scientific Committee on Solar-Terrestial Physics (SCOSTEP); World Climate Research Programme (WCRP)

1:45 PM - 1:55 PM

[U06-01]Introduction

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Achievements and Prospects of the Committee on Space Research (COSPAR): Promoting International Activities through the Science Council of Japan (SCJ)

*Takuji Nakamura[1], Masaki Fujimoto[2], Akiko Nakamura[3], Hajime Yano[2]

1. National Institute of Polar Research, 2. Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency, 3. Graduate School of Science, Kobe University

The Commitee on Space Research (COSPAR) is one of the international scientific organizations that the Science Council of Japan (SCJ) has joined on behalf of Japan. The SCJ has sent Japanese representatives to the delegate meetings, the bureau meetings, and commission/panel business meetings to contribute to the promotion of science using space craft such as satellites, sounding rockets and balloons through discussing international standard, fostering young researchers, and supporting research exchanges.

The achievements and a prospects of the COSPAR will be introduced in a five-minute presentation. The session will be concluded by a discussion on the future promotion of international activities through the SCJ.

Keywords: SCJ, International Promotion, Antarctic Research

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Achievements and Prospects of the Scientific Committee on Solar-Terrestrial Physics (SCOSTEP): Promoting International Activities through the Science Council of Japan (SCJ)

*Kazuo Shiokawa[1], Yoshizumi Miyoshi[1], Akimasa Yoshikawa[2], Takuji Nakamura[3]

1. Institute for Space-Earth Environmental Research, Nagoya University, 2. International Center for Space Weather Science and Education, Kyusyu University, 3. National Institute of Polar Research

The Scientific Committee on Solar-Terrestrial Physics (SCOSTEP) is one of the international scientific organizations that the Science Council of Japan (SCJ) has joined on behalf of Japan. SCOSTEP is a thematic organization under the International Science Council (ISC). SCOSTEP runs international interdisciplinary scientific programs and promotes solar-terrestrial physics research by providing the necessary scientific framework for international collaboration and dissemination of the derived scientific knowledge in collaboration with other ISC bodies. Scientists participating in the activities of SCOSTEP have contributed to the development of a sustainable global society by dispatching representatives to science steering committees, planning international research programs, fostering young researchers, and supporting research exchanges. The achievements and a prospects of the SCOSTEP will be introduced in a five-minute presentation, and the session will conclude with a discussion on the future promotion of international activities through the SCJ.

Keywords: SCJ, International Promotion, SCOSTEP

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Achievements and Prospects of the Scientific Committee on Antarctic Research (SCAR): Promoting International Activities through the Science Council of Japan (SCJ)

*Takuji Nakamura[1,2], Satoshi Imura[1,2], Gen Hashida[1,2]

1. National Institute of Polar Research, 2. SOKENDAI, the Graduate University for Advanced Studies

The Scientific Commitee on Antarctic Research (WCRP) is one of the international scientific organizations that the Science Council of Japan (SCJ) has joined on behalf of Japan. The SCJ has sent Japanese representatives to the delegate meetings and science group business meetings to help planning international research programs, fostering young researchers, and supporting research exchanges. The achievements and prospects of the SCAR includes the contribution to the knowledge on the future of mankind, through the international scientific research in the Antarctic region, and on the role of the Antarctic region in the Earth system.

The presentation introduces the SCAR in five minutes. The session will be concluded by a discussion on the future promotion of international activities through the SCJ.

Keywords: Antarctic Research, Science Council of Japan, International Promotion

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Achievements and Prospects of the International Arctic Science Committee (IASC): Promoting International Activities through the Science Council of Japan (SCJ)

*Hiroyuki Enomoto[1]

1. National Institute of Polar Research

The International Arctic Scientific Committee (IASC) is one of the international academic societies to which the Science Council of Japan is a member. So far, representatives of Japan have been dispatched to scientific management conferences, etc. to discuss scientific issues in the Arctic, propose research implementation through international cooperation, train young researchers, collaborate with indigenous people, and respond to social demands. Has contributed to the pursuit of science and the efforts of sustainable Arctic society and international cooperation. In this talk, we will introduce the recent activities of the International Accounting Standards Committee (IASC) on the rapidly changing environment and social changes in the Arctic. In the general discussion at the end of the session, we will discuss the promotion of future international activities through the Science Council of Japan (SCJ).

Keywords: SCJ, International Promotion, IASC



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Elucidating mechanisms of the ocean and its variations and changes-Activities of the Scientific Committee on Oceanic Research (SCOR) and Japan's contribution-

*Yukio Masumoto[1], Naomi Harada[2]

1. Graduate School of Science, The University of Tokyo, 2. Japan Agency for Marine-Earth Science and Technology

The Scientific Committee on Oceanic Research (SCOR) has been working under the International Council of Scientific Unions (ICSU; the current ISC) since its establishment in 1957 to promote the development of all the desciplines in ocean science through international cooperation. Until September 2005, the Ocean Science Research Liaison Committee of the Science Council of Japan made a strong commitment to SCOR activities as the national representative in Japan. The SCOR small committee of the International Response Subcommittee (the 20th term) and the Subcommittee for SCOR (from the 21st term on) under the Committee on Earth and Planetary Science took over this important role. The aims of the Subcommittee for SCOR is to embody the international response in line with the philosophy of the new Science Council of Japan so that related academic societies and researchers in Japan can contribute globaly to the promotion of ocean science and the development of human society through the activities of SCOR. In this session, we will introduce SCOR's activities and achievements, as well as future prospects. In the general discussion at the end of the session, we will discuss the promotion of future international activities through the Science Council.

Keywords: SCJ, International Promotion, SCOR

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Achievements and Prospects of the World Climate Research Programme (WCRP): Promoting International Activities through the SCJ

*Nobuko Saigusa[1]

1. National Institute for Environmental Studies

The World Climate Research Programme (WCRP) is one of the international scientific organizations that the Science Council of Japan (SCJ) has joined on behalf of Japan. Scientists participating in the activities of WCRP have contributed to the development of climate science and a sustainable global society by dispatching representatives to science steering committees, planning international research programs, fostering young researchers, and supporting research exchanges. The achievements and a prospects of the WCRP will be introduced in a five-minute presentation, and the session will conclude with a discussion on the future promotion of international activities through the SCJ.

Keywords: SCJ, International Promotion, WCRP

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Achievements and Prospects of the International Cartographic Association (ICA): Promoting International Activities through the Science Council of Japan (SCJ)

*Kaori Ito[1], Takashi Morita[2]

1. Tokyo University of Science, 2. Hosei University

The International Cartographic Association (ICA) is one of the international scientific organizations that the Science Council of Japan (SCJ) has joined on behalf of Japan. ICA has a mission to promote the disciplines and professions of cartography and GIScience in an international context, and has co-published a book “Mapping for a Sustainpable World” with the United Nations. Scientists and professionals participating in the activities of ICA have dispatched representatives to general assemblies and international conferences, proposed and managed new committees, fostered young researchers, and supported research exchanges. They also successfully hosted the 29th International Cartographic Conference in Tokyo in 2019. The achievements and a prospects of the ICA will be introduced in a five-minute presentation, and the session will conclude with a discussion on the future promotion of international activities through the SCJ.

Keywords: SCJ, International Promotion, ICA

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Achievements and Prospects of the International Geographical Union (IGU): Promoting International Activities through the Science Council of Japan (SCJ)

*Yasuhiro Suzuki[1]

1. Nagoya University

The International Geographical Union (IGU) is one of the international scientific organizations that the Science Council of Japan (SCJ) has joined on behalf of Japan, and one of the GeoUnions in the International Science Council (ISC). Scientists participating in the activities of IGU have contributed to the development of a sustainable global society by dispatching representatives to science steering committees, planning international research programs, fostering young researchers, and supporting research exchanges. The achievements and a prospects of the IGU will be introduced in a five-minute presentation.

The IGU homepage states as follows. https://igu-online.org/

About IGU:
The International Geographical Union (IGU) is an international, non-governmental, professional organization devoted to the development of the discipline of Geography. The purposes of the IGU are primarily to promote Geography through initiating and coordinating geographical research and teaching in all countries of the world. Its work is conducted through the instruments of its National Committees, Commissions and Task Forces. The IGU hosts the International Geographical Congress every four years and also promotes regional conferences and other meetings that further of the objectives of the Union. The IGU also facilitates the participation of geographers in the global community of scientists through its formal affiliation as a Member Union within the International Science Council (ISC) and the International Council for Philosophy and the Human Sciences (CIPSH)

History of the IGU:
The IGU was formally established in Brussels in 1922. However, the history of international meetings of geographers is much longer. The first of a series of congresses met in 1871 in Antwerp. Since its early days the Union has consisted of three major components: General Assembly of the delegates appointed by the member countries which meets at the time of the Congress and is the highest authority of the Union; an Executive Committee which consists of a President, eight Vice-Presidents and a Secretary-General and Treasurer; Commissions and Study Groups which continue their work between General Assembly meetings. The working languages of the Union are English and French.

Keywords: SCJ, International Promotion, IGU

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Activities of INQUA (International Union for Quaternary Research) and Contributions from Japan

*Yoshiki Saito[1]

1. Estuary Research Center, Shimane University

INQUA (International Union for Quaternary Research) was established in 1928 by a group of scientists seeking to improve understanding of environmental change during the glacial ages through interdisciplinary research. Currently, INQUA is the representative body for Quaternary science world-wide. The basic goal of INQUA is to promote improved communication and international collaboration in basic and applied aspects of Quaternary research. An in-depth knowledge of global developments during the past 2.58 million years (the Quaternary geological period) provides the essential template for assessing the significance of current and predicted global environmental changes and natural disasters. INQUA's goal is achieved mainly through the activities of the five Commissions: CMP: Coastal & Marine Processes, HABCOM: Humans & Biosphere, PALCOM: Paleoclimates, SACCOM: Stratigraphy & Chronology, TERPRO: Terrestrial Processes, Deposits & History. INQUA also encourages Early Career Research (ECR) activities, which provide an information gateway between young (early-career) and the senior scientists and scientific networks. INQUA supports projects contributing to the development of Quaternary science worldwide through Commissions and ECR activities. INQUA Congress is held every four years. The next Congress will be held in Rome in 2023.
Japan National Committee for INQUA was established in 1955, under the Science Council of Japan. The representative from Japan participated in INQUA Congress since 1957. Japan has been contributing key members to Executive Committee and Commissions since then. The 19th INQUA Congress was successfully held in Nagoya in 2015, hosted by the Science Council of Japan, with 1789 participants from 68 countries. One of most prominent achievements from Japan to INQUA and Quaternary science is the Middle Pleistocene "Chibanian" of GSSPs, resulting from long-lasting Quaternary research in Japan for the last several decades.

Keywords: INQUA, Chibanian, Anthropocene, Global Change

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Achievements and Prospects of the International Mineralogical Association (IMA): Promoting International Activities through the Science Council of Japan (SCJ)

*Eiji Ohtani[1]

1. Department of Earth and Planetary Materials Science, Graduate School of Science, Tohoku University

The International Mineralogical Association (IMA) is one of the international scientific organizations that the Science Council of Japan (SCJ) has joined on behalf of Japan. IMA contributed to naming and classification of newly discovered minerals, advance in mineralogical sciences such as environmental and resource mineralogy for a sustainable global society, planning international research collaborations, fostering young researchers, and supporting research exchanges. SCJ contributed to the activity of IMA by dispatching representatives to science steering committees. Achievements and prospects of IMA will be introduced in a five-minute presentation, and the session will conclude with discussions on the future promotion of international activities through the SCJ.

Keywords: SCJ, International Promotion, IMA

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Activities and Roles of International Union of Geodesy and Geophysics (IUGG): Standardization of Earth Observation and Models

*Kenji Satake[1], Kumiko Goto-Azuma[2], Masato Furuya[3], Takuji Nakamura[2], Toshio Koike[4], Maki Tsujimura[5], Hisashi Nakamura[6], Toshiyuki Hibiya[7], Keiko Kuge[8], Setsuya Nakada[9]

1. Earthquake Research Institute, University of Tokyo, 2. National Institute of Polar Research & SOKENDAI, 3. Earth and Planetary Science, Hokkaido University, 4. ICHARM, Public Works Research Institute, 5. Faculty of Life and Environmental Sciences, University of Tsukuba, 6. RCAST, University of Tokyo, 7. Earth and Planetary Science, The University of Tokyo , 8. Dept. of Geophysics, Kyoto University, 9. National Research Institute for Earth Science and Disaster Resilience

IUGG (International Union of Geodesy and Geophysics) is one of the 40 scientific unions that belong to International Science Council. Currently, IUGG has 73 member countries. IUGG consists of eight International Associations. They are

International Association of Cryospheric Sciences (IACS)

International Association of Geodesy (IAG)

International Association of Geomagnetism and Aeronomy (IAGA)

International Association of Hydrological Sciences (IAHS)

International Association of Meteorology and Atmospheric Sciences (IAMAS)

International Association for the Physical Sciences of the Oceans (IAPSO)

International Association of Seismology and Physics of the Earth's Interior (IASPEI)

International Association of Volcanology and Chemistry of the Earth's Interior (IAVCEI)

IUGG was established in 1919 as one of the four scientific unions under International Research Council, together with Astronomical Union, Mathematical Union, and Chemical Union. The first nine member countries of IUGG were Australia, Belgium, Canada, France, Italy, Japan, Portugal, the United Kingdom, and the United States. The most famous and productive scientific program that IUGG led may be the International Geophysical Year (1957-8). During the cold war period, international collaborations were made under IGY, including launching Soviet Union's Sputnik 1 and USA’s Explorer 1. Japan established Showa station and started scientific measurements in Antarctica.

IUGG leads international collaboration in studies of snow and ice, geodesy, geomagnetism and aeronomy, hydrology, meteorology, physical oceanography, seismology and volcanology, through the above eight International associations. These associations proposed standard models for earth’s shape, geomagnetic field, or global climate. They are essential for everyday life such as location by using GPS signal, or weather forecast. The international collaborations are also made for global issues such as climate change,

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global warming or water issues, or natural hazards such as earthquakes or volcanic eruptions.

In Japan, the Science Council of Japan (SCJ) is the adhering organization for IUGG, and the IUGG committee and eight subcommittees for each association of SCJ serve as national committees for the IUGG and each International Association, and work as liaison with national scientific societies. Japan also sends many officers of IUGG and International Associations and contributes their managements.

Keywords: IUGG, SCJ, International Coordination

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International Union of Geological Sciences: its activities and social contributions

*Hiroshi Kitazato[1], Hiroshi Nishi[2]

1. Tokyo University of Marine Science and Technology (TUMSAT), 2. Fukui Prefectural University, Institute of Dinosaur Research

International Union of Geological Sciences is the NGO of US Department of Treasury. The union was established on 1961 at Paris for promotion and development of geological sciences. We not only promote top level geological sciences, but also standardization of time scales of the history of the Earth. We also contribute to our society with various ways such as forenthic geology and give chances to younger generations through workshops or field courses.

Keywords: Geological Sciences, Problems of the Earth, Promotion of Sciences

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[J] Oral | U (Union) | Union

[U-06] Science Council of Japan in one hour: How it supports international organizations

convener:Nobuko Saigusa(National Institute for Environmental Studies), Takuji Nakamura(National Institute of Polar Research), Shigeko Haruyama(Mie University .Emeritus Prof.), Eiichi Tajika(Department of Earth and Planetary Science, Graduate School of Science, The University of Tokyo), Chairperson:Takuji Nakamura(National Institute of Polar Research), Nobuko Saigusa(National Institute for Environmental Studies)

Thu. Jun 3, 2021 1:45 PM - 3:15 PM Ch.01 (Zoom Room 01)

The Science Council of Japan (SCJ) joins 46 international scientific organizations, including the International Science Council (ISC), as the representative organization of Japan for the promotion of science in cooperation with the global academic community. The SCJ supports 12 organizations in the field of earth and planetary sciences by providing financial contributions and dispatching representatives to the scientific steering committee, where long-term visions and research plans are discussed with the aim of pursuing the truth and realizing global sustainability. The SCJ also supports promotion of young scientists and international research exchanges. This session covers the 12 international organizations with the latest achievements and prospects in one hour and discusses the promotion of future international activities through the SCJ.

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2:55 PM - 3:15 PM

[U06-14]Discussion

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[J] Oral | U (Union)：Union

Thu. Jun 3, 2021 3:30 PM - 5:00 PM JST | Thu. Jun 3, 2021 6:30 AM - 8:00 AM UTC | Ch.01 Zoom Room 01

[U-07] Open Science and Open Data in Academic Publishing from Japan

convener:Hirokuni Oda(Institute of Geology and Geoinformation, Geological Survey of Japan, AIST), Hodaka Kawahata(Atmosphere Ocean Research Institute, the University of Tokyo),
Chairperson:Hirokuni Oda(Institute of Geology and Geoinformation, Geological Survey of Japan, AIST), Hodaka Kawahata(Atmosphere Ocean Research Institute, the University of Tokyo)

Scientific products including journal publications, reports and data are invaluable resour
ces for human beings. These days, open science, open data, and FAIR data policies are
becoming more and more important for sustainable society and research development
s. In the proposed session, we invite presenters representative of academic journal publications from Japanese societies and institutions as well as key organizations.

3:30 PM - 3:45 PM JST | 6:30 AM - 6:45 AM UTC

[U07-01] Advanced publication of scientific journals by JpGU and the related academic societies

★Invited Papers

*Hodaka Kawahata[1] (1.Atmosphere Ocean Research Institute, the University of Tokyo)

3:45 PM - 4:00 PM JST | 6:45 AM - 7:00 AM UTC

[U07-02] Current status and issues of PEPS journal

★Invited Papers

*Eiji Ohtani[1] (1.Department of Earth and Planetary Materials Science, Graduate School of Science, Tohoku University)

4:00 PM - 4:15 PM JST | 7:00 AM - 7:15 AM UTC

[U07-03] ”Earth, Planets and Space": The current status

★Invited Papers

*Takeshi Sagiya[1] (1.Disaster Mitigation Research Center, Nagoya University)

4:15 PM - 4:30 PM JST | 7:15 AM - 7:30 AM UTC

[U07-04] STAM and STAM-M : Open Data and Open Science with Open Access Journal from Japan

★Invited Papers

*Masanobu NAITO[1] (1.National Institute for Materials Science)

4:30 PM - 4:45 PM JST | 7:30 AM - 7:45 AM UTC

[U07-05] Research data repository for journals “J-STAGE Data” launching

★Invited Papers

*Ritsuko Nakajima[1] (1.Japan Science and Technology Agency)

4:45 PM - 5:00 PM JST | 7:45 AM - 8:00 AM UTC

[U07-06] Norms in scholarly communication: changes brought by open science

★Invited Papers

*Nobuko Miyairi

Advanced publication of scientific journals by JpGU and the related academic societies

*Hodaka Kawahata[1]

1. Atmosphere Ocean Research Institute, the University of Tokyo

We have been publishing PEPS, an English-language peer-reviewed open access e-journal, by the Japan Geoscience Union (JpGU) under collaboration with 50 society members by partnership with Springer since 2014. It is intended to serve as a platform for the publication of high-quality articles covering a wider field than the usual specialist journals, thus attracting students and research scientists globally. We have been promote review papers printed in PEPS, which will contribute in order to help beginners and young scientists to learn the hot topics in this research field like several chapters in text books. Therefore we have made an effort to collect excellent review articles at 20% and good original research articles at >80%. However, the relative contribution of review articles was unfortunately reduced in 2020. We have already established the publication category of “Paper with Full Data Attached”, which contains big data with a hot scientific topic. This kind of the publication will be strongly promoted in near future because it will be related to the activity of OPEN SCIENCE.
We have been getting get some Grants-in-Aid for Scientific Research to promote scientific publication by JpGU and JpGU participating societies. With the cooperation of academic societies, we will work to promote advertising by effectively introducing published papers and requesting review paper submissions to PEPS. We are currently considering the establishment of new facilities such as "The Most Cited Paper Prize” in PEPS and widely advertizing award-winning treatises.
PEPS got the first impact factor of 2.481 for 2017 publication. Based upon the latest data base by Clarivate Analytics (the former Thomson Reuter), we will get the first 5-year IF of >3.0 with the 2-year IF of >3.0 for 2020 PEPS publication in next June. Therefore PEPS Editorial board will ask the geoscientists to submit high quality of the manuscripts to submit PEPS and to develop and enhance the intelligent activity by global community of Earth and Planetary Science for the benefit of humanity”.

Keywords: PEPS, Impact factor, JpGU, Scientific journal

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Current status and issues of PEPS journal

*Eiji Ohtani[1]

1. Department of Earth and Planetary Materials Science, Graduate School of Science, Tohoku University

Here, we will introduce the current status of PEPS, which is in its 7th year of publication, and issues to be improved. The 2019 Impact Factor and CiteScore of PEPS were 2.058 and 3.8, respectively. The estimated values for 2020 were 3.0 and 4.6 respectively, showing steady development. During this time. PEPS introduced the Most cited paper award, Most downloaded paper award, and introduction of SPEPS to promote submission. PEPS also introduced Rules for Dealing with Suspected Malpractice Associated with Papers Submitted to PEPS. PEPS needs to deal with several unachieved issues such as publication of more than 20% review articles and to promote further submission. We are considering to introduce several procedures such as encouraging academic societies to submit review articles, improving the article category to promote the submission of synthesis articles, and introducing PEPS most citation prize. There are issues that need to be considered in the future, such as operational problems of Rules for Dealing with Suspected Malpractice and data repository for submitted articles.

Keywords: PEPS, Impact Factor, CiteScore

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"Earth, Planets and Space": The current status

*Takeshi Sagiya[1]

1. Disaster Mitigation Research Center, Nagoya University

EPS (Earth, Planets and Space) is a peer-reviewed open access journal published on behalf of the five societies; Society of Geomagnetism and Earth, Planetary and Space Sciences, The Seismological Society of Japan, The Volcanological Society of Japan, The Geodetic Society of Japan, and The Japanese Society for Planetary Sciences, all of which are society members of the Japan Geoscience Union. EPS covers broad area in earth and planetary sciences with particular foci on geomagnetism, aeronomy, space science, seismology, volcanology, geodesy, and planetary science.

EPS was remodeled in 2014 as an open access journal under the SpringerOpen platform. Since then, EPS has published average of 173 papers per year. About half of the authors are from overseas. 2-year impact factor (IF) of EPS is 2.075. The editorial board of EPS is international. Among 59 members of the editorial board, 29 members are from overseas.

EPS publishes the following article types: (1) "Full paper", (2) “Express Letter” which aims at fast publications, (3) “Frontier Letter” for leading edge researches only with the invitation from the editor in chief, and (4) “Technical report" which describes technical developments for scientific researches. In addition to regular publication, EPS promotes topical article collections called special issues about various geoscientific events (earthquakes and volcanic eruptions) or scientific missions (satellite missions).

As part of the promotion of the journal we have four annual awards to recognize authors and reviewers: (1) EPS Excellent paper awards, (2) EPS Young researcher award, (3) Highlighted Paper Awards and (4) Excellent Paper Awards.

Recently we have been trying to increase the publication speed. On average, it takes 46 days for the first decision and 141 days for acceptance from the submission. We are trying to promote EPS as an important scientific contribution from Japan to the global geoscience community. We expect to receive more submissions of important science results from JpGU members.

Keywords: Earth, Planets and Space, geoscience, scientific publication

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STAM and STAM-M : Open Data and Open Science with Open Access Journal from Japan

*Masanobu NAITO[1]

1. National Institute for Materials Science

Materials science and technology has been rapidly growing, especially, since the emergence of data-driven approach, so called, materials informatics (MI) and as more databases that include variety of materials property emerged, some of which allowed researchers to freely reuse the data to obtain further dataset, the idea of MI brought a new paradigm in designing new materials science. Just like Bioinformatics has won its standing point in the sub discipline in life sciences, use of big data has led materials science to find its new discipline. However to this moment, there has been no appropriate journal for submitting articles from this emerging field. One reason being it as the field is still in its early days, and secondly this field is an interdisciplinary one between materials science, engineering and informatics which prevented new journals to be launched in the old disciplinary hierarchy. On this account, NIMS proposes to launch a brand new journal solely dedicated in advancement of MI in the purpose of systematizing this new scientific knowledge.
NIMS has been publishing Science and Technology of Advanced Materials (STAM) since 2000. It has introduced a new article category on MI in 2016 and the number of submissions on MI has been increasing since then. However, since STAM’ s aims and scope focuses on broad term of materials science and not specifically on informatics (methodology, database, instrumentation, and programming), STAM has been struggling to receive more papers on MI even though the Editors are aware that there are many unpublished good methodology and datasets stored in each laboratory of materials scientists. The new journal will be a platform to provide opportunity for these unsung papers to be read and to be reused by third parties in hope to design the future courses of materials science.

Keywords: Science and technology of advanced materials (STAM), Science and technology of advanced materials: Methods (STAM-M)



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Research data repository for journals “J-STAGE Data” launching

*Ritsuko Nakajima[1]

1. Japan Science and Technology Agency

The J-STAGE is an electronic journal platform operated by the Japan Science and Technology Agency (JST). With the aim of disseminating and promptly distributing research results from science and technology (including humanities and social sciences) published in Japan, J-STAGE supports the publishing of scientific and technological publications by academic societies, research institutes, and other publishing organizations to strengthen international information dissemination and promote open access.

In regard to J-STAGE, JST is responsible for the planning and policy-making of the service, development, and operation of the system and various support with respect to the publishing organizations. The system has the function to register and publish articles, and the service is made possible by the publishing organizations using this system to publish their articles.

Currently, more than 3,000 journals, conference proceedings, and other publications have been published on J-STAGE by more than 1,700 domestic organizations and the number of articles exceeds 5 million. Of these, more than 85% are journals freely accessible to anyone, contributing greatly to the openness of research results from Japan.

On the other hand, when we look at the world, we can see that the nature of academic publishing and the various information provision services surrounding it are changing rapidly with the recent changes in academic communication and research workflows. These changes include, for example, the diversification of publication forms and contracts relating to open access, the increase of preprints, the emergence of new publication forms such as post-publication peer review and open peer review, and the movement to publish research data associated with papers. At the root of all these movements is the trend toward open science.

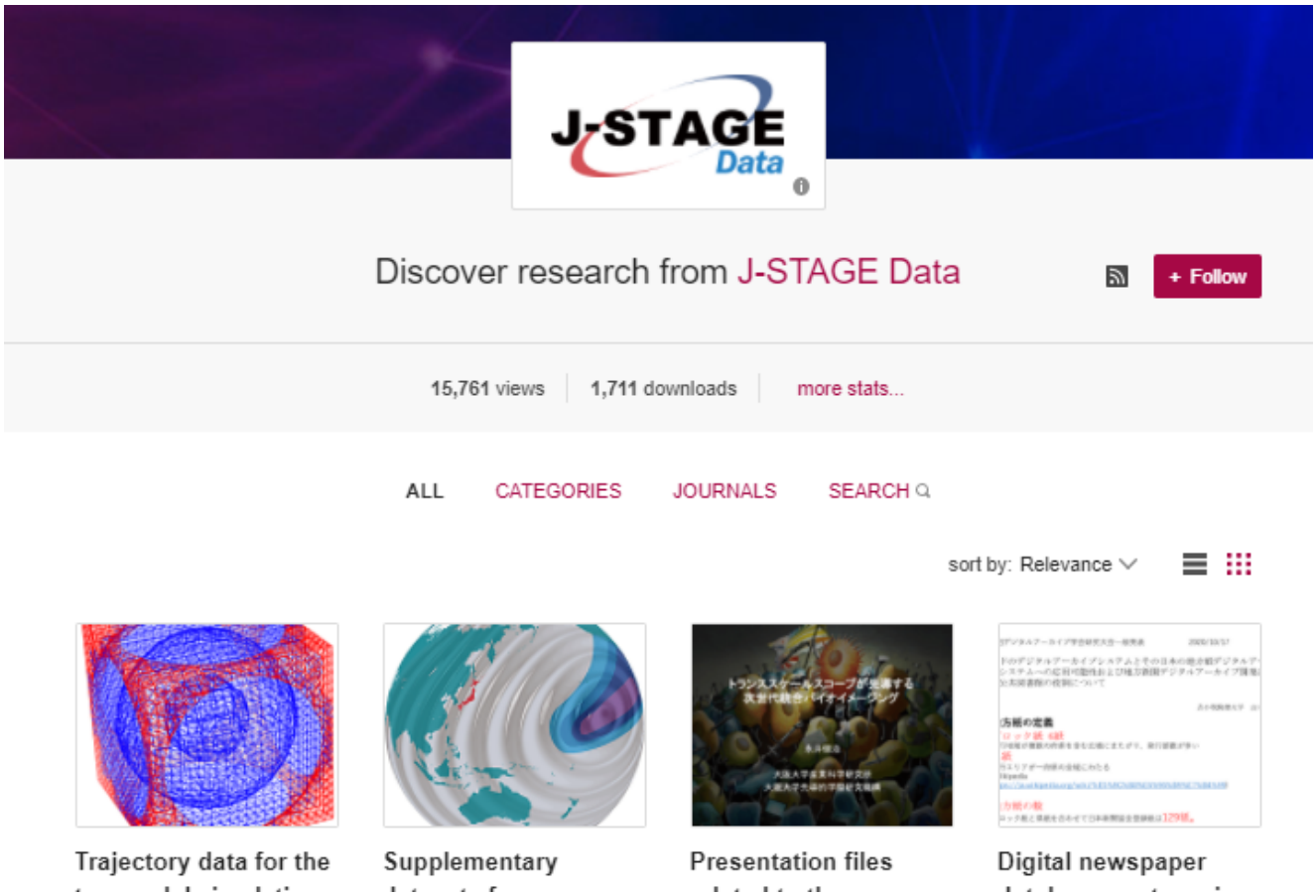
Many universities, research institutes, and research funding agencies have formulated policies for data management and disclosure in order to meet the expectations for creating new value through data sharing and utilization that accompany the development of open science, and the demands for preventing research misconduct and improving transparency. In addition, policies on open data and sharing are being developed in the field of academic publishing as well, and researchers are increasingly required to provide the data on which their research results are based when they submit their papers. Major international commercial publishers have opened their policies on research data related to their journals on their websites. They indicate the recommended and mandatory levels of data availability, repositories, data citation and linking from articles, peer review of data, licensing for reuse, etc. The journals from these publishers have guides for authors that comply with these policies.

In response to this situation, JST started the pilot operation of the publication platform "J-STAGE Data" in

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March 2020. DOI (Digital Object Identifier)s are registered for the data, and it is possible to link the data from the papers such as those on J-STAGE, and it also facilitates to distribute the research data its own. All the data on J-STAGE Data is open access, and the user organizations which publish the data grant a license that defines the scope of secondary use.
As of the end of January 2021, 37 data have been published by 3 journals, and the number of participating journals is expected to increase in the future. During this pilot period, JST is developing the operation system with the cooperation of the participating journals and aims to start the full-scale operation at the end of this fiscal year.

Keywords: open science, journal, research data, J-STAGE



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Norms in scholarly communication: changes brought by open science

*Nobuko Miyairi

Michael Nielsen, the author of *Reinventing Discovery: The New Era of Networked Science*[(1)], defined open science as the idea where “scientific knowledge of all kinds should be openly shared as early as is practical in the discovery process.” [(2)] This overly simple statement is equivocal and troublesome for those seeking to practice open science. Scientific knowledge can be available in a variety of formats, including publications, data sets, audio-visual materials, methods, software, and so forth. They may already have established ways for sharing; or they may have not been traditionally shared at all. The idea to share “as early as is practical” depends on the technical and organizational constraints that one might face. In addition, Nielsen leaves it indistinct whether “openly shared” means either simply putting on the public web or with some additional procedures required.

The public consultation conducted by the European Commission in 2014 denotes that open science is an umbrella term for a series of movements in research and related practices, referring to a system of related changes that must be considered in relation to one another. Three essential aspects of open science are: (1) its relation to digital technology, (2) changing research practices and their impact on the research system as a whole, and (3) a certain vision of science as a community of practice. The objective of this public consultation was to receive feedback from community stakeholders on ‘science 2.0’, which the majority of respondents agreed that ‘open science’ was a more appropriate term to describe. [(3)]

If we regard the scholarly community as a social group, its members share more or less mutual values, which in turn guide their behaviors as social norms. Such norms could influence not only members’ behaviors but also define goals and the means of achieving them. Scholarly publishing, or more broadly, scholarly communication is thus governed by social norms set by the research community as a whole. The visions distilled in Nielsen’s simplistic statement demand a reform of the shared values in the traditional scholarly community and the practices cultivated therein.

There are new infrastructures allowing scholarly outputs other than VoR or the version of record, such as preprints and conference presentations, to be openly shared. OA mega-journals, which simplify peer-review process and speed up the publication process only if scientific validity is met, are increasing by number and exceeding the volume produced by traditional peer-reviewed journals. Prevailing social media made it possible to quantify the online behavior of readers, leading to the wide adoption of altmetrics. These new forms of outputs and indicators have brought new perspectives to research performance evaluation.

In this presentation, we will discuss the various changes brought about by science 2.0 or open science in contrast to the perceived norms in scholarly communications.

References:

(1) Nielsen, Michael. *Reinventing Discovery: The New Era of Networked Science*. Princeton University Press, 2011, 280p.

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(2) Gezelter, Dan. (2011, July 28). *An informal definition of OpenScience | The OpenScience Project*. Openscience.org. http://openscience.org/an-informal-definition-of-openscience/

(3) European Commission. (2015, February). Validation of the results of the public consultation on Science 2.0: Science in Transition. http://ec.europa.eu/research/consultations/science-2.0/science_2_0_final_report.pdf

Keywords: scholarly publishing, scholarly communication, open science

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[J] Oral | P (Space and Planetary Sciences)：P-PS Planetary Sciences

Thu. Jun 3, 2021 1:45 PM - 3:15 PM JST | Thu. Jun 3, 2021 4:45 AM - 6:15 AM UTC | Ch.04 Zoom Room 04

[P-PS06] Planetary Sciences

convener:Yusuke Nakauchi(Japan Aerospace Exploration Agency), Hiroshi Kikuchi(Japan Aerospace Exploration Agency), Chairperson:Yuri Fujii(Graduate School of Human and Environmental Studies, Kyoto University), Haruka Hoshino(Department of Astronomy, Graduate School of Science, The University of Tokyo)

We call for general interest papers for Planetary Sciences. Planetary Sciences consist o f a variety of studies on the past, present, and future of our solar system and exoplanetary systems, Discussions based on various backgrounds are encouraged.

1:45 PM - 2:00 PM JST | 4:45 AM - 5:00 AM UTC

[PPS06-01] Size evolution of close-in super-Earths: effects of giant impacts and photoevaporation

*Yuji Matsumoto[1], Eiichiro Kokubo[2], Pin-Gao Gu[1], Kenji Kurosaki[3] (1.ASIAA, 2.NAOJ, 3.Nagoya Univ.)

2:00 PM - 2:15 PM JST | 5:00 AM - 5:15 AM UTC

[PPS06-02] Stellar mass dependence of planetary systems formed by giant impacts: minimum-mass exstrasolar nebula model and habitable planets

*Haruka Hoshino[1,2], Eiichiro Kokubo[2,1] (1.Department of Astronomy, Graduate School of Science, The University of Tokyo, 2.Division of Science, National Astronomical Observatory of Japan)

2:15 PM - 2:30 PM JST | 5:15 AM - 5:30 AM UTC

[PPS06-03] Collisional Growth and Fragmentation of Dust Aggregates with Low Mass Ratios

*Yukihiko Hasegawa[1], Takeru Suzuki[1], Hidekazu Tanaka[2], Hiroshi Kobayashi[3], Koji Wada[4] (1.The University of Tokyo, 2.Tohoku University, 3.Nagoya University, 4.Chiba Institute of Technology)

2:30 PM - 2:45 PM JST | 5:30 AM - 5:45 AM UTC

[PPS06-04] The amount of cosmic rays in protoplanetary disks and their effects on ionization degrees

*Yuri I. Fujii[1], Shigeo Kimura[2] (1.Kyoto University, 2.Tohoku University)

2:45 PM - 3:00 PM JST | 5:45 AM - 6:00 AM UTC

[PPS06-05] Suppression of the vertical shear instability in protoplanetary disks by dust growth : Implications for disk observations

*Yuya Fukuhara[1], Satoshi Okuzumi[1] (1.Department of Earth and Planetary Sciences, Tokyo Institute of Technology)

3:00 PM - 3:15 PM JST | 6:00 AM - 6:15 AM UTC

[PPS06-06] Constructing a model of metal accretion disks around white dwarf stars: toward understanding the evolution of remnant planetary systems

*Ayaka Okuya[1], Shigeru Ida[2], Ryuki Hyodo[3] (1.Department of Earth & Planetary Sciences, Tokyo Institute of Technology, 2.Earth-Life Science Institute, Tokyo Institute of Technology, 3.JAXA/ISAS)

Size evolution of close-in super-Earths: effects of giant impacts and photoevaporation

*Yuji Matsumoto[1], Eiichiro Kokubo[2], Pin-Gao Gu[1], Kenji Kurosaki[3]

1. ASIAA, 2. NAOJ, 3. Nagoya Univ.

To date, transit observations report more than 3000 exoplanets, and we know their orbital architecture, i.e., their size and period distribution. The size distribution of super-Earths in close-in orbits is bimodal with a radius gap (e.g., Fulton et al., 2017). Besides, planetary sizes within systems show that adjacent planet pairs have the same size and separations (peas in a pod; e.g., Weiss et al., 2018). We have investigated whether these features are explained simultaneously. The former feature, the radius gap, is considered as a result of envelope evolution through photoevaporation (e.g., Owen & Wu 2017) or other mechanisms (e.g., Gupta & Schlichting 2019). The latter feature, peas in a pod, is not well investigated. It still remains unclear whether this feature is reproduced in the formation processes of planetary systems. We consider planetary growth via giant impacts along with the envelope loss via both giant impacts and photoevaporation to study the size evolution of planets. We have developed the N-body simulation code where planetary sizes are derived by the summation of the core size and envelope size using the scaling law (Valencia et al. 2006) and analytical expression (Owen & Wu 2017). We also consider the envelope loss in giant impacts based on recent SPH simulation results (Kegerreis et al. 2020). We have performed simulations by changing initial envelope fractions and surface density profiles of protoplanets based on observations (Dai et al., 2020).
Our simulations show that impacts are not head-on but grazing encounters, which do not cause significant envelope loss. However, high-velocity collisions sometimes cause whole envelope loss events. As a result, some bare rocky planets are formed. These bare rocky planets are located at inner orbits and have larger masses, typically, since they tend to experience a larger number of collisions. Interestingly, these massive planets barely lose their whole envelope via photoevaporation, especially when the surface density profiles of protoplanets are shallow, i.e., inner protoplanets are massive. We also found that there are several planets located in the outer region where the initial envelopes can be retained. Small inner planets lose their envelopes via photoevaporation. The final size distribution of planets is bimodal due to the envelope loss via photoevaporation. The distribution of planets on the period-radius plane roughly agrees with that of observed planets. In addition, the neighboring formed planets have the same size and same separations. The combination of giant impacts and photoevaporation provides a possible explanation of the orbital architecture of observed super-Earths. However, our results produce too many large planets. This suggests that some additional envelope loss mechanisms are necessary to explain the observed size distributions of planets.

Keywords: Planet size, Super-Earth, Giant impact, Photoevaporation

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Stellar mass dependence of planetary systems formed by giant impacts: minimum-mass exstrasolar nebula model and habitable planets

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1. Department of Astronomy, Graduate School of Science, The University of Tokyo, 2. Division of Science, National Astronomical Observatory of Japan

Recent exoplanet surveys revealed that for solar-type stars close-in super-Earths are ubiquitous and many of them are in multi-planet systems. These systems are more compact than the solar system’s terrestrial planets. Ongoing and future exoplanet observations will find more planets around low-mass stars. However, there are not many theoretical studies on the formation of such planets around low-mass stars. Now is the time to clarify the dependence of the stellar mass on planet formation. In the standard model, the final stage of terrestrial planet formation is the giant impact stage where protoplanets gravitationally scatter and collide with each other, to evolve into a stable planetary system. We investigate the effect of the stellar mass on the architecture of planetary systems formed by giant impacts. We perform *N*-body simulations of the giant impact stage around different stellar masses. Using the minimum-mass extrasolar nebula model, we set the isolation mass of protoplanets and distribute them in 0.05 - 0.15 au from the central star. We follow the evolution for 200 million orbital periods of the innermost planet. We find that the eccentricity and inclination of orbits, and the orbital separation of adjacent planets increase with decreasing the stellar mass. This is because that as the stellar mass decreases the relative strength of planetary scattering becomes more effective. We also discuss the properties of planets formed in the habitable zone.

Keywords: planetary system formation, terrestrial planet, giant impact, stellar mass

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Collisional Growth and Fragmentation of Dust Aggregates with Low Mass Ratios

*Yukihiko Hasegawa[1], Takeru Suzuki[1], Hidekazu Tanaka[2], Hiroshi Kobayashi[3], Koji Wada[4]

1. The University of Tokyo, 2. Tohoku University, 3. Nagoya University, 4. Chiba Institute of Technology

We investigated fundamental processes of collisional sticking and fragmentation of dust aggregates composed of submicron-sized icy dust monomers. We carried out N-body simulations of dust monomers. We examined the condition for collisional growth of two colliding dust aggregates in a wide range of the mass ratio, 1-64. We found that the mass transfer from a larger dust aggregate (called a target) to a smaller one (called a projectile) is a dominant process in collisions with a mass ratio of 2-30 and the impact velocity of about 30-170 m per s. As a result, the critical velocity for collisional fragmentation of the target is considerably reduced for such unequal-mass collisions; the critical fragmentation velocity of collisions with a mass ratio of 3 is about half of that obtained from equal-mass collisions. The impact velocity is generally higher for collisions between dust aggregates with higher mass ratios because of the difference between the radial drift velocities in the typical condition of protoplanetary disks. Therefore, the reduced critical fragmentation velocity for unequal-mass collisions would delay growth of dust grains in the inner region of protoplanetary disks.

Keywords: Numerical simulation, Planet formation, Protoplanetary disk

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The amount of cosmic rays in protoplanetary disks and their effects on ionization degrees

*Yuri I. Fujii[1], Shigeo Kimura[2]

1. Kyoto University, 2. Tohoku University

Protoplanetary disk gas is weakly ionized by various ionization sources, such as cosmic rays, X-rays, ultraviolet, and decay of radionuclides. Ionization fraction of the gas is essential information to study the magnetohydrodynamic evolution of the disk, because it determines the coupling between the gas and magnetic fields. Cosmic rays are also known to play an important role in chemical evolution by triggering reactions in the disk. Thus, we need to understand how deep inside of the disk cosmic rays can penetrate. Previous studies adopted interstellar cosmic-ray ionization rate at the surface of the disk and the attenuation of cosmic rays are considered based on the vertical column of the gas from the point of interest to the surface of the disk/infinity. However, the actual path of cosmic ray particles should be affected by magnetic fields, and thus so will the column density swept by them. Cosmic rays are focused towards a protoplanetary disk from a larger area by magnetic fields, but some of them are reflected due to magnetic mirrors; in total, we found that the flux arriving at a protoplanetary disk is reduced by a factor of 4. We also found that low energy cosmic rays are captured by azimuthal component of the fields in the surface area of the disk and lose their energy before entering to the inside. Thus, the cosmic-ray ionization rate is expected to be smaller than previously thought.

Keywords: Cosmic rays, Protoplanetary Disks, Ionization fraction, Magnetic fields

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Suppression of the vertical shear instability in protoplanetary disks by dust growth : Implications for disk observations

*Yuya Fukuhara[1], Satoshi Okuzumi[1]

1. Department of Earth and Planetary Sciences, Tokyo Institute of Technology

Planet formation depends on dust evolution and distribution in protoplanetary disks. Among them, strong dust settling to the midplane in disks promotes dust growth and planetesimal formation. One of the observational evidence of this dust settling is the protoplanetary disk around HL Tau. Recent radio interferometric observations have provided us with evidence that the HL Tau disk has rings and gaps of dust. Because these gaps have well separated and showing a high degree of contrast with the rings, the dust in outer regions in the HL Tau disk settles in the vertical direction.
This dust settling to the midplane means that the vertical turbulent diffusion is weak in outer disk regions. However, the vertical shear instability (VSI), which is the most robust turbulent origin in outer disk regions, drives turbulence with efficiently preventing vertical dust settling. This is about 10 times stronger than the intensity of vertical diffusion estimated from observations of the HL Tau disk. If the VSI drives turbulence in the HL Tau, the strong settling of dust may not occur.
On the other hand, One candidate of factors that weaken the turbulence of this VSI is dust growth and settling. The VSI requires rapid gas cooling and has been suggested to operate in outer disk regions. Dust growth and settling to the midplane affect the cooling rate distribution of disks and make the cooling above the midplane inefficient.
In this study, we develop a model to estimate the diffusion coefficient of the VSI-driven turbulence based on the linear analysis, taking into account dust evolution. Furthermore, by applying this model to the HL Tau disk, we discuss whether the observed dust settling is feasible or not. The model consists of the following two steps. In the first step, we calculate the region where the VSI can be driven and the VSI growth rate by linear analysis, taking into the dust distribution with settling in the disk. In the second step, we estimate the vertical diffusion coefficient of the VSI-driven turbulence from them. We construct the model to be consistent with the hydrodynamical simulations of the VSI. Comparing the estimated diffusion coefficient and the assumed one that is necessary to calculate the dust distribution given initially, we investigate how the VSI-driven turbulence evolves.
We find that dust diffusion due to the VSI-driven turbulence is weakened and dust settling is possible consistent with the HL Tau observations. As the dust particles grow up to 1 mm, the vertical diffusion coefficient of the VSI-driven turbulence is expected to settle down to about 10^(-4), which is consistent with the maximum value of the vertical diffusion coefficient ~10^(-4) assumed from observations. Even if the dust diffuses strongly temporarily due to the VSI, the dust cannot sustain this strong diffusion and may settle on the midplane.
Our results suggest that dust evolution may suppress the VSI-driven turbulence, which causes strong dust diffusion. Given that turbulence generally prevents dust coagulation and planetesimal formation, this may promote dust growth and planetesimal formation under the VSI-driven turbulence.

Keywords: protoplanetary disks, dust evolution, turbulence, vertical shear instability, HL Tau disk

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Constructing a model of metal accretion disks around white dwarf stars: toward understanding the evolution of remnant planetary systems

*Ayaka Okuya[1], Shigeru Ida[2], Ryuki Hyodo[3]

1. Department of Earth & Planetary Sciences, Tokyo Institute of Technology, 2. Earth-Life Science Institute, Tokyo Institute of Technology, 3. JAXA/ISAS

White dwarfs are the final evolutionary state of stars with a mass less than ~8 Msun. 1/2-1/4 of all WDs exhibit metal pollution in their atmospheres (Zuckerman et al. 2010), and some of them show infrared excess from their circumstellar debris disks (Rocchetto et al. 2015). These are thought to be originated from the remnant planetary systems around WDs which evolve with their central stars. The surviving asteroids/minor planets are gravitationally scattered onto star-grazing orbits, and the subsequent tidal disruption is likely to produce compact accretion disks. Based on this scenario, an accretion disk model is essential to link a rapidly growing number of these observations around WDs to surviving planetary systems as well as their evolution.
In this study, we construct a 1-dimensional WD disk model that consistently solves key processes in such disks: advection, diffusion, sublimation, and condensation. We firstly investigated the time evolution of accretion disks composed of silicate particles and their vapor. For the particulate disk, Poynting-Robertson (PR) drag is thought to drive the metal accretion. On the other hand, observations have shown that WDs accompanied by debris disks tend to have accretion rates orders of magnitude higher than that can be explained by PR drag alone (~ 1e8 g/s). Metzger et al. (2012) demonstrated that if the aerodynamic drag due to vapor produced by the sublimation of silicate particles is effective, the accretion rate could reach such measured values. However, they neglected the back-reaction and diffusion of particles in the gas and condensation of silicate vapor. As a result of our calculation including these effects, we found that the accretion rate enhancement proposed by Metzger et al. (2012) does not occur because the vapor density determined by the saturating vapor pressure outside the sublimation line is so low that it cannot affect the particle motion. Furthermore, near the silicate sublimation line, silicate vapor advects/diffuses outward and then recondenses into the solid particles. This causes a pile-up of the particles just outside the sublimation line, resulting in a lower accretion rate than even that predicted by PR drag alone. Finally, we will discuss the possibility that the disk with vapor produced by solid components with lower sublimation points than silicates (e.g., water ice) could reproduce the observational high accretion rates.

Keywords: White dwarf stars, Debris disks, Exoplanets

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[J] Oral | P (Space and Planetary Sciences)：P-PS Planetary Sciences

Thu. Jun 3, 2021 3:30 PM - 5:00 PM JST | Thu. Jun 3, 2021 6:30 AM - 8:00 AM UTC | Ch.04 Zoom Room 04

[P-PS06] Planetary Sciences

convener:Yusuke Nakauchi(Japan Aerospace Exploration Agency), Hiroshi Kikuchi(Japan Aerospace Exploration Agency), Chairperson:Hiroshi Kikuchi(Japan Aerospace Exploration Agency), Yusuke Nakauchi(Japan Aerospace Exploration Agency)

We call for general interest papers for Planetary Sciences. Planetary Sciences consist o f a variety of studies on the past, present, and future of our solar system and exoplanetary systems, Discussions based on various backgrounds are encouraged.

3:30 PM - 3:45 PM JST | 6:30 AM - 6:45 AM UTC

[PPS06-07] ALMA high resolution observations of the transitional disk around SY Cha.

*Ryuta Orihara[1], Munetake Momose[1], Takayuki Muto[2], Jun Hashimoto[3], Hauyu Baobab Liu[4], Takashi Tsukagoshi[5], Tomoyuki Kudo[5], Sanemichi Takahashi[5], Yi Yang[5,6], Yasuhiro Hasegawa[7], Ruobing Dong[8], Mihoko Konisi[9], Eiji Akiyama[10], Masato Ishiduka[6] (1.Ibaraki University, 2.Kogakuin University, 3.Astrobiology Center, 4.Academia Sinica Institute of Astronomy and Astrophysics, 5.National Astronomical Observatory of Japan, 6.University of Tokyo, 7.NASA Jet Propulsion Laboratory, 8.University of Victoria, 9.Oita University, 10.Niigata institute of technology)

3:45 PM - 4:00 PM JST | 6:45 AM - 7:00 AM UTC

[PPS06-08] Model calculation of infrared and radio observations of the circumplanetary disks: Conditions for satellite formation

*Bochao Hu[1], Hideko Nomura[2] (1.Tokyo Institute of Technology/National Astronomical Observatory of Japan, 2.National Astronomical Observatory of Japan)

4:00 PM - 4:15 PM JST | 7:00 AM - 7:15 AM UTC

[PPS06-09] Development of a Hayabusa2 ONC image retrieval system with 2D/3D switchable maps in a web browser

*Hiroshi Kikuchi[1], Mitsuo Yamamoto[1], Yasuhiro Yokota[1], Hiroyuki Sato[1], Hisashi Otake[1], Rie Honda[2], Seiji Sugita[3], Tomokatsu Morota[3], Toru Ishikawa[4], Kazuya Imaki[4], Yasuyuki Watabe[4], Takeshi Konishi[5], Ryodo Hemmi[3], Hideaki Miyamoto[3], Yukio Yamamoto[1], Naru Hirata[6], Naoyuki Hirata[7], Sho Sasaki[8], Goro Komatsu[9], Hirohide Demura[6], Chikatoshi Honda[6], Manabu Yamada[10], ERI TATSUMI[11], Yuichiro Cho[3], Kazuo Yoshioka[3], Hirotaka Sawada[1], Naoya Sakatani[12], Masahiko Hayakawa[1], Moe Matsuoka[1], Toru Kouyama[13], Hidehiko Suzuki[14], Kazunori Ogawa[1] (1.JAXA, 2.Kochi Univ., 3.Univ. of Tokyo, 4.JAMSS, 5.Konniesystem, 6.Univ. of Aizu, 7.Kobe Univ., 8.Osaka Univ., 9.IRSPS, Università d'Annunzio, 10.Chiba Inst. Tech., 11.IAC, 12.Rikkyo Univ., 13.AIST, 14.Meiji Univ.)

4:15 PM - 4:30 PM JST | 7:15 AM - 7:30 AM UTC

[PPS06-10] Martian Moons eXploration MMX: Current Status Report 2021

*Kiyoshi Kuramoto[1,2], Yasuhiro Kawakatsu[2], Masaki Fujimoto[2], Maria Antonietta Barucci[3], Hidenori Genda[4], Naru Hirata[5], Takeshi Imamura[6], Jörn Helbert[7], Shingo Kameda[8], Masanori Kobayashi[9], Hiroki Kusano[10], David J. Lawrence[11], Koji Matsumoto[12], Patrick Michel[13], Hideaki Miyamoto[6], Hiromu Nakagawa[14], Tomoki Nakamura[14], Kazunori Ogawa[2], Hisashi Otake[2], Masanobu Ozaki[2], Sara Russell[15], Sho Sasaki[16], Hiroki Senshu[9], Naoki Terada[14], Stephan Ulamec[7], Tomohiro Usui[2], Koji Wada[9], Shoichiro Yokota[16] (1.Hokkaido University, 2.JAXA, 3.Paris Observatory, 4.Tokyo Institute of Technology, 5.Aizu University, 6.The University of Tokyo, 7.DLR, 8.Rikkyo University, 9.Chiba Institute of Technology, 10.QST, 11.Johns Hopkins University APL, 12.NAOJ, 13.Université Côte d'azur, 14.Tohoku University, 15.Natural History Museum, 16.Osaka University)

4:30 PM - 4:45 PM JST | 7:30 AM - 7:45 AM UTC

[PPS06-11] The orbital evolution of Phobos in the expanded atmosphere of early Mars under an intense solar EUV radiation

*Kohei Fujita[1], Naoki Terada[1], Shotaro Sakai[1], Kaori Terada[1] (1.Tohoku University)

4:45 PM - 5:00 PM JST | 7:45 AM - 8:00 AM UTC

[PPS06-12] Hydrodynamic escape of reduced proto-atmospheres: different consequences for surface volatile inventories between Mars and Earth

*Tatsuya Yoshida[1], Kiyoshi Kuramoto[1] (1.Hokkaido University)

ALMA high resolution observations of the transitional disk around SY Cha.

*Ryuta Orihara[1], Munetake Momose[1], Takayuki Muto[2], Jun Hashimoto[3], Hauyu Baobab Liu[4], Takashi Tsukagoshi[5], Tomoyuki Kudo[5], Sanemichi Takahashi[5], Yi Yang[5,6], Yasuhiro Hasegawa[7], Ruobing Dong[8], Mihoko Konisi[9], Eiji Akiyama[10], Masato Ishiduka[6]

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Transitional disks have a cavity with weak dust emission in the central region, and they are thought to be highly evolved protoplanetary disks. The formation mechanism of such disks is still not known. Transitional disks are identified as objects with low infrared excess in the spectral energy distribution (SED). However, it is difficult to classify transitional disks only with SED. There is a class of disks so-called "pre-transitional disks", which has a small inner disk in the cavity of the outer transitional disk. These are considered to be precursors to the transitional disks and therefore are important in understanding disk evolution processes. Since the SED of a pre-transitional disk is indistinguishable from that of a transitional disk, high-resolution observations that reveal the actual structure of gas and dust at a small scale are necessary to study disk evolution and planet formation.
In this presentation, we report the results of high-resolution (0.14 arcsec) observations of the 225 GHz dust continuum and CO molecular emission lines from SY Cha (distance: 180.7 pc, mass: 0.5-0.7 Msun, age: 3 million years), which is selected from a sample of objects showing transitional disk features in their SEDs. In the dust continuum emission, a ring structure with the radius of about 100 au is detected, as well as a central point source that has not been identified before from SED analyses. Our high resolution observations clearly reveal the inner cavity and the central point source for the first time. We fit the radial profiles of dust continuum emission and find that there is a Gaussian ring of 35 au in radial width on top of another flattened ring with the radial width of 135 au. The reduced chi-square value for the best-fit model is 1.38, which is calculated for actual visibility data in the processes of MCMC fitting. We also find that there is a weak asymmetry in dust continuum emission.
In our observations, 12CO(2-1) and 13CO(2-1) emission are also detected. We estimate the surface density of gas and find that the total gas mass is comparable with that of dust, indicating that the gas is highly depleted. We also find that the gas is present inside the dust cavity. The analysis of the velocity structure of the 12CO(2-1) emission line suggests that the velocity is distorted at the location of the dust inner disk. This may be due to warp of the disk or radial gas flow within the cavity of the dust disk. In our presentation, we report the basic properties of the transitional disk system associated with SY Cha derived from the observations.

Keywords: ALMA, protoplanetary disk, transitional disk, warp

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Model calculation of infrared and radio observations of the circumplanetary disks: Conditions for satellite formation

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Satellites are believed to be formed from circumplanetary disks. There are various theoretical models of satellite formation, but there are few observational constraints on the physical quantity of the circumplanetary disks. It is known that the ice-rock ratio of Jupiter's moons are not uniform. In the hot regions inside the water snow line in the circumplanetary disks, ice vaporizes and rocks become the main material for satellites. Therefore, it is important to investigate the physical quantity of the circumplanetary disks, especially the temperature, when considering the conditions for satellite formation. In recent years, detailed structures of protoplanetary disks around many young stars have been observed using high-resolution ALMA telescopes. In addition, structures similar to the circumplanetary disks were discovered. It is also expected that the infrared space telescope JWST, which is scheduled to be launched in 2021, will detect more circumplanetary disks.

In this study, we aim to establish a method for investigating the temperature of the circumplanetary disks by comparing model calculations with these observations. Previous studies have predicted the intensities of the dust and gas emission at (sub)millimeter wavelengths of the turbulent viscous accretion disks (Zhu et al. 2018) and the irradiation heating disks (Rab et al. 2019), for ALMA observations. In this study, we perform model calculations of dust and gas emission from circumplanetary disks, using the viscous accretion disk model, for JWST observations, and investigate how the intensities change for the models with different physical quantities, such as the accretion rate and the viscous parameter, alpha. As a result, it was shown that the circumplanetary disks is detectable relatively easily with dust continuum emission by JWST. Furthermore, chemical reaction calculations were performed to predict the intensities of various molecular lines and investigate how the infrared and (sub)millimeter line intensities depend on the physical quantity of the disk, and their detectabilities were also investigated.

Keywords: circumplanetary disk, radiative transfer calculation, infrared observations, radio observations

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Development of a Hayabusa2 ONC image retrieval system with 2D/3D switchable maps in a web browser

*Hiroshi Kikuchi[1], Mitsuo Yamamoto[1], Yasuhiro Yokota[1], Hiroyuki Sato[1], Hisashi Otake[1], Rie Honda[2], Seiji Sugita[3], Tomokatsu Morota[3], Toru Ishikawa[4], Kazuya Imaki[4], Yasuyuki Watabe[4], Takeshi Konishi[5], Ryodo Hemmi[3], Hideaki Miyamoto[3], Yukio Yamamoto[1], Naru Hirata[6], Naoyuki Hirata[7], Sho Sasaki[8], Goro Komatsu[9], Hirohide Demura[6], Chikatoshi Honda[6], Manabu Yamada[10], ERI TATSUMI[11], Yuichiro Cho[3], Kazuo Yoshioka[3], Hirotaka Sawada[1], Naoya Sakatani[12], Masahiko Hayakawa[1], Moe Matsuoka[1], Toru Kouyama[13], Hidehiko Suzuki[14], Kazunori Ogawa[1]

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Recent asteroid missions including Hayabusa, Hayabusa2, and OSIRIS-REx, have obtained various datasets of asteroidal surfaces, which are of great value for scientific analyses and future explorations (e.g., Lucy, DESTINY+, etc.). For increasing the availability and applicability of these data, it is important to develop a user-friendly system in which image data, metadata, and individual information (e.g., image position) are linked to each other. It is desirable to develop a system that allows users to easily browse and search data according to their own requirements.
There are several two-/three-dimensional (2D/3D) visualization interfaces (both in application softwares and web-based systems) for viewing and searching datasets: for example, the PILOT (U.S. Geological Survey) [1], Small Body Mapping Tool (Johns Hopkins University) [2], JMARS (Arizona State University) [3], Solar System Trek (NASA) [4], etc. As a data retrieval system for existing small celestial bodies, a 2D-3D switchable display is the most desirable interface, which helps research activities (e.g., researchers can browse and study images overlaid on a 2D map and a 3D shape model similar to the way terrestrial geologists investigate a specific area horizontally and vertically). However, the existing systems for browsing image data of small celestial bodies are limited to either a 2D or 3D display. Therefore, this study aims to develop a web system that can switch between 2D and 3D map displays of small celestial bodies in the same system.
Here we used the ONC image datasets of the asteroid Ryugu as the case study. This is because the Hayabusa2 spacecraft has achieved the acquisition of a vast amount of ONC image data of the asteroid Ryugu, which is the highest level of quality and quantity among all the data explored thus far. Furthermore, the shape of Ryugu is relatively spherical, which is useful to validate the concept of a 2D-3D switchable map. Furthermore, the ONC image datasets are well organized, and all of these data will be publicly available widely, which is useful to demonstrate the system. In this presentation, we report the current status of the system development and its usage.

References: [1] https://pilot.wr.usgs.gov [2] Ernst, C., Barnouin, O., Daly, R., Team, S. B. M. T., 2018. The Small Body Mapping Tool (SBMT) for Accessing, Visualizing, and Analyzing Spacecraft Data in Three Dimensions. Lunar and Planetary Science Conference, Vol. 49. [3] https://jmars.mars.asu.edu/ [4] https://trek.nasa.gov/

Keywords: Hayabusa2 ONC image, Image retrieval system, 2D/3D

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Martian Moons eXploration MMX: Current Status Report 2021

*Kiyoshi Kuramoto[1,2], Yasuhiro Kawakatsu[2], Masaki Fujimoto[2], Maria Antonietta Barucci[3], Hidenori Genda[4], Naru Hirata[5], Takeshi Imamura[6], Jörn Helbert[7], Shingo Kameda[8], Masanori Kobayashi[9], Hiroki Kusano[10], David J. Lawrence[11], Koji Matsumoto[12], Patrick Michel[13], Hideaki Miyamoto[6], Hiromu Nakagawa[14], Tomoki Nakamura[14], Kazunori Ogawa[2], Hisashi Otake[2], Masanobu Ozaki[2], Sara Russell[15], Sho Sasaki[16], Hiroki Senshu[9], Naoki Terada[14], Stephan Ulamec[7], Tomohiro Usui[2], Koji Wada[9], Shoichiro Yokota[16]

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As of February 2021, the MMX project is under the final phase of preliminary design reviews (PDRs), which consist of reviews on specific instruments, subsystems, total system, operations, and integration. Tests using mechanical test models and thermal test models are being conducted. The composition of science instruments (7 sensing instruments, 2 sampler systems, a return capsule, and a rover) is maintained although the architecture of the infrared spectrometer has been changed from a hyperspectrometer to a grating array detector. The plan of observations during the stay in the Mars-moons system is being extensively studied as well as measures for possible regolith contamination onto sensing instruments during landing operations. After passed the PDRs, the MMX project will proceed to phase C or the detailed design phase. Partly due to the effect of the COVID-19 pandemic, the development schedule has been slightly revised so far but maintains the launch year 2024.

The MMX mission is a sample return mission to Phobos, a small inner moon orbiting Mars. Owing to the lack of definitive evidence, the origin of Phobos and the outer Martian moon Deimos is still under debate between two leading hypotheses: the capture of volatile-rich primordial asteroid(s) and the in-situ formation from a debris disk that generated by a giant impact onto early Mars. Whichever theory is correct, the Martian moons are expected to be associated with Mars formation and preserve key records of volatile material transport that would make the terrestrial planets habitable in the early solar system. Through close-up observations of both moons and sample return from Phobos, MMX will settle the controversy of their origin, reveal their evolution, and constrain the early solar system evolution around the region near the snow line. Monitoring of global circulation and escape of the Martian atmosphere will be also conducted to reveal basic processes that have shaped and altered the Martian surface environment.

To achieve a round-trip to the Martian system within a reasonable time, the MMX spacecraft is composed of three modules equipped with a chemical propulsion system and solar generators. By releasing used modules at appropriate timings, the spacecraft mass is reduced to allow orbital tuning to quasi-satellite orbits around Phobos, landing on Phobos surfaces, and the escape from the Martian gravity to the return cruise to the Earth.

MMX will arrive at the Martian system in 2025 and start close-up observations of Phobos after the release of the propulsion module used for Mars orbit insertion. In early 2027, Mars will approach the closest distance from the Earth which minimizes the communication delay between the spacecraft and the Earth station. Together with the timing relatively far from Sun-Mars conjunctions and the Martian equinoxes,

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this period is the most favorable for landing operations that require real-time communication with the ground station and day-time solar illumination undisturbed by an eclipse. Preceded ~1 year will be largely devoted to landing site selection that requires global and zoom-up observations of Phobos confirming operational safety and availability of Phobos-indigenous materials at landing sites. After the stay near Phobos for ~3 years, the MMX spacecraft will be transferred to Deimos-flyby orbits to conduct Deimos observations, and then only the return module will depart the Martian system leaving the exploration module in a circum-Martian orbit in 2028. The sample capsule will come back to the Earth in 2029.

Keywords: Phobos, Deimos, Mars, MMX, habitable planet, early solar system

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The orbital evolution of Phobos in the expanded atmosphere of early Mars under an intense solar EUV radiation

*Kohei Fujita[1], Naoki Terada[1], Shotaro Sakai[1], Kaori Terada[1]

1. Tohoku University

Mars has two moons, Phobos and Deimos, which have the common characteristics of small orbital inclination and eccentricity. The origin of these moons can be explained by the capture scenario, in which asteroids were captured by the Martian gravity, and the giant impact scenario, in which an object crashed into Mars, and then debris accumulated to form the moons. One of the reasons why the capture scenario is supported is that the reflectance spectra of Phobos are consistent with D- and T-type asteroids, and those of Deimos are consistent with D-type asteroids. However, it is difficult to explain the characteristics of the current orbital inclination and eccentricity in both moons. In the capture scenario, we need to consider the dissipation of orbital energy after capture, since the asteroid has velocity at infinity. An example of the orbital energy dissipation process is atmospheric drag. In a stationary atmosphere, the lifetime of the captured asteroid has been found to be short due to atmospheric drag and it cannot survive for a long time (Hunten, 1979). At that time, it is possible to make the orbit circular, but it is difficult to attenuate the orbital inclination. Therefore, in the previous study, Matsuoka and Kuramoto calculated the orbit taking into account the co-rotation of the proto-Martian atmosphere. The results showed that there is a solution with a relatively long lifetime of the prograde satellite in the vicinity of the geostationary orbit, and that eccentricity and orbital inclination attenuate on a short timescale. However, in order to track the orbital evolution of the captured asteroid after its capture, the evolution of the Martian atmosphere has to be considered. The solar EUV radiation has decreased over time, so the early Martian atmosphere would have gradually shrunk. It is possible that the atmosphere was rotating at angular velocity relatively close to that of Mars when it expanded significantly beyond the co-rotation radius. However, as the atmosphere shrunk, wind systems that deviate from the co-rotation, such as day-night flow seen in the upper atmosphere, were expected to intersect the geostationary orbit and affect the orbit of the moon.
In order to take into account for the change in the solar EUV radiation, we deviate the rotation of the atmosphere by several tens of percent from the co-rotation and perform orbit calculations around the geostationary orbit, where the asteroid is expected to have a longer lifetime. As a result, the lifetime of the captured asteroid is shortened by one order of magnitude in the vicinity of the geostationary orbit when the atmosphere is reduced by 10% from the angular velocity of Mars, and the lifetime is shortened as the deviation increases. On the other hand, in order for the captured asteroid to maintain its orbit, the atmosphere needs to shrink more rapidly than the timescale of orbital evolution. We calculate the orbit taking into account the change in the atmospheric to obtain the lifetime of the captured asteroid in different atmospheric structures of the early Mars in addition to the deviation from the co-rotation since the expanded early Martian atmosphere shrunk as the solar EUV radiation evolved. In this presentation, we will discuss the validity of the capture scenario based on the calculation results of the orbital evolution of Phobos in the above scenarios.

Keywords: Phobos, Satellite formation, Capture scenario

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Hydrodynamic escape of reduced proto-atmospheres: different consequences for surface volatile inventories between Mars and Earth

*Tatsuya Yoshida[1], Kiyoshi Kuramoto[1]

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The present Martian surface is significantly depleted in volatiles compared to the Earth's one. On the other hand, Mars may have obtained a massive proto-atmosphere because Mars was likely formed from volatile-rich building blocks due to its large distance from the Sun (Dreibus and Wanke, 1985; Saito and Kuramoto, 2018). H, C, N, and noble gases on Mars are enriched in heavier isotopes, indicating that the paucity of the volatiles on Mars may be largely due to atmospheric escape.

Hydrodynamic escape is one of the few mechanisms that can change the composition of a planetary atmosphere irreversibly (Hunten, 1990). The X-ray and extreme ultraviolet (XUV) radiation from the young Sun may have induced hydrodynamic escape of early atmospheres. Proto-atmospheres on Mars and Earth are expected to have been composed of reduced species such as H_2 and CH_4 considering the chemical reduction of volatiles by reactions with metallic iron and the gravitationally capture of surrounding solar nebula gas (Kuramoto and Matsui, 1996; Saito and Kuramoto, 2018). Such hydrogen-rich atmospheres on low-gravity rocky planets are susceptible to hydrodynamic escape with rates possibly very large compared to those of other atmospheric escape processes (Catling and Kasting, 2017).

Considering the difference in the planetary masses, the hydrodynamic escape rate on Mars is expected to be much larger than that on Earth, which may largely explain the paucity of the volatiles on the present Martian surface. The difference in the planetary gravity may lead to the difference in the atmospheric temperature, radiative cooling efficiency, and thereby atmospheric escape rate. Therefore, to clarify the difference in the hydrodynamic escape of the proto-atmosphere, it is needed to investigate the radiative and photochemical processes and the energy balance in each escaping outflow. However, previous studies simplified the radiative and photochemical processes, and therefore the difference in hydrodynamic escape rates was uncertain.

Here we carry out one-dimensional hydrodynamic escape simulations considering radiative and photochemical processes for proto-atmospheres on Mars and Earth. Then, we clarify the difference in the hydrodynamic escape and its effect on the amount of surface volatiles between Mars and Earth. In this modeling, fluid equations for a multi-component gas assuming spherical symmetry are solved by numerical integration about time until the physical quantities settle into steady profiles. We apply the XUV spectrum 100 Myr after the birth of the Sun from 0.1 to 165 nm provided by Claire et al. (2012), whose total flux is about 100 times the present. We consider radiative cooling by thermal line emissions of CH_4, CO, CH, CH_3 and H_3^+. 157 photochemical reactions are considered for 23 atmospheric components. We assume that the atmospheres at their low altitudes are composed of H_2 and CH_4 for Earth, and composed of H_2, CH_4 and CO for Mars referring to the thermodynamic analysis on accreting planets (Kuramoto, 1997).

The suppression of the hydrodynamic escape by the radiative cooling on Earth's atmospheres is more drastic than that on Mars. The difference is mainly due to the differences in the planetary mass and gravity. Under smaller gravity, adiabatic cooling of expanding atmosphere is effective on Mars, leading to the lower atmospheric temperature and inefficient radiative cooling. The total amount of carbon species

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lost by hydrodynamic escape on Mars exceeds 10 bar equivalent to 20 bar of CO_2 when the proto-Mars obtained >10 bar of H_2 assuming that carbon species equivalent to 1 bar of CO_2 was left behind. On the other hand, CH_4 on Earth escapes hardly even when the mixing ratio of H_2 is as high as ~99 % due to efficient radiative cooling by photochemical products from CH_4 and H_2. The difference in the efficiency of hydrodynamic escape may have resulted in a significant difference in the amount s on the surfaces of Mars and Earth.

Keywords: hydrodynamic escape, radiative cooling, photochemistry, proto-atmosphere, Mars, Earth

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[J] Oral | P (Space and Planetary Sciences)：P-CG Complex & General

Thu. Jun 3, 2021 9:00 AM - 10:30 AM JST | Thu. Jun 3, 2021 12:00 AM - 1:30 AM UTC | Ch.04 Zoom Room 04

[P-CG18] Planetary Magnetosphere, Ionosphere, and Atmosphere

convener:Kanako Seki(Graduate School of Science, University of Tokyo), Hiroyuki Maezawa(Department of Physical Science Osaka Prefecture University), Takeshi Imamura(Graduate School of Frontier Sciences, The University of Tokyo), Naoki Terada(Graduate School of Science, Tohoku University), Chairperson:Tomoki Kimura(Tokyo University of Science), Hiroyuki Maezawa(Department of Physical Science Osaka Prefecture University), Kanako Seki(Graduate School of Science, University of Tokyo)

Exploration of Mercury, Venus, Moon, Mars, Jupiter, Saturn, and beyond together with rapid developments of numerical simulations provides us new view of planetary environment. This session collects general contributions of new findings about planetary magnetosphere, ionosphere, and atmosphere. New methodology and technology development studies for future explorations are also welcome. In order to put the common knowledge at different planets into perspective, this session aims to facilitate discussions on comparative planetary environments.

9:00 AM - 9:15 AM JST | 12:00 AM - 12:15 AM UTC

[PCG18-01] Current status, initial results, and upcoming observation plans during cruise of BepiColombo

*Go Murakami[1], Johannes Benkhoff[2] (1.Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency, 2.European Space Agency)

9:15 AM - 9:30 AM JST | 12:15 AM - 12:30 AM UTC

[PCG18-02] Revisiting Mariner-10 and MESSENGER observations: Anticipation for BepiColombo's Mercury flybys

*Sae Aizawa[1,2], Nicolas André[1], Ronan Modolo[3], James A. Slavin[4], Scott A. Boardsen[5] (1.Institute de Recherche en Astrophysique et Planetologie, 2.Graduate School of Science, Tohoku University, 3.LATMOS, 4.University of Michigan, 5.NASA/GSFC)

9:30 AM - 9:45 AM JST | 12:30 AM - 12:45 AM UTC

[PCG18-03] A belt-like distribution of gaseous hydrogen cyanide on Neptune's equatorial stratosphere detected by ALMA

*Takahiro IINO[1], Hideo Sagawa[2], Takashi Tsukagoshi[3], Satonori Nozawa[4] (1.Information Technology Center, the University of Tokyo, 2.Department of Science, Kyoto Sangyo University, 3.NAOJ, 4.ISEE, Nagoya University)

9:45 AM - 10:00 AM JST | 12:45 AM - 1:00 AM UTC

[PCG18-04] Estimation of the drift rate and intensity of Neptune's storm in 2018-2020 with Pirka Telescope

*Yuuki Sato[1], Yukihiro Takahashi[1], Mitsuteru Sato[1], Seiko Takagi[1], Masataka Imai[2], Tatsuharu Ono[1] (1.Graduate School of Science, Hokkaido University, 2.National Institute of Advanced Industrial Science and Technology)

10:00 AM - 10:15 AM JST | 1:00 AM - 1:15 AM UTC

[PCG18-05] Ion escape mechanism from a Mars-like planet under weak intrinsic magnetic field conditions: Dependence of IMF clock angle

*Shotaro Sakai[1,2], Kanako Seki[3], Naoki Terada[1], Hiroyuki Shinagawa[4], Ryoya Sakata[3], Takashi Tanaka[4,5], Yusuke Ebihara[6] (1.Department of Geophysics, Graduate School of Science, Tohoku University, 2.Planetary Plasma and Atmospheric Research Center, Graduate School of Science, Tohoku University, 3.Department of Earth and Planetary Science, Graduate School of Science, University of Tokyo, 4.National Institute of Information and Communications Technology, 5.International Center for Space Weather

Science and Education, Kyushu University, 6.Research Institute for Sustainable Humanosphere, Kyoto University)

10:15 AM - 10:30 AM JST | 1:15 AM - 1:30 AM UTC

[PCG18-06] Dependences of ion escape from Mars on the intrinsic magnetic field strength under CME-like solar conditions at 3.5 Ga

*Ryoya Sakata[1], Kanako Seki[1], Shotaro Sakai[2], Naoki Terada[2], Hiroyuki Shinagawa[3], Takashi Tanaka[3,4] (1.Department of Earth and Planetary Science, Graduate School of Science, The University of Tokyo, 2.Department of Geophysics, Graduate School of Science, Tohoku University, 3.National Institute of Information and Communications Technology, 4.International Center for Space Weather Science and Education, Kyushu University)

Current status, initial results, and upcoming observation plans during cruise of BepiColombo

*Go Murakami[1], Johannes Benkhoff[2]

1. Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency, 2. European Space Agency

The ESA-JAXA joint mission BepiColombo is now on the track to Mercury. After the successful launch of the two spacecraft for BepiColombo, Mio (Mercury Magnetospheric Orbiter: MMO) and Mercury Planetary Orbiter (MPO), commissioning operations of the spacecraft and their science payloads were completed. BepiColombo will arrive at Mercury in the end of 2025, and it has 7-years cruise with the heliocentric distance range of 0.3-1.2 AU. The long cruise phase also includes 9 planetary flybys: once at the Earth, twice at Venus, and 6 times at Mercury. Even during the interplanetary cruise phase, the BepiColombo mission can contribute to the heliospheric physics and planetary space weather in the inner solar system. In addition, NASA’s Parker Solar Probe was launched in 2018 and it is orbiting around Sun (~0.05 AU at perihelion). ESA’s Solar Orbiter was launched in February 2020 and will have a highly elliptic orbit between 1.2 AU at aphelion and 0.28AU at perihelion. These multi spacecraft observations provide us great opportunities to investigate the inner heliosphere. The Earth flyby and the first Venus flyby were successfully completed on 10 April 2020 and on 15 October 2020, respectively. Planetary flybys are great opportunities not only for scientific motivation but also for instrument calibrations. Especially ion sensors onboard MPO (SERENA/MIPA and PICAM) and Mio (MPPE/MIA and MSA) can detect ions only during the planetary flybys because of constraints on spacecraft attitude and field of views. During the two flybys in 2020 science observations are performed and plasma instruments successfully measured both the Earth’s magnetosphere and Venus’s induced magnetosphere. The second Venus flyby and the first Mercury flyby will happen on 10 August 2021 and on 1 October 2021, respectively. Here we present the updated status of BepiColombo mission, initial results of the science observations during the interplanetary cruise and planetary flybys, and the upcoming observation plans.

Keywords: Mercury, Venus, Heliosphere

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Revisiting Mariner-10 and MESSENGER observations: Anticipation for BepiColombo's Mercury flybys

*Sae Aizawa[1,2], Nicolas André[1], Ronan Modolo[3], James A. Slavin[4], Scott A. Boardsen[5]

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BepiColombo is en route to Mercury and will conduct its first Mercury flyby in October 2021. The trajectories of BepiColombo during these flybys are unique and will bring new insights into Mercury's plasma environment. Although their field of view is limited, some instruments within the Mercury Plasma Particle Experiment (MPPE) consortium onboard Mio/BepiColombo will be operated during these flybys. Unlike Mariner-10 ion measurements will be obtained, and unlike MESSENGER, low energy electrons and ions will be measured simultaneously. Thus we have revisited Mariner-10 and MESSENGER observations with the help of the hybrid model LatHys in order to constraint the plasma environment that will be encountered by BepiColombo during its forthcoming Mercury flybys.

Keywords: BepiColombo, Mercury, MESSENGER, Mariner-10, Global simulation

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A belt-like distribution of gaseous hydrogen cyanide on Neptune's equatorial stratosphere detected by ALMA

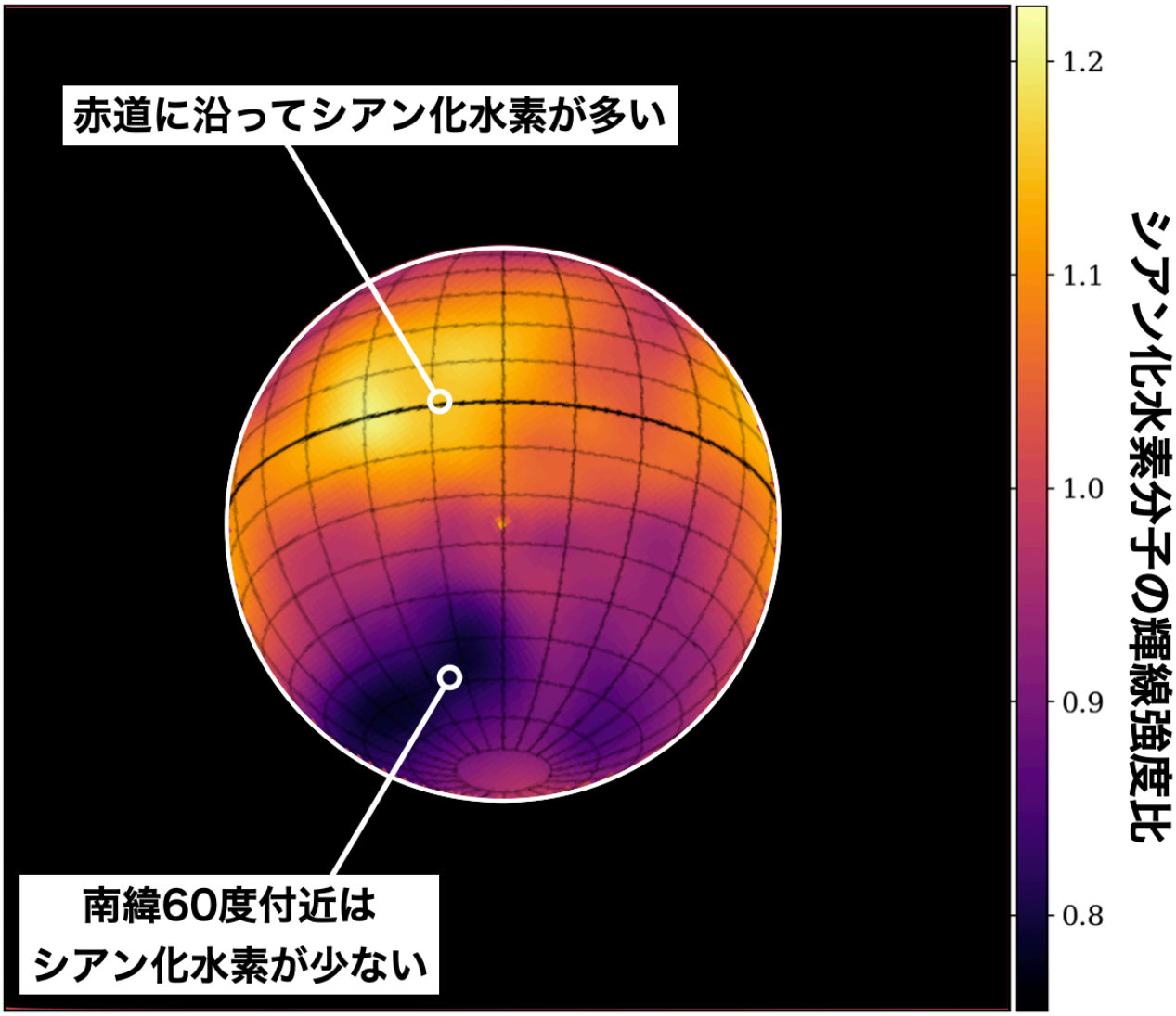
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We present a spatially resolved map of integrated- intensity and abundance of Neptune's stratospheric hydrogen cyanide (HCN).
The analyzed data were obtained from the archived 2016 observation of the Atacama Large Millimeter/submillimeter Array.
A 0.42 x 0.39 arcsec synthesized beam, which is equivalent to a latitudinal resolution of ~20 degrees at the disk center, was fine enough to resolve Neptune's 2.24 arcsec diameter disk.
After correcting the effect of different optical path lengths, a spatial distribution of HCN emissions is derived over Neptune's disk, and it clearly shows a band-like HCN enhancement at the equator.
Radiative transfer analysis indicates that the HCN volume mixing ratio measured at the equator was 1.92 ppb above the 10^{-3} bar pressure level, which is 40% higher than that measured at the southern middle and high latitudes.
The spatial distribution of HCN can be interpreted as either the effect of the transportation of N_2 from the troposphere by meridional atmospheric circulation, or an external supply such as cometary collisions (or both of these reasons).
From the meridional circulation point of view, the observed HCN enhancement on both the equator and the pole can be explained by the production and accumulation of HCN at the downward branches of the previously suggested two-cell meridional circulation models.
However, the HCN-depleted latitude of 60 degrees south does not match with the location of the upward branch of the two-cell circulation models.

Keywords: ALMA, Neptune, Atmospheric Chemistry

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Estimation of the drift rate and intensity of Neptune’s storm in 2018-2020 with Pirka Telescope

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A storm more than 4,000 km in diameter occasionally occurs in Neptune. Since Neptune is a great distance away from the Earth, storms in Neptune can be resolved only by using large telescopes such as the Keck Observatory and the Hubble Space Telescope. However, it isn't easy to always use those telescopes for Neptune observation. Therefore Neptune is not observed for the long term on a short time scale. We developed the technique to estimate the drift rate and intensity of storms by observing Neptune's whole spectrum in this study. When seeing is bad, it's possible to observe and acquire Neptune's observation data for the long term on a short time scale. The purpose is to deepen the understanding of Neptune's atmosphere convection structure by chasing the detailed change of storms. In this study, we observed Neptune by using a 1.6 m Pirka telescope that Hokkaido University owns. The observation time is from October 22, 2018, to November 26, 2018, from July 8 to November 12, 2019, and we started observation on July 20 in 2020. The wavelengths are 890, 855 nm. The apparent size of storms from the observation point changes by the rotation of Neptune, so an 890 nm flux changes by the rotation. We took the ratio of an 890 nm flux and an 855 nm flux to correct the atmosphere's effect on the earth and calculated the theoretical values of the relative intensity by the rotation. We assumed the storm's size and fit the observed values with the theoretical values in the method of least squares to estimate the drift rate and 890 nm reflectance inside storms. We estimated that the drift rate and the 890 nm reflectance are 24.6˚/ day and 0.166 in 2018, respectively. In 2019, since there are multiple storms and this analysis method assumes that there is only one storm, it is necessary to consider an analysis method when there are multiple storms from HST and amateur observation images. In 2020, we estimated that the drift rate and the 890 nm reflectance are 20.0˚/ day and 0.234 respectively. In 2018, Simon et al. (2019) discovered a new northern Great Dark Spot (NDS-2018) located at 23˚N. NDS2018 drifted westward at 2.46˚/hr in November 2018. However, NDS-2018 could not be seen because it was located on the night side during our observation, and it is considered that we observed a different storm. We will continue the observations in 2021 and compare them with other researchers and amateur observations to have a discussion in the future.

Keywords: Neptune, Ground-based telescope

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Ion escape mechanism from a Mars-like planet under weak intrinsic magnetic field conditions: Dependence of IMF clock angle

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The ion escape mechanism from planets is mainly determined by the presence of an intrinsic magnetic field, the orientation of the interplanetary magnetic field (IMF), and the solar X ray and extreme ultraviolet (XUV) irradiances. It is believed that ancient Mars had a global intrinsic magnetic field of interior origin and the magnetic field decayed by ~3.9 billion years ago (Acuña et al., 1999). One of the pieces of evidence that ancient Mars had an intrinsic field is the existence of a "crustal magnetic field" (Acuña et al., 1999). Sakai et al. (2018) investigated the effect of a weak intrinsic magnetic field at the Martian equatorial surface on the escape mechanism. It was shown that the existence of the weak field results in an enhancement of the ion escape rate. A parker-spiral IMF was however used in order to obtain the escape rate in this earlier study. The orientation of IMF also changes the escape rate and mechanism. Sakai et al. (2021) suggested that the escape rate is the lowest in the case of IMF parallel to the dipole at subsolar and comparable in the Parker-spiral and antiparallel IMF case. The parallel IMF case is dominated by the ion escape from the high-latitude lobe reconnection region, where ionospheric ions are transported upward along open field lines, while in the antiparallel IMF case, the escape flux of heavy ions increases significantly due to the mass loading of ionospheric ions, with peaks around the equatorial dawn and dusk flanks. Previous studies have investigated the ion escape rate and its mechanism for only three IMF orientations, e.g., the northward (parallel), Parker-spiral, and southward (antiparallel) IMF cases, but the factors responsible for the enhancement of escape rate have not yet been elucidated.

This paper investigates the dependence of the escape mechanism on the IMF clock angle under a weak intrinsic magnetic field of 100 nT at the surface and the present-day XUV irradiances using a multispecies magnetohydrodynamic simulation. The simulation is conducted under the condition that the IMF makes a round in twenty-four hours, which is comparable to the time scale of coronal mass ejection, after starting the northward IMF. The ion escape rate drastically increases when the clock angle is above 45° from the due north. The reconnections occur in the lobe region of the magnetosphere in the northward IMF, its location gradually moving to the flank region during the transition of the clock angle to 45°. The reconnections in the flank region also occur in the Parker-spiral IMF case (Sakai et al., 2018; 2021), leading to the enhancement of the ion escape rate. The escape rate gradually increases over time after the clock angle of 60°, reaching a maximum around the clock angle of 180° - 210° in the southward IMF.

This paper also studies the escape mechanism under the different magnetic field strengths and XUV irradiances influencing the escape mechanism, and the results are compared with those under the magnetic field strength of 100 nT and the present-day XUV irradiances.

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Keywords: Mars, Atmospheric escape, Intrinsic magnetic field, Interplanetary magnetic field, Numerical modeling

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Dependences of ion escape from Mars on the intrinsic magnetic field strength under CME-like solar conditions at 3.5 Ga

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Mars experienced drastic climate change during its early period. Atmospheric escape to space played an important role in the removal of the atmosphere and climate change on ancient Mars. In particular, escape of the ionized atmosphere, i.e., ion escape was a key process of atmospheric loss. Stronger solar X-ray and extreme ultraviolet (XUV) radiation and solar wind from the young Sun facilitate ion escape. Past studies pointed out that ion escape on ancient Mars was stronger by several orders of magnitude and contributed to the atmospheric loss. A planetary magnetic field is another important parameter controlling ion escape. Mars has crustal remnant magnetic field, which implies that ancient Mars once had a global intrinsic magnetic field. Existence of an intrinsic magnetic field affects the magnetic configuration and thus processes and rates of ion escape. Although previous studies suggested both inducing and reducing effects of an intrinsic magnetic field on ion escape, the details are not fully understood. Based on multispecies magnetohydrodynamics (MHD) simulations, Sakata et al. (2020) investigated how the strength of an intrinsic magnetic field affects ion escape from Mars under the solar XUV and solar wind conditions at 4.5 Ga. They revealed that the effects of an intrinsic magnetic field depend on the relationship between the solar wind dynamic pressure and the magnetic pressure of the intrinsic magnetic field and showed that the effects are more pronounced on molecular ions (O_2^+ and CO_2^+). Escape rates of molecular ions increase by a factor of six if Mars has a weak intrinsic magnetic field whose magnetic pressure is lower than the solar wind dynamic pressure, while they decrease by two orders of magnitude if the intrinsic magnetic field is strong enough to sustain the solar wind dynamic pressure. Effects on O^+ are milder than those on molecular ions because of the contribution of ion pickup on the extended neutral oxygen corona.

We investigated dependences of ion escape processes and rates on the intrinsic magnetic field strength under solar XUV and solar wind conditions during coronal mass ejection (CME)-like events at 3.5 Ga. As solar events such as CMEs occurred more frequently during the early period of the Sun, enhanced ion escape during CMEs is expected to play a role in atmospheric loss from ancient Mars. The solar XUV flux was set to be 50 times higher than the present value. The solar wind number density, velocity, and the interplanetary magnetic field (IMF) strength were set to be 700 cm^{-3}, 1400 km s^{-1}, and 20 nT, respectively. The intrinsic magnetic field was assumed to be a dipole field and northward at the equator. We conducted multiple simulations cases with different strength of the dipole field.

As expected, escape rates of molecular ions increase in the weak dipole field case, while they decreased strongly under the existence of a strong dipole field enough to sustain the solar wind dynamic pressure. In the intermediate case, the escape rates decrease despite the dipole field strength is lower than the threshold defined so that the dipolar magnetic pressure at the equatorial surface equals the solar wind dynamic pressure. It suggests that the relationship between the intrinsic magnetic field and the solar wind should be evaluated more carefully based on the ion escape mechanism. The effects on O^+ are seen more clearly than those in Sakata et al. (2020). The contribution of ion pickup on the neutral oxygen corona is

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smaller due to weaker solar XUV flux.

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Keywords: atmospheric escape, intrinsic magnetic field, MHD simulation, ancient Mars

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[J] Oral | P (Space and Planetary Sciences)：P-CG Complex & General

Thu. Jun 3, 2021 10:45 AM - 12:15 PM JST | Thu. Jun 3, 2021 1:45 AM - 3:15 AM UTC | Ch.04 Zoom Room 04

[P-CG18] Planetary Magnetosphere, Ionosphere, and Atmosphere

convener:Kanako Seki(Graduate School of Science, University of Tokyo), Hiroyuki Maezawa(Department of Physical Science Osaka Prefecture University), Takeshi Imamura(Graduate School of Frontier Sciences, The University of Tokyo), Naoki Terada(Graduate School of Science, Tohoku University), Chairperson:Yuki Harada(Kyoto University), Takeshi Imamura(Graduate School of Frontier Sciences, The University of Tokyo), Naoki Terada(Graduate School of Science, Tohoku University)

Exploration of Mercury, Venus, Moon, Mars, Jupiter, Saturn, and beyond together with rapid developments of numerical simulations provides us new view of planetary environment. This session collects general contributions of new findings about planetary magnetosphere, ionosphere, and atmosphere. New methodology and technology development studies for future explorations are also welcome. In order to put the common knowledge at different planets into perspective, this session aims to facilitate discussions on comparative planetary environments.

10:45 AM - 11:00 AM JST | 1:45 AM - 2:00 AM UTC

[PCG18-07] Investigation of periodic electron injection observed in Martian crustal magnetic fields with MAVEN and MGS

*Michio Kato[1], Yuki Harada[1], David L Mitchell[2], Christian Mazelle[3], Gina A DiBraccio[4], Jasper S Halekas[5], Suranga Ruhunusiri[5] (1.Department of Geophysics, Graduate School of Science, Kyoto University, 2.Space Sciences Laboratory, University of California, Berkeley, 3.RAP, University of Toulouse, CNRS, UPS, CNES , 4.NASA Goddard Space Flight Center, 5.Department of Physics and Astronomy, University of Iowa)

11:00 AM - 11:15 AM JST | 2:00 AM - 2:15 AM UTC

[PCG18-08] Modeling diffuse auroral emissions at Mars: Contribution of precipitating protons and mirror effects of crustal fields

*Yuki Nakamura[1,2], Naoki Terada[1], Francois Leblanc[2], Hiromu Nakagawa[1], Shotaro Sakai[1], Sayano Hiruba[1], Ryuho Kataoka[3], Kiyoka Murase[4] (1.Department of Geophysics, Graduate School of Science, Tohoku University, 2.LATMOS, Sorbonne University, 3.National Institute of Polar Research, 4.The Graduate University for Advanced Studies)

11:15 AM - 11:30 AM JST | 2:15 AM - 2:30 AM UTC

[PCG18-09] Effects of the magnetic field orientation on the vertical emission profile of Martian diffuse aurora: A Monte Carlo model development

*Taishin Okiyama[1], Kanako Seki[1], Nicholas M. Schneider[2], Sonal K. Jain[2] (1.Graduate School of Science, University of Tokyo, 2.LASP, University of Colorado, Boulder)

11:30 AM - 11:45 AM JST | 2:30 AM - 2:45 AM UTC

[PCG18-10] Extraction of Martian atmospheric fine structures by analyzing Mars Global Surveyor radio occultation data

*Ryutaro Sakurai[1], Takeshi Imamura[1] (1.Graduate School of Frontier Sciences, The University of Tokyo)

11:45 AM - 12:00 PM JST | 2:45 AM - 3:00 AM UTC

[PCG18-11] Variation of CO/CO_2 profile in the Martian middle atmosphere observed by TGO/NOMAD

*Nao Yoshida[1], Hiromu Nakagawa[1], Shohei Aoki[2,3], Justin Erwin[2], Ann Carine Vandaele[2], Isao Murata[1], Ian Thomas[2], Frank Daerden[2], Lori Neary[2], Shungo Koyama[1], Naoki Terada[1], Yasumasa Kasaba[1], Bojan Ristic[2], Manish R Patel[4], Giancarlo Bellucci[5], Jose-Juan Lopez-Moreno[6] (1.Dep. Geophysics Graduate School of Science Tohoku University, 2.Royal Belgian Institute for Space Aeronomy, BIRA-IASB, 3.LPAP,

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12:00 PM - 12:15 PM JST | 3:00 AM - 3:15 AM UTC

[PCG18-12] Periodic variations of hydrogen and oxygen airglow in the Martian upper atmosphere during a rapid growth of a regional dust storm

*Kei Masunaga[1], Naoki Terada[2], Nao Yoshida[2], Takeshi Kuroda[2], Kazuo Yoshioka[3], Tomoki Kimura[2], Fuminori Tsuchiya[2], Go Murakami[4], Atsushi Yamazaki[4], Ichiro Yoshikawa[3] (1.University of Colorado Boulder, 2.Tohoku University, 3.University of Tokyo, 4.Institute of Space and Astronautical Science)

Investigation of periodic electron injection observed in Martian crustal magnetic fields with MAVEN and MGS

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Mars has no global intrinsic magnetic field, but it has relatively strong crustal remanent magnetic fields. The solar wind interacts with these localized crustal magnetic fields and with the upper atmosphere of Mars, forming a complex magnetosphere. Provided that electrons get injected impulsively from the adjacent plasma into closed magnetic field lines formed above the strongly magnetized areas, they drift in an energy-dependent manner in the direction perpendicular to the magnetic field while bouncing between the mirror points, producing energy-time dispersion at a fixed observing point on the closed filed line. These energy-time dispersed electron signatures were measured by the Mars Atmosphere and Volatile EvolutioN (MAVEN) mission. It has been reported that the energy-time dispersed electron signatures sometimes occur periodically for multiple times in succession, but the generation mechanism of this periodicity has not been clarified yet. In this study, we investigate characteristics of these periodic electron energy-time dispersion observed in the crustal magnetic fields of Mars using the solar wind electron analyzer (SWEA) and magnetometer (MAG) onboard MAVEN, and the electron reflectometer (ER) and magnetometer (MAG) onboard the Mars Global Surveyor (MGS). First, we conducted a survey of the periodic events from the MAVEN data obtained from September 2014 to September 2020 at altitudes from 200 km to 1000 km. As a result, we identified 211 cases in which electron energy-time dispersion was observed for multiple times in succession. In addition, we analyze the MGS data obtained from March 1999 to November 2006. Although no cases of the periodic electron energy-time dispersion have been reported from the MGS data, we have identified such cases by utilizing the methodology originally developed for the MAVEN data analysis. We will discuss long-term trends of these events based on statistical results derived from a large amount of the MGS data.

Keywords: Mars, Martian crustal magnetic fields, the energy-time dispersed signatures, MAVEN, MGS

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Modeling diffuse auroral emissions at Mars: Contribution of precipitating protons and mirror effects of crustal fields

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Solar Energetic Particle (SEP) and the Imaging UltraViolet Spectrograph (IUVS) instruments aboard the Mars Atmosphere and Volatile EvolutioN (MAVEN) spacecraft have discovered new type of diffuse aurora that spans across nightside Mars, which resulted from the interaction of Solar Energetic Particles (SEPs) with the Martian atmosphere [Schneider et al., 2015]. Previous models suggested that 100 keV monoenergetic electron precipitation should be the origin of the low altitude (~ 60 km) peak of the limb emission, however, no models were able to reproduce the observed emission profiles by using the observed electron energy spectrum [e.g., Haider et al., 2019]. Previous auroral emission models did not take into account the contribution of MeV proton precipitation, although MeV proton can penetrate down to ~ 70 km altitude as well [e.g., Jolitz et al., 2017]. This study aims to model SEP-induced diffuse auroral emissions by both electrons and protons. In order to constrain the possible sources of the diffuse auroral emissions, we focus on the different magnetic mirror behaviors of the precipitating electrons and protons in the presence of crustal magnetic fields.

We have developed a Monte-Carlo collision and transport model of precipitating electrons and protons with magnetic fields on Mars. We calculated limb intensity profile of CO2+ ultraviolet doublet (UVD) excited by precipitating electrons and protons with energies ranging 100 eV - 100 keV and 100 eV - 5 MeV, respectively, during December 2014 SEP event and September 2017 SEP event by using electron and proton fluxes observed by MAVEN/SEP, SWEA and SWIA.

At the SEP event in December 2014, we found that calculated intensity at peak altitude of the CO2+ UVD due to proton precipitation is comparable to those by electron precipitation. On the other hand, inferred peak altitudes of the CO2+ UVD limb intensities are 80 km for protons and 110 km for electrons, respectively. In this event, we concluded that the MeV protons mainly contribute to reproduce the proton-induced CO2+ UVD emission, while the few keV electrons contribute to the electron-induced CO2+ UVD emission. At the SEP event in September 2017, the calculated peak limb intensity of CO2+ UVD due to proton precipitation is four times larger than that due to electron precipitation. Peak altitudes of the CO2+ UVD limb intensities are 60 km and 70 km for protons and electrons, respectively. In this event, 5 MeV protons contribute the most to the proton-induced CO2+ UVD emission and 100 keV electrons contribute the most to the electron-induced CO2+ UVD emission.

We compared our model results with the observations of CO2+ UVD limb intensity obtained in Schneider et al. (2015) and Schneider et al. (2018) for December 2014 SEP event and September 2017 SEP event, respectively. At the SEP event in December 2014, our result of total CO2+ UVD limb intensity of electron and proton contributions is 3 times larger than the observation. As for the peak altitude, our result is 80 km, which is 10 km higher than the observed peak at 70 km. In the SEP event in September 2017, our result of total CO2+ UVD limb intensity of electron and proton contributions is 1.5 times larger than the observation. As for the peak altitude, our result is 60km, which is almost identical to the observation. We concluded that our model results are almost consistent with observations.

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We have also investigated the effect of crustal field on the emission of CO2+ UVD. The CO2+ UVD emissions due to precipitating electrons are depleted by a factor of 10 in the region of open crustal field and disappeared in the region of closed and parallel crustal field, whereas the emissions due to precipitating protons do not change significantly due to the difference in their gyro radii and their relations to the crustal field spatial scale. Further observations of diffuse aurora in the crustal field region are needed to constrain the origin of diffuse aurora on Mars.

Keywords: Mars, Diffuse aurora, Solar energetic particles

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Effects of the magnetic field orientation on the vertical emission profile of Martian diffuse aurora: A Monte Carlo model development

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The Mars Atmosphere and Volatile Evolution (MAVEN) spacecraft first observed the diffuse aurora at Mars (Schneider et al. 2015). The aurora is thought to be caused by solar energetic particles penetrating into the Martian atmosphere along the interplanetary magnetic field lines draped around the planet. The aurora was observed over a wide area in the northern hemisphere where the crustal magnetic fields are absent or weak. The energy of these solar energetic particles, measured by SEP instrument onboard MAVEN, did not show rapid variation and changed slowly over several days. On the other hand, observations by the Imaging Ultraviolet Spectrograph (IUVS) onboard MAVEN show rapid changes in the peak altitude of the diffuse aurora emission intensity. The cause of the rapid changes of the vertical auroral emission profile is far from understood. One of the possibilities is that the change in the magnetic field orientation around Mars affects the auroral altitude profile. The purpose of this study is to investigate effects of the magnetic field orientation on the vertical emission profile of Martian diffuse aurora based on a Monte Carlo simulation.

We have developed a one-dimensional (1-D) model that calculates the vertical emission profile of CO_2^+ UVD and the CO Cameron bands, which are typical emission lines of the diffuse aurora. The methods used are similar to that of the Monte Carlo model of Bhardwaj et al. (2009), which describes the interaction between CO_2 neutral atmosphere and electrons up to 1000 eV. Our model includes elastic scattering, excitation, and ionization between electrons and CO_2, and extended the upper energy up to hundreds of keV to include high-energy electrons that cause the diffuse aurora. In addition, the effect of the draped magnetic field structure was introduced by changing the incident angle of electrons through coordinate transformation. The results of our model showed that decreasing elevation angle of the magnetic field from the horizontal direction increased the peak altitude of the emission intensity. The result might indicate that the magnetic field orientation in the vicinity of the planet is one of the important factors to change the vertical emission profile of the diffuse aurora.

Keywords: Mars, aurora, Solar Energetic particle, Monte Carlo, induced magnetosphere

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Extraction of Martian atmospheric fine structures by analyzing Mars Global Surveyor radio occultation data

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Radio occultation observation is one of the most effective methods to study fine structures in planetary atmospheres. In order to derive the vertical structure of an atmosphere from the data of radio waves transmitted from the spacecraft and recorded at the ground station after passing through the planet's atmosphere, the geometric optics method has been used to calculate the ray path at each moment and then determine the atmospheric structure sequentially. In contrast, the recently developed radio holographic method derives the atmospheric structure from the entire signal time series at once, thereby significantly improving the vertical resolution compared to the geometric optics. One of the radio holographic methods, Full Spectrum Inversion (FSI) proposed by Jensen et al. (2003), was applied to the Venusian atmosphere by Imamura et al. (2018) to reveal fine vertical structures in the atmosphere that could not be captured by previous analysis.On Mars, the temperature structure of the Martian atmosphere has been obtained by radio occultation observations by Mars Global Surveyor (MGS). Various microstructures such as atmospheric gravity waves, convective boundary layers, and thin stable layers of ice clouds that occur at night have been revealed. Such fluid dynamical processes are thought to play important roles in the transport of energy and momentum. However, conventional analysis has an altitude resolution of about 1 km, which is not sufficient to fully resolve the vertical structures of these phenomena. The purpose of this study is to apply the new analysis method, FSI, to Martian radio occultation data in order to analyze the fine structures of the Martian atmosphere at a higher resolution than before, and to reveal the details of these small-scale processes.In this study, we analyzed the MGS radio occultation data by both the geometrical optics method and FSI, and compared the results. MGS conducted many radio occultations during its mission period from 1997 to 2006, and here we report results from a portion of the data. The atmospheric profiles obtained from MGS occultation data by geometrical optics method has already been released as an official product by the MGS project. However, since the geometrical optics analysis performed in this study shows finer structures, we will also report on the comparison between the two.

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Variation of CO/CO_2 profile in the Martian middle atmosphere observed by TGO/NOMAD

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The upper atmosphere is the reservoir for atmospheric escape to space. The composition in the Martian upper atmosphere is mainly controlled by the solar Extreme-Ultraviolet (EUV) irradiance [e.g., Fox et al., 1996; Bougher et al., 2015; Krasnopolsky et al., 2002] but also varies with the altitude of homopause [Yoshida et al., 2020]. Homopause is the compositional boundary above which the molecular diffusion coefficient becomes larger than the eddy diffusion coefficient. On Mars, it is inferred that homopause altitude varies between 60 and 140 km altitudes with season, latitude, and local time [Jakosky et al., 2017; Slipski et al., 2018; Yoshida et al., 2020]. The substantial variation of homopause altitude suggests the influence of the lower atmospheric processes on the upper atmosphere. The inflation and contraction of the lower atmosphere are suggested as the main source of variations of homopause altitude. Besides, the gravity waves, planetary-scale waves, thermal tides, and global circulation are suggested to affect the homopause location [Imamura et al., 2016; Leovy et al., 1982; González-Galindo et al., 2009]. Since the variability of atmospheric composition study has been conducted by Mars Volatile Evolution spacecraft which measures the atmospheric composition in the upper atmosphere, variability of the lower-middle atmospheric composition has not acquired. To understand the dynamical coupling between the lower and the upper atmospheres, we use the Nadir and Occultation for MArs Discovery (NOMAD) instrument aboard Trace Gas Orbiter (TGO). NOMAD solar occultation is designed the combination of the Acousto Optical Turnable Filter and echelle grating [Neefs et al., 2015; Thomas et al., 2016]. NOMAD solar occultation operates in the wavelength range of 2.2 - 4.3 μm with a high-resolution (0.15 –0.22 cm^{-1}) [Vandaele et al., 2018]. It provides us CO and CO_2 spectrum below 100 km and 180 km altitudes, respectively.

The retrieved column mixing ratio of CO has the seasonal variation, which increases at the wintertime polar regions and decreases at the summertime polar regions [Smith et al., 2009; 2018; Krasnopolsky, 2007]. Seasonal variation of CO mixing ratio is controlled by CO_2 sublimation and condensation. The general circulation model including atmospheric chemistry has suggested that the vertical structure of CO mixing ratio increases along with altitude above 60 km [Daerden et al., 2018; Lefevre et al., 2008]. The CO mixing ratio is constant in the lower atmosphere because time of vertical mixing is shorter than the CO lifetime of ~6 years [Krasnopolsky, 2007]. However, the lifetime of CO becomes comparable to the time of vertical mixing around 60 km due to the production by CO_2photodissociation when a linear decrease in the eddy diffusion coefficient (e.g., Izakov, 1978) is assumed. These studies suggest that both photochemistry and eddy diffusion are important in determining the CO/CO_2 ratio profiles.

In this study, we applied the equivalent width technique [Chamberlain and Hunten, 1987; Krasnopolsky, 1986] to derive a new set of the column densities of CO and CO_2, respectively, with the observed atmospheric transmittance spectra by NOMAD solar occultation. The CO (2-0) band and the CO_2 (21102 –00001) band are carefully selected for retrievals due to the contribution of nearby and central orders [cf.

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Liuzzi et al., 2019]. It is noted that CO_2 absorption cross sections, we use, have high sensitivity to the background temperature. We found that the retrieved CO/CO_2 ratio between 60 and 90 km increases with altitudes as predicted by the models. The seasonal variation of observed CO/CO_2 profile will be discussed. For interpretation, 1D photochemical model is compared newly obtained CO/CO_2 profiles, especially in order to infer the eddy diffusion coefficient in the lower atmosphere on Mars.

Keywords: Trace Gas, Mars, IR observation, CO, Eddy diffusion, Photochemistry

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Periodic variations of hydrogen and oxygen airglow in the Martian upper atmosphere during a rapid growth of a regional dust storm

*Kei Masunaga[1], Naoki Terada[2], Nao Yoshida[2], Takeshi Kuroda[2], Kazuo Yoshioka[3], Tomoki Kimura[2], Fuminori Tsuchiya[2], Go Murakami[4], Atsushi Yamazaki[4], Ichiro Yoshikawa[3]

1. University of Colorado Boulder, 2. Tohoku University, 3. University of Tokyo, 4. Institute of Space and Astronautical Science

Analyzing extreme ultraviolet (EUV) spectra of the Martian upper atmosphere obtained from the Hisaki space telescope, we study variations of hydrogen (HI Ly-β) and oxygen (OI 135.6 nm) airglow during a rapid expansion of a regional dust storm that occurred in Mars Year 33. We find that Ly-β brightness did not vary with the solar EUV flux but significantly increased over the observation period (L_S=213°-232°), while OI 135.6 mainly varied with the solar EUV flux. After subtracting the seasonal and solar effects from Ly-β and OI 135.6 nm brightness, respectively, it was found that their residual brightness varied with a ~6-8-day periodicity and that the OI 135.6 nm residual brightness approximately varied in quadrature with that of Ly-β. The variation level for both emissions was ~20-40% for the whole disk. This indicates that when hydrogen atoms are globally produced by water vapor transported from the lower atmosphere during the dust storm expansion, the amount of oxygen atoms significantly decreases in the upper atmosphere of Mars. In this presentation, we discuss a role of atmospheric waves such as baroclinic waves that usually present in the northern hemispheric lower atmosphere in this season as a possible candidate to cause the periodic airglow variations in the upper atmosphere. We also discuss a cause of the anti-correlation between the hydrogen and oxygen airglow emissions, by analyzing variations of other emission lines such as OII 83.4 nm and ArI 106.6 nm, and CO bands as well as the hydrogen and oxygen emissions.

Keywords: Mars, Hisaki space telescope, Airglow, Dust storm

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[J] Oral | A (Atmospheric and Hydrospheric Sciences)：A-AS Atmospheric Sciences, Meteorology & Atmospheric Environment

Thu. Jun 3, 2021 9:00 AM - 10:30 AM JST | Thu. Jun 3, 2021 12:00 AM - 1:30 AM UTC | Ch.06 Zoom Room 06

[A-AS06] Stratosphere-troposphere Processes And their Role in Climate

convener:Takenari Kinoshita(Japan Agency for Marine-Earth Science and Technology), Takatoshi Sakazaki(Graduate School of Science, Kyoto University), Masashi Kohma(Department of Earth and Planet Science, Graduate School of Science, The University of Tokyo), Nawo Eguchi(Kyushu University), Chairperson:Takenari Kinoshita(Japan Agency for Marine-Earth Science and Technology)



The dynamical, radiative, and chemical processes involved in the interactions between the stratosphere and troposphere are essential for understanding the present and future climate. Both observed data and high-resolution models have now clearly demonstrated that stratospheric processes can affect various tropospheric phenomena. On the other hand, it has been confirmed that the stratospheric processes are changing significantly with climate change. For example, the polar vortex was exceptionally strong, cold, and persistent in the Northern Hemisphere winter stratosphere in 2019-2020, resulting in record ozone depletion and contributing to unusually warm temperatures in mid-latitudes.
In this session, we will focus on stratospheric phenomena and invite presentations on the latest findings (case studies, long-term variations, predictability, etc.). We welcome studies on the effects of these phenomena on the troposphere and mesosphere. Inheriting the significance of the Stratosphere-troposphere Processes And their Role in Climate (SPARC) sessions held at JpGU, this division aims to enhance the development of this field in close cooperation with the atmospheric chemistry sessions.

9:00 AM - 9:20 AM JST | 12:00 AM - 12:20 AM UTC

[AAS06-01] Updated atmospheric composition chemica reanalysis and emission estimates

★Invited Papers

*Kazuyuki Miyazaki[1] (1.NASA Jet Propulsion Laboratory)

9:20 AM - 9:40 AM JST | 12:20 AM - 12:40 AM UTC

[AAS06-02] Ozone variability associated with the dynamical fields during YMC-Sumatra2017 field campaign

★Invited Papers

*Junko Suzuki[1], Shin-Ya Ogino[1], Takenari Kinoshita[1], Ryuichi Shirooka[1], Suginori Iwasaki[2], Kunio Yoneyama[1] (1.Japan Agency for Marine-Earth Science and Technology, 2.National Defense Academy of Japan)

9:40 AM - 9:55 AM JST | 12:40 AM - 12:55 AM UTC

[AAS06-03] Tropical coastal bidirectional gravity waves robustizing QBO

*Manabu D. Yamanaka[1,2], Shin-Ya Ogino[2] (1.Research Institute for Humanity and Nature / Professor Emeritus of Kobe University, 2.Japan Agency for Marine-Earth Science and Technology)

9:55 AM - 10:10 AM JST | 12:55 AM - 1:10 AM UTC

[AAS06-04] Study for influence of temperature at TTL on evolution of deep convection and tropical cyclones

Kenta Kobayashi[1], *Nawo Eguchi[1], Tomoe Nasuno[2], Yohei Yamada[2], Kunihiko Kodera[3] (1.Kyushu University, 2.JAMSTEC, 3.Meteorological Research Institute)

10:10 AM - 10:25 AM JST | 1:10 AM - 1:25 AM UTC

[AAS06-05] Stratospheric Influence on the Troposphere During the Remarkably Strong Arctic Circumpolar Vortex Condition in 2019-2020 Winter

*Shunsuke Noguchi[1,2], Kunihiko Kodera[2], Ryo Mizuta[2], Seiji Yukimoto[2] (1.Japan Agency for Marine-Earth Science and Technology, 2.Meteorological Research Institute)

10:25 AM - 10:30 AM JST | 1:25 AM - 1:30 AM UTC

[AAS06-06] Discussion

Updated atmospheric composition chemica reanalysis and emission estimates

*Kazuyuki Miyazaki[1]

1. NASA Jet Propulsion Laboratory

This study presents the results from the Tropospheric Chemistry Reanalysis version 2 (TCR-2) for the period 2005–2018 at 1.1 horizontal resolution obtained from the assimilation of multiple updated satellite measurements of ozone, CO, NO_2, HNO_3, and SO_2 from the OMI, SCIAMACHY, GOME-2, TES, MLS, and MOPITT satellite instruments. The reanalysis calculation was conducted using a global chemical transport model MIROC-CHASER and an ensemble Kalman filter technique that optimizes both chemical concentrations of various species and emissions of several precursors, which was efficient for the correction of the entire tropospheric profile of various species and its year-to-year variations. Comparisons against independent aircraft, satellite, and ozonesonde observations demonstrate the quality of the reanalysis fields for numerous key species on regional and global scales, as well as for seasonal, yearly, and decadal scales, from the surface to the lower stratosphere. The multi-constituent data assimilation brought the model vertical profiles and interhemispheric gradient of OH closer to observational estimates, which was important in improving the description of the oxidation capacity of the atmosphere and thus vertical profiles of various species. The evaluation results demonstrate the capability of the chemical reanalysis to improve understanding of the processes controlling variations in atmospheric composition, including long-term changes in near-surface air quality and emissions. The estimated emissions can be employed for the elucidation of detailed distributions of the anthropogenic and biomass burning emissions of co-emitted species (NO_x, CO, SO_2) in all major regions, as well as their seasonal and decadal variabilities.

Keywords: Atmospheric composition, Satellite observation, Data assimilation

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Ozone variability associated with the dynamical fields during YMC-Sumatra2017 field campaign

*Junko Suzuki[1], Shin-Ya Ogino[1], Takenari Kinoshita[1], Ryuichi Shirooka[1], Suginori Iwasaki[2], Kunio Yoneyama[1]

1. Japan Agency for Marine-Earth Science and Technology, 2. National Defense Academy of Japan

The field observation focused on the atmospheric science in the troposphere and stratosphere was conducted in Bengkulu, Indonesia in December 2017 as part of the observation of the Years of the Maritime Continent (YMC). We deployed land-based the ozone sonde-observation to understand the ozone diurnal cycle.

Keywords: Ozone, Gravity wave, Diurnal cycle

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Tropical coastal bidirectional gravity waves robustizing QBO

*Manabu D. Yamanaka[1,2], Shin-Ya Ogino[2]

1. Research Institute for Humanity and Nature / Professor Emeritus of Kobe University, 2. Japan Agency for Marine-Earth Science and Technology

The equatorial lower-stratospheric quasi-biennial oscillation (QBO) is explained basically by the wave-mean flow interaction theory, but equi-amplitude east-/west-ward waves suggested from the robust periodicity and meridional-vertical extension have not been clarified. Recent observations have revealed that the coastal diurnal cycle (CDC) is the most dominant mode of cloud-rainfall generation in the equatorial troposphere, in particular along the world's longest coastlines surrounding major islands of the Indonesian maritime continent (IMC) [1]. The CDC (sea-land breeze) circulation is a sum of internal gravity waves forced by the sea-land temperature contrast dependent on sea-surface temperature variations and land-surface modifications. Therefore, the CDC gravity waves may be a key candidate to explain the robustness of QBO and its interactions with El Niño, global warming etc.

The CDC cloud (updraft) area migrations observed in the IMC [1] start from mountains in the evening with destination to seas in the morning, or from seas before sunrise to the mountainous destination in the evening. The horizontal phase velocity is 10^2 km/half a day ≒ 10 km/h ≒ 3 m/s on land, and faster off the coast. Individual cloud movements and cloud-bottom convergent winds reach about 20 m/s. Under the linear theory for |latitude| < 30° (|Coriolis factor| < 2π/1 day) the CDC circulation is given by a superposition of internal inertio-gravity waves of which the dispersion relation is a cubic equation for vertical wavenumber squared m^2. At the surface both the up-/down-ward components exist to satisfy zero vertical velocity condition, and large eddy viscosity/diffusivity (m^6 term) balancing the buoyancy (m^0 term) makes the velocity field almost similar to a steady horizontal-convection cell, of which the intensity and horizontal scale (inverse horizontal wavenumber $k^{-1} \approx 10^2$ km) are governed by the land-sea temperature contrast $k\Delta T$. Above this cell, the acceleration (m^2 term) balances the buoyancy, and the radiation condition selects upward propagating waves. $k\Delta T$ is reversed between day/night (with frequency $\omega = 2\pi$ /1 day), and the horizontal phase velocity $c = \omega/k \simeq 10^0$ m/s directs land-/sea-ward, respectively.

The CDC bidirectional (east-/west-ward) gravity-wave generation resembles the bottom condition in the Plumb's QBO analog [3] (Fig. 1). In this case the meridional range of QBO is narrower than the internal region of inertio-gravity waves, and is given by the region (|latitude| < about 10°) where the solar diurnal cycle is stronger than annual, which is close to the meridional range of the IMC. The zonal-wind amplitude of QBO is dependent on migration velocities of individual clouds, somewhat faster than c for CDC. The period of QBO decreases with an increase of the CDC amplitude, i.e., $k\Delta T$, and becomes biperiodic for too strong CDC. The QBO-period becomes longer for a weaker CDC, and decayed if too weak.

The CDCs in the low-latitudes, as well as mountain waves in the mid-latitudes [4], are mechanisms of the rotating earth controlling the atmosphere. Longitudinal locations of Africa (−90°) and South America (+180°) and rapid rotation of the earth homogenize the local solar heating zonally (Fig. 2). If the sea surface around the IMC becomes cooler by El Niño and/or Indian-Ocean dipole mode, CDCs become weaker and the QBO period becomes longer. The CDCs do not generate a "moving frame" mechanism [5] considered for global diurnal cycles (tides) in the Venusian atmosphere. The CDCs appear only on an sea-land coexistent planet such as the earth. The CDCs interact with meridional circulations, water cycles (cold trap), vegetation and human activity (heat island), and hence the QBO also may be affected by them.

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References: [1] Yamanaka et al., 2018: *Prog. Earth Planet. Sci.*, **5**, 21. [2] Rotunno, 1983: *J. Atmos. Sci.*, **40**, 1999. [3] Plumb, 1977: *J. Atmos. Sci.*, **34**, 1847. [4] Tanaka & Yamanaka, 1985: *J. Meteor. Soc. Japan*, **63**, 1047. [5] Schubert & Whitehead, 1969: *Science*, **163**(3862), 71.

Keywords: diurnal-cycle sea-land breeze circulations, internal gravity waves, wave-mean flow interaction, quasi-biennial oscillation

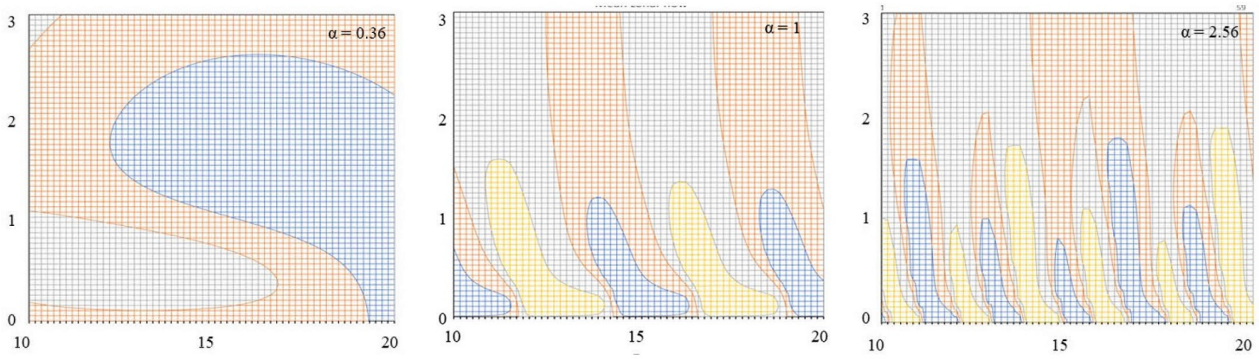


図1 Plumb モデル[3]（横軸・縦軸は適当に無次元化した時間・高度）において CDC 双方向重力波が QBO を生成する場合（中）に対し，CDC の地表温度差振幅が 40%減（運動量束 0.36 倍）の場合（左），および 60%増（2.56 倍）の場合（右）を示す．（図中 α は運動量束の比率で，Plumb 原論文の Newton 冷却率とは異なることに注意）

Fig.1 QBOs generated by the CDC gravity waves in the Plumb's model [3], plotted in the altitude (vertical) - time (horizontal) plane (units are non-dimensionalized). The "control" run (middle), and 40% weaker (left) and 60% larger (right) sea-land temperature gradients (corresponding to 0.36 and 2.56 times of the momentum fluxes for the control run) are shown. (Note that alpha is a momentum flux ratio, different from the Newtonian cooling rate in Plumb's original paper.)

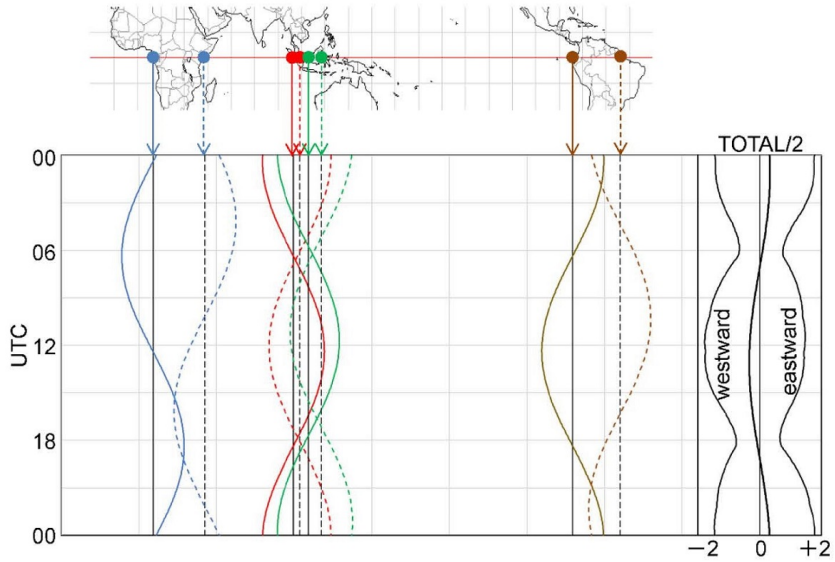


図 2 地球赤道域の海岸線が生成する CDC 重力波の東向き・西向き運動量束の時間（世界時）による変動.

Fig. 2 Variations of east-/westward momentum fluxes of the CDC gravity waves generated near the equatorial coastlines, as functions of time (UTC).

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Study for influence of temperature at TTL on evolution of deep convection and tropical cyclones

Kenta Kobayashi[1], *Nawo Eguchi[1], Tomoe Nasuno[2], Yohei Yamada[2], Kunihiko Kodera[3]

1. Kyushu University, 2. JAMSTEC, 3. Meteorological Research Institute

Previous studies based on satellite observation and general circulation model found the increase of tropical cyclone number/magnitude during a Stratospheric Sudden Warming (SSW) event [e.g., Kodera et al., ACP, 2015; Noguchi et al., GRL, 2020]. One of key factors for enhancement of deep convection and tropical cyclone is the temperature decrease at tropical tropopause layer (TTL). We evaluated the influence of stratospheric dynamical change through temperature change at TTL on the genesis/evolution of deep convection and tropical cyclones by the ensemble simulation from a global nonhydrostatic model, NICAM (Nonhydrostatic ICosahedral Atmospheric Model) [Satoh, et al., 2014] which explicitly calculates moist physics at a cloud-system-resolving resolution. We used the high-top NICAM version, approximately 50km altitude, the vertical layer is 78 number and the vertical resolution around TTL is about 380 m. The analysis period is August - September, 2019 when the tropical cyclone occurred frequently from late August to beginning September and the SSW occurred in Southern Hemisphere.

