Sat. Jun 5, 2021

[E] Oral | U (Union) : Union

9:00 AM - 10:30 AM JST | 12:00 AM - 1:30 AM UTC | Ch.01 Zoom Room 01

[U-13] Advanced understanding of Quaternary and Anthropocene hydroclimate changes in East Asia:

convener:Li Lo(Department of Geosciences, National Taiwan University), Kaoru Kubota(Graduate School of Human Development and Environment, Kobe University), Chuan-Chou Shen(National Taiwan University), Yusuke Yokoyama(Atmosphere and Ocean Research Institute, University of Tokyo), Chairperson:Li Lo(Department of Geosciences, National Taiwan University), Kaoru Kubota(Graduate School of Human Development and Environment, Kobe University), Yusuke Yokoyama(Atmosphere and Ocean Research Institute, University of Tokyo), Chuan-Chou Shen(National Taiwan University)

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

[U13-01] Insight to Western Pacific circulation from coral skeletal radiocarbon during the Anthropocene and Holocene

★Invited Papers

*Shoko Hirabayashi[1,2,3], Yusuke Yokoyama[2], Atsushi Suzuki[4], Tezer Esat[5], Yosuke Miyairi[2], Takahiro AZE[2], Fernando Siringan [6], Yasuo Maeda[7], Hironobu Kan[3] (1.Faculty of Geo-Environmental Science, Rissho University, 2.Atmosphere and Ocean Research Institute, The University of Tokyo, 3.Department of Environmental Changes, Graduate School of Social and Cultural Studies, Kyushu University, 4.Geological Survey of Japan, National Institute of Advanced Industrial Science and Technology (AIST), 5.Research School of Physics and Engineering, The Australian National University, 6.Marine Science Institute, University of the Philippines, 7.Institute of Natural and Environmental Sciences, University of Hyogo)

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

[U13-02] **Increased soil erosion since Southeast Asia economic boom recorded in *Porites* corals**

★Invited Papers

*Xiaohua Li[1], Zhen Zeng[2], Yi Liu[3], Ching-Chih Chang[4], Hong-Wei Chiang[4], Xuan-Ce Wang[5], Weidong Sun[1], Hui-Min Yu[2], Fang Huang[2], Chung-Che Wu[4], Tsai-Luen Yu[4], Chun-Yuan Huang[4], Chuan-Chou Shen[4] (1.Institute of Oceanology, Chinese Academy of Sciences, 2.University of Science and Technology of China, 3.Tianjin University, 4.National Taiwan University, 5.Yunnan University)

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

[U13-03] **Upper ocean temperatures over the last glacial in the low-to-mid latitude Western Pacific based on a systematic multiproxy approach**

★Invited Papers

*Sze Ling Ho[1], Yuan-Pin Chang[2], Min-Te Chen[3], Jeroen Groeneveld[4], Kuo-Fang Huang[5], Pei-Ting Lee[1], Shih-Yun Lin[1], Maria Makarova[1], Nele Meckler[6], Mahyar Mohtadi[7], Ren Yi Ooi[1], Chuan-Chou Shen[8], Liang-Jian Shiau[3,9], Raul Tapia[1], Masanobu Yamamoto[10] (1.Institute of Oceanography, National Taiwan University, Taipei, Taiwan, 2.Department of Oceanography, National Sun Yat-sen University, Kaohsiung, Taiwan., 3.Institute of Applied Geosciences, National Taiwan Ocean University, Keelung, Taiwan., 4.Department of Geosciences, Hamburg University, Germany. , 5.Institute of Earth Sciences, Academia Sinica, Taipei, Taiwan., 6.Bjerknes Centre for Climate Research and Department of Earth Science, University of Bergen, Norway., 7.MARUM-Center for Marine Environmental Sciences, University of Bremen, Germany. , 8.High-Precision Mass Spectrometry and Environment Change Laboratory (HISPEC), Department of Geosciences, National Taiwan University, Taipei, Taiwan., 9.Exploration and Development Research Institute, CPC Corporation, Miaoli, Taiwan., 10.Faculty of Environmental Earth Science, Hokkaido University, Sapporo, Japan.)

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

[U13-04] Ultra-high resolution oxygen isotope records from the Chiba Composite Section ratified as the Chibanian GSSP

★Invited Papers

*Yuki Haneda[1], Makoto Okada[2], Yoshimi Kubota[3], Yusuke Suganuma[4,5] (1.Geological Survey of Japan, AIST, 2.Department of Environmental Science, Ibaraki University, 3.National Museum of Nature and Science, 4.National Institute of Polar Research, 5.The Graduate University for Advanced Studies)

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

[U13-05] Sub-surface water mass exchanges around the eastern equatorial Indian Ocean during the last 50,000 years
★Invited Papers

*Hideko Takayanagi[1], Ryota Wako[1], Yuna Kimoto[1], Shigeyuki Wakaki[2], Azumi Kuroyanagi[1], Takeshige Ishiwa[3], Yusuke Yokoyama[4], Hitomi Uchimura Wakaki[5], Tsuyoshi Ishikawa[2], Yasufumi Iryu[1] (1.Tohoku Univ., 2.JAMSTEC, 3.NIPR, 4.Univ. of Tokyo, 5.Kochi Univ.)

10:15 AM - 10:30 AM JST | 1:15 AM - 1:30 AM UTC
[U13-06] **Methane, Monsoons, and Milankovitch Modulation of Millennial-Scale Climate**
★Invited Papers

*Kaustubh Thirumalai[1], Steven Clemens[2], Judson Partin[3] (1.The University of Arizona, 2.Brown University, 3.The University of Texas at Austin)

[E] 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-PS03] Regolith Science

convener:Koji Wada(Planetary Exploration Research Center, Chiba Institute of Technology), Akiko Nakamura(Graduate School of Science, Kobe University), Patrick Michel(Universite Cote D Azur Observatoire De La Cote D Azur CNRS Laboratoire Lagrange), John Kevin Walsh(Southwest Research Institute Boulder), Chairperson:Naoya Sakatani(Department of Physics, Rikkyo University)

1:45 PM - 2:00 PM JST | 4:45 AM - 5:00 AM UTC
[PPS03-01] **Landing on an asteroid: Simulations and image analysis of the OSIRIS-REx spacecraft touch-down on (101955) Bennu**
★Invited Papers

*Ronald Ballouz[1], Kevin John Walsh[2], Patrick Michel[3], Yun Zhang[3], Paul Sánchez[4], Daniel Jay Scheeres[4], Michael C Nolan[1], Stephen R Schwartz[1], Derek C Richardson[5], Olivier S Barnouin[6], Edward B Bierhaus[7], Harold C Connolly[8,1], Dante S Lauretta[1] (1.Lunar and Planetary Lab, University of Arizona, Tucson, AZ, USA, 2.Southwest Research Institute, Boulder, CO, USA, 3.Université Côte d'Azur, Observatoire de la Côte d'Azur, CNRS, Laboratoire Lagrange, Nice, France, 4.University of Colorado Boulder, CO, USA,, 5.University of Maryland, College Park, MD, USA, 6.The Johns Hopkins University Applied Physics Laboratory, Laurel, MD, USA, , 7.Lockheed Martin Space, Littleton, CO, USA, , 8.Dept. of Geology, Rowan University, Glassboro, NJ, USA)

2:00 PM - 2:15 PM JST | 5:00 AM - 5:15 AM UTC
[PPS03-02] Dust cloud mass from OSIRIS-REx sample collection event at Bennu
★Invited Papers

*Bashar Rizk[1], Kevin J. Walsh[2], Ronald Ballouz[1], Brent Bos[3], Christian Drouet d'Aubigny[1] (1.University of Arizona, 2.Southwest Research Institute, 3.Goddard Space Flight Center)

2:15 PM - 2:30 PM JST | 5:15 AM - 5:30 AM UTC
[PPS03-03] Hayabusa2 sampling operation at Ryugu and the returned regolith samples
★Invited Papers

*Shogo Tachibana[1,2], Hayabusa2 Sampler Team (1.UTokyo Organization for Planetary and Space Science, University of Tokyo , 2.ISAS, JAXA)

2:30 PM - 2:45 PM JST | 5:30 AM - 5:45 AM UTC
[PPS03-04] Surface roughness and cohesion of impact fragments of meteorite targets

*Yuuya Nagaashi[1], Akiko Nakamura[1] (1.Kobe University)

2:45 PM - 3:00 PM JST | 5:45 AM - 6:00 AM UTC
[PPS03-05] Size and Spatial Distribution of Rock Particles on Small Bodies Revealed with CNN-based Algorithm

*Yuta Shimizu[1], Taisuke Suzuki[1], Ryodo Hemmi[1], Hideaki Miyamoto[1] (1.University of Tokyo)

3:00 PM - 3:15 PM JST | 6:00 AM - 6:15 AM UTC
[PPS03-06] **Experimental Study on the Relationship between Surface distributions and Vertical Structures of Rock Particles on Small bodies.**

*Taisuke Suzuki[1], Yuta Shimizu[1], Hideaki Miyamoto[1] (1.The University of Tokyo)

[E] 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-PS03] Regolith Science

convener:Koji Wada(Planetary Exploration Research Center, Chiba Institute of Technology), Akiko Nakamura(Graduate School of Science, Kobe University), Patrick Michel(Universite Cote D Azur Observatoire De La Cote D Azur CNRS Laboratoire Lagrange), John Kevin Walsh(Southwest Research Institute Boulder), Chairperson:Yuri Shimaki(Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency)

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

[PPS03-07] Deciphering the regolith properties of small bodies from numerical modeling

★Invited Papers

*Yun Zhang[1] (1.UCA, OCA, CNRS, Lagrange, Nice, France)

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

[PPS03-08] Charge Magnitude of Electrostatically Lofted Dust Grains over the Lunar Terminator

*Necmi Cihan Orger[1], Kazuhiro Toyoda[1], Mengu Cho[1] (1.Laboratory of Lean Satellite Enterprises and In-Orbit Experiments - Kyushu Institute of Technology)

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

[PPS03-09] High-velocity impact experiments in reduced gravity: The effect of cohesive strength of particle layers

*Masato Kiuchi[1], Takaya Okamoto[1], Yuuya Nagaashi[2], Sunao Hasegawa[1], Akiko Nakamura[2] (1.Japan aerospace exploration agency, Institute of space and astronautical science, 2.Graduate School of Science, Kobe UniversityKobe University)

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

[PPS03-10] Local variation in thermal inertia around the artificial impact crater on Ryugu

*Naoya Sakatani[1], Satoshi Tanaka[2], Tatsuaki Okada[2], Toru Kouyama[3], Akira Miura[2], Naru Hirata[4], Hiroki Senshu[5], Takehiko Arai[6], Yuri Shimaki[2], Hirohide Demura[4], Tomohiko Sekiguchi[7], Jun Takita[8], Tetsuya Fukuhara[1], Thomas Müller[9], Axel Hagermann[10], Jens Biele[11], Matthias Grott[11], Maximillian Hamm[11,12], Marco Delbo[13], Masahiko Arakawa[14], Kazunori Ogawa[15], Koji Wada[5], Toshihiko Kadono[16], Rie Honda[17], Kei Shirai[14], Takanao Saiki[2], Hiroshi Imamura[2], Yasuhiko Takagi[18], Hajime Yano[2], Masahiko Hayakawa[2], Hirotaka Sawada[2], Satoru Nakazawa[2], Seiji Sugita[19], Tomokatsu Morota[19], Manabu Yamada[5], Shingo Kameda[1], ERI TATSUMI[20], Yasuhiro Yokota[2], Hidehiko Suzuki[21], Kazuo Yoshioka[19], Moe Matsuoka[2], Yuichiro Cho[2] (1.Rikkyo University, 2.Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency, 3.National Institute of Advanced Industrial Science and Technology, 4.University of Aizu, 5.Chiba Institute of Technology, 6.Ashikaga University, 7.Hokkaido University of Education, 8.Hokkaido Kitami Hokuto High School, 9.Max-Planck Institute for Extraterrestrial Physics, 10.Luleå University of Technology, 11.German Aerospace Center, 12.University of Potsdam, 13.Observatoire de la Côte d'Azur, CNRS, 14.Kobe University, 15.JAXA Space Exploration Center, Japan Aerospace Exploration Agency, 16.University of Occupational and Environmental Health, 17.Kochi University, 18.Aichi Toho University, 19.University of Tokyo, 20.Instituto de Astrofisica de Canarias, 21.Meiji University)

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

[PPS03-11] Brightness change of Hayabusa2 SCI crater ejecta observed by ONC-T and its implication to the surface status of asteroid Ryugu

*Rie Honda[1], Yasuhiro Yokota[2], Masahiko Arakawa[3], Seiji Sugita[4], Yuri Shimaki[2], Koji Wada[5], Toshihiko Kadono[6], Kei Shirai[3], Kazunori Ogawa[7], Naoya Sakatani[8], Ko Ishibashi[5], Takanao Saiki[2], Hiroshi Imamura[2], Satoru Nakazawa[2], Masahiko Hayakawa[2], Hajime Yano[2], Yasuhiko Takagi[9], Naru Hirata[10], Hirotaka Sawada[2], Tomokatsu Morota[4], Shingo Kameda[8], Eri Tatsumi[11], Manabu Yamada[5], Toru Kouyama[12], Yuichiro Cho[4], Moe Matsuoka[2], Kazuo Yoshioka[4], Hidehiko Suzuki[13], Chikatoshi Honda[10] (1.Department of Science and Technology, System of Natual Science, Kochi University, 2.Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency, 3.Kobe University, 4.The University of Tokyo, 5.Planetary Exploration Research Center, Chiba Institute of Technology, 6.University of Occupational and Environmental Health, 7.JAXA Space Exploration Center, Japan Aerospace Exploration Agency, 8.Rikkyo University, 9.Aichi Toho University, 10.The University of Aizu, 11.Instituto de Astrofisica de Canarias, University of La Laguna, 12.National Institute of Advanced Industrial Science and Technology, 13.Meiji University)

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

[PPS03-12] Study of Hydrated Asteroids via Polarimetry: Correlation between Polarimetric Properties and Degree of Aqueous Alteration of Hydrated asteroids.

*Jooyeon Geem[1], Masateru Ishiguro[1], Hiroyuki Naito[2], Daisuke Kuroda[6], Koki Takahashi[3], Tomohiko Sekiguchi[3], Seiko Takagi[4], Tatsuharu Ono[4], Kiyoshi Kuramoto[4], Tomoki Nakamura[5] (1.Astronomy program, Dept of Physics and Astronomy, Seoul National University, 2.Nayoro Observatory, 3.Hokkaido University of Education, 4.Department of Cosmosciences, Graduate School of Science, Hokkaido University, 5.Department of Earth and Planetary Material Sciences, Faculty of Science, Tohoku University, 6.Okayama Observatory, Kyoto University)

[E] Oral | P (Space and Planetary Sciences)：P-EM Solar-Terrestrial Sciences, Space Electromagnetism & Space Environment

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

[P-EM08] Space Weather and Space Climate

convener:Ryuho Kataoka(National Institute of Polar Research), A Antti Pulkkinen(NASA Goddard Space Flight Center), Kanya Kusano(Institute for Space-Earth Environmental Research, Nagoya University), Kaori Sakaguchi(National Institute of Information and Communications Technology), Chairperson:Kanya Kusano(Institute for Space-Earth Environmental Research, Nagoya University), Kaori Sakaguchi(National Institute of Information and Communications Technology)

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

[PEM08-13] Statistical analysis of variations of geoelectric field during magnetic storms/substorms in Japan

*Tian Zhang[1], Yusuke Ebihara[1] (1.Kyoto University)

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

[PEM08-14] How do auroral substorms depend on Earth's dipole magnetic moment?

*Yusuke Ebihara[1], Takashi Tanaka[2] (1.Research Institute for Sustainable Humanosphere, Kyoto University, 2.International Center for Space Weather Science and Education, Kyushu University)

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

[PEM08-15] Direct numerical simulation of the Alfvénic solar wind: a theoretical origin of magnetic switchback

★Invited Papers

*Munehito Shoda[1] (1.National Astronomical Observatory of Japan)

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

[PEM08-16] Simulation study on the deformation of magnetic field in interplanetary CMEs

*Minami Mori[1], Daikou Shiota[2], Kanya Kusano[1] (1.Institute for Space-Earth Environmental Research, Nagoya University , 2.National Institute of Information and Communications Technology (NICT))

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

[PEM08-17] Onset Mechanism of the Successive M-class Solar Flares in the Solar Active Region 12673 Based on a Nonlinear Force-Free Modeling

*Daiki Yamasaki[1], Satoshi Inoue[2], Takako T. Ishii[1], Ayumi Asai[1], Shin'ichi Nagata[1], Kiyoshi Ichimoto[1] (1.Astronomical Observatory, Kyoto University, 2.Institute for Space-Earth Environmental Research)

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

[PEM08-18] Data-driven MHD simulation of successive solar plasma eruptions

*Takafumi Kaneko[1], Sung-Hong Park[1], Kanya Kusano[1] (1.Institute for Space-Earth Environmental Research, Nagoya University)

[E] Oral | P (Space and Planetary Sciences)：P-EM Solar-Terrestrial Sciences, Space Electromagnetism & Space Environment

9:00 AM - 10:30 AM JST | 12:00 AM - 1:30 AM UTC | Ch.05 Zoom Room 05

[P-EM12] Dynamics of the Inner Magnetospheric System

convener:Kunihiro Keika(Department of Earth and Planetary Science, Graduate School of Science, The University of Tokyo), Yoshizumi Miyoshi(Institute for Space-Earth Environmental Research, Nagoya University), W Lauren Blum(University of Colorado Boulder), Yuri Shprits(Helmholtz Centre Potsdam GFZ German Research Centre for Geosciences), Chairperson:Lauren W Blum(University of Colorado Boulder), Kunihiro Keika(Department of Earth and Planetary Science, Graduate School of Science, The University of Tokyo)

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

[PEM12-01] Introduction

9:05 AM - 9:30 AM JST | 12:05 AM - 12:30 AM UTC

[PEM12-02] Convection in the Inner Magnetosphere: Effects on Plasmasphere and Ring Current

★Invited Papers

*Jerry Goldstein[1,4], B. R. Sandel[2], D. J. McComas[3], P. W. Valek[1], J. Redfern[1] (1.Southwest Research Institute, 2.The University of Arizona, 3.Princeton University, 4.University of Texas at San Antonio)

9:30 AM - 9:55 AM JST | 12:30 AM - 12:55 AM UTC

[PEM12-03] Changing Composition of the Ring Current Source Region During Storm Main Phase

★Invited Papers

*Lynn M Kistler[1,2], Christopher G Mouikis[1], Kazushi Asamura[3], Satoshi Kasahara[4], Yoshizumi Miyoshi[2], Kunihiro Keika[4], Steven M Petrinec[5], Tomoaki Hori[2], Shoichiro Yokota[6], Iku Shinohara[3] (1.University of New Hampshire Main Campus, 2.Institute for Space-Earth Environmental Research, Nagoya University, 3.JAXA, 4.Graduate School of Science, University of Tokyo, 5.Lockheed-Palo Alto, 6.Graduate School of Science, Osaka University)

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

[PEM12-04] Multisatellite observations of field-aligned low-energy O^+ ion flux enhancements in the inner magnetosphere: September 22, 2018, Event

*Masahito Nose[1], Ayako Matsuoka[2], Yoshizumi Miyoshi[1], Kazushi Asamura[3], Mariko Teramoto[4], Iku Shinohara[3], Masafumi Hirahara[1], C. A. Kletzing[5], C. W. Smith[6], R. J. MacDowall[7], H. E. Spence[6], G. D. Reeves[8] (1.Institute for Space-Earth Environmental Research, Nagoya University, 2.Graduate School of Science, Kyoto University, 3.Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency, 4.Department of Space Systems Engineering, Kyushu Institute of Technology, 5.Department of Physics and Astronomy, University of Iowa, 6.Institute for the Study of Earth, Oceans, and Space, University of New Hampshire, 7.Solar System Exploration Division, Goddard Space Flight Center, 8.Space Sciences and Applications Group, Los Alamos National Laboratory)

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

[PEM12-05] Deflection of upflowing ion beams by a converging electric field in the auroral flux tube: Alternative explanation for mass-dependent beam width

★Invited Papers

*Shun Imajo[1], Yoshizumi Miyoshi[1], Kazushi Asamura[2], Iku Shinohara[2], Masahito Nose[1], Yoshiya Kasahara[3], Yasumasa Kasaba[4], Ayako Matsuoka[5], Tomoaki Hori[1], Masafumi Shoji[1], Satoko Nakamura[1], Mariko Teramoto[6] (1.Nagoya University, 2.Institute of Space and Astronautical Science, 3.Kanazawa University, 4.Tohoku University, 5.Kyoto University, 6.Kyushu Institute of Technology)

[E] Oral | P (Space and Planetary Sciences) ： P-EM Solar-Terrestrial Sciences, Space Electromagnetism & Space Environment

10:45 AM - 12:10 PM JST | 1:45 AM - 3:10 AM UTC | Ch.05 Zoom Room 05

[P-EM12] Dynamics of the Inner Magnetospheric System

convener:Kunihiro Keika(Department of Earth and Planetary Science, Graduate School of Science, The University of Tokyo), Yoshizumi Miyoshi(Institute for Space-Earth Environmental Research, Nagoya University), W Lauren Blum(University of Colorado Boulder), Yuri Shprits(Helmholtz Centre Potsdam GFZ German Research Centre for Geosciences), Chairperson:Kazuhiro Yamamoto(Graduate School of Science, The University of Tokyo)

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

[PEM12-06] **Ion dynamics in the inner magnetosphere during Van Allen Probe Era**

★Invited Papers

*Chao Yue[1] (1.Peking University)

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

[PEM12-07] Multipoint measurements to understand the drivers and structure of EMIC waves in the inner magnetosphere

*Lauren W Blum[1] (1.University of Colorado Boulder)

11:20 AM - 11:35 AM JST | 2:20 AM - 2:35 AM UTC

[PEM12-08] Particles simulations of whistler-mode triggered emissions with subpacket structures

Takeshi Nogi[1], *Yoshiharu Omura[1] (1.Reserach Institute for Sustainable Humanosphere, Kyoto University)

11:35 AM - 11:55 AM JST | 2:35 AM - 2:55 AM UTC

[PEM12-09] Nonlinear wave-particles interaction in radiation belts: how can we include it to global models?

★Invited Papers

*Anton Artemyev[1,2], Anatoly Neishtadt[2,3], Alexei Vasiliev[2], Xiao-Jia Zhang[1], Didier Mourenas[4], Dmitri Vainchtein[5,2] (1.Institute of Geophysics and Planetary Physics, UCLA, Los Angeles, California 90095, USA, 2.Space Research Institute of the Russian Academy of Sciences (IKI), 84/32 Profsoyuznaya Str., Moscow 117997, Russia, 3.Department of Mathematical Sciences, Loughborough University, Loughborough LE11 3TU, United Kingdom, 4.Laboratoire Mati`ere sous Conditions Extremes, Paris-Saclay University, CEA, Bruy`eres-le-Chatel, France, 5.Nyheim Plasma Institute, Drexel University, Camden, NJ, USA)

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

[PEM12-10] Modeling of outer radiation belt electron dynamics associated with whistler mode chorus emissions via Green’s function method

*Yikai Hsieh[1], Yoshiharu Omura[1] (1.Reserach Institute for Sustainable Humanosphere, Kyoto University)

[E] Oral | P (Space and Planetary Sciences)：P-EM Solar-Terrestrial Sciences, Space Electromagnetism & Space Environment

1:45 PM - 3:15 PM JST | 4:45 AM - 6:15 AM UTC | Ch.05 Zoom Room 05

[P-EM12] Dynamics of the Inner Magnetospheric System

convener:Kunihiro Keika(Department of Earth and Planetary Science, Graduate School of Science, The University of Tokyo), Yoshizumi Miyoshi(Institute for Space-Earth Environmental Research, Nagoya University), W Lauren Blum(University of Colorado Boulder), Yuri Shprits(Helmholtz Centre Potsdam GFZ German Research Centre for Geosciences), Chairperson:Yikai Hsieh(Reserach Institute for Sustainable Humanosphere, Kyoto University)

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

[PEM12-11] **Statistical study on spatial distribution of plasma waves observed by PWE/OFA**

*Yoshiya Kasahara[1], Kengo Nakashima[1], Shoya Matsuda[2], Yoshizumi Miyoshi[3], Ayako Matsuoka[4], Jean-Francois Rippol[5], David M. Malaspina[6] (1.Kanazawa University, 2.ISAS/JAXA, 3.Nagoya University, 4.Kyoto University, 5.CEA/DAM/DIF, 6.University of Colorado Boulder)

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

[PEM12-12] Long period modulations of pulsating aurora and chorus waves

*Yoshizumi Miyoshi[1], Keisuke Hosokawa[2], Yasunobu Ogawa[3], Satoshi Kurita[4], Shin-ichiro Oyama[1], Mariko Teramoto[5], Shinji Saito[6], Yoshiya Kasahara[7], Shoya Matsuda[8], Satoshi Kasahara[9], Shoichiro Yokota[10], Kunihiro Keika[9], Tomoaki Hori[1], Fuminori Tsuchiya[11], Atsushi Kumamoto[11], Satoko Nakamura[1], Masahiro Kitahara[1], Masafumi Shoji[1], Ayako Matsuoka[4], Shun Imajo[1], Iku Shinohara[8] (1.Institute for Space-Earth Environmental Research, Nagoya University, 2.The University of Electro-Communications, 3.NIPR, 4.Kyoto University, 5.Kyushu Inst. of Technology, 6.NICT, 7.Kanazawa University, 8.JAXA, 9.University of Tokyo, 10.Osaka University, 11.Tohoku University)

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

[PEM12-13] Whistler Driven Electron Precipitation Measured by ELFIN CubeSat and Arase Spacecraft

*Xiaojia Zhang[1], Vassilis Angelopoulos[1], Anton V. Artemyev[1], Satoshi Kasahara[2], Colin Wilkins[1], Ethan Tsai[1], Shoichiro Yokota[3], Kunihiro Keika[2], Tomoaki Hori[4], Yoshizumi Miyoshi[4], Yoshiya Kasahara[5], Shoya Matsuda[6], Ayako Matsuoka[7], Mariko Teramoto[8], Shun Imajo[4], Iku Shinohara[9] (1.University of California Los Angeles, 2.The Univ. of Tokyo, 3.Osaka Univ., 4.Nagoya Univ., 5.Kanazawa Univ., 6.ISAS, 7.Kyoto Univ., 8.Kyushu Institute of Technology, 9.ISAS, JAXA)

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

[PEM12-14] A case study to estimate energy spectra of pulsating auroral electrons from cosmic noise absorption and auroral brightness

*Shin-ichiro Oyama[1,2], Miyamoto Taishiro[1,6], Tero Raita[3], Keisuke Hosokawa[4], Yoshizumi Miyoshi[1], Yasunobu Ogawa[2], Satoshi Kurita[5] (1.Institute for Space-Earth Environmental Research, Nagoya University, 2.National Institute of Polar Research, 3.Sodankyla Geophysical Observatory, University of Oulu, 4.University of Electro-Communications, 5.Research Institute for Sustainable Humanosphere, Kyoto University, 6.Nippon Steel Corporation Nagoya Works)

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

[PEM12-15] Statistical characteristics of the magnetic field variations observed by Arase

*Ayako Matsuoka[1], Masahito Nose[2], Yoshizumi Miyoshi[2], Mariko Teramoto[4], Reiko Nomura[3], Akiko Fujimoto[5], Yoshimasa Tanaka[6], Manabu Shinohara[7], Satoshi Kurita[8], Shun Imajo[2], Iku Shinohara[3] (1.Data Analysis Center for Geomagnetism and Space Magnetism, Graduate School of Science, Kyoto University, 2.Institute for Space-Earth Environmental Research, Nagoya University, 3.Institute of Space and Astronautical Science, JAXA, 4.Graduate School of Engineering, Kyushu Institute of Technology, 5.Graduate School of Computer Science and Systems Engineering, Kyushu Institute of Technology, 6.National Institute of Polar Research, 7.National Institute of Technology Kagoshima College, 8.Research Institute for Sustainable Humanosphere, Kyoto University)

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

[PEM12-16] Mode-coupling Pi2 pulsations on the off-equatorial plasmapause inferred from the Arase satellite observation

*Mariko Teramoto[1], Ayako Matsuoka[2], Yoshiya Kasahara[3], Yasumasa Kasaba[4], Atsushi Kumamoto[4], Fuminori Tsuchiya[4], Shoya Matsuda[6], Yoshizumi Miyoshi[5], Masahito Nose[5], Tomoko Nakagawa[7], Shun Imajo[5], Masafumi Shoji[5], Satoko Nakamura[5], Iku Shinohara[6] (1.Kyushu Institute of Technology, 2.Kyoto University, 3.Kanazawa University, 4.Tohoku University, 5.Nagoya University, 6.Japan Aerospace Exploration Agency, Institute of Space and Astronautical Science, 7.Tohoku Institute of Technology)

[E] Oral | P (Space and Planetary Sciences) ： P-EM Solar-Terrestrial Sciences, Space Electromagnetism & Space Environment

3:30 PM - 5:00 PM JST | 6:30 AM - 8:00 AM UTC | Ch.05 Zoom Room 05

[P-EM12] Dynamics of the Inner Magnetospheric System

convener:Kunihiro Keika(Department of Earth and Planetary Science, Graduate School of Science, The University of Tokyo), Yoshizumi Miyoshi(Institute for Space-Earth Environmental Research, Nagoya University), W Lauren Blum(University of Colorado Boulder), Yuri Shprits(Helmholtz Centre Potsdam GFZ German Research Centre for Geosciences), Chairperson:Kunihiro Keika(Department of Earth and Planetary Science, Graduate School of Science, The University of Tokyo)

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

[PEM12-17] Controlling factors of the occurrence of multi-harmonic toroidal ULF waves: A statistical study of the Arase satellite observations

*Kazuhiro Yamamoto[1], Kanako Seki[1], Ayako Matsuoka[2], Shun Imajo[3], Mariko Teramoto[4], Yoshiya Kasahara[5], Atsushi Kumamoto[6], Fuminori Tsuchiya[6], Masafumi Shoji[3], Yoshizumi Miyoshi[3], Iku Shinohara[7] (1.Graduate School of Science, The University of Tokyo, 2.Graduate School of Science, Kyoto University, 3.Institute for Space-Earth Environmental Research, Nagoya University, 4.Kyushu Institute of Technology, 5.Graduate School of Natural Science and Technology, Kanazawa University, 6.Graduate School of Science, Tohoku University, 7.Japan Aerospace Exploration Agency)

3:45 PM - 4:08 PM JST | 6:45 AM - 7:08 AM UTC

[PEM12-18] Probing inner magnetosphere dynamics and radial transport via observations of electron flux oscillations

★Invited Papers

*Theodore E Sarris[1] (1.Democritus University of Thrace)

4:08 PM - 4:30 PM JST | 7:08 AM - 7:30 AM UTC

[PEM12-19] Radiation belt electron acceleration during periods of low plasma density

★Invited Papers

*Hayley J Allison[1], Yuri Y Shprits[1,2,3], Irina Zhelavskaya[1], Dedong Wang[1], Artem Smirnov[1,2] (1.Helmholtz Centre Potsdam GFZ German Research Centre for Geosciences, Potsdam, Germany, 2.University of Potsdam, Potsdam, Germany, 3.University of California, Los Angeles, CA, USA)

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

[PEM12-20] Parameterized Lifetime of Energetic Electrons due to Interactions with Chorus Waves

*Dedong Wang[1], Yuri Shprits[1,2,3] (1.Helmholtz Center Potsdam German Research Centre for Geosciences Potsdam, 2.University of Potsdam, 3.UCLA)

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

[PEM12-21] Statistical Comparisons of Spin-Averaged Electron Flux from ARASE and Van Allen Probes Instruments

*Matyas Szabo-Roberts[1,2], Yuri Shprits[1,2], Hayley J Allison[1], Artem Smirnov[1,2], Nikita Aseev[7], Ruggero Vasile[1], Yoshizumi Miyoshi[4], Takefumi Mitani[4,5,6], Nana Higashio[5], Satoshi Kasahara[3] (1.Helmholtz Centre Potsdam GFZ German Research Centre for Geosciences, 2.University of Potsdam, 3.Department of Earth and Planetary Science, School of Science, The University of Tokyo, 4.Nagoya University, 5.JAXA Japan Aerospace Exploration Agency, 6.ISAS Institute of Space and Aeronautical Science, 7.Huawei Technologies)

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

9:00 AM - 10:30 AM JST | 12:00 AM - 1:30 AM UTC | Ch.09 Zoom Room 09

[A-OS11] Ocean Mixing Frontiers

convener:Toshiyuki Hibiya(Department of Earth and Planetary Science, Graduate School of Science, University of Tokyo), Chairperson:Takashi Ijichi(The University of Tokyo)

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

[AOS11-01] Tide-topography interactions with a background sheared current: critical layers and asymmetric internal wave breaking

*Kevin Lamb[1] (1.University of Waterloo)

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

[AOS11-02] Small-scale topographic effects on the generation of along-shelf propagating internal solitary waves on the Amazon Shelf

*Xiaolin Bai[1], Kevin Lamb[1], Jose C. B. da Silva[2] (1.Department of Applied Mathematics, The University of Waterloo, Canada, 2.Department of Geosciences, Environment, and Spatial Planning, and Instituto Ciencias da Terra (ICT), Polo Porto, Porto, Portugal)

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

[AOS11-03] Energetic turbulence and internal waves in Tokara Strait

*Anne Takahashi[1], Ren-Chieh Lien[1], Eric Kunze[2] (1.Applied Physics Laboratory, University of Washington, 2.NorthWest Research Associates)

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

[AOS11-04] A parameterization of local and remote tidal mixing

*Casimir de Lavergne[1] (1.LOCEAN laboratory, Sorbonne University)

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

[AOS11-05] **A new parameterization of turbulent mixing enhanced over rough seafloor topography**

*Toshiyuki Hibiya[1] (1.Department of Earth and Planetary Science, Graduate School of Science, The University of Tokyo)

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

[AOS11-06] Turbulent mixing variability in an energetic standing meander of the Southern Ocean

*Ajitha Cyriac[1,2], Helen Phillips[1,3], Nathan Bindoff[1,3], Kurt Polzin[4] (1.IMAS, University of Tasmania, Hobart, Australia, 2.ARCCSS, Hobart, Australia, 3.AAPP, Hobart, Australia, 4.WHOI, Woods Hole, USA)

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

10:45 AM - 12:15 PM JST | 1:45 AM - 3:15 AM UTC | Ch.09 Zoom Room 09

[A-OS11] Ocean Mixing Frontiers

convener:Toshiyuki Hibiya(Department of Earth and Planetary Science, Graduate School of Science, University of Tokyo), Chairperson:Toshiyuki Hibiya(Department of Earth and Planetary Science, Graduate School of Science, University of Tokyo)

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

[AOS11-07] Enhanced turbulent mixing in the equatorial thermocline

*Kelvin John Richards[1], Andrei Natarov[1], Yanli Jia[1] (1.International Pacific Research Center, School of Ocean and Earth Science Technology, University of Hawaii)

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

[AOS11-08] **Convection enhances upper ocean mixing during a tropical cyclone**

*Devang Falor[1], Bishakhdatta Gayen[1,2], Debasis Sengupta[1], Dipanjan Chaudhuri[3,1] (1.Indian Institute of Science, Bangalore, 2.University of Melbourne, Australia, 3.University of Washington, Seattle)

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

[AOS11-09] Near-inertial wave modulated turbulence in a Kuroshio anticyclonic eddy east of Japan

*Sebastian Essink[1], Ren-Chieh Lien[1], Eric Kunze[2] (1.UW/APL, 2.NWRA)

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

[AOS11-10] Upper ocean turbulence in the Icelandic Basin under strong forcing

*Harper L Simmons[1], Sophia Merrifield[2], Eric Skyllingstad[3], Louis St. Laurent[4] (1.University of Alaska Fairbanks, 2.Scripps Institution of Oceanography, University of California San Diego, 3.Oregon State University, 4.Applied Physics Laboratory, University of Washington)

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

[AOS11-11] Observed spectral distortion of temperature microstructure

*Takashi Ijichi[1], Louis St. Laurent[2] (1.Department of Earth and Planetary Science, Graduate School of Science, The University of Tokyo, 2.Applied Physics Laboratory, University of Washington)

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

[AOS11-12] 2D Horizontal-Vertical Wavenumber Spectra of Density Finestructure from a towed CTD chain

*Anda Vladoiu[1], Ren-Chieh Lien[1], Eric L Kunze[2] (1.Applied Physics Laboratory, University of Washington, Seattle, WA, USA, 2.NorthWest Research Associates, Redmond, WA, USA)

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

1:45 PM - 3:15 PM JST | 4:45 AM - 6:15 AM UTC | Ch.09 Zoom Room 09

[A-OS11] Ocean Mixing Frontiers

convener:Toshiyuki Hibiya(Department of Earth and Planetary Science, Graduate School of Science, University of Tokyo), Chairperson:Taira Nagai(Graduate School of Science, The University of Tokyo)

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

[AOS11-13] Internal tide radiation and intensified mixing in the Philippine Sea

*Zhenhua Xu[1], Jia You[1], Yang Wang[1], Qun Li[1], Toshiyuki Hibiya[2], Robin Robertson[3] (1.Institute of Oceanology, CAS, 2.Department of Earth and Planetary Science, Graduate School of Science, The University of Tokyo, Japan, 3.Xiamen University Malaysia, Malaysia)

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

[AOS11-14] Tidal and Wind Mixing in the Arafura Sea

*Robin Robertson[1] (1.Xiamen University Malaysia)

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

[AOS11-15] Verifying the parameterization of vertical eddy viscosity and diffusivity in the bottom boundary layer

*Takahiro Endoh[1], Takuya Hirooka[1] (1.RIAM Research Institute for Applied Mechanics)

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

[AOS11-16] The role of double-diffusive convection in basal melting and mixed layer under Antarctic ice shelves

*Bishakhdatta Gayen[1,2], Madi Rosevear [3,5], Ben Galton-Fenzi[4] (1.The University of Melbourne, 2. Indian Institute of Science, 3.University of Tasmania , 4.Australian Antarctic Division, 5.University of Western Australia)

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

[AOS11-17] The Kuroshio nutrient stream, where the diapycnal mixing matters

*Takeyoshi Nagai[1], Gloria Silvana Duran Gomez[1] (1.Department of Ocean Sciences, Tokyo University of Marine Science and Technology)

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

[AOS11-18] Turbulent mixing and its contribution to oxygen flux in the northwestern boundary current region of the Japan/East Sea, April-October 2015

*Dmitry Stepanov[1], Alexander Ostrovskii[2], Dmitry Kaplunenko[1], Jae-Hun Park[3], Young-Gyu Park[4], Pavel Tishchenko[1] (1.Pacific Oceanological Institute, Russia, 2.Shirshov Institute of Oceanology, Russia, 3.Department of Ocean Sciences, Inha University, Korea, 4.Korea Institute of Ocean Science and Technology, Korea)

[E] 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.11 Zoom Room 11

[A-OS12] Physical, biogeochemical, and ecological processes and variability in the Indian Ocean

convener:Yukio Masumoto(Graduate School of Science, The University of Tokyo), Hiroaki Saito(Atmosphere and Ocean Research Institute, The University of Tokyo), Chairperson:Yukio Masumoto(Graduate School of Science, The University of Tokyo), Hiroaki Saito(Atmosphere and Ocean Research Institute, The University of Tokyo)

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

[AOS12-01] Determination of nitrogen source for phytoplankton in the eastern Indian Ocean by δ^{15}N of chlorophyll *a* and divinylchlorophyll *a*

*Yuta Isaji[1], Chisato Yoshikawa[1], Nanako O. Ogawa[1], Kazuhiko Matsumoto[1], Naoto F. Ishikawa[1], Akiko Makabe[1], Hiroshi Ogawa[2], Hiroaki Saito[2], Makio Honda[1], Naohiko Ohkouchi[1] (1.Japan Agency for Marine-Earth Science and Technology, 2.Atmosphere and Ocean Research Institute, University of Tokyo)

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

[AOS12-02] **Temporary phytoplankton bloom induced by physical disturbances in the Eastern Indian Ocean**

*Siyu Jiang[1], Fuminori Hashihama[2], Hiroaki Saito[1] (1.Atmosphere and Ocean Research Institute, The University of Tokyo, 2.Tokyo University of Marine Science and Technology)

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

[AOS12-03] Intraseasonal variation of surface Chlorophyll-a associated with coastal upwelling along the southern coast of Java

*Takanori Horii[1], Eko Siswanto[2], Iskhaq Iskandar[3], Iwao Ueki[1] (1.Global Ocean Observation Research Center, Research Institute for Global Change, Japan Agency for Marine-Earth Science and Technology (JAMSTEC), 2.Earth Surface System Research Center, Research Institute for Global Change, Japan Agency for Marine-Earth Science and Technology (JAMSTEC), 3.Faculty of Mathematics and Natural Sciences, Sriwijaya University, Indonesia)

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

[AOS12-04] Interannual variability in sea surface temperature off Somalia
in boreal summer
– Similarities and differences between “Warm year” and “Cold year” –

*Kusumi Takahiro[1], Yukio Masumoto[1] (1.the Unversity of Tokyo)

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

[AOS12-05] Seasonal and Interannual Variations of Indian Ocean Subtropical Mode Water Based on the Argo Data

*Hanani Adiwira[1], Toshio Suga[1] (1.Tohoku University)

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

[AOS12-06] Distribution and movement of microplastics in the Indian Ocean

*Yukio Masumoto[1] (1.Graduate School of Science, The University of Tokyo)

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

9:00 AM - 10:30 AM JST | 12:00 AM - 1:30 AM UTC | Ch.11 Zoom Room 11

[A-OS13] Marine ecosystems and biogeochemical cycles: theory, observation and modeling

convener:Takafumi Hirata(Arctic Research Center, Hokkaido University), Shin-ichi Ito(Atmosphere and Ocean Research Institute, The University of Tokyo), E Eileen Hofmann(Old Dominion University), N Enrique Curchitser(Rutgers University New Brunswick), Chairperson:Shin-ichi Ito(Atmosphere and Ocean Research Institute, The University of Tokyo), Takafumi Hirata(Arctic Research Center, Hokkaido University), Eileen E Hofmann(Old Dominion University), Enrique N Curchitser(Rutgers University New Brunswick)

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

[AOS13-01] Introduction

9:05 AM - 9:30 AM JST | 12:05 AM - 12:30 AM UTC

[AOS13-02] Understanding Marine Ecosystems – A View to the Future

★Invited Papers

*Eileen E Hofmann[1] (1.Old Dominion University)

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

[AOS13-03] Marine Ecosystem Variations Over the North Pacific and Their Linkage to Large-Scale Climate Variability and Change

*Emi Yati[1], Shoshiro Minobe[2,3], Nathan Mantua[4], Shin-ichi Ito[5], Emanuele Di Lorenzo[6] (1.Remote Sensing Application Center, Indonesian National Institute of Aeronautics and Space, Jakarta, Indonesia, 2.Department of Natural History Sciences, Graduate School of Science, Hokkaido University, Sapporo, Japan, 3.Department of Earth and Planetary Sciences, Faculty of Science, Hokkaido University, Sapporo, Japan, 4.Fish Ecology Division, Southwest Fisheries Science Center, National Marine Fisheries Service, National Oceanographic and Atmospheric Administration, Santa Cruz, CA, United States, 5.Atmosphere and Ocean Research Institute, University of Tokyo, Kashiwa, Japan, 6.School of Earth and Atmospheric Sciences, Georgia Institute of Technology, Atlanta, GA, United States)

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

[AOS13-04] **Future biogeographic shifts of marine biodiversity in the Pacific Arctic**

*Irene Alabia[1], Jorge Garcia Molinos[1], Sei-Ichi Saitoh[1], Takafumi Hirata[1], Toru Hirawake[1], Franz Mueter[2] (1.Hokkaido University, 2.University of Alaska Fairbanks)

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

[AOS13-05] Instantaneous Acclimation allows computationally efficient modelling of the biogeochemical impacts of plankton ecophysiology

*S. Lan Smith[1], Onur Kerimoglu[2], Prima Anugerahanti[1], Yoshio Masuda[3], Yasuhiro Yamanaka[3], Yoshikazu Sasai[1] (1.Marine Ecosystem Dynamics Research Group, Research Institute for Global Change, Japan Agency for Marine-Earth Science and Technology, 2.ICBM, University of Oldenburg, Germany, 3.Faculty of Environmental Earth Science, Hokkaido University)

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

[AOS13-06] Interannual Variability in contributions of the Equatorial Undercurrent (EUC) to Peruvian Upwelling

*Gandy Maria Rosales Quintana[1], Robert Marsh[2], Luis Alfredo Icochea Salas[3] (1.Course of Applied Marine Environmental Studies, Tokyo University of Marine Science and Technology, 2.University of Southampton, UK, 3.Universidad Nacional Agraria La Molina, Peru)

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

10:45 AM - 12:15 PM JST | 1:45 AM - 3:15 AM UTC | Ch.11 Zoom Room 11

[A-OS13] Marine ecosystems and biogeochemical cycles: theory, observation and modeling

convener:Takafumi Hirata(Arctic Research Center, Hokkaido University), Shin-ichi Ito(Atmosphere and Ocean Research Institute, The University of Tokyo), E Eileen Hofmann(Old Dominion University), N Enrique Curchitser(Rutgers University New Brunswick), Chairperson:Takafumi Hirata(Arctic Research Center, Hokkaido University), Shin-ichi Ito(Atmosphere and Ocean Research Institute, The University of Tokyo), Eileen E Hofmann(Old Dominion University), Enrique N Curchitser(Rutgers University New Brunswick)

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

[AOS13-07] Influence of ENSO on surface chlorophyll-a in the Gulf of Thailand

*Dudsadee Leenawarat[1], Jutarak Luang-on[1], Anukul Buranapratheprat[2], Joji Ishizaka[3] (1.Graduate School of Environmental Studies, Nagoya University, 2.Department of Aquatic Science, Faculty of Science, Burapha University, Thailand, 3.Institute for Space-Earth Environmental Research, Nagoya University, Japan)

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

[AOS13-08] Nitrogen isotope mapping in the North Pacific using a marine nitrogen isotope model

*Chisato Yoshikawa[1], Masahito Shigemitsu[1], Akitomo Yamamoto[1], Akira Oka[2], Naohiko Ohkouchi[1] (1.JAMSTEC, 2.AORI)

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

[AOS13-09] **Interannual variations of the lower-trophic level ecosystem in the Harima-Nada, eastern Seto Inland Sea, Japan simulated by a plankton functional type model.**

*Naoki Yoshie[1], Ayaka Hiramine[1] (1.Center for Marine Environmental Studies, Ehime University)

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

[AOS13-10] **Occurrence of phytoplankton bloom as the Kuroshio passes an island**

*JIE GAO[1], Xinyu Guo[1] (1.Center for Marine Environmental Studies, Ehime University)

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

[AOS13-11] Long-term comparison between the Japanese sardine stock level and simulated zooplankton density around the Kuroshio axis

*Haruka Nishikawa[1], Hiroyuki Tsujino[2], Shiro Nishikawa[1], Hideyuki Nakano[2], Toru Sugiyama[1], Yoichi Ishikawa[1] (1.Japan Agency for Marine-Earth Science and Technology, 2.Meteorological Research Institute)

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

[AOS13-12] Changes in phytoplankton photophysiology during pre-bloom and bloom phases in the coastal Oyashio waters

*Tomonori Isada[1], Toru Hirawake[2], Koji Suzuki[3], Jun Nishioka[4], Hiromi Kasai[5] (1.Field Science Center for Northern Biosphere, Hokkaido University, 2.Faculty of Fisheries Sciences, Hokkaido University, 3.Faculty of Environmental Earth Science, Hokkaido University, 4.Institute of Low Temperature Science, Hokkaido University, 5.Japan fisheries research and education agency)

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

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

[A-OS13] Marine ecosystems and biogeochemical cycles: theory, observation and modeling

convener:Takafumi Hirata(Arctic Research Center, Hokkaido University), Shin-ichi Ito(Atmosphere and Ocean Research Institute, The University of Tokyo), E Eileen Hofmann(Old Dominion University), N Enrique Curchitser(Rutgers University New Brunswick), Chairperson:Shin-ichi Ito(Atmosphere and Ocean Research Institute, The University of Tokyo), Takafumi Hirata(Arctic Research Center, Hokkaido University), Eileen E Hofmann(Old Dominion University), Enrique N Curchitser(Rutgers University New Brunswick)

1:45 PM - 2:05 PM JST | 4:45 AM - 5:05 AM UTC

[AOS13-13] Biogeochemical fingerprints of ocean migration of Pacific salmon

★Invited Papers

*Jun Matsubayashi[1] (1.Chuo University)

2:05 PM - 2:20 PM JST | 5:05 AM - 5:20 AM UTC

[AOS13-14] Vertical habitat shifts of juvenile Japanese jack mackerel (*Trachurus japonicus*) estimated by otolith microchemistry

*Megumi Enomoto[1], Shin-ichi Ito[1], Motomitsu Takahashi[2], Chiyuki Sassa[2], Tomihiko Higuchi[1], Kotaro Shirai[1] (1.Atmosphere and Ocean Research Institute, The University of Tokyo, 2.Fisheries Resource Institute, Japan Fisheries Research and Education Agency)

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

[AOS13-15] Retrospective time-series nitrogen isotope analysis of fish otoliths

*Yota Harada[1], Chisato Yoshikawa[1], Nanako O. Ogawa[1], Saburo Sakai[1], Shin-ichi Ito[2], 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)

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

[AOS13-16] Fish specialize their metabolic performance to maximize bioenergetic efficiency in their local environment

★Invited Papers

*Chenying Guo[1], Shin-ichi Ito[1], Michio Yoneda[2], Hajime Kitano[2], Hitoshi Kaneko[3], Megumi Enomoto[1], Tomoya Aono[1], Masahiro Nakamura[2], Takashi Kitagawa[1], Nicolas C Wegner[4], Emmanis Dorval[5] (1.Atmosphere and Ocean Research Institute, the University of Tokyo, 2.Japan Fisheries Research and Education Agency, 3.Japan Agency for Marine-Earth Science and Technology (JAMSTEC), 4.Southwest Fisheries Science Center, National Marine Fisheries Service, NOAA, 5.Lynker Technologies, LLC., under contract to Southwest Fisheries Science Center, NOAA)

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

[AOS13-17] Comparative study on environment experienced by jack mackerel in the East China Sea between 1960s and 2000s.

*Tomihiko Higuchi[1], Motomitsu Takahashi[2], Megumi Enomoto[1], Kotaro Shirai[1], Shin-ichi Ito[1] (1.Atmosphere and Ocean Research Institute, The University of Tokyo, 2.Fisheries Resources Institute, Japan Fisheries Research and Education Agency, Nagasaki, Japan)

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

[AOS13-18] Discussion

[E] Oral | A (Atmospheric and Hydrospheric Sciences) : A-HW Hydrology & Water Environment

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

[A-HW20] Hydrology & Water Environment

convener:Takeshi Hayashi(Faculty of Education and Human Studies, Akita University), Keisuke Fukushi(Institute of Nature & Environmental Technology, Kanazawa University), Koichi Sakakibara(Department of Environmental Sciences, Faculty of Science, Shinshu University), Dai Yamazaki(Institute of Industrial Sciences, The University of Tokyo), Chairperson:Takeshi Hayashi(Faculty of Education and Human Studies, Akita University), Keisuke Fukushi(Institute of Nature & Environmental Technology, Kanazawa University), Koichi Sakakibara(Department of Environmental Sciences, Faculty of Science, Shinshu University), Dai Yamazaki(Institute of Industrial Sciences, The University of Tokyo)

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

[AHW20-01] Introduction

9:05 AM - 9:20 AM JST | 12:05 AM - 12:20 AM UTC

[AHW20-02] Behavior of pore-air entrapment in unsaturated soil layer in two small headwater catchments with different soil depth

*Sho Iwagami[1], Shoji Noguchi[2], Takanori Shimizu[1], Tayoko Kubota[1], Shin'ichi Iida[1] (1.Forestry and Forest Products Research Institute, Forest Research and Management Organization, National Research and Development Agency, 2.Kansai Research Center, Forestry and Forest Products Research Institute, Forest Research and Management Organization, National Research and Development Agency)

9:20 AM - 9:35 AM JST | 12:20 AM - 12:35 AM UTC

[AHW20-03] Developement of a 2D Eulerian SPH shallow water model for dam break flows

*Kao-Hua Chang[1] (1.National Taiwan Ocean University)

9:35 AM - 9:50 AM JST | 12:35 AM - 12:50 AM UTC

[AHW20-04] Investigating the validity of a meso scale constitutive equation using micro scale water dynamics simulations for hillslope rainfall-runoff processes

*Yutaka Ichikawa[1], Yuusuke Mori[1], Yasuto Tachikawa[1] (1.Graduate School of Engineering, Kyoto University)

9:50 AM - 10:05 AM JST | 12:50 AM - 1:05 AM UTC

[AHW20-05] A review of ensemble flood forecasting for operational warning

*Megumi Watanabe[1], Shunsuke Ito[2], Wenchao Ma[1], Dai Yamazaki[1] (1.Institute of Industrial Science, The University of Tokyo, Japan, 2.School of Engineering, The University of Tokyo, Japan)

10:05 AM - 10:20 AM JST | 1:05 AM - 1:20 AM UTC

[AHW20-06] ***Toward Downscaling Storage-Discharge Dynamics: Training Long Short-Term Memory (LSTM) model for Simulating Nonlinear Storage-Discharge Relation in HUC-8 Rum River Watershed, MN***

*Pai-Feng Victor Teng[1] (1.University of Minnesota)

10:20 AM - 10:30 AM JST | 1:20 AM - 1:30 AM UTC

[AHW20-07] Discussion

[E] Oral | A (Atmospheric and Hydrospheric Sciences)：A-HW Hydrology & Water Environment

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

[A-HW20] Hydrology & Water Environment

convener:Takeshi Hayashi(Faculty of Education and Human Studies, Akita University), Keisuke Fukushi(Institute of Nature & Environmental Technology, Kanazawa University), Koichi Sakakibara(Department of Environmental Sciences, Faculty of Science, Shinshu University), Dai Yamazaki(Institute of Industrial Sciences, The University of Tokyo), Chairperson:Takeshi Hayashi(Faculty of Education and Human Studies, Akita University), Koichi Sakakibara(Department of Environmental Sciences, Faculty of Science, Shinshu University), Dai Yamazaki(Institute of Industrial Sciences, The University of Tokyo), Shin'ichi Iida(Department of Disaster Prevention, Meteorology and Hydrology, Forestry and Forest Products Research Institute)

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

[AHW20-08] Introduction

10:50 AM - 11:05 AM JST | 1:50 AM - 2:05 AM UTC

[AHW20-09] Distribution of Uranium and Arsenic in Surface Water around Alkaline-Hyposaline Lake from Valley of Gobi Lakes in Mongolia

*Baasansuren Gankhurel[1], Keisuke Fukushi[1], Davaadorj Davaasuren[2], Eigo Imai[1], TAKUMA KITAJIMA[1], Tuvshin Gerelmaa[2], Yasuhito Sekine[3], Yoshio Takahashi[4], Noriko Hasebe[1] (1.Kanazawa University, 2.National University of Mongolia, 3.Tokyo Institute of Technology, 4.The University of Tokyo)

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

[AHW20-10] Differences in nitrogen biogeochemical cycles of a reservoir with a hydraulic retention time of several days, before and after the dam was built

*Qingqing Sun[1] (1.Tianjin University)

11:20 AM - 11:35 AM JST | 2:20 AM - 2:35 AM UTC

[AHW20-11] **Plastic debris as a carrier of inorganic contaminants in the urban river of Mongolia**

*Batdulam Battulga[1], Masayuki Kawahigashi[1], Bolormaa Oyuntsetseg[2] (1.Department of Geography, Tokyo Metropolitan University, Tokyo, 192-0397, Japan , 2.Department of Chemistry, National University of Mongolia, Ulaanbaatar, 210646, Mongolia)

11:35 AM - 11:50 AM JST | 2:35 AM - 2:50 AM UTC

[AHW20-12] Geochemisty and environmental impact on groundwater in Eastern Serbia

*Dragana Adamovic[1,2], Daizo Ishiyama[1], Hiroshi Kawaraya[1], Yasumasa Ogawa[1] (1.Akita University, Japan, 2.MMI Bor, Serbia)

11:50 AM - 12:05 PM JST | 2:50 AM - 3:05 AM UTC

[AHW20-13] **Measurement of reactive oxygen species (ROS) and fluorescent organic matter in selected rivers in Hiroshima Prefecture, Japan.**

*Taiwo Tolulope Ayeni[1], Takashi Umeda[1], Yoko Iwamoto[1], Kazuhiko Takeda[1], Hiroshi M. G. Sakugawa[1], Khan M. G. Mostofa[2] (1.Hiroshima University Japan, 2.Tianjin University, China)

12:05 PM - 12:15 PM JST | 3:05 AM - 3:15 AM UTC

[AHW20-14] Discussion

[E] Oral | A (Atmospheric and Hydrospheric Sciences) : A-HW Hydrology & Water Environment

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

[A-HW21] Interdisciplinary approach to support climate change adaptation measures in regional scale

convener:TEBAKARI TAICHI(Toyama Prefectural University), Sompratana Ritphring(Kasetsart University), Masashi Kiguchi(University of Tokyo), weerakaset Suanpaga(Associate professor in Civil Engineering,Kasetsart University), Chairperson:TEBAKARI TAICHI(Toyama Prefectural University), Masashi Kiguchi(University of Tokyo)

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

[AHW21-01] ADAP-T for water-related adaptation to climate change and supporting its policy making

★Invited Papers

*Taikan Oki[1], Thanya Kiatiwat[2], Hiroaki Shirakawa[3], Weerakaset Suanpaga[2], Taichi Tebakari[4], Sompratana Ritphring[2], Masashi Kiguchi[5], Kyoko Matsumoto[4] (1.Graduate School of Engineering, The University of Tokyo, 2.Faculty of Engineering, Kasetsart University, 3.Granduate School of Environmental Studies, Nagoya University, 4.Department of Civil and Environmental Engineering, Toyama Prefectural University, 5.Institute of Industrial Science, The University of Tokyo)

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

[AHW21-02] The GEWEX Regional Hydroclimate Projects in High Mountainous Terrain in Asia

★Invited Papers

*Petrus J van Oevelen[1] (1.George Mason University)

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

[AHW21-03] **Effectiveness of Flood Diversion Canals and Retention Ponds as Adaptation Strategies in the Upper Chao Phraya River Basin**

*Saritha Padiyedath Gopalan[1], Naota Hanasaki[1] (1.National Institute for Environmental Studies)

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

[AHW21-04] **The impact of sensible heat and latent heat on monsoon onset over Indochina peninsula**

Tomohito Yamada[1], Ryosuke Kato[1], *Sourabh Shrivastava[1] (1.Hokkaido University)

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

[AHW21-05] S2S prediction challenge with deep learning in Thailand

*Kiyoharu Hasegawa[1], Shinjiro Kanae[1] (1.Toyko Institute of Technology)

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

[AHW21-06] Local knowledge: A comprehensive agricultural system and incremental drought adaptation strategy for Javanese society

*Muhamad Khoiru Zaki[1], Keigo Noda[1], Kengo Ito[1], Komariah Komariah[2], Sumani Sumani[2] (1.Gifu University, 2.Sebelas Maret University)

[E] Oral | A (Atmospheric and Hydrospheric Sciences)：A-HW Hydrology & Water Environment

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

[A-HW21] Interdisciplinary approach to support climate change adaptation measures in regional scale

convener:TEBAKARI TAICHI(Toyama Prefectural University), Sompratana Ritphring(Kasetsart University), Masashi Kiguchi(University of Tokyo), weerakaset Suanpaga(Associate professor in Civil Engineering,Kasetsart University), Chairperson:Masashi Kiguchi(University of Tokyo), TEBAKARI TAICHI(Toyama Prefectural University)

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

[AHW21-07] **Climate change effect the relationship between land-use and poverty in major cities of Thailand.**

★Invited Papers

*weerakaset Suanpaga[1], Shirakawa Hiroaki[2], Nichanun Trakulphudphong [3], Wuthiporn Klinhom[3], Krittanut Thumsatsarn[3] (1.Associate professor in Civil Engineering,Kasetsart University,Thailand, 2.Associate professor in Graduate School of Engineering,Nagoya University,Japan, 3.Bachelor degree student in Civil Engineering,Kasetsart University,Thailand)

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

[AHW21-08] **Local adaptation strategy to climate change considering local context in Thailand**

★Invited Papers

*Kyoko Matsumoto[1], Sompratana Ritphring[2], Masashi Kiguchi[3], Taichi Tebakari[1], Taikan Oki[4] (1.Department of Civil and Environmental Engineering, Toyama Prefectural University, 2.Faculty of Engineering, Kasetsart University, 3.Institute of Industrial Science, The University of Tokyo, 4.School of Engineering, The University of Tokyo)

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

[AHW21-09] **Beach Nourishment to Mitigate the Impact of Beach Erosion and Sea Level Rise, Thailand**

*Sompratana Ritphring[1], Keiko Udo[2] (1.Department of Water Resources Engineering, Kasetsart University, 2.International Research Institute of Disaster Science, Tohoku University)

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

[AHW21-10] **Valuation of Sandy Beach Tourism Benefit with Respect to Hotel Room Rates by Using a Spatial Hedonic Model in Thailand**

*Chatuphorn Somphong[1], Keiko Udo[1], Sompratana Ritphring[2], Hiroaki Shirakawa[3] (1.International Research Institute of Disaster Science, Tohoku University, Japan, 2.Department of Water Resources Engineering, Kasetsart University, Thailand, 3.Graduate School of Environmental Studies, Nagoya University, Japan)

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

[AHW21-11] Impacts of urban flood and adapataion on traffic flow in Bangkok

*Shinichiro NAKAMURA[1], Horoyoshi Morita[4], Tsuyoshi Takano[4], Varameth Vichiensan[2], Sanit Wongsa[3], Napaporn Piamsa-nga[2] (1.Nagoya University, 2.Kasetsaet University, 3.King Mongkut's University of Technology Thonburi, 4.Nippon Engineering Consultants Co., Lld)

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

[AHW21-12] Effectiveness of crop calendar shift as an adaptation measure for climate change - Case study for rice production in Hokkaido, Japan

*Kenji Tanaka[1], Tomoki Yamada[2], Shigenobu Tanaka[1] (1.Disaster Prevention Research Institute, Kyoto University, 2.Faculty of Engineering, Kyoto University)

[E] 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.07 Zoom Room 07

[A-CG30] Multi-scale ocean-atmosphere interaction in the tropics

convener:Hiroki Tokinaga(Research Institute for Applied Mechanics, Kyushu University), Yu Kosaka(Research Center for Advanced Science and Technology, University of Tokyo), Ayako Seiki(Japan Agency for Marine-Earth Science and Technology), Tomoki Tozuka(Department of Earth and Planetary Science, Graduate School of Science, The University of Tokyo), Chairperson:Yu Kosaka(Research Center for Advanced Science and Technology, University of Tokyo), Ayako Seiki(Japan Agency for Marine-Earth Science and Technology)

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

[ACG30-01] The impact of North Pacific climate variability on historical ENSO and its mechanisms

★Invited Papers

*Dillon J Amaya[1,2], Yu Kosaka[3], Wenyu Zhou[4], Yu Zhang[5], Shang-Ping Xie[6], Arthur J Miller[6] (1.Cooperative Institute for Research in Environmental Sciences, 2.University of Colorado Boulder, 3.University of Tokyo, 4.Pacific Northwest National Laboratory, 5.Ocean University of China, 6.Scripps Institution of Oceanography)

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

[ACG30-02] Radiative impacts of low clouds on the subtropical North Pacific climate

*Ayumu Miyamoto[1], Hisashi Nakamura[1], Takafumi Miyasaka[2], Yu Kosaka[1], Shang-Ping Xie[3] (1.Research Center for Advanced Science and Technology,The University of Tokyo, 2.Japan Meteorological Business Support Center, 3.Scripps Institution of Oceanography, University of California San Diego)

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

[ACG30-03] Disparate Midlatitude Responses to El Niño/Southern Oscillation

*Shiozaki Masahiro[1], Takeshi Enomoto[2,3], Takaya Koutarou[4] (1.Research Institute for applied mechanics, Kyushu University, 2.Disaster Prevention Research Institute, Kyoto University, 3.Application Laboratory, Japan Agency for Marine-Earth Science and Technology, 4.Kyoto Sangyo University)

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

[ACG30-04] Formation of Barrier Layers and Temperature Inversions in the Eastern Tropical Pacific Detected by Mooring Observation

*Shota Katsura[1], Janet Sprintall[1], Thomas Farrar[2], Dongxiao Zhang[3,4], Meghan Cronin[3] (1.Scripps Institution of Oceanography, University of California, San Diego, 2.Department of Physical Oceanography, Woods Hole Oceanographic Institution, 3.NOAA Pacific Marine Environmental Laboratory, 4.Cooperative Institute for Climate, Ocean, and Ecosystem Studies, University of Washington)

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

[ACG30-05] The intraseasonal relationship between the boreal summer intraseasonal oscillation and the Pacific-Japan pattern

*Ayako Seiki[1], Yu Kosaka[2], Satoru Yokoi[1] (1.Japan Agency for Marine-Earth Science and Technology, 2.The University of Tokyo)

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

[ACG30-06] Why does convection weaken over Sumatra Island in an active phase of the MJO?

*Ning Zhao[1], Peiming Wu[1], Miki Hattori[1] (1.JAMSTEC Japan Agency for Marine-Earth Science and Technology)

[E] 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-CG30] Multi-scale ocean-atmosphere interaction in the tropics

convener:Hiroki Tokinaga(Research Institute for Applied Mechanics, Kyushu University), Yu Kosaka(Research Center for Advanced Science and Technology, University of Tokyo), Ayako Seiki(Japan Agency for Marine-Earth Science and Technology), Tomoki Tozuka(Department of Earth and Planetary Science, Graduate School of Science, The University of Tokyo), Chairperson:Hiroki Tokinaga(Research Institute for Applied Mechanics, Kyushu University), Tomoki Tozuka(Department of Earth and Planetary Science, Graduate School of Science, The University of Tokyo)

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

[ACG30-07] Understanding tropical interbasin interaction using linear inverse modelling

*Shoichiro Kido[1], Ingo Richter[1], Tomoki Tozuka[2,1], Ping Chang[3] (1.JAMSTEC Application Lab, 2.Department of Earth and Planetary Science, University of Tokyo, 3.Texas A&M University)

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

[ACG30-08] **An assessment of the tropical Atlantic influence on El Niño-Southern Oscillation**

*Ingo Richter[1], Hiroki Tokinaga[2], Yu Kosaka[3], Takeshi Doi[1], Takahito Kataoka[1] (1.Japan Agency for Marine-Earth Science and Technology, Yokohama, Japan, 2.Kyushu University, Kasuga, Japan, 3.University of Tokyo, Tokyo, Japan)

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

[ACG30-09] **The roles of diabatic heating for the seasonality of the Atlantic Niño**

★Invited Papers

*Hyacinth C. Nnamchi[1], Mojib Latif[1], Noel S. Keenlyside[2,3], Joakim Kjellsson[1], Ingo Richter[4] (1.GEOMAR Helmholtz Centre for Ocean Research Kiel, 2.Geophysical Institute, University of Bergen, and Bjerknes Centre for Climate Research, Bergen, Norway, 3.Nansen Environmental and Remote Sensing Center, Bergen, Norway, 4.Application Laboratory, Research Institute for Value-Added-Information Generation, Japan Agency for Marine-Earth Science and Technology, Yokohama, Japan)

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

[ACG30-10] Simulated thermocline tilt over the tropical Indian Ocean and its influence on future sea surface temperature variability

★Invited Papers

*Guojian Wang[1,2], Wenju Cai[1,2], Agus Santoso[1,3] (1.Center for Southern Hemisphere Oceans Research (CSHOR), CSIRO Oceans and Atmosphere, 2.Key Laboratory of Physical Oceanography–Institute for Advanced Ocean Studies, Ocean University of China and Qingdao National Laboratory for Marine Science and Technology, 3.The University of New South Wales)

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

[ACG30-11] Asymmetry in sea surface temperature anomalies and atmospheric teleconnection associated with the Indian Ocean Dipole

Mai Nakazato[1], Shoichiro Kido[2], *Tomoki Tozuka[1,2] (1.Department of Earth and Planetary Science, Graduate School of Science, The University of Tokyo, 2.Application Laboratory, Research Institute for Value-Added-Information Generation, Japan Agency for Marine-Earth Science and Technology)

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

[ACG30-12] Investigation of interannual variability in the tropical Indian Ocean based on the transfer routes of wave energy

*Zimeng Li[1], Hidenori AIKI[2] (1.Graduate school of environmental studies, Nagoya university, 2.Institute for Space-Earth Environmental Research)

[E] 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.08 Zoom Room 08

[A-CG34] Global Carbon Cycle Observation and Analysis

convener:Kazuhito Ichii(Chiba University), Prabir Patra(Research Institute for Global Change, JAMSTEC), Akihiko Ito(National Institute for Environmental Studies), Chairperson:Prabir Patra(Research Institute for Global Change, JAMSTEC), Kazuhito Ichii(Chiba University)

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

[ACG34-01] Atmospheric inversions of greenhouse gas fluxes: A story of uneven development

★Invited Papers

*Peter J Rayner[1] (1.University of Melbourne)

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

[ACG34-02] **Decadal variability in land and ocean carbon fluxes by inverse modelling of atmospheric CO_2**

★Invited Papers

*Naveen Chandra[1,2], Prabir Patra[2] (1.National Institute for Environmental Studies, Japan, 2.Japan Agency for Marine-Earth Science and Technology)

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

[ACG34-03] **Changes in the atmospheric CO_2/CH_4 variability in the East Asian outflow region caused by plummet of fossil fuel-derived CO_2 in China due to COVID-19 outbreak**

*Yasunori Tohjima[1], Prabir Patra[2], Yosuke Niwa[1], Hitoshi Mukai[1], Motoki Sasakawa[1], Toshinobu Machida[1], Shin-ichiro Nakaoka[1] (1.National Institute for Environmental Studies, 2.Japan Agency for Marine-Earth Science and Technology)

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

[ACG34-04] Impact of anomalous high temperature anomaly in the 2020 spring-summer on terrestrial environment across Siberia

*Kazuhito Ichii[1], Riku Kawase[1], Yuhei Yamamoto[1], Shunji Kotsuki[1] (1.Chiba University)

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

[ACG34-05] CH_4 surface flux estimation based on local ensemble transform Kalman filter

*Jagat Bisht[1], Prabir Patra[1,2], Masayuki Takigawa[1], Takashi Sekiya[1], Yugo Kanaya[1], Naoko Saito[2] (1.Japan Agency for Marine-Earth Science and Technology , 2.Center for Environ. Remote Sensing, Chiba University)

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

[ACG34-06] Toward multi-scale greenhouse gas monitoring system for supporting global stock take

*Akihiko Ito[1,2], Yosuke Niwa[1], Tomohiro Hajima[2], Nobuko Saigusa[1] (1.National Institute for Environmental Studies, 2.Japan Agency for Marine-Earth Science and Technology)

[E] 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.08 Zoom Room 08

[A-CG34] Global Carbon Cycle Observation and Analysis

convener:Kazuhito Ichii(Chiba University), Prabir Patra(Research Institute for Global Change, JAMSTEC), Akihiko Ito(National Institute for Environmental Studies), Chairperson:Kazuhito Ichii(Chiba University), Akihiko Ito(National Institute for Environmental Studies)

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

[ACG34-07] Co-evolution of carbon cycle and air quality fluxes constrained by CMS-Flux and MOMO-Chem assimilation systems

★Invited Papers

*Kevin W Bowman[1], Kazuyuki Miyazaki[1], Junjie Liu[1], Anthony Bloom[1] (1.Jet Propulsion Laboratory)

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

[ACG34-08] **Lower anthropogenic fossil CH_4 emissions inferred from multi-isotopic constraints on the global CH_4 budget**

★Invited Papers

*Ryo Fujita[1,2], Heather Graven[2] (1.Meteorological Research Institute, 2.Imperial College London)

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

[ACG34-09] The burned area extracting in Chernobyl Exclusion Zone using random forest

*JUN HU[1], Shunji Kotsuki[1], Yasunori IGARASHI[2], Mykola TALERKO[3], Kazuhito Ichii[1] (1.Center for Environmental Remote Sensing, Chiba University, Chiba, Japan, 2.Institute of Environmental Radioactivity, Fukushima University, Fukushima, Japan, 3.Institute for Safety Problems of Nuclear Power Plants, National Academy of Sciences of Ukraine, Kyiv, Ukraine)

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

[ACG34-10] Monitoring and evaluation of carbon absorption in pasture areas near Ulaanbaatar and far from cities

*Qinxue Wang[1], Tomohiro OKADERA[1], Masataka WATANABE[2], Ochirbat Batkhishig[3] (1.National Institute for Environmental Studies, 2.Research and Development Initiative, 3.Institute of Geography and Geoecology, Mongolian Academy of Sciences)

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

[ACG34-11] An observation-based reconstruction reveals progressive ocean acidification around Japan

*Yosuke Iida[1], Takashi Nakamura[1], Yoshikazu Fukuda[1], Masao Ishii[2] (1.Japan Meterological Agency, 2.Meteorological Research Institute)

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

[ACG34-12] Trend in Southern Ocean CO_2 sink – a review and outlook

*Prabir Patra[1], Naveen Chandra[2], Pedro S Monteiro[3], Masao Ishii[4] (1.Research Institute for Global Change, JAMSTEC, 2.National Institute for Environmental Studies, 3.CSIR-CHPC, South Africa, 4.Meteorological Research Institute)

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

3:30 PM - 5:00 PM JST | 6:30 AM - 8:00 AM UTC | Ch.15 Zoom Room 15

[H-TT15] Non-destructive techniques applied to stone cultural heritage

convener:Celine Thomachot-Schneider(University of Reims-Champagne-Ardenne), Chiaki T. Oguchi(Institute for Environmental Science and Technology, Graduate School of Science and Engineering, Saitama University), Patricia vazquez(University of Reims Champagne Ardenne), Chairperson:Celine Thomachot-Schneider(University of Reims-Champagne-Ardenne), Patricia vazquez(University of Reims Champagne Ardenne)

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

[HTT15-01] Comparison of classic aging and realistic tests: study of the compatibility between limestones and restoration mortar

*Emilie Huby[1], Celine Thomachot-Schneider[1], Patricia vazquez[1], Gilles Fronteau[1] (1.Groupe d'etude des environnements naturels, anthropiques et archeologiques - Universite de Reims-Champagne-Ardenne (France))

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

[HTT15-02] Measurement of anisotropy of liquid water diffusivity of brittle tuff stone of Takase stone buddhas using X-ray

*Masaru Abuku[1], Shuya Hiranuma[2], Takayuki Fumoto[1], Soichiro Wakiya[3], Daisuke Ogura[4] (1.Kindai University, 2.SEKISUI HOUSE. LTD., 3.Nara National Research Institute for Cultural Properties, National Institutes for Cultural Heritage, 4.Kyoto University)

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

[HTT15-03] **Granite Characterisation of Three Asynchronous Quarries of the Archaeological Site of *Touças* (North of Portugal)**

*David Martin Freire-Lista[1,2], Patricia Vazquez[3], Gerardo Vidal Gonçalves[4] (1.Universidade de Tras-os-Montes e Alto Douro. Quinta de Prados. 5001-801 Vila Real, Portugal., 2.Centro de Geociências da Universidade de Coimbra. Rua Silvino Lima. Universidade de Coimbra - Polo II. 3030-790 Coimbra, Portugal., 3.Université Reims-Champagne-Ardenne 2, esplanade Roland Garros 51100 Reims, France. , 4.Centro de Investigação e Desenvolvimento em Ciências Humanas e Sociais. Universidade de Évora, Portugal.)