The ensemble simulation was taken each calculation with 12-hourly shifted from 00UTC 23 to 12UTC 26 August, 2019. The temperature at the tropical lower stratosphere decrease small before 24 August simulation and large after 25 August simulation [Yamada et al., personal communication], the difference is about 1 degree C on tropical average at 100 hPa. We usage the difference of temperature at TTL to analyze the change of deep convection and tropical cyclone. We mainly analyze the simulation between 00UTC 23 and 00UTC 25 Aug. From the analysis of dynamical field (geopotential height), the simulation of 25 Aug could find the amplification of planetary wave at the stratosphere, but not find that in the simulation of 23 Aug. The dynamical activation in the stratosphere enhanced the Brewer-Dobson circulation and the heat flux in 25 Aug simulation was larger than in 23 Aug simulation, in addition the temperature at TTL decrease visibly in the 25 Aug simulation. The convective activity was enhanced around 10N after the onset of SSW and six tropical cyclones occurred in the 25 Aug simulation, but two cyclones occurred in the 23 Aug simulation.

Keywords: Stratosphere-Troposphere Interaction, Tropical cyclone

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Stratospheric Influence on the Troposphere During the Remarkably Strong Arctic Circumpolar Vortex Condition in 2019-2020 Winter

*Shunsuke Noguchi[1,2], Kunihiko Kodera[2], Ryo Mizuta[2], Seiji Yukimoto[2]

1. Japan Agency for Marine-Earth Science and Technology, 2. Meteorological Research Institute

Tropospheric responses to the remarkably strong stratospheric polar vortex condition in 2019-2020 Arctic winter and spring have been investigated by conducting a series of ensemble forecast experiments. In particular, by conducting ensemble "nudged" integrations, whose stratospheric circulation is relaxed toward a reanalysis, and comparing them with reference ensemble integrations, we deduce a significant effect of the stratosphere on the culmination of the anomalous circulation pattern characterized by a positive phase of the Arctic Oscillation. Various factors that led to the formation of anomalies in the stratosphere and troposphere during this extreme season will also be discussed through comparisons between the experiments and additional experiments.

Keywords: Stratosphere-Troposphere Coupling, Arctic Ozone Depletion, Arctic Oscillation/Northern Annular Mode

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[J] Oral | A (Atmospheric and Hydrospheric Sciences) | A-AS Atmospheric Sciences, Meteorology & Atmospheric Environment

[A-AS06] Stratosphere-troposphere Processes And their Role in Climate

convener:Takenari Kinoshita(Japan Agency for Marine-Earth Science and Technology), Takatoshi Sakazaki(Graduate School of Science, Kyoto University), Masashi Kohma(Department of Earth and Planet Science, Graduate School of Science, The University of Tokyo), Nawo Eguchi(Kyushu University), Chairperson:Takenari Kinoshita(Japan Agency for Marine-Earth Science and Technology)
Thu. Jun 3, 2021 9:00 AM - 10:30 AM Ch.06 (Zoom Room 06)

The dynamical, radiative, and chemical processes involved in the interactions between the stratosphere and troposphere are essential for understanding the present and future climate. Both observed data and high-resolution models have now clearly demonstrated that stratospheric processes can affect various tropospheric phenomena. On the other hand, it has been confirmed that the stratospheric processes are changing significantly with climate change. For example, the polar vortex was exceptionally strong, cold, and persistent in the Northern Hemisphere winter stratosphere in 2019-2020, resulting in record ozone depletion and contributing to unusually warm temperatures in mid-latitudes.

In this session, we will focus on stratospheric phenomena and invite presentations on the latest findings (case studies, long-term variations, predictability, etc.). We welcome studies on the effects of these phenomena on the troposphere and mesosphere. Inheriting the significance of the Stratosphere-troposphere Processes And their Role in Climate (SPARC) sessions held at JpGU, this division aims to enhance the development of this field in close cooperation with the atmospheric chemistry sessions.

10:25 AM - 10:30 AM

[AAS06-06]Discussion

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[J] Oral | A (Atmospheric and Hydrospheric Sciences)：A-AS Atmospheric Sciences, Meteorology & Atmospheric Environment

Thu. Jun 3, 2021 10:45 AM - 12:15 PM JST | Thu. Jun 3, 2021 1:45 AM - 3:15 AM UTC | Ch.06 Zoom Room 06

[A-AS06] Stratosphere-troposphere Processes And their Role in Climate

convener:Takenari Kinoshita(Japan Agency for Marine-Earth Science and Technology), Takatoshi Sakazaki(Graduate School of Science, Kyoto University), Masashi Kohma(Department of Earth and Planet Science, Graduate School of Science, The University of Tokyo), Nawo Eguchi(Kyushu University), Chairperson:Takatoshi Sakazaki(Graduate School of Science, Kyoto University)



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10:45 AM - 11:05 AM JST | 1:45 AM - 2:05 AM UTC

[AAS06-07] Do sudden stratospheric warmings boost convective activity in the tropics?

★Invited Papers

*Kohei Yoshida[1], Ryo Mizuta[1] (1.Meteorological Research Institute)

11:05 AM - 11:20 AM JST | 2:05 AM - 2:20 AM UTC

[AAS06-08] Dynamical Features of Antarctic Sudden Stratospheric Warming in 2019

*Guangyu Liu[1], Toshihiko Hirooka[2], Nawo Eguchi[3], Kirstin Krüger[4] (1.Department of Earth and Planetary Sciences, Kyushu University, 2.Department of Earth and Planetary Sciences, Faculty of Science, Kyushu University, 3.Research Institute for Applied Mechanics, Kyushu University, 4.Department of Geosciences, University of Oslo)

11:20 AM - 11:40 AM JST | 2:20 AM - 2:40 AM UTC

[AAS06-09] Seasonal predictability of the persisted negative Antarctic oscillations after sudden stratospheric warming in the Southern Hemisphere in 2019

★Invited Papers

*Chiaki Kobayashi[1], Shuhei Maeda[2] (1.Meteorological Research Institute, 2.Japan Meteorological Agency)

11:40 AM - 11:55 AM JST | 2:40 AM - 2:55 AM UTC

[AAS06-10] **The stratospheric QBO affects Antarctic sea ice through the tropical convection in early austral winter**

*Koji Yamazaki[1], Tetsu Nakamura[1] (1.Hokkaido University)

11:55 AM - 12:10 PM JST | 2:55 AM - 3:10 AM UTC

[AAS06-11] A study of Kelvin-Helmholtz billow in the Antarctic troposphere and lower stratosphere based on the PANSY radar observation using a frequency domain interferometry technique

*Yuichi Minamihara[1], Kaoru Sato[1], Masaki Tsutsumi[2] (1.Department of Earth and Planetary Science, Graduate School of Science, The University of Tokyo, 2.National Institute of Polar Research)

12:10 PM - 12:15 PM JST | 3:10 AM - 3:15 AM UTC

[AAS06-12] Discussion

Do sudden stratospheric warmings boost convective activity in the tropics?

*Kohei Yoshida[1], Ryo Mizuta[1]

1. Meteorological Research Institute

Influence of stratospheric meridional circulation changes related to sudden stratospheric warmings (SSW) on the tropical troposphere have been examined in many previous studies. However, due to small sample size of SSWs and large internal variability in the tropical troposphere, influence of the SSW on the tropical troposphere is still uncertain. We examine impact of the stratospheric circulation changes related to SSW on the tropical troposphere using 5,000-year scale ensemble simulations with a 60 km horizontal resolution global atmospheric model MRI-AGCM3.2. More than 1,000 of SSW-like circulation change events are extracted thanks to the large ensemble simulations. A composite analysis of the SSW-like events shows significant stratospheric upwelling and cooling in the tropics. Synchronized with the upwelling, statistically robust tropospheric signals such as enhanced convective activity including tropical cyclone are found. Although the mean tropospheric signals tend to be small, relative probability of their extreme events significantly increases. Influence of tropospheric waves to tropical troposphere is also discussed.

Keywords: Sudden stratospheric warming, Stratosphere-Troposphere coupling in the tropics, High-resolution large-ensemble simulations

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Dynamical Features of Antarctic Sudden Stratospheric Warming in 2019

*Guangyu Liu[1], Toshihiko Hirooka[2], Nawo Eguchi[3], Kirstin Krüger[4]

1. Department of Earth and Planetary Sciences, Kyushu University, 2. Department of Earth and Planetary Sciences, Faculty of Science, Kyushu University, 3. Research Institute for Applied Mechanics, Kyushu University, 4. Department of Geosciences, University of Oslo

The sudden stratospheric warming (SSW) is a spectacular event first discovered by Scherhag (1952). During the SSW event, a rapid deceleration or reversed westerly polar vortex along with abrupt increasing temperatures by tens of Kelvins occurs in a few days. The theoretical studies of mechanism of the SSW has been noted that enhanced quasi-stationary planetary waves propagate from the troposphere bring about the SSW (Matsuno 1971; Andrew et al., 1987). The SSW events are commonly observed in Northern Hemisphere (NH) but rarely occur in the Southern Hemisphere (SH) due to its geographical condition, topography and land-sea temperature contrast.

The present study analyzed the unusual SSW event in September 2019 (hereafter SSW2019) in the SH with comparing to the only major SSW occurred in 2002 (hereafter SSW2002) by using the Japanese 55-year Reanalysis (JRA-55) data. The reversal temperature gradient between the south pole and 60S, decelerated westerly winds in 60S and 10 hPa were observed. It is found that the quasi-stationary wave driving with zonal wavenumber 1 play an important role in the occurrence of SSW2019, which brought a large disturbance on the polar vortex and decelerate the polar nigh jet. However, because the reversal of westerly winds to easterly winds have not been observed at 60S, 10 hPa, the SSW2019 was classified as a minor warming event.

Keywords: sudden stratospheric warming

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Seasonal predictability of the persisted negative Antarctic oscillations after sudden stratospheric warming in the Southern Hemisphere in 2019

*Chiaki Kobayashi[1], Shuhei Maeda[2]

1. Meteorological Research Institute, 2. Japan Meteorological Agency

In the early September 2019, a sudden stratospheric warming (SSW) occurred in the southern hemisphere for the first time in 17 years. The impact extended downward to the Earth’ s surface, and the negative-phase of the Antarctic Oscillation (AAO) in the troposphere persisted from mid-October to the end of December. In this study, we investigate the relationship between the persistence of the negative AAO and SSW, and show that wave activity anomalies was formed in which the negative AAO is easily maintained. We also examine the seasonal predictability of the negative AAO using a seasonal prediction system of the Japan Meteorological Agency. It is shown that the persistence of the negative AAO is predictable, but that SST anomalies in the tropical Indian Ocean have little effect on this predictability.

The data used for the analysis of the circulation field is the JMA long-term reanalysis data JRA-55 (Kobayashi et al., 2015). The forecast data are the results of an ensemble 6-month forecast experiment with initial values of September 13 and 28, 2019, by an in-service seasonal forecast model (the coupled global atmosphere-ocean model CPS2, Takaya et al., 2018). The mass-weighted average method (MIM, Iwasaki 1989, 1992) on the isothermal surface is applied to these data to analyze the wave activity anomalies.

The evolution of the strength of the polar vortex from the stratosphere to the troposphere associated with SSW in the SH shows that the weakness of the polar vortex persisted in the upper stratosphere after the SSW, and the center of the anomaly descended to the lower stratosphere to the troposphere after mid-October. This was well predicted by the seasonal prediction experiment.

The zonal mean field during the period of persisted negative AAO is confirmed in terms of wave-mean flow interaction. The stratospheric polar night jet seen in the climatology is absent in the 3-month averaged zonal mean zonal winds from October to December 2019.

Corresponding to the zonal mean zonal winds, there is no waveguide along the climatological polar night jet, making it more difficult for planetary waves from the troposphere to propagate vertically than normal. In terms of wave activity, there was a strong convergence of E-P flux from 50S to 70 S in the middle and upper troposphere. As diagnosed by the spatial structure of the convergence-divergence anomalies of E-P fluxes, the direct meridional circulation in the extratropics in the troposphere showed enhanced anomalies, which suggest intensification anomalies of the cold air outflow to the mid-latitudes in the lower troposphere. This meridional circulation anomaly was also predicted in the seasonal prediction experiment.

From October to December 2019, SST anomalies in the tropical Indian Ocean were distributed high in the west and low in the east, and high temperature anomalies were also observed across the tropical Indian Ocean. In order to confirm the effect of the tropical SST on the negative phase of AAO, a sensitivity experiment was conducted by nudging the Indian Ocean tropical SST to the climatological SST.

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Similar to the seasonal prediction experiment in the previous section, the results of this sensitivity experiment predicted downward propagation of the weakness of the polar vortex and the persistence of the negative phase AAO in the troposphere after mid-October. The anomalies in the zonal-mean wave activity, EP flux, also show similar characteristics to those of the seasonal prediction experiment. This indicates that the persistent negative AAO can be predict even without the Indian Ocean tropical SST anomalies.

The results of the experiment suggest that SST anomalies in the tropical Indian Ocean has little effect on the persistence of the negative phase of the AAO. As future work, we would like to analyze what contributed to the persistence of the negative phase of the AAO and what was the source of the seasonal predictability. It is also interesting to note that the seasonal prediction experiment was able to predict the timing of the onset of negative AAO. Investigating the reasons for the predictions and improving our understanding of stratosphere-troposphere coupling are future tasks.

Keywords: sudden stratospheric warming, Antarctic Oscillation, Seasonal predictability

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The stratospheric QBO affects Antarctic sea ice through the tropical convection in early austral winter

*Koji Yamazaki[1], Tetsu Nakamura[1]

1. Hokkaido University

We found a statistically significant relationship between the stratospheric quasi-biennial oscillation (QBO) and Antarctic sea ice concentration (SIC) in austral winter. SIC differences between the easterly phase of the QBO (EQBO) and westerly phase of the QBO (WQBO) show positive anomalies of SIC in the following regions: over the Ross Sea, Weddell Sea, and around 90˚E. This wave-3 pattern is clearly seen in June and July, and decays in August. The increased SIC regions correspond to anomalous offshore wind regions, and the reduced SIC regions correspond to onshore wind regions, indicating the atmospheric circulation anomaly produced the SIC anomaly. The atmospheric circulation anomaly is barotropic and closely related with the upper atmospheric flow. The upper circulation anomaly shows a stationary Rossby wave train propagating from Indian Ocean. We show the enhanced convection in the tropical Indian Ocean in EQBO can excite the Rossby wave train. In summary, the stratospheric QBO affects the tropical convection, then generating the Rossby wave train which propagates into southern high latitude, and finally affecting Antarctic sea ice. There exists a possibility to predict winter sea ice in one-year advance, because the QBO is a quasi-regular oscillation.

Keywords: Antarctic sea ice, stratospheric quasi-biennial oscillation, Rossby wave propagation, tropical convection, Indian Ocean

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A study of Kelvin-Helmholtz billow in the Antarctic troposphere and lower stratosphere based on the PANSY radar observation using a frequency domain interferometry technique

*Yuichi Minamihara[1], Kaoru Sato[1], Masaki Tsutsumi[2]

1. Department of Earth and Planetary Science, Graduate School of Science, The University of Tokyo, 2. National Institute of Polar Research

Atmospheric turbulence plays a potentially important role in the mixing and irreversible transport of heat, momentum, and minor constituents. Due to its small spatial and temporal scales, it is difficult to observe its structure directly and the entire time evolution from the onset to the disappearance. Thus, the role of turbulence is not well understood qualitatively. Kelvin-Helmholtz instabilities (KHIs) resulting from enhanced vertical shear in the atmosphere are among the significant sources of atmospheric turbulence; when KHI occurs, it generates Kelvin-Helmholtz waves (KH waves), which mix heat and materials up and down. Fukao et al. (2011) reported that small-scale phenomena with a duration as long as 30 minutes and depth smaller than 2.5 km like KH waves are often observed based on the MU radar observation (34.8°N, 136.1°E). The purpose of this study is to elucidate the dynamical structure and formation mechanism of KH waves in the Antarctic troposphere and lower stratosphere using the PANSY radar at Syowa Station (69.0°S, 39.6°E). We used the frequency-domain interferometry (FDI) technique with the high-resolution in both time and space.

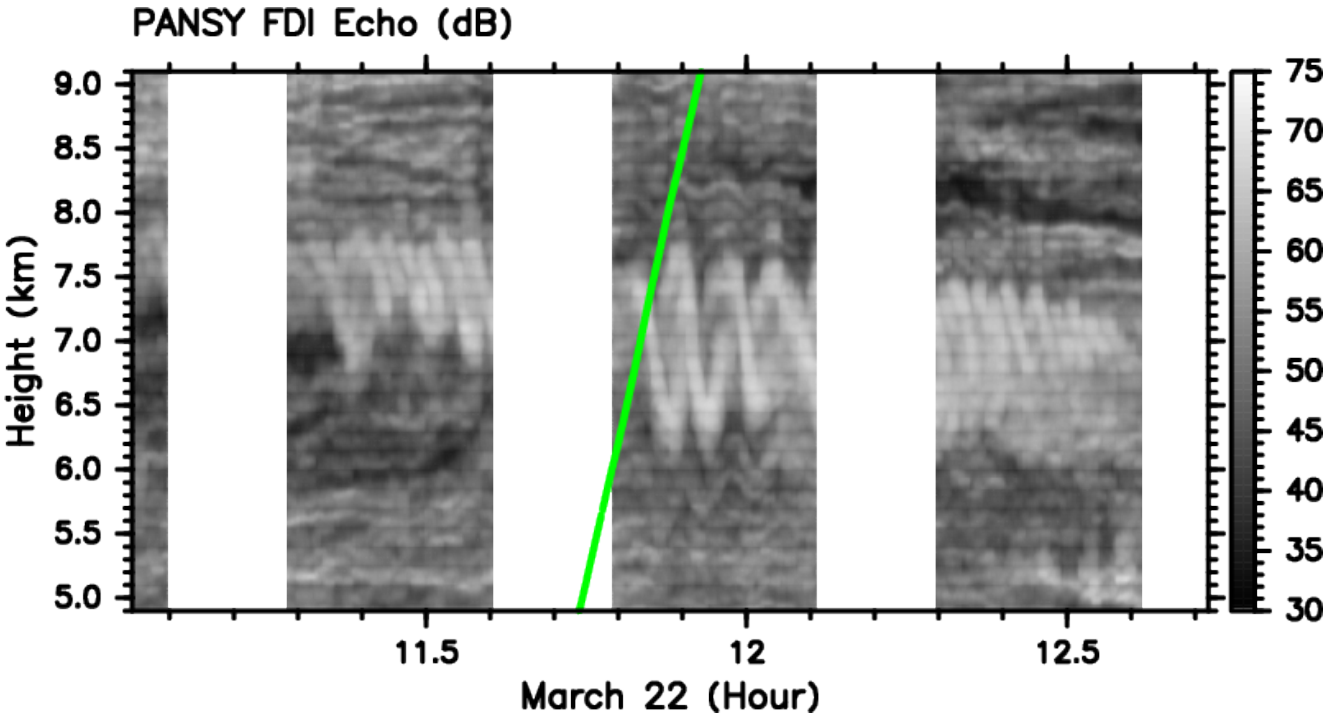
The PANSY radar observation is usually performed with standard observation mode at a fixed central frequency providing line-of-sight wind velocities for five directions at temporal and vertical resolutions of 200 seconds and 150 m, respectively. On the other hand, the FDI observation mode uses five different frequencies of transmitted waves and provides echo power with a resolution higher than the transmitted pulse width. Note that for MST radar such as the MU radar and the PANSY radar, it is considered that the echo mainly comes from Bragg scattering by isotropic atmospheric turbulence. The FDI observation campaign by the PANSY radar performed from March 14-24 and August 2-12, 2019 (20 days in total) for the troposphere and lower stratosphere. The FDI mode observations (~22 min) and the standard mode observations (~ 7 min) were repeated. Radiosonde observations were also made every 4 hours. The FDI mode observations provide fine vertical profiles of vertical winds in addition to the echo power, while the standard observation mode provides vertical profiles of the three-dimensional winds, including vertical wind. Vertical profiles of horizontal winds, temperature, and humidity were also obtained from the radiosonde observations.

During the campaign, 73 structures that appear to be KH waves were captured. In this presentation, we focus on the KH waves detected at 1100UT-1730UT on 21 March around the height of 9.0 km (A) and 1100UT-1300UT on 22 March around the height of 7.0 km (B). In case (A), a wave-like structure dominant in the horizontal winds having a wave-period shorter than one day was observed in association with the KH waves. A hodograph analysis was conducted and found that this wave-like structure is likely due to an inertia-gravity wave (GW) having a northeast- or southwestward wave vector and upward group velocity. The slow ground-based phase velocity of about 2.3 m s-1 suggests that this inertia-gravity wave is an orographic one. These dynamical properties are consistent with the generation in the northeasterly wind of about 20 m s-1 near the surface during this period. In case (B), a strong vertical shear of meridional winds localized around the height of 7.0 km was observed. This structure corresponds to the strong wind

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region in the upper troposphere associated with a developed low-pressure system approaching Syowa Station. We will also discuss how this low-pressure system was developed and accompanied such a strong wind region in the upper troposphere, based on the numerical simulations using the Nonhydrostatic ICosahedral Atmospheric Model (NICAM).

Keywords: Kelvin-Helmholtz billows, polar meteorology, middle atmosphere



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[J] Oral | A (Atmospheric and Hydrospheric Sciences) | A-AS Atmospheric Sciences, Meteorology & Atmospheric Environment

[A-AS06] Stratosphere-troposphere Processes And their Role in Climate

convener:Takenari Kinoshita(Japan Agency for Marine-Earth Science and Technology), Takatoshi Sakazaki(Graduate School of Science, Kyoto University), Masashi Kohma(Department of Earth and Planet Science, Graduate School of Science, The University of Tokyo), Nawo Eguchi(Kyushu University), Chairperson:Takatoshi Sakazaki(Graduate School of Science, Kyoto University)
Thu. Jun 3, 2021 10:45 AM - 12:15 PM Ch.06 (Zoom Room 06)
The dynamical, radiative, and chemical processes involved in the interactions between the stratosphere and troposphere are essential for understanding the present and future climate. Both observed data and high-resolution models have now clearly demonstrated that stratospheric processes can affect various tropospheric phenomena. On the other hand, it has been confirmed that the stratospheric processes are changing significantly with climate change. For example, the polar vortex was exceptionally strong, cold, and persistent in the Northern Hemisphere winter stratosphere in 2019-2020, resulting in record ozone depletion and contributing to unusually warm temperatures in mid-latitudes.
In this session, we will focus on stratospheric phenomena and invite presentations on the latest findings (case studies, long-term variations, predictability, etc.). We welcome studies on the effects of these phenomena on the troposphere and mesosphere. Inheriting the significance of the Stratosphere-troposphere Processes And their Role in Climate (SPARC) sessions held at JpGU, this division aims to enhance the development of this field in close cooperation with the atmospheric chemistry sessions.

12:10 PM - 12:15 PM

[AAS06-12]Discussion

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[J] Oral | A (Atmospheric and Hydrospheric Sciences)：A-AS Atmospheric Sciences, Meteorology & Atmospheric Environment

Thu. Jun 3, 2021 1:45 PM - 3:15 PM JST | Thu. Jun 3, 2021 4:45 AM - 6:15 AM UTC | Ch.06 Zoom Room 06

[A-AS06] Stratosphere-troposphere Processes And their Role in Climate

convener:Takenari Kinoshita(Japan Agency for Marine-Earth Science and Technology), Takatoshi Sakazaki(Graduate School of Science, Kyoto University), Masashi Kohma(Department of Earth and Planet Science, Graduate School of Science, The University of Tokyo), Nawo Eguchi(Kyushu University), Chairperson:Masashi Kohma(Department of Earth and Planet Science, Graduate School of Science, The University of Tokyo)



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1:45 PM - 2:00 PM JST | 4:45 AM - 5:00 AM UTC

[AAS06-13] LODEWAVE (LOng-Duration balloon Experiment of gravity WAVE over Antarctica)

*Yoshihiro Tomikawa[1,2], Kaoru Sato[3], Yoshitaka Saito[4], Isao Murata[5], Naohiko Hirasawa[1,2], Masashi Kohma[3], Kyoichi Nakashino[6], Daisuke Akita[7], Takuma Matsuo[8], Masatomo Fujiwara[9], Lihito Yoshida[2] (1.National Institute of Polar Research, 2.School of Multidisciplinary Sciences, The Graduate University for Advanced Studies, SOKENDAI, 3.Graduate School of Science, The University of Tokyo, 4.Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency, 5.Graduate school of Environmental Studies, Tohoku University, 6.School of Engineering, Tokai University, 7.School of Environment and Society, Tokyo Institute of Technology, 8.School of Science and Technology, Meiji University, 9.Faculty of Environmental Earth Science, Hokkaido University)

2:00 PM - 2:15 PM JST | 5:00 AM - 5:15 AM UTC

[AAS06-14] Sporadic, large gravity wave events over Syowa Station in summer -Comparison between the PANSY radar and the ERA5 reanalysis-

*Lihito Yoshida[1], Yoshihiro Tomikawa[2,1], Mitsumu K. Ejiri[2,1], Masashi Kohma[3], Kaoru Sato[3] (1.Department of Polar Science, School of Multidisciplinary Sciences, The Graduate University for Advanced Studies, 2.National Institute of Polar Research, 3.Department of Earth and Planetary Science, Graduate School of Science, The University of Tokyo)

2:15 PM - 2:35 PM JST | 5:15 AM - 5:35 AM UTC

[AAS06-15] Detection of a climatological short break in the polar night jet in early winter and its relation to cooling over Siberia

★Invited Papers

*Yuta Ando[1,2], Koji Yamazaki[3], Yoshihiro Tachibana[2], Masayo Ogi[3], Jinro Ukita[1] (1.Faculty of Science, Niigata University, 2.Weather and Climate Dynamics Division, Mie Univesity, 3.Hokkaido University)

2:35 PM - 2:55 PM JST | 5:35 AM - 5:55 AM UTC

[AAS06-16] Characteristics of planetary-wave packet propagation during a major sudden stratospheric warming event in January 2021

★Invited Papers

*Yayoi Harada[1], Takenari Kinoshita[2], Kaoru Sato[3], Toshihiko Hirooka[4] (1.Meteorological Research Institute, Japan Meteorological Agency, 2.The Japan Agency for Marine-Earth Science and Technology (JAMSTEC) , 3.Department of Earth and Planetary Sciences, University of Tokyo, 4.Department of Earth and Planetary Sciences, Kyushu University)

2:55 PM - 3:10 PM JST | 5:55 AM - 6:10 AM UTC

[AAS06-17] A Statistical Analysis of Downward Propagation of Planetary Wave Packets in the Stratosphere Using Large Ensemble Data

*Matsuyama Yuya[1], Toshihiko Hirooka[2] (1.Department of Earth and Planetary Sciences, Graduate School of Science, Kyushu University, 2.Department of Earth and Planetary Sciences, Faculty of Science, Kyushu University)

3:10 PM - 3:15 PM JST | 6:10 AM - 6:15 AM UTC

[AAS06-18] Discussion

LODEWAVE (LOng-Duration balloon Experiment of gravity WAVE over Antarctica)

*Yoshihiro Tomikawa[1,2], Kaoru Sato[3], Yoshitaka Saito[4], Isao Murata[5], Naohiko Hirasawa[1,2], Masashi Kohma[3], Kyoichi Nakashino[6], Daisuke Akita[7], Takuma Matsuo[8], Masatomo Fujiwara[9], Lihito Yoshida[2]

1. National Institute of Polar Research, 2. School of Multidisciplinary Sciences, The Graduate University for Advanced Studies, SOKENDAI, 3. Graduate School of Science, The University of Tokyo, 4. Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency, 5. Graduate school of Environmental Studies, Tohoku University, 6. School of Engineering, Tokai University, 7. School of Environment and Society, Tokyo Institute of Technology, 8. School of Science and Technology, Meiji University, 9. Faculty of Environmental Earth Science, Hokkaido University

Atmospheric gravity waves transport momentum in the atmosphere and play an important role in determining temperature and material distribution through driving the meridional circulation in the middle atmosphere. However, they have wide spatial and temporal scales, which make it difficult to capture the whole feature of gravity waves with any of the latest observations and models. The first Mesosphere-Stratosphere-Troposphere (MST)/ Incoherent Scatter (IS) radar in the Antarctic, PANSY, which was installed at Syowa Station in 2011, can directly estimate the momentum flux of gravity waves in all frequency bands by observing 3-dimensional winds with high precision and high resolution. On the other hand, the super pressure (SP) balloon observation can also estimate momentum transport due to gravity waves in all frequency bands, and its horizontal distribution is also clarified. In order to carry out this SP balloon observation in the Antarctic where the observational constraint on the momentum transport due to gravity waves is especially insufficient, we proposed the LOng-Duration balloon Experiment of gravity WAVE over Antarctica (LODEWAVE). By combining it with the PANSY observation and the state-of-the-art meteorological reanalysis data, the 3-dimensional picture of momentum transport due to gravity waves is acquired, which contributes to the improvement of the future prediction by the climate model.

We have performed a test production of SP balloon and onboard instruments during FY 2019. The further development and test of the SP balloon and onboard instruments was carried out in FY 2020. In the latter half of FY 2021, a maximum of 3 SP balloon observations will be carried out at Syowa Station in the Antarctic. By developing the SP balloon and onboard instruments which are light and small enough to ease the restrictions of the Civil Aeronautics Act, we aim to establish a regular observation system in the Antarctic.

Keywords: Gravity wave, Super pressure balloon, Antarctic, PANSY radar

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Sporadic, large gravity wave events over Syowa Station in summer -Comparison between the PANSY radar and the ERA5 reanalysis-

*Lihito Yoshida[1], Yoshihiro Tomikawa[2,1], Mitsumu K. Ejiri[2,1], Masashi Kohma[3], Kaoru Sato[3]

1. Department of Polar Science, School of Multidisciplinary Sciences, The Graduate University for Advanced Studies, 2. National Institute of Polar Research, 3. Department of Earth and Planetary Science, Graduate School of Science, The University of Tokyo

Gravity waves (GWs) are atmospheric waves whose restoring force is buoyancy. They are generated by mountains, jet streams, etc, and can change a global wind distribution through momentum transport and deposit. They do not only decelerate the mesospheric jet stream, but also affect the horizontal wind in the lower stratosphere, and the global meridional circulation. However, GW observations are not enough to verify their behaviour in the Antarctic, due to the harsh environment. In addition, GWs have a wide range of horizontal wavelength (i.e., from several km to several thousand km) and period (i.e., from Brunt-Väisälä period (approximately 5 minutes) to inertial period (over 12 hours)), which makes it difficult to reproduce GWs in the entire frequency range even in the state-of-the-art atmospheric models in spite of the recent increase of their resolution. In order to implement the effect of subgrid-scale phenomena into the models, which are not explicitly represented, a GW parameterization is introduced. In general, nonorographic GW parameterization assumes nearly constant wave sources and instantaneous upward propagation, but in reality the wave sources are not constant and GWs propagate horizontally as well (Plougonven et al., 2020). Thus it is required to constrain the GW effect in the models based on observations which cover the whole frequency range of GWs and estimate the GW momentum transport in the Antarctic.

Intermittency, a measure of how transient or intermittent a GW event is, has recently received much attention. Even if the total amount of momentum flux is the same, continuous, small amplitude events deposit momentum to higher altitudes, while sporadic, large amplitude events deposit momentum to lower altitudes. As a result, the structure and strength of the driven meridional circulation depend on the GW intermittency (Hertzog et al., 2008). In Antarctica, intermitency has been studied using super pressure balloons (Hertzog et al., 2012) and the Program of the Antarctic Syowa MST/IS radar (PANSY radar) at Syowa Station (Minamihara et al., 2020), suggesting differences in the characteristics of intermittency due to different wave generation mechanisms.

Our purpose of this study is to investigate the characteristics of GWs for sporadic, large amplitude events that have a large impact on the overall momentum transport, and also to investigate how well the reanalysis data reproduces the GWs events in the Antarctic. We used the PANSY radar, for the observation data and the ERA5 reanalysis for the reanalysis data. The PANSY radar, which was installed at Syowa Station (69˚S,40˚E) in 2011, can observe three dimensional winds in the troposphere and lower stratosphere with high accuracy and high temporal and vertical resolution. It is the only instrument in the Antarctic that enables us to capture GWs in the almost entire frequency range (Sato et. al., 2014). The ERA5 reanalysis is the latest meteorological reanalysis dataset provided by the European Centre for Medium-Range Weather Forecasts. The ERA5 data is distributed at 137 vertical levels from the surface to 0.01 hPa with a horizontal spacing of 0.25 degree every 1 hour.

We use three dimensional winds of the PANSY radar and the ERA5 reanalysis during the time period of January to March 2016. We focus on inertia GWs in austral summer period because they can be extracted from both the PANSY and ERA5 data (i.e., even one hour resolution of ERA5) and their attribution to wave

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sources are more straightforward (i.e., there are few downward group velocity waves in summer according to the past studies using the PANSY radar (Minamihara et. al., 2018)). The inertia GWs are extracted by applying a bandpass filter with a cutoff period of 4-24 h and a cutoff vertical wavelength of 1.5-8 km. As a result, we found similar wave-like structure in the PANSY radar and the ERA5 analysis.

In order to examine the propagation characteristics of inertia GWs, we use a hodograph analysis. It utilizes the feature that the hodograph (i.e., the altitude change of the horizontal wind vector drawn in the zonal and meridional wind space) becomes an ellipse, in which the amplitude, intrinsic period, vertical wavelength, phase velocity, and group velocity of GWs can be estimated. Although the hodograph analysis generally has an ambiguity of propagation direction by 180˚, we exclude it by estimating the ground-based period directly using the data both in time and altitude.

The estimated momentum flux of each GW event is larger than the most-frequently observed GWs by the PANSY radar (Minamihara et al., 2020). We will discuss the wave sources through the ray tracing analysis of the observed GWs.

Keywords: gravity wave, reanalysis, Antarctic

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Detection of a climatological short break in the polar night jet in early winter and its relation to cooling over Siberia

*Yuta Ando[1,2], Koji Yamazaki[3], Yoshihiro Tachibana[2], Masayo Ogi[3], Jinro Ukita[1]

1. Faculty of Science, Niigata University, 2. Weather and Climate Dynamics Division, Mie Univesity, 3. Hokkaido University

The polar night jet (PNJ) is a strong stratospheric westerly circumpolar wind at around 65N in winter, and the strength of the climatological PNJ is widely recognized to increase from October through late December. Remarkably, the climatological PNJ temporarily stops increasing during late November. We examined this “short break” in terms of the atmospheric dynamical balance and the climatological seasonal march. We found that it results from an increase in the upward propagation of climatological planetary waves from the troposphere to the stratosphere in late November, which coincides with a maximum of the climatological Eliassen–Palm (EP) flux convergence in the lower stratosphere. The upward propagation of planetary waves at 100 hPa, which is strongest over Siberia, is related to the climatological strengthening of the tropospheric trough over Siberia. We suggest that longitudinally asymmetric forcing by land–sea heating contrasts caused by their different heat capacities can account for the strengthening of the trough.

The part of this presentation was published as the article, Ando et al. (2018).

Ando, Y., K. Yamazaki, Y. Tachibana, M. Ogi, and J. Ukita, 2018: Detection of a climatological short break in the polar night jet in early winter and its relation to cooling over Siberia. Atmospheric Chemistry and Physics, 18, 12639-12661, doi:10.5194/acp-18-12639-2018.

Keywords: Stratosphere, Rossby wave, Land-sea thermal contrast

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Characteristics of planetary-wave packet propagation during a major sudden stratospheric warming event in January 2021

*Yayoi Harada[1], Takenari Kinoshita[2], Kaoru Sato[3], Toshihiko Hirooka[4]

1. Meteorological Research Institute, Japan Meteorological Agency, 2. The Japan Agency for Marine-Earth Science and Technology (JAMSTEC) , 3. Department of Earth and Planetary Sciences, University of Tokyo, 4. Department of Earth and Planetary Sciences, Kyushu University

Observational features of atmospheric fields during a major sudden stratospheric warming (MSSW) event that occurred in January 2021 (MSSW21) are analyzed using the Japanese 55-year Reanalysis, and a three-dimensional wave activity flux (3D-flux-W, Kinoshita and Sato 2013; Sato et al. 2013; Harada et al. 2019). MSSW21 is characterized by strong easterlies over 70 m s^{-1} around the stratopause observed in early January 2021 and a mixed signature of wavenumber 1 (WN1), WN2 and WN3 planetary waves, although WN1 has been predominant during MSSW21 except its early stage (from late December 2020 to early January 2021). In the early stage, the polar vortex was displaced from the North Pole and simultaneously broken up into two centers. After a couple of days, they were merged into one but again broken around mid-January. After that the two centers were again merged and the polar vortex begun to travel eastward around the North Pole. Thus, the synoptic feature of the polar vortex was very variable. Resultantly, MSSW21 lasted until mid-February and several warming peaks were observed during the course of its time evolution.

Further analyses revealed that wave packets repeatedly propagated upward in the Eastern Hemisphere during MSSW21. During the early stage, localized wave packets propagated upward into the upper stratosphere over western Siberia. During the mature stage (mid-January 2021), upward wave-packet propagation was observed over eastern Siberia and even in the easterly region of the upper stratosphere.

Keywords: Sudden stratospheric warming, Planetary-wave packet propagation, Three-dimensional wave activity flux

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A Statistical Analysis of Downward Propagation of Planetary Wave Packets in the Stratosphere Using Large Ensemble Data

*Matsuyama Yuya[1], Toshihiko Hirooka[2]

1. Department of Earth and Planetary Sciences, Graduate School of Science, Kyushu University, 2. Department of Earth and Planetary Sciences, Faculty of Science, Kyushu University

Our former analyses (Matsuyama and Hirooka, JpGU Meeting 2019) investigated downward propagation of planetary wave packets from the stratosphere to the troposphere during winter in the Northern Hemisphere and its influence on the tropospheric circulation by the use of JRA-55 reanalysis data over the past 60 years. In the study, we partitioned the longitudinal circle into eight sectors of 45 degrees longitude and set a criterion value for each sector to the vertical component of Plumb’ s (1985) wave activity flux (WAFz) at 30 hPa, to show the geographical frequency distribution of the extracted downward propagation events and features of the composited geopotential height distribution during the event occurrence. However, the numbers of the events were not enough for statistical analysis in some longitudinal sectors, for example, in the Western Hemisphere. Hence, we make a statistical analysis of the downward propagation using the large ensemble data, d4PDF (Mizuta et al., 2017). We introduce following two methods to extract strong downward propagation events. The first method is the same as in our former analysis. In this case, similar results are obtained to those based on JRA-55. Moreover, enough numbers of the events are extracted for statistical discussions, because of the large member number in d4PDF, i.e., 100 members. In the second method, a criterion is set for each grid point (2.5˚×2.5˚); resultantly, more detailed geographical frequency distribution of the events is successfully obtained. Although the overall feature of the geographical distributions of the events obtained by the two methods is similar each other, significant differences are found in the composited geopotential distribution during the event occurrence.

Keywords: planetary wave packet, downward propagation, wave activity flux

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[J] Oral | A (Atmospheric and Hydrospheric Sciences) | A-AS Atmospheric Sciences, Meteorology & Atmospheric Environment

[A-AS06] Stratosphere-troposphere Processes And their Role in Climate

convener:Takenari Kinoshita(Japan Agency for Marine-Earth Science and Technology), Takatoshi Sakazaki(Graduate School of Science, Kyoto University), Masashi Kohma(Department of Earth and Planet Science, Graduate School of Science, The University of Tokyo), Nawo Eguchi(Kyushu University), Chairperson:Masashi Kohma(Department of Earth and Planet Science, Graduate School of Science, The University of Tokyo)

Thu. Jun 3, 2021 1:45 PM - 3:15 PM Ch.06 (Zoom Room 06)

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3:10 PM - 3:15 PM

[AAS06-18]Discussion

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[J] Oral | A (Atmospheric and Hydrospheric Sciences)：A-OS Ocean Sciences & Ocean Environment

Thu. Jun 3, 2021 3:30 PM - 5:00 PM JST | Thu. Jun 3, 2021 6:30 AM - 8:00 AM UTC | Ch.07 Zoom Room 07

[A-OS18] Kuroshio Large Meander

convener:Toru Miyama(Japan Agency for Marine-Earth Science and Technology, Application Laboratory), Norihisa Usui(Meteorological Research Institute), Hidetaka Hirata(Rissho University), Takashi SETOU(Japan Fisheries Research and Education Agency), Chairperson:Hidetaka Hirata(Rissho University), Takashi Setou(Japan Fisheries Research and Education Agency)

The Kuroshio Large Meander that started in August 2017 is the second longest historic event in the observed record, next to the event in 1975-1980 (4 years and 8 months). In October 2020, a massive eddy separation occurred, and the Kuroshio path is beginning to take shape in a way that has not been seen before. There are strong public interests on the possible impacts of the Kuroshio Large Meander on fisheries and other phenomena along the coast. However, the actual impacts have not been well investigated. In addition, new findings such as the impacts of the Kuroshio Large Meander on weather are emerging. This session aims to shed light on this intriguing phenomenon by discussing its trends, dynamics, impacts, and comparison with past examples. Presentations from a variety of perspectives in the fields of ocean physics, biology, chemistry, and atmospheric effects will be welcomed.

3:30 PM - 3:45 PM JST | 6:30 AM - 6:45 AM UTC

[AOS18-01] Impact of the 2017 Kuroshio Large Meander on the Decadal Kuroshio Extension Variability

★Invited Papers

*Bo Qiu[1], Shuiming Chen[1], Niklas Schneider[1], Eitarou Oka[2], Shusaku Sugimoto[3] (1.University of Hawaii at Manoa, 2.University of Tokyo , 3.Tohoku University)

3:45 PM - 4:00 PM JST | 6:45 AM - 7:00 AM UTC

[AOS18-02] Subtropical Mode Water in a recent persisting Kuroshio large meander period. Part I: Formation and advection over the entire distribution region

*Eitarou Oka[1], Hatsumi Nishikawa[1], Shusaku Sugimoto[2], Bo Qiu[3], Niklas Schneider[3] (1.Atmosphere and Ocean Research Institute, The University of Tokyo, 2.Graduate School of Science, Tohoku University, 3.Department of Oceanography, University of Hawaii at Manoa)

4:00 PM - 4:15 PM JST | 7:00 AM - 7:15 AM UTC

[AOS18-03] Subtropical Mode Water in a recent persisting Kuroshio large meander period. Part II: Formation and temporal evolution in the recirculation gyre off Shikoku.

*Hatsumi Nishikawa[1], Shusaku Sugimoto[2], Eitarou Oka[1] (1.Atmosphere and Ocean Research Institute, University of Tokyo, 2.Graduate School of Science, Tohoku University)

4:15 PM - 4:30 PM JST | 7:15 AM - 7:30 AM UTC

[AOS18-04] Increase in summer surface air temperature at the Kanto district attributable to Kuroshio large meander

*Shusaku Sugimoto[1], Bo Qiu[2], Niklas Schneider[2] (1.Graduate School of Science, Tohoku University, 2.The University of Hawaii)

4:30 PM - 4:45 PM JST | 7:30 AM - 7:45 AM UTC

[AOS18-05] Comparison of the processes of their response to the Kuroshio Large Meander between explosive cyclones that differ in the development type

*Hidetaka Hirata[1], Ryuichi Kawamura[2], Masami Nonaka[3] (1.Rissho University, 2.Kyushu University, 3.Japan Agency for Marine-Earth Science and Technology)

4:45 PM - 5:00 PM JST | 7:45 AM - 8:00 AM UTC

[AOS18-06] Why has the 2017 Kuroshio large meander lasted so long?

*Norihisa Usui[1], Nariaki Hirose[1], Yosuke Fujii[1], Nadao Kohno[1] (1.Meteorological Research Institute)

Impact of the 2017 Kuroshio Large Meander on the Decadal Kuroshio Extension Variability

*Bo Qiu[1], Shuiming Chen[1], Niklas Schneider[1], Eitarou Oka[2], Shusaku Sugimoto[3]

1. University of Hawaii at Manoa, 2. University of Tokyo , 3. Tohoku University

Decadal modulations of the Kuroshio Extension (KE) system between a stable and an unstable dynamic state in the western North Pacific have prevailed in the past three decades. This dominance of decadal variations is controlled by the negative feedback loop involving the wind-forced KE variability and its feedback onto the overlying extratropical stormtracks and the basin-scale surface wind field. The wind-forced decadal KE modulations were disrupted in August 2017 due to the development of the Kuroshio large meander south of Japan. By forcing the inflow KE paths northward and by avoiding override the shallow Izu Ridge, the Kuroshio large meander was able to compel rapidly the KE from the wind-forced, pre-existing, unstable state to a stable state. Following the large meander occurrence in late 2017, the stabilized KE change is found to affect the overlying stormtracks and the basin-scale wind field the same way as those generated by the wind-forced KE change prior to 2017. Given the consistent atmospheric response to both the large-meander-induced and wind-forced KE variability, we expect that the KE dynamic state will resume its decadal modulation after the phase reset relating to the 2017 large meander event.

Keywords: Kuroshio large meander, Kuroshio Extension, decadal variability

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Subtropical Mode Water in a recent persisting Kuroshio large meander period. Part I: Formation and advection over the entire distribution region

*Eitarou Oka[1], Hatsumi Nishikawa[1], Shusaku Sugimoto[2], Bo Qiu[3], Niklas Schneider[3]

1. Atmosphere and Ocean Research Institute, The University of Tokyo, 2. Graduate School of Science, Tohoku University, 3. Department of Oceanography, University of Hawaii at Manoa

The current Kuroshio large-meander (LM) period, which started in August 2017, has exceeded three years, being second longest only to the 1975-80 occurrence. This study aims to examine how the current persisting LM has impacted the formation and advection of Subtropical Mode Water (STMW), based on observation data.

In the 137E section maintained by the Japan Meteorological Agency since 1967, the cross-sectional area of STMW had fluctuated decadally from mid-1970s to 2016 with an increase (decrease) during the stable (unstable) period of the Kuroshio Extension (KE; Oka et al., 2019). The KE transitioned from the stable state to the unstable state in mid-2016, following the start of a warm PDO phase in 2014, but unexpectedly switched back to the stable state in mid-2017 due to the LM occurrence (Qiu et al., 2020). Nevertheless, the cross-sectional area of STMW has continuously decreased since 2016, exhibiting a tendency different from the previous stable-KE periods. This might be due to the decrease of westward STMW advection from the region south of the KE to the region south of Japan in association with the LM (Suga and Hanawa, 1995), the decrease of STMW formation south of the KE, or both.

We next analyzed Argo float data during 2005-20. Out of STMW defined as low-potential vorticity water of 16-19.5C, a relatively cold variety of 16-18C, which is formed south of the KE, occupied more than 80% of the total volume. The formation volume of the 16-18C STMW was small during 2006-09 in the unstable KE period and large during 2010-15 in the stable KE period, leading to a decrease (increase) of its volume in the former (latter) period. In 2016, anomalously shallow and warm winter mixed layers were formed south of the KE, drastically decreasing the STMW formation volume. In 2018-20 after the current LM began, the formation volume of the 16-18C STMW has not restored to large amount despite the stable KE, being intermediate between the 2006-09 small and 2010-15 large values. In addition, since the current LM began, the 16-18C STMW has had to make a southern detour as indicated by previous studies, which led to the significant decrease of its westward advection from the formation region south of the KE to the region south of Japan. Due to such decline in the formation and advection, the total volume of STMW has gradually decreased since 2016.

Keywords: Subtropical Mode Water, Kuroshio large meander, Kuroshio Extension

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Subtropical Mode Water in a recent persisting Kuroshio large meander period. Part II: Formation and temporal evolution in the recirculation gyre off Shikoku.

*Hatsumi Nishikawa[1], Shusaku Sugimoto[2], Eitarou Oka[1]

1. Atmosphere and Ocean Research Institute, University of Tokyo, 2. Graduate School of Science, Tohoku University

The Kuroshio large meander (LM) since in August 2017 has continued for more the 3 years for the first time in 40 years. When the Kuroshio took a meandering path (i.e., a typical large meander path and an offshore non-large-meander path), an anomalously warm Subtropical Mode Water (STMW) exceeding 19℃ was formed in the recirculation gyre off Shikoku, forming a two-layer structure with a colder STMW formed in the previous years (Sugimoto and Hanawa, 2014), although each meandering period examined in the preceding study spanned only one year. This study aims to examine how an LM event longer than 2 years influences the formation and temporal evolution of STMW in the recirculation gyre off Shikoku, based on the data from Argo floats, satellite altimeter, and shipboard observation.

In spring 2017 before the Kuroshio large meander began, a single STMW layer with thickness of 400m and temperature of 18℃, which was thought to be formed in the late winter 2017, existed at depths of 100-500 m in the recirculation gyre off Shikoku. In the late winter 2018 after the current LM began, warm STMW with temperature exceeding 19℃ was formed to 300m depth, while the STMW layer formed in the previous year shifted downward to the depths of 350-650m, forming a two-layer structure. The shallower warmer STMW layer was not renewed in the late winter of 2019 due to insufficient mixed layer development, persisting for nearly 2 years, and then renewed in the late winter of 2020. The deeper STMW layer formed in the late winter of 2017 survived until 2020 while its thickness gradually decreased to 200 m. The two-layer structure of STMW was thus maintained.

A shipboard CTDO_2 profile obtained by the Japan Meteorological Agency near the center of the recirculation gyre in June 2018 clearly captured the two-layer structure. Apparent oxygen utilization at the potential vorticity minima in the shallower and deeper STMW layers was 0.2560 ml/l (236 m) and 0.4229 ml/l (545 m), respectively. The oxygen utilization rate estimated from their difference was 0.1669 ml/l/yr, which was much smaller than values presented by previous studies. This is presumably because the STMW layer formed in 2017 shifted to the greater depths where oxygen consumption was slow, and because the dissipation of the STMW trapped and isolated in the recirculation gyre was slow.

Keywords: Subtropical Mode Water, Kuroshio large meander, recirculation gyre off Shikoku

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Increase in summer surface air temperature at the Kanto district attributable to Kuroshio large meander

*Shusaku Sugimoto[1], Bo Qiu[2], Niklas Schneider[2]

1. Graduate School of Science, Tohoku University, 2. The University of Hawaii

The summer climate in the Kanto district, Japan, including Tokyo, where has 40 million inhabitants, is characterized by high temperature and humidity. The Kuroshio that flows off the southern coast of Kanto district has taken a large meander (LM) path since the summer of 2017, which is still continuing after three and a half years. It has been recognized that the cool water pool is broadly distributed in the onshore region between the Kuroshio and the southern coast of Kanto-Tokai district during the LM path period. Recently-developed satellite observations detected marked coastal warming off the Kanto-Tokai district during the LM path period. In this study, we conducted regional atmospheric model experiments to quantitatively assess the influence of LM-induced coastal warming on the summer climate of Japan via atmospheric responses. Results indicated that summertime coastal warming increases water vapor in the low-level atmosphere through enhanced evaporation from the ocean and influences near-surface winds via the vertical mixing effect over the warming area. These two changes induce an increase in water vapor in Kanto district, leading to an increase in downward longwave radiation at the surface and then surface warming through a local greenhouse effect. Resultantly the summer in Kanto district becomes increasingly hot and humid in LM years, with double the number of discomfort days compared with non-LM years. Our simulations and supplementary observational studies reveal the significant impacts of the LM-induced coastal warming on the summertime climate in Japan, which can exceed previously identified atmospheric teleconnections and climate patterns. Our results could improve weather and seasonal climate forecasts in this region.

Keywords: Kuroshio large meander, Hot summer, Kanto district, Greenhouse effect, Discomfort index

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Comparison of the processes of their response to the Kuroshio Large Meander between explosive cyclones that differ in the development type

*Hidetaka Hirata[1], Ryuichi Kawamura[2], Masami Nonaka[3]

1. Rissho University, 2. Kyushu University, 3. Japan Agency for Marine-Earth Science and Technology

Recent studies pointed out that the Kuroshio Large Meander affects the development of extratropical cyclones. However, the processes related to the cyclones' response to the Kuroshio Large Meander are still under debate. This study conducted multiple numerical sensitivity experiments with respect to sea surface temperature (SST) and examined the processes of their response to the Kuroshio Large Meander between extratropical cyclones that differ in the type of the intensification. We focused on two explosively developing extratropical cyclones: One is a cyclone that developed mainly due to the diabatic process (case 1), and the other is a cyclone that intensified primarily due to the baroclinic process (case 2). In both cases, the decreases in the central pressure of cyclones were suppressed in experiments with cold SST anomalies associated with the Kuroshio Large Meander path, compared with experiments with warm SST anomalies associated with the Kuroshio Straight path. Thus, the response of the cyclone central pressure to the SST anomalies of cases 1 and 2 were similar. However, primary causes leading to the cyclones' response differed between the two cases. In case 1, the SST anomalies derived from the variation of the Kuroshio path influenced the time evolution of the cyclone central pressure through the diabatic process. On the other hand, in case 2, the SST anomalies affected the central pressure via the baroclinic process. These results suggest that the main process causing the cyclones' response to the Kuroshio Large Meander varies owing to the development types.

Keywords: Explosive cyclone, Kuroshio Large Meander, Cloud Resolving Model

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Why has the 2017 Kuroshio large meander lasted so long?

*Norihisa Usui[1], Nariaki Hirose[1], Yosuke Fujii[1], Nadao Kohno[1]

1. Meteorological Research Institute

The Kuroshio large meander (KLM) occurred in the end of August 2017 for the first time in 12 years. It is still maintained in February 2021, although it became unstable and a cyclonic eddy was detached in the late 2020. The duration of the 2017 KLM exceeds three years, which is the second longest after the KLM in 1975-1980. Former studies have suggested that duration of the KLM is correlated with the Kuroshio transport and a lower transport leads to a longer duration of the KLM. In fact, the observed Kuroshio transport south of Japan has been relatively low since 2017, when the current KLM was formed. The Kuroshio transport diagnosed by a 1.5-layer reduced gravity model driven by the wind stress field of the atmospheric reanalysis also shows a low transport state, suggesting that the low Kuroshio transport caused by the wind stress field in the North Pacific is a possible cause for the long duration of the 2017 KLM. Former studies have also pointed out that the Kuroshio transport increased when past large meanders such as KLMs in 1975-1980 and 2004-2005 decayed. There is currently no signal in the wind stress field to significantly increase the Kuroshio transport. In the presentation, we would like to discuss the characteristics of the wind stress fields in the North Pacific leading to the low Kuroshio transport and their relation to climate indices.

Keywords: Kuroshio large meander, Kuroshio transport, Wind stress

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[J] Oral | A (Atmospheric and Hydrospheric Sciences)：A-CC Cryospheric Sciences & Cold District Environment

Thu. Jun 3, 2021 9:00 AM - 10:30 AM JST | Thu. Jun 3, 2021 12:00 AM - 1:30 AM UTC | Ch.13 Zoom Room 13

[A-CC25] Glaciology in the new normal

convener:Hiroto Nagai(Waseda Univ., School of Education), Kzutaka Tateyama(National University Corporation Kitami Institute of Technology), Ishikawa Mamoru(Hokkaido University), Keiko Konya(Japan Agency for Marine-Earth Science and Technology), Chairperson:Kzutaka Tateyama(National University Corporation Kitami Institute of Technology), Hiroto Nagai(Waseda Univ., School of Education)

Glaciology conducts academic research on snow and ice using a wide variety of methods such as observation, sampling, laboratory experiments, and numerical calculations. Since 2020 Coronavirus disease (COVID-19) pandemic has had a critical impact on the global society, whereas it may derive "new-normal" regimes. Glaciological studies have also had some impacts, such as the cancellation of scheduled overseas surveys and user number restriction in laboratories, but their severity depends on their study methods.
How long period of data lacking is allowed on long-term continuous observations? Is there another alternative approach? Will information and communication technologies that are rapidly becoming widespread for web meeting and/or remote work contribute for glaciological studies?
In this session, regular reports of research results are welcomed. In addition, in this year, we will share various issues caused by the pandemic and their solutions. Discussing the new normal of the glaciology, furthermore, we aim to contribute for developing a more resilient and sustainable academic community of glaciology than before.

9:00 AM - 9:15 AM JST | 12:00 AM - 12:15 AM UTC

[ACC25-01] Fieldwork under the COVID19 circumstances –Examples from Alaska and Siberia–

★Invited Papers

*Go Iwahana[1] (1.International Arctic Research Center, University of Alaska Fairbanks)

9:15 AM - 9:30 AM JST | 12:15 AM - 12:30 AM UTC

[ACC25-02] Mapping of permafrost distribution in mid-Amur basin by satellite data analysis and local vegetation research

*Yuto Tashiro[1], Muneoki Yoh[2], Takayuki Shiraiwa[3], Takeo Onishi[4] (1.Institute for Space Earth Environmental Research, Nagoya University, 2.Tokyo University of Agriculture and Technology, 3.Institute of Low Temperature Science, Hokkaido University, 4.Gifu University)

9:30 AM - 9:45 AM JST | 12:30 AM - 12:45 AM UTC

[ACC25-03] Observation at Ny-Alesund, Svalbard under the COVID-19 situation

★Invited Papers

*Junji Matsushita[1], Hiroshi Miyaoka[1] (1.National Institute of Polar Research)

9:45 AM - 10:00 AM JST | 12:45 AM - 1:00 AM UTC

[ACC25-04] Study of the formation of stratified firn on the snow surface near Dome Fuji, Antarctica, by multiple physicochemical analyses

*Ryo Inoue[1], Shuji Fujita[2,1], Kenji Kawamura[2,1,3], Jun Ogata[2], Motohiro Hirabayashi[2], Kaori Fukuda[2], Kyotaro Kitamura[2], Ayaka Yonekura[1], Kumiko Goto-Azuma[2,1], Fumio Nakazawa[2,1], Ikumi Oyabu[2], Hideaki Motoyama[2,1] (1.The Graduate University for Advanced Studies, 2.National Institute of Polar Research, 3.Japan Agency for Marine-Earth Science and Technology)

10:00 AM - 10:15 AM JST | 1:00 AM - 1:15 AM UTC

[ACC25-05] Evolution of supraglacial ponds at the southern Inylchek Glacier, Kyrgyz Republic

*Natsumi Homma[1], Chiyuki Narama[1], Naoki Sakurai[2] (1.Niigata Univ., 2.Aero Asahi Co.)

10:15 AM - 10:30 AM JST | 1:15 AM - 1:30 AM UTC

[ACC25-06] **The area fluctuations of short-lived glacial lake in the Teskey Range, Central Asia**

*Naho Yamada[1], Chiyuki Narama[1], Mirlan Daiyrov[2] (1.niigata university, 2.CAIAG)

Fieldwork under the COVID19 circumstances –Examples from Alaska and Siberia–

*Go Iwahana[1]

1. International Arctic Research Center, University of Alaska Fairbanks

This presentation introduces the impact of the COVID 19 pandemic on field research in Alaska and Siberia and the research communities' responses. Fairbanks, Alaska, where the presenter lives, is a base for fieldwork in terrestrial Alaska. Researchers across the United States and worldwide have used research infrastructure such as the University of Alaska. Since March 2020, out-of-state travelers have been required to quarantine themselves for two weeks. University of Alaska constituents have been working from home except for persons with special permits. In Alaska, fieldwork season usually starts before or after the snowmelt, and most field activities are carried out in the snow-free summer. However, COVID19 influenced all the fieldwork activities in the 2020 season. Alaska's local community, which is only accessible by plane, is particularly vulnerable to pandemics due to the limited healthcare resources. They placed substantial restrictions on external human traffic, and the research community could not conduct a field survey for the 2020 season. Besides, major scientific research foundations in the United States (NSF, DOE, etc.) restricted fieldwork also at research sites accessible by road from Fairbanks and Anchorage, which have international airports. Even if permitted, two weeks or more self-quarantine period hindered most out-of-state (including international) researchers to plan the fieldwork in Alaska. Under these circumstances, the presenter was allowed to conduct fieldwork in Fairbanks' vicinity and supported some field research activities for Japanese researchers who could not visit Alaska by themselves. On the other hand, the presenter could not conduct field surveys scheduled in Siberia and relied on collaborators' help to minimize the impact of COVID 19 on research plans. Having these experiences and comparing responses by various communities against the COVID 19 pandemic, the transition to "New Normal" in cryosphere studies, which often depends on field surveys, will be discussed.

Keywords: COVID19, Fieldwork, Alaska, Siberia

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Mapping of permafrost distribution in mid-Amur basin by satellite data analysis and local vegetation research

*Yuto Tashiro[1], Muneoki Yoh[2], Takayuki Shiraiwa[3], Takeo Onishi[4]

1. Institute for Space Earth Environmental Research, Nagoya University, 2. Tokyo University of Agriculture and Technology, 3. Institute of Low Temperature Science, Hokkaido University, 4. Gifu University

The Sea of Okhotsk is known as one of the world's richest marine ecosystems. This is because large amount of iron, an essential nutrient for the growth of phytoplankton, flows out of wetlands in the Amur River basin and supports to high primary productivity. In late 1990s, dissolved iron (dFe) concentration in the Amur river and its main tributaries increased dramatically. The reason for this is still unclear, but one possible reason may be permafrost degradation due to unusual high air temperatures in the late 1990s in Russian Far East. To consider this possibility, it is needed to understand iron dynamics in permafrost areas and reveal the permafrost distribution in Russian Far East.

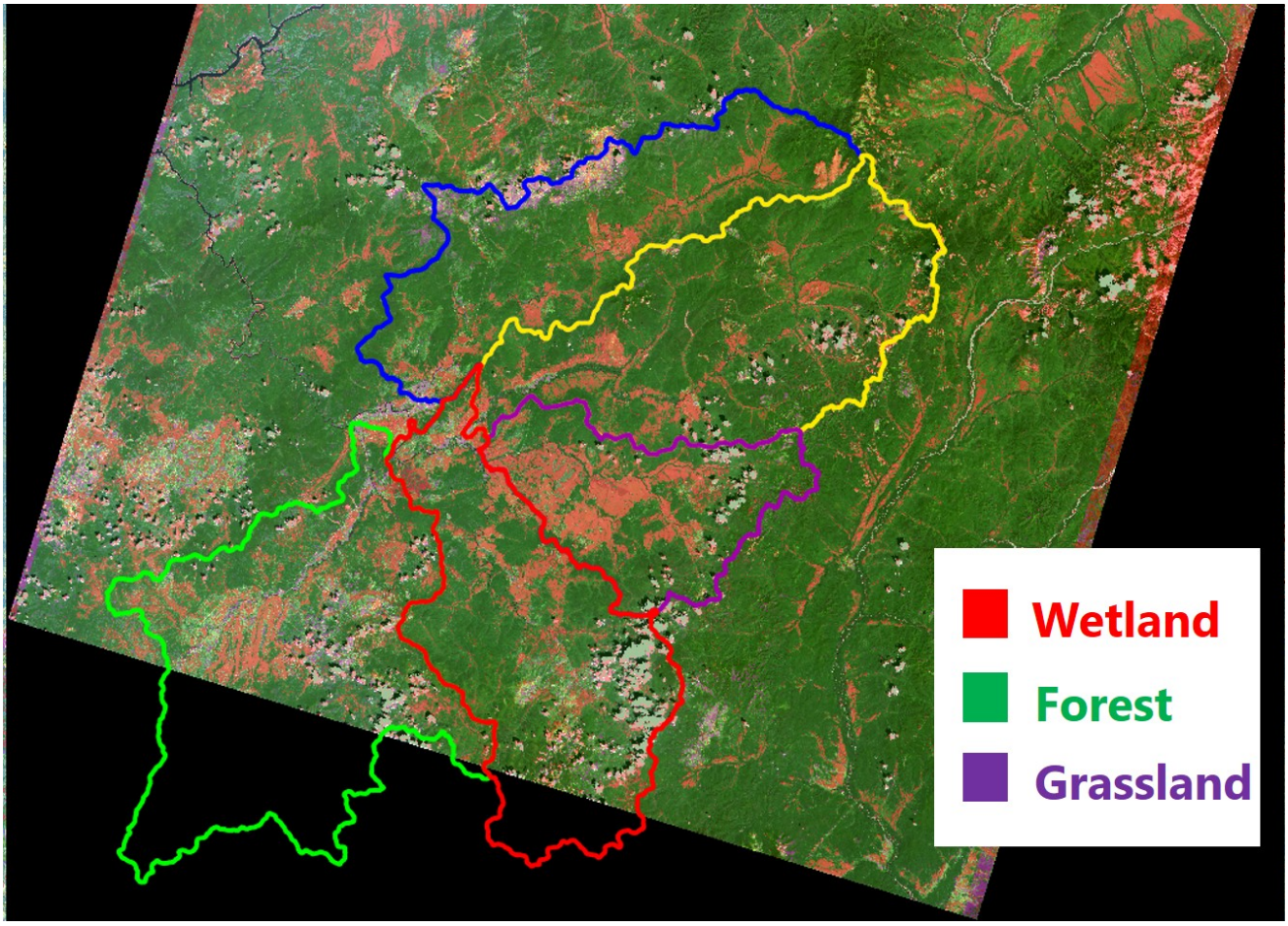
In the present study, we attempted to clarify the permafrost distribution in the Tyrma region of mid-Amur basin by using satellite data (Landsat-8) and conducting local field research. Tyrma is located in approximately 270 km northwest of Khabarovsk in the Russian Far East. Mean annual air temperature is −1.96 ℃ and annual precipitation is 654.6 mm.

Using the Landsat-8 satellite data, we calculated a normalized difference vegetation index (NDVI) and a normalized difference soil index (NDSI). Both values were summarized for typical vegetation types of wetlands, forests, and grasslands based on the local ground truth in the Tyrma region. In addition, we conducted cross-sectional field research in wetlands to confirm that permafrost continuously exists under wetlands. Landform, vegetation, soil condition, groundwater level, and permafrost existence were investigated by crossing wetland in valley area from near river to hillslope.

The range of NDVI and NDSI summarized for wetlands, forests, and grasslands were clearly different. Based on NDVI and NDSI, landcover distribution of wetlands, forests, and grasslands were extracted in the whole Tyrma region (Figure). Local field research revealed that permafrost continuously exists under wetlands, and the top layer of permafrost was confirmed at 60~80 cm depth. Therefore, permafrost will exist with high probability under the extracted wetlands in Fig.1 (Red area). Furthermore, we found that the greater the permafrost distribution area in catchment area, the higher dFe concentration in rivers, suggesting that permafrost existence strongly affects dFe discharge from land to river.

Keywords: Permafrost, Remote sensing, Wetland

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Observation at Ny-Alesund, Svalbard under the COVID-19 situation

*Junji Matsushita[1], Hiroshi Miyaoka[1]

1. National Institute of Polar Research

Located in Ny-Alesund, Svalbard, Norway (79N,12E), the Ny-Alesund NIPR Observatory was established after concluding an agreement for cooperation with the Norwegian Polar Institute (NPI) in 1991 as the Japan’s first high Arctic research station, so it marks the 30th anniversary this year. Under the international collaborative research framework in Ny-Alesund, the NIPR Obseravatory has been supporting a variety of studies such as clouds, aerosols, radiation, greenhouse gases, vegetation and ecologies in the high Arctic. In April 2019, the Observatory relocated to the brand new observation building ‘Kingsbay Veksthus’ which was constructed at the central area in Ny-Alesund. After the relocation, NIPR started to send a technical staff who stays at the Observatory to maintain facilities and supports for researchers.
Since March 2020, NPI and Kingsbay AS, in charge of management of the whole infrastructure in Ny-Alesund, started to apply the strict safety regulation to block the COVID-19 infections from the mainland and abroad. Due to this restriction, researchers and technicians have met a difficult situation, but we succeeded to send two researchers from NIPR to Ny-Alesund to maintain monitoring instruments, amid the pandemic outbreak in October by closely collaborating with NPI and the Norwegian Embassy in Tokyo.
The Arctic Environment Research Center (AERC), NIPR has been regularly updating these restrictions on immigration in Arctic countries. https://www.nipr.ac.jp/aerc/topics20200525.html
In this presentation, we will share our experience to maintain Ny-Alesund NIPR Observatory in the COVID-19 situation and some ideas for the coming operation in 2021.

Keywords: COVID-19, Ny-Alesund, Arctic

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Study of the formation of stratified firn on the snow surface near Dome Fuji, Antarctica, by multiple physicochemical analyses

*Ryo Inoue[1], Shuji Fujita[2,1], Kenji Kawamura[2,1,3], Jun Ogata[2], Motohiro Hirabayashi[2], Kaori Fukuda[2], Kyotaro Kitamura[2], Ayaka Yonekura[1], Kumiko Goto-Azuma[2,1], Fumio Nakazawa[2,1], Ikumi Oyabu[2], Hideaki Motoyama[2,1]

1. The Graduate University for Advanced Studies, 2. National Institute of Polar Research, 3. Japan Agency for Marine-Earth Science and Technology

The physicochemical properties of ice cores characterized on the surface of the ice sheet not only record past climate signals but also affect the densification and bubble formation processes of firn. For example, the impurity concentrations and microstructure such as developed vertical bonds of snow grains change the densification rate for each layer, controlling the degree of density variability. The density variability in deep firn changes the range of the bubble close-off zone, which would, in turn, affects the chronology and the degree of fractionation of gas components; e.g., when the bubble close-off zone is narrow, the age distribution at a depth is also narrowed and the amount of gas fractionation is reduced. Therefore, to better interpret paleoclimatic signals in ice cores, it is important to understand the physicochemical properties and their layering formation on the ice sheet surface.

To investigate and select a site for the third Dome Fuji deep core drilling, one of the base camp was placed at about 54 km south of the Dome Fuji station (tentatively named as NDF , 77°47’ 18S, 39° 3’ 15E, 3763 m a.s.l.), where a 152-m firn core was collected in December 2017. In this area, the accumulation rate is extremely low, and the surface snow is affected by sublimation and condensation for a long period. We performed multiple high-resolution (2.5-20 mm depth increment) continuous measurements of physical and chemical properties on this core. The properties include (1) density measured by a gamma-ray absorption method, (2) microwave permittivity ε as a proxy for density, (3) dielectric anisotropy $\Delta\varepsilon$ as a proxy for vertical elongation of ice and pore spaces, (4) reflectance R for near-infrared light as a proxy for specific surface area, and (5) water stable isotope ratios $\delta^{18}O$, δD, (6) concentration of major elements (Na, Mg, Al, S, K, Ca, Fe) measured by a continuous flow analysis system. Here, we mainly focus on the surface roughly down to a depth of 10 m.

We found significant positive correlations between ρ, ε, $\Delta\varepsilon$, R, $\delta^{18}O$, and δD, calculated within 1-m segments, near the surface. We also found significant negative correlations between these properties and the concentration of all the major elements, although impurities in the precipitation must show different seasonal fluctuations. Hoshina et al. (2016) suggested that the negative correlations between impurity concentrations and $\delta^{18}O$ at low-accumulation site can be formed by long-term sublimation and condensation within snow and between snow and atmosphere, which alter the original signal. However, the detailed process has not been clarified. In the JpGU presentation, we will discuss the snow deposition and sublimation-condensation process that alter the impurity concentrations and water stable isotope ratios, considering the development of density and microstructure of firn.

Keywords: Firn, Densification, Surface snow, Dome Fuji

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Evolution of supraglacial ponds at the southern Inylchek Glacier, Kyrgyz Republic

*Natsumi Homma[1], Chiyuki Narama[1], Naoki Sakurai[2]

1. Niigata Univ., 2. Aero Asahi Co.

A debris-covered glacier has ablation zone covered by debris produced from the rock walls around the glacier. Supraglacial lake develops on the debris glacier. Some supraglacial lakes are connected by englacial conduits. They appear and expand when the canals are closed, and a large drainage occurs from connected glacial lakes simultaneously when the canals are opened. (Sakurai et al., 2020).
Recently, outburst floods from several supraglacial lakes have caused disasters in the Asian mountains, and damages in the downstream villages. An increase in supraglacial lake which assumed to be in response to a warmer climate and glacier surface lowering, has been observed in recent decades in the Tien Shan and eastern Himalaya (Wang et al., 2013). The disasters associated with outburst floods from supraglacial lakes will be increasing in these areas.
It is important to assess the likelihood and magnitude of such events for flood risk management. In most cases, this requires an understanding of the drainage scale impounded in the lake, the structural of network and development process of the basin (Cook and Quincey, 2015).
Therefore, in this study, we investigated the topographical characteristics of the lake basin and its topographical changes using satellite images and UAV aerial images.

Keywords: debris-covered, supraglacial ponds, englacial conduit

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The area fluctuations of short-lived glacial lake in the Teskey Range, Central Asia

*Naho Yamada[1], Chiyuki Narama[1], Mirlan Daiyrov[2]

1. niigata university, 2. CAIAG

In the northern part of the Tien Shan Mountains (Kyrgyz Republic), many short-lived glacial lakes that appear and disappear within a few months are confirmed. Large-scale floods from short-lived glacial lakes have caused serious damages to the surrounding area. In the Tong district of the Teskey Range of this study area, five large-scale debris flows related to short-lived lakes have been reported since 2006 (Narama et. al., 2018; Daiyrov et al., 2020). Short-lived glacial lakes are formed by the closure of ice tunnels inside of moraine-complex, due to the freezing of stored water or deposition of ice-debris. In addition, short-lived glacial lakes appeared due to the influx of glacial meltwater (Daiyrov et al., 2020). However, there are no research reports that area changes of short-lived glacial lakes are related to the balance between inflows and outflows. In this study, we investigated the area changes of short-lived glacial lakes in the Tong district using satellite images (PlanetScope) in June-September 2017-2020.

Keywords: Glacial lake, Glacial lake outburst flood, Satellite images, Short-lived glacial lake, Tien Shan

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[J] Oral | A (Atmospheric and Hydrospheric Sciences)：A-CC Cryospheric Sciences & Cold District Environment

Thu. Jun 3, 2021 10:45 AM - 12:15 PM JST | Thu. Jun 3, 2021 1:45 AM - 3:15 AM UTC | Ch.13 Zoom Room 13

[A-CC25] Glaciology in the new normal

convener:Hiroto Nagai(Waseda Univ., School of Education), Kzutaka Tateyama(National University Corporation Kitami Institute of Technology), Ishikawa Mamoru(Hokkaido University), Keiko Konya(Japan Agency for Marine-Earth Science and Technology), Chairperson:Ishikawa Mamoru(Hokkaido University), Keiko Konya(Japan Agency for Marine-Earth Science and Technology)

Glaciology conducts academic research on snow and ice using a wide variety of methods such as observation, sampling, laboratory experiments, and numerical calculations. Since 2020 Coronavirus disease (COVID-19) pandemic has had a critical impact on the global society, whereas it may derive "new-normal" regimes. Glaciological studies have also had some impacts, such as the cancellation of scheduled overseas surveys and user number restriction in laboratories, but their severity depends on their study methods.
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10:45 AM - 11:00 AM JST | 1:45 AM - 2:00 AM UTC

[ACC25-07] The formation environment of glacier-derived rock glacier in the Tien Shan, Central Asia

*Shun Okuyama[1], Chiyuki Narama[2], Akiko Yamamura[3], Hideyuki Takadama[4], yamanokuti Tsutomu[5] (1.Graduate Student,Niigata Univ., 2.Niigata Univ., 3.Aero Asahi Co., 4.PASCO Co., 5.Remote Sensing Technology Center of Japan)

11:00 AM - 11:15 AM JST | 2:00 AM - 2:15 AM UTC

[ACC25-08] Collapse of snow patch in the Hakuba-Daisekkei, northern Japanese Alps

*Ryoji Yoshimura[1], Chiyuki Narama[1] (1.Niigata Univ.)

11:15 AM - 11:30 AM JST | 2:15 AM - 2:30 AM UTC

[ACC25-09] Characteristics of topography where glaciers can exist in the northern Japanese Alps

*Kenshiro Arie[1], Chiyuki Narama[1], Kotaro FUKUI[2], Hajime IIDA[2], Ryohei Yamamoto[3] (1.Niigata University, 2.Tateyama Caldera Sabo Museum, 3.Aero Asahi corporation)

11:30 AM - 11:45 AM JST | 2:30 AM - 2:45 AM UTC

[ACC25-10] Seasonal and altitudinal variations in snow algal bloomings in Mt. Gassan in Yamagata prefecture, Japan

*Takumi Suzuki[1], Nozomu Takeuchi[1] (1.Chiba University)

11:45 AM - 12:00 PM JST | 2:45 AM - 3:00 AM UTC

[ACC25-11] Research life under COVID19 in Colorado, USA

★Invited Papers

*Uetake Jun[1] (1.Field Science Center for Northern Biosphere, Hokkaido University)

12:00 PM - 12:15 PM JST | 3:00 AM - 3:15 AM UTC

[ACC25-12] Discussion

The formation environment of glacier-derived rock glacier in the Tien Shan, Central Asia

*Shun Okuyama[1], Chiyuki Narama[2], Akiko Yamamura[3], Hideyuki Takadama[4], yamanokuti Tsutomu[5]

1. Graduate Student,Niigata Univ., 2. Niigata Univ., 3. Aero Asahi Co., 4. PASCO Co., 5. Remote Sensing Technology Center of Japan

Rock glacier is composed of permafrost mixed with ice and debris, and flows by deformation of internal ice as well as glacier. The formation of rock glacier requires climatic constraints such as temperature and precipitation, mechanical constraints such as the supply of debris from the rock wall behind the glacier, and the existence of a debris deposit site at the base of the rock wall (Barsch, 1992; Ikeda and Yoshikawa, 2008). Rock glaciers are classified into "talus-derived type" and "glacier-derived type" based on the difference in the source of debris and internal ice (Matsuoka, 1998). The "talus-derived type" is a type in which residual snow or underground water becomes a source of permafrost, and develops on the cliff formed by gravel supplied from the bedrock behind it. The "glacier-derived type" is a type in which a glacier exists superior of a rock glacier, and develops from glacier ice and meltwater from the glacier. The distribution of "glacier-derived type" rock glaciers is limited, and its development process is not clear. Study area is unique in that "glacier-derived type" rock glacier account for about 60% of all rock glacier. In this study, we attempted to clarify the spatial distribution and formation conditions of "glacier-derived type" rock glacier in the Kyrgyz Range in the northern Tien Shan Mountains using satellite image analysis.

Keywords: rock glacier, mountain permafrost, glacier, DInSAR, Tien Shan

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Collapse of snow patch in the Hakuba-Daisekkei, northern Japanese Alps

*Ryoji Yoshimura[1], Chiyuki Narama[1]

1. Niigata Univ.

In the Chubu Mountains, the winter season from autumn 2015 to spring 2016 and the spring from autumn 2019 to spring 2020 have been the years with little snowfall even in the past few decades. As a result, in Hakuba-Daisekkei, which is located in Hakuba-mura, Kitaazumi-gun, Nagano Prefecture, the snow patch rapidly became unstable and collapsed.The trail was closed despite the climbing season due to the increased risk of the snow patch collapse.
Snow patch collapse is a phenomenon in which a cavity such as an ice tunnel is formed at the snow bottom and the upper part collapses. Climbers should avoid unstable areas to prevent accidents due to the collapse of snow patches. However, the underground topography of the bottom of the snow patch has not been elucidated, and the location of the ice tunnel that causes the snow patch to collapse and the unstable location where the snow patch is likely to collapse are unknown.
Therefore, in this study, we carried out ground penetrating radar exploration in Hakuba-Daisekkei and estimated the location of the ice tunnel formed in the main stream by restoring the underground of the snow patch. In addition, by creating ortho-images and DSM from aerial images taken multiple times using SfM-MVS technology, we considered the topographical features of the points where ice tunnels are formed.

Keywords: Hakuba-Daisekkei, collapse of snow patch, GPR, UAV, stress analysis

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Characteristics of topography where glaciers can exist in the northern Japanese Alps

*Kenshiro Arie[1], Chiyuki Narama[1], Kotaro FUKUI[2], Hajime IIDA[2], Ryohei Yamamoto[3]

1. Niigata University, 2. Tateyama Caldera Sabo Museum, 3. Aero Asahi corporation

Many perennial snow patches are distributed in the northern Japanese Alps due to the coastal area of the Sea of Japan experiences the heaviest snowfall worldwide (Asahi, 2013). In recent years, seven glaciers were confirmed in the northern Japanese Alps (e.g., Arie et al., 2019). The formation of glaciers and perennial snow patches needs particular environments that acquire the large amounts of snow accumulation in the northern Japanese Alps' current climatic environment. The distributions of glaciers and perennial snow patches in the northern Japanese Alps are limited to places where has special conditions such as snow supply due to avalanche (Higuchi, 1968). Hughes (2008) proposed that a high value of the ratio (avalanche-ratio) of the total avalanche-release area (> 30-degree slope gradient area in the glacier catchment) to the total glacier area indicates a strong avalanche contribution to glacier accumulation. This study compared the catchment area and avalanche ratio of glaciers and perennial snow patches with an area of >10000 m2 in the northern part of the northern Japanese Alps.

Keywords: Glacier, Avalanche, SfM, Mass barance

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Seasonal and altitudinal variations in snow algal bloomings in Mt. Gassan in Yamagata prefecture, Japan

*Takumi Suzuki[1], Nozomu Takeuchi[1]

1. Chiba University

Snow algae are photosynthetic microbes growing on melting snow surface. Bloomings of snow algae can be commonly observed on alpine snow in Japan during melting season and vary in color such as red, green and yellow. Previous studies showed that red snow appears under oligotrophic conditions with strong sunlight, and green snow appears under eutrophic conditions with weak sunlight (Thomas and Duval, 1995). In Mount Gassan in Yamagata Prefecture, Japan, green and yellow snow appears every year on the snow surface of the floor of broad-leaved forests. However, it is not known how the algal bloomings are distributed in alpine snow and changes with seasons. It is necessary to understand their distribution and seasonal changes in order to understand the conditions of snow algal blooming. Therefore, we aim to describe the seasonal and altitudinal variations of this bloomings and to determine the factors to induce them.

In this study, we collected colored snow from the lower deciduous forest to the upper alpine area above tree line in the period from May to July of 2019 at Mt. Gassan in Yamagata prefecture, Japan. From the collected snow, we measured the chlorophyll *a* concentration, the cell volume biomass (biovolume) of snow algae, and the absorption spectra of the algal pigment extracted from the samples. In addition, in order to determine the cause of the algal blooming, we analyzed the nutrient concentration and calculated the coverage of the forest using aerial images of satellite and drones.

Chlorophyll *a* concentration in the colored snow continuously increased at all of the sites from May to July, especially significant increase occurred at the lower area in the forest. Chlorophyll *a* in the alpine area increased in July, but it was significantly lower than the forest site. Multiple snow algal cells with different morphologies were observed by microscopic analyses. The composition of morphological types of snow algae differs between the alpine area and the forest area. In addition, as the season progressed, the dominant algal types changed at the all of sites. The absorption spectra of algal pigments extracted from the samples can be mainly divided into three types (red, green, and orange types) according to their spectral curve. These types are likely to be due to different pigment composition contained in algal cells. The snow type changed with altitude, red type appeared only in the alpine area, and the green type predominated in the forest area. As the season progressed, red type increased in the alpine area, and green type increased in the forest area. The orange type appeared only at low altitudes in the forest area in the early melting season.

We compared the altitudinal distribution of chlorophyll *a* concentration, cell type composition, nutrient concentration and the coverage of the forest leave above the snowy floor. Results showed that the nutrients are likely to be sufficiently supplied to the snow surface at all of the sites, but the vegetation changed with the altitude. The light conditions appear to differ significantly between above and below the tree line in the study area. Solar radiation was more intense on the snow surface in the alpine area than in the forest. The difference of dominant type of snow algae between alpine and forest areas is probably due to such light condition. In the alpine area, the production of red pigments was promoted against the intense radiation. On the contrary, in the forest area, the light conditions may be suitable for algal growth and thus the red pigment may not have been produced. Furthermore, the increase of chlorophyll *a*

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concentration in the forest area may be due to coming into leaf of trees, which shade and reduce the solar radiation on the snow surface at the forest floor. These results suggest that the presence of trees and their timing of coming into leaf are largely control the appearance of colored snow in this area.

Keywords: Snow algae, Bloomings of snow algae

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Research life under COVID19 in Colorado, USA

*Uetake Jun[1]

1. Field Science Center for Northern Biosphere, Hokkaido University

Coronavirus disease 2019 (COVID-19), started from Wuhan, China in December 2019, was spread all over the world very rapidly. Even after more than one year from the first report (written on 3 February 2021), pandemics have never been unrestrained.
In this presentation, I will report the research situation and activities under COVID-19 at Colorado State University (CSU), where I had worked as a Research Scientist by the end of 2020. After the pandemic surged, even all staff worked remotely at their homes, online workshops about COVID-19 was organized every week by faculty staff in the CSU. That impressed me (as a typical Japanese scientist) how quickly scientists organized the community and developed new sciences. In November 2020, CSU started operating the system to detect SARS-CoV-2 from sewage in campus facilities and saliva from staff, then from December, all staff working on the campus were screed every week by PCR test. The minimum human resources very well organized the testing. Otherwise, Japanese quarantine in the Narita Airport was unorganized because there was too much staff, and they were using the paper form in this digital era. That reminded me the social structural difference between the two countries.
Additionally, I will introduce our study, which was released during COVID-19 and Black Lives Matter activities. Probably due to under those negative atmosphere, that was unexpectedly spread over the multimedia worldwide as "Scientists say they have found the cleanest air on Earth"

Keywords: SARS-CoV-2, COVID-19, Research in the USA

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[J] Oral | A (Atmospheric and Hydrospheric Sciences) | A-CC Cryospheric Sciences & Cold District Environment

[A-CC25] Glaciology in the new normal

convener:Hiroto Nagai(Waseda Univ., School of Education), Kzutaka Tateyama(National University Corporation Kitami Institute of Technology), Ishikawa Mamoru(Hokkaido University), Keiko Konya(Japan Agency for Marine-Earth Science and Technology), Chairperson:Ishikawa Mamoru(Hokkaido University), Keiko Konya(Japan Agency for Marine-Earth Science and Technology)

Thu. Jun 3, 2021 10:45 AM - 12:15 PM Ch.13 (Zoom Room 13)

Glaciology conducts academic research on snow and ice using a wide variety of methods such as observation, sampling, laboratory experiments, and numerical calculations. Since 2020 Coronavirus disease (COVID-19) pandemic has had a critical impact on the global society, whereas it may derive "new-normal" regimes. Glaciological studies have also had some impacts, such as the cancellation of scheduled overseas surveys and user number restriction in laboratories, but their severity depends on their study methods.

How long period of data lacking is allowed on long-term continuous observations? Is there another alternative approach? Will information and communication technologies that are rapidly becoming widespread for web meeting and/or remote work contribute for glaciological studies?

In this session, regular reports of research results are welcomed. In addition, in this year, we will share various issues caused by the pandemic and their solutions. Discussing the new normal of the glaciology, furthermore, we aim to contribute for developing a more resilient and sustainable academic community of glaciology than before.

12:00 PM - 12:15 PM

[ACC25-12]Discussion

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[J] Oral | A (Atmospheric and Hydrospheric Sciences)：A-CC Cryospheric Sciences & Cold District Environment

Thu. Jun 3, 2021 1:45 PM - 3:15 PM JST | Thu. Jun 3, 2021 4:45 AM - 6:15 AM UTC | Ch.13 Zoom Room 13

[A-CC26] Ice cores and paleoenvironmental modeling

convener:Nozomu Takeuchi(Chiba University), Ayako Abe-Ouchi(Atmosphere and Ocean Research Institute, The University of Tokyo), Ryu Uemura(Nagoya University), Kenji Kawamura(National Institute of Polar Research, Research Organization of Information and Systems), Chairperson:Ayako Abe-Ouchi(Atmosphere and Ocean Research Institute, The University of Tokyo), Kenji Kawamura(National Institute of Polar Research, Research Organization of Information and Systems)

Analyses of ice cores from polar and mountain regions have contributed to the reconstruction and understanding of the past environmental changes on timescales from years to several hundred thousand years. In this session, we welcome paleoenvironmental studies using ice cores and paleoclimatic modeling. Studies on reconstruction methods, recording processes and new paleoenvironmental proxies, technical aspects of paleo-modeling are also welcomed. Studies with marine sediment cores, terrestrial sediment cores and tree-rings on similar timescales are also important and welcomed, in order to discuss past environmental changes from multidisciplinary viewpoints.

1:45 PM - 2:00 PM JST | 4:45 AM - 5:00 AM UTC

[ACC26-01] Fractionation of O_2/N_2 and Ar/N_2 in polar ice cores during bubble formation, bubble-clathrate hydrate transition, and gas loss during storage from precise gas measurements of the Dome Fuji ice core, Antarctica

★Invited Papers

*Ikumi Oyabu[1], Kenji Kawamura[1,2,3], Tsutomu Uchida[4], Shuji Fujita[1,2], Kyotaro Kitamura[1], Motohiro Hirabayashi[1], Jeffrey Severinghaus[5], Morgan Jacob[5] (1.National Institute of Polar Research, Research Organization of Information and Systems, 2.The Graduate University of Advanced Studies (SOKENDAI), 3.Japan Agency for Marine Science and Technology (JAMSTEC), 4.Hokkaido University, 5.Scripps Institution of Oceanography)

2:00 PM - 2:15 PM JST | 5:00 AM - 5:15 AM UTC

[ACC26-02] Analysis of Dome Fuji ice core fabric by dielectric tensor measurement

★Invited Papers

*Tomotaka Saruya[1], Shuji Fujita[1,2] (1.National Institute of Polar Research, 2.SOKENDAI (The Graduate University for Advanced Studies))

2:15 PM - 2:30 PM JST | 5:15 AM - 5:30 AM UTC

[ACC26-03] Methane concentration in Dome Fuji ice core measured with a continuous flow analysis system

*Ayaka Yonekura[1], Kenji Kawamura[1,2,3], Ikumi Oyabu[2], Kyotaro Kitamura[2], Jun Ogata[2], Motohiro Hirabayashi[2], Kaori Fukuda[2], Yoshimi Tsukagawa[2], Tomotaka Saruya[2], Fumio Nakazawa[1,2], Shuji Fujita[1,2], Kumiko Goto-Azuma[1,2], Hideaki Motoyama[1,2] (1.The Graduate University for Advanced Studies, SOKENDAI, 2.National Insutitute of Polar Research, 3.JAMSTEC)

2:30 PM - 2:45 PM JST | 5:30 AM - 5:45 AM UTC

[ACC26-04] The role of Southern warming on global ocean states and abrupt warming events during the last deglaciation

★Invited Papers

*Takashi Obase[1], Sam Sherriff-Tadano[1], Ayako Abe-Ouchi[1], Tristan Vadsaria[1], Christo Buizert[2] (1.Atmosphere and Ocean Research Institute, the University of Tokyo, 2.Oregon State University)

2:45 PM - 3:00 PM JST | 5:45 AM - 6:00 AM UTC

[ACC26-05] Climate model study on the driving mechanisms for abrupt climate changes during glacial periods and the effects of climatic precessions on the stability of the AMOC

*Yuta Kuniyoshi[1], Ayako Abe-Ouchi[1], Sam Sherriff-Tadano[2], Wing-Le Chan[1], Fuyuki SAITO[3] (1.The University of Tokyo, 2.University of Leeds, 3.JAMSTEC)

3:00 PM - 3:15 PM JST | 6:00 AM - 6:15 AM UTC

[ACC26-06] Comparative analysis of interglacial (MIS1, 5e, 11) climate responses to orbital elements and internal feedbacks

*Lynn Hirose[1], Ayako Abe-Ouchi[1], Wing-Le Chan[1] (1.the University of Tokyo)

Fractionation of O_2/N_2 and Ar/N_2 in polar ice cores during bubble formation, bubble-clathrate hydrate transition, and gas loss during storage from precise gas measurements of the Dome Fuji ice core, Antarctica

*Ikumi Oyabu[1], Kenji Kawamura[1,2,3], Tsutomu Uchida[4], Shuji Fujita[1,2], Kyotaro Kitamura[1], Motohiro Hirabayashi[1], Jeffrey Severinghaus[5], Morgan Jacob[5]

1. National Institute of Polar Research, Research Organization of Information and Systems, 2. The Graduate University of Advanced Studies (SOKENDAI), 3. Japan Agency for Marine Science and Technology (JAMSTEC), 4. Hokkaido University, 5. Scripps Institution of Oceanography

The variations of $\delta O_2/N_2$ and $\delta Ar/N_2$ in the Dome Fuji ice core were measured from 112 m (bubbly ice) to 2000 m (clathrate hydrate ice) at high precision. Our method combined with low storage temperature (-50 ˚C) successfully remove post-coring gas-loss fractionation signals from our data. From bubbly ice to the middle of bubble-clathrate transition zone (BCTZ) (112 –800 m) and below the BCTZ (>1200 m), the $\delta O_2/N_2$ and $\delta Ar/N_2$ data exhibit orbital-scale variations similar to local summer insolation. The data in the lower BCTZ (800 –1200 m) have large scatters, which may be caused by mm-scale inhomogeneity of air composition combined with finite sample lengths. In the clathrate hydrate zone, the scatters around the orbital-scale variability decrease with depth, indicating diffusive smoothing of $\delta O_2/N_2$ and $\delta Ar/N_2$. A simple gas diffusion model was used to reproduce the smoothing and thus constrain permeation coefficients of the gases. Relationship between $\delta Ar/N_2$ and $\delta O_2/N_2$ is markedly different for the datasets representing bubble close-off (slope ~0.5), diffusion within the ice sheet (~1), and post-coring gas-loss (~0.2), suggesting that the dominant fractionation processes are different for those cases. The method and data presented here may be useful for improving the orbital dating of deep ice cores over the multiple glacial cycles, and for further studying non-insolation-driven signals (e.g., atmospheric composition) of these gases.

Keywords: ice core, ice sheet, Dome Fuji, fractionation, O2/N2, Ar/N2

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Analysis of Dome Fuji ice core fabric by dielectric tensor measurement

*Tomotaka Saruya[1], Shuji Fujita[1,2]

1. National Institute of Polar Research, 2. SOKENDAI (The Graduate University for Advanced Studies)

Crystal orientation fabric (COF) is one of the most important factors determining the physical properties of polar ice sheets. The orientation of the c-axis is commonly determined from thin ice sections using automatic crystal fabric analyzers based on optical techniques. Recent advance of the automated fabric analyzers improved the quality of measurements dramatically; however, there are still limitations. Obtaining a continuous COF profile along a lengthy ice core section requires the labor-intensive preparation of many thin sections. Accordingly, the sampling frequency along an ice core is often limited, with typical sampling intervals of at least 5 or 10 m.

To conduct the bulk-ice-core based fabric measurements, we developed a new system by measuring tensorial components of the dielectric permittivity using an open resonator. Polycrystalline ice is known to exhibit macroscopic anisotropy in dielectric permittivity depending on the formation of a crystal orientation fabric. By measuring the macroscopic dielectric property of ice core, we can estimate the degree of c-axis clustering. This technique permits the continuous nondestructive assessment of the COF in thick ice sections.

Using a new system, we investigated the dielectric anisotropy as indicator of COF in Dome Fuji ice core. From measurements with vertical slab sections, we found the increase of dielectric anisotropy around the core axis with increasing depth, supporting previous findings that c-axes cluster around the vertical direction. Analyses of horizontal disk sections showed that the magnitude of dielectric anisotropy in the horizontal plane was 10–15% of that in the vertical plane. We confirmed that the dielectric anisotropy adequately represents preferred orientation of the c-axes, and that the anisotropy can be used as substitute of the normalized eigenvalue of COF. In this presentation, we discuss the depth variation of dielectric anisotropy and correlations with other physical and chemical properties.

Keywords: ice-sheet core, crystal orientation fabric, dielectric tensor

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Methane concentration in Dome Fuji ice core measured with a continuous flow analysis system

*Ayaka Yonekura[1], Kenji Kawamura[1,2,3], Ikumi Oyabu[2], Kyotaro Kitamura[2], Jun Ogata[2], Motohiro Hirabayashi[2], Kaori Fukuda[2], Yoshimi Tsukagawa[2], Tomotaka Saruya[2], Fumio Nakazawa[1,2], Shuji Fujita[1,2], Kumiko Goto-Azuma[1,2], Hideaki Motoyama[1,2]

1. The Graduate University for Advanced Studies, SOKENDAI, 2. National Insutitute of Polar Research, 3. JAMSTEC

We have been measuring CH_4 concentration in the Dome Fuji ice core by using a Continuous Flow Analyses (CFA) system. The CFA system can continuously measure multiple components contained in ice cores. It provides high-resolution data more efficiently than traditional discrete measurements, and thus has become a common way to obtain detailed paleoclimatic data from deep ice cores.

Millennial-scale variations of CH_4 in the last glacial period have been extensively studied by analyzing ice cores from high-accumulation sites (e.g., Rhodes et al., 2017). To reconstruct the CH_4 variabilities in older periods beyond the last glacial period, the high-resolution analysis of low-accumulation ice cores such as Dome Fuji ice core is essential. However, the currently available resolutions of the CH_4 data from the low-accumulation ice cores are insufficient for the millennial-scale reconstructions in the older glacial periods, and CH_4 data using CFA is still absent.

Here, we present the Dome Fuji CH_4 record in selected periods from the last glacial to Holocene using the CFA system. We discuss age distribution and associated smoothing of atmospheric signals for the low-accumulation core, as well as the reconstructed millennial- and centennial-scale CH_4 variabilities by comparing our results with the high-accumulation WAIS-Divide ice core data (Rhodes et al., 2017) and low-accumulation (EDC and Vostok) ice-core CFA data (Fourteau et al.,2017; 2020).

Our data includes abrupt changes such as the transitions during the last deglaciation, and the 8.2ka event in the Holocene. We find strong smoothing effect of atmospheric signals due to the broad age distribution of the Dome Fuji ice core. Moreover, we observe fine-scale age reversals along depth probably due to the so-called layered trapping (i.e., firn layers with air bubbles formed at the depths significantly different from the average close-off depth), which have originally been reported from the Vostok ice core (Fourteau et al., 2017; 2020). We will also present the CH_4 record around Dansgaard-Oeschger event 17 (about 60 kyr before present).

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Rhodes et al., 2017: Atmospheric methane variability: Centennial-scale signals in the Last Glacial Period, *Global Biogeochem. Cycles*, 31, 575–590.
Fourteau et al., 2017: Analytical constraints on layered gas trapping and smoothing of atmospheric variability in ice under low-accumulation conditions. *Clim. Past*, 13, 1815–1830.
Fourteau et al., 2020: Estimation of gas record alteration in very low-accumulation ice cores. *Clim. Past*, 16, 503–522.

Keywords: Dome Fuji ice core, Methane, CFA

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The role of Southern warming on global ocean states and abrupt warming events during the last deglaciation

*Takashi Obase[1], Sam Sherriff-Tadano[1], Ayako Abe-Ouchi[1], Tristan Vadsaria[1], Christo Buizert[2]

1. Atmosphere and Ocean Research Institute, the University of Tokyo, 2. Oregon State University

There were a number of abrupt climate changes associated with changes in Atlantic Meridional Overturning Circulation (AMOC) during the last glacial period (120 to 20 ka before present) and the last deglaciation (20 to 11 ka before present). Previous studies have elucidated that the AMOC has several distinct modes associated with sea ice extent and deep water formation in the North Atlantic, but the cause of triggering these AMOC mode shifts is still unclear. Recent climate modeling studies suggested the thermal condition in the Southern Ocean is important for the AMOC through the process of Antarctic bottom water formation and meridional density gradient in the North Atlantic.

In this study, we conduct sensitivity experiments of the last deglaciation to understand the role of the Southern thermal forcing. In the control experiment, the model was forced by changing orbital parameters and rising atmospheric CO_2 based on ice core reconstructions (same as Obase and Abe-Ouchi 2019). The control experiment exhibits abrupt AMOC recovery around 14.7 ka BP, in good agreement with observations.

Next, we conducted sensitivity experiments in which the deglacial rise in CO_2 radiative forcing was applied to a limited latitudinal band, with radiative forcing elsewhere held fixed at 18 ka levels. We find that only the experiments with rising radiative forcing in the southern high latitudes exhibit abrupt AMOC recovery. The results show that the rise in the Southern CO2, not the Northern CO2 is necessary for an abrupt AMOC increase, despite smaller SST increase in the North Atlantic. The analysis suggests that the abrupt changes in the AMOC is preconditioned with gradual density difference between the North Atlantic and the Southern Ocean, therefore Southern warming is more important than the Northern warming in the last deglaciation. We conclude that Southern hemisphere high-latitude warming is both a sufficient and a necessary condition for AMOC recovery at the Bølling onset at 14.7 ka before present.

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Climate model study on the driving mechanisms for abrupt climate changes during glacial periods and the effects of climatic precessions on the stability of the AMOC

*Yuta Kuniyoshi[1], Ayako Abe-Ouchi[1], Sam Sherriff-Tadano[2], Wing-Le Chan[1], Fuyuki SAITO[3]

1. The University of Tokyo, 2. University of Leeds, 3. JAMSTEC

It is well known that abrupt climate changes with global-scale impacts, which are called Dansgaard–Oeschger (DO) events, occurred repeatedly during the glacial periods. These abrupt climate changes have been shown to be closely related to the changes in the strength of the Atlantic meridional overturning circulation (AMOC). In recent years, a few coupled atmosphere-ocean models have successfully reproduced the self-induced oscillation of the AMOC with periods shorter than 1000 years, and several mechanisms of the DO events have been proposed, mainly due to internal factors of the atmosphere-ocean system around the North Atlantic. Our recent experiments by using the coupled atmosphere-ocean model MIROC4m reproduce not only those short-period oscillations of the AMOC but also oscillations with a period of several thousand years. Furthermore, experiments using maxima and minima as boundary conditions for the climatic precession that produces seasonal changes in the high latitudes of both the northern and southern hemispheres show that oscillations with relatively short periods occur frequently when the precession is at its maximum. In this study, from the analysis of the precession experiments and additional sensitivity experiments in which the value of precession is divided by the northern and southern hemispheres, we investigated the effect of precession on the stability of AMOC and how the seasonality of the northern and southern hemispheres is involved in each of the several mechanisms of the AMOC oscillation.

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Comparative analysis of interglacial (MIS1, 5e, 11) climate responses to orbital elements and internal feedbacks

*Lynn Hirose[1], Ayako Abe-Ouchi[1], Wing-Le Chan[1]

1. the University of Tokyo

It is generally believed that the glacial ice volume variations that define the glacial-interglacial cycle are driven by changes in summer insolation at Northern hemisphere high latitudes due to periodic changes in the Earth's orbital elements. However, MIS11, which is known to be one of the warmest interglacials with the highest sea levels, cannot be easily explained by orbital elements and greenhouse gases (GHGs) alone, pointing to the need to consider amplifying feedbacks and broader-scale effects. In this study, we compare the climate simulations of MIS11 with that of MIS1 and MIS5e using a coupled atmosphere-ocean vegetation model (MIROC 4m AOVGCM), focusing on the presence or absence of ice sheets in order to examine the effects of different internal feedbacks on temperature in the Northern Hemisphere high latitudes. The orbital elements, land cover, including ice sheet distribution, and GHGs were fixed every 5000 years as boundary conditions and the experiments were run for more than 3000 years each with appropriate initial conditions. The preliminary results of surface air temperature, sea ice distribution, and albedo at Northern Hemisphere high latitudes and the role of the North American Ice Sheet as well as vegetation change will be discussed.

Keywords: interglacial, internal feedback, North American Ice Sheet

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[J] Oral | A (Atmospheric and Hydrospheric Sciences)：A-CC Cryospheric Sciences & Cold District Environment

Thu. Jun 3, 2021 3:30 PM - 5:00 PM JST | Thu. Jun 3, 2021 6:30 AM - 8:00 AM UTC | Ch.13 Zoom Room 13

[A-CC26] Ice cores and paleoenvironmental modeling

convener:Nozomu Takeuchi(Chiba University), Ayako Abe-Ouchi(Atmosphere and Ocean Research Institute, The University of Tokyo), Ryu Uemura(Nagoya University), Kenji Kawamura(National Institute of Polar Research, Research Organization of Information and Systems), Chairperson:Nozomu Takeuchi(Chiba University), Ryu Uemura(Nagoya University)

Analyses of ice cores from polar and mountain regions have contributed to the reconstruction and understanding of the past environmental changes on timescales from years to several hundred thousand years. In this session, we welcome paleoenvironmental studies using ice cores and paleoclimatic modeling. Studies on reconstruction methods, recording processes and new paleoenvironmental proxies, technical aspects of paleo-modeling are also welcomed. Studies with marine sediment cores, terrestrial sediment cores and tree-rings on similar timescales are also important and welcomed, in order to discuss past environmental changes from multidisciplinary viewpoints.

3:30 PM - 3:45 PM JST | 6:30 AM - 6:45 AM UTC

[ACC26-07] Impacts of large scale atmospheric circulation on water isotopes of daily precipitation at Dome Fuji Station: A study with an isotope-enabled AGCM MIROC5-iso

*Kanon Kino[1,2], Okazaki Atsushi[3], Alexandre Cauquoin[2], Kei Yoshimura[2] (1.Atmosphere and Ocean Research Institute, the University of Tokyo, 2.Institute of Industrial Science, the University of Tokyo, 3.The Pennsylvania State University)

3:45 PM - 4:00 PM JST | 6:45 AM - 7:00 AM UTC

[ACC26-08] The correlations between cloud amount over Northern mid-high latitudes and aerosol proxies preserved in the SE-Dome ice core, Greenland

* AKIHISA WATARI[1], Iizuka Yoshinori[1], Koji Fujita[2], Hirohiko Masunaga[2], Kazuaki Kawamoto[3] (1.Hokkaido university, 2.Nagoya university, 3.Nagasaki university)

4:00 PM - 4:15 PM JST | 7:00 AM - 7:15 AM UTC

[ACC26-09] Possible albedo reduction of snow surface due to black carbon over the past 350 years on the Greenland Ice Sheet estimated from the SIGMA-D ice core

*Teruo Aoki[1,2], Kumiko Goto-Azuma[1,2], Sumito Matoba[3], Rigen Shimada[4], Yutaka Kondo[1], Nobuhiro Moteki[5], Makoto Koike[5], Koji Fujita[6], Hideaki Motoyama[1,2], Masahiro Hori[7] (1.National Institute of Polar Research, 2.SOKENDAI, 3.Institute of Low Temperature Science, Hokkaido University, 4.Earth Observation Research Center, Japan Aerospace Exploration Agency, 5.School of Science, University of Tokyo, 6.Graduate School of Environmental Studies, Nagoya University, 7.School of Sustainable Design, University of Toyama)

4:15 PM - 4:30 PM JST | 7:15 AM - 7:30 AM UTC

[ACC26-10] Intra-ice and intra-sediment cryopeg brine occurrence in permafrost near Utqiagvik (Barrow)

*Go Iwahana[1], Zachary S. Cooper[2], Shelly D. Carpenter[2], Jody W. Deming[2], Hajo Eicken[1] (1.International Arctic Research Center, University of Alaska Fairbanks, 2.School of Oceanography, University of Washington)

4:30 PM - 4:45 PM JST | 7:30 AM - 7:45 AM UTC

[ACC26-11] Ice core drilling on a high-elevation accumulation zone of Trambau Glacier in the Nepal Himalaya

*Nao Esashi[1], Akane Tsushima[2], Ryu Uemura[1], Yoshinori Iizuka[3], Sumito Matoba[3], Koji Fujita[1] (1.Graduate School of Environmental Studies, Nagoya University, 2.Graduate School of Science, Chiba University,

3.Institute of Low Temperature Science, Hokkaido University)

4:45 PM - 5:00 PM JST | 7:45 AM - 8:00 AM UTC

[ACC26-12] An attempt to reconstruct air temperature in the past using DNA information in ice core samples on Gregoriev Glacier, Kyrgyz Tienshan

★Invited Papers

*Segawa Takahiro[1], Koji Fujita[2], Ayumi Akiyoshi[3], Nozomu Takeuchi[4] (1.University of Yamanashi, 2.Nagoya University, 3.National Institute of Polar Research, 4.Chiba University)

Impacts of large scale atmospheric circulation on water isotopes of daily precipitation at Dome Fuji Station: A study with an isotope-enabled AGCM MIROC5-iso

*Kanon Kino[1,2], Okazaki Atsushi[3], Alexandre Cauquoin[2], Kei Yoshimura[2]

1. Atmosphere and Ocean Research Institute, the University of Tokyo, 2. Institute of Industrial Science, the University of Tokyo, 3. The Pennsylvania State University

Thanks to water isotope records in polar ice cores, it has been possible to study past Earth’ s climate variations at different time scales. However, the different contributions at regional and global scales determining the isotopic signal in these ice cores are still unclear. The observations at Dome Fuji Station, inland East Antarctica, and further analyses of weather situations have investigated the relationship between $\delta^{18}O$ of daily precipitation ($\delta^{18}O_p$) and the synoptic precipitation events, which are mostly accompanied by increased temperature [1,2], whereas the climatic understanding is not established.

One way to progress our understanding of the question is to make direct comparisons of isotopic data with simulation results from isotope-enabled General Circulation Models (GCMs). We here used such a model, the Japanese atmospheric GCM MIROC5-iso [3], and conducted a simulation with the horizontal winds nudged to the JRA-25 reanalysis [4] for 1981-2010. The simulation nicely reproduces the observed $\delta^{18}O_p$ at Dome Fuji, as well as the synoptic precipitation events.

We reveal that the large-scale atmospheric circulation variations, specifically related to the Southern Annular Mode, significantly affect the $\delta^{18}O_p$ at Dome Fuji during cold seasons (austral autumn, winter, and spring). This is because the advection of the warm air largely changes the local temperature and $\delta^{18}O_p$, supporting previous studies [1]. However, in the austral summer, the contribution of the precipitation amounts relatively large for the variability of $\delta^{18}O_p$, while temperature rise affects only a little the $\delta^{18}O_p$ signal.

Our result suggests the water isotopes in the ice cores do not capture the whole variations of local temperature, and precipitation events contribute to a warm bias in the cold seasons. Interpretation for past climate situations (e.g. Last Glacial Maximum) will be further investigated.

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[3] Okazaki and Yoshimura, J. Geophys. Res. Atmos, 124, 8972–8993, 2019.
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Keywords: climate model, water isotopes, ice cores, paleo proxies, Antarctica

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The correlations between cloud amount over Northern mid-high latitudes and aerosol proxies preserved in the SE-Dome ice core, Greenland

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1. Hokkaido university, 2. Nagoya university, 3. Nagasaki university

The SE-Dome Ice Core(SE-Core), drilled out from a high elevation and accumulation area, preserves paleoenvironmental proxies such as aerosols of the last 60 years with a high time resolution(±2month) [1)]. Past aerosols in the SE-Core mainly came from North Atlantic Ocean and North America[1)]. Although many papers suggested that aerosols act as cloud condensation nuclei (CNN)[2)3)], the relationships between past cloud amount and aerosols in ice cores are not well understood yet. If past aerosols preserved in ice cores can be a proxy of past cloud amount, that would help better understand the fluctuation mechanism of aerosol-cloud interactions than ever before.

To examine the relationships between cloud amount over Northern mid-high latitudes and the aerosol proxies preserved in the SE-Core, we used the cloud amount data sets from satellite and reanalysis of Ⅰ) Advanced Very High Resolution Radiometer(AVHRR), Ⅱ) International satellite cloud climatology project(ISCCP), and Ⅲ) ERA5 products provided by European Centre for medium-range weather forecasts(ECMWF) from 1979 to 2014.We calculated cloud-aerosol correlation coefficients at a resolution of 2.5˚latitude by 2.5˚longitude over Northern mid-high latitudes.We use 15 aerosol proxies from the SE-Core(calcium ion, sulfate ion, and so on)[4)] and cloud amount divided into 4 types (low, middle, high, and total levels) of the 3 data sets for 6 types of season or annual{Winter(DJF), Spring(MAM), Summer(JJA), Autumn(SON), Spring-Summer(AMJJAS), and Autumn-Winter(ONDJFM)}. Thus, the combination amounts to 1,260 cases (15×4×3×7) for the correlation coefficient.

Among the 1,260 cases, the correlation coefficients between total and low-levels cloud amount, and sulfate ion flux in North America(75˚W - 100˚W,45˚N - 70˚N) and North Atlantic Ocean (20˚W - 50˚W,45˚N - 60˚N) are significantly high ($R > 0.329$) in all the 3 data sets. The sulfate ion in the SE-Core mainly originates from anthropogenic SO_2 in North America and biologic SO_2 in the North Atlantic[5)]. The significant correlations suggest that sulfate aerosols may contribute to increasing cloud amount in the emission area. We also examined the correlation coefficients between sulfate ion flux and cloud amount under fixed conditions on relative humidity, temperature and surface pressure, which are considered as main factors of clouds formation. For example, we analyzed the correlation coefficients between sulfate ion flux and total cloud amount in AMJJAS when the relative humidity variability in North Atlantic Ocean was within 1 standard deviation from 1979 to 2014. The correlation coefficients were significantly high ($R > 0.496$) in North Atlantic Ocean. Thus, the correlation coefficients between cloud amount and sulfate ion flux preserved in the SE-Core are significant even under the same condition of the main factors of clouds formation.

It is suggested that sulfate aerosols contribute to an increase of cloud amount in the process of acting as a CCN.

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Keywords: SE-Dome ice core, sulfate ion flux, cloud amount, correlation coefficient, North Atlantic Ocean

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Possible albedo reduction of snow surface due to black carbon over the past 350 years on the Greenland Ice Sheet estimated from the SIGMA-D ice core

*Teruo Aoki[1,2], Kumiko Goto-Azuma[1,2], Sumito Matoba[3], Rigen Shimada[4], Yutaka Kondo[1], Nobuhiro Moteki[5], Makoto Koike[5], Koji Fujita[6], Hideaki Motoyama[1,2], Masahiro Hori[7]

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Snow surface albedo strongly depends on snow grain size and impurity concentration (Wiscombe and Warren, 1980; Warren and Wiscombe, 1980). If these snow parameters are known, the albedo can be calculated with a radiative transfer model. This study presents the possible albedo reduction due to black carbon (BC) in snow over the past 350 years on the Greenland Ice Sheet (GrIS) based on BC concentration from an ice core and satellite-derived snow grain size. The albedo is calculated with a physically based snow albedo model (PBSAM, Aoki et al., 2011) for two temporal variations of higher and lower cases of BC concentrations obtained from the SIGMA-D ice core (Matoba et al., 2015, Goto-Azuma et al., 2019) and snow grain radius R_{s1} derived from Moderate Resolution Imaging Spectroradiometer (MODIS) data from 2000 to 2019 over the GrIS (Aoki et al., 2020). We employed three R_{s1} averaged over accumulation areas in the GrIS at an elevation $h < 1$ km ($R_{s1} = 478$ μm), all range of h ($R_{s1} = 185$ μm), and $h > 3$ km ($R_{s1} = 94$ μm) based on the monthly median of R_{s1} in June when the maximum insolation is expected. The higher and lower BC concentrations are the annual maximum of monthly mean values and annual mean value, respectively. From those two BC concentrations and BC free case, and three values of R_{s1}, a total of 9 kinds of temporal albedo variations are calculated for solar zenith angle at local solar noon on June 21. The albedo reductions are calculated by the albedo difference between the BC-contained case and the BC free case. Assuming the BC concentration from SIGMA-D to be the same all over the GrIS, possible albedo reduction due to BC for lower, overall, higher elevation areas of GrIS can be estimated. The maximum albedo reduction is estimated to be 0.025 in 1925 for higher BC and the largest $R_{s1} = 478$ μm ($h < 1$ km), and the second largest reduction is 0.019 in 1710, and the average albedo reduction over the 350 years is 0.0054. In the lower BC case, the albedo reductions all over the period are almost less than 0.01 for any case of R_{s1}. For the area at $h > 3$ km ($R_{s1} = 94$ μm), the maximum albedo reductions are estimated to be 0.011 and 0.0045 in 1925 for the higher and lower BC cases, respectively. These results indicate that BC on GrIS usually has not a large effect on albedo reduction but sometimes cannot be ignored (albedo reduction > 0.01) under the high concentration events.

Keywords: albedo, ice core, Greenland Ice Sheet, black carbon, snow grain size, SIGMA-D

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Intra-ice and intra-sediment cryopeg brine occurrence in permafrost near Utqiagvik (Barrow)

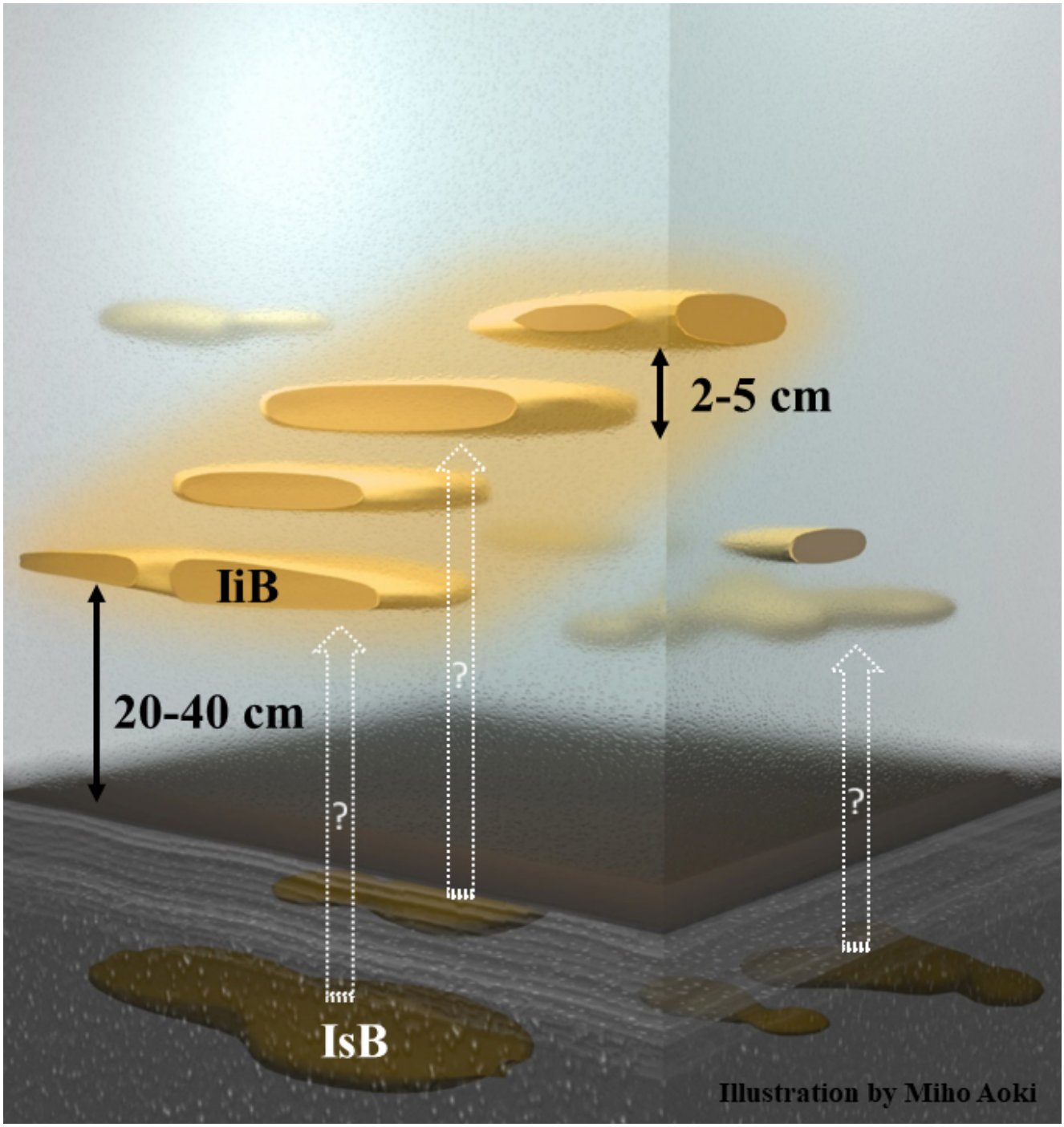
*Go Iwahana[1], Zachary S. Cooper[2], Shelly D. Carpenter[2], Jody W. Deming[2], Hajo Eicken[1]

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Cryopeg is a volume of permafrost with a significant amount of cryotic unfrozen water as a result of freezing-point depression by dissolved salt content. Cryopeg and saline permafrost have been reported for coastal areas of the Arctic seas, and their current distribution and future changes are a great concern for the warming Arctic, as the state of permafrost controls ground stability and the functioning of ice cellars in Arctic villages. To describe the distribution and segregation of cryopeg lenses, and to explore the origin and development of the cryopeg and associated brines found near Utqiagvik, we conducted extensive sampling campaigns in the Barrow Permafrost Tunnel during May of 2017 and 2018.
We found two types of cryopeg brines based on their distinctive spatial occurrences: (1) intra-ice brine (IiB), entirely bounded by massive ice; and (2) intra-sediment brine (IsB), found in unfrozen sediment lenses within permafrost. While two examples of IiB have been reported previously, they were each found within ice layers below ice-sealed lakes in the McMurdo Dry Valleys of Antarctica, geological settings very different from ours. In our study, the IiBs were at roughly atmospheric pressure and situated in small pockets of ellipsoidal or more complex shape (dimensions of up to about 30 cm wide and 3 cm height) within 17–41 cm above the underlying sediment layer (Figure). Several individual IiB pockets may have been connected by porous ice of low permeability. Radiocarbon dating suggests that, at the earliest, the IiB was segregated about 11 ka BP from IsB-bearing cryopeg underneath. IsB lenses were interpreted as having developed through repeated evaporation and cryoconcentration of seawater in a lagoonal environment, then isolated at the latest when the surrounding sediment froze up and became covered by an upper sediment unit around 40 ka BP or earlier.
Considering the common characteristics among the cryopeg brines accessed from the tunnel and those found in brine-bearing marine sediment around Utqiagvik, all occurrences of cryopeg brine in the region may have experienced analogous development despite potentially contrasting salinities and estimated ages. An increase in permafrost temperature invariably will result in expansion of cryopeg lenses and may change movement of liquids within the permafrost, which potentially become threats to Arctic coasts, infrastructure, and food security.

Keywords: cryopeg, brine, ground ice, geochemistry, isotope, Barrow

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Ice core drilling on a high-elevation accumulation zone of Trambau Glacier in the Nepal Himalaya

*Nao Esashi[1], Akane Tsushima[2], Ryu Uemura[1], Yoshinori Iizuka[3], Sumito Matoba[3], Koji Fujita[1]

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We drilled an 81.2-m-long ice core in the accumulation area (5,860 m above sea level) of the Trambau Glacier, Rolwaling region, Nepal Himalaya, during October–November 2019. The drilling operation was conducted with a lightweight electro-mechanical drill system after two reconnaissance field expeditions in the post-monsoon seasons of 2017 and 2018, during which two shallow firn cores were drilled with a hand auger. The drill system and ice core samples were transported by helicopter at a high elevation of 6,000 m above sea level. A further challenging issue was the ice core transportation between Nepal and Japan, as no regular commercial flight was available for the frozen samples. The addition of dry ice imported from India immediately prior to leaving Nepal allowed the ice core samples to be successfully transported to a cold room in Japan, and remain in a frozen state. Stratigraphic observations during the drilling operation suggest the drill site has been affected by melting and refreezing. However, preliminary water stable isotope data in the shallow firn core indicate that the ice core preserves climatic signals during the past 150 yr.

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An attempt to reconstruct air temperature in the past using DNA information in ice core samples on Gregoriev Glacier, Kyrgyz Tienshan

*Segawa Takahiro[1], Koji Fujita[2], Ayumi Akiyoshi[3], Nozomu Takeuchi[4]

1. University of Yamanashi, 2. Nagoya University, 3. National Institute of Polar Research, 4. Chiba University

Ice cores drilled from glaciers can provide a means of direct analysis of microbes in the past. The species composition of microorganisms in the ice core could reflect the environmental condition at that time. Ancient DNA analyses help clarify the phylogenetic relationships among organisms with branching dates. However, the DNA in these samples is often highly degraded and fragmented. Therefore, to analyze the small amount of DNA preserved in these samples, an effective technique to extract total DNA, shotgun sequencing, and molecular evolution analysis is required. Several recent studies have focused on glacier microorganisms such as snow algae and bacteria on glacial ice melting. Snow microorganisms are currently attracting a great deal of attention as they accelerate glacier melting. Despite the ecological importance in glacial environments, little is known about what kind of snow microorganisms lived in the past and their evolutionary dynamics because of the lack of knowledge regarding past microbial information.
We report the cyanobacterial community structure results and their evolution by molecular DNA analysis collected from the ice core samples collected on Gregoriev Glacier, Kyrgyz Tienshan. We successfully reconstruct the cyanobacterial community living on the modern glacier surface in the ice core samples. We also present detailed pictures of global distribution patterns of glacier cyanobacteria over the Arctic, Antarctic, and Asian high mountains, using the sequences of the nuclear rDNA internal transcribed spacer 2 (ITS2) region. Furthermore, we attempted to reconstruct air temperature in the past based on cyanobacteria's genetic information detected in ice cores and glacier surfaces' temperature conditions in various regions where the cyanobacteria live. Our results enhance understanding of the enigmatic time scale of cyanobacterial microevolution, which has the potential to elucidate environmental responses of them to the drastic climatic change events of the Quaternary.

Keywords: ice core, microorganism, DNA

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[J] Oral | A (Atmospheric and Hydrospheric Sciences)：A-CG Complex & General

Thu. Jun 3, 2021 9:00 AM - 10:30 AM JST | Thu. Jun 3, 2021 12:00 AM - 1:30 AM UTC | Ch.10 Zoom Room 10

[A-CG40] Coastal Ecosystems - 1. Water Cycle and Land-Ocean Interactions

convener:Masahiko Fujii(Faculty of Environmental Earth Science), Ryo Sugimoto(Faculty of Marine Biosciences, Fukui Prefectural University), Makoto Yamada(Faculty of Economics, Ryukoku University), Chairperson:Masahiko Fujii(Faculty of Environmental Earth Science), Ryo Sugimoto(Faculty of Marine Biosciences, Fukui Prefectural University), Makoto Yamada(Faculty of Economics, Ryukoku University)

Substances from land which are brought by river and/or submarine groundwater discharge are important for the process of biological production in coastal areas. This session focuses on land-ocean interactions through water cycle. The aim of this session is to create interdisciplinary discussions on the research of connectivity of ecosystems, water cycles in terrestrial and coastal areas, fishery resources and biodiversity. Comprehensive discussion on the mechanisms that promote productivity and biodiversity in coastal ecosystems will be made from the viewpoint of land-ocean interactions. Presentations on water-material cycle in terrestrial and coastal areas, fishery resources, biodiversity and connectivity of the ecosystems are encouraged.
A companion session proposed as "Coastal Ecosystems - 2. Coral reefs, seagrass meadows, and mangroves" focuses on benthic communities in shallow-water ecosystems such as coral reefs, seagrass meadows and mangroves and is dedicated to promote researches on comprehensive assessment and monitoring of ecosystem functions and development of effective means for conservation and restoration. Main focuses of these two sessions are different. However, there are much of information that covers both sessions. Scientists who work on the related field will be able to obtain information and share them with other scientists if they attend to both of these sessions.

9:00 AM - 9:15 AM JST | 12:00 AM - 12:15 AM UTC

[ACG40-01] Submarine groundwater discharge from Mt. Fuji in Suruga Bay(Ⅷ)

*Yasuhide Muranaka[1], Tomohide Kaneko[1], Tetsuhiro Watano[1], Tomoya Oka[1], Akira Ito[1], Masahiko Ono[2], Atsunao Marui[2] (1.Shizuoka Institute of Environment and Hygiene, 2.National Institute of Advanced Industrial Science and Technology)

9:15 AM - 9:30 AM JST | 12:15 AM - 12:30 AM UTC

[ACG40-02] Influence of groundwater-surface water exchange on riverine nutrient export to coastal seas: a comparative study at the six tide-less rivers in Wakasa Bay

*Toshimi Nakajima[1], Ryo Sugimoto[1] (1.Fukui Prefectural University)

9:30 AM - 9:45 AM JST | 12:30 AM - 12:45 AM UTC

[ACG40-03] Quantifying flux of groundwater-derived nutrients and phytoplankton assimilation rate of nutrients in a volcanic sandy beach

*Ryo Sugimoto[1], Ryoma Yagi[1], Toshimi Nakajima[1], Tatsuhiro Ishida[1], Makoto Yamada[2] (1.Faculty of Marine Biosciences, Fukui Prefectural University, 2.Faculty of Economics, Ryukoku University)

9:45 AM - 10:00 AM JST | 12:45 AM - 1:00 AM UTC

[ACG40-04] **Spatial and Temporal Patterns of the Physical and Biogeochemical Properties in the Nearshore Waters of Toyama Bay**

*Eligio de Raus Maure[1], Genki Terauchi[1], Yasuyuki Harada[1] (1.Northwest Pacific Region Environmental Cooperation Center)

10:00 AM - 10:15 AM JST | 1:00 AM - 1:15 AM UTC

[ACG40-05] The relationship between the timing and scale of *Karenia mikimotoi* bloom and environmental factors in the western Bungo Channel of Seto Inland Sea, Japan

*Yuma Hayashi[1], Naoki Yoshie[1], Goh Onitsuka[2] (1.Center for Marine Environmental Studies , Ehime University, 2.Japan Fisheries Research and Education Agency)

10:15 AM - 10:30 AM JST | 1:15 AM - 1:30 AM UTC

[ACG40-06] Continuous monitoring and future projection of ocean warming, acidification, and deoxygenation on the subarctic coast of Hokkaido, Japan

*Masahiko Fujii[1,2], Shintaro Takao[3], Takuto Yamaka[2], Tomoo Akamatsu[2], Yamato Fujita[2], Masahide Wakita[4], Akitomo Yamamoto[5], Tsuneo Ono[6] (1.Faculty of Environmental Earth Science, 2.Graduate School of Environmental Science, Hokkaido University, 3.National Institute for Environmental Studies, 4.Mutsu Institute for Oceanography, Japan Agency for Marine-Earth Science and Technology, 5.Japan Agency for Marine-Earth Science and Technology, 6.Japan Fisheries Research and Education Agency)

Submarine groundwater discharge from Mt. Fuji in Suruga Bay(Ⅷ)

*Yasuhide Muranaka[1], Tomohide Kaneko[1], Tetsuhiro Watano[1], Tomoya Oka[1], Akira Ito[1], Masahiko Ono[2], Atsunao Marui[2]

1. Shizuoka Institute of Environment and Hygiene, 2. National Institute of Advanced Industrial Science and Technology

Around the foot of Mt. Fuji, the main flow passages of groundwater are thought to be in the Younger Fuji volcano, which consists of the pervious basaltic lavas in new volcanic stage. Most of rainfall and melted snow have been considered to be percolating into underground, turning to groundwater, flowing down in the layers of the Younger Fuji volcano and partly discharging from seabed in Suruga Bay. Especially, the Fujikawa-kako fault zone, which stretches south to north in the southwestern side of Mt. Fuji, has a potentially effect on the local groundwater flow system into Suruga Bay. Therefore, precipitation at Mt. Fuji have been considered to be discharging partly from seabed in Suruga Bay and making a impact on the biological production at the coastal sea area.

For the purpose of contribution to make sense of the rich coastal ecosystem in Suruga Bay, we conducted a survey for submarine groundwater discharge (SGD) in Oku-Suruga Bay: from the mouth of the Fuji River, at which the fault is found, to Tagonoura, where the lavas of the Younger Fuji volcano are distributed from 100 to 200 m below sea level. We detected SGD in the top of the cliff in the west of Tagonoura using a remotely operated vehicle (ROV).This time, We used ROV for taking for the image of the spring points, sampled seawater containing a high percentage of sea bottom spring water and conducted water quality analyses. In this presentation, we introduce our works noted above.

Keywords: submarine groundwater discharge (SGD), Mt. Fuji, remotely operated vehicle (ROV), water sampling method

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Influence of groundwater-surface water exchange on riverine nutrient export to coastal seas: a comparative study at the six tide-less rivers in Wakasa Bay

*Toshimi Nakajima[1], Ryo Sugimoto[1]

1. Fukui Prefectural University

Groundwater-surface water exchange (GSE) has been increasingly recognized for its role in transferring water, heat, and chemicals across the land-ocean continuum. Although the magnitude of nutrient transport from surface rivers to coastal seas is crucial for the sustainability of coastal ecosystems, the effects of GSE in most downstream rivers and/or estuarine areas on nutrient flux have not still been clarified yet. Here, we assessed the quantitative effects on groundwater-surface water exchange on nitrogen and phosphorus transports at six tide-less rivers flowing into Wakasa Bay. We took river waters from five sites throughout the river continuum from the upstream site (< 3.7 km from the river mouth) to the most downstream site (river mouth) in each river and constructed the mass balance model for water, salt, and ^{222}Rn coupled with the direct measurement of river discharge. The water fluxes at the most downstream sites compared to the most upstream sites changed from 0.1 to 1.3 folds depending on surface water recharge into groundwaters or groundwater discharge to surface water. Export fluxes of total nitrogen (TN) and phosphorus (TP) at the most downstream sites were 0.1 −1.5 and 0.1 −3.0 folds compared to those at the most upstream sites, respectively. These changes of TN and TP fluxes between at the upstream sites and downstream sites were determined by those of dissolved inorganic nitrogen (DIN) and phosphorus (DIP), respectively. The higher contribution rates of GSE on the changes in DIN export fluxes indicated that GSE was crucial for riverine N export to coastal seas. A significant relationship for DIP was also found except for one river. We conclude that the surface water-groundwater exchange can alter net export rates of riverine nutrients to coastal seas, resulting in under- or overestimates of riverine nutrient fluxes.

Keywords: Groundwater-surface water exchange, Riverine nutrient export, Nitrogen, Phosphorus, Coastal sea, Wakasa Bay

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Quantifying flux of groundwater-derived nutrients and phytoplankton assimilation rate of nutrients in a volcanic sandy beach

*Ryo Sugimoto[1], Ryoma Yagi[1], Toshimi Nakajima[1], Tatsuhiro Ishida[1], Makoto Yamada[2]

1. Faculty of Marine Biosciences, Fukui Prefectural University, 2. Faculty of Economics, Ryukoku University

Volcanic coast is a hotspot occurring meteoric fresh groundwater discharge. Although groundwater supplies nutrients into the water column and contributes to primary productivity in nearshore coasts, there is little quantitative evidence concerning nutrient supply via groundwater discharge and nutrient assimilation by phytoplankton. In the study, we conducted the field survey at the sandy beach along the Chokai volcano coast in August 2020. Here we assessed (1) allochthonous nutrient fluxes via meteoric fresh groundwater (FGW), marine recirculated groundwater (RGW), and offshore seawater, and (2) the net primary productivity (NPP) of phytoplankton. The mass balance models of salt, ^{222}Rn, and ^{224}Ra showed that the total meteoric fresh groundwater discharge was 248 m^3 d^{-1} composed of two pathways: springs (~90%) and seeps (~10%). Recirculated marine groundwater discharge reached 2881 m^3 d^{-1}. Total allochthonous nutrient fluxes of dissolved inorganic nitrogen (DIN), phosphorous (DIP), and silica (DSi) were 25.0 mol d^{-1}, 1.4 mol d^{-1}, and 642.0 mol d^{-1}, respectively. RGW occupied 62% of total DIP flux and 78% of total DSi flux, while FGW occupied 49% of total DIN flux. The average NPP measured at six sites was 0.35±0.06 mg C L^{-1} d^{-1}, which equals 182.7 mol C d^{-1} on the beach scale. Based on the Redfield stoichiometric ratio, the assimilation rates of DIN, DIP, and DSi were 27.6 mol d^{-1}, 1.7 mol d^{-1}, and 25.9 mol d^{-1}, respectively. These results revealed that groundwaters could sustain a maximum of 74% (FGW=44%, RGW=30%) of DIN and 71% (FGW=22%, RGW=49%) of DIP assimilated by phytoplankton.

Keywords: Submarine groundwater discharge, Radioisotopes, Primary production

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Spatial and Temporal Patterns of the Physical and Biogeochemical Properties in the Nearshore Waters of Toyama Bay

*Eligio de Raus Maure[1], Genki Terauchi[1], Yasuyuki Harada[1]

1. Northwest Pacific Region Environmental Cooperation Center

Toyama Bay, located in the Japan Sea, has a very steep bottom topography with depths greater than 200 m confined to the narrow shelf. The outflow from rivers plays an important role in the physical and biological dynamics of coastal waters. Thus, it is important understand the influence of the river discharge on the spatial and temporal variations of material cycle and productivity in nearshore waters. Previous research using satellite observations of chlorophyll-a concentration suggested in the river discharge influenced waters, the phytoplankton bloom was characterized by a strong summer peak that correlated with river discharge. Although the river discharge can also be high or higher in seasons other than summer, it is not yet clear what is the influence on the spatial and temporal variations of phytoplankton during non-summer periods. In this study, we summarize the long-term in-situ observations collected by the Northwest Pacific Region Environmental Cooperation Center (NPEC) in Toyama Bay to gain insights of the influence of river discharge on the spatial and temporal patterns of physical and biogeochemical properties of the innermost waters. For this purpose, this presentation will discuss the spatial and temporal patterns obtained from monthly observations of temperature, salinity, chlorophyll-a concertation and dissolved inorganic nutrients (nitrogen and phosphorus), collected since 2004 to present in the Toyama Bay.

Keywords: Toyama Bay, Physical and Biogeochemical Properties , Nearshore Waters

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The relationship between the timing and scale of *Karenia mikimotoi* bloom and environmental factors in the western Bungo Channel of Seto Inland Sea, Japan

*Yuma Hayashi[1], Naoki Yoshie[1], Goh Onitsuka[2]

1. Center for Marine Environmental Studies , Ehime University, 2. Japan Fisheries Research and Education Agency

In recent years, harmful algae bloom of *Karenia mikimotoi* has caused serious damage for aquaculture in the eastern part of the Bungo Channel in the Seto Inland Sea, and the damage of aquaculture has been more than a billion yen per year. To reduce the fisheries damage, we try to predict the dynamics of HAB of *K.mikimotoi* such as timing of the appearance and scale of HAB using the easily-obtainable environmental data. Previous studies suggested that intrusions of oceanic water from the Kuroshio affected the HAB (Kamada et al., 2010), and weather condition also affected the HAB (Onitsuka et al., 2021). However, these studies usually focused on the sporadic HAB events, and did not comprehensively analyze using the long-term HAB data in this region. We investigated the relationships among the HAB dynamics, the oceanic water intrusions and the weather conditions from 1997 to 2020, and considered whether the environmental factors can be used for the prediction of HAB dynamics.

We estimated the strength of the two types of the oceanic water intrusions (surface water intrusion: Kyucho, bottom water intrusion: Bottom intrusion) based on Takeoka et al., (2000) using the variabilities of the surface and bottom water temperatures at the Shiokojima monitoring station every ten days from April to September. For weather conditions, we used the daily hours of daylight and precipitation at the Uwajima AMEDAS station of Japan Meteorological Agency. For dynamics of HAB, we extracted the first appearance date and the maximum cell density of the year using the HAB report of the Seto Inland Sea, Fisheries Agency.

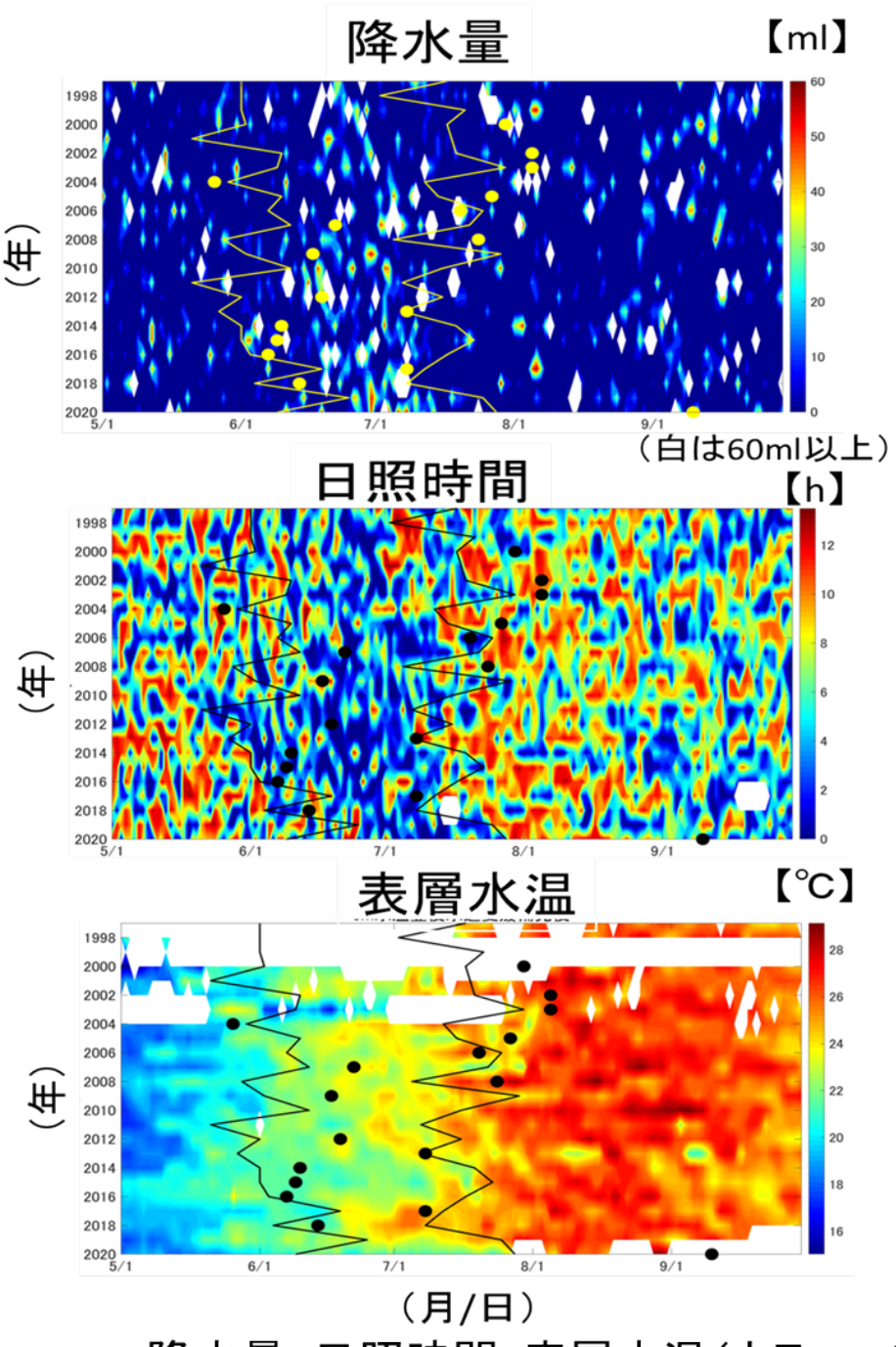
From the statistical analysis between the oceanic water intrusions and HAB dynamics, there was a significant correlation between the strength of Kyucyo in early May and the timing of appearance of HAB ($r = 0.60$, $p < 0.01$), while the strength of Bottom intrusion did not have any significant correlations. Focusing on the relationships between the weather condition and HAB dynamics, there was significant correlation between the precipitation in the early Jun and the maximum cell density of the year ($r = 0.58$, $p < 0.05$). However there was no clear relationship between the hours of daylight and the dynamics of HAB. From the view point of the growth condition for phytoplankton such as water temperature, the timing of water temperature rising in the spring has been getting faster from 2002 to 2016, and the timing of HAB also has become faster in this period. It was found the significant correlation between the arrival date of 20˚C at the surface water and the first appearance date ($r = 0.52$, $p < 0.05$), and the arrival date of 20˚C usually observed in May in this region. These results suggested that the strength of Kyucho in the early May and the arrival date of 20˚C at the surface water in May controlled the timing of appearance of HAB, and precipitation in early Jun affected the scale of HAB.

In this study, we found three important environment factors that can be used for prediction of the dynamics of HAB. First was the strength of Kyucho in early May, second was the arrival date 20˚C at the surface water in May, and third was precipitation in early Jun. These environmental factors are easily obtained from the website of Japan Meteorological Agency and the Uwa-Sea water temperature information system “*You see U-Sea*”. We suggest the step-by-step prediction of the dynamics of HAB of

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K. mikimotoi using the easily-obtainable environmental data from 1-2 months before the appearance of HAB.

Keywords: Karenia mikimotoi, Bungo Channel, open ocean water intrusion, weather condition, marine condition



降水量・日照時間・表層水温（カラーコンタ）
梅雨入り/終わりの時期（縦線）・赤潮発生日（点）の経年（縦軸）
及び時間変化（横軸）

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Continuous monitoring and future projection of ocean warming, acidification, and deoxygenation on the subarctic coast of Hokkaido, Japan

*Masahiko Fujii[1,2], Shintaro Takao[3], Takuto Yamaka[2], Tomoo Akamatsu[2], Yamato Fujita[2], Masahide Wakita[4], Akitomo Yamamoto[5], Tsuneo Ono[6]

1. Faculty of Environmental Earth Science, 2. Graduate School of Environmental Science, Hokkaido University, 3. National Institute for Environmental Studies, 4. Mutsu Institute for Oceanography, Japan Agency for Marine-Earth Science and Technology, 5. Japan Agency for Marine-Earth Science and Technology, 6. Japan Fisheries Research and Education Agency

As the ocean absorbs excessive anthropogenic CO_2 and ocean acidification proceeds, it is thought to be harder for marine calcifying organisms, such as shellfish, to form their skeletons and shells made of calcium carbonate. Recent studies have suggested that various marine organisms, both calcifiers and non-calcifiers, will be affected adversely by ocean warming anddeoxygenation. However, regardless of their effects on calcifiers, the spatiotemporal variability of parameters affecting ocean acidification and deoxygenation has not been elucidated in the subarctic coasts of Japan. This study conducted the first continuous monitoring and future projection of physical and biogeochemical parameters of the subarctic coast of Hokkaido, Japan. Our results show that the seasonal change in biogeochemical parameters, with higher pH and dissolved oxygen (DO) concentration in winter than in summer, was primarily regulated by water temperature. The daily fluctuations, which were higher in the daytime than at night, were mainly affected by daytime photosynthesis by primary producers and respiration by marine organisms at night. Our projected results suggest that, without ambitious commitment to reducing CO_2 and other greenhouse gas emissions, such as by following the Paris Agreement, the impact of ocean warming and acidification on calcifiers along subarctic coasts will become serious, exceeding the critical level of high temperature for three months in summer and being close to the critical level of low saturation state of calcium carbonate for two months in mid-winter, respectively, by the end of this century. The impact of deoxygenation might often be prominent assuming that the daily fluctuation in DO concentration in the future is similar to that at present. The results also suggest the importance of adaptation strategies by local coastal industries, especially fisheries, such as modifying aquaculture styles.

Keywords: ocean acidification, deoxygenation, subarctic, coasts, mitigation, adaptation

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[J] Oral | A (Atmospheric and Hydrospheric Sciences)：A-CG Complex & General

Thu. Jun 3, 2021 10:45 AM - 12:15 PM JST | Thu. Jun 3, 2021 1:45 AM - 3:15 AM UTC | Ch.10 Zoom Room 10

[A-CG41] Coastal Ecosystems -2. Coral reefs, seagrass and macroalgal beds, and mangroves

convener:Yu Umezawa(Tokyo University of Agriculture and Technology), Toshihiro Miyajima(Marine Biogeochemistry Group, Division of Ocean-Earth System Science, Atmosphere and Ocean Research Institute, The University of Tokyo), Atsushi Watanabe(The ocean policy research institute, The Sasakawa peace foundation), Tomihiko Higuchi(Atmosphere and Ocean Research Institute, The University of Tokyo), Chairperson:Yu Umezawa(Tokyo University of Agriculture and Technology), Toshihiro Miyajima(Marine Biogeochemistry Group, Division of Ocean-Earth System Science, Atmosphere and Ocean Research Institute, The University of Tokyo), Atsushi Watanabe(The ocean policy research institute, The Sasakawa peace foundation), Tomihiko Higuchi(Atmosphere and Ocean Research Institute, The University of Tokyo)

Coastal marine ecosystems are complex open system interacting with surrounding watersheds, outer ocean, and the atmosphere, providing a wealth of various ecosystem services to human life. Simultaneously, they are also influenced strongly and often negatively by human activities. This session, together with a companion session dedicated for the water cycle and land-ocean interactions, aims to provide a platform for interdisciplinary discussion covering various aspects of frontiers in coastal ecosystem sciences. This session particularly focuses shallow-water benthic communities ranging from temperate to tropical regions, such as coral reefs, seagrass and macroalgal beds, mangroves, intertidal flats, and saltmarshes. All these communities are characterized by intrinsically high primary production, active material cycling, and biodiversity hot spots. However, increasing human demand for coastal marine resources and industrial development concentrating on coastal regions incur the risk of rapid degradation and diminishment. Comprehensive assessment and monitoring of ecosystem functions and development of effective means for conservation and restoration are urgently needed for such communities. This session is dedicated to organizing and promoting such research and management activities by sharing state-of-the-art science and technology among ecologists, geologists, geochemists, biogeographers, etc. Field-based and modeling studies concerning the following topics are especially welcome: material cycling and ecosystem functions; community connectivity; environmental changes such as global warming, ocean acidification, and sea-level rise; ecosystem services such as carbon sequestration, nutrient regulation, and fisheries production; broad-scale comparison; long-term ecological researches.

10:45 AM - 10:50 AM JST | 1:45 AM - 1:50 AM UTC

[ACG41-01] Introduction

10:50 AM - 11:10 AM JST | 1:50 AM - 2:10 AM UTC

[ACG41-02] Current status and future of ecosystem monitoring of seagrass beds in Japan and Asia: from basic field observation to the policy making and international planning.

★Invited Papers

*Takehisa Yamakita[1], Masakazu Hori[2], Yoshiyuki Tanaka[3], Misuzu Aoki[4], Masahiro Nakaoka[5] (1.Japan Agency for Marine-Earth Science and Technology, 2.Japan Fisheries Research and Education Agency , 3.Hachinohe Institute of Technology, 4.Wetlands International Japan, 5.Hokkaido Univ)

11:10 AM - 11:30 AM JST | 2:10 AM - 2:30 AM UTC

[ACG41-03] Seagrass distribution and adaptation in a turbid tropical estuary (Brunei Bay, Borneo)

★Invited Papers

*Yasuaki Tanaka[1], Nadhirah Lamit[1] (1.Universiti Brunei Darussalam)

11:30 AM - 11:45 AM JST | 2:30 AM - 2:45 AM UTC

[ACG41-04] Detection of seagrass habitat in Himi, Toyama Bay using Google Earth Engine

*Genki Terauchi[1], Eligio de Raus Maure[1], Yasuyuki Harada[1], Wataru Matsumura[2], Tsuneo Maeda[3] (1.Northwest Pacific Region Environmental Cooperation Center, 2.Fisheries Research Institute, Toyama Prefectural Agricultural Forestry and Fisheries Research Center, 3.Toyama Prefectural Fisheries and Fishing Ports Division)

11:45 AM - 12:00 PM JST | 2:45 AM - 3:00 AM UTC

[ACG41-05] **Assessment of mangrove regeneration in abandoned aquaculture ponds using multi-temporal satellite imagery**

Kriselda Anna Delos Santos[2], Ram Avtar[1,2], *Masahiko Fujii[1,2] (1.Faculty of Environmental Earth Science, 2.Graduate School of Environmental Science, Hokkaido University)

12:00 PM - 12:15 PM JST | 3:00 AM - 3:15 AM UTC

[ACG41-06] Quantification of drag force and material trapping ability of a planted mangrove forest in the Philippines

*Yoshikai Masaya[1], Takashi Nakamura[1], Dominic Bautista[2], Eugene Herrera[2], Takuya Okamoto[1], Rempei Suwa[3], Kazuo Nadaoka[1] (1.School of Environment and Society, Tokyo Institute of Technology, 2.Institute of Civil Engineering, University of the Philippines, 3.Forestry Division, Japan International Research Center for Agricultural Sciences)

[J] Oral | A (Atmospheric and Hydrospheric Sciences) | A-CG Complex & General

[A-CG41] Coastal Ecosystems -2. Coral reefs, seagrass and macroalgal beds, and mangroves

convener:Yu Umezawa(Tokyo University of Agriculture and Technology), Toshihiro Miyajima(Marine Biogeochemistry Group, Division of Ocean-Earth System Science, Atmosphere and Ocean Research Institute, The University of Tokyo), Atsushi Watanabe(The ocean policy research institute, The Sasakawa peace foundation), Tomihiko Higuchi(Atmosphere and Ocean Research Institute, The University of Tokyo), Chairperson:Yu Umezawa(Tokyo University of Agriculture and Technology), Toshihiro Miyajima(Marine Biogeochemistry Group, Division of Ocean-Earth System Science, Atmosphere and Ocean Research Institute, The University of Tokyo), Atsushi Watanabe(The ocean policy research institute, The Sasakawa peace foundation), Tomihiko Higuchi(Atmosphere and Ocean Research Institute, The University of Tokyo)

Thu. Jun 3, 2021 10:45 AM - 12:15 PM Ch.10 (Zoom Room 10)

Coastal marine ecosystems are complex open system interacting with surrounding watersheds, outer ocean, and the atmosphere, providing a wealth of various ecosystem services to human life. Simultaneously, they are also influenced strongly and often negatively by human activities. This session, together with a companion session dedicated for the water cycle and land-ocean interactions, aims to provide a platform for interdisciplinary discussion covering various aspects of frontiers in coastal ecosystem sciences. This session particularly focuses shallow-water benthic communities ranging from temperate to tropical regions, such as coral reefs, seagrass and macroalgal beds, mangroves, intertidal flats, and saltmarshes. All these communities are characterized by intrinsically high primary production, active material cycling, and biodiversity hot spots. However, increasing human demand for coastal marine resources and industrial development concentrating on coastal regions incur the risk of rapid degradation and diminishment. Comprehensive assessment and monitoring of ecosystem functions and development of effective means for conservation and restoration are urgently needed for such communities. This session is dedicated to organizing and promoting such research and management activities by sharing state-of-the-art science and technology among ecologists, geologists, geochemists, biogeographers, etc. Field-based and modeling studies concerning the following topics are especially welcome: material cycling and ecosystem functions; community connectivity; environmental changes such as global warming, ocean acidification, and sea-level rise; ecosystem services such as carbon sequestration, nutrient regulation, and fisheries production; broad-scale comparison; long-term ecological researches.

10:45 AM - 10:50 AM

[ACG41-01]Introduction

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Current status and future of ecosystem monitoring of seagrass beds in Japan and Asia: from basic field observation to the policy making and international planning.

*Takehisa Yamakita[1], Masakazu Hori[2], Yoshiyuki Tanaka[3], Misuzu Aoki[4], Masahiro Nakaoka[5]

1. Japan Agency for Marine-Earth Science and Technology, 2. Japan Fisheries Research and Education Agency , 3. Hachinohe Institute of Technology, 4. Wetlands International Japan, 5. Hokkaido Univ

With the increasing interest in the global environment in recent years, essential observation variables of ecosystems and environments have been examined in international frameworks such as GEO, GOOS, and MBON. There is growing momentum for monitoring and data integration. In Japan monitoring of coastal ecosystems has been conducted a couple of times around the 1990s as the nationwide Green Census conducted by the Ministry of the Environment. However nationwide surveys have not been conducted since then until recently. On the other hand, annual surveys to know temporal changes of ecosystems have been conducted as Monitoring sites 1000 program since 2008 and continuing. In the Asia-Pacific region, there have been a couple of surveys and monitoring programs from Japan, Europe, and the United States. In some countries, surveys also have been conducted by domestic organizations. These data are aggregated in recent years (Fortes et al. 2018; Sudo and Nakaoka 2020). In addition, new analysis and research methods such as deep learning, Drone, and environmental DNA are expected to be used. At the same time, the IPBES is considering the assessment of Nature's Contributions to People (NCP) and the assessment of future projection of such effects under socio-economic scenarios (such as SSP).

In this report, we will review the above situation and describe the current status under the monitoring site 1000 program and future plans of international monitoring (Takeuchi et al. 2021) by focusing on the eelgrass. Secondly, as an example of a new monitoring method applied in the Asia-Pacific region, we introduce an application of deep learning for the extraction of seagrass bed change in Thailand. Finally, estimation of carbon fixation and its changes due to scenarios are introduced as examples of the application of obtained monitoring data which may be more important than simply indication of the crisis of the ecosystem itself.

As a result of the first subject, 10 years monitoring of seagrass beds showed significant impact caused by Tsunami and ground subsidence by the Great East Japan Earthquake in 2011 on the Tohoku region. In addition, trends of increase or decrease of the seagrass area were recorded in several survey points. However, there was no nationwide trend of change and the trends differed from point to point and differed by the spatial resolution. We also identified signs of rapid changes in some regions. For example, a disappearance of seagrasses after a typhoon in Ibusuki, Kagoshima, and a sudden decrease after a heatwave in the intertidal zone of Futtsu, Tokyo Bay.

The classical monitoring by field survey can be conducted only at a limited number of sites. Remote sensing is an approach to detect changes through more extensive and long-term monitoring. As a result of this second subject, we analyzed past aerial photo images using deep learning and showed that even black and white (grayscale) images can be used to extract seagrass beds with higher accuracy than that previously possible. For example, in the Hat Chao Mai National Park, Trang, Thailand, our analysis detected that changes in the flow path of the small channels from the mouth of the river were a major factor in the changes of seagrass (Yamakita et al. 2019).

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Lastly, as an example of how to utilize and evaluate the results of such monitoring, an estimate of carbon fixation based on information on the nationwide distribution of seagrass/algal beds in Japan is presented. As a result, high values were found in narrow areas with a large area of the beds, and they were sparsely distributed throughout the country, mainly in bays.In addition, we examined future changes of the bed area by scenario. The results indicate that future changes are not only along climate gradients but may also be regionally different (Yamakita et al. 2020; Hori and Yamakita 2021). It is important to consider the regional features of these ecosystem services when planning for development or conservation.

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Keywords: Asia-Pacific Marine Biodiversity Observation Network (AP-MBON), Ecosystem Service, Nature's Contributions to people, Remote sensing, in-situ observation, Zostera marina

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Seagrass distribution and adaptation in a turbid tropical estuary (Brunei Bay, Borneo)

*Yasuaki Tanaka[1], Nadhirah Lamit[1]

1. Universiti Brunei Darussalam

Seagrass studies have been predominantly conducted in coastal marine environment such as coral reefs, but estuarine seagrass have been behind in research because of its lower abundance. However, the uniqueness of seagrass physiology or adaptation to the environment would be more exerted in estuaries, where water and sediment properties are not stable compared to marine environment. In order to get a better understanding of estuarine seagrass, recent studies on seagrass and water properties at the tropical estuary, Brunei Bay, Borneo are overviewed in this presentation. A total of eight species of seagrass have been recorded in this estuary during 2016-2019, and most of them were found at intertidal zones because the Brunei estuarine water is turbid and sufficient light is not available at subtidal zones. Among the eight species, *Halodule pinifolia* was most tolerant to muddy sediment conditions, while *Halophila minor*, *Halophila ovalis*, and *Thalassia hemprichii* preferred a relatively coarse sediment. Three species (*Halodule pinifolia*, *Halodule uninervis*, and *Halophila beccarii*) were found most upstream, where the surface water salinity fluctuated between 8.5-21. Laboratory experiments showed that *Halophila ovalis*, which is now found only in the downstream estuary, could also survive the conditions of this most upstream seagrass habitat. The spatial and temporal variations in basic water properties showed a wide range of salinity, pH, and dissolved oxygen from the upstream river to the downstream estuary. In particular, the upstream pH was lowest for the estuaries recorded in Southeast Asia. Because Brunei is covered with much more pristine forest than neighboring countries, surface and groundwater discharged from the abundant forest would be contributing to forming this unique gradient of water properties along the estuary. Seagrass has adapted to this environmental gradient using its species-specific physiological advantage. Amid continuing coastal disturbance such as dredging, upstream estuary may function as a shelter for seagrass and therefore needs to be carefully monitored for conservation of the ecosystem.

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Detection of seagrass habitat in Himi, Toyama Bay using Google Earth Engine

*Genki Terauchi[1], Eligio de Raus Maure[1], Yasuyuki Harada[1], Wataru Matsumura[2], Tsuneo Maeda[3]

1. Northwest Pacific Region Environmental Cooperation Center, 2. Fisheries Research Institute, Toyama Prefectural Agricultural Forestry and Fisheries Research Center, 3. Toyama Prefectural Fisheries and Fishing Ports Division

Extent of seagrass habitat was mapped in coastal zone of Himi area in Toyama Bay using Seagrass Mapper, a web-based tool for mapping coastal habitats built upon Google Earth Engine (GEE). Results of field survey of sea floor conducted by an underwater video camera in June in 2018 were used to train satellite image of July 15, 2018 taken by Worldview-110 camera on board Worldview 2 satellite for its segmentation. The areas of seagrass beds in Himi were then estimated by the random forest supervised classification method. The estimated area of seagrass habitat was then compared with the report from the Fisheries Research Institute of Toyama Prefectural Agricultural Forestry and Fisheries Research Center published 2011. The study shows that removal of effects of water column by the Bottom Reflectance Index method better estimates area of seagrass habitats especially in deeper water.

Keywords: seagrass, Google Earth Engine, Mapping

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Assessment of mangrove regeneration in abandoned aquaculture ponds using multi-temporal satellite imagery

Kriselda Anna Delos Santos[2], Ram Avtar[1,2], *Masahiko Fujii[1,2]

1. Faculty of Environmental Earth Science, 2. Graduate School of Environmental Science, Hokkaido University

Mangroves are highly productive forest ecosystems that can recolonize their habitat after a major disturbance, such as land use conversion. They provide vital ecosystem services, including shoreline protection and habitat for other organisms, that are dependent on their size and spatial arrangement. Globally, mangrove forests have decreased in area and have become fragmented, especially in Southeast Asian regions where aquaculture is a major driver of loss. This study conducted a spatiotemporal analysis of mangrove forest change in relation to aquaculture pond development in Panguil Bay, southern Philippines, using 30m spatial resolution satellite images. It also mapped abandoned aquaculture ponds that have been recolonized by mangroves. The study analyzed Landsat 5 and 8 images for 3 periods (1993-2000, 2000-2010, 2010-2020) and processed them on the Google Earth Engine cloud computing platform. Image classification was performed using a supervised random forest classification approach. Several water and vegetation indices, Grey Level Co-Occurrence Matrix (GLCM) texture measures, and shape metrics were tested as additional input features to the classifier. The area, perimeter, and number of patches of pond and mangrove classes were then computed to analyze their spatial pattern and determine the dominant land transformation process for each period. Based on a decision tree algorithm, the transformation processes of ponds and mangroves were identified.

A preliminary testbed result shows that the GLCM measures were useful in separating water from vegetation but did not add to the classification accuracy as this was already achieved by using the Automated Water Extraction Index (AWEI) and Enhanced Vegetation Index (EVI). AWEI and EVI were also effective in discriminating ponds from other water bodies. The Mangrove Vegetation Index (MVI) was effective in discriminating mangroves from other types of vegetation. Shape metrics did not improve the classification accuracy because of the low spatial resolution in relation to the objects being observed.

From 1993 to 2000, ponds lost 4km^2 in area while mangroves gained 12km^2. From 2000 to 2010, ponds gained 10km^2 while mangroves lost 4km^2. From 2010 to 2020, ponds lost 25km^2 while mangroves gained 17km^2. Mangroves that recolonized abandoned ponds made up 29 percent of the total mangrove area in the study site in 2020. The co-occurrence of pond retraction and mangrove expansion between 1993 and 2020 may be related to the enactment of Department Administrative Order 76 in 1987 which established mangrove buffer zone areas and Republic Act 7161 in 1991 which banned cutting of all mangrove species in the Philippines. During the 3 study periods, the sequence of landscape transformation processes for ponds was fragmentation (breaking up of area into separate patches), aggregation (patch mergence), and attrition (patch reduction). Meanwhile, mangroves underwent creation (patch formation), followed by attrition, and creation again. Despite the decrease in total pond area, pond aggregation and increase in the total volume of fish production from brackish water ponds indicates aquaculture pond system intensification. Intensive pond systems require less land but higher inputs of fertilizers and feed which can affect water quality in the area.

The study provides a workflow for mapping mangrove-recolonized ponds and spatial pattern change using open access data and a cloud-based platform. Since the workflow is implemented on Google Earth Engine, it can be replicated in other regions and used for mangrove scenario planning and policy making.

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The study’ s findings show that identifying spatial patterns can provide additional insight on the landscape dynamics. It also suggests the necessity of further studies on the conditions surrounding mangrove recolonization of ponds and the integration of spatial pattern analysis in mangrove monitoring.

Keywords: mangrove rehabilitation, aquaculture ponds, spatiotemporal change, remote sensing, Google Earth Engine

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Quantification of drag force and material trapping ability of a planted mangrove forest in the Philippines

*Yoshikai Masaya[1], Takashi Nakamura[1], Dominic Bautista[2], Eugene Herrera[2], Takuya Okamoto[1], Rempei Suwa[3], Kazuo Nadaoka[1]

1. School of Environment and Society, Tokyo Institute of Technology, 2. Institute of Civil Engineering, University of the Philippines, 3. Forestry Division, Japan International Research Center for Agricultural Sciences

Mangrove forest is an important component of blue carbon ecosystem and plays a major role in climate change mitigation. The complex structures in mangroves' above-ground roots greatly attenuate flow and trap suspended materials on their surface which promote organic matter deposition in mangrove areas. This study aims to quantify the mangrove drag force and material trapping ability in a planted mangrove forest (Bakhawan Ecopark) in Panay Island, the Philippines. Field measurement was conducted in mono-specific stands of 17-year old *Rhizophora apiculata*. A precise measurement of water surface slope and velocity profiling were done to quantify the mangrove drag force from the momentum balance. We also measured the projected area of the above-ground roots of *R. apiculata* stands to estimate the value of drag coefficient (C_D). For quantification of the material trapping ability, trapping of floating mangrove leaf litter was monitored by a video camera. The results showed that the drag force by mangroves is much higher (around ten times) than the bed shear stress. While the estimated C_D values were close to those measured in other laboratory studies, the data suggested a water depth dependence of C_D which may be attributed to the vertical variations in the above-ground root projected area. Similarly, significant changes in the leaf litter dispersal patterns and the trapping efficiency with changing water depth were observed. The results may provide the first estimates of a set of field-derived drag coefficient, dispersion, and trapping ability of a planted mangrove forest.

Keywords: mangrove, drag, trapping, dispersion, blue carbon

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[J] Oral | A (Atmospheric and Hydrospheric Sciences)：A-CG Complex & General

Thu. Jun 3, 2021 1:45 PM - 3:15 PM JST | Thu. Jun 3, 2021 4:45 AM - 6:15 AM UTC | Ch.10 Zoom Room 10

[A-CG41] Coastal Ecosystems -2. Coral reefs, seagrass and macroalgal beds, and mangroves

convener:Yu Umezawa(Tokyo University of Agriculture and Technology), Toshihiro Miyajima(Marine Biogeochemistry Group, Division of Ocean-Earth System Science, Atmosphere and Ocean Research Institute, The University of Tokyo), Atsushi Watanabe(The ocean policy research institute, The Sasakawa peace foundation), Tomihiko Higuchi(Atmosphere and Ocean Research Institute, The University of Tokyo), Chairperson:Yu Umezawa(Tokyo University of Agriculture and Technology), Toshihiro Miyajima(Marine Biogeochemistry Group, Division of Ocean-Earth System Science, Atmosphere and Ocean Research Institute, The University of Tokyo), Atsushi Watanabe(The ocean policy research institute, The Sasakawa peace foundation), Tomihiko Higuchi(Atmosphere and Ocean Research Institute, The University of Tokyo)

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1:45 PM - 2:00 PM JST | 4:45 AM - 5:00 AM UTC

[ACG41-07] Photoinhibition as a strategy for corals to mitigate heat stress and resulting ROS production

Reimi Terayama[1], *Agostini Sylvain[1], Takashi Nakamura[2], Tomihiko Higuchi[3], Ikuko Yuyama[5], Sung-Yin Yang[1], Toshihiro Miyajima[3], Hiroyuki Fujimura[4] (1.Shimoda Marine Research Center, University of Tsukuba, 2.Tokyo Institute of Technology, 3.AORI, University of Tokyo, 4.University of the Ryukyus, 5.Yamaguchi University)

2:00 PM - 2:15 PM JST | 5:00 AM - 5:15 AM UTC

[ACG41-08] Epizootiology of a temperate coral disease driven by thermal stress and macroalgal interactions

*Joshua Masataro Heitzman[1], Nicole Caputo[2], Sung-Yin Yang[1], Ben P Harvey[1], Sylvain Agostini[1] (1.Shimoda Marine Research Center, University of Tsukuba, 2.CIRI-FRAME, Alma Mater Studiorum, Università di Bologna)

2:15 PM - 2:30 PM JST | 5:15 AM - 5:30 AM UTC

[ACG41-09] Disease occurrence among various zonation: Status of Coral Reefs at Karimunjawa Island, Indonesia

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2:30 PM - 2:45 PM JST | 5:30 AM - 5:45 AM UTC

[ACG41-10] Degraded turf algal systems are 'locked-in' by ocean acidification

*Benjamin Paul Harvey[1], Ro Allen[2,3], Sylvain Agostini[1], Linn J Hoffmann[2], Koetsu Kon[1], Tina C Summerfield[2], Shigeki Wada[1], Jason M Hall-Spencer[1,4] (1.Shimoda Marine Research Center, University of Tsukuba, 5-10-1 Shimoda, Shizuoka 415-0025, Japan, 2.Department of Botany, University of Otago, Dunedin, New Zealand, 3.The Marine Biological Association, Plymouth, Devon PL1 2PB, UK, 4.School of Biological and Marine Sciences, University of Plymouth, Plymouth PL4 8AA, UK)

2:45 PM - 3:00 PM JST | 5:45 AM - 6:00 AM UTC

[ACG41-11] Development of Numerical Model for Dynamics of Partial Pressure of CO_2 in Seawater Considering Effects of Stratification in the Yatsushiro Sea

*Naoki Saito[1], Bing Xiong[2], Hiroto Komori[2], Shinichiro Yano[2], Keisuke Nakayama[3], Katsuaki Komai[4], Hiroshi Yajima[5] (1.National Institute of Advanced Industrial Science and Technology, 2.Kyushu University, 3.Kobe University, 4.Kitami Institute of Technology, 5.Shimane University)

3:00 PM - 3:15 PM JST | 6:00 AM - 6:15 AM UTC

[ACG41-12] Two-way nested blue carbon tracing simulation for elucidating fates of exported organic carbon from coastal ecosystems

*Takashi Nakamura[1], Faisal Amri[1], Lawrence Patrick Cases Bernardo[2], Kazuo Nadaoka[1], Masakazu Hori[3], Masami Hamaguchi[3], Toshihiro Miyajima[4] (1.School of Environment and Society, Tokyo Institute of Technology, 2.Graduate School of Environmental Science, Hokkaido University, 3. Japan Fisheries Research and Education Agency, 4.Atmosphere and Ocean Research Institute, The University of Tokyo)

Photoinhibition as a strategy for corals to mitigate heat stress and resulting ROS production

Reimi Terayama[1], *Agostini Sylvain[1], Takashi Nakamura[2], Tomihiko Higuchi[3], Ikuko Yuyama[5], Sung-Yin Yang[1], Toshihiro Miyajima[3], Hiroyuki Fujimura[4]

1. Shimoda Marine Research Center, University of Tsukuba, 2. Tokyo Institute of Technology, 3. AORI, University of Tokyo, 4. University of the Ryukyus, 5. Yamaguchi University

Elevated water temperature due to climate change is causing massive bleaching events around the world. Two main factors that lead to coral bleaching are strong light and heat stress. Recent studies suggested that the bleaching response starting with a decrease in the carbon fixation due to heat damages of the Rubisco enzyme. Under strong light, this cause the photosystem electron transfer exceed the calvin cycle capacity. This excess in energy would cause ROS production. Photoprotective mechanisms such as photoinhibtion could mitigate the production of ROS, by restricting the electron transfer upstream carbon fixation. The loss of zooxanthellae could therefore be secondary protection mechanisms to reduce ROS production when other mechanisms are overwhelmed. Although both mechanisms reduce the photosynthesis rates of corals, photoinhibition could allow a more rapid recovery compare to the loss of zooxanthellae. We recently a theoretical model highlighting the dynamics of bleaching and the importance of photoinhibition as a protective mechanisms. However the lack of studies on the change in both photosystem efficiency and photosynthetic rates under natural diurnal cycle and temperature stress, limits the validity of the model. Here we present experimental data to validate and tune the theoritical model. Specimens of the corals *A. solitaryensis* and *P. heronensis* were incubated in the laboratory under diurnal cycle and three temperature treatment, 26ºC, 30ºC, and sustained 30ºC for one-week. In a first experiment we investigated the dynamics photosystem efficiency and, gross snd net photosynthesis using PAM fluorometry and microsensors techniques. Secondly we investigated the difference in oxygen and carbon based photosynthesis rates during bleaching under the same conditions of light and temperature. All corals bleached under the increased temperature treatment. Our results showed that high light intensity cause enhanced photoinhibition and in consequence, a reduction of the photosynthesis rates and electron transports rates in PSII. High temperature treatment enhanced photoinhibition and further decreased net and gross photosynthesis rates. The comparision of net photosynthesis rates in oxygen and carbon units showed a smaller difference under heat stress which was associated with enhanced photoinhibition. Our result suggests that photoinhibition can mitigate heat stress by reducing the difference between electron transfer rates from the photosystems and the capacity of the calvin cycles. Our observation mostly matches the previously develloped model, and will allow its tuning.

Keywords: coral bleaching, photoinhibition, reactive oxygen species

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Epizootiology of a temperate coral disease driven by thermal stress and macroalgal interactions

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Coral reefs are important marine ecosystems as they represent a large portion of global marine biodiversity. Increasing threats, including coral diseases, are resulting in their widespread loss. While coral diseases are well described in tropical and subtropical areas, none have been described in warm temperate areas. Here in Shimoda city, Japan, we report for the first time a coral disease outbreak in a warm temperate marginal coral community. The disease gross lesion is characterized by a white mat formation on the temperate coral species *Porites heronensis*, with infected coral tissue resulting in mortality. Based on its visual characteristics, we have tentatively named this disease “White Mat Syndrome” (WMS). Field surveys were conducted to determine disease incidence, the number of unique new disease occurrences weekly, and prevalence, the population of coral affected by WMS. Disease outbreaks were observed to only occur during the warm summer months from August to November, suggesting an association with high temperatures. The WMS microbial mat was analyzed, revealing a bacterial consortium mainly comprised of *Thiothrix* spp., a sulfide-oxidizing bacterium. During yearly disease outbreaks, the common macroalgae *Gelidium elegans* was associated with 75% (30/40) of WMS occurrences observed suggesting its role as a potential contributory factor. This macroalgae often overgrows corals and was observed to senesce and trap sediment during the warm summer months. Furthermore, we showed the presence of *Thiothrix* spp. within the microbial community of sediment-trapping *G. elegans*. Incubation experiments to test both the effect of seasonal temperature (winter and summer) and the pathogenicity of potential contributory factors (WMS microbial mat, sediment-trapping *G. elegans* and sediment) were conducted. These experiments confirmed that high temperature is required for disease proliferation, and that sediment-trapping *G. elegans* acts as a pathogen reservoir for WMS. As warming waters and increased macroalgal interactions contribute to WMS pathogenicity, future outbreaks may increase in duration and virulence. With tropical and subtropical coral reefs continuing to degrade into algal-dominant ecosystems, algal-mediated diseases like WMS may increase in number and spread. In this context, warm temperate marginal coral community may provide clues for future management strategies of both future algal dominated coral reefs and marginal coral communities.

Keywords: *Porites heronensis*, coral disease, warm temperate, marginal coral communities, *Gelidium elegans*, *Thiothrix* spp.

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Disease occurrence among various zonation: Status of Coral Reefs at Karimunjawa Island, Indonesia

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Coral reef ecosystems are known to have high rates of endemism and being considered as “biodiversity hotspots” (Roberts, 2002). However, coral reefs in the Anthropocene are also being subjected to global as well as local stressors. Local disturbances such as overfishing, habitat destruction, and pollution along with the impacts of climate change such as coral bleaching have been identified as major threats to coral reefs. Coral diseases have been recognized as important drivers to the coral decline worldwide (Weil et al., 2012) where the pathogenic diseases take advantage of the corals that are under other stressors to increase their abundance, becoming more prevalent in degraded environments (Muller et al., 2018). Located within the biodiversity hotspot, coral reefs in Karimunjawa,Indonesia has been surveyed to assess the status since 2000. Although different approaches were utilized to reveal the condition of Karimunjawa reefs, reports on coral disease incidence are scarce. Located in the northern part separate from the mainland Indonesia, Karimunjawa has been utilized for tourism and marine culture activity that may have been dragged down its pristine reef ecosystem. Additionally, there is almost no report available that clarify which of coral genera in Karimunjawa are susceptible to various diseases. To emphasize how far the Karimunjawa reef's current condition altered, disease prevalence; coral genus diversity and coral cover were assessed at 6 sites within three different zones (Tourism, Aquaculture and Protected zones) using two assessment methods (Point Intercept Transect method and Quadrat method with digital image analysis by Coral Point Count with Excel extension). Coral cover (CC) and disease prevalence (DP) results from all site shown strong similar trendline among methods with average PIT results 56.5%±7.89 (CC); 8.23%±3.11(DP) and CPCe results 43.21%±5.91(CC); 9.66%±4.55(DP) respectively. Thus, multivariate and ordination statistics were performed to construct comprehensive analysis on disease prevalence and zonation. Disease prevalence slightly differs from each zone while similar coverage on hard corals has been detected from all site. However, a strong correlation between genus diversity and disease prevalence has been detected in both tourism and aquaculture zones. There are several types of diseases that have not been reported previously from the Karimunjawa were found in these study sites. There are two types of coral killing sponges of *Terpios hoshinota* and *Chalinula nematifera* that haven’t been reported previously from the Karimunjawa were found in these study sites. These findings indicated Karimunjawa reefs may have been impacted by human activities. We suggest to continue periodical evaluation in order to keep comprehensive assessment-based on-site zonation as useful tools to guide a better conservation for Karimunjawa reefs in the future.

Keywords: Conservation, Disease Prevalence, Genus Diversity, Karimunjawa, Zonation

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Degraded turf algal systems are ‘locked-in’ by ocean acidification

*Benjamin Paul Harvey[1], Ro Allen[2,3], Sylvain Agostini[1], Linn J Hoffmann[2], Koetsu Kon[1], Tina C Summerfield[2], Shigeki Wada[1], Jason M Hall-Spencer[1,4]

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Human activities are rapidly changing the structure and function of coastal marine ecosystems. Large-scale replacement of kelp forests and coral reefs with turf algal mats is resulting in homogenous habitats that have less ecological and human value. Ocean acidification has strong potential to substantially favour turf algae growth, which led us to examine the mechanisms that stabilise turf algal states. Here we show that ocean acidification promotes turf algae over corals and macroalgae, mediating new habitat conditions that create stabilising feedback loops (altered physicochemical environment and microbial community, and an inhibition of recruitment) capable of locking turf systems in place. Such feedbacks help explain why degraded coastal habitats persist after being initially pushed past the tipping point by global and local anthropogenic stressors. An understanding of the mechanisms that stabilise degraded coastal habitats can be incorporated into adaptive management to better protect the contribution of coastal systems to human wellbeing.

Keywords: Regime Shifts, Feedback Loops, Hysteresis, CO2 Seeps, Turf Algae



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Development of Numerical Model for Dynamics of Partial Pressure of CO_2 in Seawater Considering Effects of Stratification in the Yatsushiro Sea

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About 55 % of the carbon fixed by living organisms on the Earth is that fixed by marine organisms, so-called "*blue carbon*". In particular, coastal areas with vegetation such as seagrass are considered to be important in reducing atmospheric CO_2.
On the other hand, estimates of the amount of CO_2 absorbed by coastal areas are currently uncertain. In general, the partial pressure of CO_2 in seawater (pCO_2) is used to calculate the amount of CO_2 absorbed from the atmosphere to seawater. However, pCO_2 in the coastal zone fluctuates greatly in space and time affected by flow, biological activities, *etc*. Therefore, in order to improve the accuracy of estimating the amount of CO_2 absorbed in coastal areas, it is necessary to accumulate data on pCO_2 based on various conditions such as flow and ecosystem (Macreadie *et al*., 2019).
It has also been reported by Kone *et al*. (2008) and others that pCO_2 fluctuates with the development of stratification. However, there are few examples of field studies and model development focusing on the relationship between stratification and pCO_2.
In this study, we conducted the following to obtain basic knowledge on CO_2 dynamics in coastal areas. First, we conducted a field survey on pCO_2 under three stratification conditions. Then, based on the survey results, a numerical model that can reproduce the pCO_2 dynamics under each stratification condition was developed. Furthermore, using the model, we made an attempted to elucidate the spatio-temporal variability of CO_2 absorption in coastal areas. The Yatsushiro Sea, the target area of this study, is characterized as a temperate area where both seagrasses and corals live.
The survey sites were selected near the mouth of the Kuma River, where strong stratification could develop. The survey dates were August 26, 2018 (weak stratification period), December 7, 2018 (mixed period), and August 2, 2019 (strong stratification period). Measured items were vertical distribution of water temperature, salinity, *etc*. from water quality measurement, and the dissolved inorganic carbon concentration (DIC) and total alkalinity (TA) from water samples. pCO_2 was calculated from water temperature, salinity, DIC, and TA from the chemical equilibrium relationship of the carbon system.
A numerical model of pCO_2 was developed using Delft3D, a general-purpose numerical model for coastal flow. The model consists of a flow model and an ecological model. The horizontal resolution is about 250 m, and the vertical resolution is 17 layers in the σ - coordinate system. The components of the ecological model were phytoplankton, nutrients, particulate organic matter, dissolved oxygen DO, DIC and TA. The main processes are photosynthesis, respiration, and death of phytoplankton, sedimentation and mineralization of organic matter, nitrification, and re-aeration.
The vertical fluctuation of pCO_2 with stratification development was revealed from the field survey. Based on the observations, a numerical model of pCO_2 dynamics was developed. The model was able to reproduce the vertical distribution of pCO_2 under each stratification conditions. The model results confirmed that the CO_2 sinks around the mouth of the river fluctuated significantly in space and time with the river discharge. In addition, the following two effects of saline stratification on CO_2 absorption in coastal areas were confirmed; (1) After a flood, the saline stratification develops and river water

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concentrates in the surface layer, which accelerates the release of CO_2 from seawater. (2) As mixing progresses and the saline stratification weakens, a large layer of phytoplankton appears on the surface, and CO_2 absorption into the seawater is promoted by photosynthesis.
In the future, it is necessary to investigate the effects of seagrass and coral inhabitation, through field observations and to incorporate these effects into the model. These studies are expected to contribute to the understanding of blue carbon dynamics in coastal areas.

Keywords: partial pressure of CO2 in seawater, air-sea CO2 flux, ecological model, blue carbon

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Two-way nested blue carbon tracing simulation for elucidating fates of exported organic carbon from coastal ecosystems

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A considerable amount of the organic carbon produced by coastal organisms such as seagrasses, mangroves, corals, is flushed out offshore, and may be potentially important for the global carbon cycles. However, the fates of the effused organic carbon of coastal origin are not well-known due to limited quantitative observation. In this study, a numerical simulation model for tracing the exported organic carbon was developed for elucidating the fates of the exported organic carbon.

The model composed of an ocean circulation model based on the Coupled-Ocean-Atmosphere-Wave-Sediment Transport (COAWST) Modeling System (Warner et al., 2010) and a newly developed low-trophic ecosystem model (modified from Nakamura et al., 2018). The low-trophic ecosystem model has the following compartments: dissolved inorganic carbon (DIC), total alkalinity (TA), dissolved oxygen (DO), ammonium (NH_4), nitrate (NO_3), phosphate (PO_4), labile dissolved organic carbon (LDOC), nitrogen (LDON), and phosphorus (LDOP), refractory organic carbon (RDOC), nitrogen (RDON), and phosphorus (RDOP), coarse particulate organic carbon (CPOC), nitrogen (CPON), and phosphorus (CPOP), detritus type particulate organic carbon (DPOC), nitrogen (DPON), and phosphorus (DPOP), three functional groups of phytoplankton (dinoflagellates, diatoms, coccolithophorids), one functional group of zooplankton, and particulate inorganic carbon (PIC; dead $CaCO_3$ shell of coccolithophorids). An additional carbon isotope module along with its compartments, such as DI^{13}C, RDO^{13}C, LDO^{13}C, CPO^{13}C, DPO^{13}C, and ^{13}C of the aforementioned phytoplankton, ^{13}C of zooplankton, and PI^{13}C, was incorporated into the model to trace the fates of the carbon. Isotope fractionations by all physical and biological processes were currently deactivated as the module was used for carbon tracing.

This model was applied to the Yaeyama Islands region, focusing on Nagura Bay, Ishigaki Island, for tracing organic carbon exported from the mangrove ecosystem around Nagura River. A two-grid nested configuration consisting of a coarser domain YAEYAMA1 (1.5 km grid resolution) covering the East-coast of Taiwan to Miyako Island and downscaled YAEYAMA2 (300 m grid resolution) covering the entire Ishigaki - Iriomote Island was used for the simulation. The dispersion process of the organic carbon from finer-scale to coarser-scale domain was tracked by applying two-way online nesting in the simulation.

In this simulation, completely 0% of carbon isotope is included in all compartments, and 100% of the CPOC as mangrove leaf carbon is marked as CPO^{13}C and released from the Nagura river mouth. Then the CPOC (CPO^{13}C) is dispersed by advection and diffusion. The carbon tracer model is able to capture the fates of the released CPOC including decomposition from CPOC to detritus to DIC, CPOC grazing and assimilation by zooplankton, detritus re-formation through organism mortality, and detritus deposition in ocean bottom sediment. This kind of carbon cycle was able to be chased and visualized by the carbon tracer. Simulation results also indicated a fraction of detritus that originated from mangrove leaves deposited into deeper water areas such as the Okinawa Trough after being dispersed from the Nagura

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River mouth. The amount of these mangrove-generated detritus, however, was much smaller than pelagic organism-generated detritus. Therefore, this modeling study suggests a challenge that might occur in detecting mangrove organic carbon from pelagic sediment core analysis by conventional techniques.

Keywords: blue carbon, exported organic carbon, numerical simulation

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[J] Oral | A (Atmospheric and Hydrospheric Sciences)：A-CG Complex & General

Thu. Jun 3, 2021 1:45 PM - 3:15 PM JST | Thu. Jun 3, 2021 4:45 AM - 6:15 AM UTC | Ch.11 Zoom Room 11

[A-CG42] Water and sediment dynamics from land to coastal zones

convener:Shinichiro Kida(Research Institute for Applied Mechanics, Kyushu University), Yuko Asano(The University of Tokyo), Keiko Udo(International Research Institute of Disaster Science, Tohoku University), Dai Yamazaki(Institute of Industrial Sciences, The University of Tokyo), Chairperson:Dai Yamazaki(Institute of Industrial Sciences, The University of Tokyo), Keiko Udo(International Research Institute of Disaster Science, Tohoku University), Yuko Asano(The University of Tokyo), Shinichiro Kida(Research Institute for Applied Mechanics, Kyushu University)

The dynamics of water and sediments from land to the ocean, such as hillslope runoff generation, river flow and flooding, sediment transport and geomorphology, and coastal river plumes, are inter-connected through processes with various spatial- and temporal-scales. As compound disasters and environmental changes often involve these processes occurring simultaneously at multiple scales, integrated understanding of the dynamics of water and sediments across hillslope, floodplain, river mouth, and coastal-zone are required. We welcome wide-range studies related to the dynamics of water and sediments from land to the ocean with theoretical, observational, and simulation-based approaches such as basic process understanding, in-situ and remote-sensing observations, big-data analysis and supercomputing.

1:45 PM - 2:00 PM JST | 4:45 AM - 5:00 AM UTC

[ACG42-01] The fate of riverine freshwater in the ocean

*Shinichiro Kida[1], Ryo Abe[2], Yosuke Alexandre Yamashiki[3] (1.Research Institute for Applied Mechanics, Kyushu University, 2.Interdisciplinary Graduate School of Engineering Sciences, 3.Graduate School of Advanced Integrated Studies in Human Survivability)

2:00 PM - 2:15 PM JST | 5:00 AM - 5:15 AM UTC

[ACG42-02] Interpreting the sediment dynamics from mountains to the sea in the Saru River souce-to-sink system using radionuclide tracers

★Invited Papers

*Shigeru Mizugaki[1], Junichi Otsuka[1], Yasuhiro Murakami[1], Keiko Iwakura[1] (1.Civil Engineering Research Institute for Cold Region, Public Works Research Institute)

2:15 PM - 2:30 PM JST | 5:15 AM - 5:30 AM UTC

[ACG42-03] River survey using airborne laser bathymetry (ALB) and its applications

★Invited Papers

*Keigo Nakamura[1] (1.Public Works Research Institute)

2:30 PM - 2:45 PM JST | 5:30 AM - 5:45 AM UTC

[ACG42-04] How much suspended sediment is transported from land to oceans globally?

*Misako Hatono[1], Kei Yoshimura[2] (1.Hiroshima University, 2.The University of Tokyo)

2:45 PM - 3:00 PM JST | 5:45 AM - 6:00 AM UTC

[ACG42-05] Estimation of coastal freshwater discharge using surface salinity of Nanao Bay

*Shiho Kobayashi[1], Satoshi Nakada[2], Kei Senbokuya[3], Jun-ichi Okuno [3] (1.Kyoto University, 2.National Institute for Environmental Studies, 3.Ishikawa Prefecture Fisheries Research Center)

3:00 PM - 3:15 PM JST | 6:00 AM - 6:15 AM UTC

[ACG42-06] Storm runoff at hillslopes and channels in mountain catchment

*Yuko Asano[1], Taro Uchida[2], Mitsuhide Tomomura[3], Naoko Miura[1] (1.The University of Tokyo, 2.University of Tsukuba, 3.Meteorological Engineering Center)

The fate of riverine freshwater in the ocean

*Shinichiro Kida[1], Ryo Abe[2], Yosuke Alexandre Yamashiki[3]

1. Research Institute for Applied Mechanics, Kyushu University, 2. Interdisciplinary Graduate School of Engineering Sciences, 3. Graduate School of Advanced Integrated Studies in Human Survivability

Riverine freshwater is a buoyancy source for the ocean and spreads the coast as it mixes with oceanic water and establishes a river plume at the sea surface. Continental-scale rivers tend to create river plumes that are trapped along the coast and continue for a long distance. Regional-scale rivers, on the other hand, tend to create river plumes that mix close to the river mouth and are more short-lived. We investigated the fate of riverine freshwater after a heavy rain event for regional-scale rivers using a river-ocean seamless model. Model results show the formation of gravity-current like river plumes and that the roles of small-scale rivers are non-negligible for establishing the salinity distribution near the coast. We will also introduce recent high-resolution observations using drones which is becoming a convenient method to capture the behavior of river plumes.

Keywords: river plume

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Interpreting the sediment dynamics from mountains to the sea in the Saru River souce-to-sink system using radionuclide tracers

*Shigeru Mizugaki[1], Junichi Otsuka[1], Yasuhiro Murakami[1], Keiko Iwakura[1]

1. Civil Engineering Research Institute for Cold Region, Public Works Research Institute

Coastal erosion has been a nationwide problem in Japan since the 1950s, and there is a need for comprehensive sediment management in stream systems from mountains to coasts. In addition to understanding the sediment dynamics in the stream-sediment system, it is an extremely important basic issue to understand the source of sediment production. To clarify the sediment dynamics in the source to sink sediment transport system, we collected a variety of sediments such as suspended sediment, fluvial material, beach sand, and coastal sediment from the mountains to the sea in the Saru River basin in Hokkaido, and conducted the fingerprinting sources of those sediment using radioisotope tracers. The results show that coastal sand and sediment are mainly composed of sand, and that the contribution of accretionary sedimentary rocks, melange substrates, and plutonic rocks in the upstream region is high. On the other hand, suspended sediment is mainly composed of silt and clay, and sedimentary and metamorphic rock areas are the main sources of production. Since the riverbed material contains little silt and clay, the suspended sediment could be originated from the mountain slopes in the mid- and down-stream areas of the Saru River basin. Sand components may contribute to the coastal and littoral sediments not only from the mountain slopes but also from the re-migration of the fluvial materials. These results suggest that countermeasures against coastal erosion and beach loss require in-channel storage and continuity from the upper reaches of mountainous areas to the sea to supply sufficient quantities of sand to the sea.

Keywords: sediment fingerprinting, natural radionuclides, particle size

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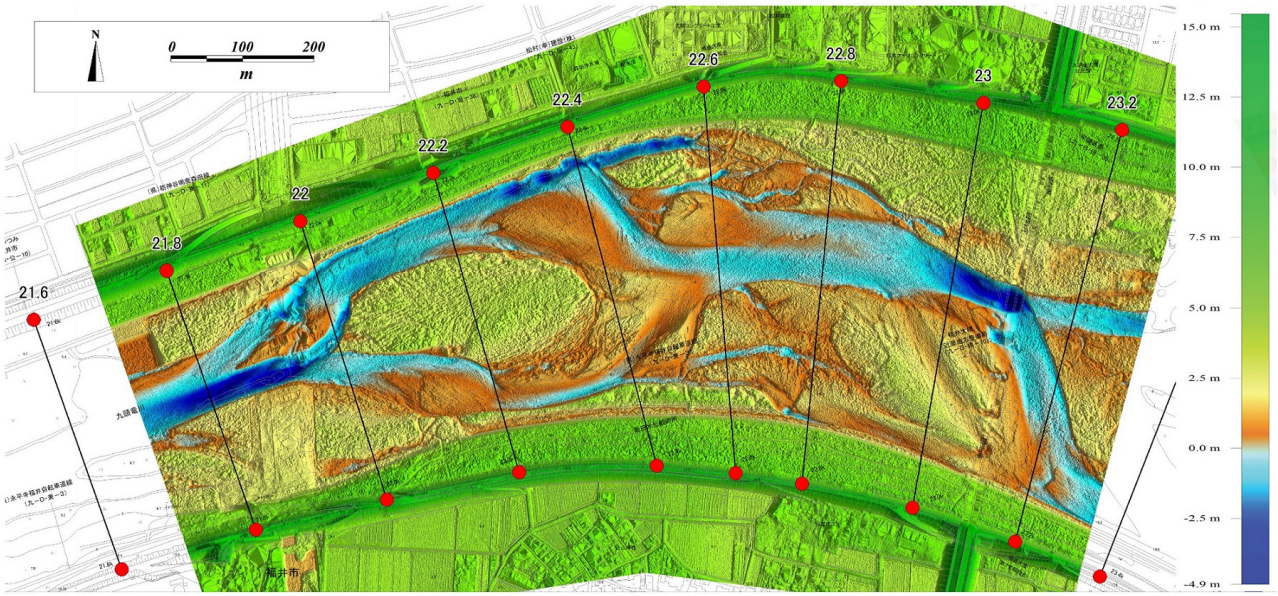
River survey using airborne laser bathymetry (ALB) and its applications

*Keigo Nakamura[1]

1. Public Works Research Institute

In the rivers throughout the country, periodic transverse survey by actual measurement is being carried out for the purpose of planning river management and river improvement. However, survey under the water has caused danger in working especially in a rapid river, and it takes a great deal of time to measure one survey line. To solve this problem, river survey was carried out by using ALB which is a recently-developed technique and can measure under the water surface. In this study, in order to create a cross section from point cloud data by using ALB which can perform underwater measurement in recent years, the accuracy verification with the actual measurement was carried out and the transverse map drawing was made in survey under the water surface. We also considered the application to river management that makes full use of the characteristics of aviation laser measurement.

Keywords: river survey, ALB, BIM



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How much suspended sediment is transported from land to oceans globally?

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1. Hiroshima University, 2. The University of Tokyo

While fluvial suspended sediment plays a vital role in material transport through rivers, there are still large uncertainties in global scale estimates, partly due to its high regional dependency and lack of comprehensive observation networks. There have been several attempts to assess the global suspended sediment load to the oceans including regions with insufficient observation data by extrapolating the relationship between regional characteristics and suspended sediment load in data-rich regions. Milliman and Farnsworth (2011) compiled annual suspended sediment load data for over one thousand river basins globally, and combined various data such as elevation, precipitation, and geological features to estimate the annual suspended sediment load for river basins without observation data. The most significant are the rivers in the cluster of small islands in Oceania which is estimated to transport 6800 Mt/yr, approximately 35% of the global sum. This is significantly large considering the 13 rivers in this region included in the original database account for only 290 Mt/yr. To evaluate its validity, we used our global sediment dynamics model at 0.5 degree spatial resolution to compare the annual suspended sediment load to oceans. We found that the total suspended sediment load from this region in our model was less than a third of the previously estimated value even when calibrating model parameters to fit the annual suspended sediment load of the observed 13 rivers. Here we discuss the source of the large discrepancy in the region by comparing our model results with previous extrapolated estimates in river basins with insufficient data and its impact on the global suspended sediment load.

Keywords: Global sediment dynamics, Numerical modeling, Oceania

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Estimation of coastal freshwater discharge using surface salinity of Nanao Bay

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Extremely heavy rainfall impacts on marine environment; it causes the significant decrease of surface salinity and intensifies density stratification in coastal seas, and might result in depletion of dissolved oxygen in the lower layer. The study area, Nanao Bay is a semi-enclosed bay in Noto Peninsula faced on Japan Sea. There is no public data of river discharge flowing into the bay, which is important to investigate the impacts of heavy rainfall on the marine environment. On the other hand, salinity in the bay has been monthly measured by Ishikawa Prefecture Fisheries Research Center and daily rainfall is publicized by Japan Meteorological Agency. This study employed a numerical model, FVCOM (Chen et al., 2003) for estimating the decrease of salinity in the surface layer of the bay associated with freshwater discharge which was estimated using the catchment area, rainfall data and runoff coefficients. The Green’s functions method was then applied for inverse estimation of the runoff coefficients using the simulated and the observed salinity in the bay.

Keywords: freshwater discharge, catchment area, surface salinity, coastal sea model, runoff coefficients

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Storm runoff at hillslopes and channels in mountain catchment

*Yuko Asano[1], Taro Uchida[2], Mitsuhide Tomomura[3], Naoko Miura[1]

1. The University of Tokyo, 2. University of Tsukuba, 3. Meteorological Engineering Center

It is important to clarify the dynamics of water and sediment in mountainous watersheds to understand the dynamics of water and sediment continuously from land to coastal zones. In Japan, about 70% of the land is mountainous, thus, water and sediment from mountain watershed transported to downstream plains and used for human activities, and the remaining will be brought to the coastal zones. Therefore, the amount of water and sediment transported from mountain watersheds is one of the most important conditions that determine the dynamics of water and sediment not only on land but also in coastal zones. However, information is still limited in mountain watershed because water and sediment dynamics changes dramatically between normal and storm condition and measurements during heavy storm is very difficult. In this study, we introduce the recent studies on flood flow from hillslopes and channels in mountainous watersheds based on field observations and literature review.

In mountainous watersheds, where the watershed area is steep and relatively small, it has been thought that the rainfall hyetographs transformed to discharge hydrographs mainly in hillslopes because water movement in hillslope soil should have greater effect on the waveform transformation and/or peak delay than that in the open channel flow. Researches have been conducted in hillslopes and the processes that control flood flow during small to middle sized storms have been clarified. However, responses and processes that occur during heavy storms have not been well understood. In addition, because mountain rivers have rough bed morphology consisting of gravels of various sizes, water depth and velocity distribution changes greatly during storms. However, even if the discharge is known, prediction of the water depth and velocity is still difficult.

To understand flood flow from hillslopes, we installed 16 water level recorders within a 4.5 km2 watershed in the University Forest of The University of Tokyo in Minami-Izu, Shizuoka and measured water levels for every minute. Because there were linear relationships between the channel flowpath length and the peak lag time during heavy storms, the peak propagation speeds in the channels were estimated from the slopes of these linear relationships, and the peak lag times in the hillslope flowpath were estimated from the intercepts. During heavy storms, that occur once every year to several years, the peak lag times in the hillslopes were -1 to 2 minutes, and the peak propagation speeds in the hillslopes were as fast as a few m/s. While the peak propagation speeds in the channels were 2.9 m/s at maximum. These small contributions of lateral flows in hillslopes on the catchment peak lag times have been demonstrated by other experimental and theoretical studies.

For flood flow in channels, we found the drastic changes in channel resistance during heavy storms. In practice, Manning's roughness coefficient has been used for flood analysis even in mountain rivers. The channel resistance decreased significantly as the water level rises, from more than 0.5 to less than 0.1 in terms of Manning's roughness coefficient. We also found that the change in the channel resistance with water depth became smaller when water depth increased to certain depth as most of gravel submerge, but that the measured minimum values of the channel resistance were often larger than the range that has been used as the reference.

In mountain watershed, when hillslopes become sufficiently wet during heavy storms, peak propagation

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speed in hillslopes increases and rainwater is expected to discharge to channel simultaneously and quickly from all hillslopes. While in mountain rivers with rough bed, the flow speed does not become very fast due to the high resistance. Therefore, the delay between the peak of rainfall and the peak of runoff during heavy storms is small on lateral water movement in hillslopes and occurs mainly in the channel.

Keywords: mountain river, peak propagation, velocity, celerity, hillslope, channel

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[J] Oral | A (Atmospheric and Hydrospheric Sciences)：A-CG Complex & General

Thu. Jun 3, 2021 3:30 PM - 5:00 PM JST | Thu. Jun 3, 2021 6:30 AM - 8:00 AM UTC | Ch.11 Zoom Room 11

[A-CG42] Water and sediment dynamics from land to coastal zones

convener:Shinichiro Kida(Research Institute for Applied Mechanics, Kyushu University), Yuko Asano(The University of Tokyo), Keiko Udo(International Research Institute of Disaster Science, Tohoku University), Dai Yamazaki(Institute of Industrial Sciences, The University of Tokyo), Chairperson:Shinichiro Kida(Research Institute for Applied Mechanics, Kyushu University), Yuko Asano(The University of Tokyo), Dai Yamazaki(Institute of Industrial Sciences, The University of Tokyo), Keiko Udo(International Research Institute of Disaster Science, Tohoku University)

The dynamics of water and sediments from land to the ocean, such as hillslope runoff generation, river flow and flooding, sediment transport and geomorphology, and coastal river plumes, are inter-connected through processes with various spatial- and temporal-scales. As compound disasters and environmental changes often involve these processes occurring simultaneously at multiple scales, integrated understanding of the dynamics of water and sediments across hillslope, floodplain, river mouth, and coastal-zone are required. We welcome wide-range studies related to the dynamics of water and sediments from land to the ocean with theoretical, observational, and simulation-based approaches such as basic process understanding, in-situ and remote-sensing observations, big-data analysis and supercomputing.

3:30 PM - 3:45 PM JST | 6:30 AM - 6:45 AM UTC

[ACG42-07] Sediment budget analysis and geomorphological evolution in alluvial river – Case study in the lower Yodo River –

★Invited Papers

*Ryoukei Azuma[1] (1.Osaka Institute of Technology)

3:45 PM - 4:00 PM JST | 6:45 AM - 7:00 AM UTC

[ACG42-08] Toward an improvement of river runoff in the Japanese Coastal Ocean Monitoring and Forecasting System

★Invited Papers

*Kei Sakamoto[1], Shogo Urakawa[1], Nariaki Hirose[1], Hideyuki Nakano[1], Takahiro Toyoda[1], Norihisa Usui[1], Goro Yamanaka[1] (1.Meteorological Research Institute)

4:00 PM - 4:15 PM JST | 7:00 AM - 7:15 AM UTC

[ACG42-09] Long river plume around Akkeshi Bay formed by snowmelt runoff

*Satoshi Nakada[1], Tomonori Isada[2] (1.National Institute for Environmental Studies, 2.Hokkaido University)

4:15 PM - 4:30 PM JST | 7:15 AM - 7:30 AM UTC

[ACG42-10] Application of suspended sediment and physical process interaction to river-plume simulations in the microtidal coastal region during a flood

*Yasuhiro Hoshiba[3], Yoshimasa Matsumura[2], Sachihiko Itoh[3], Hiroyasu Hasumi[1] (1.Division of Climate System Research, Atmosphere and Ocean Research Institute, University of Tokyo, 2.Division of Marine Life Science, Atmosphere and Ocean Research Institute, University of Tokyo, 3.Center for Earth Surface System Dynamics, Atmosphere and Ocean Research Institute, University of Tokyo)

4:30 PM - 4:45 PM JST | 7:30 AM - 7:45 AM UTC

[ACG42-11] Experimental study on the effect of vegetation cover and location by a forest floor model on reducing sediment transport

*Ako YAMAMOTO[1], Akira Kojima[2], Ryusei Shiotsuki[2], Keita Kawaharada[3], Makjoto Sotoyama[3], Tsuyoshi Tada[2], Yoshinori Shigihara[2], Yo Fukutani[3] (1.Forest of Research and Management Organization Forestry and Forest Products Research Institute, 2.National Defense Academy, 3.Kanto Gakuin University)

4:45 PM - 5:00 PM JST | 7:45 AM - 8:00 AM UTC

[ACG42-12] Sediment transport and morphology change in coastal areas

*Keiko Udo[1] (1.International Research Institute of Disaster Science, Tohoku University)

Sediment budget analysis and geomorphological evolution in alluvial river –Case study in the lower Yodo River –

*Ryoukei Azuma[1]

1. Osaka Institute of Technology

This study starts with presenting field evidences that illustrate the occurrence of significant bank erosion in the lower section of the Yodo River. It then demonstrates that the resulting escarpments were not mere local adjustments, but are an indicator as to how extensively the Yodo River has undergone appreciable amounts of channel erosion over the entire 70km-long section. The datasets on which the discussion is based include: the cross-channel topographical data (200m intervals along the river course) in first half of 1970s, early 1990s and late 2000s made available from the Yodogawa Office, MLIT. A careful geomorphological analysis of the datasets in terms of GIS, permitted the determination of tempo-spatial changes of areal sediment storage in the Uji River, a tributary of Yodo River.
When integrated over the entire river course, the overall volume of sediment loss due to erosion proved to amount to 41.3 $\times 10^4$ tons a year in the period from first half of 1970s up to late 2000s. A discussion is made to identifying its practical implications for future riverine management. Furthermore, a discussion is made of the linkage between the extent of the channel erosion and the depositional environments of the sediment that constitutes the boundary of the river channel.

Keywords: Alluvial river, Sediment budget, Geomorphological evolution

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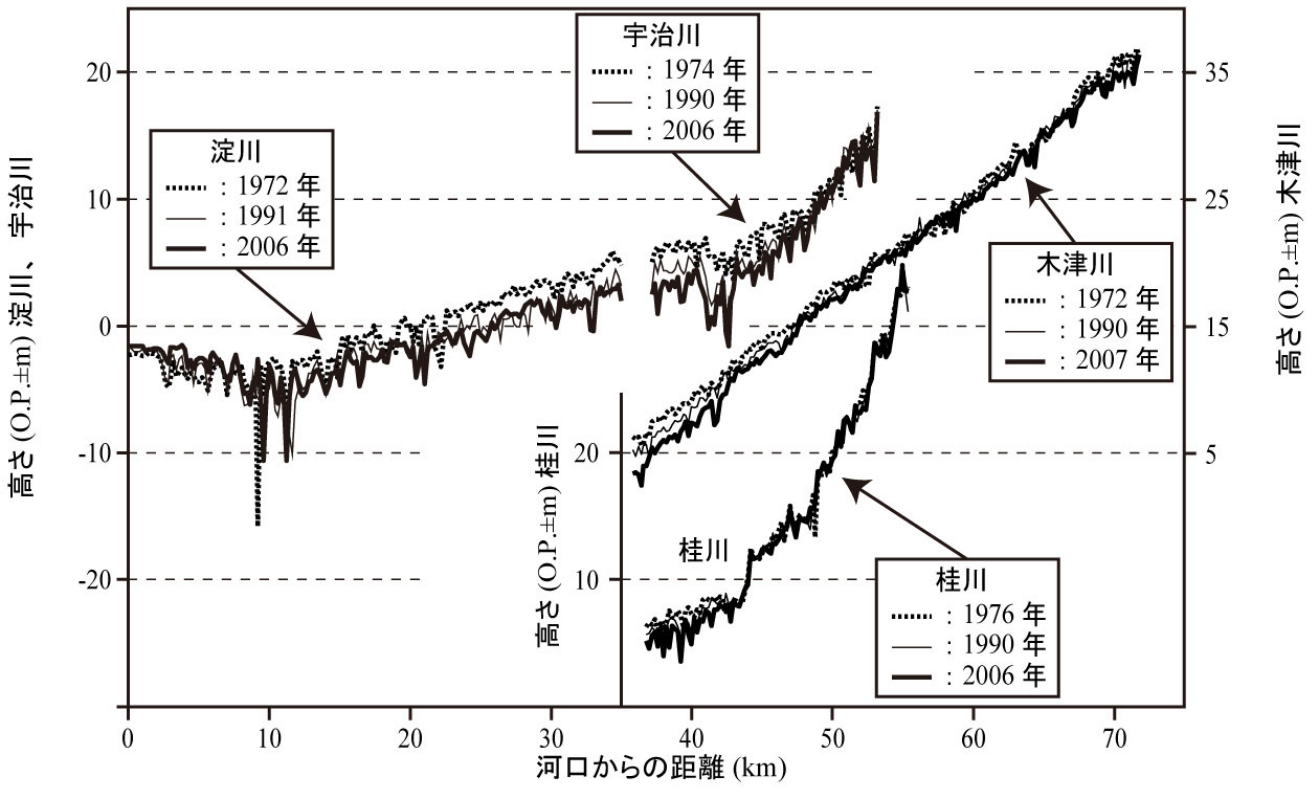


図　淀川中下流域における河床最深部の沿川縦断プロフィール

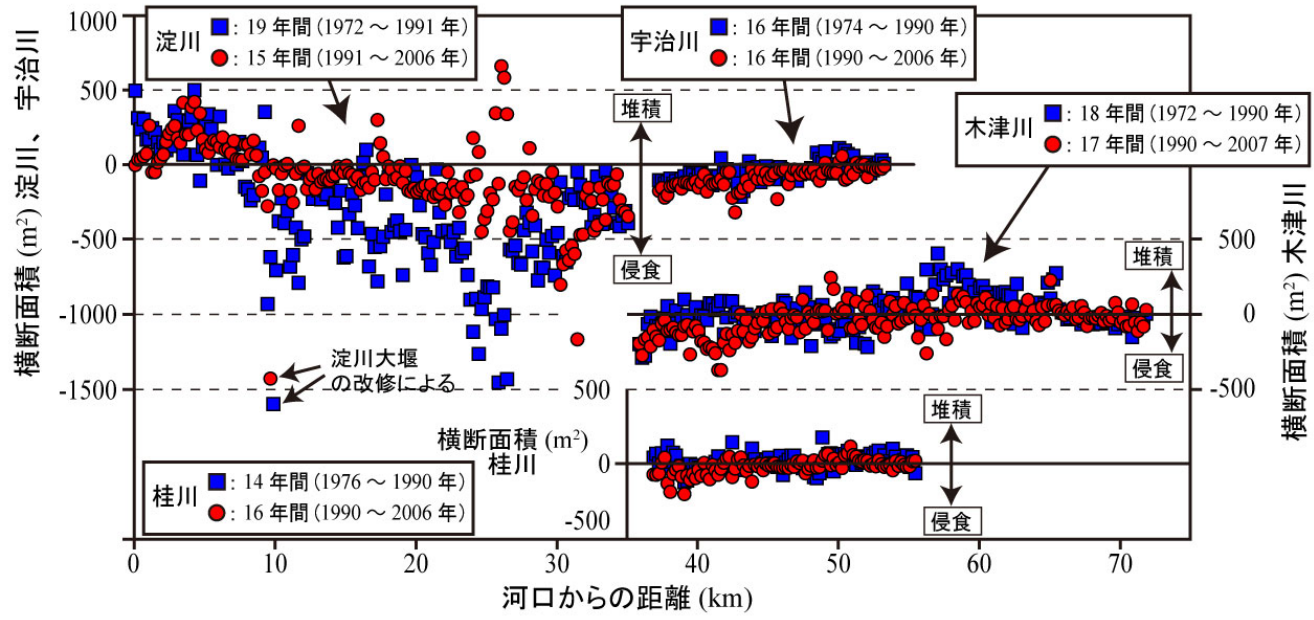
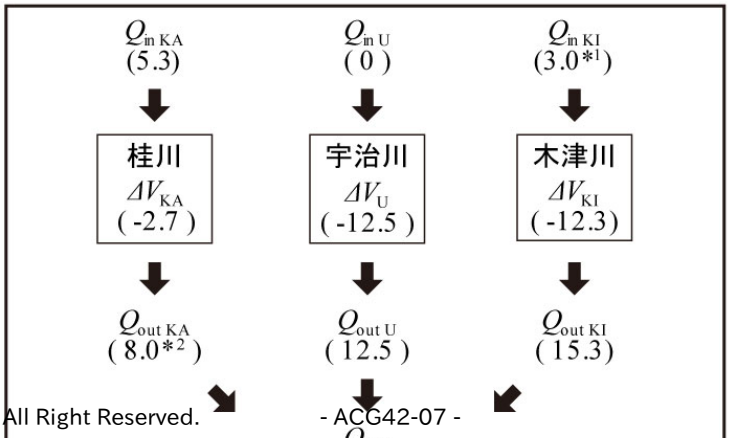


図　淀川中下流域における河道横断面積の変化量



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Toward an improvement of river runoff in the Japanese Coastal Ocean Monitoring and Forecasting System

*Kei Sakamoto[1], Shogo Urakawa[1], Nariaki Hirose[1], Hideyuki Nakano[1], Takahiro Toyoda[1], Norihisa Usui[1], Goro Yamanaka[1]

1. Meteorological Research Institute

The Japan Meteorological Agency (JMA) started the operation of the "Japanese Coastal Ocean Monitoring and Forecasting System" (JPN System) in October 2020 for the purpose of grasping ocean states around Japan in detail. This system was developed by the Meteorological Research Institute (MRI) and consists of an OGCM that covers a wide area around Japan with a horizontal resolution of about 2 km (JPN model) and a four-dimensional variational data assimilation system. The JPN model incorporates major coastal processes such as tidal and pressure response, enabling ocean simulations that can be directly compared to the real ocean. With the start of operation of the JPN system, new marine information such as detailed coastal current fields are being provided by the JMA, and we hope that it will be widely utilized by the ocean community across industry, government, and academia. The JPN quick analysis and prediction data can be obtained from the Japan Meteorological Business Support Center, and, in addition, a long-term reanalysis data from 2008 is also being provided by the MRI.
(https://mri-ocean.github.io/mricom/mri.com-user_jpn_start.html)
Although the JPN system has incorporated major coastal processes, there is still room for improvement in the system specifications. One of them is that daily climatology of Japanese first-class rivers is used for river runoff in the model, not taking the actual time variations into consideration. As a result, low-salinity plumes formed in estuaries during freshets due to heavy rain cannot be reproduced by the JPN system. Therefore, we conducted an experiment to introduce real-time river runoff data for the purpose of improving the JPN system in the future. Specifically, following Urakawa et al. (2016, Weather Service Bulletin), we made an hourly runoff dataset of 3986 rivers nationwide, based on the JMA Runoff Index, which has been used for flood warnings by the JMA, and we ran the JPN model under the new dataset. First, we executed a long-term free-run experiment, and confirmed that this dataset realistically reproduces seasonal changes in sea surface salinity in the Seto Inland Sea. Next, a hindcast experiment was conducted using an initial field by data assimilation, in order to reproduce coastal states after a typhoon passed in September 2011. In the inner part of the Osaka Bay, a low-salinity plume developed due to a freshet of the Yodo River, and surface salinity decreased by more than 5 psu there. This result is consistent with salinity observations along the coast of the Osaka Bay. These results indicate the possibility of improving river runoff in the JPN system. Now, we are planning an experiment to reproduce the low-salinity plume at the time of freshet using an Osaka Bay model, which is downscaled to a resolution of several hundred meters.

Keywords: coastal model, operational oceanograpy, river runoff, Japanese coastal seas

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Long river plume around Akkeshi Bay formed by snowmelt runoff

*Satoshi Nakada[1], Tomonori Isada[2]

1. National Institute for Environmental Studies, 2. Hokkaido University

This study investigated the seasonal variation in the river plumes formed in the coastal sea around Akkeshi Bay, Hokkaido, using a sea-surface salinity (SSS) map estimated from the colored dissolved organic matter (CDOM) product derived from the geostationary ocean color imager, GOCI-COMS. Focusing on the high correlation relationship between the CDOM and the SSS in the sea surface water, we developed a estimation method of the SSS maps from the CDOM data of high-resolution (500 m) and high-frequency (8 times a day) GOCI-COMS products in eight times a day based on the results of field observations and water sampling obtained in Akkeshi Bay. We analyzed the SSS maps created in 9 years from 2012 to 2020, and found that the remarkably large river plume was formed in the coastal sea around Akkeshi Bay during the snowmelt season from March to April every year. This river plume was a part of the long river plume that developed in coastal ocean and elongated from off Cape Erimo in the south to off Cape Nosappu in the east. This river plume shrank in the summer in phase with the increase of the SSS. This inferred that the snowmelt runoff occurred in the spring could form the river plumes in estuaries located along the coast, and coalesce into the long river plume.

Keywords: sea surface salinity, snowmelt runoff, river plume, colored dissolved organic matter, geostationary ocean color satellite

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Application of suspended sediment and physical process interaction to river-plume simulations in the microtidal coastal region during a flood

*Yasuhiro Hoshiba[3], Yoshimasa Matsumura[2], Sachihiko Itoh[3], Hiroyasu Hasumi[1]

1. Division of Climate System Research, Atmosphere and Ocean Research Institute, University of Tokyo, 2. Division of Marine Life Science, Atmosphere and Ocean Research Institute, University of Tokyo, 3. Center for Earth Surface System Dynamics, Atmosphere and Ocean Research Institute, University of Tokyo

Rivers transport freshwater, suspended sediment matter (SSM), and nutrients from land to coastal seas. In coastal seas termed as regions of freshwater influence (ROFIs), SSM is not only passively transported but also changes density of ambient water and influences physical characteristics especially in flood events, when a lot of SSM and nutrients are supplied to ROFIs. The interaction between SSM and water density in ROFIs can significantly change estuarine circulations and river plumes' mode such as hypopycnal (i.e. the riverine sediment-freshwater is not denser than the seawater) or hyperpycnal (i.e., the density of the riverine sediment-freshwater mixture exceeds that of the ambient seawater) plumes. In this study here, we investigate the interactive effects on salinity, nutrient, phytoplankton distributions in river plumes, and so on. We also discuss whether the interactive effects should be considered or not in ROFIs' simulations of various cases (e.g., changing riverine SSM-input flux, SSM particle diameter, and nutrient concentration). In order to quantitatively estimate the interactive effects of SSM, we employed a non-hydrostatic ocean model with Lagrangian particles, which represented SSM and affects the density and buoyancy of ambient water. A simple lower-trophic-level marine ecosystem model was also incorporated with the model. Many simulations (175 cases) reproducing river plumes during the developing stage initiated by a flood on a microtidal open bay were conducted to study the quantitative sensitivities of the interactive processes to the riverine SSM and nutrient flux, and SSM particle size. As a result, we strongly recommend that the interaction should be considered in hyperpycnal cases because the effects could make differences of the mean nutrient concentrations by 20 % or more in the river plumes. On the other hand, in hypopycnal cases, whether the interaction should be considered or not depends on the time scale (daily or not) and the substances (river originated or not) to focus on.

Keywords: Coastal region of river-water influence, River plume simulations, Interaction between suspended sediment and water density

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Experimental study on the effect of vegetation cover and location by a forest floor model on reducing sediment transport

*Ako YAMAMOTO[1], Akira Kojima[2], Ryusei Shiotsuki[2], Keita Kawaharada[3], Makjoto Sotoyama[3], Tsuyoshi Tada[2], Yoshinori Shigihara[2], Yo Fukutani[3]

1. Forest of Research and Management Organization Forestry and Forest Products Research Institute, 2. National Defense Academy, 3. Kanto Gakuin University

In coastal areas hit by the 2011 Tohoku Tsunami, coastal forests were reported to have mitigated the disaster and prevented some damage, including reducing water levels and flow velocities as well as trapping sediment. Coastal forests are being restored on embankments in the affected coastal areas. The embankments were created using soft engineering to maintain the deep root system of the trees. There is a concern that another tsunami may cause erosion and sediment runoff. To prevent the trees from being washed away, it is necessary to control sediment runoff at the ground surface. However, there is no method to evaluate the effect of vegetation cover on sediment transport at present. In this study, hydraulic experiments were carried out to clarify the effects of vegetation trapping and location on sediment transport. A two-dimensional wave-making tank was used for the experiments, consisting of a water storage tank, a 30-m long channel, and a drainage tank from the upstream side. The upstream gate was opened abruptly to generate a tsunami-like stepped wave. A forest floor model with different vegetation coverage and locations was set up in the sand bed section of the channel. We also conducted experiments using models with more complex vegetation patterns to simulate native coastal vegetation. The results confirmed that there was a decrease in the amount of sediment transported with an increase in the degree of cover when the location was the same. However, it was found that the amount of sediment transport was affected not only by the amount of vegetation cover, but also by the direction and density of the vegetation in relation to the flow. It was also confirmed from the image analysis that the effect of the waveform of the wave on the vegetation was very different. It is not clear whether these causes are due to the effect of vegetation trapping or location.

Keywords: Vegetation coverage, Hydraulic experiments, Tsunami

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Sediment transport and morphology change in coastal areas

*Keiko Udo[1]

1. International Research Institute of Disaster Science, Tohoku University

Future sea-level rise and wave climate change are projected to further increase the coastal erosion risk in Japan, where coastal erosion has already progressed due to rapid development after 1950s. Although there have been many studies on coastal erosion, the simplest one-dimensional equilibrium beach profile model is still used for long-term projection of future coastlines because of the difficulty in estimating coastal morphology change accurately. On the other hand, the risk may decrease if the heavy rainfall frequency increases because the heavy rainfall may increase the amount of sediment supply from rivers to the coasts. Knowledge of sediment supply from rivers to the coasts has not yet been sufficient, and further knowledge needs to be obtained.
In this presentation, existing studies on the characteristics of coastal morphology change and their models, as well as existing studies on sediment dynamics in rivers and sediment supply to the coast, which have been discussed separately, are introduced, the problems of the current coastal morphology change models are summarized, and future prospects are discussed.

Keywords: coastal erosion, sediment budget, sediment size

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[J] Oral | A (Atmospheric and Hydrospheric Sciences)：A-CG Complex & General

Thu. Jun 3, 2021 1:45 PM - 3:15 PM JST | Thu. Jun 3, 2021 4:45 AM - 6:15 AM UTC | Ch.07 Zoom Room 07

[A-CG43] Earth & Environmental Sciences and Artificial Intelligence/Machine Learning

convener:Tomohiko Tomita(Faculty of Advanced Science and Technology, Kumamoto University), Shigeki Hosoda(Japan Marine-Earth Science and Technology), Ken-ichi Fukui(Osaka University), Satoshi Ono(Kagoshima Univeristy), Chairperson:Tomohiko Tomita(Faculty of Advanced Science and Technology, Kumamoto University), Shigeki Hosoda(Japan Marine-Earth Science and Technology)

In recent years, we have been required to explore various gigantic data leading earth and environmental sciences such as modern meteorology, oceanography, hydrology and so on to accomplish Society 5.0 and Sustainable Development Goals (SDGs). To examine such gigantic environmental data faithfully, it may be required to use the techniques of artificial intelligence/machine learning (AI/ML) including spatiotemporal data modeling of AI, prediction and detection by ML, techniques of automated data mining, and so forth. At the present, AI/ML is also expected to lead the data-driven science as a bridge connecting science and big data. This session calls for various studies applying the techniques of AI/ML to scientific/environmental issues and will discuss them in both natural and information sciences.

1:45 PM - 1:50 PM JST | 4:45 AM - 4:50 AM UTC

[ACG43-01] Introduction

1:50 PM - 2:10 PM JST | 4:50 AM - 5:10 AM UTC

[ACG43-02] Deep Learning that Ensures Laws of Physics and Other Constraints and Its Applications

★Invited Papers

*Takashi Matsubara[1] (1.Osaka University)

2:10 PM - 2:30 PM JST | 5:10 AM - 5:30 AM UTC

[ACG43-03] Recent trends in earth and environmental informatics

★Invited Papers

*Daisuke Matsuoka[1,2] (1.Japan Agency for Marine-Earth Science and Technology, 2.Japan Science and Technology Agency)

2:30 PM - 2:45 PM JST | 5:30 AM - 5:45 AM UTC

[ACG43-04] Adversarial Multi-task Learning Algorithm for Solving Partial Differential Equations

*Pongpisit Thanasutives[1], Masayuki Numao[1], Ken-ichi Fukui[1] (1.Osaka University)

2:45 PM - 3:00 PM JST | 5:45 AM - 6:00 AM UTC

[ACG43-05] Statistical Downscaling of Meteorological Fields from the Synoptic Scale to the Mesoscale Using Deep Convolutional Neural Networks

*Thomas Sekiyama[1] (1.Meteorological Research Institute)

3:00 PM - 3:15 PM JST | 6:00 AM - 6:15 AM UTC

[ACG43-06] Deep learning approach for rainfall forecasting using U-Net with data augmentation

*Ryo Kaneko[1], Shiho Onomura[2], Makoto Nakayoshi[2] (1.The University of Tokyo, 2.Tokyo University of Science)

[J] Oral | A (Atmospheric and Hydrospheric Sciences) | A-CG Complex & General

[A-CG43] Earth &Environmental Sciences and Artificial Intelligence/Machine Learning

convener:Tomohiko Tomita(Faculty of Advanced Science and Technology, Kumamoto University), Shigeki Hosoda(Japan Marine-Earth Science and Technology), Ken-ichi Fukui(Osaka University), Satoshi Ono(Kagoshima Univeristy), Chairperson:Tomohiko Tomita(Faculty of Advanced Science and Technology, Kumamoto University), Shigeki Hosoda(Japan Marine-Earth Science and Technology)

Thu. Jun 3, 2021 1:45 PM - 3:15 PM Ch.07 (Zoom Room 07)

In recent years, we have been required to explore various gigantic data leading earth and environmental sciences such as modern meteorology, oceanography, hydrology and so on to accomplish Society 5.0 and Sustainable Development Goals (SDGs). To examine such gigantic environmental data faithfully, it may be required to use the techniques of artificial intelligence/machine learning (AI/ML) including spatiotemporal data modeling of AI, prediction and detection by ML, techniques of automated data mining, and so forth. At the present, AI/ML is also expected to lead the data-driven science as a bridge connecting science and big data. This session calls for various studies applying the techniques of AI/ML to scientific/environmental issues and will discuss them in both natural and information sciences.

1:45 PM - 1:50 PM

[ACG43-01]Introduction

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Deep Learning that Ensures Laws of Physics and Other Constraints and Its Applications

*Takashi Matsubara[1]

1. Osaka University

Machine learning and artificial intelligence are attracting much attentions, mainly thanks to the flexibility of deep learning. When feeding big data to deep learning, it learns meaningful representations and builds a sophisticated model of decision making automatically. However, the flexibility is not the sole requirements. For example, deep learning is expected to learn physical phenomena and to accelerate the physical simulations. Then, deep learning has to reproduce the underlying geometric structure that admits laws of physics rather than the superficial dynamics. Indeed, most of deep learning methods gain outstanding performances by being associated with certain symmetries and constraints based on prior knowledge, e.g., a convolutional neural network is designed to be shift-invariant. The same can be said of probabilistic modeling and reinforcement learning. This talk introduces such deep learning based on prior knowledge.

Keywords: artificial intelligence, physics simulation, geometric structure, prior knowledge

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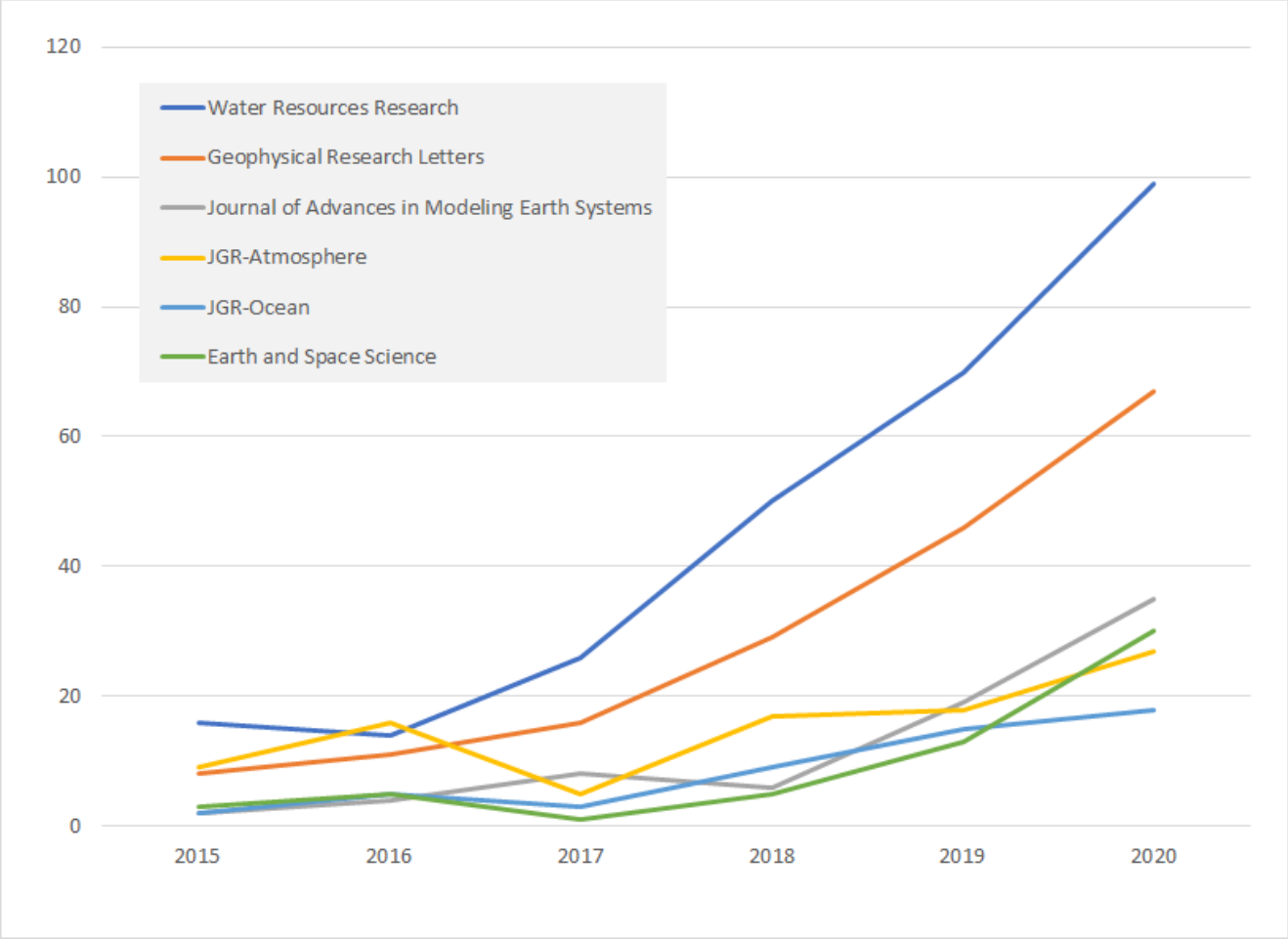
Recent trends in earth and environmental informatics

*Daisuke Matsuoka[1,2]

1. Japan Agency for Marine-Earth Science and Technology, 2. Japan Science and Technology Agency

In recent years, the application of machine learning techniques, such as deep learning, has been actively promoted in the earth and environmental sciences. For example, the number of relevant papers published by the American Geophysical Union (search using machine learning as keywords) has increased rapidly as shown in the figure. Comparing the number of papers published in 2015 and 2020, there is a total increase of about seven times. Especially in the atmospheric and climate sciences, many studies have been published on pattern detection, parameterization, downscaling, bias correction, and future prediction. Some studies utilizing adversarial generative networks (GANs), which artificially generate data, have also been reported. In addition, benchmark data such as WeatherBench (Rasp et al., 2020; Rasp and Thuerey, 2021) is also available to the public with the aim of accelerating data-driven weather and climate prediction research. From these kinds of background, some research organizations such as NOAA and ECMWF have published roadmaps on the use of AI and data-driven science to provide a direction for future research and development. In this presentation, we will introduce some notable studies published in recent years, and present our personal opinions on the research trends and future directions.

Keywords: Deep learning, Machine learning, AI, Big data, data-driven science



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Adversarial Multi-task Learning Algorithm for Solving Partial Differential Equations

*Pongpisit Thanasutives[1], Masayuki Numao[1], Ken-ichi Fukui[1]

1. Osaka University

Recently, researchers have utilized neural networks to accurately solve partial differential equations (PDEs), enabling the mesh-free method for scientific computation. Unfortunately, the network performance drops when encountering a high nonlinearity domain. To improve the generalizability, we introduce the novel approach of employing multi-task learning techniques, the uncertainty-weighting loss, and the gradients surgery, in the context of learning PDE solutions. The multi-task scheme exploits the benefits of learning shared representations, controlled by cross-stitch modules, between multiple related PDEs, which are obtainable by varying the PDE parameterization coefficients, to generalize better on the original PDE. Letting the network pay closer attention to the high nonlinearity domain regions that are more challenging to learn, we also propose adversarial training for generating supplementary high-loss samples, similarly distributed to the training distribution. In the experiment, our proposed methods are found to be effective and reduce the error on the unseen data points as compared to the previous approaches in various PDE examples, including high-dimensional stochastic PDEs.

Keywords: Burgers' equation, Multi-task learning, Adversarial training, Physics-informed neural networks

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Statistical Downscaling of Meteorological Fields from the Synoptic Scale to the Mesoscale Using Deep Convolutional Neural Networks

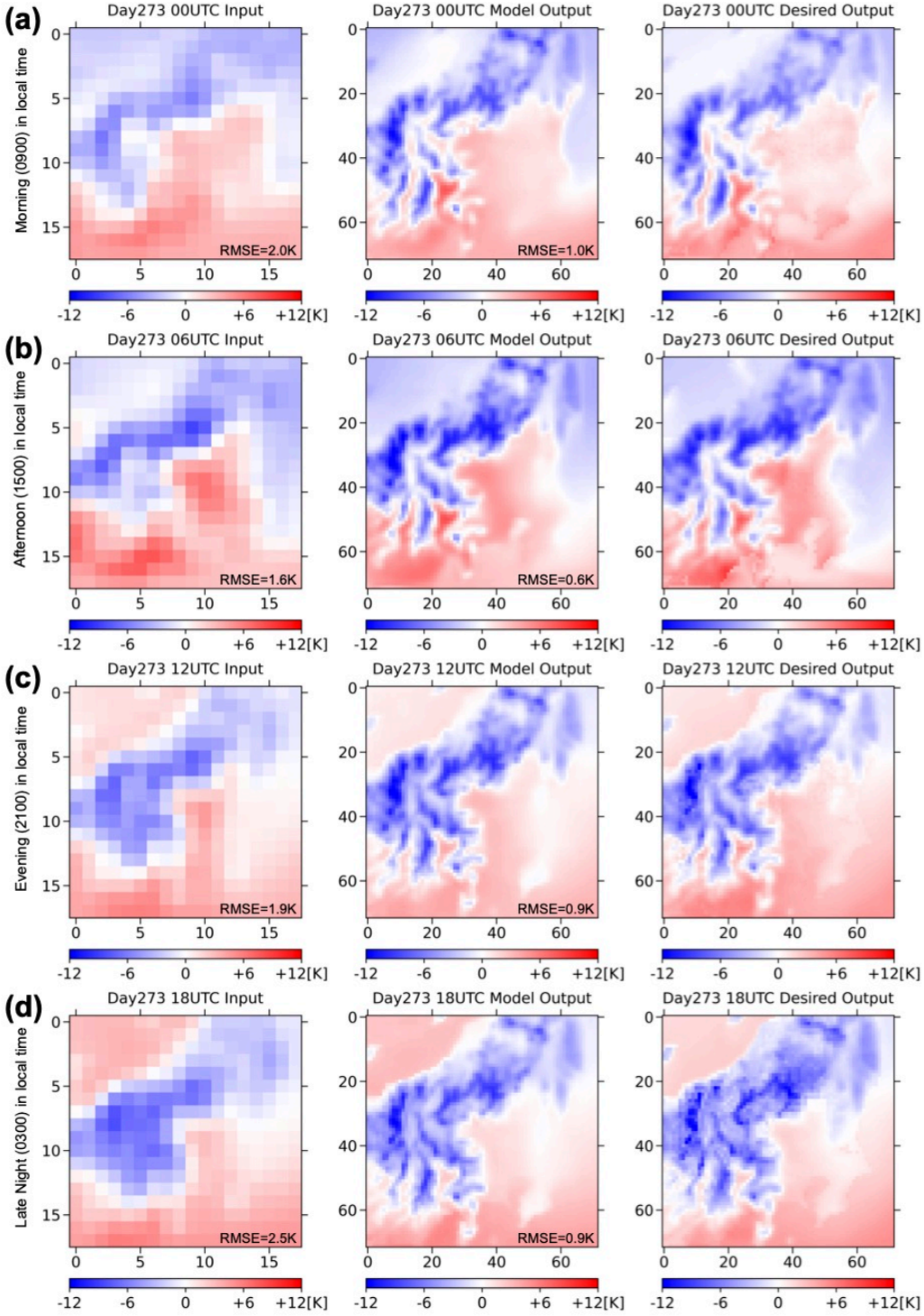
*Thomas Sekiyama[1]

1. Meteorological Research Institute

Deep learning, particularly convolutional neural networks for image recognition, has been recently used in meteorology. One of the promising applications is developing a statistical surrogate model that converts the output images of low-resolution dynamic models to high-resolution images. Our study exhibits a preliminary experiment that evaluates the performance of a model that downscales synoptic temperature fields to mesoscale temperature fields every 6 hours. The deep learning model was trained with operational 22-km gridded global analysis surface winds and temperatures as the input, operational 5-km gridded regional analysis surface temperatures as the desired output, and a target domain covering central Japan. The results confirm that our deep convolutional neural network (DCNN) is capable of estimating the locations of coastlines and mountain ridges in great detail, which are not retained in the inputs, and providing high-resolution surface temperature distributions. For instance, while the average root-mean-square error (RMSE) is 2.7 K between the global and regional analyses at altitudes greater than 1000 m, the RMSE is reduced to 1.0 K, and the correlation coefficient is improved from 0.6 to 0.9 by the surrogate model. Although this study evaluates a surrogate model only for surface temperature, it probably can be improved by augmenting the downscaling variables and vertical profiles. Surrogate models of DCNNs require only a small amount of computational power once their training is finished. Therefore, if the surrogate models are implemented at short time intervals, they will provide high-resolution weather forecast guidance or environment emergency alerts at low cost.

Keywords: numerical weather modeling, surrogate modeling, artificial intelligence, deep learning, super resolution

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Unbiased surface temperature snapshots from December 29, 2019, at (a) 00:00 UTC or 09:00 local time, (b) 06:00 UTC or 15:00 local time, (c) 12:00 UTC or 21:00 local time, and (d) 18:00 UTC or 03:00 local time. The snapshots are taken from the inputs of the test data (left), the model outputs (middle), and the desired outputs of the test data (right).

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Deep learning approach for rainfall forecasting using U-Net with data augmentation

*Ryo Kaneko[1], Shiho Onomura[2], Makoto Nakayoshi[2]

1. The University of Tokyo, 2. Tokyo University of Science

Recently, heavy rainfall disaster occurs almost every year in Japan. The Japan meteorological agency (JMA) expects the rainfall to become severer and more frequent in the future. In those situations, predicting precipitation accurately in the short term is essential to leave enough time for people to evacuate to safer places. In recent years, deep learning technology has attracted attention for its achievements in various fields such as autonomous cars and machine translation. Although deep learning is gradually being applied to precipitation predictions, there is no example of its extension to heavy rainfall prediction to the best of our knowledge. In this study, we aimed to develop a deep learning model that can predict heavy rainfall events.

We trained U-Net (Ronneberger et al., 2015), a deep learning architecture for semantic segmentation, with the nationwide Radar-AMeDAS precipitation (RAP) data produced by JMA, which spatial resolution is 1 km and temporal resolution is 30 minutes. We divided the data into 13 regions of 256 km square because the nationwide data is too large for learning. The input data is the continuous variables of rainfall intensity for 6 hours up to the current time (30-minute intervals), and the teacher data is the categorized rainfall intensity for the next 6 hours (1-hour intervals). The output category was determined referring to the JMA's precipitation categories: Cat.0 denotes no precipitation, i.e., less than 0.1 mm h^{-1}, Cat.1 0.1 - 10 mm h^{-1}, Cat.2 10 - 30 mm h^{-1}, Cat.3 30 - 50 mm h^{-1}, and Cat.4 over 50 mm h^{-1}. We divided the 13 years' precipitation data as follows: The data of 2006 - 2012 was prepared for training, 2013 - 2015 was used as validation for checking the learning progress. The data between 2016 and 2018 was for a test in which the prediction accuracy was evaluated.

Furthermore, we applied data augmentation to training data by generating pseudo data. We used affine transformations, such as rotations from -60 degrees to 60 degrees and expansions from 1x to 4x to heavy rain events. We made two calculation cases, CNT with no augmented data and AUG with augmentation. The two cases were compared in terms of prediction accuracy.

Figure1 shows the prediction of the July 2017 heavy rainfall event occurring in the northern Kyushu region from 10 a.m. to 3 p.m. on 5th July. We can find that the CNT model predicted only light rain but unable to predict the heavy rainfall. On the other hand, the AUG model could predict the two linear precipitation systems extending east-west at 6 hours ahead, though it tended to overestimate. It was also found that the accuracy of the AUG's prediction was higher with the shorter prediction time. Furthermore, we evaluated the forecast results of AUG for the entire test period (Figure2). Even for Cat.4, the critical success index (CSI) exceeded 0.3 at 1 hour ahead, but the false alarm rate (FAR) decreased rapidly with the longer forecast time, and the CSI decreased accordingly. However, the probability of detection (POD) decreased gradually with longer forecast times in all categories. Thus, the model trained with pseudo data could predict some heavy rainfall events six hours prior to the occurrence, even though it has a tendency of overestimation.

We found that data augmentation is a powerful tool for predict low-frequency events such as heavy rainfall and our method of transformation was appropriate to reproduce the real phenomena. On the

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other hand, there was a tendency of overestimation, which might be partly due to the lack of balance in the sample size during training. For example, the sample size is different among categories and also for prediction time. That leads to a bias toward a specific category during training. For preventing this problem, the method of data augmentation and data balance control has to be explored.

Keywords: Precipitation forecasting, Radar precipitation, Deep learning, Heavy rainfall, Disaster

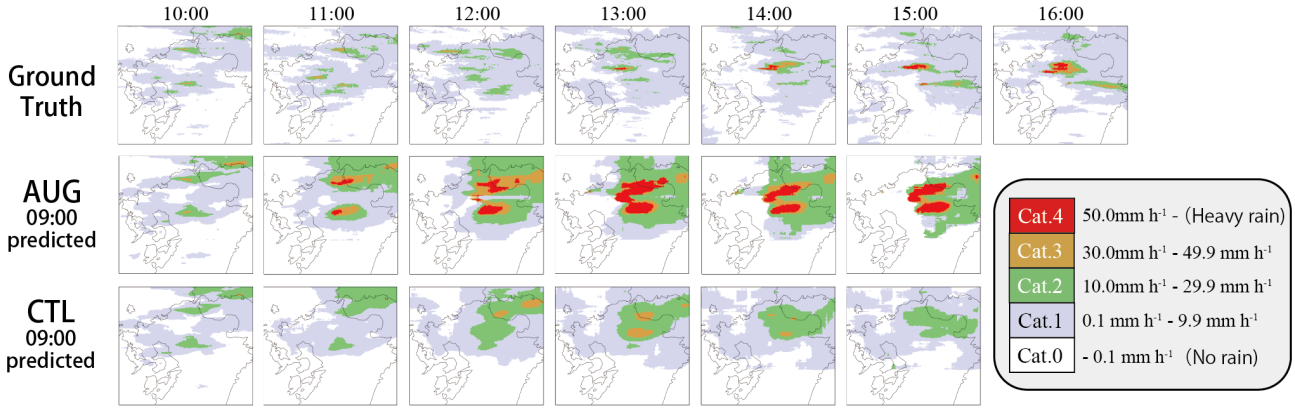


Figure1 The northern Kyushu region from 10 a.m. to 3 p.m. on 5th July 2017.

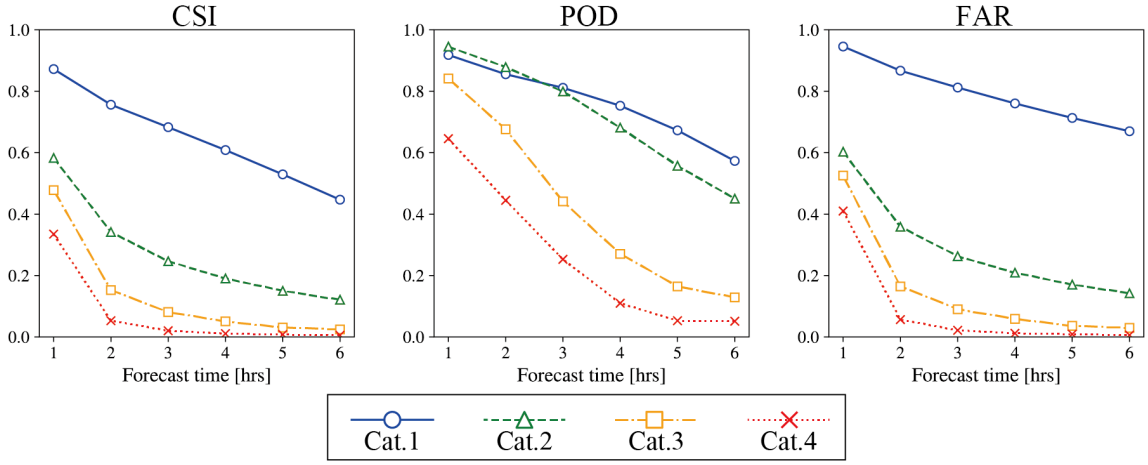


Figure2 The scores of the AUG model.

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[J] Oral | A (Atmospheric and Hydrospheric Sciences)：A-CG Complex & General

Thu. Jun 3, 2021 3:30 PM - 5:00 PM JST | Thu. Jun 3, 2021 6:30 AM - 8:00 AM UTC | Ch.06 Zoom Room 06

[A-CG43] Earth & Environmental Sciences and Artificial Intelligence/Machine Learning

convener:Tomohiko Tomita(Faculty of Advanced Science and Technology, Kumamoto University), Shigeki Hosoda(Japan Marine-Earth Science and Technology), Ken-ichi Fukui(Osaka University), Satoshi Ono(Kagoshima Univeristy), Chairperson:Shigeki Hosoda(Japan Marine-Earth Science and Technology), Tomohiko Tomita(Faculty of Advanced Science and Technology, Kumamoto University)

In recent years, we have been required to explore various gigantic data leading earth and environmental sciences such as modern meteorology, oceanography, hydrology and so on to accomplish Society 5.0 and Sustainable Development Goals (SDGs). To examine such gigantic environmental data faithfully, it may be required to use the techniques of artificial intelligence/machine learning (AI/ML) including spatiotemporal data modeling of AI, prediction and detection by ML, techniques of automated data mining, and so forth. At the present, AI/ML is also expected to lead the data-driven science as a bridge connecting science and big data. This session calls for various studies applying the techniques of AI/ML to scientific/environmental issues and will discuss them in both natural and information sciences.

3:30 PM - 3:50 PM JST | 6:30 AM - 6:50 AM UTC

[ACG43-07] Automated identification of tornadic vortex with Doppler radar data using deep learning approaches: Recent progress and challenges

★Invited Papers

*Kusunoki Kenichi[1], Naoki Ishitsu[2], Toru Adachi[1], Hanako Inoue[1], Osamu Suzuki[1], Ken-ichiro Arai[2], Chusei Fujiwara[3], Hiroto Suzuki[3] (1.Meteorological Research Institute, 2.Alpha-denshi Co., Ltd., 3.East Japan Railway Company)

3:50 PM - 4:10 PM JST | 6:50 AM - 7:10 AM UTC

[ACG43-08] **Estimation of cloud and meteorological state from satellite image by deep neural network**

★Invited Papers

*Hironobu Iwabuchi[1], Xinyue Wang[1], Hana Kato[1], Takaya Yamashita[1] (1.Graduate School of Science, Tohoku University)

4:10 PM - 4:25 PM JST | 7:10 AM - 7:25 AM UTC

[ACG43-09] Clustering global ocean profiles according to temperature-salinity structure

*Nozomi Sugiura[1] (1.Japan Agency for Marine-Earth Science and Technology)

4:25 PM - 4:40 PM JST | 7:25 AM - 7:40 AM UTC

[ACG43-10] **Automated Hybrid Machine Learning Approaches for Groundwater Level Forecasting in Kumamoto area, Japan**

*A T M Sakiur Rahman[1], Takahiro Hosono[4,5], John Quilty[2], Jayanta Das[3], Amiya Basak[3] (1.Postdoctoral researcher, Kumamoto University, 2.Department of Civil and Environmental Engineering , University of Waterloo, Waterloo, ON, Canada , 3.Department of Geography and Applied Geography, University of North Bengal, Darjeeling - 734013, India , 4.Faculty of Advanced Science and Technology, Kumamoto University, 2-39-1 Kurokami, Kumamoto 860-8555, Japan, 5.International Research Organization for Advanced Science and Technology, Kumamoto University, 2-39-1 Kurokami, Kumamoto 860-8555, Japan)

4:40 PM - 4:55 PM JST | 7:40 AM - 7:55 AM UTC

[ACG43-11] **Improving Detection of Tropical Cyclones by Deep Convolutional Neural Network through a Two-step Training**

*TAKERU TSUCHIYA[1], Shunji Kotsuki[2], Ryota Kikuchi[3], Takeshi Umezawa[4], Noritaka Osawa[4] (1.Department of Information Engineering, Chiba University, Chiba, Japan, 2.Center for Environmental Remote Sensing, Chiba University, Chiba, Japan, 3.Office of Society Academia Collaboration for

Innovation, Kyoto University, Japan, 4.Graduate School & Faculty of Engineering, Chiba University, Chiba, Japan)

4:55 PM - 5:00 PM JST | 7:55 AM - 8:00 AM UTC

[ACG43-12] Discussion

Automated identification of tornadic vortex with Doppler radar data using deep learning approaches: Recent progress and challenges

*Kusunoki Kenichi[1], Naoki Ishitsu[2], Toru Adachi[1], Hanako Inoue[1], Osamu Suzuki[1], Ken-ichiro Arai[2], Chusei Fujiwara[3], Hiroto Suzuki[3]

1. Meteorological Research Institute, 2. Alpha-denshi Co., Ltd., 3. East Japan Railway Company

In recent years, deep learning (DL) techniques have been applied in many fields.The Convolutional Neural Network (CNN) is one of the most widely used DL techniques mainly for image processing tasks. The collaborative study between the Meteorological Research Institute and the East Japan Railway company has developed a CNN model to extract vortex pattern from Doppler velocity field while reducing false pattern.

The accuracies of the CNN model is applicable for detection of wintertime tornadic vortices over the coast of the Sea of Japan and has been in operational use since November 2020. In this presentation, we will introduce the basic concepts of our model and further approaches to extend to other regions and/or other seasons especially tornadoes of warm- season over the Pacific coast in Japan.

This study is partly supported by Cabinet Office, Government of Japan, Public/Private R&D Investment Strategic Expansion Program (PRISM).

Keywords: tornado, Doppler radar, deep learning

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Estimation of cloud and meteorological state from satellite image by deep neural network

*Hironobu Iwabuchi[1], Xinyue Wang[1], Hana Kato[1], Takaya Yamashita[1]

1. Graduate School of Science, Tohoku University

Machine learning has been applied to satellite remote sensing of atmosphere, ocean, and land. Recent machine learning techniques show high ability to represent a relationship between satellite measurement signals and an atmosphere/surface state utilizing rich information contained in high-dimensional, spatial/temporal/spectral measurement data. This well meets both a requirement of processing big data available from recent satellite observation systems and a demand for high accuracy of estimation. Popular deep neural networks are good at analysis of satellite measurement image, effectively using spatial/temporal features contained in the image or a sequence of images. If we use time series of satellite images, information about temporal variation of meteorological state can be well obtained. This is a big difference from previous satellite data analysis because traditional satellite remote sensing uses data at an image pixel at a time step. The authors have applied deep neural networks to cloud retrieval from GCOM-C and Himawari-8 satellites. With a multispectral image as input, a deep neural network estimates a spatial distribution of cloud properties fusing multi-scale, spatial and spectroscopic features. We show two different training approaches. One makes a training dataset from physics-based (realistic) simulations, and the other takes independent observations that are assumed to be correct. Prior of cloud and radiative transfer imprinted in multispectral images should be learned by machine in the training process. High accuracy of estimation is shown for cloud properties from visible or thermal infrared channels. Infrared-only method is particularly attractive because it can be used uniformly irrespective to sunlight. We show not only cloud properties but also meteorological states such as wind and humidity can be estimated from a snapshot or time series of Himawari-8 infrared image. An advantage of deep learning is the usage of spatial and temporal features for estimation/prediction of atmospheric properties, which is a new direction for the community.

Keywords: deep learning, satellite earth observation, cloud

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Clustering global ocean profiles according to temperature-salinity structure

*Nozomi Sugiura[1]

1. Japan Agency for Marine-Earth Science and Technology

An unsupervised clustering using a Gaussian mixture model is applied to Argo profiles distributed over the entire ocean. We employ as the coordinate components in feature space the path signature, which is a central notion in rough path theory. This allows us to better identify the oceanic condition at each horizontal point with distinct clusters, than by using conventional temperature and salinity coordinate. To the best of my knowledge, it is the first attempt at clustering almost all of the existing Argo profiles with the full use of measured sequences of temperature, salinity, and pressure. We will also discuss why the path signature is relevant to representing the property of a profile.