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

[HTT15-04] **Spatiotemporal evaluation of weathering-induced depressions in sandstone blocks by terrestrial laser scanning**

*Yuichi S. Hayakawa[1], Hisashi Aoki[2] (1.Faculty of Environmental Earth Science, Hokkaido University, 2.Faculty of Education, Tokyo Gakugei University)

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

[HTT15-05] From photogrammetric modelling of the built heritage to the evaluation of the durability of stones via GIS

*Sebastien LARATTE[1,2], Celine Thomachot-Schneider[1,2], Gilles FRONTEAU[1,2], Alexandra GUILLANEUF[1,2] (1.University of Reims-Champagne-Ardenne, 2.GEGENAA)

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

[HTT15-06] Discussion

[E] 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.23 Zoom Room 23

[S-IT17] Property and role of liquids inside terrestrial planets

convener:Tatsuya Sakamaki(Department of Earth Science, Tohoku University), Yoichi Nakajima(Kumamoto University, Priority Organization for Innovation and Excellence), Chairperson:Tatsuya Sakamaki(Department of Earth Science, Tohoku University), Yoichi Nakajima(Kumamoto University, Priority Organization for Innovation and Excellence)

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

[SIT17-01] Pressure-induced structural change of basaltic glass up to 18 GPa

*Tomonori Ohashi[1], Tatsuya Sakamaki[1], Ken-ichi Funakoshi[2], Takanori Hattori[3], Naoki Hisano[1], Jun Abe[2], Akio Suzuki[1] (1.Department of Earth Science, Tohoku University, 2.Neutron Science and Technology Center, Comprehensive Research Organization for Science and Society (CROSS), 3.J-PARC Center, Japan Atomic Energy Agency)

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

[SIT17-02] Atomic structure of CO_2-bearing melts along the carbonatite-basalt join at high pressure and temperature

*Veronica Stopponi[1], Annalisa D'Arco[2,3], Rostislav Hrubiak[4], Yoshio Kono[5], Stefano Lupi[2,6], Craig E Manning[7], Manuela Nazzari[8], Brent T Poe[9], Claudia Romano[10], Vincenzo Stagno[1,8] (1.Department of Earth Sciences, Sapienza University of Rome, Rome, Italy, 2.INFN National Institute of Nuclear Physics, Rome, Italy, 3.SBAI Department of Basic and Applied Sciences for Engineering, Physics, Sapienza University of Rome, Rome, Italy, 4.High Pressure Collaborative Access Team (HPCAT), X-ray Science Division, Argonne National Laboratory, Argonne, IL, USA, 5.Geodynamic Research Center, Ehime University, Matsuyama, Japan, 6.Department of Physics, Sapienza University of Rome, Rome, Italy, 7.Department of Earth, Planetary and Space Sciences, University of California, Los Angeles, CA, USA, 8.Istituto Nazionale di Geofisica e Vulcanologia (INGV), Rome, Italy, 9.Department of Engineering and Geology, University of Chieti-Pescara, Chieti Scalo, Italy, 10.Department of Sciences, University of Studies Roma Tre, Rome, Italy)

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

[SIT17-03] ***In situ X-ray study of liquid geomaterials under extreme conditions using Free-Electron Lasers***

★Invited Papers

*Guillaume Morard[1] (1.ISTerre, UGA, CNRS)

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

[SIT17-04] Density and thermal expansion of liquid and solid iron at 1 atm determined using high-temperature furnace

★Invited Papers

*Hidenori Terasaki[1], Asaka Kamiya[2], Tadashi Kondo[2] (1.Department of Earth science, Okayama University, 2.Department of Earth and Space science, Osaka University)

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

[SIT17-05] Sound velocity measurements of liquid Fe-N up to 100 GPa

Asaki Iwamoto[1], *Yoichi Nakajima[1,2], Daisuke Kinoshita[1], Yasuhiro Kuwayama[3], Kei Hirose[3,5], Daisuke Ishikawa[2,4], Alfred Q.R. Baron[2,4] (1.Kumamoto Univ., 2.RIKEN MDL, 3.Univ. Tokyo, 4.JASRI, 5.Tokyo Tech. ELSI)

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

[SIT17-06] Density and Sound Velocity of Liquid Fe and FeO at High Pressure

*Yasuhiro Kuwayama[1], Kei Hirose[1,2], Yoichi Nakajima[3,4], Yuki Adachi[3], Alfred Q.R. Baron[4], Guillaume Morard[5], Saori I. Kawaguchi[6], Daisuke Ishikawa[6,4], Naohisa Hirao[6], Yasuo Ohishi[6] (1.The University of Tokyo, 2.Tokyo Institute of Technology, 3.Kumamoto University, 4.RIKEN MDR, 5.Laboratoire ISTERRE, Université Grenoble Alpes, 6.JASRI)

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

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

[S-IT20] MAGMA, FLUID TRANSPORT, AND SEISMICITY IN THE EARTH'S INTERIOR

convener:Eiji Ohtani(Department of Earth and Planetary Materials Science, Graduate School of Science, Tohoku University), Saeko Kita(International Institute of Seismology and Earthquake Engineering, BRI), Michihiko Nakamura(Division of Earth and Planetary Materials Science, Department of Earth Science, Graduate School of Science, Tohoku University), Bjorn Mysen(Geophysical Laboratory, Carnegie Inst. Washington), Chairperson:Bjorn Mysen(Geophysical Laboratory, Carnegie Inst. Washington), Michihiko Nakamura(Division of Earth and Planetary Materials Science, Department of Earth Science, Graduate School of Science, Tohoku University)

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

[SIT20-07] HDAC experiments on silica solubility and speciation in Na_2CO_3–H_2O fluids at high pressure and temperature

*Naoko Takahashi[1], Tatsuki Tsujimori[1,2], Seiji Kamada[1,3], Michihiko Nakamura[1] (1.Department of Earth Science, Graduate School of Science, Tohoku University, 2.Center for Northeast Asian Studies, Tohoku University, 3.Frontier Research Institute for Interdisciplinary Sciences, Tohoku University)

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

[SIT20-08] Permeability determination from multi-anvil experiments: Implications for the fluid flux in subduction zones

★Invited Papers

*Lisa Eberhard[1], Philipp Eichheimer[1], Marcel Thielmann[1], Michihiko Nakamura[2], Gregor Golabek[1], Dan Frost[1] (1.Bayerisches Geoinstitut, University of Bayreuth, Germany, 2.Departement of Earth Science, Tohoku University, Japan)

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

[SIT20-09] Fluid segregation and chemical compaction through efficient solute transport along wet grain boundaries

*Wakana Fujita[1], Michihiko Nakamura[1], Kentaro Uesugi[2] (1.Graduate School of Science, Tohoku University, 2.Synchrotron Radiation Research Institute (JASRI/SPring-8))

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

[SIT20-10] Coupling between fluid flux and dynamical permeability evolution in the middle-lower crust, an example from Sør Rondane Mountains (SRM), East Antarctica.

*Diana Mindaleva[1], Masaoki Uno[1], Atsushi Okamoto[1], Noriyoshi Tsuchiya[1] (1.Graduate school of environmental studies, Tohoku University)

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

[SIT20-11] Attenuation contrast in mantle wedge across the volcanic front of NE Japan that controls propagations of high-frequency S-wave later phases

*Takahiro Shiina[1], Kei Katsumata[2], Kiyoshi Yomogida[2], Aitaro Kato[3] (1.National Institute of Advanced Industrial Science and Technology (AIST), 2.Graduate School of Science, Hokkaido University, 3.Earthquake Research Institute, the University of Tokyo)

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

[SIT20-12] The effect of water on energy dispersion of olivine and its implications for the origin of the sharp contrast of seismic observation at the lithosphere-asthenosphere boundary

*Chao Liu[1], Takashi Yoshino[1] (1.Institute for Planetary Materials, Okayama University)

[E] Oral | S (Solid Earth Sciences) ： S-MP Mineralogy & Petrology

1:45 PM - 3:15 PM JST | 4:45 AM - 6:15 AM UTC | Ch.20 Zoom Room 20

[S-MP24] Supercontinents and Crustal Evolution

convener:Tomokazu Hokada(National Institute of Polar Research), Tetsuo Kawakami(Graduate School of Science, Kyoto University), Krishnan Sajeev(Centre for Earth Sciences, Indian Institute of Science), Madhusoodhan Satish-Kumar(Department of Geology, Faculty of Science, Niigata University), Chairperson:Tomokazu Hokada(National Institute of Polar Research), Madhusoodhan Satish-Kumar(Department of Geology, Faculty of Science, Niigata University)

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

[SMP24-01] Decompression *P-T* evolution recorded in a pelitic gneiss from Tangarden, Sør Rondane Mountains, East Antarctica

*Tetsuo Kawakami[1], Fumiko Higashino[2], Tatsuro ADACHI[3], Masaoki Uno[4] (1.Graduate School of Science, Kyoto University, 2.Okayama University of Science, 3.Advanced Asian Archaeological Research Center, Kyushu University, 4.Graduate School of Environmental Studies, Tohoku University)

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

[SMP24-02] Post-peak Cl- and CO_2-bearing fluids in a Grt-Sil-Bt gneiss from southern Perlebandet, Sør Rondane Mountains, East Antarctica

*Fumiko Higashino[1], Tetsuo Kawakami[2], Tatsuro ADACHI[3], Masaoki Uno[4] (1.Faculty of Science, Okayama University of Science, 2.Kyoto University, 3.Kyushu University, 4.Tohoku University)

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

[SMP24-03] **Contrasting chemical reactions and fluid transport by melt and aqueous fluids during middle crustal fracturing (Sør Rondane Mountains, East Antarctica)**

*Masaoki Uno[1], Tetsuo Kawakami[2], Tatsuro Adachi[3], Fumiko Higashino[4], Noriyoshi Tsuchiya[1] (1.Tohoku University, 2.Kyoto University, 3.Kyushu University, 4.Okayama University of Science)

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

[SMP24-04] Geochemical characterization of zircon for U-Pb age determination in Fyfe Hills of the Napier Complex, East Antarctica

*Mami Takehara[1], Kenji Horie[1,2], Tomokazu Hokada[1,2] (1.National Institute of Polar Research, 2.The Graduate University for Advanced Studies, SOKENDAI)

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

[SMP24-05] Petrology, metamorphic conditions, and monazite dating of metapelites of the Zambezi Belt supracrustal sequence, Zambia

*Kabangu Grace Sakuwaha[1], Toshiaki Tsunogae[1] (1.University of Tsukuba)

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

[SMP24-06] Petro-tectonic setting of the Karagwe–Ankole Belt (Rwanda) and implications for the amalgamation of Rodinia

*Claude Nambaje[1], Madhusoodhan Satish-Kumar[2], Ian S. Williams[3], Toshiro Takahashi[2], Krishnan Sajeev[1] (1.Indian Institute of Science, 2.Niigata University, 3.Australian National University)

[E] Oral | S (Solid Earth Sciences) : S-MP Mineralogy & Petrology

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

[S-MP24] Supercontinents and Crustal Evolution

convener:Tomokazu Hokada(National Institute of Polar Research), Tetsuo Kawakami(Graduate School of Science, Kyoto University), Krishnan Sajeev(Centre for Earth Sciences, Indian Institute of Science), Madhusoodhan Satish-Kumar(Department of Geology, Faculty of Science, Niigata University), Chairperson:Krishnan Sajeev(Centre for Earth Sciences, Indian Institute of Science), Tetsuo Kawakami(Graduate School of Science, Kyoto University)

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

[SMP24-07] **A comparison between carbon isotope thermometry and Raman spectra of carbonaceous material (RSCM) thermometry in low-medium grade carbonate rocks from the Chitradurga Schist Belt, Dharwar Craton**

*Kiran Sasidharan[1], Madhusoodhan Satish-Kumar[1], Yoshihiro Nakamura[2], Hiroaki Ohfuji[3] (1.Niigata University, 2.Geological Survey of Japan, AIST, 3.Tohoku University)

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

[SMP24-08] Insights into failed rift processes in the Archean, evidence from the Western Dharwar Craton, southern India.

*Sreehari Lakshmanan[1], Tsuyoshi Toyoshima[2], Madhusoodhan Satish-Kumar[2] (1.Graduate School of Science and Technology, Niigata University, Niigata, Japan, 2.Department of Geology, Niigata University, Niigata, Japan)

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

[SMP24-09] **Trace and rare earth element geochemistry of the clinopyroxene of dolerite dykes from Western Dharwar craton, southern India**

*Silpa Ammini Sasidharan[1], Madhusoodhan Satish-Kumar[1], Eiichi TAKAZAWA[1], Krishnan Sajeev[2] (1.Faculty of Science Niigata University, 2.Indian Institute of Science, Bangalore, India)

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

[SMP24-10] Evidence of carbonic crustal fluid during deep to shallow crustal evolution of the interior of Eastern Ghats Belt India: Grenvillian to Kuunga orogenies

*Kaushik Das[1,6], Sankar Bose[2,6], Junji Torimoto[3], Yasutaka Hayasaka[1,6], Daniel Dunkley[4,5] (1.Hiroshima University, 2.Presidency University, 3.JAMSTEC, Yokotsuka, 4.NIPR, Tokyo, 5.IG-PAS, Poland, 6.HiPeR, Japan)

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

[SMP24-11] **Metasomatic Corundum-Sapphirine-Spinel-Clinozoisite assemblage Indications for Ca-Al rich fluid**

*Krishnan Sajeev[1], S Veni[1] (1.Centre for Earth Sciences, Indian Institute of Science)

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

[SMP24-12] A geochemical perspective on tectonic setting and depositional environment of Precambrian metacarbonate rocks in collisional orogenic belts

*Madhusoodhan Satish-Kumar[1] (1.Department of Geology, Faculty of Science, Niigata University)

[E] Oral | S (Solid Earth Sciences) ： S-GC Geochemistry

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

[S-GC32] Volatiles in the Earth - from Surface to Deep Mantle

convener:Takeshi Hanyu(Japan Agency for Marine-Earth Science and Technology, Research Institute for Marine Geodynamics), E Gray Bebout(Lehigh University), Yuji Sano(Division of Ocean and Earth Systems, Atmosphere and Ocean Research Institute, University of Tokyo), Hirochika Sumino(Department of General Systems Studies, Graduate School of Arts and Sciences, The University of Tokyo), Chairperson:Gray E Bebout(Lehigh University), Hirochika Sumino(Department of General Systems Studies, Graduate School of Arts and Sciences, The University of Tokyo)

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

[SGC32-01] Helium isotope analyses of volcanic gases and HESJ standard gas using a multi-turn time-of-flight mass spectrometer

*Yuki Hattori[1], Yoshihide Akiyama[1], Hirochika Sumino[1] (1.Graduate School of Arts and Science, The University of Tokyo)

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

[SGC32-02] Systematic depth variation of water in the lithosphere-asthenosphere boundary beneath Ichinomegata, NE Japan

*Yuto Sato[1], Eiichi Takahashi[1], Kazuhito Ozawa[2] (1.State Key Labolatory of Isotope Geochemistry, Guangzhou Institute of Geochemistry, CAS, 2.Department of Earth and Planetary Science, Graduate School of Science, The University of Tokyo)

11:15 AM - 11:45 AM JST | 2:15 AM - 2:45 AM UTC

[SGC32-03] **Impact of mantle hydration on the global carbon cycle**

★Invited Papers

*Ikuo Katayama[1] (1.Department of Earth and Planetary Systems Science, Hiroshima University)

11:45 AM - 12:15 PM JST | 2:45 AM - 3:15 AM UTC

[SGC32-04] **The story of Earth’s volatile accretion and evolution**

★Invited Papers

*Sujoy Mukhopadhyay[1], Sandrine Peron[1] (1.Department of Earth and Planetary Sciences, University of California Davis, Davis, CA, USA)

[E] Oral | S (Solid Earth Sciences) ： S-GC Geochemistry

1:45 PM - 3:15 PM JST | 4:45 AM - 6:15 AM UTC | Ch.23 Zoom Room 23

[S-GC32] Volatiles in the Earth - from Surface to Deep Mantle

convener:Takeshi Hanyu(Japan Agency for Marine-Earth Science and Technology, Research Institute for Marine Geodynamics), E Gray Bebout(Lehigh University), Yuji Sano(Division of Ocean and Earth Systems, Atmosphere and Ocean Research Institute, University of Tokyo), Hirochika Sumino(Department of General Systems Studies, Graduate School of Arts and Sciences, The University of Tokyo), Chairperson:Yuji Sano(Center for Advanced Marine Core Research, Kochi University), Takeshi Hanyu(Japan Agency for Marine-Earth Science and Technology, Research Institute for Marine Geodynamics)

1:45 PM - 2:15 PM JST | 4:45 AM - 5:15 AM UTC

[SGC32-05] H/D partitioning between forsterite, wadsleyite and ringwoodite : ab initio free energy calculation

★Invited Papers

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

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

[SGC32-06] **Volatile characteristics of Central American geothermal fluids**8.6.0

★Invited Papers

*Peter H Barry[1], David V Bekaert[1], J M de Moor[2], Jabrane Labidi[3], Esteban Gazel[4], M Nakagawa[5], Donato Giovannelli[6], Matt Schrenk[7], Karen G Lloyd[8] (1.Woods Hole Oceanographic Institution, 2.Observatorio Volcanológico y Sismológico de Costa Rica (OVSICORI), Universidad Nacional, Costa Rica, 3.Université de Paris, Institut de physique du globe de Paris, CNRS, Paris, France, 4.Department of Earth and Atmospheric Sciences, Cornell University, Ithaca, New York 14853, USA, 5.Earth-Life Science Institute, Tokyo Institute for Technology, Tokyo, Japan, 6.Department of Biology, University of Naples “Federico II”, Naples, Italy, 7.Department of Earth and Environmental Sciences, Michigan State University, MI, USA, 8.Department of Microbiology, University of Tennessee, TN, USA)

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

[SGC32-07] Halogen and noble gas compositions of mantle wedge and subducted sediment, recorded in metamorphic rocks from the Sanbagawa belt

*JIE REN[1], Hirochika Sumino[1], Yui Kouketsu[2], Simon Richard Wallis[3] (1.Graduate School of Arts and Sciences, The University of Tokyo , 2.Graduate School of Environmental Studies, Nagoya University, 3.Graduate School Sciences, The University of Tokyo)

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

[SGC32-08] Discussion

[E] 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-CG39] Science of slow earthquakes: Toward unified understandings of whole earthquake process

convener:Satoshi Ide(Department of Earth an Planetary Science, University of Tokyo), Hitoshi Hirose(Research Center for Urban Safety and Security, Kobe University), Kohtaro Ujiie(Faculty of Life and Environmental Sciences, University of Tsukuba), Takahiro Hatano(Department of Earth and Space Science, Osaka University), Chairperson:Kohtaro Ujiie(Faculty of Life and Environmental Sciences, University of Tsukuba)

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

[SCG39-01] The stabilizing effect of pore-fluid pressure along subduction megathrust faults: Evidence from experiments on Nankai Trough sediments

*John D Bedford[1,2], Daniel R Faulkner[2], Michael J Allen[2], Takehiro Hirose[1] (1.JAMSTEC, 2.Univ. of Liverpool)

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

[SCG39-02] **Depth-dependent deep-slow earthquakes controlled by temperature dependence of brittle-ductile transitional rheology**

*Ryosuke Ando[1], Kohtaro Ujiie[2], Naoki Nishiyama[2], Yasushi Mori[3] (1.Graduate School of Science, University of Tokyo, 2.Graduate School of Life and Environmental Sciences, University of Tsukuba, 3.Kitakyushu Museum of Natural History and Human History)

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

[SCG39-03] **Localized megathrust slip controlled by chemical reactions in subduction mélanges**

*Kohtaro Ujiie[1], Kazuya Noro[2], Norio Shigematsu[3], Ake Fagereng[4], Naoki Nishiyama[1], Christopher Tulley[4], Haruna Masuyama[2], Yasushi Mori[5] (1.Faculty of Life and Environmental Sciences, University of Tsukuba, 2.Graduate School of Life and Environmental Sciences, University of Tsukuba, 3.Geological Survey of Japan, National Institute of Advanced Industrial Science and Technology, 4.School of Earth and Environmental Sciences, Cardiff University, 5.Kitakyushu Museum of Natural History and Human Histor)

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

[SCG39-04] Lithological heterogeneity and fluid flow related to seamount subduction: an exhumed example from Amami-Oshima Island

*Madison Frank[1], Ginta Motohashi[1], Kohtaro Ujiie[2] (1.Graduate School of Life and Environmental Sciences, University of Tsukuba, 2.Faculty of Life and Environmental Sciences, University of Tsukuba)

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

[SCG39-05] Constraints on silica transport along subduction boundaries based on volume change estimates of metamorphic rocks

*Shogo Soejima[1], Simon Richard Wallis[1] (1.Department of Earth and Planetary Science, Graduate School of Science, The University of Tokyo)

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

[SCG39-06] Discussion

[E] 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-CG39] Science of slow earthquakes: Toward unified understandings of whole earthquake process

convener:Satoshi Ide(Department of Earth an Planetary Science, University of Tokyo), Hitoshi Hirose(Research Center for Urban Safety and Security, Kobe University), Kohtaro Ujiie(Faculty of Life and Environmental Sciences, University of Tsukuba), Takahiro Hatano(Department of Earth and Space Science, Osaka University), Chairperson:Takahiro Hatano(Department of Earth and Space Science, Osaka University)

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

[SCG39-07] Systematic understanding of the slip-front-propagation velocity in terms of Linear Marginal Stability Hypothesis

*Takehito Suzuki[1] (1.Department of Physics and Mathematics, Aoyama Gakuin University)

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

[SCG39-08] Effects of periodic stress perturbations on earthquake nucleation

*Takuya Saito[1], Takahiro Hatano[2] (1.Aoyama Gakuin University, 2.Osaka University)

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

[SCG39-09] Feasibility of periodic solution in Rate-State friction Law

*Ryo Mizushima[1], Takahiro Hatano[1] (1.Department of Earth and Space Science, Osaka University)

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

[SCG39-10] **Slow earthquake signatures in the ratio between acoustic and internal gravity wave amplitudes in coseismic ionospheric disturbances**

*Kosuke Heki[1], Yuki Takasaka [1] (1.Department of Earth and Planetary Sciences, Faculty of Science, Hokkaido University)

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

[SCG39-11] Observation of shallow slow slip event propagating updip to the trough in the Nankai Trough.

*Eiichiro Araki[1], Takeshi Iinuma[1], Yojiro Yamamoto[1], Toshinori Kimura[1], Yuya Machida[1], Ryoichiro Agata[1], Keisuke Ariyoshi[1], Tsuyoshi Ichimura[2], Takane Hori[1], Shuichi Kodaira[1] (1.Japan Agency for Marine-Earth Science and Technology, 2.Earthquake Research Insitute, the University of Tokyo)

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

[SCG39-12] Discussion

[E] Oral | S (Solid Earth Sciences) ： S-CG Complex & General

3:30 PM - 5:00 PM JST | 6:30 AM - 8:00 AM UTC | Ch.21 Zoom Room 21

[S-CG39] Science of slow earthquakes: Toward unified understandings of whole earthquake process

convener:Satoshi Ide(Department of Earth an Planetary Science, University of Tokyo), Hitoshi Hirose(Research Center for Urban Safety and Security, Kobe University), Kohtaro Ujiie(Faculty of Life and Environmental Sciences, University of Tsukuba), Takahiro Hatano(Department of Earth and Space Science, Osaka University), Chairperson:Hitoshi Hirose(Research Center for Urban Safety and Security, Kobe University)

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

[SCG39-13] Development of the detection method for short-term slow slip events using GNSS data and its application to the Nankai subduction zone

*Yutaro Okada[1], Takuya Nishimura[2], Takao Tabei[3], Takeshi Matsushima[4], Hitoshi Hirose[5] (1.Graduate School of Science, Kyoto University, 2.Disaster Prevention Research Institute, Kyoto University, 3.Faculty of Science and Technology, Kochi University, 4.Faculty of Science, Kyushu University, 5.Research Center for Urban Safety and Security, Kobe University)

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

[SCG39-14] Spatiotemporal slip distributions of the 2018-2019 Bungo Channel long-term slow slip event

*Yukinari Seshimo[1], Shoichi Yoshioka[2,1] (1.Department of Planetology, Graduate School of Science, Kobe University, 2.Research Center for Urban Safety and Security, Kobe University)

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

[SCG39-15] What controls along-strike variations in Long term SSE recurrence intervals in the Western Nankaui Subduction Zone?

*Takanari Ohata[1], SHINICHI MIYAZAKI[1], Kazuro Hirahara[2] (1.KYOTO UNIVERSITY, 2.KAGAWA UNIVERSITY)

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

[SCG39-16] Post-seismic to Co-seismic Moment Ratio: a Case Study of the 2016 Moderate Earthquakes along Chaman Fault Inferred from Sentinel-1 InSAR Time-Series

*Masato Furuya[1], Fumiko Matsumoto[2] (1.Department of Earth and Planetary Sciences Hokkaido University, 2.PASCO)

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

[SCG39-17] The moment release rate of short-term slow slip events in the northern Kii Peninsula from 2002 to 2015 based on NIED Hi-net tilt data

*Naoya Chujo[1], Hitoshi Hirose[2,1,3], Takeshi Kimura[3] (1.Department of Planetology, Graduate School of Science, Kobe University, 2.Research Center for Urban Safety and Security, Kobe University, 3.National Research Institute for Earth Science and Disaster Resilience)

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

[SCG39-18] Discussion

[E] Oral | M (Multidisciplinary and Interdisciplinary)：M-IS Intersection

10:45 AM - 12:15 PM JST | 1:45 AM - 3:15 AM UTC | Ch.03 Zoom Room 03

[M-IS07] Effects of lightning, severe weather and tropical storms

convener:Mitsuteru Sato(Department of Cosmoscience, Hokkaido University), Hisayuki Kubota(Hokkaido University), C. Glenn Vincent Lopez(- - -), Purwadi Purwadi(Department of Cosmosciences, Hokkaido University, Sapporo 0600810, Japan), Chairperson:Mitsuteru Sato(Department of Cosmoscience, Hokkaido University), Hisayuki Kubota(Hokkaido University)

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

[MIS07-01] Current status and prospects of ULAT/SATREPS

*Yukihiro Takahashi[1,2], Mitsuteru Sato[1,2], Hisayuki Kubota[1,2], Tetsuro Ishida[1,2], Ellison Castro[3], Loren Jay Estrebillo[3], Purwadi Purwadi[4], Meryl Algodon[1], Gay Perez[3], Joel Marciano[5], Jun Matsumoto[6], Jun-Ichi Hamada[6] (1.Department of Cosmosciences, Graduate School of Science, Hokkaido University, 2.Department of Earth and Planetary Sciences, Faculty of Science, Hokkaido University, 3.University of the Philippines, Diliman, 4.BPPT, Indonesia, 5.PhilSA, Phlippines, 6.Tokyo Metropolitan University)

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

[MIS07-02] **The relationship between CG lightning detected by AVON V-POTEKA and thunderstorm parameters**

*Purwadi Purwadi[1], Yukihiro Takahashi[2], Mitsuteru Sato[2], Hisayuki Kubota[2], Kozo Yamashita[3] (1.Agency for Assessment and Application for Technology, Jakarta 10340, Indonesia, 2.Faculty of Science, Hokkaido University, Sapporo 0600810, Japan, 3.Department of Electrical Engineering, Salesian Polytechnic, Tokyo, Japan)

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

[MIS07-03] Machine Learning Prediction of Precipitation in Metro Manila, Philippines

★Invited Papers

*Akira Noda[1], Yukihiro Takahashi[2], Hisayuki Kubota[2], Ken-ichi Fukui[3], Mitsuteru Sato[2] (1.Department of Earth and Planetary Sciences, School of Science, Hokkaido University., 2.Department of Cosmosciences, Graduate School of Science, Hokkaido University, 3.The Institute of Scientific and Industrial Research, Osaka University)

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

[MIS07-04] **3D Reconstruction of Typhoon Trami Eye Using Airborne Camera**

★Invited Papers

*Meryl Regine Llenaresas Algodon[1], Yukihiro Takahashi[2], Mitsuteru Sato[2], Hisayuki Kubota[3], Tetsuro Ishida[3], Kozo Yamashita[4], Ellison Caparas Castro[5], Gay Jane Perez[6], Joel Joseph Marciano[7], Jun Matsumoto[8], Jun-Ichi Hamada[9], Kazuhisa Tsuboki[10], Hiroyuki Yamada[11] (1.Hokkaido University, Graduate School of Science, 2.Hokkaido University, 3.Hokkaido University, Faculty of Science, 4.Ashikaga University, 5.University of the Philippines Quezon City (Philippines), 6.NASA Goddard Space Flight Center Earth Science Division Greenbelt MD 20771-0000 (United States), 7.Advanced Science and Technology Institute Quezon City (Philippines), 8.Tokyo Metropolitan University Tokyo 192, 9.Tokyo Metropolitan University Hachioji, 10.Nagoya University, Institute for Space–Earth Environmental Research Nagoya 464, 11.University of the Ryukyus Nishihara)

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

[MIS07-05] Successive observation of atmospheric electric observation at Kakioka Geomagnetic Observatory

*Masashi Kamogawa[1], Tomoyuki Suzuki[1], Toshiyasu Nagao[3], Yasuhiro Minamoto[2] (1.Global Center for Asian and Regional Research, University of Shizuoka, 2.Laboratory for Environmental Research at Mount Fuji, 3.Institute of Oceanic Research and Development, Tokai University)

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

[MIS07-06] Observation of Elves and Transient Luminous Events from the International Space Station with the Mini-EUSO telescope

*Marco Casolino[1], Toshikazu Ebisuzaki[1], Yoshiyuki Takizawa[1], Naoto Sakaki[1], Satoshi Wada[1] (1.Riken)

[E] Oral | M (Multidisciplinary and Interdisciplinary)：M-IS Intersection

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

[M-IS09] Weathering and conservation of cultural heritage and geosites

convener:Luigi Germinario(University of Padova, Italy), Chiaki T. Oguchi(Institute for Environmental Science and Technology, Graduate School of Science and Engineering, Saitama University), Akos Torok(Budapest University of Technology and Economics), Tetsuya Waragai(Graduate School of Science and Engineering, Nihon University), Chairperson:Luigi Germinario(University of Padova, Italy), Chiaki T. Oguchi(Institute for Environmental Science and Technology, Graduate School of Science and Engineering, Saitama University)

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

[MIS09-01] Evaluation of the degradation state of dinosaur footprint based on 3D measurement.

*Nobuaki Kuchitsu[1], Shuji SAKAI[2], Masato FUJITA[3] (1.Tokyo National Research Institute for Cultural Properties, 2.Toppan Printing Co., Ltd., 3.Toyama Science Museum)

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

[MIS09-02] Study on relations between deterioration of tuff stone used as exteriors of a historical building and microenvironment factors

*Uno Tomoko[1], Chiemi Iba[2], Masaru Abuku[3] (1.Mukogawa Womens University, 2.Kyouto University, 3.Kinki University)

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

[MIS09-03] Changes in pore-size distribution of rocks induced by thermal cycles of low temperature

*Tetsuya Waragai[1] (1.Graduate School of Science and Engineering, Nihon University)

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

[MIS09-04] **Non-destructive strength tests of heritage buildings: an overview of Schmidt hammer and Duroskop tests**

*Akos Torok[1] (1.Budapest University of Technology and Economics)

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

[MIS09-05] Numerical analysis of heat, moisture, and salt transfer and deformation in porous materials under atmospheric conditions

*Masaru Abuku[1], Koichi Ishii[2] (1.Kindai University, 2.Research Center of Computational Mechanics, Inc.)

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

[MIS09-06] **HYPERION: understanding and quantifying the effects of climate change on cultural heritage**

*Chiara Coletti[1], Luigi Germinario[1], Fabrizio Antonelli[2], Renzo Bertoncello[3], Antonio Galgaro[1], Lara Maritan[1], Matteo Massironi[1], Jacopo Nava[1], Rebecca Piovesan[2], Raffaele Sassi[1], Elena Tesser[2], Claudio Mazzoli[1] (1.Department of Geosciences, University of Padova, Via Gradenigo 6, 35131 Padova, Italy, 2.LAMA - Laboratory for Analysing Materials of Ancient origin, University Iuav of Venice, San Polo 2468/B, 30125 Venice, Italy, 3.Department of Chemical Sciences, University of Padova, Via Marzolo 1, 35131 Padova, Italy)

[E] Oral | EVENT：EVENT

9:00 AM - 9:45 AM JST | 12:00 AM - 12:45 AM UTC | Ch.07 Zoom Room 07

[EV-23] Exhibitors' Seminar

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

[E-11-23] Latest Application Developments from Picarro

[E] Oral | U (Union) : Union

Sat. Jun 5, 2021 9:00 AM - 10:30 AM JST | Sat. Jun 5, 2021 12:00 AM - 1:30 AM UTC | Ch.01 Zoom Room 01

[U-13] Advanced understanding of Quaternary and Anthropocene hydroclimate changes in East Asia:

convener:Li Lo(Department of Geosciences, National Taiwan University), Kaoru Kubota(Graduate School of Human Development and Environment, Kobe University), Chuan-Chou Shen(National Taiwan University), Yusuke Yokoyama(Atmosphere and Ocean Research Institute, University of Tokyo), Chairperson:Li Lo(Department of Geosciences, National Taiwan University), Kaoru Kubota(Graduate School of Human Development and Environment, Kobe University), Yusuke Yokoyama(Atmosphere and Ocean Research Institute, University of Tokyo), Chuan-Chou Shen(National Taiwan University)

For the sustainability of biosphere and human society, it is crucial to in-depth understand Earth's climate system changes on different timescales. Anthropogenic forcing is also strongly affecting different aspects of human living environments, natural ecological through physical and chemical climatic perturbations, especially in East Asia with swift economic takeoff in the recent decades. We welcome climate and environmental reconstructions based on natural archives, proxy data, numerical simulations on the topics of monsoon, precipitation beef shifting, typhoon, and drought histories in Quaternary and Anthropocene. atmospheric and oceanic interactions, greenhouse gases radiative forcing and anthropogenic forcing impact from regional to global are also welcomed.

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

[U13-01] Insight to Western Pacific circulation from coral skeletal radiocarbon during the Anthropocene and Holocene

★Invited Papers

*Shoko Hirabayashi[1,2,3], Yusuke Yokoyama[2], Atsushi Suzuki[4], Tezer Esat[5], Yosuke Miyairi[2], Takahiro AZE[2], Fernando Siringan [6], Yasuo Maeda[7], Hironobu Kan[3] (1.Faculty of Geo-Environmental Science, Rissho University, 2.Atmosphere and Ocean Research Institute, The University of Tokyo, 3.Department of Environmental Changes, Graduate School of Social and Cultural Studies, Kyushu University, 4.Geological Survey of Japan, National Institute of Advanced Industrial Science and Technology (AIST), 5.Research School of Physics and Engineering, The Australian National University, 6.Marine Science Institute, University of the Philippines, 7.Institute of Natural and Environmental Sciences, University of Hyogo)

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

[U13-02] **Increased soil erosion since Southeast Asia economic boom recorded in *Porites* corals**

★Invited Papers

*Xiaohua Li[1], Zhen Zeng[2], Yi Liu[3], Ching-Chih Chang[4], Hong-Wei Chiang[4], Xuan-Ce Wang[5], Weidong Sun[1], Hui-Min Yu[2], Fang Huang[2], Chung-Che Wu[4], Tsai-Luen Yu[4], Chun-Yuan Huang[4], Chuan-Chou Shen[4] (1.Institute of Oceanology, Chinese Academy of Sciences, 2.University of Science and Technology of China, 3.Tianjin University, 4.National Taiwan University, 5.Yunnan University)

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

[U13-03] **Upper ocean temperatures over the last glacial in the low-to-mid latitude Western Pacific based on a systematic multiproxy approach**

★Invited Papers

*Sze Ling Ho[1], Yuan-Pin Chang[2], Min-Te Chen[3], Jeroen Groeneveld[4], Kuo-Fang Huang[5], Pei-Ting Lee[1], Shih-Yun Lin[1], Maria Makarova[1], Nele Meckler[6], Mahyar Mohtadi[7], Ren Yi Ooi[1], Chuan-Chou Shen[8], Liang-Jian Shiau[3,9], Raul Tapia[1], Masanobu Yamamoto[10] (1.Institute of Oceanography, National Taiwan University, Taipei, Taiwan, 2.Department of Oceanography, National Sun Yat-sen University, Kaohsiung, Taiwan., 3.Institute of Applied Geosciences, National Taiwan Ocean University, Keelung, Taiwan., 4.Department of Geosciences, Hamburg University, Germany. , 5.Institute of Earth Sciences, Academia

Sinica, Taipei, Taiwan., 6.Bjerknes Centre for Climate Research and Department of Earth Science, University of Bergen, Norway., 7.MARUM-Center for Marine Environmental Sciences, University of Bremen, Germany. , 8.High-Precision Mass Spectrometry and Environment Change Laboratory (HISPEC), Department of Geosciences, National Taiwan University, Taipei, Taiwan., 9.Exploration and Development Research Institute, CPC Corporation, Miaoli, Taiwan., 10.Faculty of Environmental Earth Science, Hokkaido University, Sapporo, Japan.)

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

[U13-04] Ultra-high resolution oxygen isotope records from the Chiba Composite Section ratified as the Chibanian GSSP

★Invited Papers

*Yuki Haneda[1], Makoto Okada[2], Yoshimi Kubota[3], Yusuke Suganuma[4,5] (1.Geological Survey of Japan, AIST, 2.Department of Environmental Science, Ibaraki University, 3.National Museum of Nature and Science, 4.National Institute of Polar Research, 5.The Graduate University for Advanced Studies)

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

[U13-05] Sub-surface water mass exchanges around the eastern equatorial Indian Ocean during the last 50,000 years

★Invited Papers

*Hideko Takayanagi[1], Ryota Wako[1], Yuna Kimoto[1], Shigeyuki Wakaki[2], Azumi Kuroyanagi[1], Takeshige Ishiwa[3], Yusuke Yokoyama[4], Hitomi Uchimura Wakaki[5], Tsuyoshi Ishikawa[2], Yasufumi Iryu[1] (1.Tohoku Univ., 2.JAMSTEC, 3.NIPR, 4.Univ. of Tokyo, 5.Kochi Univ.)

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

[U13-06] **Methane, Monsoons, and Milankovitch Modulation of Millennial-Scale Climate**

★Invited Papers

*Kaustubh Thirumalai[1], Steven Clemens[2], Judson Partin[3] (1.The University of Arizona, 2.Brown University, 3.The University of Texas at Austin)

Insight to Western Pacific circulation from coral skeletal radiocarbon during the Anthropocene and Holocene

*Shoko Hirabayashi[1,2,3], Yusuke Yokoyama[2], Atsushi Suzuki[4], Tezer Esat[5], Yosuke Miyairi[2], Takahiro AZE[2], Fernando Siringan [6], Yasuo Maeda[7], Hironobu Kan[3]

1. Faculty of Geo-Environmental Science, Rissho University, 2. Atmosphere and Ocean Research Institute, The University of Tokyo, 3. Department of Environmental Changes, Graduate School of Social and Cultural Studies, Kyushu University, 4. Geological Survey of Japan, National Institute of Advanced Industrial Science and Technology (AIST), 5. Research School of Physics and Engineering, The Australian National University, 6. Marine Science Institute, University of the Philippines, 7. Institute of Natural and Environmental Sciences, University of Hyogo

Coral skeletal radiocarbon ($\Delta^{14}C$) records can be used as a sensitive proxy of water mass mixing. Compiling coral skeletal $\Delta^{14}C$ datasets in the western Pacific will contribute to our understanding of the oceanography of the region and its relationship to climate change such as El Nino-Southern Oscillation.

In this study, high-resolution coral skeletal $\Delta^{14}C$ dataset during the Anthropocene and Holocene are reported from the western Pacific. Our $\Delta^{14}C$ data indicates the unusual, rapid $\Delta^{14}C$ increase (early bomb-^{14}C spikes) in the 1950s related to the "close-in fallout" found in the corals from Ishigaki and Luzon Island. The amplitude of the bomb-^{14}C spike in the Luzon Island was less than half that in Ishigaki, likely due to upwelling around Luzon Island and the Kuroshio intrusion into the South China Sea. We also calculated the local marine reservoir age (R) and the regional offset (ΔR) during the Holocene using paired analyses of $\Delta^{14}C$ and ^{230}Th in pristine corals. An abrupt ΔR shift occurred between 5.5 ka BP and 4.0 ka BP in the northwest Pacific. Compared with the previously reported data from the Tropical East Pacific and Great Barrier reef, the timing of the shift is different because the ^{14}C content of the northwestern Pacific was affected by not only the intensity of upwelling at the Peru-Chile coast, but also by the East Asian monsoon.

Keywords: Radiocarbon, U/Th dating, Local marine reservoir age, Corals, Kuroshio

Increased soil erosion since Southeast Asia economic boom recorded in *Porites* corals

*Xiaohua Li[1], Zhen Zeng[2], Yi Liu[3], Ching-Chih Chang[4], Hong-Wei Chiang[4], Xuan-Ce Wang[5], Weidong Sun[1], Hui-Min Yu[2], Fang Huang[2], Chung-Che Wu[4], Tsai-Luen Yu[4], Chun-Yuan Huang[4], Chuan-Chou Shen[4]

1. Institute of Oceanology, Chinese Academy of Sciences, 2. University of Science and Technology of China, 3. Tianjin University, 4. National Taiwan University, 5. Yunnan University

Soil erosion has raised public concern in Southeast Asia which has been poorly documented due to the lack of long, continuous records. Here we present two *Porites* coral records of monthly-resolved Ba/Ca ratios and monthly and yearly-resolved $\delta^{137/134}$Ba from the Nanwan (NW), southern Taiwan, and Son Tra Island (STI), central Vietnam, to explore the extent of soil erosion. Our major finding is that erosion and sediment transport have increase substantially since the regional economic boom and resulted in Ba/Ca ratios significantly elevated during 1987-1996 and 1992-2001 for NW and STI corals, respectively, principally due to increasing pressure on land use. Due to terrestrial inputs yield a homogeneous Ba isotope composition, the $\delta^{137/134}$Ba values of coral NW and STI show essentially constant with the mean isotope fractionation between coral and seawater $\Delta^{137/134}Ba_{coral\ -\ seawater}$ is -0.1‰, suggesting that *Porties* coral could be used to trace the Ba isotope composition in ambient seawater. Coupled Ba/Ca and Ba isotopes analysis on *Porites* coral has the potentially to provide new information about the historical soil erosion events.

Keywords: soil erosion, Porites coral, Ba/Ca, δ137/134Ba, Southeast Asia, economic boom

Upper ocean temperatures over the last glacial in the low-to-mid latitude Western Pacific based on a systematic multiproxy approach

*Sze Ling Ho[1], Yuan-Pin Chang[2], Min-Te Chen[3], Jeroen Groeneveld[4], Kuo-Fang Huang[5], Pei-Ting Lee[1], Shih-Yun Lin[1], Maria Makarova[1], Nele Meckler[6], Mahyar Mohtadi[7], Ren Yi Ooi[1], Chuan-Chou Shen[8], Liang-Jian Shiau[3,9], Raul Tapia[1], Masanobu Yamamoto[10]

1. Institute of Oceanography, National Taiwan University, Taipei, Taiwan, 2. Department of Oceanography, National Sun Yat-sen University, Kaohsiung, Taiwan., 3. Institute of Applied Geosciences, National Taiwan Ocean University, Keelung, Taiwan., 4. Department of Geosciences, Hamburg University, Germany. , 5. Institute of Earth Sciences, Academia Sinica, Taipei, Taiwan., 6. Bjerknes Centre for Climate Research and Department of Earth Science, University of Bergen, Norway., 7. MARUM-Center for Marine Environmental Sciences, University of Bremen, Germany. , 8. High-Precision Mass Spectrometry and Environment Change Laboratory (HISPEC), Department of Geosciences, National Taiwan University, Taipei, Taiwan., 9. Exploration and Development Research Institute, CPC Corporation, Miaoli, Taiwan., 10. Faculty of Environmental Earth Science, Hokkaido University, Sapporo, Japan.

Upper ocean (0-200 m) temperature reflects large-scale ocean circulation and the atmosphere-ocean heat exchange. It is therefore a useful metric in characterizing paleoclimate, including the roles played by the East Asian Monsoon and the Indo-Pacific Warm Pool in driving climate change in the low-to-mid latitude Western Pacific. Biomarker- and calcite-based geochemical proxies are widely used to reconstruct past ocean temperature, but may yield discrepant estimates due to chemical and ecological differences of the proxy carriers. Deriving temperature estimates from multiple proxies for the same site may shed light on proxy systematics and improve the robustness of ocean temperature reconstruction, yet there are few multiproxy temperature records spanning the upper water column in the aforementioned region. Therefore, we aim to fill in the gap by using a network of sediment cores from the South China Sea, Indo-Pacific Warm Pool and Okinawa Trough. We compile and generate for each site paleotemperature records of the sea surface and thermocline, inferred from proxies based on vastly different proxy carriers, namely planktic foraminifera-based Mg/Ca and clumped isotopes, haptophyte-based $U^{K'}_{37}$, and archaea-based TEX_{86}. Preliminary results show that the sea surface glacial cooling estimates inferred from clumped isotopes are stronger than the Mg/Ca-derived estimates, despite both proxies being based on the same proxy carriers. At several sites, the temporal patterns of planktic foraminifera Mg/Ca records differ for the mixed layer and thermocline, as the thermocline warms while the surface ocean cools during the last glacial. Thermocline glacial warming, however, is not replicated by TEX_{86} which is increasingly interpreted as shallow subsurface or thermocline temperature signal. Despite consistent glacial-interglacial patterns, the magnitude of change in TEX_{86} temperature records differ substantially across sites, in contrast to that suggested by $U^{K'}_{37}$ and Mg/Ca of mixed layer-dwelling planktic foraminifera. We discuss possible causes leading to the abovementioned proxy discrepancies. We envisage that such a systematic multiproxy approach will refine our understanding of past changes in the oceans surrounding East Asia as well as proxy interpretation in general.

Keywords: UK’37, Mg/Ca, TEX86, Clumped isotopes, South China Sea, Okinawa Trough

Ultra-high resolution oxygen isotope records from the Chiba Composite Section ratified as the Chibanian GSSP

*Yuki Haneda[1], Makoto Okada[2], Yoshimi Kubota[3], Yusuke Suganuma[4,5]

1. Geological Survey of Japan, AIST, 2. Department of Environmental Science, Ibaraki University, 3. National Museum of Nature and Science, 4. National Institute of Polar Research, 5. The Graduate University for Advanced Studies

Marine isotope stage (MIS) 19 has been suggested as one of the best orbital analogs for present interglacial, because of the similarity of the orbital configurations between both interglacial periods. Therefore, paleoenvironmental reconstructions of MIS 19 will provide valuable knowledge to evaluate the anthropogenic impacts for present and future climate changes. The Chiba composite section (CbCS) in the Boso Peninsula, central Japan, is a marine succession straddling the Early–Middle Pleistocene boundary, ranges from the late MIS 20 to early MIS 18. The Chiba section, a main portion of the CbCS, has been ratified as the Global Boundary Stratotype Section and Point (GSSP) of the Chibanian Stage/Age by the Executive Committiee of the International Union of Geological Science on January 17, 2020 (Suganuma et al., 2021). The subtropical Kuroshio and subpolar Oyashio currents generate the large latitudinal water temperature gradient off the Boso Peninsula, and strongly influence the East Asian climate. Therefore, the CbCS sensitively documents a behavior of the Kuroshio Current across the Early–Middle Pleistocene boundary. In this study, we reconstructed detailed oxygen isotope ($\delta^{18}O$) records using surface and subsurface planktonic, and benthic foraminifera from the CbCS to reveal paleoceanographic variation in the northwestern Pacific from the late MIS 20 to early MIS 18.

The age model of the CbCS was established by correlating the benthic $\delta^{18}O$ record to the sea level curve obtained from the southwestern Pacific (Elderfield et al., 2012). The resultant age interval of the $\delta^{18}O$ records is 747.6–801.1 ka on average temporal resolution of 160 yr with a chronological uncertainty of 5 kyr. MIS 19 (MIS 19a, 19b, and 19c) substages are assigned based on climatic variability proposed by Nomade et al. (2019). Vertical water temperature structure and their gradient (ΔT) exhibit latitudinal displacements of the Kuroshio Extension Front (KEF) on multi-millennial scale across the MIS 20–19 transition and during late MIS 19 (MIS 19b to 19a). Results of the spectral and wavelet analyses for the $\delta^{18}O$ records show periodicities of approximately 3,000–6,000 year from MIS 19b to 19a. Similarities of timing and periodicity between paleoceanographic records from the CbCS, North Atlantic, and Mediterranean indicate that disruption of the Atlantic meridional overturning circulation due to freshwater discharge into the North Atlantic caused the southward displacements of the KEF via atmospheric dynamic.

Keywords: Chibanian, Early–Middle Pleistocene boundary, Oxygen isotope ratio, Kuroshio Extension Front, Marine Isotope Stage 19

Sub-surface water mass exchanges around the eastern equatorial Indian Ocean during the last 50,000 years

*Hideko Takayanagi[1], Ryota Wako[1], Yuna Kimoto[1], Shigeyuki Wakaki[2], Azumi Kuroyanagi[1], Takeshige Ishiwa[3], Yusuke Yokoyama[4], Hitomi Uchimura Wakaki[5], Tsuyoshi Ishikawa[2], Yasufumi Iryu[1]

1. Tohoku Univ., 2. JAMSTEC, 3. NIPR, 4. Univ. of Tokyo, 5. Kochi Univ.

The eastern equatorial Indian Ocean (EEIO) is part of the Indo-Pacific Warm Pool and its oceanographic conditions change responding to that of the Indonesian Through Flow (ITF). The EEIO plays an important role in the global ocean overturning circulation. Therefore, it is crucial to unravel temporal variations in the interaction between the Pacific and Indian oceans and their relationships with local (around EEIO) and global paleoclimate and paleoceanography at various time scales. In this study, we studied neodymium (Nd) isotope composition (ε Nd) of bulk benthic foraminifers from a shallow-water to hemipelagic carbonate sediment core drilled at northwestern Australia (IODP Exp. 356, Hole U1464B) to understand changes in surface to sub-surface water mass structures induced probably by the strength of the ITF in the EEIO for the last 50,000 years.
Nd isotope results showed that ε Nd values of bulk benthic foraminifers fluctuated between −9.1 and −5.2, and its variations accord well with the phase and periodicity of the Earth’s axial obliquity. The ε Nd values indicated that such variations were caused by exchanges of the source of sub-surface water masses between the Pacific and Indian oceans. Since an increased/decreased axial obliquity is known to result in a reduced/enhanced meridional gradient of solar insolation, respectively, our results indicate that such water mass exchanges in the sub-surface layer around the EEIO are caused by changes in atmospheric and oceanic circulation (including the ITF) as well as those in thermocline depths in the northwestern Pacific Ocean during the last 50,000 years.

Keywords: Eastern Indian Ocean, Thermocline, Water mass, Indonesian ThroughFlow

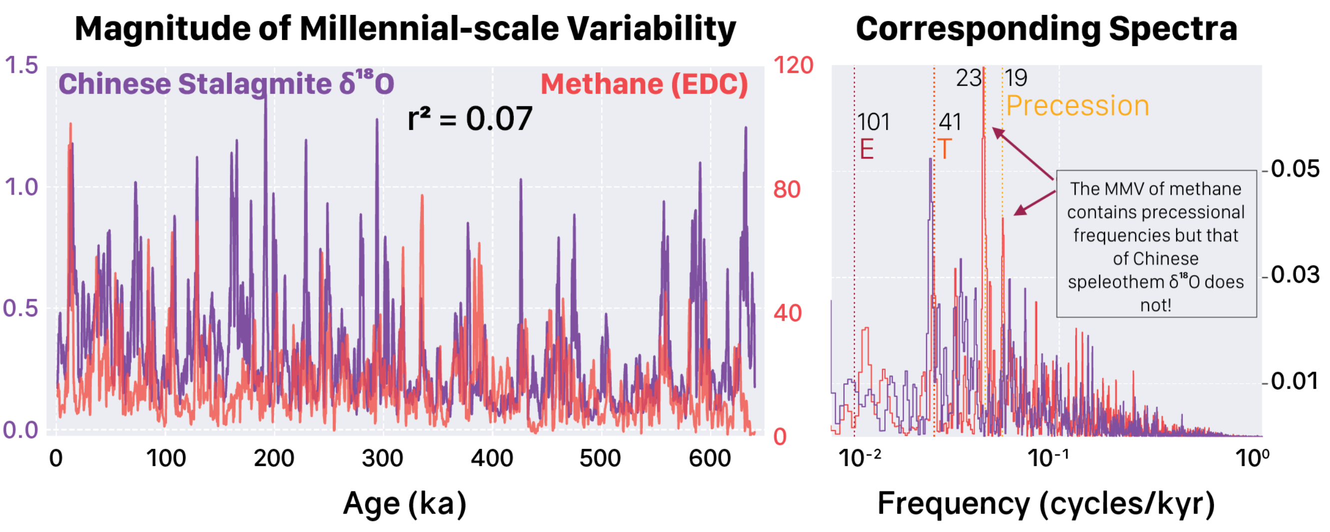
Methane, Monsoons, and Milankovitch Modulation of Millennial-Scale Climate

*Kaustubh Thirumalai[1], Steven Clemens[2], Judson Partin[3]

1. The University of Arizona, 2. Brown University, 3. The University of Texas at Austin

Earth's orbital geometry exerts a profound influence on climate by regulating changes in incoming solar radiation. Superimposed on orbitally paced climate change, Pleistocene records reveal substantial millennial-scale variability characterized by abrupt changes and rapid swings. However, the extent to which orbital forcing modulates the amplitude and timing of these millennial variations is unclear. Here we isolate the magnitude of millennial-scale variability (MMV) in two well-dated records, both linked to precession cycles (19,000- and 23,000-year periodicity): composite Chinese speleothem $\delta^{18}O$, commonly interpreted as a proxy for Asian monsoon intensity, and atmospheric methane. At the millennial timescale (1,000–10,000 years), we find a fundamental decoupling wherein precession directly modulates the MMV of methane but not that of speleothem $\delta^{18}O$, which is shown to be strikingly similar to the MMV of Antarctic ice core $\delta^{2}H$. One explanation is that the MMV of methane responds to changes in midlatitude to high-latitude insolation, whereas speleothem $\delta^{18}O$ is modulated by internal climate feedbacks.

Keywords: Millennial-scale climate, Methane, Monsoon, Paleomonsoon, Orbital Forcing



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

Sat. Jun 5, 2021 1:45 PM - 3:15 PM JST | Sat. Jun 5, 2021 4:45 AM - 6:15 AM UTC | Ch.04 Zoom Room 04

[P-PS03] Regolith Science

convener:Koji Wada(Planetary Exploration Research Center, Chiba Institute of Technology), Akiko Nakamura(Graduate School of Science, Kobe University), Patrick Michel(Universite Cote D Azur Observatoire De La Cote D Azur CNRS Laboratoire Lagrange), John Kevin Walsh(Southwest Research Institute Boulder), Chairperson:Naoya Sakatani(Department of Physics, Rikkyo University)

Recent planetary explorations have revealed that almost all solid bodies in the solar system are covered with small particles, called regolith. The surface geology, especially regolith behavior on the surfaces of solid bodies, becomes increasingly more important as represented by Hayabusa mission and other on-going and planned sample-return missions such as Hayabusa2, OSIRIS-REx, and MMX.
For fully understanding the regolith science, it is required to know and compare the regolith conditions on various celestial bodies, from asteroids to planets, with various methods.
Therefore, this session welcomes broad topics related to regolith on various celestial bodies, such as asteroids, comets, the Moon, the martian moons, Mars, etc. Papers on the formation, evolution, and alteration processes of regolith particles and regolith systems on the surface of planetary bodies, remote and in-situ observational results and techniques, analyses and results of returned samples, and laboratory, numerical, and theoretical studies on the fundamental physical and chemical processes are all welcome.
Note that what we call regolith is not just fine grains: all kinds of materials (more or less loose) that lie on the surface, from cobbles to finer grains, are our targets.

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

[PPS03-01] **Landing on an asteroid: Simulations and image analysis of the OSIRIS-REx spacecraft touch-down on (101955) Bennu**

★Invited Papers

*Ronald Ballouz[1], Kevin John Walsh[2], Patrick Michel[3], Yun Zhang[3], Paul Sánchez[4], Daniel Jay Scheeres[4], Michael C Nolan[1], Stephen R Schwartz[1], Derek C Richardson[5], Olivier S Barnouin[6], Edward B Bierhaus[7], Harold C Connolly[8,1], Dante S Lauretta[1] (1.Lunar and Planetary Lab, University of Arizona, Tucson, AZ, USA, 2.Southwest Research Institute, Boulder, CO, USA, 3.Université Côte d’Azur, Observatoire de la Côte d’Azur, CNRS, Laboratoire Lagrange, Nice, France, 4.University of Colorado Boulder, CO, USA,, 5.University of Maryland, College Park, MD, USA, 6.The Johns Hopkins University Applied Physics Laboratory, Laurel, MD, USA, , 7.Lockheed Martin Space, Littleton, CO, USA, , 8.Dept. of Geology, Rowan University, Glassboro, NJ, USA)

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

[PPS03-02] Dust cloud mass from OSIRIS-REx sample collection event at Bennu

★Invited Papers

*Bashar Rizk[1], Kevin J. Walsh[2], Ronald Ballouz[1], Brent Bos[3], Christian Drouet d'Aubigny[1] (1.University of Arizona, 2.Southwest Research Institute, 3.Goddard Space Flight Center)

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

[PPS03-03] Hayabusa2 sampling operation at Ryugu and the returned regolith samples

★Invited Papers

*Shogo Tachibana[1,2], Hayabusa2 Sampler Team (1.UTokyo Organization for Planetary and Space Science, University of Tokyo , 2.ISAS, JAXA)

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

[PPS03-04] Surface roughness and cohesion of impact fragments of meteorite targets

*Yuuya Nagaashi[1], Akiko Nakamura[1] (1.Kobe University)

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

[PPS03-05] Size and Spatial Distribution of Rock Particles on Small Bodies Revealed with CNN-based Algorithm

*Yuta Shimizu[1], Taisuke Suzuki[1], Ryodo Hemmi[1], Hideaki Miyamoto[1] (1.University of Tokyo)

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

[PPS03-06] **Experimental Study on the Relationship between Surface distributions and Vertical Structures of Rock Particles on Small bodies.**

*Taisuke Suzuki[1], Yuta Shimizu[1], Hideaki Miyamoto[1] (1.The University of Tokyo)

Landing on an asteroid: Simulations and image analysis of the OSIRIS-REx spacecraft touch-down on (101955) Bennu

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Spacecraft exploration of near-Earth asteroids (NEAs) has shown that their surfaces are composed of both fine regolith and larger meter-scale boulders. For asteroid sample-return missions, characterizing the geotechnical properties of the surface is critical for ensuring spacecraft safety and sampling success. Constraints on these geotechnical properties from remote observations can provide insight into their expected response from an interaction with a spacecraft; however, there is still a poor understanding of the behavior of granular materials in the low-gravity environment of NEAs. Here, we show direct simulations of the OSIRIS-REx spacecraft touching down on the NEA (101955) Bennu and compare them to images taken during the OSIRIS-REx sampling attempt on October 20, 2020. We discuss how these simulations, combined with observations of the surface and telemetry from spacecraft proximity operations, may provide insight into the behavior of granular materials in low gravity.

We discuss the results of varying the angle of friction, ϕ, and subsurface porosity as it is most pertinent for interpreting the data returned by OSIRIS-REx during the sampling maneuver. In our simulations, we found that the angle of friction of the material can strongly influence its response to an impact by a relatively massive spacecraft. We found that for low angles of friction, the OSIRIS-REx Touch and Go Sample Acquisition Mechanism (TAGSAM) is essentially unperturbed by the spacecraft. Past a friction angle of approximately 30 deg, the constant-force spring of TAGSAM engages. The porosity of the sub-surface can influence the manner in which the regolith resist the load of a spacecraft by changing the number of grain-to-grain contacts in the medium. These grain-to-grain contacts build a network of contacting particles known as a force chain, which we visualize in Fig. 1 for two different cases of regolith friction angle.

The value of ϕ for terrestrial granular materials typically ranges between approximately 20 and 40 deg and is controlled by the physical properties of individual grains such as size, shape, and roughness. We find that, for cases with high ϕ, the grains more strongly interlock in response to motion-loading from the spacecraft' s intrusion. This allows the regolith to more readily resist penetration, leading to the spacecraft resting at shallower depths. For these same values of ϕ, a more porous bed may have a different response, as there would be fewer surfaces for particles to develop frictional contacts, allowing TAGSAM to penetrate deeper in to the bed.

Keywords: Asteroid, OSIRIS-REx, Regolith

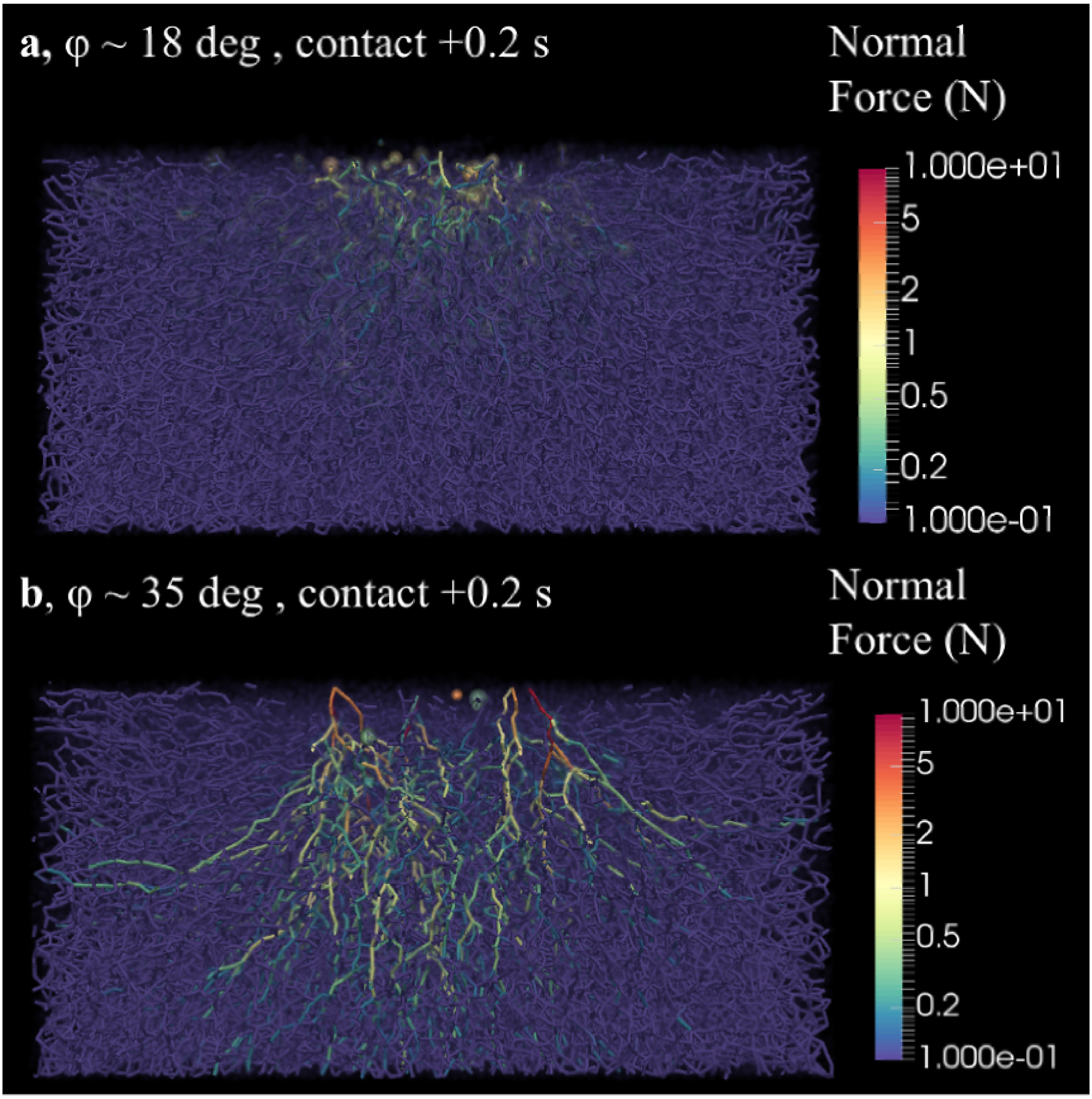

Figure 1. Snapshot of simulations showing the force-chain network for two simulation cases where the horizontal dimension is 120 cm, and the vertical dimension is 60 cm. The color represents the normal force (N) that each particle experiences 0.2 s after contact. **a)** For regolith with low φ, the force chains are relatively shallow and weak. **b)** For regolith with high φ, the force chains are relatively deep and strong.

Dust cloud mass from OSIRIS-REx sample collection event at Bennu

*Bashar Rizk[1], Kevin J. Walsh[2], Ronald Ballouz[1], Brent Bos[3], Christian Drouet d'Aubigny[1]

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The high-pressure gas released during the OSIRIS-REx sampling event, on 20 October 2020, lofted a cloud of sub-millimeter and smaller particles from the surface of asteroid Bennu . We attempted to determine the mass of this sub-millimeter dust cloud, and its initial layer thickness. The analysis relied on two images acquired before and after the event agitated Bennu’s regolith at Nightingale, the sampling site. We measured the optical depth of the expanding cloud as a function of distance from the center of the expansion during the moment of sample acquisition. Specific values of mass and thickness relied on simplifying assumptions and varied with particle size. We integrated the imaged profile of radially varying optical depth to significantly narrow, or even collapse, the range of average optical depth. We recruited observations from other instruments and analyses to do the same for particle size. With our result, we hope to constrain the nature of the microphysical environment at and near the surface of Bennu’s regolith by establishing the presence, or confirming the absence, of a population of sub-millimeter particles and measuring its magnitude.

Keywords: Regolith, Bennu, TAG, Dust, Sampling, Contamination

Hayabusa2 sampling operation at Ryugu and the returned regolith samples

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C-type asteroids have been hypothesized to be parent bodies of carbonaceous chondrites that are primitive meteorites containing hydrated minerals and organic matter. The hydrated minerals and organics in carbonaceous chondrites could be a source of volatiles to the proto Earth. The JAXA's Hayabusa2 spacecraft explored the near Earth C-type asteroid (162173) Ryugu to return its surface regolith samples. During the seventeen-month proximity observation, Hayabusa2 discovered (1) Ryugu is a rubble pile body with a low albede, darker than typical carbonaceous chondrites (e.g., Watanebe et al., 2019; Sugita et al., 2019; Morota et al., 2020), (2) hydrated minerals are present ubiquitously on the surface (e.g., Kitazato et al., 2019, 2021), and (3) surface pebbles and boulders have lower thermal inertia than meteorites, implying the porous nature of Ryugu materials (e.g., Grott et al., 2019; Okada et al., 2020).

Hayabusa2 landed on Ryugu at two different surface locations for regolith sample collection in February and July, 2019. The second landing aimed at collecting sub-surface samples excavated by the artifical cratering experiment (Arakawa et al., 2020). The basic concept and design of the Hayabusa2 projectile-shooting sampling device are the same as those of the Hayabusa sampling device (Yano et al., 2006). A 5-gram tantalum projectile was successfully shot through a 1-m long sampler horn at an impact velocity 300 m/s at the timing of each touchdown (Sawada et al., 2017). Two landing operations of Hayabusa2 proved for the first time that the projectile-shooting sampling device works at the asteroid surface.

Hayabusa2 delivered its reentry capsule on December 6, 2020 to Woomera, South Australia. Numerous millimeter- to centimeter-sized particles were found in two separate chambers inside the sample container, which were used for two landing operations at Ryugu. The particles are black in color, consistent with the color of Ryugu boulders (e.g., Sugita et al., 2019; Morota et al., 2020). Centimeter-sized grains, close to the maximum collectible size with the sampler system (Sawada et al., 2017), are found in the sample obtained during the second landing operation. The total weight of the sample exceeds 5 g, which is far more than the mission requirement (100 mg) for scientific analysis (Tachibana et al., 2014). All the sample characteristics suggest that the Hayabusa2 sampler system worked efficiently and effectively to collect surface regoligh at the Ryugu surface.

The regolith sampling oreration and the characteristics of returned particles will be presented and discussed in detail at the meeting.

Keywords: Hayabusa2, asteroid, Solar System, sampling

Surface roughness and cohesion of impact fragments of meteorite targets

*Yuuya Nagaashi[1], Akiko Nakamura[1]

1. Kobe University

The shape and cohesive force of particles making up small bodies have significant effects on the physical properties of the bodies. The shape of particles affects the angle of internal friction and thus the porosity of the particle layer [1]. The cohesive force of particles would enable the fast rotation of small bodies [2]. Also, the deformation and failure modes of rubble piles depend on the angle of internal friction and the cohesive force [3]. We have measured the shape and cohesive force of meteorite particles ground with a pestle and mortar. We showed that the smaller the circularity C (= $4\pi S/L^2$; S and L are the two-dimensional projected area and perimeter of the particle, respectively) and the larger the arithmetic mean roughness *Ra* (the average of the deviations from the mean surface), the smaller the cohesive force [4]. However, the ground meteorite particles have larger circularities than Itokawa rocks and basalt impact fragments, although they are different in size, and may also have different surface roughness. Therefore, we conducted impact experiments and collected tens of micron-sized particles ejected from meteorite targets to measure the circularity, surface roughness, and cohesion.
We collected the ejecta particles from impacts of a 1/8-inch stainless steel projectile and 1 mm aluminum projectiles to blocks of Allende at a speed of ~0.13 and ~2.9 km/s, respectively. We measured the circularity C and the axial ratio b/a (the ratios of the long-axis a and short-axis b lengths of the ellipsoidal approximation of the two-dimensional projection) of the ejecta using an optical microscope. We measured the roughness *Ra* of the ejecta using a confocal laser microscope.
The axial ratio b/a of the ejecta is 0.69–0.70 on average, similar to that of tens of micron-sized impact fragments of basalts and L5 chondrites (~0.7) [5] and the ground Allende particles (0.72 on average) [4]. The circularity C of the ejecta is 0.66–0.67 on average, similar to that of Itokawa rocks and basalt impact fragments (0.64–0.73 on average) [4], but smaller than that of the ground Allende particles (0.75 on average). Here, we compared the values of the circularity when the number of constituent pixels of each particle was corrected to 3000 pixels because the circularity depends on the number, i.e., image resolution [4]. The roughness *Ra* of the ejecta was ~500 nm, larger than that of the ground Allende particles (~300 nm) [4]. We will also compare the cohesive force of the Allende ejecta and ground particles, measured using a centrifugal method [4,6].

This research was supported by the Hypervelocity Impact Facility (former facility name: The Space Plasma Laboratory), ISAS, JAXA.

[1] Suzuki et al., 2003, *J. Soc. Powder Technol. Japan* **40**, 348-354. [2] Sánchez & Scheeres, 2014, *Meteorit. Planet. Sci* **49**, 788-811. [3] Sánchez & Scheeres, 2016, *Icarus* **271**, 453-471. [4] Nagaashi et al., in press, *Icarus*. [5] Michikami et al., 2018, *Icarus* **302**, 109-125. [6] Nagaashi et al., 2018, *Prog Earth Planet Sci* **5**, 52.

Keywords: impact fragment, surface roughness, cohesion

Size and Spatial Distribution of Rock Particles on Small Bodies Revealed with CNN-based Algorithm

*Yuta Shimizu[1], Taisuke Suzuki[1], Ryodo Hemmi[1], Hideaki Miyamoto[1]

1. University of Tokyo

As the number of small body exploration increases, the amount of science data obtained is expanding. Analyses of that data have yielded an unprecedented amount of knowledge about small bodies, and especially unexpected surfaces of small bodies covered by numerous rock particles have been revealed by high-resolution images [e.g., 1]. The size/shape/spatial distribution, sorting, and direction of rock particles have led us to discuss the origins and surface processes of small bodies [2, 3, 4]. Analysis of rock particles is also critical for landing missions to avoid hazardous objects [5], resulting in the growing demand for identifying countless rock particles. In many cases, the identification of particles has been manually conducted by fitting ellipses to the profile of particles. The profiles are generally blurred and difficult to be distinguished from the background due to irregular particle shapes, overlapping particles, image resolution limits, which makes the analysis time-consuming and difficult to be reconducted, leading to the lack of reproducibility. Therefore, a method to analyze a massive amount of rock particles with objectivity and reproducibility has to be established. Here, we develop the computational approach for the automated identifications of rock particles based on the image feature extraction algorithm, the convolutional neural networks (CNNs). We prepare images of the simulated surface of small bodies in a laboratory, and then carefully identified thousands of particles. Using the data of profiles, we trained the model, enabling nearly 90 % of profiles of particles to be correctly traced without the aid of manual analysis. Moreover, by using the model, rock particles on the global surface of asteroid Itokawa are mapped, revealing the size and spatial distribution of particles. The approach of this study can rapidly identify numerous particles, which can be a promising tool for analyzing countless images of the surface of small bodies taken by the current and future small body exploration missions.

References

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Keywords: Rock Particles, Automated Identification, Deep Learning

Experimental Study on the Relationship between Surface distributions and Vertical Structures of Rock Particles on Small bodies.

*Taisuke Suzuki[1], Yuta Shimizu[1], Hideaki Miyamoto[1]

1. The University of Tokyo

Small celestial bodies are covered by numerous rock particles. The distributions of rock particles on small bodies differ significantly from one body to another, reflecting the formation and evolution process of the body [1], and thus needs to be studied in detail. However, the information obtained by exploration is limited, and the distributions of rock particles are studied mostly by analyzing surface images, especially measuring cumulative size distributions (CSFD) of particles [2, 3, 4]. In general, the CSFD of small bodies can be fit by power-law, and the values of power-law index are compared between celestial bodies and different regions on the bodies. However, it is not clear to what extent the power-law indexes contain essential information. In fact, in order to understand the distributions of rock particles, it is necessary to focus not only on the surface but also on the subsurface. For example, layer structure and macroporosity of subsurface is fundamental for investigating the internal structure of small bodies[1]. However, the internal structures of small bodies have never been observed, and can only be inferred from gravity and grain density [5, 6]. Therefore, research has been conducted to infer the internal structures of celestial bodies from the results of image analyses [7, 8]. Such studies are based on the assumption that the particle size distributions obtained from surface images represent the interior, but this assumption has never been verified. Therefore, this study aims to verify the extent to which the information obtained from surface images of small bodies reflects the essential information including that of subsurface. Although such study can be performed by numerical simulation assuming spherical particles [9], reflecting the effects of the complex shapes of the rock particles of small bodies is extremely difficult. On the other hand, our approach is to conduct an experiment in a laboratory, where we use rock material made from fractured hornfels which are blended to have the power-law index of -3. When the rock material was laid out on a flat surface, the slopes of CSFD obtained from surface images were less steep than the actual value. In addition, when the material was placed in an acrylic container with an inner diameter of 140mm, the slopes of CSFD obtained from surface images got even less steep than when it was laid out on a flat surface. These results suggest that slope of the CSFD obtained from the images of the surfaces of the small bodies is less steep than the actual slope of the CSFD including the interior. Therefore, constraining the physical properties of the interior only from the surface images of small bodies is revealed to be challenging. Moreover, the material was vibrated in order to observe the effects of surface modifications. The result showed that the slope of the CSFD gradually got less steep. This suggests that the comparisons of the CSFD are important when we discuss surface modification processes of small bodies. Furthermore, the internal structure is visualized by micro-focus X-ray CT to understand how the CSFD on the surface relates to the subsurface structure. From the broad view and high contrast 3D images obtained, the values of macroporosity of the horizontal cross-sections are calculated, and we suggest that the macroporosity falls between 30% and 40%. These findings can be applied to image analyses and simulations to advance discussions on the geology of small bodies.

References

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

Sat. Jun 5, 2021 3:30 PM - 5:00 PM JST | Sat. Jun 5, 2021 6:30 AM - 8:00 AM UTC | Ch.04 Zoom Room 04

[P-PS03] Regolith Science

convener:Koji Wada(Planetary Exploration Research Center, Chiba Institute of Technology), Akiko Nakamura(Graduate School of Science, Kobe University), Patrick Michel(Universite Cote D Azur Observatoire De La Cote D Azur CNRS Laboratoire Lagrange), John Kevin Walsh(Southwest Research Institute Boulder), Chairperson:Yuri Shimaki(Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency)

Recent planetary explorations have revealed that almost all solid bodies in the solar system are covered with small particles, called regolith. The surface geology, especially regolith behavior on the surfaces of solid bodies, becomes increasingly more important as represented by Hayabusa mission and other on-going and planned sample-return missions such as Hayabusa2, OSIRIS-REx, and MMX.
For fully understanding the regolith science, it is required to know and compare the regolith conditions on various celestial bodies, from asteroids to planets, with various methods.
Therefore, this session welcomes broad topics related to regolith on various celestial bodies, such as asteroids, comets, the Moon, the martian moons, Mars, etc. Papers on the formation, evolution, and alteration processes of regolith particles and regolith systems on the surface of planetary bodies, remote and in-situ observational results and techniques, analyses and results of returned samples, and laboratory, numerical, and theoretical studies on the fundamental physical and chemical processes are all welcome.
Note that what we call regolith is not just fine grains: all kinds of materials (more or less loose) that lie on the surface, from cobbles to finer grains, are our targets.

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

[PPS03-07] Deciphering the regolith properties of small bodies from numerical modeling

★Invited Papers

*Yun Zhang[1] (1.UCA, OCA, CNRS, Lagrange, Nice, France)

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

[PPS03-08] Charge Magnitude of Electrostatically Lofted Dust Grains over the Lunar Terminator

*Necmi Cihan Orger[1], Kazuhiro Toyoda[1], Mengu Cho[1] (1.Laboratory of Lean Satellite Enterprises and In-Orbit Experiments - Kyushu Institute of Technology)

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

[PPS03-09] High-velocity impact experiments in reduced gravity: The effect of cohesive strength of particle layers

*Masato Kiuchi[1], Takaya Okamoto[1], Yuuya Nagaashi[2], Sunao Hasegawa[1], Akiko Nakamura[2] (1.Japan aerospace exploration agency, Institute of space and astronautical science, 2.Graduate School of Science, Kobe UniversityKobe University)

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

[PPS03-10] Local variation in thermal inertia around the artificial impact crater on Ryugu

*Naoya Sakatani[1], Satoshi Tanaka[2], Tatsuaki Okada[2], Toru Kouyama[3], Akira Miura[2], Naru Hirata[4], Hiroki Senshu[5], Takehiko Arai[6], Yuri Shimaki[2], Hirohide Demura[4], Tomohiko Sekiguchi[7], Jun Takita[8], Tetsuya Fukuhara[1], Thomas Müller[9], Axel Hagermann[10], Jens Biele[11], Matthias Grott[11], Maximillian Hamm[11,12], Marco Delbo[13], Masahiko Arakawa[14], Kazunori Ogawa[15], Koji Wada[5], Toshihiko Kadono[16], Rie Honda[17], Kei Shirai[14], Takanao Saiki[2], Hiroshi Imamura[2], Yasuhiko Takagi[18], Hajime Yano[2], Masahiko Hayakawa[2], Hirotaka Sawada[2], Satoru Nakazawa[2], Seiji Sugita[19], Tomokatsu Morota[19], Manabu Yamada[5], Shingo Kameda[1], ERI TATSUMI[20], Yasuhiro Yokota[2], Hidehiko Suzuki[21], Kazuo Yoshioka[19], Moe Matsuoka[2], Yuichiro Cho[2] (1.Rikkyo University, 2.Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency, 3.National Institute of Advanced Industrial Science and Technology, 4.University of Aizu, 5.Chiba Institute of Technology, 6.Ashikaga University, 7.Hokkaido University of Education, 8.Hokkaido Kitami Hokuto High School, 9.Max-Planck Institute for Extraterrestrial Physics, 10.Luleå University of Technology, 11.German Aerospace Center, 12.University of Potsdam, 13.Observatoire de la Côte d'Azur, CNRS, 14.Kobe University, 15.JAXA Space Exploration Center, Japan Aerospace Exploration Agency, 16.University of Occupational and Environmental Health, 17.Kochi University, 18.Aichi Toho University, 19.University of Tokyo, 20.Instituto de Astrofisica de Canarias, 21.Meiji University)

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

[PPS03-11] Brightness change of Hayabusa2 SCI crater ejecta observed by ONC-T and its implication to the surface status of asteroid Ryugu

*Rie Honda[1], Yasuhiro Yokota[2], Masahiko Arakawa[3], Seiji Sugita[4], Yuri Shimaki[2], Koji Wada[5], Toshihiko Kadono[6], Kei Shirai[3], Kazunori Ogawa[7], Naoya Sakatani[8], Ko Ishibashi[5], Takanao Saiki[2], Hiroshi Imamura[2], Satoru Nakazawa[2], Masahiko Hayakawa[2], Hajime Yano[2], Yasuhiko Takagi[9], Naru Hirata[10], Hirotaka Sawada[2], Tomokatsu Morota[4], Shingo Kameda[8], Eri Tatsumi[11], Manabu Yamada[5], Toru Kouyama[12], Yuichiro Cho[4], Moe Matsuoka[2], Kazuo Yoshioka[4], Hidehiko Suzuki[13], Chikatoshi Honda[10] (1.Department of Science and Technology, System of Natual Science, Kochi University, 2.Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency, 3.Kobe University, 4.The University of Tokyo, 5.Planetary Exploration Research Center, Chiba Institute of Technology, 6.University of Occupational and Environmental Health, 7.JAXA Space Exploration Center, Japan Aerospace Exploration Agency, 8.Rikkyo University, 9.Aichi Toho University, 10.The University of Aizu, 11.Instituto de Astrofisica de Canarias, University of La Laguna, 12.National Institute of Advanced Industrial Science and Technology, 13.Meiji University)

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

[PPS03-12] Study of Hydrated Asteroids via Polarimetry: Correlation between Polarimetric Properties and Degree of Aqueous Alteration of Hydrated asteroids.

*Jooyeon Geem[1], Masateru Ishiguro[1], Hiroyuki Naito[2], Daisuke Kuroda[6], Koki Takahashi[3], Tomohiko Sekiguchi[3], Seiko Takagi[4], Tatsuharu Ono[4], Kiyoshi Kuramoto[4], Tomoki Nakamura[5] (1.Astronomy program, Dept of Physics and Astronomy, Seoul National University, 2.Nayoro Observatory, 3.Hokkaido University of Education, 4.Department of Cosmosciences, Graduate School of Science, Hokkaido University, 5.Department of Earth and Planetary Material Sciences, Faculty of Science, Tohoku University, 6.Okayama Observatory, Kyoto University)

Deciphering the regolith properties of small bodies from numerical modeling

*Yun Zhang[1]

1. UCA, OCA, CNRS, Lagrange, Nice, France

Surfaces of small bodies experience a wide range of processes that alter their local and global characteristics. Numerical modeling allows us to investigate these processes and decipher the history and physical properties of small bodies from their surface characteristics. I will present an overview of our recent investigations based on numerical modeling and give some examples below.
For objects whose surfaces have been characterized in detail by spacecrafts, e.g., Ryugu by Hayabusa2 (JAXA) and Bennu by OSIRIS-REx (NASA), comparisons with numerical modeling can be used to shed some light on the formation of these surface features. For instance, some surface local mass movement features in the downslope direction were detected on asteroid Bennu [1]. This direction and color variation analyses suggest that these mass movements occurred at times close to the current spin-period regime, which may result from YORP rotational accelerations. We carried out a numerical study using the soft-sphere discrete element modeling (SSDEM) to test Bennu’s structural evolution under the YORP spin-up effect. The current surface slope, the recent surface mass movement, and the old surface age of the equatorial bulge are used as constraints to shed some light on Bennu’s surface properties and internal structure.
Direct interaction with a small body surface is the most effective way to understand the regolith mechanical properties and behavior in the actual gravitational environment. The outcome also provides precious opportunities to interpret the results using numerical modeling. For instance, the experiment performed by the Hayabusa2 Small Carry-on Impactor (SCI) on asteroid Ryugu in April 2019 offers the first opportunity for a direct confrontation of cratering on small bodies with numerical modeling [2]. We conducted SCI-like cratering tests using a hybrid Smooth Particle Hydrodynamics (SPH) and SSDEM framework. The preliminary results show that regolith near the SCI-cratering region should have little cohesion in order to match the crater morphology.
In an indirect way, the regolith properties can also be inferred for some small bodies that are at the limit of maintaining their structural stability. For instance, there are dozens of fast-rotating asteroids that require material cohesion to keep their integrity. With comprehensive numerical exploration, we can derive the minimum required amount of cohesion of their regolith and the corresponding grain size distribution.
Connecting the regolith properties with other observational data can help to reveal the formation mechanism of small bodies. For instance, our numerical modeling showed that the lack of apparent cometary activity of the interstellar object 1I/‘Oumuamua can be explained by the way its surface was built during its formation through a close encounter with its host star in another planetary system [3].

Reference: [1] Jawin et al. (2020) JGR: Planets, 125, e2020JE006475. [2] Arakawa M. et al. (2020) Science, 368: 67–71. [3] Zhang & Lin (2020) Nature Astronomy, 4, 852–860.

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Keywords: Small body formation and evolution, Regolith properties, Granular material, Numerical modeling

Charge Magnitude of Electrostatically Lofted Dust Grains over the Lunar Terminator

*Necmi Cihan Orger[1], Kazuhiro Toyoda[1], Mengu Cho[1]

1. Laboratory of Lean Satellite Enterprises and In-Orbit Experiments - Kyushu Institute of Technology

The interaction with the solar wind has several consequences on the lunar surface, and one of them can be described as electrostatic transportation of the lunar dust grains. It has been proposed that the emitted electrons within micro-cavities between the neighboring dust grains can produce strong repulsion to detach the dust particles from the loose upper layer of the lunar regolith, and this mechanism has been demonstrated in several laboratory experiments. In order to launch a charged dust particle from the lunar surface, the electrostatic repulsion should overcome the forces of contact and gravity. In this study, the charge magnitude requirement of the lofted dust particles in the range of 0.1 μm –10 μm in radius is investigated through a function of (1) specific gravity that is determined by the particle type such as agglutinates, basalt, or breccia, (2) inter-particle contact forces, (3) the surface electric field that is controlled by the solar wind, (4) the launch angle based on the experimental results, and (5) the characteristic size of micro-cavity that is related to the regolith configuration. It has been observed that the charge magnitude variation increases with the particle size, and the particles with 5-6 μm radius can gain sufficient charges to loft and produce the near-surface lunar horizon glow.

Keywords: lunar regolith, lunar dust charging, electrostatic dust lofting, lunar horizon glow

High-velocity impact experiments in reduced gravity: The effect of cohesive strength of particle layers

*Masato Kiuchi[1], Takaya Okamoto[1], Yuuya Nagaashi[2], Sunao Hasegawa[1], Akiko Nakamura[2]

1. Japan aerospace exploration agency, Institute of space and astronautical science, 2. Graduate School of Science, Kobe UniversityKobe University

The surfaces of small bodies are in a microgravity environment, and it is important to understand how gravity affects crater size to estimate the physical properties of the surface. Several studies have investigated the effect of gravity on crater size for low-velocity to high velocity (1 m s^{-1} to 6.6 km s^{-1}) impacts: the gravitational dependence of crater size was obtained in the low and high gravity range (Gault & Wedekind, 1977; Schmidt & Housen, 1987; Cintala et al., 1989; Takagi et al., 2007; Kiuchi et al., 2019). In most of the studies, the crater diameter was shown to be proportional to −0.165 ~ −0.19 power of the gravitational acceleration. However, in a microgravity environment such as the surface of small bodies, the effect of the cohesive strength of the regolith layer on crater formation may be more dominant than the effect of the gravity. The transition condition between the gravity regime and the strength regime is not well understood because the available laboratory data is limited.

We assembled a simple drop tower in the vacuum chamber of a two stage light gas gun at the Japan Aerospace Exploration Agency (JAXA) to conduct high velocity impact experiments in reduced gravity. We used quartz sand (particle size is ~425 μm) as the target material, and used a glass sphere of diameter 1 mm as the projectile. The target material was loosely filled in a stainless steel container with a diameter of 30 cm and a height of 10 cm. A projectile was impacted at a velocity of 1.2 km s^{-1}. As a result, the diameters of craters formed at 0.05 G was about 1.8 times larger than the one formed at 1 G and gravitational dependence of the crater diameter was clearly observed(Kiuchi et al., 2020, JpGU–AGU). We compiled the results using pi-scaling (e.g., Holsapple, 1994) and showed that our results in reduced gravity agreed well with the crater size scaling law for non–cohesive sand targets (Housen and Holsapple, 2011).

In addition, we used targets of fine glass beads (particle size is ~40 μm) and fused alumina particles (particle size is ~40 μm). As a result, the crater diameter formed at 0.05 G was not much different from the one formed at 1 G for both targets. We infer that the gravitational dependence of the crater diameter was reduced due to the effect of the cohesive strength of these targets. We constrained the transition condition between the gravity regime and the strength regime by estimating the tensile strength of the particle layers based on the measured cohesive force of the particles (Nagaashi et al., in press). From our experimental results, it was found that the effect of the target strength becomes dominant when the tensile strength of the particle layer is larger than $10 \rho g D$, where ρ is the density of the particle layer, g is the gravitational acceleration, and D is the crater diameter. We will discuss the effect of the cohesive strength on the size frequency distribution of small craters on particle layers.

This research was supported by the Hypervelocity Impact Facility (former facility name: The Space Plasma Laboratory) of ISAS, JAXA, and JSPS KAKENHI Grant Number JP19K14824 and 18K03723.

Keywords: Impact crater formation experiments, Gravitational dependence of the crater diameter, Cohesive strength of particle layers

Local variation in thermal inertia around the artificial impact crater on Ryugu

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The Hayabusa2 spacecraft has completed the rendezvous phase around Cb-type asteroid Ryugu in 2019. From thermal infrared imaging by TIR, global temperature distribution of Ryugu is consistent with the thermal calculation with thermal inertia of 300±100 J m^{-2} K^{-1} $s^{-0.5}$ [1], and thermal inertia values of the floors of craters are in general roughly comparable with the global average [2]. On the other hand, few small and fresh craters show anomalously low thermal inertia less than 100 J m^{-2} K^{-1} $s^{-0.5}$, contributed from the highly porous nature of boulders exposed by the impact cratering [3]. On April 2019, Hayabusa2 performed an artificial impact (Small Carry-on Impactor or SCI) experiment [4], whereby a ~2 kg mass was fired at 2 km/s against the asteroid surface. As a result of the successful operation, an artificial crater (SCI crater) with diameter larger than 10 m was created on the asteroid.

In the preliminary analysis of TIR data of the SCI crater, we suggested no thermally-anomalous materials on the crater floor [3]. In other words, the SCI crater has similar thermal inertia with the global average, and physical properties of the subsurface materials are similar to that of the top surface, at least on the SCI impact site. However, regional difference in the thermal inertia inside and outside the SCI crater have not been discussed. We will present whether the regional variation of the thermophysical properties appears around the SCI craters.

References: [1] Okada et al. (2020), *Nature* 579, 518-522. [2] Shimaki et al. (2020), *Icarus* 348, 113835. [3] Sakatani et al. (2021), *LPSC* #1832, #2189. [4] Arakawa et al. (2020), Science 368, 67-71.

Brightness change of Hayabusa2 SCI crater ejecta observed by ONC-T and its implication to the surface status of asteroid Ryugu

*Rie Honda[1], Yasuhiro Yokota[2], Masahiko Arakawa[3], Seiji Sugita[4], Yuri Shimaki[2], Koji Wada[5], Toshihiko Kadono[6], Kei Shirai[3], Kazunori Ogawa[7], Naoya Sakatani[8], Ko Ishibashi[5], Takanao Saiki[2], Hiroshi Imamura[2], Satoru Nakazawa[2], Masahiko Hayakawa[2], Hajime Yano[2], Yasuhiko Takagi[9], Naru Hirata[10], Hirotaka Sawada[2], Tomokatsu Morota[4], Shingo Kameda[8], Eri Tatsumi[11], Manabu Yamada[5], Toru Kouyama[12], Yuichiro Cho[4], Moe Matsuoka[2], Kazuo Yoshioka[4], Hidehiko Suzuki[13], Chikatoshi Honda[10]

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Introduction:
On April 5, 2019, Hayabusa2 Small Carry-on Impactor (SCI) experiment was conducted to form an artificial crater on the asteroid Ryugu. As a result, a crater with a rim diameter of 17.6 meters was successfully formed on the surface of Ryugu [1]. Comparison of the Hayabusa2 Telescopic Onboard Navigation Camera (ONC-T) [2] image data before and after the impact revealed that the brightness around the crater was darkened by 20% at the maximum due to ejecta rays [1]. Investigating the cause of this darkening and its temporal change will provide important insights into the weathering and alteration process on the asteroid's surface. We conducted a detailed analysis on the brightness of the SCI crater and its surrounding area by using the images of ONC-T v-band (0.55 μm) just before SCI impact and after SCI impact until the end of the proximity phase, Oct. 2019.

The analysis is conducted by two methods: (1) comparison of reflectance at the standard viewing geometry derived from images at a different time and phase angles and (2) evaluation of global phase-ratio map created by dividing two global mosaics at phase angle 31° and 1°.

Analysis1. Comparison of images over 7 months:
High spatial resolution ONC-T images around the SCI crater was obtained just during the operations of the Hayabusa2 sampling (touchdown) and rehearsals. Thus we used images taken at an altitude of 20 km distance. This dataset contains various solar phase angle (1–33°) observations. We used the photometrically corrected reflectance images (Level 2e product) for this analysis. In addition, we normalized each image by the average of a reference area defined far from the SCI crater.

From comparison around the SCI crater over 7 months, we found that the relative brightness of the ejecta and SCI crater varies with solar phase angle, rather than the elapsed time from SCI impact. Since the photometric correction for this Level 2e product did not concern the regional photometric difference, this residual dependency on the phase angle means that the photometric characteristic (surface roughness/texture) around the SCI crater is different from the reference area.

Analysis 2. Phase ratio image: To search the area of hidden ejecta around the natural crater similar to SCI crater ejecta, we made a global phase-ratio map by dividing two global mosaics (phase angle 31° / 1°).

The ratio of two different phase angle images is often used as a method to identify the distribution of a characteristic surface roughness/texture area. In this map image, the SCI crater ejecta deposit is recognized as an area with a lower ratio than the surroundings. However, the results showed that there were no areas similar to the SCI crater ejecta deposit. This may suggest that the natural crater ejecta deposits have been smoothed out over a long time.

Summary:

It was found that the surface roughness/texture may play a major role in the darkening of the SCI crater ejecta deposit. The contribution of the intrinsic albedo is still unknown and needs to be studied in detail. It is also a future issue whether there was any change in roughness/texture or albedo during the 7-month period. However, observation of the natural craters on Ryugu suggests that the darkening area may fade over a long period of time.

References:

[1] Arakawa M. et al. (2020) Science 368, 67. [2] Sugita S., et al. (2019) Science 364, 252.

Keywords: Asteroid, Ryugu, Impact, Ejecta

Study of Hydrated Asteroids via Polarimetry: Correlation between Polarimetric Properties and Degree of Aqueous Alteration of Hydrated asteroids.

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1. Astronomy program, Dept of Physics and Astronomy, Seoul National University, 2. Nayoro Observatory, 3. Hokkaido University of Education, 4. Department of Cosmosciences, Graduate School of Science, Hokkaido University, 5. Department of Earth and Planetary Material Sciences, Faculty of Science, Tohoku University, 6. Okayama Observatory, Kyoto University

Hydrated asteroids have been attracting widespread interest due to the Hayabusa2 and OSIRIS-REx mission. These asteroids are considered as fragments that have experienced varying degrees of aqueous alteration in their parent bodies. Such aqueously altered asteroids have been extensively investigated by spectroscopic observations and laboratory experiments of carbonaceous chondrites. From spectroscopy, it is known that the spectral features in 0.7 μm or the 3 μm bands depend on the degree of aqueous alteration [2, 3]. On the other hand, mineralogical studies of chondrites found that the transition of composed minerals such as the cronstedtite converting to Mg-rich serpentine occurs as the alteration progressed [4]. While approaches via spectroscopy and meteoritics are widely employed, “polarimetry” has rarely been used to study hydrated asteroids.

Polarimetry has the advantage of being able to know the physical properties like albedo, particle size, and porosity of the target’s surface even without conducting space explorations [1]. The polarization degree (P) of reflected light from atmosphereless bodies exhibits the phase angle (α) dependence, where the α is the angle between Sun-Target-Observer. The $\alpha-P$ profile consists of several key parameters such as the minimum polarization degree (P_{min}) appearing at α˜ 10º. The polarimetric parameters are useful diagnostic tools to estimate the surface properties. In this study, we examine “how the physical properties change depending on the degree of aqueous alteration” by utilizing polarimetry.

In 2020, we made the polarimetric observation for 35 nights with the visible Multi-Spectral Imager (MSI) attached on the 1.6m Pirka Telescope at the Nayoro Observatory. We observed 18 C-complex main-belt asteroids in the visible band, including Ch type asteroids (i.e., hydrated asteroids). These asteroids were observed at $\alpha \leqq 20º$, which allows us to obtain the P_{min} values of our targets. We also gathered archival data and derived the polarimetric parameters and spectral information of asteroids from the previous research.

As a result, we found that polarimetric parameters (e.g., the P_{min}) show a strong correlation with spectral features (e.g., the 0.7 μm and 3 μm range absorption). Because P_{min} is attributed to the physical properties (albedo, particle size, or porosity) of the surface materials, our observation suggests these physical properties changed as the aqueous alteration progressed. In this presentation, we will introduce our polarimetric observation, and discuss possible interpretations of these results.

[1] Cellino et al., 2015, MNRAS, 451,4.; [2] Fornasier et al., 2014, Icarus, 233, 163-178.; [3]Takir et al., 2013, Meteoritics and Planetary Science, 48, 9.; [4] Tomeoka et al., 1985, GCA, 49, 10.

Keywords: Asteroids, Polarimetry, Aqueous alteration process, Hydrated asteroids

[E] Oral | P (Space and Planetary Sciences) : P-EM Solar-Terrestrial Sciences, Space Electromagnetism & Space Environment

Sat. Jun 5, 2021 9:00 AM - 10:30 AM JST | Sat. Jun 5, 2021 12:00 AM - 1:30 AM UTC | Ch.06 Zoom Room 06

[P-EM08] Space Weather and Space Climate

convener:Ryuho Kataoka(National Institute of Polar Research), A Antti Pulkkinen(NASA Goddard Space Flight Center), Kanya Kusano(Institute for Space-Earth Environmental Research, Nagoya University), Kaori Sakaguchi(National Institute of Information and Communications Technology), Chairperson:Kanya Kusano(Institute for Space-Earth Environmental Research, Nagoya University), Kaori Sakaguchi(National Institute of Information and Communications Technology)

We share the latest scientific papers to understand how the space environment changes in various time scales, and to discuss how we will react via international and interdisciplinary collaborations. More specifically, welcomed papers include space climate studies to reconstruct the long-term variations from radio isotopes; cutting-edge observational and modeling studies of the ionosphere, geospace, heliosphere and the sun; simulation and statistical studies to predict the future space weather and space climate; applied science such as operational space weather forecast and mitigation of the social impact due to extreme space hazards. Focused topics in 2021 include extreme events, theoretical maxima and benchmarks for hazard assessments, and space weather and deep space human spaceflight activities at Moon and at Mars.

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

[PEM08-13] Statistical analysis of variations of geoelectric field during magnetic storms/substorms in Japan

*Tian Zhang[1], Yusuke Ebihara[1] (1.Kyoto University)

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

[PEM08-14] How do auroral substorms depend on Earth's dipole magnetic moment?

*Yusuke Ebihara[1], Takashi Tanaka[2] (1.Research Institute for Sustainable Humanosphere, Kyoto University, 2.International Center for Space Weather Science and Education, Kyushu University)

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

[PEM08-15] Direct numerical simulation of the Alfvénic solar wind: a theoretical origin of magnetic switchback

★Invited Papers

*Munehito Shoda[1] (1.National Astronomical Observatory of Japan)

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

[PEM08-16] Simulation study on the deformation of magnetic field in interplanetary CMEs

*Minami Mori[1], Daikou Shiota[2], Kanya Kusano[1] (1.Institute for Space-Earth Environmental Research, Nagoya University , 2.National Institute of Information and Communications Technology (NICT))

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

[PEM08-17] Onset Mechanism of the Successive M-class Solar Flares in the Solar Active Region 12673 Based on a Nonlinear Force-Free Modeling

*Daiki Yamasaki[1], Satoshi Inoue[2], Takako T. Ishii[1], Ayumi Asai[1], Shin'ichi Nagata[1], Kiyoshi Ichimoto[1] (1.Astronomical Observatory, Kyoto University, 2.Institute for Space-Earth Environmental Research)

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

[PEM08-18] Data-driven MHD simulation of successive solar plasma eruptions

*Takafumi Kaneko[1], Sung-Hong Park[1], Kanya Kusano[1] (1.Institute for Space-Earth Environmental Research, Nagoya University)

Statistical analysis of variations of geoelectric field during magnetic storms/substorms in Japan

*Tian Zhang[1], Yusuke Ebihara[1]

1. Kyoto University

Since the GIC (geomagnetically induced current) of power grids is a global problem, to effectively prevent geomagnetic storm disaster is an important problem. Predicting the GIC is considered as a possible solution to this problem. Since GIC is directly generated by GIE (geomagnetically induced electric field), we used GIE measured at Kakioka Magnetic Observatory (geomagnetic latitude of 28 deg) as a proxy of GIC flowing in the Japanese power grid to acquire a statistical view of the response of GIC to magnetic storms and substorms, and to understand how the magnetospheric and ionospheric current systems affect GIC. The magnetic storms were sorted in accordance with the minimum value of the SYM-H index. The magnetic storms driven by coronal mass ejections (CMEs) and the corotating interaction regions (CIRs) were in particular focused on. A total of 38 intense storms associated with (during 1996-2004), 31 CME- and 69 CIR-associated moderate storms (during 1996-2008), as well as 17,273 substorms (during 1996-2004) are used to perform superposed epoch analyses. The east-west component of the electric field |Ey| dominates the north-south component |Ex| for all the three kinds of magnetic storms. For the CME-associated storms, Ey tends to show a negative excursion during the initial phase, a positive one during the main phase and a negative one during the recovery phase, which can be understood the contribution from the magnetopause current and the ring current. Ey responds largely to substorms with its polarity depending on magnetic local time. We discuss the possible current systems that can cause the large-amplitude GIE at geomagnetically low latitude by shown histograms of the maximum |Ey| during the magnetic storms and substorms.

Keywords: geoelectric field , magnetic storms, coronal mass ejections, corotating interaction regions

How do auroral substorms depend on Earth's dipole magnetic moment?

*Yusuke Ebihara[1], Takashi Tanaka[2]

1. Research Institute for Sustainable Humanosphere, Kyoto University, 2. International Center for Space Weather Science and Education, Kyushu University

The near-Earth space environment is suggested to depend on Earth's dipole magnetic moment *M*. The dependence on *M* is not straightforward since the solar wind-magnetosphere-ionosphere coupling system is complicated. Here, we show how the change in *M* affects the development of an auroral substorm by using global magnetohydrodynamics (MHD) simulation. We artificially increased *M* by a factor of 1.5 (corresponding to the Earth about 630 BC) and decreased *M* by a factor of 1.5 (corresponding to the Earth about 2850 AD) in the MHD simulation. The ionospheric conductivity decreases with increasing *M*, in accordance with the aid of empirical relations. An auroral substorm took place regardless of *M*, but its development depends largely on *M*. The major results can be summarized as follows. In the future (when *M* decreases monotonically), (1) the expansion onset of the substorm takes place later, (2) the auroral electrojet develops slowly, (3) the amount of energy coming into the magnetosphere decreases whereas the maximum auroral electrojet increases, and (4) the bright auroral region expands more equatorward. The first two consequences are probably associated with the slow magnetospheric convection. The third consequence is associated with the dependence the ionospheric conductivity on *M*. The fourth consequence is related to the weakness of the magnetic pressure force that impedes earthward penetration of hot plasma. It is shown that the evolution of substorms depends largely on the value of Earth's dipole moment.

Keywords: Auroral substorm, Strength of Earth's magnetic field, MHD simulation

Direct numerical simulation of the Alfvénic solar wind: a theoretical origin of magnetic switchback

*Munehito Shoda[1]

1. National Astronomical Observatory of Japan

One of the most important early findings from Parker Solar Probe is the ubiquitous presence of sudden reversals of magnetic polarity in the near-Sun solar wind. Such events are called "magnetic switchbacks". The presence of magnetic switchbacks in the near-Sun solar wind is not predicted from the standard solar wind model, in which the solar wind is heated and accelerated by Alfvén waves and turbulence. Our theoretical understanding of the solar wind acceleration is now challenged.
In this presentation, we propose the idea that the magnetic switchbacks emerge as a natural consequence of large-amplitude Alfvén waves, thus explaining the origin of magnetic switchbacks without disturbing the standard understanding. We have performed an unprecedentedly large simulation of the solar wind acceleration from the corona to the sufficiently distant region beyond the orbits (perihelions) of Parker Solar Probe. By imposing Alfvénic fluctuations from the bottom boundary, magnetic switchbacks that exhibit several observational properties are reproduced, meaning that the presence of magnetic switchback is not contradictory to the wave/turbulence-driven solar wind model. The appearance rate (filling factor) of switchback is, however, 100 times smaller than the observed value. We also directly compare our model with Parker Solar Probe observation. The simulated data show quite similar behavior to the observed data in the "quiet phase" in which the number of switchbacks is small. Our conclusion is that a part of magnetic switchbacks originates from large-amplitude Alfvén waves in the solar wind.

Keywords: solar wind, turbulence, Parker Solar Probe

Simulation study on the deformation of magnetic field in interplanetary CMEs

*Minami Mori[1], Daikou Shiota[2], Kanya Kusano[1]

1. Institute for Space-Earth Environmental Research, Nagoya University , 2. National Institute of Information and Communications Technology (NICT)

Coronal mass ejections (CMEs) are the largest eruption in the solar system. CMEs carry huge plasmas in the solar corona of 10^11 to 10^13 kg into interplanetary space at velocities of a few hundred - thousand km/s. CMEs can affect a variety of space weather conditions when they collide with the magnetosphere of the earth. In particular, the magnetic field of CMEs is a serious factor of space weather disturbance, because the southward component of the magnetic field in CMEs could cause the geomagnetic field storm. We developed a numerical simulation of CME propagation in the inner heliosphere using the magnetohydrodynamic (MHD) model, SUSANOO-CME (Shiota & Kataoka, 2016). In this model, the CME magnetic field is given by the distorted spheromak force-free field in which the orientation of the major axis and position of the spheromak is determined with free parameters. To make the simulation and its analysis simple, we assume that the major axis of the spheromak is on the equator plane of the Sun and direct westward. To clarify the interaction between the CME magnetic field and the solar wind motion, we assume that the background magnetic field of the solar wind is negligibly small, omitting the effect of the interplanetary magnetic field (IMF). We calculated the four different cases in which the toroidal and poloidal components of the spheromak magnetic field are respectively inverted. As the results of the simulations, we found that the toroidal and poloidal magnetic fluxes in the front torus of the spheromak shrink in the initial phase of the CME propagation when the CMEs keep fast speed. The results can be explained as the result that the magnetic fluxes in the front side of the spheromak are convected to the rear side of the CMEs by the interaction with the solar wind. It looks like the CME's internal magnetic structure is almost reversed along the propagation direction. After the initial phase, however, the magnetic structure of the interplanetary CMEs (ICMEs) is sustained during the propagation. The results suggest that the interaction with the solar wind may largely deform the ICME magnetic field mainly in the initial phase of propagation. Based on the simulations, we will discuss how the magnetic field of ICME can be deformed by the interactions with the solar wind and the IMF.

Keywords: MHD, CME, solar wind

Onset Mechanism of the Successive M-class Solar Flares in the Solar Active Region 12673 Based on a Nonlinear Force-Free Modeling

*Daiki Yamasaki[1], Satoshi Inoue[2], Takako T. Ishii[1], Ayumi Asai[1], Shin'ichi Nagata[1], Kiyoshi Ichimoto[1]

1. Astronomical Observatory, Kyoto University, 2. Institute for Space-Earth Environmental Research

Active region (AR) 12673 successively produced M5.5 and M4.2 flares, between 2017 September 4th 20:30UT and September 5th 01:30UT. On one hand, in both flares, the initial brightenings and the flare ribbons were observed in 1600 angstrom at the similar location. On the other hand, coronal mass ejection (CME) was only observed just after the peak time of the M5.5 flare. The purpose of this study is to answer the following questions; ” How the magnetic free energy of the M4.2 flare was build up in just 5 hours?” , ” Whether the onset mechanisms of these two flares were same or not?” , and ” Why only the M5.5 flare was accompanied with CME?” . According to the analyses of the photospheric magnetic field before the flares and the extreme-ultraviolet images during the flares, we found that the small-scale magnetic flux evolved at the polarity inversion line and the flare ribbons were observed outside of it. Thus, we suggest that the evolution of the small-scale magnetic flux played an important role in the rapid formation of the magnetic flux rope. We extrapolated the three-dimensional (3D) coronal magnetic field by using a nonlinear force-free field (NLFFF) extrapolation method before and after the time when the brightening on the small-scale magnetic flux was observed. As a result, we found that strongly twisted lines are formed compared to the NLFFF just after the M5.5 flare. Furthermore, we compared the 3D coronal magnetic field before the two flares. We found that, in both of the flares, the magnetic null point exists in the overlying field lines. We suggest that, in both cases, the null point reconnection would play an important role in the initiation of the flares. Eventually, we will discuss the generation mechanism of the CME in terms of a relationship between the flare-triggering process and global magnetic field covering the twisted magnetic field lines.

Keywords: Sun: flares, Sun: magnetic fields, Magnetohydrodynamics (MHD)

Data-driven MHD simulation of successive solar plasma eruptions

*Takafumi Kaneko[1], Sung-Hong Park[1], Kanya Kusano[1]

1. Institute for Space-Earth Environmental Research, Nagoya University

Solar flares and plasma eruptions are the origins of the strong space weather events. They are manifestations of sudden energy release in the solar magnetized atmosphere. To understand the physical mechanisms and predict their occurrences, three-dimensional magnetic fields from the photosphere up to the corona must be studied. The solar photospheric magnetic fields are observable, whereas the coronal magnetic fields cannot be measured. One method for inferring coronal magnetic fields is performing data-driven simulations, which involves time-series observational data of the photospheric magnetic fields with the bottom boundary of magnetohydrodynamic simulations. We developed a data-driven method in which temporal evolutions of the observational vector magnetic field can be reproduced at the bottom boundary in the simulation by introducing an inverted velocity field. This velocity field is obtained by inversely solving the induction equation and applying an appropriate gauge transformation. Using this method, we performed a data-driven simulation of successive small eruptions observed by the Solar Dynamics Observatory and the Solar Magnetic Activity Telescope in November 2017. The simulation well reproduced the converging motion between opposite-polarity magnetic patches, demonstrating successive formation and eruptions of helical flux ropes.

Keywords: solar filament/prominence, filament eruption, data-driven simulation

[E] Oral | P (Space and Planetary Sciences)：P-EM Solar-Terrestrial Sciences, Space Electromagnetism & Space Environment

Sat. Jun 5, 2021 9:00 AM - 10:30 AM JST | Sat. Jun 5, 2021 12:00 AM - 1:30 AM UTC | Ch.05 Zoom Room 05

[P-EM12] Dynamics of the Inner Magnetospheric System

convener:Kunihiro Keika(Department of Earth and Planetary Science, Graduate School of Science, The University of Tokyo), Yoshizumi Miyoshi(Institute for Space-Earth Environmental Research, Nagoya University), W Lauren Blum(University of Colorado Boulder), Yuri Shprits(Helmholtz Centre Potsdam GFZ German Research Centre for Geosciences), Chairperson:Lauren W Blum(University of Colorado Boulder), Kunihiro Keika(Department of Earth and Planetary Science, Graduate School of Science, The University of Tokyo)

The inner magnetosphere is highly variable because dynamical variations of incoming energy from the solar wind, magnetospheric tail, and the ionosphere. Cross-regional, cross-scale, and cross-energy couplings are the key processes for understanding this dynamical system. Coordinated observations by multi-satellites and ground-based observations are very essential to revealing these processes. In the 24th and 25th solar cycles, a number of satellites such as Van Allen Probes, MMS, THEMIS, DSX and Arase; coordinated ground-based observations (THEMIS-GBO, SuperDARN, EISCAT, magnetometers, riometer, etc); and numerical simulations (global kinetic model, MHD model, micro PIC, hybrid simulations) have successfully investigated the inner magnetosphere system. We invite papers on recent results of the inner magnetosphere and/or its coupling with the other regions including the ionosphere and the outer magnetosphere. Presentations on new projects such as sounding rocket experiments and data assimilation/machine learning are also welcome.

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

[PEM12-01] Introduction

9:05 AM - 9:30 AM JST | 12:05 AM - 12:30 AM UTC

[PEM12-02] Convection in the Inner Magnetosphere: Effects on Plasmasphere and Ring Current

★Invited Papers

*Jerry Goldstein[1,4], B. R. Sandel[2], D. J. McComas[3], P. W. Valek[1], J. Redfern[1] (1.Southwest Research Institute, 2.The University of Arizona, 3.Princeton University, 4.University of Texas at San Antonio)

9:30 AM - 9:55 AM JST | 12:30 AM - 12:55 AM UTC

[PEM12-03] Changing Composition of the Ring Current Source Region During Storm Main Phase

★Invited Papers

*Lynn M Kistler[1,2], Christopher G Mouikis[1], Kazushi Asamura[3], Satoshi Kasahara[4], Yoshizumi Miyoshi[2], Kunihiro Keika[4], Steven M Petrinec[5], Tomoaki Hori[2], Shoichiro Yokota[6], Iku Shinohara[3] (1.University of New Hampshire Main Campus, 2.Institute for Space-Earth Environmental Research, Nagoya University, 3.JAXA, 4.Graduate School of Science, University of Tokyo, 5.Lockheed-Palo Alto, 6.Graduate School of Science, Osaka University)

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

[PEM12-04] Multisatellite observations of field-aligned low-energy O^+ ion flux enhancements in the inner magnetosphere: September 22, 2018, Event

*Masahito Nose[1], Ayako Matsuoka[2], Yoshizumi Miyoshi[1], Kazushi Asamura[3], Mariko Teramoto[4], Iku Shinohara[3], Masafumi Hirahara[1], C. A. Kletzing[5], C. W. Smith[6], R. J. MacDowall[7], H. E. Spence[6], G. D. Reeves[8] (1.Institute for Space-Earth Environmental Research, Nagoya University, 2.Graduate School of Science, Kyoto University, 3.Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency, 4.Department of Space Systems Engineering, Kyushu Institute of Technology, 5.Department of Physics and Astronomy, University of Iowa, 6.Institute for the Study of Earth, Oceans, and Space, University of New Hampshire, 7.Solar System Exploration Division, Goddard Space Flight Center, 8.Space Sciences and Applications Group, Los Alamos National Laboratory)

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

[PEM12-05] Deflection of upflowing ion beams by a converging electric field in the auroral flux tube: Alternative explanation for mass-dependent beam width

★Invited Papers

*Shun Imajo[1], Yoshizumi Miyoshi[1], Kazushi Asamura[2], Iku Shinohara[2], Masahito Nose[1], Yoshiya Kasahara[3], Yasumasa Kasaba[4], Ayako Matsuoka[5], Tomoaki Hori[1], Masafumi Shoji[1], Satoko Nakamura[1], Mariko Teramoto[6] (1.Nagoya University, 2.Institute of Space and Astronautical Science, 3.Kanazawa University, 4.Tohoku University, 5.Kyoto University, 6.Kyushu Institute of Technology)

[E] Oral | P (Space and Planetary Sciences) | P-EM Solar-Terrestrial Sciences, Space Electromagnetism & Space Environment

[P-EM12] Dynamics of the Inner Magnetospheric System

convener:Kunihiro Keika(Department of Earth and Planetary Science, Graduate School of Science, The University of Tokyo), Yoshizumi Miyoshi(Institute for Space-Earth Environmental Research, Nagoya University), W Lauren Blum(University of Colorado Boulder), Yuri Shprits(Helmholtz Centre Potsdam GFZ German Research Centre for Geosciences), Chairperson:Lauren W Blum(University of Colorado Boulder), Kunihiro Keika(Department of Earth and Planetary Science, Graduate School of Science, The University of Tokyo)

Sat. Jun 5, 2021 9:00 AM - 10:30 AM Ch.05 (Zoom Room 05)

The inner magnetosphere is highly variable because dynamical variations of incoming energy from the solar wind, magnetospheric tail, and the ionosphere. Cross-regional, cross-scale, and cross-energy couplings are the key processes for understanding this dynamical system. Coordinated observations by multi-satellites and ground-based observations are very essential to revealing these processes. In the 24th and 25th solar cycles, a number of satellites such as Van Allen Probes, MMS, THEMIS, DSX and Arase; coordinated ground-based observations (THEMIS-GBO, SuperDARN, EISCAT, magnetometers, riometer, etc); and numerical simulations (global kinetic model, MHD model, micro PIC, hybrid simulations) have successfully investigated the inner magnetosphere system. We invite papers on recent results of the inner magnetosphere and/or its coupling with the other regions including the ionosphere and the outer magnetosphere. Presentations on new projects such as sounding rocket experiments and data assimilation/machine learning are also welcome.

9:00 AM - 9:05 AM

[PEM12-01]Introduction

Convection in the Inner Magnetosphere: Effects on Plasmasphere and Ring Current

*Jerry Goldstein[1,4], B. R. Sandel[2], D. J. McComas[3], P. W. Valek[1], J. Redfern[1]

1. Southwest Research Institute, 2. The University of Arizona, 3. Princeton University, 4. University of Texas at San Antonio

We present two key elements of the effects of inner magnetospheric convection.

The first element is plasmaspheric erosion, a fundamental element of the dynamic magnetospheric response to solar wind driving. We use extreme ultraviolet (EUV) images from the Imager for Magnetopause-to-Aurora Global Exploration (IMAGE) mission to examine the relative timing of dayside and nightside plasmapause motion following southward interplanetary magnetic field turnings. For two case studies we find the delay between the dayside and nightside plasmapause response is less than the 10 min temporal resolution of IMAGE EUV, and the time-averaged plasmapause electric (E) field is 9% to 10% of the solar wind E-field. This first result yields important observational constraints on the day-to-night magnetospheric propagation of solar wind energy.

The second element of convection's effects is ring current intensification, widely considered a defining aspect of storms. We use a large database of energetic neutral atom (ENA) images from Two Wide-angle Imaging Neutral-atom Spectrometers (TWINS) to examine the statistical response of the ring current to solar wind driving. The database comprises 61 events, including 1838 maps of TWINS-derived equatorial ion flux. We find a strong correlation between solar wind E-field and ring current flux intensification: correlation coefficients are [0.95, 0.94, 0.88] at [1, 16, 30] keV. The strongest solar wind driven convection preferentially increases the least energetic ions. Lower-energy ions are increased farther eastward and higher-energy ions closer to midnight. Enhanced RC ion flux occurs or peaks (on average) at higher L-shells for strong solar wind pressure than for strong convection. This second result confirms and quantifies the high geoeffectiveness of convection.

Keywords: inner magnetosphere, convection, plasmasphere, ring current, erosion, storms

Changing Composition of the Ring Current Source Region During Storm Main Phase

*Lynn M Kistler[1,2], Christopher G Mouikis[1], Kazushi Asamura[3], Satoshi Kasahara[4], Yoshizumi Miyoshi[2], Kunihiro Keika[4], Steven M Petrinec[5], Tomoaki Hori[2], Shoichiro Yokota[6], Iku Shinohara[3]

1. University of New Hampshire Main Campus, 2. Institute for Space-Earth Environmental Research, Nagoya University, 3. JAXA, 4. Graduate School of Science, University of Tokyo, 5. Lockheed-Palo Alto, 6. Graduate School of Science, Osaka University

The ionospheric and solar wind contributions to the magnetosphere can be distinguished by their composition. While both sources contain significant H+, the heavy ion species from the ionospheric source are generally singly ionized, while the solar wind consists of highly ionized ions. Both the solar wind and the ionosphere contribute to the plasma sheet. It has been shown that with both enhanced geomagnetic activity and enhanced solar EUV, the ionospheric contribution, and particularly the ionospheric heavy ions contribution increases. However, the details of this transition from a solar wind dominated to more ionospheric dominated plasma sheet are not well understood. An initial study using AMPTE/CHEM data, a data set that includes the full charge state distributions of the major species, shows that the transition can occur quite sharply during storms, with the ionospheric contribution becoming dominant during the storm main phase. However, during the AMPTE time-period, there were no continuous measurements of the upstream solar wind, and so both the simultaneous solar wind composition and the driving solar wind and IMF parameters were not known. The HPCA instrument on MMS and both the LEPi and MEPi instruments on Arase are able to measure He++. With these data sets, the He++/H+ ratio can be compared to the simultaneous He++/H+ ratios in the solar wind to more definitively identify the solar wind contribution to the plasma sheet. This allows the ionospheric contribution to the H+ population to be determined, so that the full ionospheric population is known. We find that when the IMF turns southward during the storm main phase, the dominant source of the hot plasma sheet becomes ionospheric. This composition change explains why the storm time ring current also has a high ionospheric contribution.

Keywords: Ring Current, Ionospheric Source, Ion Composition, Plasma Sheet

Multisatellite observations of field-aligned low-energy O^+ ion flux enhancements in the inner magnetosphere: September 22, 2018, Event

*Masahito Nose[1], Ayako Matsuoka[2], Yoshizumi Miyoshi[1], Kazushi Asamura[3], Mariko Teramoto[4], Iku Shinohara[3], Masafumi Hirahara[1], C. A. Kletzing[5], C. W. Smith[6], R. J. MacDowall[7], H. E. Spence[6], G. D. Reeves[8]

1. Institute for Space-Earth Environmental Research, Nagoya University, 2. Graduate School of Science, Kyoto University, 3. Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency, 4. Department of Space Systems Engineering, Kyushu Institute of Technology, 5. Department of Physics and Astronomy, University of Iowa, 6. Institute for the Study of Earth, Oceans, and Space, University of New Hampshire, 7. Solar System Exploration Division, Goddard Space Flight Center, 8. Space Sciences and Applications Group, Los Alamos National Laboratory

Recent studies employing the Arase and Van Allen Probes satellites [Chaston et al., 2015; Kistler et al., 2016; Nosé et al., 2016, 2018; Gkioulidou et al., 2019] have shown that unidirectional/bidirectional energy-dispersed O^+ flux appears a few minutes after substorms in the inner magnetosphere and lasts for ~10 min with a decrease in its energy from ~5 keV to 10–100 eV. Nosé et al. [2016] found that the unidirectional energy-dispersed O^+ flux is observed in 80% of the total events and that its direction is parallel (antiparallel) to the magnetic field when the satellites are located below (above) the geomagnetic equator. This strongly implies that these O^+ ions are extracted from the ionosphere at the onset of substorms and flow along the magnetic field toward the geomagnetic equator. Low-energy O^+ ions may be scattered near the geomagnetic equator and remain there, although the scattering mechanism is yet unknown. They may contribute to the O^+ content of the inner magnetospheric plasma such as the warm plasma cloak and the oxygen torus, and the resultant increase in the O^+ density may provide a precondition for the O^+-rich ring current.
In the present study, we examine the low-energy O^+ ion flux variations simultaneously observed by multiple satellites, Arase, Van Allen Probe A and B satellite, on September 22, 2018. The O^+ fluxes are enhanced after a substorm onset at 05:24 UT, at which three satellites are located in the nightside inner magnetosphere (Arase at MLT=0.3 hr, L=6.2, GMLAT=−9.6°; Probe A at MLT=0.7 hr, L=5.5, GMLAT=14.7°; Probe B at MLT=0.0 hr, L=5.3, GMLAT=10.6°). Arase observes O^+ flux enhancements only in the parallel direction to the magnetic field in the energy range from a few keV to 200 eV. Probe A and B, however, identify O^+ flux enhancements in both parallel and antiparallel directions at 1 keV to 10 eV. The antiparallel fluxes appear earlier than the parallel fluxes. Multiband flux enhancements are detected only by Probe A. We perform numerical calculation of O^+ ion trajectories to reproduce the observed E-t spectorgrams at three satellites. In the presentation, we will show results of data analysis and numerical simulation in more detail, and discuss the contribution of the low-energy O^+ ion flux enhancements to the O^+ content of the inner magnetospheric plasma.

Keywords: field-aligned low-energy O+ ion flux enhancements, inner magnetosphere, warm plasma cloak, oxygen torus

Deflection of upflowing ion beams by a converging electric field in the auroral flux tube: Alternative explanation for mass-dependent beam width

*Shun Imajo[1], Yoshizumi Miyoshi[1], Kazushi Asamura[2], Iku Shinohara[2], Masahito Nose[1], Yoshiya Kasahara[3], Yasumasa Kasaba[4], Ayako Matsuoka[5], Tomoaki Hori[1], Masafumi Shoji[1], Satoko Nakamura[1], Mariko Teramoto[6]

1. Nagoya University, 2. Institute of Space and Astronautical Science, 3. Kanazawa University, 4. Tohoku University, 5. Kyoto University, 6. Kyushu Institute of Technology

The pitch angle distribution of O^+ upflowing ion beams wider than that of H^+ beams has often been explained by mass-dependent perpendicular heating. Contrary to this conventional explanation, here we show that the mass-dependent pitch angle distribution of the ion beams can arise from a deflection of ion beams by a converging electric field in the auroral flux tube. On May 20, 2017, the Arase (ERG) satellite at ~32,000 km altitude and 1.1 h magnetic local time observed two consecutive ion beam events associated with an inverted-V shape spectrum in an energy range of ~1–8 keV. Magnetic and electric field variations during the ion beams corresponded to a relative equatorward motion of upward-field aligned current and converging perpendicular electric field, respectively, in the flux tube above the auroral acceleration region. Examining the gyro-phase distribution of the beam component, we found that the ion beams were significantly deflected in an east-west direction. The direction of ion flux was reversed from westward to eastward at the same time concurrently with the electric field reversal from outward to inward, indicating the ExB drift by the converging electric field causes this beam deflection. The difference of beam width between H^+ and O^+ tended to be large when the magnitude of the electric field was large. The field-aligned velocity of the H^+ beams is ~4 times higher than that of the O^+ beams, while the perpendicular beam velocity is consistent with the ExB drift. Because of the slower field-aligned velocity of O^+ beams, they are more easily deflected by the ExB drift compared with the light ions like H^+. This non-negligible perpendicular drift can result in an overestimation of beam width when it is estimated from a pitch angle distribution averaged over the entire gyro phase in a satellite-centered coordinate system.

Keywords: upflowing ion beam, auroral accelaration region, electric drift, mass-dependent characteristics

[E] Oral | P (Space and Planetary Sciences)：P-EM Solar-Terrestrial Sciences, Space Electromagnetism & Space Environment

Sat. Jun 5, 2021 10:45 AM - 12:10 PM JST | Sat. Jun 5, 2021 1:45 AM - 3:10 AM UTC | Ch.05 Zoom Room 05

[P-EM12] Dynamics of the Inner Magnetospheric System

convener:Kunihiro Keika(Department of Earth and Planetary Science, Graduate School of Science, The University of Tokyo), Yoshizumi Miyoshi(Institute for Space-Earth Environmental Research, Nagoya University), W Lauren Blum(University of Colorado Boulder), Yuri Shprits(Helmholtz Centre Potsdam GFZ German Research Centre for Geosciences), Chairperson:Kazuhiro Yamamoto(Graduate School of Science, The University of Tokyo)

The inner magnetosphere is highly variable because dynamical variations of incoming energy from the solar wind, magnetospheric tail, and the ionosphere. Cross-regional, cross-scale, and cross-energy couplings are the key processes for understanding this dynamical system. Coordinated observations by multi-satellites and ground-based observations are very essential to revealing these processes. In the 24th and 25th solar cycles, a number of satellites such as Van Allen Probes, MMS, THEMIS, DSX and Arase; coordinated ground-based observations (THEMIS-GBO, SuperDARN, EISCAT, magnetometers, riometer, etc); and numerical simulations (global kinetic model, MHD model, micro PIC, hybrid simulations) have successfully investigated the inner magnetosphere system. We invite papers on recent results of the inner magnetosphere and/or its coupling with the other regions including the ionosphere and the outer magnetosphere. Presentations on new projects such as sounding rocket experiments and data assimilation/machine learning are also welcome.

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

[PEM12-06] **Ion dynamics in the inner magnetosphere during Van Allen Probe Era**

★Invited Papers

*Chao Yue[1] (1.Peking University)

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

[PEM12-07] Multipoint measurements to understand the drivers and structure of EMIC waves in the inner magnetosphere

*Lauren W Blum[1] (1.University of Colorado Boulder)

11:20 AM - 11:35 AM JST | 2:20 AM - 2:35 AM UTC

[PEM12-08] Particles simulations of whistler-mode triggered emissions with subpacket structures

Takeshi Nogi[1], *Yoshiharu Omura[1] (1.Reserach Institute for Sustainable Humanosphere, Kyoto University)

11:35 AM - 11:55 AM JST | 2:35 AM - 2:55 AM UTC

[PEM12-09] Nonlinear wave-particles interaction in radiation belts: how can we include it to global models?

★Invited Papers

*Anton Artemyev[1,2], Anatoly Neishtadt[2,3], Alexei Vasiliev[2], Xiao-Jia Zhang[1], Didier Mourenas[4], Dmitri Vainchtein[5,2] (1.Institute of Geophysics and Planetary Physics, UCLA, Los Angeles, California 90095, USA, 2.Space Research Institute of the Russian Academy of Sciences (IKI), 84/32 Profsoyuznaya Str., Moscow 117997, Russia, 3.Department of Mathematical Sciences, Loughborough University, Loughborough LE11 3TU, United Kingdom, 4.Laboratoire Mati`ere sous Conditions Extremes, Paris-Saclay University, CEA, Bruy`eres-le-Chatel, France, 5.Nyheim Plasma Institute, Drexel University, Camden, NJ, USA)

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

[PEM12-10] Modeling of outer radiation belt electron dynamics associated with whistler mode chorus emissions via Green's function method

*Yikai Hsieh[1], Yoshiharu Omura[1] (1.Reserach Institute for Sustainable Humanosphere, Kyoto University)

Ion dynamics in the inner magnetosphere during Van Allen Probe Era

*Chao Yue[1]

1. Peking University

Ion dynamics are controlled by the energy-dependent source, transport, energization, and loss processes. Systematic changes in the ion dynamics are essential to understand the ring current variations in the inner magnetosphere. The Van Allen Probes mission, which orbits near the equatorial plane inside the geosynchronous orbit, has a wide energy coverage with high energy resolution and state-of-the-art ion composition instrumentation. It provides a great opportunity to investigate the ion dynamics. In this talk, I will present some of our recent studies on the ion dynamics of different populations and species during geomagnetic quiet and active times.

Keywords: ion dynamics, ion composition , plasma waves

Multipoint measurements to understand the drivers and structure of EMIC waves in the inner magnetosphere

*Lauren W Blum[1]

1. University of Colorado Boulder

Wave-particle interactions provide a primary source of scattering and energization of energetic electrons in the Earth’s radiation belts. Electromagnetic ion cyclotron (EMIC) waves are one intense wave mode observed in the inner magnetosphere that have been shown to contribute to scattering and loss of both energetic electrons and ions. Using multi-point measurements from the Heliospheric Systems Observatory, including NASA’s Van Allen Probes, we examine the properties and source regions of EMIC waves in the inner magnetosphere, exploring the formation and evolution of plasma structures as they relate to observed wave growth. We also investigate the effects of this wave structure on energetic electrons in the outer radiation belt. These studies aid in the understanding of outer radiation belt dynamics and the relationship between electromagnetic waves, global magnetospheric conditions, and solar wind drivers.

Keywords: EMIC waves, inner magnetosphere, radiation belt

Particles simulations of whistler-mode triggered emissions with subpacket structures

Takeshi Nogi[1], *Yoshiharu Omura[1]

1. Reserach Institute for Sustainable Humanosphere, Kyoto University

We perform one-dimensional simulations[1] of whistler-mode triggered emissions to study nonlinear signatures of rising-tone emissions. We assume a parabolic magnetic field and energetic electrons with temperature anisotropy. We oscillate currents with a fixed frequency, 0.3 of electron cyclotron frequency, at the magnetic equator to inject finite amplitude whistler-mode waves. We observe rising-tone triggered emissions with sub-packet structures from 0.3 to 0.75 of electron cyclotron frequency. We find a clear separation of triggered emissions from the triggering waves. The first triggered wave packet is formed with growing wave amplitude and smooth rising-tone frequency over the frequency range 0.3-0.5 of electron cyclotron frequency. The electron hole initially formed at the equator expands spatially to the upstream region. The formation of electron holes takes place in the spatial range with the inhomogeneity factor |S| less than 1. When the frequency approaches to 0.5fce, we find some density modulation of the untrapped resonant particles around the electron holes. The modulation causes oscillations of resonant currents with a frequency of the same order of trapping frequencies, resulting in the generation of sub-packet structures.

[1] Nogi, T., Nakamura, S., & Omura, Y. (2020). Full particle simulation of whistler-mode triggered falling-tone emissions in the magnetosphere. Journal of Geophysical Research: Space Physics, 125, e2020JA027953, https://doi.org/10.1029/2020JA027953.

Keywords: wave-particle interaction, whistler-mode wave, nonlinear process

Nonlinear wave-particles interaction in radiation belts: how can we include it to global models?

*Anton Artemyev[1,2], Anatoly Neishtadt[2,3], Alexei Vasiliev[2], Xiao-Jia Zhang[1], Didier Mourenas[4], Dmitri Vainchtein[5,2]

1. Institute of Geophysics and Planetary Physics, UCLA, Los Angeles, California 90095, USA, 2. Space Research Institute of the Russian Academy of Sciences (IKI), 84/32 Profsoyuznaya Str., Moscow 117997, Russia, 3. Department of Mathematical Sciences, Loughborough University, Loughborough LE11 3TU, United Kingdom, 4. Laboratoire Mati`ere sous Conditions Extremes, Paris-Saclay University, CEA, Bruy`eres-le-Chatel, France, 5. Nyheim Plasma Institute, Drexel University, Camden, NJ, USA

The resonant wave-particle interaction is known to be one of the main drivers of dynamics of energetic electron fluxes in the Earth’s radiation belts. The quasi-linear diffusion theory describes a sufficiently weak resonant scattering in energy/pitch-angle space and operates with a Fokker-Planck diffusion equation for the charged particle distribution function. In contrast to this description, the nonlinear resonant interact includes effects of phase trapping that assumes a fast transport in energy/pitch-angle space, when even a single resonant interaction changes significantly the electron's energy/pitch-angle. This essentially non-diffusive process cannot be directly included into the Fokker-Planck equation. This presentation reviews recent results for the mapping approach for a system with nonlinear resonant interaction. The main advances of this approach are the possibility to consider effects of many nonlinear resonances and to simulate the evolution of the resonant particle ensemble on long time ranges. For illustrative purposes we consider the system with resonant relativistic electrons and whistler-mode waves.

Keywords: radiation belts, wave-particle interaction, nonlinear resonances

Modeling of outer radiation belt electron dynamics associated with whistler mode chorus emissions via Green’ s function method

*Yikai Hsieh[1], Yoshiharu Omura[1]

1. Reserach Institute for Sustainable Humanosphere, Kyoto University

Energetic electron accelerations and precipitations in the Earth’ s outer radiation belt are highly associated with wave-particle interactions between whistler mode chorus waves and electrons. Two main processes take place in the whistler mode wave-particle interactions. One is the untrapped resonance process, which makes electron energy slightly smaller and lowers the equatorial pitch angle of the electron. The other is the nonlinear trapping process, which makes effective energy gain of the resonant electrons. We perform test particle simulation in a 3D dipole field to reproduce the interactions in the radiation belt and investigate the electron acceleration and precipitation interacting with both parallel and obliquely propagating chorus emissions. We build up a database of Green’ s functions, which are treated as results of the input electrons interacting with one emission, for a large number of electrons interacting with whistler mode chorus emissions. The formation processes and the loss processes of the outer radiation belt electron fluxes interacting with consecutive chorus emissions are traced by applying the convolution integrals for the Green’ s functions. In the acceleration parts, MeV electrons are generated promptly due to the combination of cyclotron resonance and Landau resonance of oblique chorus waves. We compare the precipitation phenomena between parallel waves and oblique waves, and the results show that oblique chorus emissions lead to more electron precipitation than that led by parallel chorus emissions. Since the precipitations by chorus emissions are much less than the accelerations, in this study we further take energetic electron precipitations by EMIC waves into account to simulate the overall acceleration and loss processes in the outer radiation belt.

Keywords: outer radiation belt, whistler mode chorus emissions, Green's function, energetic electron precipitation, Landau resonance, cyclotron resonance

[E] Oral | P (Space and Planetary Sciences)：P-EM Solar-Terrestrial Sciences, Space Electromagnetism & Space Environment

Sat. Jun 5, 2021 1:45 PM - 3:15 PM JST | Sat. Jun 5, 2021 4:45 AM - 6:15 AM UTC | Ch.05 Zoom Room 05

[P-EM12] Dynamics of the Inner Magnetospheric System

convener:Kunihiro Keika(Department of Earth and Planetary Science, Graduate School of Science, The University of Tokyo), Yoshizumi Miyoshi(Institute for Space-Earth Environmental Research, Nagoya University), W Lauren Blum(University of Colorado Boulder), Yuri Shprits(Helmholtz Centre Potsdam GFZ German Research Centre for Geosciences), Chairperson:Yikai Hsieh(Reserach Institute for Sustainable Humanosphere, Kyoto University)

The inner magnetosphere is highly variable because dynamical variations of incoming energy from the solar wind, magnetospheric tail, and the ionosphere. Cross-regional, cross-scale, and cross-energy couplings are the key processes for understanding this dynamical system. Coordinated observations by multi-satellites and ground-based observations are very essential to revealing these processes. In the 24th and 25th solar cycles, a number of satellites such as Van Allen Probes, MMS, THEMIS, DSX and Arase; coordinated ground-based observations (THEMIS-GBO, SuperDARN, EISCAT, magnetometers, riometer, etc); and numerical simulations (global kinetic model, MHD model, micro PIC, hybrid simulations) have successfully investigated the inner magnetosphere system. We invite papers on recent results of the inner magnetosphere and/or its coupling with the other regions including the ionosphere and the outer magnetosphere. Presentations on new projects such as sounding rocket experiments and data assimilation/machine learning are also welcome.