Keywords: path signature, Argo, clustering

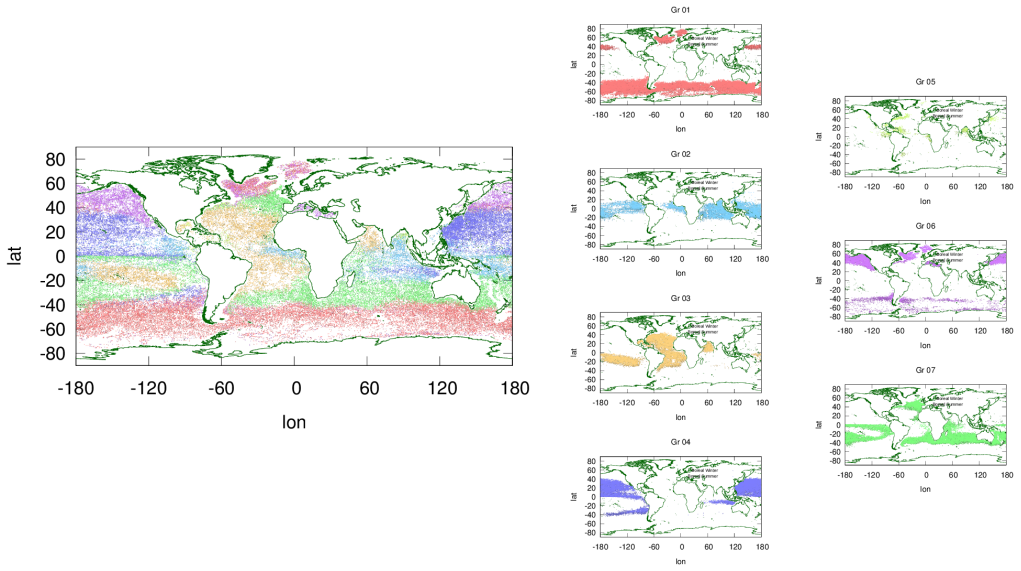


Figure: Seven clusters of Argo profiles identified by the Gaussian mixture model in terms of their path signature

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Automated Hybrid Machine Learning Approaches for Groundwater Level Forecasting in Kumamoto area, Japan

*A T M Sakiur Rahman[1], Takahiro Hosono[4,5], John Quilty[2], Jayanta Das[3], Amiya Basak[3]

1. Postdoctoral researcher, Kumamoto University, 2. Department of Civil and Environmental Engineering , University of Waterloo, Waterloo, ON, Canada , 3. Department of Geography and Applied Geography, University of North Bengal, Darjeeling - 734013, India , 4. Faculty of Advanced Science and Technology, Kumamoto University, 2-39-1 Kurokami, Kumamoto 860-8555, Japan, 5. International Research Organization for Advanced Science and Technology, Kumamoto University, 2-39-1 Kurokami, Kumamoto 860-8555, Japan

Groundwater level (GWL) forecasting is crucial task for planning and management of water resources. However, accurate GWL forecasting is challenging due to nonlinear relationships between GWL and driving hydro-meteorological (input) variables (e.g., rainfall, air temperature). One of the pre-requisites for developing accurate machine learning (ML) models is to select relevant input variables from a range of candidates and afterwards optimizing the model parameters. To address these problems, this study tested the ability of ML approaches such as Random Forests (RF) and eXtreme Gradient Boosting (XGB), which can select input variable internally during model development, for GWL forecasting. Afterwards, RF and XGB were compared with Support Vector Regression (SVR), which has a history of high performance for GWL forecasting. Further, RF, XGB, and SVR models were fed with multiscale information obtained through wavelet transforms (WT) to develop new hybrid ML approaches (WT-RF, WT-XGB, and WT-SVR) for GWL forecasting in Kumamoto, Japan. ML approaches were also coupled with Bayesian hyper-parameter optimization (BHO) to estimate the model parameters automatically. The capability of the models was tested for different monthly lead times (1, 2, and 3 months-ahead) GWL forecasting. The obtained results revealed that standalone ML approaches can successfully forecast the GWL across all lead times and revealed that XGB and SVR had very similar accuracy, while RF showed higher error in Kumamoto, Japan. Although the accuracy was similar for SVR and XGB, it is necessary to apply external algorithms for proper selection of input variables prior to develop model using the SVR. Further, the WT-based models showed improved performance (3-5%) over the standalone models. Therefore, coupling BHO, WT, and ML is a new promising framework for GWL forecasting and is recommended to be explored for short and long-term forecasting of other hydro-meteorological variables (e.g., streamflow, evaporation).

Keywords: Automated Hybrid Machine Learning, Groundwater level forecasting, Kumamoto, Japan

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Improving Detection of Tropical Cyclones by Deep Convolutional Neural Network through a Two-step Training

*TAKERU TSUCHIYA[1], Shunji Kotsuki[2], Ryota Kikuchi[3], Takeshi Umezawa[4], Noritaka Osawa[4]

1. Department of Information Engineering, Chiba University, Chiba, Japan, 2. Center for Environmental Remote Sensing, Chiba University, Chiba, Japan, 3. Office of Society Academia Collaboration for Innovation, Kyoto University, Japan, 4. Graduate School & Faculty of Engineering, Chiba University, Chiba, Japan

Detecting tropical cyclones (TCs) is important to mitigate disasters induced by TCs. The Japan Meteorological Agency operationally uses the Dvorak method that manually estimates TC intensities by cloud patterns. With the recent progress of machine learning algorithms, TC detections using deep neural network have been explored. Matsuoka et al. (2018) used a deep convolutional neural network (DCNN) to detect TCs or non-TC for simulated cloud images. They found that the classifications were less accurate when images were densely or sparsely covered by clouds.

This study aims at developing an efficient approach for training DCNN for TC or non-TC classifier. We first developed a VGG16-based DCNN that has one additional layer with two features before the classifier (Machine 1). We trained Machine 1 using Matsuoka et al. (2018)’ s cloud images, and found that the classification was less accurate when the two features were close to zero. Based on this preliminary results, we developed a new machine (Machine 2) that uses three inputs for the fully-connected NN: (1) cloud cover ratio, (2) two features from pre-trained Machine 1, and (3) outputs from standard VGG16-based DCNN. This two-step training improved detection accuracy significantly with relative to the classical VGG16. Although cloud images contain cloud cover ratio and two features implicitly, using “extracted features” explicitly enables efficient training with limited training data. At the conference, we will introduce the details of our DCNN approach together with preliminary unsuccessful experiments.

Keywords: Tropical Cyclones, Deep Learning

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[J] Oral | A (Atmospheric and Hydrospheric Sciences) | A-CG Complex & General

[A-CG43] Earth &Environmental Sciences and Artificial Intelligence/Machine Learning

convener:Tomohiko Tomita(Faculty of Advanced Science and Technology, Kumamoto University), Shigeki Hosoda(Japan Marine-Earth Science and Technology), Ken-ichi Fukui(Osaka University), Satoshi Ono(Kagoshima Univeristy), Chairperson:Shigeki Hosoda(Japan Marine-Earth Science and Technology), Tomohiko Tomita(Faculty of Advanced Science and Technology, Kumamoto University)
Thu. Jun 3, 2021 3:30 PM - 5:00 PM Ch.06 (Zoom Room 06)

In recent years, we have been required to explore various gigantic data leading earth and environmental sciences such as modern meteorology, oceanography, hydrology and so on to accomplish Society 5.0 and Sustainable Development Goals (SDGs). To examine such gigantic environmental data faithfully, it may be required to use the techniques of artificial intelligence/machine learning (AI/ML) including spatiotemporal data modeling of AI, prediction and detection by ML, techniques of automated data mining, and so forth. At the present, AI/ML is also expected to lead the data-driven science as a bridge connecting science and big data. This session calls for various studies applying the techniques of AI/ML to scientific/environmental issues and will discuss them in both natural and information sciences.

4:55 PM - 5:00 PM

[ACG43-12]Discussion

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[J] Oral | A (Atmospheric and Hydrospheric Sciences)：A-CG Complex & General

Thu. Jun 3, 2021 3:30 PM - 5:00 PM JST | Thu. Jun 3, 2021 6:30 AM - 8:00 AM UTC | Ch.10 Zoom Room 10

[A-CG44] Biogeochemical linkages between the surface ocean and atmosphere

convener:Sohiko Kameyama(Hokkaido University), Yoko Iwamoto(Graduate School of Integrated Sciences for Life, Hiroshima University), Noguchi Maki Aita(Japan Agency for Marine-Earth Science and Technology), Daisuke Sasano(Japan Meteorological Agency), Chairperson:Sohiko Kameyama(Hokkaido University)

Multi-scale vertical and horizontal ocean mixing processes can strongly influence the distribution of dissolved and suspended substances including macro- and micro-nutrients, and may impact on the global carbon cycles. The changes in nutrient dynamics generally affect the abundance, composition and metabolic activity of marine organisms such as phytoplankton and bacteria during the bloom. Marine phytoplankton can produce volatile organic compounds (VOCs) and marine atmospheric aerosols, which strongly influence on atmospheric chemistry. Primary and secondary organic and inorganic components produced via marine phytoplankton activity can contribute to the Earth's radiative forcing, and in turn marine ecosystems including biogeochemical processes directly or indirectly. Therefore, the biogeochemical cycles have a tight linkage between the ocean and the atmosphere. In order to understand physical, chemical and biological processes relevant to phytoplankton bloom formation in the ocean, dynamics of VOCs and marine aerosols in the atmosphere, and the biogeochemical linkage between the ocean and the atmosphere, we welcome new interdisciplinary presentations and active discussions on physical, chemical, and biological sciences both from ocean and atmospheric fields in this session. Studies linked to the Surface Ocean-Lower Atmosphere Study (SOLAS) project are good examples, but other related studies are also invited.

3:30 PM - 3:45 PM JST | 6:30 AM - 6:45 AM UTC

[ACG44-01] R/V Mirai cruise for IMPACT-SEA project 2021: Preliminary results

*Fumikazu Taketani[1], Kana Nagashima[1], Minoru Kitamura[1] (1.Japan Agency for Marine-Earth Science and Technology)

3:45 PM - 4:00 PM JST | 6:45 AM - 7:00 AM UTC

[ACG44-02] **Seasonal and interannual variations of surface water carbonate chemistry in the Indian sector of the Southern Ocean**

*Manami Tozawa[1], Daiki Nomura[1,2,3], Shin-ichiro Nakaoka[4], Masaaki Kiuchi[1], Daisuke Hirano[5], Shigeru Aoki[5], Hiroko Sasaki[6], Hiroto Murase[7] (1.Faculty of Fisheries Sciences, Hokkaido University, 2.Field Science Center for Northern Biosphere, Hokkaido University, 3.Arctic Research Center, Hokkaido University, 4.National Institute for Environmental Studies, 5.Institute of Low Temperature Science, Hokkaido University, 6.Fisheries Resources Institute, Japan Fisheries Research and Education Agency, 7.Tokyo University of Marine Science and Technology)

4:00 PM - 4:15 PM JST | 7:00 AM - 7:15 AM UTC

[ACG44-03] **Summer carbonate chemistry near the Totten Ice Shelf, Sabrina Coast, East Antarctica**

*Tetsuya Tamura[1], Daiki Nomura[1,2,3], Daisuke Hirano[3,4], Takeshi Tamura[5], Masaaki Kiuchi[1], Gen Hashida[5], Shigeru Aoki[4], Hiroko Sasaki[6], Hiroto Murase[7] (1.Faculty of Fisheries Science, Hokkaido University, 2.Field Science Center for Northern Biosphere, 3.Arctic Research Center, 4.Institute of Low Temperature Science, 5.National Institute of Polar Research, 6.Fisheries Resources Institute, Japan Fisheries Research and Education Agency, 7.Tokyo University of Marine Science and Technology)

4:15 PM - 4:30 PM JST | 7:15 AM - 7:30 AM UTC

[ACG44-04] Iodomethane and Iodoethane distributions in coastal seawater of subarctic Pacific and Northern Bering sea

*Atsushi Ooki[1], Keita Minamikawa[1], Fanxing Meng[1] (1.Hokkaido University)

4:30 PM - 4:45 PM JST | 7:30 AM - 7:45 AM UTC

[ACG44-05] Effects of marine nitrogen fixation on the formation of atmospheric water-soluble organic nitrogen revealed by a laboratory incubation experiment

*Tsukasa Dobashi[1,2], Koji Suzuki[2], Yuzo Miyazaki[1] (1. Institute of Low Temperature Science, Hokkaido Univ., 2.Graduate School of Env. Sci., Hokkaido Univ.)

4:45 PM - 5:00 PM JST | 7:45 AM - 8:00 AM UTC

[ACG44-06] Characterization of Adhesivity of marine organic aerosols by atomic force microscopy

*Kohei Ono[1], Ayumi Iwata[2], Takeshi Fukuma[3], Yoko Iwamoto[4], Koji Hamasaki[5], Atsushi Matsuki[6] (1.Graduate School of Natural Science and Technology, Kanazawa University, 2.Faculty of Science and Technology, Keio University, 3.Nano Life Science Institute, Kanazawa University, 4.Graduate School of Integrated Sciences for Life, Hiroshima University, 5.Atmosphere and Ocean Research Institute, The University of Tokyo, 6.Institute of Nature and Environmental Technology, Kanazawa University)

R/V Mirai cruise for IMPACT-SEA project 2021: Preliminary results

*Fumikazu Taketani[1], Kana Nagashima[1], Minoru Kitamura[1]

1. Japan Agency for Marine-Earth Science and Technology

We carried out the cruise to investigate the influence of atmospheric species to the marine ecosystem in the subarctic/subtropical of the North Pacific Ocean from February 13 to March 24 using R/V Mirai(IMPACT-SEA projest). In this cruise, we performed several observations. In the presentation, we are planning to introduce the preliminary results.

Keywords: air-sea interaction, deposition, marine ecosystem

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Seasonal and interannual variations of surface water carbonate chemistry in the Indian sector of the Southern Ocean

*Manami Tozawa[1], Daiki Nomura[1,2,3], Shin-ichiro Nakaoka[4], Masaaki Kiuchi[1], Daisuke Hirano[5], Shigeru Aoki[5], Hiroko Sasaki[6], Hiroto Murase[7]

1. Faculty of Fisheries Sciences, Hokkaido University, 2. Field Science Center for Northern Biosphere, Hokkaido University, 3. Arctic Research Center, Hokkaido University, 4. National Institute for Environmental Studies, 5. Institute of Low Temperature Science, Hokkaido University, 6. Fisheries Resources Institute, Japan Fisheries Research and Education Agency, 7. Tokyo University of Marine Science and Technology

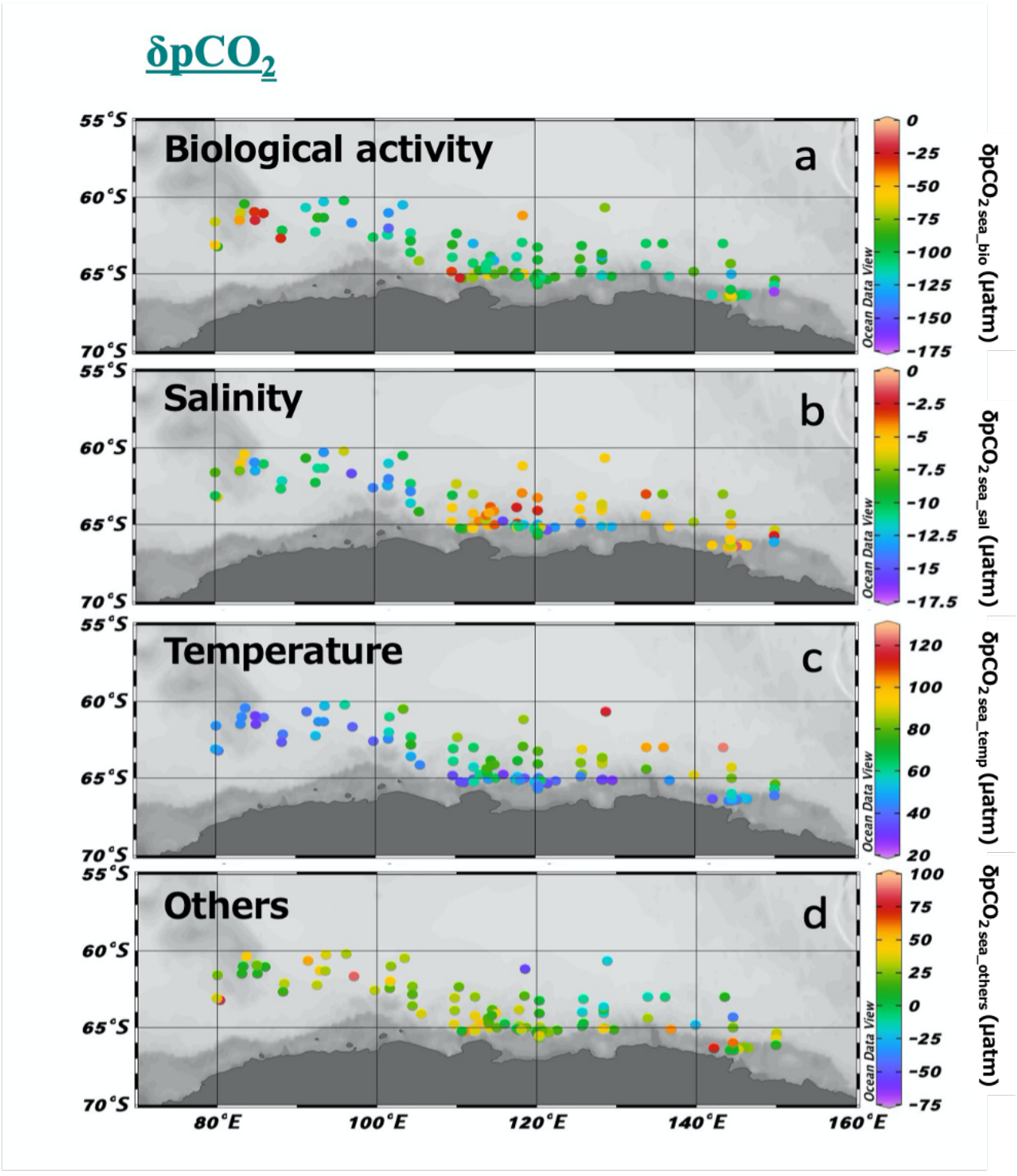
To assess carbon cycling in the Indian sector of the Southern Ocean (80˚E–150˚E, south of 60˚S) quantitatively, we measured seawater temperature, salinity, chlorophyll-*a* concentration, partial pressure of carbon dioxide (pCO_2), dissolved inorganic carbon (DIC) concentration, alkalinity (TA), and nutrient concentrations.

The air-sea CO_2 flux in this region was evaluated to be −7.6±10.9 mmol C m^{-2} day^{-1} (−75.6 −+14.1 mmol C m^{-2} day^{-1}) suggesting that the region was a weak sink. Then, we estimated the change in pCO_2 from winter to summer (pCO_2) due to changes in seawater temperature, salinity, and biological activity on the basis of the assumption that the observed values of DIC concentration and TA in the temperature minimum layer remain the same as in the winter under sea-ice with a temperature of −1.8℃ and salinity of 34.25. The spatial distribution of pCO_2 in the western area (80˚E–120˚E) observed from December to early January was influenced by biological activity, and that in the eastern area (120˚E–150˚E) observed from January to February was influenced by temperature and salinity.

We also examined the annual change in oceanic and atmospheric CO_2 concentrations (xCO_2) between 1996 and 2019. The mean values of oceanic and atmospheric xCO_2 increased by 24 ppm and 45 ppm, respectively. This suggests that the main reason of the rise in oceanic xCO_2 is that the ocean have absorbed CO_2 from atmosphere as a result of the rise in atmospheric xCO_2. However, it also indicates that the oceanic xCO_2 rise is due to the rise in sea water temperature and changes in the ocean circulation.

Keywords: Southern Ocean, carbon cycling, pressure of carbon dioxide, air-sea CO2 flux

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Summer carbonate chemistry near the Totten Ice Shelf, Sabrina Coast, East Antarctica

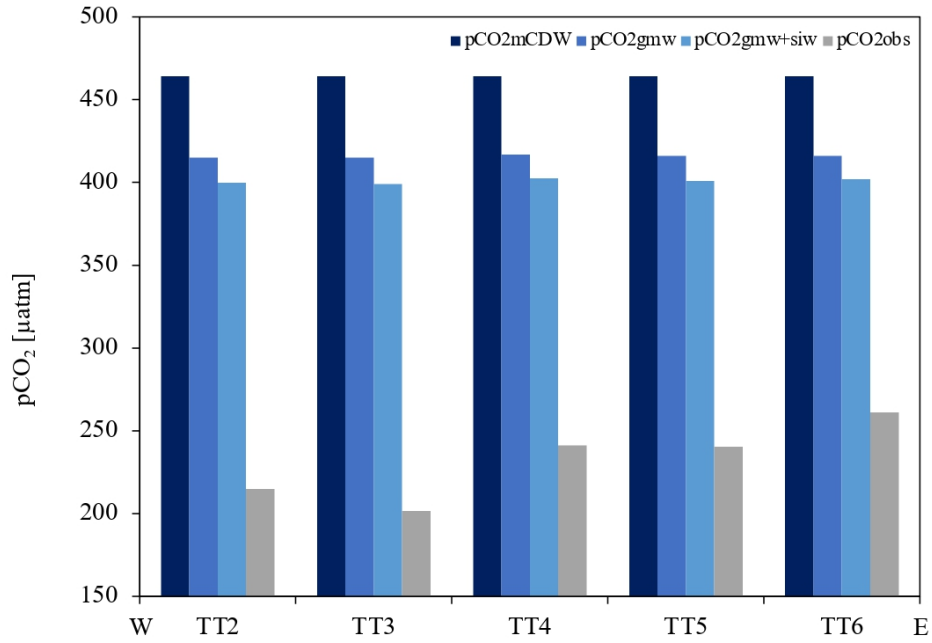
*Tetsuya Tamura[1], Daiki Nomura[1,2,3], Daisuke Hirano[3,4], Takeshi Tamura[5], Masaaki Kiuchi[1], Gen Hashida[5], Shigeru Aoki[4], Hiroko Sasaki[6], Hiroto Murase[7]

1. Faculty of Fisheries Science, Hokkaido University, 2. Field Science Center for Northern Biosphere, 3. Arctic Research Center, 4. Institute of Low Temperature Science, 5. National Institute of Polar Research, 6. Fisheries Resources Institute, Japan Fisheries Research and Education Agency, 7. Tokyo University of Marine Science and Technology

To clarify the effect of basal melting of Antarctic ice sheet on the marine biogeochemical components in the coast of the Southern Ocean, dissolved inorganic carbon (DIC), total alkalinity (TA), nutrients (NO_3^-, PO_4^{3-}, $Si(OH)_4$), oxygen stable isotope ratio ($\delta^{18}O$), chlorophyll *a* were measured off from offshore slope (ice margin area) to Totten Ice Shelf ice front (sea ice area) during summer 2018 and 2019 conducted by *Kaiyo-maru* and *Shirase*. The distribution of DIC concentration, TA and nutrients concentration was corresponded to a following ocean current: (1) mCDW existing on the offshore slope flows beneath the Totten Ice Shelf along the trough, (2) the flow mixes with Totten Ice Shelf basal melt water and (3) the becomes low density and rises to the surface. DIC concentration and TA on the surface of the ice front were strongly influenced by the dilution effect of the ice shelf basal melt water and the inflow of mCDW. The ratio of ice shelf basal melt water with respect to the other water masses (sea ice water and mCDW) calculated using $\delta^{18}O$ was about 1.4% and the ratio of sea ice melt water was 2.9 % and the rest ratio was inflow of mCDW. Because of the dilution effect, DIC concentration decreased about 80 μmol kg^{-1}, and this decrease was corresponded to a decrease of about 64 μatm for the partial pressure of carbon dioxide (pCO_2). However, the surface of the ice front was strongly influenced by biological processes. The nDIC and nTA that normalized to salinity (34.3 pus) to remove the dilution effect of melt water were changed along nDIC:nTA = 106:16 by the photosynthesis of phytoplankton. Furthermore, the net community production (NCP) from 20 to 100 dbar was higher than that for the previous study (December 31st, 2014-January 1st, 2015, [Arroyo et al., 2019]) because the open water area was higher and availability of light for phytoplankton during this study observation was greater in our study period than those in previous study. Therefore, the decrease of more than 150 μatm for pCO_2 would be resulted by the biological productivity in this study. On the west side of the ice shelf, both the ratio of ice shelf basal melt water and NCP were higher and pCO_2 was lower than those of east side of the ice shelf. Therefore, the mCDW mixed with the ice shelf basal melt water floats on the west side of the ice shelf. This study highlighted that ice shelf basal melt water has a significant impact on marine biogeochemical components.

Keywords: Southern Ocean, ice shelf, basal melting, carbon cycling

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Iodomethane and Iodoethane distributions in coastal seawater of subarctic Pacific and Northern Bering sea

*Atsushi Ooki[1], Keita Minamikawa[1], Fanxing Meng[1]

1. Hokkaido University

Volatile organic iodine compounds (VOIs) such as iodomethane (CH_3I), iodoethane (C_2H_5I), diiodomethane (CH_2I_2) and chloroiodomethane (CH_2ClI) carry iodine from the ocean into the atmosphere (Chameides and Davis, 1980). These VOIs have the potential to deplete ozone in boundary layer air on a wide scale (e.g., Carpenter et al., 1999) via the catalytic ozone destruction of iodine atom released from VOIs. Marine organisms are the dominant producers of VOIs. Many studies have reported the productions of VOIs from marine organisms of macro algae, micro algae, photosynthetic bacteria, and heterotrophic bacteria (e.g. Schall et al. 1994; Tokarczyk and Moore 1994; Hughes et al. 2008). The vertical distributions of VOIs in water column have been measured in many ocean areas, however, VOIs in ocean sediment have not ever measured so far. In this study, we have firstly measured VOIs in coastal ocean sediment of Chukchi Sea, northern Bering Sea, and Funka bay, Japan. We found that iodoethane (C_2H_5I), which is a minor VOIs anywhere in the air and ocean water, becomes overwhelming majority of VOIs in the surface of ocean sediment on the sea floor of Arctic and subarctic coastal area. The iodoethane concentrations in the sediment drastically increased soon after the diatom spring bloom in water column above the sediment. We verified that the aggregates of dead diatom cells in a dark incubation bottle produced large amounts of iodoethane as well as small amounts of iodomethane (CH_3I) within 7 days. Live marine algae have been thought to drive sea-air cycle of iodine via. biogenic CH_3I, CH_2ClI, and CH_2I_2 productions. Dead marine algae (diatom) drive sea-sediment cycle of iodine via. biogenic C_2H_5I production. Iodoethane in the ocean sediment will give us a key to understand global iodine cycle.

Keywords: haloarbon, Volatile Organic Compounds (VOCs), Iodine

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Effects of marine nitrogen fixation on the formation of atmospheric water-soluble organic nitrogen revealed by a laboratory incubation experiment

*Tsukasa Dobashi[1,2], Koji Suzuki[2], Yuzo Miyazaki[1]

1. Institute of Low Temperature Science, Hokkaido Univ., 2. Graduate School of Env. Sci., Hokkaido Univ.

Marine atmospheric aerosols formed in the sea surface play a key role in the climate system, as they act as cloud condensation nuclei (CCN) and ice nuclei (IN) and thus can control the atmospheric radiative budget through cloud formation. Water-soluble organic nitrogen (WSON) in marine aerosols affects the physicochemical properties such as water-solubility, acidity, and light-absorbing properties of aerosol particles. A previous ship-board measurement of atmospheric and marine biological paraments in the subtropical North Pacific suggests that nitrogen-fixation in the ocean surface significantly contributed to the formation of aerosol WSON in the atmosphere. *Trichodesmium* is a genus of filamentous cyanobacteria and is one of the most representative nitrogen-fixing organisms, which is widely distributed in the tropical and subtropical oceans. It has been recognized that *Trichodesmium* contributes up to approximately 50% of marine nitrogen fixation in the global ocean. However, effects of nitrogen fixation in the ocean surface on the formation of atmospheric reactive nitrogen have not been understood. This study aims to elucidate the contribution of nitrogen-fixing organisms to the formation of atmospheric reactive nitrogen including WSON by a laboratory incubation experiment.

In the laboratory experiment, *Trichodesmium erythraeum* IMS101 (hereafter referred to as *Trichodesmium*) was cultured in artificial seawater YBC-II medium (15-L) in a polycarbonate bottle installed in an incubator, the temperature of which was set at 25°C. Atmospheric aerosol ($PM_{2.5}$) and gas samples were collected on quartz fiber filters set at three stages of a NILU impactor. Atmospheric and seawater samples were collected every 24 hours. Water-soluble total nitrogen (WSTN) and water-soluble organic carbon (WSOC) concentrations in the atmospheric sample as well as dissolved nitrogen (DN) and dissolved organic carbon (DOC) concentrations in the seawater samples were measured by a total organic carbon analyzer with a TN unit (TOC/TN). The WSON concentration was defined as the difference between the concentrations of WSTN and inorganic nitrogen (IN) which was measured by ion chromatography. To investigate the temporal variation of *Trichodesmium*, *in vivo* chlorophyll *a* (Chl *a*) fluorescence intensity was measured using a Qubit 2.0 fluorometer and chlorophyll *a* concentration was measured using an ultra-high performance liquid chromatography (UHPLC). In addition, heterotrophic bacterial concentration in the seawater was measured using a flow cytometry.

A life cycle of *Trichodesmium* was confirmed by monitoring the Chl *a* concentration in seawater during the incubation period of about one month. In the growth phase, the increase in the Chl *a* concentrations corresponded well with the increase in the DN and DOC concentrations as well as the DN/DOC ratio in the seawater. The results suggest that the growth of *Trichodesmium* released DN and DOC in the seawater, where DN was preferentially released more than DOC. The temporal variation of the Chl *a* concentration showed a significant positive correlation with the WSON concentration in the atmospheric samples. The overall results demonstrate that the growth of *Trichodesmium* in seawater contributed to the formation of atmospheric WSON, mostly through the nitrogen fixation process.

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Keywords: Organic nitrogen, Marine atmospheric aerosol, Nitrogen fixation, Trichodesmium, Biogeochemical linkage between the atmosphere and the ocean

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Characterization of Adhesivity of marine organic aerosols by atomic force microscopy

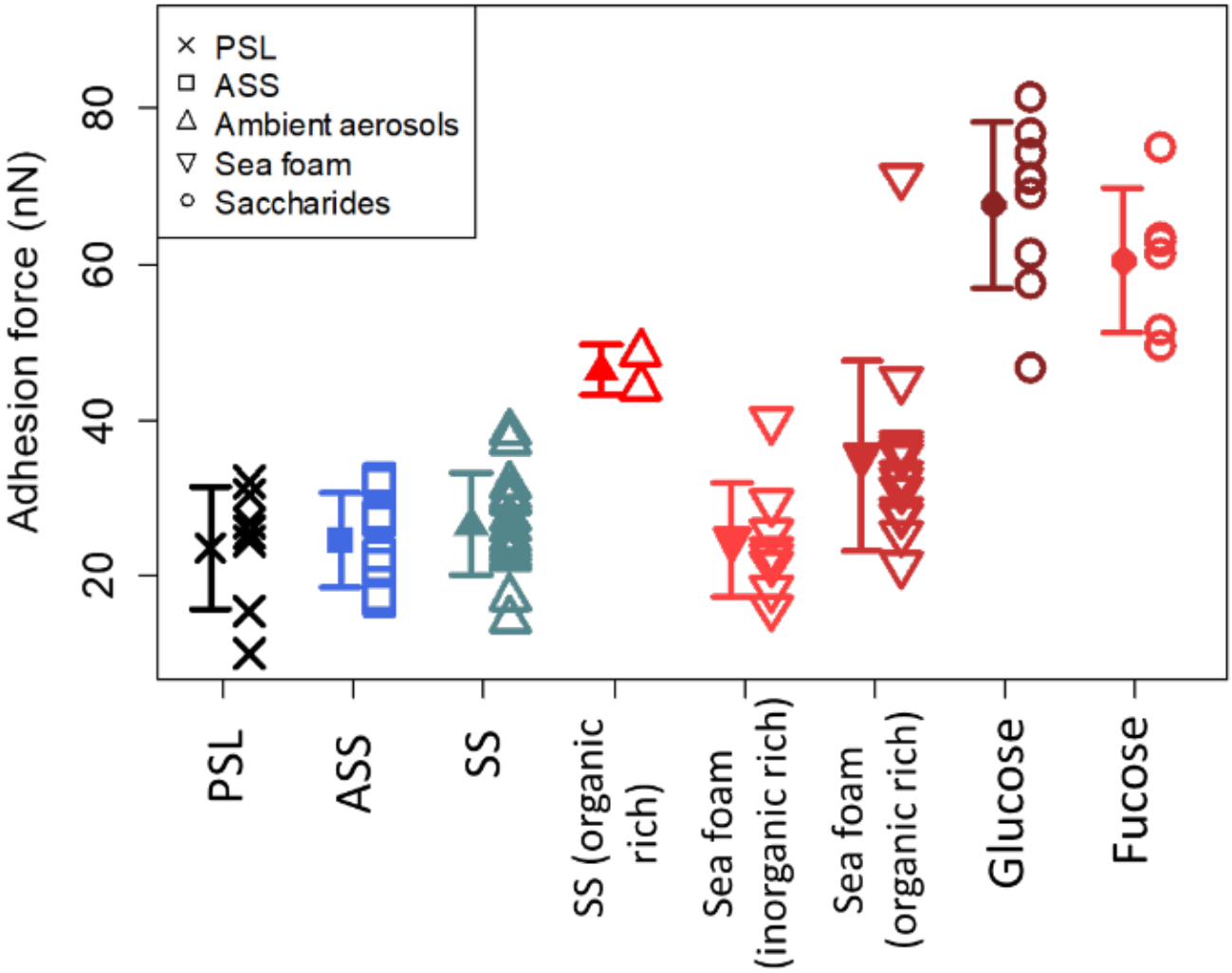
*Kohei Ono[1], Ayumi Iwata[2], Takeshi Fukuma[3], Yoko Iwamoto[4], Koji Hamasaki[5], Atsushi Matsuki[6]

1. Graduate School of Natural Science and Technology, Kanazawa University, 2. Faculty of Science and Technology, Keio University, 3. Nano Life Science Institute, Kanazawa University, 4. Graduate School of Integrated Sciences for Life, Hiroshima University, 5. Atmosphere and Ocean Research Institute, The University of Tokyo, 6. Institute of Nature and Environmental Technology, Kanazawa University

Aerosol particles can trigger various environmental issues even after their deposition at the interface with the atmosphere. For example, sea spray aerosols (SSA) can deposit on the surfaces and cause corrosion of infrastructures such as electrical power cables and tower, as well as related polymer insulators especially in coastal areas. The adhesion force is the force by which aerosol particles continue to remain in contact with the deposition surface. The adhesion behavior of ambient aerosol particles is largely controlled by this force but has not earned enough attention. The aim of this study was to evaluate the physical property of SSA by measuring adhesion forces of simulated SSA on an individual particle basis using atomic force microscopy (force-distance curve mapping method). In order to simulate an organic enriched SSA, aerosols were generated using a bulk sea foam sample collected at Noto Peninsula during the Sea Surface Microlayer-Aerosol Project (SSMAP). The adhesion force of sea foam particles was compared with that of standard monosaccharide (glucose and fucose), artificial sea salt (ASS), as well as ambient SS particles. Mono saccharide particles showed significantly larger adhesion forces than ASS and SS. In addition, it was found that a few of sea foam particles and ambient SS particles showed similar adhesion forces and morphological features as the pure mono saccharides, suggesting that organic (e.g. mono saccharides) enriched SSA can be significantly more adhesive than the inorganic salts. Therefore, in the case of evaluating adhesive property of SSA, it is necessary to consider the presence of organics such as saccharides.

Keywords: Sea Spray Aerosol, Sea Foam, Atomic Force Microscopy (AFM), Adhesion Force, Deposition

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[J] Oral | H (Human Geosciences)：H-RE Resource and Engineering Geology

Thu. Jun 3, 2021 1:45 PM - 3:15 PM JST | Thu. Jun 3, 2021 4:45 AM - 6:15 AM UTC | Ch.15 Zoom Room 15

[H-RE12] Resource Geology

convener:Tsubasa Otake(Division of Sustainable Resources Engineering, Faculty of Engineering, Hokkaido University), Kenzo Sanematsu(Mineral Resource Research Group, Institute for Geo-Resources and Environment, Geological Survey of Japan, National Institute of Advanced Industrial Science and Technology), Ryohei Takahashi(Graduate School of International Resource Sciences, Akita University), Tatsuo Nozaki(Submarine Resources Research Center, Research Institute for Marine Resources Utilization, Japan Agency for Marine-Earth Science and Technology), Chairperson:Tatsuo Nozaki(Submarine Resources Research Center, Research Institute for Marine Resources Utilization, Japan Agency for Marine-Earth Science and Technology), Ryohei Takahashi(Graduate School of International Resource Sciences, Akita University)

Ore deposits containing valuable elements and minerals at high concentrations in supracrustal rocks are formed by the Earth's dynamics including magmatism, hydrothermal activity, metamorphism, and weathering. The formation of ore deposits is also closely associated with global environmental changes and biological evolution in the Earth's history. Involvement of difference academic fields in earth sciences including geology, petrology, geochemistry, mineralogy, and microbiology is required to understand the genesis of ore deposits. The field of resource geology is essential not only for efficient exploration and development of ore deposits but also for better understanding and assessment of hazardous elements that may be caused by the resource development. This session widely covers various topics of field investigation and observation, laboratory experiments, theoretical calculation, development of analytical methods and others related to the supracrustal migration and concentration of elements.

1:45 PM - 2:00 PM JST | 4:45 AM - 5:00 AM UTC

[HRE12-01] Formation of various types of iron ore deposits in the Earth's surface environments: A review

*Tsubasa Otake[1] (1.Division of Sustainable Resources Engineering, Faculty of Engineering, Hokkaido University)

2:00 PM - 2:15 PM JST | 5:00 AM - 5:15 AM UTC

[HRE12-02] A rapid analytical method of Re-Os isotope on sulfides by MC-ICP-MS and sparging method: Its application to the Kamaishi deposit in NE Japan

*Mizuki Ogasawara[1], Junichiro Ohta[1,2], Mizuki Ishida[1], Moei Yano[2,1], Ryota Maki[1], Tatsuo Nozaki[3,1,4,2], Yutaro Takaya[5,3,2], Koichiro Fujinaga[2,1], Kazutaka Yasukawa[1,2], Yasuhiro Kato[1,2] (1.School of Engineering, The University of Tokyo, 2.ORCeNG, Chiba Institute of Technology, 3.JAMSTEC, 4.Kobe University, 5.Waseda University)

2:15 PM - 2:30 PM JST | 5:15 AM - 5:30 AM UTC

[HRE12-03] Geochemical Characterization of Rivers Contaminated by Acid Mine Drainage from an Abandoned Mine in Northern Japan

*Sereyroith Tum[1], Tatsuya Matsui[1], Frances Chikanda[1], Ryosuke Kikuchi[2], Yoko Ohtomo[2], Tsubasa Otake[2], Susumu Norota[3], Tsutomu Sato[2] (1.Graduate School of Engineering, Hokkaido University, 060-8628, Sapporo, Japan , 2.Faculty of Engineering, Hokkaido University, 060-8628, Sapporo, Japan, 3.Geological Survey of Hokkaido, Hokkaido Research Organization, 060-0819, Sapporo, Japan)

2:30 PM - 2:45 PM JST | 5:30 AM - 5:45 AM UTC

[HRE12-04] Utilizing isotopic Fe fractionations to trace the behaviour of dissolved and colloidal Fe in mine drainages

*Frances Chikanda[1], Tsubasa Otake[2], Tatsuya Matsui[1], Sereyroith Tum[1], Tsutomu Sato[2] (1.Division of Sustainable Resources Engineering, Graduate School of Engineering, Hokkaido University, 2.Division of Sustainable Resources Engineering, Faculty of Engineering, Hokkaido University)

2:45 PM - 3:15 PM JST | 5:45 AM - 6:15 AM UTC
[HRE12-05] Discussion

Formation of various types of iron ore deposits in the Earth’s surface environments: A review

*Tsubasa Otake[1]

1. Division of Sustainable Resources Engineering, Faculty of Engineering, Hokkaido University

Iron is the fourth abundant element on the Earth’s surface, and it has been mined and utilized for various industrial activities. Whereas average continental crust contains ~5 wt% of Fe (as FeO), the minimum Fe grade for minable ore is 20–25 wt%. Although its concentration factor (4–5) is not as high as that for some other elements, formation of iron ore deposits requires crystallization of iron as oxides (e.g., magnetite and hematite), not either silicates or sulfides, which occurs more commonly in ordinary igneous and sedimentary rocks. There are various geological processes, including magmatic, hydrothermal, and sedimentary processes, to concentrate Fe and form Fe ore deposits. However, ore genesis may be ambiguous for some deposits, which makes exploration difficult. The objective of this study is to review various types of Fe ore deposits and geochemical factors controlling concentration of Fe in the Earth’s surface environments. Some recent geochemical techniques to indicate Fe ore genesis are also reviewed.

Based on previous literatures, Fe ore deposits can be divided into orthomagmatic (or Fe-Ti-V type), iron oxide-apatite (IOA) type (or Kiruna type), skarn, submarine volcanogenic iron oxide (SVIO), banded iron formations (BIF), and phanerozoic iron stone. Production of iron ores, particularly high-grade ores, in the world is currently dominated by those associated with BIFs, Fe-rich chemical sedimentary rocks formed in Precambrian era. Complication of ore reserves and average grade on various (~200) Fe ore deposits over the world demonstrates that a number of large and high-grade Fe deposits belong to BIF-associated deposits although some other types of Fe deposits, such as orthomagmatic, Kiruna-type, skarn, contain gigantic deposits (>1 billion ton reserve). Although other hydrothermal and sedimentary deposits contain fairly large deposits, the average ore grades are not as great as those associated with BIFs.

In magmatic processes, fractional crystallization may concentrate Fe as magnetite since it is one of the minerals that crystallize at the early stage of magma cooling. However, further enrichment of Fe to form Fe-Ti-V or IOA type deposits requires to decrease in SiO_2 activity in magma, possibly due to immiscible segregation of oxide melts from silicate melts. Although hydrothermal processes typically precipitate Fe as sulfides (e.g., pyrite), highly oxidized and Cl^--rich fluids may cause enrichment of Fe as oxides in some magmatic-hydrothermal systems. Other important parameters to form hydrothermal Fe deposits include CO_2 fugacity and temperature for skarn and SVIO Fe deposits, respectively. In sedimentary processes, redox state of sweater is the key parameter since reduced seawater is needed to dissolve and transport Fe in a large scale in the surface environments. However, primary precipitates and its mechanism to form BIF in Archean is still controversial. Recently, trace element chemistry of magnetite as well as Fe and O isotopes are developing geochemical indicators for Fe ore genesis although there will be more case studies needed to verify the indicators.

Keywords: Iron, concentration factor, magma, hydrothermal fluid, sedimentation, redox conditions

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A rapid analytical method of Re-Os isotope on sulfides by MC-ICP-MS and sparging method: Its application to the Kamaishi deposit in NE Japan

*Mizuki Ogasawara[1], Junichiro Ohta[1,2], Mizuki Ishida[1], Moei Yano[2,1], Ryota Maki[1], Tatsuo Nozaki[3,1,4,2], Yutaro Takaya[5,3,2], Koichiro Fujinaga[2,1], Kazutaka Yasukawa[1,2], Yasuhiro Kato[1,2]

1. School of Engineering, The University of Tokyo, 2. ORCeNG, Chiba Institute of Technology, 3. JAMSTEC, 4. Kobe University, 5. Waseda University

The Re-Os isotope system is a powerful tool in geological/geochemical studies, especially in radiometric dating of sulfide minerals, black shale and meteorite. Since both Re and Os are siderophile and chalcophile elements enriched in various sulfide minerals, the Re-Os isotope geochronology has been applied to the direct age determination of sulfide mineralization. However, the conventional analytical method of the Re-Os isotope dating using a N-TIMS is time-consuming and requires some reagents harmful to the human body. Also, the simpler, more rapid and safer sparging method for Os isotope analysis using a MC-ICP-MS [1,2] had not been applied to sulfide minerals.

Here, we present an improved analytical method for the Re-Os isotope and its first application to the Kamaishi skarn sulfide deposits in NE Japan. In our method, 0.4 g of powdered sulfide was digested by 1 mL of $HClO_4$ and 4 mL of inverse aqua regia in the Carius tube, which was analyzed using a MC-ICP-MS. The isotopic compositions of $^{187}Os/^{188}Os$ and $^{187}Re/^{188}Os$ obtained in the present study showed good agreements with those obtained by the conventional method digesting 0.5 g of the same powdered sample using 10 mL of inverse aqua regia and measuring with a N-TIMS. The less volume of sample solution is favorable for Re-Os isotope analysis by the sparging method using a MC-ICP-MS to accomplish low blank level, which enables us a simpler and more efficient analytical procedure for Re-Os dating on sulfide deposits.

1: Nozaki, T. et al. (2012) *Geostand. Geoanal. Res.* **36**, 131-148.

2: Kimura, J.-I. et al. (2014) *J. Anal. Atom. Spectr.* **29**, 1483-1490.

Keywords: Re-Os isotopes, MC-ICP-MS, sparging method, sulfide deposits

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Geochemical Characterization of Rivers Contaminated by Acid Mine Drainage from an Abandoned Mine in Northern Japan

*Sereyroith Tum[1], Tatsuya Matsui[1], Frances Chikanda[1], Ryosuke Kikuchi[2], Yoko Ohtomo[2], Tsubasa Otake[2], Susumu Norota[3], Tsutomu Sato[2]

1. Graduate School of Engineering, Hokkaido University, 060-8628, Sapporo, Japan , 2. Faculty of Engineering, Hokkaido University, 060-8628, Sapporo, Japan, 3. Geological Survey of Hokkaido, Hokkaido Research Organization, 060-0819, Sapporo, Japan

Acid mine drainage (AMD) of an abandoned mine in northern Japan riches of Fe, As, Pb, and Cd, has been flowing into river A and B. At the monitoring point, the contaminants of river A decreased to below the environmental standard level. In contrast, river B's contaminants remain slightly higher than the environmental standard level, even though the two rivers have the same contamination source. The natural process in river A makes the contaminants attenuated, but not in the river B. If the geochemical differences between A and B are well understood, information from the two rivers is ambiguously valuable for the geochemical passive treatment in river B. Therefore, river A and river B detail studies were investigated to determine the geochemical differences in both rivers, and define the natural attenuation mechanisms in river A.

AMD from both rivers contains a high ferric iron concentration with an average pH of 2.8. After AMD having mixed with the natural river water, river A's pH is 3.1. The formation of schwertmannite (ferric hydroxide sulfate mineral) appears on the riverbed. At the mixing point, As concentration decrease due to its adsorption on to schwertmannite surface. Yet, the concentrations of Pb and Cd were decreased by dilution of the natural water in river A. Oppositely, the pH of AMD in river B pH is 2.9 after mixing with the natural river water. No reduction of dissolved ferric, As, Pb, and Cd concentrations, neither precipitation of ferric minerals such as schwertmannite, were significantly found after the mixing in river B. Dilution of the natural river water plays an important role to make the geochemical differences in the study area. The mixing ratios of both rivers to the natural water do not only control the pH changes, but it is also responsible for the decreasing of the contaminants' concentration in the rivers. The dilution ratio of river A to the natural water is comparatively more than it is in river B. Learning from the natural attenuation process in river A, the geochemical passive treatment of river B is applicable by increasing pH to 3.2 by using a dilution method and an open limestone channel.

Keywords: Natural attenuation, Schwertmannite , Adsorption

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Utilizing isotopic Fe fractionations to trace the behaviour of dissolved and colloidal Fe in mine drainages

*Frances Chikanda[1], Tsubasa Otake[2], Tatsuya Matsui[1], Sereyroith Tum[1], Tsutomu Sato[2]

1. Division of Sustainable Resources Engineering, Graduate School of Engineering, Hokkaido University, 2. Division of Sustainable Resources Engineering, Faculty of Engineering, Hokkaido University

Mining-related water contamination is on the rise, thereby increasing the popularity of passive treatment in mine drainages. Fe, a commonly occurring element in mine drainages significantly affects the behaviour of other elements, therefore, understanding its behaviour would highlight the fate of the co-existing elements. This study utilizes iron isotope fractionations as important tracers of the contamination caused by mining, given that varying Fe sources and phases have varied δ^{56}Fe values.
An investigation was carried out at two mine drainages; circumneutral mine drainage that has Fe^{2+} input, that oxidizes to Fe^{3+}, resulting in the formation of ferrihydrite colloids, and acidic mine drainage that has a Fe^{3+}input, which, through hydrolysis, forms schwertmannite colloids. The isotopic fractionations were observed in three fractions; the total (0.2 μm + 200 kDa), colloidal (0.2 μm to 200 kDa) and dissolved (< 200 kDa).
In both drainages, the total fractions displayed δ^{56}Fe values representing averaged isotopic fractionation values of the different filtered sizes and that are near continental crust values (0.07 ±0.03 ‰). However, in the circumneutral system, clear fractionation was observed in the dissolved and colloidal fractions. The colloidal fraction had heavier δ^{56}Fe values compared to the dissolved fraction, which was attributed to the preferential complexation of heavier Fe by hydroxyl groups to form stronger bonds. This trend was not seen in the acidic drainage, thereby strongly showing that the oxidation process is a significant factor for the δ^{56}Fe fractionation. An overall negative fractionation is observed in both colloidal and dissolved fractions towards the downstream. These trends correspond with the Rayleigh fractionation model; however, misfits are observed, particularly in the colloidal fraction. The misfit, $\Delta^{56}Fe_{colloid\text{-}rayleigh}$ is considered to reflect the Fe colloids transported in the drainage.
Utilizing Fe isotopes, we understand that (i) filtration of samples highlights δ^{56}Fe fractionation behaviours, (ii) a certain amount of Fe in the drainage is transported in colloidal phase to rivers, transporting along the other toxic elements.

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[J] Oral | H (Human Geosciences) | H-RE Resource and Engineering Geology

[H-RE12] Resource Geology

convener:Tsubasa Otake(Division of Sustainable Resources Engineering, Faculty of Engineering, Hokkaido University), Kenzo Sanematsu(Mineral Resource Research Group, Institute for Geo-Resources and Environment, Geological Survey of Japan, National Institute of Advanced Industrial Science and Technology), Ryohei Takahashi(Graduate School of International Resource Sciences, Akita University), Tatsuo Nozaki(Submarine Resources Research Center, Research Institute for Marine Resources Utilization, Japan Agency for Marine-Earth Science and Technology), Chairperson:Tatsuo Nozaki(Submarine Resources Research Center, Research Institute for Marine Resources Utilization, Japan Agency for Marine-Earth Science and Technology), Ryohei Takahashi(Graduate School of International Resource Sciences, Akita University)

Thu. Jun 3, 2021 1:45 PM - 3:15 PM Ch.15 (Zoom Room 15)

Ore deposits containing valuable elements and minerals at high concentrations in supracrustal rocks are formed by the Earth's dynamics including magmatism, hydrothermal activity, metamorphism, and weathering. The formation of ore deposits is also closely associated with global environmental changes and biological evolution in the Earth's history. Involvement of difference academic fields in earth sciences including geology, petrology, geochemistry, mineralogy, and microbiology is required to understand the genesis of ore deposits. The field of resource geology is essential not only for efficient exploration and development of ore deposits but also for better understanding and assessment of hazardous elements that may be caused by the resource development. This session widely covers various topics of field investigation and observation, laboratory experiments, theoretical calculation, development of analytical methods and others related to the supracrustal migration and concentration of elements.

2:45 PM - 3:15 PM

[HRE12-05]Discussion

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[J] Oral | H (Human Geosciences)：H-TT Technology & Techniques

Thu. Jun 3, 2021 9:00 AM - 10:30 AM JST | Thu. Jun 3, 2021 12:00 AM - 1:30 AM UTC | Ch.16 Zoom Room 16

[H-TT16] Development and application of environmental traceability methods

convener:Ichiro Tayasu(Research Institute for Humanity and Nature), Ki-Cheol Shin(Research Institute for Humanity and Nature), Nozomu Takeuchi(Chiba University), Chairperson:Nozomu Takeuchi(Chiba University)

Modern society uses almost all the elements present in the natural world. Although there have long been calls for the sustainable use of the resources that provide these elements and the building of human societies that are in harmony with the environment, the survival of the human race is increasingly at risk as a result of qualitative changes to the environment as a whole. Implementation by the society of methodologies for diagnosing and tracking these various elements of the natural environment and their relationships with humans are now required.
Elements cycle within and among the Earth system spheres, human society, and the human body. Information on the concentrations and stable isotopes of elements is a powerful tool for tracing this cycling and has been applied in studies of atmosphere-hydrosphere circulation, ecological systems, and the life, health, and history of humans. We propose a session to discuss the development and applications of environmental traceability methods toward the goal of establishing traceability in natural and human systems.
We encourage the presentation of research integrating isotopic information in various disciplines, such as geochemistry, hydrology, ecology, geology, mineralogy, anthropology, food science, and forensics. We call the research Environmental Isotope Study.

9:00 AM - 9:15 AM JST | 12:00 AM - 12:15 AM UTC

[HTT16-01] Application of environmental traceability methodology by multi-isotopes

*Ichiro Tayasu[1], Ki-Cheol Shin[1] (1.Research Institute for Humanity and Nature)

9:15 AM - 9:30 AM JST | 12:15 AM - 12:30 AM UTC

[HTT16-02] Daily variation in winter precipitation isotopes over Hirosaki and associate atmospheric circulation - Case study of a winter season 2019/2020 -

*Akiyo Yatagai[1], Syota Nishioka[2], Kei Yoshimura[3] (1.Graduate School of Science and Technology, Hirosaki University, 2.Faculty of Science and Technology, Hirosaki University, 3.IIS Chiba Experimental Station, The University of Tokyo)

9:30 AM - 9:45 AM JST | 12:30 AM - 12:45 AM UTC

[HTT16-03] Identification of snow characteristics in the basin to applied chemical composition and meteorological hydrological data

*kawagoe seiki[1], shiho yabusaki[2] (1.Faculty of Symbiotic Systems science/Fukushima university, 2.Research institute for Humanity and Nature)

9:45 AM - 10:00 AM JST | 12:45 AM - 1:00 AM UTC

[HTT16-04] Distribution of trace element concentrations in groundwater and spring water near coastal and inland area of Fukushima prefecture

*Shiho Yabusaki[1] (1. Research Institute for Humanity and Nature・Faculty of Symbiotic Systems Science, Fukushima University)

10:00 AM - 10:15 AM JST | 1:00 AM - 1:15 AM UTC

[HTT16-05] Response of forest ecosystems to reduction of atmospheric sulfur deposition

*Hiroyuki Sase[1], Tsuyoshi Ohizumi[1], Yayoi Inomata[2], Naoyuki Yamashita[3], Toko Tanikawa[4], Masamichi Takahashi[3], Tatsuyoshi Saito[5], Masayuki Morohashi[1], Hiroki Yotsuyanagi[1] (1.Asia Center for Air Pollution Research, 2.Kanazawa University, 3.Forestry and Forest Products Research Institute, 4.Nagoya University, 5.Niigata Prefectural Government)

10:15 AM - 10:30 AM JST | 1:15 AM - 1:30 AM UTC

[HTT16-06] Estimate the origin of nutrients supplied to coastal areas using Ulva pertusa's nitrogen and carbon stable isotope ratios.

*Tatsuhiro Ishida[1], Osamu Tominaga[1], Ryo Sugimoto[1], Naoki Kisa[1], Keisuke Koba[2], Keitaro Fukushima[2]
(1.Fukui Prefectural University, 2.Center for Ecological Research,Kyoto University)

Application of environmental traceability methodology by multi-isotopes

*Ichiro Tayasu[1], Ki-Cheol Shin[1]

1. Research Institute for Humanity and Nature

Stable isotope ratios of elements, together with the concentrations of elements, can trace a matter flow, the environmental condition of sites, ecosystem structure, and food products. Spatio-temporal variation of isotope ratios of multiple elements (multi-isoscapes) can be used to study the earth systems from local to global points of view. Using the traceability function of the multi-isotopes, we can conduct research that contributes to solving global environmental problems covering various regions and time scales. Spatio-temporal variation of multi-isotopes can be used for studying earth systems, ranging from local to global scales. The information may serve as a key decision-making factor for local people to consider water, food, and environmental security, all of which are fundamental for the sustainability of human society.

Research Institute for Humanity and Nature is conducting collaborative research named “Environmental Isotope Study” that researchers from various universities and research institutes can use facilities of mass spectrometers for multiple elements. From 2017 to 2019, we have conducted research to establish a methodology for how to use the concept of environmental traceability “Proposal and verification of the validity of isotope environmental traceability methodology in environmental studies.” In this study, we indicated that the role and perception of traceability methods in transdisciplinary processes differ among stakeholders and that the co-production of “Multi-Isoscapes” can act as an effective “bridging tool” for understanding and explaining variation in local environments. Based on the research results, we started a project, “Applied research platform based on environmental traceability,” from 2020 and established an internet website, “The world on the view of Environmental Isotope Study (https://www.environmentalisotope.jp),” to serve as a platform that shares and develops the environmental traceability methodology. The website aims to connect providers of the environmental traceability methodology with potential users.

Keywords: Stable isotopes, Multi-isoscapes, Environmental traceability

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Daily variation in winter precipitation isotopes over Hirosaki and associate atmospheric circulation - Case study of a winter season 2019/2020 -

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1. Graduate School of Science and Technology, Hirosaki University, 2. Faculty of Science and Technology, Hirosaki University, 3. IIS Chiba Experimental Station, The University of Tokyo

The precipitation stable isotope ratio is an index that allows inverse estimation of the phase change and circulation process that the water has undergone. Therefore, understanding the variability of precipitation stable isotope ratios, especially snowfall stable isotope ratios, will improve the accuracy of paleoclimate reconstructions and lead to a better understanding of present-day hydrological processes, but it is also necessary to analyze them meteorologically because they are affected by atmospheric circulation. A regional isotope circulation model Iso-RSM (Yoshimura et al., 2010), which incorporates known isotope fractionation processes into an atmospheric general circulation model and a regional meteorological model, can be able to reproduce the isotope ratio variations. In this study, we used modeled isotope ratios of precipitation and water vapor to improve our understanding of the observed isotope variations, and for the processes that did not reproduce the isotope ratio variations, the observed isotope ratio results can be used to improve the model.

In this paper, we report the results of the observed variations of winter precipitation in Hirosaki during the last winter (2019/2020). There were few days of snowfall due to a warm winter and less snowfall, but precipitation from the previous day was collected from December 24th to March 17th, including rainfall days. The oxygen and hydrogen isotope ratios of 40 samples were measured by Picarro spectroscopy at Research Institute for Humanity and Nature. δ 18O varied between -1.39‰ and -18.87‰, and δ D varied between -9.9‰ and -142.2‰. The trend of isotopic variation of precipitation in Hirosaki by Iso-RSM was qualitatively consistent from mid-January to early March, while that of d-excess was not consistent with observation except for a period in February.

Based on the observed precipitation stable isotope ratios and the water vapor transport field by ERA5 reanalysis, we found the following.

(1) when the isotope ratio is low and the d-excess is high, precipitation is brought to Hirosaki by the rapid evaporation of cold, dry air from Eurasia over the Japan Sea (no moist air from the south);

(2) when the isotope ratio is high and the d-excess is low, precipitation is brought by warm, moist air masses from the southwest;

(3) when the isotope ratio is high and the d-excess is high, the northwest monsoon passes near the Korean Peninsula and the rapid merging of evaporated water vapor in the Sea of Japan and moist air from the southwest is observed.

During the period of the study, we identified three periods that show the precipitation isotope ratio gradually increased over several days. These trends are reproduced in the Iso-RSM. Period-1: on January 10th to 14th, water vapor from (3) mixed with water vapor from (1) resulting in little change in d-excess;

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Period-2: on February 9th to 13th, water vapor from (2) mixed with water vapor from (1), resulting in an increase in isotope ratio but a decrease in d-excess; Period-3: on February 17th to 21st, air masses from (1) merged with air masses from (3), resulting in a decrease in d-excess; and on February 17th to February 21st, air masses from (1) merged with water vapor from (1), resulting in a decrease in d-excess. During the period-3, a low-pressure system moved northward (17th -19th) and a local circulation effect (20th -21st) which was strongly affected by Shirakami mountains seems to affect the precipitation isotope characteristics. In order to clarify the cause of the decrease in d-excess during the period, vertical precipitation isotope ratio in the clouds and cloud development process according to the topography should be considered.

In the winter of 2020/2021, we measured not only daily snowfall but also water vapor isotopes once or twice a day. The comparison between the two years and the snowfall process that can be understood from the water vapor isotope variation will also be reported at the meeting.

Keywords: snowfall, isotope, water vapor

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Identification of snow characteristics in the basin to applied chemical composition and meteorological hydrological data

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Changes in the water environment due to climate change have been pointed out, and data development is being undertaken to guide the future image of the quantity and quality of the water cycle. As part of these efforts, we have analyzed the chemical composition of snowfall and snowfall in the Agano River basin, which is a heavy snowfall area. The Agano River depends on snow resources and is responsible for water resources such as power generation. In addition, multiple national parks are distributed, and ecotourism associated with the natural environment is formed. Therefore, the impact of climate change on the water environment is positioned as a large basin. Due to the changes in the chemical composition of snowfall and snowfall that have been carried out since 2014, snowfall other than that derived from the Sea of Japan was rarely observed in the Urabandai area and Tajima area located in the upstream, northeastern, and southeastern parts of the basin. It was suggested that the Tajima area was mostly covered with snow from the Pacific Ocean. On the other hand, the results suggest that the Urabandai area is covered with snow that does not originate from both the Sea of Japan and the Pacific Ocean. In order to verify the results of these chemical properties, we compared the relationship with meteorological hydrological data. As a result, there was a tendency that the weather was more related to the short-term scale than the yearly scale. We report on this characteristic.

Keywords: short time scale, stable isotope ratio analysis, regional water cycle

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Distribution of trace element concentrations in groundwater and spring water near coastal and inland area of Fukushima prefecture

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The salination or water quality change for some parts of groundwater neat the coastal area in Fukushima prefecture was occurred which was caused by the tsunami of the 2011 off the Pacific coast of Tohoku Earthquake. As a result of investigation from April 2012, it was obviously that multiple groundwater flows were existed and it was related with the depth of groundwater or aquifer. The recharge area of groundwater and spring water were mainly divided into two groups by the oxygen and hydrogen stable isotopes and dissolved component concentration of water; one is plateau near the coastal area, the other is highland around the Abukuma mountains (Yabusaki, 2020). This result agrees with the residence time estimated by the CFCs and SF_6. Furthermore, it may be more cleared by using the multiple tracers.
The 51 trace elements of groundwater, spring water and river water in this study area sampled from April in 2014 to August in 2020 were analyzed by ICP-MS (Agilent 7500cx). As a result of analysis, concentration of B, Al, Mn, Fe, Zn, Sr and Ba was relatively high in some sites. Especially, Mn and Fe were extremely high near the coastal area (exceed 500 μg/L of Mn and exceed 10,000 μg/L of Fe), it is probably influenced by the local geological condition. Sr concentration for all sites was from 10 to 900 μg/L, it was higher near the coastal area in Minami-soma City and Shinchi Town than the inland area. In the former area was affected by the tsunami. Sr concentration of sea water is very high about 7.8 mg/L (Nozaki, 1997), so the Sr concentration near the coastal area might be high caused by the tsunami. Because in these sites water quality indicated Na-Cl and dissolved concentration was relatively high, this result suggested mentioned earlier. As a result of trace element analysis, it is considered trace element concentration reflected the difference of geology and residence time, and also influence of tsunami.
In future, we will measure the $^{87}Sr/^{86}Sr$ of groundwater and spring water in this study area, and will consider the recharge area and groundwater flow system by using the multi-tracer methods.

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Keywords: coastal area of Fukushima prefecture, groundwater flow, water quality, stable isotopes of oxygen and hydrogen, trace elements

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Response of forest ecosystems to reduction of atmospheric sulfur deposition

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Sulfur oxides (SO_X) derived from anthropogenic fossil fuel combustions have been causing so-called “acid rain problem” in various regions of the world. In fact, sulfate (SO_4^{2-}) derived from atmospheric deposition is a major counter ion of proton (H^+) in terrestrial ecosystems and sulfur deposition was a primary cause of acidification. While SO_X emissions have already been enough reduced in Europe and the United States and just started declining in Asia, recovery processes from acidification are still concerned in these regions. However, dynamics of sulfur has not been investigated in terrestrial ecosystems in Asia, where recovery from acidification has just started in accordance with reduction of air pollution. To clarify the sulfur dynamics in Asia, we have been applying the isotopic analysis to rainwater, soil and soil solution, and/or stream water in forest catchments in Japan, Thailand and Malaysia. In this paper, outputs from two catchment sites in Japan will be presented mainly based on the recent publications (Sase et al. 2019, 2021) and perspectives on relevant studies may also be introduced with information on sites in Thailand and Malaysia.

Field surveys on atmospheric deposition and stream water started in Lake Ijira catchment in Gifu Prefecture (IJR) and Kajikawa catchment in Niigata Prefecture (KJK) in 1988 and 2002, respectively. For these sites, sulfur isotopic ratio ($\delta^{34}S$) has been determined for rainwater, soil solutions, and stream water since 2014 and 2012, respectively. The $BaSO_4$ precipitates obtained from water samples were analyzed using a mass spectrometer equipped with an elemental analyzer, EA-IRMS (EA2500−Delta Plus by Conflo II or EA IsoLink CN −Delta Plus Advantage by Conflo IV, Thermo Fisher Scientific, USA) according to the methods described in the previous publications (Inomata et al. 2019; Sase et al. 2019, 2021).

Atmospheric S deposition at IJR and KJK decreased over the last decade, possibly reflecting reduction of both transboundary air pollution and domestic air pollution. Accordingly, pH and/or alkalinity increased with decrease of SO_4^{2-} concentrations in stream water, suggesting recovery from acidification. At IJR, the sulfur outputs via stream water exceeded the atmospheric inputs significantly, larger than two times (Sase et al. 2019). On the other hand, at KJK, the outputs gradually increased and exceeded the inputs occasionally (Sase et al. 2021). The phenomena seemed to be similar, however, the isotopic evidence showed a clear difference between them. The $\delta^{34}S$ values in stream water at IJR were stable with negative values, which were significantly lower than the range of rainwater, while the values in stream water at KJK were stable within the range of rainwater. It was suggested that the stream water at IJR was largely influenced by sources other than atmospheric deposition, such as geological (rock) sulfur (Sase et al. 2019). In the presentation, importance of a retention - release cycle of sulfur in forest ecosystems and possibility of disturbing recovery processes by climate change will also be highlighted.

This work was supported by grants from the Asia-Pacific Network for Global Change Research (ARCP2012-18NMY-Sase; ARCP2013-13CMY- Sase) and the Japan Society for the Promotion of Science (JSPS) KAKENHI Grant Numbers JP19H00955, JP19K12315 and JP18K11616.

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References. Inomata et al. 2019. Science of the Total Environment; Sase et al. 2019. Biogeochemistry; Sase et al. 2021. Atmospheric Environment.

Keywords: sulfur, acidification, recovery, climate change

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Estimate the origin of nutrients supplied to coastal areas using Ulva pertusa's nitrogen and carbon stable isotope ratios.

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1. Fukui Prefectural University, 2. Center for Ecological Research,Kyoto University

In recent years, attention is focused on various problems caused by nutrients flowing into coastal areas. However, there is little specific knowledge about how the influx of nutrients is incorporated into coastal ecosystems. In this study, in order estimate the contribution of nutrients of multiple origins to primary producers, we recorded fluctuations in the stable nitrogen and carbon isotope ratio through a culture experiment of *Ulva pertusa* in Obama Bay, Fukui Prefecture. We conducted *Ulva pertusa* culture experiments four times in July-August 2018, October-November, April-May 2019, and September-October in Obama Bay and the laboratory outdoor aquarium. The maximum culture period was 25 days. Finally, the stable nitrogen and carbon isotope ratio were measured, and the fluctuation of the isotope ratio was verified through the culture experiment. Fluctuations in the nitrogen and carbon stable isotope ratios of *Ulva pertusa* were confirmed through culture experiments. *Ulva pertusa* placed in nutrient environments of different origins had large fluctuations in isotope ratio from the first day of culture, and the error between cultured individuals was small. Our results suggest that *Ulva pertusa* can be used to estimate the origin of nutrients.

Keywords: δ15N, δ13C, environmental tracer

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[J] Oral | H (Human Geosciences)：H-TT Technology & Techniques

Thu. Jun 3, 2021 10:45 AM - 12:15 PM JST | Thu. Jun 3, 2021 1:45 AM - 3:15 AM UTC | Ch.16 Zoom Room 16

[H-TT16] Development and application of environmental traceability methods

convener:Ichiro Tayasu(Research Institute for Humanity and Nature), Ki-Cheol Shin(Research Institute for Humanity and Nature), Nozomu Takeuchi(Chiba University), Chairperson:Ichiro Tayasu(Research Institute for Humanity and Nature)

Modern society uses almost all the elements present in the natural world. Although there have long been calls for the sustainable use of the resources that provide these elements and the building of human societies that are in harmony with the environment, the survival of the human race is increasingly at risk as a result of qualitative changes to the environment as a whole. Implementation by the society of methodologies for diagnosing and tracking these various elements of the natural environment and their relationships with humans are now required.
Elements cycle within and among the Earth system spheres, human society, and the human body. Information on the concentrations and stable isotopes of elements is a powerful tool for tracing this cycling and has been applied in studies of atmosphere-hydrosphere circulation, ecological systems, and the life, health, and history of humans. We propose a session to discuss the development and applications of environmental traceability methods toward the goal of establishing traceability in natural and human systems.
We encourage the presentation of research integrating isotopic information in various disciplines, such as geochemistry, hydrology, ecology, geology, mineralogy, anthropology, food science, and forensics. We call the research Environmental Isotope Study.

10:45 AM - 11:00 AM JST | 1:45 AM - 2:00 AM UTC

[HTT16-07] A comparative study of diet of winged and wingless stoneflies on alpine snow in Mt. Gassan, Yamagata Prefecture, using carbon and nitrogen stable isotopes

*Nozomu Takeuchi[1], Risako Yonechi[1] (1.Chiba University)

11:00 AM - 11:15 AM JST | 2:00 AM - 2:15 AM UTC

[HTT16-08] The spatial variations in carbon and nitrogen stable isotopes of organic matter on the surface of Gulkana Glacier in Alaska

*Tsubasa Takahashi[1], MASATO ONO[1], Ayumi Kizawa[2], Nozomu Takeuchi[1] (1.Chiba University, 2.Chuo University)

11:15 AM - 11:30 AM JST | 2:15 AM - 2:30 AM UTC

[HTT16-09] Reconstructing lifetime isotope baselines of fish from eye lenses

*Yota Harada[1], Shin-ichi Ito[2], Chisato Yoshikawa[1], Nanako O. Ogawa[1], Naoto Ishikawa[1], Naohiko Ohkouchi[1] (1.Biogeochemistry Research Center, Japan Agency for Marine-Earth Science and Technology, 2.Atmosphere and Ocean Research Institute, The University of Tokyo)

11:30 AM - 11:45 AM JST | 2:30 AM - 2:45 AM UTC

[HTT16-10] Tracing habitat areas and migration of marine fishes from fish bone Pb isotopes

*Keiji Horikawa[1], Hinako Nishimura[2], Ki-Cheol Shin[3] (1.Faculty of Science, University of Toyama, 2.Graduate School of Engineering and Science for Education, University of Toyama, 3.Research Institute of Humanity and Nature)

11:45 AM - 12:00 PM JST | 2:45 AM - 3:00 AM UTC

[HTT16-11] Dietary evaluation through zinc isotope ratios of human skeletal remains from Yoshigo shell mound of Jomon period

*Soichiro Kusaka[1], Ki-Cheol Shin[2] (1.Tokai Univ., 2.RIHN)

12:00 PM - 12:15 PM JST | 3:00 AM - 3:15 AM UTC

[HTT16-12] Origin of prehistoric pottery clay deciphered from Sr-Nd-Pb isotope ratios

*Eriko Ishimaru[1], Ki-Cheol Shin[2], Makoto Tomii[3], Yoshiki Nobusato[4] (1.Hiroshima Univ., 2.RIHN, 3.Kyoto Univ., 4.Kagawa Mus.)

A comparative study of diet of winged and wingless stoneflies on alpine snow in Mt. Gassan, Yamagata Prefecture, using carbon and nitrogen stable isotopes

*Nozomu Takeuchi[1], Risako Yonechi[1]

1. Chiba University

Wingless-stoneflies are commonly observed in spring on the snow surface in Japan. Lack of wing in adult of the stoneflies is consider to be adaptive to cold environment. On the same snow surface, we also often find winged-stoneflies, which appear to be different species and to come accidentally from the downstream area without snow. However, recent studies showed some stoneflies enable to control the presence of wing in the adult stage depending on the environmental conditions. However, there has been no comparative study of ecology and morphology between wingless and winged stoneflies on snow surface in Japan. We collected the wingless and winged stoneflies on snow surface of Mt. Gassan in Yamagata prefecture in Japan. We described their morphology, distribution, and timing of appearance, and analyzed carbon and nitrogen stable isotopes of their body to compare their diet. Results showed that the wingless and winged stoneflies have distinctive morphology and distribution. The stable isotopes were also significantly different between them. Results suggest that the wingless and winged stoneflies have distinctive ecology although both of them are active on the snow surface at the same time.

Keywords: wingless stonefly, Gassan, stable isotope

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The spatial variations in carbon and nitrogen stable isotopes of organic matter on the surface of Gulkana Glacier in Alaska

*Tsubasa Takahashi[1], MASATO ONO[1], Ayumi Kizawa[2], Nozomu Takeuchi[1]

1. Chiba University, 2. Chuo University

Light absorbing impurities in snow and ice can reduce surface albedo and accelerate melting of snow and ice. In particular, photosynthetic algae growing on snow and ice are major constituents of the albedo reducing impurities on glaciers. The algae growing on the glacier ice surface have dark purple pigments in their cells and are mostly species of *Ancylonema nordenskioeldii* and *Mesotaenium berggrenii*. On the other hand, the algae growing on the snow surface have red pigments in their cells and are genus of *Sanguina*. Their distribution usually varies on a glacier, however, their controlling factors are not understood well. In this study, we investigate spatial variations in carbon and nitrogen stable isotopes of biogenic impurities on Gulkana Glacier in Alaska, where these algae dominate on glacier surface, and discuss formation process of organic matter on the glacier.

The field investigation was carried out in July of 2019 on Gulkana Glacier, which is a small mountain glacier with a total length of 4 km, locates on the Alaska Range. We collected surface ice samples and biogenic impurities at the 46 points on the glacier surface and analyzed carbon and nitrogen stable isotopes, concentrations of chlorophyll a and soluble ions, and cell volume biomass of algae.

The carbon and nitrogen stable isotopes of organic matter on the glacier ranged from -26.3 to -23.9‰ (Mean: -25.0±0.5) and from -5.7 to -2.9‰ (Mean: -3.8±0.6), respectively. They were higher in the downstream area but lower at the upstream area. This suggests that the organic matter on the glacier is not derived from a single source, but from microbial activities varied among the study sites. The chlorophyll a concentration and cell volume biomass showed that the biomass was higher and *Sanguina* spp. was dominant in the upstream areas whereas the biomass is lower and *A. nordenskioeldii*e dominated at the mid and downstream sites. The variation in the nitrogen stable isotopes is likely to reflect the sources of nitrogen used by the algae at each site. The algae in the upstream area probably assimilate the nitrogen with low nitrogen isotope ratio supplied currently from atmosphere whereas the algae in the downstream area assimilate the nitrogen with high nitrogen ratio derived from the glacier ice, which had been deposited on the glacier in the age before the Industrial Revolution.

This study revealed that the organic matter on glacier were products of various algae, which assimilate different nutrient sources depending on area of the glacier. The difference of the algal community and products may affect glacier darkening.

Keywords: carbon and nitrogen stable isotope, snow algae, glacier

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Reconstructing lifetime isotope baselines of fish from eye lenses

*Yota Harada[1], Shin-ichi Ito[2], Chisato Yoshikawa[1], Nanako O. Ogawa[1], Naoto Ishikawa[1], Naohiko Ohkouchi[1]

1. Biogeochemistry Research Center, Japan Agency for Marine-Earth Science and Technology, 2. Atmosphere and Ocean Research Institute, The University of Tokyo

Compound-specific nitrogen isotope analysis of amino acids archived in eye lens laminae was carried out to reconstruct lifetime nitrogen isotope baselines and trophic position of Chub mackerel (*Scomber japonicus*), a commercially important fish species in Japan. The bulk ^{15}N values gradually increased from the eye lens core (~ 2‰) to the outer layers (~ 10‰). The trophic position increased slightly from 2.6 (larval-juvenile stage) to 2.8 (adult stage). However, nitrogen baselines (phenylalanine) shifted substantially from -2.8‰ (larval-juvenile stage) to 2.8 (adult stage), likely associated with the typical ontogenetic migration of Chub mackerel in the western North Pacific that migrate from the subtropical ^{15}N depleted Kuroshio region to subarctic ^{15}N enriched Oyashio region. This study shows that lifetime trends in N isotope baselines can be reconstructed from eye lens laminae and are useful for studying ontogenetic migration of individual fish.

Keywords: isotope, nitrogen, fish

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Tracing habitat areas and migration of marine fishes from fish bone Pb isotopes

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1. Faculty of Science, University of Toyama, 2. Graduate School of Engineering and Science for Education, University of Toyama, 3. Research Institute of Humanity and Nature

Lead (Pb) isotopes will be a useful tracer that enable to discern geographic origin of marine fishes because the average residence time of Pb in the ocean is short (about 10 to 100 years) and Pb isotopes have characteristic values in each oceanic region reflecting different anthropogenic Pb sources. Pb is highly accumulated in fish bones up to several ppm, allowing us to measure Pb isotopes with a small amount of bone samples. Therefore, fine bone Pb isotope ratios have a potential as a new method to trace migration patterns and/or to determine geographic origin of even small and juvenile fishes.

In this study, we measured Pb isotopes of Mackerels and Horse mackerels inhabited in the Japan Sea, the East China Sea, the western North Pacific, and the North Atlantic (totally 163 samples). Bones were digested by ultrapure HNO_3, and Pb was separated from bulk solution using either Sr resin (Eichrom) or anion resion. Then, Pb isotopes were measured by a MC-ICP-MS (NEPTUNE, Thermo Scientific) at RIHN.

Atlantic mackerels habited (n = 23) in the North Atlantic and Blue mackerels (n = 50) habited near Japan represented distinctly different 208Pb/206Pb ratios. Likewise, Atlantic horse mackerels, Japanese scads, and Japanese jack mackerels in the Atlantic and near Japan also showed different 208Pb/206Pb ratios. These fish bone Pb isotopes of Mackerels and Horse mackerels obtained from the Northwest Pacific and the North Atlantic exhibited almost identical Pb isotopic compositions of the surface seawaters where fishes grew. This consistency between fish bone and seawater Pb isotopes suggests that fish bone Pb isotopes faithfully record seawater Pb isotopes. Cluster analysis based on fish bone Pb isotopes shows that geographic origins of Atlantic and Northwest Pacific fishes can be identified.

We also found a large scater of Pb isotope in Japanese jack mackerels (n = 19) caught in Kurobe (Toyama Bay), which can be interpreted as reflecting some fishes had migrated between the East China Sea and Japan Sea and some fishes had not migrated seasonally down to the Each China Sea. Similar scattering of Pb isotopes was also found in Blue mackerels habited in the Pacific Ocean near Japan. These scatters were strongly related to the ages of fishes; elder fishes tended to show lower 208Pb/206Pb ratios, which might reflect a migration pattern biased toward the upstream Kuroshio Current. In summary, we concluded that fine bone Pb isotope ratios can trace a north-south migration pattern and identify a geographic origin of marine fishes at least Mackerel and Horse mackerel of North Atlantic and Northwest Pacific, respectively.

Keywords: Pb isotope, fish bone, geographical origin, migration pattern

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Dietary evaluation through zinc isotope ratios of human skeletal remains from Yoshigo shell mound of Jomon period

*Soichiro Kusaka[1], Ki-Cheol Shin[2]

1. Tokai Univ., 2. RIHN

This study investigates zinc isotope ratios in tooth enamels of human skeletal remains of the Jomon period in Japan. Carbon and nitrogen isotope analysis on bone collagen was traditionary used to reconstruct diet and trophic levels on prehistoric human populations. The progress of isotope measurements using MC-ICP-MS enables us to analyze isotope ratios of zinc and other metals. Some researchers report that the zinc isotope ratios of animals reflect dietary sources and vary according to trophic levels. This study newly develops zinc isotope analysis on human tooth enamels. The zinc isotope analysis has great potential to reconstruct dietary information from inorganic materials of archaeological bones or fossils which do not contain organic components.
The material used in this study is 37 samples of human tooth enamels from the Yoshigo shell mound of Aichi prefecture, and faunal remains (six deer enamels, three boar enamels, six marine fish bones, 12 modern marine shellfish, and six modern plant leaves). Zinc was purified from these samples using anion exchange resin. Zinc isotope ratios were measured by MC-ICP-MS with the zinc standard solution of AA-ETH. The mass bias was corrected with Cu standard solution added to all standards and samples. The deer, marine fish and shellfish samples showed the value expected from their dietary ecology. The zinc isotope ratios of Jomon skeletal remains were higher than those of plants, but lower than deer and marine fish. The combination of the zinc isotope ratios and carbon and nitrogen isotope ratios previously reported showed wide distribution between the endmembers of C_3 plants, marine fish, and shellfish. This result indicates that the isotopic variation of zinc for humans were largely influenced by these dietary sources. The results indicate that the sources of zinc for humans were evaluated through zinc isotopes in tooth enamels of human skeletal remains.

Keywords: Jomon period, Human skeletal remains

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Origin of prehistoric pottery clay deciphered from Sr-Nd-Pb isotope ratios

*Eriko Ishimaru[1], Ki-Cheol Shin[2], Makoto Tomii[3], Yoshiki Nobusato[4]

1. Hiroshima Univ., 2. RIHN, 3. Kyoto Univ., 4. Kagawa Mus.

In archaeological research, it is important to know the production place of pottery and the clay source for discussing the migration, distribution of goods, and exchange in each era. Among the Jomon and Yayoi pottery in western Japan, a pottery group called "Ikoma seirokusan" has a brown color characterized by amphibole-rich pottery. It is thought that this pottery group was manufactured in villages in the western foot of Mt. Ikoma (Higashi-Osaka City, etc.) in the eastern part of the Osaka Plain and distributed in each area centered on the Kinki region. Clay sources of the pottery group have been estimated from the viewpoint of archaeological observation, texture analysis of sand grain, X-ray fluorescence analysis, etc. Until now, these methods cannot identify their origin.
We analyzed the production locality of the pottery using Sr (strontium) -Nd (neodymium) -Pb (lead) isotope analysis, which has different isotope ratios depending on the geology and the age of the formation. In this presentation, we report the radiogenic isotope analysis of Jomon and Yayoi pottery excavated from the two regions. One is the eastern part of Osaka Plain on Mt. Ikoma's west side, and the other in the northeastern part of the Kyoto Basin on the west side of Mt.Hiei. We have measured with bulk samples, separated amphiboles, and matrix clay to verify amphibole effects.
As a result of the analysis, the isotopic difference observed between the pottery from "Ikoma seirokusan" and "Hi-Ikoma seirokusan"(none Ikoma seirokusan pottery). The former's Sr-Nd isotope ratios are included in the range of the Ikoma gabbro's isotopic values. A few separated amphiboles and matrix clay from the same sample have different isotopic values from each other and their bulk isotopic values. With a new data set of lead isotope ratios, grain analysis of sand, and X-ray fluorescent analysis of the bulk samples, we will evaluate the effectiveness and the prospect of the radiogenic isotope analysis to estimate the origin of source materials.

Keywords: Jomon and Yayoi pottery, Sr-Nd-Pb isotope ratios, source of clay material

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[J] Oral | H (Human Geosciences)：H-TT Technology & Techniques

Thu. Jun 3, 2021 9:00 AM - 10:30 AM JST | Thu. Jun 3, 2021 12:00 AM - 1:30 AM UTC | Ch.15 Zoom Room 15

[H-TT17] New Developments in Shallow Geophysics

convener:Kyosuke Onishi(Public Works Research Institute), Kunio Aoike(Oyo corporation), Tishiyuki Yokota(National Institute of Advanced Industrial Science and Technology), Toru Takahashi(Fukada Geological Institute), Chairperson:Toru Takahashi(Fukada Geological Institute), Kunio Aoike(Oyo corporation)

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9:00 AM - 9:05 AM JST | 12:00 AM - 12:05 AM UTC

[HTT17-01] Introduction

9:05 AM - 9:25 AM JST | 12:05 AM - 12:25 AM UTC

[HTT17-02] Accumulation pattern of near-seafloor methane gas revealed by a shallow seismic survey in the northern Tokyo Bay

*Tetsuro Tsuru[1], Kazuki Takanaka[1], Koichi Fujimoto[1], Osamu Takano[2], Yukio Nakagawa[3], Naoto Kumagai[1] (1.Tokyo University of Marine Science and Technology, 2.University of Tsukuba, 3.Tobako LLC)

9:25 AM - 9:45 AM JST | 12:25 AM - 12:45 AM UTC

[HTT17-03] Imaging of near surface structure beneath a coastal plain by means of high-resolution S-wave seismic reflection survey

*Tomio INAZAKI[1], Kyoko Kagohara[2], Shinsuke Okada[3], Takayuki Nakano[4], Nobuhisa Matta[5] (1.Research Institute of Geology and Geoinformation, AIST, 2.Yamaguchi Univ., 3.Iwate Univ., 4.GSI, 5.Okayama Univ.)

9:45 AM - 10:05 AM JST | 12:45 AM - 1:05 AM UTC

[HTT17-04] Differences in P-wave velocities due to velocity logging in overlapping sections of horizontal boring surveys in sedimentary rock tunnel ground

*Kenji OKAZAKI[1], Toshiyuki KURAHASHI[1] (1.Civil Engineering Research Institute for cold region, Public Works Research Institute)

10:05 AM - 10:25 AM JST | 1:05 AM - 1:25 AM UTC

[HTT17-05] Applicability of Distributed Acoustic Sensing (DAS) technology for surface wave measurement

*Hayato Nonaka[1], Peter Hubbard[2], Koichi Hayashi[3], Yasuhiro Yokota[1], Kensuke Date[1], Kazuhiko Masumoto[1], Kenichi Soga[2] (1.Kajima corporation, 2.University of California, Berkeley, 3.OYO Corporation)

10:25 AM - 10:30 AM JST | 1:25 AM - 1:30 AM UTC

[HTT17-06] Discussion

[J] Oral | H (Human Geosciences) | H-TT Technology & Techniques

[H-TT17] New Developments in Shallow Geophysics

convener:Kyosuke Onishi(Public Works Research Institute), Kunio Aoike(Oyo corporation), Tishiyuki Yokota(National Institute of Advanced Industrial Science and Technology), Toru Takahashi(Fukada Geological Institute), Chairperson:Toru Takahashi(Fukada Geological Institute), Kunio Aoike(Oyo corporation)

Thu. Jun 3, 2021 9:00 AM - 10:30 AM Ch.15 (Zoom Room 15)

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9:00 AM - 9:05 AM

[HTT17-01]Introduction

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Accumulation pattern of near-seafloor methane gas revealed by a shallow seismic survey in the northern Tokyo Bay

*Tetsuro Tsuru[1], Kazuki Takanaka[1], Koichi Fujimoto[1], Osamu Takano[2], Yukio Nakagawa[3], Naoto Kumagai[1]

1. Tokyo University of Marine Science and Technology, 2. University of Tsukuba, 3. Tobako LLC

Recently, activity of seismic survey is extremely reducing in shallow waters where marine traffic is busy and fishing activity is high. Accordingly, the shallow waters are becoming brank zones in seismic survey. For example, in the northern part of the Tokyo Bay, no seismic surveys have been conducted since in the late 2000s. Therefore, we have been developing a new seismic data acquisition system using an underwater speaker (UWS) as a seismic source available even in the extremely shallow waters. The UWS shoots a non-pulsive source wave with significantly smaller sound pressure level than explosive sources such as airgun guns, mitigating environmental impacts to marine ecosystems. This mitigation effect is similar with that of a vibroseis survey on land.

In December 2017, *T/B Hiyodori* of Tokyo University of Marine Science and Technology conducted a seismic survey using the USWS off the Urayasu in the inner part of the Tokyo Bay. As a result, a low-velocity zone was detected about 7 m below the seafloor, whose stacking velocity was estimated 1100 m/s from velocity analysis, suggesting the existence of gas. The subsequent investigations revealed that the gas was composed mainly of methane and the gas layer was widely distributed in the northern part of the Tokyo Bay.

In addition to the widely distributed near-seafloor methane gas, a possible local gas pool was found about 17-20 m below the seafloor, from its low-velocity and reverse reflection polarity. The local gas pool is laterally bounded by a fault. Interestingly, no low-velocity anomalies can be detected in the other side of the fault. The gas appears to be sealed laterally by the fault, like a so-called fault trap. If the fault is activated by an earthquake in future, the gas will be released from the seafloor into the water. Total volume of the gases is unknown at this moment. However, considering the high flammability of methane, potential risks from the methane gases might be assumed from a viewpoint of disasters on marine traffic and offshore structures. Further seismic surveys would unveil potential risks as well as potential resources in the shallow waters.

Keywords: shallow seismic survey, underwater speaker, environment-friendly, Tokyo bay, gas

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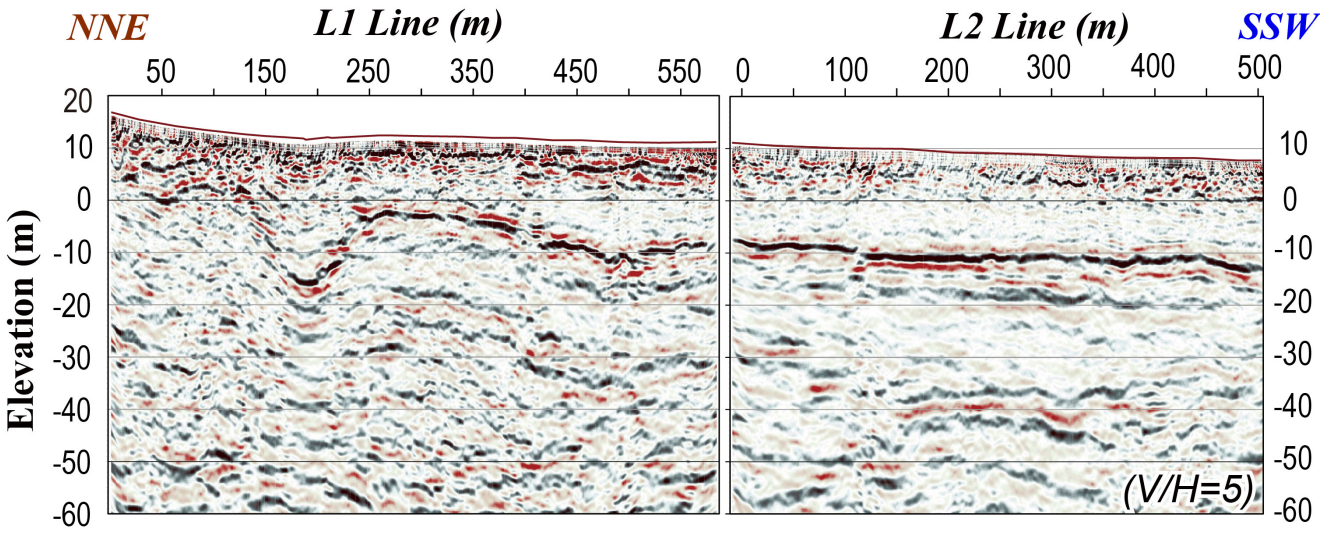
Imaging of near surface structure beneath a coastal plain by means of high-resolution S-wave seismic reflection survey

*Tomio INAZAKI[1], Kyoko Kagohara[2], Shinsuke Okada[3], Takayuki Nakano[4], Nobuhisa Matta[5]

1. Research Institute of Geology and Geoinformation, AIST, 2. Yamaguchi Univ., 3. Iwate Univ., 4. GSI, 5. Okayama Univ.

We conducted a high-resolution S-wave seismic reflection survey to delineate the near surface structure beneath a beach ridge plain facing Ensyu-nada, Ohbuchi District, Kakegawa City, Sizuoka Prefecture. The field survey was carried out in August to September 2020 along a total of 1.1 km long survey lines set on a road extending from the foot of Ogasa-yama Hills to the shoreline. We adopted an S-wave type Landstreamer, consisted of a total of 96 channel, 14 Hz horizontal geophone units at 50 cm intervals mounted on stainless wires, as the survey tool. Horizontal hitting of wooden plank was employed to generate a polarized SH-wave impulsive signal. Total shotpoints and recorded files amounted to 1,084 and 3780 respectively. All the shot records were visually inspected to eliminate miss-triggered records and dead traces, and to estimate shot statics before applying diversity stack. Migrated time sections were reconstructed through the ordinary processing flow with iterative velocity analyses and statics. Finally, we obtained migrated depth sections along the survey lines based on the NMO RMS velocity and on time to depth conversion curves estimated from an empirical relationship between S-wave velocities and geotechnical data.
A clear event was delineated at about -10 m in altitude, or 20 m in depth. The reflector showed flat structure beneath the coastal side line, and gradually ascended towards the hill side. In addition, it formed a small buried valley near the foot of the hills. Reflectors having similar trends were also traced at depths but not so clear. Boring and VSP are being planned to obtain core sample and direct S-wave velocity profile of the near surfaces.

Keywords: S-waves, seismic reflection survey, Land Streamer, beach ridge plain, Kakegawa City



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Differences in P-wave velocities due to velocity logging in overlapping sections of horizontal boring surveys in sedimentary rock tunnel ground

*Kenji OKAZAKI[1], Toshiyuki KURAHASHI[1]

1. Civil Engineering Research Institute for cold region, Public Works Research Institute

P-wave velocity is one of the evaluation indexes in the ground classification of tunnels. At the time of design, it is measured from the ground surface of the tunnel, and at the time of construction, it is measured at the core, inside the borehole, and rock fragments by the horizontal boring survey from the tunnel face. In addition, the P-wave velocity at the time of construction is used for reviewing the ground classification as the value closest to the excavation site. In one horizontal boring survey, about 100 m is excavated, but the next horizontal boring survey may be carried out before the tunnel excavation reaches the deepest part excavated in the horizontal boring survey. Therefore, in the first horizontal boring survey and the next horizontal boring survey, there may be an overlapping section of about 30 m. The P-wave velocity by the velocity logging of the first horizontal boring survey is the P-wave velocity about 100 m ahead of the tunnel face and in the state where the ground before tunnel excavation is not loosened. On the other hand, the P-wave velocity by the velocity logging of the next horizontal boring survey is the P-wave velocity in the state where loosening occurs due to tunnel excavation at the tunnel face. It is important information for reviewing the ground classification and deciding the selection of auxiliary construction method by knowing the change of P wave velocity in advance.

Therefore, in this survey, we collected P-wave velocities by velocity logging in the overlapping section (8 boreholes total length 197 m) at the time of the horizontal boring survey (104 boreholes in total) for 5 tunnels (total length 11,104 m) with sedimentary rock tunnel ground. Then, the difference between the P-wave velocity by the velocity logging of the first horizontal boring survey and the velocity logging of the next horizontal boring survey was investigated.

As a result of the survey, the overlapping section was 25 m on average. The P-wave velocity by velocity logging in the first horizontal boring survey was 2.5-3.2 Km/s (average 2.7 Km/s). On the other hand, the P-wave velocity by velocity logging in the next horizontal boring survey was 1.0 to 2.8 Km/s (average 2.2 Km/s). From this results, it was clarified that the P wave velocity in the overlapping section decreased by about 17% due to the excavation of the tunnel.

Keywords: tunnel, velocity logging , P-wave velocity

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Applicability of Distributed Acoustic Sensing (DAS) technology for surface wave measurement

*Hayato Nonaka[1], Peter Hubbard[2], Koichi Hayashi[3], Yasuhiro Yokota[1], Kensuke Date[1], Kazuhiko Masumoto[1], Kenichi Soga[2]

1. Kajima corporation, 2. University of California, Berkeley, 3. OYO Corporation

Recently, the distributed acoustic sensing (DAS), which is one of the distributed fiber optic sensing technologies using fiber optics, is receiving increased attention. DAS is promising as an innovative vibration monitoring tool in various fields including geophysics because it utilizes an optical fiber itself as a sensor and it can acquire data over long length at spatially high density. In civil engineering, preliminary investigation of underground conditions with boring survey and/or geophysical survey techniques are often required for the safe and rational construction of underground structures. This study aimed at investigating the applicability of DAS for geophysical exploration using elastic wave and Multi-channel Analysis of Surface Waves (MASW) survey was performed to understand the basic performance of DAS.

A trench with a length of about 100 m was excavated in a research field located in Richmond, California, USA, and fiber optic sensor cables were directly buried in the trench. Surface waves induced by an active source using a sledgehammer were measured at 1 m intervals along with a fiber optic sensor. The result with a tightly coupled sensing cable (i.e. high-sensitivity cable) showed that the clear surface waves propagating to the other end. On the other hand, the wave propagation could not be clearly detected due to background noise in the latter part of the loosely coupled telecommunication-cable (i.e. low-sensitivity cable). These results indicated that the cable structure affects the response sensitivity for the seismic wave. However, stacking of the waveforms in low-sensitivity cables allowed the signal-to-noise ratio to improve and showed almost the same results as high-sensitivity cables. In addition, surface waves were measured using a three-component geophone to compare with DAS measurement results. It could be found that similar waveform recordings and the phase velocity dispersion curve as DAS were obtained from the geophone with the measurement results of the horizontal component in the same direction as the fiber optic cable.

In the frequency band necessary for the analysis of geophysical exploration, surface wave measurement of the active source can be performed with almost the same performance as existing survey method with geophones. DAS, which can simultaneously acquire data at intervals of several meters over several tens of kilometers, will enable an application to a wider range of subjects.

Keywords: Distributed Acoustic Sensing (DAS), Surface wave,, Multi-channel Analysis of Surface Waves (MASW), Phase velocity dispersion curve

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[J] Oral | H (Human Geosciences) | H-TT Technology & Techniques

[H-TT17] New Developments in Shallow Geophysics

convener:Kyosuke Onishi(Public Works Research Institute), Kunio Aoike(Oyo corporation), Tishiyuki Yokota(National Institute of Advanced Industrial Science and Technology), Toru Takahashi(Fukada Geological Institute), Chairperson:Toru Takahashi(Fukada Geological Institute), Kunio Aoike(Oyo corporation)

Thu. Jun 3, 2021 9:00 AM - 10:30 AM Ch.15 (Zoom Room 15)

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10:25 AM - 10:30 AM

[HTT17-06]Discussion

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[J] Oral | H (Human Geosciences)：H-TT Technology & Techniques

Thu. Jun 3, 2021 10:45 AM - 12:15 PM JST | Thu. Jun 3, 2021 1:45 AM - 3:15 AM UTC | Ch.15 Zoom Room 15

[H-TT17] New Developments in Shallow Geophysics

convener:Kyosuke Onishi(Public Works Research Institute), Kunio Aoike(Oyo corporation), Tishiyuki Yokota(National Institute of Advanced Industrial Science and Technology), Toru Takahashi(Fukada Geological Institute), Chairperson:Kyosuke Onishi(Public Works Research Institute), Tishiyuki Yokota(National Institute of Advanced Industrial Science and Technology)

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10:45 AM - 10:50 AM JST | 1:45 AM - 1:50 AM UTC

[HTT17-07] Introduction

10:50 AM - 11:10 AM JST | 1:50 AM - 2:10 AM UTC

[HTT17-08] CCR survey using plate electrodes

*Chisato Konishi[1], Hiroshi Kisanuki[1], Dennis Wilkison (1.OYO Corporation)

11:10 AM - 11:30 AM JST | 2:10 AM - 2:30 AM UTC

[HTT17-09] Differential tomography of continuously repeated measurement data using electrical exploration method - Application to monitor changes in soil moisture content due to rainfall

*Ryota Watatani[1], Koichi Suzuki[2] (1.Cooperative Program for Resources Engineering, Graduate School of Engineering, Hokkaido University, 2.Research Group of Geoenvironmental Engineering, Division of Sustainable Resource Engineering, Faculty of Engineering, Hokkaido University)

11:30 AM - 11:50 AM JST | 2:30 AM - 2:50 AM UTC

[HTT17-10] Subsurface exploration by multifrequency electromagnetic portable senser GEM-2 at the Goshogake geothermal area

*Shin'ya Sakanaka[1], Keigo Tsuboe[1], Yuya Tada[1], Inoue Yusuke[2], Shura Taomote[3], Ritsu Sakiyama[1] (1.Graduate school of International Resource Sciences, Akita University, 2.OYO corporation, 3.Faculty of International Resource Sciences, Akita University)

11:50 AM - 12:10 PM JST | 2:50 AM - 3:10 AM UTC

[HTT17-11] Bayesian estimation method of near-surface density under irregular distribution of gravity network

*Yuanyuan Niu[1], Jiancang Zhuang[1] (1.Institute of Statistical Mathematics)

12:10 PM - 12:15 PM JST | 3:10 AM - 3:15 AM UTC

[HTT17-12] Discussion

[J] Oral | H (Human Geosciences) | H-TT Technology & Techniques

[H-TT17] New Developments in Shallow Geophysics

convener:Kyosuke Onishi(Public Works Research Institute), Kunio Aoike(Oyo corporation), Tishiyuki Yokota(National Institute of Advanced Industrial Science and Technology), Toru Takahashi(Fukada Geological Institute), Chairperson:Kyosuke Onishi(Public Works Research Institute), Tishiyuki Yokota(National Institute of Advanced Industrial Science and Technology)

Thu. Jun 3, 2021 10:45 AM - 12:15 PM Ch.15 (Zoom Room 15)

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10:45 AM - 10:50 AM

[HTT17-07]Introduction

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CCR survey using plate electrodes

*Chisato Konishi[1], Hiroshi Kisanuki[1], Dennis Wilkison

1. OYO Corporation

The CCR (Capacitively coupled resistivity) survey system using dipole-cable has an issue of low sensitivity for estimating resistivity profile of shallow subsurface less than 2m in depth due to a limitation of dipole-cable length. A new system using cylinder electrode was developed (Konishi et al., 2018) to solve the problem. Because the length of the cylinder electrode is one eighth of the shortest dipole-cable length, it enables the separation between the transmitter and the receiver small; however, the signal was interfered by EM coupling between the receiver and the transmitter when the separation was too small. To resolve the new issue, which was probably associated with EM wave in the air, plate electrodes were developed and tested. The plate electrode is the same as long as the cylinder electrode and is placed only towards the ground. In the field experiment, we found that the EM coupling was significantly reduced by using the plate electrodes. Additionally, the measured apparent resistivity was comparable with the one measured by ordinary resistivity measurement with dipole-dipole array configuration using iron stakes placed at the center positions of the plate electrodes. Therefore, it is possible to obtain a resistivity profile from the surface to 10 m in depth effectively by the CCR survey using both the plate electrodes and the dipole-cables.

Keywords: CCR survey, resistivity, plate electrode

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Differential tomography of continuously repeated measurement data using electrical exploration method - Application to monitor changes in soil moisture content due to rainfall

*Ryota Watatani[1], Koichi Suzuki[2]

1. Cooperative Program for Resources Engineering, Graduate School of Engineering, Hokkaido University, 2. Research Group of Geoenvironmental Engineering, Division of Sustainable Resource Engineering, Faculty of Engineering, Hokkaido University

Slopes at risk of large-scale landslides should be evaluated across the entire slope for the behavior toward groundwater infiltration from heavy rainfall. It is imperative to establish monitoring techniques to visualize rainwater infiltration across the entire slope for the long-term risk management of landslides. However, it is difficult to quantitatively evaluate the saturation rate change caused by rainwater infiltration using only the electrical exploration data. Suzuki et al. (2018) estimated the porosity and saturation rate sections by combining the S-wave velocity and resistivity based on an unconsolidated sand model (Avseth, 2005). In this study, differential tomography by Sugimoto (1995) was performed on the electrical exploration data measured repeatedly on the slope formed on the Joso Plateau, and the cross section of the resistivity change rate was obtained. In addition, by combining the S-wave velocity structures obtained by surface wave exploration conducted on the same survey line, the cross-section of the rate of change in saturation due to precipitation infiltration was estimated according to the analysis flow shown by Suzuki et al. (2018). Hence, the differential tomography result had a smaller RMS residual than the conventional method and was consistent with the geological structure. In the cross-section of the rate of change in saturation, saturation increased from the ground surface and a region where the saturation decreased appeared below it; a minor change in saturation was observed in the region below the clayey layer.

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Sugimoto, Y., *Proceeding of the SEGJ Conference 92*, 57-62, 1995. (in Japanese)
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Suzuki, K. *et.al., BTSURI-TANSA,* **71,** 1-14, 2018. (in Japanese)

Keywords: electrical exploration, differential tomography, RMS residual

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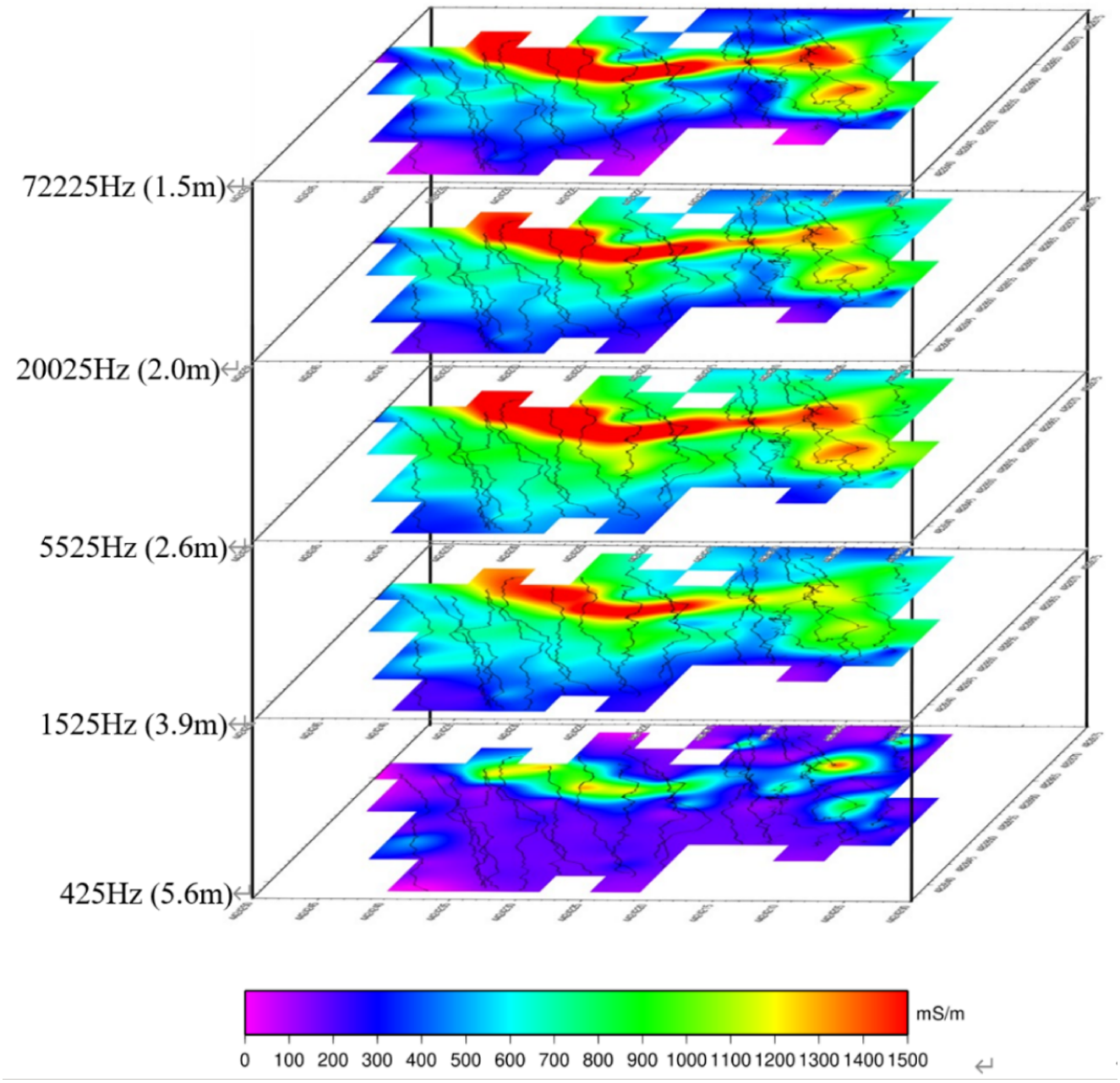
Subsurface exploration by multifrequency electromagnetic portable senser GEM-2 at the Goshogake geothermal area

*Shin'ya Sakanaka[1], Keigo Tsuboe[1], Yuya Tada[1], Inoue Yusuke[2], Shura Taomote[3], Ritsu Sakiyama[1]

1. Graduate school of International Resource Sciences, Akita University, 2. OYO corporation, 3. Faculty of International Resource Sciences, Akita University

Since 2016 the high temperature watery mud has eroded the promenade called Goshogake Onsen Nature Trail at the Goshogake geothermal area, Kazuno city, Akita prefecture, northeast of Japan. For the purpose of delineate subsurface hydrothermal activity, geophysical explorations were carried out. Various methods were utilized like as GPR (Ground Penetrating Radar), ERT (Electrical Resistivity Tomography), SP (Self Potential) and electromagnetic induction method by the instrument called GEM-2. Especially GEM-2 can clearly delineate subsurface structure. The GEM-2 is an instrument that can observe changes of conductivity in the depth direction by using multiple frequencies simultaneously. In this study, five frequencies were used: 425 Hz, 1525 Hz, 5525 Hz, 20025 Hz, and 72225 Hz. The two types of exploration, VDM (vertical direction mode) on August 21, 2020 and HDM (horizontal direction mode) on October 21, 2020, were conducted over two days.
In advance of HDM measurement, free air calibration was performed at 4 m height above the ground using a pipe made by vinyl chloride but at the VDM measurement free air calibration couldn’t be done. Free air calibration is the process of a calibration setting the zero-level of the GEM-2 instrument free from the influence of the ground.
Within the active mud pots area, measurement range was set as 28 m in the direction of the survey line and 34m perpendicular to the survey line for GEM-2 measurement. Location of two mud pods in the measurement range were surveyed by GNSS. Electrical conductivity contour diagram was created based on the GEM-2 measurement data with median processing in the range of 3 m. Attached figure shows the conductivity maps arranged at equal intervals in the depth direction. The depths in the figure were derived based on the average values of the electrical conductivity at each frequency and calculated by the square root of skin depth by Huang (2005). In addition, topographical map was drawn by using GNSS data in the function of GEM-2 instrument and Geographical Survey Institute’s DEM data.
As a result, high electrical conductivity at lower elevations can be seen. The cause of the high electrical conductivity can be clay. The areas of high electrical conductivity in the deeper layers are the possibly the pathways of the clay and hot liquid.

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Bayesian estimation method of near-surface density under irregular distribution of gravity network

*Yuanyuan Niu[1], Jiancang Zhuang[1]

1. Institute of Statistical Mathematics

Bouguer gravity anomaly is an important data to reveal underground structure and construction. It is calculated by terrain correction and Bouguer correction of Free-air gravity data. Near-surface density is an important parameter to be determined in these two corrections. We proposed an Bayesian estimation method to simultaneously estimate Bouguer gravity anomaly and near-surface density. Firstly, the inversion objective function is constructed from the observed Free-air gravity data, near-surface density model and Bouguer gravity anomaly model. At the same time, considering the irregular distribution of 2D gravity network, we use Delaunay triangulation and quadratic polynomial fitting to constrain the faltness and smoothness of Bouguer gravity anomaly model. Then, trade-off parameters are automatically determined by Akaike's Bayesian Information Criteria (ABIC). Finally, the optimal estimated results are obtained by maximizing the posterior estimation of model parameters. Estimated near-surface density can be used to indicate shallow geologic structure and estimated Bouguer gravity anomaly can provide more reliable data onto the study of regional deep structure and tectonics.

Keywords: ABIC, Delaunay triangulation, Second-order smoothness, Quadratic polynomial fitting, Near-surface density

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[J] Oral | H (Human Geosciences) | H-TT Technology & Techniques

[H-TT17] New Developments in Shallow Geophysics

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Thu. Jun 3, 2021 10:45 AM - 12:15 PM Ch.15 (Zoom Room 15)

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12:10 PM - 12:15 PM

[HTT17-12]Discussion

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[J] Oral | H (Human Geosciences)：H-CG Complex & General

Thu. Jun 3, 2021 1:45 PM - 3:15 PM JST | Thu. Jun 3, 2021 4:45 AM - 6:15 AM UTC | Ch.14 Zoom Room 14

[H-CG28] Earth surface processes related to deposition, erosion and sediment transport

convener:Koji Seike(Geological Survey of Japan, AIST), Masayuki Ikeda(University of Tokyo), Hajime Naruse(Department of Geology and Mineralogy, Graduate School of Science, Kyoto University), Hideko Takayanagi(Institute of Geology and Paleontology, Graduate School of Science, Tohoku University), Chairperson:Koji Seike(Geological Survey of Japan, AIST), Masayuki Ikeda(University of Tokyo), Hajime Naruse(Department of Geology and Mineralogy, Graduate School of Science, Kyoto University), Hideko Takayanagi(Institute of Geology and Paleontology, Graduate School of Science, Tohoku University)

To understand landscape evolution and dynamics of erosion, transport and sedimentation of earth-surface materials, the latest results of multiple research fields including engineering and earth sciences will be presented. As well as any researches of sedimentology and sedimentary petrology, interaction between fluid, sediments and geomorphology is focused. Interdisciplinary discussions of science, disaster prevention and resource exploration will be expected.

1:45 PM - 2:00 PM JST | 4:45 AM - 5:00 AM UTC

[HCG28-01] Sedimentary environment and earthquake history off Cape Muroto, SW Japan

*Juichiro Ashi[1], Toshiya Kanamatsu[2], Masafumi MURAYAMA[3] (1.The University of Tokyo, 2.JAMSTEC, 3.Kochi University)

2:00 PM - 2:15 PM JST | 5:00 AM - 5:15 AM UTC

[HCG28-02] Detrital Zircon and Provenance Analysis of Sedimentary Rock in the Nemuro and Urahoro Groups, Eastern Hokkaido, Northern Japan

*Harisma Harisma[1], Hisashi Asanuma[2], Takafumi Hirata[2], Hajime Naruse[1] (1.Kyoto University, 2.University of Tokyo)

2:15 PM - 2:30 PM JST | 5:15 AM - 5:30 AM UTC

[HCG28-03] Numerical study on formation mechanism of *shoal* and *cauldron* topographies on the seafloor in the eastern Seto Inland Sea

*Motoki Ubara[1], Yusuke Uchiyama[1], Taichi Kosako[2] (1.Graduate School of Engineering, Kobe University, 2.Coastal and Estuarine Environment Department, Port and Airport Research Institute)

2:30 PM - 2:45 PM JST | 5:30 AM - 5:45 AM UTC

[HCG28-04] Long-term perspectives on coastal changes of the Mekong delta, Vietnam

*Toru Tamura[1] (1.Institute of Geology and Geoinformation Geological Survey of Japan, AIST)

2:45 PM - 3:00 PM JST | 5:45 AM - 6:00 AM UTC

[HCG28-05] Ichnodiversity in the Upper Cretaceous submarine channel-levee deposits: examples from the northern and southwest Japan

*Kazuki Kikuchi[1], Hajime Naruse[1] (1.Division of Earth and Planetary Sciences, Guraduate School of Science, Kyoto University)

3:00 PM - 3:15 PM JST | 6:00 AM - 6:15 AM UTC

[HCG28-06] Behavior of plucking of bedrock with fully developed joints and its sensitivity to surface roughness

*Masahiro Ishizuka[1], Noritaka Endo[1] (1.Kanazawa University)

Sedimentary environment and earthquake history off Cape Muroto, SW Japan

*Juichiro Ashi[1], Toshiya Kanamatsu[2], Masafumi MURAYAMA[3]

1. The University of Tokyo, 2. JAMSTEC, 3. Kochi University

Submarine landslide morphology is developed off the east cost of the Cape Muroto. Baba et al. (2017, JpGU abstract) estimated that this landslide caused tsunami disaster at the Shishikui village during the 1512 Eisho earthquake by numerical investigation. Hakuho-maru KH-16-5 and KH-17-2 cruises conducted subbottom profile survey (SBP) using ROV "NSS" and surface sediment core sampling at the largest landslide of this region. However, these studies did not show any evidence for recent landslide sedimentation and deformation. On the other hand, Baba et al. (2019, Tectonophysics) discovered a recent landslide west of our survey site by high resolution swath bathymetric survey, and suggests possibility of tsunami generation by the submarine landslide. The old landslide studied by core sampling and SBP survey at a water depth of 1050 m shows characteristic morphology and sedimentary structures associated with coutour current. Sedimentary structure of core samples also indicates contourite deposition. Moreover, turbidite deposits are obtained at the base of this slope. Recurrence interval of deep-sea turbdites is similar to that at the adjacent confined basin (Iwai et al., 2004, Mem.Geol.Soc.Japan). Limitation of direct sediment supply through river to our study site suggests earthquake-triggered mobilization of the surface slope sediments.

Keywords: contourite, turbidite, landslide

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Detrital Zircon and Provenance Analysis of Sedimentary Rock in the Nemuro and Urahoro Groups, Eastern Hokkaido, Northern Japan

*Harisma Harisma[1], Hisashi Asanuma[2], Takafumi Hirata[2], Hajime Naruse[1]

1. Kyoto University, 2. University of Tokyo

This study aims to examine the development processes of the Cretaceous to Paleogene sedimentary basins in the collisional zone between North East Japan and Kuril Arc systems on the basis of the U-Pb age distribution of detrital zircon grains in sandstones. The study area is located in the eastern part of Hokkaido Island, a part of the Nemuro Belt, which has been interpreted as a complex of deposits of forearc and foreland basins. Recently, the paleomagnetic analysis suggested that the Nemuro Belt complex records collisional process associated with block rotation that was driven by tectonic activity. This tectonic event is likely to cause uplifting of colliding arc crusts, and thus sediment provenance analysis in the depositional sequences of the Nemuro Belt will provide information about the exact timing and mode of the collision of two arc systems. For this purpose, this study investigated the Nemuro and Urahoro Groups that are well exposed in the Nemuro Belt complex area.

We report the first record of the U-Pb age distributions of detrital zircon grains in the Nemuro Belt. Fifty-five samples of sandstones were collected from outcrops. Detrital zircons were separated using standard mineral separation techniques at the Kyoto University. Approximately 200 grains were mounted for each sample, and their U-Pb age was measured by LA-ICP-MS (*Laser Ablation Inductively Coupled Plasma Mass Spectrometry*) to estimate the temporal variation of sediment provenances. In total, we evaluated 1053 LA-ICP-MS U-Pb detrital zircon ages, and these U-Pb sandstones analyses resulted four stratigraphic intervals with age peaks: (1) Early Jurassic (200-175 Ma), (2) Late Cretaceous (100-69 Ma), (3) Paleocene (66-56 Ma), and (4) Eocene (55 and 41 Ma). Dating results also define two detrital zircon U-Pb type signatures based on a similarity pattern of age populations. Type 1 signatures are found in the sandstones of the Shiomi, Beppo, Harutori, Tenneru, Yuubetsu, and Shitakara Formations and are characterized by peaks in the Paleogene (66-41 Ma), and type 2 signatures are found in the Hamanaka and Akkeshi Formations and are distinguished by the persistence of Mesozoic grains in the Early Jurassic (200-175 Ma). This result implies that the significant transition of the sediment provenance areas occurred at the uppermost horizon of the Nemuro Group (~60 Ma), which can be associated with the progression of the collision event between two island arcs.

Keywords: Nemuro Group, Sandstone, Urahoro Group, U-Pb dating, Zircon

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Numerical study on formation mechanism of *shoal* and *cauldron* topographies on the seafloor in the eastern Seto Inland Sea

*Motoki Ubara[1], Yusuke Uchiyama[1], Taichi Kosako[2]

1. Graduate School of Engineering, Kobe University, 2. Coastal and Estuarine Environment Department, Port and Airport Research Institute

The topography of the seafloor has an elemental importance to determining physical phenomena such as ocean currents, favorable habitats for marine organisms, optimal vessel navigation, exploration of undersea resources, etc. Prevailing currents and waves, as well as associated shear stresses acting on the ocean floor, are responsible for formation of typical topographic features including sea caldrons and sandbanks through erosion of bedrocks and sediments and their deposition processes. In the Seto Inland Sea (SIS), the most extensive semi-enclosed estuary in Japan, tidal currents are well known to serve pronouncedly for the formation of seafloor topographic features. However, due to the spatiotemporal complexity in 3-D flow field and resultant sediment transport, the formation processes of bathymetry and their underlying mechanisms have not been fully studied yet, in particular from a hydrodynamic viewpoint. This study aims at understanding bathymetric formation under predominance of tidal currents in a semi-enclosed estuary, where the SIS is chosen for the study area. The simulation results from a 3-D high-resolution Seto Inland Sea circulation model using the Regional Ocean Modeling System (ROMS) in a double nested configuration embedded in an assimilative JCOPE2 oceanic reanalysis product were utilized to examine detailed hydrodynamic processes for the topography formations in the SIS. First, the bottom shear stress and residual flow were evaluated from the modeled flow field to assess the potential for erosion of the seafloor topography. A strong correlation between the bottom shear stress and the scour depth of the erosive areas is observed, suggesting that seafloor is most likely eroded by the erosion effect of the near-bed tidal currents. Second, a simple sediment budget model was developed based on sediment erosion fluxes for each particle size typical of the bottom sediments of the SIS, i.e., gravel, sand, silt and clay, using the modeled bottom shear stresses primarily due to tidal currents. This budget model presumes depth-independent sediment concentration in each water column determined by the erosion and deposition fluxes and considers horizontal suspended sediment transport to investigate where and how erosion and deposition occur. Horizontal divergence of the residual flows indicates consistency between divergence (convergence) and erosion (deposition); the divergent outflow occurs on the eroded terrains, while the convergent inflow is prevailed on the deposited terrains frequently appeared in the vicinity of the eroded terrains. The sediment budget model also exhibits that sediments are generally transported from deep to shallow areas in the eroded terrains to form the deposited terrains fringing the eroded terrains, whereas sedimentation tendency differs largely from location to location.

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Long-term perspectives on coastal changes of the Mekong delta, Vietnam

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The Mekong delta, southern Vietnam, has suffered serious coastal erosion, following catchment disturbances, such as hydropower dams and river sand mining, over the last decades. Indeed, the delta area has shrunk since 2005 in contrast to the overwhelming expansion during Holocene. Here, long-term perspectives on coastal changes of the Mekong delta are presented by taking into account temporal and spatial variability based on sedimentological, geomorphological, and chronological characterization. The Mekong delta represents a typical mixed-energy delta, in which relative contributions of fluvial, wave, and tidal processes are spatially variable; tide-modulated wave processes dominate the open coast, whereas distributary channels are characterized by an upstream to downstream transition from fluvial to tide-dominated estuarine processes. All regions are influenced by strong contrasts between the winter and summer monsoons, which define an annual sedimentary cycle; the weaker southwesterly summer monsoon causes river flooding and sediment supply, whereas the northeasterly winter monsoon is dry and stronger, associated with limited fluvial sediment supply and asymmetric longshore sediment drift toward the southwest. The shrinkage of the Mekong delta has not happened evenly over the coast, but reflected a decline in accretion rate in the sandy river mouth area and significant erosion of the downdrift muddy coast. Behaviors of the sandy coast are characterized by 200–600 year cycles in which an emergence of river mouth bar causes a jump of elongate barrier shoreline several kilometers offshore, followed by a filling of back barrier with mud. This sporadic nature introduces uncertainties in estimate of sediment budget from short-term coastal mapping just over several decades. The serious erosion of the downdrift coast has continued for > 100 years and thus is not attributable to river dams and sand mining in the last decades. It may have reflected land-use changes in the catchment, construction of canal networks on the delta plain, climate changes, and possibly autoretreat. These spatially- and temporally-variable behaviors of the Mekong delta coast questions a view to simply link human disturbances with the delta shrinkage and motivates further sedimentological and geomorphological investigations.

Keywords: Human activity, coast, Southeast Aisa

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Ichnodiversity in the Upper Cretaceous submarine channel-levee deposits: examples from the northern and southwest Japan

*Kazuki Kikuchi[1], Hajime Naruse[1]

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This study aimed to describe spatio-temporal variation of ichnoassemblages in the Upper Cretaceous deep-marine deposits in the northwestern Pacific area. It has been known that composition and number of ichnotaxa vary depending on depositional environments. Therefore, they are important and useful parameters to estimate depositional environments on the seafloor. Generally, ichnoassemblages in the submarine channel or proximal part of frontal splays are dominated in dwelling traces produced by crustacean. In contrast, small-sized, diverse patterned feeding or dwelling structures (graphoglyptids) are dominant in levees or distal parts of frontal splays. However, it is possible that the deep-marine ichnofacies was significantly different between those in Cretaceous and Cenozoic. Indeed, it is considered that some representative ichnotaxa in the Cenozoic deep-marine setting immigrated from the shallow-marine to deep-marine setting during Cretaceous. This study investigated the Upper Cretaceous submarine channel-levee deposits of the Nemuro, Himenoura, and Izumi groups to describe the ichnoassemblages and compare their characteristics with the Cenozoic ichnofacies model.

As a result, the ichnoassemblages in study areas showed low ichnodiversity and were different in composition from the previous ichnofacies models based on Cenozoic ichnoassemblages. In the Nemuro Group, 12 ichnogenera occurred from the levee deposits and no trace fossil was found in the channel-fill deposits. The ichnotaxa in the levee facies of the Nemuro Group consisted of the component ichnospecies of *Paleodictyon* ichnosubfacies while the number of ichnotaxa was smaller than that known in the Cenozoic models. In the Himenoura Group, 9 ichnogenera occurred from the channel-fill deposits and 7 ichnogenera were found in the levee deposits. The ichnoassemblages of the both of the channel-fill and levee deposits in the Himenoura Group were dominated in the grazing or dwelling traces produced by crustaceans and echinoids, and scarce in the patterned structures that consist of the *Paleodictyon* ichnosubfacies. In the Izumi Group, 11 ichnogenera occurred from the channel-fill deposits and 9 ichnogenera were found from the levee deposits. The ichnoassemblage in the Izumi Group was mainly composed of grazing or sessile feeding traces. In the Himenoura and Izumi groups, it was also characterized by high bioturbation intensity in the mudstone beds by the dwelling or grazing traces.

The difference among ichnoassemblages occurred in the groups can be explained by variation of preservation potential for each ichnotaxon caused by interactions of the benthic activity. The graphoglyptids, which is a representative group of the deep-marine trace fossils, are generally observable as convex hyporeliefs on the sole of turbidite sandstones. It is considered that they were primarily burrows or tunnels formed in fine-grained deposits near to the seafloor, and cast by subsequent deposition of sand. The high bioturbation intensity in the mudstone beds of the Himenoura and Izumi groups suggest high frequency of the dwelling or grazing behavior by large-sized benthic animals such as echinoids during inter-event[n1] periods of turbidity currents. This intense bioturbation could destroy the primary burrows or tunnels by the graphoglyptid producers and prevent to preserve the graphoglyptids.
The results of this study imply that the ichnoassembalges in the Upper Cretaceous deep-marine deposits may be characterized by high bioturbation intensity and low ichnodiversity. It is possible that decrease of bioturbation intensity in the near-surface deposits and consequent increase of preservation potential of the graphoglyptids may be a cause of the difference between the Cretaceous and Cenozoic

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ichnoassemblages. In future works, further observation focused on the bioturbation in the mudstone beds and benthic interactions will be needed.

Keywords: Trace fossil, Bioturbation intensity, Nemuro Group, Himenoura Group, Izumi Group

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Behavior of plucking of bedrock with fully developed joints and its sensitivity to surface roughness

*Masahiro Ishizuka[1], Noritaka Endo[1]

1. Kanazawa University

In bedrock rivers, the dominated mechanisms of riverbed erosion are abrasion and plucking; in the former, bedrocks are abraded by transported detrital particles, while in the latter, rock masses are detached at weakly bonded joints. While much experimental researches on abrasion have been performed from decades ago, only few experimental researches on plucking have been conducted, and the effect of roughness of rock riverbeds is unknown. In this study, we observed the influence of roughness on plucking, using a physical model in a circulating flume of 12 m long, 0.4 m wide, and 0.4 m deep. The modeled riverbed was examined while increasing the average flow velocity by gradually lowering the downstream weir, with a flow rate and channel gradient constant at 30 L/s and 0.1 %, respectively. A gypsum (specific density 1.32 to 1.44 g/cm^3) block was used as the analog material for the bedrock. Five conditions were tested: the blocks were arranged by differentiating the wavelength and height with regard to roughness of the bed surface. Results showed that plucking is more likely to occur for bedrocks with sufficiently developed joints if there is roughness. Plucking is more likely to occur in a block with a larger height of unevenness. This result simply means that the larger convex part receives a larger lift. In addition, however (somewhat opposite to intuition), as the wavelength of roughness decreases, the faster flow velocity is needed to make plucking occur. This result suggests that the flow modulated by the presence of the downstream concave portion reduces the lift from the flow applied to the block of the upstream convex portion on the other hand, our observation showed that plucking in a bedrock with roughness does not occur like a chain-reaction, i.e., following plucking after plucking is difficult to happen, because the detached blocks are likely to deposit in a concave potion and suppress the next plucking. Therefore, in the field, large fluctuations in hydraulic conditions and weather in a short period of time are necessary to promote plucking by breaking a temporarily stable arrangement of detached blocks, and these fluctuations are considered to control the long-term erosion rate in nature. Thus, it is likely that not only the time average value of hydraulic conditions but also the range and frequency (namely, pattern) of the fluctuation are also important.

Keywords: plucking, flume experiment, riverbed roughness, bedrock river, bedrock erosion

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[J] Oral | S (Solid Earth Sciences)：S-SS Seismology

Thu. Jun 3, 2021 1:45 PM - 3:15 PM JST | Thu. Jun 3, 2021 4:45 AM - 6:15 AM UTC | Ch.22 Zoom Room 22

[S-SS05] Crustal Deformation

convener:Masayuki Kano(Graduate school of science, Tohoku University), Tadafumi Ochi(Institute of Earthquake and Volcano Geology, Geological Survey of Japan, The National Institute of Advanced Industrial Science and Technology), Fumiaki Tomita(Japan Agency for Marine-Earth Science and Technology), Chairperson:Yoshiyuki Tanaka(Earth and Planetary Science, The University of Tokyo), Keisuke Yano(The Institute of Statistical Mathematics)

Study of crustal deformation plays an extremely important role in the investigation of wide scale earth dynamics those are earthquake and volcanic activity, plate motion and so on. In our session, we discuss the study related to crustal deformation, such as development of observation instrument, observed crustal deformation, analysis method, and simulation study.

1:45 PM - 2:00 PM JST | 4:45 AM - 5:00 AM UTC

[SSS05-01] Formation simulation of imbrication and décollement under uniform compression based on the elasto-plastic soil mechanics

*Tomohiro Toyoda[1], Toshihiro Noda[1], Kazuya Onishi[2], Akira Asaoka[3] (1.Nagoya University, Disaster Mitigation Research Center, 2.Nagoya University, School of Engineering, 3.Association for the Development of Earthquake Prediction)

2:00 PM - 2:15 PM JST | 5:00 AM - 5:15 AM UTC

[SSS05-02] **Estimate of Strain Rate Field in Japan from GNSS Data: Comparison between Shen's Method and Basis Function Expansion**

*Tomohisa Okazaki[1], Yukitoshi Fukahata[2], Takuya NISHIMURA[2] (1.RIKEN Center for Advanced Intelligence Project, 2.Disaster Prevention Research Institute, Kyoto University)

2:15 PM - 2:30 PM JST | 5:15 AM - 5:30 AM UTC

[SSS05-03] A Bayesian approach to estimating the crustal strain-rate fields from GNSS data and application to data from Mainland China

*ZIYAO XIONG[1], Jiancang Zhuang[1] (1.Institute of Statistical Mathematics)

2:30 PM - 2:45 PM JST | 5:30 AM - 5:45 AM UTC

[SSS05-04] Effects of curvature and lateral heterogeneities in elasticity constants on coseismic deformation

*Yoshiyuki Tanaka[1] (1.Department of Earth and Planetary Science, The University of Tokyo)

2:45 PM - 3:00 PM JST | 5:45 AM - 6:00 AM UTC

[SSS05-05] Applicability of the Hamiltonian Monte Carlo method for single rectangular fault estimation

*Taisuke Yamada[1], Yusaku Ohta[1] (1.Research Center for Prediction of Earthquakes and Volcanic Eruptions, Graduate School of Science, Tohoku University)

3:00 PM - 3:15 PM JST | 6:00 AM - 6:15 AM UTC

[SSS05-06] Automatic detection of short-term slow slip events using GNSS data: An l1-trend filtering approach

*Keisuke Yano[1], Masayuki Kano[2] (1.The Institute of Statistical Mathematics, 2.Tohoku University)

Formation simulation of imbrication and décollement under uniform compression based on the elasto-plastic soil mechanics

*Tomohiro Toyoda[1], Toshihiro Noda[1], Kazuya Onishi[2], Akira Asaoka[3]

1. Nagoya University, Disaster Mitigation Research Center, 2. Nagoya University, School of Engineering, 3. Association for the Development of Earthquake Prediction

A wide variety of topography is known to be formed in the ground subjected to lateral compression, depending on the constituent materials and boundary conditions. In terms of a single displacement discontinuity, there exist "reverse faults" over 45 degree, “thrust faults” under 45 degree, and horizontal "décollements". A partitioned ground by the faults exhibits a “pop-up” structure with conjugate slip surfaces or “imbrication” with parallel slip surfaces. To simulate their irreversible and multi-step formation process, (1) the elasto-plastic constitutive model for describing material nonlinearity and (2) finite deformation scheme for tracing changes in shape and state of the ground are necessary. In this abstract, we introduce the results of the formation analysis of these structures based on our analysis code *GEOASIA* [1] that can consider (1), (2), the presence of pore water, and dynamics.

First, an elasto-plastic deformation analysis was performed with three plane-strain finite element meshes with different boundary conditions shown in Fig. 1 (a)-(c). Here, we conducted a single-phase elasto-plastic analysis considering the self-weight of the model. SYS Cam-clay model [2] was incorporated as an elasto-plastic constitutive model. The overconsolidated parameters in Noda et al. [3] exhibiting remarkable softening behavior after the peak strength (Fig. 2) were used. The shear strain distributions in Fig. 3 indicate that the analysis without fixation of the bottom displacement in (a) exhibited pop-up, whereas the analysis with the prescription of the linear bottom displacement distribution (uniform compression) in (b) obtained imbrication. Furthermore, the separation of the imbrication and the thrust sequence, i.e., piggyback in (b) and overstep in (c), were affected by the presence of the end friction. We successfully simulated characteristic structures with the irreversible and multi-step strain localization in the compressed ground based on the elasto-plastic finite deformation analysis and confirmed the effect of boundary condition.

Next, the soil-water coupled elasto-plastic analysis for the saturated ground was conducted. Material constants of semi-consolidated ground were adopted conforming to Yamada et al. [4] and the identical mesh of Fig. 1(c) was used. The lateral compressive behavior obtained by analysis of one-element width is indicated in Fig. 4. Figure 5 shows the transition of the shear strain distribution. At the beginning of the analysis, the appearance of the imbrication was confirmed in (a). However, in (b), the occurrence of dé collement with horizontal slip was solved at the central depth of the model. Then, a second slip occurred on the lower side of the first décollement and the region II accreted to the bottom of the region I in (c)-(d). The occurrence of the positive excess pore water pressure (Fig. 6) and the generation of a seismic wave due to brittle deformation (Fig. 7) were also solved.

(Acknowledgement) We received Grant-in-Aid for Scientific Research (Grant-in-Aid for Scientific Research (A): No. 17H01289).

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[2] Noda, T., Asaoka, A. and Nakano, M. (2008): Soil-water coupled finite deformation analysis based on a rate-type equation of motion incorporating the SYS Cam-clay model, Soils and Foundations, Vol.48, No.6, pp.771-790.

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I_463-I_474.
[4] Yamada, E., Nakai, K. and Asaoka, A. (2021): Soil-water coupled elasto-plastic analysis on the formation process of normal faults in submarine ground due to its uplift and inclination, Proc. 20th Int. Conf. on Soil Mechanics and Geotechnical Engineering (Accepted).

Keywords: Compression, Thrust fault, Imbrication, Décollement, Elasto-plasticity, Finite element analysis

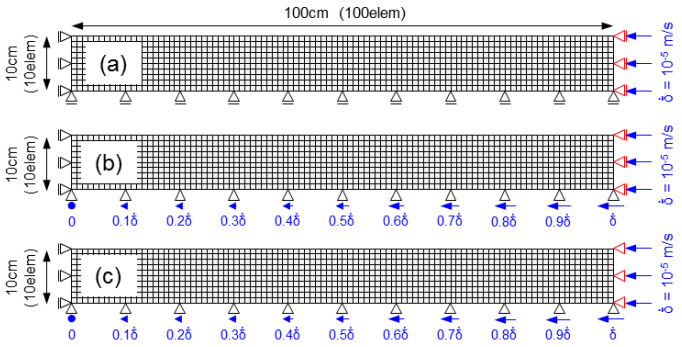


Figure 1. Finite element mesh

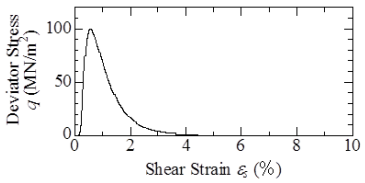


Figure 2. Drained triaxial compression behavior (p_0' = 82.8kPa)

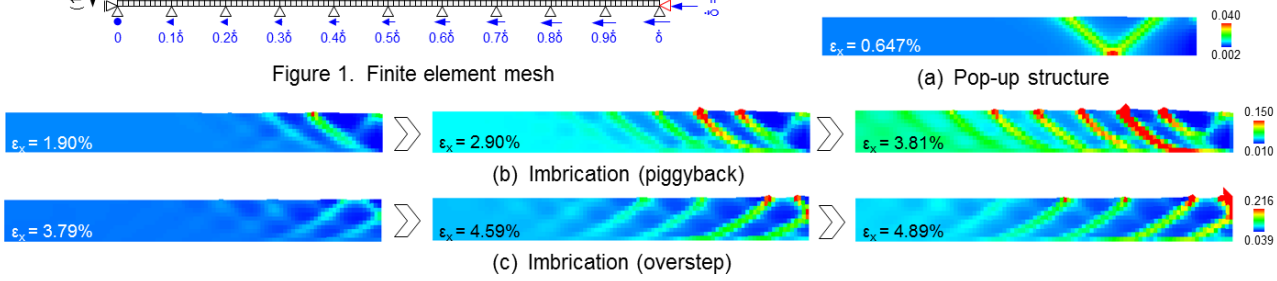


Figure 3. Shear strain distribution (single-phase analysis) (ε_x : horizontal strain of the model)

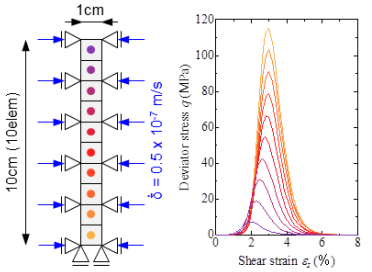


Figure 4. Lateral compressive behavior of one-element width analysis (plane-strain condition)

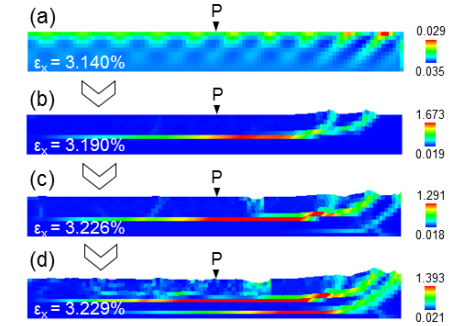


Figure 5. Shear strain distribution (two-phase analysis)

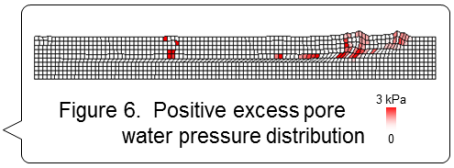


Figure 6. Positive excess pore water pressure distribution

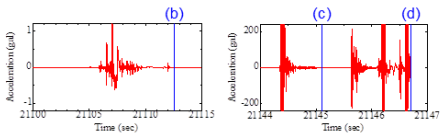


Figure 7. Vertical acceleration at point P in Fig. 5

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Estimate of Strain Rate Field in Japan from GNSS Data: Comparison between Shen's Method and Basis Function Expansion

*Tomohisa Okazaki[1], Yukitoshi Fukahata[2], Takuya NISHIMURA[2]

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The method of Shen et al. (1996) (Shen's method) has been widely used to estimate strain rate fields from GNSS velocity data in various regions; for example, Sagiya et al. (2000) found a high strain-rate region named the Niigata-Kobe tectonic zone in central Japan. However, we point out three theoretical disadvantages of the method: inconsistency between estimated velocity and strain rate fields, inability to objectively determine the optimal value of the hyperparameter that controls the degree of smoothing, and inaccurate estimation of uncertainty. As an alternative, we propose a method of basis function expansion (Fukahata et al. 1996) with Akaike's Bayesian information criterion (ABIC) to estimate a velocity field; the above mentioned difficulties are overcome in the ABIC method, because the strain rate field is obtained by analytically differentiating the velocity field and the optimal values of hyperparameters are objectively determined with ABIC.

We applied both methods to GNSS data in Japan. The results of Shen's method significantly depend on a value of the hyperparameter, and show instability and inconsistency in peripheral regions of the observation network. On the other hand, the ABIC method does not suffer from these problems. The advantage of the ABIC method is also clear in terms of the trade-off between resolution and robustness. The strain rate field in Japan estimated form the ABIC method exhibits local deformation at active volcanos as well as regional deformation related to plate motions. The ABIC method is thus effective for analyzing crustal deformation using GNSS velocity data.

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A Bayesian approach to estimating the crustal strain-rate fields from GNSS data and application to data from Mainland China

*ZIYAO XIONG[1], Jiancang Zhuang[1]

1. Institute of Statistical Mathematics

We proposed a new Bayesian approach to estimate continuous crustal strain-rate fields from spatially discrete displacement-rate data, based on Global Navigation Satellite System (GNSS) observations, under the prior constraint on spatial flatness of the strain-rate fields. The optimal values of the hyperparameters in the model of strain-rate fields are determined by using Akaike's Bayesian Information Criterion. A methodological merit of this approach is that, by introducing a two-layer Delaunay tessellation technique, the time-consuming computation of strain rates can be omitted through the model estimation process. We applied the Bayesian approach to GNSS displacement-rate data in Mainland China and examined the correlation between the estimated strain-rate fields and seismic activity by using Molchan’ s Error Diagram. The results show that the increase rate of maximum shear strain is positively correlated with the occurrence of earthquakes, indicating the strain rate can be used to augment probability earthquake models for background seismicity forecasting.

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Effects of curvature and lateral heterogeneities in elasticity constants on coseismic deformation

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Recently, new geodetic observation data such as seafloor crustal deformation data and satellite gravity data have been used to study wide-area crustal movements and variations in the gravity field, associated with great earthquakes. These data are compared with a theoretical model to infer a space-time distribution of the fault slip and the locked region and mantle rheology that explain the data.

The essential component to construct a theoretical model is a Green’s function (GF) prescribing the elastic response to an internal dislocation. Many existing GFs assume a flat Earth and treat the effects of self-gravitation only approximately. Such GFs cause modeling errors when dealing with wide-area deformations obtained by the above observations. A spherical Earth model can be used to calculate the global deformation including the change in the gravity field naturally. However, most models considering lateral heterogeneities, based on an ordinary finite-element method (FEM), do not solve the deformation over the entire sphere and the effects of self-gravitation are also approximated.

In this presentation, we first compare a flat-Earth model with the PREM in the coseismic elastic deformation due to a great earthquake and show that a spherical model is necessary to deal with near-field (i.e., seafloor deformation) and far-field (i.e., GNSS) observation data consistently. Next, we introduce a spectral FEM, which combines a 1-D finite element and a spherical harmonic representation, to calculate global coseismic deformation effectively. We modify this method to include lateral heterogeneities in the elasticity constants and apply it to a deep earthquake. The effects of lateral heterogeneities in Lame’s constants are evaluated by comparing a surface displacement obtained for a laterally heterogeneous model with that obtained for a spherically symmetric case (PREM). A preliminary result indicates that the effect of lateral heterogeneity in the shear modulus is larger than in the bulk modulus and that a local heterogeneity including the source region can affect the coseismic deformation as strongly as a regional-scale heterogeneity outside the source region.

Keywords: crustal deformation, lateral heterogeneity, finite element method, gravity, satellite geodesy, seafloor crustal deformation

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Applicability of the Hamiltonian Monte Carlo method for single rectangular fault estimation

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The rapid estimation of the coseismic fault model and its uncertainty are extremely important to predict the possible hazard such as tsunami. Based on such motivation, Ohno et al. (in revision) developed the estimation method of single rectangular fault model deduced from Markov Chain Monte Carlo (MCMC) method in real-time. They adopted conventional Metropolis-Hasting (M-H) method to sample the probability density function. The M-H method, however, require long Markov chain because of the ideal acceptance ration is around 20-30%. Therefore, the large dimensional problem requires the very long mixing time.

To overcome such problem, we investigate the new estimation approach for single rectangular fault model based on the Hamiltonian Monte Carlo (HMC) method. HMC is a MCMC method that uses the derivatives of the density function being sampled to generate efficient transitions spanning the posterior. It uses an approximate Hamiltonian dynamics simulation based on numerical integration which is then corrected by performing a Metropolis acceptance step. To calculate the numerical integration, we adopted the leapfrog integrator, which is a numerical integration algorithm. During the leapfrog integrator, we need to assume the discretization time (e) and number of steps (L). To estimate the appropriate number of leapfrog (L), we adopted the no-U-turn sampler (NUTS). We also assumed the discretization time (e) as 10^{-4} which was determined by try-and-error. The model parameter vector that contains fault parameters of a single rectangular fault model (Okada 1992). To optimize amount of each step size for unknown parameters, we installed logit transformation for all unknown parameters except for latitude and longitude.

We applied the developed approach to numerical experience which was under the optimum site coverage. Obtained results clearly shows the rapid convergence (~1000 steps) which clearly shorter step number compared with M-H method. We will show the more detail of our developed method and results for more realistic site coverage.

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Automatic detection of short-term slow slip events using GNSS data: An l1-trend filtering approach

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Short-term slow slip events (SSEs) are fault slip events that occur at a slower rate than regular earthquakes and are observed by geodetic instruments such as the Global Navigation Satellite System (GNSS) and tiltmeters. The durations of short-term SSEs generally ranges from a few days to a few weeks (Obara and Kato, 2016), and SSEs occur beneath subduction zones (e.g., Sekine et al., 2010, Nishimura et al., 2013). Since SSEs have close connections to the other seismic activities such as megathrust earthquakes and low-frequency earthquakes (Kano et al., 2019), detection of SSEs is important. Nishimura et al. (2013) proposed a short-term SSE detection method based on model comparison in a moving window using the Akaike information criterion (AIC) and detected short-term SSEs in southwest Japan. This method has high detection accuracy when hyperparameters such as the length of a moving window are given properly, yet it is difficult to determine these parameters properly.

In this presentation, we propose a detection method from multiple GNSS stations based on l1 trend filtering. We apply the proposed method to GNSS data in western Shikoku, and present the results of inversion analysis using Markov Chain Monte Carlo (MCMC) method for estimating the fault models of the detected events. The proposed method considers short-term SSEs as the change points in GNSS displacement data, and quantifies the uncertainty of the change points using multiple observation points. The hyperparameters in the proposed method can be appropriately determined by using Mallows' Cp.

The proposed method conducts (a) trend filtering, (b) testing using neighboring observation stations, and (c) integrating the test results in a stepwise manner. We first fit a piecewise linear function to the observed time series by l1 trend filtering (Kim et al., 2009). The length of the interval before and after the node is automatically determined by using the nodes of the l1 trend filtering. We finally integrate the p-values of the tests for detection uncertainty at multiple observation stations. l1 trend filtering is a sparse estimation method, also called higher order total variation regularization, that accurately estimates piecewise polynomial function hidden in the input. In the subsequent tests, we use the segmentation points obtained by l1 trend filtering.

To validate the accuracy of the proposed method, we use GNSS data for western Shikoku during April 1, 2004 to March 31, 2009, and synthetic data generated from this data; GNSS common mode errors are removed by subtracting the average time series of three stations in the Goto Islands (Kano et al, 2019), and the two-dimensional displacement data are projected in the direction of subduction of the Philippine Sea Plate relative to the Amur Sea Plate (N45W). The comparison using synthetic data shows that the missed event rate and noise false positive rate of the spatial average of AIC vary with the window width, while the proposed method performs as well as the spatial average of AIC with an appropriate window width. We report the results of using the proposed method on real data and the fault model estimation using MCMC.

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[J] Oral | S (Solid Earth Sciences)：S-SS Seismology

Thu. Jun 3, 2021 3:30 PM - 5:00 PM JST | Thu. Jun 3, 2021 6:30 AM - 8:00 AM UTC | Ch.22 Zoom Room 22

[S-SS05] Crustal Deformation

convener:Masayuki Kano(Graduate school of science, Tohoku University), Tadafumi Ochi(Institute of Earthquake and Volcano Geology, Geological Survey of Japan, The National Institute of Advanced Industrial Science and Technology), Fumiaki Tomita(Japan Agency for Marine-Earth Science and Technology), Chairperson:Yusaku Ohta(Research Center for Prediction of Earthquakes and Volcanic Eruptions, Graduate School of Science, Tohoku University), Yusuke Yokota(Institute of Industrial Science, The University of Tokyo)

Study of crustal deformation plays an extremely important role in the investigation of wide scale earth dynamics those are earthquake and volcanic activity, plate motion and so on. In our session, we discuss the study related to crustal deformation, such as development of observation instrument, observed crustal deformation, analysis method, and simulation study.

3:30 PM - 3:45 PM JST | 6:30 AM - 6:45 AM UTC

[SSS05-07] New stable slip on the plate in a wide area after 2015 detected by postseismic deformation model of 2011 Tohoku-Oki Earthquake

*Satoshi Fujiwara[1], Mikio Tobita[1], Shinzaburo Ozawa[1] (1.Geospatial Information Authority of Japan)

3:45 PM - 4:00 PM JST | 6:45 AM - 7:00 AM UTC

[SSS05-08] Preliminary results of sea-floor crustal deformation measured by GNSS-Acoustic technique in Nemuro-Oki, southwestern part of Kuril Trench

*Yusaku Ohta[1], Motoyuki Kido[2], Chie Honsho[1], Yukiho Kimura[1], Makiko Sato[1], Syuichi Suzuki[1], Ryosuke Azuma[1], Mako Ohzono[3,5], Hiroki Aota[3], Hiroaki Takahashi[3], Fumiaki Tomita[4], Takeshi Iinuma[4], Masanao Shinohara[5], Ryota Hino[1] (1.Research Center for Prediction of Earthquakes and Volcanic Eruptions, Graduate School of Science, Tohoku University, 2.International Research Institute of Disaster Science, Tohoku University, 3. Institute of Seismology and Volcanology, Faculty of Science, Hokkaido University, 4.Japan Agency for Marine-Earth Science and Technology, 5.Earthquake Research Institute,The University of Tokyo)

4:00 PM - 4:15 PM JST | 7:00 AM - 7:15 AM UTC

[SSS05-09] Monitoring of the inter-plate coupling using GNSS-A seafloor geodesy along the Nankai trough

*Tadashi Ishikawa[1], Shun-ichi Watanabe[1], Yuto Nakamura[1], Yusuke Yokota[2] (1.Hydrographic and Oceanographic Department, Japan Coast Guard, 2.Institute of Industrial Science, the University of Tokyo)

4:15 PM - 4:30 PM JST | 7:15 AM - 7:30 AM UTC

[SSS05-10] Relationship between observation ability of GNSS-A and its detection ability for coupling condition and SSE

*Yusuke Yokota[1], Tadashi Ishikawa[2], Shun-ichi Watanabe[2], Yuto Nakamura[2] (1.Institute of Industrial Science, The University of Tokyo, 2.Hydrographic and Oceanographic Department, Japan Coast Guard)

4:30 PM - 4:45 PM JST | 7:30 AM - 7:45 AM UTC

[SSS05-11] **Estimation of Average Displacement Rate Vector Using GNSS Data in Yaeyama Islands**

*Aoi Ikeichi[1], Masayuki Kano[1], Hisashi Nakahara[1], Takeshi Nishimura[1], Kazuki Komano[2], Takuya NISHIMURA[3], SHINICHI MIYAZAKI[2] (1.Graduate School of Science, Tohoku University, 2.Graduate School of Science, Kyoto University, 3.Disaster Prevention Research Institute, Kyoto University)

4:45 PM - 5:00 PM JST | 7:45 AM - 8:00 AM UTC

[SSS05-12] **Possible overlap of coseismic slip and afterslip investigated by InSAR analysis**

*Kanami Sakamoto[1], Yo Fukushima[2] (1.Graduate School of Science, Tohoku University, 2.International Research Institute of Disaster Science, Tohoku University)

New stable slip on the plate in a wide area after 2015 detected by postseismic deformation model of 2011 Tohoku-Oki Earthquake

*Satoshi Fujiwara[1], Mikio Tobita[1], Shinzaburo Ozawa[1]

1. Geospatial Information Authority of Japan

Outline

The time series of the postseismic deformation of the 2011 off the Pacific coast of Tohoku earthquake (Tohoku-Oki earthquake) is fitted by a function to predict the future changes over a wide area. In this presentation, we validate the model of the postseismic deformation using data up to December 2020, and find that a new stable slip on the plate has occurred since 2015 in the residuals between the observed data and the model.

Method

It has been shown by Tobita (2016) that a mixed model of two logarithmic and one exponential functions, represented by the following equation, can be used to predict with high accuracy the spatial distribution of postseismic deformation:

$$D(t) = a \ln(1+ t/b) + c + d \ln(1+ t/e) - f \exp(- t/g) + Vt$$

where $D(t)$ is each component of the postseismic deformation, t is days after the earthquake, ln is the natural logarithm, b, e, and g are the relaxation time constants of logarithmic or exponential functions common to all stations, and V is the steady-state velocity at each station. The time constants were determined for stations, Miyako, Yamoto, Minase, and Choshi, which show representative variations, as used in Tobita (2016); for the other stations, the determined time constants were given in common, and the amplitude coefficients were determined for each station and component by the least-squares method.

Results

Fig. 1 shows the observed values of the east-west component at two GEONET stations, the predicted values based on the 3.9-year fitting (until February 2015), and their residuals. The predicted values agreed with the observed values to within 1 cm until February 2015, but then showed a different trend after earthquakes in Sanriku-Oki (M6.9) in February 2015 and Miyagi-Oki (M6.8) in May 2015. This is not only shown in the residuals, but also the time constant g of the exponent in the above prediction model becomes computationally saturated if we include 2015 and beyond in the fitting period, indicating that another event occurred in 2015 different from the postseismic deformation of the Tohoku-Oki earthquake.

Obtaining a slip model from residuals

The systematic changes in residual from the prediction model after 2015 occurred simultaneously over a wide area from Hokkaido to the Chubu region, and each continued at an almost constant rate. In order to investigate the cause of this phenomenon, a slip velocity model on the plate surface was calculated as shown in Fig. 2, which shows a few centimeters of slip per year.

The location of this slip can be roughly divided into two areas: Sanriku-Miyagi-Oki and Urakawa-Oki. The Sanriku-Miyagi-Oki area is almost coincident with the afterslip region that began immediately after the Tohoku-Oki earthquake. In contrast, no significant slip was observed in the Urakawa offshore area before 2015, and it was newly added after 2015.

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The location and timing of the systematic residuals coincide with those of the Sanriku-Oki earthquake (M6.9) in February 2015 and the Miyagi-Oki earthquake (M6.8) in May 2015. This suggests that the onset of the slip and the occurrence of these medium-sized earthquakes are somehow related.

Conclusion

The prediction model by Tobita (2016) is able to predict the postseismic deformation of the Tohoku-Oki earthquake with an accuracy of a few centimeters even after 9 years. The residuals obtained from the prediction model are very effective in detecting the occurrence of other events that are not the postseismic deformation (e.g. Ozawa *et al.* 2016), and are expected to be used in various fields.

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Ozawa S, Tobita M and Yarai H (2016) Earth Planets Space. https://doi.org/10.1186/s40623-016-0430-4.
Tobita M (2016) Earth Planets Space. https://doi.org/10.1186/s40623-016-0422-4.

Keywords: the 2011 off the Pacific coast of Tohoku Earthquake, crustal deformation, postseismic deformation, stable slip, GNSS time series, predicting model

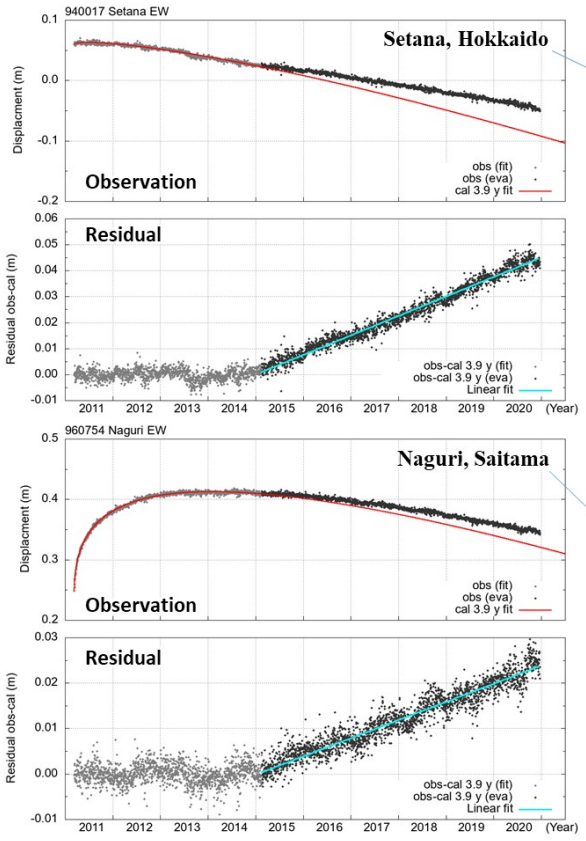


Fig 1.
above : EW displacement (dot) and forecasting model (red line) at Setana and Naguri stations.
below: Residual (dot, obs – model cal) and linear fit after 2015 (light blue line).

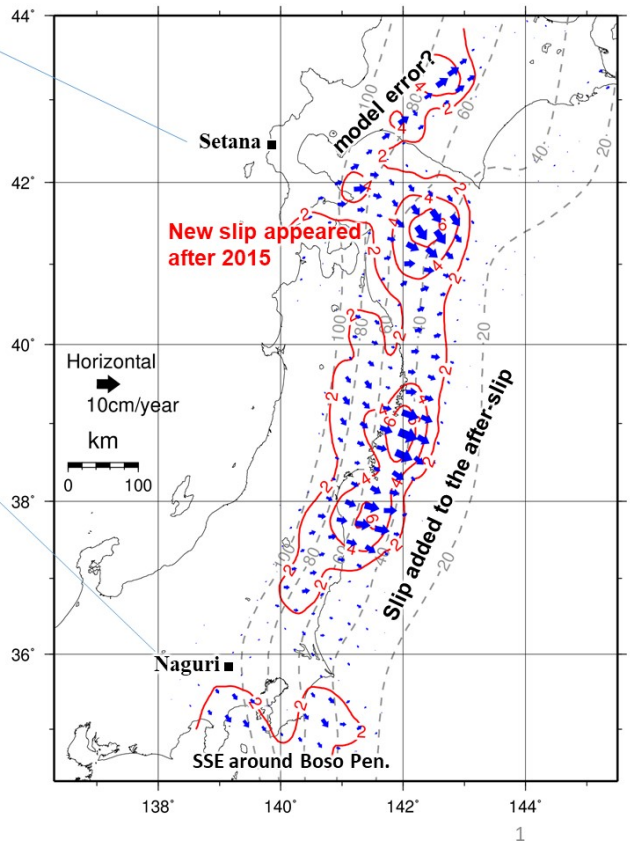


Fig 2. Slip rate model on the plate after 2015.

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Preliminary results of sea-floor crustal deformation measured by GNSS-Acoustic technique in Nemuro-Oki, southwestern part of Kuril Trench

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The sea-floor geodetic technique including GNSS-Acoustic measurement played an important role to understand the coseismic slip behavior in the 2011 Tohoku-Oki earthquake and revealed that more than 50m coseismic slip occurred at the shallow part of the plate boundary. In order to understand the diversity of earthquakes, it is essential to clarify the factors that determine the large slip at the shallow part of the plate boundary from comparative studies with past huge earthquakes in other regions.
In the Nemuro-Oki of the southwestern part of Kuril Trench, M8 class earthquakes have repeatedly occurred in the Tokachi-Oki and Nemuro-Oki segments. On the other hand, based on the survey of the distribution of tsunami deposits, it has been pointed out that a large slip may have occurred in the shallow part of the plat boundary in the 17th century, rupturing both of the Tokachi-Oki and Nemuro-Oki segments, and that the slip characteristic is similar with the 2011 Tohoku-Oki earthquake (Ioki and Tanioka, 2016). In contrast, Nemuro-Oki is no sea-floor geodetic network.
Based on these backgrounds, Tohoku University and Hokkaido University have jointly developed a sea-floor geodetic network to estimate the interplate locking at the shallower portion of the subducting plate interface, and installed three GNSS-A stations (G21, G22, and G23) in Nemuro-Oki. The G21 and G22 were installed on the landward slope, and the G23 installed on the incoming Pacific plate. The first observation was carried out in July 2019, and the second in October 2020. Although the obtained results are still tentative because of the only two times observations, the estimated horizontal velocity shows the more than 9cm/year to the northwest direction relative to the Okhotsk plate in both of G21 and G22. This result is expected to suggest that the interplate locking at the shallow part of the subducting plate interface. The modeling of these results will be discussed in detail in the presentation.

Keywords: Sea-floor geodesy, GNSS-A, Nemuro-Oki

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Monitoring of the inter-plate coupling using GNSS-A seafloor geodesy along the Nankai trough

*Tadashi Ishikawa[1], Shun-ichi Watanabe[1], Yuto Nakamura[1], Yusuke Yokota[2]

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Recurring inter-plate megathrust earthquakes have occurred along the Nankai Trough subduction zone and the next earthquake in this region is predicted to occur in the near future. Because megathrust earthquakes are driven by accumulated inter-plate slip deficit, it is necessary to monitor the inter-plate coupling state. Crustal deformation data obtained from geodetic observations is an important tool for monitoring the coupling state. However, as the focal region of the Nankai trough earthquake is located beneath the seafloor, estimations based on terrestrial observations provide limited accuracy. Therefore, seafloor geodetic observations are particularly important for monitoring the coupling state. The Hydrographic and Oceanographic Department of the Japan Coast Guard has been developing a seafloor geodetic observation system based on the combined GNSS-Acoustic ranging (GNSS-A) technique and collecting data to monitor the coupling state.

Yokota et al. (2016) estimated inter-plate slip deficit rate of the Nankai trough subduction zone using the GNSS-A seafloor geodetic data. However, temporal variation of the coupling state could not be investigated due to the inadequacy of temporal resolution of the GNSS-A data. On the other hands, slow earthquake phenomena such as slow slip events (SSE) frequently occur along the Nankai trough. Therefore, it is essential to understand the temporal variations of the coupling state.

To clarify the difference between the SSE regions and the strong coupling regions, we evaluate the average coupling state estimated from the long-term GNSS-A data updated from Yokota et al. (2016). Because the long-term data include the SSE occurrence periods, the crustal velocity becomes relatively slow in the SSE regions. Therefore, the difference from the strong coupling regions where the crustal velocity is relatively fast becomes clear. Attritionary, we investigate temporal variations of the coupling state represented as deviation from the average state.

Keywords: GNSS-A, Seafloor geodesy, Nankai trough earthquake

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Relationship between observation ability of GNSS-A and its detection ability for coupling condition and SSE

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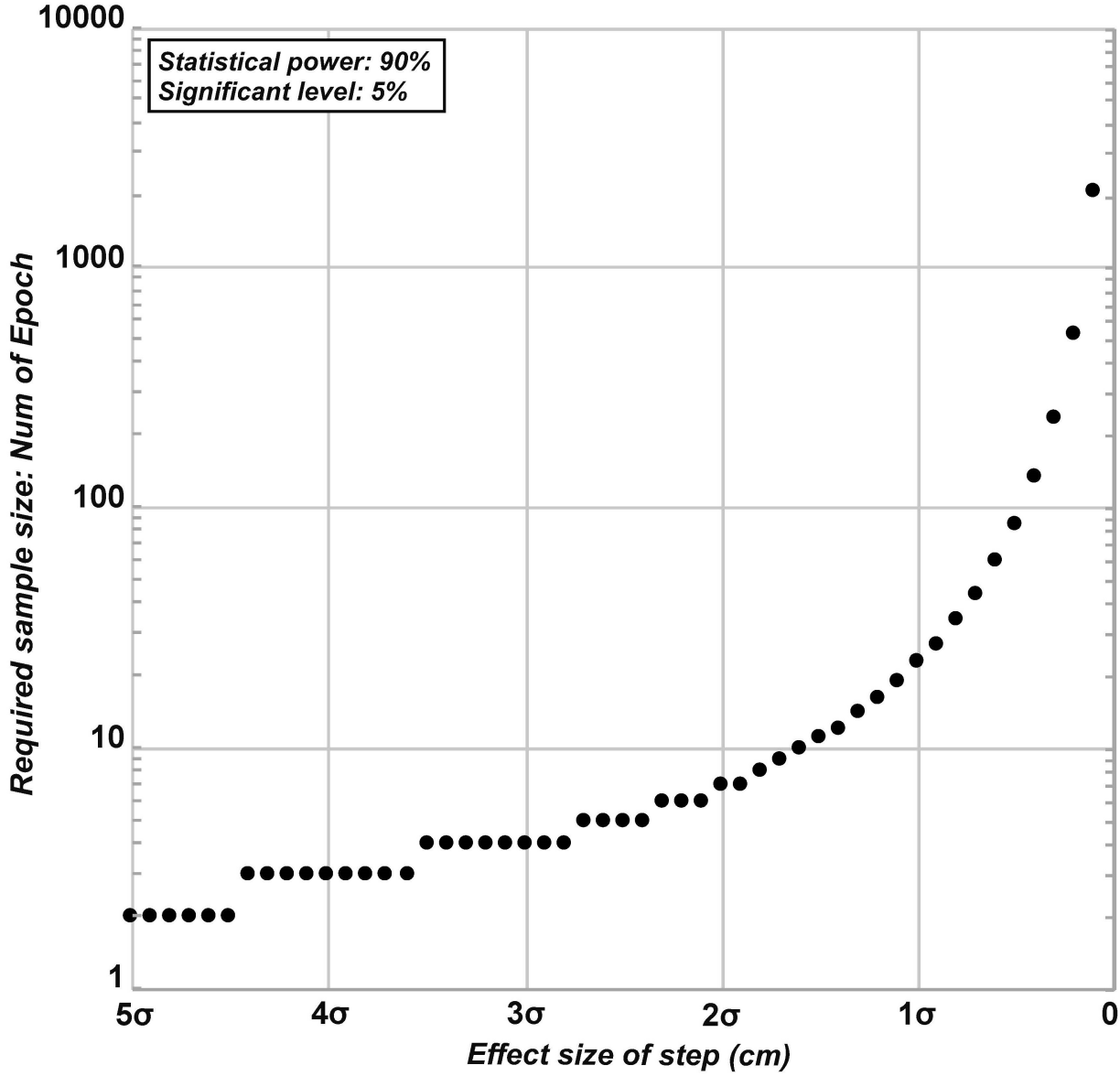
The observation frequency and observation accuracy of GNSS-A seafloor geodetic observations carried out by the Japan Coast Guard are currently 4 times/year and 2 cm (1-σ) due to technological development in about 20 years [Ishikawa et al., 2020]. By accumulating long-term observation data, it has become possible to measure interplate coupling condition and shallow slow slip events along the Nankai Trough in recent years [Yokota et al., 2016; Yokota and Ishikawa, 2020], and it has become possible to interpret the time change of postseismic deformation following the 2011 Tohoku-oki earthquake [Watanabe et al., 2014]. However, the physical process of the plate boundary can be understood by understanding the more detailed time change of a coupling condition and the postseismic processes and improving the SSE detection accuracy. This consideration will also be useful for understanding the observation results of new observation points. In this presentation, we will understand how a steady state and an event can be detected by improving GNSS-A observation ability in the future, and set development goals for that purpose.

In order to understand the detection ability of the steady state, it is sufficient to generate pseudo data with frequency and accuracy and compare the accuracy of linear regression. On the other hand, in order to understand the ability to detect events, comparison is made using detection power. Attached figure compares effect size of event step (here, the magnitude of crustal deformation due to an event) and required sample size (here, annual observation frequency). σ means the accuracy of GNSS-A obseravtion. It shows how much an event can be detected regarding to the GNSS-A observing ability. From this figure, it can be seen that when the scale of crustal movement caused by the event approaches the same level as the error, it is difficult to detect it at the current observation frequency (several times per year).

The observation ability about time constant cannot be determined by this numerical test. In this presentation, we also discuss the accuracy of event time constant and magnitude detections through some numerical experiments.

Keywords: GNSS-A, SSE, interplate coupling

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Estimation of Average Displacement Rate Vector Using GNSS Data in Yaeyama Islands

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The Southern Ryukyu region including Yaeyama Islands is located in the southwestern part of the Ryukyu Trench, where the Philippine Sea Plate is subducting beneath the Eurasian Plate. It is well known that this region has been recurrently damaged by tsunami, e.g. the 1771 Yaeyama earthquake. Nakamura (2009) estimated the source region of the 1771 earthquake at the shallow part of plate boundary. On the other hand, on the deeper part of the plate interface at depths of 30 –60 km, SSEs with Mw ~6.6 recur with intervals of ~6 months (Heki and Kataoka, 2008; Nishimura, 2014; Tu and Heki, 2017). To understand crustal deformation in this region, GNSS observations have been conducted since 2010 by Kyoto University in addition to the permanent GEONET stations. Although these GNSS data have revealed the detail source processof the SSEs (e.g. Kano et al, 2018), few studies discussed interplate locking along the plate boundery. Therefore, we estimate average displacement rate in Yaeyama Islands based on GNSS data and discuss the interplate locking along the southern Ryukyu Trench.

We used daily coordinate data in the IGS14 coordinate system from 2010 to 2018 in a 18 GNSS stations consisting of 10 GEONET and 8 GNSS stations by Kyoto University. The average displacement rate was estimated by removing deformation due to SSEs, steps by earthquakes and antenna replacement from timeseries. Following Tu and Heki (2017), the time constant for each SSE was determined by grid search using the N20W components at 0751 (Hateruma Island), the nearest station to the trench. This direction is almost parallel to that of the plate convergence. We used the onset of each event determined by Tu and Heki (2017) or Kano et al. (2018) for the SSEs before the 2016 and visually defined for those after 2017. We considered the steps of earthquakes larger than M6.0. Then, the average displacement rate, steps of earthquakes and antenna replacements, amplitudes of SSEs were estimated using the least squares method.

As a result, Yaeyama Islands are entirely moving in a southeast direction at a rate of 5 to 8 cm/yr with respect to the IGS14 coordinate system. This steady motion is thought to be the sum of the rigid block motion, consisting of translation and rotation component, and the effect of the plate subduction. The translation component of rigid block motion was removed by subtracting the rate of reference site (0498, Miyako Island). The rotation component of the southern Ryukyu block relative to the Amurian plate was calculated from the Euler-pole and angular rate estimated in Nishimura et al. (2004).

We estimated coupling area based on the back-slip model. A fault model was approximated by a single rectangle assuming a semi-infinite homogeneous elastic body (Okada, 1992). For the fault locations, we assumed two areas: one in the shallow part near the 1771 Yaeyama earthquake and the other in the deep SSE area. We referred to Nakamura (2009) for the fault parameters such as fault length and fault width to the values for the shallow part and to Heki and Kataoka (2008) for those of the deeper part. The fault width, rake angle, and back-slip were adjusted by trial and error to reduce the difference between the observed and calculated rates. We successfully reproduced the observations at most of the stations although there were some negligible misfits at stations in Yonaguni and Ishigaki Island. The back-slip rate

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are 9 cm/yr at the shallow part and 12 cm/yr at the deeper part. By comparing the plate subduction rate of ~9 cm/yr, our results suggest the existence of the interplate locking on the shallow part of the southern Ryukyu subduction zone.

Keywords: Average displacement rate, interplate locking, Ryukyu Trench, GNSS, back-slip, Yaeyama earthquake

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Possible overlap of coseismic slip and afterslip investigated by InSAR analysis

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1. Graduate School of Science, Tohoku University, 2. International Research Institute of Disaster Science, Tohoku University

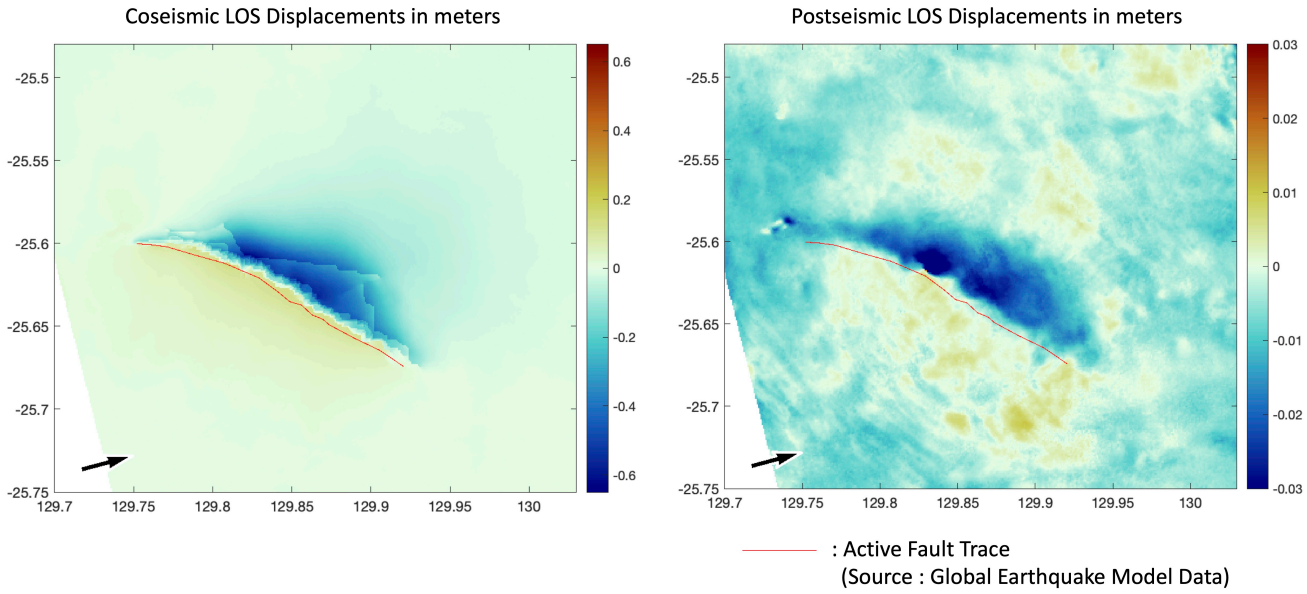
According to previous studies using seismic waves and crustal deformation data, the afterslip area on a fault is often estimated around the coseismic slip area, which is theoretically understood in such a way that the stress concentration caused by the unstable coseismic slip induces the surrounding stable slip area to slip (e.g., Marone et al., 1991, Boatwright & Cocco, 1996 etc.). In this study, we report the results of the 20 May 2016 earthquake in central Australia, where the coseismic slip and the afterslip areas may largely overlap.

We used ALOS-2 ascending data of path 124, frame 6670. For the extraction of the coseismic deformation, the pair of 15 December 2015 and 14 June 2016 were used. For the extraction of the postseismic deformation, the pairs of 14 June 2016 and 13 December 2016 (about six months after the earthquake), and 14 June 2016 and 28 November 2017 (about a year and a half after the earthquake) were used. In both InSAR analyses, spatial patterns of deformation, dominantly LOS shortening consistent with the reverse faulting, were confirmed along the known active fault trace (figure). In these results, the deformed area is localized around the fault, suggesting that the mechanism of the postseismic deformation is dominantly afterslip. The maximum coseismic LOS shortening was about 60cm, and that of the postseismic period was about 3cm. The two interferograms of the postseismic deformation periods showed no temporal increase of the deformation. Preliminary inversion analysis using the coseismic and postseismic interferograms indicated that the slip occurred on similar areas on the fault. Here we assumed that the deformation in the postseismic interferograms was due to afterslip.

The coseismic interferogram was created using the SAR image taken 25 days after the main shock, so it may contain a considerable amount of postseismic deformation. Assuming that the actual coseismic slip is significantly larger than the afterslip, however, we can consider that the “coseismic” interferogram is dominated by actual coseismic deformation. If so, an identical spatial pattern in “coseismic” and postseismic interferograms indicates an identical slip area. Based on the above results and consideration, we infer that the coseismic slip and afterslip areas largely overlapped for the case of the 2016 Australia earthquake.

Keywords: InSAR, ALOS-2, Afterslip

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[J] Oral | S (Solid Earth Sciences)：S-SS Seismology

Thu. Jun 3, 2021 9:00 AM - 10:30 AM JST | Thu. Jun 3, 2021 12:00 AM - 1:30 AM UTC | Ch.20 Zoom Room 20

[S-SS06] Statistical seismology and underlying physical processes

convener:Yasuhiro Yoshida(Meteorological Research Institute, Japan Meteorological Agency), Chairperson:Youichi Asano(National Research Institute for Earth Science and Disaster Prevention), Yohei Yukutake(Earthquake Research Institute, University of Tokyo)

This session aims to improve our understanding on seismicity. Any contribution on behavior of earthquakes as a cluster, such as regional seismicity and aftershocks, are welcomed. We also welcome contribution on temporal and spatial interactions that control seismicity, and tectonic processes, and geological and thermal structures that regulate seismicity.

9:00 AM - 9:15 AM JST | 12:00 AM - 12:15 AM UTC

[SSS06-01] Aseismic process driving the earthquake swarm, revealed by the dense seismic observation

*Yohei Yukutake[1], Keisuke Yoshida[2], Ryou Honda[1] (1.Hot Springs Research Institute of Kanagawa Prefecture, 2.Tohoku University)

9:15 AM - 9:30 AM JST | 12:15 AM - 12:30 AM UTC

[SSS06-02] Statistical analysis and its characteristics of the earthquake activity near the border of Nagano, Gifu and Fukui prefectures

*Takao Kumazawa[1], Yosihiko Ogata[2] (1.Earthquake Research Institute, The University of Tokyo, 2.The Institute of Statistical Mathematics)

9:30 AM - 9:45 AM JST | 12:30 AM - 12:45 AM UTC

[SSS06-03] Seismic activity around Kamikochi, Nagano Prefecture after the M5.5 earthquake on April 23, 2020

*Takayuki Kawabe[1] (1.Ex. Faculty of Education, Arts and Sciences, Yamagata University)

9:45 AM - 10:00 AM JST | 12:45 AM - 1:00 AM UTC

[SSS06-04] A simple way to distinguish rather shallow PAC-intraplate events from interplate ones around Japan

*Ritsuko S. Matsu'ura[1], Takeo Ishibe[1], Koji Iwasa[1] (1.Earthquake Research Center, Association for the Development of Earthquake Prediction)

10:00 AM - 10:15 AM JST | 1:00 AM - 1:15 AM UTC

[SSS06-05] Hypocenter determination assuming a 1-D velocity model with station corrections and its result for the Tohoku region

*Youichi Asano[1] (1.National Research Institute for Earth Science and Disaster Resilience)

10:15 AM - 10:30 AM JST | 1:15 AM - 1:30 AM UTC

[SSS06-06] Seismicity distribution in the Tonankai and Nankai seismogenic zones and its spatial relationship with interplate coupling and slow earthquakes

*Yojiro Yamamoto[1], Shuichiro Yada[1], Keisuke Ariyoshi[1], Takane Hori[1], Narumi Takahashi[2] (1.JAMSTEC, 2.NIED)

Aseismic process driving the earthquake swarm, revealed by the dense seismic observation

*Yohei Yukutake[1], Keisuke Yoshida[2], Ryou Honda[1]

1. Hot Springs Research Institute of Kanagawa Prefecture, 2. Tohoku University

The models for earthquake swarms are proposed as a migration of highly pressurized fluid (e.g., Parotidis et al., 2005) or an aseismic slip on a fault plane (e.g., Lohman and McGuire, 2007). However, the detailed process of fluid migration and aseismic deformation for the occurrence of earthquake swarms has not been fully understood. In Hakone volcano, central Japan, shallow intense swarm activities have been observed. Based on the dense seismic observation data, a previous study found a diffusion-like migration of swarm hypocenters that follows a diffusion equation and gives hydraulic diffusivity between 0.5 and 1.0 m^2/s (Yukutake et al., 2011). The observation implies that the occurrence of the earthquake swarms is related to the fluid migration. On the other hand, during the swarm activity from May 11 to 19, 2019, beneath Lake-Ashi, the western part of Hakone caldera, we observed a precursive seismic activity, repeating earthquakes, and tilt change. These observations may indicate the involvement of the aseismic process in addition to highly pressurized fluid in the occurrence of swarms.
We used 34 seismic stations in and around the caldera of Hakone volcano to determine the hypocenter locations and focal mechanisms. The double-difference method (Waldhauser and Ellsworth, 2000) was applied, using the differential arrival time data obtained by the manually picking and waveform cross-correlation process. The focal mechanisms of earthquakes were determined by using the P-wave polarities and P/SH wave amplitudes. To detect the events with smaller magnitude, we applied the Matched Filter method, using the template events based on the HSRI earthquake catalog. For the detection of repeating earthquakes, we applied a criterion with a correlation coefficient of >= 0.95 at more than four stations for the waveform records of 1 sec before and 5 sec after the theoretical P-wave arrival time. The borehole tiltmeters installed in Hakone volcano were also used as crustal deformation data, after removing the trend and tidal response.
The hypocenter distribution represents a plane-like distribution oriented to the azimuth of the E-W direction and nearly vertical dipping angle. One of two nodal planes of the focal mechanism is generally consistent with the orientation of planar hypocenter distribution. The detailed temporal-spatial distribution of seismicity estimated by the Matched filter method shows that the precursive seismic activity started from May 11 on the plane-like distribution, following the remarkable earthquake swarms from 05:18 (JST), May 18. We observe a downward migration of precursive seismicity to the starting point of the remarkable earthquake swarms at the speed of 70m/day, and the remarkable earthquake swarms show a diffusion-like migration of hypocenter that gives a hydraulic diffusivity of 3.0 m^2/sec. Fifty-six groups of repeating earthquakes were identified during the seismic activity. Averaged aseismic slip histories inferred from the repeating earthquakes indicate that a subtle aseismic slip of 0.3 mm occurred during the precursive seismic activity, while the aseismic slip accelerated from May 18 up to the cumulative slip of 3 mm. The tilt changes at the borehole stations can be explained most appropriately by assuming the tensile-shear on the planar hypocenter zone. The shear slip dislocation in this model is estimated as 3mm that is consistent with the result of repeating earthquakes. These observations may imply that the aseismic process due to the intrusion of highly pressurized fluid into the fault plane was also related to the triggering the earthquake swarms.

Keywords: Earthquake swarm, Fluid, Aseismic slip

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Statistical analysis and its characteristics of the earthquake activity near the border of Nagano, Gifu and Fukui prefectures

*Takao Kumazawa[1], Yosihiko Ogata[2]

1. Earthquake Research Institute, The University of Tokyo, 2. The Institute of Statistical Mathematics

An earthquake swarm activity has occurred in April 2020 near the border between Nagano and Gifu prefectures. In the same region another event had started in August 1998. These two events have comparable sizes, similar period of activities and similar transitions in time. We analyzed these events with statistical models, ETAS model and its variations to capture the characteristics of the earthquakes in the focal region.

These earthquake swarms have many strike-slip fault types with the northwest-southeast direction as the compression axis, reflecting the stress field. Since it occurred near the volcanic area, it may be related to the movement of hot water and magma fluid and the diffusion of pore pressure.

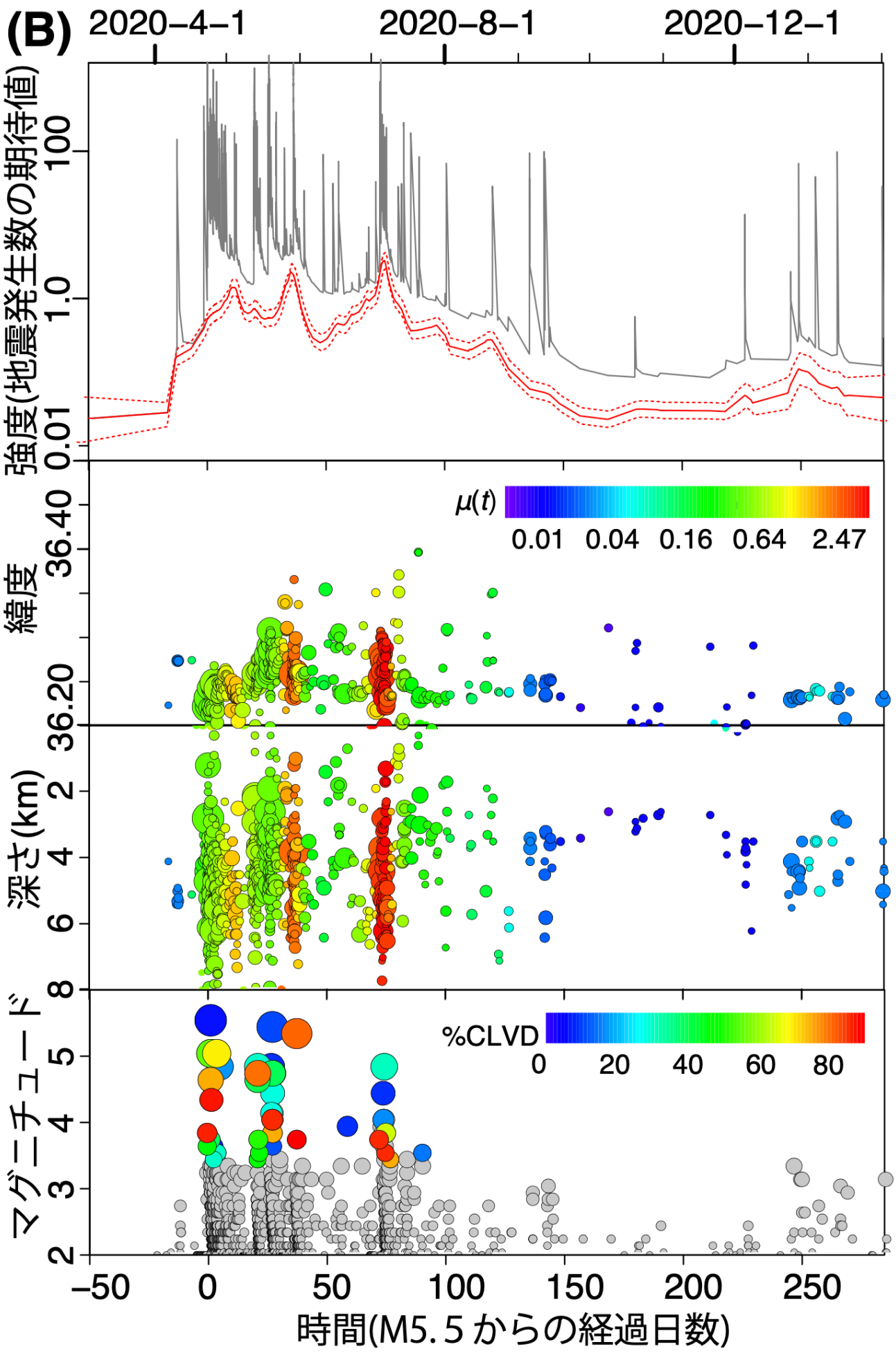
The proportion of non-double couple components (% CLVD) in the CMT solution in the focal region shows a relatively high value. Comparing to the surrounding area, other high values appear only near Mt. Ontake; many are low in the Itoigawa-Shizuoka Tectonic Line and other major active fault areas.

For the spatiotemporal patterns, there earthquake swarms both started in the southernmost region the moved northward. Earthquakes with high % CLVD occur in relatively deep locations.

The background seismic activity in 1998, which is estimated by the non-stationary ETAS model, reached dozens to hundreds of times larger than the normal level in 50 days from the beginning. This active area is concentrated in the southernmost region. In 2020, three similar peaks with similar sizes are estimated. There was another increased activity from the end of 2020, but it is settling down; the background seismic activity is dropping down to the normal level. High % CLVD values are connected with these high values in the background.

Keywords: Earthquake swarm, background seismicity, nonstationary modeling

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Seismic activity around Kamikochi, Nagano Prefecture after the M5.5 earthquake on April 23, 2020

*Takayuki Kawabe[1]

1. Ex. Faculty of Education, Arts and Sciences, Yamagata University

Introduction
The southern part of the Hida Mountains is one of the areas where shallow earthquakes occur most frequently in Honshu. Among these activities since 1922, the series of seismic activities that started at 13:44 on April 23, 2020, around Kamikochi, Matsumoto City, Nagano Prefecture, triggered by the Mj5.5 earthquake, have been carried out so far. It can be said that this is the largest activity in the seismic record.

Seismic activity around Kamikochi
Seismic activity around Kamikochi has been active in a narrow range of 25km north-south and 15km east-west, including medium-seismic earthquakes reaching a depth of about 50km for at least the past 100 years. It has been. The three-dimensional shape of the distribution area is exactly the shape of a funnel.
Looking at the seismic activity around Kamikochi up to the present, there is a cycle in which Mj5 to 5.5 class earthquakes are active in a cycle of several years to about 10 years, and among the aftershocks caused by water reduction. In addition, there is an activity cycle around Mj4 with a cycle of about one week, and an activity cycle with a cycle of half a day to one day is also observed.
More characteristically, earthquakes up to a depth of several tens of kilometers occur within hours after an earthquake of Mj5 or higher that occurs in a shallow layer with a depth of several kilometers. During this time, the depth at which earthquakes occur gradually increases. Earthquakes up to a depth of several tens of kilometers do not occur in all cycles, and the continuity between shallow and deep earthquakes may not be clear.

Mechanism of seismic activity around Kamikochi
It is possible to consider the involvement of thermofluids in such a phenomenon that shallow earthquakes and deep earthquakes occur intermittently in a narrow range (Omi, 2001; 2020, Kawabe, 2017). If thermofluids are involved, the general pattern is that a deep earthquake occurs first, and then the active area gradually shifts to shallow areas. However, in the case of an earthquake around Kamikochi, on the contrary, it is always a transition from a shallow earthquake to a deep earthquake, which is the opposite of the direct involvement of thermofluids.
according to the actual condition of the lower bottom surface of the shallow earthquake and the rise of the quaternary granite body in the southern part of the Hida Mountains, the upper crust is more brittle due to the bending deformation of the crust caused by the magma derived from the upper mantle. A model is conceivable in which rupture occurs from the ground, and the rupture progresses further downward, and eventually the rupture propagates to the lower crust and upper mantle in the plastic region under the original stress field.

Keywords: earthquake swarm activity, northern Hida Mountains, up-warping deformation

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A simple way to distinguish rather shallow PAC-intraplate events from interplate ones around Japan

*Ritsuko S. Matsu'ura[1], Takeo Ishibe[1], Koji Iwasa[1]

1. Earthquake Research Center, Association for the Development of Earthquake Prediction

On Feb. 13, 2021, a shallow* M_{JMA}7.3 (M_{rapid} was 7.1) event occurred off Fukushima prefecture. The hypocenter depth (rapid 60km-> 55km) was very close to the assumed PAC plate surface. Since S-net has been used for hypocenter determinations by JMA, its aftershock distribution within an hour after helped us to assume that the event was intra-slab event.

However, there is the much easier and faster way to judge the source type of such a shallow event in the east off Tohoku district by the intensity distributions in Japanese islands available within a few minutes. In Fig. 1, the expected intensity distributions by the useful GMPE (Matsu’ura et al, 2020) are shown of the same epicenter and M (37.7°N, 141.8°E, Mw7.1) events with three source types (crustal, interplate, and intraplate), respectively. Their GMPE is classified by the source type, and robust for the estimation errors of M and depth.

In Fig. 2, differences between expected intensities for some PAC-intraplate, PAC-interplate, and very shallow crustal earthquakes are compared on epicentral distance. In Fig. 3, the observed intensities of the 2021 Feb. 13 event observed at K-NET and KiK-net stations are shown with some expected intensities on hypocentral distances.

Solid marks show the adjusted intensities to exclude differences between sites on the abnormal intensity effect of PAC slab, and on the amplification factors by the surface soil. We can obtain a hypocenter, M and intensities within a few minutes after an event occur. Then the GMPE can expect intensities for various source types, and we can compare them with observed intensities. The source type can be judged, without F-net mechanism solution nor the aftershock distribution.

Acknowledgements
We used K-NET, KiK-net data by National Research Institute for Earth Science and Disaster Resilience. This study was done with funding from the Ministry of Education, Culture, Sports, Science and Technology, Japan for the Headquarters of Earthquake Research Promotion of the Japanese government.

Reference: Matsu’ura, R. S., H. Tanaka, M. Furumura, T. Takahama, andA. Noda (2020). A New Ground-Motion Prediction Equation of Japanese Instrumental Seismic Intensities Reflecting Source Type Characteristics in Japan, Bull. Seismol. Soc. Am. 110, 2661–2692, doi: 10.1785/0120180337

* In the depth classification by Utsu (1979), "very shallow" is a crustal event, "intermediate" is an intermediate intra-slab event deeper than 60km, and shallow indicates 60km or shallower interplate or intraplate in the eastern off-shore areas of Japan. He knew that it is hard to distinguish "Intra" from "Inter" for old earthquakes.

Keywords: judge source type with the intensity distribution, difference between interplate and intraplate events, the useful GMPE of intensities in Japan, Off Fukushima earthquake on Feb. 13, 2021, Ground Motion Prediction Equation

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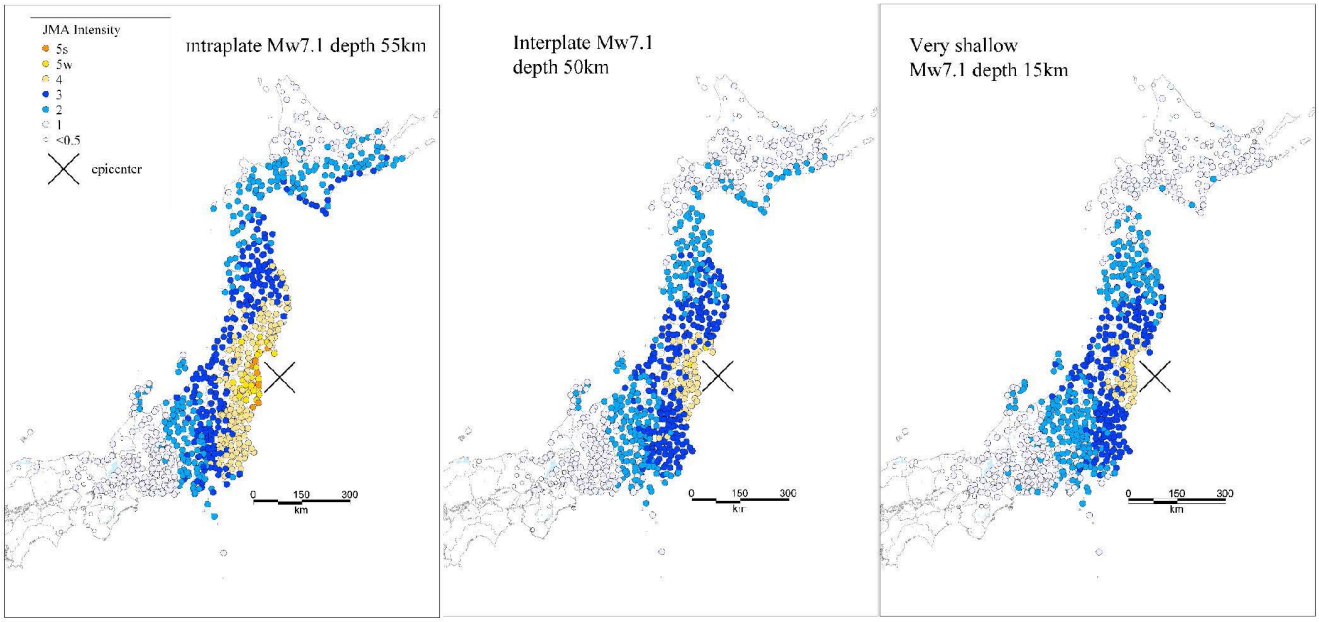


Fig. 1. Expected intensity distribution of K-NET and KiK-net stations for various source types of Mw7.1 at the same epicenter.

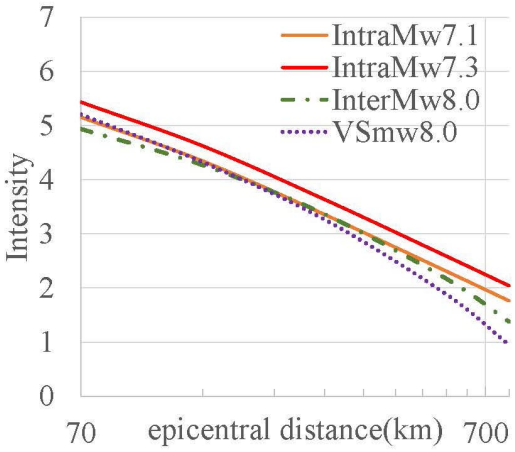


Fig. 2. Expected intensities v.s. epicentral distance for various cases.

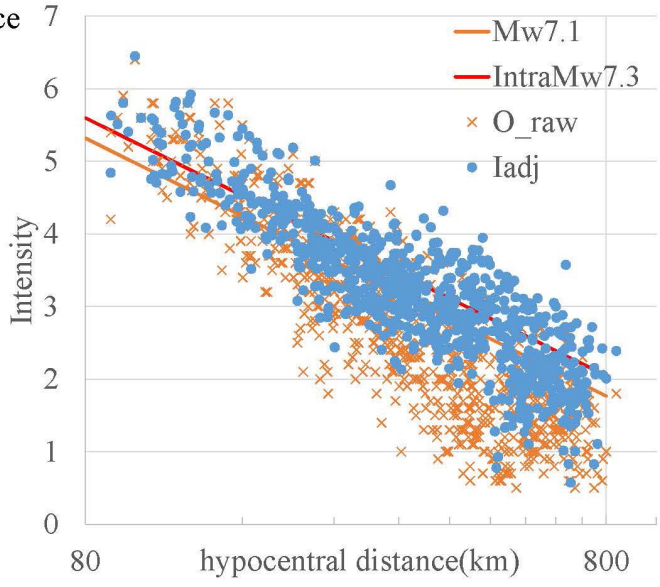


Fig. 3. Expected intensities and observed and adjusted (as PAC depth 80km and Vs30=300m/s) intensities of M_{JMA}7.3 off Fukushima event on 2021 Feb. 13.

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Hypocenter determination assuming a 1-D velocity model with station corrections and its result for the Tohoku region

*Youichi Asano[1]

1. National Research Institute for Earth Science and Disaster Resilience

We have evaluated station corrections for our routinely hypocenter determination assuming a 1-D velocity model. At first, we estimated centroid moment tensors (CMTs) for 653 earthquakes in the period of 2016-2020 from the waveform data of the F-net broadband seismometers and Hi-net tiltmeters. Next, we estimated hypocenters of these earthquakes from picked P- and S-wave arrival times at the S-net, Hi-net, and other stations operated by the JMA, ADEP, Hokkaido University, Hirosaki University, Tohoku University or University of Tokyo. Station corrections were evaluated from the residuals of this hypocenter determination under a constraint of hypocentral depths fixed to centroid depths of CMTs. Considering epicentral distance dependency of the residuals for shallow earthquakes, we used the residuals for deeper earthquakes than 20 km and longer epicentral distance than 75 km. We applied these station corrections to our hypocenter determination and relocated earthquakes used for evaluating these station corrections. The estimated depths of the earthquakes mainly located within 10 km from their centroid depths showed effectiveness of our station corrections. Finally, we analyzed 3019 earthquakes which occurred off Fukushima and Miyagi in the period from June, 2016 to February 14, 2021. In the obtained results, we can see an ENE dipping earthquake cluster probably just along the boundary between the subducting Pacific Plate and the overriding plate. Some earthquakes probably along the plate boundary are also distributed in focal area of the 2011 Tohoku earthquake. Furthermore, the 2021 off Fukushima earthquake with M_{JMA} 7.3 and its aftershocks are distributed below the dipping earthquake cluster. Therefore, these earthquakes are considered to be intraplate events in the subducting Pacific Plate.

Keywords: hypocenter determination, station correction, Tohoku earthquake, interplate earthquake, intraplate earthquake

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Seismicity distribution in the Tonankai and Nankai seismogenic zones and its spatial relationship with interplate coupling and slow earthquakes

*Yojiro Yamamoto[1], Shuichiro Yada[1], Keisuke Ariyoshi[1], Takane Hori[1], Narumi Takahashi[2]

1. JAMSTEC, 2. NIED

The Nankai Trough subduction zone is well known for repeated M8 class mega-earthquakes, which have occurred at intervals of 100–150 years (Ando, 1975). The area off the Kii Peninsula is key to understanding the seismic behavior of these large earthquakes because it includes the boundary between two of the largest seismogenic segments in the subduction zone, the Tonankai and Nankai segments. The most recent mega-earthquakes in this region, the 1944 Tonankai (Mw8.1) and 1946 Nankaido (Mw8.3) earthquakes, occurred about 75 years ago. For this reason, various seismological and geodetic studies have been carried out in the Nankai Trough. These are revealing the existence of subsurface structural heterogeneities that can control rupture propagation (e.g., Kodaira et al., 2002, 2006), slow seismic phenomena and their distribution (e.g., Nakano et al., 2018; Takemura et al., 2019), and current slip-deficit distribution (e.g., Yokota et al., 2016; Nishimura et al., 2018). However, not much research has been done on regular earthquake activity because of their low activity level and the difficulty in determining the hypocenter location with high accuracy due to offshore condition. Monitoring the spatio-temporal distribution of not only slow earthquakes but also regular earthquakes at the plate boundary is important for studying the occurrence process of large earthquakes.

In this study, we attempted to determine the hypocenter location detected by DONET (Kawaguchi et al., 2011; Kaneda et al., 2015) since 2012 with high accuracy to clarify the seismically active region on the plate boundary of the Nankai Trough. To improve the accuracy of the estimated hypocenter location, we performed seismic tomography by adding DONET data to the previous 3D tomographic study (Yamamoto et al., 2017), and updated the velocity structure and hypocenter location simultaneously.

The spatial characteristics of the updated velocity model are not so different from the previous model (Yamamoto et al., 2017), but the recovery of the checkerboard resolution test is greatly improved. From the obtained hypocenter catalog, we extract earthquakes near the plate boundary based on the plate boundary model (Nakanishi et al., 2018) and found that these earthquakes were localized in several clusters. Most of them are located outside the large slip deficit area suggested by the geodetic data (Nishimura et al., 2018). They also seem not to overlap with the active area of VLFE (Takemura et al., 2019). These spatial relationships indicate the monitoring of regular earthquakes may provide useful information about the interplate coupling status.

Keywords: Nankai Trough, Ocean bottom seismographic observation, DONET, Seismicity

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[J] Oral | S (Solid Earth Sciences)：S-SS Seismology

Thu. Jun 3, 2021 10:45 AM - 12:15 PM JST | Thu. Jun 3, 2021 1:45 AM - 3:15 AM UTC | Ch.20 Zoom Room 20

[S-SS06] Statistical seismology and underlying physical processes

convener:Yasuhiro Yoshida(Meteorological Research Institute, Japan Meteorological Agency), Chairperson:Kohei Nagata(Meteorological Research Institute), Masatoshi Miyazawa(Disaster Prevention Research Institute, Kyoto University)

This session aims to improve our understanding on seismicity. Any contribution on behavior of earthquakes as a cluster, such as regional seismicity and aftershocks, are welcomed. We also welcome contribution on temporal and spatial interactions that control seismicity, and tectonic processes, and geological and thermal structures that regulate seismicity.

10:45 AM - 11:00 AM JST | 1:45 AM - 2:00 AM UTC

[SSS06-07] Toward the construction of an integrated assessment method of crustal activity - characterization of “normal” seismicity in Japan-

*Kohei Nagata[1], Koji Tamaribuchi[1], Fuyuki Hirose[1], Akemi Noda[1] (1.Meteorological Research Institute)

11:00 AM - 11:15 AM JST | 2:00 AM - 2:15 AM UTC

[SSS06-08] A hierarchical model of earthquake asperity

*Yoshio Fukao[1] (1.Center for Earthquake and Tsunami / Japan Agency for Marine-Earth Science & Technology)

11:15 AM - 11:30 AM JST | 2:15 AM - 2:30 AM UTC

[SSS06-09] Radiation-corrected empirical Green's function in slip inversion

*Ritsuya Shibata[1], Genki Oikawa[1], Naofumi Aso[1], Junichi Nakajima[1], Satoshi Ide[2] (1.Department of Earth and Planetary Sciences, Tokyo Institute of Technology, 2.Department of Earth and Planetary Science, The University of Tokyo)

11:30 AM - 11:45 AM JST | 2:30 AM - 2:45 AM UTC

[SSS06-10] Modeling dynamic rupture and statistical properties of earthquakes with cellular automaton models.

*Kota Fukuda[1], Takahiro Hatano[2], Kimihiro Mochizuki[1] (1.Earthquake Research Institute The University of Tokyo, 2.Department of Earth and Space Science Osaka University)

11:45 AM - 12:00 PM JST | 2:45 AM - 3:00 AM UTC

[SSS06-11] Dynamic earthquake triggering in Southern California in high resolution

*Masatoshi Miyazawa[1], Emily E Brodsky[2], Huiyun Guo[2] (1.Disaster Prevention Research Institute, Kyoto University, 2.University of California, Santa Cruz)

12:00 PM - 12:15 PM JST | 3:00 AM - 3:15 AM UTC

[SSS06-12] Discussion

Toward the construction of an integrated assessment method of crustal activity -characterization of “normal” seismicity in Japan-

*Kohei Nagata[1], Koji Tamaribuchi[1], Fuyuki Hirose[1], Akemi Noda[1]

1. Meteorological Research Institute

Meteorological Research Institute is progressing research to develop the method to assess the crustal activity such as seismicity and crustal deformation by integrating the various parameters that characterize the activities. The ultimate goal is to assess the potential of the integrated method to express the current anomaly of crustal activity. For that purpose, it is necessary to quantify the “normal” crustal activity from a more integrated perspective not only from the conventional viewpoint based on the results of individual parameters. In the presentation, we will report the result of the analysis of the joint distribution of the parameters characterizing the size distribution, tidal correlation, and activation/quiescence of seismicty estimated from hypocenter data for the past 20 years in Japan conducted as an attempt to develop the integrated assessment method.

In the analysis, we used the JMA unified seismic catalog from 2000 to August 2021. We extracted two types of dataset consist of shallow-inland earthquakes ($M \geqq 2.0$, depth ≦30 km) and earthquakes including subduction-zone earthquakes ($M \geqq 3.5$, depth≦100 km) from the catalog. For each dataset, the parameter values are estimated for the same N consecutive earthquakes in dl degree square spatial grids. The results are smoothed by shifting the analysis window by half, that is, $N/2$ in the temporal direction and $dl/2$ in the spatial direction. The results give us a joint distribution in addition to the individual distributions of each parameter. When comparing the distribution with parameter values observed in specific time or space, it is possible to apply a conventional statistical test such as the goodness-of-fit test by extracting the results of grids that do not overlap each other.

As a parameter characterizing the size distribution of seismicity, the GR law’s b value was estimated. The earthquakes that clearly deviate from the GR law, such as aftershocks just after a large earthquake, were excluded by the R value (Wiemer and Wyss 2000, 2002). As a parameter characterizing the tidal correlation of seismicity, based on Schuster's test (Schuster 1897), we used the D value ($D^2=(\Sigma_{i=1}^{N} \cos\theta_i)^2+(\Sigma_{i=1}^{N} \sin\theta_i)^2$, where θ_i is the tidal phase angle of i'th earthquake) to estimate the correlation between seismicity and phase angle of tidal response of volumetric strain. To eliminate the apparent correlation caused by swarming earthquakes, instead of using declustered data, which makes difficult to estimate joint distribution, we excluded the case where $N/4$ or more events occurred within half of the tidal cycle. For characterizing activation/quiescence of seismicity, the expected number of earthquakes in the analysis window by the ETAS model (E value, hereafter), whose parameters were estimated in each spatial grid, is used. Some of the ETAS parameters used here can also be used as indicators of seismicity’s regionality.

The probability density distributions of the three parameters (b, D, E) are close to, but different from those expected from theory and model. Though the difference should include the spatiotemporal fluctuations that should be investigated in detail, it makes sense to quantify them as an average characteristic of "normal" seismic activity by excluding the known "abnormal" cases such as the very early stage of aftershocks where the frequency distribution clearly deviates from the GR law or where earthquakes occur too frequently to estimate tidal correlation. With the joint distributions of these parameters, for example, when anomalies in the size distribution and tidal correlation of seismicity occur simultaneously, it will be

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possible to quantify how abnormal the observed phenomena are. It is also important to know whether a distribution of the parameter values different from "normal" may be obtained before the occurrence of a significant earthquake or in response to crustal deformations. In the presentation, we would like to introduce some examples from this perspective.

Keywords: seismicity, tidal correlation, ETAS, starain rate

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A hierarchical model of earthquake asperity

*Yoshio Fukao[1]

1. Center for Earthquake and Tsunami / Japan Agency for Marine-Earth Science & Technology

Introduction

Asperity models (Lay and Kanamori, 1981) have contributed greatly to understanding of such phenomena as regional characteristics of great earthquakes (Lay et al., 1982) and repeating earthquakes on plate boundaries (Matsuzawa et al., 2002). Hierarchical rupture models, on one hand, have been developed by remarking the self-similar characteristics of seismic rupture growth (Smalley et al., 1985; Fukao and Furumoto, 1985). The self-similarity implies unpredictability of the eventual size of rupture growth by observing seismic radiation. Recent careful analyses of seismic waves seem to support this implication (Maier et al., 2016; Okuda and Ide, 2018; Ide, 2019). The self-similar behavior is a phenomenon expected at a critical state of the stress system (Allégre et al., 1982; Turcotte, 1997). The power law of the event-size distribution known as the Gutenberg-Richter relation (Gutenberg and Richter, 1954) is regarded as an expression of this critical state (Narteau, 2007). Here, we explore a hierarchical asperity model in which asperity patches are distributed to allow their progressive unlocking from smaller to larger scales at a critical state.

Basic idea of the model

The elastic upper plate and the rigid lower plate are in frictional contact. The lower plate is kept at rest. The elasticity of the upper plate is modeled by an array of springs connecting the rigid surface at the top and a fractal set of asperities at the bottom (Fig.1). Uniform shear traction across the top surface is transmitted to the asperities through the equally deflected springs. Fig.1 shows our one-dimensional asperity model (Cantor set) and two-dimensional asperity model (Sierpinski carpet). The basic slip-system consists of the central major asperity and the surrounding minor asperities mutually isolated by already slipped patches. The major and minor asperities have the same frictional strength but their sizes are different, so stresses concentrate more on the minor asperities (Stage A). All the minor asperities are eventually unlocked and the imposed force is now supported only by the major asperity (Stage B). This state is understood as the rebirth of Stage A at the next larger scale (Stage C). The subsequent process is then the rebirth of Stage-B at this larger scale (Stage D). Rupture develops self-similarly from the smallest to larger scales, if the process A→B is appropriately renormalized to the process C→D.

Renormalization of the system

The process A→B involves the stress-release from the surrounding minor asperities and the consequent stress-accumulation on the central major asperity. Such stress transfer is guaranteed in our model by imposing the scale-independent condition that the probability for all the surrounding minor asperities to be unlocked equals the probability for the central asperity to be unlocked. These two probabilities can be calculated as functions of $p_o(\sigma / \sigma_o)$, where $p_o(\sigma / \sigma_o)$ describes the probability for an asperity to be unlocked by relative applied stress σ / σ_o (Turcotte, 1997). For the one-dimensional asperity model, the equality of the two probabilities occurs at $p_o = 0.42565$ or $\sigma / \sigma_o = 0.74466$. For the two-dimensional asperity model, the equality occurs at $p_o = 0.55831$ or $\sigma / \sigma_o = 0.90396$. If the system is tuned to this critical state, the basic system at any scale grows self-similarly into one at the next larger scale with probability p_o.

Characteristics of the two-dimensional hierarchical asperity model

(1)The asperity distribution in Sierpinski carpet →Fault plane with a fractal dimension D of 1.8928. (2)Non-asperity patches = Already unlocked asperities →GR law with a b-value of 1 (b ≠D/2). (3)Stresses on minor asperities 9 times higher than one applied on the top surface →Frictional strength of asperity

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much higher than the overall stress drop. (4)Successively upscaled radiations from surrounding minor asperities and from the central major asperity →Unpredictbility of final earthquake size by observing seismic radiation.

Keywords: earthquake, fault, asperity, hierarchy, self-similarity

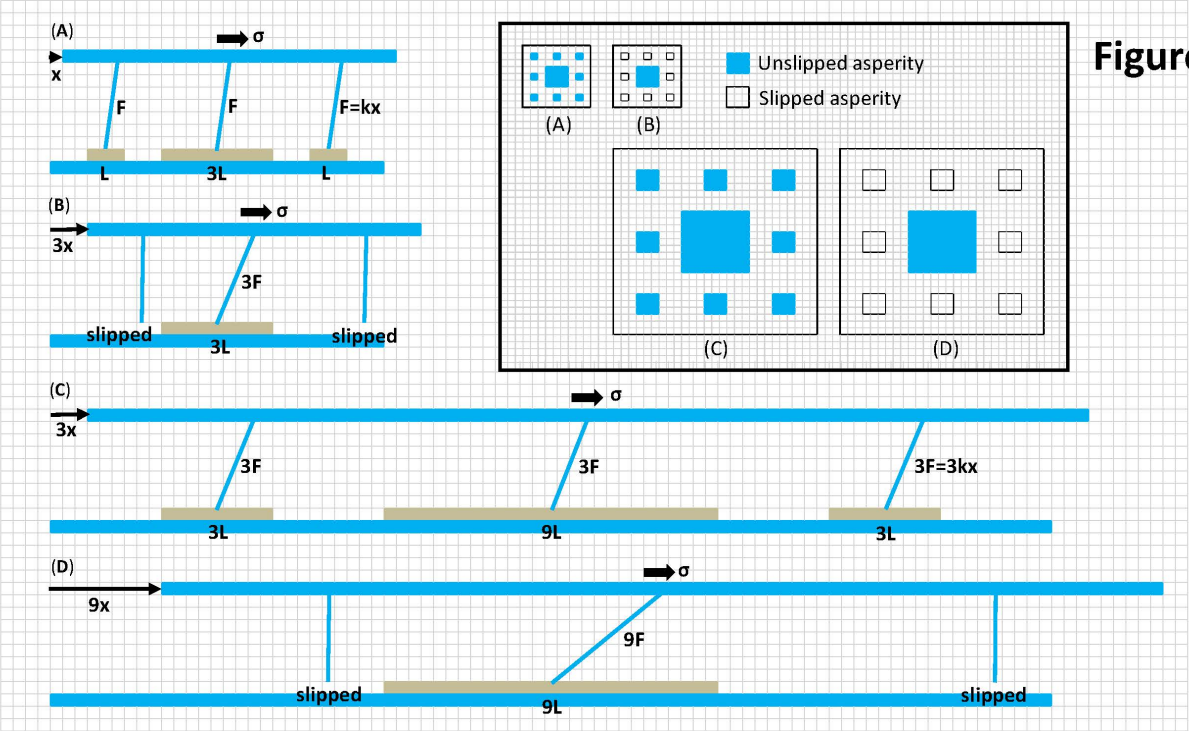


Figure 1

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Radiation-corrected empirical Green's function in slip inversion

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Slip inversion is one of the useful methods to analyze source processes, which have the advantage of being able to estimate the detailed spatial and temporal slip distribution. In this method, the least square problem is solved for the slip amount at each time step and each spatial step to minimize the waveform misfit between the observed waveforms and the synthetic waveforms which are generated by convolving the Green’s functions and the source time functions. Therefore, we need to estimate the accurate Green’s functions for the slip inversion and there have been numerous efforts to accurately estimate Green’s functions. In the case of theoretical Green’s function that is calculated from a given velocity structure, detailed a priori information on seismic velocity structure is required (e.g. Bouchon, 1981; Takeo, 1985). In contrast, empirical Green’s function (EGF), which is obtained by utilizing the seismograms of nearby small earthquakes with similar focal mechanisms, requires the occurrence of such appropriate events nearby the target event (e.g. Hartzell, 1978). To release these strict constraints partially, we proposed “radiation-corrected EGF” by correcting the radiation patterns of the EGF seismograms (Fig. 1). In particular, based on the ray theory, we can calculate the theoretical radiation patterns of the target event and the EGF event. Then, using the ratio of the radiation patterns in each component at each station, we correct the amplitude of the EGF seismogram for each of P, SV, and SH waves.

The effectiveness of the radiation correction was confirmed by the simplest synthetic tests with a triangular source time function in our previous study. Therefore, in this study, we investigate the applicability of the radiation-corrected EGF to the multi-time-window method (Olson and Apsel, 1982; Hartzell and Heaton, 1983). As a first step in applying the radiation-corrected EGF to the multi-time window method, we solve inversion problems in a setting that the fault finiteness is negligible. Therefore, we consider only time steps for the inversion.

At first, we applied this radiation-corrected EGF and the conventional EGF to the real data to confirm the superiority of the radiation pattern correction. We investigated the reproductivity of the synthetic waveforms and the estimated moment using the observed waveforms of three Mw~5 class earthquakes: the 2007 Mw 5.0 Mie earthquake, the 2011 M_w 5.2 Hiroshima earthquake, and the 2016 Mw 4.8 Kumamoto earthquake. We used the underground KiK-net stations of the National Research Institute for Earth Science and Disaster Resilience (NIED) within the epicentral distance of 50 km from each of the target event. To calculate the radiation pattern, we estimated the take-off and incident angles by ray tracing in a horizontally-layered structure of the JMA2001 (Ueno et al., 2002) using the TauP package (Crotwell et al., 1999). As a result of the real data application, we confirmed that the better moment estimations with better waveform fittings can be obtained by the radiation-corrected EGF compared to the conventional method for the three cases.

Next, to investigate the validity of the results obtained in the real data application, we performed recovery tests of the source time functions. In these recovery tests, we verified the reproductivity of the estimated source time functions using theoretical waveforms calculated from given source time functions which were determined randomly under the same station distribution, focal mechanisms, and hypocenter

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location as three analyzed earthquakes in the real data application. The theoretical waveforms are calculated using the FK application (Zhu and Rivera, 2002) in the velocity structure of JMA2001. We made 1,000 randomly determined source time functions and solved the inversion problems with the radiation-corrected EGF and the conventional EGF for each given source time function. As a result of the recovery tests, for all samples, the results with the radiation-corrected EGF have better waveform fittings, better moment estimations, and better reproductivity of the source time functions than those with the conventional EGF for three earthquakes. In addition, we confirm that the inversion results are fairly stable regardless of the shape of the source time functions.

Keywords: empirical Green's function, slip inversion, source process

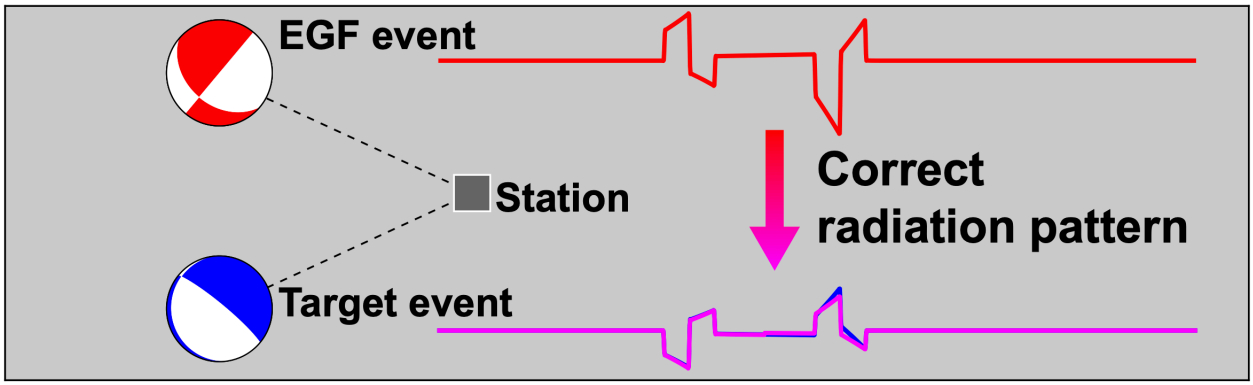


Figure 1. Concept of this study.

The blue beach ball represents a target event and the red beach ball represents the EGF event with different focal mechanism at a different location. The radiation-corrected EGF (purple line), which is generated from the seismogram of the EGF event (red line) by correcting radiation patterns of far-field P and S waves, matches the seismogram of the target event (blue). Two events at depths of 20 km have the same triangle slip rate function with a duration of 1 s and the same moment magnitude. Epicentral distances from the events to the station (grey square) are 10 km. All the seismograms use a velocity record of 15 s from the origin time in vertical component in the same scale. A homogeneous media without a free surface is assumed, where the P-wave velocity is 5.0 km/s and S-wave velocity is 3.0 km/s. A subtle mismatch corresponds to the near-filed and intermediate terms.

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Modeling dynamic rupture and statistical properties of earthquakes with cellular automaton models.

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How to understand seismic activity from deterministic rupture mechanics is an important issue in seismology. In recent years, the development of rupture mechanics-based cycle simulations has been remarkable, and we are now at the stage where we need to figure out how to simulate more complex fault structures. However, due to issues such as understanding friction at high speeds and computational costs, rupture mechanics-based earthquake cycle simulations that fully incorporate realistic heterogeneous structures have not yet been realized. In this study, we tackle this issue by considering complex heterogeneous structures as a multibody problem, and using a statistical physics approach that understand the multibody system in a simplified way through good coarse-graining. The goal of this study is to develop a cellular automaton model that reproduces both the fracture and the statistical properties, and to improve our understanding of the coarse-graining that is useful for understanding complex seismic activity. Such an attempt can serve as a useful relay point for understanding seismic activity on a fracture mechanics basis.

Conventional studies of cellular automata models have focused on statistical properties and have not touched on dynamic behavior [Carlson and Langer,1989:Olami et al.] In addition, it has been pointed out that the BK model with a simple friction law has a pulsed rupture behavior with constant slip and does not show the characteristics of a regular earthquake as a rupture behavior [Ide and Yabe, 2019]. Therefore, the OFC model, which is said to reproduce the GR, was extended to include a finite time constant of the rupture chain to create a cellular automaton model that can handle rupture behavior (Dynamic OFC model). The rupture behavior of the Dynamic OFC model shows a behavior similar to that of the tremor, which is one of the slow earthquakes, rather than a regular earthquake.

The Dynamic OFC model that we have been using so far incorporates the assumption that the rupture threshold (corresponding to the strength) does not change even at the end of one rupture step.
This assumption implies that the strength recovery is very fast in relation to the rupture chain (i.e., the rupture chain is slow). In this study, the model was further extended to include a new parameter, the ratio of the time constant of loading and strength recovery to the time constant of the fracture chain. This model is capable of discussing slow phenomena (slow rupture propagation) and fast phenomena (fast rupture propagation) in a unified manner, using the competition between the two time constants of (1) fracture and stress accumulation, and (2) fracture and strength recovery as parameters.

We introduce that this model reproduces both the crack-like rupture behavior, where the moment rate spectrum is proportional to the square of the frequency, and the Gutenberg-Grichter law, where the size frequency distribution is the power law distribution. We will also discuss how such a cellular automaton model can provide a perspective on the coarse-graining of fracture phenomena. The results of the parameter range of the slow phenomenon (slow fracture propagation) will be introduced in the poster presentation in the S-CG39 session.

Keywords: Cellular automaton model, Gutenberg-Grichter law, nonequilibrium statistics, Dynamic rupture, Omega squared model

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Dynamic earthquake triggering in Southern California in high resolution

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Earthquake triggering by seismic waves has been recognized as a phenomenon for nearly thirty years. However, our ability to study dynamic triggering has been limited by our ability to capture the triggering stresses accurately and record the resultant earthquakes. Here we use full waveforms from a dense seismic network and a modern, high-resolution seismic catalog to measure triggering in Southern California from 2008 to 2017 based on interevent time ratios. We find that the fractional seismicity rate change, which we term triggering intensity or triggerability, as a function of peak strain change for the period of ~20 s due to distant earthquakes is monotonically increasing and compatible with earlier measurements made with a disjoint dataset from 1984 to 2008. A triggering strain of 1 microstrain is equivalent to the local productivity generated by an *M*1.8 earthquake. This result implies that a prediction of seismicity rate changes can be made based on recorded ground shaking using the same formalism as currently used for aftershock prediction. For a teleseismic event, this small level of triggering occurs throughout the region and thus aggregates to a regional effect. We find that the triggering rate decays after the triggerer follows an Omori-Utsu law, whereas at a much slower rate than a typical aftershock sequence. The slow decay rate suggests that an ancillary process such as creep or fluid flow must be part of dynamic triggering. The prevalence of triggering in areas of creep or fluid involvement reinforces this inference. A triggering cascade of secondary earthquakes is insufficient to explain the data.

Keywords: dynamic triggering, delayed triggering, equivalent magnitude, triggering intensity

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[J] Oral | S (Solid Earth Sciences) | S-SS Seismology

[S-SS06] Statistical seismology and underlying physical processes

convener:Yasuhiro Yoshida(Meteorological Research Institute, Japan Meteorological Agency), Chairperson:Kohei Nagata(Meteorological Research Institute), Masatoshi Miyazawa(Disaster Prevention Research Institute, Kyoto University)

Thu. Jun 3, 2021 10:45 AM - 12:15 PM Ch.20 (Zoom Room 20)

This session aims to improve our understanding on seismicity. Any contribution on behavior of earthquakes as a cluster, such as regional seismicity and aftershocks, are welcomed. We also welcome contribution on temporal and spatial interactions that control seismicity, and tectonic processes, and geological and thermal structures that regulate seismicity.

12:00 PM - 12:15 PM

[SSS06-12]Discussion

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[J] Oral | S (Solid Earth Sciences)：S-SS Seismology

Thu. Jun 3, 2021 10:45 AM - 11:45 AM JST | Thu. Jun 3, 2021 1:45 AM - 2:45 AM UTC | Ch.19 Zoom Room 19

[S-SS07] Crustal Structure

convener:Mikiya Yamashita(National Institute of Advanced Industrial Science and Technology), Chairperson:Kazuya Shiraishi(Japan Agency for Marine-Earth Science and Technology)

The aim of this session is to cover seismological and geophysical studies on the Earth's crust and uppermost mantle. Contribution on seismological and geophysical structure of the crust, processes that develop in the crust which include earthquakes, volcanoes and geological descriptions of the crust are welcomed. We also welcome theoretical and methodological studies that will serve as basics in such explorations.

10:45 AM - 11:00 AM JST | 1:45 AM - 2:00 AM UTC

[SSS07-01] Examination of applicability of seismic interferometry in exploration of underground structure under a volcanic body

*Hirofumi Kowari[1], Koji Yamada[1], Tatsuyuki Ueno[1] (1.Hanshin Consultants Co., Ltd.)

11:00 AM - 11:15 AM JST | 2:00 AM - 2:15 AM UTC

[SSS07-02] Deep seismic reflection profiling across the Tsugaru peninsula, northern Honshu, Japan

*Hiroshi Sato[1,2], Tatsuya Ishiyama[1], Hideo Saito[3], Mamoru Nakata[3], Naoko Kato[1], Susumu Abe[3] (1.Earthquake Research Institute, The University of Tokyo, 2.Center for integrated Research and Education of Natural Hazards, Shizuoka University, 3.JGI, Inc.)

11:15 AM - 11:30 AM JST | 2:15 AM - 2:30 AM UTC

[SSS07-03] Deep crustal seismic profiling from airgun-OBS surveys offshore Niigata-Yamagata: reflection imaging via reverse time migration

*Kazuya Shiraishi[1], Tetsuo No[1], Gou Fujie[1] (1.Japan Agency for Marine-Earth Science and Technology)

11:30 AM - 11:45 AM JST | 2:30 AM - 2:45 AM UTC

[SSS07-04] Revealing structures in the shallow crust beneath Botswana, southern Africa: considering dip and anisotropy

*Admore Phindani Mpuang[1,2], Takuo Shibutani[2] (1.Graduate School of Science, Kyoto University, 2.Research Center for Earthquake Prediction, Disaster Prevention Research Institute, Kyoto University)

Examination of applicability of seismic interferometry in exploration of underground structure under a volcanic body

*Hirofumi Kowari[1], Koji Yamada[1], Tatsuyuki Ueno[1]

1. Hanshin Consultants Co., Ltd.

Reflection seismic survey using a large vibrator is difficult to apply to underground structure exploration of rugged mountain bodies. In addition, it is hard to conduct exploration by blasting because it is practically tough to secure a sufficient number of blasting points. Therefore, we tried to apply the seismic interferometry using microtremors as a part of the study of the underground structure exploration of mountain body. Daisen volcano in Tottori Prefecture, which is known to have had several eruptions, was selected for our analysis.

The data used in this analysis is a continuous velocity records observed by NIED (Hi-net) and Kyoto University, at a total of 16 stations. These stations are located within a distance of approximately 50 km from the summit of Daisen Volcano. The data were collected for one year from January 1, 2019. Missing periods of microtremor recordings were visually searched from the raw data and removed before the analysis.

The analysis method is described. First, processing to reduce large-amplitude events due to natural earthquakes or noise was conducted with the spectral whitening method (Bensen *et al.*, 2007), and the records were bandpass-filtered in the frequency range of 0.05 Hz and 2Hz. Then, data with a length of 409.6 seconds was cut out while moving the time window every 450 seconds, and the cross-correlation function was estimated for each time window. Rayleigh wave and Love wave extracted by interfering the UD component and the transverse component, respectively. In the case of there is no data loss, the maximum number of stacks is 70,080. Cross-correlation function obtained by interfering UD components is shown in Fig. 1. Group velocity between the two observation points was obtained by reading the peak of the nonstationary spectrum which calculated by the multiple filter method for data that folded the cross-correlation function with a delay time of 0. Phase velocity was converted from the group velocity using the phase shift calculated in the previous process. The frequency band to obtain a plausible the group velocity was manually determined. The plot of the obtained the phase velocity with results of Yamada (2018, 2019) is shown in Fig. 2. Finally, 2D tomography was performed using the FMST routine (Rawlinson and Sambridge, 2005) to obtain the spatial distribution of the group velocity and the phase velocity for Rayleigh and Love waves, respectively. The settings are as follows: grid width is 0.05 degrees, the initial value of the model is the average of all ray paths, and iterative calculation was performed 7 times. Fig. 3 shows the spatial distribution of the phase velocity of the Rayleigh wave at 0.4 Hz.

The results are shown below. Most of the cross-correlation functions are asymmetric. In addition, the seasonal change in the ratio of the maximum amplitude for each of the positive and negative delay times of the cross-correlation functions was remarkable in some pair of stations located in the north-south direction. This ratio is highest in January and lowest in June. Therefore, it tends to behave as if there was a wave source at the north of the group of stations (Sea of Japan) in winter. The region where the phase velocity of Rayleigh wave is slow in Fig. 3 is almost coincident with the region where negative gravity anomalies are observed in Fig. 4. Because it reflects a thick sedimentary layer of about 1.5 km (Nishida, 2003), propagation velocity is slow at Yumigahama where negative gravity anomalies are most prominent within the range shown in Fig. 3. In areas where the north-eastern side of the tectonic line from Mt. Koreisan to Mt. Daisen (Ota, 1962) and around of Hiruzen volcanic group, negative gravity anomalies are observed (Komuro *et al.*, 1997), and propagation velocity of surface wave is slow compared to the surrounding area. This tendency was remarkable at low frequencies that are affected by deeper layers. A

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similar tendency appeared in the group velocity of Rayleigh waves and the phase velocity and the group velocity of Love waves. Since these volcanoes are composed of relatively low-density volcanic rocks, they are considered to form contrast with the surroundings where the base rock (plutonic rock) is exposed as a region where surface wave propagation velocity is slow or negative gravity anomaly is observed.

Acknowledgment: we used continuous velocity records observed by NIED (Hi-net) and Kyoto University.

Keywords: exploration of underground structure, seismic interferometry, microtremor, tomography, Daisen volcano

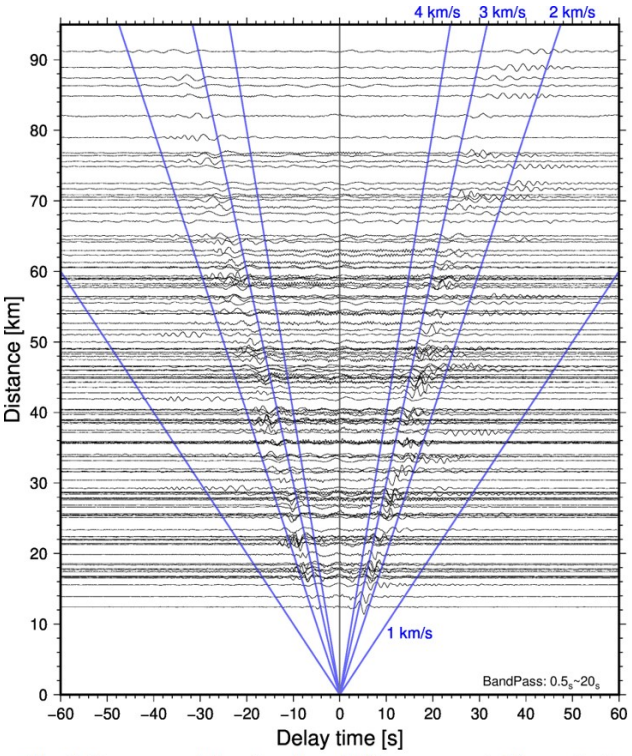


Fig. 1. Cross-correlation function of UD-component. The vertical axis corresponds to the distance between the pair of stations. Bandpass filter 0.05 - 2 Hz is applied.

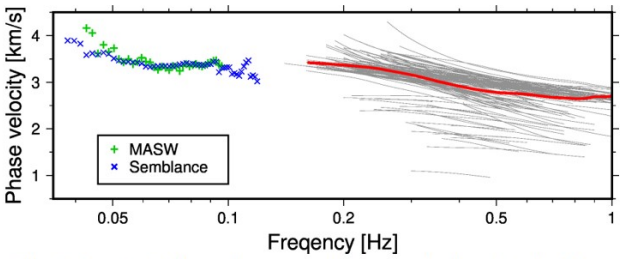


Fig. 2. Obtained dispersion curve of phase velocity of Rayleigh wave (gray line). Red line denotes average of those. Green + and blue x indicate phase velocity estimated by Yamada (2018, 2019).

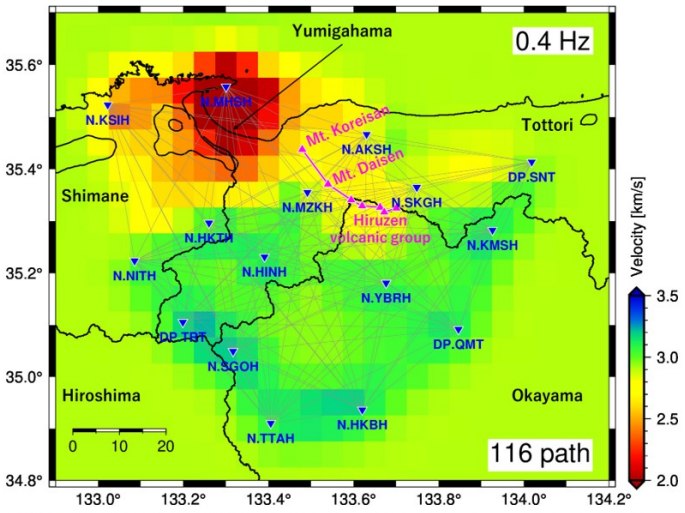


Fig. 3. Spatial distribution of phase velocity of Rayleigh wave at 0.4 Hz. Blue triangles denote stations used for this analysis. Gray lines indicate the ray path coverage. Purple triangles show volcano.

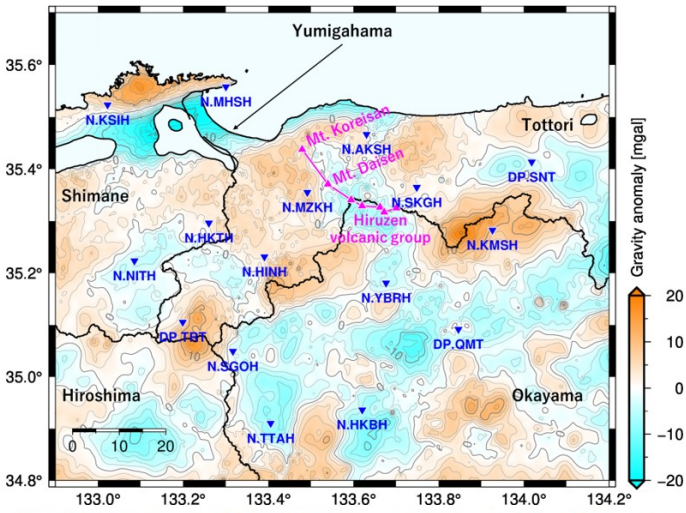


Fig. 4. Bouguer anomaly. Contour lines are drawn every 2 mgal. See the caption of Fig. 3 for explanation of the triangle symbols.

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Deep seismic reflection profiling across the Tsugaru peninsula, northern Honshu, Japan

*Hiroshi Sato[1,2], Tatsuya Ishiyama[1], Hideo Saito[3], Mamoru Nakata[3], Naoko Kato[1], Susumu Abe[3]

1. Earthquake Research Institute, The University of Tokyo, 2. Center for integrated Research and Education of Natural Hazards, Shizuoka University, 3. JGI, Inc.

A large number of active reverse faults are distributed along the Sea of Japan coast of Norther Honshu. To reveal their deep geometry is significant for better estimates of strong ground motions and tsunami hazards. In 2020, a deep seismic reflection profiling was carried out across the southern part of the Tsugaru peninsula as a part of the “Integrated Research Project on Seismic and Tsunami Hazards around the Sea of Japan” funded by MEXT. The length of the seismic line is 59 km from the coast of the Aomori bay to the coast of the Sea of Japan across the Tsugaru mountains and Tsugaru plain. Seismic source was four vibroseis trucks and seismic signals were recorded by 5 Hz geophones. As a standard mode, receiver interval was 50 m and shot interval was 100 m. In a higher-resolution mode, we used 25 m receiver interval and 50 m shot interval. Fixed 1887 channel were used for the seismic survey. To obtain deeper P-wave velocity structure, 50 to 100 stationary sweeps were carried out at every 4 km along the seismic line. Seismic data were processed using standard CMP-method and refraction tomography method. Geologic were interpreted using geological maps published by Geological survey, Japan.

The seismic sections revealed the geologic structure down to 6 km and portray an anticlinorium with steeper eastern limb beneath the Tsugaru mountains. P-wave velocity profile shows the thick low velocity layer, suggesting basin inversion processes. The reverse faults bounding the eastern limb of the range was generated as normal faults during the opening of the Sea of Japan. The 1766 Meiwa Tsugaru earthquake (M 7.0) damaged the southern part of the Tsugaru plain. The damaged area is located at the hanging wall of the faults bounding the eastern edge of the Tsugaru mountains. Thus, it is highly probable that this fault was the source fault of the earthquake of 1766.

Along the western margin of the Tsugaru plain, west dipping blind-reverse fault is clearly demonstrated on the seismic profile. On the hangingwall of this fault, stage 5e marine terraces are distributed, suggesting the late Quaternary movements along this fault. Based on the Bougue anomaly and distribution of marine terraces, this subsurface active fault extends 40 km trending NS. From the P-wave velocity structure and pattern of reflectors, this fault also shows the basin inversion.

Keywords: Seismogenic source fault, deep seismic reflection profiling, Tsugaru Peninsula, 1766 Tsugaru Meiwa Earthquake

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Deep crustal seismic profiling from airgun-OBS surveys offshore Niigata-Yamagata: reflection imaging via reverse time migration

*Kazuya Shiraishi[1], Tetsuo No[1], Gou Fujie[1]

1. Japan Agency for Marine-Earth Science and Technology

In offshore seismic exploration, estimating lithosphere-scale velocity structures by Traveltime tomography and waveforms inversion is general application to the data of ocean bottom seismographs (OBS) with airgun shooting. On the other hand, reflection imaging from the airgun-OBS data, is not general because of low folds from the sparse OBS deployment. However, reflections in the long offset data, which may contain information from the deep like the Moho discontinuity and deeper structures, is important challenge for further understanding of the deep earth structures. Furthermore, reflection profiling of crustal structures from the airgun-OBS is useful when multichannel seismic (MCS) surveys with hydrophone streamer cables are not available due to weather conditions and difficulties on the equipment or vessels.

In this study, we applied reflection imaging by reverse time migration (RTM) to the airgun-OBS data acquired in the Japan Sea by JAMSTEC. The RTM method is based on numerical modeling of the wave equation to simulate forward wavefields from source with a function and backward wavefields from receivers with observed seismic records, then reflections are imaged by the time integration after correlating the two wavefields. Although this method requires more computation costs than conventional ray-based imaging methods, it can provide higher quality images in complicated structures. In case of the airgun-OBS data, the source-receiver reciprocity can be adopted on the relation between airgun shooting and OBSs to save of the computation cost.

We applied this method to the airgun-OBS data of two survey lines in the western offshore area of Niigata and Yamagata: EMJS1003 (297 km) in 2010 and SJ1901 (366 km) in 2019. These two lines were crossed each other at approximately 220 km offshore from the coast line. Airguns were fired every 200 m for both survey lines. OBSs were deployed with 5 km spacing on EMJS1003 and with variable spacing of 2km, 8 km, and 16 km from near the coast to the offshore on SJ1901. Reflections from the Moho were observed on most of the OBS records in both surveys. While MCS data was available on the same line of EMJS1003, MCS survey was not conducted on SJ1901 due to weather condition. Velocity models obtained by traveltime tomography (Sato et al., 2014, JGR; No et al., 2020, SSJ fall meeting) were available for wavefield modeling in the RTM application.
The Moho reflections were clearly imaged on seismic reflection profiles for both lines. The depth of the Moho was traced from approximately 20 km in the Yamato Basin to approximately 30 km near the coast through the Sado Ridge and the Mogami Trough. This result was consistent with the crust thickness inferred from analyses of the airgun-OBS data of EMJS1003 (Sato et al., 2014). The reflection profile from the OBS data showed clear image of the Moho that was difficult to be imaged by the MCS survey on EMJS1003. We also obtained the reflection profile on SJ1901 where the MCS data was not available. These results showed high potential for application of our method to airgun-OBS survey data with different varieties of OBS spacing. Updating velocity models by waveform inversion and using surface-related multiples by mirror imaging or interferometric OBS imaging are useful for better reflection profiles including sediment layers and structures in the crust. Complimentary improvement of subsurface information by both MCS and OBS surveys is important for further understanding of the deep structures.

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Keywords: airgun-OBS survey, deep crustal structure, seismic reflection profile, reverse time migration, Japan Sea

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Revealing structures in the shallow crust beneath Botswana, southern Africa: considering dip and anisotropy

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In receiver function analysis, velocity models developed under the assumption of horizontal isotropic interfaces suffer inaccuracies in the presence of dipping and anisotropic structures. In such cases, the receiver functions exhibit back-azimuthal variation of amplitude and delay time. Such features of receiver functions have been observed in records from stations located in the Okavango rift zone and Limpopo belt in Botswana, with evidence for strong P-to-S conversions from high Vs contrasts in the shallow crust. In this study, the presence and nature of seismic structures at shallow crustal depths beneath Botswana is investigated in order to improve the current understanding of the seismic structure beneath the various tectonic regions in southern Africa. As a first step, 3Hz P-to-S receiver functions are computed for teleseismic events from epicentral distances between 30 and 85 degrees recorded at 37 stations located within Botswana, with magnitudes Mw>5.8. After carrying out a quality assessment, receiver functions with good quality are stacked in 30-degree back azimuth bins. These receiver function stacks are then subjected to harmonic decomposition (Bianchi et al., 2010) to constrain the presence, or lack thereof, of dipping and anisotropic structures in the shallow crust. The resulting harmonic stacks suggest that at shallow depths in the Limpopo belt, the metasedimentary sequences lie unconformably over uneven crystalline metamorphic basement surfaces, while plunging anisotropy may be present in the metamorphosed clastic sediments and basalts of the Kheis belt. In the Okavango rift zone, harmonic stacks indicate presence of very shallow strong heterogeneity in the overlying unconsolidated sediments. Applying a genetic algorithm inversion technique is expected to give optimum estimates for Vs, dip and anisotropy magnitude and orientation of the structures.

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[J] Oral | S (Solid Earth Sciences)：S-SS Seismology

Thu. Jun 3, 2021 3:30 PM - 5:00 PM JST | Thu. Jun 3, 2021 6:30 AM - 8:00 AM UTC | Ch.20 Zoom Room 20

[S-SS08] Fault Rheology and Earthquake Physics

convener:Shunya Kaneki(Disaster Prevention Research Institute, Kyoto University), Makiko Ohtani(Earthquake Research Institute, the University of Tokyo), Keishi Okazaki(Japan Agency for Marine-Earth Science and Technology), Keisuke Yoshida(Tohoku University), Chairperson:Makiko Ohtani(Earthquake Research Institute, the University of Tokyo), Keisuke Yoshida(Tohoku University)

The goal of this session is to integrate theoretical, experimental, observational, and numerical perspectives from various fields such as seismology, geodesy, geology, mineralogy, and so on, to define what is known about earthquake source processes and the physical and chemical elementary processes of faulting. This session welcomes studies that address such issues as pre-, co-, and post-seismic processes, the rheology of seismogenic faults and fault rocks, laboratory experiments on elementary processes, numerical models based on frictional laws, and estimates of the stress field in the seismogenic zones. We also welcome studies on fault-zone drilling projects and in situ stress measurements.

3:30 PM - 3:45 PM JST | 6:30 AM - 6:45 AM UTC

[SSS08-01] **Fault frictional heterogeneities can explain earthquakes with no foreshocks, accelerating foreshocks and earthquake swarms observed in central Alaska**

★Invited Papers

*Yoshihiro Kaneko[1], Nealey Sims[2], Carl Tape[2], Stephen Holtkamp[2], Andrea Perez[3] (1.Kyoto University, 2.University of Alaska - Fairbanks, 3.Victoria University of Wellington)

3:45 PM - 4:00 PM JST | 6:45 AM - 7:00 AM UTC

[SSS08-02] Rupture segmentation caused by fault bends in simulated earthquake sequences

*So Ozawa[1], Ryosuke Ando[1] (1.Graduate School of Science, the University of Tokyo)

4:00 PM - 4:15 PM JST | 7:00 AM - 7:15 AM UTC

[SSS08-03] Energy-based scenarios for the Nankai trough subduction earthquakes: Stress accumulation model taking historical earthquakes into account

*Akemi Noda[1], Tatsuhiko Saito[2] (1.Meteorological Research Institute, Japan Meteorological Agency, 2.National Research Institute for Earth Science and Disaster Resilience)

4:15 PM - 4:30 PM JST | 7:15 AM - 7:30 AM UTC

[SSS08-04] **Estimation of absolute shear stress in the source region of large earthquakes based on estimates of fault fracture energy**

*Nelson Pulido[1] (1.National Research Institute for Earth Science and Disaster Resilience)

4:30 PM - 4:45 PM JST | 7:30 AM - 7:45 AM UTC

[SSS08-05] Three-dimensional tectonic stress fields estimated from seismic data for long-term periods with direct prior information

*Toshiko Terakawa[1] (1.Earthquake and Volcano Research Center, Graduate School of Environmental Studies, Nagoya University)

4:45 PM - 5:00 PM JST | 7:45 AM - 8:00 AM UTC

[SSS08-06] Spatial and temporal change of stress field in the focal area of the 2016 Kaikoura earthquake, New Zealand (2)

Miu Matsuno[1], Ayaka Tagami[1], *Tomomi Okada[1], Satoshi Matsumoto[2], Yuta Kawamura[2], Yoshihisa Iio[3], Tadashi Sato[1], Takashi NAKAYAMA[1], Satoshi Hirahara[1], Stephen Bannister[4], John Ristau[4], Martha K Savage[5], Clifford H Thurber[6], Richard H Sibson[7] (1.Research Center for Prediction of Earthquakes and Volcanic Eruptions, Graduate School of Science, Tohoku University, 2.Institute of Seismology and

Volcanology, Faculty of Science, Kyushu University, 3.Disaster Prevention Research Institute, Kyoto University, 4.GNS Science, New Zealand, 5.Victoria University of Wellington, New Zealand, 6.University of Wisconsin - Madison, United States of America, 7.University of Otago, New Zealand)

Fault frictional heterogeneities can explain earthquakes with no foreshocks, accelerating foreshocks and earthquake swarms observed in central Alaska

*Yoshihiro Kaneko[1], Nealey Sims[2], Carl Tape[2], Stephen Holtkamp[2], Andrea Perez[3]

1. Kyoto University, 2. University of Alaska - Fairbanks, 3. Victoria University of Wellington

While most earthquakes start abruptly, with no evidence for a nucleation process, accelerating foreshock sequences within or in the vicinity of the eventual mainshock rupture zone for some moderate to large crustal earthquakes have been documented previously. In particular, Tape et al. (2018) reported unique observations of nucleation signals of crustal earthquakes in the Minto Flats fault zone in central Alaska, manifested by ~20 seconds of simultaneous high-frequency foreshocks and a very low-frequency earthquake. One potential explanation for such observations is a slow slip front propagating over the fault and triggering these foreshocks as it transitions into the mainshock rupture (e.g., Tape et al., 2018). Another explanation may be that accelerating foreshocks represent cascading sequences of fault ruptures due to static and/or dynamic stress changes, without underlying slow slip, as known as a cascading hypothesis (e.g., Ellsworth and Bulut, 2018). Here we show that a numerical fault model incorporating full inertial dynamics and rate-and-state friction laws with frictional heterogeneities reproduces ~20 seconds long, accelerating foreshock sequence that led to a mainshock as observed in the Minto Flats fault zone. We find that the time scale of accelerating foreshock sequence depends on the degree and size of frictional heterogeneities and tectonic loading rate. Furthermore, an accelerating foreshock sequence occurs in only a transitional regime between an earthquake swarm regime and the regime of mainshocks with no foreshocks. This may explain why the observations of accelerating foreshock sequences are relatively rare. We conclude that reproducing the observations of ~20 seconds long, accelerating foreshock sequence would require slow physical process, such as slow slip, fluid diffusion or rock damage, in between small-scale, seismogenic asperities.

Keywords: Accelerating foreshocks, Fault frictional heterogeneities, Earthquake cycle deformation

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Rupture segmentation caused by fault bends in simulated earthquake sequences

*So Ozawa[1], Ryosuke Ando[1]

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Observations show, in several faults, earthquake ruptures are segmented by barriers - locations that tend to stop rupture propagations. One plausible mechanism of barriers is geometrical complexity on the fault. For example, Elliott et al. 2018 shows geomorphological evidence for persistent rupture terminations at a restraining bend in the Altyn Tigh fault.

Here, we study how earthquake ruptures are arrested at bends from physics-based modeling and numerical simulations. Specifically, we consider two fault segments connected each other via a restraining/releasing bend as a simple and instructive example. An important mechanical result of slip on a nonplanar fault is the change of normal stresses. Normal stress increases at restraining bends and decreases at releasing bends. The rupture termination occurs when the fracture energy exceeds the static energy release rate at the rupture front. Because the fracture energy is proportional to normal stress, we expect that ruptures is arrested around the center of a restraining bend.

To verify our hypothesis, we perform quasi-dynamic earthquake sequence simulations on two fault segments connected by a restraining/releasing bend. The use of earthquake sequence simulations allows us to obtain the initial condition of ruptures in a self-consistent manner, and to ask how often the bend acts as a barrier. In the case of restraining bends, our simulation shows a clear segmentation due to the bend, and the ratio of partial ruptures increases with increasing cumulative slip. Hypocenters are concentrated at both edges of the bend, where normal stress takes local minimum. Although much less effective than restraining bends, releasing bends could also act as barriers.

We perform systematic geometrical parameter investigation; the length and slope of the bend. The ratio of full ruptures decreases with increasing the slope of the bend. The effect of the bend length on the ratio of full ruptures is more complex because it interacts with the process zone size. Lastly, we compare geometrical barriers and rheological barriers in concept, and discuss unmodeled effects, such as inertia and off-fault plasticity.