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

[PEM12-11] **Statistical study on spatial distribution of plasma waves observed by PWE/OFA**

*Yoshiya Kasahara[1], Kengo Nakashima[1], Shoya Matsuda[2], Yoshizumi Miyoshi[3], Ayako Matsuoka[4], Jean-Francois Rippol[5], David M. Malaspina[6] (1.Kanazawa University, 2.ISAS/JAXA, 3.Nagoya University, 4.Kyoto University, 5.CEA/DAM/DIF, 6.University of Colorado Boulder)

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

[PEM12-12] Long period modulations of pulsating aurora and chorus waves

*Yoshizumi Miyoshi[1], Keisuke Hosokawa[2], Yasunobu Ogawa[3], Satoshi Kurita[4], Shin-ichiro Oyama[1], Mariko Teramoto[5], Shinji Saito[6], Yoshiya Kasahara[7], Shoya Matsuda[8], Satoshi Kasahara[9], Shoichiro Yokota[10], Kunihiro Keika[9], Tomoaki Hori[1], Fuminori Tsuchiya[11], Atsushi Kumamoto[11], Satoko Nakamura[1], Masahiro Kitahara[1], Masafumi Shoji[1], Ayako Matsuoka[4], Shun Imajo[1], Iku Shinohara[8] (1.Institute for Space-Earth Environmental Research, Nagoya University, 2.The University of Electro-Communications, 3.NIPR, 4.Kyoto University, 5.Kyushu Inst. of Technology, 6.NICT, 7.Kanazawa University, 8.JAXA, 9.University of Tokyo, 10.Osaka University, 11.Tohoku University)

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

[PEM12-13] Whistler Driven Electron Precipitation Measured by ELFIN CubeSat and Arase Spacecraft

*Xiaojia Zhang[1], Vassilis Angelopoulos[1], Anton V. Artemyev[1], Satoshi Kasahara[2], Colin Wilkins[1], Ethan Tsai[1], Shoichiro Yokota[3], Kunihiro Keika[2], Tomoaki Hori[4], Yoshizumi Miyoshi[4], Yoshiya Kasahara[5], Shoya Matsuda[6], Ayako Matsuoka[7], Mariko Teramoto[8], Shun Imajo[4], Iku Shinohara[9] (1.University of California Los Angeles, 2.The Univ. of Tokyo, 3.Osaka Univ., 4.Nagoya Univ., 5.Kanazawa Univ., 6.ISAS, 7.Kyoto Univ., 8.Kyushu Institute of Technology, 9.ISAS, JAXA)

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

[PEM12-14] A case study to estimate energy spectra of pulsating auroral electrons from cosmic noise absorption and auroral brightness

*Shin-ichiro Oyama[1,2], Miyamoto Taishiro[1,6], Tero Raita[3], Keisuke Hosokawa[4], Yoshizumi Miyoshi[1], Yasunobu Ogawa[2], Satoshi Kurita[5] (1.Institute for Space-Earth Environmental Research, Nagoya

University, 2.National Institute of Polar Research, 3.Sodankyla Geophysical Observatory, University of Oulu, 4.University of Electro-Communications, 5.Research Institute for Sustainable Humanosphere, Kyoto University, 6.Nippon Steel Corporation Nagoya Works)

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

[PEM12-15] Statistical characteristics of the magnetic field variations observed by Arase

*Ayako Matsuoka[1], Masahito Nose[2], Yoshizumi Miyoshi[2], Mariko Teramoto[4], Reiko Nomura[3], Akiko Fujimoto[5], Yoshimasa Tanaka[6], Manabu Shinohara[7], Satoshi Kurita[8], Shun Imajo[2], Iku Shinohara[3] (1.Data Analysis Center for Geomagnetism and Space Magnetism, Graduate School of Science, Kyoto University, 2.Institute for Space-Earth Environmental Research, Nagoya University, 3.Institute of Space and Astronautical Science, JAXA, 4.Graduate School of Engineering, Kyushu Institute of Technology, 5.Graduate School of Computer Science and Systems Engineering, Kyushu Institute of Technology, 6.National Institute of Polar Research, 7.National Institute of Technology Kagoshima College, 8.Research Institute for Sustainable Humanosphere, Kyoto University)

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

[PEM12-16] Mode-coupling Pi2 pulsations on the off-equatorial plasmapause inferred from the Arase satellite observation

*Mariko Teramoto[1], Ayako Matsuoka[2], Yoshiya Kasahara[3], Yasumasa Kasaba[4], Atsushi Kumamoto[4], Fuminori Tsuchiya[4], Shoya Matsuda[6], Yoshizumi Miyoshi[5], Masahito Nose[5], Tomoko Nakagawa[7], Shun Imajo[5], Masafumi Shoji[5], Satoko Nakamura[5], Iku Shinohara[6] (1.Kyushu Institute of Technology, 2.Kyoto University, 3.Kanazawa University, 4.Tohoku University, 5.Nagoya University, 6.Japan Aerospace Exploration Agency, Institute of Space and Astronautical Science, 7.Tohoku Institute of Technology)

Statistical study on spatial distribution of plasma waves observed by PWE/OFA

*Yoshiya Kasahara[1], Kengo Nakashima[1], Shoya Matsuda[2], Yoshizumi Miyoshi[3], Ayako Matsuoka[4], Jean-Francois Rippol[5], David M. Malaspina[6]

1. Kanazawa University, 2. ISAS/JAXA, 3. Nagoya University, 4. Kyoto University, 5. CEA/DAM/DIF, 6. University of Colorado Boulder

In the present paper, we investigated the spatial distribution of the power spectrum measured by the PWE/OFA (Plasma Wave Experiment/Onboard Frequency Analyzer) on board the Arase.

The OFA (onboard frequency analyzer) measures electric and magnetic wave spectra in the frequency range below 20 kHz continuously with a time resolution of 1 second as a nominal operation mode. This frequency range is crucial for plasma wave observation because chorus waves, magnetospheric hiss, lightning whistlers and magnetosonic waves are detected.

First, we compared our results with the previous statistical work done using the spectral data recorded by the Van Allen Probes (e.g. Malaspina et al., 2017), and confirmed that the results are almost consistent with those derived from the observation by Van Allen Probes at low latitudes. Next we examined the spatial distribution of the wave activities in the off-equatorial region. Because the inclination of the Arase is 31 degrees, which is much larger than that of Van Allen Probes (~10 degrees), this orbital configuration provides the ability to explore not only the equatorial region but also the off-equatorial region in the inner magnetosphere.
In the presentation, we report the global distributions of various plasma waves as a function of magnetic latitude, magnetic local time and L-value.

Keywords: Arase, plasma wave, Inner magnetosphere

Long period modulations of pulsating aurora and chorus waves

*Yoshizumi Miyoshi[1], Keisuke Hosokawa[2], Yasunobu Ogawa[3], Satoshi Kurita[4], Shin-ichiro Oyama [1], Mariko Teramoto[5], Shinji Saito[6], Yoshiya Kasahara[7], Shoya Matsuda[8], Satoshi Kasahara[9], Shoichiro Yokota[10], Kunihiro Keika[9], Tomoaki Hori[1], Fuminori Tsuchiya[11], Atsushi Kumamoto[11], Satoko Nakamura[1], Masahiro Kitahara[1], Masafumi Shoji[1], Ayako Matsuoka[4], Shun Imajo[1], Iku Shinohara[8]

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Pulsating aurora (PsA) is primarily caused by intermittent precipitation of tens of keV electrons by the magnetospheric chorus waves. Variations of different time scales have been known to exist in the optical emission amplitude of PsA: the main pulsations of PsA with a few seconds are caused by chorus bursts and internal modulations of PsA within 1 second are caused by chorus short-lived elements composing the bursts. Here, we report chorus bundles that appear every a few tens of seconds as observed by Arase/PWE observations. Each chorus bundle includes several chorus bursts. In association with chorus bundles in the magnetosphere, we observed temporal variations in a series of the main pulsation of PsA using ground based EMCCD cameras. During the period of chorus bundles, continuous activities of main pulsations were observed. Concurrently, enhancements in the temperature anisotropy of tens of keV electrons as well as ULF pulsations were observed by Arase/MEPe and MGF, respectively. In this presentation, we report fundamental characteristics of chorus bundles and the corresponding signatures of PsA and discuss possible mechanisms to cause the long period modulations in order to fully understand the hierarchical temporal variation of PsA.

Keywords: Arase, chorus, pulsating aurora

Whistler Driven Electron Precipitation Measured by ELFIN CubeSat and Arase Spacecraft

*Xiaojia Zhang[1], Vassilis Angelopoulos[1], Anton V. Artemyev[1], Satoshi Kasahara[2], Colin Wilkins[1], Ethan Tsai[1], Shoichiro Yokota[3], Kunihiro Keika[2], Tomoaki Hori[4], Yoshizumi Miyoshi[4], Yoshiya Kasahara[5], Shoya Matsuda[6], Ayako Matsuoka[7], Mariko Teramoto[8], Shun Imajo[4], Iku Shinohara[9]

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Resonant interaction with whistler mode waves is the primary driver for electron acceleration and precipitation in Earth's radiation belts. Although scattering rates and the resonant scattering process over long timescales can be well explained by quasi-linear theory, microphysics of electron resonant interaction with coherent, intense whistlers is still poorly understood. One important limitation is that most available observations lack direct measurements of electron fluxes within the loss cone, i.e., direct measurements of scattered electrons. High-energy (>50keV) electron flux measurements within the loss cone, as provided by the new low-altitude ELFIN CubeSats, can significantly advance our understanding of the scattering mechanism and their efficiency. In this presentation, we analyze ELFIN measurements in conjunction with near-equatorial Arase spacecraft. We focus on whistler-driven precipitation and discuss ELFIN measurements in different regimes of resonant electron scattering.

Keywords: Radiation Belts, Energetic Electron Precipitation, Whistler Mode Wave Scattering

A case study to estimate energy spectra of pulsating auroral electrons from cosmic noise absorption and auroral brightness

*Shin-ichiro Oyama[1,2], Miyamoto Taishiro[1,6], Tero Raita[3], Keisuke Hosokawa[4], Yoshizumi Miyoshi [1], Yasunobu Ogawa[2], Satoshi Kurita[5]

1. Institute for Space-Earth Environmental Research, Nagoya University, 2. National Institute of Polar Research, 3. Sodankyla Geophysical Observatory, University of Oulu, 4. University of Electro-Communications, 5. Research Institute for Sustainable Humanosphere, Kyoto University, 6. Nippon Steel Corporation Nagoya Works

This study focused on a pulsating aurora event associated with aurora morphological changes in Fennoscandia at early morning time on 7 March 2017. A high-speed sampling all-sky camera captured equatorward development of the pulsating auroral patch in association with a substorm centered at Greenland/North America region. Of particular interest of this event is interconnection between the auroral intensity and the cosmic noise absorption (CNA) derived from three riometers aligned meridionally in Finland (from north to south: Ivalo, Sodankylä and Rovaniemi). The analysis was made by dividing optical measurements into two oscillation components; longer and shorter than 40 s, that is, non-pulsating and pulsating auroral modulations. The interrelation showed linear correlation and change of the inclination would be interpreted as hardening or softening of the precipitating electron spectrum. In terms of the low-pass component, the inclination of the CNA-vs-intensity interrelation increased at the three riometer latitudes at the substorm recovery phase. On the other hand, in terms of the high-pass component, the inclination decreased at Rovaniemi (lower latitude) but stayed uniform at Sodankylä (higher latitude). These features suggest that the precipitating electron spectrum has softened in the low-pass or non-pulsating auroral component but the spectrum has hardened in the high-pass or pulsating auroral component at the lower side in latitudes of the auroral patch region. This study proposes a new application of the riometer-camera measurement to examination of the auroral particle precipitation.

Keywords: pulsating aurora, ionosphere, riometer

Statistical characteristics of the magnetic field variations observed by Arase

*Ayako Matsuoka[1], Masahito Nose[2], Yoshizumi Miyoshi[2], Mariko Teramoto[4], Reiko Nomura[3], Akiko Fujimoto[5], Yoshimasa Tanaka[6], Manabu Shinohara[7], Satoshi Kurita[8], Shun Imajo[2], Iku Shinohara[3]

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We are investigating the magnetic field variations in association with the relativistic electrons in the inner magnetosphere. The magnetospheric disturbance phenomena, e.g., dipolarization and bursty bulk flow from the night-side plasma sheet, are often accompanied by the broadband magnetic field variation. The variation between a few Hz and a few tens Hz has the potential for factor of the rapid increase of the relativistic electrons in the inner magnetosphere.
The magnetic field variations in those frequencies are measured by MGF, fluxgate magnetometer, onboard the Arase satellite. We have investigated the magnetic disturbance in the outer radiation belt; intensity, spatial distribution, occurrence probability and polarization are statistically analyzed. In the overview, large-amplitude magnetic variations often appear in accordance with the substorm and dipolarization phenomena in the pre-midnight sencor and the EMIC waves in the afternoon sector. The amplitude in the xy plane in the SM coordinate overwhelm and therefore indicate the transverse polarization characteristics. It should be examined in detail in the reference frame to the background field.
We are extending our study to the spectral characteristics associated with the local proton (and other ions) cyclotron frequency, dependence on the magnetic activity and solar-wind condition.

Keywords: magnetic field disturbance, radiation belt, inner magnetosphere

Mode-coupling Pi2 pulsations on the off-equatorial plasmapause inferred from the Arase satellite observation

*Mariko Teramoto[1], Ayako Matsuoka[2], Yoshiya Kasahara[3], Yasumasa Kasaba[4], Atsushi Kumamoto [4], Fuminori Tsuchiya[4], Shoya Matsuda[6], Yoshizumi Miyoshi[5], Masahito Nose[5], Tomoko Nakagawa [7], Shun Imajo[5], Masafumi Shoji[5], Satoko Nakamura[5], Iku Shinohara[6]

1. Kyushu Institute of Technology, 2. Kyoto University, 3. Kanazawa University, 4. Tohoku University, 5. Nagoya University, 6. Japan Aerospace Exploration Agency, Institute of Space and Astronautical Science, 7. Tohoku Institute of Technology

We investigated Pi2 pulsations in the electric and magnetic field and their relation to the ambient plasma density observed from the Arase satellite to explore the generation mechanism of low-latitude Pi2. At a geomagnetically quiet time, Pi2 pulsations were observed in all three components of the magnetic field and in the radial and azimuthal components of the electric field when the Arase satellite was located on the plasmapause off the equatorial plane (about 25 degrees Mlat) at midnight. The coherence and cross phase between the orthogonal electric and magnetic field components are high and approximately 90 degrees. The compressional component of the magnetic field has high coherence with the azimuthal component of the electric field. The cross phase properties indicate that the radial and field-aligned standing waves are excited on the plasmapause. These results confirm the mode coupling between the fast mode wave and Alfven waves in the plasmasphere, which was proposed by Takahashi et al. [2018].

We compared these Pi2 pulsations with those on the ground over a wide latitudinal and longitudinal range. Additionally, we discussed the generation mechanism of this event.

[E] Oral | P (Space and Planetary Sciences)：P-EM Solar-Terrestrial Sciences, Space Electromagnetism & Space Environment

Sat. Jun 5, 2021 3:30 PM - 5:00 PM JST | Sat. Jun 5, 2021 6:30 AM - 8:00 AM UTC | Ch.05 Zoom Room 05

[P-EM12] Dynamics of the Inner Magnetospheric System

convener:Kunihiro Keika(Department of Earth and Planetary Science, Graduate School of Science, The University of Tokyo), Yoshizumi Miyoshi(Institute for Space-Earth Environmental Research, Nagoya University), W Lauren Blum(University of Colorado Boulder), Yuri Shprits(Helmholtz Centre Potsdam GFZ German Research Centre for Geosciences), Chairperson:Kunihiro Keika(Department of Earth and Planetary Science, Graduate School of Science, The University of Tokyo)

The inner magnetosphere is highly variable because dynamical variations of incoming energy from the solar wind, magnetospheric tail, and the ionosphere. Cross-regional, cross-scale, and cross-energy couplings are the key processes for understanding this dynamical system. Coordinated observations by multi-satellites and ground-based observations are very essential to revealing these processes. In the 24th and 25th solar cycles, a number of satellites such as Van Allen Probes, MMS, THEMIS, DSX and Arase; coordinated ground-based observations (THEMIS-GBO, SuperDARN, EISCAT, magnetometers, riometer, etc); and numerical simulations (global kinetic model, MHD model, micro PIC, hybrid simulations) have successfully investigated the inner magnetosphere system. We invite papers on recent results of the inner magnetosphere and/or its coupling with the other regions including the ionosphere and the outer magnetosphere. Presentations on new projects such as sounding rocket experiments and data assimilation/machine learning are also welcome.

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

[PEM12-17] Controlling factors of the occurrence of multi-harmonic toroidal ULF waves: A statistical study of the Arase satellite observations

*Kazuhiro Yamamoto[1], Kanako Seki[1], Ayako Matsuoka[2], Shun Imajo[3], Mariko Teramoto[4], Yoshiya Kasahara[5], Atsushi Kumamoto[6], Fuminori Tsuchiya[6], Masafumi Shoji[3], Yoshizumi Miyoshi[3], Iku Shinohara[7] (1.Graduate School of Science, The University of Tokyo, 2.Graduate School of Science, Kyoto University, 3.Institute for Space-Earth Environmental Research, Nagoya University, 4.Kyushu Institute of Technology, 5.Graduate School of Natural Science and Technology, Kanazawa University, 6.Graduate School of Science, Tohoku University, 7.Japan Aerospace Exploration Agency)

3:45 PM - 4:08 PM JST | 6:45 AM - 7:08 AM UTC

[PEM12-18] Probing inner magnetosphere dynamics and radial transport via observations of electron flux oscillations

★Invited Papers

*Theodore E Sarris[1] (1.Democritus University of Thrace)

4:08 PM - 4:30 PM JST | 7:08 AM - 7:30 AM UTC

[PEM12-19] Radiation belt electron acceleration during periods of low plasma density

★Invited Papers

*Hayley J Allison[1], Yuri Y Shprits[1,2,3], Irina Zhelavskaya[1], Dedong Wang[1], Artem Smirnov[1,2] (1.Helmholtz Centre Potsdam GFZ German Research Centre for Geosciences, Potsdam, Germany, 2.University of Potsdam, Potsdam, Germany, 3.University of California, Los Angeles, CA, USA)

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

[PEM12-20] Parameterized Lifetime of Energetic Electrons due to Interactions with Chorus Waves

*Dedong Wang[1], Yuri Shprits[1,2,3] (1.Helmholtz Center Potsdam German Research Centre for Geosciences Potsdam, 2.University of Potsdam, 3.UCLA)

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

[PEM12-21] Statistical Comparisons of Spin-Averaged Electron Flux from ARASE and Van Allen Probes Instruments

*Matyas Szabo-Roberts[1,2], Yuri Shprits[1,2], Hayley J Allison[1], Artem Smirnov[1,2], Nikita Aseev[7], Ruggero Vasile[1], Yoshizumi Miyoshi[4], Takefumi Mitani[4,5,6], Nana Higashio[5], Satoshi Kasahara[3] (1.Helmholtz Centre Potsdam GFZ German Research Centre for Geosciences, 2.University of Potsdam, 3.Department of Earth and Planetary Science, School of Science, The University of Tokyo, 4.Nagoya University, 5.JAXA Japan Aerospace Exploration Agency, 6.ISAS Institute of Space and Aeronautical Science, 7.Huawei Technologies)

Controlling factors of the occurrence of multi-harmonic toroidal ULF waves: A statistical study of the Arase satellite observations

*Kazuhiro Yamamoto[1], Kanako Seki[1], Ayako Matsuoka[2], Shun Imajo[3], Mariko Teramoto[4], Yoshiya Kasahara[5], Atsushi Kumamoto[6], Fuminori Tsuchiya[6], Masafumi Shoji[3], Yoshizumi Miyoshi[3], Iku Shinohara[7]

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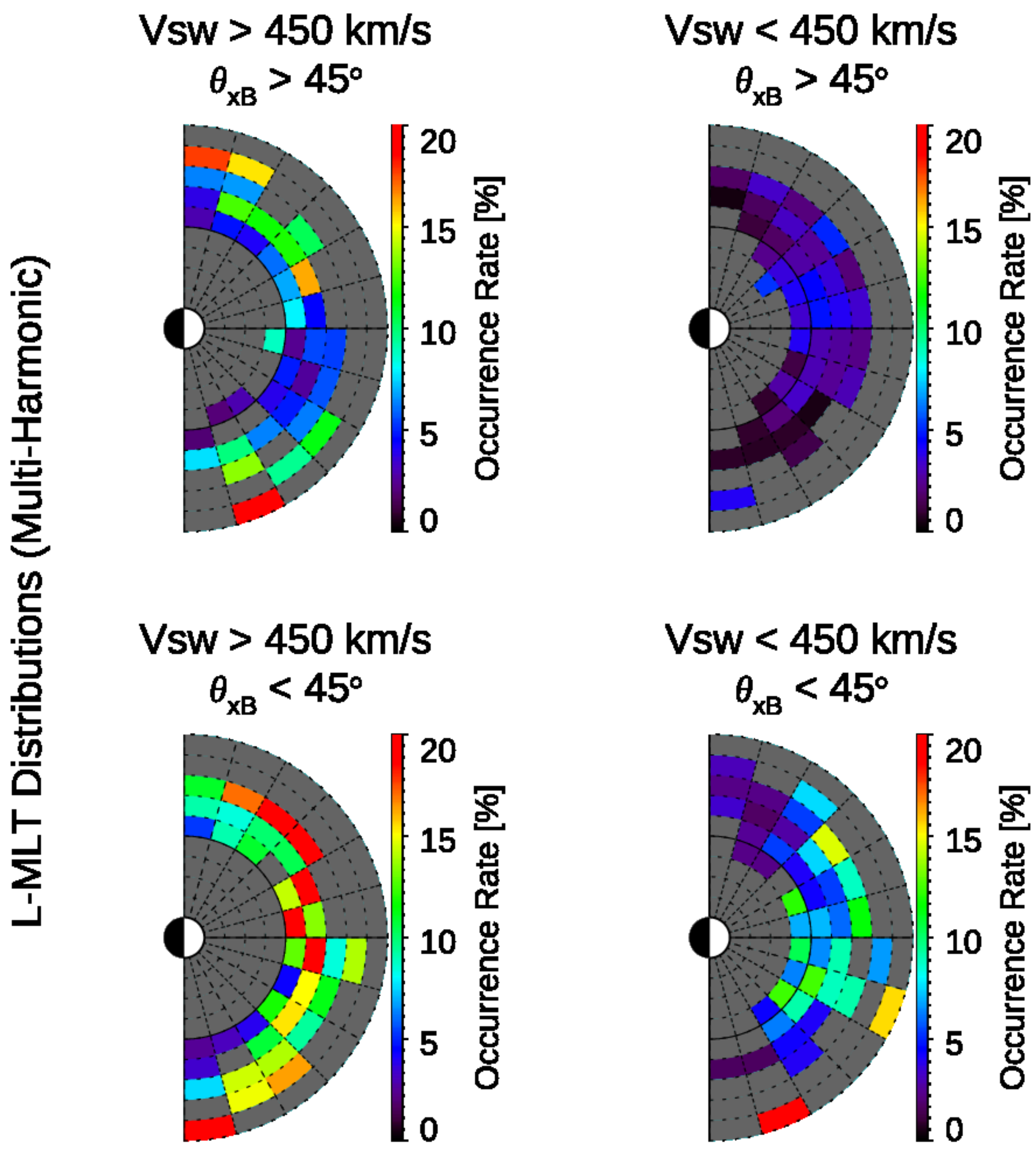
Ultralow frequency (ULF) waves can coherently or stochastically interact with charged particles through drift/drift-bounce resonance (e.g., Claudepierre et al., 2013; Schulz & Lanerotti, 1974). In the wave-particle interaction, wave frequency is one of the parameters which determine the energy where the interaction occurs. Because differences of frequency spectra may cause different results of wave-particle interaction, as numerically simulated by Sarris et al. (2017), ULF waves with a discrete frequency and those with broadband frequencies are investigated separately (e.g., Murphy et al., 2020). Therefore, classification of ULF waves according to their frequency spectra is important to accurately understand the wave-particle interaction.

Toroidal ULF waves with multiple discrete frequencies were also reported in event studies (e.g., Takahashi & McPherron, 1984; Engebretson et al., 1986; Takahashi et al., 2020). It was suggested that multi-harmonic toroidal waves (hereinafter MTWs) occur when the cone angle (θ_{xB}) of the solar wind is small; however, controlling factors of MTWs are not fully investigated. One of the difficulties in investigation of the relation between ULF waves and the solar wind is that solar wind parameters are correlated with each other and it is difficult to determine which one controls wave excitation. To circumvent this difficulty, we conducted statistical analysis of the occurrence of MTWs under four conditions for the first time: high/low speed solar wind (V_{SW} greater/less than 450 km/s) and large/small cone angle (θ_{xB} greater/less than 45°).

From the ULF wave observations by the Arase/Magnetic Field Experiment (MGF) instrument, we found that not only θ_{xB} but also V_{SW} is correlated with the occurrence of MTWs. MTWs are frequently observed around noon sector when the cone angle is small, while the occurrence frequency and wave amplitude of MTWs on the flank side increase as V_{SW} increases. This result suggests that both the upstream waves excited in the ion foreshock region and the Kelvin-Helmholtz (KH) instability at the magnetopause can be the energy sources of MTWs at each sectors in the magnetosphere. We also examined the influence of the plasmasphere on the occurrence of MTWs. The occurrence frequency dramatically increases as the cold electron density (N_e) increases. This is probably because the interval of eigenfrequencies of wave harmonics decreases with the increase of N_e, and field line resonance (FLR) at multiple harmonic frequencies may be caused by disturbances with a finite frequency band. Outside the plasmasphere (N_e < 50 cm^{-3}), the occurrence frequency of MTWs is relatively low, but the wave amplitudes are large on the flank side in the case of high speed solar wind. Thus, the plasmasphere has negative effect on the amplitudes of the waves driven by the KH instability. We further examined the relation between MTWs and fluctuation of the solar wind dynamic pressure (P_{dyn}), and revealed that P_{dyn} fluctuation can be the energy source of MTWs especially in the case of low speed solar wind. On the basis of our statistical analysis, V_{SW} , θ_{xB} and background plasma density are the principal controlling factors of the occurrence of MTWs, and

P_{dyn} fluctuation is categorized into the second group of the controlling factors.

Keywords: ULF waves, magnetosphere, solar wind, upstream waves, Kelvin-Helmholtz instability



Probing inner magnetosphere dynamics and radial transport via observations of electron flux oscillations

*Theodore E Sarris[1]

1. Democritus University of Thrace

Relativistic electrons in the inner magnetosphere undergo dynamical variations due to acceleration, transport, and loss processes under various physical mechanisms. One of the prevalent mechanisms is radial diffusion, caused by the resonant interaction between energetic electrons and ultra-low frequency (ULF) waves. We discuss how an indication of this resonant interaction is the appearance of periodic flux oscillations. These oscillations are observed in the form of drift-periodic flux fluctuations and have distinct characteristics from the more commonly observed drift echoes following storm- or substorm-related energetic particle injections. The amplitudes of such flux oscillations is dependent on a number of parameters, such as the local phase space density gradients, the amplitude of ULF waves and the width of electron energy channels. In particular, the latter is a critical parameter affecting the observed amplitude of flux oscillations, with narrower energy channel widths enabling the observation of higher-amplitude flux oscillations; this potentially explains why such features were not observed regularly before the Van Allen Probes era, as previous spacecraft generally had lower energy resolution. We present simulations and observations demonstrating the dependence of the observed flux oscillations on various parameters and we discuss how such flux oscillations could be used as indicators of radial transport rates.

Keywords: Radial transport, Electron flux oscillations, Phase space density, Radial diffusion

Radiation belt electron acceleration during periods of low plasma density

*Hayley J Allison[1], Yuri Y Shprits[1,2,3], Irina Zhelavskaya[1], Dedong Wang[1], Artem Smirnov[1,2]

1. Helmholtz Centre Potsdam GFZ German Research Centre for Geosciences, Potsdam, Germany, 2. University of Potsdam, Potsdam, Germany, 3. University of California, Los Angeles, CA, USA

Electrons in the Van Allen radiation belts can have energies in excess of 7 MeV. We present a unique way of analyzing phase space density data which demonstrates that local acceleration is capable of heating electrons up to 7 MeV. The Van Allen Probes mission not only provided unique measurements of ultra-relativistic radiation belt electrons, but also simultaneous observations of plasma waves that allowed for the routine inference of total plasma number density. Based on long-term observations, we show that the underlying plasma density has a controlling effect over local acceleration to ultra-relativistic energies, which occurs only when the plasma number density drops down to very low values (~10 cm^{-3}). The VERB-2D model is used to simulate ultra-relativistic electron acceleration during an event which exhibits an extreme cold plasma depletion. The results show that a reduced electron plasma density allows chorus waves to efficiently resonate with electrons up to ultra-relativistic energies, producing enhancements from 100s of keV up to >7 MeV via local diffusive acceleration. We analyse statistically the observed chorus wave power during ultra-relativistic enhancement events, considering the contribution from both upper and lower band chorus waves. The PINE density model allows for the investigation of global magnetospheric density changes. We analyze the how the global cold plasma density changes during ultra-relativistic enhancement events and compare to in-situ point measurements of the plasma density.

Keywords: chorus acceleration, Electron radiation belts, Plasma density, Ultra-relativistic electrons

Parameterized Lifetime of Energetic Electrons due to Interactions with Chorus Waves

*Dedong Wang[1], Yuri Shprits[1,2,3]

1. Helmholtz Center Potsdam German Research Centre for Geosciences Potsdam, 2. University of Potsdam, 3. UCLA

Chorus waves can cause the loss of energetic electrons in the Earth's radiation belts and ring current via pitch-angle diffusion. We calculated the bounce-averaged quasi-linear diffusion coefficients to quantify these processes. In this study, using these diffusion coefficients, we parameterize the lifetime of the electrons with energy range from 1 keV to 2 MeV. In each magnetic local time (MLT), we calculate the lifetime for each energy and L-shell using two different methods. By applying polynomial fits, we parameterize the electron life time as a function of L-shell and electron kinetic energy in each MLT. we derive the lifetime parameterization as a function of geomagnetic activity (Kp index), L, magnetic local time (MLT) and energy of electrons. The parameterized electron lifetimes show a strong functional dependence on Kp, L-shell and electron energy. During the storm time, the lifetimes for higher energy (> 100 keV) electrons range from hours to days in the heart of the radiation belts. In contrast, the lifetimes for electrons with lower energy (< 100 keV) range from minutes to hours. This parameterization of electron lifetime is convenient for inclusion in simulations in the inner magnetosphere.

Keywords: radiation belt electrons, lifetime, chorus waves

Statistical Comparisons of Spin-Averaged Electron Flux from ARASE and Van Allen Probes Instruments

*Matyas Szabo-Roberts[1,2], Yuri Shprits[1,2], Hayley J Allison[1], Artem Smirnov[1,2], Nikita Aseev[7], Ruggero Vasile[1], Yoshizumi Miyoshi[4], Takefumi Mitani[4,5,6], Nana Higashio[5], Satoshi Kasahara[3]

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Following the end of the Van Allen Probes mission, the ARASE satellite offers a unique opportunity to continue in-situ radiation belt particle measurements into the next solar cycle. In this study we compare spin-averaged flux measurements from the MEPe, HEP-L, HEP-H, and XEP-SSD instruments on ARASE with those from the MagEIS and REPT instruments on the Van Allen Probes, calculating Pearson R and the mean ratio of fluxes at L* conjunctions between the spacecraft. ARASE and Van Allen Probes measurements show a close agreement over a wide range of energies, observing a similar general evolution of electron flux, as well as average, peak, and minimum values. Measurements from the two missions agree especially well in the 3.5<L*<4.5 range where ARASE is at similar magnetic latitudes as the Van Allen Probes. ARASE tends to record higher flux <670 keV with longer decay times after flux enhancements, particularly for L*<3.5 . Conversely, for energies >1.4 MeV, ARASE flux measurements are generally lower than those of Van Allen Probes, especially for L*>4.5 . The Person R values show that the >1.4 MeV flux from both missions are well correlated and thus, although flux magnitudes differ, all spacecraft observe a similar general evolution. However, the correlation decreases as L* increases due to ARASE measuring at magnetic latitudes outside Van Allen Probes orbits for L*>4.5. We perform a preliminary intercalibration between the two missions using the mean ratio of the fluxes as an energy- and L*- dependent correction factor. The correction factor significantly improves agreement between the fluxes above 1.4 MeV.

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

Sat. Jun 5, 2021 9:00 AM - 10:30 AM JST | Sat. Jun 5, 2021 12:00 AM - 1:30 AM UTC | Ch.09 Zoom Room 09

[A-OS11] Ocean Mixing Frontiers

convener:Toshiyuki Hibiya(Department of Earth and Planetary Science, Graduate School of Science, University of Tokyo), Chairperson:Takashi Ijichi(The University of Tokyo)

Ocean mixing plays crucial roles both in the open and coastal ocean, affecting key physical, biological and chemical processes. Mixing in the upper ocean influences the sea surface temperature and hence air-sea interactions which impact global climate change, while mixing in the deep ocean maintains abyssal stratification of the world's oceans and impacts the global overturning circulation. In coastal oceans, mixing modulates the transport and dispersal of dissolved and suspended materials including pollutants and nutrients. Planktonic ecosystems are controlled by nutrient pumping associated with ocean mixing.

In this session, we encourage contributors to present recent findings of ocean mixing obtained through field observations as well as theoretical, numerical, and laboratory studies. Through the related detailed discussions, we would like to confirm how far has our understanding of the ocean mixing processes advanced, defining the new frontier of ocean mixing research to be tackled in the next decade. The session encompasses a wide variety of aspects of coastal and open ocean mixing processes; within the water column from the surface through the interior to the near boundary benthic mixing, including the roles of mixing in the biological processes and productivity of the ocean. Observational, theoretical, and numerical modeling studies are all encouraged.

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

[AOS11-01] Tide-topography interactions with a background sheared current: critical layers and asymmetric internal wave breaking

*Kevin Lamb[1] (1.University of Waterloo)

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

[AOS11-02] Small-scale topographic effects on the generation of along-shelf propagating internal solitary waves on the Amazon Shelf

*Xiaolin Bai[1], Kevin Lamb[1], Jose C. B. da Silva[2] (1.Department of Applied Mathematics, The University of Waterloo, Canada, 2.Department of Geosciences, Environment, and Spatial Planning, and Instituto Ciencias da Terra (ICT), Polo Porto, Porto, Portugal)

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

[AOS11-03] Energetic turbulence and internal waves in Tokara Strait

*Anne Takahashi[1], Ren-Chieh Lien[1], Eric Kunze[2] (1.Applied Physics Laboratory, University of Washington, 2.NorthWest Research Associates)

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

[AOS11-04] A parameterization of local and remote tidal mixing

*Casimir de Lavergne[1] (1.LOCEAN laboratory, Sorbonne University)

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

[AOS11-05] **A new parameterization of turbulent mixing enhanced over rough seafloor topography**

*Toshiyuki Hibiya[1] (1.Department of Earth and Planetary Science, Graduate School of Science, The University of Tokyo)

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

[AOS11-06] Turbulent mixing variability in an energetic standing meander of the Southern Ocean

*Ajitha Cyriac[1,2], Helen Phillips[1,3], Nathan Bindoff[1,3], Kurt Polzin[4] (1.IMAS, University of Tasmania, Hobart, Australia, 2.ARCCSS, Hobart, Australia, 3.AAPP, Hobart, Australia, 4.WHOI, Woods Hole, USA)

Tide-topography interactions with a background sheared current: critical layers and asymmetric internal wave breaking

*Kevin Lamb[1]

1. University of Waterloo

Internal wave generation by tide-topography interactions has been the subject of many studies in recent decades. Many of these studies have considered the generation of internal waves over a two-dimensional symmetric ridge in the absence of steady background currents. In this situation, waves propagating to the left and right of the ridge are the same. This symmetry is broken in the presence of steady background currents. In this talk, the effects of a uni-directional steady background current confined to lie above a ridge will be discussed. The background current introduces asymmetries in the characteristics of the leftward and rightward propagating waves. If the current is strong enough, then critical layers are present on one side of the ridge for low mode waves that further modify the wave field. The implications for wave breaking and mixing will be discussed.

Keywords: Internal waves, Tide-topography interactions, Critical layers, Wave-breaking

Small-scale topographic effects on the generation of along-shelf propagating internal solitary waves on the Amazon Shelf

*Xiaolin Bai[1], Kevin Lamb[1], Jose C. B. da Silva[2]

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In this talk, we consider the joint effects of tidal and steady currents to investigate internal wave generation and propagation on the Amazon shelf, a hotspot for internal solitary wave (ISW) generation. The Amazon Shelf is off the mouth of the Amazon River in the southwest tropical Atlantic Ocean, affected by strong tidal constituents over complex bottom bathymetry and a strong western boundary current, the North Brazilian Current (NBC). Satellite observations and numerical modelling are used in this study. Satellite observations provide a clear visualization of the wave characteristics, such as temporal and spatial distributions, propagating direction and its relation to background currents. These ISWs appear as streak-like patterns in satellite images along a narrow path within the NBC propagating against the current. Near-critical conditions (Froude number close to 1) created by the NBC and tide result in strong ISW generation, while the dominant subcritical conditions result in the upstream propagation of these ISWs. Their streak-like patterns are a result of the quasi-two-dimensional bathymetry below, suggesting the possibility of using sea surface imprints to detect the topographic features beneath. This study demonstrates that small-scale topographic features can result in a rich generation of ISWs, which are expected to significantly contribute to ocean mixing and, potentially, sediment resuspension. The ISW-induced current also contributes to sea surface wave breaking as observed by satellites.

Keywords: Internal solitary wave, Along-shelf propagation, Small-scale topography, ISW-induced mixing

Energetic turbulence and internal waves in Tokara Strait

*Anne Takahashi[1], Ren-Chieh Lien[1], Eric Kunze[2]

1. Applied Physics Laboratory, University of Washington, 2. NorthWest Research Associates

Internal lee waves generated by geostrophic flows interacting with small-scale topography are one leading energy sink for the 1-TW wind-forcing input to gyre-scale circulation and eddies. In this study, we examine the relationship between turbulence and finescale velocity variations above and downstream of where the Kuroshio interacts with a ˜O(10-km) wide seamount in the Tokara Strait. Data were collected during November 2019 using Chi-augmented EM-APEX profiling floats which measured temperature, salinity, horizontal velocity (u, v) and microstructure temperature variance dissipation rate χ from the surface to bottom at vertical resolutions of $\Delta z \approx 5$ m. Finescale vertical velocity w is also estimated following Cusack et al. (2016).

Average turbulent kinetic energy dissipation rates ε and diapycnal diffusivities K_ρ, inferred from χ, are at least an order of magnitude greater than open ocean thermocline values with ε ˜10^{-8} W/kg and K_ρ ˜10^{-4} m^2/s. They are further enhanced above the seamount (ε ˜10^{-7} W/kg and K_ρ ˜10^{-2} m^2/s) and in a ˜200-m layer below the surface mixed layer downstream of the seamount (ε ˜10^{-6} W/kg and K_ρ ˜10^{-2} m^2/s). The vertical wavenumber shear spectrum Φ_{Sh}(m) is an order of magnitude higher than the canonical GM level and resembles the saturated spectral slope −1 above a rolloff vertical wavenumber $m_c \approx 0.01$ cpm and shows no correlation with ε. The ratio of horizontal kinetic energy to vertical kinetic energy decreases from 100 at m = 0.01 cpm to 10 at m = 0.1 cpm, suggesting that the velocity field is more isotropic at small vertical scales. Dissipation rates ε are correlated within a factor of three with vertically-high-passed (m > 130 cpm) vertical velocity w and vertical divergence dw/dz, consistent with the large-eddy parameterization (e.g., Beaird et al. 2012). The internal-wave finescale parameterization scheme fails in this energetic regime.

Keywords: Turbulence, Internal waves, Kuroshio, Internal lee waves

A parameterization of local and remote tidal mixing

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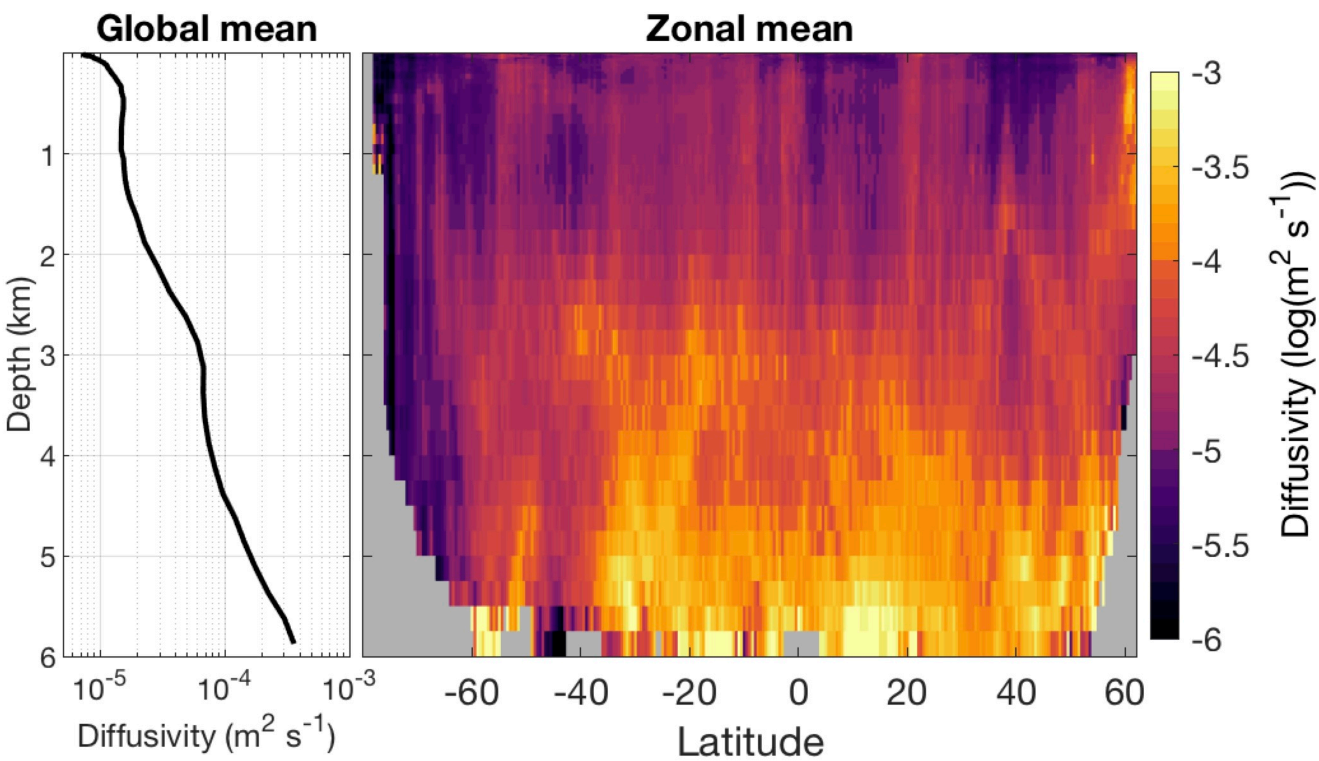
1. LOCEAN laboratory, Sorbonne University

Internal tides power much of the observed small-scale turbulence in the ocean interior. To represent mixing induced by this turbulence in climate-scale ocean models, energy routes from the generation to the dissipation of internal tides must be understood and mapped. Here we present a mixing scheme which accounts for the local breaking of high-mode internal tides and the distant dissipation of low-mode internal tides. The scheme relies on four static 2D maps of internal tide dissipation, constructed using mode-by-mode Lagrangian tracking of energy beams from sources to sinks. Each map is associated with a distinct dissipative process and a corresponding vertical structure. Applied to an observational climatology of stratification, the scheme produces a global 3D map of dissipation and mixing which compares well with available microstructure observations and with upper-ocean finestructure mixing estimates. Implemented in the NEMO global ocean model, the scheme improves the representation of deep water-mass transformation and obviates the need for a constant background diffusivity.

Keywords: ocean mixing, tides, turbulence, parameterization



A new parameterization of turbulent mixing enhanced over rough seafloor topography

*Toshiyuki Hibiya[1]

1. Department of Earth and Planetary Science, Graduate School of Science, The University of Tokyo

In the present study, I propose a new parameterization of tidal mixing enhanced over a rough seafloor with the revised formulation of its vertical decay scale. Of special importance is that internal waves emanating from the seafloor transform from internal tides to internal lee waves as tide-topography interaction strengthens. Taking into account this fact, I formulate the vertical decay scale of the energy dissipation rate off the seafloor assuming that it can be substituted by a "vertical mean free path" of the internal lee waves emanating from the seafloor and then resonantly interacting with the background Garrett-Munk internal wave field. The resulting formula predicts that the vertical extent of the mixing hotspot off the seafloor increases in proportion to U_0 squared, but independently of k_H, where U_0 is the amplitude of the barotropic tidal flow and k_H is the dominant horizontal wavenumber of the seafloor. Encouraged by the fact that this theoretical prediction is consistent with the results of the eikonal calculations by *Hibiya et al*. [2017], as well as the results of microstructure measurements in the Southern Ocean by *Sheen et al*. [2013], I propose a new parameterization of tidal mixing enhanced over the rough seafloor by incorporating the above formulated vertical decay scale of energy dissipation rates.

As is well known, tidal mixing in the global ocean is classified into the "far-field" mixing and the "near-field" mixing; it has long been believed that the far-field mixing is associated with nonlinear interactions between propagating low-mode internal tidal waves and the background internal wave field in the ocean interior, while the near-field mixing is associated with nonlinear interactions between high-mode internal tidal waves and the background internal wave field near the seafloor. However, even if tidal flow over the rough seafloor in the deep ocean is barely sufficient to generate internal tidal waves, it can be locally amplified, for example, over the rough seafloor at the top of the ocean ridge so that internal lee waves might occur. In such a case, we can expect that resulting tidal mixing region extends further upward from the seafloor, even possibly reaching the thermocline; thus compensating the shortfall of turbulent mixing required to sustain the global overturning circulation. The intensity and the vertical extent of the near-field tidal mixing employed in the current global ocean circulation models should therefore be reconsidered on the basis of the present study.

Keywords: Parameterization of turbulent mixing, Rough seafloor topography, Tidal flow, Geostrophic flow, Internal lee waves, Southern Ocean

Turbulent mixing variability in an energetic standing meander of the Southern Ocean

*Ajitha Cyriac[1,2], Helen Phillips[1,3], Nathan Bindoff[1,3], Kurt Polzin[4]

1. IMAS, University of Tasmania, Hobart, Australia, 2. ARCCSS, Hobart, Australia, 3. AAPP, Hobart, Australia, 4. WHOI, Woods Hole, USA

Turbulent mixing is a crucial mechanism that controls the distribution of heat, salt, sediments and organisms throughout the world oceans. It also plays an important role in driving large-scale oceanic processes such as watermass transformation, overturning circulation and stratification. Here we present mixing estimates from field observations of a standing meander near the Macquarie ridge, a major topographic obstacle for the Antarctic Circumpolar Current (ACC). It is a region of high eddy kinetic energy and interior upwelling. We collected more than 1400 profiles of temperature, salinity and velocity of the upper ocean using state of the art Electromagnetic Autonomous Profiling Explorer (EM-APEX) profiling floats in the upper 1600 m. By applying a finescale parameterization, we estimated the spatial and temporal variability of diapycnal mixing along the float tracks and investigated the sources. Elevated turbulent mixing is mostly associated with regions of subantarctic front and mesoscale eddies. In the upper layers, wind-generated downward propagating near-inertial waves dominate the enhanced mixing. The mixing is also high in cyclonic eddies associated with upward propagating internal waves. The dissipation rate estimates over rough and smooth topography has similar magnitudes suggesting that topography plays less role in mixing the upper 1600 m.

Keywords: Turbulent mixing, Internal waves

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

Sat. Jun 5, 2021 10:45 AM - 12:15 PM JST | Sat. Jun 5, 2021 1:45 AM - 3:15 AM UTC | Ch.09 Zoom Room 09

[A-OS11] Ocean Mixing Frontiers

convener:Toshiyuki Hibiya(Department of Earth and Planetary Science, Graduate School of Science, University of Tokyo), Chairperson:Toshiyuki Hibiya(Department of Earth and Planetary Science, Graduate School of Science, University of Tokyo)

Ocean mixing plays crucial roles both in the open and coastal ocean, affecting key physical, biological and chemical processes. Mixing in the upper ocean influences the sea surface temperature and hence air-sea interactions which impact global climate change, while mixing in the deep ocean maintains abyssal stratification of the world's oceans and impacts the global overturning circulation. In coastal oceans, mixing modulates the transport and dispersal of dissolved and suspended materials including pollutants and nutrients. Planktonic ecosystems are controlled by nutrient pumping associated with ocean mixing.

In this session, we encourage contributors to present recent findings of ocean mixing obtained through field observations as well as theoretical, numerical, and laboratory studies. Through the related detailed discussions, we would like to confirm how far has our understanding of the ocean mixing processes advanced, defining the new frontier of ocean mixing research to be tackled in the next decade. The session encompasses a wide variety of aspects of coastal and open ocean mixing processes; within the water column from the surface through the interior to the near boundary benthic mixing, including the roles of mixing in the biological processes and productivity of the ocean. Observational, theoretical, and numerical modeling studies are all encouraged.

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

[AOS11-07] Enhanced turbulent mixing in the equatorial thermocline

*Kelvin John Richards[1], Andrei Natarov[1], Yanli Jia[1] (1.International Pacific Research Center, School of Ocean and Earth Science Technology, University of Hawaii)

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

[AOS11-08] **Convection enhances upper ocean mixing during a tropical cyclone**

*Devang Falor[1], Bishakhdatta Gayen[1,2], Debasis Sengupta[1], Dipanjan Chaudhuri[3,1] (1.Indian Institute of Science, Bangalore, 2.University of Melbourne, Australia, 3.University of Washington, Seattle)

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

[AOS11-09] Near-inertial wave modulated turbulence in a Kuroshio anticyclonic eddy east of Japan

*Sebastian Essink[1], Ren-Chieh Lien[1], Eric Kunze[2] (1.UW/APL, 2.NWRA)

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

[AOS11-10] Upper ocean turbulence in the Icelandic Basin under strong forcing

*Harper L Simmons[1], Sophia Merrifield[2], Eric Skyllingstad[3], Louis St. Laurent[4] (1.University of Alaska Fairbanks, 2.Scripps Institution of Oceanography, University of California San Diego, 3.Oregon State University, 4.Applied Physics Laboratory, University of Washington)

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

[AOS11-11] Observed spectral distortion of temperature microstructure

*Takashi Ijichi[1], Louis St. Laurent[2] (1.Department of Earth and Planetary Science, Graduate School of Science, The University of Tokyo, 2.Applied Physics Laboratory, University of Washington)

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

[AOS11-12] 2D Horizontal-Vertical Wavenumber Spectra of Density Finestructure from a towed CTD chain

*Anda Vladoiu[1], Ren-Chieh Lien[1], Eric L Kunze[2] (1.Applied Physics Laboratory, University of Washington, Seattle, WA, USA, 2.NorthWest Research Associates, Redmond, WA, USA)

Enhanced turbulent mixing in the equatorial thermocline

*Kelvin John Richards[1], Andrei Natarov[1], Yanli Jia[1]

1. International Pacific Research Center, School of Ocean and Earth Science Technology, University of Hawaii

Enhanced mixing caused by small vertical scale features (SVSs) in the equatorial thermocline is known to impact the state of the ocean and its interaction with the atmosphere, in particular the sea temperature of the Pacific cold tongue and ENSO variability. The SVSs are produced by wind variability and instabilities. The good news is that with enough resolution these features can be captured in both observations and models. From observations we show that the vertical distribution of turbulent activity in the thermocline is very dependent on the turbulent length scale. From models we show that inertial and parametric subharmonic instability play a role and that wind driven inertia-gravity waves lead to an enhancement in mixing by a combination of three factors: a stronger super-inertial component of the wind forcing close to the equator, wave action convergence at turning latitudes for equatorially trapped waves, and nonlinear wave-wave interactions between equatorially trapped waves. Using a combination of ideal models and an OGCM we investigate the properties of SVS activity and its impact on mixing. Of particular interest is the dependency on stratification, the spatial and temporal variability of wind forcing and model resolution (both vertical and horizontal). The impact of the spatially and temporally varying mixing on the seasonal and inter-annual variability of the Pacific with be discussed. Such knowledge is invaluable in the planning of future observational studies and the design of the next generation climate models.

Keywords: Ocean turbulence, Ocean/atmosphere interaction

Convection enhances upper ocean mixing during a tropical cyclone

*Devang Falor[1], Bishakhdatta Gayen[1,2], Debasis Sengupta[1], Dipanjan Chaudhuri[3,1]

1. Indian Institute of Science, Bangalore, 2. University of Melbourne, Australia, 3. University of Washington, Seattle

Cyclones are extreme weather events accompanied by large wind shear and high latent heat loss on the ocean surface. Due to these large surface forcings, the ocean usually responds with enhanced upper ocean turbulence and a drop in the sea surface temperature (SST). This study investigates the upper ocean turbulent mixing in the Bay of Bengal from a category 5 tropical cyclone, Phailin, using both in-situ data and large-eddy simulations (LES). We show the presence of both diffusive convection and near-inertial shear in the upper ocean response. We are able to capture turbulent boundary layer dynamics and also quantify the associated turbulent mixing during the cyclone event for the first time. Our simulated mixed layer depth, SST, and other dynamical variables match the observed mooring data well. We estimate the mixing efficiency, η, which is defined as the energy sink ratio due to irreversible diapycnal mixing to the total mechanical energy sink. η was found to be close to 0.2 in the first half of the response, when the wind shear was picking up, while it increased to about 0.5 in the second half, as convection became dominant and the surface stress decreased. Our study further improves the mixing parametrization used by a large-scale ocean model to predict ocean response better during the cyclones.

Keywords: Turbulent Mixing, Cyclone, Convection

Near-inertial wave modulated turbulence in a Kuroshio anticyclonic eddy east of Japan

*Sebastian Essink[1], Ren-Chieh Lien[1], Eric Kunze[2]

1. UW/APL, 2. NWRA

Storm-generated near-inertial waves are a significant source for deep-ocean mixing. However, their energy pathways beyond wind generation and equatorward propagation as low modes are still elusive. Previous studies suggest that the bulk of inertial wind power is lost in the nearfield of storm forcing, but there is little observational evidence to confirm this.

Finescale horizontal velocity, temperature, salinity and microscale temperature profiles to 500-m depth were collected in the Kuroshio-Oyashio Confluence east of Japan during the storm-seasons of 2016 and 2017 with -augmented EM-APEX floats. Temporal sampling was at 1-h resolution during storms, sufficient to resolve near-inertial motions. Turbulent dissipation rates and diapycnal diffusivities *K* were inferred from microscale temperature-gradient spectra. Several floats were trapped near the velocity maximum of anticyclonic eddies. Mesoscale eddies are known to trap and amplify near-inertial waves and to modulate near-inertial wave distribution and dissipation.

Near-inertial energy-fluxes within the eddy are mostly inward and downward. Signatures of a critical layer, e.g., increasing vertical wavenumbers, shear, and turbulence are present at the depth where the eddy vorticity approaches the surface value, and strong vertical mean shears and vorticity-gradients occur. Turbulence is reduced by a factor of 10 above 180-m depth, despite elevated near-inertial energy, and enhanced between 200 and 255 m. Three mechanisms for the generation of enhanced turbulence are hypothesized: i) local and remotely forced near-inertial waves superimposing to create shear-unstable layers, ii) kinematic superposition of eddy and near-inertial shear that generates patches of turbulence at inertial periods, iii) a near-inertial critical layer due to dynamic wave/mean interaction. Ray tracing simulations will be performed to examine whether vertical vorticity gradients and/or Doppler shifting are responsible for the presence of a critical layer.

Keywords: Turbulence, Near-inertial waves, Mixing, Mesoscale eddy, Profiling float, Kuroshio

Upper ocean turbulence in the Icelandic Basin under strong forcing

*Harper L Simmons[1], Sophia Merrifield[2], Eric Skyllingstad[3], Louis St. Laurent[4]

1. University of Alaska Fairbanks, 2. Scripps Institution of Oceanography, University of California San Diego, 3. Oregon State University, 4. Applied Physics Laboratory, University of Washington

Concurrent near-surface measurements of turbulence and air-sea interactions can be difficult to obtain in the open ocean, and the challenges are exacerbated in high sea states. In May 2018 a field program in the Icelandic Basin made measurements of air-sea interactions, significant wave height, and upper ocean turbulence.

Winds were strong through most of the mission with a series of storms with significant wave heights from 5m to over 8m. The combination of nearby ship sampling, drifters and autonomous turbulence measurements from a Slocum Glider equipped with a Rockland Microrider turbulence package allowed comparisons of known shear and convective turbulence scalings to direct shear-probe estimates of turbulence in the upper 200m of the ocean. Mixed layers depths varied in space and time from 150 to 200m so that the measurements were predominantly in the upper ocean boundary layer.

Conventional near-surface dissipation scalings are based on competition between buoyancy and shear-driven production. Buoyancy forcing transitioned from cooling in the first week to warming however the turbulence was in a shear-dominated regime throughout the mission. Turbulence exceeded scaling predictions suggesting that the observations are in a strongly forced wind-wave range and highlight the need for improvements to boundary layer turbulence in extreme sea states.

Large-eddy simulations confirm that the addition of surface wave Stokes vortex forcing is essential for correctly modeling the measured mixed layer depth. Without the Stokes drift term, mixed layer depth was roughly 60% of the observations.

Keywords: Boundary layer turbulence, Large eddy simulation, Surface wave mixing

Observed spectral distortion of temperature microstructure

*Takashi Ijichi[1], Louis St. Laurent[2]

1. Department of Earth and Planetary Science, Graduate School of Science, The University of Tokyo, 2. Applied Physics Laboratory, University of Washington

Measurements of temperature microstructure from fast response thermistors are becoming more prevalent in the ocean-mixing community to estimate dissipation rates of both turbulent kinetic energy and thermal variance. This dissipation estimation method relies on the spectral shape of scalar microstructure prescribed in the high-Reynolds number turbulence theory. Using diverse datasets, we discuss some problematic cases where observed temperature spectra deviate from the corresponding theoretical one, leading to potential bias in dissipation estimates. From a technical viewpoint, the high-frequency thermistor response is suggested to depend on a vehicle flight condition. When temperature microstructure was measured on board autonomous underwater gliders, the thermistor response is found to be better corrected by a single-pole frequency function with a stronger vehicle speed dependence rather than the conventional double-pole function supported from free-falling vertical microstructure profiler data. From a physics viewpoint, the viscous-convective subrange is found to be greatly contaminated by thermohaline finestructure associated with salt finger convection. The Ozmidov wavenumber is suggested to be a threshold parameter that distinguishes turbulent microstructure from such finestructure contamination.

Keywords: temperature microstructure, finestructure contamination

2D Horizontal-Vertical Wavenumber Spectra of Density Finestructure from a towed CTD chain

*Anda Vladoiu[1], Ren-Chieh Lien[1], Eric L Kunze[2]

1. Applied Physics Laboratory, University of Washington, Seattle, WA, USA, 2. NorthWest Research Associates, Redmond, WA, USA

2D horizontal and vertical wavenumber spectra of isopycnal slope, vertical strain and isopycnal salinity-gradient were characterized on horizontal scales between 50 m and 250 km and on vertical scales between 2 and 48 m, using towed CTD chain measurements complemented by shipboard ADCP surveys and concurrent EM-APEX float profiles. 2D wavenumber spectra of isopycnal slope and vertical strain are similar to the Garrett-and-Munk internal-wave model spectrum at vertical wavenumbers below the 0.1-cpm rolloff. At vertical scales smaller than 10 m, the horizontal wavenumber spectrum of isopycnal slope has a +1/3 spectral slope and the vertical wavenumber spectrum of vertical strain has a -1 spectral slope, consistent with previous 1D measurements, numerical simulations and the predictions of anisotropic turbulence theory. Turbulent diapycnal diffusivities were estimated using a vertical strain-based finescale parameterization in the internal-wave subrange at vertical wavelengths of 10-48 m and horizontal wavelengths of 1-5 km, and using horizonal wavenumber spectra of isopycnal slope in the finescale subrange at vertical wavelengths of 2-10 m and horizontal wavelengths of 50-200 m. The two independent estimates from the internal-wave and finescale subranges show good agreement, suggesting that the energy cascade between weakly nonlinear internal waves and isotropic turbulence is connected by a distinct subrange between the rolloff and Ozmidov wavenumbers, consistent with anisotropic turbulence theory. At vertical wavenumbers below 0.1 cpm, horizontal wavenumber spectra for isopycnal salinity-gradient are approximately flat, analogous to most previous studies, while at vertical wavenumbers above 0.1 cpm, the spectra have slopes between +1/3 and +1, similar to passive tracer spectra in the isotropic turbulence subrange. Further investigation of dynamic variables might explain the disagreements between the observed spectra and theoretical predictions.

Keywords: 2D horizontal-vertical wavenumber spectra, isopycnal slope, vertical strain, isopycnal salinity-gradient, anisotropic turbulence, towed CTD chain -measured density finescale

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

Sat. Jun 5, 2021 1:45 PM - 3:15 PM JST | Sat. Jun 5, 2021 4:45 AM - 6:15 AM UTC | Ch.09 Zoom Room 09

[A-OS11] Ocean Mixing Frontiers

convener:Toshiyuki Hibiya(Department of Earth and Planetary Science, Graduate School of Science, University of Tokyo), Chairperson:Taira Nagai(Graduate School of Science, The University of Tokyo)

Ocean mixing plays crucial roles both in the open and coastal ocean, affecting key physical, biological and chemical processes. Mixing in the upper ocean influences the sea surface temperature and hence air-sea interactions which impact global climate change, while mixing in the deep ocean maintains abyssal stratification of the world's oceans and impacts the global overturning circulation. In coastal oceans, mixing modulates the transport and dispersal of dissolved and suspended materials including pollutants and nutrients. Planktonic ecosystems are controlled by nutrient pumping associated with ocean mixing.

In this session, we encourage contributors to present recent findings of ocean mixing obtained through field observations as well as theoretical, numerical, and laboratory studies. Through the related detailed discussions, we would like to confirm how far has our understanding of the ocean mixing processes advanced, defining the new frontier of ocean mixing research to be tackled in the next decade. The session encompasses a wide variety of aspects of coastal and open ocean mixing processes; within the water column from the surface through the interior to the near boundary benthic mixing, including the roles of mixing in the biological processes and productivity of the ocean. Observational, theoretical, and numerical modeling studies are all encouraged.

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

[AOS11-13] Internal tide radiation and intensified mixing in the Philippine Sea

*Zhenhua Xu[1], Jia You[1], Yang Wang[1], Qun Li[1], Toshiyuki Hibiya[2], Robin Robertson[3] (1.Institute of Oceanology, CAS, 2.Department of Earth and Planetary Science, Graduate School of Science, The University of Tokyo, Japan, 3.Xiamen University Malaysia, Malaysia)

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

[AOS11-14] Tidal and Wind Mixing in the Arafura Sea

*Robin Robertson[1] (1.Xiamen University Malaysia)

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

[AOS11-15] Verifying the parameterization of vertical eddy viscosity and diffusivity in the bottom boundary layer

*Takahiro Endoh[1], Takuya Hirooka[1] (1.RIAM Research Institute for Applied Mechanics)

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

[AOS11-16] The role of double-diffusive convection in basal melting and mixed layer under Antarctic ice shelves

*Bishakhdatta Gayen[1,2], Madi Rosevear [3,5], Ben Galton-Fenzi[4] (1.The University of Melbourne, 2. Indian Institute of Science, 3.University of Tasmania , 4.Australian Antarctic Division, 5.University of Western Australia)

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

[AOS11-17] The Kuroshio nutrient stream, where the diapycnal mixing matters

*Takeyoshi Nagai[1], Gloria Silvana Duran Gomez[1] (1.Department of Ocean Sciences, Tokyo University of Marine Science and Technology)

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

[AOS11-18] Turbulent mixing and its contribution to oxygen flux in the northwestern boundary current region of the Japan/East Sea, April-October 2015

*Dmitry Stepanov[1], Alexander Ostrovskii[2], Dmitry Kaplunenko[1], Jae-Hun Park[3], Young-Gyu Park[4], Pavel Tishchenko[1] (1.Pacific Oceanological Institute, Russia, 2.Shirshov Institute of Oceanology, Russia, 3.Department of Ocean Sciences, Inha University, Korea, 4.Korea Institute of Ocean Science and Technology, Korea)

Internal tide radiation and intensified mixing in the Philippine Sea

*Zhenhua Xu[1], Jia You[1], Yang Wang[1], Qun Li[1], Toshiyuki Hibiya[2], Robin Robertson[3]

1. Institute of Oceanology, CAS, 2. Department of Earth and Planetary Science, Graduate School of Science, The University of Tokyo, Japan, 3. Xiamen University Malaysia, Malaysia

The spatially inhomogeneous and seasonally variable diapycnal diffusivities in the upper Philippine Sea were estimated from ARGO float data using a strain-based finescale parameterization. We found that internal tides are the main driving process for diapycnal diffusivities. Based on a coordinated analysis of multi-source data, we provide evidence that the mesoscale environment in the Philippine Sea played a significant role in regulating the intensity and shaping the spatial inhomogeneity of the internal tidal mixing. The combined and relative contributions of various factors to the long-range radiation and dissipation map of internal tides were also clarified.

Keywords: Internal tides, Turbulent mixing

Tidal and Wind Mixing in the Arafura Sea

*Robin Robertson[1]

1. Xiamen University Malaysia

Time series of shipboard observations in the southern Arafura Sea near the Tiwi Islands indicated that the water column dynamics differed between the east and west sides of the islands. On the west side, the water column, defined as temperature, salinity, and velocity, was barotropic and tidal advection dominated. On the east side, the water column was baroclinic and internal tides were present along with tidal advection. These conditions affected the distribution of the turbidity and fluorescence in the water column with the fluorescence distributed throughout the water column on the western side, but concentrated in the lower layer on the eastern side. Likewise, the influence of the daily solar radiation cycle reached the bottom on the western side, but was limited to the upper layer above the thermocline on the eastern side. The fluorescence peaks also differed between the east and west sides, with the eastern side dominated by the semidiurnal tides and the western side by the daily solar cycle. Also on the eastern side, fluorescence was limited to the lower layer, while on the western side, it encompassed the entire water column at times and peaked below the warmer, higher oxygen water generated by solar radiation. These dynamics have distinct implications for biological productivity and also may affect a proposed tidal power system in the region.

Keywords: wind, Tides, Arafura Sea

Verifying the parameterization of vertical eddy viscosity and diffusivity in the bottom boundary layer

*Takahiro Endoh[1], Takuya Hirooka[1]

1. RIAM Research Institute for Applied Mechanics

By estimating the terms of the steady-state turbulent kinetic energy (TKE) budget from microstructure data obtained over the continental shelf of the East China Sea, we verify a recently proposed parameterization of vertical eddy viscosity and diffusivity in the bottom boundary layer (BBL), where mixing efficiency is expressed as a function of the gradient Richardson number (Ri). The dissipation term (ε) is calculated from the micro-scale vertical shear measured with a freely-falling microstructure profiler, whereas the production term (P) is calculated from Reynolds stress and the fine-scale vertical shear measured with an acoustic Doppler current profiler (ADCP) mounted on the seabed. If the proportional relationship between the flux Richardson number (Rf) and Ri holds, which is assumed in the proposed BBL parameterization, the buoyancy flux term (B) as well as the transport term (T) can be estimated from P, ε , and Ri. Therefore, we use the iterative procedure to find a constant of proportionality which is close to a slope of the regression line for Rf (=-B/(P+T)) and Ri. The resulting constant is within the range suggested by laboratory experiments, large eddy simulations, and observations of the atmospheric boundary layer. The parameterized eddy viscosity agrees remarkably well with the observed one, whereas the parameterization underestimates the observed eddy diffusivity by a factor of two to three presumably because of the uncertainty involved in the estimated values of B.

Keywords: Bottom boundary layer, Vertical eddy viscosity, Vertical eddy diffusivity, Flux Richardson number, Gradient Richardson number, Turbulent kinetic energy budget

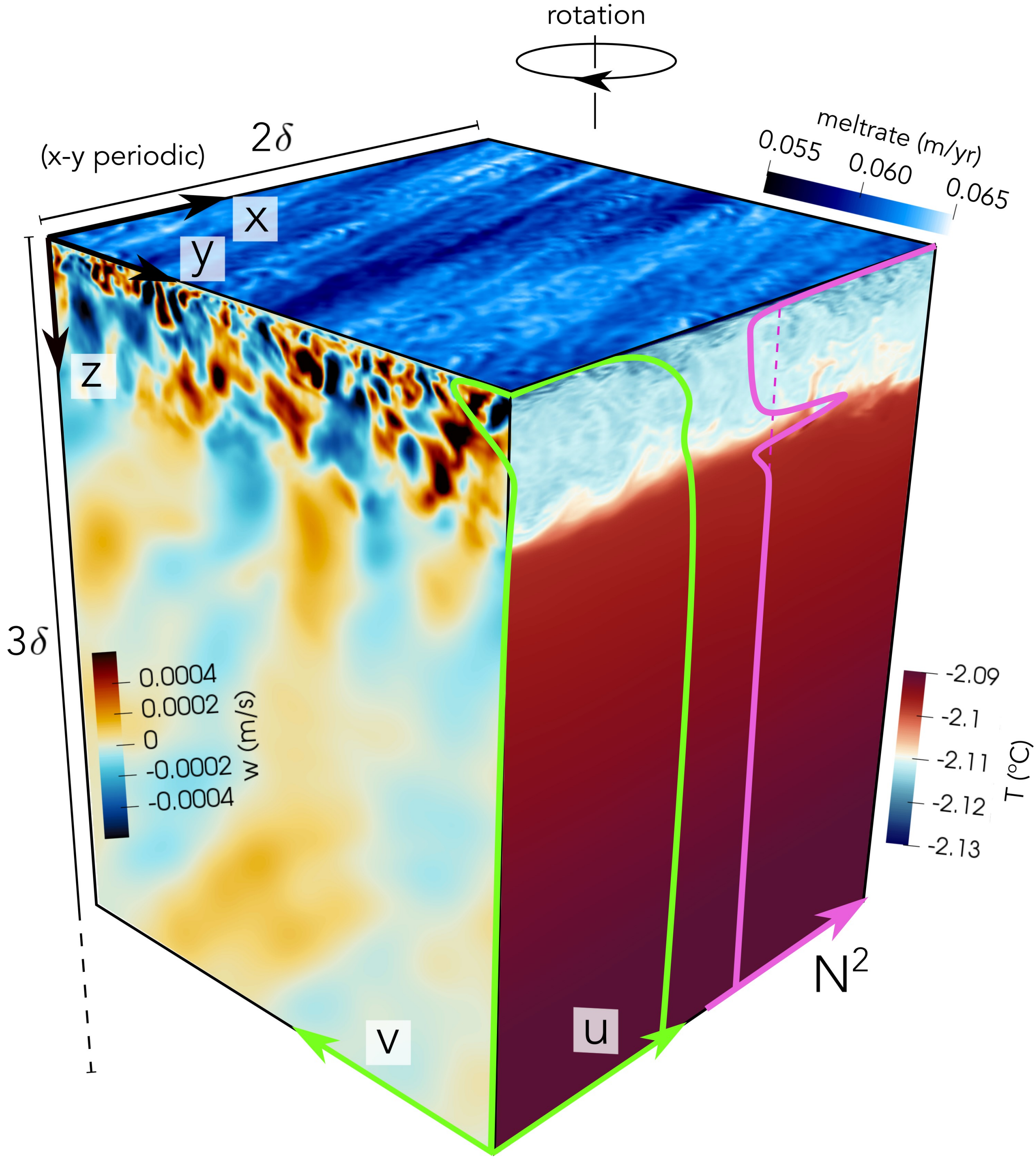
The role of double-diffusive convection in basal melting and mixed layer under Antarctic ice shelves

*Bishakhdatta Gayen[1,2], Madi Rosevear [3,5], Ben Galton-Fenzi[4]

1. The University of Melbourne, 2. Indian Institute of Science, 3. University of Tasmania , 4. Australian Antarctic Division, 5. University of Western Australia

The Antarctic Ice Sheet, which comprises the enormous ice volume on our planet, is losing mass at an alarming rate, contributing to a considerable global sea-level rise in the future. Ocean-driven melting is the largest cause of ice mass loss from the Antarctic continent. Therefore, accurate representation of ocean-driven melting is crucial for future sea-level predictions; however, the fine-scale ice shelf-ocean boundary layer (ISOBL) processes that control ocean melt rates are not well understood. Ocean-climate models cannot resolve the ISOBL and rely on parameterizations to predict melting. In this study, we use cutting-edge Large Eddy Simulation to examine the geostrophic boundary layer beneath an ice shelf for the first time. A small-scale mixing process (Diffusive Convection) is an emergent property of our simulations. It explains the water column structure and low melt rates observed beneath the Ross Ice Shelf under similar conditions. We show that Diffusive Convection is the primary control of basal melting and oceanic mixed layer formation and persists despite shear-generated turbulence. Thus, our finding has significant potential implications for ice-sheet models that rely on ocean melt rate parameterizations to predict ice sheet stability and evolution.