Keywords: Earthquake cycle, Fault segmentation, Numerical simulation, Rate and state friction, Barrier, Fault geometry

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Energy-based scenarios for the Nankai trough subduction earthquakes: Stress accumulation model taking historical earthquakes into account

*Akemi Noda[1], Tatsuhiko Saito[2]

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The occurrence of earthquakes is controlled by the balance between the shear stress that drives faulting and the frictional stress that resists it. This perspective of the mechanics of faulting is necessary to create scenarios of anticipated megathrust earthquakes for preparing for unprecedented events in the Nankai trough subduction zone. Based on such an idea, Noda et al. (2020) proposed a new energy-based method to construct rupture scenarios, which is composed of two steps: (1) Estimating a coseismic slip model from the distribution of shear stress accumulation based on an interseismic slip-deficit rate distribution. (2) Examining whether the model follows the mechanics of faulting by comparing the strain energy released by the fault slip ΔW and the energy dissipated on the fault E_D. They introduced a new parameter "residual energy" defined as $E_R \equiv \Delta W - E_{D.}$ Positive residual energy is a necessary condition for earthquake generation in terms of the law of conservation of energy. The scenario with negative residual energy is supposed to be unreasonable.

Noda et al. (2020) assumed a constant stress accumulation rate and calculated the shear stress accumulation from a reference time when the shear stress was zero over the entire seismogenic region of plate interface along the Nankai trough, for simplicity. However, the slip history of earthquake cycles in the Nankai trough is more complex. For example, the latest great earthquakes, the 1944 Tonankai and 1946 Nankai earthquakes, did not rupture the entire plate interface from the Suruga bay to off Shikoku at once. In addition, the segmentation of historical earthquakes before the 20th century remains controversial because there are insufficient observation records. It has been considered that the source region of the 1854 Ansei-Tokai earthquake comprises segments in the Kumano-nada, Enshu-nada, and Suruga bay (Ishibashi & Satake, 1998); however, Seno (2012) suggested that the source region did not include the segment in the Kumano-nada. Segments that have not ruptured for some time accumulate substantial shear stress and will release a large amount of strain energy during the next event.

In this study, for more realistic earthquake rupture scenarios, we improved the scenarios of Noda et al. (2020) by integrating the earthquake rupture history into the stress accumulation model. First, we assumed that the stress accumulation rate is constant and that the shear stress accumulated since the last event is fully released during the next event. We estimated slip models of the 1854 Ansei Tokai and Nankai earthquakes, the 1944 Tonankai earthquake, and the 1946 Nankai earthquake following the method of Noda et al. (2020) and evaluated the residual energy for each model. We found that the earthquake rupture history of Seno (2012) is more reasonable in terms of energy budget than that of Ishibasi & Satake (1998).

Next, we calculated the distribution of stress accumulation in 2021 based on Seno (2012) and generated various earthquake scenarios including single-segment ruptures and multi-segment ruptures. We found that the strain energy stored in the elastic medium is not enough for generating great thrust earthquakes in 2021 because all scenarios showed negative residual energy. However, as the shear stress continues to

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accumulate at the same rate, the residual energy becomes positive by 2025 in a scenario which ruptures the segment in the Suruga bay, satisfying a necessary condition of earthquake generation. For the scenario rupturing all segments along the Nankai trough, the residual energy becomes positive by 2070. It should be noted that these estimations strongly depend on the assumptions of uncertain parameters such as the dissipated energy on the fault. We will discuss the effects of the assumed parameters on the earthquake scenarios.

Keywords: Earthquake scenarios, Interplate earthquake, Nankai trough, The mechanics of fault rupture

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Estimation of absolute shear stress in the source region of large earthquakes based on estimates of fault fracture energy

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Fault fracture energy (G), a fundamental physical property of earthquake rupture has been widely estimated from the energy budget during earthquake fault rupture. To that purpose a simple relationship between fault slip and shear stress (linear slip weakening friction law without under or overshoot), as well as a constant fault rupture velocity are usually assumed. Under these assumptions, an estimate of fracture energy often referred to as G', can be obtained from the difference of the average stress drop and two times the apparent stress. However fault rupture propagation and shear stress release during large earthquakes can be highly heterogeneous, and therefore the estimation of G from seismic radiation and the aforementioned assumptions, may lead to wrong estimates. To clarify this point, in a previous study I calculated fracture energy of large earthquakes (G) based on a heterogeneous fault rupture process, using the finite width slip pulse dynamic rupture model of Rice et al (2005). I also estimated G' values based on fault average stress drops and apparent stress (earthquake radiated energy normalized by seismic moment times rigidity). To calculate G and G' I used the extensive database of finite fault rupture models of large earthquakes (M>7) by NEIC. My results indicated that G' systematically underestimates G. To provide a physical explanation for this difference I compared the energy budget from earthquakes obtained from simple linear slip weakening friction law, to the one obtained from a more general relationship where dynamic shear stress values (σ_d) can drop below fault residual shear stress (σ_r) during fault rupture. It can be shown that G can be expressed as follows; $G = G' + (\sigma_r - \sigma_d)\ \delta$, where δ is fault slip. Assuming a nearly complete strength drop during fault rupture (namely, $\sigma_d \sim 0$) for large earthquakes (as suggested by recent megathrust earthquakes), residual shear stress can be obtained as the difference between G and G' divided by fault slip. Based on this idea I calculated lower bound estimates of absolute residual fault shear stress (as well as absolute initial shear stress , σ_o, by adding stress drops), using my dataset of G and G' values. My estimations of average fault shear stress ($[\sigma_o + \sigma_r]/2$) range from 0.3 MPa to 40 MPa. These results also enable the estimation of seismic efficiency (the ratio of radiated energy to total available potential energy), which has remained unresolved for earthquakes to date. My estimation of average seismic efficiency for the entire dataset is around 12%. I also obtained that seismic efficiency increases with increasing average fault rupture velocity.
My results also indicate that average shear stress is highly correlated with apparent stress. These results render possible the first order estimation of absolute shear stress in source regions of earthquakes globally, based on available measurements of apparent stress (radiated energy). My results also show that average shear stress and earthquake slip, have a weak negative correlation with seismic efficiency. These results may indicate to some extent that large earthquakes within high background shear stress regions might be less seismically efficient compared to earthquakes in regions with lower background shear stress.

Keywords: fracture energy, large earthquake, shear stress, apparent stress, rupture velocity, fault

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Three-dimensional tectonic stress fields estimated from seismic data for long-term periods with direct prior information

*Toshiko Terakawa[1]

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Stress is one of the important physical quantities for understanding earthquake generation. The CMT data inversion is a statistical method that derives the tectonic stress pattern from centroid moment tensor data of seismicity, based on the Bayesian statistical inference and Akaike’s Bayesian Information Criterion (ABIC) (Terakawa and Matsu’ura, 2008). With this method Terakawa and Matsu’ura (2010) estimated 3-D tectonic stress pattern in and around Japan from 12500 moment tensor data of seismicity (period: January 1997 to January 2007) listed in the F-net moment tensor catalog. More than ten years have passed after the study period of the previous study. New data have been certainly stored in the catalog.

The original method of CMT data inversion incorporates indirect prior information that stress fields are smooth to some degrees into observed data to construct a Bayesian model with hyperparameters. In order to estimate tectonic stress pattern from data for long-term periods, we improved the method of CMT data inversion so that we can consider results of stress fields obtained by a previous analysis as prior information as well as information from new observed data. In the improved method, we can incorporate both indirect and direct prior information into new observed data in a proper way, based on the formulation for geodetic inversion by Matsu’ura et al. (2007). In general, this improvement enables us to estimate the stress pattern from more data with smaller uncertainties. If uncertainties become larger in an analysis with the direct prior information and new data, it will indicate that statistical feature for the new data are inconsistent with the direct prior information obtained from previous data. This suggests that the stress pattern would have changed between the two study periods.

I targeted the Kyushu district in Japan where the 2016 Kumamoto earthquake (Mw 7.0) and the largest pre-shock (Mw 6.1) occurred on 16 and 14 April 2016. I applied moment tensor data of seismicity for 22 years (January 1997 to April 2019) listed in the F-net catalog to the improved method, and estimated the tectonic stress pattern in the district. I divided the whole study period into three periods: the period 1 (1 January 1997 to 31 January 2007), the period 2 (1 February 2007 to 13 April 2016), and the period 3 (14 Aril 2016 to 30 April 2019). Firstly, considering the results of stress patterns estimated from the data during the period 1 (Case 1) as the direct prior information, I estimated the stress pattern from data during the period 2 (Case 2). The stress pattern in the Kyushu district is characterized by normal to strike-skip faulting with north-south tension. The results of the stress pattern in Case 2 are consistent with those obtained only from the original data of the period 1 (Case 1). Furthermore, the uncertainties become smaller on the whole, indicating that we obtained more reliable results of the stress pattern from more data for the longer period. Next, considering the results of Case 2 as the direct prior information, I estimated the stress pattern from data during the period 3. The stress pattern which reflects all the data during the whole period (Case 3) is roughly consistent with those of Cases 1 and 2. However, the stress patterns at a shallow depth around the Futagawa fault, which is the main part of the source region of the Kumamoto earthquake, is different from those in Case 1 and 2, indicating that the stress pattern would have locally changed after the large earthquake. Furthermore, the uncertainties around the Futagawa fault becomes larger than those in Case 2, although the number of data there in Case 3 is larger than that in Case 2. These results suggest that types of earthquake would have changed after the Kumamoto earthquake. Large coseismic slip on the Futagawa fault basically released shear stress at the source

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region. Therefore, temporal changes in types of earthquake may be caused by some factors other than stress changes. A plausible mechanism is a decrease in fault strength due to an increase in pore fluid pressure, which triggers many aftershocks.

Keywords: stress, earthquake, inversion

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Spatial and temporal change of stress field in the focal area of the 2016 Kaikoura earthquake, New Zealand (2)

Miu Matsuno[1], Ayaka Tagami[1], *Tomomi Okada[1], Satoshi Matsumoto[2], Yuta Kawamura[2], Yoshihisa Iio[3], Tadashi Sato[1], Takashi NAKAYAMA[1], Satoshi Hirahara[1], Stephen Bannister[4], John Ristau[4], Martha K Savage[5], Clifford H Thurber[6], Richard H Sibson[7]

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The 2016 Kaikoura earthquake (Mw 7.8) earthquake is one of the most complex earthquakes in the world. In our previous studies (e.g., Okada et al., 2019; Okada et al., 2020, GSNZ), we found seismic low-velocity and high Vp/Vs in and along the focal area of the earthquake. This suggests overpressured fluid promotes the occurrence of the Kaikoura earthquake. Here we consider stress conditions.

We study spatio-temporal change of the stress field due to the 2016 Kaikoura earthquake in the northern area of the South Island of New Zealand. Data from 51 temporary stations and 22 permanent GeoNet stations were used. We determined focal mechanisms, combined with the GeoNet Moment Tensor Solutions, and estimated the stress field in the period from 2013 to 2019 before and after the Kaikoura main shock using stress tensor inversion. We improved the stability of the solution by adopting Vavrycuk (2014)’s method.

If there are many aftershocks on the fault plane of the main shock, the fault plane may be distributed with a bias. Therefore, it is necessary to study the effect of focal mechanisms of aftershocks that occurred off the fault plane of the main shock. So, we attempted to remove the mechanism solution on the fault plane of the main shock using the fault model of Hamling et al. (2017) and the Kagan angle. We found that the stress field did not change significantly independent of the value of the Kagan angle, and we consider that the effect of the aftershocks occurring on the fault plane of the main shock on the result is small.

We carried out the analysis by dividing the hypocenters into several regions. The stress field types are strike-slip types. The maximum horizontal stress direction is about ESE both before and after the Kaikoura earthquake. This would be consistent with shear wave splitting analysis (Graham et al., 2020) which also didn’t show significant coseismic temporal change. This absence of coseismic change of orientations of stress axes suggests large differential stress (sigma1-sigma3) before the Kaikoura earthquake. The stress ratio (R = (sigma1-sigma2)/(sigma1-sigma3)) decreased after the main shock in the northeastern and central regions, and increased in the southwestern region. The coseismic changes in the northeastern and central regions might be interpreted as coseismic stress drops (e.g., Hardebeck and Haukson, 2001).

We considered the possibility that the stress field has a postseismic temporal change after the main shock. We calculated the stress fields in three time windows after the main shock (2016/11/13-2016/11/31, 2016/12/01-2017/5/31, 2017/6/1-2019/12/4), so that the number of events in these three time windows would be approximately the same. In all three windows after the main shock, a stress field of the strike-slip fault type was determined. The value of stress ratio was about 0.8-0.9 in all three windows. This means no significant temporal change after the Kaikoura earthquake through 2019.

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The stress field was obtained by dividing the southwestern region into four regions in order to consider spatial change. The stress fields are all strike-slip fault types except in an eastern area where the stress field was intermediate between reverse and strike-slip fault type. This could be interpreted as stress heterogeneity change due to the Kaikoura earthquake (e.g., Michael et al., 1990). This could be also consistent with the co-existence of strike-slip and reverse faults in the North Canterbury Domain (e.g., Ghisetti and Sibson, 2012).

We calculated the slip tendency (Morris et al., 2016) for the fault model (Hamling et al., 2016) using the stress tensor inversion result before the Kaikoura earthquake. High slip tendency is observed at the sub-faults which correspond to the hypocenter and the large slip, and low slip tendency is at the northernmost sub-fault where the slip process of the Kaikoura earthquake stopped.

We conclude that there was no significant temporal change in stress related to the Kaikoura earthquake and pre-stress could explain the slip process of the Kaikoura earthquake.

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[J] Oral | S (Solid Earth Sciences)：S-EM Earth's Electromagnetism

Thu. Jun 3, 2021 9:00 AM - 10:30 AM JST | Thu. Jun 3, 2021 12:00 AM - 1:30 AM UTC | Ch.23 Zoom Room 23

[S-EM14] Electromagnetic Induction in the Earth and Planetary Interiors, and Tectono-Electromagnetism

convener:Maki Hata(Earthquake Research Institute, the University of Tokyo), Mitsuru Utsugi(Aso Volcanological Laboratory, Institute for Geothermal Sciences, Graduate School of Science, Kyoto University), Chairperson:Takuto Minami(Division of Frontier Planetology, Department of Planetology, Graduate School of Science, Kobe University), Maki Hata(Earthquake Research Institute, the University of Tokyo)

This session welcomes papers on electromagnetism in the Earth and planetary interiors. The topics include but not limited to electromagnetic phenomena associated with earthquakes and volcanism, electrical conductivity structure, laboratory experiments, results of simulations, new equipment for observation, and methods of data analysis.

9:00 AM - 9:15 AM JST | 12:00 AM - 12:15 AM UTC

[SEM14-01] Imaging the magma plumbing system of Mt. Meakandake volcano based on broadband magnetotellurics and three-dimensional resistivity modelling

*Tomohiro Inoue[1], Takeshi Hashimoto[1], Ryo Tanaka[1], Yusuke Yamaya[2], Hiroshi Ichihara[3] (1.Graduate School of Science,Hokkaido University, 2.National Institute of Advanced Industrial Science and Technology, 3.Graduate School of environmental Studies, Nagoya University)

9:15 AM - 9:30 AM JST | 12:15 AM - 12:30 AM UTC

[SEM14-02] Three-dimensional resistivity structure of the Tarumae volcanic region using MT data

*Takaya Yamagiwa[1], KENTARO AOYAMA[1], Koichi Suzuki[1], Toru Mogi[2], Yusuke Yamaya[3] (1.Hokkaido University, 2.Faculty of Science, Tokyo Institute of Technology, 3.National Institute of Advanced Industrial Science and Technology)

9:30 AM - 9:45 AM JST | 12:30 AM - 12:45 AM UTC

[SEM14-03] 3-D resistivity models beneath Aso caldera by new and old Network-MT dipole data arranged into reticular shapes

*Maki Hata[1], Makoto Uyeshima[1], Mitsuru Utsugi[2], Nobuo Matsushima[3], Yoshikazu Tanaka, Takeshi Hashimoto[4], Ryokei Yoshimura[5], Naoto Oshiman[5] (1.Earthquake Research Institute, the University of Tokyo , 2.Aso Volcanological Laboratory, Institute for Geothermal Sciences, Graduate School of Science, Kyoto University, 3.Geological Survey of Japan, 4.Institute of Seismology and Volcanology, Graduate School of Science, Hokkaido University, 5.Disaster Prevention Research Institute, Kyoto University)

9:45 AM - 10:00 AM JST | 12:45 AM - 1:00 AM UTC

[SEM14-04] Toward joint inversion of AMT and ACTIVE data sets for better understanding of the hydrothermal system of Aso volcano

*Takuto Minami[1], Mitsuru Utsugi[2], Wataru Kanda[3], Marceau Gresse[4] (1.Division of Frontier Planetology, Department of Planetology, Graduate School of Science, Kobe University, 2.Aso Volcanological Laboratory, Graduate School of Science, Kyoto University, 3.Volcanic Fluid Research Center, School of Science, Tokyo Institute of Technology, 4.Earthquake Research Institute, University of Tokyo)

10:00 AM - 10:15 AM JST | 1:00 AM - 1:15 AM UTC

[SEM14-05] Electromagnetic field fluctuations by infrasound during the eruption of Kirishima Shinmoe-dake in 2018

*Satoru ANIYA[1], Koki Aizawa[2], Takeshi Matsushima[2] (1.Department of Earth and Planetary Sciences,Graduate School of Sciences,Kyushu University, 2.Institute of Seismology and Volcanology, Faculty of Sciences, Kyushu University)

10:15 AM - 10:30 AM JST | 1:15 AM - 1:30 AM UTC

[SEM14-06] **Time Series Analyses of EM-ACROSS Data**

*Sohei Serita[1], Yasuo Ogawa[1], Kuo Hsuan Tseng[1], Keiichi Ishizu[1], Takahiro Kunitomo[2], Takuto Minami[3], Hiroshi Ichihara[2], T Grant Caldwell[4] (1.Tokyo Institute of Technology, 2.Nagoya University, 3.Kobe University, 4.GNS Science)

Imaging the magma plumbing system of Mt. Meakandake volcano based on broadband magnetotellurics and three-dimensional resistivity modelling

*Tomohiro Inoue[1], Takeshi Hashimoto[1], Ryo Tanaka[1], Yusuke Yamaya[2], Hiroshi Ichihara[3]

1. Graduate School of Science,Hokkaido University, 2. National Institute of Advanced Industrial Science and Technology, 3. Graduate School of environmental Studies, Nagoya University

This study reports an updated resistivity model for Mt. Meakandake, one of the active volcanoes in eastern Hokkaido. On the northeastern foot of the volcano, a remarkable ground inflation was observed during the period from 2016 to 2017 (Geospatial Information Authority of Japan, 2018). We modelled the resistivity structure targeting at the inflation source, based on the BBMT data in 2018 and 2019 (Inoue et al., 2020; SGEPSS) and the AMT/BBMT data in 2010 recorded on the south shore of Lake Akan (Mogi et al., 2011). Our previous resistivity model has imaged a distinct conductive column C1 (about 1-10 Ωm) extending from 0.5 km BSL just below the summit to a deeper part of Mt. Meakandake. However, the geometry and spatial extent of C1 has not been well constrained by the lack of MT observation sites. Therefore, in the fall of 2020, we deployed six additional BBMT sites in the summit area and the western foot of the volcano to achieve a better constraint on C1.

We acquired the time series of five components (2E+3H) for about seven days using the ADU07e system (Metronix Ltd.) for the three sites in the western foot of Mt. Meakandake. On the summit area, we measured only 2E using the Elog-dual recorder (NT System Design Ltd.). In calculating the response functions, we used the BIRRP (Chave and Thomson, 2004) and applied the remote reference processing (Gamble et al., 1997) using the data at the continuous station in Yamagata Prefecture (about 700 km southwest from our study area) that was provided by Geothermal Energy Research & Development Co., Ltd.

The overall characteristics of the apparent resistivity and phase curves suggested the structure of roughly middle–low–high resistivity from the surface toward deeper part. Some of the additional sites showed anomalous phases in Zyx component in a period range over 1000 s. The induction vectors at the western sites directed roughly to Mt. Fuppushidake and east, in constant to those at the sites in the northern to eastern foot of the volcano, pointing to an opposite direction. It suggested another conductive body beneath Mt. Fuppushidake in the north side of Mt. Meakandake.

We performed a provisional inversion using the previous 3D resistivity model (Inoue et al., 2020; SGEPSS) as a starting model and examined how the additional data would affect the result. We inverted the full impedance and tipper of 39 existing sites and six additional sites using by the ModEM (Egbert and Kelbert, 2012; Kelbert et al., 2014).

It resulted in a final RMS misfit about 2.8 for the input data with an error floor of 5 %, comparable to the final misfit of the previous inversion modelling by Inoue et al (2020; SGEPSS). Responses at the additional sites were also well reproduced by this provisional inversion in which no significant modification was made from the previous modelling. The additional data acquisition and modelling in this study confirmed that the C1 was meaningful down to about 30 km BSL. We consider it may be a part of the magma plumbing system. As a next step, we plan to discuss the physical state in the C1 based on the estimation of rock properties such as melt fraction.

Acknowledgments: This study was supported by the Ministry of Education, Culture, Sports, Science and Technology (MEXT) of Japan, under it’ s the Second Earthquake and Volcano Hazards Observation and Research Program (Earthquake and Volcano Hazard Reduction Research).

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Keywords: magnetotelluric, Meakandake, resistivity, magma plumbing system

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Three-dimensional resistivity structure of the Tarumae volcanic region using MT data

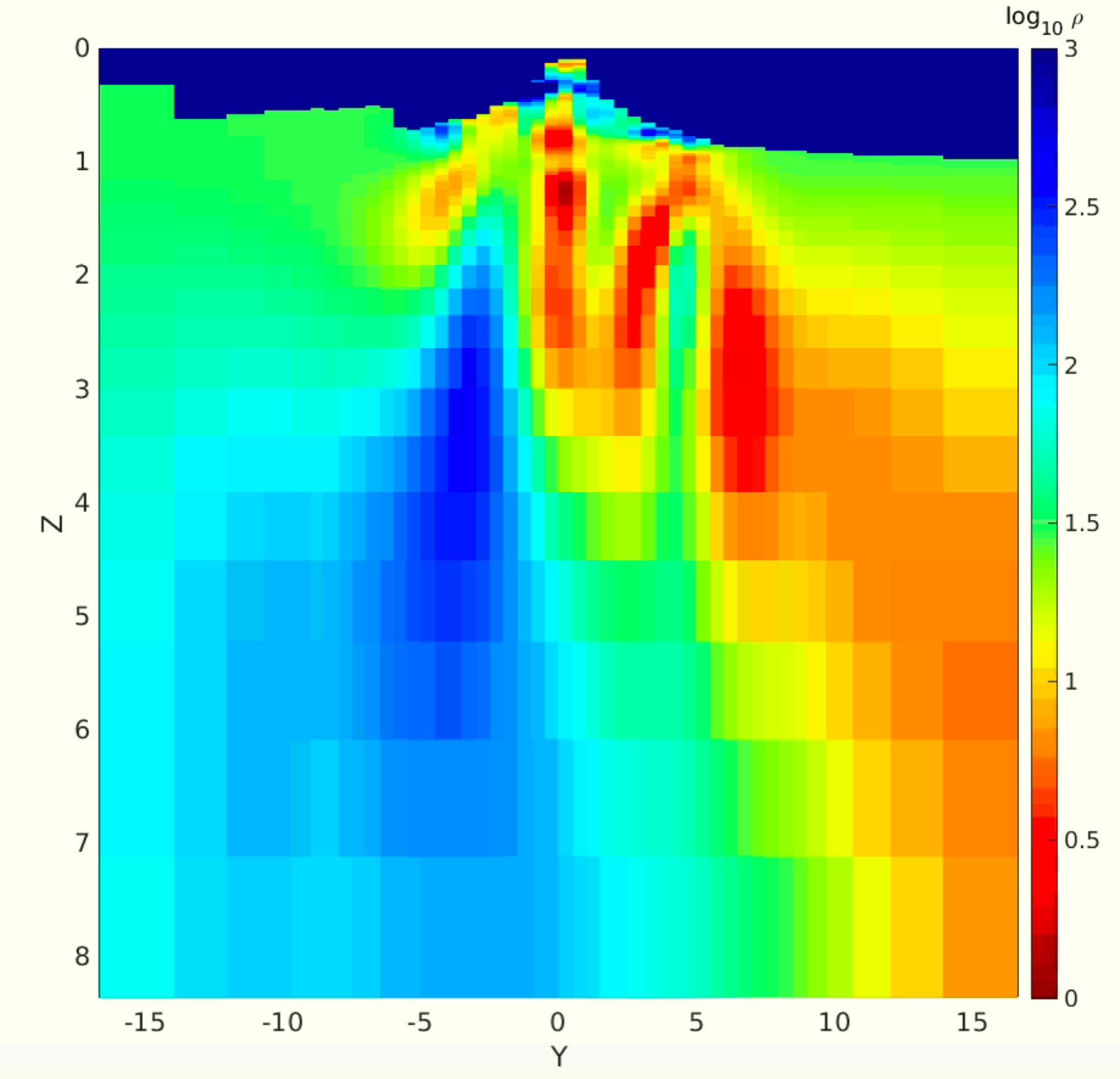
*Takaya Yamagiwa[1], KENTARO AOYAMA[1], Koichi Suzuki[1], Toru Mogi[2], Yusuke Yamaya[3]

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Mt. Tarumae is an active volcano located in the southwestern part of Hokkaido, Japan. 2D resistivity inversion using magnetoterullic (MT) data and 3D resistivity forward modeling using audio-magnetoterullic (AMT) data were performed in this area by Yamaya et al. (2005 and 2009), respectively; however, the structure of the deep subsurface remained unexplored. In this study, we modeled the magma chamber and flow path of hydrothermal fluids and volcanic gases that exist beneath Mt. Tarumae using a recently developed MT 3D inversion method. We used 70 stations to conduct the inversion: 28 stations near Mt. Tarumae and 42 stations in the east of Ishikari lowland, distant from Mt. Tarumae. In the analysis software ModEM (Egbert and Kelbert, 2012), we attempted an iterative calculation using the initial resistivity, the undetermined Lagrange multiplier, and the covariance of the smoothing term as variable parameters. The selected optimal model had the smallest root mean square residual. Consequently, we identified two low resistivity zones—one corresponding to the ascending path of hydrothermal fluids and volcanic gases beneath the summit of the Tarumae volcano and the other leading the Ishikari lowland low-resistivity zone—and a high-resistivity zone corresponding to the Pre-Tertiary strata.

Keywords: Geophysical Exploration, MT method, Mt.Tarumae

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3-D resistivity models beneath Aso caldera by new and old Network-MT dipole data arranged into reticular shapes

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Mt. Aso, an active Quaternary volcano, with a large caldera lie at the Beppu-Shimabara graben in the island of Kyushu. Aso caldera was formed at the central part of the graben by a series of huge eruptions, with a volcanic explosivity index of 7, during 270–90 ka. A post-caldera cone of Naka-dake in Aso caldera is a quite active volcano, at which magmatic and phreatomagmatic eruptions occurred during 2014–2016 and ash eruptions (emissions) have continued since July 2019. In and around Aso caldera, network-MT surveys for measuring the electric potential difference (the electric field) were carried out during 1993–1998 by using long metallic wires/dipoles of the commercial telephone company's networks [e.g., Uyeshima et al., 1995; Tanaka et al., 1998; Hashimoto et al., 1999; Hata et al., 2015]. We determined two components of network-MT response functions between the potential differences for respective dipoles and the two horizontal components of the magnetic field at the Kanoya Geomagnetic Observatory. On the other hand, we newly performed network-MT surveys at Aso caldera during 2019–2020 and determined response functions. Three-dimensional (3-D) inversion analyses were performed by using two data sets in a period up to tens of thousands s for obtaining resistivity models beneath Aso caldera in a crustal depth scale. In the inversion analyses, we used a data-space inversion code, which can be considered the length and direction of respective dipoles [e.g., Siripunvaraporn et al., 2004]. Moreover, the dipoles are distributed as to cover Aso caldera into reticular formation in order to obtain well-resolved 3-D models. In this presentation, we discuss a magma supply system beneath Aso caldera, which are inferred from the two 3-D resistivity models based on the new and old Network-MT data.

Keywords: 3-D electrical resistivity models, Network-MT data, Aso caldera, magma supply system

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Toward joint inversion of AMT and ACTIVE data sets for better understanding of the hydrothermal system of Aso volcano

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The resistivity structure beneath a volcano is an important proxy for understanding hydrothermal and magmatic systems. The Audio-frequency Magnetotelluric (AMT) survey, which utilizes magnetic variations due to natural ionospheric disturbances and lightning, is a popular method used to investigate shallow resistivity structures. On the other hand, controlled-source electromagnetic (CSEM) methods are also important mainly for the monitoring purpose, because of their stable signal-to-noise ratio. A CSEM volcano monitoring method called ACTIVE (Array of Controlled Transient-electromagnetics for Imaging Volcano Edifice; Utada et al. 2007) can reveal the temporal change in resistivity structures. Minami et al. (2018) applied the three-dimensional (3-D) finite element inversion to the ACTIVE data sets and inferred the temporal variation in the 3-D resistivity structure associated with the magmatic eruption of Aso volcano, Japan, starting in November 2014.

However, to date, there are no effective inversion tools to infer a resistivity structure using AMT and ACTIVE data sets simultaneously. To fill this gap, we are developing an inversion code that can jointly invert AMT (e.g. Kanda et al. 2008) and ACTIVE data sets (e.g. Minami et al. 2018). Since ACTIVE consists of an array of induction-coil receivers that measure the vertical component of the magnetic variation and grounded electric dipole sources, ACTIVE data sets are theoretically free from the effect of galvanic distortion. This is also an advantage of using both AMT and ACTIVE data sets in the same inversion. Furthermore, the AMT-ACTIVE joint inversion can use a common coefficient matrix in solving each linear problem when the Dirichlet boundary conditions are adopted in both ACTIVE and MT problems. This means that the ACTIVE inversion code with a direct solver and the Dirichlet boundary condition developed by Minami et al. (2018) is easily extended to the joint inversion with AMT data sets without modification of the coefficient matrix. In the presentation, we report the algorithm of our joint inversion code and show preliminary results of joint inversions of AMT and ACTIVE data sets obtained at Aso volcano.

Keywords: inversion, resistivity, AMT, volcano, Aso, CSEM

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Electromagnetic field fluctuations by infrasound during the eruption of Kirishima Shinmoe-dake in 2018

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Shinmoe-dake is an active volcano located in the center of Kirishima volcanic area in Kyushu. In January 2011, magmatic eruption occurred for the first time in about 300 years and erupted again in October 2017 and March to June 2018. In this study, we discuss the relationship between electromagnetic signals obtained by broadband MT (magnetotelluric) observation and infrasound and seismic data close to the Shinmoe-dake volcano.

Twenty eruptions during March to June 2018 were selected for an analysis. We use the MT data recorded at two sites ((1): 3.2km WSW of the Shinmoe-dake crater, and (2) 5.0km NW of the Shinmoe-dake crater) and infrasound and seismic observations data recorded at 30m away from (1) MT site and 1km away from (2) MT site. We obtained MT time series data with physical unit (mV/km, nT) by incorporating the frequency responses of instruments. We also got time series data of physical units (Pa, μm/s) from infrasound and seismic data, and recalculated seismic data to the correct displacement waveform (μm) considering the frequency characteristics.

The electromagnetic signals of explosive eruptions well synchronized with the infrasound and seismic vertical motions. It is seemed that infrasound and seismic vertical motion associated with the eruption arrived at the observation point and generated electromagnetic field fluctuations in the very near vicinity of the observation point (Aniya, 2020, JpGU). As in the case in Popocatépetl Volcano (Matoza et al., 2019), the infrasound waveforms are associated with clear air-ground-coupled arrivals on seismometers, and it indicates that the ground is being pushed by infrasound. We conclude that the infrasound is moving the fluid in the aquifer just below the observation point and exciting the electromagnetic field fluctuation. In this study, we focused on the electromagnetic field fluctuation caused by infrasound, which has not been reported so far, and summarized the differences in the amount and particle motion of fluctuation among the stations and the possible mechanism of electrokinetic phenomena at present.

Using the resistivity ρ (ohm-m) and phase (deg) estimated from the impedance tensor Z and the geomagnetic transformation function T at each MT station, we calculated the 1D structural analysis from Ssq impedance (Rung-Arunwan et al., 2017). The result showed that the subsurface structure in the very shallow area just below the station is different, so it might be that the depth and interconnection of groundwater are related to the electromagnetic field variation.

Keywords: electromagnetic signal, explosive eruption, infrasound, seismic motions, electrokinetic phenomena, aquifer

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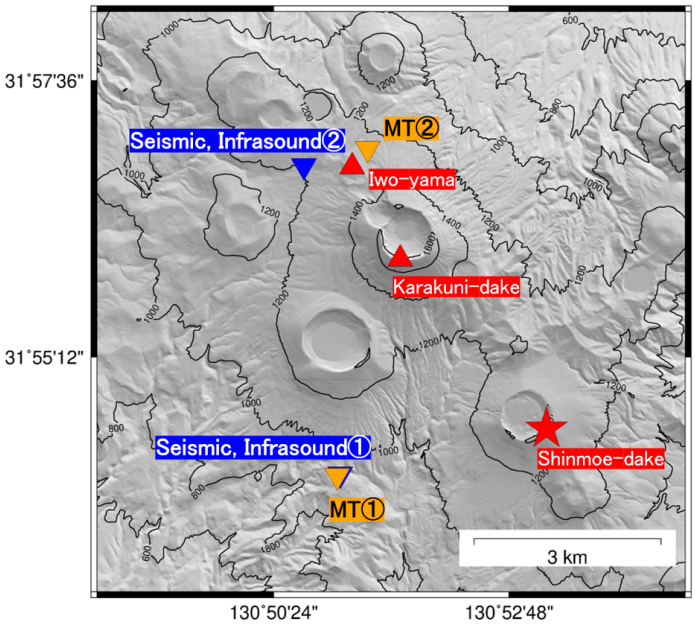


Fig. 1 Map of the study region and observation points. The yellow lower triangle, blue lower triangle indicate MT and Seismic & Infrasound sites, respectively. The Red star and red upper triangle indicate that Shinmoe-dake, Iwo-yama and Karakuni-dake, respectively.

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Time Series Analyses of EM-ACROSS Data

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In volcanic eruption prediction research, it is important to image magma and hydrothermal systems and monitor and observe their temporal variations. Resistivity is a geophysical quantity sensitive to magma, hydrothermal fluids, and clay minerals. It is possible to detect resistivity distribution and its temporal variation in the subsurface by electromagnetic exploration. In the Kusatsu-Shirane volcano, the past MT surveys revealed the resistivity structure (Nurhasan et al., 2006; Matsunaga et al., 2020; Tseng et al., 2020a). Time-lapse MT observation is one way to detect the time variation of the resistivity structure (Aizawa et al., 2011; Peacock, 2012), but for signal stability and noise suppression, the method using artificial electromagnetic signals is advantageous (Utada et al., 2007; Hino Ho, 2014; Minami et al. 2018). We installed an EM-ACROSS (ElectoMagnetic-Accurately-Controlled-Routinely-Operated-Signal-System) transmitter system Kusatsu-Shirane volcano (Tseng et al., 2020b). It has two grounded dipoles in two directions, and two signal series consisting of line spectra with slightly different frequency sets are transmitted simultaneously from independent transmitters. We can measure the two series of signals from the received signals at all times.

So far, we have been analyzing the EM-ACROSS data as follows (Tseng et al., 2020b). First, a data window of 1,000 seconds, consisting of 10 sets of 100 seconds, which is the repetition period of the signal, was used as the unit of analysis. The data in each 1,000-second data is detrended and cosine-tapered, and then Fourier transformed. This Fourier component is obtained for each data window and stacked, but of course, this includes noises. If we focus on the frequency of a signal and plot the Fourier components obtained for each data window of 1,000 seconds on the complex plane, we can recognize clusters and outliers. Here, we use the median absolute deviation to discriminate and remove the outliers from the stack. As a result, only good data can be selectively stacked (Tseng et al., 2020b). On the other hand, there is a problem of decreasing the number of stacks by excluding data.

In this new study, we work in the time domain. The data is represented as a sum of a sine wave consisting of signal components and a drift component to extract a weak stationary signal. The drift component represents the non-Gaussian noises, which are constrained to fluctuate smoothly. In the lecture, as a prelude to the analysis of the actual data acquired, test data with the noise of about ten times the known signal's amplitude was prepared for one-day length and analyzed. Then, we apply the method to the field data obtained in 2018.

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[J] Oral | S (Solid Earth Sciences)：S-EM Earth's Electromagnetism

Thu. Jun 3, 2021 10:45 AM - 12:15 PM JST | Thu. Jun 3, 2021 1:45 AM - 3:15 AM UTC | Ch.23 Zoom Room 23

[S-EM14] Electromagnetic Induction in the Earth and Planetary Interiors, and Tectono-Electromagnetism

convener:Maki Hata(Earthquake Research Institute, the University of Tokyo), Mitsuru Utsugi(Aso Volcanological Laboratory, Institute for Geothermal Sciences, Graduate School of Science, Kyoto University), Chairperson:Ken'ichi Yamazaki(Disaster Prevention Research Institute, Kyoto University), Mitsuru Utsugi(Aso Volcanological Laboratory, Institute for Geothermal Sciences, Graduate School of Science, Kyoto University)



This session welcomes papers on electromagnetism in the Earth and planetary interiors. The topics include but not limited to electromagnetic phenomena associated with earthquakes and volcanism, electrical conductivity structure, laboratory experiments, results of simulations, new equipment for observation, and methods of data analysis.

10:45 AM - 11:10 AM JST | 1:45 AM - 2:10 AM UTC

[SEM14-07] Accuracy and precision evaluation of the new method for the absolute magnetic measurements

★Invited Papers

*Hideyuki Hirahara[1], Junpei Oogi[1], Megumi Kaito[1], Seiki Asari[1] (1.Kakioka Magnetic Observatory, Japan Meteorological Agency.)

11:10 AM - 11:25 AM JST | 2:10 AM - 2:25 AM UTC

[SEM14-08] Piezomagnetic fields associated with a dislocation source in a layered elastic medium

*Ken'ichi Yamazaki[1] (1.Disaster Prevention Research Institute, Kyoto University)

11:25 AM - 11:40 AM JST | 2:25 AM - 2:40 AM UTC

[SEM14-09] Development and Application of Noise Reduction Method using two-stage MSSA (Multichannel Singular Spectrum Analysis) for MT data in Boso, Japan

*Shu Kaneko[1], Katsumi Hattori[2], Toru Mogi[2], Chie Yoshino[2] (1.Chiba University Graduate School of Science and Engineering, 2.Chiba University Graduate School of Science)

11:40 AM - 11:55 AM JST | 2:40 AM - 2:55 AM UTC

[SEM14-10] Understanding the spatial distribution characteristics of the MT response using Variogram

*Nagi Yamashita[1], Tada-nori Goto[1], Satoru Yamaguchi[2] (1.University of Hyogo, 2.Osaka City University)

11:55 AM - 12:10 PM JST | 2:55 AM - 3:10 AM UTC

[SEM14-11] Development of a 3D inversion code to consider ocean bottom magnetotelluric data including topographic distortion ~forward modeling part~

*Masamitsu Araki[1], Tetsuo Matsuno[1], Nobukazu Seama[1], Takuto Minami[1] (1.Department of Planetology, Graduate School of Science, Kobe University)

12:10 PM - 12:15 PM JST | 3:10 AM - 3:15 AM UTC

[SEM14-12] Discussion

Accuracy and precision evaluation of the new method for the absolute magnetic measurements

*Hideyuki Hirahara[1], Junpei Oogi[1], Megumi Kaito[1], Seiki Asari[1]

1. Kakioka Magnetic Observatory, Japan Meteorological Agency.

The absolute magnetic measurements, which consists of measurements of the total magnetic force (F), the declination (D) and the inclination (I) at a given location and time, are performed for the purpose of precisely acquiring absolute values of the three components of the geomagnetic vector. A scalar magnetometer, such as proton magnetometer, is used for measuring F, and an instrument called `DI-meter' for D and I. The DI-meter is operated manually, for which a certain skill is required for the observers to ensure the accuracy of the measurements (0.1 arcmin or less).
In order to observe the geomagnetic secular variation accurately, it is desirable for the measurements to be repeated as frequently as possible, while it is generally unpractical for observers. The measurements usually take place at intervals of days to months at magnetic observatories, and annually or even less often at repeat stations.
Currently, the DI-meters commonly used at world's major magnetic observatories are those equipped with a uniaxial fluxgate magnetometer mounted on a non-magnetic theodolite, THEO, produced by Zeiss. D and I are determined from a certain number of angular measurements of specific directions perpendicular to either of them, or the “null-directions” (Jankowski & Sucksdorff 1996). The "null method" of the absolute measurements, which has been exclusively used in Japan, requires some manual skills for an operation to strictly align the magnetometer axis to the null-direction.
The proficiency required makes it hard particularly for inexperienced observers to hold the accuracy in circumstances, for instance, where the measurements are conducted outdoors or allowable time is limited. Meanwhile, for its handiness, an alternative method called "residual method" has become more common through the past years (Worthington & Matzka 2017). In the residual method, the null direction is derived indirectly by calculating it from angular measurements of the magnetometer axis roughly oriented in the null direction. Without the delicate manipulation, observers may enjoy multiple advantages: reduction in physical and psychological stresses, quickness in learning, and alleviation of the magnetic cleanliness for observers, etc.
We report the results of an evaluation test the accuracy of the absolute magnetic measurements with the residual method. The test was carried out for 10 months from April 2020 to January 2021.
In the Calibration House of Kakioka Magnetic Observatory, D and I were measured with the residual method using a DI-meter (THEO 010B), to investigate their differences (referred to as instrumental error) from the corresponding values obtained by DI-72, the reference instrument of Kakioka for measuring D and I. The measurements were carried out by seven members of the observatory staff abundantly experienced in the null method.
It was confirmed that the instrumental error was <0.1 arcmin, which compares to that for the null method with the same DI meter. The observation error was also about the same as that for the null method. The observation duration was generally shorter for the residual method.
The duration would be shortened even more effectively under severe situations, such as outdoors, or in cases with limited time, all thanks to the absence of the fine manipulation, and hence of the psychological burden. An experiment of the residual method is now underway for the absolute measurements at Syowa Station, Antarctica, in order to investigate the effect of increasing the measurement frequency on stabilization of the baseline values. Furthermore, the residual method is planned to be introduced in the operation of the magnetic station Chichijima, where the absolute measurements are made outdoors.

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Prof. Hisayoshi Shimizu (ERI, U. Tokyo) provided a great deal of support for one of the authors in this study to receive training of the residual method at Niemegk magnetic observatory in Germany.

Keywords: Geomagnetic field, Observation, Measurement, Accuracy, Secular variation, Residual method

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Piezomagnetic fields associated with a dislocation source in a layered elastic medium

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The piezomagnetic effect describes changes in magnetization with applied stress. Changes in the geomagnetic field because of the piezomagnetic effect, referred to as the piezomagnetic field, have been theoretically estimated and compared by previous studies to interpret observed variations in the geomagnetic field. However, the piezomagnetic field estimated in previous studies may not provide an accurate estimation because they ignored spatial variations in elasticity, leading to only a rough approximation of the properties of Earth’ s crust.

In this study, a semi-analytical procedure for calculating the piezomagnetic field arising from a point dislocation source embedded in a layered elastic medium is derived. Following a well-established method of vector surface spherical harmonics, all of the governing equations written in partial differential equations in a real domain, together with the linear constitutive law of the piezomagnetic effect, are converted to a set of ordinary differential equations in a wavenumber domain. Equations in the wavenumber domain are solved analytically, and each component of the piezomagnetic field in the real domain is obtained after applying the Hankel transform. By using the derived procedure, the piezomagnetic and displacement fields due to a finite fault with strike-slip, dip-slip, and tensile-opening mechanisms are estimated for media with layered elasticity structures. Results for a finite fault are obtained by integrating the point source solution over the fault plane.

The results of the numerical analysis allow the effect of heterogeneities in rigidity on the piezomagnetic effect to be examined and implications for the findings of previous investigations to be drawn. In cases where the moment-release at the dislocation source is fixed, the effect of the rigidity differences between upper and lower layers on the piezomagnetic field is minor even in the case where the Curie point depth is near the source of dislocation. This result is in contrast to a previous study that assumed the Mogi model and suggested that heterogeneities in the horizontal direction may be of importance when combined with layered rigidity structures. A contrast is seen between the piezomagnetic and displacement fields corresponding to models with layered rigidity structures: the piezomagnetic field is roughly proportional to the moment-release on a source fault, whereas the displacement field is proportional to slip or opening of the fault. Provided that the rigidity of the crust increases with increasing depth, the calculated piezomagnetic field is likely to have been underestimated in many earlier studies, which assumed uniform rigidity and a geodetically inverted size of slip.

Keywords: piezomagnetic effect, layered-medium, elasticity, displacement field, magnetic field

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Development and Application of Noise Reduction Method using two-stage MSSA (Multichannel Singular Spectrum Analysis) for MT data in Boso, Japan

*Shu Kaneko[1], Katsumi Hattori[2], Toru Mogi[2], Chie Yoshino[2]

1. Chiba University Graduate School of Science and Engineering, 2. Chiba University Graduate School of Science

There is a triple junction of the Pacific Plate, the Philippine Sea Plate, and the North American Plate off the coast of the Boso Peninsula and it is one of the most active areas of the crustal activity. To investigate the subsurface resistivity structure of the whole Boso area, magnetotelluric (MT) survey with 41 sites (inter-sites distance of 7 km) has been conducted in 2014-2016, using U43 (12 sites, 1 Hz sampling ; Tierra Technica) and MTU-5, 5A, net (41 sites, 15, 150, and 2400 Hz sampling; Phoenix Geophysics). However, the Boso area is greatly affected by leak current from DC-driven trains, factories, and power lines, so the observed data are severely contaminated by artificial noises. When we tried to apply the conventional noise reduction methods (e.g., remote reference (Gamble et al., 1979) and BIRRP (Chave and Thomson, 2004)) in frequency domain, the obtained MT sounding curve was not ideal. In particular, the phases between the periods of 20 and 400 sec were close to 0 degrees. It suggests that these conventional methods are insufficient to reduce the near-field effects for the Boso data. Thus, we developed a new noise reduction method using MSSA (Multi-channel Singular Spectrum Analysis) as a time domain pre-processing method.

The procedure is as follows;
(1) Decompose 6 component data (Hx, Hy, Ex, Ey, Hxr and Hyr: H and E means magnetic and electric field, respectively, x and y indicates NS and EW component, and r denotes the reference field observed at a quiet station) using MSSA into 6×L principal components (PCs). Here, L shows the window length of MSSA.
(2) Check each PC's contribution and periods and eliminate the PCs corresponding to the longer than 400 sec. That means "detrend" of the original data.
(3) Apply the second MSSA to the detrended time series data to separate signals and noises shorter than 400 sec.
(4) Calculate correlation coefficients between H and Hr and between E and Hr for each PC and select the PCs with higher correlation to "reconstruct" time series data to make MT analysis.

Then, we perform MT analysis by BIRRP to estimate MT response functions,
As a result, the MT sounding curve became smoother than those results by the conventional noise reduction methods. It indicates that the effectiveness of the proposed noise reduction.

In the presentation, we report the effectiveness of this method in the MT response function.

Keywords: MT method, Multi-channel Singular Spectrum Analysis, Noise reduction, Boso peninsula

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Understanding the spatial distribution characteristics of the MT response using Variogram

*Nagi Yamashita[1], Tada-nori Goto[1], Satoru Yamaguchi[2]

1. University of Hyogo, 2. Osaka City University

In the magnetotelluric method (MT method), the subsurface resistivity structure can be estimated based on the apparent resistivity and phase (MT response) for each frequency. Recently, in order to reduce the influence due to the small-scale heterogeneous structure near the surface (static distortion), the analysis of resistivity structure is done based on Zssq, a rotational invariant of impedance tensor. However, the spatial characteristics of Zssq, especially the horizontal distribution feature s, have not been discussed.

In this study, the spatial distribution and the characteristics of the MT response (Zssq) obtained from various two-dimensional resistivity structures are discussed qualitatively. We investigated the spatial correlation of MT response using Variogram often used in geostatistical researches. We prepared seven different types of subsurface resistivity models, and compared the spatial wavelength of the distributions of Zssq apparent resistivity and phase values for three different frequencies. Prior to that discussion, we also investigated the relationship between the range in Variogram and the wavelength of spatial changes, whose wave shape follows the normal distribution function.

As a result, it was found that there is no simple correlation in spatial wavelength between Zssq apparent resistivity and phase, and also found that the range of Zssq apparent resistivity is greater than the range of Zssq phase. Furthermore, it was clarified that the range is up to about 3.6 times the spatial wavelength (standard deviation of normal distribution function), and that the range also depends on the spacing of the resistivity anomalies. From the spatial relationship between apparent resistivity and phase, it was suggested that the degree of static shift, often seen in actual MT exploration, is discussed based on the geostatistical analysis.

Keywords: Magnetotelluric, Variogram, Static shift correction method

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Development of a 3D inversion code to consider ocean bottom magnetotelluric data including topographic distortion ~forward modeling part~

*Masamitsu Araki[1], Tetsuo Matsuno[1], Nobukazu Seama[1], Takuto Minami[1]

1. Department of Planetology, Graduate School of Science, Kobe University

In recent years, new experiments using Ocean Bottom ElectroMagnetometers (OBEMs) around Japan have greatly increased the amount of seafloor electromagnetic field data that can be used to estimate sub-bottom resistivity structures using the MT method. In order to analyze such data sets, this study develops a 3D inversion method for seafloor MT data.

In this study, we are developing a code suitable for seafloor EM data based on ModEM (Egbert and Kelbert, 2012), which is a three-dimensional inversion algorithm using the finite difference method. The Flattening Seafloor (FS) technique (Baba and Seama, 2002) is introduced into ModEM to incorporate the undulations of the seafloor topography with fewer computational elements. The seafloor topography corresponds to thickness variations of the ocean and of the underlying crust. With this method, these thickness variations are transformed into variations in the electrical properties of cells that have anisotropic conductivity. As a result, the seafloor topography is represented as flat, with only two layers above and below the seafloor that retain the electrical properties of the topographic undulations. This simplification of the seafloor in numerical calculation also saves computer resources and computation time, which is especially crucial for 3D inversion.

In this study, we first investigate the correlation between the thickness of the grid cells above and below the seafloor and the computed MT response. We consider the case of a one-dimensional structure that is flat and uniformly 100 Ωm below the seafloor. The thickness of the grid cells above and below the seafloor was varied, and the MT response values obtained by forward calculation were compared with the theoretical ones. As a result, for a period of 10 seconds, the difference between the forward calculated MT response value and the theoretical one is about 5% for a thickness of 5 m above and below the seafloor, but it is as large as 80% for a thickness of 200 m above and below the seafloor. In other words, it is clear that the accuracy of the forward calculation can be improved by adding thin layers above and below the seafloor when you use seafloor MT data.

We next used ModEM with the experimental FS method to compare the FS method forward calculation with (A) and without (B) a thin layer of 0.01 m above and below the seafloor, with the forward calculation with a direct grid representation of the seafloor topography(C). The original topography was a two-dimensional topography with a smooth change in water depth from 2750 to 3250m, which is the same as the one used by Baba and Seama (2002). As a result of the comparison of (A) and (C), at a period of 1000 seconds, the apparent resistivity of (A) was 20-40% smaller and the phase of (A) was 30-40° smaller than that from (C). On the other hand, in the case of (B) the MT response values were generally consistent with the results of (C). The error in MT response is about 10% in the undulating part of the topography.

Furthermore, we found that it is necessary to prepare a wide computational domain outside the two-dimensional undulating target region when creating a numerical grid for the ModEM forward

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calculation using the FS method. When the numerical grid is created using only the undulating region, the values at the edge of the numerical grid, mainly for the TM mode of the MT response, show anomalous values. The difference between the anomalous values and normal values that are calculated with the direct numerical grid representation of the topography is about 40-80% for a period of 1000 seconds. In order to avoid these anomalous values in this topography with a period of 1000 seconds, it was necessary to expand the computational domain horizontally by more than 300 km. This is probably due to the fact that the boundary conditions of the ModEM numerical grid are not suitable for the FS method because the boundary conditions in ModEM do not consider the anisotropic conductivity.

Keywords: magnetotelluric

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[J] Oral | S (Solid Earth Sciences) | S-EM Earth's Electromagnetism

[S-EM14] Electromagnetic Induction in the Earth and Planetary Interiors, and Tectono-Electromagnetism

convener:Maki Hata(Earthquake Research Institute, the University of Tokyo), Mitsuru Utsugi(Aso Volcanological Laboratory, Institute for Geothermal Sciences, Graduate School of Science, Kyoto University), Chairperson:Ken'ichi Yamazaki(Disaster Prevention Research Institute, Kyoto University), Mitsuru Utsugi(Aso Volcanological Laboratory, Institute for Geothermal Sciences, Graduate School of Science, Kyoto University)

Thu. Jun 3, 2021 10:45 AM - 12:15 PM Ch.23 (Zoom Room 23)

This session welcomes papers on electromagnetism in the Earth and planetary interiors. The topics include but not limited to electromagnetic phenomena associated with earthquakes and volcanism, electrical conductivity structure, laboratory experiments, results of simulations, new equipment for observation, and methods of data analysis.

12:10 PM - 12:15 PM

[SEM14-12]Discussion

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[J] Oral | S (Solid Earth Sciences)：S-IT Science of the Earth's Interior & Techtonophysics

Thu. Jun 3, 2021 1:45 PM - 3:15 PM JST | Thu. Jun 3, 2021 4:45 AM - 6:15 AM UTC | Ch.24 Zoom Room 24

[S-IT21] Innovation through the Integration of Solid Earth Science and Materials Science

convener:Kenji Kawai(Department of Earth and Planetary Science, School of Science, University of Tokyo), Jun Tsuchiya(Geodynamics Research Center, Ehime University), Ryuichi Nomura(Kyoto University), Satoshi Ohmura(Hiroshima Institute of Technology), Chairperson:Kenji Kawai(Department of Earth and Planetary Science, School of Science, University of Tokyo), Ryuichi Nomura(Kyoto University)

In recent years, collaborative studies on the physical and chemical properties of the Earth's interior, at depths from the mantle to the Earth's core, and on the formation and evolution of the Earth, have led to the elucidation of the dynamic behavior of deep Earth materials, such as core-mantle interaction and coevolution. This session will bring together researchers in Earth science and materials science to exchange information on the development of new technologies, which have the potential to revolutionize studies of the deep Earth's interior. These technologies include high-resolution electron microscopy, large-scale multi-scale computation, and machine-learning methods that allow us to design materials at an atomic scale.

1:45 PM - 1:50 PM JST | 4:45 AM - 4:50 AM UTC

[SIT21-01] Introduction

1:50 PM - 2:20 PM JST | 4:50 AM - 5:20 AM UTC

[SIT21-02] Time-resolved transmission electron microscopy toward operando-measurement in geoscience

★Invited Papers

*Kuwahara Makoto[1] (1.Nagoya University)

2:20 PM - 2:35 PM JST | 5:20 AM - 5:35 AM UTC

[SIT21-03] Ab initio modeling of antigorite transported by subducting oceanic plates

*Jun Tsuchiya[1], Sayako Inoue[1] (1.Geodynamics Research Center, Ehime University)

2:35 PM - 3:05 PM JST | 5:35 AM - 6:05 AM UTC

[SIT21-04] Properties of liquid Fe mixtures under high-pressure conditions

★Invited Papers

*Satoshi Ohmura[1], Taku Tsuchiya[2] (1.Hiroshima Institute of Technology, 2.Ehime Univ.)

3:05 PM - 3:15 PM JST | 6:05 AM - 6:15 AM UTC

[SIT21-05] Discussion

[J] Oral | S (Solid Earth Sciences) | S-IT Science of the Earth's Interior & Techtonophysics

[S-IT21] Innovation through the Integration of Solid Earth Science and Materials Science

convener:Kenji Kawai(Department of Earth and Planetary Science, School of Science, University of Tokyo), Jun Tsuchiya(Geodynamics Research Center, Ehime University), Ryuichi Nomura(Kyoto University), Satoshi Ohmura(Hiroshima Institute of Technology), Chairperson:Kenji Kawai(Department of Earth and Planetary Science, School of Science, University of Tokyo), Ryuichi Nomura(Kyoto University)

Thu. Jun 3, 2021 1:45 PM - 3:15 PM Ch.24 (Zoom Room 24)

In recent years, collaborative studies on the physical and chemical properties of the Earth's interior, at depths from the mantle to the Earth's core, and on the formation and evolution of the Earth, have led to the elucidation of the dynamic behavior of deep Earth materials, such as core-mantle interaction and coevolution. This session will bring together researchers in Earth science and materials science to exchange information on the development of new technologies, which have the potential to revolutionize studies of the deep Earth's interior. These technologies include high-resolution electron microscopy, large-scale multi-scale computation, and machine-learning methods that allow us to design materials at an atomic scale.

1:45 PM - 1:50 PM

[SIT21-01]Introduction

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Time-resolved transmission electron microscopy toward operando-measurement in geoscience

*Kuwahara Makoto[1]

1. Nagoya University

Time-resolved measurement in a transmission electron microscopy (TEM) holds promises of reveling intrinsic feature in nano-materials. Our group had developed time-resolved TEM (TR-TEM) using photocathode-type electron gun which could synchronize with time-structure of pulsed laser. The TR-TEM can provide a narrow energy width of below 0.3 eV and 1-ps pulse duration of electron beam. Furthermore, it has been clarified that the pulsed electron could contribute to observe time evolutions of electromagnetic field. High charge electron pulse in TRTEM also has possibility to realize operando-measurement of rock friction via nanosecond single-shot imaging, which can investigate rock friction at high sliding velocity and effect of ambient temperature, pressure, and pore pressure on friction. The technique will open to access nanometer-scale mechanics of faulting origin in geoscience. We would like to introduce overview of our apparatus and recent status of ultrafast measurement in electron microscopy.

Keywords: operando measurement, transmission electron microscopy, material science

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Ab initio modeling of antigorite transported by subducting oceanic plates

*Jun Tsuchiya[1], Sayako Inoue[1]

1. Geodynamics Research Center, Ehime University

Serpentine is hydrous phyllosilicate known to be formed in the mantle wedge by a reaction between mantle peridotit and upwelling water released by the decomposition of hydrous minerals in the subducting slab [e.g. Schmidt and Poli,1998]. Partially serpentinized peridotite may be a significant reservoir of water in the mantle wedge and the dehydration of serpentine is considered to have an important contribution to the generation of arc magmatism. This was also extensively investigated in connection with intermediate and deep earthquakes [e.g. Irifune et al. , 1996].
In order to investigate the transporting processes of water into the Earth’ s interior, the thermodynamic stabilities and the elastic properties of antigorite should be clarified. Antigorite is the high-temperature polymorph of serpentine and thus the relevant phase in the subduction zone. This phase has been reported to show polysomatism depending on the pressure and temperature conditions. Previous TEM study reported that *m* value (*m* = number of SiO_4 tetrahedra in a wavelength along the *a* axis) increases/decreases with pressure/temperature [e.g. Wunder et al. 2001]. However, there is no sufficient structural and thermodynamic corroboration regarding the stable polysome of antigorite along the pressure and temperature conditions of the subducting oceanic plate.
In the present study, we investigated the structure and elasticity of antigorite with several different *m* values by ab intio calculation and discuss the stable polysome of antigorite in the subducting oceanic plate.

Keywords: ab initio calculation, serpentine

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Properties of liquid Fe mixtures under high-pressure conditions

*Satoshi Ohmura[1], Taku Tsuchiya[2]

1. Hiroshima Institute of Technology, 2. Ehime Univ.

The effects of light elements such as H, C, O, Si, and S on the local structures of liquid Fe under high pressure are investigated by ab initio molecular dynamics (MD) simulations. The simulations clarify that H, C, and O are incorporated into liquid Fe interstitially while Si and S are “substitutional” type impurities. In addition, the interaction between light elements depends on the type of element. The C-C interactions are stronger than those of other light elements. The S-S interactions depend on the S concentration. From our simulations of liquid sulfur, it is found that the liquid sulfur has a covalent-like interactions even in metallic state, and liquid sulfur has a simple liquid structure at 320 GPa and higher pressures.

Keywords: high pressure, ab initio molecular dynamics, liquid

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[J] Oral | S (Solid Earth Sciences) | S-IT Science of the Earth's Interior & Techtonophysics

[S-IT21] Innovation through the Integration of Solid Earth Science and Materials Science

convener:Kenji Kawai(Department of Earth and Planetary Science, School of Science, University of Tokyo), Jun Tsuchiya(Geodynamics Research Center, Ehime University), Ryuichi Nomura(Kyoto University), Satoshi Ohmura(Hiroshima Institute of Technology), Chairperson:Kenji Kawai(Department of Earth and Planetary Science, School of Science, University of Tokyo), Ryuichi Nomura(Kyoto University)
Thu. Jun 3, 2021 1:45 PM - 3:15 PM Ch.24 (Zoom Room 24)

In recent years, collaborative studies on the physical and chemical properties of the Earth's interior, at depths from the mantle to the Earth's core, and on the formation and evolution of the Earth, have led to the elucidation of the dynamic behavior of deep Earth materials, such as core-mantle interaction and coevolution. This session will bring together researchers in Earth science and materials science to exchange information on the development of new technologies, which have the potential to revolutionize studies of the deep Earth's interior. These technologies include high-resolution electron microscopy, large-scale multi-scale computation, and machine-learning methods that allow us to design materials at an atomic scale.

3:05 PM - 3:15 PM

[SIT21-05]Discussion

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[J] Oral | S (Solid Earth Sciences)：S-IT Science of the Earth's Interior & Techtonophysics

Thu. Jun 3, 2021 3:30 PM - 5:00 PM JST | Thu. Jun 3, 2021 6:30 AM - 8:00 AM UTC | Ch.24 Zoom Room 24

[S-IT21] Innovation through the Integration of Solid Earth Science and Materials Science

convener:Kenji Kawai(Department of Earth and Planetary Science, School of Science, University of Tokyo), Jun Tsuchiya(Geodynamics Research Center, Ehime University), Ryuichi Nomura(Kyoto University), Satoshi Ohmura(Hiroshima Institute of Technology), Chairperson:Satoshi Ohmura(Hiroshima Institute of Technology), Jun Tsuchiya(Geodynamics Research Center, Ehime University)

In recent years, collaborative studies on the physical and chemical properties of the Earth's interior, at depths from the mantle to the Earth's core, and on the formation and evolution of the Earth, have led to the elucidation of the dynamic behavior of deep Earth materials, such as core-mantle interaction and coevolution. This session will bring together researchers in Earth science and materials science to exchange information on the development of new technologies, which have the potential to revolutionize studies of the deep Earth's interior. These technologies include high-resolution electron microscopy, large-scale multi-scale computation, and machine-learning methods that allow us to design materials at an atomic scale.

3:30 PM - 4:00 PM JST | 6:30 AM - 7:00 AM UTC

[SIT21-06] High spatial resolution electronic structure analysis by scanning transmission electron microscopy and electron energy loss spectroscopy

★Invited Papers

*Mitsutaka Haruta[1] (1.Kyoto University)

4:00 PM - 4:30 PM JST | 7:00 AM - 7:30 AM UTC

[SIT21-07] Molecular Dynamics Simulation of Shock-Induced Structural Transformation of Silica Using Artificial Neural Network

★Invited Papers

*Masaaki Misawa[1], Kohei Shimamura[2], Fuyuki Shimojo[2] (1.Okayama Univ., 2.Kumamoto Univ.)

4:30 PM - 4:45 PM JST | 7:30 AM - 7:45 AM UTC

[SIT21-08] Deformation mechanisms maps of bridgmanite based on high pressure experiments

*Noriyoshi Tsujino[1], Daisuke Yamazaki[1] (1.Institute for Planetary Materials, Okayama University)

4:45 PM - 5:00 PM JST | 7:45 AM - 8:00 AM UTC

[SIT21-09] Waveform inversion for the structure of Earth's deep interior: Progress and Prospects

*Kenji Kawai[1] (1.Department of Earth and Planetary Science, School of Science, University of Tokyo)

High spatial resolution electronic structure analysis by scanning transmission electron microscopy and electron energy loss spectroscopy

*Mitsutaka Haruta[1]

1. Kyoto University

Since transition metal (TM) oxides exhibit a variety of physical properties, which are sensitively related to their complex crystal structures and constituent elements, many experimental and theoretical studies has been conducted for not only bulk but also thin film. In particular, the relationship between localized TM *d* -band and oxygen 2*p* band is one of the key factors to control of the property. For further understanding, it is important to examine individual electronic structure with atomic resolution. This is because it has often some nonequivalent atomic sites in a unit cell even a single crystal, and they have different electronic structure for the same element.

In the field of high spatial resolution analysis, scanning transmission electron microscopy (STEM) combined with electron energy-loss spectroscopy (EELS) is the one way to know both elemental and electronic structure with atomic scale. However, while this technique can offer elemental and electronic state mapping with atomic resolution, it is, in principle, difficult to experimentally extract the information with truly atomic resolution due to the physically limited spatial resolution caused by the delocalization of inelastic scattering electrons[1] although sub-Å size electron probe has achieved thanks to the development spherical aberration corrector. Therefore, the interpretation of STEM-EELS with atomic scale is not simple, and careful attention of the mixing of signals from neighboring atomic-columns is required. In our previous researches, we focus on electronic structure of oxygen 2*p* band and transition metal 3d band with high spatial resolution for transition metal oxide which has layered structure. Since the fine structure of O *K*-edge reflects the unoccupied 2p state which hybridized with cation electronic orbital due to its covalent bonding character, it includes much information about chemical bond. In the presentation, I will introduce some applications of high spatial resolution STEM-EELS combined with some theoretical calculations.

Keywords: STEM, EELS

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Molecular Dynamics Simulation of Shock-Induced Structural Transformation of Silica Using Artificial Neural Network

*Masaaki Misawa[1], Kohei Shimamura[2], Fuyuki Shimojo[2]

1. Okayama Univ., 2. Kumamoto Univ.

Artificial neural network (ANN) potential, which is an interatomic potential constructed by machine-leaning, attracts attention as a promising method to achieve extra-large-scale molecular dynamics (MD) simulation with first-principles accuracy (Behler, 2007; Artrith, 2016). Application of this ANN-MD to far-from-equilibrium phenomena, such as fracture and pressure-induced transformation, is important to understand structural properties of materials under extreme conditions. For this purpose, we have tried to perform ANN-MD simulation of shock-induced structural transformation of silica.

To compute shock-compression behaviors within the framework of MD method, the multiscale-shock technique (Reed, 2003) was employed in our simulations. Potential energy of shock-compressed α-quartz obtained by first-principles MD (FPMD) method is used as a reference data for training of ANN-potential. As a result of ANN-MD simulation for elastic shock-wave region, elastic-deformation behaviors of α-quartz was successfully reproduced with high-accuracy (Misawa, 2020). On the other hand, for plastic shock-wave region, the ANN-potential has completely failed on prediction of both structure and energy, because of that irregular structure appears and rapid movement of atoms occurs during the elastic-to-plastic transition process.

In order to improve the predicting ability of ANN-potential, we introduce a more accurate training method that uses not only potential energy but also atomic force and pressure as reference data (Shimamura, 2020). Using this improved ANN-potential, it was succeeded that reproducing the elastic-to-plastic transition behavior and plastic deformation of α-quartz with an accuracy close to FPMD simulation. Thus, the ANN-potential trained with energy, force, and pressure is a potentially powerful tool to investigate wide range of far-from-equilibrium phenomena and will also provide useful information for solid earth physics field in future.

Reference

E. Reed *et al.*, *Phys. Rev. Lett.* **90**, 235503 (2003).
J. Behler and M. Parrinello, *Phys. Rev. Lett.* **98**, 146401 (2007).
N. Artrith and A. Urban, *Comput. Mater. Sci.* **114**, 135 (2016)
M. Misawa *et al.*, *J. Phys. Chem. Lett.* **11**, 4536 (2020).
K. Shimamura *et al.*, *J. Chem. Phys.* **153**, 234301 (2020).

Keywords: Molecular dynamics , Machine learning, Shock compression

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Deformation mechanisms maps of bridgmanite based on high pressure experiments

*Noriyoshi Tsujino[1], Daisuke Yamazaki[1]

1. Institute for Planetary Materials, Okayama University

Geophysical observations have revealed that the lower mantle has the largest viscosity in the Earth’s mantle. The lower mantle viscosity would play a key role in the global mantle dynamics. In order to understand the lower mantle viscosity, it is important to determine viscosity of bridgmanite which is regarded as the most dominant mineral of the lower mantle. Nevertheless, experimental data on viscosity of bridgmanite is quite limited due to experimental difficulty. Therefore, we conducted in-situ stress-strain measurements of bridgmanite by uniaxial deformation experiments at the lower mantle pressure conditions by newly developed deformation apparatuses with the Kawai type cell. Experimental conditions covered temperatures of 1473-1673 K and pressures of 23-27 GPa. The obtained stress exponent and activation enthalpy suggest that the dominant deformation mechanism of bridgmanite is climb-controlled dislocation creep. Bridgmanite is found to have the largest creep strength among mantle constituent minerals at same strain-rate even under nominally dry conditions. Based on this results and diffusion coefficient of Si in bridgmanite reported by Yamazaki et al. (2000), the deformation mechanisms map of bridgmanite was constructed. Combining deformation mechanism map of bridgmanite with geophysical observations indicates that grain-size of bridgmanite and stress conditions at top of the lower mantle would be > 8 mm and $< 3\times10^5$ Pa, respectively. The expected grain size of bridgmanite with 3-8 mm is much larger than that of bridgmanite in multi-phase system after the phase transition from ringwoodite across the 660 km discontinuity during convection of the mantle even followed by the grain growth for 1 billion years (e.g., Yamazaki et al., 1996). This fact suggests that large amount of the lower mantle materials would not have experienced the dissociation during the mantle convection and would have been isolated from the mixing by mantle stirring after crystallization of the magma ocean.

Keywords: deformation mechanisms map, bridgmanite, high pressure experiments, rheology

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Waveform inversion for the structure of Earth's deep interior: Progress and Prospects

*Kenji Kawai[1]

1. Department of Earth and Planetary Science, School of Science, University of Tokyo

We formulated the inverse problem of waveform inversion for localized 3-D seismic structure, computing partial derivatives of waveforms with respect to the elastic moduli at arbitrary points in space for anisotropic and anelastic media (Geller and Hara 1993) and applied our method to the assembled dataset to invert for 3-D seismological structure (Kawai et al. 2014; Konishi et al. 2014). In this presentation, we will introduce the recent progress of mainly our research group (Borgeaud et al. 2017, 2019; Suzuki et al. 2020) and discuss perspectives of waveform inversion studies on the structure of Earth's deep interior.

Keywords: Waveform inversion, Studies of the Earth's deep interior

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[J] Oral | S (Solid Earth Sciences)：S-VC Volcanology

Thu. Jun 3, 2021 1:45 PM - 3:15 PM JST | Thu. Jun 3, 2021 4:45 AM - 6:15 AM UTC | Ch.25 Zoom Room 25

[S-VC30] Volcanic and igneous activities, and these long-term forecasting

convener:Takeshi Hasegawa(Department of Earth Sciences, College of Science, Ibaraki University), Teruki Oikawa(GSJ, National Institute of Advanced Industrial Science and Technology), Daisuke MIURA(Department of Physical Science, Graduate School of Science, Osaka Prefecture University), Nobuo Geshi(Geological Survey of Japan, The National Institute of Advanced Industrial Science and Technology), Chairperson:Tomohiro Tsuji(Division of Earth Science The Graduate School of Science and Technology for Innovation Yamaguchi University), Chisato Anai(Aso Volcanological Laboratory, Institute for Geothermal Sciences, Graduate School of Science, Kyoto University)

This session focuses on generation and accumulation processes of magmas, magma-crust interaction and degassing, and modes of eruption, long-term forecast of eruption, dispersal and emplacement of the volcanic products. The discussion spans petrological, geochemical, geophysical, and geological processes related with volcanic activity and products in the past, the present and the future.

1:45 PM - 2:00 PM JST | 4:45 AM - 5:00 AM UTC

[SVC30-01] Paleomagnetic evidence for polygenetic origin of Mamiyadake tephra ring, Ohachidaira maar-caldera complex, Hokkaido, Japan

*Yuki Yasuda[1] (1.Institute of Seismology and Volcanology, Faculty of Science, Hokkaido University)

2:00 PM - 2:15 PM JST | 5:00 AM - 5:15 AM UTC

[SVC30-02] Constraining residence times of plagioclase phenocrysts at the latest activity of Zao volcano

*Motohiro Sato[1], Masao Ban[1] (1.Graduate School of Science and Technology, Yamagata University)

2:15 PM - 2:30 PM JST | 5:15 AM - 5:30 AM UTC

[SVC30-03] Inverse crystallization order of phenocrysts in high-Mg basalt from Ryozen Formation, Fukushima prefecture

*Tsukasa Ohba[1], Tokiya Ando[1] (1.Faculty of International Resource Sciences, Akita University)

2:30 PM - 2:45 PM JST | 5:30 AM - 5:45 AM UTC

[SVC30-04] Discovery of new block and ash flow deposit from Azuma-kofuji volcano, Fukushima, Japan

*Takeshi Hasegawa[1], Suzuki Kazuma[1] (1.Department of Earth Sciences, College of Science, Ibaraki University)

2:45 PM - 3:00 PM JST | 5:45 AM - 6:00 AM UTC

[SVC30-05] Reexamination of the characteristics and eruption style of Haruna-Hakoda tephra found from the southern foot of Akagi Volcano to the eastern foot of Haruna Volcano in North Kanto, Northeast Japan

*Junichi Sato[1], Takehiko Suzuki[2] (1.Department of Geography, Graduate School of Urban Environmental Sciences, Tokyo Metropolitan University, 2.Faculty of Urban Environmental Sciences, Tokyo Metropolitan University)

3:00 PM - 3:15 PM JST | 6:00 AM - 6:15 AM UTC

[SVC30-06] What have been erupted from the 2020 eruption of Nishinoshima?

*Yoshihiko Tamura[1], Tomoki Sato[1], Kenta Yoshida[1], Fukashi Maeno[2], Osamu Ishizuka[1,3], Yasuhiro Hirai[1], Noriko Tada[1], Kiyoshi Baba[2], Daisuke Suetsugu[1], Maiko Miyoshi[4], Shigeaki Ono[1] (1.Research Institute for Marine Geodynamics, Japan Agency for Maine-Earth Science and Technology, 2.ERI, Univ. of Tokyo, 3.GSJ/AIST, 4.NHK)

Paleomagnetic evidence for polygenetic origin of Mamiyadake tephra ring, Ohachidaira maar-caldera complex, Hokkaido, Japan

*Yuki Yasuda[1]

1. Institute of Seismology and Volcanology, Faculty of Science, Hokkaido University

Maar volcanoes are surrounded by tephra rings that consist of well-bedded tephra layers. Due to the undisturbed nature of the successive tephra layers, tephra-ring deposits are generally considered to be emplaced over a short time interval (days to years) without significant time breaks; hence, maars are generally interpreted as being monogenetic. In this presentation I describe paleomagnetic evidence for polygenetic origin of the Mamiyadake tephra ring which was formed during maar-forming eruptions at Ohachidaira volcano, central Hokkaido, Japan. In this study, oriented block samples (mostly scoria clasts) were collected from >30 sites throughout the sequence of the Mamiyadake tephra ring for paleomagnetic analysis. Like other maar-tephra-ring deposits elsewhere, pyroclastic layers making up the Mamiyadake tephra ring show no sedimentological evidence for significant time breaks, but with one unconformity between the layers occurring in the southwest rim. The paleomagnetic directions obtained from the ring deposits significantly vary vertically through the sequence. This significant variations in paleomagnetic directions between the sites are interpreted as recording snapshots of paleomagnetic secular variation (PSV) of the geomagnetic field over time. By using the average rate of PSV in Japan calculated from the Holocene archaeomagnetic and paleomagnetic records, I conclude that the deposits of the Mamiyadake tephra ring were emplaced intermittently over a time span of at least 1000 yr. The results of this study suggest a possibility of maar’ s longer lifespans (hundreds to thousands of years) that are at least three orders of magnitude longer than previously thought.

Keywords: paleomagnetic direction, tephra ring, maar-caldera complex

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Constraining residence times of plagioclase phenocrysts at the latest activity of Zao volcano

*Motohiro Sato[1], Masao Ban[1]

1. Graduate School of Science and Technology, Yamagata University

1. Introduction

Time scales of magmatic processes are critical information to reveal eruption mechanisms and evaluate volcanic hazards. To estimate magmatic time scales, diffusion modeling of crystals has been used recently. Plagioclase, a ubiquitous phenocryst in volcanic rocks, provides the benefit of detecting magmatic processes. We report the residence times of plagioclase phenocrysts and constrain the pre-eruptive processes at the latest activity of Zao volcano.

2. Samples and analytical methods

Juvenile bomb samples are collected from Okama activity products (OKP), which were erupted between 12 and 19C. These samples are medium-K and calc-alkaline series basaltic andesite to andesite (56-57% SiO2), including plagioclase, orthopyroxene, clinopyroxene, and rare olivine as phenocryst.

Mg and CaAl-NaSi in plagioclase were used to estimate residence times. Zoning profiles of plagioclase were measured by electron probe microanalysis. High spatial resolution An zoning profiles are required to detect the nm-scale diffusion of CaAl-NaSi. An zoning profiles were also obtained by calibrated BSE images using the ImageJ software.

3. Processes recorded by plagioclase textures and compositions

Textures and compositions of plagioclase phenocrysts record various crystallization histories. Four populations of plagioclase phenocrysts are present in OKP samples. Type A has oscillatory zoned cores. The oscillatory zoning reflects cyclic changes of the chemical and physical conditions induced by injections of hotter magma into the shallow reservoir. Type B and C have patchy zoned cores of low- and high- An, respectively. The patchy texture was formed by partial dissolution. The former was formed by injection of hotter magma, whereas the latter was formed by decompression at calcic and H2O-undersaturated melt conditions. Type D shows the honeycomb texture, which was formed by skeletal growth under supercooling conditions. The dusty zoned or high-An rim, which is observed in type A, B, and C, reflects the interaction of hotter and calcic melt before eruptions. The low-An outermost rim observed in all types was produced by supercooling or an increase in the liquidus temperature due to water exsolution induced by magma ascent.

4. Residence times of plagioclase phenocrysts

Residence times of plagioclase phenocrysts were calculated using Mg and CaAl-NaSi diffusion modeling. The former one includes the effects of coupling with An content and provides more precise determinations than the other steady-state diffusion models. However, this model failed to calculate residence times of type A and B plagioclase phenocrysts because of strong changes of the An composition in small steps. To avoid this problem, we used type C and D phenocrysts which have a lower degree of partial dissolution. The initial Mg concentrations were estimated from measured An content. The boundary conditions were assumed to be in equilibrium with the groundmass composition. The diffusion equation was calculated numerically by a finite-difference scheme.

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We first used the one-step model, which assumes that diffusion starts only after the entire crystal grew. The calculated profiles at the crystal cores reach the measured Mg concentrations within 50-300 yrs. However, this model could not obtain good fits in the dusty and high-An rim. We used the multi-step model, which provides the time scales of different processes recorded in different parts of the crystals. An example of a type C plagioclase gave first step residence time of 100 yrs for the core profile resulted from diffusion in a high-temperature melt and gave second step residence time of < 5 yrs for the rim profile by the diffusion in a low-temperature melt. This model obtained better fits to the dusty and high-An rim.

In contrast, the CaAl-NaSi diffusion time scales indicate shorter residence times (10-50 yrs) than Mg diffusion. In a simple case, we evaluated the effect of multi-dimensional diffusion in the case of Mg diffusion and found this becomes significant when diffusion progresses to the center part of the crystal. Compared to the two-dimensional diffusion model, the one-dimensional one gives several times longer results. The results of the two-dimensional model are in good agreement with those of CaAl-NaSi diffusion modeling. These results indicate that the shallow magma reservoir had been mixed continuously with the newly injected high-temperature magma just before the eruption.

Keywords: Diffusion modeling, Plagioclase, Zoning profile, Zao volcano

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Inverse crystallization order of phenocrysts in high-Mg basalt from Ryozen Formation, Fukushima prefecture

*Tsukasa Ohba[1], Tokiya Ando[1]

1. Faculty of International Resource Sciences, Akita University

Since the proposal of Bowen’s reaction theory (Bowen, 1928), chemical and mineralogical diversities of basaltic rocks have been attributed to crystallization differentiation. In primitive basalt magmas, olivine is assumed to be the initial crystallization phase followed by crystallization of pyroxene and plagioclase. The orders of crystallization are often determined with microscopic observations for natural basalt samples (e.g., Aoki, 1989). Recently, an inverse crystallization order (pyroxenes - olivine - plagioclase) from basaltic magma was identified by Rafren et al. (2020) from Manguao basalt, Palawan Island, Philippines. The inverse crystallization order was accounted for by decompression crystallization during magma ascent. They explained the crystallization process based on mineral chemistry, mineral textures, and MELTS simulation (Gualda and Ghiorso, 2014). Decompression crystallization models have been applied for some basaltic volcanoes (Kuritani, 1999; Ohba et al., 2009), but is still not a widely accepted model. Ohba et al. (2009) pointed out that chemical variation trends from Hakkoda are not consistent with the fractionation of phenocryst minerals, and explained that cryptic crystallization at MOHO resulted in the chemical trends whereas phenocrysts were formed in the shallow crust during ascent.

The Miocene Ryozen Formation, Fukushima, northern Honshu Japan, is a basaltic volcanic suite composed of high-Mg basalt. Shuto et al. (1985) identified four types of phenocryst mineral assemblages. The least differentiated basalt is one of the basaltic samples containing olivine phenocrysts solely and is one of the highest in MgO content of the samples. However, a pyroxene-bearing rock has a similar while rock chemistry. When whole rock compositions of Ryozen Formation are plotted on variation diagrams, pyroxene-free rocks show a wide MgO range, and pyroxene-bearing rocks overlaps the entire trend of pyroxene-free rocks. An evolved mineral assemblage in the gauge of Bowen’s reaction theory (olivine + clinopyroxene + orthopyroxene + plagioclase) has a similar chemical composition to the rocks with the primitive mineral assemblage (olivine alone). This fact indicates that the variation of observed phenocryst assemblage is not necessarily relevant to the chemical differentiation.
We re-examined whole rock chemistry and mineral chemistry of some basaltic rocks from Ryozen. The analyzed basaltic rock samples contain olivine and clinopyroxene as phenocrysts. Plagioclase is contained in a sample. In these samples, clinopyroxene phenocryst cores have higher Mg# than those of olivine. At the basaltic temperature of 1200 C which is consistent with the plagioclase-melt geothermo- hygrometer for the plagioclase-bearing sample, Mg-Fe partitioning between olivine and clinopyroxene is close to 1. The difference of Mg# between olivine and clinopyroxene cores indicates earlier crystallization of clinopyroxene than olivine. The observation is consistent with MELTS modeling of isothermal decompression, resulting in the early crystallization of clinopyroxene and later crystallization of olivine. The model calculation also resulted in early crystallization of Low-Ca pyroxene (pigeonite or orthopyroxene) which is contained in some other samples but not in the examined samples. Low-Ca pyroxene may be replaced by olivine through the peritectic reaction during the decompression.

Keywords: Order of crystallization, basaltic magma, Ryozen

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Discovery of new block and ash flow deposit from Azuma-kofuji volcano, Fukushima, Japan

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Azuma volcano is located on the west side of Fukushima-city. The volcanic complex consists of three volcanoes, called Nishi-Azuma, Naka-Azuma and Higashi-Azuma (from west to east). The Higashi-Azuma volcano has a large (2 km in diameter) summit crater, Jododaira, with an opening to the east side. It formed by sector collapse/Plinian eruption and produced debris avalanche deposits on eastern foot of the volcano at around 140 ka. Azuma-kofuji is one of the active volcanoes in the Azuma volcanic complex generated on the Jododaira crater during 6 ky to 5 ky ago. Azuma-kofuji is composed of a scoria cone, and widely distributed lava flows that covers the debris avalanche deposits at the eastern base of Higashi-Azuma. In this study, we discovered a new block and ash flow deposit (BAF) from Azuma-kofuji that has not been recognized and has not been considered for volcanic hazard assessment of Fukushima-city before. Here, we present the geological (lithofacies, stratigraphy, distribution) and petrological (petrography, bulk-rock chemistry) characteristics of the deposit (Azuma-kofuji block and ash flow deposit: Ak-BAF) and discuss its generation/emplacement processes.

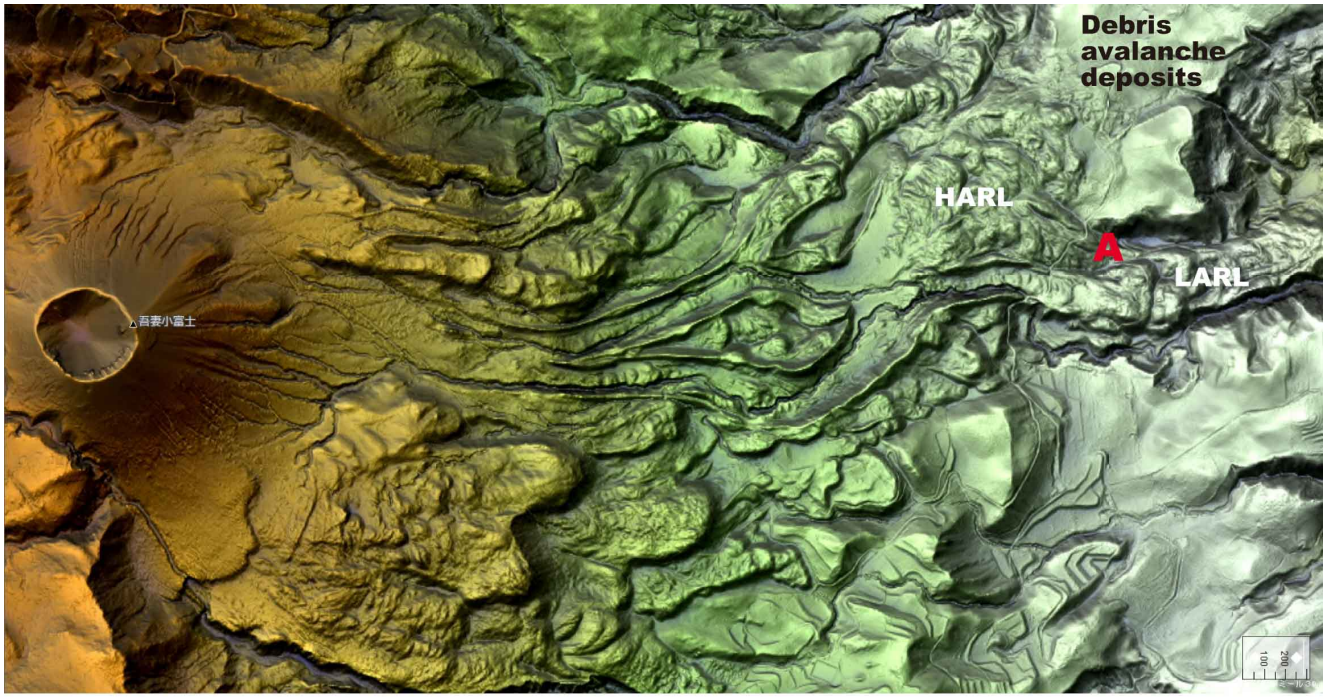
Ak-BAF is distributed at the valley between the eroded cliffs of the debris avalanche deposit and the edge of the most extensive lava flow (Shiratugawa lava flow) 10 km east from Azuma-kofuji cone. On the basis of the estimated distribution area and the average thickness (10~20 m) of the deposit, the volume of Ak-BAF can be estimated to be 1 x 10^{-3} cubic km. Ak-BAF is a gray colored, coarse ash matrix, supported and lava block rich pyroclastic flow deposit covered by the Nm-NK tephra that was derived from Numazawa volcano around the 5 ka. Large mega-blocks (> 2~3 m in diameter) of lava flow are contained at the most upstream outcrop (loc. A at attached figure). Smaller (< 1 m) vesiculated gray blocks are commonly included and can be determined as juvenile materials in Ak-BAF. Petrologic features of the smaller gray blocks are homogeneous, whereas those of mega-blocks are relatively various. Bulk-rock compositions of these blocks are basaltic andesite to andesite (SiO2=59-62%) and are almost as same as those of lava flows of Auzma-kofuji except for some mega-blocks.

Ak-BAF is not recognized at upper-stream area from the edge (tip) of the Shiratugawa lava flow inferring the Ak-BAF was not derived from Azuma-kofuji cone. There exist at least two multiple flow units at the end of Shiratsugawa lava flow. One flow unit flowed down a longer distance with smoother surface/lava levees indicative of a more fluidal nature (= lower aspect ratio lava: LARL). Another unit (adjacent to the north side of LARL) shows a characteristic morphology, it is more rugged (blocky) and has a spreading distribution (= higher aspect ratio lava: HARL). The distribution of Ak-BAF starts at the southern edge (lobe) of the HARL (loc. A at attached figure) at the steep cliff of the debris avalanche deposit. We suggest that the HARL unit occurred and grew slowly after the emplacement of LARL unit. Then, the southern edge, which might have hardened thick crust, finally reached and collapsed at the steep cliff to generate Ak-BAF. We are investigating a more detailed distribution on the downstream side for volcanic hazard evaluation of Fukushima city.

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Keywords: Azuma volcano, Block and ash flow, Fukushima, Lava

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Shaded relief (Kashmir 3D) map of Azuma-kofuji volcano. See text for details.



A photograph of outcrop of Ak-BAF at loc. A in the upper figure.

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Reexamination of the characteristics and eruption style of Haruna-Hakoda tephra found from the southern foot of Akagi Volcano to the eastern foot of Haruna Volcano in North Kanto, Northeast Japan

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1. Department of Geography, Graduate School of Urban Environmental Sciences, Tokyo Metropolitan University, 2. Faculty of Urban Environmental Sciences, Tokyo Metropolitan University

Haruna Volcano on the volcanic front at the Northeast Japan Arc is located in the center of Gunma Prefecture. Tephra such as Haruna-Hassaki (Hr-HP), Haruna-Futatsudake Shibukawa (Hr-FA), and Haruna-Ikaho (Hr-FP) that erupted from the Late Pleistocene to the Holocene from this Haruna Volcano have been studied in detail (Soda, 1989; Oishi et al. 2011, etc.). In addition, Haruna Miharada pumice deposited about 32ka (Takemoto, 2008) was called Miharada pumice firstly (Takemoto, 1985), and its source was presumably provided from Haruna Volcano (Takemoto, 1998). On the other hand, Soda (1996) called the same tephra bed Haruna-Hakoda tephra (Hr-HA). Its stratigraphic position shown by previous researches is above Hr-HP and Akagi Kanuma tephra (Ag-KP: Machida and Arai, 2003), and below Aira-Tn tephra (AT: Machida and Arai, 2003). However, the mineral assemblage differs depending on the literature, such as the composition of heavy minerals contained in this tephra. Furthermore, although it has been reported that this tephra has a distribution axis in the northeast direction from Haruna Volcano (Takemoto, 1998), but its distribution range has not been clearly determined. Therefore, the purpose of this study is to clarify the heavy mineral composition, refractive index of hornblende and orthopyroxene, the distribution and eruption style of this tephra. The name of this tephra is called Haruna-Hakoda tephra according to Soda (1996). However, the abbreviation Hr-HA called in the same thesis is derived from Haruna-Hassaki Ash (HA), which was the former name of this tephra, so we newly named it Hr-Hkd.

As a result of investigating from the southern foot of Akagi Volcano to the eastern foot of Haruna Volcano, outcrops exposing Hr-Hkd were found at eight locations. These outcrops are distributed in the range of 8 to 30 km in the east-northeast direction from Haruna Volcano. Hr-Hkd was divided into four units A to D from the bottom. Unit A is a light brown to gray falling ash layer containing accretionary lapilli. At some locations, white fall pumice is clustered at the bottom of unit A. Unit B is a white fall pumice layer composed of poorly sorted and fine-grained pumice. Unit C is a white fall pumice layer composed of poorly sorted and coarse-grained pumice. The matrix of unit C is gray to brown volcanic ash containing gray lapilli of about 1 mm in diameter. Unit D is a pyroclastic surge deposit containing white fall pumice. Furthermore, from the thickness of tephric soil deposits including Hr-Hkd, AT, and Ag-KP determined at several outcrops, it can be inferred that the eruption age of Hr-Hkd is around 37.4-40.0 ka.

Analyses of the heavy mineral composition of Hr-Hkd is shown below in descending order. Unit A, B, and D is hornblende, orthopyroxene, titanomagnetite, and cummingtonite, and unit C is hornblende, orthopyroxene, cummingtonite, and titanomagnetite. Furthermore, the measurement of the refractive index by RIMS2000 revealed that the refractive indices of hornblende and orthopyroxene contained in Hr-Hkd differed from unit to unit. Comparing the modes for each unit. For hornblende, unit A is 1.671-1.681 (1.677), unit B is 1.674-1.683 (1.680), unit C is 1.670-1.682 (1.675), and the unit D is 1.671-1.682 (1.676). Thus, the refractive index of hornblende decreases from unit A to D. For orthopyroxene, unit A is 1.706-1.714 (1.710), unit B is 1.705-1.713 (1.709), unit C is 1.703-1.713 (1.708), and the unit D is 1.701-1.712 (1.709). Thus, the refractive index of orthopyroxene tends to decrease from unit A to D. These indicates that the upper unit has less iron.

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In addition, the series of eruptive event which provided Hr-Hkd can be estimated as below. Unit A contained abundant accretionary lapilli, and pumice was contained at the bottom of unit A at 8 to 19 km from the Haruna Volcano, these are consistent with the characteristics of the phreatomagmatic eruption ejecta mentioned in Hiroi et al. (2015). Therefore, it is considered that the first Hr-Hkd eruption was a phreatomagmatic eruption. Then, in transition to the Plinian eruption, white fall pumice of unit B and unit C erupted. Of these, unit C had multiple fall units at two locations about 8 km east and about 15 km northeast of the Haruna Volcano. Therefore, the eruption of unit C is considered to be multiple eruptions with almost no time-gap. Finally, it is probable that the pyroclastic flow flowed down unit D was deposited.
In the future, if the outcrops of Hr-Hkd are found in a wider area, more detailed distribution and eruption style can be considered. It will be important basic data for studying the history of eruptive activity of the Haruna Volcano.

Keywords: Haruna Volcano, Haruna Hakoda tephra, volcanic product, distribution, refractive index

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What have been erupted from the 2020 eruption of Nishinoshima?

*Yoshihiko Tamura[1], Tomoki Sato[1], Kenta Yoshida[1], Fukashi Maeno[2], Osamu Ishizuka[1,3], Yasuhiro Hirai[1], Noriko Tada[1], Kiyoshi Baba[2], Daisuke Suetsugu[1], Maiko Miyoshi[4], Shigeaki Ono[1]

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Nishinoshima, a submarine volcano in the Ogasawara Arc, erupted in 2013 after 40 years of dormancy. Andesites erupted from Nishinoshima that were produced in the recent history of the volcano have been generated by olivine fractionation of primary andesitic magmas (Tamura et al., 2018). These primary andesitic magmas are derived from the partial melting of hydrous mantle (plagioclase peridotites) at relatively low pressures because the lithosphere is currently thin in this region of the Ogasawara arc. A “stockpile” of continental crust (andesitic magma) might be produced when most crust was thin (Tamura et al., 2016).

The eruption mode of Nishinoshima changed from a Strombolian characterized by effusive andesite lava flows to a violent Strombolian in the middle of June, 2020. The eruption plume reached a maximum altitude of ~8 km on July 4th. Does the sudden and drastic change of the eruption styles suggest some advance warning of a large volume violent eruption in the near future?

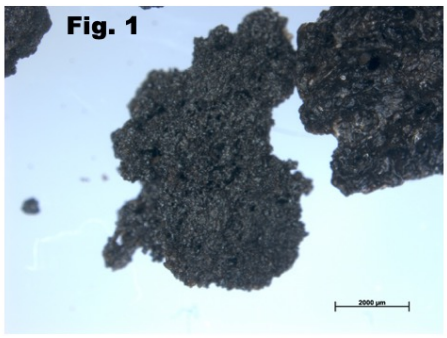
Caldera-forming eruptions sometimes happen in oceanic arcs (e.g. Yuasa et al., 1991). Sumisu-jima in the Izu arc and West Rota volcano in the Mariana arc, for example, have large submarine calderas of ~10 km in diameter, which have been resulted from a large volume eruption of pumices. The alternations of black and white tephra layers were observed by using submersibles and ROVs along the sections of caldera walls just below the top of caldera walls consisting of large pumice layers (Tamura et al, 2005; Shukuno et al., 2006; Tani et al., 2008; Stern et al., 2008). Thus, these violent caldera-forming eruptions were preceded by bimodal volcanisms. Had the 2020 eruption of Nishinoshima been bimodal in composition or not?

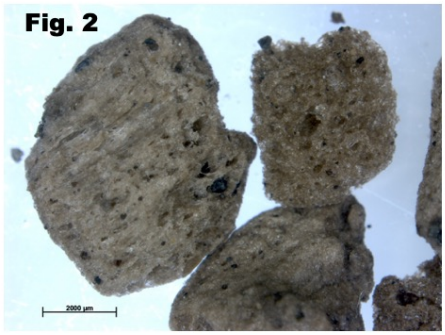
Volcaniclastic rocks erupted in 2020 were sampled on two separate occasions from December 2020 to January 2021. Samples at water depths between 1,000 m and 1,500 m were collected by a Box Corer using R/V Kairei during KR20-E06 from December 15th to December 29th, 2020. Fresh scorias (Fig. 1) and pumices (Fig. 2) were collected by the Box Corer. Northern submarine flank of Nishinoshima, ~15 km north of the island at the water depths of ~2,500 m, has been observed and sampled using the remotely operate submersible HyperDolphin and the R/V Shinseimaru during KS-21-2 from January 21st to January 30th, 2021. Small faults on the surface of submarine flank showed outcrops, suggesting bimodal volcanism of the recent eruption (Fig. 3), in which white layers consist of dacitic pumices having 67 % SiO_2.

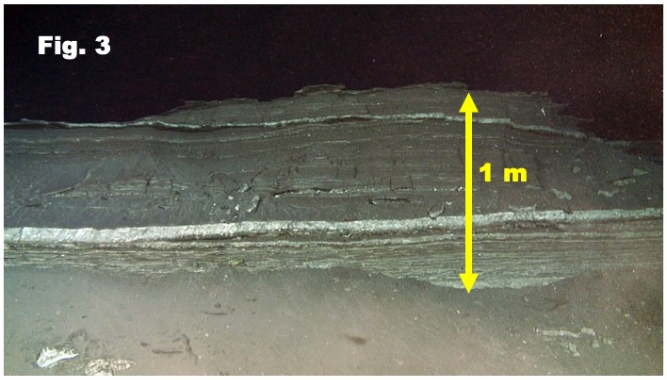
The 2020 violent Strombolian eruption of Nishinoshima was a bimodal volcanism consisting of basaltic andesite and dacite. It is possible that the magma system of Nishinoshima has changed from andesitic to basalt-dacite bimodal volcanisms, so it is essential to monitor the future course of the activity from the view point of disaster reduction.

Keywords: violent stronbolian eruption, andesite magma, bimodal volcanism

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[J] Oral | S (Solid Earth Sciences)：S-VC Volcanology

Thu. Jun 3, 2021 3:30 PM - 5:00 PM JST | Thu. Jun 3, 2021 6:30 AM - 8:00 AM UTC | Ch.25 Zoom Room 25

[S-VC30] Volcanic and igneous activities, and these long-term forecasting

convener:Takeshi Hasegawa(Department of Earth Sciences, College of Science, Ibaraki University), Teruki Oikawa(GSJ, National Institute of Advanced Industrial Science and Technology), Daisuke MIURA(Department of Physical Science, Graduate School of Science, Osaka Prefecture University), Nobuo Geshi(Geological Survey of Japan, The National Institute of Advanced Industrial Science and Technology), Chairperson:Takeshi Hasegawa(Department of Earth Sciences, College of Science, Ibaraki University), Yuki Yasuda(Institute of Seismology and Volcanology, Faculty of Science, Hokkaido University)

This session focuses on generation and accumulation processes of magmas, magma-crust interaction and degassing, and modes of eruption, long-term forecast of eruption, dispersal and emplacement of the volcanic products. The discussion spans petrological, geochemical, geophysical, and geological processes related with volcanic activity and products in the past, the present and the future.

3:30 PM - 3:45 PM JST | 6:30 AM - 6:45 AM UTC

[SVC30-07] Estimating magma flux from contact metamorphic aureoles

*Ken Yamaoka[1], Simon Richard Wallis[1], Akira Miyake[2], Catherine Annen[3] (1.The University of Tokyo, 2.Aichi University of Education, 3.University of Bristol)

3:45 PM - 4:00 PM JST | 6:45 AM - 7:00 AM UTC

[SVC30-08] Petrogenesis of Quaternary Yokota alkaline basalts, southwestern Japan

*Tetsuya Sakuyama[1], Izumi Kirishiki[1], Jun-Ichi Kimura[2] (1.Faculty of Science, Osaka City University, 2.JAMSTEC)

4:00 PM - 4:15 PM JST | 7:00 AM - 7:15 AM UTC

[SVC30-09] The history of 54 ka eruption of Kuju volcano

*Tomohiro Tsuji[1], Kishimoto Hiroshi[2], Koji Fujita[3], Chisato Nakamura[4], Tomohiro Nagata[4], Kazunari Kimura[4], Kozo Onishi[5], Michiharu Ikeda[6], Naoki Nishizaka[5] (1.Division of Earth Science The Graduate School of Science and Technology for Innovation Yamaguchi University, 2.kagoshima Meteorological Office, 3.Asia Air Survey Co. Ltd., 4.Naiba, 5.Shikoku Electric Power Co. Inc., 6.Shikoku Research Institute, Inc.)

4:15 PM - 4:30 PM JST | 7:15 AM - 7:30 AM UTC

[SVC30-10] Reappraising the Eruptive Age and Classification of Holocene Volcanic Products around Nakadake Crater, Aso Volcano Using Paleomagnetic and Rock Magnetic Methods

*Chisato Anai[1], Yasuo Miyabuchi[2], Mitsuru Utsugi[1], Shin Yoshikawa[1], Nobutatsu Mochizuki[3], Hidetoshi Shibuya[3], Takahiro Ohkura[1] (1.Aso Volcanological Laboratory, Institute for Geothermal Sciences, Graduate School of Science, Kyoto University, 2.Center for Water Cycle, Marine Environment and Disaster Management, Kumamoto University, 3.Department of Earth and Environmental Sciences, Faculty of Advanced Science and Technology, Kumamoto University)

4:30 PM - 4:45 PM JST | 7:30 AM - 7:45 AM UTC

[SVC30-11] Petrogenesis of Nekodake magma in Aso volcano

*Soko Kado[1], Katsuya Kaneko[1] (1.Department of Planetology, Graduate school of science, Kobe university)

4:45 PM - 5:00 PM JST | 7:45 AM - 8:00 AM UTC

[SVC30-12] Silicic magma formations in the Aira caldera region during the last 100,000 years inferred from geochemical characteristics of plagioclase

*Ayumu Nishihara[1,2], Katsuya Kaneko[1], Qing Chang[3], Nobuo Geshi[2] (1.Department of Planetology, Graduate School of Science , Kobe University, 2.Geological Survey of Japan, National Institute of Advanced Industrial Science and Technology., 3.Research Institute for Marine Geodynamics, Japan Agency for Marine-Earth Science and Technology)

Estimating magma flux from contact metamorphic aureoles

*Ken Yamaoka[1], Simon Richard Wallis[1], Akira Miyake[2], Catherine Annen[3]

1. The University of Tokyo, 2. Aichi University of Education, 3. University of Bristol

The distribution of melt beneath volcanos and how it coalesces during large eruptions are major unresolved issues and better knowledge of these features would contribute to improving our ability to forecast destructive eruptions. Plutons are a clear record of magma emplacement into the crust and studies of these domains are an important source of information on sub-volcanic processes. However, in nearly all cases exposure of the pluton at the earth’ s surface is associated with the erosion and removal of the overlying volcanic edifice and only very rarely can the relationship between plutonic and eruptive processes be examined in the same region. The magmatic flux into the pluton region is the most important controlling factor in determining whether the magma will be eruptible or not during incremental growth of a pluton. Previous estimates of this flux have mainly been based on zircon geochronology (e.g. de Saint-Blanquat et al., 2011). An alternative but relatively unexplored approach is to use thermal modeling to investigate whether a pluton has been associated with large amounts of a magmatic eruption (Schöpa & Annen, 2013).

In this study we use thermal modeling of an unusually broad contact metamorphic aureole around a pluton to estimate the associated magmatic flux. Although it is generally difficult to discuss magma that is no longer in the pluton, we suggest that broad contact metamorphic aureoles around plutons that imply enthalpy input disproportionately large compared to the volume of the pluton are good markers of magmatic centers associated with significant magma flux and volcanic eruption.

Recent zircon geochronological studies have established that numerous plutons exposed in central Japan are coeval with a series of extensive ignimbrite deposits associated with caldera-forming eruption formed in around 70 Ma and with a present volume reaching 5000–7000 km^3 (Koido, 1991; Sonehara & Harayama, 2007; Hoshi et al., 2016; Takatsuka et al., 2018). The existence of this world-class volcano-plutonic complex provides a valuable opportunity to discuss the relationship between pluton characteristics and amount of associated volcanic ejecta. In this study, we focus on a contact metamorphic aureole around the Shinshiro tonalite that formed around 70 Ma at ~9 km depth. The thermal structure is well defined by changes in the crystallinity of carbonaceous material, Ti content in quartz, and mineral assemblages of metamudstone and the dimensions of the intrusion are well constrained by field observations and gravity anomaly data. Numerical modeling shows that the contact metamorphic aureole is too broad to be simply explained by the volume of the intrusive body. However, a model that incorporates continuous magma replenishment and tapping of magma can yield the observed broad contact metamorphic aureole with > 550 km^3/myr as a long-term magma influx rate. The estimated minimum magma influx rate can maintain an eruptible magma chamber and suggest the Shinshiro tonalite acted as one of the magmatic cores to a large caldera-forming eruption during the ~70 Ma magmatic flare-up event of SW Japan.

A new compilation of the thickness of the contact metamorphic aureoles around plutons where there is information on the depth and shape of the intrusion shows a wide range of pluton thermal types. Several plutons are similar to the Shinshiro tonalite and show much broader contact metamorphic aureole than can be accounted for by intrusion models that do not incorporate fluxes of erupted magma irrespective. We suggest that for a wide range of different crustal conditions and magma types, the thickness of contact

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metamorphic aureole can be used to identify those associated with the passage of large amounts of erupted magma.

Keywords: pluton formation, thermal modeling, magma flux, caldera-forming eruption, contact metamorphic aureole, Ryoke plutonic rocks

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Petrogenesis of Quaternary Yokota alkaline basalts, southwestern Japan

*Tetsuya Sakuyama[1], Izumi Kirishiki[1], Jun-Ichi Kimura[2]

1. Faculty of Science, Osaka City University, 2. JAMSTEC

Upwelling of the asthenosphere associated with the opening of the Japan Sea in addition to the subduction of the Philippine Sea plate has been considered to be the origin of the late Cenozoic volcanism in the Chugoku district. The Yokota basalts erupted 2.17 - 0.97 Ma and temporally expanded outwards from the center of the volcanic cluster to the margin forming a volcanic cluster with a diameter of 40km over Shimane and Tottori prefectures. The Yokota basalts have been divided into two subtypes in terms of Nd-Sr isotopes: the ABL with lower $^{87}Sr/^{86}Sr$ and the ABH with higher $^{87}Sr/^{86}Sr$ for the same $^{143}Nd/^{144}Nd$ (Kimura *et al.*, 2014). The ABH basalts are distributed at the periphery of the cluster in the late stage of the activity. Such concentric expansion of the volcanic activity may suggest that the magmas were produced by the diapiric mantle upwelling. However, petrogenesis of the Yokota basalts remains unclear because primary magma water content has not been petrologically constrained from natural samples. We analyzed whole-rock major and trace element and mineral compositions of the fresh basaltic samples newly collected from the Yokota basalts in order to determine the water content of the basalts and estimate the mantle melting conditions.

The Yokota samples have primitive and alkaline basaltic compositions, ranging from 47.7 to 54.2 wt% SiO_2 and from 0.67 to 1.31 FeO*/MgO. There is no clear difference between ABL and ABH in major element compositions except that the ABL have systematically higher K_2O content than the ABH. Whole-rock multi-element trace element patterns for the ABL and ABH normalized to the Primitive mantle composition are generally similar to those of typical arc-type alkaline volcanic rocks (Kimura *et al.*, 2014). No significant Eu anomaly is observed in the REE concentration patterns of the ABH and ABL samples. The modal abundance of phenocrysts is typically less than 10 vol%. Olivine and clinopyroxene phenocrysts are common but olivine is the major phenocryst phase for all the samples. Most olivine and clinopyroxene phenocrysts are normally-zoned and euhedral to subhedral. Several samples of the ABL and ABH additionally contain small amount of normally-zoned euhedral plagioclase phenocrysts. The An content of the plagioclase cores is 66 - 71.8 and 74 - 82.4 for the ABL and ABH, respectively, and their distributions are unimodal.

We estimated the water content of the ABL and ABH magmas using plagioclase-melt hygrometer at an assumed pressure condition of 0.3 GPa. Estimated water content of the ABL and ABH magmas was 3.6 wt% and 4.6 wt%, respectively, which are the highest among the volcanic activities of the same period in the Chugoku region. The estimated melting conditions were 1330 ˚C and 2.4 GPa for the ABL and 1300 ˚C and 2.6 GPa for the ABH. The mantle potential temperature for the Yokota basalts was estimated to be ~1280 ˚C, which was as high as that of the mantle beneath normal mid-ocean ridges, suggesting that the upper mantle beneath Yokota was not hot.

If magmas were progressively generated and released from a single mantle diapir, water content of the magmas should decrease as the mantle diapir uprises due to progressive dehydration from the mantle. However, more hydrous ABH magma erupted at the later stage than less hydrous ABL, suggesting that simple mantle diapir model cannot reproduce spatiotemporal geochemical variation of the Yokota basalts. We propose that the following model. (1) Mantle metasomatized by the ancient sediment-derived

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fluid upwelled from the mantle transition zone. (2) Fluid derived from the sediment on the Philippine Sea slab mixed with the upwelled metasomatized mantle and melted to produce the ABL magma. (3) As the contact area between the upwelled metasomatized mantle and the Philippine Sea slab increases, more fluid were from the slab supplied to the upwelled metasomatized mantle and enhanced further melting to generate more hydrous ABH magma.

Keywords: alkaline basalt, Quaternary, southwestern Japan, Yokota, Chugoku district, water content of the magma

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The history of 54 ka eruption of Kuju volcano

*Tomohiro Tsuji[1], Kishimoto Hiroshi[2], Koji Fujita[3], Chisato Nakamura[4], Tomohiro Nagata[4], Kazunari Kimura[4], Kozo Onishi[5], Michiharu Ikeda[6], Naoki Nishizaka[5]

1. Division of Earth Science The Graduate School of Science and Technology for Innovation Yamaguchi University, 2. kagoshima Meteorological Office, 3. Asia Air Survey Co. Ltd., 4. Naiba, 5. Shikoku Electric Power Co. Inc., 6. Shikoku Research Institute, Inc.

The 54 ka eruption of Kuju volcano released various pyroclastic deposits including ash, surge, large-scale pyroclastic flow deposits and plinian pumice fall deposits, which is the largest scale in the eruption history of Kuju volcano. However, there is no consensus on the eruption history. Then, in this study, to examine the history of Kuju volcano 54 ka eruption, geological investigation of the pyroclastic deposits, especially focusing on Kj-D which is the key tephra to elucidating the stratigraphy.

In this study, we use the classification of Matsumoto (1983) and Ohta (1991) on the pfls: the pfl that has formed Handa highland at the northern to northwestern foot is Hnd pfl (Matsumoto, 1983), and the one that has formed Kuju highland at the southern foot is K pfl (Kpf of Ohta, 1991). At the bottom of the whole ejecta, Kj-D tephra is overlain by Hnd pfl deposits. There are pumice flow deposits including bi-cpx bearing opx-hbl dacite pumice. Large-scale secondary pyroclastic flows were deposited after the deposition of both pfls, and Kj-D and Kj-P1 overly them. Kj-P1 is constituted with Kj-P1 lower and upper layer, and a small pyroclastic flow of K2 pfl that overlies K pfl at Kuju highland.

Kj-D is overlain by Kj-P1 at the eastern foot. Kj-D is composed of lower lapilli layers and upper volcanic ash layers. The upper layer of Kj-D was classified into five unites; Kj-D-u1, 3 and 5: lowermost, middle and uppermost bluish gray ash layers, and Kj-D-u2 and 4: lower and upper light brown volcanic ash layers. The blue-gray volcanic ash layer in the upper layer is a stack of dozen of thin layers mainly composed of fine-grained sand-sized volcanic fragments. Kj-D-u2 and 4 are both fine-grained sand-sized volcanic ash, mainly composed of pumice-type glass, and contains mafic minerals of hbl, opx, cpx and bi as decreasing order that is similar mineral composition of that of K pfl. The lower part of Kj-D-u4 contains a pumice layer with a maximum grain size of ~5 cm in diameter. The pumice is opx-hbl dacite. Based on the Kj-D-u2 and 4 isopach maps, the source of each is found in the area of the Hnd pfl and K plf. The source of the Kj-D-u4 pfa is found in the central or eastern part of Kuju volcano based on the isopach map.

The history of the eruption is considered as follows: The eruption began with two lapilli layers (Kj-D l1 and 2). After that, relatively small-scale explosive eruptions occurred repeatedly, and deposited Kj-D-u blue-gray ash layers. During this repeated adh deposit, three large-scale pyroclastic flow eruption occurred in the central part of the volcano. In the first two times, Hnd pfl flowed down to the northerm foot and released Kj-D-u2 as co-ignimbrite ash. A plinian eruption occurred to deposit the Kj-D-u4 pumice layer in the late Kj-D upper ash deposition, and the K pfl, an intra-plinian pfl, was deposited at the southern foot. Along with this, Kj-D-u4 was deposited as a co-ignimbrite ash. The eruption of Kj-D-u5 blue-gray ash continued for a while, and two huge plinian eruptions occurred at the end of the eruption, depositing the lower and upper layers of Kj-P1. The last eruption deposited K2 pfl, an intra-plinian pfl at the southern foot.

Keywords: Kuju volcano, eruption history, stratigraphy

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Reappraising the Eruptive Age and Classification of Holocene Volcanic Products around Nakadake Crater, Aso Volcano Using Paleomagnetic and Rock Magnetic Methods

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Nakadake volcano, the current active center of the Aso central cones (Kyushu), is one of the most active volcanoes in Japan. It has been active since ca. 22-21 ka, and has formed the old edifice (22-21 ka), the young edifice (around 5 ka) and a younger pyroclastic cone (up to the present). The lava flows from the young edifice spread on the flank of the cone several times in recent 5 ka. These lavas are supposed to give stratigraphic markers for constructing the eruptive history of Nakadake volcano, but the similarity in chemical composition and lithology hampers distinguishing and correlating them. We have conducted a paleomagnetic study to distinguish and correlate the lavas of different ages since the paleomagnetic secular variation (PSV) provides a high-resolution age information. If lava units have a temporal difference of more than 50 years, they could be distinguished by their paleomagnetic directions. The samples were collected from 14 lava flows and 6 agglutinates layers (welded scoria-fall deposits) and were subjected to the paleomagnetic and rock-magnetic measurements. These samples appear to be influenced by chemical alteration in the surface of the outcrop by sulfides of volcanic gases. To check a rock-magnetic effect of the chemical alteration of the lavas and agglutinates, thermomagnetic analyses were made on chip samples from the top (surface of rock) and bottom (inside of rock) of the collected paleomagnetic cores. The thermomagnetic analyses indicate that the core top and bottom samples show the same behaviors, in spite of the difference in color, and the carrier of magnetization of each core is either titanium rich (titanium content, x, is about 0.6) or poor (x is about 0.15 to 0.3) titanomagnetites. The natural remanent magnetization of each sample shows a simple, single vector component in alternating field demagnetization experiments, which well defines the primary component. Site mean directions can be divided into three different direction groups. These data suggest that the eruption producing lava flows and/or agglutinates occurred at three different ages. One of the direction group is not consistent with the directions of the eruptive ages of Nakadake young edifice assigned from the previous stratigraphic studies. Comparing these directions with the paleomagnetic secular variation curve drawn from basaltic volcanoes in the Aso central cones, the ages of the direction groups can be assigned to around 6.0-4.3 ka and 3.5 ka. The present result will contribute not only to the volcanology, but also to the disaster prevention and disaster risk reduction.

Keywords: Aso Nakadake, paleomagnetic secular variation (PSV)

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Petrogenesis of Nekodake magma in Aso volcano

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Caldera volcanoes, which cause large-volume explosive eruptions (more than tens cubic kilometers), have magma plumbing systems producing voluminous magma. Aso volcano is one of the largest caldera volcanoes in Japan, and its activities are characterized by four large-scale eruptions (Aso-1, -2, -3, and -4) and many small eruptions (e.g., Ono and Watanabe, 1985). Previous studies have shown that the Aso magmas with high K_2O content to SiO_2 content (high-K series) are petrologically distinctive from magmas of other quaternary volcanoes around Aso volcano (e.g., Ono and Watanabe, 1985) and are generated by melting of the lower crust (Kaneko et al., 2015).
Nekodake is a small volcano with about 3 km in diameter and about 700 m higher than its base and located near the eastern rim of the Aso caldera like the post-caldera central cones in Aso volcano. Geological study and radiometric dating indicate that the activity of Nekodake occurred during the activities of Aso volcano although the activity age is not strictly determined (before Aso-3 or near Aso-4). On the other hand, the Nekodake magma is clearly lower in K_2O content than the Aso magmas. Then, it has been considered that the Nekodake magma came from a different magma plumbing system from Aso volcano. The purpose of this study is to clarify petrogenesis of the Nekodake magma. The distinctive feature of the Nekodake magma means that a different type of magma was generated adjoining to the large magma plumbing system of Aso volcano. Understanding this is important to elucidate the entire magma plumbing system of caldera volcanoes.

We carried out detailed petrological description and compositional analyses of whole-rock, groundmass, and phenocryst minerals. Important petrological features are in the following.
(1) Whole-rock compositions of the the Nekodake rocks are 53 - 60 wt.% SiO_2.
(2) All the rocks are very porphyritic (47- 69 vol.% in modal composition) and commonly contain plagioclase, clinopyroxene, orthopyroxene, and opaque minerals as phenocryst. Rocks with less SiO_2 content contain olivine phenocryst while with more SiO_2 content hornblende phenocryst.
(3) The whole-rock compositions show a single linear trend on each of the Harker diagrams.
(4) Anorthite (An) contents of plagioclase phenocrysts are bimodal; the peak An-contents are 58 and 76, respectively. Corroded textures are observed in plagiocalse, pyroxene, and olivine phenocrysts. Part of plagioclase phenocrysts have reverse zonation in An-contents and part of pyroxene and hornblende phenocrysts in Mg/Fe ratio.
(5) Sr isotopic ratio of the Nekodake rocks is higher (0.7041-0.7047) than those of the Aso magmas (0.7040 –0.7042)(Shinmura, 2013).

Features 3 and 4 suggest that the Nekodake magmas were formed by two-component mixing of mafic and intermediate magmas. We estimated the endmember magmas using our original calculation method on the basis of number of An-contents distribution of plagioclase phenocryst and whole-rock composition. The estimated mafic magma is 49 –52 wt.% SiO_2, which is compositionally similar to the mafic magma of Aso volcano. The estimated intermediate magma is 59 - 60 wt.% SiO_2 and compositionally different from the Aso magmas, and is not generated by fractional crystallization from the estimated mafic magma. This result and Feature 5 suggest that this high Sr isotopic ratio comes from the intermediate endmember magma which was produced by melting of some shallower crust than the magma generation level of the Aso magmas. We conclude that the magma plumbing system of Nekodake is not completely different from

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Aso volcano but only the magma generation process of the SiO_2-rich magma is different from Aso magmas. Our result shows that crustal melting occurs at the shallower level as well as in the lower crust in Aso volcano.

We thank Dr. Takehiro Koyaguchi and Mr. Hiroshi Ikemoto for their providing rock samples of Nekodake.

Keywords: Aso volcano, Caldera volcano, Nekodake, Magma plumbing system, Magma mixing

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Silicic magma formations in the Aira caldera region during the last 100,000 years inferred from geochemical characteristics of plagioclase

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Plagioclase phenocrysts record geochemical characteristics of magmas when they crystallize and grow. Chemical and isotopic variations on the plagioclase micro area enable us to unravel the hidden magma formation processes. The Aira caldera was formed by the 30 ka VEI-7 supereruption (the AT eruption), and two VEI-6 eruptions occurred at 90 and 60 ka as the pre-AT volcanism. After the AT eruption, two eruptive activities of the Sakurajima volcano and the Wakamiko volcano have continued, and their largest eruptions occurred at 12.8 ka and 13 ka, respectively. The latest plinian eruption of the Sakurajima volcano occurred in AD 1914. These eruptions have mainly discharged silicic (>60 SiO_2 wt.%) magmas having different geochemical characteristics in whole-rock compositions. In order to clarify the genesis of the silicic magmas produced in the Aira caldera region, we examined $^{87}Sr/^{86}Sr$ values of the plagioclase phenocrysts contained in juvenile pumice clasts of the above six eruptions.
All the clasts contain plagioclase with cores of both low-An (<An_{60}) and high-An (>An_{60}). Except for the 13 ka Wakamiko clasts, $^{87}Sr/^{86}Sr$ values of the low-An plagioclase in the clasts of the five eruptions are within the range of 0.7049-0.7062. On the other hand, the high-An plagioclases can be classified into three types based on the $^{87}Sr/^{86}Sr$ values; the identical to the low-An (0.7049-0.7061), the lower $^{87}Sr/^{86}Sr$ (0.7043-0.7049), and the higher $^{87}Sr/^{86}Sr$ (0.7063-0.7076). The high-An plagioclases having $^{87}Sr/^{86}Sr$ identical to the low-An are contained in the 90 ka, 60 ka, 30 ka, and 12.8 ka clasts. The 30 ka clasts also contain the high-An plagioclase with high $^{87}Sr/^{86}Sr$. The low-$^{87}Sr/^{86}Sr$ and high-An plagioclase are contained in the AD1914 clasts. The 13 ka Wakamiko clasts contain plagioclase of high-$^{87}Sr/^{86}Sr$ (0.7073±3, 1SD).
Bimodal distributions of An-contents observed in all the clasts indicate that the silicic magmas in the Aira caldera region experienced mixing between felsic and mafic magmas crystallizing the low-An and high-An plagioclases, respectively. The similar $^{87}Sr/^{86}Sr$ values of the felsic magmas suggest that, except for the Wakamiko clasts, the felsic magmas in the Aira caldera region have a same source material during the last 100,000 years. The identical $^{87}Sr/^{86}Sr$ values of the low-An and high-An plagioclase imply that a dominant process producing the magmas is an anatexis of a mafic crustal rock, which can produce both felsic and mafic magmas by difference of degree of partial melting. This process produced the silicic magmas discharged by the 90 ka, 60 ka, and 12.8 ka eruptions. The geochemical variation observed in the 30 ka clast indicates that the silicic magma discharged by the 30 ka supereruption was produced by mixing between the crust-derived low-$^{87}Sr/^{86}Sr$ magma and a high-$^{87}Sr/^{86}Sr$ mafic magma. The low-$^{87}Sr/^{86}Sr$ plagioclases in the AD 1914 clasts suggest that the AD 1914 silicic magma experienced mixing with a low-$^{87}Sr/^{86}Sr$ mantle-derived basaltic magma. Origin of the high-$^{87}Sr/^{86}Sr$ magmas discharged by the 13 ka Wakamiko eruption can be explained by fractionation of the high-$^{87}Sr/^{86}Sr$ mafic magma or partial melting of another crustal material with high-$^{87}Sr/^{86}Sr$. In conclusion, crustal melting is the crucial process to produce magmas in the Aira caldera region, and the variable origin of the mafic magmas generates the geochemical variations of the silicic magmas.

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Keywords: Aira caldera, Sr isotope ratios, silicic magma, caldera-forming eruption

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[J] Oral | S (Solid Earth Sciences)：S-TT Technology & Techniques

Thu. Jun 3, 2021 3:30 PM - 5:00 PM JST | Thu. Jun 3, 2021 6:30 AM - 8:00 AM UTC | Ch.23 Zoom Room 23

[S-TT34] Airborne surveys and monitoring of the Earth

convener:Shigekazu Kusumoto(Institute for Geothermal Sciences, Graduate School of Science, Kyoto University), Shigeo Okuma(Geological Survey of Japan, AIST), Takao Koyama(Earthquake Research Institute, The University of Tokyo), Yuji Mitsuhata(AdvancedIndustrial Science and Technology), Chairperson:Shigekazu Kusumoto(Institute for Geothermal Sciences, Graduate School of Science, Kyoto University), Takao Koyama(Earthquake Research Institute, The University of Tokyo), Shigeo Okuma(Geological Survey of Japan, AIST), Yuji Mitsuhata(AdvancedIndustrial Science and Technology)

Airborne surveys are useful to better understand the whole and/or the detailed structures of the Earth and their variations. They can be implemented from a traditional manned and newly-developed unmanned aircraft to efficiently map very large or remote areas with difficult access. We invite studies on theory, instrumentation, processing, modeling or inversion and applications of airborne surveys.

3:30 PM - 3:45 PM JST | 6:30 AM - 6:45 AM UTC

[STT34-01] Introduction

3:45 PM - 4:00 PM JST | 6:45 AM - 7:00 AM UTC

[STT34-02] Comparison of airborne magnetic surveys by different types of aircrafts - A case of Izu-Oshima Volcano

*Shigeo Okuma[1], Tadashi Nakatsuka[1], Ayumu Miyakawa[1], Masahiko Makino[2], Shogo Komori[3], Takao Koyama[4], Takayuki Kaneko[4], Takao Ohminato[4], Atsushi Yasuda[4], Yoshiaki Honda[5] (1.Institute of Geology and Geoinformation, AIST, 2.Geological Survey of Japan, AIST, 3.Research Institute for Geo-Resources and Environment, AIST, 4.Earthquake Research Institute, Univ. of Tokyo, 5.Center for Environmental Remote Sensing, Chiba univ)

4:00 PM - 4:15 PM JST | 7:00 AM - 7:15 AM UTC

[STT34-03] Aeromagnetic survey in Kusatsu-Shirane volcano by unmanned helicopter

*Takao Koyama[1], Wataru Kanda[2], Mitsuru Utsugi[3], Takayuki Kaneko[1], Takao Ohminato[1], Atsushi Watanabe[1], Hiroshi Tsuji[1], taro nishimoto[1], Yoshiaki HONDA[4] (1.Earthquake Research Institute, The University of Tokyo, 2.Tokyo Institute of Technology, 3.Kyoto University, 4.Chiba University)

4:15 PM - 4:30 PM JST | 7:15 AM - 7:30 AM UTC

[STT34-04] Automatic estimation of regression curves indicating average depths of causative layers from power spectrum of gravity anomaly or gravity gradient (g_{zz}) data

*Shigekazu Kusumoto[1], Motonori Higashinaka[2] (1.Institute for Geothermal Sciences, Graduate School of Science, Kyoto University, 2.JGI, Inc.)