Keywords: Diffusive-convection, ocean interactions, large-eddy simulation, thermohaline staircases


rotation
(x-y periodic)
2δ
x
y
z
meltrate (m/yr)
0.055
0.060
0.065
3δ
0.0004
0.0002
0
-0.0002
-0.0004
w (m/s)
-2.09
-2.1
-2.11
-2.12
-2.13
T (°C)
N^2
v
u

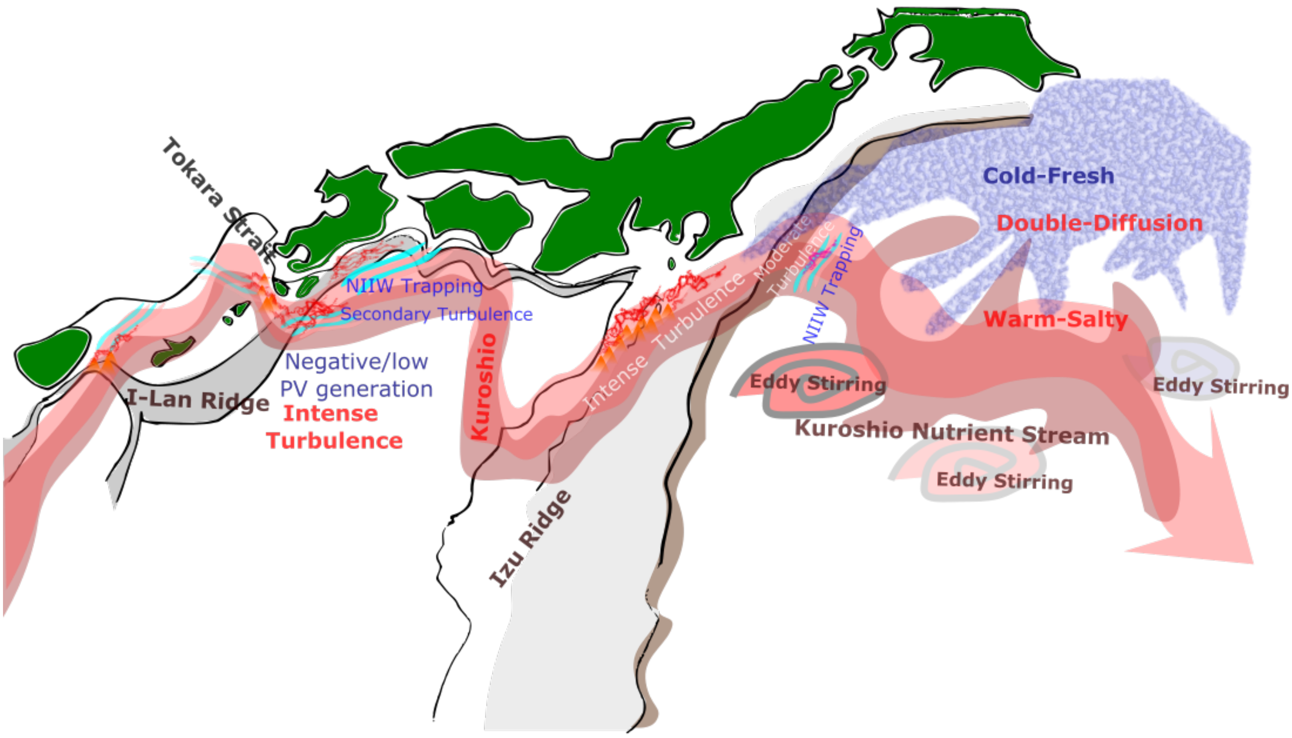
The Kuroshio nutrient stream, where the diapycnal mixing matters

*Takeyoshi Nagai[1], Gloria Silvana Duran Gomez[1]

1. Department of Ocean Sciences, Tokyo University of Marine Science and Technology

While the Kuroshio and the Gulf Stream carry a large amount of nutrients in dark subsurface layers and supply them to the downstream subpolar regions, it has remained unclear how the elevated nutrient concentrations along these nutrient streams are formed and/or maintained. This is particularly important as these positive nutrient anomalies on the relatively less dense water along the nutrient streams can be injected more easily to the euphotic zone. In the North Pacific, the regions of anomalously high nitrate concentrations along the Kuroshio Extension coincide with one of the major net CO_2 sinks of the world oceans. Although the elevated nutrient concentrations on the density surface were attributed to diapycnal nutrient flux along the nutrient stream in the earlier studies, recent studies concluded that the horizontal advection carries this anomaly from the upstream tropical regions and that diapycnal mixing can be negligible in the Gulf Stream. However, because the Kuroshio flows over rough topography more frequently than the Gulf Stream, it still remains elusive whether the diapycnal mixing is really not playing a role at all to form the high nutrient concentration layer along the Kuroshio nutrient stream.
In this study, using a numerical model of the Kuroshio nutrient stream, and direct microscale turbulence measurements, the importance of the diapycnal mixing in the Kuroshio is examined.
The eddy flux analyses on the density surface in the simulation suggest that the eddies stir and dilute the elevated nitrate concentration, resulting in the decreasing trend of nitrate along the nutrient stream with the increasing trends on the both sides of the stream.
A series of the tow-yo microstructure observations in the Kuroshio flowing over the rough topography shows that the large nitrate diffusive diapycnal flux of 1-10 mmol $m^{-2}day^{-1}$ are frequently observed in the Tokara Strait, the Hyuganada Sea, and over the Izu Ridge. The time scale required for the diapycnal nitrate flux at 1 mmol $m^{-2}day^{-1}$ to generate the observed positive anomaly of nitrate concentrations, which is estimated to be 26 Gmol over 5000 km, is found to be as short as 50 days, assuming the area of nitrate injection of 1000 km^2. The observations suggest that the nitrate injection at 1 mmol $m^{-2}day^{-1}$ over the area of 1000 km^2 is plausible if the all the contributions in these mixing hot-spots along the Kuroshio are integrated.
This time scale of 50 days is comparable to or slightly less than the advection time scale, and therefore, unlike the Gulf Stream, the diapycnal turbulent diffusive flux is unlikely negligible in the Kuroshio nutrient stream. Furthermore, in the Kuroshio Extension, rich high vertical wavenumber thermohaline interleaving structures are found to induce a large double-diffusive nitrate flux at 1-10 mmol mmol $m^{-2}day^{-1}$ in the pycnostad of sigma_theta=26-27 kgm^{-3}. Because these relatively dense layers in this region are not outcropping even during winter, whether this nitrate diffused upward by double-diffusion can be supplied to the euphotic zone depends on further stirring processes such as the northward and upward eddy fluxes. In addition, although the detailed mechanisms still remain unclear, the Argo float data analyses show that these double-diffusive flux in the dense layers modulates interannually.

Keywords: Kuroshio, Nutrient sream, Diapycnal mixing


Tokara Strait
NIIW Trapping
Secondary Turbulence
Negative/low
PV generation
Intense
Turbulence
I-Lan Ridge
Kuroshio
Intense Turbulence
Moderate Turbulence
NIIW Trapping
Izu Ridge
Cold-Fresh
Double-Diffusion
Warm-Salty
Eddy Stirring
Kuroshio Nutrient Stream
Eddy Stirring
Eddy Stirring

Turbulent mixing and its contribution to oxygen flux in the northwestern boundary current region of the Japan/East Sea, April-October 2015

*Dmitry Stepanov[1], Alexander Ostrovskii[2], Dmitry Kaplunenko[1], Jae-Hun Park[3], Young-Gyu Park[4], Pavel Tishchenko[1]

1. Pacific Oceanological Institute, Russia, 2. Shirshov Institute of Oceanology, Russia, 3. Department of Ocean Sciences, Inha University, Korea, 4. Korea Institute of Ocean Science and Technology, Korea

The Japan/East Sea is well ventilated and is the most oxygen-rich region in the Pacific. However, quantitative estimates of the turbulent fluxes are missing due to a lack of observational data. To assess turbulent mixing, we employ data from the moored profiler Aqualog survey of April - October 2015 near the northwestern boundary of this region. The survey allowed observation of collocated depth profiles of conductivity, temperature, ocean current, and dissolved oxygen 8 times per day. Based on the finescale parameterization framework, the dissipation rate, the eddy diffusivity, and the diapycnal fluxes of heat, salt and oxygen are estimated in the depth range from 130 to 350 m throughout the profiler deployment period.
The survey average diffusivity increased with depth from 0.5×10^{-5} to 4.0×10^{-5} m^2 s^{-1}. The month-to-month variability in the mixing is presented. It was shown that the turbulent mixing undergoes intraseasonal variability. Early in May 2015, a transition in mixing occurred from the winter regime with upward turbulent fluxes of both heat and salt to the summer regime with the downward mixing of heat. The turbulent mixing was elevated in June when large anticyclonic eddies passed the profiler mooring. The probability distributions of the ratios of the turbulent heat and oxygen fluxes to the observed local changes in heat and oxygen were rather stable, particularly in the warm season. The application of the MX Toolbox to the profiler mooring data yields an estimate of the downward oxygen flux of roughly 8.6×10^3 μmol m^{-2} $month^{-1}$.

The data analysis was partly performed in the framework of the assignment of FASO Russia (theme 0149-2019-0011) and supported in part by RFBR grant 19-05-00459. The contribution of Dmitry Stepanov in modifying the Mixing Oceanographic Toolbox was supported by RFBR grant 20-05-00083.

Keywords: diapycnal mixing, Japan/East Sea, fine-scale parameterization, diapycnal fluxes of heat and salt, downward oxygen flux

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

Sat. Jun 5, 2021 3:30 PM - 5:00 PM JST | Sat. Jun 5, 2021 6:30 AM - 8:00 AM UTC | Ch.11 Zoom Room 11

[A-OS12] Physical, biogeochemical, and ecological processes and variability in the Indian Ocean

convener:Yukio Masumoto(Graduate School of Science, The University of Tokyo), Hiroaki Saito(Atmosphere and Ocean Research Institute,　The University of Tokyo), Chairperson:Yukio Masumoto(Graduate School of Science, The University of Tokyo), Hiroaki Saito(Atmosphere and Ocean Research Institute,　The University of Tokyo)

The Indian Ocean has been recognized to play important roles in regional and global climate systems, material circulations, ecosystems, and their variability, with linked biophysical phenomena that span a wide range of spatial and temporal scales. These phenomena include, for example, diurnal cycling, intraseasonal disturbances, seasonal variations, Indian Ocean dipole events, and decadal to multi-decadal variations as well as secular trends under the global warming stress. In situ and remotely-sensed physical and biogeochemical observations using the Indian Ocean Observing System (IndOOS) and other means are now accumulating high quality data, and research efforts with numerical models and analyses of comprehensive datasets are also being conducted under International Indian Ocean Expedition-2 (IIOE-2) and the Eastern/Western Indian Ocean Upwelling Research Initiative (EIOURI/WIOURI). To advance our understanding of such Indian Ocean phenomena, disciplinary studies are essential, as are interdisciplinary investigations that elucidate the linkages between the physical and biogeochemical/ecological researches realms.
The objective of this session is to share our knowledge on, and to advance our understanding of, all facets of Indian Ocean variability. We invite papers on physical, biogeochemical and ecological aspects of the variability, as well as those related to atmosphere-ocean interactions, over the full spectrum of temporal and spatial scales. Discussions to facilitate mutual interactions among different research communities would also be expected and encouraged.

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

[AOS12-01] Determination of nitrogen source for phytoplankton in the eastern Indian Ocean by δ^{15}N of chlorophyll *a* and divinylchlorophyll *a*

*Yuta Isaji[1], Chisato Yoshikawa[1], Nanako O. Ogawa[1], Kazuhiko Matsumoto[1], Naoto F. Ishikawa[1], Akiko Makabe[1], Hiroshi Ogawa[2], Hiroaki Saito[2], Makio Honda[1], Naohiko Ohkouchi[1] (1.Japan Agency for Marine-Earth Science and Technology, 2.Atmosphere and Ocean Research Institute, University of Tokyo)

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

[AOS12-02] **Temporary phytoplankton bloom induced by physical disturbances in the Eastern Indian Ocean**

*Siyu Jiang[1], Fuminori Hashihama[2], Hiroaki Saito[1] (1.Atmosphere and Ocean Research Institute, The University of Tokyo, 2.Tokyo University of Marine Science and Technology)

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

[AOS12-03] Intraseasonal variation of surface Chlorophyll-a associated with coastal upwelling along the southern coast of Java

*Takanori Horii[1], Eko Siswanto[2], Iskhaq Iskandar[3], Iwao Ueki[1] (1.Global Ocean Observation Research Center, Research Institute for Global Change, Japan Agency for Marine-Earth Science and Technology (JAMSTEC), 2.Earth Surface System Research Center, Research Institute for Global Change, Japan Agency for Marine-Earth Science and Technology (JAMSTEC), 3.Faculty of Mathematics and Natural Sciences, Sriwijaya University, Indonesia)

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

[AOS12-04] Interannual variability in sea surface temperature off Somalia in boreal summer – Similarities and differences between “Warm year” and “Cold year” –

*Kusumi Takahiro[1], Yukio Masumoto[1] (1.the Unversity of Tokyo)

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

[AOS12-05] Seasonal and Interannual Variations of Indian Ocean Subtropical Mode Water Based on the Argo Data

*Hanani Adiwira[1], Toshio Suga[1] (1.Tohoku University)

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

[AOS12-06] Distribution and movement of microplastics in the Indian Ocean

*Yukio Masumoto[1] (1.Graduate School of Science, The University of Tokyo)

Determination of nitrogen source for phytoplankton in the eastern Indian Ocean by $\delta^{15}N$ of chlorophyll *a* and divinylchlorophyll *a*

*Yuta Isaji[1], Chisato Yoshikawa[1], Nanako O. Ogawa[1], Kazuhiko Matsumoto[1], Naoto F. Ishikawa[1], Akiko Makabe[1], Hiroshi Ogawa[2], Hiroaki Saito[2], Makio Honda[1], Naohiko Ohkouchi[1]

1. Japan Agency for Marine-Earth Science and Technology, 2. Atmosphere and Ocean Research Institute, University of Tokyo

The eastern Indian Ocean is unique for its meridional gradients in physical and chemical properties with distinct biogeochemical regimes. Constraining the biogeochemical parameters in each of these regions is critical as the Indian Ocean represents 15–20% of global ocean net primary production (Behrenfeld and Falkowski, 1997). The nitrogen source assimilated by phytoplankton is of particular importance, because new production is supported by nitrate supplied from the subsurface ocean or by N_2 fixation, and regenerated production by ammonium and other reduced nitrogen species remineralized within the photic zone. Here, we conducted compound-specific nitrogen isotope analysis of chloropigments in order to determine nitrogen source assimilated by phytoplankton, and to obtain detailed snapshot of primary production in the eastern Indian Ocean. Suspended particulate materials were collected on GF-75 glass-fiber filter on board at subsurface chlorophyll maximum along 88˚E transect in the eastern Indian Ocean (16˚N–20˚S) during the cruise KH-18-6 Leg 2. The depth of subsurface chlorophyll maximum was shallowest at the northernmost station and deepened southward, with chlorophyll *a* concentration showing decreasing trend toward southern stations. Compositions of chlorophylls (i.e., chlorophyll *a*, *b*, *c*, and divinylchlorophyll *a*) and carotenoids (i.e., fucoxanthin, 19’-hexanoyloxyfucoxanthin, 19’-butanoyloxyfucoxanthin, prasinoxanthin, zeaxanthin) indicated predominance of eukaryotic phytoplankton in the northern and equatorial stations. The proportion of *Prochlorococcus* increased in the southern stations in response to deepening of the nutricline. The $\delta^{15}N$ values of eukaryotic phytoplankton and *Prochlorococcus* were estimated by those of chlorophyll *a* and divinylchlorophyll *a*, respectively. We will present meridional variation in the nitrogen source assimilated by each group of phytoplankton, and discuss its possible causes as well as implications of our results.

Keywords: Indian Ocean, primary production, nitrogen isotope, Prochlorococcus, divinylchlorophyll

Temporary phytoplankton bloom induced by physical disturbances in the Eastern Indian Ocean

*Siyu Jiang[1], Fuminori Hashihama[2], Hiroaki Saito[1]

1. Atmosphere and Ocean Research Institute, The University of Tokyo, 2. Tokyo University of Marine Science and Technology

Phytoplankton growth and microzooplankton grazing are critical processes which support higher trophic levels in marine ecosystems. In oligotrophic marine ecosystems, these processes are generally coupled with each other and the balance between them keeps phytoplankton biomass consistently low. However, it has been reported the coupling was easily violated by physical disturbances. The Eastern Indian Ocean is an oligotrophic ecosystem with strong seasonal and intraseasonal variabilities induced by physical activities. However, phytoplankton growth and microzooplankton grazing mortality were rarely studied in this area, and their responses to physical disturbances remain unclear. In this study, we conducted a series of dilution experiments in the surface layer (10 m) in subtropical and tropical Eastern Indian Ocean (88˚E, 16.5 ˚N to 20 ˚S) to measure phytoplankton growth and microzooplankton grazing mortality rates. The study area was throughout oligotrophic (dissolved inorganic nitrogen concentration lower than 60 nM). The Chl *a* concentration was low (0.13 ±0.09 $\mu g\ L^{-1}$) except the equatorial stations (0.26 ±0.06 $\mu g\ L^{-1}$). However, the high biomass at the equator decreased to approximate 0.1 $\mu g\ L^{-1}$ after the cruise, as demonstrated by satellite Chl *a* observations. Further, the phytoplankton growth at the equator was low or even negative (-0.07 and 0.28 d^{-1}) and was limited by nutrients availability, while at other stations growth rates were higher (0.68 ±0.33 d^{-1}) and the nutrient limitation was not serious. The significant response of phytoplankton growth to additional ammonium (by ˜3.3 times high growth rate) and the higher phytoplankton Chl:C ratio at the equator indicated there was once relatively abundant nutrients. The equatorial Wyrtki Jet formed before the cruise possibly transported the nutrient-rich water to the Eastern Indian Ocean. The time-lag between the jet formation and the cruise might allow phytoplankton to exhaust the nutrients and accumulate the biomass. Our results indicated in the Eastern Indian Ocean, the balance between phytoplankton growth and grazing mortality could be violated by physical disturbances and the growth exceeded mortality could induce temporary phytoplankton blooms.

Keywords: Indian Ocean, Phytoplankton, Microzooplankton, Dilution technique, Physical disturbances, Wyrtki Jet

Intraseasonal variation of surface Chlorophyll-a associated with coastal upwelling along the southern coast of Java

*Takanori Horii[1], Eko Siswanto[2], Iskhaq Iskandar[3], Iwao Ueki[1]

1. Global Ocean Observation Research Center, Research Institute for Global Change, Japan Agency for Marine-Earth Science and Technology (JAMSTEC), 2. Earth Surface System Research Center, Research Institute for Global Change, Japan Agency for Marine-Earth Science and Technology (JAMSTEC), 3. Faculty of Mathematics and Natural Sciences, Sriwijaya University, Indonesia

Coastal upwelling along the southern coast of Java brings cold and nutrient-rich subsurface water upward and plays an important role in controlling ocean surface heat balance, biogeochemical balance, coastal ecosystem, and regional fisheries. To understand the coastal upwelling, we investigated satellite-based Chlorophyll-a data south of Java, with a focus on the seasonal and intraseasonal-scale variability. We first interpolated the data and produced daily timeseries. The spectrum analysis showed that annual, semi-annual, and intraseasonal (20-60-day) variations were significant in the Chlorophyll-a variations. The Chlorophyll-a peaks were accompanied with decreases in the local sea level and sea surface temperature, suggesting a coastal upwelling of cold and nutrient-rich subsurface water at the intraseasonal timescale. A relationship between the intraseasonal Chlorophyll-a variations and the Indian Ocean Dipole will be discussed.

Keywords: Surface Chlorophyll-a, Java island, Indian Ocean Dipole

Interannual variability in sea surface temperature off Somalia in boreal summer –Similarities and differences between “Warm year” and “Cold year” –

*Kusumi Takahiro[1], Yukio Masumoto[1]

1. the Unversity of Tokyo

Strong alongshore southwesterly winds in the western Arabian Sea (AS) associated with the Indian summer monsoon locally force coastal upwelling, northward western boundary current, known as the Somali Current, and two oceanic Gyres, called the Southern Gyre and the Great Whirl. Interannual modulations of all these phenomena are believed to affect sea surface temperature (SST) anomaly during boreal summer in the western AS. To investigate processes responsible for interannual variability in the SST anomaly there, a composite analysis is performed for years with positive (negative) SST anomaly in the western AS during summer, hereafter referred as “Warm year (Cold year)”, using outputs from a regional model based on the Regional Ocean Modeling System (ROMS).
While the overall evolutions of anomalous upper-ocean conditions are similar in the two cases, with the sign of anomalies reversed, there is a significant difference in the SST anomaly field. Two regions of filament-like SST anomaly appear around 4°N and 10°N near the coast of Somalia by mid-June both in Warm and Cold years. These two filament-like anomalies remain almost the same locations through the summer in Warm years. On the other hand, in Cold years, the cold SST anomaly and associated cyclonic circulation around 4°N move northward along the coast of Somalia and eventually coalesces with another filament-like cold SST structure located around 10°N. When this coalescence occurs, the SST around 10°N near the Somali coast decreases rapidly and the cold SST anomaly around 4°N disappears. This merger of two gyres does not occur every year but tends to occur in the Cold years. The merger between two filament-like cold SST anomalies may be related to the stronger alongshore southwesterly winds in the Cold years compared to that in the normal years. This discrepancy between the two cases may result in asymmetric responses in interannual variations of the Indian summer monsoon to the SST anomalies over the western AS.

Keywords: Western Arabian Sea, Interannual variation, Filament, Coalescence

Seasonal and Interannual Variations of Indian Ocean Subtropical Mode Water Based on the Argo Data

*Hanani Adiwira[1], Toshio Suga[1]

1. Tohoku University

Subtropical Mode Water (STMW) is a water mass that is formed during winter season and located in the western part of subtropical gyre. STMW covers a large area both in horizontal and vertical, and distinguished by the extreme uniformity of water properties. Extensive studies have been done for STMWs in the Pacific and Atlantic Oceans, meanwhile, there are only few studies that specifically discuss about Indian Ocean Subtropical Mode Water (IOSTMW). Sparseness of observational data was the obstacle for studying the Indian Ocean. However, this situation has been changing due to Argo program started in 1999, where numerous Argo floats were deployed to collect temperature and salinity data globally. Until now, the increasing Argo data in Subtropical Indian Ocean region has not been fully utilized. The seasonal and interannual variability of IOSTMW is still not clear yet. Therefore, by using the Argo data, this study investigates the interannual variability of IOSMTW in a longer time period and the mechanisms behind the variability. In Situ Analysis System (ISAS) gridded fields of temperature and salinity, which entirely based on in situ measurements, are used to examine the temporal variability of IOSTMW. Additionally, the turbulence heat flux data from OAFlux (Yu et al., 2018) and the radiative heat flux data from CERES (Kato et al., 2018) are used to see the relationship between winter atmospheric cooling and the formation of IOSTMW.

The definition of IOSTMW layer itself is not clearly defined yet. IOSTMW has been defined differently by each of the previous study. In this study, IOSTMW layer is defined by using the temperature gradient (dT/dz) and temperature range. Based on the previous studies, there are four IOSTMW definitions that are analyzed in this study: (1) dT/dz < 1.5˚C/100 m with temperature of 15-18˚C, (2) dT/dz < 1.5˚C/100 m with temperature of 16-18˚C, (3) dT/dz < 1˚C/100 m with temperature of 15-18˚C, (4) dT/dz < 1˚C/100 m with temperature of 16-18˚C.

The correlation coefficients between late-winter IOSTMW thickness and both winter (Jun-Aug) heat flux and ocean summer (Jan-Mar) stratification are examined. Significant correlation coefficients are found between winter heat flux and IOSTMW thickness for the definitions with dT/dz < 1˚C/100 m ($p < 0.01$), higher than the definitions with dT/dz < 1.5˚C/100 m. This implies IOSTMW defined as layer with dT/dz < 1.5˚C/100 m, or the older and more stratified mode water, is less sensitive to the atmospheric forcing in the same year. Moreover, the comparison between cumulative winter heat flux and the difference of ocean heat content at the beginning of the winter and the end of winter also indicates the strong connection between atmospheric forcing and the upper ocean stratification. On the other hand, low correlation coefficients are found between IOSTMW thickness of each definition and summer stratification (0-150 m).

Therefore, the atmospheric cooling is found more dominant in determining the formation of IOSTMW, while the summer stratification is less influential. Layer with dT/dz < 1˚C/100 m and temperature of 16-18˚C is chosen as the definition of IOSTMW in the further analysis because this layer is sensitive to air-sea interaction and correlates relatively well with the summer stratification among all definitions.

Keywords: Indian Ocean, Subtropical Mode Water, Argo Float, Air-Sea Interaction

Distribution and movement of microplastics in the Indian Ocean

*Yukio Masumoto[1]

1. Graduate School of Science, The University of Tokyo

Considering that one of the largest microplastic source regions is located in the maritime continent between the Pacific and Indian Oceans and that the Indonesian throughflow is passing through the maritime continent toward the Indian Ocean, much of microplastics injected in the region would be expected to flow into the Indian Ocean. However, details on their distributions and movements within the Indian Ocean have not been investigated. Using outputs of a high-resolution ocean general circulation model (OFES), particle tracking calculations are conducted to determine horizontal distribution of the microplastics in the Indian Ocean and to quantify how much of the microplastics flow into the Indian Ocean from the maritime continent. Most of the microplastics are accumulated within the subtropical gyre in the southern hemisphere. Although microplastics have been observed in the Southern Oceans near Antarctica, this study suggests that it is difficult to reach far south near Antarctica by the simple dispersion of the materials flowing at the sea surface. Further analysis on a role of three-dimensional circulations to transport microplastics farther south across the Antarctic Circumpolar Currents would be required.

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

Sat. Jun 5, 2021 9:00 AM - 10:30 AM JST | Sat. Jun 5, 2021 12:00 AM - 1:30 AM UTC | Ch.11 Zoom Room 11

[A-OS13] Marine ecosystems and biogeochemical cycles: theory, observation and modeling

convener:Takafumi Hirata(Arctic Research Center, Hokkaido University), Shin-ichi Ito(Atmosphere and Ocean Research Institute, The University of Tokyo), E Eileen Hofmann(Old Dominion University), N Enrique Curchitser(Rutgers University New Brunswick), Chairperson:Shin-ichi Ito(Atmosphere and Ocean Research Institute, The University of Tokyo), Takafumi Hirata(Arctic Research Center, Hokkaido University), Eileen E Hofmann(Old Dominion University), Enrique N Curchitser(Rutgers University New Brunswick)

The ocean accounts for about 50% of global net primary production. This production is significant for carbon cycling and ecosystem functioning, and is related directly or indirectly to a variety of climatic and ecological phenomena. The responses to natural and anthropogenic environmental stressors that influence marine production and diversity can cause perturbations to marine ecosystems that alter trophic dependencies and interactions among organisms at a range of space and time scales. Quantification of the principal mechanisms driving spatio-temporal variability of marine ecosystem remains to be done, especially in terms of evaluation of uncertainty in responses. As a result, evaluating vulnerability of marine ecosystems to environmental change requires systematic and holistic approaches that integrate physics to ecology and are based in observations and modelling. In addition, expectations to deliver these science to public society is raising. This session aims to provide a venue for not only discussing recent advances in understanding marine biogeochemical cycles, ecosystems and their interactions, but also networking with a variety of people to seed new ideas in marine ecological research. Observational, modeling and conceptual studies, including technological development and operational applications, that consider linkages among biogeochemical and ecosystem processes, biodiversity, and the effects of multiple stressors from molecular to planetary scales are encouraged.

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

[AOS13-01] Introduction

9:05 AM - 9:30 AM JST | 12:05 AM - 12:30 AM UTC

[AOS13-02] Understanding Marine Ecosystems – A View to the Future

★Invited Papers

*Eileen E Hofmann[1] (1.Old Dominion University)

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

[AOS13-03] Marine Ecosystem Variations Over the North Pacific and Their Linkage to Large-Scale Climate Variability and Change

*Emi Yati[1], Shoshiro Minobe[2,3], Nathan Mantua[4], Shin-ichi Ito[5], Emanuele Di Lorenzo[6] (1.Remote Sensing Application Center, Indonesian National Institute of Aeronautics and Space, Jakarta, Indonesia, 2.Department of Natural History Sciences, Graduate School of Science, Hokkaido University, Sapporo, Japan, 3.Department of Earth and Planetary Sciences, Faculty of Science, Hokkaido University, Sapporo, Japan, 4.Fish Ecology Division, Southwest Fisheries Science Center, National Marine Fisheries Service, National Oceanographic and Atmospheric Administration, Santa Cruz, CA, United States, 5.Atmosphere and Ocean Research Institute, University of Tokyo, Kashiwa, Japan, 6.School of Earth and Atmospheric Sciences, Georgia Institute of Technology, Atlanta, GA, United States)

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

[AOS13-04] **Future biogeographic shifts of marine biodiversity in the Pacific Arctic**

*Irene Alabia[1], Jorge Garcia Molinos[1], Sei-Ichi Saitoh[1], Takafumi Hirata[1], Toru Hirawake[1], Franz Mueter[2] (1.Hokkaido University, 2.University of Alaska Fairbanks)

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

[AOS13-05] Instantaneous Acclimation allows computationally efficient modelling of the biogeochemical impacts of plankton ecophysiology

*S. Lan Smith[1], Onur Kerimoglu[2], Prima Anugerahanti[1], Yoshio Masuda[3], Yasuhiro Yamanaka[3], Yoshikazu Sasai[1] (1.Marine Ecosystem Dynamics Research Group, Research Institute for Global Change, Japan Agency for Marine-Earth Science and Technology, 2.ICBM, University of Oldenburg, Germany, 3.Faculty of Environmental Earth Science, Hokkaido University)

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

[AOS13-06] Interannual Variability in contributions of the Equatorial Undercurrent (EUC) to Peruvian Upwelling

*Gandy Maria Rosales Quintana[1], Robert Marsh[2], Luis Alfredo Icochea Salas[3] (1.Course of Applied Marine Environmental Studies, Tokyo University of Marine Science and Technology, 2.University of Southampton, UK, 3.Universidad Nacional Agraria La Molina, Peru)

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

[A-OS13] Marine ecosystems and biogeochemical cycles: theory, observation and modeling

convener:Takafumi Hirata(Arctic Research Center, Hokkaido University), Shin-ichi Ito(Atmosphere and Ocean Research Institute, The University of Tokyo), E Eileen Hofmann(Old Dominion University), N Enrique Curchitser(Rutgers University New Brunswick), Chairperson:Shin-ichi Ito(Atmosphere and Ocean Research Institute, The University of Tokyo), Takafumi Hirata(Arctic Research Center, Hokkaido University), Eileen E Hofmann(Old Dominion University), Enrique N Curchitser(Rutgers University New Brunswick)

Sat. Jun 5, 2021 9:00 AM - 10:30 AM Ch.11 (Zoom Room 11)

The ocean accounts for about 50% of global net primary production. This production is significant for carbon cycling and ecosystem functioning, and is related directly or indirectly to a variety of climatic and ecological phenomena. The responses to natural and anthropogenic environmental stressors that influence marine production and diversity can cause perturbations to marine ecosystems that alter trophic dependencies and interactions among organisms at a range of space and time scales. Quantification of the principal mechanisms driving spatio-temporal variability of marine ecosystem remains to be done, especially in terms of evaluation of uncertainty in responses. As a result, evaluating vulnerability of marine ecosystems to environmental change requires systematic and holistic approaches that integrate physics to ecology and are based in observations and modelling. In addition, expectations to deliver these science to public society is raising. This session aims to provide a venue for not only discussing recent advances in understanding marine biogeochemical cycles, ecosystems and their interactions, but also networking with a variety of people to seed new ideas in marine ecological research. Observational, modeling and conceptual studies, including technological development and operational applications, that consider linkages among biogeochemical and ecosystem processes, biodiversity, and the effects of multiple stressors from molecular to planetary scales are encouraged.

9:00 AM - 9:05 AM

[AOS13-01]Introduction

Understanding Marine Ecosystems –A View to the Future

*Eileen E Hofmann[1]

1. Old Dominion University

Integrated ecosystem analyses provide an approach for understanding and projecting responses of marine ecosystems to changing climate conditions and direct human impacts such as fisheries. Complex interactions within food webs modify responses of individual species and influence the responses of entire ecosystems to change. Reliable projections of the impacts of past and future changes on marine ecosystems require fundamental understanding of the factors that determine the structure and function of the food webs at multiple scales, incorporation of this understanding into coupled modeling frameworks, and approaches for translating information so that it can be used for development of policies and regulations. Ecosystem adjustments resulting from exploitation of living resources and climate change are ongoing and significant changes are becoming apparent at all trophic levels. Management Strategy Evaluations (MSE), which are systems of linked models, allow the cascade of effects initiated by changes in climate, ocean or food webs to be identified using comprehensive mechanistic descriptions of ecosystem responses, which are then evaluated in terms of potential social and economic effects. The information from a MSE then provides inputs for evaluating and developing management and regulatory policies for a resource. This presentation overviews MSEs developed for marine ecosystems and implications for management and policy. The lessons learned from MSE implementation point to research needs that in turn will inform development of initiatives for the UN Decade of Ocean Science for Sustainable Development.

Keywords: Management Strategy Evaluation , IMBeR

Marine Ecosystem Variations Over the North Pacific and Their Linkage to Large-Scale Climate Variability and Change

*Emi Yati[1], Shoshiro Minobe[2,3], Nathan Mantua[4], Shin-ichi Ito[5], Emanuele Di Lorenzo[6]

1. Remote Sensing Application Center, Indonesian National Institute of Aeronautics and Space, Jakarta, Indonesia, 2. Department of Natural History Sciences, Graduate School of Science, Hokkaido University, Sapporo, Japan, 3. Department of Earth and Planetary Sciences, Faculty of Science, Hokkaido University, Sapporo, Japan, 4. Fish Ecology Division, Southwest Fisheries Science Center, National Marine Fisheries Service, National Oceanographic and Atmospheric Administration, Santa Cruz, CA, United States, 5. Atmosphere and Ocean Research Institute, University of Tokyo, Kashiwa, Japan, 6. School of Earth and Atmospheric Sciences, Georgia Institute of Technology, Atlanta, GA, United States

In order to understand how North Pacific (NP) marine ecosystems have varied, 120 marine biological time series for both the western (29 time series) and eastern (91 time series) NP were analyzed with a Principal Component Analysis (PCA) for the period 1965–2006. This is the first attempt to conduct a multivariate analysis for a large number of marine biological data in the western and eastern NP combined. We used Monte-Carlo simulation to evaluate confidence levels of correlations and explained variance ratio of PCA modes while accounting for auto-correlation within the analyzed time series. All first mode principal components (PC1s), which are the time coefficients of the first PCA modes, calculated for the data in the whole, western, and eastern NP exhibit a long-term trend. The PC1s were associated with an overall increase of Alaskan and Japanese/Russian salmon, and decreases of groundfish across the basin. This mode was closely related to the warming of sea-surface temperature over the NP and over the global oceans, thereby suggesting that the strongest mode of the NP marine ecosystem was already influenced by global warming. The eastern NP PC2, characterized by multi-decadal variability, was correlated positively with salmon and negatively with groundfish. On the other hand, the western NP PC2 exhibited slightly shorter timescale interdecadal variability than the eastern NP PC2 and was negatively correlated with zooplankton and two small pelagic fish time series around Japan. The eastern NP PC2 was most strongly related to the Pacific (inter-)Decadal Oscillation index, while the western NP PC2 was most closely related to the North Pacific Gyre Oscillation index. Consequently, the present analysis provides a new and unified view of climate change and marine ecosystem variations across the western and eastern NP. In particular, it is suggested that global warming has already substantially influenced the NP marine ecosystem, and that groundfish may suffer more than pelagic fish in response to future global warming.

This study has been published in Frontiers in Marine Science. 7:578165. doi: 10.3389/fmars.2020.578165

Keywords: marine ecosystem, decadal climate variability, global warming, North Pacific, regime shift

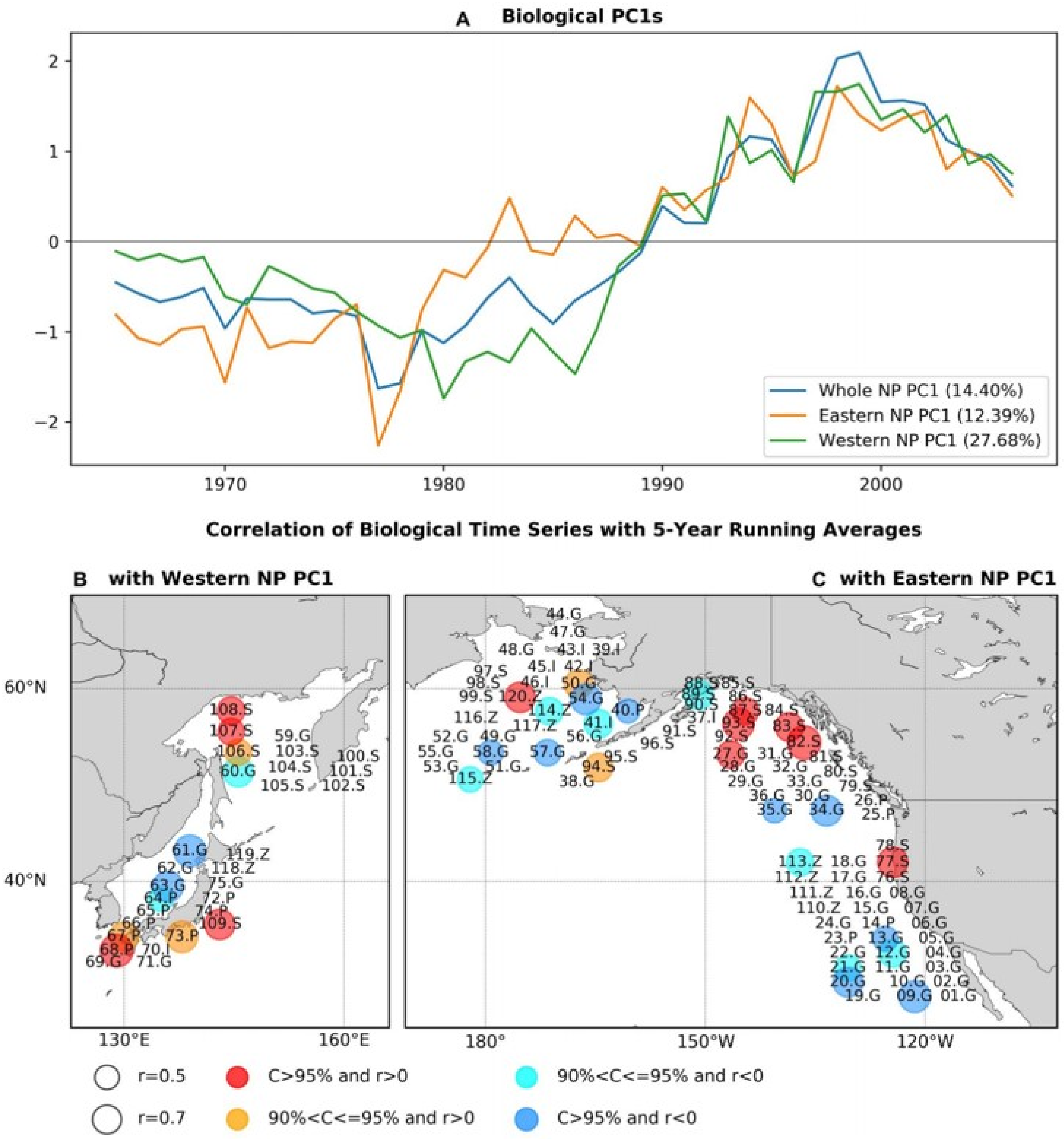


FIG 1. **(A)** PC1s for the whole NP, eastern NP, and western NP marine biological time series, and statistically significant correlations of marine biological time series **(B)** with the western NP PC1, **(C)** with the eastern NP PC1. Before calculating correlations 5-year running means are applied to PC1s and marine biological time series. In (B,C), numbers indicate species ID, while S, G, P, Z, and I indicate salmon, groundfish, small-pelagic, zooplankton, and invertebrate, respectively. Circle size indicates the absolute values of correlations and colors of the circles (red, orange, cyan, blue) indicate the sign of correlations and the corresponding confidence levels

Future biogeographic shifts of marine biodiversity in the Pacific Arctic

*Irene Alabia[1], Jorge Garcia Molinos[1], Sei-Ichi Saitoh[1], Takafumi Hirata[1], Toru Hirawake[1], Franz Mueter[2]

1. Hokkaido University, 2. University of Alaska Fairbanks

Climate change triggers a global reorganization of marine life. Biogeographical transition zones are redistribution hotspots that offer a unique opportunity to understand the mechanisms and consequences of climate-driven thermophilization processes in natural communities. Here, we examined the impacts of climate change projections in the 21st century (2026-2100) on marine biodiversity in the Eastern Bering and Chukchi seas, a climate-sensitive boreal-to-Arctic transition zone. Overall, projected changes in species distributions, resulted in poleward increases in species richness and functional redundancy, along with pronounced reductions in phylogenetic distances by century’ s end (2076-2100). Future poleward shifts of boreal species in response to warming and sea ice changes are projected to alter the biogeography of present-day Arctic communities as larger, longer-lived, and predatory taxa expand their leading distribution margins. Drawing from the existing evidence from other Arctic regions, these changes are anticipated to increase the future vulnerability of Arctic ecosystems, as trophic connectivity between biotic components increases. Our findings provided key insights into relationships between climate change, species composition, and ecosystem functioning across marine biogeographic regions.

Keywords: Biodiversity, climate change, biogeographic transition zones, Pacific arctic, species distribution

Instantaneous Acclimation allows computationally efficient modelling of the biogeochemical impacts of plankton ecophysiology

*S. Lan Smith[1], Onur Kerimoglu[2], Prima Anugerahanti[1], Yoshio Masuda[3], Yasuhiro Yamanaka[3], Yoshikazu Sasai[1]

1. Marine Ecosystem Dynamics Research Group, Research Institute for Global Change, Japan Agency for Marine-Earth Science and Technology, 2. ICBM, University of Oldenburg, Germany, 3. Faculty of Environmental Earth Science, Hokkaido University

Many coupled physical-biogeochemical models reproduce large-scale patterns of chlorophyll, primary production and biogeochemistry, but they often underestimate observed variability and gradients. One common reason is insufficient representation of systematic variations in the elemental composition and chlorophyll (Chl) content of phytoplankton. Chl is widely taken as a proxy for phytoplankton biomass, despite well known variations in Chl:biomass ratios as an acclimative response to changing environmental conditions. However, for the sake of simplicity and computational efficiency, many large scale biogeochemical models ignore this flexibility, compromising their ability to capture phytoplankton dynamics. Although some models account for the dynamics of phytoplankton composition by adding state variables (one for each element or pigment considered), that approach substantially increases computational requirements in spatially explicit (1-D and 3-D) setups. The Instantaneous Acclimation (IA) approach addresses these challenges by assuming that Chl:C:nutrient ratios are instantly optimized locally (within each modelled grid cell, at each timestep), such that they can be resolved as diagnostic variables.However, the IA approach was developed in a 0-D model and has not yet been rigorously tested in spatially explicit models. Here we present tests of IA in various spatially explicit models, including: an idealized, 1D vertical setup in the Framework for Aquatic Biogeochemical Models (FABM) coupled with the General Ocean Turbulence Model (GOTM), as well as a 3-D regional model and another 3-D global model. We show that the IA model and a fully dynamic, otherwise equivalently acclimative (DA) variant with an additional state variable behave similarly, and that both resolve chlorophyll

patterns and nutrient and growth dynamics not captured by the typical fixed-stoichiometry (FS) models [e.g., 1].

(1) Kerimoglu, O.; Anugerahanti, P.; Smith, S. Geosci. Model Dev. Discuss., in review 2021 , DOI: 10.5194/gmd-2020-396 .

Keywords: nutrients, photo-acclimation, phytoplankton, Earth System Modelling, marine ecosystems, biogeochemistry

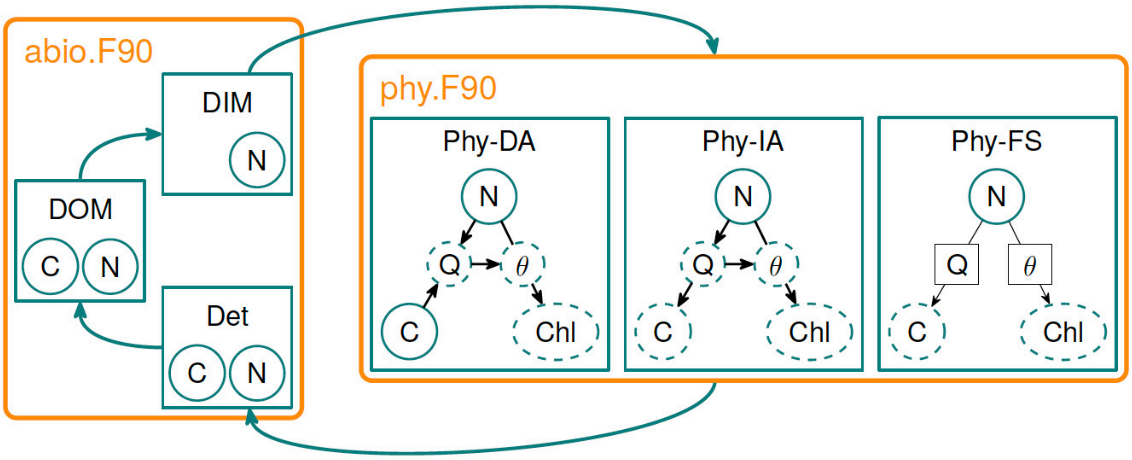


Figure 1: (Taken from [1]) Diagram of the FABM-NflexPD model. Abitoic components, DOM, DIM and Det are calculated by the module `abio.F90`, which are then coupled to the phytoplankton simulated by the module `phy.F90` that simulates the dynamics of Phy_N, Phy_C and Phy_{Chl} by the DA, IA and FS variants. Solid circles in the phytoplankton module represent state variables, dashed circles/ellipsoids represent diagnostically calculated variables and solid squares (for FS) represent prescribed values. The DA variant estimates the N, C and Chl content of phytoplankton based on a resource allocation scheme, whereas the FS variant estimates only N prognostically, while C and Chl are based on prescribed values of nitrogen quota (Q) and cellular Chl:C ratio (θ).

Interannual Variability in contributions of the Equatorial Undercurrent (EUC) to Peruvian Upwelling

*Gandy Maria Rosales Quintana[1], Robert Marsh[2], Luis Alfredo Icochea Salas[3]

1. Course of Applied Marine Environmental Studies, Tokyo University of Marine Science and Technology, 2. University of Southampton, UK, 3. Universidad Nacional Agraria La Molina, Peru

Time-varying sources of upwelling waters off the coast of northern Peruvian are analysed in a Lagrangian frame- work, tracking virtual particles backwards in time. Particle trajectories are calculated with temperature, salinity and velocity fields from a hindcast spanning 1988-2007, obtained with an eddy-resolving (1/12o) global configuration of the NEMO ocean model. At 30 and 100 m, where late-December coastal upwelling rates exceed 50 m per month, particles are seeded in proportion to the upwelling rate. Ensemble maps of particle concentration, age, depth, temperature, salinity and density reveal that a substantial but variable fraction of the particles upwelling off Peru arrive via the Equatorial Undercurrent (EUC). Particles follow the EUC core at around 250 m, characterized by temperatures of around 15-17oC, salinities in the range 34.9-35.2, and densities of = 25.5-26.5 . Additional inflows are via two slightly deeper branches further south from the main system, at around 3oS and 8o. The annual percentage of particles recruited by the EUC (17.5-47% and 16.5-54.6%, from 30 and 100 m respectively) reveal that more of the Peruvian upwelling can be tracked back to the EUC during El Niño and weak La Niña events. In contrast, upwelling waters are of more local origin during a strong La Niña,. Annually averaging EUC transport at specific longitudes, notable anomalies are evident during the major El Niño /La Niña transition of 1997-99. On short timescales, a degree of longitudinal coherence is evident in EUC transport, with transport anomalies at 160oW evident at the Galapagos Is- lands (92oW) around 30-35 days later. We conclude that the Peruvian upwelling system is subject to a variable EUC influence, on a wide range of timescales, most notably the interannual timescale of El Niño Southern Oscillation (ENSO).

Keywords: Peruvian Upwelling, Equatorial Undercurrent, Particle tracking

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

Sat. Jun 5, 2021 10:45 AM - 12:15 PM JST | Sat. Jun 5, 2021 1:45 AM - 3:15 AM UTC | Ch.11 Zoom Room 11

[A-OS13] Marine ecosystems and biogeochemical cycles: theory, observation and modeling

convener:Takafumi Hirata(Arctic Research Center, Hokkaido University), Shin-ichi Ito(Atmosphere and Ocean Research Institute, The University of Tokyo), E Eileen Hofmann(Old Dominion University), N Enrique Curchitser(Rutgers University New Brunswick), Chairperson:Takafumi Hirata(Arctic Research Center, Hokkaido University), Shin-ichi Ito(Atmosphere and Ocean Research Institute, The University of Tokyo), Eileen E Hofmann(Old Dominion University), Enrique N Curchitser(Rutgers University New Brunswick)

The ocean accounts for about 50% of global net primary production. This production is significant for carbon cycling and ecosystem functioning, and is related directly or indirectly to a variety of climatic and ecological phenomena. The responses to natural and anthropogenic environmental stressors that influence marine production and diversity can cause perturbations to marine ecosystems that alter trophic dependencies and interactions among organisms at a range of space and time scales. Quantification of the principal mechanisms driving spatio-temporal variability of marine ecosystem remains to be done, especially in terms of evaluation of uncertainty in responses. As a result, evaluating vulnerability of marine ecosystems to environmental change requires systematic and holistic approaches that integrate physics to ecology and are based in observations and modelling. In addition, expectations to deliver these science to public society is raising. This session aims to provide a venue for not only discussing recent advances in understanding marine biogeochemical cycles, ecosystems and their interactions, but also networking with a variety of people to seed new ideas in marine ecological research. Observational, modeling and conceptual studies, including technological development and operational applications, that consider linkages among biogeochemical and ecosystem processes, biodiversity, and the effects of multiple stressors from molecular to planetary scales are encouraged.

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

[AOS13-07] Influence of ENSO on surface chlorophyll-a in the Gulf of Thailand

*Dudsadee Leenawarat[1], Jutarak Luang-on[1], Anukul Buranapratheprat[2], Joji Ishizaka[3] (1.Graduate School of Environmental Studies, Nagoya University, 2.Department of Aquatic Science, Faculty of Science, Burapha University, Thailand, 3.Institute for Space-Earth Environmental Research, Nagoya University, Japan)

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

[AOS13-08] Nitrogen isotope mapping in the North Pacific using a marine nitrogen isotope model

*Chisato Yoshikawa[1], Masahito Shigemitsu[1], Akitomo Yamamoto[1], Akira Oka[2], Naohiko Ohkouchi[1] (1.JAMSTEC, 2.AORI)

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

[AOS13-09] **Interannual variations of the lower-trophic level ecosystem in the Harima-Nada, eastern Seto Inland Sea, Japan simulated by a plankton functional type model.**

*Naoki Yoshie[1], Ayaka Hiramine[1] (1.Center for Marine Environmental Studies, Ehime University)

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

[AOS13-10] **Occurrence of phytoplankton bloom as the Kuroshio passes an island**

*JIE GAO[1], Xinyu Guo[1] (1.Center for Marine Environmental Studies, Ehime University)

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

[AOS13-11] Long-term comparison between the Japanese sardine stock level and simulated zooplankton density around the Kuroshio axis

*Haruka Nishikawa[1], Hiroyuki Tsujino[2], Shiro Nishikawa[1], Hideyuki Nakano[2], Toru Sugiyama[1], Yoichi Ishikawa[1] (1.Japan Agency for Marine-Earth Science and Technology, 2.Meteorological Research Institute)

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

[AOS13-12] Changes in phytoplankton photophysiology during pre-bloom and bloom phases in the coastal Oyashio waters

*Tomonori Isada[1], Toru Hirawake[2], Koji Suzuki[3], Jun Nishioka[4], Hiromi Kasai[5] (1.Field Science Center for Northern Biosphere, Hokkaido University, 2.Faculty of Fisheries Sciences, Hokkaido University, 3.Faculty of Environmental Earth Science, Hokkaido University, 4.Institute of Low Temperature Science, Hokkaido University, 5.Japan fisheries research and education agency)

Influence of ENSO on surface chlorophyll-a in the Gulf of Thailand

*Dudsadee Leenawarat[1], Jutarak Luang-on[1], Anukul Buranapratheprat[2], Joji Ishizaka[3]

1. Graduate School of Environmental Studies, Nagoya University, 2. Department of Aquatic Science, Faculty of Science, Burapha University, Thailand, 3. Institute for Space-Earth Environmental Research, Nagoya University, Japan

The Gulf of Thailand (GoT) is a tropical and semi-enclosed sea. This area is surrounded by Vietnam, Cambodia, Thailand, and Malaysia, and connected to the South China Sea via southeastern part. The variation of surface chlorophyll-a (chl-a) in this region was controlled by monsoon system. The large-scale phenomena such as El Niño Southern Oscillation (ENSO) also caused the variation over the monsoon system. These environmental changes caused by ENSO may increase/decrease phytoplankton production. To investigate the impact of ENSO on surface chl-a in each season, monthly chl-a data from MODIS from 2002 to 2018 were used in this study. Environmental parameters including sea surface temperature (SST), wind, precipitation, and discharge were also considered to describe the variability. It was found that the influence of ENSO on chl-a was stronger during the northeast monsoon (NEM; November to February) to the non-monsoon (NON; March to May) than the southwest monsoon (SWM; June to October). In the coastal area, surface chl-a responded to abnormally low/high precipitation and river discharge during El Niño/La Niña in all seasons. In the offshore area, chl-a was affected by changes in wind and water mixing. Weak/strong wind and increased/decreased SST may reduce/enhance in mixing from deep layer water mass that contains higher nutrients. Under El Niño condition, weak/strong wind and increased SST were found during NEM/NON and the opposite condition was found during La Niña condition. Weak in mixing from the deep layer and strong mixing of warm water mass in the upper layer were expected to occur during NEM and NON under El Niño condition. In addition, wind anomaly seems to create the shifting in the high chl-a area near the GoT mouth.

Keywords: Gulf of Thailand , Chlorophyll-a, ENSO

Nitrogen isotope mapping in the North Pacific using a marine nitrogen isotope model

*Chisato Yoshikawa[1], Masahito Shigemitsu[1], Akitomo Yamamoto[1], Akira Oka[2], Naohiko Ohkouchi[1]

1. JAMSTEC, 2. AORI

Understanding the special distribution of nitrogen isotope composition ($\delta^{15}N$) of phytoplankton in the surface ocean is useful for uncovering the life histories of marine organisms including fish. The $\delta^{15}N$ of phenylalanine (one of the "source" amino acids) of fish tissues inherits the $\delta^{15}N$ of phytoplankton where the fish grew up. Recently, Vane et al. (2018) determined $\delta^{15}N$ of amino acids in otoliths and showed that otoliths preserved a record of the $\delta^{15}N$ of phytoplankton over the lifetime of individual fish. Moreover, Matsubayashi et al. (2020) determined time-series $\delta^{15}N$ of amino acids in vertebra centra and successfully tracked a migration of chum salmon. Thus, the reconstruction of the temporal variations of $\delta^{15}N$ of amino acids from various fish tissues has made remarkable progress. However, there is as yet no accurate $\delta^{15}N$ map of phytoplankton due to observational heterogeneity, and it prevents improvement in the accuracy of migratory route estimation. In this study, we made a $\delta^{15}N$ map of phytoplankton in the North Pacific by using a global ocean nitrogen isotope model. We installed a marine nitrogen isotope model (Yoshikawa et al., 2005) with denitrification (Shigemitsu et al., 2016) and N_2 fixation (Coles et al., 2007) schemes into an off-line biogeochemical model that is driven by climatological monthly mean physical fields obtained from the outputs of a preindustrial control simulation performed with MIROC 3.2 (K-1 Model Developers, 2004). The simulated phytoplankton was enriched in ^{15}N in the northern Bering and Chukchi Seas where sedimentary denitrification is significant. The simulated phytoplankton was depleted in ^{15}N in the Kuroshio extension region where N_2 fixation occurs, and in the subarctic North Pacific region where the phytoplankton never uses up nitrate in the surface water due to iron limitation. In this talk, we will report the validation result of the simulated $\delta^{15}N$ map with the various $\delta^{15}N$ data set obtained from the North Pacific.

Keywords: Nitrogen isotope ratio, Marine nitrogen cycle, Marine ecosystem model

Interannual variations of the lower-trophic level ecosystem in the Harima-Nada, eastern Seto Inland Sea, Japan simulated by a plankton functional type model.

*Naoki Yoshie[1], Ayaka Hiramine[1]

1. Center for Marine Environmental Studies, Ehime University

In recent years, the effects of considerable decline of nutrient concentration with the strong and long-term regulation of nutrient discharge on the lower-trophic level ecosystem have received a lot of attention in the Harima-nada, eastern Seto Inland Sea, Japan. To investigate these effects, we conducted the numerical simulations using a plankton functional type model from 2000 to 2013 with the several different boundary conditions, which included decreasing of nutrient concentration with the discharge regulation and increasing of water temperature with the climate change. The model successfully reproduced the observed quite strange interannual variations, which were almost constant biomass of total phytoplankton in spite of the considerable decline of nutrient concentration, and also reproduced significant decrease in biomass of meso-zooplankton such as copepod. This is because the decrease in large-sized phytoplankton such as diatom due to both the decline of nutrient and increase of water temperature was canceled out by the increase in small-sized phytoplankton associated with the increase of water temperature. The decrease of diatom with both the decline of nutrient and increase of water temperature caused the decrease of copepod, which was extremely important feed for anchovy and sand eel in this region. It might be a reason for significant reduce of fish resources in the Harima-Nada.

Keywords: nutrient, phytoplankton, zooplankton, ecosystem model, coastal ocean

Occurrence of phytoplankton bloom as the Kuroshio passes an island

*JIE GAO[1], Xinyu Guo[1]

1. Center for Marine Environmental Studies, Ehime University

When the Kuroshio flows over islands or seamounts, it causes irregular fluid motions in the wake, such as eddy generation and shedding (Von Karman Vortex Street), turbulence mixing, upwelling and downwelling, and even instability. Vertical perturbations such as mixing and upwelling, bring the nutrients from deep layer to the oligotrophic surface layer and therefore enhance biological activity in the euphotic layer. Biological enrichment forms in the vicinity of the island and extends downstream, which is known as 'Island Mass Effect' (IME).

To investigate the IME and its community variation in the Kuroshio region, we combine a hydrodynamic model (Princeton Ocean Model) and a lower-trophic-level ecosystem model (eNEMURO). The eNEMURO includes 4 nutrient compartments (NO_3, NH_4, $Si(OH)_4$, PO_4), 4 phytoplankton compartments (2 types of micro-phyt, nano-phyt, pic-phyt), 4 zooplankton compartments (macro-zoo, meso-zoo, micro-zoo, nano-zoo), 3 detritus compartments (POM, DOM, Opal). We apply the combined two models to a simulation of ideal baroclinic geostrophic current flowing over an island with an ambient biological condition similar to the situation at the PN section across the Kuroshio in the East China Sea.

The model produces the Von Karman Vortex Street in the case of a current with a speed of 1m/s passing over an island with a diameter of 10 km. The eddies form just behind the island and shed toward downstream with a period of 13 hours. The cold water in the cyclonic recirculation corresponds to local upwelling that supplies extra nutrient to the oligotrophic surface and induces the surface phytoplankton bloom and uplift of Subsurface Chl-a Maximum (SCM) in the downstream wake area. At the depth below SCM (50m), the concentration of DIN increases inside the cyclonic eddies, while the phytoplankton decreases in the same location in the vicinity of the island. The variation of biological components in Von Karmen Vortex Street is caused by a combination of physical processes and biochemical processes. From the island to the place 100 km behind the island, the variation is mainly controlled by physical processes. After that, with the eddies extending downstream, effects of biogeochemical process increase and gradually become important. The increase in the cyclonic eddy region caused by biogeochemical processes is mainly contributed by photosynthesis supported by extra nutrient supply. In the oligotrophic surface water, the supply of nitrate is more efficient to the photosynthesis of PS, which has the lowest half-saturation concentration of nitrate.

In the realistic ocean, the Kuroshio passes islands with a variety of diameter and with a variety of speed. The variation in current speed and island size can cause different hydrodynamic condition for the ecosystem. To understand the effect of such variation, we design a series of numerical simulations to obtain a general understanding of hydrodynamic condition and biological response at island wake in the Kuroshio region.

Keywords: biogeochemical model, kuroshio, island

Long-term comparison between the Japanese sardine stock level and simulated zooplankton density around the Kuroshio axis

*Haruka Nishikawa[1], Hiroyuki Tsujino[2], Shiro Nishikawa[1], Hideyuki Nakano[2], Toru Sugiyama[1], Yoichi Ishikawa[1]

1. Japan Agency for Marine-Earth Science and Technology, 2. Meteorological Research Institute

Food availability in the larval stage is thought to be one of the important control factors for the Japanese sardine (*Sardinops melanostictus*) stock fluctuation. However, it is hard to compare the stock level with food availability, because there are few long-term data set of zooplankton. In this study, we simulated the past zooplankton density in the Northwestern Pacific from 1930s by using an NPZD model to solve the problem. Following a previous study that suggested an importance of the Kuroshio axis region as a larval feeding grounds, we compared the modeled zooplankton density in that region with the logarithm of recruitment per spawner (LNRPS) from 1978 to 2017 and catch from 1938 to 2017. This is the first study that shows the timeseries of modeled zooplankton density in the Japanese sardine feeding grounds. We found that there is a significant positive correlation between the zooplankton density and the LNRPS. Also the zooplankton density variation is consistent with the catch variation. These results suggested that the zooplankton density variation in the Kuroshio axis region affected the stock fluctuation of the Japanese sardine over the past few decades.

Keywords: Japanese sardine, NPZD model, Kuroshio

Changes in phytoplankton photophysiology during pre-bloom and bloom phases in the coastal Oyashio waters

*Tomonori Isada[1], Toru Hirawake[2], Koji Suzuki[3], Jun Nishioka[4], Hiromi Kasai[5]

1. Field Science Center for Northern Biosphere, Hokkaido University, 2. Faculty of Fisheries Sciences, Hokkaido University, 3. Faculty of Environmental Earth Science, Hokkaido University, 4. Institute of Low Temperature Science, Hokkaido University, 5. Japan fisheries research and education agency

Measurement of phytoplankton biomass and productivity in the ocean serve fundamental information about marine biogeochemical cycles and the trophic status of marine ecosystems. Photosynthesis–irradiance (*PE*) curve experiment can provide a means of comparing the photosynthetic characteristics of phytoplankton across different natural populations. Here, we investigated changes over time in phytoplankton community structure and their photosynthetic properties in the coastal Oyashio region, NW Pacific, where massive spring phytoplankton blooms occur every year and the blooms contribute to the highest seasonal biological drawdown effect on seawater pCO_2 in the world’ s oceans, from March 2015 to January 2016 through HPLC-CHEMTAX pigment analyses and the PE curve experiments with ^{13}C tracer technique. Our CHEMTAX outputs showed that diatoms were consistently predominant from the pre-bloom to bloom periods, although chlorophyll (Chl) *a* concentrations during bloom were significantly higher than those in pre-bloom. We found the E_k-independent variability associated with the parallel changes in the Chl *a* specific maximum photosynthetic rate (P^B_{max}) and the initial slope of the *PE* curve (α^B) in each phase, suggesting the different photoacclimation strategies of phytoplankton assemblages between pre-bloom and bloom phases. These results could be of help for the parameterization of primary production models using satellite ocean color data and of ecosystem models in the coastal Oyashio waters.

Keywords: phytoplankton, photosynthetic parameters, spring bloom, Coastal Oyashio

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

Sat. Jun 5, 2021 1:45 PM - 3:15 PM JST | Sat. Jun 5, 2021 4:45 AM - 6:15 AM UTC | Ch.11 Zoom Room 11

[A-OS13] Marine ecosystems and biogeochemical cycles: theory, observation and modeling

convener:Takafumi Hirata(Arctic Research Center, Hokkaido University), Shin-ichi Ito(Atmosphere and Ocean Research Institute, The University of Tokyo), E Eileen Hofmann(Old Dominion University), N Enrique Curchitser(Rutgers University New Brunswick), Chairperson:Shin-ichi Ito(Atmosphere and Ocean Research Institute, The University of Tokyo), Takafumi Hirata(Arctic Research Center, Hokkaido University), Eileen E Hofmann(Old Dominion University), Enrique N Curchitser(Rutgers University New Brunswick)

The ocean accounts for about 50% of global net primary production. This production is significant for carbon cycling and ecosystem functioning, and is related directly or indirectly to a variety of climatic and ecological phenomena. The responses to natural and anthropogenic environmental stressors that influence marine production and diversity can cause perturbations to marine ecosystems that alter trophic dependencies and interactions among organisms at a range of space and time scales. Quantification of the principal mechanisms driving spatio-temporal variability of marine ecosystem remains to be done, especially in terms of evaluation of uncertainty in responses. As a result, evaluating vulnerability of marine ecosystems to environmental change requires systematic and holistic approaches that integrate physics to ecology and are based in observations and modelling. In addition, expectations to deliver these science to public society is raising. This session aims to provide a venue for not only discussing recent advances in understanding marine biogeochemical cycles, ecosystems and their interactions, but also networking with a variety of people to seed new ideas in marine ecological research. Observational, modeling and conceptual studies, including technological development and operational applications, that consider linkages among biogeochemical and ecosystem processes, biodiversity, and the effects of multiple stressors from molecular to planetary scales are encouraged.

1:45 PM - 2:05 PM JST | 4:45 AM - 5:05 AM UTC

[AOS13-13] Biogeochemical fingerprints of ocean migration of Pacific salmon

★Invited Papers

*Jun Matsubayashi[1] (1.Chuo University)

2:05 PM - 2:20 PM JST | 5:05 AM - 5:20 AM UTC

[AOS13-14] Vertical habitat shifts of juvenile Japanese jack mackerel (*Trachurus japonicus*) estimated by otolith microchemistry

*Megumi Enomoto[1], Shin-ichi Ito[1], Motomitsu Takahashi[2], Chiyuki Sassa[2], Tomihiko Higuchi[1], Kotaro Shirai[1] (1.Atmosphere and Ocean Research Institute, The University of Tokyo, 2.Fisheries Resource Institute, Japan Fisheries Research and Education Agency)

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

[AOS13-15] Retrospective time-series nitrogen isotope analysis of fish otoliths

*Yota Harada[1], Chisato Yoshikawa[1], Nanako O. Ogawa[1], Saburo Sakai[1], Shin-ichi Ito[2], 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)

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

[AOS13-16] Fish specialize their metabolic performance to maximize bioenergetic efficiency in their local environment

★Invited Papers

*Chenying Guo[1], Shin-ichi Ito[1], Michio Yoneda[2], Hajime Kitano[2], Hitoshi Kaneko[3], Megumi Enomoto[1], Tomoya Aono[1], Masahiro Nakamura[2], Takashi Kitagawa[1], Nicolas C Wegner[4], Emmanis Dorval[5]
(1.Atmosphere and Ocean Research Institute, the University of Tokyo, 2.Japan Fisheries Research and Education Agency, 3.Japan Agency for Marine-Earth Science and Technology (JAMSTEC), 4.Southwest Fisheries Science Center, National Marine Fisheries Service, NOAA, 5.Lynker Technologies, LLC., under contract to Southwest Fisheries Science Center, NOAA)

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

[AOS13-17] Comparative study on environment experienced by jack mackerel in the East China Sea between 1960s and 2000s.

*Tomihiko Higuchi[1], Motomitsu Takahashi[2], Megumi Enomoto[1], Kotaro Shirai[1], Shin-ichi Ito[1]
(1.Atmosphere and Ocean Research Institute, The University of Tokyo, 2.Fisheries Resources Institute, Japan Fisheries Research and Education Agency, Nagasaki, Japan)

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

[AOS13-18] Discussion

Biogeochemical fingerprints of ocean migration of Pacific salmon

*Jun Matsubayashi[1]

1. Chuo University

Long-distance ocean migration by marine fish has long fascinated scientists, and a better understanding of such migrations may hold important keys to understanding the impacts of ongoing climate change as well as the evolutionary history and mechanisms of niche partitioning in these taxa. However, research into this topic has been hampered by the substantial investment of time and effort required to monitor fishes in the ocean using field surveys.

The migration history of a fish can be recorded as isotope ratios in tissues such as the otolith and vertebral centrum that undergo incremental growth. Specifically, by combining data on spatial patterns in isotope ratios (isoscapes) with retrospective isotope analysis of vertebral centra, it is possible to reconstruct potential individual migration routes.

In this study, I revealed chum salmon migration routes using the isoscape and retrospective isotope analysis of the salmon. Initially, the isoscape of stable nitrogen isotope ratios ($\delta^{15}N$) at the base of the food web ($\delta^{15}N_{Base}$) in the northern North Pacific was generated by conducting compound-specific isotope analysis of amino acids from copepods sampled across the region. Then, I performed retrospective stable nitrogen isotope analysis of mature chum salmon sampled from different streams in Japan. Finally, the migration routes of individual salmon were estimated by using a state-space model which can incorporate the isoscape and retrospective isotope shifts of salmon.

The isotope tracking successfully reproduced a known salmon migration route between the Okhotsk and Bering seas. In addition, the results suggested the presence of a new migration route to the continental shelf of the eastern Bering Sea during a later growth stage. The later stage of skeletal growth of salmon is corresponds to the timing of sexual maturation of this species. For this reason, this study strongly suggested that the Bering Sea Shelf is a destination of ocean migration of chum salmon, and the purpose of their journey should be fulfilling the nutritional demands of sexual maturation in this highly-productive region.

The results of this study suggested that Asian population of chum salmon strongly depend on the nutrient in the Bering Sea Shelf in the far distance from Japan. It anticipates that monitoring and management of the environment of their habitat while traveling in the ocean as well as their natal river and coastal area are important for sustainable use of salmon resources. The isoscape of stable nitrogen isotope ratios generated in this study can be applied for isotope tracking of various animals which migrate the North Pacific Ocean. Hence, the method of this study will strongly promote the future use of isoscape for migration study of marine animals.

Keywords: isoscape, salmon, migration, nitrogen stable isotope ratios

Vertical habitat shifts of juvenile Japanese jack mackerel (*Trachurus japonicus*) estimated by otolith microchemistry

*Megumi Enomoto[1], Shin-ichi Ito[1], Motomitsu Takahashi[2], Chiyuki Sassa[2], Tomihiko Higuchi[1], Kotaro Shirai[1]

1. Atmosphere and Ocean Research Institute, The University of Tokyo, 2. Fisheries Resource Institute, Japan Fisheries Research and Education Agency

Japanese jack mackerel (*Trachurus japonicus*) are distributed in the semi-demersal layer, while larvae are distributed in the surface layer in the East China Sea. Smooth vertical habitat layer shift (HLS) is important for their survival. However, details (start timing and duration) of HLS have been unclarified. To elucidate HLS, otolith oxygen stable isotope ratio ($\delta^{18}O_{oto}$), of which the value increases at lower temperature and higher salinity, was analyzed in high resolution by 5 days segment. From the history of $\delta^{18}O_{oto}$, HLS timing was estimated by two types of indices; HLS moment and HLS duration, which were identified by the largest $\delta^{18}O_{oto}$ gap signal and gradual $\delta^{18}O_{oto}$ change, respectively. In addition, daily ages and water temperature variances fish experienced were compared among three life history traits; the metamorphosis, the behavioral change from planktonic to self-swimming and the swimming ability increase. As a result, average HLS moment was estimated to be 42.2±18.2 daily age. HLS started at 28.0±11.0 daily age and average HLS duration was 27.9±16.2 days on average. The start of HLS duration corresponded to the start of metamorphosis, and development of swimming ability was happened simultaneously with HLS moment. From the $\delta^{18}O_{oto}$ value of edge, observed temperature and salinity in the layer fish caught and the relationship between salinity and $\delta^{18}O_{sw}$ ($\delta^{18}O$ of sea water) from the previous study, an equation between $\delta^{18}O$ ($\delta^{18}O_{oto} - \delta^{18}O_{sw}$) and temperature was estimated; Temperature(˚C) = -3.51 (±0.49) × $\delta^{18}O$ (‰) + 15.86 (±0.29). Temperature variance converted from $\delta^{18}O_{oto}$ suggested that juveniles gradually shift habitat layer as they experience early life history traits, not suddenly after specific trait.

Keywords: otolith, otolith oxygen stable isotope ratio, Japanese jack mackerel, vertical habitat layer shift, early life history, East China Sea

Retrospective time-series nitrogen isotope analysis of fish otoliths

*Yota Harada[1], Chisato Yoshikawa[1], Nanako O. Ogawa[1], Saburo Sakai[1], Shin-ichi Ito[2], 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

Fish otoliths that allow both age estimation and retrospective isotope analysis are a powerful tool for investigating life and movement histories of fish. Nitrogen isotopes that vary spatially in the ocean are useful for tracking fish migration, but fish otoliths that consist of calcium carbonate deposited within a proteinaceous matrix, generally do not contain enough nitrogen to allow retrospective δ^{15}N comparisons with the conventional elemental analyzer/isotope ratio mass spectrometry (EA IRMS) system. To achieve retrospective time-series nitrogen isotope analysis of otoliths from individual fish, an EA-IRMS system that was optimised for microscale isotope analysis was used. Otoliths from commercially important fish such as japanese sardine (*Sardinops melanostictus*), chub mackerel (*Scomber japonicus*), pacific saury (*Cololabis saira*), and jack mackerel (*Trachurus japonicus*) contained 0.31, 0.28, 0.26 and 0.18 % of nitrogen by weight, respectively. The weight of the otoliths were 2.7, 6.4, 0.7 and 22.9 mg, respectively. Although pacific saury had the smallest otolith, we were able to achieve retrospective bulk ^{15}N analysis with the δ^{15}N values ranging from 5.3 to 6.6‰ and recreated a known migration route of pacific saury in North west pacific. Retrospective time-series ^{15}N analysis of otoliths can be used with other isotopes, for example, oxygen isotopes that are used to estimate experienced water temperatures to improve the estimation of fish migration.

Keywords: isotope, nitrogen, fish, otolith

Fish specialize their metabolic performance to maximize bioenergetic efficiency in their local environment

*Chenying Guo[1], Shin-ichi Ito[1], Michio Yoneda[2], Hajime Kitano[2], Hitoshi Kaneko[3], Megumi Enomoto[1], Tomoya Aono[1], Masahiro Nakamura[2], Takashi Kitagawa[1], Nicolas C Wegner[4], Emmanis Dorval[5]

1. Atmosphere and Ocean Research Institute, the University of Tokyo, 2. Japan Fisheries Research and Education Agency, 3. Japan Agency for Marine-Earth Science and Technology (JAMSTEC), 4. Southwest Fisheries Science Center, National Marine Fisheries Service, NOAA, 5. Lynker Technologies, LLC., under contract to Southwest Fisheries Science Center, NOAA

Species-specific ecological traits in fishes are likely to vary between populations or stocks due to differences in regional oceanic conditions, such as latitudinal temperature. We examined potential intraspecific differences in the swimming performance and metabolism of chub mackerel (*Scomber japonicus*) from the Northwest and Northeast stocks, which are distributed on opposite sides of the North Pacific at similar latitudes, but where the temperature contrast is large. Swimming bioenergetics and metabolic data of Northwest stock were measured at 14°C, 18°C, and 24°C using variable-speed swim-tunnel respirometers, and then the resulting bioenergetic parameters were compared with previous findings from the Northeast stock. At a given size, the maximum sustainable swimming speed (U_{max}) of the Northwest stock showed no significant difference compared to the Northeast stock at 18°C and 24°C, but was lower at 14°C. In addition, the oxygen consumption rate (M_{O2}) of the Northwest stock showed lower mass dependence and different temperature dependence at a given swimming speed than in the Northeast stock. Combined with stock-specific data on growth and experienced temperatures in the wild, these bioenergetic differences indicate that the swimming performance and metabolism of the two stocks are specific to their local environment to maximize bioenergetic efficiency. This study has been already published on Frontiers in Marine Science (doi:10.3389/fmars.2021.613965).

Keywords: chub mackerel, Scomber japonicus, metabolism, oxygen consumption rate, temperature, swimming speed

Comparative study on environment experienced by jack mackerel in the East China Sea between 1960s and 2000s.

*Tomihiko Higuchi[1], Motomitsu Takahashi[2], Megumi Enomoto[1], Kotaro Shirai[1], Shin-ichi Ito[1]

1. Atmosphere and Ocean Research Institute, The University of Tokyo, 2. Fisheries Resources Institute, Japan Fisheries Research and Education Agency, Nagasaki, Japan

Jack mackerel *Trachurus japonicus* is distributed on the continental shelf waters along with the subtropical Kuroshio Current and the Tsushima Warm Current in the western North Pacific. The East China Sea (ECS) is one of the major spawning and nursery grounds for jack mackerel and understanding the recruitment processes of jack mackerel into the fishing grounds in the ECS is important. However, information on how jack mackerel respond to decadal temperature variability is limited. Also, it is known that jack mackerel change their habitat from the surface to the semi-demersal layer in early life stage in the ECS. This study aims to know the migration history including the vertical habitat layer change of jack mackerel in the ECS during the 1960s and the 2000s. To estimate their environment experienced during the larval and juvenile stages, oxygen ($\delta^{18}O$) stable isotope of jack mackerel otolith was analyzed by using isotope ratio mass spectrometer (n=422). Fish samples were taken at the ECS in 1960-70s and 2000-2010s (15 individuals, each period). The high-precision micro-milling system GEOMILL 326 was used for otolith subsampling. At every 10 daily rings (20-30 daily rings in section including core), a ring was tracked and used as the boundary of the micro-milling increment. As a result, there was no significant differences in temperature experienced by the larval-juvenile stages, which is estimated from $\delta^{18}O$, between the two survey periods. This indicate that both jack mackerel from different periods likely utilized a similar environment under a changing ocean state. By using assimilated ocean data (SODA2.2.4 for 1960s, 3.12.2 for 2000s), we estimated the distribution area of jack mackerel in each age. In the early life stage (~60 daily age), distribution areas were different between the periods and individuals in the 1960s migrated in the north compared with those in the 2000s. There was a significant positive relationship between habitat temperature and growth rates based on otolith increment width during the juvenile stage. This suggested that the effect of water temperature on the growth of jack mackerel in the early life stage. Thus, jack mackerel in ECS likely adapted to decadal climate variability and select the preferred environment.

Keywords: otolith isotope analysis, fish migration, temperature history

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

[A-OS13] Marine ecosystems and biogeochemical cycles: theory, observation and modeling

convener:Takafumi Hirata(Arctic Research Center, Hokkaido University), Shin-ichi Ito(Atmosphere and Ocean Research Institute, The University of Tokyo), E Eileen Hofmann(Old Dominion University), N Enrique Curchitser(Rutgers University New Brunswick), Chairperson:Shin-ichi Ito(Atmosphere and Ocean Research Institute, The University of Tokyo), Takafumi Hirata(Arctic Research Center, Hokkaido University), Eileen E Hofmann(Old Dominion University), Enrique N Curchitser(Rutgers University New Brunswick)

Sat. Jun 5, 2021 1:45 PM - 3:15 PM Ch.11 (Zoom Room 11)

The ocean accounts for about 50% of global net primary production. This production is significant for carbon cycling and ecosystem functioning, and is related directly or indirectly to a variety of climatic and ecological phenomena. The responses to natural and anthropogenic environmental stressors that influence marine production and diversity can cause perturbations to marine ecosystems that alter trophic dependencies and interactions among organisms at a range of space and time scales. Quantification of the principal mechanisms driving spatio-temporal variability of marine ecosystem remains to be done, especially in terms of evaluation of uncertainty in responses. As a result, evaluating vulnerability of marine ecosystems to environmental change requires systematic and holistic approaches that integrate physics to ecology and are based in observations and modelling. In addition, expectations to deliver these science to public society is raising. This session aims to provide a venue for not only discussing recent advances in understanding marine biogeochemical cycles, ecosystems and their interactions, but also networking with a variety of people to seed new ideas in marine ecological research. Observational, modeling and conceptual studies, including technological development and operational applications, that consider linkages among biogeochemical and ecosystem processes, biodiversity, and the effects of multiple stressors from molecular to planetary scales are encouraged.

3:10 PM - 3:15 PM

[AOS13-18]Discussion

[E] Oral | A (Atmospheric and Hydrospheric Sciences) : A-HW Hydrology & Water Environment

Sat. Jun 5, 2021 9:00 AM - 10:30 AM JST | Sat. Jun 5, 2021 12:00 AM - 1:30 AM UTC | Ch.12 Zoom Room 12

[A-HW20] Hydrology & Water Environment

convener:Takeshi Hayashi(Faculty of Education and Human Studies, Akita University), Keisuke Fukushi(Institute of Nature & Environmental Technology, Kanazawa University), Koichi Sakakibara(Department of Environmental Sciences, Faculty of Science, Shinshu University), Dai Yamazaki(Institute of Industrial Sciences, The University of Tokyo), Chairperson:Takeshi Hayashi(Faculty of Education and Human Studies, Akita University), Keisuke Fukushi(Institute of Nature & Environmental Technology, Kanazawa University), Koichi Sakakibara(Department of Environmental Sciences, Faculty of Science, Shinshu University), Dai Yamazaki(Institute of Industrial Sciences, The University of Tokyo)

We focus on various issues of water cycle and environment and aim to answer questions of hydrological and earth system sciences; 1) surface, subsurface and their boundary hydrological processes of water cycle, 2) natural and anthropogenic hydrothermal systems, 3) environments issues and studies on a watershed or global scale, 4) water-related issues with ecological, environmental, and geochemical aspects, and 5) other issues in hydrological sciences. We welcome presentations regarding various kinds of approaches and techniques such as field survey, remote sensing, chemical and isotope tracers, numerical simulation, and theoretical analysis. This session is jointly hosted by societies of water-related geoscience (Geochemical Society of Japan, Japanese Association of Groundwater Hydrology, Japanese Association of Hydrological Sciences, and Japan Society of Hydrology and Water Resources), and accepts wide-range research topics related to water cycle and environment described above.

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

[AHW20-01] Introduction

9:05 AM - 9:20 AM JST | 12:05 AM - 12:20 AM UTC

[AHW20-02] Behavior of pore-air entrapment in unsaturated soil layer in two small headwater catchments with different soil depth

*Sho Iwagami[1], Shoji Noguchi[2], Takanori Shimizu[1], Tayoko Kubota[1], Shin'ichi Iida[1] (1.Forestry and Forest Products Research Institute, Forest Research and Management Organization, National Research and Development Agency, 2.Kansai Research Center, Forestry and Forest Products Research Institute, Forest Research and Management Organization, National Research and Development Agency)

9:20 AM - 9:35 AM JST | 12:20 AM - 12:35 AM UTC

[AHW20-03] Developement of a 2D Eulerian SPH shallow water model for dam break flows

*Kao-Hua Chang[1] (1.National Taiwan Ocean University)

9:35 AM - 9:50 AM JST | 12:35 AM - 12:50 AM UTC

[AHW20-04] Investigating the validity of a meso scale constitutive equation using micro scale water dynamics simulations for hillslope rainfall-runoff processes

*Yutaka Ichikawa[1], Yuusuke Mori[1], Yasuto Tachikawa[1] (1.Graduate School of Engineering, Kyoto University)

9:50 AM - 10:05 AM JST | 12:50 AM - 1:05 AM UTC

[AHW20-05] A review of ensemble flood forecasting for operational warning

*Megumi Watanabe[1], Shunsuke Ito[2], Wenchao Ma[1], Dai Yamazaki[1] (1.Institute of Industrial Science, The University of Tokyo, Japan, 2.School of Engineering, The University of Tokyo, Japan)

10:05 AM - 10:20 AM JST | 1:05 AM - 1:20 AM UTC

[AHW20-06] ***Toward Downscaling Storage-Discharge Dynamics: Training Long Short-Term Memory (LSTM) model for Simulating Nonlinear Storage-Discharge Relation in HUC-8 Rum***

River Watershed, MN

*Pai-Feng Victor Teng[1] (1.University of Minnesota)

10:20 AM - 10:30 AM JST | 1:20 AM - 1:30 AM UTC

[AHW20-07] Discussion

[E] Oral | A (Atmospheric and Hydrospheric Sciences) | A-HW Hydrology & Water Environment

[A-HW20] Hydrology &Water Environment

convener:Takeshi Hayashi(Faculty of Education and Human Studies, Akita University), Keisuke Fukushi(Institute of Nature &Environmental Technology, Kanazawa University), Koichi Sakakibara(Department of Environmental Sciences, Faculty of Science, Shinshu University), Dai Yamazaki(Institute of Industrial Sciences, The University of Tokyo), Chairperson:Takeshi Hayashi(Faculty of Education and Human Studies, Akita University), Keisuke Fukushi(Institute of Nature &Environmental Technology, Kanazawa University), Koichi Sakakibara(Department of Environmental Sciences, Faculty of Science, Shinshu University), Dai Yamazaki(Institute of Industrial Sciences, The University of Tokyo)

Sat. Jun 5, 2021 9:00 AM - 10:30 AM Ch.12 (Zoom Room 12)

We focus on various issues of water cycle and environment and aim to answer questions of hydrological and earth system sciences; 1) surface, subsurface and their boundary hydrological processes of water cycle, 2) natural and anthropogenic hydrothermal systems, 3) environments issues and studies on a watershed or global scale, 4) water-related issues with ecological, environmental, and geochemical aspects, and 5) other issues in hydrological sciences. We welcome presentations regarding various kinds of approaches and techniques such as field survey, remote sensing, chemical and isotope tracers, numerical simulation, and theoretical analysis. This session is jointly hosted by societies of water-related geoscience (Geochemical Society of Japan, Japanese Association of Groundwater Hydrology, Japanese Association of Hydrological Sciences, and Japan Society of Hydrology and Water Resources), and accepts wide-range research topics related to water cycle and environment described above.

9:00 AM - 9:05 AM

[AHW20-01]Introduction

Behavior of pore-air entrapment in unsaturated soil layer in two small headwater catchments with different soil depth

*Sho Iwagami[1], Shoji Noguchi[2], Takanori Shimizu[1], Tayoko Kubota[1], Shin'ichi Iida[1]

1. Forestry and Forest Products Research Institute, Forest Research and Management Organization, National Research and Development Agency, 2. Kansai Research Center, Forestry and Forest Products Research Institute, Forest Research and Management Organization, National Research and Development Agency

Many researches have been conducted to clarify the mechanism of rainfall-runoff process in a forested catchment in humid warm-temperate regions, however it remains only partially understood. Since the 1980’s, the important issue in rainfall-runoff process studies has been solving how pre-event old water stored in the slope discharge in rapid response during rainstorm event. To explain it, there has been a focus on preferential flows, such as flow in macro-pore, pipe flow, flow in the soil–bedrock interface, and subsurface flow in bedrock fractures. One of other possible explanations of the rapid outflow of pre-event old water is the effect of pore-air entrapment. Experimental studies have shown that pore-air entrapment in the unsaturated zone of soil by infiltrating rainwater and the underlying groundwater table will effect on discharge. Although there have been few reports of pore-air behavior in the field, entrapped pore-air may have an impact on stream discharge.
Despite the fact that the pore pressure measured using a tensiometer is the sum of the pore-water pressure and the pore-air pressure (P_{air}), P_{air} has been neglected. We observed the behavior of P_{air} in the soil layer in a mountainous slope using a simple handmade probe together with the atmospheric pressure (P_{atm}). Pore-air entrapment and its compression was considered to be detected by the positive pressure difference ($\Delta P = P_{air} - P_{atm}$). Also, we expected that entrapped pore-air develops more frequently in a thinner soil catchment because the space between the ground surface and the bedrock is smaller. Thus, two catchments with thin and thick soil were selected for this study: One was a sub-catchment of Hitachi-ohta Experimental Watershed (HA) and another was a sub-catchment of Tsukuba Experimental Watershed (TC), respectively. Both sites are located in Ibaraki Prefecture, Japan, and observations were conducted for about 1 year. As a result, the number of pore-air entrapment events detected were 21 at HA (thin soil catchment), while it was 6 at TC (thick soil catchment). The values of ΔP at the discharge peak were correlated with peak discharge at one of the nearby spring observation points in HA, suggesting the importance of the pore-air entrapment in the rainfall-runoff process, particularly for a headwater catchment with relatively thin soil.

Keywords: Rainfall-runoff process, Pore-air pressure, Pore-air entrapment, Soil layer, Headwater catchment

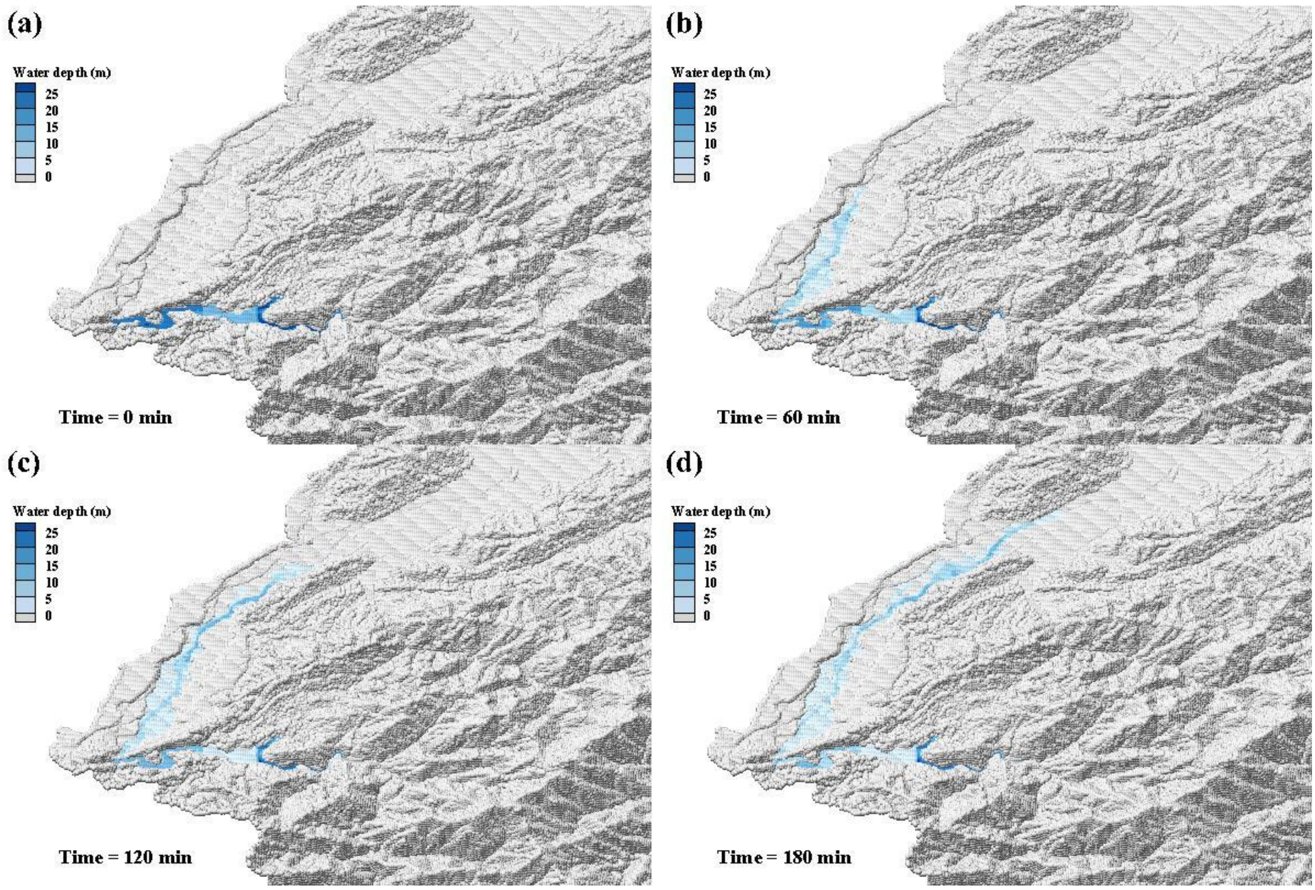
Developement of a 2D Eulerian SPH shallow water model for dam break flows

*Kao-Hua Chang[1]

1. National Taiwan Ocean University

In the study, we propose a two-dimensional (2D) Eulerian meshless shallow water model (SWM) using smoothed particle hydrodynamics (SPH) to simulate various dam break flows. The proposed Eulerian SPH-SWM can significantly improve the efficiency of the existing Lagrangian SPH-SWMs for handling real-world cases. To ensure the stability of the proposed model, an HLLC approximate Riemann solver and a hydrostatic reconstruction scheme are introduced to satisfy the well-balanced and positivity-preserving properties. Two study cases such as dam-break flows respectively on a dry flat bed and through a dry 45-degree bend channel are used to validate the proposed model against the exact and measured solutions. Finally, a scenario of the Shihmen dam in Taiwan broken is investigated to predict 3-hour-ahead flood extent to show the ability of the proposed model dealing with large-scale problems.

Keywords: smoothed particle hydrodynamics, meshless, shallow water equations, dam break flow



Investigating the validity of a meso scale constitutive equation using micro scale water dynamics simulations for hillslope rainfall-runoff processes

*Yutaka Ichikawa[1], Yuusuke Mori[1], Yasuto Tachikawa[1]

1. Graduate School of Engineering, Kyoto University

A number of rainfall-runoff models have been developed in the field of hydraulic and hydrologic engineering, with a special attention on simulating temporal patterns of river discharge in order to meet practical demands such as discharge predictions. Conceptual rainfall-runoff models were initially developed, followed by physical-based models. The physical-based models have achieved a certain level of success, which was partly due to the considerable advancement of computers and the increasing availability of a variety of datasets. It is pointed out, however, that recent important findings based on field studies are not incorporated into rainfall-runoff models, especially used for engineering purposes. To examine the raised issue, this study conducted detailed simulations coupling surface flow and saturated-unsaturated flow for hillslope rainfall-runoff dynamics, and investigated the validity of a constitutive equation used in a rainfall-runoff model. The results revealed that the constitutive equation was capable of describing depth-discharge relationships for hillslopes with relatively shallow soil layers but not for those with thick soil layers.

Keywords: rainfall-runoff, hillslope, depth-discharge relationship, constitutive equation

A review of ensemble flood forecasting for operational warning

*Megumi Watanabe[1], Shunsuke Ito[2], Wenchao Ma[1], Dai Yamazaki[1]

1. Institute of Industrial Science, The University of Tokyo, Japan, 2. School of Engineering, The University of Tokyo, Japan

There is growing international interest in the potential of ensemble flood forecast to improve operational warning. Ensemble flood forecasting systems promise two significant advantages over conventional deterministic forecasting techniques depending on water level observations of upstream rivers. First, ensemble flood forecasting systems have a long lead time for effective evacuation. Second, ensemble flood forecasting systems can also provide quantitative probability to estimate the uncertain forecasts. The introduction of an ensemble flood forecasting system has been under consideration in Japan. We need a comprehensive and integrated assessment based on multiple information from ensemble flood forecasting systems. This study surveyed ways to deliver detailed information in operational ensemble flood forecast systems outside of Japan. We summarized effective visualizations and improvements of the forecast systems by user feedbacks. We found that forecasts with multiple variables are delivered to public administration units with low spatial resolution while forecasts with fewer variables are delivered to each local point or each river segment with high spatial resolution. We also found that user feedbacks have improved the forecasts systems through discussions, although ensemble forecasts are complicated, and they have different characters from local forecasts. Communication with potential users concerning the forecasts is necessary for an effective operation.

Keywords: ensemble, flood, forecast, probabilistic, communication

Toward Downscaling Storage-Discharge Dynamics: Training Long Short-Term Memory (LSTM) model for Simulating Nonlinear Storage-Discharge Relation in HUC-8 Rum River Watershed, MN

*Pai-Feng Victor Teng[1]

1. University of Minnesota

Flooding is one of the most financially devastating natural hazards in the world. The current hydrological models have focused on rainfall-runoff models in flood forecasting, and studying storage-discharge relations has the potential to improve existing flood forecasting. This presentation will assess the relation between daily water storage (ΔS) and discharge (Q) with physical-based hydrological modeling, and storage-discharge dynamics with the machine-learning mechanism located at Rum River Watershed, a HUC8 watershed in Minnesota, between 1995-2015. Currently, linear regression models cannot adequately predict the relationship between the total ΔS and total Q at the HUC-8 watershed (R^2 = 0.3667). Since machine learning (ML) algorithms have already been used for predicting the outputs that represent arbitrary non-linear functions between predictors and predictands, this research will determine how ML algorithms will be used for improving the accuracy of the non-linear relation of the storage-discharge dynamics. Long Short-Term Memory (LSTM), the time-series deep learning neural network that has been used for predicting rainfall-runoff relations, will be used for simulating non-linear relations between ΔS and Q. It will compare two sets of storage-discharge relationships with the hydrological variables simulated by the semi-distributed Hydrological Simulated Program-Fortran (HSPF): dynamics between simulated discharge and input hydrological variables, including air temperature, cloud cover, dew point, potential evapotranspiration, precipitation, evapotranspiration, solar radiation, and wind speed, and the dynamics between simulated discharge and input variables that also includes total water storage at the HUC-8 watershed. 7670 samples are used. 90% of the inputs will be used for training the LSTM network and 10% will be used for testing the prediction. The result shows that the inclusion of total water storage can improve the prediction of total discharge at Rum River Watershed. Inputs of LSTM network can already adequately predict the discharge (NSE = 0.6147, R^2 = 0.8801, Bias Test = -0.4127) without including total water storage; inputting total water storage can significantly improve the prediction (NSE = 0.6977, R^2 = 0.9652, Bias Test = -0.4127). Yet, the main challenge is that both results underpredicted the discharge values in the spring of 2014. The result of the research lays the foundation for assessing the accuracy of downscaling storage-discharge dynamics by applying LSTM networks to evaluate storage-discharge dynamics at smaller, HUC-12 watershed simulated by hydrological models.

Keywords: Hydrological Modeling, Machine Learning , Long Short-Term Memory , Hydrology

[E] Oral | A (Atmospheric and Hydrospheric Sciences) | A-HW Hydrology & Water Environment

[A-HW20] Hydrology &Water Environment

convener:Takeshi Hayashi(Faculty of Education and Human Studies, Akita University), Keisuke Fukushi(Institute of Nature &Environmental Technology, Kanazawa University), Koichi Sakakibara(Department of Environmental Sciences, Faculty of Science, Shinshu University), Dai Yamazaki(Institute of Industrial Sciences, The University of Tokyo), Chairperson:Takeshi Hayashi(Faculty of Education and Human Studies, Akita University), Keisuke Fukushi(Institute of Nature &Environmental Technology, Kanazawa University), Koichi Sakakibara(Department of Environmental Sciences, Faculty of Science, Shinshu University), Dai Yamazaki(Institute of Industrial Sciences, The University of Tokyo)

Sat. Jun 5, 2021 9:00 AM - 10:30 AM Ch.12 (Zoom Room 12)

We focus on various issues of water cycle and environment and aim to answer questions of hydrological and earth system sciences; 1) surface, subsurface and their boundary hydrological processes of water cycle, 2) natural and anthropogenic hydrothermal systems, 3) environments issues and studies on a watershed or global scale, 4) water-related issues with ecological, environmental, and geochemical aspects, and 5) other issues in hydrological sciences. We welcome presentations regarding various kinds of approaches and techniques such as field survey, remote sensing, chemical and isotope tracers, numerical simulation, and theoretical analysis. This session is jointly hosted by societies of water-related geoscience (Geochemical Society of Japan, Japanese Association of Groundwater Hydrology, Japanese Association of Hydrological Sciences, and Japan Society of Hydrology and Water Resources), and accepts wide-range research topics related to water cycle and environment described above.

10:20 AM - 10:30 AM

[AHW20-07]Discussion

[E] Oral | A (Atmospheric and Hydrospheric Sciences) : A-HW Hydrology & Water Environment

Sat. Jun 5, 2021 10:45 AM - 12:15 PM JST | Sat. Jun 5, 2021 1:45 AM - 3:15 AM UTC | Ch.12 Zoom Room 12

[A-HW20] Hydrology & Water Environment

convener:Takeshi Hayashi(Faculty of Education and Human Studies, Akita University), Keisuke Fukushi(Institute of Nature & Environmental Technology, Kanazawa University), Koichi Sakakibara(Department of Environmental Sciences, Faculty of Science, Shinshu University), Dai Yamazaki(Institute of Industrial Sciences, The University of Tokyo), Chairperson:Takeshi Hayashi(Faculty of Education and Human Studies, Akita University), Koichi Sakakibara(Department of Environmental Sciences, Faculty of Science, Shinshu University), Dai Yamazaki(Institute of Industrial Sciences, The University of Tokyo), Shin'ichi Iida(Department of Disaster Prevention, Meteorology and Hydrology, Forestry and Forest Products Research Institute)

We focus on various issues of water cycle and environment and aim to answer questions of hydrological and earth system sciences; 1) surface, subsurface and their boundary hydrological processes of water cycle, 2) natural and anthropogenic hydrothermal systems, 3) environments issues and studies on a watershed or global scale, 4) water-related issues with ecological, environmental, and geochemical aspects, and 5) other issues in hydrological sciences. We welcome presentations regarding various kinds of approaches and techniques such as field survey, remote sensing, chemical and isotope tracers, numerical simulation, and theoretical analysis. This session is jointly hosted by societies of water-related geoscience (Geochemical Society of Japan, Japanese Association of Groundwater Hydrology, Japanese Association of Hydrological Sciences, and Japan Society of Hydrology and Water Resources), and accepts wide-range research topics related to water cycle and environment described above.

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

[AHW20-08] Introduction

10:50 AM - 11:05 AM JST | 1:50 AM - 2:05 AM UTC

[AHW20-09] Distribution of Uranium and Arsenic in Surface Water around Alkaline-Hyposaline Lake from Valley of Gobi Lakes in Mongolia

*Baasansuren Gankhurel[1], Keisuke Fukushi[1], Davaadorj Davaasuren[2], Eigo Imai[1], TAKUMA KITAJIMA[1], Tuvshin Gerelmaa[2], Yasuhito Sekine[3], Yoshio Takahashi[4], Noriko Hasebe[1] (1.Kanazawa University, 2.National University of Mongolia, 3.Tokyo Institute of Technology, 4.The University of Tokyo)

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

[AHW20-10] Differences in nitrogen biogeochemical cycles of a reservoir with a hydraulic retention time of several days, before and after the dam was built

*Qingqing Sun[1] (1.Tianjin University)

11:20 AM - 11:35 AM JST | 2:20 AM - 2:35 AM UTC

[AHW20-11] **Plastic debris as a carrier of inorganic contaminants in the urban river of Mongolia**

*Batdulam Battulga[1], Masayuki Kawahigashi[1], Bolormaa Oyuntsetseg[2] (1.Department of Geography, Tokyo Metropolitan University, Tokyo, 192-0397, Japan , 2.Department of Chemistry, National University of Mongolia, Ulaanbaatar, 210646, Mongolia)

11:35 AM - 11:50 AM JST | 2:35 AM - 2:50 AM UTC

[AHW20-12] Geochemisty and environmental impact on groundwater in Eastern Serbia

*Dragana Adamovic[1,2], Daizo Ishiyama[1], Hiroshi Kawaraya[1], Yasumasa Ogawa[1] (1.Akita University, Japan, 2.MMI Bor, Serbia)

11:50 AM - 12:05 PM JST | 2:50 AM - 3:05 AM UTC

[AHW20-13] **Measurement of reactive oxygen species (ROS) and fluorescent organic matter in selected rivers in Hiroshima Prefecture, Japan.**

*Taiwo Tolulope Ayeni[1], Takashi Umeda[1], Yoko Iwamoto[1], Kazuhiko Takeda[1], Hiroshi M. G. Sakugawa[1], Khan M. G. Mostofa[2] (1.Hiroshima University Japan, 2.Tianjin University, China)

12:05 PM - 12:15 PM JST | 3:05 AM - 3:15 AM UTC

[AHW20-14] Discussion

[E] Oral | A (Atmospheric and Hydrospheric Sciences) | A-HW Hydrology & Water Environment

[A-HW20] Hydrology &Water Environment

convener:Takeshi Hayashi(Faculty of Education and Human Studies, Akita University), Keisuke Fukushi(Institute of Nature &Environmental Technology, Kanazawa University), Koichi Sakakibara(Department of Environmental Sciences, Faculty of Science, Shinshu University), Dai Yamazaki(Institute of Industrial Sciences, The University of Tokyo), Chairperson:Takeshi Hayashi(Faculty of Education and Human Studies, Akita University), Koichi Sakakibara(Department of Environmental Sciences, Faculty of Science, Shinshu University), Dai Yamazaki(Institute of Industrial Sciences, The University of Tokyo), Shin'ichi Iida(Department of Disaster Prevention, Meteorology and Hydrology, Forestry and Forest Products Research Institute)
Sat. Jun 5, 2021 10:45 AM - 12:15 PM Ch.12 (Zoom Room 12)

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10:45 AM - 10:50 AM

[AHW20-08]Introduction

Distribution of Uranium and Arsenic in Surface Water around Alkaline-Hyposaline Lake from Valley of Gobi Lakes in Mongolia

*Baasansuren Gankhurel[1], Keisuke Fukushi[1], Davaadorj Davaasuren[2], Eigo Imai[1], TAKUMA KITAJIMA[1], Tuvshin Gerelmaa[2], Yasuhito Sekine[3], Yoshio Takahashi[4], Noriko Hasebe[1]

1. Kanazawa University, 2. National University of Mongolia, 3. Tokyo Institute of Technology, 4. The University of Tokyo

Saline lakes represent 23% of the area of all lakes on Earth and located mostly in arid and semiarid climates.
Saline lakes are mainly fed by precipitation and surface flow. But also, water lost by evaporation has significant role in saline lakes. Evaporation of the lake water results the formation of contaminated lake water and salt deposits containing high levels of dissolved species including trace elements such as arsenic and uranium. The chemical speciation of trace elements in sediments and distribution between the sediments and lake water are essential for the understanding of formation process and the mobility of trace elements.
This study aims to clarify distribution and formation process of As and U in saline lake water based on their sediment and water chemistry analysis of surface waters (springs, rivers, wells) around the study area. The sediment and water chemistry samples of alkaline-hyposaline lake catchment area (Orog and Olgoy lakes) in semi-arid climates of the Valley of Gobi lakes in Mongolia were studied. We measured lakes, river and spring water samples in different seasons from 2015 to 2020. Also, well water samples around the study area in 2017 and 2018 were measured. Sediment samples were analyzed by using sequential extraction procedure (SEP), X-ray diffraction (XRD) and synchrotron-based X-ray absorption spectroscopy (XAFS).
Olgoy and Orog lakes exhibited pH exceeded 9 and salinity above 1300 mg/kg. The lake waters major cation and anion is Na^{+}, Cl^{-} and SO_4^{2-}. The high Na and Cl concentrations are result of evaporation of the lake waters. Also, our results showed that high concentrations of As (˜3019ppb) and U (˜590ppb) in lake water, respectively. Therefore, the concentration of arsenic and uranium differed in different months throughout the year which need more clarification to understand the process between lake-sediment interaction. The results of SEP of lake sediment showed that arsenic and uranium in sediments are distributed into calcium carbonates rather than amorphous iron oxide. XRD analysis results shows that sediment sample has authigenic minerals including calcite and Monohydrocalcite. The results of XAFS analysis shown As in Orog lake sediment was As (V) and primarily coprecipitated with calcite and secondarily adsorbed on ferrihydrite. As in Olgoi lake sediment was mainly As (V) and 20-30% was As (III) and coprecipitated with calcite. As and U possibly are removed by the authigenic carbonates. Carbonates are not “source” of these elements but “sink”. However, we need to clarify how much the carbonates play a role of “sink”. The springs, rivers, and well water have pH around 6.3-8.3 and low salinity. The major cation of surface water excluding lake water are Ca^{2+} and concentrations of Na^{+}, Cl^{-}, SO_4^{2-} were low. But we found in some well and spring point has high concentration of U(˜39ppb) and As (˜61ppb). The high concentrations of As and U in lake water might be related to the surface water around lake and the evaporation of river water.

Keywords: saline lake, water, uranium, arsenic

Differences in nitrogen biogeochemical cycles of a reservoir with a hydraulic retention time of several days, before and after the dam was built

*Qingqing Sun[1]

1. Tianjin University

Despite the fragmentation of rivers and irreparable damage to biodiversity, around the world, more and more DAMS are being built to alleviate energy, water, and food shortages. The retention time of these reservoirs varies from a few days to several years. Suofengying Reservoir ((26°94’N, 106°35’E, 70 m of depth) in Wujiang River Watershed of China was selected. The dam was built and put into use in 2004, mainly for power generation, with a hydraulic retention time of 0.012 years. It made the reservoir change a little vertically, which interacts with aquaculture. On the one hand, the proportion of fish prefers rapid water or still water. On the other hand, a large number of nutrients are input, etc.
In this abstract, I used environmental fluid dynamics code, ArcGIS, water balance model, mass balance model, and box model to build the reservoir hydrodynamic model, water quality model of nitrogen. I discussed 1) The dam's interdicting effect on the river is interpreted in combination with atmospheric nitrogen deposition, sediment-water interface release, and settlement. Because of the hydrodynamic defense, nitrogen cycle differences occur in the river, mixing zones, and still water zones. 2) The effects of other biogenic elements, especially P limitation, on nitrogen bioavailability. 3) Interaction of the whole system of atmosphere, surface water, groundwater, soil, sediment, and organisms.
Special thanks to China National Meteorological Data Center (https://data.cma.cn/), Watershed Biogeochemistry Team, School of Earth System Science, Tianjin University, School of Environment and Chemistry, Shanghai University, and State Key Laboratory of Environmental and Chemical Engineering, Institute of Geochemistry, Chinese Academy of Sciences, Guizhou Hydrological Resources Bureau and DSI LLC. for their foundation work.

Keywords: Nitrogen, Environmental fluid dynamics code, Suofengying Reservoir

Plastic debris as a carrier of inorganic contaminants in the urban river of Mongolia

*Batdulam Battulga[1], Masayuki Kawahigashi[1], Bolormaa Oyuntsetseg[2]

1. Department of Geography, Tokyo Metropolitan University, Tokyo, 192-0397, Japan , 2. Department of Chemistry, National University of Mongolia, Ulaanbaatar, 210646, Mongolia

Plastic pollution in the aquatic environment has become a social concern by their long life in the ecosystems. Although a global survey has mainly focused on the accumulation and distribution of plastic debris, interactions between plastic debris and inorganic pollutants and the behavior of those plastics aggregates are still unclear. In this study, we addressed plastics associated with inorganic pollutants in the urban river of Mongolia. The aims of the current study are i.) identification of inorganic pollutants on the surface of plastic debris, particularly on polystyrene foam (PSF), and ii.) evaluation of the elemental association and potential sources of inorganic pollutants with the PSFs in the river environment.

The PSF samples were collected from the 6 sampling locations of the urban river shores. The concentrations of major (Al and Na) and trace (B, Cr, Cu, Mn, Mo, Ni, Pb and Zn) elements were determined in the macro (20-100 mm), meso (5-20 mm), and micro (<5 mm) sized PSFs. The mixture of hydrogen peroxide (30%, H_2O_2) and iron (II) catalyst solution (0.05 M) was used to digest all organic substances and separate surface adhered inorganic pollutants from the PSF samples. The digested solution was applied to determine the concentrations of major and trace elements adhered on the PSFs using an Inductively Coupled Plasma Atomic Emission Spectrometer (ICP-AES).

The mean concentrations of Al, B, Cr, Cu, Mn, Mo, Na, Ni, Pb and Zn accumulated on the PSFs (n=57) were determined as 1967.0±270.5, 119.5±43.2, 16.1±7.5, 39.4±8.7, 174.2±20.7, 9.6±2.5, 1506.8±476.8, 40.8±11.2, 17.7±9.2 and 283.0±100.8 $\mu g\ g^{-1}$ (mean content ±standard error), respectively. Comparing levels of elements among the different size fractions, rather higher values of elements were measured in the meso-sized PSFs except for Al and Mo, which were higher in micro-sized PSF particles. In addition, strong correlations among B, Na and Zn indicate the chemical association of those elements with the environmental PSFs. A wide range of the elemental concentrations illustrates the adsorption of the elements from the surrounding environment on the surface of PSFs which might be mediated by a biofilm. On the contrary, some elements (i.e., Zn) can be leached from additives of PSFs through degradation. The widespread plastic debris could be one of the carriers and sources of hazardous chemicals in the aquatic environment.
While the consequences of plastic debris on environmental health are poorly understood, the fate and behavior of hetero-aggregates of plastics in the aquatic environment should be continuously studied in future.

Keywords: Plastic debris, Inorganic pollutants, Polystyrene foam (PSF), Urban river, Aggregates

Geochemisty and environmental impact on groundwater in Eastern Serbia

*Dragana Adamovic[1,2], Daizo Ishiyama[1], Hiroshi Kawaraya[1], Yasumasa Ogawa[1]

1. Akita University, Japan, 2. MMI Bor, Serbia

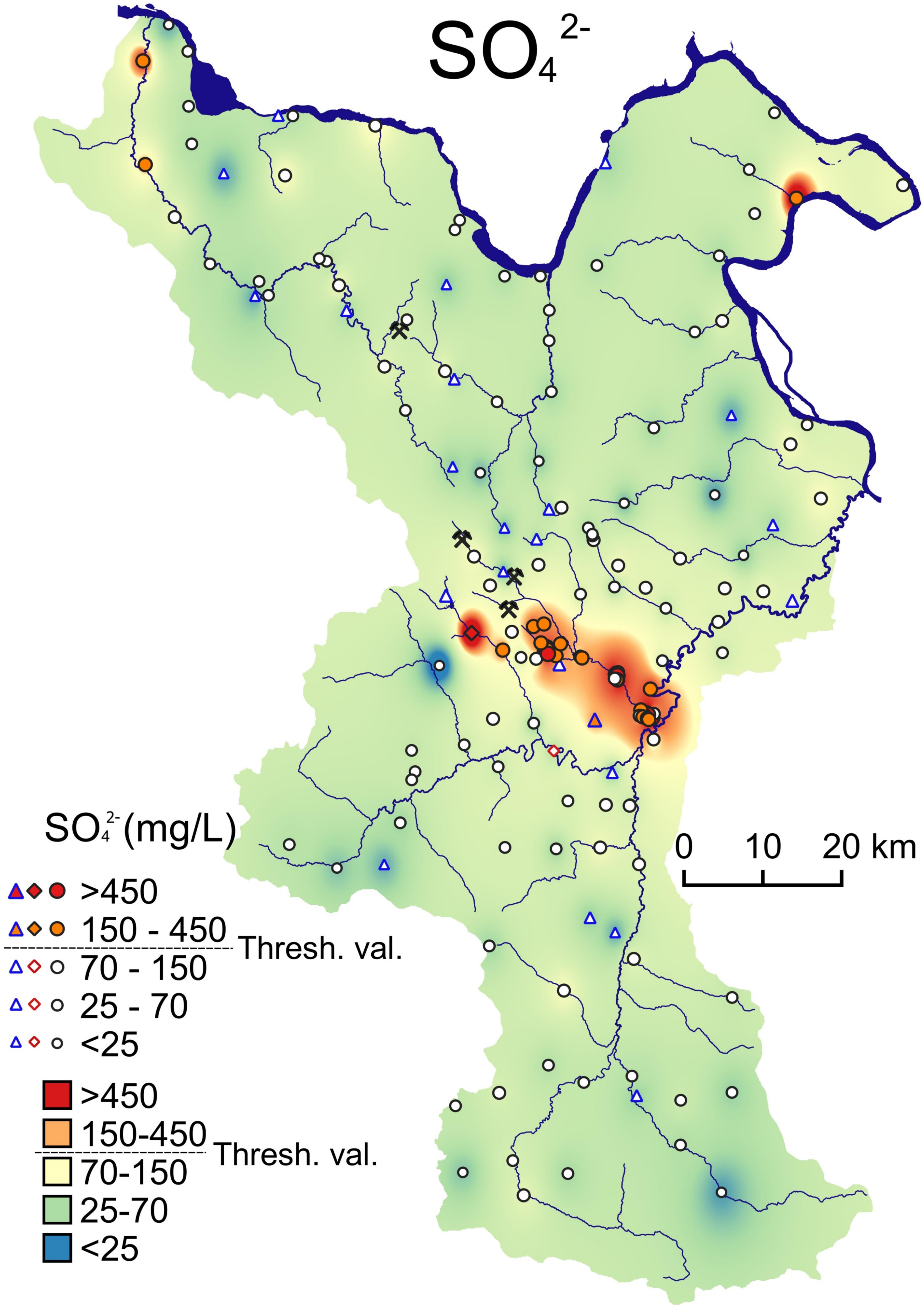
Contamination of water bodies is a large problem in many mining areas in the world. Mining activities have been carried out for about 120 years in Eastern Serbia. Nowadays, there are four active copper mines in two mining areas, the Bor mining area and the Majdanpek mining area, in Eastern Serbia. The long history of mining in Eastern Serbia causes serious environmental problems, which are most pronounced on water pollution downstream of the mining sites. Many studies focused on river water pollution. However, there is no comprehensive research about groundwater in Eastern Serbia. Therefore, this research aims to clarify the geochemistry of groundwater and to know whether mining activities give an effect on groundwater quality or not.

Sample collection was carried on in August and September 2019. The total number of groundwater samples was 172, including 144 samples collected from wells, 23 cold spring samples, 3 hot spring samples and 2 samples from boreholes. All water samples were filtrated through a 0.2 μm cellulose acetate hydrophilic filters. After filtration, two kinds of samples were prepared. They are non-acidified samples used for the determination of major elements and acidified samples (with ultrapure HNO_3) used for the determination of trace elements. In the field, coordinates of sampling points, pH and Eh values, water temperature and the concentration of HCO_3^- were also determined.

To understand the geochemical signature and environmental impact of groundwater in the study area, geochemical maps were created. Threshold values for discrimination of anomalous populations from background populations were also estimated for Ca^{2+}, SO_4^{2-}, Cu and As.

Groundwater in the study area is characterized by pH values from 6.4 to 8.8 and a high concentration of HCO_3^- (30 to 930 mg/L). In general, groundwater from the study area has good quality. However, anomalous concentrations of Ca^{2+}, SO_4^{2-}, Cu and As are recognized in groundwater around ore deposits of the Bor mine and along polluted rivers downstream of the Bor mine. Distributions of anomalous concentrations of major elements (Ca^{2+} and SO_4^{2-}) in groundwater are similar to the distributions of anomalous concentrations of these components in river water. Therefore, there is a possibility that groundwater along highly polluted river water in the Bor mining area is affected by acid mine drainage bearing-river water. Based on mass balance calculation between components in polluted river water and groundwater, polluted river water having high concentrations of Ca^{2+} and SO_4^{2-} in riverbed sediments flows into groundwater in the area where the water surface level of polluted river water is higher than the level of the groundwater table. On the other hand, the mixing was not observed based on the mass balance calculation based on the concentrations of Cu and As in river water and groundwater because of the precipitation of these elements as a result of the change of pH value from acidic to neutral. An appropriate component for groundwater monitoring in mining areas located in Eastern Serbia is SO_4^{2-}, which can be present as aqueous species without precipitation in groundwater from acidic to neutral pH.

Keywords: Bor, Groundwater pollution, Mining activities, Threshold value


SO_4^{2-}
SO_4^{2-} (mg/L)
>450
150 - 450
Thresh. val.
70 - 150
25 - 70
<25
>450
150-450
Thresh. val.
70-150
25-70
<25
0 10 20 km

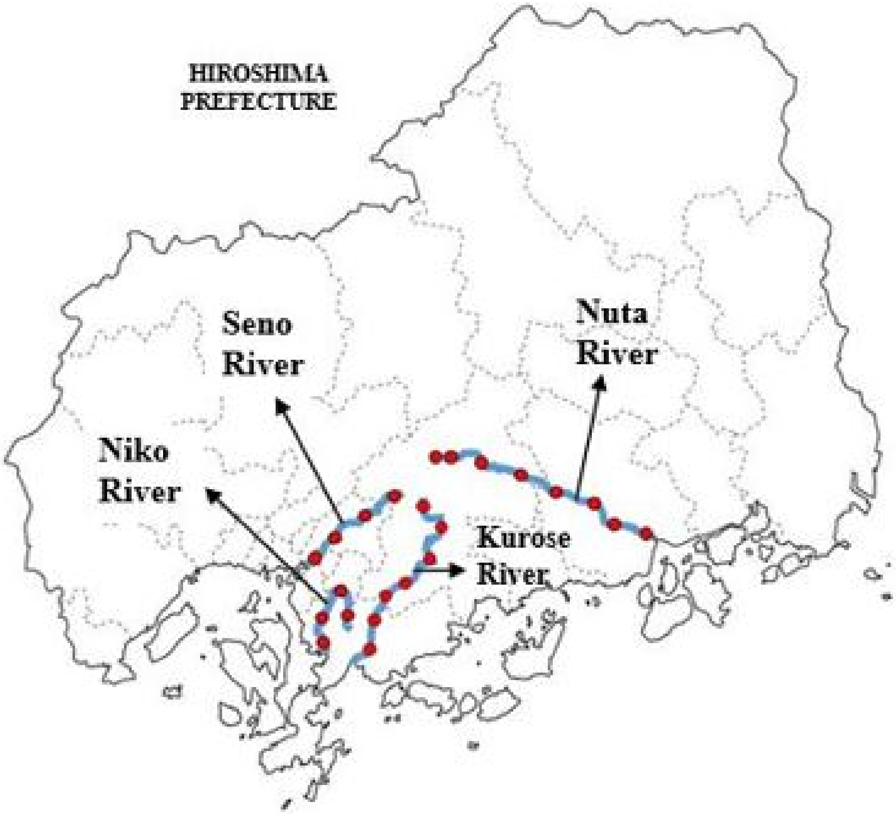
Measurement of reactive oxygen species (ROS) and fluorescent organic matter in selected rivers in Hiroshima Prefecture, Japan.

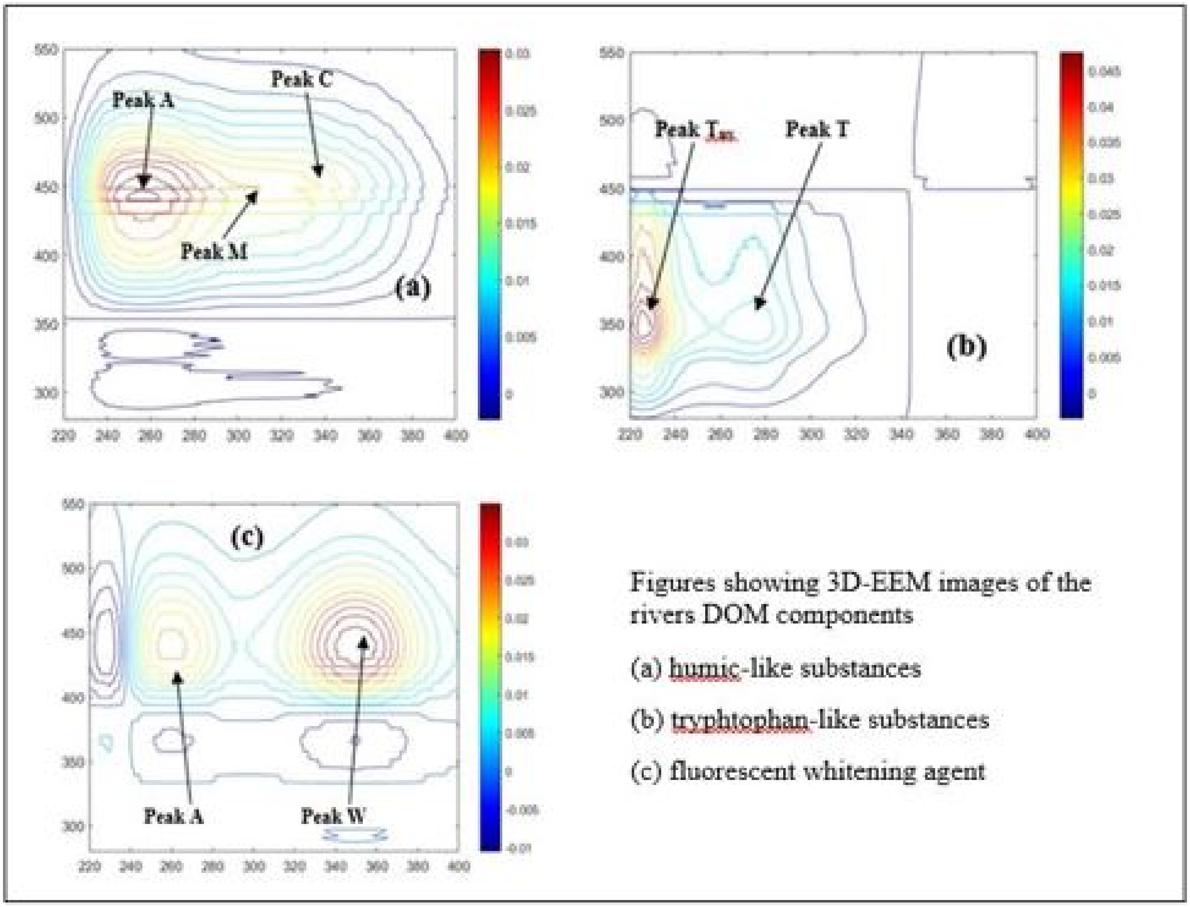
*Taiwo Tolulope Ayeni[1], Takashi Umeda[1], Yoko Iwamoto[1], Kazuhiko Takeda[1], Hiroshi M. G. Sakugawa[1], Khan M. G. Mostofa[2]

1. Hiroshima University Japan, 2. Tianjin University, China

The incidence of solar irradiation on natural water surfaces could excite their inorganic or organic components to produce some transitory species otherwise called reactive oxygen species (ROS) such as hydroxyl radical (•OH), nitric oxide radical (NO•) and singlet oxygen ($^1O_2$). These species could facilitate the photochemical degradation of natural organic matter or pollutants and also partake in some biological or redox reactions. Recent comprehensive study on Japanese rivers reveals that nitrite was the major source of •OH and NO• while $^1O_2$ was predominantly sourced from Chromophoric dissolved organic matter (CDOM). In the present study, the photogeneration of these three ROS and investigation of their dissolved organic components were carried out across 23 stations in four rivers (Niko, Seno, Kurose, and Nuta) located in the Hiroshima Prefecture of Japan during the winter of 2020. Analysis involving dissolved organic carbon (DOC), absorption properties, and ions were carried out using TOC-V_{CSH} analyzer, UV-Visible spectrophotometer, and Ion chromatography, respectively. Parallel factor analysis (PARAFAC) modelling was employed in identifying the DOM components of the rivers. The photogeneration rates of the ROS were determined by means of established HPLC methods. The DOC values across the rivers ranged from the low of 34.7 μM C in the Nuta river to the high of 259 μM C in the Kurose river. The absorption coefficient at 300 nm (a_{300}), which is a measure of CDOM abundance and the concentration of inorganic nitrite also followed the same pattern as that of the DOC and were within the ranges of (1.61 to 9.06) m^{-1} and (0.07 and 17.9) μM, respectively. The ROS values ranged from (12.4 –392) ×10^{-12} M s^{-1} for •OH, (4.17 –1050) ×10^{-12} M s^{-1} for NO• and (4.66 –32.4) ×10^{-9} M s^{-1} for $^1O_2$ and were also minimum in the Nuta river and maximum in the Kurose river. Humic-like and tryptophan-like components were the predominant organic matter across the rivers, however fluorescent whitening agent was observed in some stations of the rivers.

Keywords: hydroxyl radical, nitric oxide radical, singlet oxygen, dissolved organic matter, PARAFAC, river water





Figures showing 3D-EEM images of the rivers DOM components

(a) humic-like substances

(b) tryphtophan-like substances

(c) fluorescent whitening agent

[E] Oral | A (Atmospheric and Hydrospheric Sciences) | A-HW Hydrology & Water Environment

[A-HW20] Hydrology &Water Environment

convener:Takeshi Hayashi(Faculty of Education and Human Studies, Akita University), Keisuke Fukushi(Institute of Nature &Environmental Technology, Kanazawa University), Koichi Sakakibara(Department of Environmental Sciences, Faculty of Science, Shinshu University), Dai Yamazaki(Institute of Industrial Sciences, The University of Tokyo), Chairperson:Takeshi Hayashi(Faculty of Education and Human Studies, Akita University), Koichi Sakakibara(Department of Environmental Sciences, Faculty of Science, Shinshu University), Dai Yamazaki(Institute of Industrial Sciences, The University of Tokyo), Shin'ichi Iida(Department of Disaster Prevention, Meteorology and Hydrology, Forestry and Forest Products Research Institute)

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12:05 PM - 12:15 PM

[AHW20-14]Discussion

[E] Oral | A (Atmospheric and Hydrospheric Sciences) : A-HW Hydrology & Water Environment

Sat. Jun 5, 2021 9:00 AM - 10:30 AM JST | Sat. Jun 5, 2021 12:00 AM - 1:30 AM UTC | Ch.13 Zoom Room 13

[A-HW21] Interdisciplinary approach to support climate change adaptation measures in regional scale

convener:TEBAKARI TAICHI(Toyama Prefectural University), Sompratana Ritphring(Kasetsart University), Masashi Kiguchi(University of Tokyo), weerakaset Suanpaga(Associate professor in Civil Engineering,Kasetsart University), Chairperson:TEBAKARI TAICHI(Toyama Prefectural University), Masashi Kiguchi(University of Tokyo)

In Japan, the impact of climate change has already become apparent and may become even more serious in the future. For example, there are the following specific damages; crop damage such as mandarin orange edema and white immature grains of rice, health hazards such as the northward distribution of Aedes albopictus and heat stroke patients, meteorological disasters such as increased torrential rain and increased number of strong typhoons, and coral bleaching Ecosystem.
The climate change adaptation law, which was enacted in 2018, clarified the legal position of adaptation measures in Japan, and is a legal for the national, local governments, businesses and citizens to cooperate and cooperate to promote adaptation measures. Based on this law, the Climate Change Adaptation Information Platform (A-PLAT) was established to develop and provide tools to support information provision and adaptation actions, and to collect, organize and provide best practices. AP-PLAT and T -Overseas development such as -PLAT is also progressing. Overseas expansion such as AP-PLAT and T-PLAT are also progressing.
In each research field, it is necessary to promote effective adaptation measures based on reliable and detailed information, and measures based on scientific knowledge of future impacts and strengthening of adaptation in the region are urgently needed.
This proposed session would like to invite presentations on the latest achievements in interdisciplinary fields such as hydrology, agriculture, forestry, weather, and climate that support specific climate change adaptation measures, as well as on the development of new research.

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

[AHW21-01] ADAP-T for water-related adaptation to climate change and supporting its policy making

★Invited Papers

*Taikan Oki[1], Thanya Kiatiwat[2], Hiroaki Shirakawa[3], Weerakaset Suanpaga[2], Taichi Tebakari[4], Sompratana Ritphring[2], Masashi Kiguchi[5], Kyoko Matsumoto[4] (1.Graduate School of Engineering, The University of Tokyo, 2.Faculty of Engineering, Kasetsart University, 3.Granduate School of Environmental Studies, Nagoya University, 4.Department of Civil and Environmental Engineering, Toyama Prefectural University, 5.Institute of Industrial Science, The University of Tokyo)

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

[AHW21-02] The GEWEX Regional Hydroclimate Projects in High Mountainous Terrain in Asia

★Invited Papers

*Petrus J van Oevelen[1] (1.George Mason University)

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

[AHW21-03] **Effectiveness of Flood Diversion Canals and Retention Ponds as Adaptation Strategies in the Upper Chao Phraya River Basin**

*Saritha Padiyedath Gopalan[1], Naota Hanasaki[1] (1.National Institute for Environmental Studies)

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

[AHW21-04] **The impact of sensible heat and latent heat on monsoon onset over Indochina peninsula**

Tomohito Yamada[1], Ryosuke Kato[1], *Sourabh Shrivastava[1] (1.Hokkaido University)

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

[AHW21-05] S2S prediction challenge with deep learning in Thailand

*Kiyoharu Hasegawa[1], Shinjiro Kanae[1] (1.Toyko Institute of Technology)

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

[AHW21-06] Local knowledge: A comprehensive agricultural system and incremental drought adaptation strategy for Javanese society

*Muhamad Khoiru Zaki[1], Keigo Noda[1], Kengo Ito[1], Komariah Komariah[2], Sumani Sumani[2] (1.Gifu University, 2.Sebelas Maret University)

ADAP-T for water-related adaptation to climate change and supporting its policy making

*Taikan Oki[1], Thanya Kiatiwat[2], Hiroaki Shirakawa[3], Weerakaset Suanpaga[2], Taichi Tebakari[4], Sompratana Ritphring[2], Masashi Kiguchi[5], Kyoko Matsumoto[4]

1. Graduate School of Engineering, The University of Tokyo, 2. Faculty of Engineering, Kasetsart University, 3. Granduate School of Environmental Studies, Nagoya University, 4. Department of Civil and Environmental Engineering, Toyama Prefectural University, 5. Institute of Industrial Science, The University of Tokyo

The anthropogenic climate change is increasing water-related disaster risks such as flood and drought because most of the adverse impacts of climate change is delivered to society through water. Mitigation efforts to reduce the greenhouse gas, e.g., CO2, emission and to reduce the speed of climate change are essentially important, and at the same time, adaptation measures to reduce the vulnerability and exposure of human lives and properties from the risks exacerbated by climate change are also relevant. After the Paris Agreement of UNFCCC in 2015, all the member states are encouraged to set their National Adaptation Plans (NAPs).

The formulation of “Thailand’s National Adaptation Plan” is being led by the Office of Natural Resources and Environmental Policy and Planning (ONEP) under Ministry of Natural Resources and Environment as a plan for the implementation of adaptation measures by each ministry and agency. For supporting the NAP formulation and development of climate change measures that contribute to a resilient and sustainable society, a new research project entitled "Advancing co-design of integrated strategies with adaptation to climate change in Thailand (ADAP-T)" with international collaboration between Thailand and Japan was proposed, approved, and implemented since 2016, supported by JICA and JST under the framework of SATREPS.

ADAP-T has three piers of research, namely i) Knowledgebase of climate change, ii) Adaptation measures to climate change, and iii) Co-designing adaptation measures. Disciplines relevant for the major sectors prone to climate change, such as riverine hydrology, forest hydrology, sediment erosion, coastal erosion, urban hydrology, and agricultural hydrology are collaborating under ADAP-T, and Kasetsart University, Thai Meteorological Department, Royal Irrigation Department, and ONEP are managing the ADAP-T project in Thailand with close communication with The University of Tokyo and associated researchers in several universities in Japan.

The overall goal of ADAP-T is to support the development of a climate change adaptation strategy that can maximize the benefits of society by combining various countermeasures through dialogue with various stakeholders such as the government and citizens. These research results have been contributed to the formulation of NAP, which was compiled and published as ADAP-T Special Report 2018 and research and implementation of good practice of adaptation measures in each sector are expected to contribute to NAP guidelines which currently being developed by ONEP for policy makers. Moreover, these results and basic information on cost-benefit estimation of adaptation options in each sector based on future scenarios are integrated into a web-based adaptation simulator as a tool to assist the multilateral dialogue among citizens, policy makers, and researchers. Furthermore, it is expected that these outcomes will be expanded to neighboring Southeast Asian countries for adaptation to climate change, which is becoming increasingly necessary and important in developing countries.

Keywords: Thailand, National Adaptation Plan, water resources management

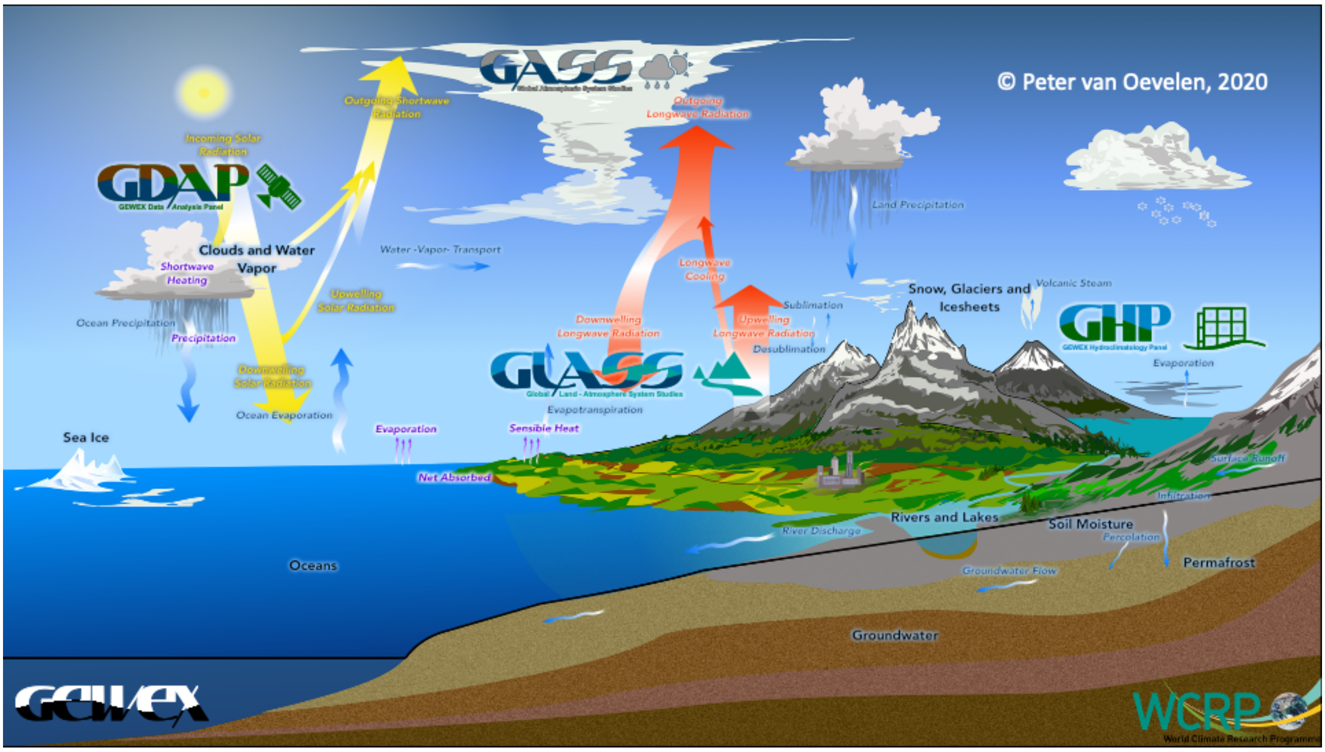
The GEWEX Regional Hydroclimate Projects in High Mountainous Terrain in Asia

*Petrus J van Oevelen[1]

1. George Mason University

The Global Energy and Water EXchanges Project (GEWEX) of the World Climate Research Programme focuses on in particular process understanding of how water and energy manifest themselves in the earth system. To address the science at a more regional level the Regional Hydroclimate Projects (RHPs) provide a unique opportunity to bring better the scientific community and rally around those issues that are specific and relevant to the region. High mountainous regions of the world and in particular those in Asia provide a unique challenge both in terms of observations as well as modeling. At the same time these regions are of crucial importance to our water resources for a major part of the global population. Better understanding of the processes in these regions under climate and environmental change is of the essence to provide for sustainable solutions. These mountainous regions act not only as physical barriers but also link communities as they provide the (water) resources they depend upon. At the same time these regions are also more vulnerable and strongly impacted by climate change. The GEWEX Regional Hydroclimate Projects in the Asian mountain regions can help bridge the knowledge gap and expertise and as such translate global environmental change to local change and impacts.

Keywords: Regional Climate, Water Resources, Global Science Collaboration



Effectiveness of Flood Diversion Canals and Retention Ponds as Adaptation Strategies in the Upper Chao Phraya River Basin

*Saritha Padiyedath Gopalan[1], Naota Hanasaki[1]

1. National Institute for Environmental Studies

The flood assessment in the upper Chao Phraya River basin (CPRB) is vital due to frequent flood occurrence in the past decades that has caused tremendous economic as well as agricultural losses. The upper CPRB is characterized by four major tributaries of Ping, Wang, Yom, and Nan. Among the tributaries, flooding is regular in the lower Yom Basin due to its gentle slope, lack of major flow regulation structures, and the low channel carrying capacity at various locations. The government has implemented flood mitigation measures such as Yom-Nan flood diversion canal system to divert water from Yom to Nan River and retention ponds since 2014. Hence, the objective of this study is to analyze the effect of this diversion canal system and retention ponds as adaptation strategies on reducing the daily discharge below the channel carrying capacity for the historic (1980-1999) as well as future (2080-2099) scenarios under representative concentration pathway (RCP) 4.5 and 8.5 emission scenarios using the H08 global hydrological model with the generalized scheme (GS; universal parameters) as well as the regionalized scheme (RS; regional parameters). The effect was mainly analyzed at three stations of Sukhothai, Bang Rakam, and Sam Ngam in Yom basin, where the channel carrying capacities are 550, 207, and 614 m^3/s, respectively.