4:30 PM - 4:45 PM JST | 7:30 AM - 7:45 AM UTC

[STT34-05] Study on the behavior of the groundwater in the slope in the heavy rain using Drone Airborne TEM

*Atsuhiko Kinoshita[1,2], Suguru Shibata[2], Takao Yamakoshi[1], Hiroaki Nakaya[1], Atsuyoshi Jomori[3], Tetsuya Toyama[3], Akira Jomori[3], Kentaro Kanayama[4], Minoru Okumura[4], Katsushi Kawato[4], Muneki Mitamura[5], Tamotsu Matsui[6] (1.National Institute for Land and Infrastructure Management, 2.Sediment Disaster Prevention Technology Center, 3.NEOSCIENCE CO.LTD., 4.NIPPON ENGINEERING CONSULTANTS CO.,LTD., 5.Osaka City University, 6.Osaka University)

4:45 PM - 5:00 PM JST | 7:45 AM - 8:00 AM UTC

[STT34-06] Discussion

[J] Oral | S (Solid Earth Sciences) | S-TT Technology & Techniques

[S-TT34] Airborne surveys and monitoring of the Earth

convener:Shigekazu Kusumoto(Institute for Geothermal Sciences, Graduate School of Science, Kyoto University), Shigeo Okuma(Geological Survey of Japan, AIST), Takao Koyama(Earthquake Research Institute, The University of Tokyo), Yuji Mitsuhata(AdvancedIndustrial Science and Technology), Chairperson:Shigekazu Kusumoto(Institute for Geothermal Sciences, Graduate School of Science, Kyoto University), Takao Koyama(Earthquake Research Institute, The University of Tokyo), Shigeo Okuma(Geological Survey of Japan, AIST), Yuji Mitsuhata(AdvancedIndustrial Science and Technology)

Thu. Jun 3, 2021 3:30 PM - 5:00 PM Ch.23 (Zoom Room 23)

Airborne surveys are useful to better understand the whole and/or the detailed structures of the Earth and their variations. They can be implemented from a traditional manned and newly-developed unmanned aircraft to efficiently map very large or remote areas with difficult access. We invite studies on theory, instrumentation, processing, modeling or inversion and applications of airborne surveys.

3:30 PM - 3:45 PM

[STT34-01]Introduction

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Comparison of airborne magnetic surveys by different types of aircrafts - A case of Izu-Oshima Volcano

*Shigeo Okuma[1], Tadashi Nakatsuka[1], Ayumu Miyakawa[1], Masahiko Makino[2], Shogo Komori[3], Takao Koyama[4], Takayuki Kaneko[4], Takao Ohminato[4], Atsushi Yasuda[4], Yoshiaki Honda[5]

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The Geological Survey of Japan (GSJ) has been developing drone magnetic survey systems for geophysical survey in volcanic areas these years. In 2019, we introduced a newly developed UAV-enabled magnetometer "MagArrow" and conducted practical test flights of the magnetometer in Izu-Oshima Volcano, south of Tokyo (Okuma et al., 2020). On Izu-Oshima Island, many airborne magnetic surveys have been conducted by using various types of aircrafts so far. In this study, we compare the results of magnetic surveys using an unmanned autonomous helicopter and a drone (multicopter).

The Earthquake Research Institute (ERI), Univ. of Tokyo conducted airborne magnetic surveys using an unmanned autonomous helicopter in March and November 2008 inside the summit caldera of the volcano. The former and latter surveys cover the northern and southern parts of the summit caldera including Mt. Mihara, respectively. The survey was flown using a portable Cesium magnetometer at an altitude of around 50 m above terrain along survey lines spaced around 50 m apart. They conducted apparent magnetization mapping from the observed anomaly and indicated magnetization highs in the northwestern flank of Mt. Mihara (Kaneko et al., 2011) and in the southeastern flank of Mt. Mihara (ERI and Chiba Univ., 2009) both trending NW aligned to a major tectonic direction on the island. These results of magnetization mapping suggest subsurface intrusions overlain by surface volcanic products, which are very interesting interpretation about the subsurface structure. However, the evaluation of magnetic anomalies itself might be insufficient since they did not produce a detailed magnetic anomaly map. Hence, a compilation of such a magnetic anomaly map has been newly conducted. Magnetic anomalies (total magnetic intensity) were reduced onto a smoothed observation surface assuming equivalent anomaly below the observation surface and reduction to the pole anomalies are also calculated on the same surface. The resultant reduction to the pole anomaly map clearly shows magnetic highs on the northern and southern flanks of Mt. Mihara. Magnetic lows are dominant over the eruptive crater and the northeastern foot of Mt. Mihara. A local magnetic high seems to lie over one of B craters of the 1986 eruption. 3D magnetic imaging was then applied to terrain-corrected magnetic anomalies and the result was compared with preceding studies. These newly compiled aeromagnetic maps and interpreted subsurface structures have finer space resolution than those of airborne magnetic surveys using airplanes at a higher altitude (e.g. Makino et al., 1988).

According to the compilation of detailed magnetic anomaly maps using ERI's data, GSJ specified a survey area of drone magnetic survey using MagArrow on the island. In 2019, a drone magnetic survey was flown at an altitude of 25 m above terrain along E-W survey lines spaced 25 m apart in the northern part of the summit crater (Okuma et al., 2020). Unfortunately, many typhoons attacked Izu-Oshima Island in 2019, causing difficulties in surveying on calm days with a wind speed less than 2 m/s. Because of the harsh weather, the flights covered only a half of the provisional survey area. Magnetic anomalies (total magnetic intensity) were reduced onto a smoothed observation surface assuming equivalent anomaly below the observation surface and reduction to the pole anomalies are also calculated on the same surface. Many

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magnetic highs and lows are distributed on the maps. Comparing the result of the drone magnetic survey with that of the unmanned autonomous helicopter survey, it is obvious that the former is superior to the latter in spatial resolution. Many short-wavelength anomalies can be attributed to topography consisted of volcanic products on magnetic maps of the drone magnetic survey. Even the magnetization heterogeneity of the 1986 lava can be estimated on the same maps.

Keywords: magnetic survey, drone , unmanned autonomous helicopter, airplane, volcano, Izu-Oshima

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Aeromagnetic survey in Kusatsu-Shirane volcano by unmanned helicopter

*Takao Koyama[1], Wataru Kanda[2], Mitsuru Utsugi[3], Takayuki Kaneko[1], Takao Ohminato[1], Atsushi Watanabe[1], Hiroshi Tsuji[1], taro nishimoto[1], Yoshiaki HONDA[4]

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Kusatsu-Shirane volcano is one of the active volcanoes in Japan, and phreatic explosions have occurred in Mt. Shirane in 1983 and most recently, Mt. Motoshirane in 2018. Information on the subsurface structure is crucial for understanding the activity of volcanoes with well-developed hydrothermal systems where phreatic eruptions occur.
Here, we report aeromagnetic surveys conducted at low altitudes using an unmanned helicopter. The survey aimed to obtain magnetic data of high spatial resolution to map the magnetic anomaly and infer the magnetization intensity structure in the region, just after the 2018 Mt. Motoshirane eruption. The helicopter used in the survey was YAMAHA FAZER R G2, an autonomously-driven-model that can fly along a programmed course. The flight height above the ground and a measurement line spacing were set to ~150 m and ~100 m, respectively, and the total flight distance was 191 km. The measured geomagnetic total intensity was found to vary by ~1000 nT peak-to-peak.
The estimated magnetization intensity structure derived from measured data showed a magnetized surface layer with a normal polarity of a few hundred meters thick, composed of volcanic deposits of recent activities. Underneath, a structure with reverse-polarity magnetization was found. This probably corresponds to the Takai lava flow in the Early Quaternary period (~1 Ma) to which, it is believed that the basement rock of this region can be dated back to. Just beneath the crater lake of Mt. Shirane (Yugama) and Mt. Motoshirane, normally magnetized structures were inferred even at 1500 m depth from the surface. This may have been caused by the replacement of old lava with a new one because of frequent repetition of volcanic events which occurred through the two main pathways.

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Automatic estimation of regression curves indicating average depths of causative layers from power spectrum of gravity anomaly or gravity gradient (g_{zz}) data

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In this study, we propose a method of automatically estimating regression lines or curves indicating the average depths of causative layers from the power spectrum of gravity anomaly or gravity gradient data (g_{zz}).

To estimate the average depth of a causative layer, we select a frequency range and apply linear or curve approximation to the power spectrum of gravity anomaly or gravity gradient data and estimate the optimum regression line or curve for the data. In general, the frequency range is selected by an analyst; therefore, the analysis depends on the skill level of the analyst. If the effective-frequency range for each causative layer can be automatically determined from the power spectrum according to a suitable index, we can estimate the regression line or curve more objectively. If a technique for the automatic and direct determination of the regression curve from the data with one indicator is developed, it would be the best way for performing quantitative analysis of gravity anomaly or gravity gradient data.

In this study, we focused on estimating the regression line and employed the coefficient of determination (R^2) as the indicator. R^2 was used to measure the goodness of fit for the regression line. It generally distributes in the range of less than 1.0; the closer R^2 is to 1.0, the better the explanation of data by the estimated regression line.

In the analysis, the data in all the frequency zones were set as the initial data, and the regression line indicating the depth of the deepest layer was first estimated. The regression lines were estimated by sequentially reducing data from the higher frequency side, and R^2 was also calculated each time the regression line was estimated. When R^2 of one line assumed the highest value, we used the line as the optimum regression line. Next, we applied the same process to the residual data (high-frequency side) and obtained the regression line indicating the second-deepest layer. By repeating these processes, we automatically determined the number of causative layers and the regression lines indicating the layer depths.

The radial average of the power spectrum of gravity is known to draw a relatively smooth curve. Instead of L_2 norm minimisation (least square method), we employed L_1 norm minimisation, which is robust, for estimating the regression line from these data. R^2 has been used to measure the goodness of fit for the regression line via the least square method and is not a suitable indicator for evaluating the goodness of fit for the regression line provided by L_1 minimisation but only an indicator. However, as shown in Fig. 1, we could extract the regression lines indicating the average depths in the regional, local, and noise frequency zones by evaluating R^2.

Keywords: Gravity anomaly, Power spectrum, Automatic estimation of average depth of causative layer

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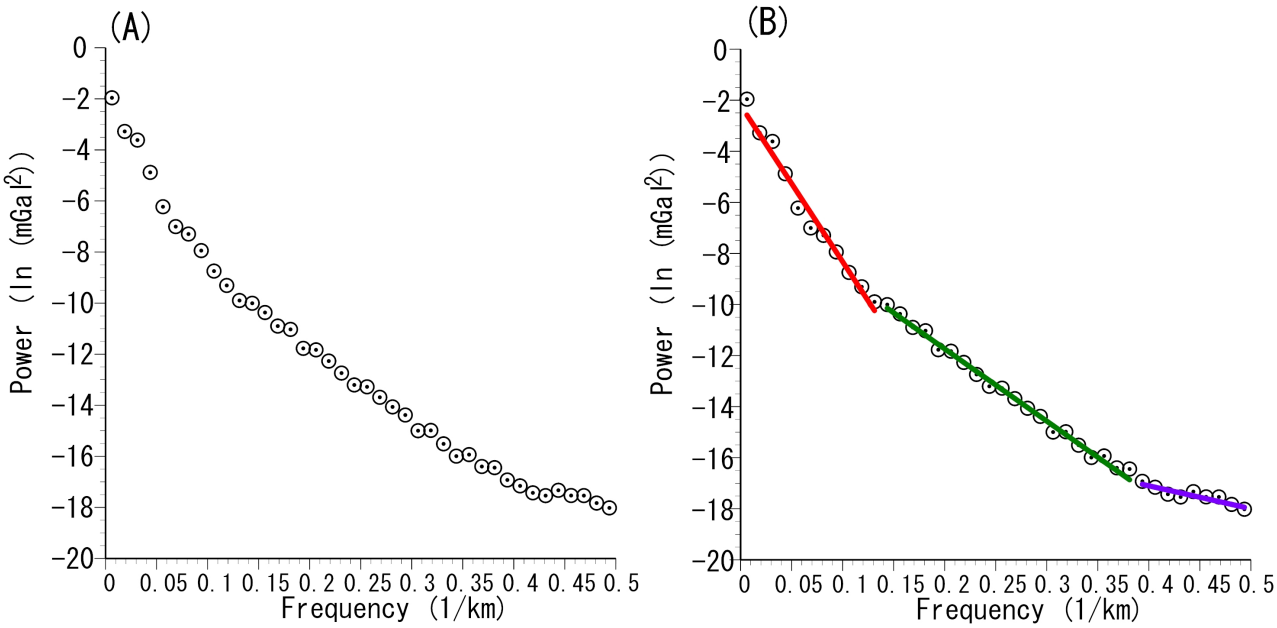


Fig. 1. Power spectrum and regression lines. (A) Power spectrum of Bouguer anomaly in Toyama prefecture. (B) Regression lines estimated automatically by the proposed method. Red, green, and purple lines represent the regression lines indicating average depths in the regional, local, and noise frequency zones.

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Study on the behavior of the groundwater in the slope in the heavy rain using Drone Airborne TEM

*Atsuhiko Kinoshita[1,2], Suguru Shibata[2], Takao Yamakoshi[1], Hiroaki Nakaya[1], Atsuyoshi Jomori[3], Tetsuya Toyama[3], Akira Jomori[3], Kentaro Kanayama[4], Minoru Okumura[4], Katsushi Kawato[4], Muneki Mitamura[5], Tamotsu Matsui[6]

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In the survey by Drone Airborne Transient Electromagnetics (TEM), a cable of about 100 to 1000 m is laid on the ground and the cable is energized. By causing a rapid time change of the magnetic field (primary magnetic field) generated there, an induced current proportional to the resistivity of the underground is generated on the ground. The resistivity value in the underground is obtained by measuring and analyzing the time change (transient response) of the new magnetic field (secondary magnetic field) generated by this. With the development of this technology, we could verify the landslide mechanisms after the sediment-related disasters and the design method of the countermeasures would change significantly in the future. The reasons for this are that it is cheaper than the electrical prospecting and the Airborne Electromagnetic Survey by helicopter that have been often used so far, and that it can be measured immediately after the heavy rain. In this study, we conducted a survey in the Iya district in Tanabe City, Wakayama Prefecture, where the deep-seated landslide was occurred due to Typhoon Talas in 2011. Drone Airborne TEM was conducted to clarify the behavior of groundwater in the slope during the heavy rain.

A survey line of about 700 m length was set at the upper right of the landslide slope. And Drone Airborne TEM was conducted in the flood season and in the dry season. From the results of the field survey, multiple fault crush zones were distributed around the area where the survey line was set. The measurement day in the flood season was three days after the end of rainfall of 217 mm in total rainfall of Typhoon CHAN-HOM in 2020 (October 13, 2020). The measurement day in the dry season was set on December 2, 2020, when there was no rainfall for 11 days. By taking the difference between the measurement results of the resistivity values, the behavior of the groundwater during Typhoon CHAN-HOM in 2020 was estimated.

By Drone Airborne TEM, we could estimate the behavior of groundwater in the slope during the heavy rain, which was previously unknown without observing the water level under the ground using the boring hole. As a result, it was found that the four fault crush zones distributed in the Iya area induce groundwater and block the flow of the groundwater in the slope. We think that the deep-seated landslide in the 2011 disaster was caused due to the effects of these fault crush zones. In this way, we would evaluate the roles of the fault crush zones during the heavy rains can be evaluated by using Drone Airborne TEM.

Keywords: Drone Airborne TEM, groundwater, deep-seated landslide

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[J] Oral | S (Solid Earth Sciences) | S-TT Technology & Techniques

[S-TT34] Airborne surveys and monitoring of the Earth

convener:Shigekazu Kusumoto(Institute for Geothermal Sciences, Graduate School of Science, Kyoto University), Shigeo Okuma(Geological Survey of Japan, AIST), Takao Koyama(Earthquake Research Institute, The University of Tokyo), Yuji Mitsuhata(AdvancedIndustrial Science and Technology), Chairperson:Shigekazu Kusumoto(Institute for Geothermal Sciences, Graduate School of Science, Kyoto University), Takao Koyama(Earthquake Research Institute, The University of Tokyo), Shigeo Okuma(Geological Survey of Japan, AIST), Yuji Mitsuhata(AdvancedIndustrial Science and Technology)
Thu. Jun 3, 2021 3:30 PM - 5:00 PM Ch.23 (Zoom Room 23)

Airborne surveys are useful to better understand the whole and/or the detailed structures of the Earth and their variations. They can be implemented from a traditional manned and newly-developed unmanned aircraft to efficiently map very large or remote areas with difficult access. We invite studies on theory, instrumentation, processing, modeling or inversion and applications of airborne surveys.

4:45 PM - 5:00 PM

[STT34-06]Discussion

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[J] Oral | S (Solid Earth Sciences)：S-TT Technology & Techniques

Thu. Jun 3, 2021 10:45 AM - 12:15 PM JST | Thu. Jun 3, 2021 1:45 AM - 3:15 AM UTC | Ch.18 Zoom Room 18

[S-TT37] Seismic Big Data Analysis Based on the State-of-the-Art of Bayesian Statistics

convener:Hiromichi Nagao(Earthquake Research Institute, The University of Tokyo), Aitaro Kato(Earthquake Research Institute, the University of Tokyo), Keisuke Yano(The Institute of Statistical Mathematics), Takahiro Shiina(National Institute of Advanced Industrial Science and Technology), Chairperson:Ryo Kurihara(Earthquake Research Institute, The University of Tokyo), Takayuki Nagata(Tohoku University)

Recently, a big seismic database has been being constructed that collects data of vibrators implemented in such as buildings, lifelines and smartphones, in addition to seismic data of the conventional continuous/temporal dense seismic observation arrays. Development of methodologies and algorithms, which are inadequate at this moment, optimized to comprehensively analyze the seismic big data is essential in order to utilize the big database as much as possible for prevention/mitigation of earthquake disasters and clarification of earthquake phenomena. On the other hand, recent progress of Bayesian statistics is significant, which is the mathematical basis of various methodologies, such as machine learning, especially deep learning, to extract valuable information from big data. The state-of-the-art of Bayesian statistics is expected to substantially advance seismic big data analyses.
This session mainly accepts presentations that focus on analyses of seismic big data, especially related to analysis methods based on Bayesian statistics such as machine learning, sparse modeling and data assimilation, and their applications to real seismic data. Presentations related to mathematical or statistical theories beneficial to data analyses, feasibility studies of algorithms eventually applicable to real seismic data, and the current status of seismic observations and analysis results are also highly welcome.

10:45 AM - 11:00 AM JST | 1:45 AM - 2:00 AM UTC

[STT37-01] Seismic noise reduction in MeSO-net during COVID-19 pandemic

★Invited Papers

*Suguru Yabe[1], Kazutoshi Imanishi[1], Kiwamu Nishida[2] (1.National Institute of Advanced Industrial Science and Technology, 2.Earthquake Research Institute, University of Tokyo)

11:00 AM - 11:15 AM JST | 2:00 AM - 2:15 AM UTC

[STT37-02] MCMC-based joint determination of earthquake hypocenters and 1-D velocity structures around a fault zone

*Takahiro Shiina[1], Masayuki Kano[2] (1.National Institute of Advanced Industrial Science and Technology (AIST), 2.Graduate School of Science, Tohoku University)

11:15 AM - 11:30 AM JST | 2:15 AM - 2:30 AM UTC

[STT37-03] Application of structured regularization to seismic tomography for adaptation to discontinuities

*Sumito Kurata[1], Yohta Yamanaka[1], Keisuke Yano[2], Fumiyasu Komaki[1], Takahiro Shiina[3], Aitaro Kato[1] (1.The University of Tokyo, 2.The Institute of Statistical Mathematics, 3.National Institute of Advanced Industrial Science and Technology)

11:30 AM - 11:45 AM JST | 2:30 AM - 2:45 AM UTC

[STT37-04] Bayesian Dynamic Mode Decomposition

★Invited Papers

*Hideitsu Hino[1] (1.The Institute of Statistical Mathematics)

11:45 AM - 12:00 PM JST | 2:45 AM - 3:00 AM UTC

[STT37-05] Sensor Selection for Seismic Wavefield Reconstruction based on Sparse Observation (Part I. Proposal and Evaluation on Method based on Linearized Model of Governing Equation)

*Kumi Nakai[1], Takayuki Nagata[1], Yuji Saito[1], Taku Nonomura[1], Masayuki Kano[1], Shin-ichi Ito[2], Hiromichi Nagao[2] (1.Tohoku University, 2.Earthquake Research Institute, The University of Tokyo)

12:00 PM - 12:15 PM JST | 3:00 AM - 3:15 AM UTC

[STT37-06] **Modeling space-time heterogeneities of hypocenter catalog**

*Yosihiko Ogata[1], Koiti Katsura[1] (1.Research Organization of Information and Systems, The Institute of Statistical Mathematics)

Seismic noise reduction in MeSO-net during COVID-19 pandemic

*Suguru Yabe[1], Kazutoshi Imanishi[1], Kiwamu Nishida[2]

1. National Institute of Advanced Industrial Science and Technology, 2. Earthquake Research Institute, University of Tokyo

Japanese society has been forced to change due to COVID-19 pandemic started in 2020. Japanese people were requested to stay home when the state of emergency was declared in April 2020. The number of commuters was decreased by introducing remote working. Such changes in social activities have been visualized through location information of smartphones. We report that seismic noise at high frequency (>1 Hz) in Metropolitan Seismic Observation network (MeSO-net) also records social activity changes due to COVID-19.

It has been known that seismic stations record noise generated by social activities at frequency higher than 1 Hz. The noise level is usually higher on weekdays than on weekends, on daytime than on night, which corresponds to social activeness. The noise level becomes lower during long holidays, such as new-year holidays, which also corresponds to social activeness. However, we have not had opportunities to compare seismic noise level with any quantitative indexes of social activities. This study compares seismic noise level with population data around train stations, which is published during COVID-19 pandemic as an opportunity.

The seismic noise level varies temporally at several timings. Its first small drop was occurred at the beginning of March, which corresponds to when schools were shut down. A larger drop was recorded when the Governors of the Tokyo metropolitan area requested citizens to stay home (the end of March 2020) and when the state of emergency was declared for the Tokyo metropolitan area by the government (8th April 2020). The noise reduction reached 10-20% at most in many stations. On the middle of May 2020, the noise level in turn started to increase, which occurred before the state of emergency was lifted on the end of May. The noise level recovered to that of normal years in June at many stations, though the noise level at some stations (especially at central Tokyo) are kept at ~5 % lower than that of normal years. The state of emergency was declared again on 8th Jan 2021, though seismic noise level just shows a slight drop.

The observed temporal changes in seismic noise level are correlated with social activeness visualized though the location information of smartphones. We refer population data around train stations published by Agoop corp. According to their data, population drops occurred at the same timing when seismic noise level reduction occurred. Population recovery at the middle of May also corresponds to seismic noise-level recovery. On the other hand, there are also several inconsistencies between population data and the seismic noise level. For example, population after the state of emergency in 2020 was lifted did not recover to that before COVID-19 pandemic started, though seismic noise level was recovered at many stations. Population after new-year holiday is fewer than that before the holiday, though the seismic noise level just shows a slight decrease. These observations suggest that, although the primary noise source at high frequency is social activities, the population data does not directly reflect activeness of seismic noise source.

Seismic noise source is considered to be mobility such as cars and trains and machine vibrations in buildings and factories. However, we do not understand how they actually contribute to the observed

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seismic noise. There should be various indexes for social activities other than the population data we referred in this study. Data mining with such various indexes will enables us to develop a social monitoring method through seismic data.

Keywords: Seismic noise, COVID-19, Social activity

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MCMC-based joint determination of earthquake hypocenters and 1-D velocity structures around a fault zone

*Takahiro Shiina[1], Masayuki Kano[2]

1. National Institute of Advanced Industrial Science and Technology (AIST), 2. Graduate School of Science, Tohoku University

Determination of earthquake hypocenters is the fundamental analysis in seismology. For example, locations of a large earthquake and its aftershocks provide information for understanding generation mechanisms of the mainshock and spatiotemporal activity of the aftershocks. Earthquake locations are estimated from arrival times of P and S waves picked from observed seismic records. In order to calculate theoretical travel times to compare with observed ones, velocity structure between earthquakes and stations has to be given. In general, a pre-estimated velocity model (e.g., JMA2001 model [Ueno et al., 2002]) is used to determine the earthquake locations. Meanwhile, the activity of earthquakes often concentrates on structural boundaries. Across such structural boundary, seismic velocity varies to reflect spatial variations of materials. Methods for simultaneously estimating earthquake locations and velocity structures were proposed to accurately determine earthquake hypocenters in such heterogeneous structures [e.g., Zhang and Thurber, 2003; Ryberg and Haberland, 2019].
For simultaneous determination of earthquake locations and velocity structures from a limited amount of dataset, e.g., in the case when immediately after a large earthquake, it would be practical to assume a one-dimensional (1-D) velocity model that varies only in the depths. The structural boundary related to the inland earthquakes often has a nearly-vertical dip angle. In that case, the estimation accuracy of earthquake hypocenters can be improved by assuming a different 1-D velocity model in each station group divided by the structural boundary [Sakai et al., 2004; 2005]. However, because prior constraints of subsurface heterogeneity should be necessary for dividing station groups, applications for determining earthquake locations using several 1-D velocity models are limited in the region where the subsurface velocity structure has been investigated well.
In this presentation, we propose a method for simultaneously determining earthquake hypocenters and 1-D velocity models, in addition to station clustering reflecting subsurface velocity structure. The target is considered to be an active earthquake area where velocity structures vary horizontally. In the proposed method, we perform the estimation based on the Markov chain Monte Carlo (MCMC) method: the Metropolis-Hasting algorithm for estimating locations of hypocenter and station corrections in travel times, and the reversible-jump MCMC algorithm [Green, 1995] for determining 1-D velocity models with the number of layers. The stations are clustered in a data-driven manner using the framework of the Metropolis-Hasting algorithm. Numerical experiments will demonstrate to verify the proposed method. Moreover, we estimate earthquake locations and velocity structures around the source area of the 2004 mid-Niigata prefecture earthquake by the proposed method to examine the application to real seismic data.

Acknowledgment: This study is supported by JST CREST [Grant Number JPMJCR1763] and JSPS KAKENHI [Grant Number JP18K03796].

Keywords: MCMC, Hypocenter determination, 1D velocity structure

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Application of structured regularization to seismic tomography for adaptation to discontinuities

*Sumito Kurata[1], Yohta Yamanaka[1], Keisuke Yano[2], Fumiyasu Komaki[1], Takahiro Shiina[3], Aitaro Kato[1]

1. The University of Tokyo, 2. The Institute of Statistical Mathematics, 3. National Institute of Advanced Industrial Science and Technology

Seismic tomography is a method for estimating the velocity structure of seismic waves propagating in the Earth, based on arrival times of seismic waves recorded by seismic observation networks. Grid points are placed in three-dimension to estimate velocity parameters and their heterogenous distributions. A value of velocity at an arbitrary point is calculated by interpolating them at the nearest eight grids. The SIMUL2000 (Thurber, 1993) is a widely-used estimation algorithm that estimates velocity parameters based on minimizing the sum of squared residuals.
In seismology, it is well known that there are regions of varying velocity drastically, such as the Moho discontinuity, in the vertical (depth) direction. On the other hand, in the horizontal direction, velocity changes are generally smooth, that is, rapid changes of the velocity is less likely to occur. In this presentation, we propose a new tomographic method based on structured regularization to incorporate such structural properties of the Earth's interior.
We use different penalty terms in the vertical and horizontal directions to express the above-mentioned properties in seismic velocity changes. For the depth direction, we employ a penalty term that has a form of l1-sum of l2-norm of the second-order differences of the horizontal units. This penalty term is intended to represent the sharp velocity jumps associated with the presence of discontinuities, by making average velocities in the depth piecewise linear. On the other hand, in the horizontal direction, we set a penalty term based on the l2-norm to express smooth velocity trends.
In the presentation, we conduct numerical experiments to discuss properties of the proposed methods by comparing to conventional methods, SIMUL2000 with the Laplacian regularization. We show that the proposed method is superior to the conventional ones in estimating velocity structures, especially in terms of accuracy in the presence of discontinuous increasing in seismic velocity.

Keywords: Seismic tomography, Velocity structure, Computational seismology, Velocity discontinuity, Structured regularization

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Bayesian Dynamic Mode Decomposition

*Hideitsu Hino[1]

1. The Institute of Statistical Mathematics

Dynamic mode decomposition (DMD) is a data-driven deterministic method that has substantially contributed to our understanding of dynamical systems. In this work, a Bayesian formulation of DMD is proposed. It first determines the subspace of observables, and then compute the modes on that subspace. Variational matrix factorization makes it possible to realize a fully-Bayesian scheme of DMD. The proposed Bayesian DMD is capable of dealing with incomplete or missing data, which demonstrates the advantage of probabilistic modeling. Finally, both nonlinear simulated and real-world datasets are used to illustrate the potential of the proposed method. This is joint work with Mr. Takahiro Kawashima and Dr. Hayaru Shouno.

Keywords: Bayesian modeling, mode decomposition

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Sensor Selection for Seismic Wavefield Reconstruction based on Sparse Observation (Part I. Proposal and Evaluation on Method based on Linearized Model of Governing Equation)

*Kumi Nakai[1], Takayuki Nagata[1], Yuji Saito[1], Taku Nonomura[1], Masayuki Kano[1], Shin-ichi Ito[2], Hiromichi Nagao[2]

1. Tohoku University, 2. Earthquake Research Institute, The University of Tokyo

In the present study, we propose a sparse sensor selection method for the accurate reconstruction of the seismic wavefield. The sensor candidate matrix, which presents the sensitivity of each sensor candidate to the wavefield, is constructed using simulations of the seismic wavefield with the horizontally layered subsurface structure model. Then, the sparse sensor positions are determined by the greedy method based on D-optimality for the optimal experimental design. Finally, the parameters related to the source and local subsurface structure are estimated using the selected sensors, and the proposed method is evaluated by comparing to the results using random sensor selection.

Keywords: Sparse sensor optimization, Low-dimensional model, model-based approach

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Modeling space-time heterogeneities of hypocenter catalog

*Yosihiko Ogata[1], Koiti Katsura[1]

1. Research Organization of Information and Systems, The Institute of Statistical Mathematics

A spatio-temporal model of earthquake detection rate was devised and implemented to enable unbiased prediction of seismic activity and probability from long-term heterogeneous data, even if the earthquake magnitude threshold is reduced.

As seismographs and seismic observation networks develop over time, the number of detected earthquakes will increase significantly over time. In addition, the detection rate of small and medium earthquakes is decreasing with respect to distant offshore from the Japanese archipelago. Thus, the catalog of earthquakes over a long period of time is not homogeneous. In addition, there are many aftershocks immediately after major earthquakes, but many of them cannot be detected and located because their waveforms overlap each other on the seismograph records, making it difficult to determine their hypocentre coordinates. For example, the spatiotemporal changes in detection rates before and after the M9 Tohoku earthquake are extreme and large-scale.

In order to fit a seismic activity model with an analysis that avoids bias, conventional methods limit the time interval and analysis area, and use data restricted to use only earthquakes of magnitude or greater that are fully detectable, but this results in the loss of a large amount of data. This is not only fatal for research and analysis related to long memory and self-similarity, which are common in geophysical sciences, but also seriously hampers research and prediction of seismic activity to be applied to seismic activity directly beneath inland areas, active offshore areas, and the world at large.

On the other hand, we can consider a seismic model that uses non-homogeneous earthquake data by assuming the Gutenberg-Richter law for magnitude frequency and modeling the detection rate of earthquakes of magnitude. For this, we use the cumulative function of the Normal distribution. That is, the parameter of the mean of the Normal distribution (mu value) represents the magnitude at which half of the earthquakes are detected, and the parameter of the standard deviation value (sigma value) relates to the range of magnitudes over which the earthquakes are partially detected. In fact, these parameters are generally assumed to be expressed as a function of time and location, rather than as constants, to investigate spatio-temporal heterogeneity. The best Bayesian inverse solution for this purpose is to use all detected earthquakes to analyze changes in b-values and seismic activity.

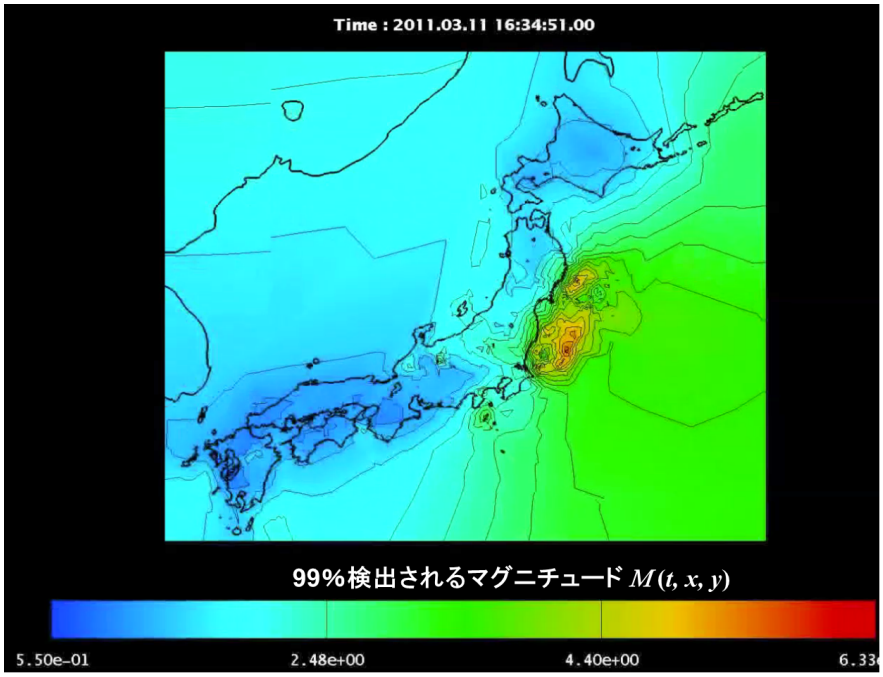
In this presentation, we present the results of the analysis in 2D space plus 1D axis for the epicenter and time of occurrence, ignoring the depths of the earthquakes in the JMA catalog. Therefore, the Delaunay tetrahedral partition by using the earthquake coordinates is effectively constructed. Namely, it is effectively designed to control the computational complexity caused by the huge increase of data after the unification of the sources, and to quantify the sharp incompleteness during a period immediately after large earthquakes. The spatio-temporal b-, mu- and sigma-values are represented by spline functions defined by piecewise linear functions on Delaunay tetrahedra, and the respective weights of the spatial and temporal constraints of smoothing are properly devised and determined by the Akaike Bayesian Information Criterion (ABIC).

The calculated results of the spatio-temporal detection rates and b-value changes for the inland and

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offshore periphery of Japan obtained in this way are visualized in a movie.

Keywords: earthquake magnitude, Detection rates of earthquakes, Gutenberg-Richter law, Space-time partition by Delaunay tetrahedra, Bayesian inversion solution, Akaike Bayesian Information Criterion



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[J] Oral | S (Solid Earth Sciences)：S-CG Complex & General

Thu. Jun 3, 2021 9:00 AM - 10:30 AM JST | Thu. Jun 3, 2021 12:00 AM - 1:30 AM UTC | Ch.21 Zoom Room 21

[S-CG50] Dynamics in mobile belts

convener:Yukitoshi Fukahata(Disaster Prevention Research Institute, Kyoto University), Hikaru Iwamori(Earthquake Research Institute, The University of Tokyo), Kiyokazu Oohashi(Graduate School of Sciences and Technology for Innovation, Yamaguchi University), Chairperson:Akinori Hashima(Japan Agency for Marine-Earth Science and Technology), Kiyokazu Oohashi(Graduate School of Sciences and Technology for Innovation, Yamaguchi University)

The dynamic behaviors of mobile belts are expressed across a wide range of time scales, from the seismic and volcanic events that impact society during our lifetimes, to orogeny and the formation of large-scale fault systems which can take place over millions of years. Deformation occurs on length scales from microscopic fracture and flow to macroscopic deformation to plate-scale tectonics. To gain a physical understanding of the dynamics of mobile belts, we must determine the relationships between deformation and the driving stresses associated with plate motion and other causes, which are connected through the rheological properties of the materials. To understand the full physical system, an integration of geophysics, geomorphology, geology, petrology, and geochemistry is necessary, as is the integration of observational, theoretical and experimental approaches. In particular, rheological properties, which are physically affected by fluids in the crust and chemical reactions assisted by fluids, can be resolved only through such an interdisciplinary approach. After the 2011 great Tohoku-oki earthquake, large-scale changes in seismic activity and regional scale crustal deformation were observed, making present-day Japan a unique natural laboratory for the study of the dynamics of mobile belts. This session welcomes presentations from different disciplines, such as seismology, geodesy, tectonic geomorphology, structural geology, petrology, geochemistry and hydrology, as well as interdisciplinary studies, that relate to the dynamic behaviors of mobile belts.

9:00 AM - 9:15 AM JST | 12:00 AM - 12:15 AM UTC

[SCG50-01] 3D numerical simulation of island arc deformation due to steady plate subduction: Effects of a bend along a trench axis

*Yutaro Mori[1], Yukitoshi Fukahata[2] (1.Graduate School of Science, Kyoto University, 2.Disaster Prevention Research Institute, Kyoto University)

9:15 AM - 9:30 AM JST | 12:15 AM - 12:30 AM UTC

[SCG50-02] Effect of the Philippine Sea slab–overriding plate contact on the stress field in the Southwest Japan arc

*Akinori Hashima[1], Takashi Iidaka[1] (1.Earthquake Research Institute, The University of Tokyo)

9:30 AM - 9:45 AM JST | 12:30 AM - 12:45 AM UTC

[SCG50-03] A Framework to Understand Deformation in Japanese Islands: Inter-arc Deformation and Intra-arc Deformation

*Yukitoshi Fukahata[1], Tomohisa Okazaki[2] (1.Disaster Prevention Research Institute, Kyoto University, 2.RIKEN)

9:45 AM - 10:00 AM JST | 12:45 AM - 1:00 AM UTC

[SCG50-04] Visualization of crustal deformation in a high-strain shear zone by geodetic, geomorphologic, and geologic approaches

★Invited Papers

*Masakazu Niwa[1], Koji Shimada[1], Tsuyoshi Watanabe[1], Akira Goto[1], Shinya Hiratsuka[1] (1.Tono Geoscience Center, Japan Atomic Energy Agency)

10:00 AM - 10:15 AM JST | 1:00 AM - 1:15 AM UTC

[SCG50-05] Deciphering 3-dimensional crustal movements before and after the 2011 Tohoku-oki earthquake using principal component analysis

Shuntaro Fukaya[2], *Takeshi Sagiya[1] (1.Disaster Mitigation Research Center, Nagoya University, 2.Graduate School of Environmental Studies, Nagoya University)

10:15 AM - 10:30 AM JST | 1:15 AM - 1:30 AM UTC

[SCG50-06] Effects of a crustal heterogeneity in the postseismic deformation of 2008 Iwate-Miyagi Nairiku Earthquake

*Youichiro Takada[1], Yoshiki Takei[2], James Daniel Paul Moore[3], Mako Ohzono[4] (1.Faculty of Science, Hokkaido University, 2.Graduate School of Science, Hokkaido University, 3.Nanyang Technological University, Earth Observatory of Singapore, 4.Earthquake Research Institute, University of Tokyo)

3D numerical simulation of island arc deformation due to steady plate subduction: Effects of a bend along a trench axis

*Yutaro Mori[1], Yukitoshi Fukahata[2]

1. Graduate School of Science, Kyoto University, 2. Disaster Prevention Research Institute, Kyoto University

Island arc-trench systems are characterised by a pair of topography and free-air gravity anomaly that is high on the island arc and low around the trench. These features are observed worldwide without exceptions. However, the physical mechanism of island-arc deformation has not been well understood. To this problem, based on the elastic dislocation theory, Fukahata and Matsu'ura (2016, GJI) calculated the deformation of the island arc lithosphere due to steady plate subduction for a two-dimensional elastic-viscoelastic layered half space. They explained the deformation mechanism of the island arc-trench system by the combination of block rotations of the oceanic and island-arc lithospheres and gravitational restoring of them. However, we cannot neglect the effect of three-dimensional geometry for actual island arc-trench systems. For example, we observe the trench axis has a bend at the junction of the Japan Trench and the Kuril Trench (off the Shimokita Peninsula), where large negative free-air gravity anomalies are observed (Sandwell and Smith. 1997, JGR). The large negative free-air gravity anomalies have been reproduced by numerical models (Hashimoto et.al., 2004, 2008, PAGEOPH), but the physical mechanism of them has not been well understood.

In this study, developing a 3-D numerical model for an elastic-viscoelastic layered half-space (Fukahata and Matsu’ura, 2005, 2006, GJI), we compute displacement rates in the lithosphere caused by steady slip on a plate interface, which has a bend along the trench axis. By changing the bending angle of the trench axis, we investigated the effect of bending on island-arc deformation when the bend of a trench axis is convex toward the island arc. The computation shows that a significant subsidence area appears on the island arc lithosphere around the bend and that the amount and spatial scale of the subsidence become larger as the bend of the trench axis is larger. On the other hand, when the trench axis bends convexly toward the ocean, the significant uplift occurs on the island arc lithosphere around the bend. We also observed that the uplift became larger as the bend of the trench axis is larger.

These results can be reasonably explained by the following mechanism. When the oceanic plate subducts across the trench axis, with a convex bend toward the island arc, the surface mass of the subducting oceanic plate becomes excessive, as understood from the analogy of a tablecloth. Since the upper surface of the oceanic plate and the lower surface of the island arc plate move exactly in the opposite direction due to dislocation, mass deficit inevitably occurs in the island arc plate, which lead to subsidence. When the trench axis bends convexly toward the ocean, the same idea can be applied, that is to say mass deficit on the upper surface of the oceanic plate. Based on this mechanism, the larger the bend angle of the trench axis is, the larger the excess or deficit of mass on the top of the oceanic plate. This is consistent with the results of numerical computation in this model.

Keywords: island arc-trench system, plate subduction, free-air gravity anomaly, crustal deformation, arc-arc junction

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Effect of the Philippine Sea slab–overriding plate contact on the stress field in the Southwest Japan arc

*Akinori Hashima[1], Takashi Iidaka[1]

1. Earthquake Research Institute, The University of Tokyo

The Southwest (SW) Japan arc is formed by the subduction of the Philippine Sea plate, the movement of which is currently northwestward. The regional stress field is east-west compression in general. While the Philippine Sea slab has almost no deformation at the beginning of the subduction, which is inferred by the linear geometry of the Nankai Trough, it is strongly deformed at depth, which is rare compared with the other subducted slabs. In particular, a remarkable folded geometry can be seen under the Nobi plain and the Kii Peninsula, in the middle of the SW Japan arc. A recent receiver function analysis revealed that the Philippine Sea slab strongly indents into the bottom of the lower crust of the overriding plate under the Nobi plain. Above and west of the slab-crust contact zone, a lot of reverse faults develop forming a part of the deformation zone of the Kinki triangle. East of the slab-crust contact zone is the zone of strike slip faults, including the source faults of the 1891 Nobi earthquake, which has been the maximum inland earthquake (M8) ever observed in the Japanese islands. The recently revealed slab-crust contact raises the problem of how it has contributed to such a pattern of crustal activity.

In order the investigate the slab-crust contact, we construct a 3D finite element model including the region. The geometry of the plate interface in the model is taken from the previous study based on the distribution of interplate earthquakes. Previous studies show that the regional inland earthquakes can be explain by the long-term east-west compression. Therefore, we impose the boundary condition of lateral compression, while we ignore the direct effect of subduction of the Philippine Sea slab. On the plate interface, we impose the constraint of no relative vertical movement and allow the relative horizontal movement only in the direction along the Philippine Sea subduction. We also assume that the overriding lithosphere and the slab are elastic and that the region under them are viscoelastic, since we consider the long-term stress loading. We consider the variation of the thickness of the overriding lithospheric between 20 km and 70 km while we fix the thickness of the slab to be 70 km. Taking the standard viscosity value of 10^{19}Pa s, the model achieves the steady stress loading state. In this state, we perform the parameter study for the lithospheric thickness, the angle of the lateral compression, and the maximum depth of the slab.

We first take the lithospheric thickness to be 35 km, the angle of lateral compression to be 0 degree (east-west), and the maximum slab depth to be 100 km, as the reference model, and computed the stress loading rates. The stress rate field at the depth of the seismogenic zone (5-20 km) shows the pattern of reverse-type stress above and west of the slab-crust contact zone and strike-slip type stress east of the slab-crust contact zone. This pattern is well consistent with the observed stress pattern. Then we examine the stressing pattern change with the change of the lithospheric thickness. We obtained similar stressing pattern to the reference model for the lithospheric thickness of or below 40 km, but uniform reverse-type stress pattern for the lithospheric thickness of or more than 50 km. The effect of the angle of lateral compression and the maximum slab depth is negligible.

These results suggest the significant effect of slab-crust contact on the east-west compression in the SW Japan. The lithospheric thickness under the SW Japan is estimated to be 40 km. This model cannot explain the stress pattern of the western SW Japan (the Chugoku district). In this area, the direct effect of the subduction of the Philippine Sea plate might be dominant.

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Keywords: Stress loading, Southwest Japan arc, Philippine Sea slab, Kinki triangle, 1891 Nobi Earthquake, Finite element method

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A Framework to Understand Deformation in Japanese Islands: Inter-arc Deformation and Intra-arc Deformation

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Deformation of Japanese islands is quite complicated. Japanese islands are composed of five island arcs: Kuril, Northeast Japan, West Japan, Izu, and Ryukyu. In this paper, we propose to understand deformation of Japanese islands by decomposing it into inter-arc deformation and intra-arc deformation. Of course, we notice that many researchers have already used similar ideas consciously or unconsciously, but we propose to use this idea as a framework to consider Japanese island deformation with a help of a cutting edge result of GNSS data analysis (Okazaki, Fukahata & Nishimura, 2021, JpGU).

Before considering inter- and intra-arc deformation, we need to consider the relation between island arc deformation and subducting oceanic slabs. Subduction of oceanic slabs cause large crustal displacements, but most of them are cyclic. However, subducting oceanic slabs are often the causes of inter- and intra-arc deformation.

Kuril and Northeast Japan arcs are colliding in the EW direction in Hokkaido, which results in Hidaka Mountains. The cause of the collision is the southwestward motion of Kuril arc as a forearc sliver due to oblique subduction of the Pacific plate, but large active faults are not known to bound the forearc sliver. Probably because of that, large strain rates are observed in the forearc of eastern Hokkaido (Okazaki et al., 2021).

Northeast and West Japan arcs are contracting in the EW direction, due to the northwestward motion of the triple junction off Boso (Takahashi, 2006). The boundary of them are usually taken at the Itoigawa-Shizuoka tectonic line, but the result of GNSS data analysis (Okazaki et al., 2021) suggests a wider deformation zone.

Izu arc is colliding with Northeast and West Japan arcs. On the other hand, Ryukyu arc is splitting from West Japan arc in the NS direction in central and southern Kyusyu. According to recent GNSS data, the splitting is more active in southern Kyusyu than in central Kyushu, where Beppu-Shimabara graben passes through (Okazaki et al. 2021).

Representative intra-arc deformations are dextral movement of Median tectonic line, EW extension of Izu arc, and back-arc spreading of Ryukyu arc, which are caused by subduction of oceanic plates. We observe considerable contraction along the Ou-backbone range, while the forearc region from Ibaraki to Nara has relatively small deformation (Okazaki et al., 2021). Some volcanoes also show significant deformation locally (Okazaki et al., 2021).

Keywords: inter-arc deformation, intra-arc deformation, GNSS, strain rate field, Japanese islands

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Visualization of crustal deformation in a high-strain shear zone by geodetic, geomorphologic, and geologic approaches

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In Japanese Islands, most active faults were activated millions to 500,000 years ago, and there is no known fault emerged 100,000 years ago or later (Doke et al., 2012, Active Fault Res.). However, it is probable that newborn faults could not be identified by previous surveys, because tectonic landform attributed to such faults is likely unclear.

Owing to a nationwide GNSS network installed since mid-1990s, several high-strain shear zones defined as concentrated regions of strain rates have been recognized (Sagiya et al., 2000, PAGEOPH; Nishimura and Takada, 2017, EPS). Newborn faults are likely concealed in such high-strain shear zones.

As a case study to visualize crustal deformation induced by concealed faults and related structures, we applied integrated approaches of geodesy, geomorphology, and geology to a high-strain shear zone in southern Kyushu, Japan. Previous GNSS data analyses have suggested an occurrence of a sinistral, E-W trend high-strain shear zone in the study area (Nishimura and Hashimoto, 2006, Tectonophysics; Wallace et al., 2009, Geology). Our GNSS observation for recent 4.7 years by a network composed of 10 stations revealed that locking depth and slip velocity of the deeper extension of the fault were estimated to be 8 km and left-lateral slip of 10 mm/year.

In the geomorphological approach, active faults and lineaments in southern Kyushu were mapped by aerial photograph interpretation (Goto et al., 2020, JAEA-Research 2020-013). Whereas there are few active faults with tectonic landforms, concentration of E-W trend lineaments is identified in northwestern Kagoshima, near the center of the sinistral high-strain shear zone detected by the GNSS observation and along the E-W trend aftershock distribution by the 1997 Northwestern Kagoshima Earthquakes (Faculty of Science, Kagoshima Univ., 1997, Rep. CCEP). Based on the aerial photography, we conducted field survey in the area of 20 ×20 km, including the concentrating area of E-W trend lineaments.

The field survey showed that minor faults were common in the study area, though occurrences of crush zones including fault gouge, breccia, and cataclasite were sparse and not continuous. Thus, we estimated stress field from slip data of the minor faults, and compared it with the stress field corresponding to the sinistral high-strain shear zone. First, present stress field in the study area was calculated by inversion from focal mechanisms of microearthquakes (n=181) observed from 06/2002 to 12/2015, using the method by Michael (1987, JGR). The calculated best-fit stress is NE-SW trending σ_1 and NW-SE trending σ_3, consistent with the sinistral high-strain shear zone. Next, we calculated the direction of maximum shear stress when the present best-fit stress affects each minor fault. Then we further calculated misfit angles between real slip directions of minor faults and the calculated directions of maximum shear stress. Spatial distribution of minor faults with small misfit angle (<30°) shows that the densest cluster occurs in the concentrating area of E-W trend lineaments along the aftershock distribution by the 1997 Earthquakes. In addition, the second densest cluster is also E-W trend and occurs in 4 km north of the densest cluster.

In addition, we applied the multiple inverse method (Yamaji, 2000, JSG; Sato et al., 2017, J. Geol. Soc.

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Jpn.) to the slip data of minor faults to determine the orientations of paleostress fields. The calculated stress field in the densest cluster is NW-SE trending σ_3 showing sinistral strike-slip to normal sense for the E-W trend shear zone. The stress field in the second cluster is somewhat different from the densest cluster, but partly includes sinistral sense NE-SW trending σ_1. These findings suggest that the subsurface deformation is localized rather than dispersed in the sinistral high-strain shear zone estimated from the GNSS observation.

This study was funded by the Ministry of Economy, Trade and Industry, Japan as part of its R&D supporting program titled “Establishment of Advanced Technology for Evaluating the Long-term Geosphere Stability on Geological Disposal Project of Radioactive Waste (FYs 2018-2020)”.

Keywords: High-strain shear zone, GNSS observation, Lineament, Multiple inverse method, Southern Kyushu

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Deciphering 3-dimensional crustal movements before and after the 2011 Tohoku-oki earthquake using principal component analysis

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In northeast Japan, significant crustal deformation has been observed by the continuous GNSS network (GEONET) and its pattern drastically changed before and after the 2011 Tohoku-oki earthquake, reflecting various processes such as locking or slipping on the plate subduction interface, activities of inland active faults and volcanoes, and the mechanical properties of the island arc crust. In this study, we attempt to separate the components caused by different deformation sources by applying the principal component analysis (PCA) to 3-dimensional GNSS data. In this study, data matrices for the PCA analysis are created for the preseismic (2004/1-2010/12) and postseismic period (2011/5-2019/12), respectively. As a result, crustal deformation pattern in each time period is represented as a superposition of multiple modes. Each mode is represented by a simple product of a spatial mode representing a spatial pattern of the displacement and a temporal mode representing temporal changes common to all the GNSS stations and their components. The first mode of the preseismic period shows steady-state deformation due to interplate coupling. E-W strain shows a broad contraction field and a localized large contraction (-2.1×10^{-7}/year) along the Ou-backbone range. In contrast, in the postseismic period, relaxation processes with different time constants are found for the first two modes. Depending on the time constant and spatial distribution, the first mode corresponds to steady-state displacement and viscoelastic relaxation with a larger time constant (~213 days), while the second mod corresponds to afterslip with a smaller time constant (~58 days). The contribution of the first mode accounts for 99.8% of the original data, representing the overwhelming dominance of a single mechanism in the postseismic deformation. The E-W strains of the first two modes show extensional strains in the wide area pattern. However, along the Ou-backbone range, the first mode shows a contraction while the second mode shows a larger extension than the surrounding area. The former implies contribution of an inelastic deformation driven by the absolute stress which does not change significantly before and after the earthquake, while the latter reflects an elastic response of elastically heterogeneous medium to rapid stress changes.

Keywords: principal component analysis, crustal deformation, GNSS, 2011 Tohoku-oki earthquake, inelastic deformaiton, postseismic deformation

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Effects of a crustal heterogeneity in the postseismic deformation of 2008 Iwate-Miyagi Nairiku Earthquake

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The Iwate-Miyagi Nairiku Earthquake (hereafter IMNE) occurred on June 14, 2008 (Mj 7.2) at the eastern flank of Mt. Kurikoma, an active volcano. The IMNE is characterized by conjugate fault rupture: west-dipping and east-dipping faults brought about complex surface deformation (e.g., Takada et al., 2009). A relatively large amount of post-seismic deformation has been observed by GNSS surveys (e.g., Ohzono et al., 2012) and InSAR analyses. The post-seismic displacement field at high spatial resolution detected by InSAR should reflect multi-scale crustal heterogeneities in the hypocentral area (e.g., Yoshida, 2001), which, however, has not been investigated so far.

In this study, first, we executed InSAR time-series analysis (SBAS by Berardino et al. 2002) to elaborate the post-seismic displacements in the hypocentral area using a series of SAR images taken by ALOS from descending orbit. During 2.2 years after IMNE, we detected the following signals: (1) LOS length increase at the footwall of the west-dipping fault, (2) LOS shortening at the hanging wall of the east-dipping fault, and (3) LOS shortening to the west of Mt. Kurikoma. We also found that these three signals accumulate with time. The first and the second signals would be due to afterslip on the west- and the east-dipping faults, respectively. The third signal reaches more than 10 cm in ~2 years, which indicates the existence of rheological heterogeneity to the west of Mt. Kurikoma. Interestingly, the location of the third signal coincides with the area of localized subsidence triggered by the 2011 Tohoku-Oki Earthquake (Takada and Fukushima, 2013).

To understand the physical effects of such a crustal heterogeneity, we construct a physical model of the postseismic deformation following IMNE using a numerical code Unicycle (Barbot et al., 2017; Moore et al., 2017) with which we consider fault slip, viscoelastic flow, and those interactions through the stress redistribution. We set the coseismic slip distribution as proposed by Iinuma et al. (2009). We also assume that the fault slip obeys the rate-and-state friction law (Dietrich, 1979; Ruina, 1983). First, we modeled crust-mantle structure as an elastic layer of 20 km thickness overlying a Maxwell viscoelastic substratum following Ohozono et al. (2012). Next, we put a localized viscoelastic volume at 8-20 km depth to the west of Mt. Kurikoma where the viscosity is three times lower than that of the substratum. The numerical result indicates that the postseismic slip on the west-dipping fault expands to the shallower and the deeper portion of the coseismic rupture area with time. Furthermore, the deeper extension of the postseismic slip reaches the low viscosity region to the west of Mt. Kurikoma, and it causes volumetric flow which strongly enhances surface uplift to the west of Mt. Kurikoma and explains LOS shortening there. As a result, our model well explains the time-series of postseismic LOS change obtained by the SBAS analysis. Our model also well explains the LOS length increase to the east of the west-dipping fault through the shallow postseismic slip. Thus, we suggested that localized crustal heterogeneities have the potential to cause a large-scale postseismic deformation through physical interaction with fault slips. Combining our result with the instantaneous subsidence in this area due to the 2011 Tohoku-Oki earthquake (Takada and Fukushima, 2013), we may say that the shallower portion of Mt. Kurikoma is characterized by heterogeneously low elasticity, and the deeper portion is characterized by heterogeneously low viscosity. For the east-dipping fault, the coseismic slip area overlapped with the

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postseismic slip area especially at the shallower portion, which indicates the importance of pre-stress. In the presentation, we mention how the postseismic slip depends on the pre-stress distribution.

Keywords: Intra-plate Earthquake, Viscoelasticity, InSAR, postseismic deformation, crustal heterogeneity

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[J] Oral | S (Solid Earth Sciences)：S-CG Complex & General

Thu. Jun 3, 2021 10:45 AM - 12:15 PM JST | Thu. Jun 3, 2021 1:45 AM - 3:15 AM UTC | Ch.21 Zoom Room 21

[S-CG50] Dynamics in mobile belts

convener:Yukitoshi Fukahata(Disaster Prevention Research Institute, Kyoto University), Hikaru Iwamori(Earthquake Research Institute, The University of Tokyo), Kiyokazu Oohashi(Graduate School of Sciences and Technology for Innovation, Yamaguchi University), Chairperson:Katsushi Sato(Division of Earth and Planetary Sciences, Graduate School of Science, Kyoto University), Hikaru Iwamori(Earthquake Research Institute, The University of Tokyo)

The dynamic behaviors of mobile belts are expressed across a wide range of time scales, from the seismic and volcanic events that impact society during our lifetimes, to orogeny and the formation of large-scale fault systems which can take place over millions of years. Deformation occurs on length scales from microscopic fracture and flow to macroscopic deformation to plate-scale tectonics. To gain a physical understanding of the dynamics of mobile belts, we must determine the relationships between deformation and the driving stresses associated with plate motion and other causes, which are connected through the rheological properties of the materials. To understand the full physical system, an integration of geophysics, geomorphology, geology, petrology, and geochemistry is necessary, as is the integration of observational, theoretical and experimental approaches. In particular, rheological properties, which are physically affected by fluids in the crust and chemical reactions assisted by fluids, can be resolved only through such an interdisciplinary approach. After the 2011 great Tohoku-oki earthquake, large-scale changes in seismic activity and regional scale crustal deformation were observed, making present-day Japan a unique natural laboratory for the study of the dynamics of mobile belts. This session welcomes presentations from different disciplines, such as seismology, geodesy, tectonic geomorphology, structural geology, petrology, geochemistry and hydrology, as well as interdisciplinary studies, that relate to the dynamic behaviors of mobile belts.

10:45 AM - 11:00 AM JST | 1:45 AM - 2:00 AM UTC

[SCG50-07] The evolving structure and material of normal fault in Yonaguni Island, Okinawa prefecture, Japan

*Kiyokazu Oohashi[1], Haruya Miyaki[1], Makoto Otsubo[2] (1.Graduate School of Sciences and Technology for Innovation, Yamaguchi University, 2.Geological Survey of Japan, Research Institute of Earthquake and Volcano Geology)

11:00 AM - 11:15 AM JST | 2:00 AM - 2:15 AM UTC

[SCG50-08] Tectonic development in the Median Tectonic Line and surrounding regions during the Late Cretaceous to Paleogene periods: Spatiotemporal development

★Invited Papers

*Toru Takeshita[1] (1.Department of Natural History Sciences, Graduate School of Science, Hokkaido University)

11:15 AM - 11:30 AM JST | 2:15 AM - 2:30 AM UTC

[SCG50-09] Relationship between the Northern Osaka Prefecture earthquake and the Arima-Takatsuki Tectonic Line estimated from dense aftershock observations

*Yoshihisa Iio[1], Satoshi Matsumoto[2], Joint aftershock observation group of the Northern Osaka Prefecture earthquake (1.Disater Prevention Research Institute, Kyoto University, 2.Institute of Seismology and Volcanoloty, Kyushu University)

11:30 AM - 11:45 AM JST | 2:30 AM - 2:45 AM UTC

[SCG50-10] Fracture as an electrical conduction path under pressure

*Tohru Watanabe[1], Arina Tomioka[2] (1.Faculty of Sustainable Design, University of Toyama, 2.Graduate school of science and engineering, University of Toyama)

11:45 AM - 12:00 PM JST | 2:45 AM - 3:00 AM UTC

[SCG50-11] Grain-boundary diffusion creep of olivine and the rheology of the oceanic upper mantle

★Invited Papers

*Kosuke Yabe[1], Takehiko Hiraga[1] (1.Earthquake Research Institute, the University of Tokyo)

12:00 PM - 12:15 PM JST | 3:00 AM - 3:15 AM UTC

[SCG50-12] An inversion method of fault-slip analysis to deteremine stress tensor and friction coefficient

*Katsushi Sato[1] (1.Division of Earth and Planetary Sciences, Graduate School of Science, Kyoto University)

The evolving structure and material of normal fault in Yonaguni Island, Okinawa prefecture, Japan

*Kiyokazu Oohashi[1], Haruya Miyaki[1], Makoto Otsubo[2]

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Map-scale normal faults which trending NE-SW, NW-SE, and E-W directions are widely recognized in Yonaguni Island, the westernmost island of Japan, and these faults clearly displaces the ground surface which is composed of upper Pleistocene coral reef deposits (the Ryukyu Group). Since Yonaguni Island is surrounded by various tectonic elements such as the subducting Philippine sea plate (the Ryukyu trough), the spreading back-arc basin (the Okinawa trough), and the arc-continent collision zone (Taiwan), it is important to know how and when these faults are created to understanding the tectonic process and crustal evolution of island arc. Thus, we have analyzed fault zone structure and paleo-thermal structure in the eastern coast of the island.

In the eastern coast of the island, one of the NE-SW trending faults is widely exposed along the shoreline. The fault zone strikes ENE-WSW direction and dipping 60 degree to the north. In the outcrop, the Ryukyu Group and the Yaeyama Group (middle Miocene) are distributed in the hanging wall and footwall, respectively, suggesting about 70 m normal offset after the deposition of the Ryukyu Group. ~3 m wide fault gouge and fault breccia zone is recognized between the hanging wall and footwall. Also ~40 m wide damage zone is developed in the footwall of the fault. In this presentation, we will discuss the temporal evolution of structure and material of the fault zone.

Keywords: The Okinawa Trough, Fault core, Damage zone, Vitrinite reflectance, Clay mineral, Yaeyama Group

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Tectonic development in the Median Tectonic Line and surrounding regions during the Late Cretaceous to Paleogene periods: Spatiotemporal development

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The tectonic development of the Median Tectonic Line (MTL) during the period from the Late Cretaceous to Paleogene has been studied for a long time, and a synthesis on it was given in the Special Issue entitled “Median Tectonic Line of Southwest Japan” published by the Geological Society of Japan in 1980. Here, it has been summarized that the proto-MTL was originated as mylonitic shear zones in the Ryoke granitoids in the Late Cretaceous (Kashio phase), and then the Uppermost Cretaceous Izumi Group was deposited in pull-apart basins formed at the north side of MTL. Subsequently, the Sambagawa metamormorphic rocks in the outer belt was greatly elevated, and juxtaposed against the Ryoke granitoids and Izumi Group before the deposition of the Eocene Kuma Group (the formation of the MTL sensu stricto at the so-called Ichinokawa phase). Further, it has been believed that the Uppermost Cretaceous Izumi Group thrusted over the Eocene Kuma Group at the Tobe phase in the Eocene.

The tectonic development of the MTL had not been studied much since then until Takeshita and co-workers made new discoveries about it after 1990s. Although the fault rocks and kinematics of the MTL at the Kashio phase in the Late Cretaceous have been intensely investigated by e.g. Hara et al. (1986) and Takagi (1986), the kinematics of the MTL during the Paleogene period has remained to be unclear. This is not only because the kinematics of the so-called Ichinokawa phase has not been described at the type locality, but also because most of the Kuma Group has been found to be the Early Miocene, not Eocene in age (Kashima and Takechi, 1996; Narita et al., 1999; Takeshita et al., 2000). In the following, the tectonic development of the MTL from the Late Cretaceous to Paleogene will be summarized including the new discoveries, including some geophysical implications.

(a) Kashio phase in the Late Cretaceous

It has been known that large-scale sinistral shearing occurred along the proto-MTL based on the foliation deflection and microstructures in mylonites (e. g. Hara et al., 1980; Takagi ,1986). Similarly, a top-to-the-west sense of shear was recorded in the Sambagawa metamorphic rocks (e. g. Takeshita and Yagi, 2004). The movement around the MTL can be ascribed to the oblique subduction of the Izanagi plate in the NNW direction relative to the NNE-SSW trending proto-Japanese arc.

(b) So-called Ichinokawa phase at c. 59 Ma in the Paleocene

It has been discovered by Kubota and Takeshita (2008) for the first time that the Ichinokawa phase is characterized by top-to-the-north, large-scale normal faulting based on the occurrence of a few hundred meter thick boudinaged belt and the north-vergent drape folds in the Izumi Group at the north side of the MTL (Kubota and Takeshita, 2008). On the other hands, in the Sambagawa metamorphic rocks, not only numerous low angle normal faults developed at the Ichinokawa phase, but also it has been found by seismic reflection studies (Sato et al., 2005; Ito et al., 2009) that the original shape of the MTL itself was a low-angle north dipping fault. This low-angle normal faults, which are common to those seismogenic faults in Italy, perhaps resulted from the anisotropic ductile strength of the Sambagawa metamorphic rocks, which are more prone to ductile flow parallel to the foliation.

(c) pre-Tobe phase at c. 47 Ma in the Eocene

The Kumamoto earthquake in 2016 in fact made it clear that the MTL has been still fairly active during the Quaternary period. It should be known however that the position of the active MTL systems does not

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coincide with the one of the MTL sensu stricto, but located in the Izumi Group at the north of the MTL (e. g. Okada, 1973). While there has been no information on when and under what kinematics the active MTL systems were originally formed, it has been newly discovered that the faults systems were originally formed under the setting of sinistral transpression at c. 47 Ma in the Eocene (Kubota et al., 2020). This phase of movement of the MTL has been named as the pre-Tobe phase, because the Tobe thrusting has been now found to occur at 15 Ma (Takeshita et al., 2000).

Keywords: Median Tectonic Line, The Late Cretaceous to Paleogene, Kinematics, Oblique subduction, Low-angle normal faulting, Sinistral transpression

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Relationship between the Northern Osaka Prefecture earthquake and the Arima-Takatsuki Tectonic Line estimated from dense aftershock observations

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The 2018 Northern Osaka Prefecture Earthquake (Mj6.1) occurred at a depth of 10 to 15 km immediately below the Arima-Takatsuki Tectonic Line (ATL) in the northern part of the Osaka Plain, however, the relationship with nearby active faults is well understood. In this study, the location of the deeper part of the Arima-Takatsuki fault zone was estimated using the arrival time data of aftershocks, and the relative location between the estimated source fault of the northern Osaka Prefecture earthquake and the deeper part of ATL was investigated.

At each observation station, the relationship between O-C (observed - calculated value) of P wave arrival times in the hypocenter calculation and aftershock locations was investigated, assuming uniform horizontal layer structures. At the observation stations located on the north side of ATL, O-C was almost the same for the aftershocks occurring in the north of ATL, however for the aftershocks south of a certain point, O-C tended to increase toward the south. This is probably because there is a low velocity zone near ATL. When this relationship was best fitted with the flat-ramp function to determine the bending position, the bending position was estimated within an error of about 1 km at 15 observation stations. On the other hand, at the observation stations located on the south side of ATL, O-C tended to increase as the aftershocks in the north. In addition, at the observation stations, aftershocks north of ATL are considered to have a shorter distance through the low-velocity zone than aftershocks in the low-velocity region, but the delay of seismic waves is larger. Thus, it is estimated that the northward and shallower the low velocity anomaly is larger. This suggests that the seismic velocity anomaly near the aftershock zone is due to the fault damage zone, not the geological boundary (material boundary) between the Tamba zone on the north side and the Ryoke zone on the south side.
It was found that the position of the northern end of the estimated low velocity zone is located so as to limit the northern end of the estimated source fault by Asano (2018). Regarding the southern end of the low velocity zone, aftershocks have not occurred far to the south of the estimated fault, and even if there is a flat part, its length is short, so it cannot be reliably estimated at this time. Although it was not, it is suggested that the source fault of the northern Osaka Prefecture earthquake may have occurred inside the fault damage zone of ATL. In particular, the fact that the northern limit of the source fault is limited by the ATL implies that although the earthquake started from the deepest part, the fault was limited to a depth of about 10 km or deeper and the rupture did not propagate to the shallow part.

Keywords: Intraplate earthquake, Active fault, Arima-Takatsuki Tectonic Line, Aftershock observation

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Fracture as an electrical conduction path under pressure

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Geophysical mapping of fluids is critical for understanding crustal processes. Interpretation of seismic velocity and electrical resistivity structures requires a thorough understanding of the pore structure that governs physical properties under high pressures. Watanabe et al. (2019) showed that wide aperture parts in cracks remain open to govern physical properties under high pressure. In the crust, there should be cracks with various sizes: from grain boundary to large faults. In order to understand the role of a fracture as a conduction path under high pressure, we have made measurements of elastic wave velocities and electrical conductivity in a brine-saturated granitic rock with single fracture. A cylindrical rock sample (D=26 mm, L=30 mm) with a single fracture was cored from a block (20 cm x 20 cm x 20 cm) of Aji granite, which was artificially fractured. The fracture goes through the sample from top to bottom. 3D structure of a fracture was imaged by X-ray micro CT before measurements. A sample was filled with 0.1 M KCl aqueous solution, and velocity and conductivity were simultaneously measured by using a 200 MPa hydrostatic pressure vessel. The pore-fluid was electrically insulated from the metal work by using plastic devices. Compressional wave velocity was measured in the direction subperpendicular to the fracture, while electrical conductivity in the axial direction.

Compressional wave velocity increases and electrical conductivity decreases with increasing confining pressure. The electrical conductivity at the atmospheric pressure was around one order of magnitude higher than that in intact samples. It greatly decreased from 0.1 MPa to 5 MPa and showed a gradual decrease at higher pressure. The conductivity at 150 MPa is only a few times as high as that in intact samples. Compared with grain boundary cracks, this fracture cannot work as a remarkably good conduction path. A misfit of fracture surfaces must increase conductivity at high pressure.

Keywords: crack, electrical conductivity, fluid

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Grain-boundary diffusion creep of olivine and the rheology of the oceanic upper mantle

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The mantle is known to have anisotropic elasticity, which is primarily explained by crystallographic preferred orientation (CPO) of olivine that forms during mantle flow. Because the CPO has long been considered to result uniquely from dislocation processes, diffusion creep has received less attention than dislocation processes. Recently, olivine CPO has been found to develop during diffusion creep under a condition that seems to correspond to the depth of seismically anisotropic mantle (Miyazaki et al., 2013). This led us to examine mantle viscosity in terms of olivine diffusion creep.
Diffusion creep of olivine is, however, a subject of some debate. Differences of up to two orders of magnitude in viscosity at the same grain sizes and temperatures have been reported from experimental diffusion creep studies. Impurity content can range significantly among samples synthesized by different methods and is known to affect diffusional properties through grain-boundary segregation.
Motivated by our previous findings on the segregation of Ca and Al at olivine grain boundaries, we synthesized and reported experimental creep results for fine-grained Fe-bearing olivine ($Mg_{1.8}Fe_{0.2}SiO_4$; so-called Fo_{90} olivine) aggregates that were variably doped with $CaO \pm Al_2O_3$ to explore the effect of Ca and Al on creep rate. By comparing creep properties of undoped and doped olivine aggregates, we identified the roles of Ca and Al in enhancing grain-boundary diffusion creep at $>0.92T_s$ (T_s: solidus in K), an effect which became significant with increasing temperature. We considered the enhancement to result from grain-boundary disordering promoted by grain-boundary segregation. Based on the Arrhenius-like behavior of the disordering effect, we established an olivine diffusion creep law that suitably describes the creep rates in both temperature ranges of $<0.92T_s$ and $>0.92T_s$.
We estimated solidus temperatures of the samples used in the previous diffusion creep experiments. These temperatures were used to compare previously reported diffusion creep rates for olivine with our established diffusion creep law. We found that the law explains a difference of up to two orders of magnitude in olivine creep rates at the same temperatures, stresses, grain sizes, and water contents in the previous studies. The geotherm normalized by the mantle solidus was calculated for the upper mantle with water contents up to 200 wt. ppm, which predicts depths where weak (low-viscosity) mantle is expected to occur due to enhanced grain-boundary diffusion creep.
Constructed viscosity–depth profiles based on our diffusion creep law reveal a very thin mantle lithosphere beneath mid-ocean ridges, with development of the lithosphere away from the ridge, leaving a low-viscosity region below. Given a grain size of 1 mm and depending on the water content, a viscosity of $2–5*10^{19}$ Pa s is predicted for the low-viscosity asthenospheric mantle beneath 50-million-year-old seafloor.

Keywords: olivine aggregates, Grain-boundary diffusion creep, The rheology of the oceanic upper mantle

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An inversion method of fault-slip analysis to deteremine stress tensor and friction coefficient

*Katsushi Sato[1]

1. Division of Earth and Planetary Sciences, Graduate School of Science, Kyoto University

Stress tensor inversion techniques are widely used to infer crustal stress state from fault-slip data and seismic focal mechanisms. A majority of the techniques is based on the assumption that a fault slips along shear stress direction on the fault planes (Wallace-Bott hypothesis). Such inversion techniques try to minimize the misfit angles between observed slip directions and calculated shear stress directions.
Since the orientations of fault planes themselves are expected to reflect mechanical condition of faulting, Sato (2016) proposed a method to calculate friction coefficient of observed faults by maximizing the fault instability (Vavrycuk, 2014). This method has a defect that it does not consider the precision of the optimal stress tensor separately determined by the preceding stress tensor inversion. In order to solve this problem, this study proposes a new method to simultaneously infer stress condition and friction coefficient from a set of fault-slip data. The present method combines the objective functions of inversion techniques to minimize the misfit angles and to maximize the fault instability.
Some artificial fault-slip data were analyzed to understantd the performance of the present method. As the result of the numerical experiments, the folowing two advantages were found. Firstly, the present method enhances the detectability of stresses when fault planes are concentrated in the orientations of high fault instability, although it was difficult to accurately determine the friction coefficients from heterogeneous (caused by multiple stresses) fault-slip data. Secondly, the method is moderately robust to the change in stress state after formation of fault planes.
The new method was applied to some examples of natural outcrop-scale faults. The first example is from the Pleistocene Oita Group, southwest Japan, which filled the Beppu-Shimabara graben. A NNE-SSW trending tensional stress and the friction coefficient of 0.58. The second example is from the Awa Group in the Boso Peninsula, central Japan, which filled a forearc basin of the Sagami Trough. The analysis showed NE-SW and NW-SE trending tensional stresses clearly. Additionally, a N-S trending compressional stress was detected, which has been difficult to detect with Wallace-Boot hypothesis-based stress tensor inversion techniques.

References
Sato, K., 2016, Journal of Structural Geology, 89, 44-53.
Vavrycuk, V., Bouchaala, F. and Fischer, T., 2013, Tectonophysics, 590, 189-195.

Keywords: fault-slip analysis, stress tensor inversion, friction coefficient, fault instability

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[J] Oral | S (Solid Earth Sciences)：S-CG Complex & General

Thu. Jun 3, 2021 1:45 PM - 3:15 PM JST | Thu. Jun 3, 2021 4:45 AM - 6:15 AM UTC | Ch.21 Zoom Room 21

[S-CG50] Dynamics in mobile belts

convener:Yukitoshi Fukahata(Disaster Prevention Research Institute, Kyoto University), Hikaru Iwamori(Earthquake Research Institute, The University of Tokyo), Kiyokazu Oohashi(Graduate School of Sciences and Technology for Innovation, Yamaguchi University), Chairperson:Keisuke Yoshida(Tohoku University), Yukitoshi Fukahata(Disaster Prevention Research Institute, Kyoto University)

The dynamic behaviors of mobile belts are expressed across a wide range of time scales, from the seismic and volcanic events that impact society during our lifetimes, to orogeny and the formation of large-scale fault systems which can take place over millions of years. Deformation occurs on length scales from microscopic fracture and flow to macroscopic deformation to plate-scale tectonics. To gain a physical understanding of the dynamics of mobile belts, we must determine the relationships between deformation and the driving stresses associated with plate motion and other causes, which are connected through the rheological properties of the materials. To understand the full physical system, an integration of geophysics, geomorphology, geology, petrology, and geochemistry is necessary, as is the integration of observational, theoretical and experimental approaches. In particular, rheological properties, which are physically affected by fluids in the crust and chemical reactions assisted by fluids, can be resolved only through such an interdisciplinary approach. After the 2011 great Tohoku-oki earthquake, large-scale changes in seismic activity and regional scale crustal deformation were observed, making present-day Japan a unique natural laboratory for the study of the dynamics of mobile belts. This session welcomes presentations from different disciplines, such as seismology, geodesy, tectonic geomorphology, structural geology, petrology, geochemistry and hydrology, as well as interdisciplinary studies, that relate to the dynamic behaviors of mobile belts.

1:45 PM - 2:00 PM JST | 4:45 AM - 5:00 AM UTC

[SCG50-13] Spatio-temporal patterns of inland stress field: Characteristics revealed by a new method using focal mechanisms and interseismic plate coupling, and its tectonic implication

★Invited Papers

*Kazutoshi Imanishi[1], Akemi Noda[2] (1.National Institute of Advanced Industrial Science and Technology, 2.Meteorological Research Institute)

2:00 PM - 2:15 PM JST | 5:00 AM - 5:15 AM UTC

[SCG50-14] Effects of ETS on seismicity and stress in the subducting oceanic plate

*Saeko Kita[1], Heidi Houston[2], Suguru Yabe[3], Sachiko Tanaka[4], Youichi Asano[4], Takuo Shibutani[5], Naoki Suda[6] (1.Building Research Institute, 2.University of California, 3.AIST, 4.NIED, 5.DPRI, Kyoto University, 6.Hiroshima University)

2:15 PM - 2:30 PM JST | 5:15 AM - 5:30 AM UTC

[SCG50-15] Prevailing updip ruptures in small interplate earthquakes along the Japan Trench revealed from land-based and offshore observations

*Keisuke Yoshida[1], Naoki Uchida[1], Hisahiko Kubo[2], Ryota Takagi[1], Shiqing Xu[3] (1.Tohoku University, 2.National Research Institute for Earth Science and Disaster Resilience, 3. Southern University of Science and Technology)

2:30 PM - 2:45 PM JST | 5:30 AM - 5:45 AM UTC

[SCG50-16] Spatiotemporal change in the inelastic strain rate due to aftershock activity of the 2016 Kumamoto earthquake sequence, in central Kyushu, Japan

*Ayaho Mitsuoka[1], Satoshi Matsumoto[2] (1.Department of Earth and Planetary Sciences, Graduate School of Science, Kyushu University, 2.Institute of Seismology and Volcanology, Faculty of Science, Kyushu University)

2:45 PM - 3:00 PM JST | 5:45 AM - 6:00 AM UTC

[SCG50-17] **Toward understanding earthquake mechanism based on theories of strain energy**
★Invited Papers

*Tatsuhiko Saito[1] (1.National Research Institute for Earth Science and Disaster Resilience)

3:00 PM - 3:15 PM JST | 6:00 AM - 6:15 AM UTC

[SCG50-18] Reconsideration of the energy balance in earthquake faulting - I: The origin of the background stress field

*Mitsuhiro Matsuura[1] (1.Institute of Statistical Mathematics)

Spatio-temporal patterns of inland stress field: Characteristics revealed by a new method using focal mechanisms and interseismic plate coupling, and its tectonic implication

*Kazutoshi Imanishi[1], Akemi Noda[2]

1. National Institute of Advanced Industrial Science and Technology, 2. Meteorological Research Institute

It is known that the activity of shallow inland earthquakes in the Kinki region, southwest Japan, increased from about 50 yr before to 10 yr after the occurrence of large interplate earthquakes along the Nankai trough (Utsu 1974; Hori & Oike 1999). We also know that inland seismic activity significantly changed before and after the 2011 Tohoku-oki earthquake. These observations indicate that the shallow inland earthquakes occur in response to the interseismic plate coupling, facilitating further research on the causal relationship between the inland earthquake activity and the interplate coupling state.

Imanishi and Noda (The 2020 SSJ Fall Meeting) proposed a method to investigate the inland stress field by examining whether the focal mechanisms of inland small earthquakes align with the stress field due to the plate coupling or not. The basic concept of this method is as follows:
(1) The total stress field is described as the background stress plus the temporally varying stress due to the plate coupling.
(2) There exist pre-existing faults with various orientations in the crust, most of which are close to a critically stressed state.
(3) Earthquakes will preferentially occur on faults whose slip direction is close or in agreement with the stress field due to the plate coupling, although earthquakes may occur on faults that are favorably oriented to the background stress field.

When an earthquake occurs in agreement with the stress field caused by the plate coupling, the misfit angle (i.e., the angle between the observed slip direction and the tangential traction predicted by the reference stress tensor) is expected to be a small value, and vice versa. Therefore, we can visualize the spatio-temporal patterns of inland stress field with respect to the plate coupling by taking the spatio-temporal average of the misfit angles.

We applied the method to inland earthquakes in southwestern Japan. We merged the JUNEC catalog (Ishibe et al. 2014) and the JMA catalog to produce the consolidated one, which results in a 35-year-long catalog. For the calculation of the stress tensor caused by the plate coupling, we adopted the slip-deficit model of Noda et al. (2018). The spatio-temporal distribution of misfit angles was obtained by taking a one-year moving average for each mesh at 0.25 ˚intervals. The results indicate that the misfit angle fluctuates considerably both temporally and spatially. We observe that earthquakes with a magnitude of 6 or larger, including the 2016 Kumamoto earthquake, tend to occur when the misfit angle was small. This is consistent with the observation that inland earthquakes occur in response to the interseismic plate coupling. On the other hand, the misfit angle fluctuates at a high level in the Chugoku region compared to other regions. We infer that a stress loading by the San-in shear zone (Nishimura and Takada, 2017) dominates the stress field in this area. It is also noted that the misfit angles change with a period of a few years in some regions. Such a cyclic stress change has also been reported by repeated measurements of in-situ stress in northern Kinki (Tanaka et al., 1998). Because the present method evaluates the effect of the plate coupling, this cyclic fluctuation can be attributed to the change of the state along the plate

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boundary (e.g., occurrence of slow slip event).

In summary, the subtle spatio-temporal variation of inland stress field can be detected by this method, which will lead to the elucidation of the relationship between the subduction process and the stress field in the Island-arc and the mechanism of inland earthquake generation. In the presentation on the day, we will report the characteristics of inland stress field before and after the Tohoku-oki earthquake by applying this method to the Tohoku region.

Keywords: inland stress field, spatio-temporal pattern, focal mechanism, interseismic plate coupling, tectonics

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Effects of ETS on seismicity and stress in the subducting oceanic plate

*Saeko Kita[1], Heidi Houston[2], Suguru Yabe[3], Sachiko Tanaka[4], Youichi Asano[4], Takuo Shibutani[5], Naoki Suda[6]

1. Building Research Institute, 2. University of California, 3. AIST, 4. NIED, 5. DPRI, Kyoto University, 6. Hiroshima University

Slow slip phenomena appear related to geofluids, but the detailed relationships among slow slip, geofluids, and intraslab earthquakes remain unknown. Here we report changes in seismicity rates, b-values, and stresses in the oceanic slab before and after slow slip episodes beneath Kii Peninsula, Japan. One month before slow slip occurrence, the seismic rate and b-value become high, consistent with the effects of fluid-induced seismicity. Intraslab stress orientations below the plate interface in the ETS zone change only slightly, whereas below the plate interface updip of ETS, the intraslab stress orientations rotate by a larger amount, suggesting that transient aseismic slip occurs on the interface updip. The existence of repeating earthquakes and seismicity on the plate boundary also implies that aseismic slip occurs on the updip zone after the ETS, which could reset the stress state of the slab and the boundary to its prior condition. The proposed methodology, which is based primarily on intraslab earthquakes, may help monitor plate boundary conditions and slow slip phenomena, which can signal the beginning stages of megathrust earthquakes in subducting plates.

Keywords: Slow slip, intrslab earthquake, stress field, seismicity, the southwestern Japan, Kii peninsula

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Prevailing updip ruptures in small interplate earthquakes along the Japan Trench revealed from land-based and offshore observations

*Keisuke Yoshida[1], Naoki Uchida[1], Hisahiko Kubo[2], Ryota Takagi[1], Shiqing Xu[3]

1. Tohoku University, 2. National Research Institute for Earth Science and Disaster Resilience, 3. Southern University of Science and Technology

A physical understanding of earthquakes involves not only the static characteristics of the ruptures but also the dynamics. Rupture directivity is a fundamental characteristic of earthquake growth and is essential for improving our current physical understanding of earthquakes. The recent development of seafloor seismic observations facilitates reliable estimation of the rupture directivities of offshore earthquakes. The present study used seismic waveforms obtained by a new seafloor seismic network (S-net) and onland stations to systematically examine the rupture directivities of interplate earthquakes along the Japan trench.

We first selected interplate earthquakes and estimated the apparent moment rate functions (AMRFs) by using the empirical Green’ s functions. We then estimated the rupture directions by applying the simple unilateral rupture model of Haskell (1964) to the duration of the AMRFs. As a result, the rupture directions were derived for 206 M_w 3.5–5 events, most of which occurred near the base of the seismogenic zone.

We found that most earthquake ruptures (>80 %) were directional. They primarily propagated in the updip direction, which is the opposite of the prediction from the bimaterial effect. On the contrary, deep, steady creep and upward fluid migration along the plate interface can facilitate rupture initiation near the deeper edge of the seismic patch and propagation in the updip direction, given that the nucleation size is sufficiently smaller than the final rupture area. The predominance of updip rupture in interplate earthquakes suggests that other effects, such as deep creep and upward fluid migration, can overtake the bimaterial effect in affecting earthquake ruptures in the subduction zone.

The updip ruptures redistributed the accumulated shear stress from the base of the seismogenic zone to the shallow large seismic patches. The updip ruptures may also open up ways for deeper fluids to migrate further upward along the plate interface. Both effects facilitate the occurrence of shallow megathrust earthquakes.

Keywords: Rupture directivity, interplate earthquakes, S-net

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Spatiotemporal change in the inelastic strain rate due to aftershock activity of the 2016 Kumamoto earthquake sequence, in central Kyushu, Japan

*Ayaho Mitsuoka[1], Satoshi Matsumoto[2]

1. Department of Earth and Planetary Sciences, Graduate School of Science, Kyushu University, 2. Institute of Seismology and Volcanology, Faculty of Science, Kyushu University

For a purpose of understanding physical process of earthquake generation, we investigate the stress and strain field around the hypocentral area of the 2016 Kumamoto earthquake sequence. The stress field around the region is normal or strike-slip type, and the magnitude of the stress tensor was estimated to be comparable to the stress change due to the maximum foreshock (Mj 6.5) and mainshock (Mj 7.3) [Mitsuoka et al., 2020]. Aftershock activity following the mainshock has persisted in the region to the present day.

Aftershock activity can be considered as an inelastic response to stress loading by large co-seismic slip of a mainshock. As known the modified Omori' s law [Utsu 1957], earthquake rate of the aftershocks follows the power law of lapse time from occurrence of the mainshock. Similarly, inelastic strain rate by aftershock activity follows a power law ($d\varepsilon/dt \propto t^{-p}$) [Matsumoto et al., 2020]. We defined the power -p in this relation as the *p-value* and investigated the spatial distribution of the p-value in the aftershock area of the 2016 Kumamoto earthquake sequence. We estimated the inelastic strain tensor in a spatial bin by summing the moment tensors [Kostrov, 1974] at several lapse time windows, and calculated the inelastic strain rate by the time length of each time window. In addition, we estimated the p-value by the least squares method, assuming that the inelastic strain rate follows the power law ($d\varepsilon/dt \propto t^{-p}$).

The p-value around large co-seismic slip area [e.g., Asano and Iwata, 2016; Mitsuoka et al., 2020] is high ($p>1$), therefore the deformation at this area can be interpreted as a response to elastic strain by the co-seismic faults when considering exponentiation fluids [e.g., Nanjo, 2007].

At extensions of the co-seismic fault (i.e. the southern Hinagu fault and the western of the Futagawa fault), we found the low p-value ($p<1$). The low p-value areas correspond to the area of the low co-seismic stress change (approximately less than 1 MPa) by the maximum foreshock and mainshock. The low p-value indicates the slow decay rate of the strain rate, and $p<1$ condition is that the inelastic strain increase over time. This suggests that post-earthquake activities such as afterslip cause the low p-value area. We discuss a fault slip model or an inelastic deformation in and around the target area that can explain the inelastic deformation in this low p-value region.

Keywords: inelastic strain rate, stress field, aftershock activity

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Toward understanding earthquake mechanism based on theories of strain energy

*Tatsuhiko Saito[1]

1. National Research Institute for Earth Science and Disaster Resilience

Earthquake faulting releases some strain energy from the earth. Some of the energy is dissipated on the fault and the rest of the energy radiates from the fault (e.g., Kostrov 1974; Rudnick & Freund 1981). This energy transformation is irreversible for earthquake faulting. We introduce our recent results using the theories of strain energy.

(i) Seismicity and strain energy
When the strain energy increases, the seismicity would become active. We developed a method to calculate the strain energy change caused by a dislocation in a stressed medium. Using this method, we evaluated the energy change distribution in the inland area of southwestern Japan caused by the Nankai-trough plate locking. In most of the inland area, the shear strain energy decreases by the NS compressional stress due to the plate subduction. In some areas, on the other hand, the shear strain energy increases because the plate coupling varies in space. We found that the seismicity tends to be high in the area where the shear strain energy increases (Saito et al. 2018 JGR; Noda et al. GRL 2020).

(ii) Minimum stress necessary for earthquake faulting
Since the amount of the released strain energy is identical to the sum of the energy dissipated on the fault and the radiated energy (e.g. Kostrov 1974), the strain energy, represented by the seismic moment, the initial stress, and the stress drop, needs to be larger than the radiated energy (Terakawa et al. 2018; Noda et al. 2020 GRL). Using this relationship, the minimum initial stress necessary for the earthquake generation can be derived (Saito and Noda 2020 GJI). Note that elastic dislocation theory predicts that seismic waves radiated from the fault are independent of the initial stress (e.g., Aki and Richards 2002). However, we can constrain the minimum initial stress by considering the energy transformation from the elastic energy to the radiated energy (e.g., Yoshida et al. 2020 JGR).

(iii) Necessary conditions for multi-segment ruptures.
If we assume a simple slip-weakening law in the energy conservation, we can estimate the fracture energy from the available energy and the radiated energy (Abecrombi and Rice 2005). The fracture energy is reported to be increased with the seismic moment (e.g., Viesca et al. 2015).
The available energy needs to be larger than the radiated energy for earthquake generation. We propose a necessary condition for multi-segment ruptures (Noda et al. 2020 EGU). We first estimated the stress rate distribution along the Nankai Trough by analyzing GNSS records (Noda et al. 2018 JGR) and recognized 4 peak stress-rate areas (off Cape Muroto, off Kii channel, Kumano-nada, and Enshu-nada) as asperity. We created various rupture scenarios including multi-segment ruptures of these asperities and evaluated available energy. If the stress accumulation rate is constant during the intersismic period, the available energy increases with the square of time since both average slip and the stress drop increases linearly. On the other hand, the fracture energy empirically increases more slowly than the available energy (e.g. Viesca et al. 2015; Ye et la. 2016). The available energy evaluated for each scenario increases with time, and eventually becomes larger than the fracture energy. Based on this idea, we introduce a necessary stress-accumulation time for each multi-segment rupture.

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We presented the energy conservation for an earthquake. It is also important to consider energy conservation over seismic cycles. Since the Nankai Trough has historical earthquake data, it is important to evaluate the energy balance taking into account the historical events for creating possible rupture scenarios (Noda and Saito 2021JpGU).

Keywords: strain energy, seismicity, multi-segment rupture

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Reconsideration of the energy balance in earthquake faulting - I: The origin of the background stress field

*Mitsuhiro Matsuura[1]

1. Institute of Statistical Mathematics

The occurrence of earthquakes can be regarded as brittle shear fracture at a fault, which releases a part of the total potential energy of the earth. Since the 1950s, many researchers have studied the energy balance in earthquake faulting, but there seems to be some incoherence among these studies. The essential reason is probably in various scientific developments during the last half-century; the introduction of the new paradigm of plate tectonics, the concept of moment tensor as source representation, and the fault constitutive law governing shear rupture. So, it will be worthwhile to reconsider the energy balance in earthquake faulting from the current perspective. In the first presentation of this study, we focus on the static energy balance and discuss the origin of the background stress field in the earth.

At the end of the 1950s, Steketee (1958) introduced the elasticity theory of dislocation into geophysics and considered the static energy balance for the formation of dislocation (tangential displacement discontinuity) in a prestressed elastic body bounded by a traction-free surface. He concluded that the strain energy is always increased, independently of the initial stress state, when a dislocation is formed (Steketee's paradox). An essential question is how the prestressed state can be made in the isolated elastic body. At the end of the 1960s, Savage (1969) gave a geophysical interpretation of the interaction energy between two stress systems (Eshelby, 1956) and shown that the formation of dislocation can decrease the elastic energy of the total system including a loading machine to produce the prestressed state. To sum up, in the case of the non-gravitating earth model, the release of elastic potential energy balances with the work done for shear faulting. I will give a straightforward derivation of the energy balance equation mentioned above. The point is that the loading process must be inelastic as well as the formation of dislocation, because the earth is an isolated body.

In reality, the earth is a self-gravitating body, and so we should consider the change in gravitational potential energy as well as the change in elastic potential energy. In the case of the self-gravitating earth model, as shown by Kostrov (1974) and Dahlen (1977), the release of the total (elastic and gravitational) potential energy balances with the work done for shear faulting. In their formulations, the total release of the gravitational potential energy is represented by the volume integral of the scalar product of gravity force and coseismic displacement over the entire earth. Savage & Walsh (1978) found that this volume integral could be transformed into the surface integral of the scalar product of gravity-origin deviatoric stress vector and tangential displacement discontinuity vector over the fault. The point is that the isotropic part of gravity-origin stress is independent of the work done for shear faulting. Anyway, they evaluated the change in gravitational potential energy due to earthquake faulting in a homogeneous, isotropic, elastic earth model, and concluded as follows: For dip-slip faulting in the earth, the gravitational energy change may be several orders of magnitude greater than the energy released; that large change in gravitational energy is compensated for by a similar change in stored elastic initial energy. If it is true, to evaluate the coseismic change in elastic potential energy alone will be meaningless.

In actuality, considering the rheological property of the earth's mantle and the steady seafloor spreading and oceanic plate subduction in long time scale, the stress field caused by self-gravitation must be nearly

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isotropic, and so it affects the strength of faults but not the energetics of earthquake faulting substantially. In other words, we may use the energy balance equation for the non-gravitating earth model in a good approximation, where the background deviatoric stress field is tectonic origin.

Keywords: earthquake faulting, elastic potential energy, gravitational potential energy, background stress field, inelastic strain

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[J] Oral | S (Solid Earth Sciences)：S-CG Complex & General

Thu. Jun 3, 2021 1:45 PM - 3:15 PM JST | Thu. Jun 3, 2021 4:45 AM - 6:15 AM UTC | Ch.19 Zoom Room 19

[S-CG51] New perspectives of subduction zone earthquake dynamics through experiments across-scales

convener:Masataka Kinoshita(Earthquake Research Institute, University of Tokyo), Chairperson:Masataka Kinoshita(Earthquake Research Institute, University of Tokyo), Toshinori Kimura(Japan Agency for Marine-Earth Science and Technology)

Knowledge on subduction zone earthquake phenomena has considerably increased in the last decade. On the other hand, there are limits to seismological approach alone to comprehensively elucidate the earthquake mechanism in which phenomena that differ by 10 orders of magnitude in space and time, from earthquake nucleation/growth processes to its driving force. Steps to enable scientific earthquake forecasting should include; monitoring regional seismic/tectonic activity using networked observatories, sampling of and insitu measurement in seismogenic faults and plate materials through ultra-deep drilling, and reproduction/insitu-observation of fracture nucleation processes by high-pressure quantum-beam experiments. Through a close collaboration, we challenge a dynamic imaging of earthquake processes. Based on the proposal approved as a Large Research Master Plan 2020 of the Science Council of Japan, we will deepen the interdisciplinary discussion on subduction-zone earthquakes and the state & property of lithosphere. We welcome, but not limited to, presentations from fields of ocean and land networks observation, seismogenic zone drilling, rock mechanical & quantum beam experiments, fracture process
theory, etc.

1:45 PM - 2:00 PM JST | 4:45 AM - 5:00 AM UTC

[SCG51-01] Current status and future plan of deformation and fracture experiments at SPring-8/BL04B1

★Invited Papers

*Yuji Higo[1] (1.Japan Synchrotron Radiation Research Institute)

2:00 PM - 2:15 PM JST | 5:00 AM - 5:15 AM UTC

[SCG51-02] Ultrasonic elastic wave velocity measurement of antigorite at high pressures to 10 GPa

*Yoshio Kono[1], Riseno Nose[1], Nozomi Kondo[1], Ken-ichi Hirauchi[2] (1.Geodynamics Research Center, Ehime University, 2.Shizuoka University)

2:15 PM - 2:30 PM JST | 5:15 AM - 5:30 AM UTC

[SCG51-03] Depth-dependent frictional properties of mud gouge in the Nankai Trough accretionary prism

*Kyuichi Kanagawa[1], Tomohiro Ishii[2], Tomoya Funaki[2], Junya Fujimori[3], Michiyo Sawai[1] (1.Graduate School of Science, Chiba University, 2.Faculty of Science, Chiba University, 3.Graduate School of Science and Engineering, Chiba University)

2:30 PM - 2:45 PM JST | 5:30 AM - 5:45 AM UTC

[SCG51-04] Seafloor fiber optic strainmeter performance with different cable laying condition.

*Eiichiro Araki[1], Shuhei Nishida[1], Takashi Yokobiki[1], Matthew James Cook[1], Mark Zumberge[2], Toshinori Kimura[1], Yuya Machida[1], Shuichi Kodaira[1] (1.Japan Agency for Marine-Earth Science and Technology, 2.IGPP, Scripps Institution of Oceanography)

2:45 PM - 3:00 PM JST | 5:45 AM - 6:00 AM UTC

[SCG51-05] Real-time SSE monitoring by optical borehole tiltmeter in the Nankai Trough, Japan

*Toshinori Kimura[1], Eiichiro Araki[1], Takashi Yokobiki[1], Shuhei Nishida[1], Matthew J Cook[1], Mark Zumberge[2], Keisuke Takahashi[3], Takane Hori[1], Shuichi Kodaira[1] (1.Japan Agency for Marine-Earth

Science and Technology, 2.Scripps Institution of Oceanography, 3.UBE Industries, Ltd.)

3:00 PM - 3:15 PM JST | 6:00 AM - 6:15 AM UTC

[SCG51-06] Thermal maturity observations depend on the structural history of the wedge

*Utsav Mannu[1], David Fernández-Blanco[2], Ayumu Miyakawa[3], Taras Gerya[4], Masataka Kinoshita[5]
(1.Indian Institute of Science Education and Research Pune, 2.Barcelona Center of Subsurface Imaging, Institut de Ciències del Mar (ICM-CSIC), Barcelona, 3.Geological Survey of Japan, AIST, 4.Institute of Geophysics, ETHZ Zurich, 5.Earthquake and Volcano Information, Earthquake Research Institute, Tokyo-U)

Current status and future plan of deformation and fracture experiments at SPring-8/BL04B1

*Yuji Higo[1]

1. Japan Synchrotron Radiation Research Institute

In the past 20 years, the understanding of the crystal structure and chemical composition of minerals that make up the Earth's inner spherical shell structure has been dramatically improved by in situ observation experiments using synchrotron radiation under high pressure at SPring-8. On the other hand, high-resolution seismic tomography and other techniques have revealed the heterogeneity of the Earth's interior, and a unified understanding of global dynamics and geological phenomena such as earthquakes and volcanoes, which are closely related to human life, is now required. In the future, there is an urgent need to accumulate experimental data necessary for constructing a dynamic picture of the Earth, such as the fracture of mantle minerals, plastic flow, viscoelasticity, elemental diffusion, and viscosity, foaming, and partial melting of magma, which are necessary for interpreting seismic tomography from a material science perspective. In this presentation, we will introduce the past efforts of deformation and fracture experiments at SPring-8/BL04B1, and the future plans for the advancement of these experiments to capture the dynamic phenomena.

Keywords: Synchrotron Radiation Experiment, High pressure

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Ultrasonic elastic wave velocity measurement of antigorite at high pressures to 10 GPa

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Knowledge of P- (Vp) and S-wave (Vs) velocities of antigorite is important to understand low seismic wave velocity anomalies in subduction zones. Efforts have been made to understand Vp and Vs of antigorite at high pressure conditions of subduction zones, while there are serious discrepancies in the Vp and Vs results at high pressures (>1 GPa) in previous studies (Bezacier et al., 2013; Wang et al., 2019). Here we investigated elastic wave velocities of natural antigorite sample up to ~10 GPa. The natural serpentinite sample, collected from the Nagasaki metamorphic rocks, is mainly composed of antigorite with minor amounts (<3.5 %) of other minerals. The sample does not show any clear planar and/or linear structures. Four samples were cored from orthogonal directions to check possible inhomogeneity of the rock sample. Sample size is 4.5 mm in diameter and 1.5-1.9 mm in length. Ultrasonic Vp and Vs measurements were conducted up to 8.5-10.3 GPa under room temperature condition in 1000 ton multi-anvil high-pressure apparatus.

Vp of the antigorite increases with increasing pressure below 4-5 GPa, while it starts to decrease at higher pressures. Vs also increases with increasing pressure at low pressures of <2.5-3.5 GPa, while it decreases at higher pressures. Vp/Vs ratio shows increase with increasing pressure. There are some variations in the Vp, Vs, and Vp/Vs ratio of antigorite obtained in four experiments, which are interpreted as due to inhomogeneous proportion of other mineral constituents. Vp, Vs, and Vp/Vs ratio of pure antigorite is calculated by linear fitting of four experimental results as a function of proportion of other mineral constituents. Our obtained Vp, Vs, and Vp/Vs ratio of antigorite is consistent with the results of Bezacier et al. (2013). In contrast, Vp, Vs, and Vp/Vs ratio reported in Wang et al. (2019) shows markedly different values compared to those of this study and Bezacier et al. (2013).

Keywords: Serpentine, Elastic wave velocity, High pressure

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Depth-dependent frictional properties of mud gouge in the Nankai Trough accretionary prism

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In order to investigate the depth-dependent frictional properties of mud gouge in the Nankai Trough accretionary prism, we conducted triaxial friction experiments on gouge of a mud sample cored from 2183.6 mbsf (meters below seafloor) at IODP Site C0002, at pressure, pore-water pressure and temperature conditions supposed at depths of 1000–6000 mbsf there, and axial displacement rates V_{axial} changed stepwise among 0.1, 1 and 10 μm/s.

The results show that the steady-state friction coefficient μ_{ss} decreases from 0.32–0.35 at the 1000 mbsf condition to 0.29–0.31 at the 3000 mbsf condition, while it increases from those values at that condition to 0.34–0.37 at the 6000 mbsf condition. Fitting the friction data for each step change in V_{axial} by the rate-and state-dependent friction constitutive law reveals that ($a-b$) value (rate dependence of μ_{ss}) monotonously decreases from positive values at the 1000 mbsf condition through ≈0 at the 5000 mbsf condition to negative values at the 6000 mbsf condition.

Dehydration of smectite at the 3000 mbsf condition where temperature was 100℃ possibly increased pore pressure in the impermeable gouge layer, which was likely responsible for the minimum μ_{ss} at this condition. This suggests the presence of a high pore-pressure zone at ≈3000 mbsf of IODP Site C0002 due to dehydration of smectite in impermeable mud sediments. Our experimental results also suggest a transition from aseismic faulting with $a-b>0$ to potentially seismic faulting with $a-b<0$ at ≈5000 mbsf of IODP Site C0002. In fact, stick-slip corresponding to seismic faulting was observed at the 6000 mbsf condition.

Keywords: mud gouge, frictional properties, Nankai Trough accretionary prism

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Seafloor fiber optic strainmeter performance with different cable laying condition.

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1. Japan Agency for Marine-Earth Science and Technology, 2. IGPP, Scripps Institution of Oceanography

Measuring seafloor strain in long baseline, can be powerful means to observe dynamics occurring at depth, because local interference at the seafloor may be reduced by averaging over the long baseline, while the effect of strain source at depth does not. Aiming at capturing slow crustal deformation which may episodically occur in the subducting plate interface, we installed a seafloor fiber strainmeter, which measures length of 200 m long optical fiber laid in the seafloor, in the Nankai Trough seafloor in June, 2019 (Araki et al., 2019). The instrument is linked to the DONET (Dense Ocean-floor Network for Earthquake and Tsunamis) and data is continuously obtained through the network. Since the initial installation, we have conducted a series of seafloor experiments by remotely operated vehicle (ROV) to investigate how we can make observation of seafloor strain with low-noise enough to capture expected slow slip event.

In the initial installation, we aimed to surficial bury the fiber cable in the seafloor by a few cm by ROV towed sled. This was partially successful, but we noticed the laid fiber was slightly meandered and suspected if the measured strain really represents distances between two end points of the fiber cable. Therefore, we pulled up and retention the fiber in October 2019 to lay the cable straight but not buried in the seafloor. The modified lay resulted in more reasonable response of the fiber length over long-term, which showed more rapid, but decaying drift. We consider the decaying drift characteristics reflected that the tension acting on the fiber was distributed along the whole length unlike the initial installation. The drawback of the retention fiber in the seafloor, on the other hand, is that a part of the fiber is not in friction to the seafloor sediment, but suspended in the water due to small undulation of the seafloor topography. Behavior of such suspended fiber is difficult to predict, because slight change in the contact surface of the fiber cable could result in the shift of the cable, leading to the total length change. We considered that reasonable friction between the laid fiber cable and the seafloor sediment was necessary to suppress such non-linear behavior. So, we revisited the seafloor strainmeter site again in August 2020, to visually check the condition of laid fiber by ROV camera, and placed metallic plates to secure the cable in contact with the sediment where was suspended in the water. After the seafloor operation, unexpected shift of observed strain data did not occur, and the strain data became quiet enough for low frequency seismic observation. Long-period stability of the measured fiber strain data is approximately 200 nano-strain after reduction of long-term trend and effect of ocean tide, stable enough to expect observation of slow slip event of moderate size, if occurred at the plate interface beneath the instrument.

We are currently planning to install more fiber strainmeters in the Nankai Trough. In the future installations, care need to be taken to completely bury the sensing fiber in the sediment while the whole length is laid straight so that measured fiber strain truly represents strain of the seafloor sediment.

Keywords: fiber optic strainmeter, seafloor observation, slow slip event, slow earthquakes

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Real-time SSE monitoring by optical borehole tiltmeter in the Nankai Trough, Japan

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In the Nankai Trough subduction zone, a submarine cable network observation system named DONET has been in operation. The DONET system was originally equipped with broadband seismometers and pressure gauges to observe broadband real-time seismic and tsunami activities and vertical displacement of the seafloor above the source region of the mega-thrust earthquake which occurs every 100 to 150 years. The DONET system has an ability to expand observation by connecting new sensors to the observation node. To monitor small and slow crustal deformation, three borehole observatories, each having a tiltmeter, a strainmeter and a pore-fluid pressure gauge installed in the bottom of boreholes with depths of 500 to 900 mbsf, have been connected to the DONET nodes since 2013. Long-term data observed by the borehole sensors revealed that a slow slip event (SSE) of several weeks period has occurred repeatedly and accommodated about half of the plate motion (Araki et al., 2017). SSE monitoring in a wide area along the plate subduction zone enables us to estimate spatio-temporal change of interplate coupling, which would be a key parameter for the assessment of the rupture region of the future mega-thrust earthquakes.

In recent efforts, we have developed and installed new sensors, including a fiber optic strainmeter on seafloor and a bubble type tiltmeter in the shallow borehole with diameter of 104 mm and depth of 8.6 mbsf drilled by BMS (Boring Machine System) in the DONET 2F and 1B areas since 2019. These pilot observatories have been installed and operated to observe SSE distributed along the DONET region. Initial data observed by these sensors suggested that they have the ability to capture weak signals related to SSE. However, the observed data suggested that the coupling condition of sensors on the seafloor and in the borehole is very important to measure weak signals. Also, new sensors which have higher stability and lower self-noise than conventional sensors are still needed.

Accordingly, we prepared a new sensor and installation scheme for high-quality real-time SSE monitoring. For the new sensor, we fabricated an optical tiltmeter, which was originally developed by Scripps Institution of Oceanography. The tiltmeter has two long pendulums that swing with length of ~40 cm around orthogonal horizontal axes while their weighted ends are tracked by Michelson interferometers (Zumberge et al., 2018). The power unit and data transmission scheme were modified for DONET protocol. The optical tiltmeter was tested in a shallow borehole drilled in the Kamioka mine for 6 weeks from Oct. to Dec. 2020, and was compared with a broadband seismometer, CMG3T, same as DONET seismometers. We performed power spectral density analysis and phase analysis using ambient noise records and teleseismic records. Results confirmed that the optical tiltmeter can observe broadband signals from approx. 0.001 Hz to several ten Hz with the same flat amplitude and phase responses as those of the broadband seismometer. In long-term data, the stability of the optical tiltmeter was almost the same level as the bubble type tiltmeter. These results suggest that the optical tiltmeter can observe broadband seismic signals and geodetic signals. We developed a new installation scheme for the tiltmeter in a high stability environment created by drilling a borehole and cementing in the sensor. BMS was modified for drilling a large diameter of Φ230 mm with 20 m depth for the optical tiltmeter.

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Cement-based mortar with special formulation for sensor installation was developed. A mortar deployment system by ROV (Remotely operated vehicle) was developed including the pumping system. A special winch unit was also developed for the tiltmeter installation by ROV.

The tiltmeter was successfully installed into a 19 m borehole on 26 Jan. 2021 by KM-ROV. Before the installation, the borehole was drilled by the BMS, and a greater than 2 m interval at the bottom of the borehole was filled with cement. The optical tiltmeter was then installed by the winch system. On 11 Feb. 2021, the tiltmeter was connected to the DONET network by ROV Hyper Dolphin. The optical tiltmeter is now on-line transmitting continuous tilt data. Preliminary results of timeseries and PSD analysis suggest that the optical borehole tiltmeter has lower noise level than that of horizontal component of the DONET broadband seismometer in long-period seismic band. We expect that the tiltmeter can measure weak horizontal signal related to teleseismic and very low frequency earthquakes, which cannot be captured by DONET seismometer. In this presentation we will show initial data observed by the tiltmeter including seismic signals and tidal response.

Keywords: Nankai Trough, Slow slop event, Optical tiltmeter

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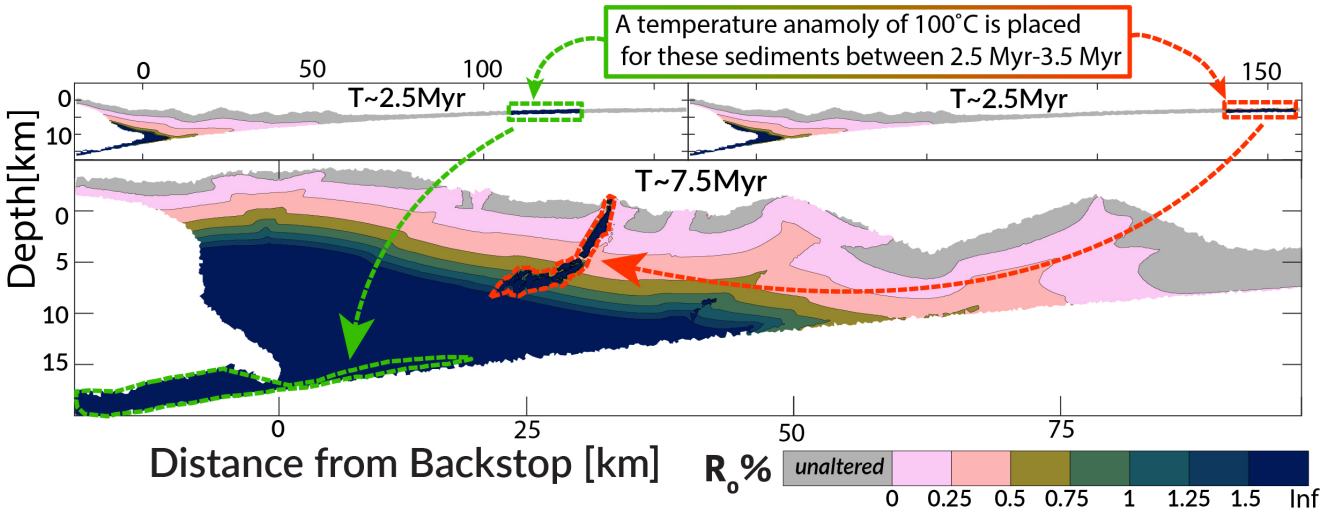
Thermal maturity observations depend on the structural history of the wedge

*Utsav Mannu[1], David Fernández-Blanco[2], Ayumu Miyakawa[3], Taras Gerya[4], Masataka Kinoshita[5]

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Estimations of the thermal evolution of sediments from thermal maturity proxies like vitrinite reflectance overlook the influence of fault patterns in wedge evolution. Our numerical study uses conservative 2D finite-difference thermomechanical models of subduction to show that the distribution of faults in the wedge, and particularly, the location of the frontal thrust, is critical to providing feasible inferences for thermal maturity observations. Given that the fault patterns that occur during wedge evolution are influenced by external factors, such as sedimentation, erosion, incoming sediment thickness, the topographic gradient in the slab, etc., these factors also control the thermal maturity of wedge sediments. Our observations support the existence of low and high maturity paths in the wedge, and more relevantly, constraint the conditions of preference of specific pathways. Our results also show that the thermal maturity distribution inside the wedge is most robust in the shallower part of the wedge for sediments at the highest structural locations and that thermal maturity inferences ought to account for the structural patterns of wedge evolution.

Keywords: Accretionary Wedge, Thermal maturity, Geodynamic modeling



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[J] Oral | S (Solid Earth Sciences)：S-CG Complex & General

Thu. Jun 3, 2021 9:00 AM - 10:30 AM JST | Thu. Jun 3, 2021 12:00 AM - 1:30 AM UTC | Ch.18 Zoom Room 18

[S-CG52] Driving Solid Earth Science through Machine Learning

convener:Hisahiko Kubo(National Research Institute for Earth Science and Disaster Resilience), Yuki Kodera(Meteorological Research Institute, Japan Meteorological Agency), Makoto Naoi(Kyoto University), Keisuke Yano(The Institute of Statistical Mathematics), Chairperson:Yuki Kodera(Meteorological Research Institute, Japan Meteorological Agency)

The development of machine learning techniques, such as deep learning, has led to innovations in various fields and is gaining ground in the solid earth sciences. This session provides an opportunity to inspire each other for future developments by bringing studies of machine learning applications in various fields including solid earth science. We especially welcome researches that have led to the discovery of phenomena and theories in solid earth science. We also look forward to studies on the black box problem of deep learning and efforts toward explainable AI.

9:00 AM - 9:15 AM JST | 12:00 AM - 12:15 AM UTC

[SCG52-01] Crustal stress inferred from focal mechanism solutions based on P wave first-motion polarities picked using deep learning

*Takahiko Uchide[1], Takahiro Shiina[1], Kazutoshi Imanishi[1] (1.Research Institute of Earthquake and Volcano Geology, Geological Survey of Japan, National Institute of Advanced Industrial Science and Technology (AIST))

9:15 AM - 9:30 AM JST | 12:15 AM - 12:30 AM UTC

[SCG52-02] Automatic seismic arrival-time picking of seismogram sampled at 250 Hz using Deep Learning

*Shinya Kato[1], Yoshihisa Iio[2], Hiroshi Katao[2], Masayo Sawada[2], Kazuhide Tomisaka[2], Rie Mizushima[2] (1.Graduate School of Science, Kyoto University., 2.Disater Prevention Research Institute, Kyoto University)

9:30 AM - 9:45 AM JST | 12:30 AM - 12:45 AM UTC

[SCG52-03] Deep-neural-network-based arrival-time picking and earthquake location: application to S-net

*Rintaroh Suzuki[1], Naoki Uchida[1], Weiqiang Zhu[2], Takashi NAKAYAMA[1], Genti Toyokuni[1], Ryota Takagi[1], Ryosuke Azuma[1], Gregory C Beroza[2] (1.Graduate School of Science, Tohoku University, 2.Department of Geophysics, Stanford University)

9:45 AM - 10:00 AM JST | 12:45 AM - 1:00 AM UTC

[SCG52-04] Induced Earthquakes Before and After Cessation of Longterm Injections in Rongchang Gas Field, Sichuan, China

*Zhiwei Wang[1], Xinglin Lei[2], Jinrong Su[3], Shengli Ma[1], Yusuke Mukuhira[4] (1.Institute of Geology, China Earthquake Administration, 2.Geological Survey of Japan, AIST, 3.Earthquake Monitoring Centre, Sichuan Earthquake Administration, 4.Institute of Fluid Science, Tohoku University)

10:00 AM - 10:15 AM JST | 1:00 AM - 1:15 AM UTC

[SCG52-05] Site Generalization Performance of Ground Motion Models: Application of Monotonic Neural Networks

*Tomohisa Okazaki[1], Nobuyuki Morikawa[2], Hiroyuki Fujiwara[2], Naonori Ueda[1] (1.RIKEN Center for Advanced Intelligence Project, 2.National Research Institute for Earth Science and Disaster Resilience)

10:15 AM - 10:30 AM JST | 1:15 AM - 1:30 AM UTC

[SCG52-06] Prediction of natural disasters based on a hybrid approach of physics-driven and data-driven method

★Invited Papers

*Takashi Miyamoto[1] (1.University of Yamanashi)

Crustal stress inferred from focal mechanism solutions based on P wave first-motion polarities picked using deep learning

*Takahiko Uchide[1], Takahiro Shiina[1], Kazutoshi Imanishi[1]

1. Research Institute of Earthquake and Volcano Geology, Geological Survey of Japan, National Institute of Advanced Industrial Science and Technology (AIST)

Understanding of crustal deformation and forecast of inland earthquakes need knowledge on the crustal stress orientation. Estimated stress orientations have been compiled as the World Stress Map (Heidbach et al., 2018). In the case of the Japan Islands, Terakawa et al. (2010) estimated the stress orientations using moment tensor solutions from the routine catalog of NIED F-net for typically M 3.5 or greater. Yukutake et al. (2015) used focal mechanism solutions that were determined using manual picks of P wave first-motion polarities. The resolution of the stress field estimation is limited by data. Moreover, there are many areas with no focal mechanism solutions and then the stress field cannot be estimated in this way. There is a case that stress orientations inferred from focal mechanism solutions of microearthquakes were clearly different from their surroundings (e.g., Imanishi et al. (2012)), which suggests that the interpolation of the stress estimation does not always work. Therefore, we desire the focal mechanisms of even more earthquakes. Thanks to the recent development of deep learning, Uchide (2020) studies focal mechanisms of ~ 110 thousand events with M 1.5 or larger beneath Japan Islands. Using this technique, we estimate focal mechanisms of even more earthquakes and the crustal stress orientation of the Japan Islands.

First, we determined focal mechanisms of small to microearthquakes around Japan Islands by the HASH method (Hardebeck and Shearer, 2002) using P-wave first-motion polarities. Seismic data were from NIED Hi-net, JMA, and GSJ/AIST. P-wave arrival times were from the JMA catalog and first-motion polarities were picked by the neural network model of Uchide (2020). We selected earthquakes with JMA magnitudes greater than 0.5, inside of or within 50 km from coastlines of Japan Islands, and at depths less than 20 km. As a result, we analyzed ~ 573 thousand events, which is approximately five times more than those studies by Uchide (2020). We obtained “A” to “C” rank solutions for more than 195 thousand events, which was used for the following stress inversion analysis.

The stress orientation was estimated using the SATSI code (Hardebeck and Michael, 2006). The grid interval was 0.2° for both latitude and longitude. Several small-scale stress anomalies were seen: normal faulting areas in northeast Japan and stress anomaly around Cape Shionomisaki of Kii peninsula, beneath which a high-density block was detected (Honda and Kono, 2005). The spatial changes in the stress orientation were often seen on tectonic lines and faults, such as the southern end of Itoigawa-Shizuoka Tectonic Line, the Median Tectonic Line in Shikoku island, Nagato-Hida marginal Tectonic Line in Chugoku region, and Hinagu and Futagawa faults in Kyushu island. This spatial correspondence can be a clue to investigate the cause of the stress orientation changes.

Acknowledgment
We used phase data from JMA Unified Earthquake Catalog, and seismic data from NIED Hi-net, JMA, and GSJ/AIST. We also used the HASH code (Hardebeck and Shearer, 2002) and the SATSI code (Hardebeck and Michael, 2006). This work was supported by the AIST EDGE Runners project.

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Keywords: Seismology, Crustal Stress, Focal Mechanisms, Stress Inversion, Deep Learning

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Automatic seismic arrival-time picking of seismogram sampled at 250 Hz using Deep Learning

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1. Graduate School of Science, Kyoto University., 2. Disater Prevention Research Institute, Kyoto University

Accurate seismic arrival-times are required to detect accurate earthquake location and to estimate a velocity structure. In recent years, the number of observation data has been increasing. In particular, We have installed high dense seismic station networks (Manten network) with 250 Hz sampling in Kinki, San-in and Nagano (Miura et al., 2010; Iio., 2010; Iio et al., 2017). The amount of data used for analysis has been increasing as seismic stations have been increasing, but the workload has also been increasing since arrival-time picking is a very time-consuming task.

Automatic arrival-time picking algorithms that can detect arrival-time in a shorter time than humans have been proposed. Conventional automatic arrival-time picking algorithms (Allen., 1978; Sleemen & van Eck., 1999) has poor accuracy, but recently, automatic arrival-time picking algorithms using deep learning (Ross et al., 2018; Zhu and Beroza, 2018; Hara et al., 2020) has been proposed and reported that models made by automatic arrival-time picking algorithms using deep learning are comparable to human accuracy.

In this study, in order to reduce the workload, we made an automatic arrival-time picking model. An algorithm used to make the model is PhaseNet (Zhu and Beroza., 2018). It can output probability values of P-wave, S-wave, and Noise (The Noise probability is calculated by Prob.(Noise) = 1− Prob.(P-wave) −Prob.(S-wave)) for each sampling point of input waveform. Currently, the automatic arrival-time picking model made by PhaseNet is available (https://github.com/wayneweiqiang/PhaseNet), but that model used 100 Hz sampling waveforms for training. Therefore, it is necessary to make the model that is suitable for seismic waveforms obtained with 250 Hz sampling.

For the training of PhaseNet, we used waveforms of M-0.9 to 4.7 recorded by the Manten network in San-in during the period of March to October 2015, whose arrival-times were detected by experts. Although this data set and data set used in Hara et al.(2020) are partially the same, the accuracy of the arrival-time used in this study is better than data used in Hara et al.(2020) due to the redetection of experts. The inputs to PhaseNet are three-component waveforms, and the available model was trained with UD, NS, and EW as input. In this study, we trained PhaseNet for the following three cases, taking into account the fact that when we have detected S-wave arrival-times of seismic waveforms obtained by Manten network, we have usually used SH components.

Case 1 : Model trained by UD, EW and NS
Case 2 : Model trained by UD, SH wave and 0 as missing value
Case 3 : Model trained by UD, SH wave and SH wave (copy)

The accuracies of the three models were evaluated, and the automatic arrival-time picking model of the 250 Hz sampling waveform was made. In this presentation, the accuracy evaluation of the models and the results by the models will be presented.

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Keywords: deep learning, arrival-time picking, Manten network

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Deep-neural-network-based arrival-time picking and earthquake location: application to S-net

*Rintaroh Suzuki[1], Naoki Uchida[1], Weiqiang Zhu[2], Takashi NAKAYAMA[1], Genti Toyokuni[1], Ryota Takagi[1], Ryosuke Azuma[1], Gregory C Beroza[2]

1. Graduate School of Science, Tohoku University, 2. Department of Geophysics, Stanford University

1. Introduction

Off the Pacific coast of Tohoku Japan, the new cabled ocean bottom seismic network (S-net) gives us a large number of seismograms of offshore earthquakes. Automatic arrival time picking (hereafter, phase picking) and event location methods make an important contribution for fast earthquake detection and location from such a large dataset. In our previous study, we evaluated a phase picking method based on a deep neural network, PhaseNet (Zhu and Beroza, 2019) for application to S-net (Suzuki et al., 2020: JpGU-AGU Joint Meeting). Although we used the pre-trained model with the seismic data in northern California for the phase picking, PhaseNet showed comparable or better performance compared with two other automatic phase picking methods. In this study, we train PhaseNet using S-net data and estimate arrival times with the newly trained PhaseNet. We then, associate the phases to detect events and estimate their hypocenters.

2. Data and method

The S-net has been deployed since 2013 by the National Research Institute for Earth Science and Disaster Resilience, and the continuous records from 2016 are available. We focused on a M5.6 event on Aug. 8. 2018 (hereafter, the mainshock) that occurred near the Japan trench offshore Miyagi. Note that the S-net data has been used for JMA’ s hypocenter location since September 2020. We first trained the PhaseNet with data from 150 S-net and 492 other land stations by 727 events. We used 98,766 manual picks from onshore (39,858) and offshore (58,918) stations in the Tohoku region. The number of the P and S wave picks are the same. After training PhaseNet, we used continuous waveform data from 9 S-net stations near the mainshock for phase picking by the newly trained PhaseNet for the period from 1 week before to 2 weeks after the mainshock. We then performed earthquake detection by associating the picked phases to individual events using a phase association method (REAL; Zhang et al., 2019) to find new events offshore Tohoku. This method REAL associates P and S phases from multiple stations with a single event and locates its hypocenter with a grid search to minimize the travel time residuals. We searched potential hypocenters shallower than 50 km and within the area of 0.48 ×0.48 degrees area centered at the station that recorded the first-arriving phase for each events. Finally, we refined the hypocenter location by a nonlinear earthquake location method (hypomh; Hirata and Matsu’ ura, 1987).

3. Results

The newly trained PhaseNet using S-net and land stations data achieved good performance (F1 score: harmonic mean of precision and recall rate) for both P (0.745) and S (0.494) waves. This F1 score is better than that of the original model (0.409 for P waves and 0.283 for S waves) that was trained by the northern California data. This suggests despite the smaller number (1/10) of training data, the new model trained with S-net data has better performance for S-net data.

Using the newly trained model of PhaseNet and the phase association method (REAL), we detected 106 events in the region during the three-week period while JMA listed 43 events using land data only. This suggests the sequential application of PhaseNet and REAL is potentially effective to automatically detect new earthquakes. We expect that the phase picking method based on a deep neural network will

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contribute to revealing the detailed seismicity offshore Tohoku, Japan by using S-net waveform data.