The results of the historic simulation (Figure 1) show that the incorporated adaptation strategies can reduce the discharge below the channel carrying capacity at Sukhothai and Sam Ngam, while there was no significant reduction in the discharge at the Bang Rakam due to the low channel capacity. Although a similar pattern was observed in the future scenarios with adaptation strategies, the number of flooding days were still quite high in all the considered stations. Therefore, from this result, it can be envisaged that the canal system along with retention ponds alone cannot manage future floods in the basin. Regarding the effectiveness of the diversion schemes, the highest reduction in flooding days was exhibited by the RS simulation at both Sukhothai and Sam Nagam stations due to the regionalized parameters. On the contrary, the GS simulation has been found to be superior at Bang Rakam. This is because a part of the water diverted from the upstream of Yom River is returning to its lower reaches (at Bang Rakam station) through the canal system in RS simulation, whereas this return flow is absent in GS simulation due to universal parameters. The GS would be comparable with the RS by better parameterizations and can be implemented in hydrological models.

Keywords: Climate change, Thailand, H08 model

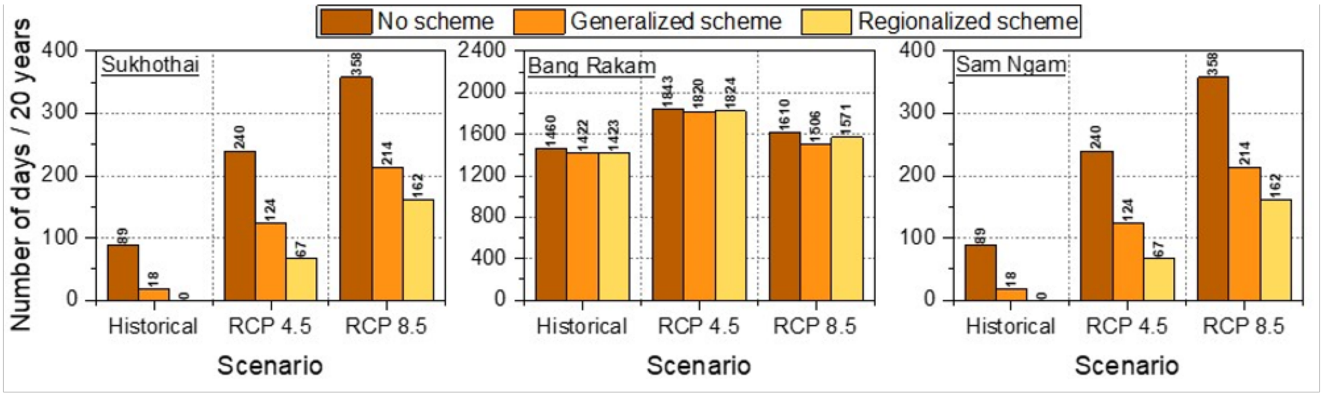


Figure 1. The number of days the daily discharge exceeded the channel carrying capacity at Sukhothai, Bang Rakam, and Sam Ngam stations in the historic as well as the future scenarios.

The impact of sensible heat and latent heat on monsoon onset over Indochina peninsula

Tomohito Yamada[1], Ryosuke Kato[1], *Sourabh Shrivastava[1]

1. Hokkaido University

In this study, interannual variations of the summer monsoon onset over the Indochina Peninsula were studied using the CPC Merged Analysis of Precipitation (CMAP) panted rainfall and NCEP reanalysis data from 1979 to 2016. For the climatological onset over Indochina Peninsula, 27th panted is considered. Equal numbers (9-9) of early and late monsoon onset years are identified during the last 3 decades. Sensible heat flux (Q1) and latent heat flux (Q2) influence the atmospheric circulation over the Indochina peninsula during monsoon onset. Composite analysis of Q1 and Q2 shows that the large change in Q1 and Q2 over the mainland of Indochina peninsula during early (late) monsoon years. The positive Q1 and Q2 anomalies suggest the strong convection in the early monsoon over the Indochina peninsula. It seems to be a dipole pattern over the mainland of the Indochina peninsula and the eastern Indian Ocean, where north-central Thailand have a positive (negative) anomaly and the eastern Indian Ocean have a negative (positive) anomaly during early (late) monsoon onset. Results also suggested the strong cyclonic flow at 850 hPa winds associated with the rainfall over the Indochina peninsula during early monsoon onset.

Keywords: Monsoon onset, Sensible Heat, latent heat

S2S prediction challenge with deep learning in Thailand

*Kiyoharu Hasegawa[1], Shinjiro Kanae[1]

1. Toyko Institute of Technology

Subseasonal to seasonal (S2S) prediction still remains as a challenge task even today. S2S prediction refers to a lead time ranging from one to several months, which is known to result in rapidly decreasing forecast accuracy. Deep learning (DL), one of the most powerful statistical models, is expected to overcome current difficulty of S2S prediction because of its spatio-temporal locality. In this study, one-month rainfall prediction is carried out for the Chao Phraya River basin in Thailand during the rainy season from May to October, where the introduction of long-term rainfall prediction to dam management is urgently required for flood mitigation. The DL model is constructed using global maps of sea surface temperature and heat content as input values. 17 climate models output from CMIP5 dataset is used to expand the training data from 65 existing observations to 2500, which enables us to train the DL model proper. The prediction accuracy of the DL model is compared with that of the physical model and the linear regression model. The results show that the DL model is slightly inferior to the physical model, but has higher prediction accuracy than the linear model. In addition, the deep learning model has the highest prediction accuracy when trained only on the CMIP5 dataset, indicating that the DL model has potential to outperform the physical model in the future.

Keywords: deep learning, 1 month rainfall prediction, Thailand, CMIP5, Sea surface temperature, ECMWF

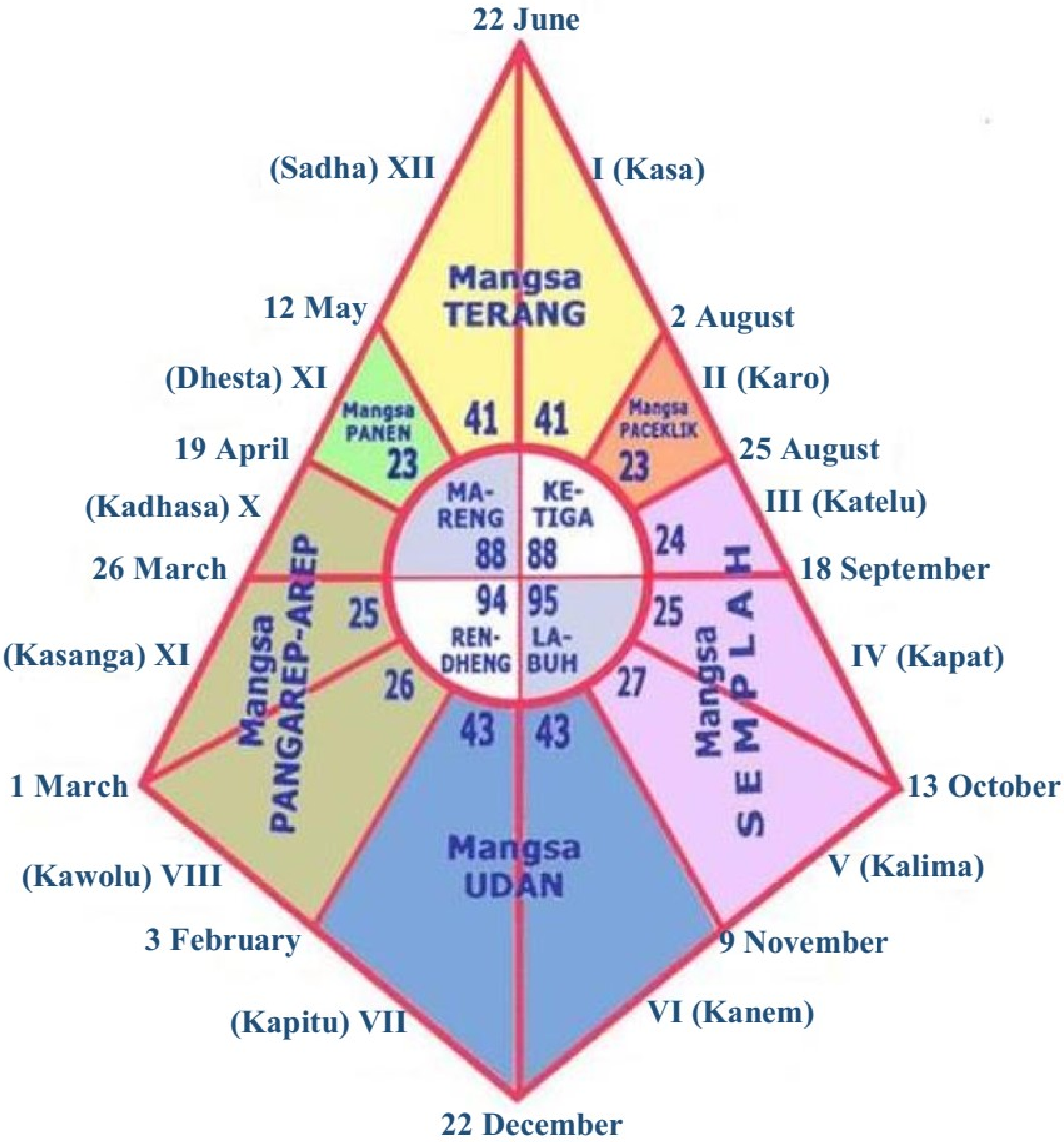
Local knowledge: A comprehensive agricultural system and incremental drought adaptation strategy for Javanese society

*Muhamad Khoiru Zaki[1], Keigo Noda[1], Kengo Ito[1], Komariah Komariah[2], Sumani Sumani[2]

1. Gifu University, 2. Sebelas Maret University

Local knowledge can be defined as a person' s ability to use his/her understanding and senses to respond to an event, object, or situation in the local environment. We reevaluate *Pranata Mangsa* as a form of local knowledge that can aid in adapting to drought. *Pranata Mangsa* is used on the Indonesian islands of Java and Bali, particularly by farmers, for managing agricultural activities in fields and is based on *Titen*, i.e., the observation of natural signs. The relationships between natural signs and farming activities are arranged in four primary and twelve secondary *Mangsa*, or seasons. Each *Mangsa* is characterized by activities such as *Bero* (maintaining fallow land) and burning rice straw, which reduce the loss of crops from meteorological drought and soil moisture deficits caused by agricultural drought. These practices suggest the potential for applying local knowledge to drought adaptation and indicate that a revaluation of the local knowledge of *Pranata Mangsa* with its specific characteristics could provide an effective strategy for adapting to drought and meeting the 2030 Sustainable Development Goals. This study integrated local knowledge (Pranata Mangsa) in Jawa, Indonesia, with scientific data on diurnal rainfall, extreme precipitation events, using the Local and Indigenous Knowledge System (LINKS). The results showed that Pranata Mangsa has informed aspects of agriculture including crop calendars, crop patterns, and farming activities, for over 1000 years in Jawa. Pranata Mangsa also enhances community resilience by mitigating the effects of extreme droughts; this finding was validated using scientific data.

Keywords: Pranata Mangsa, Local and scientific knowledge, LINKS method, Community ressiliences


22 June
(Sadha) XII
I (Kasa)
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12 May
2 August
(Dhesta) XI
II (Karo)
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1 March
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Mangsa
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(Kawolu) VIII
V (Kalima)
3 February
9 November
(Kapitu) VII
VI (Kanem)
22 December

[E] Oral | A (Atmospheric and Hydrospheric Sciences) : A-HW Hydrology & Water Environment

Sat. Jun 5, 2021 10:45 AM - 12:15 PM JST | Sat. Jun 5, 2021 1:45 AM - 3:15 AM UTC | Ch.13 Zoom Room 13

[A-HW21] Interdisciplinary approach to support climate change adaptation measures in regional scale

convener:TEBAKARI TAICHI(Toyama Prefectural University), Sompratana Ritphring(Kasetsart University), Masashi Kiguchi(University of Tokyo), weerakaset Suanpaga(Associate professor in Civil Engineering,Kasetsart University), Chairperson:Masashi Kiguchi(University of Tokyo), TEBAKARI TAICHI(Toyama Prefectural University)

In Japan, the impact of climate change has already become apparent and may become even more serious in the future. For example, there are the following specific damages; crop damage such as mandarin orange edema and white immature grains of rice, health hazards such as the northward distribution of Aedes albopictus and heat stroke patients, meteorological disasters such as increased torrential rain and increased number of strong typhoons, and coral bleaching Ecosystem.
The climate change adaptation law, which was enacted in 2018, clarified the legal position of adaptation measures in Japan, and is a legal for the national, local governments, businesses and citizens to cooperate and cooperate to promote adaptation measures. Based on this law, the Climate Change Adaptation Information Platform (A-PLAT) was established to develop and provide tools to support information provision and adaptation actions, and to collect, organize and provide best practices. AP-PLAT and T -Overseas development such as -PLAT is also progressing. Overseas expansion such as AP-PLAT and T-PLAT are also progressing.
In each research field, it is necessary to promote effective adaptation measures based on reliable and detailed information, and measures based on scientific knowledge of future impacts and strengthening of adaptation in the region are urgently needed.
This proposed session would like to invite presentations on the latest achievements in interdisciplinary fields such as hydrology, agriculture, forestry, weather, and climate that support specific climate change adaptation measures, as well as on the development of new research.

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

[AHW21-07] Climate change effect the relationship between land-use and poverty in major cities of Thailand.

★Invited Papers

*weerakaset Suanpaga[1], Shirakawa Hiroaki[2], Nichanun Trakulphudphong [3], Wuthiporn Klinhom[3], Krittanut Thumsatsarn[3] (1.Associate professor in Civil Engineering,Kasetsart University,Thailand, 2.Associate professor in Graduate School of Engineering,Nagoya University,Japan, 3.Bachelor degree student in Civil Engineering,Kasetsart University,Thailand)

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

[AHW21-08] Local adaptation strategy to climate change considering local context in Thailand

★Invited Papers

*Kyoko Matsumoto[1], Sompratana Ritphring[2], Masashi Kiguchi[3], Taichi Tebakari[1], Taikan Oki[4] (1.Department of Civil and Environmental Engineering, Toyama Prefectural University, 2.Faculty of Engineering, Kasetsart University, 3.Institute of Industrial Science, The University of Tokyo, 4.School of Engineering, The University of Tokyo)

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

[AHW21-09] Beach Nourishment to Mitigate the Impact of Beach Erosion and Sea Level Rise, Thailand

*Sompratana Ritphring[1], Keiko Udo[2] (1.Department of Water Resources Engineering, Kasetsart University, 2.International Research Institute of Disaster Science, Tohoku University)

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

[AHW21-10] Valuation of Sandy Beach Tourism Benefit with Respect to Hotel Room Rates by Using a Spatial Hedonic Model in Thailand

*Chatuphorn Somphong[1], Keiko Udo[1], Sompratana Ritphring[2], Hiroaki Shirakawa[3] (1.International Research Institute of Disaster Science, Tohoku University, Japan, 2.Department of Water Resources Engineering, Kasetsart University, Thailand, 3.Graduate School of Environmental Studies, Nagoya University, Japan)

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

[AHW21-11] Impacts of urban flood and adapataion on traffic flow in Bangkok

*Shinichiro NAKAMURA[1], Horoyoshi Morita[4], Tsuyoshi Takano[4], Varameth Vichiensan[2], Sanit Wongsa[3], Napaporn Piamsa-nga[2] (1.Nagoya University, 2.Kasetsaet University, 3.King Mongkut's University of Technology Thonburi, 4.Nippon Engineering Consultants Co., Lld)

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

[AHW21-12] Effectiveness of crop calendar shift as an adaptation measure for climate change - Case study for rice production in Hokkaido, Japan

*Kenji Tanaka[1], Tomoki Yamada[2], Shigenobu Tanaka[1] (1.Disaster Prevention Research Institute, Kyoto University, 2.Faculty of Engineering, Kyoto University)

Climate change effect the relationship between land-use and poverty in major cities of Thailand.

*weerakaset Suanpaga[1], Shirakawa Hiroaki[2], Nichanun Trakulphudphong [3], Wuthiporn Klinhom[3], Krittanut Thumsatsarn[3]

1. Associate professor in Civil Engineering,Kasetsart University,Thailand, 2. Associate professor in Graduate School of Engineering,Nagoya University,Japan, 3. Bachelor degree student in Civil Engineering,Kasetsart University,Thailand

Nowadays, the effect of climate change in Thailand causes floods, storms, and drought that lead to land-use change. According to the report in 2015, the heavy rain caused floods in Khon Kaen province, Thailand. In 2019 the forest area in Khon Kaen has decreased by 0.67 percent. The urban and agricultural areas have been increasing. The objective of these studies was to determine the relationship between climate change and land-use change, also to determine the relationship of the land-use change effects on poverty which is one of the problem factors that influence the economy of Thailand.

The study areas were the four major cities (Chiang Mai, Khon Kaen, Chai Nat, and Songkla) of Thailand. The changes of monthly current income per capita and Gross Provincial Product (GPP) of each province were analyzed.

The land-use were classified into 4 categories, named agriculture area, built-up area, water, forest, and miscellaneous area.
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Keywords: Climate change , Land-use change, poverty

The climate change effect the relationship between land-use and poverty in major cities of Thailand

Weerakaset suanpaga[1*], Hiroki Shirakawa[2], Nichanun Trakulphudphong [3], Wuthiporn Klinhom[4] and Krittanut Thumsatsarn[5]

Email: 1 weerakaset.s@ku.ac.th , Faculty of Engineering, Kasetsart University,Thailand * corresponding author.

2. sirakawa@urban.env.nagoya-u.ac.jp , Graduate School of Engineering, Nagoya University,Japan
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4. wuthiporn.k@ku.th , Faculty of Engineering, Kasetsart University,Thailand
5. Krittanut.t@ku.th , Faculty of Engineering, Kasetsart University,Thailand

Abstract

Nowadays, the effect of climate change in Thailand causes floods, storms, and drought that lead to land-use change. According to the report in 2015, the heavy rain caused floods in Khon Kaen province, Thailand. In 2019 the forest area in Khon Kaen has decreased by 0.67 percent. The urban and agricultural areas have been increasing. The objective of these studies was to determine the relationship between climate change and land-use change, also to determine the relationship of the land-use change effects on poverty which is one of the problem factors that influence the economy of Thailand.

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Local adaptation strategy to climate change considering local context in Thailand

*Kyoko Matsumoto[1], Sompratana Ritphring[2], Masashi Kiguchi[3], Taichi Tebakari[1], Taikan Oki[4]

1. Department of Civil and Environmental Engineering, Toyama Prefectural University, 2. Faculty of Engineering, Kasetsart University, 3. Institute of Industrial Science, The University of Tokyo, 4. School of Engineering, The University of Tokyo

This presentation deal with the issue on building local adaptation strategy to climate change considering local context and how to deliver the scientific knowledge into local level to promote the implementation of adaptation in rural area in Thailand.

Thai government formulated the Climate Change Master Plan 2015-2050 in 2015. The plan outlines steps to achieve climate resilience and low carbon growth in accordance with a sustainable development agenda. The Master Plan includes three key strategies: adaptation, mitigation, and capacity building. Thailand has also adopted a National Adaptation Plan following The Master Plan, and the NAP guidelines for policy makers currently is developed. Although adaptation plans have been developed on the national level, there are still gaps in implementation at the local level. The content, scale of the climate change impact and those vulnerability vary depending on the local characteristics such as the climatic, geographical, and socio-economic conditions. Formulation of local adaptation strategies needs to be addressed among various stakeholders, especially the decision-making in facing the uncertainties in climate scenarios requires promoting a understanding of climate change among stakeholders. It is important to know the awareness and needs of each stakeholder in addition to information of scientific knowledge to formulate adaptation strategies.

Moreover, the current situation on people’s perception to climate change based on our field survey in rural area in Thailand will be introduced. It was found that a high proportion of residents recognized climate change as causing changes to their daily lives, however, there is still a need to raise awareness concerning the implementation of climate change adaptation measures. It is necessary to promote adaptation measures with local community cohesion in accordance with an understanding of the way in which resident’s perception of climate change and adaptation, as well as the impact to each stakeholder by climate change and accessibility to government support.

Keywords: Adaptation to climate change, Thailand, Local adaptation strategy

Beach Nourishment to Mitigate the Impact of Beach Erosion and Sea Level Rise, Thailand

*Sompratana Ritphring[1], Keiko Udo[2]

1. Department of Water Resources Engineering, Kasetsart University, 2. International Research Institute of Disaster Science, Tohoku University

In the twenty-first century, global sea level rise associated with climate change will affect beach areas, which contribute a number of benefits that include benefits to the recreational sector of the economy. In Thailand, the use of structural measures to slow beach erosion and mitigate the impact of sea level rise is commonly implemented. However, structural measures often bring about negative effects on adjacent coastal areas. For this reason, beach nourishment was adopted as a suitable solution to protect and reclaim beach areas and to preserve the Tourism Carrying Capacity of the beach. This research analysed historical shoreline changes using satellite images and assessed beach value with the hedonic pricing method. We used a benefit-cost ratio analysis to evaluate the economic valuation assessment of two beaches. The results indicated that the beach values of Pattaya Beach and Chalatat Beach were 1,072,250 and 92,092 USD, respectively. The benefit-cost ratio analysis proposes that it is worth implementing beach nourishment to cope with all climate change scenarios. In response to climate change, these findings could be applied to protect beach tourism.

Keywords: climate change, sea level rise, beach erosion, beach nourishment, Pattaya beach, Chalatat beach

Valuation of Sandy Beach Tourism Benefit with Respect to Hotel Room Rates by Using a Spatial Hedonic Model in Thailand

*Chatuphorn Somphong[1], Keiko Udo[1], Sompratana Ritphring[2], Hiroaki Shirakawa[3]

1. International Research Institute of Disaster Science, Tohoku University, Japan, 2. Department of Water Resources Engineering, Kasetsart University, Thailand, 3. Graduate School of Environmental Studies, Nagoya University, Japan

An economic assessment for a non-market resource like sandy beaches is always a challenge for Thailand’s coastal policy planners due to the lack of data availability, especially on the national scale. While beach tourism in Thailand has been representing an essential part of the Thai economy, the sandy beaches are probably exposed to the future sea-level rise. Therefore, the need for tourism benefit of the beaches should be conducted. The research attempted to measure the effect of sandy beach characteristics and hotel location with respect to the hotel room rates. A sample of 3,331 hotel rooms across Thailand’s coastal sub-districts, covering the entire sandy beaches in Thailand, was collected through a hotel-booking online database during the country peak season. The considered variables include hotel room attributes, sandy beach characteristics, hotel locations, and coastal infrastructures. Through a hedonic price model based on geographically weighted regression analysis, the relationship between the dependent variables (hotel room rate) and the independent variables (selected beach variable) was estimated to evaluate the marginal effect and its spatial variations. The tourism benefit was assumedly calculated from the marginal effect of the hotel’s beachfront locations on hotel price. The study suggested the location in front of the beach raised the average hotel room rates by 15.0-36.5%. The results emphasized the significant spatial variability of the estimated *Beachfront* coefficient. In addition, the effect of beach protection structures (i.e. seawall, breakwaters, groins) on the hotel price was also investigated and implied a slight drop by 1.0-3.0% of the average price. The other sandy beach variables (such as beach length, width, slope) effects on hotel price were also investigated.

Keywords: Coastal tourism, Hedonic pricing method, Hotel Price, Geographically weighted regression analysis, climate change adaptation

Impacts of urban flood and adapataion on traffic flow in Bangkok

*Shinichiro NAKAMURA[1], Horoyoshi Morita[4], Tsuyoshi Takano[4], Varameth Vichiensan[2], Sanit Wongsa[3], Napaporn Piamsa-nga[2]

1. Nagoya University, 2. Kasetsaet University, 3. King Mongkut's University of Technology Thonburi, 4. Nippon Engineering Consultants Co., Lld

Traffic is an important economic and social activities in urban area, and its congestion tends to be a bottleneck for their activities and economic developments, especially in developing countries. Heavy rainfall and urban flood are factors which generate or enhance the traffic congestions in urban area. Bangkok, our target city, has been under a rapid economic growth in last decades and the traffic congestion have been one of important and urgent social issue through the increasing population and economic activities. This study aims to analyze the impacts of urban flood and effects of adaptation measures on the traffic flow in Bangkok with connecting rainfall/floods and probe data which obtained from a large number of vehicles in motion through communication networks. In addition, we evaluated the effectiveness of adaptation measures to reduce the impacts of urban flood on traffic by applying the connected flood and traffic models to several adaptation scenarios.

Keywords: Urban flood, Traffic, Bangkok, Adaptation

Effectiveness of crop calendar shift as an adaptation measure for climate change - Case study for rice production in Hokkaido, Japan

*Kenji Tanaka[1], Tomoki Yamada[2], Shigenobu Tanaka[1]

1. Disaster Prevention Research Institute, Kyoto University, 2. Faculty of Engineering, Kyoto University

In this study, effectiveness of the shifting crop calendar as an adaptation measure against climate change is assesssed for the rice production in Hokkaido, Japan. Future climate scenario was produced by dynamical downscalling from 6GCMs using WRF with 9km resolution. Rice growth model SIMRIW, land surface model SiBUC, distributed hydrological model CaMa-Flood were used to evaluate the suitable growing period, irrigation water demand, river discharge etc.
SIMRIW generally showed the higher potential yield under future climate conditon, and the optimal transplant date will be 2 weeks to 1 month earlier by the end of this century. Also, from the point of climate condition, the areas suitable for rice production will extend toward north and east, suggesting that Hokkaido will have higher potential for the rice production in future climate condition.
Irrigation water demand was evaluated by SiBUC considering the deep water irrigation, an additional water demand against cold damage. Even in the future warm climate condition, cold air temperature caused by summer time storms will still remain until 2070's. Also, due to the temperature rise, base irrigation water demand will continue to increase year by year.
River discharge was evaluated by the result of SiBUC and CaMa-Flood. Due to the earlier snowmelt under warmer climate will shift the timing of snowmelt flood in sprinf season. So shifting crop calendar earlier is reasonable from the point of hydrological condition. Deep water irrigation in future condition will tend to provide water stress as the river discharge in July will decrease in future.

Keywords: rice production, cropping calendar, irrigation water demand, climate change

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

Sat. Jun 5, 2021 10:45 AM - 12:15 PM JST | Sat. Jun 5, 2021 1:45 AM - 3:15 AM UTC | Ch.07 Zoom Room 07

[A-CG30] Multi-scale ocean-atmosphere interaction in the tropics

convener:Hiroki Tokinaga(Research Institute for Applied Mechanics, Kyushu University), Yu Kosaka(Research Center for Advanced Science and Technology, University of Tokyo), Ayako Seiki(Japan Agency for Marine-Earth Science and Technology), Tomoki Tozuka(Department of Earth and Planetary Science, Graduate School of Science, The University of Tokyo), Chairperson:Yu Kosaka(Research Center for Advanced Science and Technology, University of Tokyo), Ayako Seiki(Japan Agency for Marine-Earth Science and Technology)

Tropical ocean-atmosphere interactions exert a significant impact on regional and global climate on a broad range of spatio-temporal scales. Since the 1980s, in-situ and satellite observations, reanalysis products, and advancements in climate modeling have led to depicting various aspects of intraseasonal (e.g., MJO), interannual (e.g., ENSO, IOD, and Atlantic Nino) and decadal (e.g., IPO) variability in the tropical ocean basins and their linkages with tropical (e.g., monsoons) and extratropical (e.g., storm track) climate. Newer studies find an active role of salinity in tropical ocean-atmosphere interaction, including tropical cyclone intensification. Other recent studies highlight the tropical inter-basin coupling among the Pacific, Indian Ocean, and Atlantic in seasonal prediction of the Asian summer monsoon and decadal redistribution of ocean heat content associated with the so-called "hiatus" of global warming. Long term change in the Pacific Walker circulation has been recapturing attention in terms of the pattern effect of warming on climate feedback and sensitivity against radiative forcing as well as ENSO modulations under a warmer climate. A variety of processes are mutually interrelated and shape the climate, its variability, and change. To examine these challenging issues from various perspectives and foster understanding of the role of tropical ocean-atmosphere interaction in the climate system, this session offers a forum to discuss recent progress in observational, modeling and theoretical studies of multi-scale ocean-atmosphere interaction in the tropics.

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

[ACG30-01] The impact of North Pacific climate variability on historical ENSO and its mechanisms

★Invited Papers

*Dillon J Amaya[1,2], Yu Kosaka[3], Wenyu Zhou[4], Yu Zhang[5], Shang-Ping Xie[6], Arthur J Miller[6] (1.Cooperative Institute for Research in Environmental Sciences, 2.University of Colorado Boulder, 3.University of Tokyo, 4.Pacific Northwest National Laboratory, 5.Ocean University of China, 6.Scripps Institution of Oceanography)

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

[ACG30-02] Radiative impacts of low clouds on the subtropical North Pacific climate

*Ayumu Miyamoto[1], Hisashi Nakamura[1], Takafumi Miyasaka[2], Yu Kosaka[1], Shang-Ping Xie[3] (1.Research Center for Advanced Science and Technology,The University of Tokyo, 2.Japan Meteorological Business Support Center, 3.Scripps Institution of Oceanography, University of California San Diego)

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

[ACG30-03] Disparate Midlatitude Responses to El Niño/Southern Oscillation

*Shiozaki Masahiro[1], Takeshi Enomoto[2,3], Takaya Koutarou[4] (1.Research Institute for applied mechanics, Kyushu University, 2.Disaster Prevention Research Institute, Kyoto University, 3.Application Laboratory, Japan Agency for Marine-Earth Science and Technology, 4.Kyoto Sangyo University)

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

[ACG30-04] Formation of Barrier Layers and Temperature Inversions in the Eastern Tropical Pacific Detected by Mooring Observation

*Shota Katsura[1], Janet Sprintall[1], Thomas Farrar[2], Dongxiao Zhang[3,4], Meghan Cronin[3] (1.Scripps Institution of Oceanography, University of California, San Diego, 2.Department of Physical Oceanography, Woods Hole Oceanographic Institution, 3.NOAA Pacific Marine Environmental Laboratory, 4.Cooperative Institute for Climate, Ocean, and Ecosystem Studies, University of Washington)

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

[ACG30-05] The intraseasonal relationship between the boreal summer intraseasonal oscillation and the Pacific-Japan pattern

*Ayako Seiki[1], Yu Kosaka[2], Satoru Yokoi[1] (1.Japan Agency for Marine-Earth Science and Technology, 2.The University of Tokyo)

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

[ACG30-06] Why does convection weaken over Sumatra Island in an active phase of the MJO?

*Ning Zhao[1], Peiming Wu[1], Miki Hattori[1] (1.JAMSTEC Japan Agency for Marine-Earth Science and Technology)

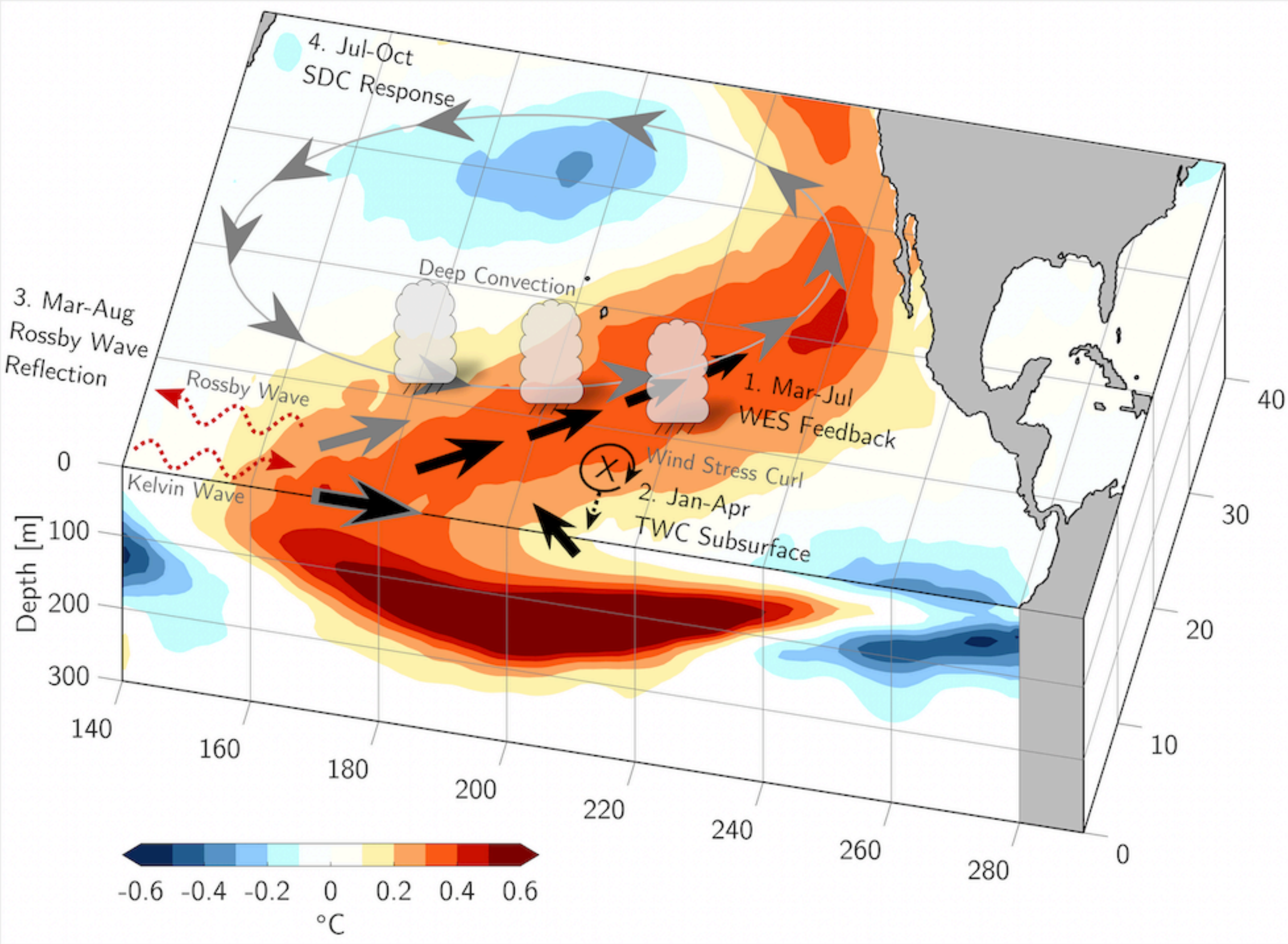
The impact of North Pacific climate variability on historical ENSO and its mechanisms

*Dillon J Amaya[1,2], Yu Kosaka[3], Wenyu Zhou[4], Yu Zhang[5], Shang-Ping Xie[6], Arthur J Miller[6]

1. Cooperative Institute for Research in Environmental Sciences, 2. University of Colorado Boulder, 3. University of Tokyo, 4. Pacific Northwest National Laboratory, 5. Ocean University of China, 6. Scripps Institution of Oceanography

Studies have indicated that North Pacific sea surface temperature (SST) variability can significantly modulate the El Nino–Southern Oscillation (ENSO), but there has been little effort to put these extratropical–tropical interactions into the context of historical events. To quantify the role of the North Pacific in pacing the timing and magnitude of observed ENSO, we use a fully coupled climate model to produce an ensemble of North Pacific Ocean–Global Atmosphere (nPOGA) SST pacemaker simulations. In nPOGA, SST anomalies are restored back to observations in the North Pacific (>15°N) but are free to evolve throughout the rest of the globe. We find that North Pacific SST has significantly influenced observed ENSO variability, accounting for approximately 15% of the total variance in boreal fall and winter. The connection between the North and tropical Pacific arises from two physical pathways: 1) a wind–evaporation–SST (WES) propagating mechanism, and 2) a Gill-like atmospheric response associated with anomalous deep convection in boreal summer and fall, which we refer to as the summer deep convection (SDC) response. The SDC response accounts for 25% of the observed zonal wind variability around the equatorial date line. On an event-by-event basis, nPOGA most closely reproduces the 2014/15 and the 2015/16 El Ninos. In particular, we show that the 2015 Pacific Meridional Mode event increased wind forcing along the equator by 20%, potentially contributing to the extreme nature of the 2015/16 El Nino. Our results illustrate the significant role of extratropical noise in pacing the initiation and magnitude of ENSO events and may improve the predictability of ENSO on seasonal time scales.

Keywords: Climate Variability, ENSO, Teleconnection, Tropics, Air-Sea Interactions, Climate Model


4. Jul-Oct
SDC Response
Deep Convection
3. Mar-Aug
Rossby Wave
Reflection
Rossby Wave
Kelvin Wave
1. Mar-Jul
WES Feedback
Wind Stress Curl
2. Jan-Apr
TWC Subsurface
Depth [m]
0
100
200
300
140
160
180
200
220
240
260
280
0
10
20
30
40
-0.6 -0.4 -0.2 0 0.2 0.4 0.6
°C

Radiative impacts of low clouds on the subtropical North Pacific climate

*Ayumu Miyamoto[1], Hisashi Nakamura[1], Takafumi Miyasaka[2], Yu Kosaka[1], Shang-Ping Xie[3]

1. Research Center for Advanced Science and Technology,The University of Tokyo, 2. Japan Meteorological Business Support Center, 3. Scripps Institution of Oceanography, University of California San Diego

Low clouds that cool the Earth radiatively are extensive off California over the North Pacific. The present study assesses their radiative impacts on the subtropical North Pacific climate with coupled general circulation model experiments. Comparison of a freely coupled control experiment with a sensitivity experiment where low-cloud radiative effect off California is artificially switched off demonstrates that low clouds lower sea surface temperature (SST) and reinforce the subtropical anticyclone locally. These responses extend southwestward from off California, suggestive of wind-evaporation-SST feedback. Following enhanced albedo effect of low clouds in spring and summer, the responses become strongest in summer and autumn in association with suppressed deep convective precipitation. In these seasons, low clouds strengthen surface trade winds and upper-tropospheric subtropical westerly jet, explaining 25% of climatological vertical wind shear around Hawaii. Low clouds thus act to protect Hawaii from hurricanes by lowering SST and increasing vertical wind shear.

Keywords: Low clouds, North Pacific

Disparate Midlatitude Responses to El Niño/Southern Oscillation

*Shiozaki Masahiro[1], Takeshi Enomoto[2,3], Takaya Koutarou[4]

1. Research Institute for applied mechanics, Kyushu University, 2. Disaster Prevention Research Institute, Kyoto University, 3. Application Laboratory, Japan Agency for Marine-Earth Science and Technology, 4. Kyoto Sangyo University

To investigate the disparate influences of the eastern Pacific (EP) El Niño on the winter climate in the Far East, we conducted composite analyses using long-term reanalysis datasets.

Our analysis shows that the western Pacific (WP) pattern dominates in the warm winter (typical) composite and the Pacific–North American (PNA) pattern dominates in the non-warm winter (atypical) composite.

In the warm winter case, the amplitudes of the negative sea surface temperature (SST) anomalies in the western Pacific Ocean are large whereas in the non-warm winter case, these amplitudes are small. In addition, the Indian Ocean basin warming occurs following the Indian Ocean dipole mode, as seen in the warm winter composite.

We investigated the dynamical mechanisms responsible for the disparate midlatitude responses to the EP El Niño by focusing on Rossby wave sources and propagation. These SST anomalies modulate the Walker and Hadley circulations and the convective activity in the western Pacific Ocean. Upper-tropospheric divergences at the mid-latitudes due to the anomalous Hadley circulation result in different teleconnection patterns. In the warm winter composite, the anticyclonic anomaly in the southern part of the WP pattern is created by the upstream negative Rossby wave source, while the other cyclonic anomaly is reinforced by the northward Rossby wave propagation. The cyclonic second and fourth centers of action of the PNA pattern are created by the positive Rossby wave sources. Furthermore, the equatorial SST gradient near the date line is found be a good precursor of the winter climate in the Far East.

We will also discuss the cold and the non-cold winter cases in East Asia during La Niña.

Keywords: El Niño/Southern Oscillation, winter climate, teleconnection pattern

Formation of Barrier Layers and Temperature Inversions in the Eastern Tropical Pacific Detected by Mooring Observation

*Shota Katsura[1], Janet Sprintall[1], Thomas Farrar[2], Dongxiao Zhang[3,4], Meghan Cronin[3]

1. Scripps Institution of Oceanography, University of California, San Diego, 2. Department of Physical Oceanography, Woods Hole Oceanographic Institution, 3. NOAA Pacific Marine Environmental Laboratory, 4. Cooperative Institute for Climate, Ocean, and Ecosystem Studies, University of Washington

It is known that salinity plays a dominant role in determining the stratification of the upper ocean, especially where barrier layers (BLs) form between the bases of the mixed layer and the isothermal layer in some regions. The BL interferes with heat and momentum exchange between surface and subsurface layers and can affect sea surface temperature and air-sea interactions. In the eastern tropical Pacific, BLs are distributed along the SSS front south of the eastern Pacific fresh pool in boreal summer and autumn and tend to be associated with temperature inversions (TIs) in boreal autumn. A mixed layer salinity and temperature budget was constructed based on time-series from three mooring observations to investigate the formation of BLs and TIs in the eastern tropical Pacific. BLs and TIs observed at the moorings showed a clear seasonality in their formation and amplitude, which is consistent with the previous climatological studies. However, in contrast to previous studies in the region, the mixed layer salinity budget indicates that precipitation was dominant for the surface freshening in boreal summer and autumn and contributed to the BL formation. The mixed layer temperature budget found that the penetration of shortwave radiation through the mixed layer base had a dominant contribution to the surface cooling and hence the TI formation during the boreal summer and autumn. Geostrophic and Ekman advection also occasionally contributed to the BL and TI formation. The existence of BLs significantly reduced the entrainment cooling and detrainment warming. In addition, the entrainment warmed the mixed layer when BLs with TIs existed. The shallower mixed layers associated with BLs were more sensitive to surface heat and freshwater flux than when BLs were not observed in the water column.

Keywords: Barrier Layer, Temperature Inversion, Eastern Tropical Pacific

The intraseasonal relationship between the boreal summer intraseasonal oscillation and the Pacific-Japan pattern

*Ayako Seiki[1], Yu Kosaka[2], Satoru Yokoi[1]

1. Japan Agency for Marine-Earth Science and Technology, 2. The University of Tokyo

The influence of the dominant tropical intraseasonal variability during boreal summer, called the boreal summer intraseasonal oscillation (BSISO), on the tropical-midlatitudes teleconnection, called the Pacific-Japan (PJ) pattern, is investigated. A lag correlation analysis between the intraseasonal PJ index and phases of the BSISO index shows that the positive correlation between the BSISO and the PJ pattern peaks during the early stage of the BSISO phase 8 when the center of the BSISO enters the central north Pacific. Composite analysis based on the BSISO events shows that intraseasonal responses to the migration of the BSISO are apparent even in midlatitudes. During the phase 7-8, cyclonic wind anomalies with low pressure signals north of the Philippines are drastically intensified and easterly wind anomalies blow into the southern side of Japan. Apparent intraseasonal signals in surface pressure anomalies are also found over the central north Pacific around 40°N. The migration of the BSISO might influence summer climate in East Asia through the PJ pattern at intraseasonal time scales.

Keywords: the boreal summer intraseasonal oscillation, the Pacific-Japan pattern

Why does convection weaken over Sumatra Island in an active phase of the MJO?

*Ning Zhao[1], Peiming Wu[1], Miki Hattori[1]

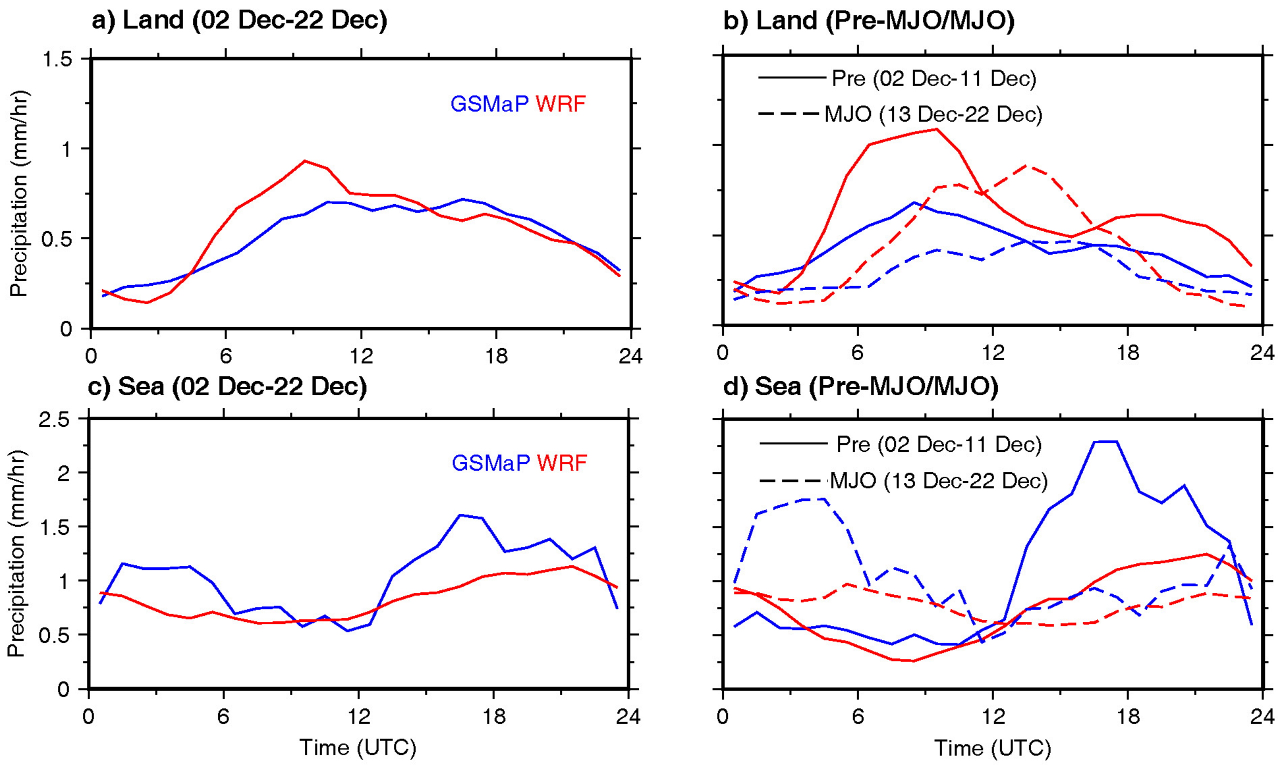
1. JAMSTEC Japan Agency for Marine-Earth Science and Technology

This study examined the diurnal cycle of convection over Sumatra Island in an active phase of the Madden-Julian Oscillation (MJO) during the pre-Years of the Maritime Continent (YMC) observation campaign in December 2015 based on observations and convection-permitting numerical model. Satellite observation indicates that, prior to an active phase of the MJO in early December, convection frequently occurred over the island in the afternoon. In contrast, during the active phase of the MJO in mid-December, afternoon convection over the island was suppressed, and a gap in convection aligned with the island was evident during the early morning hours. On the contrary, convective activities were observed over the offshore region within the whole day, especially during the daytime that was much weaker before.

Our numerical experiments successfully replicated the main features of the observed modulation of the diurnal convection. Results suggest that, during the active phase of the MJO, although the moisture was accumulated within the boundary layer over the mountainous areas as before, the afternoon convection was suppressed and delayed. Moisture budget analysis demonstrates that vertical moisture advection over the island, the dominating factor of diurnal convection, was weakened and delayed during the MJO active phase. It further became negative within the lower-to-mid troposphere from midnight to the next morning, indicating that the convection over the island was suppressed by the subsidence. Our results showed that such subsidence was highly related to the enhanced convective activities over the offshore region. On the other hand, our results also suggest that the strong westerlies played a secondary role in weakening and delaying the diurnal convection over the island, which induced the negative horizontal moisture advection within the mid-troposphere.

Overall, this study suggests that the modulated diurnal cycle over Sumatra Island was likely induced by the enhanced convective activities over the offshore region during the active phase of the MJO. Detailed results and further analyses would be shown in our presentation.

Keywords: Diurnal Convection, Land-sea Interaction, Madden–Julian Oscillation, Pre-YMC 2015


a) Land (02 Dec-22 Dec)
GSMaP WRF
Precipitation (mm/hr)
b) Land (Pre-MJO/MJO)
Pre (02 Dec-11 Dec)
MJO (13 Dec-22 Dec)
c) Sea (02 Dec-22 Dec)
GSMaP WRF
Precipitation (mm/hr)
Time (UTC)
d) Sea (Pre-MJO/MJO)
Pre (02 Dec-11 Dec)
MJO (13 Dec-22 Dec)
Time (UTC)

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

Sat. Jun 5, 2021 1:45 PM - 3:15 PM JST | Sat. Jun 5, 2021 4:45 AM - 6:15 AM UTC | Ch.07 Zoom Room 07

[A-CG30] Multi-scale ocean-atmosphere interaction in the tropics

convener:Hiroki Tokinaga(Research Institute for Applied Mechanics, Kyushu University), Yu Kosaka(Research Center for Advanced Science and Technology, University of Tokyo), Ayako Seiki(Japan Agency for Marine-Earth Science and Technology), Tomoki Tozuka(Department of Earth and Planetary Science, Graduate School of Science, The University of Tokyo), Chairperson:Hiroki Tokinaga(Research Institute for Applied Mechanics, Kyushu University), Tomoki Tozuka(Department of Earth and Planetary Science, Graduate School of Science, The University of Tokyo)

Tropical ocean-atmosphere interactions exert a significant impact on regional and global climate on a broad range of spatio-temporal scales. Since the 1980s, in-situ and satellite observations, reanalysis products, and advancements in climate modeling have led to depicting various aspects of intraseasonal (e.g., MJO), interannual (e.g., ENSO, IOD, and Atlantic Nino) and decadal (e.g., IPO) variability in the tropical ocean basins and their linkages with tropical (e.g., monsoons) and extratropical (e.g., storm track) climate. Newer studies find an active role of salinity in tropical ocean-atmosphere interaction, including tropical cyclone intensification. Other recent studies highlight the tropical inter-basin coupling among the Pacific, Indian Ocean, and Atlantic in seasonal prediction of the Asian summer monsoon and decadal redistribution of ocean heat content associated with the so-called "hiatus" of global warming. Long term change in the Pacific Walker circulation has been recapturing attention in terms of the pattern effect of warming on climate feedback and sensitivity against radiative forcing as well as ENSO modulations under a warmer climate. A variety of processes are mutually interrelated and shape the climate, its variability, and change. To examine these challenging issues from various perspectives and foster understanding of the role of tropical ocean-atmosphere interaction in the climate system, this session offers a forum to discuss recent progress in observational, modeling and theoretical studies of multi-scale ocean-atmosphere interaction in the tropics.

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

[ACG30-07] Understanding tropical interbasin interaction using linear inverse modelling

*Shoichiro Kido[1], Ingo Richter[1], Tomoki Tozuka[2,1], Ping Chang[3] (1.JAMSTEC Application Lab, 2.Department of Earth and Planetary Science, University of Tokyo, 3.Texas A&M University)

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

[ACG30-08] **An assessment of the tropical Atlantic influence on El Niño-Southern Oscillation**

*Ingo Richter[1], Hiroki Tokinaga[2], Yu Kosaka[3], Takeshi Doi[1], Takahito Kataoka[1] (1.Japan Agency for Marine-Earth Science and Technology, Yokohama, Japan, 2.Kyushu University, Kasuga, Japan, 3.University of Tokyo, Tokyo, Japan)

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

[ACG30-09] **The roles of diabatic heating for the seasonality of the Atlantic Niño**

★Invited Papers

*Hyacinth C. Nnamchi[1], Mojib Latif[1], Noel S. Keenlyside[2,3], Joakim Kjellsson[1], Ingo Richter[4] (1.GEOMAR Helmholtz Centre for Ocean Research Kiel, 2.Geophysical Institute, University of Bergen, and Bjerknes Centre for Climate Research, Bergen, Norway, 3.Nansen Environmental and Remote Sensing Center, Bergen, Norway, 4.Application Laboratory, Research Institute for Value-Added-Information Generation, Japan Agency for Marine-Earth Science and Technology, Yokohama, Japan)

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

[ACG30-10] Simulated thermocline tilt over the tropical Indian Ocean and its influence on future sea surface temperature variability

★Invited Papers

*Guojian Wang[1,2], Wenju Cai[1,2], Agus Santoso[1,3] (1.Center for Southern Hemisphere Oceans Research (CSHOR), CSIRO Oceans and Atmosphere, 2.Key Laboratory of Physical Oceanography–Institute for

Advanced Ocean Studies, Ocean University of China and Qingdao National Laboratory for Marine Science and Technology, 3.The University of New South Wales)

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

[ACG30-11] Asymmetry in sea surface temperature anomalies and atmospheric teleconnection associated with the Indian Ocean Dipole

Mai Nakazato[1], Shoichiro Kido[2], *Tomoki Tozuka[1,2] (1.Department of Earth and Planetary Science, Graduate School of Science, The University of Tokyo, 2.Application Laboratory, Research Institute for Value-Added-Information Generation, Japan Agency for Marine-Earth Science and Technology)

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

[ACG30-12] Investigation of interannual variability in the tropical Indian Ocean based on the transfer routes of wave energy

*Zimeng Li[1], Hidenori AIKI[2] (1.Graduate school of environmental studies, Nagoya university, 2.Institute for Space-Earth Environmental Research)

Understanding tropical interbasin interaction using linear inverse modelling

*Shoichiro Kido[1], Ingo Richter[1], Tomoki Tozuka[2,1], Ping Chang[3]

1. JAMSTEC Application Lab, 2. Department of Earth and Planetary Science, University of Tokyo, 3. Texas A&M University

Many observational and modelling studies have recently underlined the importance of tropical interbasin coupling in understanding climate variability and predictability. The coupling among tropical basins can be separated into three components; the interaction between Pacific and Indian Oceans (the PO-IO interaction), that between Pacific and Atlantic Oceans (the PO-AO interaction), and that between the Atlantic and Indian Oceans (the AO-IO interaction). Though many previous studies have discussed the significance of individual components, the relative importance of these coupling components has not been carefully evaluated and fully understood. To address this issue, we have constructed a linear inverse model (LIM) based on observed sea surface temperature (SST) anomalies in the tropical Pacific, Atlantic, and Indian Oceans, and performed a series of prediction experiments using this LIM. We found that our LIM has a good skilll in forecasting tropical SST variability, including those associated with the El Niño and Southern Oscillation (ENSO). To assess the impact of interbasin interaction, we have removed individual coupling component by modifying off-diagonal elements of the linear operator. Using this “decoupled” operator, we have conducted several prediction experiments. We find that the decoupling leads to a substantial decrease in prediction skill of ENSO and related SST variability, especially at longer lead times. Partial decoupling experiments that nullify specific coupling components suggest that the PO-IO interaction has the largest impact on the prediction skill of ENSO-related variability, whereas the PO-AO interaction also has a nonnegligible contribution. On the other hand, the impacts of the AO-IO interaction seem to be smaller than those of the other two coupling components. Results from the LIM simulations with white noise forcing, as well as an analysis of optimum initial conditions will be also discussed. These are aimed to examine the underlying statistical relations and physical processes.

Keywords: Interbasin interaction, Linear inverse modeling

An assessment of the tropical Atlantic influence on El Niño-Southern Oscillation

*Ingo Richter[1], Hiroki Tokinaga[2], Yu Kosaka[3], Takeshi Doi[1], Takahito Kataoka[1]

1. Japan Agency for Marine-Earth Science and Technology, Yokohama, Japan, 2. Kyushu University, Kasuga, Japan, 3. University of Tokyo, Tokyo, Japan

The influence of the tropical Atlantic on El Niño-Southern Oscillation (ENSO) is examined using sensitivity experiments with the SINTEX-F general circulation model with prescribed sea surface temperature (SST) distributions based on observations for the period 1982-2018. In the control experiment (CTRL) observed SSTs are prescribed over the global oceans, whereas in the sensitivity experiment (OTA) observed SSTs are prescribed in the tropical Atlantic only while in other regions the climatological annual cycle is prescribed.

A composite analysis of the model output suggests that cold SST events in the northern tropical Atlantic (NTA) during boreal spring are associated with near-surface wind changes over the equatorial and subtropical Pacific that are conducive to the development of El Niño, consistent with previous studies. The amplitude of these changes, however, is at most 20% of those observed during typical El Niño events. Likewise, warm events in the equatorial Atlantic produce only about 10% of the wind changes seen in the western equatorial Pacific during the developing phase of typical La Niña events. Similar results are obtained from a partial regression analysis performed on an ensemble of atmosphere-only simulations from the Atmospheric Model Intercomparison Project (AMIP) Phase 6. Further analysis of the AMIP models indicates that model biases do not have a major impact on the Atlantic-to-Pacific influence. Overall, the results suggest that the tropical Atlantic has a weak influence on ENSO development, and that this influence mostly acts to modulate ongoing events rather than to initiate them.

Keywords: tropical Atlantic, ENSO, teleconnections

The roles of diabatic heating for the seasonality of the Atlantic Niño

*Hyacinth C. Nnamchi[1], Mojib Latif[1], Noel S. Keenlyside[2,3], Joakim Kjellsson[1], Ingo Richter[4]

1. GEOMAR Helmholtz Centre for Ocean Research Kiel, 2. Geophysical Institute, University of Bergen, and Bjerknes Centre for Climate Research, Bergen, Norway, 3. Nansen Environmental and Remote Sensing Center, Bergen, Norway, 4. Application Laboratory, Research Institute for Value-Added-Information Generation, Japan Agency for Marine-Earth Science and Technology, Yokohama, Japan

The physics underlying the Atlantic Niño remain under debate; however, the role of diabatic heating which represents the atmospheric component of the Bjerknes feedback loop is often overlooked. In this study, we use multiple observations to show that diabatic heating variability that is linked to the seasonal migration of the inter-tropical convergence zone controls the seasonality of the Atlantic Niño. The strongest diabatic heating variability in spring leads that in the SST in summer, whereas the atmospheric response to the SST variability is relatively weak. This can be linked to net surface heat flux tendencies which drive the mixed-layer temperature anomalies in spring, but is the major damping term in June-July when the SST variability peak, although observational uncertainty is quite large. Entrainment is the dominant heating term associated with the peak SST variability in June. Our findings point to the existence of a strong meridional variability in the atmosphere, which by terminating the Bjerknes feedback, controls the seasonality of the Atlantic Niño.

Keywords: Bjerknes feedback, Atlantic Niño, Diabatic heating, ITCZ

Simulated thermocline tilt over the tropical Indian Ocean and its influence on future sea surface temperature variability

*Guojian Wang[1,2], Wenju Cai[1,2], Agus Santoso[1,3]

1. Center for Southern Hemisphere Oceans Research (CSHOR), CSIRO Oceans and Atmosphere, 2. Key Laboratory of Physical Oceanography–Institute for Advanced Ocean Studies, Ocean University of China and Qingdao National Laboratory for Marine Science and Technology, 3. The University of New South Wales

Most coupled climate models simulate an overly shallow thermocline over the southeastern equatorial Indian Ocean (SEIO). Through the Bjerknes feedback loop, the associated unrealistic thermocline tilt leads to warmer sea surface temperature (SST) over the western equatorial Indian Ocean than the SEIO, which is conducive to equatorial easterly winds. Similar to phase 5 of the Coupled Model Intercomparison Project (CMIP), phase 6 of the CMIP continues to simulate such overly tilted thermocline. On the one hand, this leads to overly strong SST variability, and on the other hand, it provides an inherent limit for the thermocline to incline further under greenhouse warming. Consequently, models with a more realistic tilt in the present-day climate project a greater shoaling of the thermocline under global warming, which facilities upwelling of cool subsurface water, leading to stronger increase in SST variability over the SEIO, compared to models with an overly large thermocline tilt.

Keywords: Thermocline bias, Tropical Indian Ocean

Asymmetry in sea surface temperature anomalies and atmospheric teleconnection associated with the Indian Ocean Dipole

Mai Nakazato[1], Shoichiro Kido[2], *Tomoki Tozuka[1,2]

1. Department of Earth and Planetary Science, Graduate School of Science, The University of Tokyo, 2. Application Laboratory, Research Institute for Value-Added-Information Generation, Japan Agency for Marine-Earth Science and Technology

One of the important features of the Indian Ocean Dipole (IOD) is its asymmetry; negative sea surface temperature (SST) anomalies in the eastern pole during the positive IOD are stronger than positive SST anomalies during the negative IOD. Based on an online mixed layer heat budget analysis using the Regional Ocean Modeling System, it is shown that the vertical diffusion term plays an important role in generating this asymmetry in addition to the contributions from the nonlinear advection and the thermocline feedback proposed by some previous studies. To understand the origin of the asymmetry in the vertical diffusion term, a detailed decomposition is carried out. It is found that the asymmetry is primarily explained by differences in subsurface temperature anomalies; during positive IOD events, anomalous cooling below the mixed layer contributes to SST cooling via vertical mixing. However, such effects are weaker in the case of negative IOD events due to weaker subsurface temperature anomalies. Furthermore, analyses of the Rossby wave source and wave activity fluxes suggest that the SST asymmetry in the IOD indeed have asymmetric impacts on the mid-latitudes via atmospheric teleconnection.

Keywords: Indian Ocean Dipole, Mixed layer heat budget analysis, Atmospheric teleconnection, Tropical Indian Ocean

Investigation of interannual variability in the tropical Indian Ocean based on the transfer routes of wave energy

*Zimeng Li[1], Hidenori AIKI[2]

1. Graduate school of environmental studies, Nagoya university, 2. Institute for Space-Earth Environmental Research

We have performed a set of 61-year hindcast experiments of Indian Ocean using monthly wind forcing and provide a new perspective for the interannual variability in the tropical Indian Ocean based on the transfer routes of wave energy using a new diagnostic scheme. There are two sets of Rossby waves along the equator during 1994 IOD positive event. One is the same phase speed with theoretical phase speed of equatorial Rossby waves, the other is slightly slower than theoretical phase speed of equatorial Rossby waves. First set is the boundary-reflected equatorial Rossby waves at eastern boundary from the equatorial Kelvin waves. Second set is the off-equatorial Rossby waves generated by southeasterly winds from the southeastern Indian Ocean, which may account for the appearance of slightly slower phase speed of Rossby wave along the equator.

Keywords: Indian Ocean, interannual variability, wave energy, Kelvin wave, Rossby wave

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

Sat. Jun 5, 2021 9:00 AM - 10:30 AM JST | Sat. Jun 5, 2021 12:00 AM - 1:30 AM UTC | Ch.08 Zoom Room 08

[A-CG34] Global Carbon Cycle Observation and Analysis

convener:Kazuhito Ichii(Chiba University), Prabir Patra(Research Institute for Global Change, JAMSTEC), Akihiko Ito(National Institute for Environmental Studies), Chairperson:Prabir Patra(Research Institute for Global Change, JAMSTEC), Kazuhito Ichii(Chiba University)

The Paris Agreement under the United Nations Framework Convention on Climate Change (UNFCCC) is a landmark agreement, which aims at reduction of greenhouse gases (GHGs) emission to keep the global warming below 2 deg C. The national commitments and progresses should be carefully monitored and verified by international bodies using different but complementary methodologies.

Many observation and technique to monitor GHGs budget have been improved in recent years. The improvements include observational platforms for monitoring atmospheric GHGs, national or regional emission inventories, top-down estimations (e.g. atmospheric inverse analysis), and bottom-up estimations (e.g. process-based models). However, due to uncertainties in sparse observation network and integration methods, large uncertainty remains in GHGs sources/sinks estimations at global and regional scales.

The purpose of the session is to discuss state-of-the-art techniques for estimations of GHGs (e.g. CO2, CH4, N2O) budget at global and regional scales. The topic includes natural and anthropogenic processes, various methodologies (e.g. in-situ observation, aircraft monitoring, remote sensing, modeling), and various targets (e.g. atmosphere, terrestrial, and ocean), various spatial and temporal coverage (e.g. regional to global scales and past-present-future). Improved estimates of emissions from land use change, forest fires, and other anthropogenic sources (urban developments and thermal power station etc.) are also of interest. We also welcome discussions for designs and plans for future studies targeting city and country scale emission estimations using sophisticated modeling tools and inventories.

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

[ACG34-01] Atmospheric inversions of greenhouse gas fluxes: A story of uneven development

★Invited Papers

*Peter J Rayner[1] (1.University of Melbourne)

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

[ACG34-02] **Decadal variability in land and ocean carbon fluxes by inverse modelling of atmospheric CO_2**

★Invited Papers

*Naveen Chandra[1,2], Prabir Patra[2] (1.National Institute for Environmental Studies, Japan, 2.Japan Agency for Marine-Earth Science and Technology)

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

[ACG34-03] **Changes in the atmospheric CO_2/CH_4 variability in the East Asian outflow region caused by plummet of fossil fuel-derived CO_2 in China due to COVID-19 outbreak**

*Yasunori Tohjima[1], Prabir Patra[2], Yosuke Niwa[1], Hitoshi Mukai[1], Motoki Sasakawa[1], Toshinobu Machida[1], Shin-ichiro Nakaoka[1] (1.National Institute for Environmental Studies, 2.Japan Agency for Marine-Earth Science and Technology)

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

[ACG34-04] Impact of anomalous high temperature anomaly in the 2020 spring-summer on terrestrial environment across Siberia

*Kazuhito Ichii[1], Riku Kawase[1], Yuhei Yamamoto[1], Shunji Kotsuki[1] (1.Chiba University)

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

[ACG34-05] CH_4 surface flux estimation based on local ensemble transform Kalman filter

*Jagat Bisht[1], Prabir Patra[1,2], Masayuki Takigawa[1], Takashi Sekiya[1], Yugo Kanaya[1], Naoko Saito[2] (1.Japan Agency for Marine-Earth Science and Technology , 2.Center for Environ. Remote Sensing, Chiba University)

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

[ACG34-06] Toward multi-scale greenhouse gas monitoring system for supporting global stock take

*Akihiko Ito[1,2], Yosuke Niwa[1], Tomohiro Hajima[2], Nobuko Saigusa[1] (1.National Institute for Environmental Studies, 2.Japan Agency for Marine-Earth Science and Technology)

Atmospheric inversions of greenhouse gas fluxes: A story of uneven development

*Peter J Rayner[1]

1. University of Melbourne

Atmospheric inversion is a technique for estimating the fluxes of tracers (here greenhouse gases) given observations and a model of atmospheric transport. The dominant methodology is Bayesian inference in which a model of atmospheric transport is combined with prior information and observations. Bayesian inference describes all input quantities as probability distributions. The methods differ in how they describe their inputs and the technique for constructing the posterior distribution. In this talk I will outline the current state of development of each of these inputs. I will argue that this development has proceeded unevenly. For much of their history inversions were limited by the sparsity of observations. The advent of increasingly accurate and dense satellite measurements has changed this so that the chief weakness is now the atmospheric models. I will sketch some possible remedies for this state of affairs.

Decadal variability in land and ocean carbon fluxes by inverse modelling of atmospheric CO_2

*Naveen Chandra[1,2], Prabir Patra[2]

1. National Institute for Environmental Studies, Japan, 2. Japan Agency for Marine-Earth Science and Technology

An improved understanding of the variabilities and trends in the CO_2 fluxes due to the land-biosphere and oceanic exchange is essential for the predictions of future climate feedback. Inverse modelling of atmospheric CO_2 provides estimation of spatio-temporal variation of the fluxes, allowing us to relate the CO2 flux variabilities with the modes of regional climate and with trends in socio-economic changes.

Monthly CO_2 fluxes for the period 1996-2019 are estimated by a time dependent inverse (TDI) model that uses measurements of CO_2 at 34 sites across the globe and MIROC4-ACTM forward model simulation. The inversion fluxes are evaluated in detail using the independent aircraft measurements of CO_2. The simulations of CO_2 concentrations using inverted fluxes agree within ±0.5 ppm at all the aircraft vertical profile sites. The long-term global land (ocean) fluxes are estimated to be -2.2±0.8 (-1.4±0.2) PgC yr^{-1} for the 2000s (2000-2009) and -2.7±0.7 (-1.6±0.2) PgC yr^{-1} for the 2010s (2010-2019. A large fraction of the interannual variability in global CO_2 flux anomaly originate over the tropical land regions, induced by El-Nio Southern oscillation. Sensitivity studies, based different prior flux uncertainty, different set of prior fluxes, and different data network including ship-based measurements and JAL/NIES CONTRAIL aircraft data, are conducted to get the uncertainty range in the estimated fluxes.

Keywords: Inverse modelling, CO2 flux, ENSO

Changes in the atmospheric CO_2/CH_4 variability in the East Asian outflow region caused by plummet of fossil fuel-derived CO_2 in China due to COVID-19 outbreak

*Yasunori Tohjima[1], Prabir Patra[2], Yosuke Niwa[1], Hitoshi Mukai[1], Motoki Sasakawa[1], Toshinobu Machida[1], Shin-ichiro Nakaoka[1]

1. National Institute for Environmental Studies, 2. Japan Agency for Marine-Earth Science and Technology

To prevent the spread of the new coronavirus (COVID-19) in China, the government of China imposed a nationwide lockdown and strict restrictions on the inter-city transport and socio-economic activity during the period from the end of January through March in 2020. Such restrictions were expected to significantly reduce the fossil-fuel-derived CO_2 ($FFCO_2$) emissions from China during the above period. Previous study revealed that the ratio of the synoptic-scale variability between CO_2 and CH_4 ($\Delta CO_2/\Delta CH_4$) observed in the downwind region of the East Asian continent reflected the emission ratio of the source region. Accordingly, since the restrictions would not cause any immediate effects on the CH4 emissions in China, the atmospheric observations in the downwind region would detect the significant reduction of $\Delta CO_2/\Delta CH_4$ ratio during the restriction period.

The National Institute of Environmental Studies (NIES) has been monitoring the atmospheric greenhouse gases including CO_2 and CH_4 mainly in the Asia Pacific region by using variety of platforms including ground sites, commercial cargo ships, and passenger airplane. The continental marginal region of the East Asia corresponds to the outflow region of the continental emissions during the period from late fall through early spring because of the East Asian monsoon. In this presentation, we examined the temporal or spatial variability ratio between the atmospheric CO_2 and CH_4 mole fractions obtained from continuous measurements at Hateruma Island (HAT; lat. 24.1°N, long. 123.8°E), in-situ measurements aboard cargo ships sailing between Japan and Southeast Asia, and airplane sampling over Shanghai. For example, the monthly mean ratio of the synoptic scale variations between CO_2 and CH_4 observed at HAT in February 2020 showed significant decrease in comparison with those observed in the previous decadal period (2010-2019). The decrease in the $\Delta CO_2/\Delta CH_4$ ratio was well reproduced by the model simulation based on an atmospheric transport model (NICAM-TM) and a set of corresponding CO_2 and CH_4 fluxes when the $FFCO_2$ emissions from China reduced by 30%. The relationship between the atmospheric CO_2 and CH_4 observed over Shanghai and in the South and East China sea in February 2020 agreed well with the simulated relationship with the similarly reduced $FFCO_2$ emissions from China. These results show the utility of high-precision measurements of CO_2 and CH_4 to detect signals from the emission change from specific regions.

Keywords: COVID-19 outbreak, lockdown, atmospheric CO2, atmospheric CH4, synoptic-scale variation

Impact of anomalous high temperature anomaly in the 2020 spring-summer on terrestrial environment across Siberia

*Kazuhito Ichii[1], Riku Kawase[1], Yuhei Yamamoto[1], Shunji Kotsuki[1]

1. Chiba University

Siberia has been experiences one of the most distinct warming trends across global, and this tendency will continue in future. Among the effects of global climate change, extreme climate anomaly is one of the important issues. Siberia experienced anomalous high temperature in 2020 spring to summer. However, the effects of the anomaly on terrestrial environment have not been studied so far. In this study, we analyzed multiple satellite remote sensing datasets/products and model outputs to understand the response of terrestrial environment to the warming. We detected clear positive anomaly in land surface temperature, and it exceeds over five degree above long-term (20 years) mean based on MODIS products. Snow cover duration also show much earlier snowmelt (e.g. one month) compared with the normal. NDVI and LAI also consistently shows positive anomalies in March to June seasons. Gross primary productivity (GPP) also shows 10-20% larger than those of normal years. We will report further progress on this analysis, including river outflow, whole carbon cycle (including resporation). Further analysis is expected to include greenhouse gas observing satellite data, such as GOSAT, to detect carbon atmospheric CO2 concentration signals.