Keywords: S-net, Neural networks, Computational seismology, Seismic monitoring

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Induced Earthquakes Before and After Cessation of Longterm Injections in Rongchang Gas Field, Sichuan, China

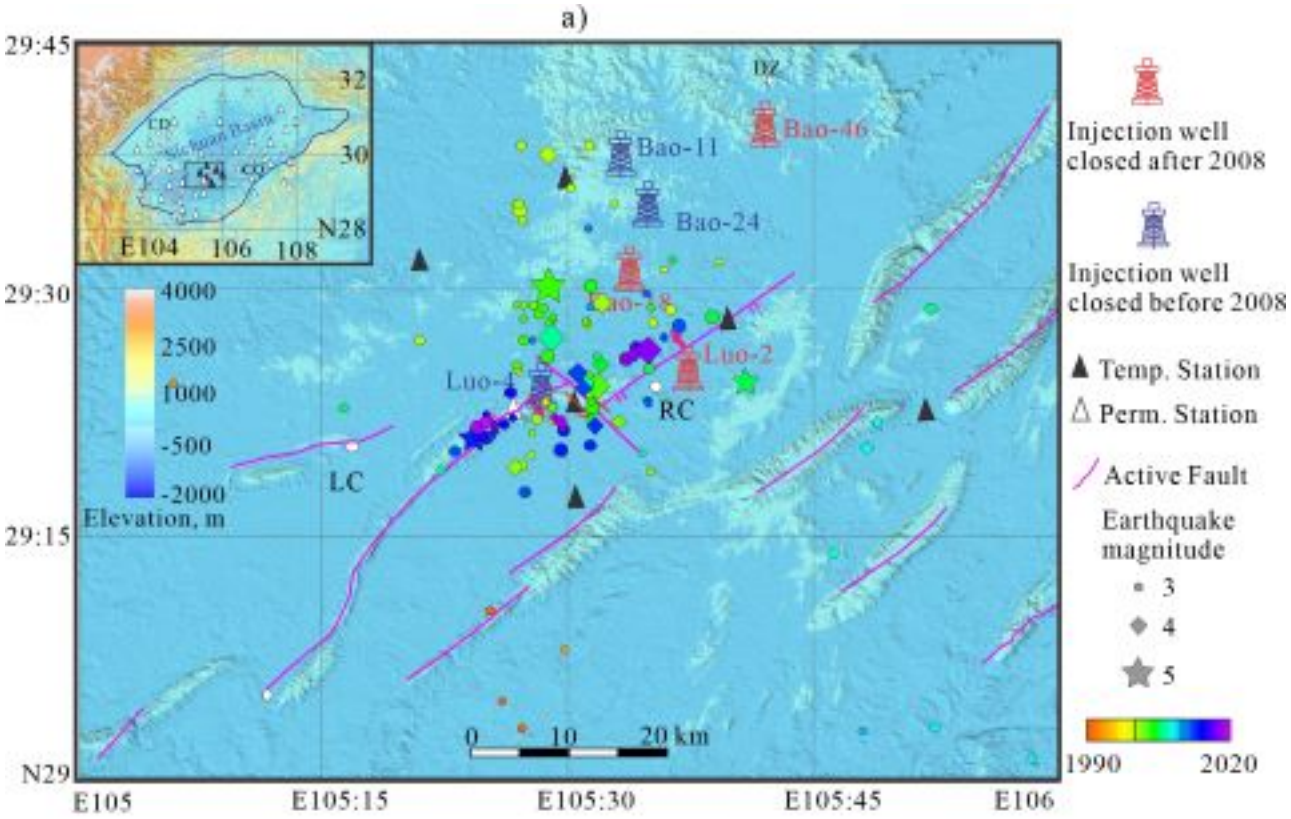
*Zhiwei Wang[1], Xinglin Lei[2], Jinrong Su[3], Shengli Ma[1], Yusuke Mukuhira[4]

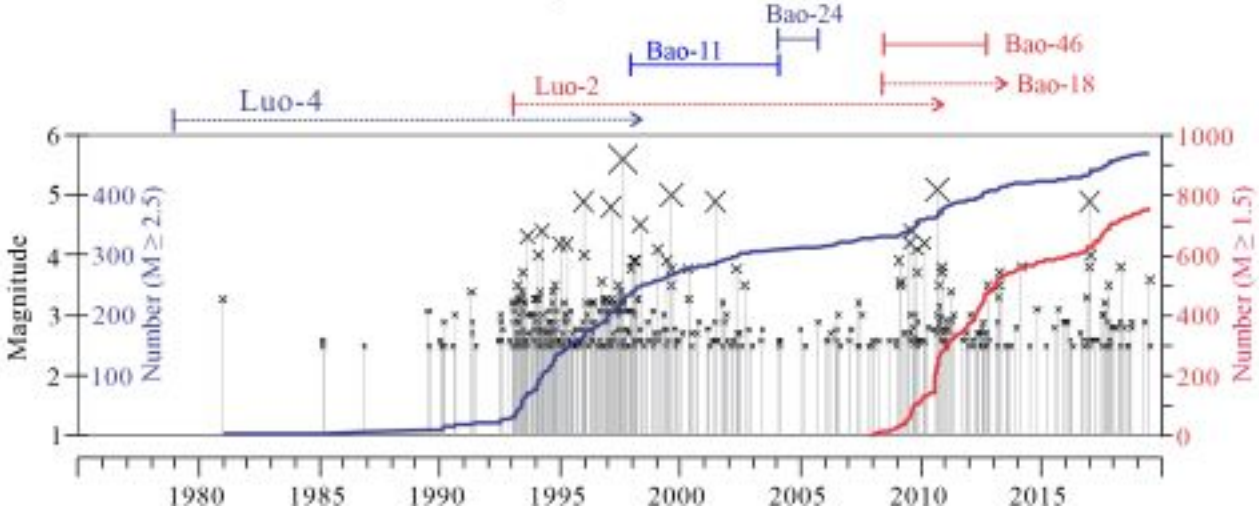
1. Institute of Geology, China Earthquake Administration, 2. Geological Survey of Japan, AIST, 3. Earthquake Monitoring Centre, Sichuan Earthquake Administration, 4. Institute of Fluid Science, Tohoku University

For more than three decades, the depleted Rongchang gas reservoir in China's Sichuan Basin was used for the disposal of unwanted water, which resulted in induced earthquakes, with magnitudes as high as 5.2. After all wells were closed, the frequency of seismic activity was observed to decay following a modified Omori law, and since April 2015, seismic activity again began to increase, and a M4.9 earthquake occurred on 27 December. The results of an Epidemic Type Aftershock Sequence (ETAS) model analysis show that forced seismicity accounted for more than 70% of the total events. For most Magnitude greater than 3.5 earthquakes, including two Magnitude greater than 4 events, the estimated overpressure was lower than the maximum injection pressure. These results, coupled with the fact that postinjection seismic activity has similar characteristics to seismicity during injection, indicate that the injected overpressure fluid was still the driving factor for postinjection seismic activity.

Keywords: Longterm Injection Induced Earthquakes, Postinjection Seismic Activity, Overpressure Fluid

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Site Generalization Performance of Ground Motion Models: Application of Monotonic Neural Networks

*Tomohisa Okazaki[1], Nobuyuki Morikawa[2], Hiroyuki Fujiwara[2], Naonori Ueda[1]

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Ground motion models (GMM) provide empirical relationships between earthquake parameters and ground-motion intensities. In addition to regression models developed over the past 50 years, machine learning (ML) methods recently came into use. ML models can obtain input-output relationships without assumptions, but are in danger of overfitting owing to their flexibility. To evaluate the predictive power (generalization performance) of ML GMMs, observational records are customary divided into training and test datasets based on records or earthquakes.

In this presentation, however, we demonstrate that the above division of dataset does not work for monitoring overfitting to recorded site when a model includes site-condition proxies (SCP) as input variables; complex deep neural network (DNN) models with many SCPs apparently exhibit good predictive power at trained sites but show serious overfitting at new sites. Therefore, it is crucial to divide dataset based on recorded site for correctly evaluating site generalization performance. As a possible solution to maintain generalization performance in DNN models, we propose to impose monotonic dependence on input variables. An experimental application supports the effectiveness of this simple approach.

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Prediction of natural disasters based on a hybrid approach of physics-driven and data-driven method

*Takashi Miyamoto[1]

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Data-driven science methods, which have made remarkable progress in recent years, are expected to be utilized in the field of disaster management, and their applications in hazard prediction, current situation assessment, and disaster response are being studied. On the other hand, because it is difficult to assure the quality and quantity of data under the inherent uncertainty of natural phenomena and the rarity of major events, the application of data-driven science methods is becoming increasingly difficult. In particular, predicting the temporal evolution of disaster events is necessary to predict future states, including situations that have never been experienced before, and improving the accuracy of such extrapolative predictions is a major challenge for data-driven science.

To solve this problem, an approach that combines physical methods where natural laws are modeled with data-driven science methods has recently gained popularity. Such an approach makes complementary use of the advantages of data-driven methods, which build models flexibly from data, and the advantages of physical methods, which enable extrapolative prediction by applying natural laws.

In this presentation, after an overview of the integration of physical and data-driven methods, a method for short-term rainfall prediction is presented as a concrete example of research by the presenter. In this method, the governing equation of rainfall is divided into two terms, i.e., the substantial change term and the advection term under the Lagrangian coordinates, then each term is modeled by different data-driven methods. The substantial change term is modeled using the Koopman mode analysis, a data-driven method for discovering the laws behind dynamic phenomena. The method's performance in representing the development and decay of rainfall is presented compared with conventional short-term forecasting methods.

Keywords: Prediction of phenomena, data-driven science, spatio-temporal data

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[J] Oral | M (Multidisciplinary and Interdisciplinary)：M-IS Intersection

Thu. Jun 3, 2021 10:45 AM - 12:15 PM JST | Thu. Jun 3, 2021 1:45 AM - 3:15 AM UTC | Ch.25 Zoom Room 25

[M-IS21] Chemosynthetic community and mud volcano: biology, geochemistry, and geophysics of fluid discharge

convener:Yusuke Miyajima(Geomicrobiology Research Group, Research Institute for Geo-Resources and Environment, Geological Survey of Japan, National Institute of Advanced Industrial Science and Technology), Kayama Hiromi WATANABE(Japan Agency for Marine-Earth Science and Technology), Akira Ijiri(Japan Agency for Marine-Earth Science and Technology), Tomohiro Toki(Faculty of Science, University of the Ryukyus), Chairperson:Yusuke Miyajima(Geomicrobiology Research Group, Research Institute for Geo-Resources and Environment, Geological Survey of Japan, National Institute of Advanced Industrial Science and Technology), Hiromi Kayama WATANABE(Japan Agency for Marine-Earth Science and Technology)

Fluid discharge at mud volcanoes, cold seeps, and hydrothermal vents brings subsurface materials to the Earth's surface. Unique chemosynthesis-based ecosystems are fueled by the substances provided by discharged fluids, and have played a role in the evolution and diversification of life. Knowing fluid geochemistry, driving forces, and geological background of fluid discharge provides key to understand the distribution and evolution of chemosynthetic ecosystems. Multidisciplinary studies from viewpoints of geology, biology, geochemistry, and geophysics are essential to reveal the relationship between fluid discharge and material cycling, environmental changes, and natural hazards, in addition to elucidate spatio-temporal variation of chemosynthesis-based ecosystems. This session welcomes talks and posters focusing on organisms and geological phenomena related to mud volcanoes, cold seeps, hydrothermal vents, and other similar environments. We aim to understand interactions between geosphere, biosphere, and human both on land and in ocean through Earth history.

10:45 AM - 11:00 AM JST | 1:45 AM - 2:00 AM UTC

[MIS21-01] Characteristic and Origin of erupted sediments in submarine mud volcanoes, off Tanegashima Island

*Ryoma Setoguchi[1], Akira Ijiri[2], Takeyasu Yamagata[3], Hiroyuki Matsuzaki[3], Kyoko Hagino[1], Juichiro Ashi[4], Masafumi MURAYAMA[1] (1.Kochi University, 2.Japan Agency for Marine-Earth Science and Technology, 3.The University Museum, The University of Tokyo, 4.Atmosphere and Ocean Research Institute, The University of Tokyo)

11:00 AM - 11:15 AM JST | 2:00 AM - 2:15 AM UTC

[MIS21-02] Methanogenesis in deep subseafloor sediments −living methanogen diversity, distribution, physiology and activity−

★Invited Papers

*Taiki Katayama[1], Hideyoshi Yoshioka[1], Masanori Kaneko[1], Susumu Sakata[1], Miki Amo[2], Tetsuya Fujii[2] (1.National Institute of Advanced Industrial Science and Technology, 2.Japan Oil, Gas and Metals National Corporation)

11:15 AM - 11:30 AM JST | 2:15 AM - 2:30 AM UTC

[MIS21-03] Aerobic and anaerobic methanotrophs and their activity in methane-seep sediments of the northeastern Japan Sea offshore Sakata assessed by ^{13}C-labelling experiments

*Yusuke Miyajima[1], Hideyoshi Yoshioka[1], Tomo Aoyagi[2], Tomoyuki Hori[2], Hiroshi A Takahashi[3], Masahiro Suzumura[2] (1.Geomicrobiology Research Group, Research Institute for Geo-Resources and Environment, Geological Survey of Japan, National Institute of Advanced Industrial Science and Technology, 2.Environmental Management Research Institute, National Institute of Advanced Industrial Science and

Technology (AIST), Japan, 3.Research Institute of Earthquake and Volcano Geology, Geological Survey of Japan, National Institute of Advanced Industrial Science and Technology (AIST), Japan)

11:30 AM - 11:45 AM JST | 2:30 AM - 2:45 AM UTC

[MIS21-04] Could listening underwater sounds reveal the dynamics of chemosynthetic ecosystems?

★Invited Papers

*Tzu-Hao Lin[1], Chong Chen[2], Hiromi Kayama Watanabe[2], Shinsuke Kawagucci[2], Yung-Che Tseng[3] (1.Biodiversity Research Center, Academia Sinica, 2.X-STAR, Japan Agency for Marine-Earth Science and Technology (JAMSTEC), 3.Marine Research Station, Institute of Cellular and organismic Biology, Academia Sinica)

11:45 AM - 12:00 PM JST | 2:45 AM - 3:00 AM UTC

[MIS21-05] The minor-yet-crucial roles of gut microbiomes in a deep-sea hydrothermal vent snail

*Yi YANG[1,2], Jin SUN[1,3], Chong CHEN[4], Yadong ZHOU[5], Cindy Lee Van Dover[6], Chunsheng WANG[5,7], Jian-Wen QIU[2,8], Pei-Yuan QIAN[1,2] (1.Department of Ocean Science and Hong Kong Branch of the Southern Marine Science and Engineering Guangdong Laboratory (Guangzhou), The Hong Kong University of Science and Technology, Hong Kong, China, 2.Southern Marine Science and Engineering Guangdong Laboratory (Guangzhou), Guangzhou, China, 3.Institute of Evolution & Marine Biodiversity, Ocean University of China, Qingdao 266003, China, 4.X-STAR, Japan Agency for Marine-Earth Science and Technology (JAMSTEC), 2-15 Natsushima-cho, Yokosuka, Kanagawa 237-0061, Japan, 5.Laboratory of Marine Ecosystem and Biogeochemistry, Second Institute of Oceanography, State Oceanic Administration, Hangzhou, China, 6.Division of Marine Science and Conservation, Nicholas School of the Environment, Duke University, Beaufort, NC, United States, 7.State Key Laboratory of Satellite Ocean Environment Dynamics, Second Institute of Oceanography, State Oceanic Administration, Hangzhou, China, 8.Department of Biology, Hong Kong Baptist University, Hong Kong, China)

12:00 PM - 12:15 PM JST | 3:00 AM - 3:15 AM UTC

[MIS21-06] Dual symbiosis in the deep-sea hydrothermal vent snail *Gigantopelta aegis* revealed by its hologenome

*Yi Lan[1], Jin Sun[1,2], Chong Chen[3], Jian-Wen Qiu[4], Pei-Yuan Qian[1] (1.Hong Kong University of Science and Technology, 2.Ocean University of China, 3.Japan Agency for Marine-Earth Science and Technology , 4.Hong Kong Baptist University)

Characteristic and Origin of erupted sediments in submarine mud volcanoes, off Tanegashima Island

*Ryoma Setoguchi[1], Akira Ijiri[2], Takeyasu Yamagata[3], Hiroyuki Matsuzaki[3], Kyoko Hagino[1], Juichiro Ashi[4], Masafumi MURAYAMA[1]

1. Kochi University, 2. Japan Agency for Marine-Earth Science and Technology, 3. The University Museum, The University of Tokyo, 4. Atmosphere and Ocean Research Institute, The University of Tokyo

Mud volcanoes are remarkable geological features formed by the vertical intrusion of low density and deformable sediments from deep subsurface to the surface, and are distributed both on land and seafloor at the continental margins. The mud volcanoes are an important source of methane to the hydrosphere and the atmosphere. In the sea around Japan, it is widely distributed in the Kumano Basin off the Kii Peninsula and off Tanegashima Island. The mud volcanoes in the Kumano Basin are well studied compared to those off Tanegashima, and the mechanism of the eruption has been inferred from fluid and sediment analyses. So far, 15 mud volcanoes have been identified in topographic surveys off Tanegashima Island and numbered from MV#1 to #15. During the KH-15 and KH-19 cruises in 2015 and 2019 by R/V Hakuho-Maru, we retrieved piston cores from MV#1 (30°53´N, 131°46´E; water depth: 1540 m), #2 (30° 55´N, 131°50´E; water depth: 1430 m) , #3 (31°03´N, 131°41´E; water depth: 1200 m) , and #14 (30° 11´N, 131°23´E; water depth: 1700 m) . We investigated the origin of sediments and fluids based on the chemical analyses of them. For the sediment cores, the internal structure was observed by X-ray CT, and the sediment age was estimated by ^{10}Be and calcareous nannofossils. Bulk mineral composition and clay mineral compositions were estimated by XRD analysis, and then the temperature history of sediments was estimated from the clay mineral composition. The origin of methane were investigated by the methane to ethane concentration ratio (C_1/C_2), and the carbon isotopic composition ($\delta^{13}C$) of methane. The sediments of MVs # 1, # 2, and #3 contain a large amount of mud breccia, and the modern hemi-pelagic sediments covered on the erupted sediments were not observed, suggesting that those mud volcanoes are active. On the other hand, nannofossils observations suggest that MV # 14 is dormant mud volcano in which the hemi-pelagic Quaternary sediments have covered on the erupted sediments. The nannofossil ages and the ^{10}Be ages of MVs#2 and #3 consistently show the Middle to Late Miocene. These ages are younger than the Eocence Shimanto belt distributed around Tanegashima (Ujiie et al., 2000), suggesting that the mud-volcano sediments are provided from the sedimentary layers above the Shimanto belt. The mud-volcano sediments were generally dominated in quartz, illite, and plagioclase, and there is no particular mineralogical difference among the mud volcanoes. Clay minerals were mostly dominated in illite, suggesting the experience 60–160 °C where smectite to illite transformation occurs. There were some differences in clay mineral composition among the mud volcanoes. The illite/smectite mixed-layer (I/S) was detected in MV # 1, but not detected in MVs #2, #3, and #14. In MV #1, the illite content in the I/S mixed-layer, estimated from the diffraction pattern, is 42 to 45%. The content indicates the early stage of illitization, suggesting that the experienced temperature is 60 to 100 °C. On the other hand, the MVs#2, #3 and #14 sediments, in which the mixed-layer was not detected, might be experienced higher temperatures than MV#1, due to the progress of smectite to illite transformation. At the active MVs #1, # 2, and #3, generally low C_1/C_2 ratio (30–50) and $\delta^{13}C$ of methane (-57‰ –-42‰) indicate that the hydrocarbon gases are derived from thermal decompositions of organic matter in deep sediments where the in situ temperature is >80°C. At the inactive MV#14, the C_1/C_2 ratios were high as 700–4000, and $\delta^{13}C$ of methane were -75‰ and -77‰, respectively. The data indicate the biogenic origin. Considering the geothermal gradient (25–50 °C/km) observed in the area, the conditions for thermogenic gas production (> 80 °C), and the temperature history of the sediments, the sediments and hydrocarbon gas would be

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provided from deep sedimentary realm deeper than 1.5 km below seafloor.

Keywords: Mud Volcano, Submarine Mud Volcano, Methane Gas, Clay mineral

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Methanogenesis in deep subseafloor sediments –living methanogen diversity, distribution, physiology and activity–

*Taiki Katayama[1], Hideyoshi Yoshioka[1], Masanori Kaneko[1], Susumu Sakata[1], Miki Amo[2], Tetsuya Fujii[2]

1. National Institute of Advanced Industrial Science and Technology, 2. Japan Oil, Gas and Metals National Corporation

Gas hydrates deposited in subseafloor sediments are considered to be the Earth’ s largest natural gas reservoir of biogenic methane based on geochemical analyses. However, thus far, viable methanogens, microorganisms that are responsible for biogenic methane formation, have been poorly obtained and characterized. Characterization of living methanogens in subseafloor sediments at hydrate sites are fundamental for understanding biogenic gas hydrate formation and our estimations of gas hydrate reserves. We performed cultivation dependent and independent analyses of microorganisms in the hydrate-bearing sediments from the eastern Nankai Trough. In this presentation, I will show previously overlooked phylogenetic and metabolic diversity of viable methanogens and importance of methylotrophic methanogenesis and discuss their depth-related profiles. This study was part of the Research Consortium for Methane Hydrate Resources program in Japan (MH21 Research Consortium).

Keywords: gas hydrate, biogenic methane formation, cultivation, deep subseafloor sediment

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Aerobic and anaerobic methanotrophs and their activity in methane-seep sediments of the northeastern Japan Sea offshore Sakata assessed by ^{13}C-labelling experiments

*Yusuke Miyajima[1], Hideyoshi Yoshioka[1], Tomo Aoyagi[2], Tomoyuki Hori[2], Hiroshi A Takahashi[3], Masahiro Suzumura[2]

1. Geomicrobiology Research Group, Research Institute for Geo-Resources and Environment, Geological Survey of Japan, National Institute of Advanced Industrial Science and Technology, 2. Environmental Management Research Institute, National Institute of Advanced Industrial Science and Technology (AIST), Japan, 3. Research Institute of Earthquake and Volcano Geology, Geological Survey of Japan, National Institute of Advanced Industrial Science and Technology (AIST), Japan

Microbial oxidation of methane plays a major role in regulating the release of subsurface methane into the ocean and atmosphere. Up to 80% of methane migrating to the seafloor is consumed by aerobic and/or anaerobic methane-oxidizing microorganisms (Reeburgh, 2007; Boetius and Wenzhöfer, 2013). Identifying microbes involved in methane oxidation and assessing their activity in sediments can provide insights into subsurface microbial diversity and methane dynamics of gas hydrate systems. However, activity of both aerobic and anaerobic methanotrophs in marine sediments has been poorly investigated. Although lipid biomarkers are utilized as strong tools to examine the community structure and distribution of microbes in sediments, they have not been clearly linked to their source organisms, especially aerobic methanotrophs (e.g., Rush et al., 2016).

By combining genetic analysis, lipid biomarker analysis, and incubation experiments with ^{13}C-labelled methane, this study investigated aerobic/anaerobic methanotrophs and their activity in methane-seep sediments of the northeastern Japan Sea offshore Sakata. Push core samples were taken from sediments with microbial-mats like surface and used for the analyses. The sediments from 0–10 cm below seafloor (bsf) were aerobically and anaerobically incubated with CH_4 (20% ^{13}C) for more than 100 days at 4˚C, both showing ^{13}C uptake into dissolved inorganic carbon due to oxidation of ^{13}C-methane. The detection of both aerobic and anaerobic methanotroph activity in the same sediments is distinct from the predominance of either aerobic or anaerobic methanotrophs in mud volcano sediments (Niemann et al., 2006), and has important implications for the methane flux at the study site. Anaerobic oxidation of ^{13}C-methane was also observed at a much lower rate for deeper sediments (10–14 cmbsf). High-throughput sequencing of archaeal and bacterial 16S rRNA genes showed that anaerobic methane-oxidizing archaeal group ANME-1 was highly abundant in the sediments. The relative abundance of the ANME-1 archaea increased from less than 5% at the surface to more than 50% of the whole microbial communities at 10–14 cmbsf. Lipid biomarkers specific for archaea including ANME groups, archaeol and hydroxyarchaeol, were detected in trace amounts in the surface sediments above 4 cmbsf. From the same sediments, bacteriohopanepolyols, which are characteristic biomarkers for aerobic methanotrophs and other bacteria, were detected as degradation products released by periodic acid treatment of another aliquot of the total lipid extracts. Ongoing analyses of archaeal and bacterial lipids in the deeper sediments and ^{13}C uptake into the lipids will specify which lipids were produced by the source methanotrophs deduced from the gene sequences. The results for the ^{13}C-labelling approach could improve the use of lipid biomarkers in studying the composition, distribution, and activity of methanotrophic communities in methane-rich sediments and sedimentary rocks.

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This study was conducted as a part of the methane hydrate research project funded by the Ministry of Economy, Trade and Industry (METI), Japan.

Keywords: Aerobic/anaerobic oxidation of methane, Archaea, Bacteria, 13C-labelling, Lipid biomarker

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Could listening underwater sounds reveal the dynamics of chemosynthetic ecosystems?

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Chemosynthesis-based ecosystems support unique communities fed by chemical energy generated from subsurface geological and microbial processes. Hydrothermal vents are the best-known of such ecosystems, often occurring along active ocean ridges, seamounts, and back-arc basins. Active geological activities produce low-frequency sounds, which can propagate a long distance underwater. Such signals likely serve as acoustic signposts for deep-sea larvae to remotely locate these isolated, island-like geological hotspots among the vast abyssal plain –as has been demonstrated in previous experiments associated with the settlement of coral, mollusk, and reef-associated fish larvae in shallow-water habitats. As such, habitat-specific soundscapes, a composite of sounds from geophysical and biological sources, may be key to maintaining the resilience of vent ecosystems, as they are threatened by fast-approaching deep-sea mining. Although the heterogeneity of underwater soundscapes has begun to gain attraction as a useful proxy of habitat quality and biodiversity, soundscapes of hot vents remain poorly studied. Here, we review modern techniques of soundscape-based ecosystem sensing and then discuss the applications in monitoring vents dynamics. We also investigate the uniqueness of vent soundscapes by using two new recordings, one from a deep-sea vent in Suiyo Seamount, Izu-Bonin Arc, and another from a shallow-water vent at Guishan Island, northeastern Taiwan. Both fields are dominated by low-frequency sounds generated from vent orifices. The observed spectral pattern is entirely different from soundscapes recorded at estuaries, coral reefs, continental shelves, and other deep-sea habitats. Our results support the hypothesis that hydrothermal vents are acoustically different from other habitats, but many questions remain open. For example, do different vents possess different acoustic characteristics? Can we predict the amount of fluid discharge and temperature by measuring the intensities of vent-associated sounds? How do these low-frequency sounds propagate across the surrounding three-dimensional terrain that varies from vent to vent? Do vent-associated organisms produce sounds, and how frequently do they vocalize? Answer these questions will require future, more detailed acoustic assessments of the dynamics of vents and their associated communities. Based on the experience in shallow-water marine ecosystems, soundscape-based ecosystem assessments can reveal the interactions between a biological community and its habitat, as well as the ecological impacts due to anthropogenic development. We believe the same approach will improve our knowledge of the ecological dynamics of hydrothermal vents. Beyond that, additional data from cold seeps and organic falls will also help evaluate the feasibility of using soundscapes in monitoring other chemosynthesis-based ecosystems.

Keywords: Ecoacoustics, Underwater acoustics, Hydrothermal vents

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The minor-yet-crucial roles of gut microbiomes in a deep-sea hydrothermal vent snail

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Eukaryotes often exhibit a complex symbiotic relationship with gut microbes to attain better use of the available resources. Many animals endemic to deep-sea chemosynthetic ecosystems host chemoautotrophic bacteria endocellularly, and are thought to rely entirely on these symbionts for energy and nutrition. The provannid snail *Alviniconcha marisindica* hosts a *Campylobacterial* endosymbiont in its gill, but unlike many other chemosymbiotic animals, its gut is reduced but still functional. Here, we show through metagenomic and metatranscriptomic analyses that the gut microbiome of *A. marisindica* plays key nutritional and metabolic roles. The diversity of *A. marisindica* gut microbiota is comparable to that of the snails without symbionts but its composition and relative abundance differed from these snails. The relative abundance of microbial composition remains similar among three *A. marisindica* and their microbial community shows significant multi-taxa associations, suggesting a long-term association. Functional profiling of the gut microbiome reveals thousands of additional genes for the holobiont to cope with the shortage of amino acids, vitamins, and lipids, as well as the accumulation of metabolic waste and the maintenance of homeostasis. These microbes have the potential to form the protective slime capsule to protect themselves from the host’ s immune system, thereby contributing to their survival and development. Our findings advance the understanding of how deep-sea chemosymbiotic animals obtain available resources through considering an additional contribution of gut microbiota. The widespread less-abundant gut microbiota is potential to help hosts survive and thrift in extreme environments.

Keywords: Deep-sea vent, Provannid snail, Gut, Microbiome, Metagenome, Metatranscriptome

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Dual symbiosis in the deep-sea hydrothermal vent snail *Gigantopelta aegis* revealed by its hologenome

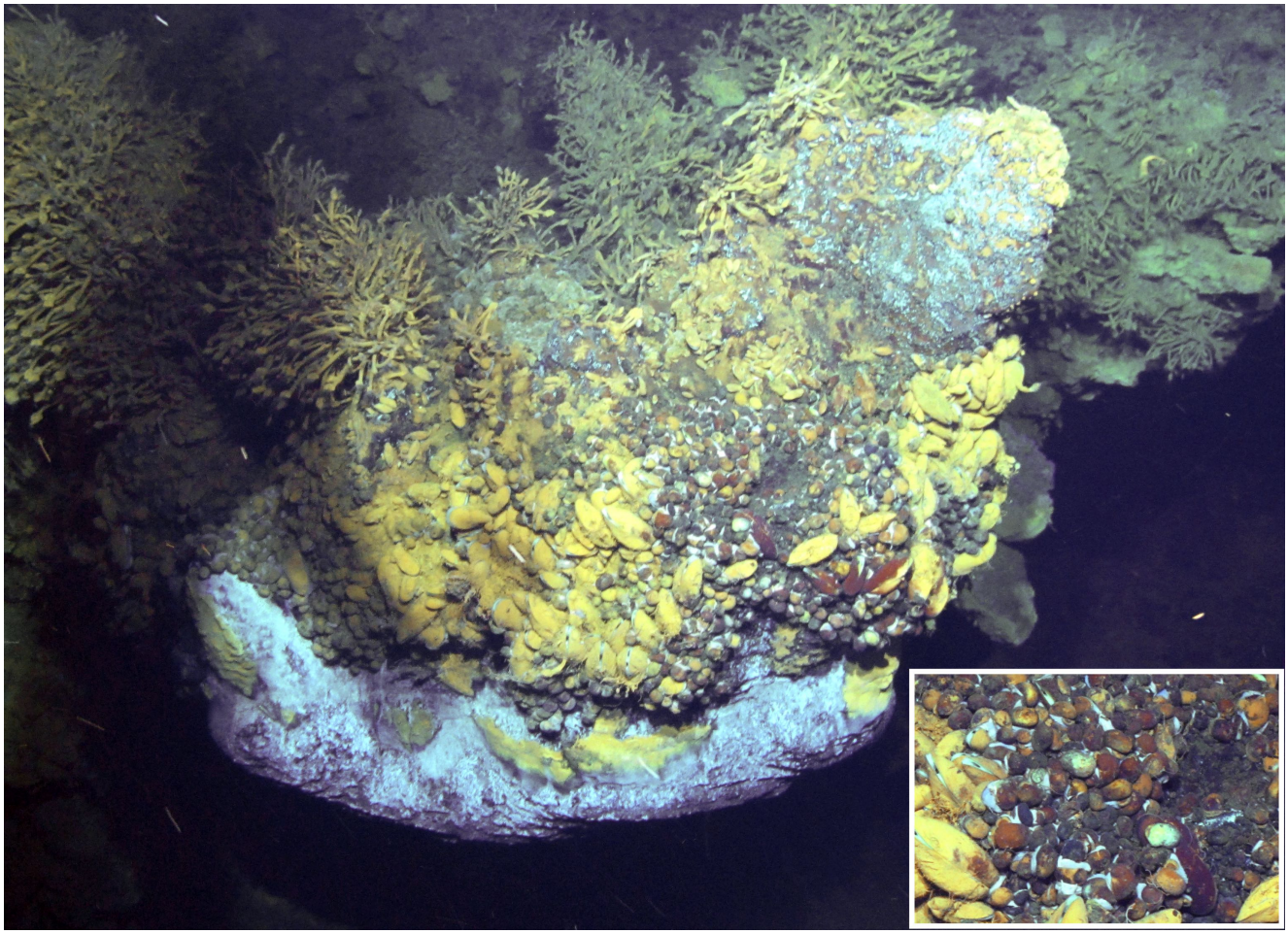
*Yi Lan[1], Jin Sun[1,2], Chong Chen[3], Jian-Wen Qiu[4], Pei-Yuan Qian[1]

1. Hong Kong University of Science and Technology, 2. Ocean University of China, 3. Japan Agency for Marine-Earth Science and Technology , 4. Hong Kong Baptist University

Animals endemic to deep-sea hydrothermal vents often form obligatory relationships with bacterial symbionts, maintained by intricate host–symbiont interactions. Most genomic studies focusing on symbiotic systems failed to simultaneously investigate the host and symbionts to a similar depth. Here, we report novel dual symbiosis in the peltospirid snail *Gigantopelta aegis* with two gammaproteobacterial endosymbionts: one being a sulphur oxidiser and the other a methane oxidiser. We assembled high-quality genomes for all three parties of this holobiont, with a chromosome-level assembly for the snail host (1.15 Gb, 15 pseudo-chromosomes). In-depth analyses of these genomes revealed an intimate mutualistic relationship with complementarity in nutrition and metabolic co-dependency, resulting in a system that is highly versatile in transportation and utilisation of chemical energy. Moreover, *G. aegis* likely has remodelled its immune system to facilitate hosting more than one type of symbiont. Comparisons with *Chrysomallon squamiferum*, another chemosymbiotic snail in the same family but with only a sulphur-oxidising gammaproteobacterial endosymbiont, showed that the two snails' sulphur-oxidising endosymbionts are phylogenetically distant. This finding was consistent with previous results that the two snails have evolved endosymbiosis independently and convergently. Notably, same capabilities in the biosynthesis of specific nutrients lacking in the host genomes are shared by the two sulphur-oxidising endosymbionts of the two snail genera, which may be a key criterion in symbiont selection by the hosts.

Keywords: chemosynthesis, sulphur-oxidising, methane-oxidising, Mollusca

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[J] Oral | M (Multidisciplinary and Interdisciplinary)：M-GI General Geosciences, Information Geosciences & Simulations

Thu. Jun 3, 2021 1:45 PM - 3:15 PM JST | Thu. Jun 3, 2021 4:45 AM - 6:15 AM UTC | Ch.18 Zoom Room 18

[M-GI33] Data-driven geosciences

convener:Tatsu Kuwatani(Japan Agency for Marine-Earth Science and Technology), Hiromichi Nagao(Earthquake Research Institute, The University of Tokyo), Kenta Ueki(Japan Agency for Marine-Earth Science and Technology), Shin-ichi Ito(The University of Tokyo), Chairperson:Kenta Ueki(Japan Agency for Marine-Earth Science and Technology), Tatsu Kuwatani(Japan Agency for Marine-Earth Science and Technology)

It is important to extract essential processes and structures from observed data sets in order to understand and predict the dynamic behavior of the earth and planetary systems. Recently, many powerful methodologies have been proposed to extract useful information from high-dimensional data sets in mathematical and information sciences. This session aims to provide an opportunity to gather various geoscientists to have a productive discussion for interdisciplinary collaborations.

1:45 PM - 2:15 PM JST | 4:45 AM - 5:15 AM UTC

[MGI33-01] Data-driven low-dimensional model/sparse sensing of fluid dynamics and its application to seismic waves

★Invited Papers

*Taku Nonomura[1], Yuji Saito[1], Takayuki Nagata[1], Kumi Nakai[1], Keigo Yamada[1], Sayumi Kaneko[1] (1.Tohoku University)

2:15 PM - 2:30 PM JST | 5:15 AM - 5:30 AM UTC

[MGI33-02] Reclassification of oceanic intraplate basalts using trace element compositions of hotspots and petit-spots

*Yosuke Shimbo[1], Taku Yutani[1], Naoto Hirano[1] (1.Tohoku University)

2:30 PM - 2:45 PM JST | 5:30 AM - 5:45 AM UTC

[MGI33-03] Spatial distributions of source components for REY-rich mud based on independent component analysis on major- and trace-element composition

*Masahiro Hirako[1], Kazutaka Yasukawa[1,2], Erika Tanaka[1], Koichiro Fujinaga[2,1], Kentaro Nakamura[1], Yasuhiro Kato[1,2] (1.School of Engineering, The University of Tokyo, 2.Ocean Resources Research Center for Next Generation, Chiba Institute of Technology)

2:45 PM - 3:00 PM JST | 5:45 AM - 6:00 AM UTC

[MGI33-04] Independent Component Analysis of bulk chemical compositions of submarine hydrothermal deposits in the Okinawa Trough

*Akito Aichi[1], Kazutaka Yasukawa[1,2], Tatsuo Nozaki[3,1,4,2], Yutaro Takaya[5,3,2], Mizuki Ishida[1], Erika Tanaka[1], Kentaro Nakamura[1], Yasuhiro Kato[1,2] (1.School of Engineering, The University of Tokyo, 2.ORCeNG, Chiba Institute of Technology, 3.JAMSTEC, 4.Kobe University, 5.Waseda University)

3:00 PM - 3:15 PM JST | 6:00 AM - 6:15 AM UTC

[MGI33-05] Spatial resolution of Bayesian sensing

*Tatsu Kuwatani[1], Hideitsu Hino[2], Nagata Kenji[3], Takahiro Kawashima[4], mitsuhiro toriumi[1], Masato Okada[5] (1.Japan Agency for Marine-Earth Science and Technology, 2.The Institute of Statistical Mathematics, 3.National Institute for Materials Science, 4.Graduate University for Advanced Studies, 5.The University of Tokyo)

Data-driven low-dimensional model/sparse sensing of fluid dynamics and its application to seismic waves

*Taku Nonomura[1], Yuji Saito[1], Takayuki Nagata[1], Kumi Nakai[1], Keigo Yamada[1], Sayumi Kaneko[1]

1. Tohoku University

In this presentation, the low-dimensional model/sparse sensing techniques developed in the fields of fluid dynimacs will be rewiewed with presenting the recent results of the research group of the authors. The real-time/cost-efficient fluid dynimic experiments will be explained to be realized using those techniques. In addition to that, the application of the low-dimensinoal model/sparse sensing to seismic waves will be addressed.

Keywords: Data-driven science, Low-dimensional model, Sparse sensing

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Reclassification of oceanic intraplate basalts using trace element compositions of hotspots and petit-spots

*Yosuke Shimbo[1], Taku Yutani[1], Naoto Hirano[1]

1. Tohoku University

Oceanic hotspot and petit-spot basalts are generally categorized as oceanic island basalts (OIBs) in their geochemical characteristics of enriched incompatible element compositions. The basalts derived from hotspot volcanoes show systematic evolution in magmatic compositions for several volcanic stages. The petit-spot basalts showing similar composition to OIB, on the other hand, must have different processes in their petrogenesis from hotspot magmas. Here, we adopt the principal component analysis (PCA) for selected trace elements in order to explain their geochemical features along the eruptive settings and magmatic evolution. The compositional variations of OIBs from selected intraplate volcanism in the Pacific Ocean and their structure of high-dimensional geochemical data are recognized using PCA for 26 incompatible elements in this study. The first principal component simply demonstrates their concentrations of all incompatible elements. The second principal component expresses depletions of HREE and fertilizations of LREE designating residual garnet in source mantle. The third principal component enhances HFSE anomaly, particularly in negative Nb, Ta, Zr, Hf and Ti, and positive Ba, Pb and Sr anomalies. This component evidently discriminates between the petit-spot basalts together with some rejuvenated stage lavas and other OIBs. The data suggest the similar mechanism in the petrogenesis of both petit-spots and lavas on the rejuvenated stage.

Keywords: OIB, petit-spot, principal component analysis

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Spatial distributions of source components for REY-rich mud based on independent component analysis on major- and trace-element composition

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1. School of Engineering, The University of Tokyo, 2. Ocean Resources Research Center for Next Generation, Chiba Institute of Technology

Deep-sea sediments highly enriched in rare-earth elements and yttrium (termed REY-rich mud) are widely distributed in the Pacific and Indian Oceans [1, 2]. Because of the huge resource potential [3], REY-rich mud is expected as a new source for the industrially critical elements (i.e., REY). Toward future exploration and development, it is important to precisely understand the origin of REY-rich mud.

Independent Component Analysis (ICA), a method of multivariate analysis, was successfully applied to a chemical composition dataset of deep-sea sediments in the Pacific and Indian Oceans to elucidate the genesis of REY-rich mud [4]. However, in the previous study, only major-elements and REY were considered. In this study, ICA was performed on a higher-dimensional dataset consisting of major- and trace-elements to characterize source components of deep-sea sediments including REY-rich mud more comprehensively. Although the overall result was generally consistent with the previous work [4], some components were newly extracted and characterized mainly by trace elements. We also visualized the spatiotemporal distributions of the independent components containing information on 44 elements. In the presentation, we will present the results of the new and comprehensive analysis.

[1] Kato et al. (2011) *Nat. Geosci.* **4**, 535-539.

[2] Yasukawa et al. (2014) *J. Asian Earth Sci.* **93**, 25-36.

[3] Takaya et al. (2018) *Sci. Rep.* **8**, 5763.

[4] Yasukawa et al. (2016) *Sci. Rep.* **6**, 29603.

Keywords: deep-sea sediment, REY-rich mud, Independent Component Analysis, chemical composition, multivariate analysis

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Independent Component Analysis of bulk chemical compositions of submarine hydrothermal deposits in the Okinawa Trough

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1. School of Engineering, The University of Tokyo, 2. ORCeNG, Chiba Institute of Technology, 3. JAMSTEC, 4. Kobe University, 5. Waseda University

Submarine hydrothermal activity is one of the key processes controlling the transfer of energy and materials from the Earth’s interior to surface systems including hydrosphere and biosphere. It is also an important process that produces mineral deposits of economic interest. In recent years, multiple scientific drilling cruises were conducted in the Okinawa Trough, a back-arc basin with a number of active hydrothermal vents [1-3], using the drilling vessel CHIKYU. The core samples contain various altered/unaltered volcaniclastic and hemipelagic sediments, as well as sulfide minerals. By ICP-QMS analysis, a comprehensive dataset of bulk chemical composition (>1,300 samples x 47 element contents) of the drilling core samples has been constructed.

In this study, we statistically analyzed the huge dataset using independent component analysis (ICA). ICA is a powerful method to recover mutually independent signals from an observed mixture of the source signals and it has been successfully applied to geochemical data [4-6]. We implemented ICA to identify multi-elemental features and their distributions involving geochemical heterogeneities in the (sub)seafloor hydrothermal deposits. In the presentation, through consideration of information of the extracted components, we will discuss the geochemical characteristics of the hydrothermal activities in the study area.

[1] Glasby et al. (2003) *Ore. Geol. Rev.* **23,** 299-339.
[2] Nakajima et al. (2015) *PLoS One.* **10**, e0123095.
[3] Nozaki et al. (2016) *Sci. Rep.* **6**, 22163.
[4] Iwamori & Albarède (2008) *Geochem. Geophys. Geosyst.* **9**, Q04033.
[5] Yasukawa et al. (2016) *Sci. Rep.* **6**, 29603.
[6] Yasukawa et al. (2019) *Geochem. Geophys. Geosyst.* **20**, 3402-3430.

Keywords: hydrothermal deposits, Okinawa Trough, hydrothermal mineralization, multivariate analysis, independent component analysis

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Spatial resolution of Bayesian sensing

*Tatsu Kuwatani[1], Hideitsu Hino[2], Nagata Kenji[3], Takahiro Kawashima[4], mitsuhiro toriumi[1], Masato Okada[5]

1. Japan Agency for Marine-Earth Science and Technology, 2. The Institute of Statistical Mathematics, 3. National Institute for Materials Science, 4. Graduate University for Advanced Studies, 5. The University of Tokyo

Bayesian sensing is a general framework that uses Bayesian estimation to advance measurement and observation in order to understand the essential physics of a target system. It utilizes prior knowledge and forward models through Bayes' theorem, to enable the accurate estimation of not only the model parameters that indicate the target physical quantities, but also the hyperparameters that indicate the hidden physical parameters governing the process and structure of the target and sensing systems. This paper discusses the physical meaning and mechanism of the Bayesian sensing using the concept of resolution in spatial inversion problem. It describes that the spatial resolution of the model parameters can be spatially mapped using a resolution matrix, dened as a linear mapping from the true model parameter to the recovered model parameter. We also show that the optimal hyperparameters are obtained by internally-consistent equations between the estimated optimal and the actual hyperparameters calculated from the estimated model parameters, in terms of resolution. The obtained equations contribute toward understanding the hidden physical process and the structure of the target and sensing system in various problems, as well as the potential to reduce the computational cost.

Keywords: Bayesian estimation, Inversion, Measurement informatics

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[J] Oral | M (Multidisciplinary and Interdisciplinary)：M-GI General Geosciences, Information Geosciences & Simulations

Thu. Jun 3, 2021 3:30 PM - 5:00 PM JST | Thu. Jun 3, 2021 6:30 AM - 8:00 AM UTC | Ch.18 Zoom Room 18

[M-GI33] Data-driven geosciences

convener:Tatsu Kuwatani(Japan Agency for Marine-Earth Science and Technology), Hiromichi Nagao(Earthquake Research Institute, The University of Tokyo), Kenta Ueki(Japan Agency for Marine-Earth Science and Technology), Shin-ichi Ito(The University of Tokyo), Chairperson:Tatsu Kuwatani(Japan Agency for Marine-Earth Science and Technology), Kenta Ueki(Japan Agency for Marine-Earth Science and Technology)

It is important to extract essential processes and structures from observed data sets in order to understand and predict the dynamic behavior of the earth and planetary systems. Recently, many powerful methodologies have been proposed to extract useful information from high-dimensional data sets in mathematical and information sciences. This session aims to provide an opportunity to gather various geoscientists to have a productive discussion for interdisciplinary collaborations.

3:30 PM - 4:00 PM JST | 6:30 AM - 7:00 AM UTC

[MGI33-06] Sedimentology as a science of reconstruction

★Invited Papers

*Hajime Naruse[1], Rimali Mitra[1], Zhirong Cai[1] (1.Department of Geology and Mineralogy, Graduate School of Science, Kyoto University)

4:00 PM - 4:15 PM JST | 7:00 AM - 7:15 AM UTC

[MGI33-07] Data-driven Analysis of Nonlinear Heterogeneous Reactions through Sparse Modeling and Bayesian Statistical Approaches

*Masaki Ito[1], Tatsu Kuwatani[2], Ryosuke Oyanagi[2], Toshiaki Omori[1] (1.Kobe University, 2.Japan Agency for Marine-Earth Science and Technology)

4:15 PM - 4:30 PM JST | 7:15 AM - 7:30 AM UTC

[MGI33-08] Development of a deep learning approach to estimate numerical simulation parameters of a hydrothermal system: Evaluation using a two-dimensional model

*Akihiro Shima[1], Kazuya Ishitsuka[1], Elvar Karl Bjarkason[2], Anna Suzuki[2], Weiren Lin[1] (1.Kyoto University, 2.Tohoku University)

4:30 PM - 4:45 PM JST | 7:30 AM - 7:45 AM UTC

[MGI33-09] Testing on Earthquake Prediction by Deep CNN-Labeling Model

*mitsuhiro toriumi[1] (1.Japan agency of marine science and technology)

4:45 PM - 5:00 PM JST | 7:45 AM - 8:00 AM UTC

[MGI33-10] Discussion

*Tatsu Kuwatani[1] (1.Japan Agency for Marine-Earth Science and Technology)

Sedimentology as a science of reconstruction

*Hajime Naruse[1], Rimali Mitra[1], Zhirong Cai[1]

1. Department of Geology and Mineralogy, Graduate School of Science, Kyoto University

Sedimentology is a geological science that aims to understand the mechanisms of sedimentation and erosion that form landforms, and to reconstruct the past environment of the Earth's surface from information recorded in strata. Strata are accumulations of sedimentary rocks formed by buried landforms that once existed on the Earth's surface. Landforms change their shape in response to variation in sediment supply and water discharge caused by orogenic activity and climatic changes, and these topographic changes are preserved in the strata. Sedimentology solves the inverse problem of the environmental changes that resulted in the landform changes from the strata. In the field of sedimentology, however, quantitative inverse analyses have rarely been performed.

This situation is changing drastically with the recent development of morphodynamics. Morphodynamics is a research field that combines fluid dynamics and sediment transport models to understand the dynamics of landform development due to sedimentation and erosion. Morphodynamics has been developed in the fields of river and coastal engineering, and has been mainly applied to river and coastal management and disaster prevention. Recently, however, it has been recognized that morphodynamics is an effective research method for understanding longer-term, large-scale geomorphic development, and has been widely accepted as a research method in the field of sedimentology. In this talk, we will discuss the recent advances in the field of geomorphology and sedimentology, including the use of morphodynamics-based forward models and inverse analysis. We will show the recent trend of research using inverse analysis in the field of sedimentology, and introduce the efforts of our research group.

In sedimentology, inverse analysis is particularly popular in (1) reconstruction of uplift rates of mountainous regions from longitudinal profiles of rivers and (2) estimation of hydraulic conditions from tsunami deposits. In addition to the above, our research group is working on (3) estimation of hydraulic conditions of turbidity currents from turbidites. (1) The inverse analysis of mountain uplift rate can reconstruct the uplift rate of the continental crust over a wide area and a long period of time (more than several hundred thousand years). (2) The inverse analysis of tsunami sediments is an important research topic for social application of sedimentology because it can estimate the magnitude of tsunamis in the past and the disaster risk of the region. (3) The inverse analysis of turbidite is an attempt to estimate the conditions of turbidity currents that occur in deep sea environments, which are difficult to observe directly. Turbidity currents that deposit turbidites build huge topographic features called submarine fans on the deep seafloor, and the deposits often become large-scale oil and gas reservoirs, making them an economically important subject of research. The ability to read the hydraulic conditions of turbidity currents is expected to shed light on the shape and properties of deep-sea reservoir rocks from limited geological information.
In order to solve these research problems, we are working on the development of inverse models using artificial neural networks. A serious problem in inverse analysis in sedimentology is the high computational loads of forward models. Common inverse modeling methods such as the Markov Chain Monte Carlo (MCMC) method often require tens of thousands of iterations of the forward model calculation, which cannot be parallelized and therefore cannot be used for inverse analysis of sedimentological subjects. Therefore, we attempted to generate an inverse model by performing several thousand iterations of the forward model with randomly generated initial conditions, and training the

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neural network with the resulting combination of sedimentary data and initial conditions as teacher data. The advantage of this method is that the generation of the teacher data can be completely parallelized, so that the computational load of the forward model becomes less of a problem. This method is particularly useful for the inverse analysis of tsunamis and turbidity currents in (2) and (3), and it has been confirmed that it can reproduce the hydraulic conditions of modern tsunamis and recover the hydraulic conditions of experimental turbidity currents from turbidites in experiments. In the future, it is expected that the analysis of past tsunami sediments and submarine fan deposits will be carried out.

Keywords: inverse analysis, turbidite, tsunami deposit

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Data-driven Analysis of Nonlinear Heterogeneous Reactions through Sparse Modeling and Bayesian Statistical Approaches

*Masaki Ito[1], Tatsu Kuwatani[2], Ryosuke Oyanagi[2], Toshiaki Omori[1]

1. Kobe University, 2. Japan Agency for Marine-Earth Science and Technology

Heterogeneous reactions are chemical reactions with conjugation of multiple phases, and they have the intrinsic nonlinearity of their dynamics caused by the effect of surface area between different phases. It is important not only in earth science, but also in engineering to understand heterogeneous reactions in order to figure out the dynamics of rock formation near surface of the earth. Since demand for the geosphere environment is increasing, such as the development of deposits and geothermal fields, the geological disposal of radioactive waste, and the underground storage of carbon dioxide. However, such dynamics is generally nonlinear and there are a lot of candidate nonlinear terms. Furthermore, observed time series data is generally partial and noisy. Therefore, it is necessary to establish a data driven approach for estimating the dynamics of heterogeneous reactions.

In this study, we propose a data-driven method for simultaneously extracting substantial reaction terms and surface models from a number of candidates based on sequential Monte Carlo algorithm and sparse modeling algorithm by using noisy partial observation data. We focus on surface area reactions between the solid phase and the liquid phase, and assume a model of the dissolution-precipitation reaction in which the reactant (solid phase) => intermediate product (liquid phase) => product (solid phase). Based on the state space model, we introduce sequential Monte Carlo method in order to estimate hidden variables of solid reactant, liquid intermediate product and solid product from a noisy observed data. Moreover, we employ sparse modeling algorithm to extract rate constants and determine a surface area reaction from many candidates. In addition to uniform sparsity, we introduce sparse modeling approach with non-uniform sparsity and make sparse modeling algorithm more robust in order to improve the estimation accuracy of rate constants. Therefore, we propose an effective method to simultaneously estimate rate constants and concentrations from nonlinear dynamics of heterogeneous reaction by using sparse modeling and sequential Monte Carlo method.

Using our proposed method, we show that the rate constants of dissolution and precipitation reactions, which are typical examples of surface heterogeneous reactions, necessary surface models and reaction terms underlying observable data were successfully estimated only from the observable temporal changes in the concentration of the dissolved intermediate product.

Keywords: Sparse Modeling, Bayesian Statistical Approaches, Heterogeneous Reactions

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Development of a deep learning approach to estimate numerical simulation parameters of a hydrothermal system: Evaluation using a two-dimensional model

*Akihiro Shima[1], Kazuya Ishitsuka[1], Elvar Karl Bjarkason[2], Anna Suzuki[2], Weiren Lin[1]

1. Kyoto University, 2. Tohoku University

For the development of a hydrothermal energy resource, it is important to understand its subsurface temperature distribution. In this study, we proposed a new method for estimating subsurface temperature distributions using deep learning, and investigated the accuracy and characteristics of this proposed method using two-dimensional simulation data. The proposed method first learns the relationship between the simulation parameters (e.g., permeability) and simulated temperatures at well locations (training step), and then estimates the parameters from observed temperature logs (estimation step). The data used in the training step is called training data. In general, the distribution of training data needs to be consistent with the observations; however, a procedure to ensure that this requirement is met has not been established. Therefore, we developed a procedure for visualizing and selecting training data based on multidimensional scaling (MDS), and examined whether the procedure can reduce estimation errors.

In this study, we used multiple sets of two-dimensional training and test data generated using the AUTOUGH2 hydrothermal simulator. For generating the simulation data, formation permeabilities and bottom boundary conditions provided to the simulator were varied. Subsequently, we trained a deep neural network to learn the relationship between the variable parameters and temperatures at pseudo-well locations. In addition, we used MDS analysis to check whether (pseudo) observed temperature logs were included in the range of temperature profiles covered by the training data, and we examined whether parameter estimation errors can be reduced by selecting training data that are most consistent with the pseudo temperature logs.

We found that estimation errors were smallest when using training data generated based on small parameter variabilities. This demonstrates the effectiveness of narrowing down the parameter ranges used to generate the training data in order to improve estimation accuracy. Then, based the MDS analysis results, we compared the estimation reliability between cases where the pseudo temperature logs were consistent and inconsistent with the training data. The error rate for the consistent case was 1.4%, while the error rate for the inconsistent case was 29.5%. Thus, we concluded that the data to be estimated must be included in the range covered by the training data, and the consistency can be assessed based on MDS analysis. Further, the error rate was reduced when selecting the training data based on the MDS analysis. These results demonstrate the effectiveness of using MDS analysis to improve the estimation accuracy of deep learning.

Keywords: Deep learning, Neural network, MDS, Hydrothermal system, Permeability, Geothermal

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Testing on Earthquake Prediction by Deep CNN-Labeling Model

*mitsuhiro toriumi[1]

1. Japan agency of marine science and technology

The global and regional correlated seismicity time series calculated from micro to small earthquakes seismicity data matrix by means of singular value decomposition method are characteristic in earth mechanics and seismicity. The correlated seismicity time series, then potential macroscopic features showing the mechanical behavior of plate boundary zones in the global and regional scales. In this consequence, the relative large earthquakes occurred in the plate subduction zones are possibly corresponded to the multivariate correlated seismicity time series by means of deep neural network type transformation techniques such as RNN, LSTM, CNN, state-space modeling and VAE modeling. This study is the first attempt for prediction testing by these methods with multiple labeling on large earthquake event and shows the available results on global and Japanese island region. The available methods of 1dCNN of various timestep and time-shift are suggested from the viewpoint of accuracy scores and small number of incorrect prediction result. The variational autoencoder (VAE) is also applied for investigation of possible pre-seismic signals appeared in the correlated seismicity time series.

Keywords: prediction testing of earthquake, deep convolutional neural network, variational timestep and time-shift method

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Discussion

*Tatsu Kuwatani[1]

1. Japan Agency for Marine-Earth Science and Technology

Discussion

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[J] Oral | M (Multidisciplinary and Interdisciplinary)：M-GI General Geosciences, Information Geosciences & Simulations

Thu. Jun 3, 2021 9:00 AM - 10:30 AM JST | Thu. Jun 3, 2021 12:00 AM - 1:30 AM UTC | Ch.03 Zoom Room 03

[M-GI34] Earth and planetary informatics with huge data management

convener:Ken T. Murata(National Institute of Information and Communications Technology), Susumu Nonogaki(Geological Survey of Japan, National Institute of Advanced Industrial Science and Technology), Rie Honda(Department of Science and Technology, System of Natual Science, Kochi University), Keiichiro Fukazawa(Academic Center for Computing and Media Studies, Kyoto University), Chairperson:Keiichiro Fukazawa(Academic Center for Computing and Media Studies, Kyoto University), Ken T. Murata(National Institute of Information and Communications Technology)

Increasingly large and complex data are produced by observations and numerical simulations in earth and planetary sciences. The target of this session is to discuss a broad range of practices and new knowledge of informatics, international standard and modelling, including techniques for large-scale data processing and numerical simulation, data preservation and publication, data transfer and collection and other data technologies with a vision to advance an emerging data-intensive science, namely "geoplanetary informatics".

9:00 AM - 9:15 AM JST | 12:00 AM - 12:15 AM UTC

[MGI34-01] Development of snow detection techniques by using visual IoT

*Yuki MURAKAMI[1], Ken T. Murata[1], Shigeto Watanabe[2] (1.National Institute of Information and Communications Technology, 2.Hokkaido Information University)

9:15 AM - 9:30 AM JST | 12:15 AM - 12:30 AM UTC

[MGI34-02] Environment Monitoring Using a Technology of Visual Internet of Things

*Tsutomu Nagatsuma[1], Ken T. Murata[1], Junji Tokairin[1], Kazunori Yamamoto[1], Yuki MURAKAMI[1], Takamichi Mizuhara[2] (1.National Institute of Information and Communications Technology, 2.CLEALINK TECHNOLOGY Co. Ltd.)

9:30 AM - 9:45 AM JST | 12:30 AM - 12:45 AM UTC

[MGI34-03] Release of three-dimensional geological map of central Tokyo

*Susumu Nonogaki[1], Tsutomu Nakazawa[1], Tomonori Naya[1], Junko Komatsubara[1], Yoshinori Miyachi[1], Masanori Ozaki[1], Toshio Nakayama[2] (1.Geological Survey of Japan, National Institute of Advanced Industrial Science and Technology, 2.Civil Engineering Support and Training Center, Tokyo Metropolitan Government)

9:45 AM - 10:00 AM JST | 12:45 AM - 1:00 AM UTC

[MGI34-04] Introduction of Ultra-large-scale Visualization Method for 3D Geographical Information Using a Web Browser-based Scalable Display System

Tomohiro Kawanabe[1], Kenji Ono[2], *Ken T. Murata[3], Atsushi Higuchi[4] (1.Institute of Physical and Chemical Research, 2.Kyushu University, 3.National Institute of Information and Communications Technology, 4.Chiba University)

10:00 AM - 10:15 AM JST | 1:00 AM - 1:15 AM UTC

[MGI34-05] Environmental Monitoring Experiment with the Sensor Network in Chikuma City

*Kohei Mizuani[1], Ken T. Murata[1], Kazunori Yamamoto[1], Yuki MURAKAMI[1], Kazuya Muranaga[2], Takamichi Mizuhara[3] (1.National Institute of Information and Communications Technology, 2.Systems Engineering Consultants Co., LTD., 3.CLEALINKTECHNOLOGY Co.,Ltd.)

10:15 AM - 10:30 AM JST | 1:15 AM - 1:30 AM UTC

[MGI34-06] Data Quality Control and Data Disclosure of Phased Array Weather Radar

*Shinsuke Satoh[1], Fusako Isoda[1], Hiroshi HANADO[1], Katsuhiro Nakagawa[1], Susumu Uchino[2], Kohei Yamashita[2], Kazuya Muranaga[2] (1.National Institute of Information and Communications Technology, 2.Systems Engineering Consultants (SEC))

Development of snow detection techniques by using visual IoT

*Yuki MURAKAMI[1], Ken T. Murata[1], Shigeto Watanabe[2]

1. National Institute of Information and Communications Technology, 2. Hokkaido Information University

There is low-cost single board computer such as Raspberry Pi, Arduino, etc., and it can connect the cloud service through the Internet. The single board computer is expected as architecture for Internet of Things (IoT), and many users connect sensors and actuators to the computer. Visual IoT is a kind of IoT, and it is remote sensing method to extract information from image and/or video data in real time. Video transmission is not easy in low-band network like mobile environment, it is practical method to transmit extracted information in real time to cloud server through mobile network. In other words, remote camera is used as remote visual sensor instead of video transmitter. We selected snow detection as one of visual IoT applications. We developed and tested basis algorithm for snow detection. In test, we used field camera set up in Ebetsu city (Hokkaido prefecture) and Chikuma city (Nagano prefecture), and we focused on detection of trigger when snow fall begin or end. Now, we report abstract of the algorithm and test results.

Keywords: Visual IoT

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Environment Monitoring Using a Technology of Visual Internet of Things

*Tsutomu Nagatsuma[1], Ken T. Murata[1], Junji Tokairin[1], Kazunori Yamamoto[1], Yuki MURAKAMI[1], Takamichi Mizuhara[2]

1. National Institute of Information and Communications Technology, 2. CLEALINK TECHNOLOGY Co. Ltd.

Visual Internet of Things (Visual IoT) is a technology which realizes high quality and intelligent visual data transfer via every IP network including mobile network using low-cost and programable visual data transfer system. High-performance video transmission protocol (HpVT) which was developed by CLEALINK TECHNOLOGY Co., Ltd. is a foundation of visual IoT measurement and data transfer system (visual IoT system) developed by NICT. To monitor the current traffic condition on route 398 along Mangoku-ura, we are collecting visual and meteorological data by a visual IoT system which was installed at clean center in Onagawa since Dec. 2020 under the cooperation with Onagawa town office. The main objectives of our visual IoT system in Onagawa is to monitor the traffic condition on route 398 along Mangoku-ura, and to estimate number of vehicles and its velocities using image analysis technology for quantitative understanding of traffic condition, and to study the quantitative relationship between traffic and weather condition. In addition, a PTZ camera in our system is capable to measure any image with any direction. We can extract and analyze many kinds of information, such as conditions of ships in the bay and the condition of snow falling by advanced image analysis technology. We will report current efforts and future perspectives in our activity.

Keywords: Visual IoT, Environment Monitorng, Advanced Image Analysis Technology

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Release of three-dimensional geological map of central Tokyo

*Susumu Nonogaki[1], Tsutomu Nakazawa[1], Tomonori Naya[1], Junko Komatsubara[1], Yoshinori Miyachi[1], Masanori Ozaki[1], Toshio Nakayama[2]

1. Geological Survey of Japan, National Institute of Advanced Industrial Science and Technology, 2. Civil Engineering Support and Training Center, Tokyo Metropolitan Government

For promoting utilization of geo-information in urban areas, Geological survey of Japan (GSJ) has carried out the three-dimensional (3D) urban geological mapping project. In this project, we create a 3D geological map to a depth of several tens of meters using borehole logs obtained from drilling surveys for scientific research and public construction work. Additionally, we develop a web system for sharing 3D geo-information. In the spring of 2021, the 3D geological map covering the 23 special wards of Tokyo will be released as a cooperative work with the Civil Engineering Support and Training Center, Tokyo Metropolitan Government (CETC) on the Internet.

The 3D geological map of central Tokyo is the integrated map of topographical information and geological information. With regard to topographical information, we have created a landform classification map, which comprised with 11 categories, using geospatial data, such as digital elevation models (DEMs), aerial photos, and geological maps. With regard to geological information, we have performed stratal correlation of about 50 thousand borehole logs created for public construction work, which are provided by CETC, using a standard stratigraphic framework beneath central Tokyo established based on high-quality stratigraphic data obtained from drilling surveys and laboratory works by GSJ. The GSJ stratigraphic data includes detailed core descriptions (sedimentary facies, marker tephra layers, and fossils); age measurement; and PS velocity and density logging. Further, based on the result of stratal correlation, we have generated DEMs of basal surfaces of geological layers beneath central Tokyo and constructed a surface-based 3D geological model, which has 10 geological layers.

The 3D geological map of central Tokyo will be open to the public on the website “Urban Geological Map” (https://gbank.gsj.jp/urbangeol/). On the website, users can browse the GSJ stratigraphic data, visualize the borehole log images used for mapping and the geological map in 3D, and generate a vertical cross-section image of subsurface geological structure along arbitrary line.

In this presentation, we will talk about an outline of the 3D mapping project and the result of central Tokyo.

Keywords: three-dimensional geological map, borehole logs, DEM, urban area

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Introduction of Ultra-large-scale Visualization Method for 3D Geographical Information Using a Web Browser-based Scalable Display System

Tomohiro Kawanabe[1], Kenji Ono[2], *Ken T. Murata[3], Atsushi Higuchi[4]

1. Institute of Physical and Chemical Research, 2. Kyushu University, 3. National Institute of Information and Communications Technology, 4. Chiba University

In recent years, the drawing and expression capabilities of Web browsers have evolved remarkably, making it possible to replace many desktop applications. This is largely due to advances in web technologies such as HTML5 and JavaScript. Especially in 3D graphics, with the advent of WebGL, it has become possible to bring out the same performance as native applications. ChOWDER [1] is open-source software that is being jointly researched and developed by RIKEN and Kyushu University. It is a web-based scalable display system that builds an ultra-high-resolution display environment by arranging multiple displays (full-screen Web browsers) in tiles that cannot be realized with a single PC. As an advanced and practical function of this system, we have published last year the ability to perform distributed rendering of 3D Web GIS applications on multiple display devices. [2] Using iTowns [3], a WebGL-based open source GIS, as a base software, it displays ultra-high-resolution 3D geographic information on ChOWDER's distributed display. The overlay display function of user-defined data (polygons, point clouds, etc.) provided by iTowns can also be used as it is. Fig.1 shows a 3D point cloud of the cloud observation data of the meteorological satellite HIMAWARI and the map data published by The Geospatial Information Authority of Japan overlayed on a ChOWDER display which consists of 15 4K resolution displays (total resolution: 19200x6430 pixels). Operations such as changing the viewpoint can be performed interactively on the user's PC. In this presentation, we will introduce an overview of the basic technologies that make up this function and examples of some visualization results.

[1] https://github.com/SIPupstreamDesign/ChOWDER

[2] Kawanabe, T., Hatta, K., & Ono, K. (2020, September). ChOWDER: A New Approach for Viewing 3D Web GIS on Ultra-High-Resolution Scalable Display. In 2020 IEEE International Conference on Cluster Computing (CLUSTER) (pp. 412-413). IEEE.

[3] http://www.itowns-project.org/

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Environmental Monitoring Experiment with the Sensor Network in Chikuma City

*Kohei Mizuani[1], Ken T. Murata[1], Kazunori Yamamoto[1], Yuki MURAKAMI[1], Kazuya Muranaga[2], Takamichi Mizuhara[3]

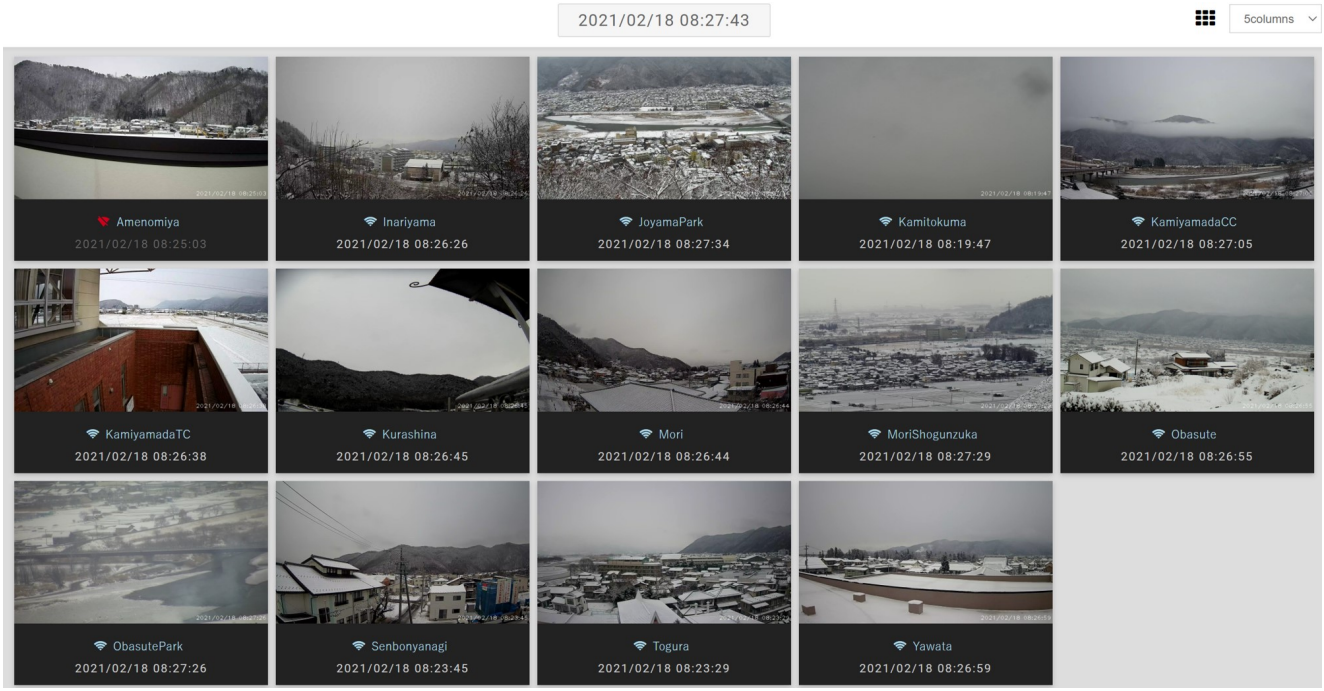
1. National Institute of Information and Communications Technology, 2. Systems Engineering Consultants Co., LTD., 3. CLEALINKTECHNOLOGY Co.,Ltd.

Internet of Things (IoT), where physical objects are connected and data of many kinds of sensors are collected over the Internet, becomes one of important social infrastructure technologies. Various sorts of data collection experiments through many kinds of network technologies in many areas have been implemented to improve services and solve problems in the community through uses and applications of the collected data. We are conducting environmental data monitoring experiments using private LoRa, which is one of the low-power wide area (LPWA) communication technologies, BLE and LTE over Chikuma city, Nagano prefecture, Japan. We recently abolished the LoRa relay station on the Koshoku governmental building which was one site of 10 LoRa relay stations and set up 5 new LoRa relay stations, resulting to 14 LoRa relay stations. The LoRa relay stations have Cameras, and high-quality images including short-time movies are transferred (Fig.1). Vaisala Weather stations are set near the all relay stations and weather data are transferred by LoRa. A few tenths of small environmental sensors are set in Togurakamiyamada Junior High School. The environmental data from these sensors are connected to the Data Cloud by BLE to LTE relay stations. Data are monitored in quasi-real time over the Internet and the various sensors are controlled over the Internet. Many kinds of sensors could be connected through this sensor network and some sensors of private companies are used in the network. A LoRa relay station has been set at Shinshu University Faculty of Engineering in Nagano city. We expect that this sensor network will be expanded and used for more applications.

Fig.1 Images from Cameras set in Chikuma city

Keywords: IoT, Sensor network, LoRa

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Data Quality Control and Data Disclosure of Phased Array Weather Radar

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1. National Institute of Information and Communications Technology, 2. Systems Engineering Consultants (SEC)

The Phased Array Weather Radar (PAWR), which was developed for early detection and prediction of torrential rain, performs detailed 3D observation in 30 seconds, and generate observation big data at 100 times the data rate of conventional parabolic antenna type weather radar. NICT is engaged in observation operation and data storage / distribution of four PAWRs installed in Suita (Osaka University), Kobe, Okinawa, and Saitama University. In general, the weather radar observation data is used in real-time to grasp and predict rainfall distribution. The PAWR real-time observation data every 30 seconds is also used in the smartphone apps "3D Amagumo Weather" and "RIKEN Weather Forecast." On the other hand, past observation data is also important for studying various rainfall events. Long-term data archiving is needed to investigate various heavy rainfall mechanisms, improved precipitation forecasting, and recent record heavy rainfall increases. On the PAWR web page (https://pawr.nict.go.jp/), a quick look (QL) image showing the rainfall distribution at an altitude of 2 km is created and published within 1 minute after observation. All QL images and rainfall summaries (graphs) are posted on the "Past Data" page. The rainfall summary includes the average rainfall, maximum rainfall, and rainfall area at an altitude of 2 km as daily and weekly graphs, and text data every 30 seconds. This QL image and rainfall summary are created for searching past data, but they are also used as useful data in themselves. Millions of QL images can be used for machine learning, and the rainfall summary can be used not only for grasping long-term rainfall conditions but also for investigating fluctuations in data quality.

Data quality control is important for the use of real-time and past data. The PAWR observation data includes unnecessary data such as surface clutter, noise, and pseudo-echo, so a data quality control (QC) flag is created within 10 seconds. However, because there are the issues of the QC accuracy due to various rainfalls, we are developing a clutter identification method using semantic segmentation. We are proceeding with the policy of disclosing past observation data as open data, but there are many issues. First, there is the problem of data capacity. The past data is saved in multiple storage servers as hourly tgz files in consideration of capacity reduction and handling, but it has already exceeded 3 PB. Since it is not realistic to publish all the data, only the requested data is copied to the data public server. Another problem is that the data is saved in polar coordinates in the original binary format, which makes it difficult for general users to use. In order to be widely used by many users as open data, it is necessary to perform data quality control and process it into an easy-to-use data format.

Keywords: Phased Array Weather Radar, Data Quality Control, Data Disclosure, Observation Big Data

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[J] Oral | M (Multidisciplinary and Interdisciplinary)：M-GI General Geosciences, Information Geosciences & Simulations

Thu. Jun 3, 2021 10:45 AM - 12:15 PM JST | Thu. Jun 3, 2021 1:45 AM - 3:15 AM UTC | Ch.03 Zoom Room 03

[M-GI34] Earth and planetary informatics with huge data management

convener:Ken T. Murata(National Institute of Information and Communications Technology), Susumu Nonogaki(Geological Survey of Japan, National Institute of Advanced Industrial Science and Technology), Rie Honda(Department of Science and Technology, System of Natual Science, Kochi University), Keiichiro Fukazawa(Academic Center for Computing and Media Studies, Kyoto University), Chairperson:Susumu Nonogaki(Geological Survey of Japan, National Institute of Advanced Industrial Science and Technology), Rie Honda(Department of Science and Technology, System of Natual Science, Kochi University)

Increasingly large and complex data are produced by observations and numerical simulations in earth and planetary sciences. The target of this session is to discuss a broad range of practices and new knowledge of informatics, international standard and modelling, including techniques for large-scale data processing and numerical simulation, data preservation and publication, data transfer and collection and other data technologies with a vision to advance an emerging data-intensive science, namely "geoplanetary informatics".

10:45 AM - 11:05 AM JST | 1:45 AM - 2:05 AM UTC

[MGI34-07] Efforts of Aizu Research Center for Space Informatics, Univ. of Aizu as a Joint Usage / Research Center

★Invited Papers

*Hirohide Demura[1] (1.The University of Aizu)

11:05 AM - 11:20 AM JST | 2:05 AM - 2:20 AM UTC

[MGI34-08] Development of a Data Analysis Environment for Small Irregular-Shaped Bodies Centered on a 3D-GIS

*Naru Hirata[1,2], Takuma Furudate[1], Hiroshi Kikuchi[3], Hirohide Demura[1,2], Hiroyuki Sato[3], Koji Matsumoto[4], Naoto Nakasato[1], Fumiya Kono[1] (1.Dep. of Computer Science and Engineering, Univ. of Aizu, 2.ARC-Space, Univ. of Aizu, 3.Japan Aerospace Exploration Agency, 4.RISE Project, National Astronomical Observatory of Japan)

11:20 AM - 11:35 AM JST | 2:20 AM - 2:35 AM UTC

[MGI34-09] Practice, Application and Future Potential of High-Capacity Space Data Processing

*Junya Terazono[1], Ken T. Murata[1], Tomohiro Sato[1], YASUKO KASAI[1] (1.National Institute of Information and Communication Technology)

11:35 AM - 11:50 AM JST | 2:35 AM - 2:50 AM UTC

[MGI34-10] **Construction of hot spring database over Japan for clarifying thermal and fluid flow structures in the upper crust**

*Jacek Scibek[1], Katsuaki Koike[1], Koki Kashiwaya[1] (1.Kyoto University)

11:50 AM - 12:05 PM JST | 2:50 AM - 3:05 AM UTC

[MGI34-11] Detection of geothermal fluids paths in highly vegetated area through a vegetation stress index using hyperspectral satellite imagery

*Taiki Kubo[1], Hiroaki Gonnokami[1], Mohamad Nur Heriawan[2], Katsuaki Koike[1] (1.Graduate School of Engineering, Kyoto University, 2.Institut Teknologi Bandung)

12:05 PM - 12:15 PM JST | 3:05 AM - 3:15 AM UTC

[MGI34-12] Discussion

Efforts of Aizu Research Center for Space Informatics, Univ. of Aizu as a Joint Usage / Research Center

*Hirohide Demura[1]

1. The University of Aizu

Efforts of Aizu Research Center for Space Informatics, Univ. of Aizu as a Joint Usage / Research Center

Keywords: Archive Science, Lunar and Planetary Explorations, Data Informatics

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Development of a Data Analysis Environment for Small Irregular-Shaped Bodies Centered on a 3D-GIS

*Naru Hirata[1,2], Takuma Furudate[1], Hiroshi Kikuchi[3], Hirohide Demura[1,2], Hiroyuki Sato[3], Koji Matsumoto[4], Naoto Nakasato[1], Fumiya Kono[1]

1. Dep. of Computer Science and Engineering, Univ. of Aizu, 2. ARC-Space, Univ. of Aizu, 3. Japan Aerospace Exploration Agency, 4. RISE Project, National Astronomical Observatory of Japan

The geographical information system (GIS) is a powerful tool integrate map data in which observed values are associated with particular locations on the surface of a target body. The GIS and GIS-oriented tools are now widely used in various research fields that study the Earth and other large bodies such as the Moon and Mars. However, datasets of irregular-shaped bodies are hard to handle with usual GIS software. They support only spherical bodies with geographical coordinate system (by longitude and latitude), which is not the unique identifier on the irregular-shaped bodies.
We proposed a concept of 3D-GIS that uses 3D representation of the body shapes to solve this problem. The shapes of an irregular-shaped bodies is represented by a 3D polygon model and the 3D model is visualized as 3D-CG.
AiGIS is a implementation of this 3D-GIS concept. can display a polygon-based 3D shape model of the target body, and users can manipulate viewing conditions and a lighting condition by mouse operations. Map data and graph map data on AiGIS are a set of data that are associated with polygons consisting of the shape model. Polygons of the shape model are displayed with a color that is assigned according to a value in the selected map data with the look-up table.
We attempt to construct an data visualization and analysis environment based on AiGIS for small body exploration data. The pixel DB, developed as a piece of the environment, can store individual pixel values of images with observational conditions such as incidence angle, emission angle, and phase angle. This DB enable us to make analysis using pixel values throughout all available images. Estimation of the parameters of phase function on the surface at each local regions is an example of application of the DB. Results of such analysis can also be visualize on the 3D-GIS. We also develop a GPGPU-based code to compute the gravitation field on and around an irregular-shaped body. Computation of the gravitation field of an irregular-shaped object requires much time or CPU resource. The GPGPU-based code will greatly reduce computation time by parallel processing by GPU.
We will present not current status of AiGIS, pixel DB, and GPGPU-based gravitation field calculation code, but also future prospects of the analysis environment or small body exploration data.

Keywords: asteroid, GIS, image DB, gravitation field, GPGPU

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Practice, Application and Future Potential of High-Capacity Space Data Processing

*Junya Terazono[1], Ken T. Murata[1], Tomohiro Sato[1], YASUKO KASAI[1]

1. National Institute of Information and Communication Technology

The author continued his research on integrated visualization of scientific data, particularly image data, obtained by lunar and planetary exploration. The method consists primarily of constructing an image-based map on the Web-GIS system and overlaying visualized scientific data. The author constructed a prototype system called "WISE-CAPS" (Web-based Integrated Secure Environment for Collaborative Analysis of Planetary Science) which displays scientific data acquired in lunar explorations overlapping image data on a web browser window. Such a system will assist scientists in making new discoveries more easily by easily comparing various types of scientific data.
The amount of scientific information obtained from an exploration program increases rapidly over these years. Moreover, the total amount of data gathering all explorations made so far is also increasing. This means that the quantity of data that scientists should be processed is increasing. This leads to a growing demand for the development of data processing systems that scientists can operate intuitively and comprehensively.
Also, such system can be used, not by scientists, but by general citizens. The "Citizen Science" movement, which is led by citizens themselves to carry out scientific activities, is broadening its pace. Also, the publication and public outreach are currently generally regarded as an essential element of the scientific activity to deliver importance and progress of scientific research. The author should point out that the system useful for scientists may also be useful for citizens in general.
In this presentation, in addition to the lunar and planetary data processing system that the author has been working on for many years, authors address the outline of the ground data processing system for the GOSAT-GW, Global Observing Satellite for Greenhous Gases and Water Cycle, and outreach-oriented games using data obtained by Himawari 8, Geostationary Meteorological Satellite of Japan. These systems and applications demonstrate the essence of what the high-capacity space data handling system should have. Also, we address the future potential and ideal form of high-capacity space data processing system.

Keywords: lunar and plaentary exploration, data processing, earth observation, GIS, outreach

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Construction of hot spring database over Japan for clarifying thermal and fluid flow structures in the upper crust

*Jacek Scibek[1], Katsuaki Koike[1], Koki Kashiwaya[1]

1. Kyoto University

At Kyoto University, there is an on-going project that involves a review of various sources of geothermal data in Japan. The databases are updated using GIS, 3D models, and deep-learning algorithms to extract and correlated useful data. In the case of geothermal water use, the data exist in several categories that we must review and merge. One type of data are historical and modern records, maps, and statistics about the "hot spring" (thermal spring from warm to hot) development and management. Another important source of geothermal data are technical studies related to the geothermal energy exploration and development projects, but also in many of the managed hot spring areas, and natural volcanic areas. Finally, all data from deep drilling and studies are put together in a 3D hydro-structural-geothermal models and maps of heat flow and hydrothermal circulation and tectonic structure in Japan. This presentation is focused on the extraction of useful geothermal data for the national model from the observations of "hot springs" and thermally-heated groundwater anomalies in general. We are interested in the situation at the top of crystalline bedrock below surficial sediments and basins, although the hot and other springs usually emerge, or are pumped, within those shallow sediments because of the shallow depth (good access), and of high permeability and porosity (thermal water aquifers). These sediments usually obscure the true source of the thermal water up-flow location, but many fault zones are suspected to be sources in volcanic areas, and in some case, from deeper bedrock. There is some difficulty with understanding of some available data for many reasons: 1) commercial development (drilling, capturing, redistribution, etc.) of spring waters in Japan, 2) different definitions and labels used in geoscientific, local government statistics of "hot spring" use, and historical documents, 3) existing databases created for different purposes (e.g. whole hot spring areas vs. individual wells), 4) significant changes over the years of "hot spring" production and natural state. In our review in 2020, we noted that in many areas of Japan, almost the whole thermal plume in groundwater is captured and quantified, but in other areas only a small part of the thermal up-flow is used. Much of the thermal groundwater is lost to the hydrologic system or the ocean coast without counting the heat and mass flow. The improvement in these databases, and joining with other heat flow models (e.g. deep geothermal wells) can help to model the hydrothermal systems under Japan, and perhaps to also estimate the permeability of fault zone conduits and other conduits. Although the heat flow through rocks has been mapped regionally so far, the focus is also now on particular more permeable hot water conducting structures and the rates of heat flow through rocks and convectively by hot water circulation. The "hot spring" information is very abundant and is one of the best expressions of the underlying hydrothermal flow system and hydraulic structures under Japan. Therefore, these data and mappingresults can contribute to comprehensive understandings of the thermal fluid flow patters, geochemical water properties, and its relation with heat flow and geology within the upper Earth's Crust under Japan.

Keywords: hot spring, database, geothermal, structures, heat flow

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Detection of geothermal fluids paths in highly vegetated area through a vegetation stress index using hyperspectral satellite imagery

*Taiki Kubo[1], Hiroaki Gonnokami[1], Mohamad Nur Heriawan[2], Katsuaki Koike[1]

1. Graduate School of Engineering, Kyoto University, 2. Institut Teknologi Bandung

Detection of geothermal fluids paths including steam and gas from a geothermal reservoir is a major target of geothermal prospecting. Remote sensing analysis is one of the low-cost and effective methods to detect fractures distribution that have a function as fluid flow paths. However, vegetation cover is an obstacle for prospecting when the geothermal potential field are located in tropical mountainous areas. In this study, we extracted geothermal manifestations from highly vegetated areas using the linear spectral unmixing (LSU) method and a vegetation stress index. Hede et al. (2015) applied a vegetation stress index calculated from multispectral data, and we improved the index, termed as Vegetation Index considering Blue shift and Shortwave infrared (VIBS), using hyperspectral data which has a higher wavelength resolution. The Wayang Windu Geothermal Field (WWGF) situated in West Java, Indonesia was selected as a study site. Vegetation-covered zones were extracted from a hyperspectral image, obtained by Hyperion using the application of LSU. The spatial distribution of VIBS was clarified over the whole vegetation-covered area. The high-stress zones by VIBS were mainly overlapped with the location of geothermal manifestations in WWGF. In addition, lineament distribution was estimated from DEMNAS, the digital elevation model provided by the geospatial information agency of Indonesia. The high permeable zones were estimated from the lineament distribution and the result of the radon gas survey (Heriawan et al., 2020). The corresponding high-stress with the estimated high permeable zones suggested the presence of permeable fractures that act as the ascent paths of geothermal fluid flows.

Keywords: geothermal resource exploration, Hyperion, Indonesia, remote sensing, spectral unmixing

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[J] Oral | M (Multidisciplinary and Interdisciplinary) | M-GI General Geosciences, Information Geosciences & Simulations

[M-GI34] Earth and planetary informatics with huge data management

convener:Ken T. Murata(National Institute of Information and Communications Technology), Susumu Nonogaki(Geological Survey of Japan, National Institute of Advanced Industrial Science and Technology), Rie Honda(Department of Science and Technology, System of Natual Science, Kochi University), Keiichiro Fukazawa(Academic Center for Computing and Media Studies, Kyoto University), Chairperson:Susumu Nonogaki(Geological Survey of Japan, National Institute of Advanced Industrial Science and Technology), Rie Honda(Department of Science and Technology, System of Natual Science, Kochi University)

Thu. Jun 3, 2021 10:45 AM - 12:15 PM Ch.03 (Zoom Room 03)

Increasingly large and complex data are produced by observations and numerical simulations in earth and planetary sciences. The target of this session is to discuss a broad range of practices and new knowledge of informatics, international standard and modelling, including techniques for large-scale data processing and numerical simulation, data preservation and publication, data transfer and collection and other data technologies with a vision to advance an emerging data-intensive science, namely "geoplanetary informatics".

12:05 PM - 12:15 PM

[MGI34-12]Discussion

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[J] Oral | M (Multidisciplinary and Interdisciplinary)：M-TT Technology & Techniques

Thu. Jun 3, 2021 9:00 AM - 10:30 AM JST | Thu. Jun 3, 2021 12:00 AM - 1:30 AM UTC | Ch.17 Zoom Room 17

[M-TT42] Frontiers in Geochemistry

convener:Tsuyoshi Iizuka(University of Tokyo), Yoshio Takahashi(Department of Earth and Planetary Science, Graduate School of Science, The University of Tokyo), Urumu Tsunogai(Graduate School of Environmental Studies, Nagoya University), Chairperson:Tsuyoshi Iizuka(University of Tokyo), Aya Sakaguchi(Faculty of Pure and Applied Science)

The Earth and planetary sciences have been advanced through utilizing chemical approaches and state-of-the-art analytical techniques. Recent analytical developments allow us to obtain highly precise and accurate data, but at the same time require deepen knowledge on the methodology to use the data correctly and effectively. This session aims at providing an opportunity for various researchers to get together and have a strategic discussion on frontiers in geochemistry and cosmochemistry. In particular, researchers who would like to apply innovative analytical techniques will have chances to discuss with those who work on devising new geochemical methods. We welcome a wide range of cutting-edge geochemical topics, including technical developments, which have a potential for breakthrough of the Earth and planetary sciences. Any presentations related to the direction of future geochemistry and cosmochemistry are also welcome. We expect wide-ranged and future-oriented discussion to further develop geochemistry and cosmochemistry. Note that presentation language in this session can be either English or Japanese.

9:00 AM - 9:15 AM JST | 12:00 AM - 12:15 AM UTC

[MTT42-01] High energy resolution fluorescence XAFS for the speciation of trace elements in environment

Yamaguchi Akiko[1,4], Hikaru Miura[3], Makoto Nagasawa[1], *Yoshio Takahashi[1,2] (1.Department of Earth and Planetary Science, Graduate School of Science, The University of Tokyo, 2.Photon Factory, 3.CRIEPI, 4.JAEA)

9:15 AM - 9:30 AM JST | 12:15 AM - 12:30 AM UTC

[MTT42-02] Quantifying denitrification rate across water-sediment interface in aquatic areas by using triple oxygen isotopes as tracers

*FEI CUIXIA[1], Fumiko Nakagawa[1], Urumu Tsunogai[1], Masanori Ito[1], Hiroka Mizuno (1.Nagoya University)

9:30 AM - 9:45 AM JST | 12:30 AM - 12:45 AM UTC

[MTT42-03] High-precision measurement of ^{17}O-excess in phosphate in hydrosphere

*Takashi Sambuichi[1], Urumu Tsunogai[1], Fumiko Nakagawa[1], Masanori Ito[1] (1.Graduate School of Environmental Studies, Nagoya university)

9:45 AM - 10:00 AM JST | 12:45 AM - 1:00 AM UTC

[MTT42-04] Development of iron stable isotope measurement for biological tissue and its application to the marine organisms

*Nanako Hasegawa[1], TAKAAKI ITAI[1], Yoshio Takahashi[1], Tatsuya Kunisue[2], Shinsuke Tanabe[2] (1.Department of Earth and Planetary Science, The University of Tokyo, 2.CMES, Ehime Univ.)

10:00 AM - 10:30 AM JST | 1:00 AM - 1:30 AM UTC

[MTT42-05] Interaction between Cerium and H_2O in Hydrous Rhyolitic Melts

★Invited Papers

*Nozomi Kondo[1], Yoshio Kono[1], Koji Ohara[2], Ryoichi Nakada[3], Toshiaki Ina[2], Etienne Skrzypek[4,7], Akihiro Yamada[5], Satoshi SAITO[6] (1.Geodynamics Research Center, Ehime University, 2.Center for Synchrotron Radiation Research, Japan Synchrotron Radiation Institute, 3.Kochi Institute for Core Sample Research, Japan Agency for Marin-Earth Science and Technology, 4.Graduate School of Science, Kyoto University, 5.Center of Glass Science and Technology, The University of Shiga Prefecture, 6.Department of Earth

Science, Graduate School of Science and Engineering, Ehime University, 7.Institute of Earth Science, University of Graz)

High energy resolution fluorescence XAFS for the speciation of trace elements in environment

Yamaguchi Akiko[1,4], Hikaru Miura[3], Makoto Nagasawa[1], *Yoshio Takahashi[1,2]

1. Department of Earth and Planetary Science, Graduate School of Science, The University of Tokyo, 2. Photon Factory, 3. CRIEPI, 4. JAEA

Speciation of trace elements in environment is essential for better understanding of their behaviors in environment. For this purpose, X-ray absorption fine structure spectroscopy (XAFS) in fluorescence mode is one of most effective methods, but interference on the signal of each trace element by those from background elements is a severe problem to selectively obtain the signal from trace elements. To overcome the difficulties, we have employed two methods, which are using (i) high energy resolution energy dispersive detector and (ii) wavelength dispersive detection system. In this presentation, various applications of the two methods were shown for chemical state analysis of trace elements in geochemical samples. For example, oxidation state of Eu in feldspar, oxidation state of Ce in weathered granite, and radiocesium (RCs) species in cesium-bearing silica microparticles (CsMP) using X-ray absorption near-edge structure (XANES) analysis in fluorescence mode. It is also evident that to measure extended X-ray absorption fine structure (EXAFS) spectroscopy is not possible due to the lower signal to noise ratio. On the other hand, XANES, which can be obtained for trace elements, is not very informative in terms of chemical state analysis of various elements in the samples. However, higher energy resolution detection of fluorescence X-ray than the degree of lifetime broadening enables us to measure XANES itself by better energy resolution, which is known as high energy resolution fluorescence detection (HERFD) XANES. The HERFD-XANES has more information on electronic state of each element given by the method, by which we can extract chemical information to the maximum degree possible. As an example of HERFD-XANES, speciation of cesium and barium adsorbed within the interlayer of phyllosilicates will be presented.

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Quantifying denitrification rate across water-sediment interface in aquatic areas by using triple oxygen isotopes as tracers

*FEI CUIXIA[1], Fumiko Nakagawa[1], Urumu Tsunogai[1], Masanori Ito[1], Hiroka Mizuno

1. Nagoya University

Nitrate is one of the most important nutrients in aquatic systems, however, increasing nutrients result in eutrophication. Denitrification, the microbial reduction of nitrate (NO_3^-) to gaseous products (N_2 and/or N_2O), is an important process removing excess loaded nitrate from aquatic systems. Denitrification primarily occurs in the sediment (Seitzinger, 1988). Methods to quantifying denitrification rates at water-sediment interface has been established, such as acetylene inhibition method (Sorensen, 1978). However, the rates quantified by using the method is not accurate, sediment slurries for assay of denitrification rates probably overestimate in situ rates because denitrification is severely limited by nitrate, and shaking forces nitrate into zones where it would not normally be present (Oremland et al., 1984).

Recently, triple oxygen isotopic composition has been used to quantify nitrogen dynamics in various ecosystems. While atmospheric nitrate shows anomalous ^{17}O-enrichment with mean ^{17}O-excess ($\Delta^{17}O$) of +26‰, remineralized nitrate shows $\Delta^{17}O$ of 0‰ (Tsunogai et al., 2016). Besides, $\Delta^{17}O$ of nitrate is constant during bacterial processes of denitrification and assimilation on nitrate. As a result, changes in $\Delta^{17}O$ of nitrate occur only through addition of remineralized nitrate newly produced through nitrification. Therefore, both denitrification and nitrification rates can be independently quantified by using $\Delta^{17}O$ nitrate as tracer.

The object of this study is to apply the $\Delta^{17}O$ method to quantify both denitrification and nitrification rates at water-sediment interface in aquatic systems. Sediment samples were collected from Lake Biwa, in summer (31st, Aug) and winter (1st, Dec) of 2020. The cores contained 2 L ~ 3 L of sediment with 1.2 L ~ 2.5 L of overlying water, and were incubated in the dark at 7 ℃ for 48 hours, after the $\Delta^{17}O$ nitrate tracer ($\Delta^{17}O \fallingdotseq +19.2‰$) was added to the overlying water. Water samples were collected at 12-hour interval with originally made sampler. Nitrate $\Delta^{17}O$ measurements were determined by converting the nitrate in each sample to N_2O using the chemical method (Nakagawa et al., 2013). Purified N_2O was introduced into our original gold tube unit (Komatsu et al., 2008), which was held at 780℃ for the thermal decomposition of N_2O to N_2 and O_2. The produced O_2 purified from N_2 was then subjected to a continuous-flow isotope ratio mass-spectrometry system to determine the $\delta 33$ and $\delta 34$ by simultaneous monitoring of O_2^+ isotopologues at m/z ratios of 32, 33 and 34.

Results showed that denitrification rates were about 20.0 μmol m^2 h^{-1} and 3.0 μmol m^2 h^{-1} in summer and winter respectively while the removal constant was stable at around 0.01h^{-1} between two seasons. Denitrification rate from the entire lake sediments was determined and compared with that from the entire water column of Lake Biwa in summer, at around 77.1 μmol m^2 h^{-1}. Denitrification rates in the water-sediment interface was about a quarter of that from the water column in summer.

Keywords: denitrification rate, sediment, triple oxygen isotopic compositions

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High-precision measurement of ^{17}O-excess in phosphate in hydrosphere

*Takashi Sambuichi[1], Urumu Tsunogai[1], Fumiko Nakagawa[1], Masanori Ito[1]

1. Graduate School of Environmental Studies, Nagoya university

Since the pioneer work by Tudge (1960), the oxygen isotope ratio ($\delta^{18}O$) of inorganic phosphate (PO_4^{3-}) has been widely used as a proxy for the sources of dissolved inorganic phosphate (DIP), an essential nutrient in hydrosphere. While phosphate assimilated into biosphere rapidly exchange oxygen atoms with those in H_2O through enzymatic reactions, the P–O bonds in phosphate are always stable during the inorganic processes in hydrosphere. Therefore, DIP preserves isotopic signals that primary reflect the environment in which DIP had interacted with biosphere.

The $\delta^{18}O$ value of DIP remineralized from organic phosphorus (Org-P), however, is a function of temperature and $\delta^{18}O$ of H_2O when DIP had been assimilated into biosphere and converted to Org-P. Besides, it also varies depending on the type of Org-P and enzymes which hydrolyzes Org-P into DIP. As a result, it was often difficult to fix $\delta^{18}O$ values of remineralized DIP in general and to clarify the sources of DIP in hydrosphere only by using $\delta^{18}O$ as a tracer.

Our aim in this study is to quantify the ^{17}O-excess of DIP in hydrosphere ($\Delta'^{17}O \approx \delta^{17}O - 0.528 \times \delta^{18}O$) as an additional tracer to overcome the problems in using $\delta^{18}O$ of DIP. Influences of the isotope fractionation process on ^{17}O-excess should be negligible owing to mass-dependent fractionation between the corresponding $\delta^{17}O$ and $\delta^{18}O$ values during the progress of the enzymatic reactions. As a result, the ^{17}O-excess in DIP remineralized from Org-P corresponds with that of ambient H_2O when DIP had been assimilated into biosphere and converted to Org-P. Therefore, the ^{17}O-excess in DIP can be a robust tracer to clarify the sources of DIP, such as biosphere or the other sources such as igneous rocks, which should be depleted in ^{17}O relative to hydrosphere. This is the first study to report accurate and precise ^{17}O-excess in DIP.

Firstly, we extracted phosphate from the samples of river water (Tempaku river, Aichi prefecture), igneous apatite, and chemical fertilizers and precipitate phosphate as Ag_3PO_4. The decomposition of Ag_3PO_4 to extract oxygen atoms as O_2 was performed with a fluorination technique using BrF_5 at 250℃. Extracted and purified O_2 was analyzed using the dual inlet mode of a mass spectrometer with a cup configuration of m/z = 32, 33, and 34. The SD during multiple measurements of in-house Ag_3PO_4 standards showed 0.3 ‰for $\delta^{17}O$, 0.6 ‰for $\delta^{18}O$, and 0.02 ‰for $\Delta'^{17}O$. The O_2 yield relative to the ideal oxygen quantity in the decomposed Ag_3PO_4 was 119 % ±7 %, implying that all oxygen in a sample was extracted quantitatively. Additionally, during the measurements on all samples including in-house Ag_3PO_4 standards, we could not find any significant correlations between the oxygen isotope ratios and the reciprocal of the O_2 quantity, which implies that contribution of blank O_2 was minimum. Thus, the $\delta^{17}O$ and $\delta^{18}O$ values were obtained as the mean of multiple measurements in this study.

While the $\Delta'^{17}O$ value of DIP under the oxygen isotope exchange equilibrium with ambient river H_2O was estimated to be $+27 \times 10^{-6}$, those of the riverine DIP determined in this study ranged from -71 to $+3 \times 10^{-6}$. It is difficult to explain this ^{17}O-depleted DIP through remineralization of Org-P in hydrosphere. Besides to DIP remineralized from biosphere, we should assume some additional sources for the ^{17}O-depleted DIP in this river. Because the $\Delta'^{17}O$ value of the ^{17}O-depleted DIP endmember coincided with that of chemical

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fertilizer ($\Delta'^{17}O = -94 \times 10^{-6}$) determined in this study, we concluded that direct input of chemical fertilizer into the DIP pool of this river might be highly responsible for the source of the ^{17}O-depleted DIP. Based on the isotopic mass balance of the $\Delta'^{17}O$ values, we estimated that 20–80 % of DIP in this river was derived from the chemical fertilizer.

Keywords: Triple oxygen isotope, Dissolved inorganic phosphate, Hydrosphere, Biosphere

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Development of iron stable isotope measurement for biological tissue and its application to the marine organisms

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Iron (Fe) is one of the essential elements in the biota and its biogeochemical cycle strongly controls the primary productivity in the ocean. Despite complexity of Fe cycle in surface ocean, application of Fe stable isotope through marine ecosystem has been limited. Here we show the variation of δ^{56}Fe of marine organisms collected from Northwest Pacific Ocean. The samples (n=32) include fishes (4 species), cephalopod (1 species), cetaceans (3 species), and zooplankton (mainly copepods) inhabiting around Japan. The process of Fe stable isotope fluctuation was discussed by focusing on (1) trophic level, (2) habitat, and (3) metabolic process.

The δ^{56}Fe was analyzed using multi-collector inductively coupled plasma mass spectrometer (MC-ICP-MS, Thermo Fisher Scientific, Germany). The pretreatment was established by improving the anion-exchange column separation for removing matrixes. The accuracy of the analytical method was evaluated using 4 types of biological certified reference materials (CRM; DORM-4, DOLT-5, BCR-414, and ERM-CE464). The difference between measured and certified values was <0.06 ‰which is smaller than the precision of duplicate measurements (0.09‰). We obtained new δ^{56}Fe value for BCR-414 and DOLT-5 which showed -0.09 ±0.07 ‰and -2.32 ±0.07 ‰, respectively.

The measured δ^{56}Fe of marine organisms were as following, zooplankton: -0.03 ±0.08 ‰(n = 1), fish muscle: -2.64 ‰to -0.71 ‰(n = 19, average: -1.65 ‰), cetacean muscle: −2.37 ‰to −1.74 ‰(n = 9, average: −2.15 ‰). Most biological samples had lower δ^{56}Fe than the reported value of surface seawater (+0.3 to +0.7‰, Conway and John, 2014). The δ^{56}Fe values increased in order of cetacean < fish < zooplankton, suggesting that light isotopes tend to enrich with increase of trophic level. This is consistent with the sequential change of isotope value through the food chain as observed by other elements such as nitrogen and calcium although directions of isotope shift are variable. Despite general decreasing trend of δ^{56}Fe with trophic level, Japanese sardines (*Sardinops melanostictus*), an important prey for migratory fish, showed significantly lower values than the higher predator fishes. This indicated that sequential depletion of heavy isotope is not only the predominant fractionation process, thereby species specific fractionation process controlled by physiological characteristics should be examined.

Regional differences were assessed by comparing δ^{56}Fe of Japanese sardines (off Kochi and off Miyagi) and skipjack tuna (*Katsuwonus pelamis*, offshore Kamchatka, off Sanriku, off Guam, and East China Sea) of which data of multiple regions were available. No significant regional difference was observed, although the number of samples from each region was limited. The range of δ^{56}Fe of all skipjack tuna (-1.46 ‰to -0.71 ‰) had clearly higher than that of sardines (-2.64 ‰to -1.73 ‰), suggesting that the difference of species control δ^{56}Fe greater than that of region.
According to the pharmacokinetic property of Fe, potential isotope fractionation processes are classified into absorption, metabolism (change in chemical form), and excretion. The higher δ^{56}Fe in the liver than in muscle was plausibly derived from large isotope fractionation between heme Fe (predominat Fe form in red blood cell and muscle) and non-heme Fe (mainly stored in liver) in the body. Hence, the ratio of Fe burden between heme Fe and non-hem Fe pools possibly control tissue specific isotope value. Intestinal absorption is another important fractionation process. Rate of absorption can be a controlling factor of δ

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^{56}Fe of whole body due to the preferential absorption of light isotope. Although precise estimation of absorption efficiency of each species is difficult, mass balance calculation using fisheries ecological data suggested absorption efficiency can be a most important controlling factor. Our data provided here can be useful benchmark of Fe isotope systematics through marine ecosystem.

Keywords: iron stable isotope, metabolism, marine food web

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Interaction between Cerium and H_2O in Hydrous Rhyolitic Melts

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Cerium (Ce) in silicate melt is considered to provide important information about the nature of silicate magmas in the Earth’ s and planetary interiors, especially about their oxidation state. However, the behavior of Ce in a silicate melt may not be simple, particularly in hydrous silicate melt, where a strong depression of the Ce^{4+}/Ce^{3+} ratio occurs. Here we investigate the interaction between cerium and H_2O in the structure of hydrous rhyolitic melts. Hydrous rhyolitic glasses quenched from melts at 1 GPa and 1300 ˚C show a significant decrease of H_2O solubility by the incorporation of Ce. Pair distribution function analyses show no distinct change in the local structures of hydrous rhyolitic glasses with the incorporation of Ce, while we found a distinct change in the intensity of the T-OH (where T is Si or Al) Raman peak. The incorporation of Ce decreases the proportion of T-OH species and increases those of Q^4 and Q^3 species. These results suggest the occurrence of a direct charge transfer reaction between OH^- in the melt and incorporated Ce as $Ce^{4+}_{melt} + 2(OH)^-_{melt} \rightarrow Ce^{3+}_{melt} + H_2O + O^-_{melt}$. This reaction causes a charge transfer from Ce^{4+} to Ce^{3+} in the hydrous rhyolitic melt, and it inevitably produces Ce^{3+}. X-ray absorption near-edge structure (XANES) measurements show almost completely trivalent Ce (Ce^{3+}) in the Ce-incorporated hydrous rhyolitic glasses, which supports the production of Ce^{3+} through the charge transfer reaction between Ce and OH^-. The decrease of Ce^{4+}/Ce^{3+} ratio reported in hydrous silicate melts would be due to the charge transfer reaction between Ce and OH^-, which implies that the Ce^{4+}/Ce^{3+} ratio in hydrous silicate melts may bear a complex relationship to the oxidation state of magmas.

Keywords: Cerium, Rhyolitic melt, Water

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[J] Oral | M (Multidisciplinary and Interdisciplinary)：M-TT Technology & Techniques

Thu. Jun 3, 2021 10:45 AM - 12:15 PM JST | Thu. Jun 3, 2021 1:45 AM - 3:15 AM UTC | Ch.17 Zoom Room 17

[M-TT42] Frontiers in Geochemistry

convener:Tsuyoshi Iizuka(University of Tokyo), Yoshio Takahashi(Department of Earth and Planetary Science, Graduate School of Science, The University of Tokyo), Urumu Tsunogai(Graduate School of Environmental Studies, Nagoya University), Chairperson:Urumu Tsunogai(Graduate School of Environmental Studies, Nagoya University), Yoshio Takahashi(Department of Earth and Planetary Science, Graduate School of Science, The University of Tokyo)

The Earth and planetary sciences have been advanced through utilizing chemical approaches and state-of-the-art analytical techniques. Recent analytical developments allow us to obtain highly precise and accurate data, but at the same time require deepen knowledge on the methodology to use the data correctly and effectively. This session aims at providing an opportunity for various researchers to get together and have a strategic discussion on frontiers in geochemistry and cosmochemistry. In particular, researchers who would like to apply innovative analytical techniques will have chances to discuss with those who work on devising new geochemical methods. We welcome a wide range of cutting-edge geochemical topics, including technical developments, which have a potential for breakthrough of the Earth and planetary sciences. Any presentations related to the direction of future geochemistry and cosmochemistry are also welcome. We expect wide-ranged and future-oriented discussion to further develop geochemistry and cosmochemistry. Note that presentation language in this session can be either English or Japanese.

10:45 AM - 11:00 AM JST | 1:45 AM - 2:00 AM UTC

[MTT42-06] High resolution mass spectrometry analysis of alkaline copper oxide degradation products from insoluble organic matter in carbonaceous chondrite

*Miho Shigenaka[1], Tomoko Amimoto[1], Hikaru Yabuta[1] (1.Hiroshima University)

11:00 AM - 11:15 AM JST | 2:00 AM - 2:15 AM UTC

[MTT42-07] Analysis of single platinum nanoparticles using high-time resolution multiple collector ICP-MS (HTR-MC-ICP-MS) and application to cosmochemical samples

*Norika Numa[1], Shuji Yamashita[1], Takafumi Hirata[1] (1.School of science, The University of Tokyo)

11:15 AM - 11:30 AM JST | 2:15 AM - 2:30 AM UTC

[MTT42-08] On-site Magnetic Separation of Heterogeneous Geological Particles

*Chiaki Uyeda[1] (1.Institute of earth and Space Science Graduate School of Science Osaka University)

11:30 AM - 11:45 AM JST | 2:30 AM - 2:45 AM UTC

[MTT42-09] Towards quantitative evaluation of the chondritic Earth model: A combined geo-neutrino, -physics, and -chemistry study

*Tsuyoshi Iizuka[1], Nozomu Takeuchi[1], Kenta Ueki[2], Akiko Tanaka[3], Sanshiro Enomoto[4], Hiroko Watanabe[5], Satoru Haraguchi[1] (1.University of Tokyo, 2.JAMSTEC, 3.AIST, 4.University of Washington, 5.Tohoku University)

11:45 AM - 12:00 PM JST | 2:45 AM - 3:00 AM UTC

[MTT42-10] Element abundance modeling method with the gamma distribution for quantitative balance calculations

*Sanshiro Enomoto[1,2], Kenta Ueki[3], Tsuyoshi Iizuka[4], Nozomu Takeuchi[5], Akiko Tanaka[6], Hiroko Watanabe[7], Satoru Haraguchi[5] (1.Kavli Institute for the Physics and Mathematics of the Universe, University of Tokyo, 2.University of Washington, 3.Japan Agency for Marine-Earth Science and Technology, 4.University of Tokyo, 5.Earthquake Research Institute, University of Tokyo, 6.National Institute of Advanced Industrial Science and Technology, 7.Research Center for Neutrino Science, Tohoku University)

12:00 PM - 12:15 PM JST | 3:00 AM - 3:15 AM UTC

[MTT42-11] Prospects of Ocean Bottom Geoneutrino Detector for direct observation of mantle radioactive element distribution

*Kenta Ueki[1], Natsue Abe[1], Hiroko Watanabe[2], Kunio Inoue[2], Taichi Sakai[2], William F McDonough[2,3,4], Eiichiro Araki[1], Takafumi Kasaya[1], Kyo Masanori[1], Noriaki Sakurai[1] (1.Japan Agency for Marine-Earth Science and Technology, 2.Tohoku University Research Center for Neutrino Science, 3.Graduate School of Science, Tohoku University, 4.University of Maryland)

High resolution mass spectrometry analysis of alkaline copper oxide degradation products from insoluble organic matter in carbonaceous chondrite

*Miho Shigenaka[1], Tomoko Amimoto[1], Hikaru Yabuta[1]

1. Hiroshima University

Introduction

It has been thought that asteroids, comets, and cosmic dusts delivered prebiotic organic molecules to the early Earth (Ehrenfreund et al. 2000). Carbonaceous chondrite, which are probably derived from carbonaceous asteroids, contains acid-insoluble organic matter (IOM) that accounts for a major part of the total organic carbon of the meteorite (Pizzarello et al. 2006). According to the previous studies, IOM is composed of aromatic molecular network crosslinking with short-branched aliphatic chains and various oxygen functional groups (Cody et al. 2002). However, because of its complex structure, the intact structure of IOM is still unknown. For better understanding of the chemical structure of IOM at a molecular level, we chemically degraded IOM by an alkaline CuO oxidation, which selectively cleaves ether bonds of macromolecules, and analyzed the decomposition products by using a high resolution mass spectrometry.

Sample and Methods

Insoluble organic matter was purified from the powdered sample (676 mg) of Murchison carbonaceous CM2 chondrite by an acid treatment with HCl/HF. The obtained IOM was heated with CuO (10 mg), 2N NaOH aq (2.5 ml), and ammonium iron (II) sulfate hexahydrate (1.2mg) at 170℃, 3 hours. After heating, the sample were extracted with ethyl acetate. The extracts were concentrated into 100 μl and were analyzed by a high-resolution mass spectrometry (LTQ Orbitrap XL, Thermo Fisher Scientific) negative ion mode.

Results and Discussion

In this study, 222 ion peaks were identified as the alkaline CuO oxidation products of IOM from Murchison meteorite. Based on the exact masses of the ion peaks, possible composition formula were individually estimated. The main ion peaks, such as m/z 165.01946 ($C_8H_6O_4$), m/z 121.02982 ($C_7H_6O_2$), m/z 181.01428 ($C_8H_6O_5$), m/z 137.02463 ($C_7H_6O_3$), m/z 209.00905 ($C_9H_6O_6$), are probably corresponded to benzendicarboxylic acid, benzoic acid, hydroxybenzendicarboxylic acid, hydroxybenzoic acid, and benzenetricarboxylic acid, respectively, which were previously identified by a gas chromatography coupled with mass spectrometry (GCMS) measurement of the alkaline CuO oxidation products of Murchison IOM (Hayatsu et al. 1980). In addition, the ion peaks corresponded to the other twenty-two compounds identified by Hayatsu et al. (1980), were also detected in this study. As a result, 195 ion peaks were newly identified in this study. According to an unsaturation degree of the possible

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composition formula, the peaks can be classified into 95 kinds of aliphatic carboxylic acids, 98 kinds of 1-3 ring-aromatic carboxylic acids and/or phenols, 9 kinds of nitrogen-containing compounds, 15 kinds of sulfur-containing compounds. Furthermore, the composition formula corresponded to dicarboxylic acids ranging from C_2 to C_{15} were identified in this study, implying that longer aliphatic chains are ether-linked between aromatic moieties in IOM than reported by the previous studies. There results demonstrate that a structure of IOM in carbonaceous chondrite is more complex than previously thought, and they constrain the origin and evolution of organic compounds in the early Solar System.

Keywords: Carbonaceous chondrite, Insoluble organic matter(IOM), Alkaline copper oxide degradation, High resolution mass spectrometry analysis, Asteroid

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Analysis of single platinum nanoparticles using high-time resolution multiple collector ICP-MS (HTR-MC-ICP-MS) and application to cosmochemical samples

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Introduction

Heavy elements, which played an important role to define the physicochemical evolution of both the Earth and life, are mainly produced by a neutron capture reaction, including s- and r-processes (Burbidge et al., 1957). The r-process is an explosive reaction process, and thus, the estimating of amount and isotopic composition of the elements produced have been retarded. To overcome this, we are trying to derive the material evidence or constraints from presolar grains in meteorites.

The presolar grains are the small grains of sizes varying from nm to μm (Lewis and Anderson, 1983). Isotopic signatures of the light elements, such as C, N, O, or Si, have been widely used to identify the presolar grains, and very few approaches were made to identify the presolar grains based on heavy elements. To understand both the origin and transport mechanism of the heavy elements, new identification protocol using the heavy elements is highly desired. In this study, the element Pt, which enriched in r-process isotopes is used as a test element to establish the new identification protocol for the presolar grains in meteorites. To do this, we have developed a new analytical technique for both the sensitive and fast Pt isotopic ratio measurements from small particles (i.e., nanoparticles).

With the isotopic analysis of nanoparticles using the ICP-MS technique, great care must be placed on the systematical error in the measured isotopic ratio caused by counting loss due to very high-count rates of the analytes (Obayashi et al., 2017). Faced with this, careful correction for the counting loss due to detector dead time was made to obtain reliable isotopic ratio measurements from the transient signals emanating from nanoparticles.

Another important development is that the sampling technique of the cosmic nanoparticles from meteorites. In this study, a laser ablation in liquid (LAL) technique was applied to extract the cosmic nanoparticles in meteorites. With the LAL technique, sample grains can be collected into the small volume of water without nearly no chemical invasions, and also the particles could be physically dispersed in the liquid by the laser-induced shock wave (Okabayashi et al., 2011). Moreover, since the size of laser pit is about 10 μm, and thus, the sampling from specific area can be made with the LAL technique. In this study, development of both the analytical technique for the Pt isotopes and sampling procedures were conducted.

Experiments and results

In this study, dead time was carefully measured for reliable correction of the counting loss. The MC-ICP-MS instrument is the Nu Plasma 2 equipped with in-house high-time resolution ion counter (e.g.,

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maximum time resolution 10 μs). Dead time of the ion counter was calibrated using the W and Ba mixed solutions of various concentrations (0.24, 0.48, 1.2, 2.4, 4.8, 12, 24 μg/L). To evaluate the reliability of dead time obtained here, the isotope ratios for Pt nanoparticles of various sizes (30 nm, 50 nm, and 70 nm) were measured, and the resulting $^{196}Pt/^{194}Pt$ was 0.77143±0.02905 (2SE) for 30 nm Pt NPs, 0.76856±0.01597 (2SE) for 50 nm Pt NPs and 0.76889±0.00309 (2SE) for 70 nm Pt NPs. Relative deviations from the natural isotopic ratios ($^{196}Pt/^{194}Pt$ = 0.76566) were 0.74% for 30 nm Pt NPs, 0.38% for 50 nm Pt NPs, and 0.42% for 70 nm Pt NPs, suggesting that the relative deviation of the measured $^{196}Pt/^{194}Pt$ ratio agreed with the natural value within analytical uncertainties.

This is followed by the optimization of the sample extraction procedures using the LAL. Hence, Nd:YAG laser (wavelength 266 nm and pulse width 1 ns) was used. Laser ablation was carried out with a repetition rate of 1 kHz, laser fluence of 0.7 J cm^{-2}, and laser scanning speed of 20 μm/s.

The resulting nanoparticle-dispersed solutions obtained through LAL sampling on the matrix phase of the carbonaceous chondrite were subsidized to the Pt isotopic analysis using the HTR-MC-ICP-MS technique. From the resulting sample solution, Pt NPs being sizes of 20 –200 nm were detected, suggesting the effectiveness of both the analytical protocol and sampling procedure using the LAL technique. In this presentation, we will demonstrate the $^{196}Pt/^{194}Pt$ and $^{196}Pt/^{194}Pt$ ratios for individual small grains collected from the meteorites, and also discuss the possible sources of these grains.

Keywords: ICP-MS, Nanoparticles, Isotopic ratio, meteorites

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On-site Magnetic Separation of Heterogeneous Geological Particles

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A principle to perform chemical analysis of a solid sample in a non-descrutive manner was proposed based on its translation caused by a magnetic force. The field was generated by a permenent magnetic circuit;note that most solids, whihc are diamagnetic or weakly paramagnetic materials, were not considered to cause dynamic motions at a low field intensity.Here the practicability of the aforementioned technique was examined on single mg-size particles with various diamagnetic susceptibility (χ_{dia}), whihc was reproduced from its velocity v, assuming a classical energy conservation law, and practicability of identifying its material was confirmed; identification is performed by collating the *meausred* χ_{dia} with a list of published values. Th origin of χ_{dia} of a material is mainly attributed to its configuration of electron orbitals; hence, by using these parameters, a reliable material identification is possible which derive from its intrinsic structure. The experimental v did not depennd on particle mass m ; unlike the conventional magnetization measurements, χ_{dia} was obtained without measuring m. Similar m-independent property, as seen in the translations, was previously observed in the period of magnetic oscillation of mg-size silica-chips, and was obtained without measuring m. The m-independent properties appeared in the two motions because they were driven by body forces which were proportional to m, and in principle, magnetization of a very small sample is detected even if m of particle is difficult to obtain. Reliability of chemical analysis based on field-induced motions increases by parallelly consulting χ_{dia}. By realizing the proposed measurements in nm-size particles, extent of structural reconstruction in the surface layers, which generally proceed with reduction of particle diameter, are estimated from the anomalies observed in χ_{dia} values.[1]Uyeda et al., (2010) J. Phys. Soc. Jpn. 79, 064709, [2] Hisayoshi, et al, (2016) Sci. Rep 6, 38431. [3]Uyeda et al, (2019) Sci. Rep 9, 3931.

Keywords: magnetic separation, material analysis, on-site analysis

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Towards quantitative evaluation of the chondritic Earth model: A combined geo-neutrino, -physics, and -chemistry study

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It is commonly assumed that the bulk Earth has chondritic relative abundances of refractory elements. Evaluating the validity of this long-standing paradigm is crucial for a wide range of issues in Earth science, such as the timing of Earth’ s formation and differentiation and the structure of the mantle. Electron antineutrinos produced by natural radioactivity within the Earth, the so-called geoneutrinos, offer a unique opportunity to quantify the abundances of refractory-lithophile elements U and Th in the entire mantle, which in turn allows us to evaluate the chondritic Earth model. The geoneutrinos have been measured with a liquid scintillator detector at KamLAND in Japan since 2005. The uncertainty of the geoneutrino flux measurement is now reduced to a level small enough to set useful constraints on the mantle U and Th abundances, provided that the crustal contribution to the measured total geoneutrino flux is well established by determining U and Th distributions around the detector. Yet, the U and Th distributions in the Japan Arc crust, in particular deep crust, remains to be constrained quantitatively. Towards quantitative evaluation of the chondritic Earth model, we have conducted a combined geo-neutrino, -physics, and -chemistry study. We first developed a methodological framework to construct a 3-D crustal composition model by combining geological, seismic, and geochemical data (Takeuchi et al., 2019 PEPI). In this method, we utilized the Bayesian inference technique to model the 3-D lithology map by combining seismic data as “observation” with a prior model based on a geologic map of local deep crustal exposure. Besides, we constructed U and Th abundance distribution models for different rock types based on published geochemical data for rock samples. We adopted the gamma distribution for the elemental abundance modeling, whereas previous studies adopted normal and log-normal distributions. Importantly, the gamma distribution modeling allows to estimate the unbiased mean from rock sample data that could be distorted due to detection limit and outliers. This point is crucial but often overlooked in mass balance calculations of geochemistry and geophysics, as detailed in a companion presentation by Enomoto et al. By convolving the 3-D lithology model with the rock U and Th distribution models, we constructed 3-D probability density function (PDF) models of U and Th abundances in the Japan Arc crust, and then calculated crustal geoneutrino flux. This new methodology enables constructing a fully probabilistic flux model, but the uncertainties are large at ~70%. This is due to the difficulty in handling of correlations among all the PDFs at different locations in the flux integration: We conservatively assumed maximum correlations, leading to the large uncertainties. An investigation into the correlations is in progress. In this presentation, we report the current status and prospects of our interdisciplinary study.

Keywords: geoneutrino, chondritic Earth, crustal modeling

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Element abundance modeling method with the gamma distribution for quantitative balance calculations

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Rocks display highly variable trace element abundances, even those with similar major element compositions. To estimate the trace element compositions of geochemical reservoirs containing various rocks, such as the continental crust, trace element distributions must be modeled. Normal and log-normal distributions have been widely adopted to model trace element data of rocks and the median has been widely used as a representative value of trace element abundance. However, such modeling or treatment does not preserve the mean value of the distribution, leading to biased results of mass balance calculations. On the other hand, it is often impossible to directly use the mean of the samples because of sample imperfections due to analytical detection limits, outliers, and other reasons. Here we present a method to model unknown true distributions without causing a bias on the means, combined with proper treatment of sample cutoffs. We show that the new method preserves the mean values of ideal samples of any distributions and is robust against actual sample imperfections. Although the method was primarily developed for geoneutrino analysis in Japan, for which mass and energy balance calculations among the crust, mantle, and the whole Earth are essential, it is applicable to many balance calculations that require the conservation of mean values.

Keywords: geochemical modeling, continental crust, geoneutrino

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Prospects of Ocean Bottom Geoneutrino Detector for direct observation of mantle radioactive element distribution

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Geoneutrino is an anti-neutrino emitted in the beta decay of radioactive isotopes in the earth. Geoneutrinos derived from uranium and thorium can be observed with the current observation. It means that the total amount of uranium and thorium in the whole solid earth can be directly estimated by geoneutrino observation. The information from geoneutrino, the amount of uranium and thorium in the earth, is key for understanding the amount of radiogenic heat in the earth that drives geodynamics and understand the origin of the solid earth.

Current geoneutrino observations are being carried out by the neutrino detector "KamLAND" in Kamioka, Gifu Prefecture. Since uranium and thorium are enriched in the crustal rocks, we have to estimate the neutrino flux from the nearby Japanese crust and subtract the crustal neutrino from the observations of KamLAND to obtain mantle geoneutrino. As such, the mantle information obtained from the current observations has a large error due to uncertainties related to crustal geoneutrino.

Ocean Bottom Geoneutrino Detector (OBD) has been proposed as a possible innovation of geoneutrino science. Since the oceanic crust is thinner and contains less uranium and thorium than the continental crust, OBD will allow us to observe mantle-derived geoneutrino with higher accuracy than the current on-land observation. Furthermore, OBD will be movable and will allow us to conduct global multipoint geoneutrino observations. Consequently, ocean bottom neutrino observation will enable us to obtain direct information of the high accuracy three-dimensional distribution of radioactive elements inside the earth. We will introduce the results of geoneutrino observations so far. Also, we will present the future prospects for ocean floor geoneutrino observations.

Keywords: Geoneutrino, Radioactive elements

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[J] Oral | EVENT：EVENT

Thu. Jun 3, 2021 1:45 PM - 3:15 PM JST | Thu. Jun 3, 2021 4:45 AM - 6:15 AM UTC | Ch.16 Zoom Room 16

[EV-13] Exhibitors' Pop-Up

New for 2021 Meeting !
Exhibitors will introduce the highlights of their organizations and exhibits in about one minute in real time. Exhibitors will be given one minute to introduce their organization and exhibit highlights in real time.
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There will be an exchange with the moderator, and you may be able to hear things you can't hear anywhere else.

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