Keywords: Siberia, extreme climate event, Terrestrial environment, Remote Sensing

CH_4 surface flux estimation based on local ensemble transform Kalman filter

*Jagat Bisht[1], Prabir Patra[1,2], Masayuki Takigawa[1], Takashi Sekiya[1], Yugo Kanaya[1], Naoko Saito[2]

1. Japan Agency for Marine-Earth Science and Technology , 2. Center for Environ. Remote Sensing, Chiba University

Methane (CH_4) is an important greenhouse gas which is substantially increased during last decade in the atmosphere, raising serious sustainability and climate change issues. With the advancement of satellite observations with global coverage, we aim to study the regional or country-wise contributions of CH_4 emissions to the global CH_4 increase. Present study attempts to estimate the CH_4 fluxes using Local Ensemble Transform Kalman Filter (LETKF) data assimilation technique. Since atmospheric CH_4 is primarily affected by surface fluxes, its variability should be large near the surface. We perform the sensitivity experiment on Observation System Simulation Experiment (OSSE) setting by updating observed changes only into the lower tropospheric CH_4. We also update the observed change into the full column my mimicking the GOSAT observations in the OSSE experiment. It has been found that LETKF is able to retrieve the true fluxes to a larger extent, from the perturbed emission intensities of 20 or 30% relative to the true flux over the East and South Asia regions. We have also found that longer assimilation window (at least 20 days long) is advantageous to CH_4 flux estimation.

Toward multi-scale greenhouse gas monitoring system for supporting global stock take

*Akihiko Ito[1,2], Yosuke Niwa[1], Tomohiro Hajima[2], Nobuko Saigusa[1]

1. National Institute for Environmental Studies, 2. Japan Agency for Marine-Earth Science and Technology

Achievement of the carbon-neutral society is one of the overarching tasks for the sustainability of humanity. Under the Paris Agreement of the United Nations Framework Convention of Climate Change, it becomes an important task for research community to establish a comprehensive, high-precision, and transparent system of greenhouse gas (GHG) budget estimation. In April 2021, a new task-force project will be launched in Japan to develop a GHG monitoring system, provisionally called the Comprehensive Observation and Modeling for Multi-scale Estimation of Greenhouse Gas budgetS (COMM-EGGS), funded by the Ministry of the Environment, Japan. This is a joint project of National Institute for Environmental Studies, Japan Agency for Marine-Earth Science and Technology, Chiba University, and Meteorological Research Institute. The project is composed of three research components: 1) observation and top-down estimation of GHG budget, 2) evaluation of GHG mitigation with an Earth system model, and 3) bottom-up estimation of GHG budget. These activities cover different spatial scales spanning from major city to national and global emissions, by using ground observatory, aircraft, and satellite observations and fine-mesh atmospheric and surface emission models. In the project, we put emphasis on the Asia-Pacific region, in which a comprehensive GHG monitoring system is deficient to date. Through mutual comparison and validation, we will make attempt to improve confidence of the estimation system for GHG budget verification. Finally, the system aims at contributing to the Global Stocktake of the Paris Agreement by providing scientific evidence for GHG emission reduction.

Keywords: Global Warming, Paris Agreement, Greenhouse Gas Budget

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

Sat. Jun 5, 2021 10:45 AM - 12:15 PM JST | Sat. Jun 5, 2021 1:45 AM - 3:15 AM UTC | Ch.08 Zoom Room 08

[A-CG34] Global Carbon Cycle Observation and Analysis

convener:Kazuhito Ichii(Chiba University), Prabir Patra(Research Institute for Global Change, JAMSTEC), Akihiko Ito(National Institute for Environmental Studies), Chairperson:Kazuhito Ichii(Chiba University), Akihiko Ito(National Institute for Environmental Studies)

The Paris Agreement under the United Nations Framework Convention on Climate Change (UNFCCC) is a landmark agreement, which aims at reduction of greenhouse gases (GHGs) emission to keep the global warming below 2 deg C. The national commitments and progresses should be carefully monitored and verified by international bodies using different but complementary methodologies.

Many observation and technique to monitor GHGs budget have been improved in recent years. The improvements include observational platforms for monitoring atmospheric GHGs, national or regional emission inventories, top-down estimations (e.g. atmospheric inverse analysis), and bottom-up estimations (e.g. process-based models). However, due to uncertainties in sparse observation network and integration methods, large uncertainty remains in GHGs sources/sinks estimations at global and regional scales.

The purpose of the session is to discuss state-of-the-art techniques for estimations of GHGs (e.g. CO2, CH4, N2O) budget at global and regional scales. The topic includes natural and anthropogenic processes, various methodologies (e.g. in-situ observation, aircraft monitoring, remote sensing, modeling), and various targets (e.g. atmosphere, terrestrial, and ocean), various spatial and temporal coverage (e.g. regional to global scales and past-present-future). Improved estimates of emissions from land use change, forest fires, and other anthropogenic sources (urban developments and thermal power station etc.) are also of interest. We also welcome discussions for designs and plans for future studies targeting city and country scale emission estimations using sophisticated modeling tools and inventories.

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

[ACG34-07] Co-evolution of carbon cycle and air quality fluxes constrained by CMS-Flux and MOMO-Chem assimilation systems

★Invited Papers

*Kevin W Bowman[1], Kazuyuki Miyazaki[1], Junjie Liu[1], Anthony Bloom[1] (1.Jet Propulsion Laboratory)

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

[ACG34-08] **Lower anthropogenic fossil CH_4 emissions inferred from multi-isotopic constraints on the global CH_4 budget**

★Invited Papers

*Ryo Fujita[1,2], Heather Graven[2] (1.Meteorological Research Institute, 2.Imperial College London)

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

[ACG34-09] The burned area extracting in Chernobyl Exclusion Zone using random forest

*JUN HU[1], Shunji Kotsuki[1], Yasunori IGARASHI[2], Mykola TALERKO[3], Kazuhito Ichii[1] (1.Center for Environmental Remote Sensing, Chiba University, Chiba, Japan, 2.Institute of Environmental Radioactivity, Fukushima University, Fukushima, Japan, 3.Institute for Safety Problems of Nuclear Power Plants, National Academy of Sciences of Ukraine, Kyiv, Ukraine)

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

[ACG34-10] Monitoring and evaluation of carbon absorption in pasture areas near Ulaanbaatar and far from cities

*Qinxue Wang[1], Tomohiro OKADERA[1], Masataka WATANABE[2], Ochirbat Batkhishig[3] (1.National Institute for Environmental Studies, 2.Research and Development Initiative, 3.Institute of Geography and

Geoecology, Mongolian Academy of Sciences)

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

[ACG34-11] An observation-based reconstruction reveals progressive ocean acidification around Japan

*Yosuke Iida[1], Takashi Nakamura[1], Yoshikazu Fukuda[1], Masao Ishii[2] (1.Japan Meterological Agency, 2.Meteorological Research Institute)

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

[ACG34-12] Trend in Southern Ocean CO_2 sink – a review and outlook

*Prabir Patra[1], Naveen Chandra[2], Pedro S Monteiro[3], Masao Ishii[4] (1.Research Institute for Global Change, JAMSTEC, 2.National Institute for Environmental Studies, 3.CSIR-CHPC, South Africa, 4.Meteorological Research Institute)

Co-evolution of carbon cycle and air quality fluxes constrained by CMS-Flux and MOMO-Chem assimilation systems

*Kevin W Bowman[1], Kazuyuki Miyazaki[1], Junjie Liu[1], Anthony Bloom[1]

1. Jet Propulsion Laboratory

Rapid regional changes in anthropogenic emissions in response to the COVID-19 pandemic have underscored the contribution of fossil fuel (FF) emission uncertainty to regional carbon budgets. Typical methods for spatially-explicit FF emissions are dependent on national reporting, which can incur substantial latencies. However, the concomitant changes in short-lived pollutants from common emission sources point to opportunities to develop independent low-latency estimates of fossil fuel emissions and to better understand anthropogenic processes. Here we combine state-of-the-art Multiple Model Multi Constituent chemical data assimilation system (MOMO-Chem) with bottom-up FF emissions to repartition the net carbon fluxes from the NASA Carbon Monitoring System Flux (CMS-Flux) project. To that end, we implement a novel Kalman filtering algorithm that predicts emission ratio co-evolution of air quality (AQ) and carbon species. Based upon top-down estimates of AQ emissions, FF CO2 emissions and uncertainties can be rapidly determined. We show overall good agreement between predicted FF fluxes and the latest bottom-up inventories. These data are in turn used to interpret the decadal evolution of CMS-Flux net carbon exchange. This approach is an important step in quantifying both regional fossil fuel and natural carbon fluxes contributions to the atmospheric CO2 growth rate.

Lower anthropogenic fossil CH_4 emissions inferred from multi-isotopic constraints on the global CH_4 budget

*Ryo Fujita[1,2], Heather Graven[2]

1. Meteorological Research Institute, 2. Imperial College London

Stable isotope measurements of atmospheric CH_4 ($\delta^{13}C$-CH_4, δD-CH_4) have been utilized to resolve major three CH_4 sources (i.e., biogenic, fossil fuel, and biomass burning sources) in the global CH_4 budget. However, given the uncertainty of both the source isotope signatures and kinetic isotope effects, recent estimates of the global CH_4 budget using stable isotope observations are still inconclusive. Radiocarbon measurements ($\Delta^{14}C$-CH_4) could provide stronger additional constraint on the fossil-fuel CH_4 sources (i.e., ^{14}C-free), but the uncertainty of $^{14}CH_4$ emissions from nuclear power facilities and a lack of data have limited such utilization. Here we present a new approach to estimate plausible global CH_4 emissions and sinks scenarios over 1750–2015 using historical observations and Monte Carlo simulations of atmospheric CH_4, $\delta^{13}C$-CH_4, δD-CH_4, and $\Delta^{14}C$-CH_4. We utilize a particle filter (or Sequential Monte Carlo filter) approach to optimize the key 19 parameters of global CH_4 sources and sinks. The ensemble members of CH_4 source and sink scenarios, generated by the ensembles of 19 parameter combinations considering their uncertainties, were used to simulate atmospheric CH_4, $\delta^{13}C$-CH_4, δD-CH_4, and $\Delta^{14}C$-CH_4, and then retained when matching the historical observations. Our multi-isotopic model-data analysis suggests that current bottom-up estimates in natural and anthropogenic fossil and natural biogenic CH_4 emissions are too high, whereas those in anthropogenic biogenic and biomass burning emissions are too low. The estimated global total fossil emission is also lower than the recent $\Delta^{14}C$-CH_4-derived top-down estimates, but an independent estimate of global nuclear $^{14}CH_4$ emissions would rather support our result. To obtain more robust estimates from multi-isotopic model-data analysis, many more global background observations of atmospheric $\delta^{13}C$-CH_4, δD-CH_4, and $\Delta^{14}C$-CH_4, with their inter-laboratory measurement differences reduced, are indispensable to characterize their global representatives.

Keywords: methane, isotope, GHGs, carbon cycle, atmospheric chemistry

The burned area extracting in Chernobyl Exclusion Zone using random forest

*JUN HU[1], Shunji Kotsuki[1], Yasunori IGARASHI[2], Mykola TALERKO[3], Kazuhito Ichii[1]

1. Center for Environmental Remote Sensing, Chiba University, Chiba, Japan, 2. Institute of Environmental Radioactivity, Fukushima University, Fukushima, Japan, 3. Institute for Safety Problems of Nuclear Power Plants, National Academy of Sciences of Ukraine, Kyiv, Ukraine

The Chernobyl Nuclear Power Plant (CNPP) accident that happened in 1986 is the largest source of anthropogenic radionuclides released into the environment in history. In recent 20 years, the climate and land-use changes have increased the frequency of large forest fires in and around the Chernobyl Exclusion Zone. It is critical to extract the burned areas accurately, because they are the basis to estimate the biomass burning emission and then analyze the second diffusion of radioactive residue released from the CNPP accident. In this study, we established a burned area extracting method based on the random forest (RF) algorithm using the Moderate Resolution Imaging Spectroradiometer (MODIS) MOD09GA / MYD09GA and LANDSAT -7 ETM+ /-8 OLI images. The field observation in 2015 and MODIS MOD14A1 (thermal anomaly data) product were adopted to generate sampling points for RF. The reflectance difference spectroscopy of near-infrared band and difference in vegetation indices (NDVI, NBR, NDWI) between pre- and post-fire imagery were used as input data for the RF classifier. Subsequently, the historical burned area in 2015 and 2020 were detected using the trained RF classifier. The preliminary results of the identified burned area show good consistency with the MODIS MCD64A1.006 product of NASA and FireCCI51product of ESA. It should be noted that our RF algorithm can even detect the relatively small fire scars compared to the two existing products due to the usage of high-resolution LANDSAT image.

Keywords: Wildfire, Chernobyl Exclusion Zone, Random forest, Satellite observation, Landsat, MODIS

Monitoring and evaluation of carbon absorption in pasture areas near Ulaanbaatar and far from cities

*Qinxue Wang[1], Tomohiro OKADERA[1], Masataka WATANABE[2], Ochirbat Batkhishig[3]

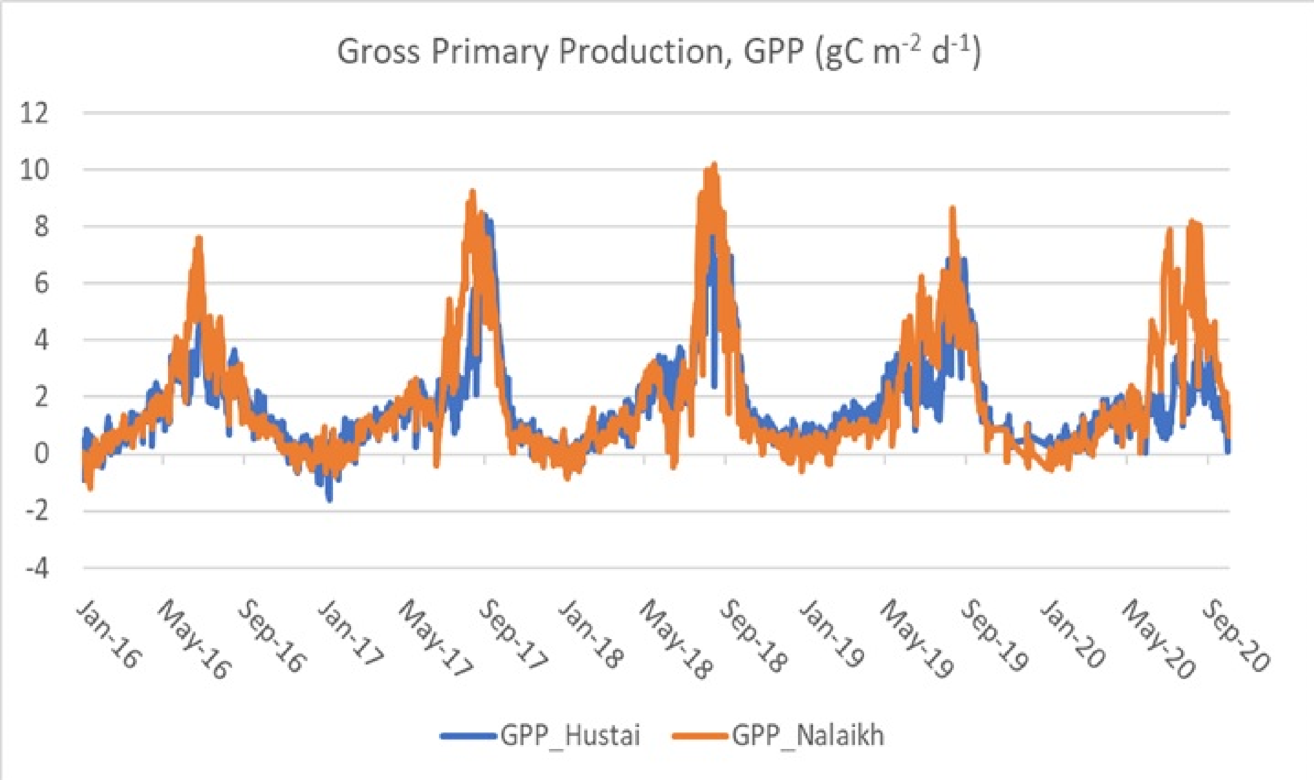
1. National Institute for Environmental Studies, 2. Research and Development Initiative, 3. Institute of Geography and Geoecology, Mongolian Academy of Sciences

To obtain the ground observation data to verify the data products derived from the greenhouse gas observation technology satellite (GOSAT) series, this study targets the carbon emission and absorption in Mongolia. For this purpose, we have established two flux towers to monitor the greenhouse gas CO2 in the pastures near Ulaanbaatar (Nalaikh site) and a vast grassland area far from cities (Hustai site), where the net ecosystem exchange (NEE) has been monitored by the eddy correlation method since 2015. To guarantee the accuracy of the measurement data, the accuracy of the CO2 analyzer was calibrated regularly by using standard gas.

According to the meteorological data observed during 2016-2019, the daily average wind speeds at both sites are in the range of 1 to 10 m/s, but the annual averages are 2.4 m/s and 2.8 m/s at Hustai and Naliakh site, respectively. The temperature fluctuation range is -30 dgr. C to 30 dgr. C, and the annual fluctuation range is 60 dgr. C or more, but the annual average values are only 2.0 dgr. C and -1.6 dgr. C, respectively. Annual precipitation is 193.6 mm at the Hustai site and 165.7 mm at the Nalaikh site. Looking at the heat balance measured at both sites, we found that the net radiant flux (Rn) is in the range of -50 to 200 W m-2, and the annual average is 59.6 W m-2 at the Hustai site and 60.6 W m-2 at the Nalaikh site, which is almost the same. The soil heat flux is in the range of -30 to 30 W m-2, and the annual average values are 0.8 W m-2 and 1.9 W m-2, respectively. The annual averages of sensible heat are 28.1 W m-2 and 28.2 W m-2, respectively, which are almost the same, but the latent heat is 20.3 W m-2 and 25.6 W m-2, respectively.

Finally, the net ecosystem exchanges (NEE) measured at both sites were analyzed using EddyPro 7 and ToviTM which were jointly developed by LI-COR in the United States and the related research communities. These tools are developed for analyzing carbon absorption, so-called gross primary production (GPP), respiration by ecosystems (RECO) as well as net absorption (NEP=GPP-RECO). The results of daily variation of GPP, RECO, and NEP are shown in Fig. 1. Further analysis shows that, first, only looking into the growing seasons of grassland, GPP at Hustai and Nalaikh site is 527.2 gC m-2 y-1 and 599.2 gC m-2 y-1, respectively, and RECO are 457.2 gC m-2 y-1 and 446.2 gC m-2 y-1, respectively. As a result, the NEP are 87.4 gC m-2 y-1 and 152.5 gC m-2 y-1, respectively, which means both sites are carbon sinks, and about 1.7 times larger at the Nalaikh site than the Hustai site. On the other hand, when we count together both the growing seasons and the non-growing seasons, the annual GPP at two sites are 686.0 gC m-2 y-1 and 654.9 gC m-2 y-1, respectively, and RECO are 700.1 gC m-2 y-1 and 611.8 gC m-2 y-1, respectively. As a result, the annual NEP are -45.2 gC m-2 y-1 and 74.3 gC m-2 y-1, respectively, which means the grassland at the Nalaikh site is a carbon sink, but it is a carbon source at the Hustai site throughout the year. Here, the large uncertainty in the non-growing seasons may be influenced not only by the error of equipment due to freezing but also by the influence of carbon emissions from cities and residents nearby.

Keywords: carbon absorption, pasture area, Mongolia


Gross Primary Production, GPP (gC m-2 d-1)
12
10
8
6
4
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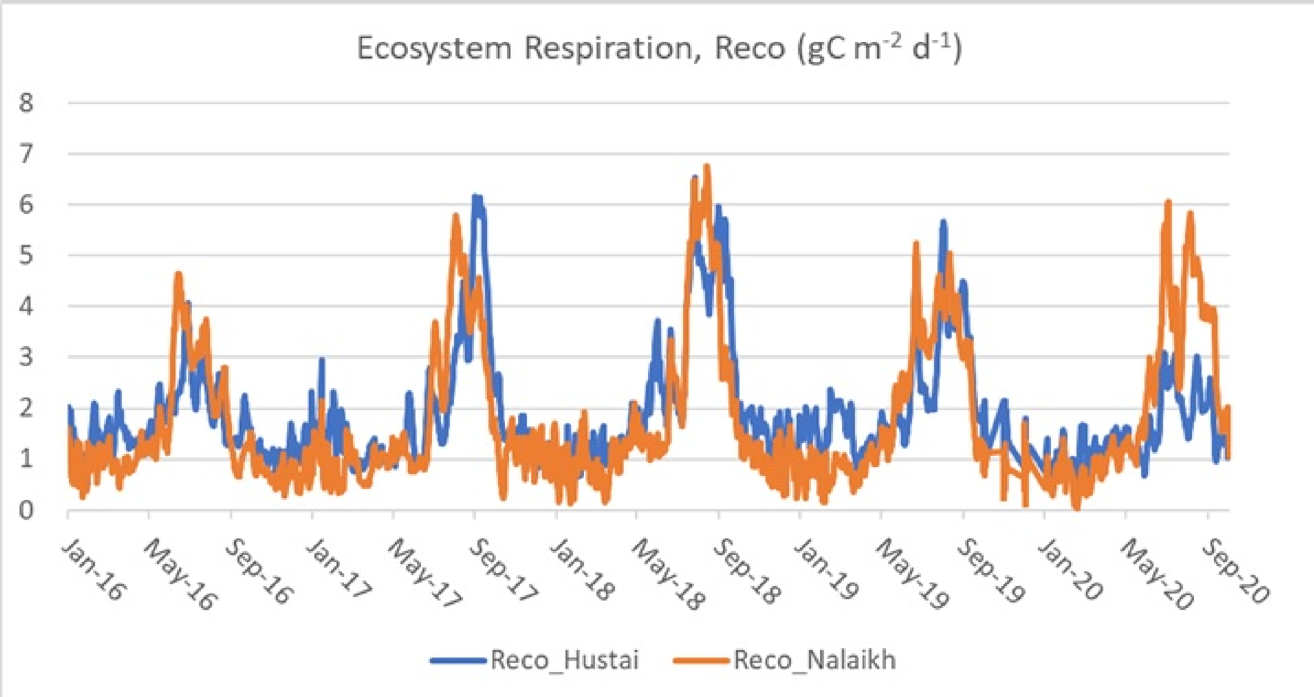
0
-2
-4
Jan-16 May-16 Sep-16 Jan-17 May-17 Sep-17 Jan-18 May-18 Sep-18 Jan-19 May-19 Sep-19 Jan-20 May-20 Sep-20
GPP_Hustai
GPP_Nalaikh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7
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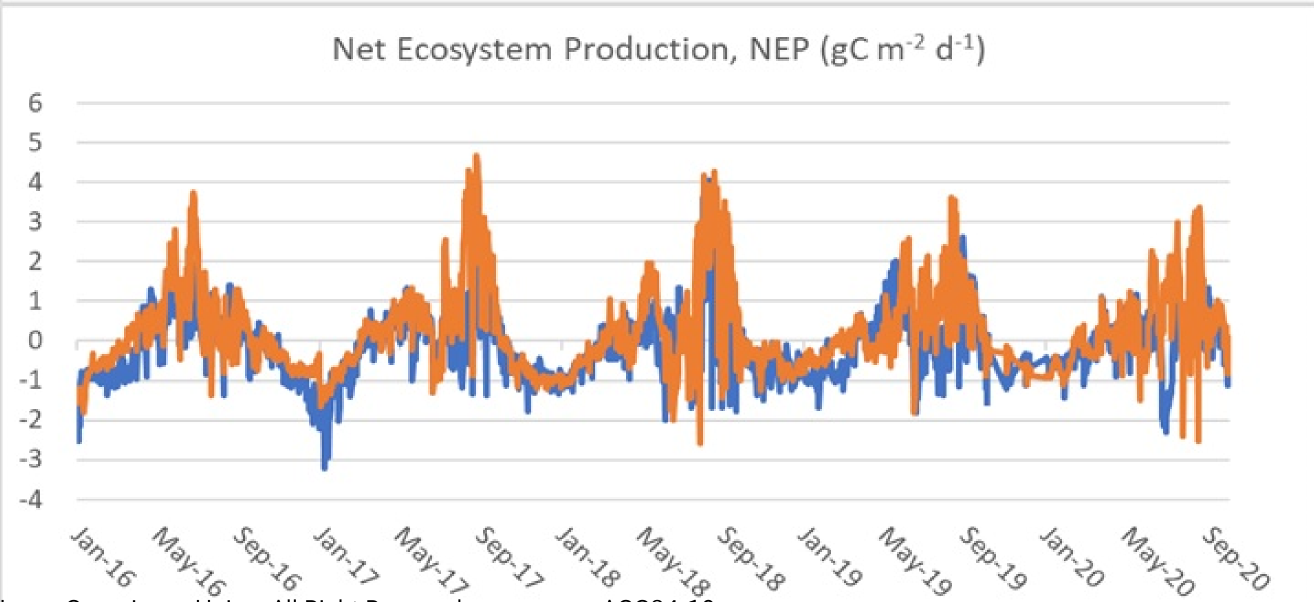
Jan-16 May-16 Sep-16 Jan-17 May-17 Sep-17 Jan-18 May-18 Sep-18 Jan-19 May-19 Sep-19 Jan-20 May-20 Sep-20
Reco_Hustai
Reco_Nalaikh


Net Ecosystem Production, NEP (gC m-2 d-1)
6
5
4
3
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1
0
-1
-2
-3
-4
Jan-16 May-16 Sep-16 Jan-17 May-17 Sep-17 Jan-18 May-18 Sep-18 Jan-19 May-19 Sep-19 Jan-20 May-20 Sep-20

An observation-based reconstruction reveals progressive ocean acidification around Japan

*Yosuke Iida[1], Takashi Nakamura[1], Yoshikazu Fukuda[1], Masao Ishii[2]

1. Japan Meterological Agency, 2. Meteorological Research Institute

Ocean acidification caused by anthropogenic carbon has reduced ecosystem service of our ocean through its adverse impacts on the chemistry and biology in the seawater. Recent studies have well revealed the increase of carbon in the surface seawaters in global open ocean to coastal zones (Bates et al. 2014, Landschützer et al. 2020), and also have clarified progress of coastal ocean acidification in Japan (Ishizu et al. 2019). The results of these studies imply that the ocean ecosystem service is ubiquitously under threat, of course in the seas around Japan. To frame comprehensive ocean policy that would address the threat, it is necessary for us to recognize how vulnerable our sea is. We investigated the rates of pH decrease in the seas around Japan based on surface ocean carbon measurements, which can provide information on a science basis of ocean vulnerability for progressive acidification. We reconstructed monthly pH fields around Japan by 0.25 degrees latitude and longitude by using a moving-window multiple linear regression method. The sea around Japan as a whole has decreased its pH value by −0.021/decade during the period 1998-2020 (Figure), similar to that for the global ocean (−0.016/decade CMEMS 2020; −0.018/decade MEXT and JMA 2020). Japan’s global indicator of SDG 14.3, based on winter pH values observed along the 137°E meridian, is 8.096 in 2010 and 8.070 in 2020 (Japan SDGs Action Platform 2021). The pH value averaged over the sea around Japan of 8.103 in 2010 and 8.083 in 2020 estimated in this study, in which the regional and seasonal variability were considered, could provide information to support the indicator. The estimated rates of pH decreases have regional differences, −0.027/decade in the Sea of Japan whereas −0.019/decade in the seas around Kyushu and Okinawa, and what controls the variations is to be investigated. We can obtain the fields of seawater $p\mathrm{CO_2}$ as well from the same method as used in reconstructing pH fields, which potentially be used for evaluating sea-air CO_2 flux and carbon sink in the seas around Japan in combination with a proper atmospheric CO_2 product.

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Landschützer et al. 2020: Earth Syst. Sci. Data, 12, 2537–2553
MEXT and JMA 2020: https://www.data.jma.go.jp/cpdinfo/ccj/index.html

Keywords: carbon cycle, ocean acidification, the seas around Japan, SDGs

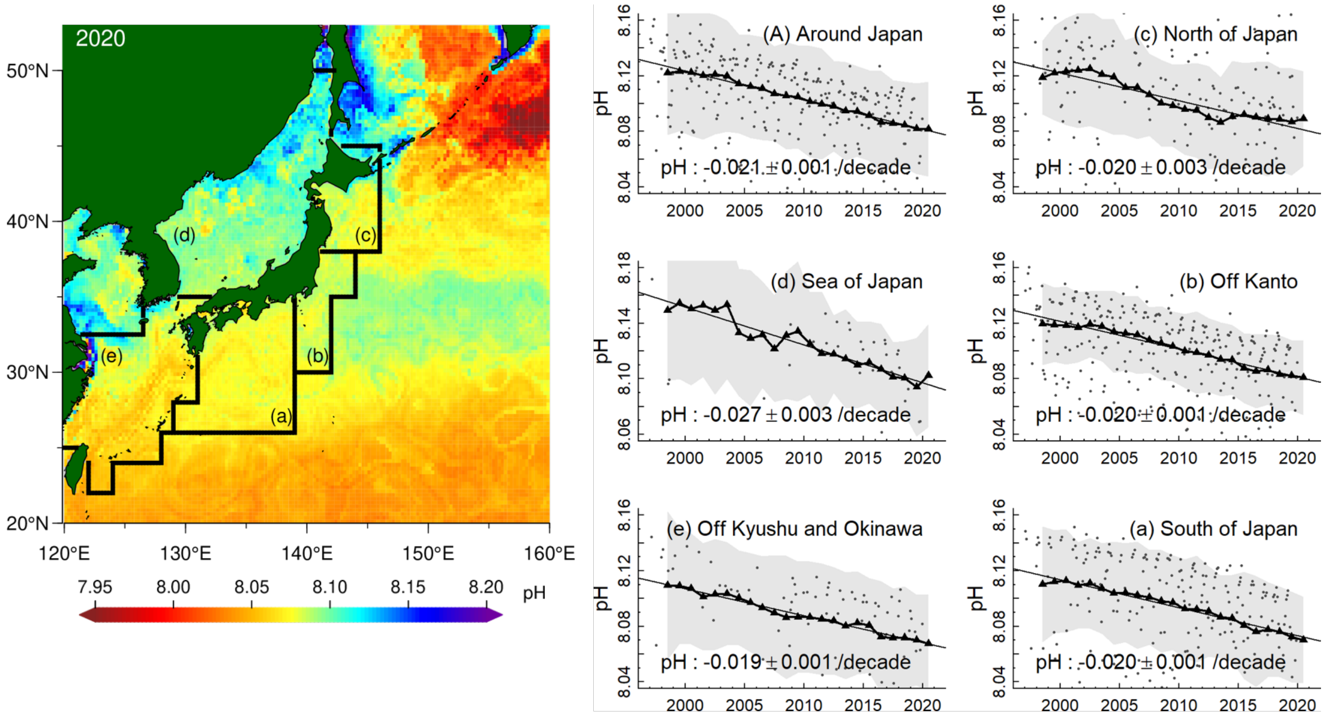


Figure The map left shows pH distribution around Japan averaged in 2020 and the time-series right shows the annual pH anomaly averaged over the area bordered by black lines in the left map (a-e). The triangles of the right indicate annual mean pH values and the color-shaded means spatial variance (1σ). The thin line indicates the long-term trend of the values and small plots show observed pH values.

Trend in Southern Ocean CO_2 sink –a review and outlook

*Prabir Patra[1], Naveen Chandra[2], Pedro S Monteiro[3], Masao Ishii[4]

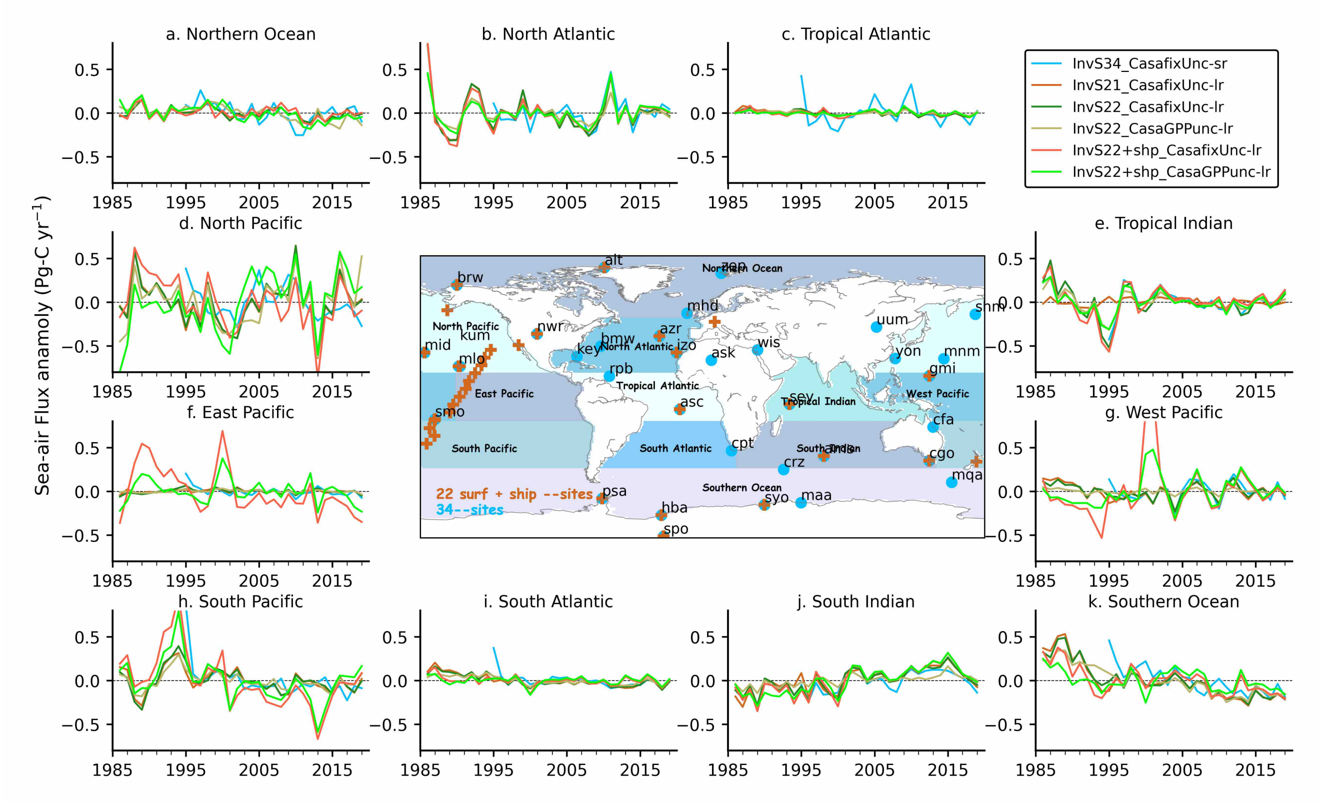
1. Research Institute for Global Change, JAMSTEC, 2. National Institute for Environmental Studies, 3. CSIR-CHPC, South Africa, 4. Meteorological Research Institute

The Southern Ocean (south of 14°S) has played significant role in removing carbon dioxide (CO_2) from the atmosphere in the past decades. There several studies which discussed a slowing down of CO_2 uptake rate or even an opposite trend in CO_2 uptake since the late 1980s through the early 2000s, in contrast to that is expected from the pCO_2 increase in the atmosphere and the ocean biogeochemical models. The JAMSTEC’s inverse model, based on MIROC4-ACTM forward simulations, climatological sea-air CO_2 flux and atmospheric CO_2 observations, shows more or less systematic increase in sink uptake since the late 1980s to the present. We suspect there are issues with data coverage with time that is posing challenges in the pCO_2 observation based upscaling products; and for the global ocean biogeochemical models difficulty in the simulation of seasonal cycle of sea-air pCO_2 difference may inadvertently lead to a wrong climate sensitivity.

In this presentation, we will review some of these issues and possibly come up with a revised assessment of the trends in Southern Ocean CO_2 flux.

The figure below shows the CO_2 flux anomalies calculated by 6 cases of MIROC4-ACTM inversions, by varying the prior flux model (flxUnc vs GPPunc) or network of CO_2 observations (S34, S22, S22+ship). Although the magnitude of flux anomalies vary between the inversions, the long-term trends and phase of the variability are consistently derived for the overlapping inversion periods.

Keywords: Southern Ocean CO2 flux, Inverse modelling, Global ocean CO2 flux models


a. Northern Ocean
b. North Atlantic
c. Tropical Atlantic
d. North Pacific
e. Tropical Indian
f. East Pacific
g. West Pacific
h. South Pacific
i. South Atlantic
j. South Indian
k. Southern Ocean
Sea-air Flux anamoly (Pg-C yr^{-1})
InvS34_CasafixUnc-sr
InvS21_CasafixUnc-lr
InvS22_CasafixUnc-lr
InvS22_CasaGPPunc-lr
InvS22+shp_CasafixUnc-lr
InvS22+shp_CasaGPPunc-lr
22 surf + ship --sites
34--sites

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

Sat. Jun 5, 2021 3:30 PM - 5:00 PM JST | Sat. Jun 5, 2021 6:30 AM - 8:00 AM UTC | Ch.15 Zoom Room 15

[H-TT15] Non-destructive techniques applied to stone cultural heritage

convener:Celine Thomachot-Schneider(University of Reims-Champagne-Ardenne), Chiaki T. Oguchi(Institute for Environmental Science and Technology, Graduate School of Science and Engineering, Saitama University), Patricia vazquez(University of Reims Champagne Ardenne), Chairperson:Celine Thomachot-Schneider(University of Reims-Champagne-Ardenne), Patricia vazquez(University of Reims Champagne Ardenne)

Non destructive and non invasive techniques applying to cultural heritage made of stones, soils and earthen materials have been significantly developed over past years, and thus, the interest in such techniques has greatly increased. Here, we focus the session on new devices, new protocols and new data treatments that allow better understanding of weathering mechanisms, decay states and response to treatments. A few topics would be listed as follows: 1) The development of new techniques and devices in cultural heritage and new protocols using non-destructive techniques; 2) The application of these techniques and protocols on indoor and outdoor case studies and laboratory studies; 3) The assessment of weathering mechanisms, weathering kinetics, decay state, and response to treatments and 4) The modeling and simulation of decay processes.

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

[HTT15-01] Comparison of classic aging and realistic tests: study of the compatibility between limestones and restoration mortar

*Emilie Huby[1], Celine Thomachot-Schneider[1], Patricia vazquez[1], Gilles Fronteau[1] (1.Groupe d'etude des environnements naturels, anthropiques et archeologiques - Universite de Reims-Champagne-Ardenne (France))

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

[HTT15-02] Measurement of anisotropy of liquid water diffusivity of brittle tuff stone of Takase stone buddhas using X-ray

*Masaru Abuku[1], Shuya Hiranuma[2], Takayuki Fumoto[1], Soichiro Wakiya[3], Daisuke Ogura[4] (1.Kindai University, 2.SEKISUI HOUSE. LTD., 3.Nara National Research Institute for Cultural Properties, National Institutes for Cultural Heritage, 4.Kyoto University)

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

[HTT15-03] **Granite Characterisation of Three Asynchronous Quarries of the Archaeological Site of *Touças* (North of Portugal)**

*David Martin Freire-Lista[1,2], Patricia Vazquez[3], Gerardo Vidal Gonçalves[4] (1.Universidade de Tras-os-Montes e Alto Douro. Quinta de Prados. 5001-801 Vila Real, Portugal., 2.Centro de Geociências da Universidade de Coimbra. Rua Silvino Lima. Universidade de Coimbra - Polo II. 3030-790 Coimbra, Portugal., 3.Université Reims-Champagne-Ardenne 2, esplanade Roland Garros 51100 Reims, France. , 4.Centro de Investigação e Desenvolvimento em Ciências Humanas e Sociais. Universidade de Évora, Portugal.)

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

[HTT15-04] **Spatiotemporal evaluation of weathering-induced depressions in sandstone blocks by terrestrial laser scanning**

*Yuichi S. Hayakawa[1], Hisashi Aoki[2] (1.Faculty of Environmental Earth Science, Hokkaido University, 2.Faculty of Education, Tokyo Gakugei University)

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

[HTT15-05] From photogrammetric modelling of the built heritage to the evaluation of the durability of stones via GIS

*Sebastien LARATTE[1,2], Celine Thomachot-Schneider[1,2], Gilles FRONTEAU[1,2], Alexandra GUILLANEUF[1,2]
(1.University of Reims-Champagne-Ardenne, 2.GEGENAA)

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

[HTT15-06] Discussion

Comparison of classic aging and realistic tests: study of the compatibility between limestones and restoration mortar

*Emilie Huby[1], Celine Thomachot-Schneider[1], Patricia vazquez[1], Gilles Fronteau[1]

1. Groupe d'etude des environnements naturels, anthropiques et archeologiques - Universite de Reims-Champagne-Ardenne (France)

Laboratory aging tests allow the study of stones' behaviors on the monument indirectly. **Classic aging tests** are designed to compare materials' resistance to different weathering mechanisms: they are **more intense than the on-site conditions** and do not reflect the real weathering intensity and kinetics. To study the **real weathering on a monument** and the **materials' behavior**, a **non-destructive experimental setup** using **realistic experimental conditions** was designed.

Materials of the Saint-Remi basilica of Rheims (France)were studied. In particular, the **compatibility of the restoration mortar Lithomex**, used in recent years, with the **Courville limestone** (original stone) and the **Savonnières limestone** (restoration stone) were compared.

The realistic experimental setup was designed to **reproduce the thermal and hydric strains experienced by a stone on a vertical façade** in a stone sample (10x5x4.5cm). The hybrid samples were constituted of a 1cm thick mortar layer applied on the limestones.

The temperature and humidity variations were based on **typical variations identified with an *in-situ* monitoring** of the basilica: **sunny days** with temperature cycles (20/35°C), **rainy days** with a 1h imbibition followed by temperature variations (20/35°C), and **frost days** with a 1h imbibition preceding low-temperature cycles (5/-10°C). The mild conditions, similar to the on-site conditions, did not damage the samples.

Temperature and humidty variations were applied unidirectionally through one surface, defined as the exposed surface, placed against a heating/cooling plate or immersed in 5mm water for a 1h imbibition. The sample's behavior was monitored with thermocouples and strain gauges measuring **heat transfer** and **differential micro-dilatation**.

The stress **at the interface between the mortar and the limestones** was calculated from the deformation data. It appeared that higher stress was generated at the Lithomex-Savonnières interface. Unlike the Courville, the Savonnières limestone dilated very little compared to the mortar; the differential deformation generated higher stress. This indicated **a better compatibility between the Lithomex mortar and the Courville limestone.**

Accelerated aging tests were also applied on hybrid samples (Ø= 4.5cm and h=5cm) constituted of the limestones presenting a 1 or 3cm thick layer of mortar**. 29 thermal shock cycles** (10h at 70°C followed by 2h immersion in 20°C water) and **17 freeze/thaw cycles** (10h at -10°C followed by 2h immersion in 10°C water) were carried out and monitored with weight and ultrasound velocity measurements.

The harsh conditions and number of cycles **caused visible damage**. Some hybrids {Lithomex+Courville} were broken during the cycles, while the hybrids {Lithomex+Savonnières} did not present any measurable or visual damage. These results let us suppose, contrary to the realistic experiments, a **better compatibility between the restoration mortar Lithomex and the Savonnières limestone than between the Lithomex and the Courville limestone**.

The realistic setup allowed a **simulation of the temperature and water repartitions in the samples closer to reality**. The materials' properties, such as thermal conductivity and water transport properties, were taken into account. The water rarely attained the limestones underneath the mortar due to the low capillarity of the Lithomex. On the contrary, the accelerated aging tests with total sample's immersion led to both wet limestone and mortar, generating stress that does not normally occur on the monument.

These experiments highlighted the **need for realistic experimental conditions** to assess the durability of restoration mortars and stones on which it is applied. This experimental setup provides more **relevant information in this specific environment** and **more accurate description of the real behavior of materials without damaging the samples**.

Keywords: Aging test, Thermo-hydric strain, Limestone, Restoration mortar

Measurement of anisotropy of liquid water diffusivity of brittle tuff stone of Takase stone buddhas using X-ray

*Masaru Abuku[1], Shuya Hiranuma[2], Takayuki Fumoto[1], Soichiro Wakiya[3], Daisuke Ogura[4]

1. Kindai University, 2. SEKISUI HOUSE. LTD., 3. Nara National Research Institute for Cultural Properties, National Institutes for Cultural Heritage, 4. Kyoto University

Takase Stone Buddhas is one of the important old stone buddha sculptures curved into the inner wall of the caves in Oita, Japan. It is located in a cave curved into the cliff of a hill of volcanic tuff. In general, because the cave is currently protected from rain and direct solar radiation by the roof shelter and waterproof treatment, the Buddhas is well conserved and no currently ongoing weathering can be clearly observed. However, because of a high ground water level, there is a concern in the influence of water evaporation at and near the surface of the stone buddhas and the wall of the cave on their deterioration. In the past, we have been conducting our long-term field survey of the conservation environment and numerical analyses of heat and moisture transport in the cliff and stone buddhas. The field survey provided a yearly data set of the conservation environment that was used as input of the succesive numerical simulation of heat and water transport in the material, which strongly depends on the material properties of the tuff stone.

In this study, we have conducted a holistic study of the material properties of the tuff stone of Takase stone buddhas, with special attention to the anisotropy of liquid water diffusivity. Because the tuff stone of the Takase stone buddhas is rather brittle, X-ray was applied to enable non-destructive measurement of the anisotropy of the diffusivity so that the specimen neither deforms nor collapse. X-ray CT was used to understand the three dimensional characteristics of a specimen. The liquid water diffusivity of the specimen was measured for different directions using X-ray radiography. The results showed a strong anisotropy of the liquid water diffusivity. The measured data were taken into account the succesive numerical study to quantify the importance of the anisotropy of the liquid water diffusivity for the conservation of the stone buddhas.

Keywords: Stone Buddha, Boltzmann transformation, Material property

Granite Characterisation of Three Asynchronous Quarries of the Archaeological Site of *Touças* (North of Portugal)

*David Martin Freire-Lista[1,2], Patricia Vazquez[3], Gerardo Vidal Gonçalves[4]

1. Universidade de Tras-os-Montes e Alto Douro. Quinta de Prados. 5001-801 Vila Real, Portugal., 2. Centro de Geociências da Universidade de Coimbra. Rua Silvino Lima. Universidade de Coimbra - Polo II. 3030-790 Coimbra, Portugal., 3. Université Reims-Champagne-Ardenne 2, esplanade Roland Garros 51100 Reims, France. , 4. Centro de Investigação e Desenvolvimento em Ciências Humanas e Sociais. Universidade de Évora, Portugal.

Quarries deepen as extraction techniques evolve over time. Quarries were superficial in the Iron Age, and the granite extracted from them had more developed exfoliation microcracks than the one extracted from medieval quarries, when new techniques allowed to extract a sounder granite. Today's quarries can go tens of meters deep and produce sound granite, whose exfoliation microcracks are less developed.

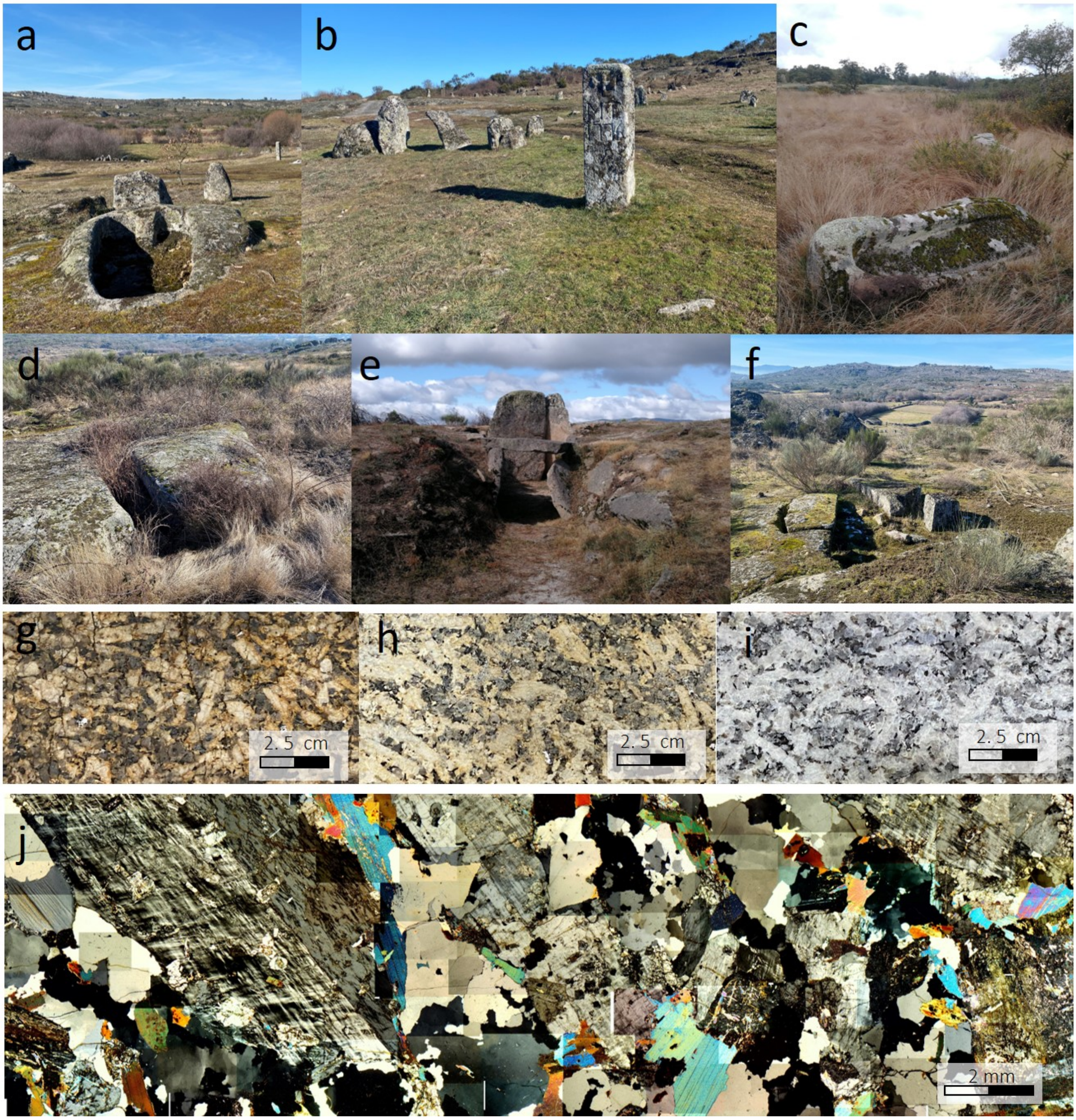
Prehistoric, medieval and current quarries of the same granite exist near the archaeological site of *Touças* . It is located 500 meters to the northeast of *Garganta* village, in *São Martinho de Anta*, municipality of *Sabrosa* (North of Portugal). It consists of about 70 prehistoric standing stones of granite, several medieval granite sarcophagi, a twin carved grave in the outcropping granite and a granite landmark of Malta military order dated from 1776. In addition, *Madorras* dolmen has been excavated at approximately 700 meters from the archaeological site of *Touças*. These elements have been built with the same granite but with different degrees of alteration.

Granite from each quarry has been sampled for an in-depth analytical study. Eight cubic samples of each granite with dimensions of 5×5×5±0.5 cm were characterised. Effective porosity, water absorption and bulk density were obtained using the Natural Stone Test Method described in European standard UNE-EN 1936. Ultrasonic pulse velocity (wave propagation in??) of the granite cubes was measured with a CNS Electronics PUNDIT equipment following European standard UNE-EN 14579. The colour was assessed with an X-Rite colorimeter (model 964), using the three chromatic coordinates of CIE-L*a*b*system. Thin sections were prepared and analysed under a Leica DM-4500-P polarisation microscope equipped with a Leica DFC290-HD digital camera and LAS-4.9 software. Mercury intrusion porosimetry was conducted on single prismatic specimens (12±2 mm in diameter and 20±2 mm high) in a Micromeritics Autopore IV 9520 porosimeter. The capillary coefficient of each alteration grade of the granite was calculated based on the NF-EN 15801 standard. Infrared thermography monitoring was used to evaluate the alteration degree by means of the cooling rate index.

This archaeological site presents extremely relevant evidence for the understanding of the use of quarries throughout human occupation of *Trás-os-Montes e Alto Douro* territory. The main building granite of the archaeological site is a coarse-crystal-size granite with elongated pseudo-oriented feldspars. Granites mined in prehistoric times are much more susceptible to decay than those mined from deeper quarries. The alteration degree of the granite is directly related to the colour, number of microcracks, ultrasonic pulse velocity, hydric properties and thermal effect. Consequently, the conservation of granite must be adapted to its state of alteration.

Acknowledgements: Fundação para a Ciência e a Tecnologia (FCT) of Portugal. Stimulus of Scientific Employment, Individual Support 2017. CEECIND/03568/2017.

Keywords: Infrared thermography monitoring , Mercury intrusion porosimetry , Ultrasonic pulse velocity , Micrograph mosaic



Spatiotemporal evaluation of weathering-induced depressions in sandstone blocks by terrestrial laser scanning

*Yuichi S. Hayakawa[1], Hisashi Aoki[2]

1. Faculty of Environmental Earth Science, Hokkaido University, 2. Faculty of Education, Tokyo Gakugei University

For the quantitative evaluation of damages in stone-based cultural heritage by weathering, repeated measurements by terrestrial laser scanning (TLS) are an efficient way to monitor the surficial changes of the stone material. In particular, TLS enables quantifying the spatiotemporal changes in the morphology of rock surface by weathering at a high resolution. We apply TLS measurements to damaged masonry piers of a bridge (Yayoi Bridge at Aoshima, Miyazaki Prefecture, southwestern Japan; constructed in 1951) comprising vulnerable sandstone blocks in a coastal area, for which salt weathering is primarily responsible. The weathering-induced depressions in the sandstone block surface are quantified over six years and the weathering rates are assessed. The spatial distribution of the depression seems to correspond to the effectiveness of weathering conditions in the spray zone. The non-destructive assessment of the weathering conditions by TLS can thus provide basic information for the conservation of cultural heritage.

Keywords: salt weathering, TLS, change detection

From photogrammetric modelling of the built heritage to the evaluation of the durability of stones via GIS

*Sebastien LARATTE[1,2], Celine Thomachot-Schneider[1,2], Gilles FRONTEAU[1,2], Alexandra GUILLANEUF[1,2]

1. University of Reims-Champagne-Ardenne, 2. GEGENAA

The “Porte de Mars”, is one of the most emblematic ancient monuments of the city of Rheims. This three-bay roman arch rises at the northern end of former *Durocortorum,* capital of *Gallia Belgica* province. Its construction dates from the mid 2nd to early 3rd c. AD. It was then integrated into the Late Roman rampart of the city. Encased, from 1162 to 1856, in the medieval city wall and then in the castle of the city's archbishops, it was completely cleared and restored during the 19th century. During this period, it was barely saved from being dismantled after the ruin of the archbishops'castle and its complete dismantling by the town's population. It is considered the largest "arch" of the Roman Empire north of Roma. It is 32.35 m long, 6.45 m wide and 12 m high today. Since its rediscovery and until today, the “Porte de Mars” is located in the centre of Rheims.

Prior to restore the monument, a campaign to study the materials of the arch was achieved. For this purpose, a photogrammetric survey was carried out using a total of 370 high-resolution photos. Part of the photos were taken by fixing the camera on a pole and using a tablet as a means of preview, georeferencing and remote control. Pictures were processed with the Agisoft Metashape software which allows to carry out all the operations of the photogrammetry calculation chain (Close range photogrammetry - Structure From Motion method). This method allows the reconstruction of 3D objects from 2D data. The technique is based on an algorithm that automatically matches points in a set of photos. The model spatial coordinates were calculated by the software from the sets of photographs. Then the distances between 125 key points of the monument were measured using a laser rangefinder to scale the model. The software enabled orthophotographs to be extracted from the 3D mesh according to the chosen orientations.

The 3D data and derived orthophotos were injected into an interoperable geographic information system (QGis 3.4). Considered objects were then digitized in the form of polygons and a multifactor database was associated with them. This data included architectural information (typology, position, renovation phases) as well as petrographic and petrophysical information. Historical documents were also digitised in order to trace the recent evolution of the monument. Qualitative data (nature of the stone, petrography, presumed origin, restoration phase, etc.) were used to support the work of the monument's restoration teams, while quantitative data (chemical composition, mineralogy, porosity, capillarity, etc.) were used to produce durability assessment maps on the old parts of the building. The maps of alterations carried out in situ were also superimposed in order to relate their location to the characteristics of the building and the nature of the stones concerned. This approach could be supplemented by the projection of multiscalar data from other sensors such as thermal imaging data or the monitoring of parameters over time (magnetic, chemical or colorimetric for instance) and become a 4D tool.

Keywords: Building heritage, photogrammetry, GIS

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

[H-TT15] Non-destructive techniques applied to stone cultural heritage

convener:Celine Thomachot-Schneider(University of Reims-Champagne-Ardenne), Chiaki T. Oguchi(Institute for Environmental Science and Technology, Graduate School of Science and Engineering, Saitama University), Patricia vazquez(University of Reims Champagne Ardenne), Chairperson:Celine Thomachot-Schneider(University of Reims-Champagne-Ardenne), Patricia vazquez(University of Reims Champagne Ardenne)

Sat. Jun 5, 2021 3:30 PM - 5:00 PM Ch.15 (Zoom Room 15)

Non destructive and non invasive techniques applying to cultural heritage made of stones, soils and earthen materials have been significantly developed over past years, and thus, the interest in such techniques has greatly increased. Here, we focus the session on new devices, new protocols and new data treatments that allow better understanding of weathering mechanisms, decay states and response to treatments. A few topics would be listed as follows: 1) The development of new techniques and devices in cultural heritage and new protocols using non-destructive techniques; 2) The application of these techniques and protocols on indoor and outdoor case studies and laboratory studies; 3) The assessment of weathering mechanisms, weathering kinetics, decay state, and response to treatments and 4) The modeling and simulation of decay processes.

4:45 PM - 5:00 PM

[HTT15-06]Discussion

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

Sat. Jun 5, 2021 3:30 PM - 5:00 PM JST | Sat. Jun 5, 2021 6:30 AM - 8:00 AM UTC | Ch.23 Zoom Room 23

[S-IT17] Property and role of liquids inside terrestrial planets

convener:Tatsuya Sakamaki(Department of Earth Science, Tohoku University), Yoichi Nakajima(Kumamoto University, Priority Organization for Innovation and Excellence), Chairperson:Tatsuya Sakamaki(Department of Earth Science, Tohoku University), Yoichi Nakajima(Kumamoto University, Priority Organization for Innovation and Excellence)

Liquids of silicates and metals inside terrestrial planets play important role in the physical, chemical, and thermal evolutions of planets. This session aims at understanding the physical and chemical properties of liquids from shallow to deep parts of terrestrial planets, which are strongly related to the long history of those planets from the planetary accretion to the present-day dynamics. In addition, we call for presentations by researchers from various backgrounds of geochemical, experimental, theoretical/computational, and seismic/geodynamical ones, who investigate the physical and chemical properties of liquids and the behaviors and roles inside of terrestrial planets. Relevant topics include, but are not limited to, partial melting and melt extraction, liquid-solid partitioning, high pressure experiments on melts, and seismic detections of mantle melts and outer core anomaly.

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

[SIT17-01] Pressure-induced structural change of basaltic glass up to 18 GPa

*Tomonori Ohashi[1], Tatsuya Sakamaki[1], Ken-ichi Funakoshi[2], Takanori Hattori[3], Naoki Hisano[1], Jun Abe[2], Akio Suzuki[1] (1.Department of Earth Science, Tohoku University, 2.Neutron Science and Technology Center, Comprehensive Research Organization for Science and Society (CROSS), 3.J-PARC Center, Japan Atomic Energy Agency)

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

[SIT17-02] Atomic structure of CO_2-bearing melts along the carbonatite-basalt join at high pressure and temperature

*Veronica Stopponi[1], Annalisa D'Arco[2,3], Rostislav Hrubiak[4], Yoshio Kono[5], Stefano Lupi[2,6], Craig E Manning[7], Manuela Nazzari[8], Brent T Poe[9], Claudia Romano[10], Vincenzo Stagno[1,8] (1.Department of Earth Sciences, Sapienza University of Rome, Rome, Italy, 2.INFN National Institute of Nuclear Physics, Rome, Italy, 3.SBAI Department of Basic and Applied Sciences for Engineering, Physics, Sapienza University of Rome, Rome, Italy, 4.High Pressure Collaborative Access Team (HPCAT), X-ray Science Division, Argonne National Laboratory, Argonne, IL, USA, 5.Geodynamic Research Center, Ehime University, Matsuyama, Japan, 6.Department of Physics, Sapienza University of Rome, Rome, Italy, 7.Department of Earth, Planetary and Space Sciences, University of California, Los Angeles, CA, USA, 8.Istituto Nazionale di Geofisica e Vulcanologia (INGV), Rome, Italy, 9.Department of Engineering and Geology, University of Chieti-Pescara, Chieti Scalo, Italy, 10.Department of Sciences, University of Studies Roma Tre, Rome, Italy)

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

[SIT17-03] *In situ X-ray study of liquid geomaterials under extreme conditions using Free-Electron Lasers*

★Invited Papers

*Guillaume Morard[1] (1.ISTerre, UGA, CNRS)

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

[SIT17-04] Density and thermal expansion of liquid and solid iron at 1 atm determined using high-temperature furnace

★Invited Papers

*Hidenori Terasaki[1], Asaka Kamiya[2], Tadashi Kondo[2] (1.Department of Earth science, Okayama University, 2.Department of Earth and Space science, Osaka University)

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

[SIT17-05] Sound velocity measurements of liquid Fe-N up to 100 GPa

Asaki Iwamoto[1], *Yoichi Nakajima[1,2], Daisuke Kinoshita[1], Yasuhiro Kuwayama[3], Kei Hirose[3,5], Daisuke Ishikawa[2,4], Alfred Q.R. Baron[2,4] (1.Kumamoto Univ., 2.RIKEN MDL, 3.Univ. Tokyo, 4.JASRI, 5.Tokyo Tech. ELSI)

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

[SIT17-06] Density and Sound Velocity of Liquid Fe and FeO at High Pressure

*Yasuhiro Kuwayama[1], Kei Hirose[1,2], Yoichi Nakajima[3,4], Yuki Adachi[3], Alfred Q.R. Baron[4], Guillaume Morard[5], Saori I. Kawaguchi[6], Daisuke Ishikawa[6,4], Naohisa Hirao[6], Yasuo Ohishi[6] (1.The University of Tokyo, 2.Tokyo Institute of Technology, 3.Kumamoto University, 4.RIKEN MDR, 5.Laboratoire ISTERRE, Université Grenoble Alpes, 6.JASRI)

Pressure-induced structural change of basaltic glass up to 18 GPa

*Tomonori Ohashi[1], Tatsuya Sakamaki[1], Ken-ichi Funakoshi[2], Takanori Hattori[3], Naoki Hisano[1], Jun Abe[2], Akio Suzuki[1]

1. Department of Earth Science, Tohoku University, 2. Neutron Science and Technology Center, Comprehensive Research Organization for Science and Society (CROSS), 3. J-PARC Center, Japan Atomic Energy Agency

The structures of cold-compressed basaltic glass were investigated at pressures of up to 18 GPa using in situ X-ray and neutron diffraction to acquire insights into the physicochemical properties of deep magmas. On compression, basaltic glass changes its compression behavior: the mean O-O coordination number (CN_{OO}) starts to rise with maintaining the mean O-O distance (r_{OO}) above about 2–4 GPa, and then CN_{OO} stops increasing and r_{OO} begins to shrink along with the increase in the mean coordination number of Al (CN_{AlO}) above ~9 GPa. The change around 9 GPa is interpreted by the change in the contraction mechanism from bending tetrahedral networks of glass to increasing oxygen packing ratio via the increase in CN_{AlO}. The analysis of the oxygen packing fraction (η_O) under high pressure revealed that η_O exceeds the value for dense random packing, suggesting that the oxygen-packing hypothesis recently proposed cannot account for the pressure-induced structural transformations of silica and silicate glasses. The rise of the CN_{OO} at 2–4 GPa reflects the elastic softening of fourfold-coordinated silicate glass, which may be the origin of anomalies of elastic moduli in basaltic glass at ~2 GPa previously reported by Liu and Lin (2014).
The widths of both the first sharp diffraction peak and the principal peak show contrastive compression behaviors between modified silicate and silica glasses. This result suggests that modified silicate glasses represent different pressure evolutions in the ranges of the intermediate- and the extended-range order structures from those of silica glass, likely due to the presence of modifier cations and the resultant formations of smaller rings and cavity volume.

Reference

Liu, J., and Lin, J.-F. (2014) Abnormal acoustic wave velocities in basaltic and (Fe,Al)-bearing silicate glasses at high pressures. Geophysical Research Letters, 41, 8832–8839.

Keywords: silicate glass, oxygen packing, X-ray diffraction, neutron diffraction

Atomic structure of CO_2-bearing melts along the carbonatite-basalt join at high pressure and temperature

*Veronica Stopponi[1], Annalisa D'Arco[2,3], Rostislav Hrubiak[4], Yoshio Kono[5], Stefano Lupi[2,6], Craig E Manning[7], Manuela Nazzari[8], Brent T Poe[9], Claudia Romano[10], Vincenzo Stagno[1,8]

1. Department of Earth Sciences, Sapienza University of Rome, Rome, Italy, 2. INFN National Institute of Nuclear Physics, Rome, Italy, 3. SBAI Department of Basic and Applied Sciences for Engineering, Physics, Sapienza University of Rome, Rome, Italy, 4. High Pressure Collaborative Access Team (HPCAT), X-ray Science Division, Argonne National Laboratory, Argonne, IL, USA, 5. Geodynamic Research Center, Ehime University, Matsuyama, Japan, 6. Department of Physics, Sapienza University of Rome, Rome, Italy, 7. Department of Earth, Planetary and Space Sciences, University of California, Los Angeles, CA, USA, 8. Istituto Nazionale di Geofisica e Vulcanologia (INGV), Rome, Italy, 9. Department of Engineering and Geology, University of Chieti-Pescara, Chieti Scalo, Italy, 10. Department of Sciences, University of Studies Roma Tre, Rome, Italy

Melting of carbonated peridotite rocks in the Earth’ s interior produces a variety of magmas the composition of which is controlled by pressure, temperature and oxygen fugacity (Gudfinnsson and Presnall 2015; Stagno 2019). Within a depth interval of 25 and 250 km, the continuum from carbonatitic, kimberlitic, melilititic, picritic and basaltic melts is characterized by CO_2 content that decreases gradually with increasing temperature and, therefore, melt fraction. As a consequence, the rheology of these magmas is expected to change dramatically with implications for their migration rate and the geodynamic transport of carbon.

The aim of this study was to investigate the atomic structure and vibrational properties of a variety of synthetic glasses representative of CO_2-bearing melts (i.e. carbonatite-kimberlite-melilitite-nephelinite-picrite-basalt) as a function of the increasing SiO_2 content, pressure and temperature.

The atomic structure of molten glasses was investigated at pressures of about 1-7 GPa and temperatures varying from about 1150 to 2000°C using the Paris-Edinburgh press installed at beamline 16BM-B of the Advanced Photon Source (Argonne, IL, USA) combined with synchrotron radiation to perform in situ multi-angle energy dispersive X-ray diffraction measurements. The vibrational properties were studied on the recovered quenched glasses using both micro-Raman and micro-reflectance-FTIR.

Preliminary results shed light on different compressibility mechanisms upon increasing pressure both in the intermediate-range ordering and in the local structure of melts. The position of the first sharp diffraction peak in the structure factor S(q) shows that kimberlitic, melilititic and nephelinitic melts display a much less closely packed structure with respect to volatile-free depolymerized silicate melts. Bond lengths between tetrahedrally coordinated cations, such as Si^{4+}, Al^{3+}, and oxygen (T-O) increase for all the compositions investigated in the experimental pressure range, with the exception of T-O lengths of the basalt melt where a turnover at about 4.5 GPa is observed as in Sakamaki et al. (2013).

The vibrational spectroscopic investigation shows significant changes in the speciation of C-O molecular bonds that likely reflect a more complex C-dominated atomic environment than what is known so far.

Gudfinnsson and Presnall 2005, J Petrol 46, 8, 1645-1659.

Sakamaki et al. 2013, Nat Geosci 6, 1041-1044.
Stagno 2019, J Geol Soc London 176, 375-387.

Keywords: High pressure, Melt structure, Carbonate-bearing melts, Paris-Edinburgh press, Vibrational spectroscopy, Mantle melting

In situ X-ray study of liquid geomaterials under extreme conditions using Free-Electron Lasers

*Guillaume Morard[1]

1. ISTerre, UGA, CNRS

Study of liquids and partial melting under extreme conditions is of great interest for the geophysical community, to understand the Magma Ocean dynamics during Early Earth stage as well as to constrain the present day Earth’ s core dynamics and composition. However, probing geomaterials (e.g. silicates and iron alloys) in the liquid state under extreme conditions using Laser-Heated Diamond Anvil Cell could present several drawbacks, related to chemical contamination from the diamonds and chemical migration along temperature gradient. Studying the melting properties during transient state using the time-resolved capabilities of Free Electron Laser sources, under dynamic or static compression, can give access to physical properties of high quality for molten geomaterials.

Keywords: Liquid silicates, Liquid iron alloys, Planetary Interior

Density and thermal expansion of liquid and solid iron at 1 atm determined using high-temperature furnace

*Hidenori Terasaki[1], Asaka Kamiya[2], Tadashi Kondo[2]

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To estimate the structure and composition of a planetary core, the equation of state of iron alloys is an important information, along with planetary exploration data. The density and thermal expansion coefficient is one of the most fundamental characteristics to describe the equation of state. In this study, we precisely measured the densities of solid and liquid iron at high temperatures and ambient pressure using a high-temperature furnace with optical windows. The sample volume was determined from the optical image measured at each temperature. The density error of solid Fe was estimated to 0.11–0.7% in the temperature range of 295–1803 K with increments of 1–10 K. The two discontinuous density jumps were observed at 1162 and 1666 K which were derived from phase transitions (alpha/gamma/delta phases). The density decreased linearly with increasing temperature in each phase. For liquid, the density of liquid Fe was determined with uncertainty of 0.4–0.7% in the range of 1818–1998 K with temperature increments of 5 K. The obtained thermal expansion coefficient of liquid iron was 2.42(1) x 10^{-4} K^{-1}.

Keywords: density, thermal expansion, iron, liquid

Sound velocity measurements of liquid Fe-N up to 100 GPa

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The Earth' s liquid outer core consists of iron alloy with ~5 wt.% nickel and ~10 wt.% lighter elements [1]. Nitrogen is one of the candidates for the core light elements. The Earth' s atmosphere and silicate mantle is depleted in nitrogen relative to carbonaceous chondrites, which indicates that a large portion of the nitrogen in bulk earth can be stored in the core [2,3]. To examine the possibility of nitrogen in the core, it is utilized to compare the sound velocity of liquid Fe-N alloy under high-pressure and –temperature conditions relevant to the core conditions with seismological observations. We have determined the longitudinal (P-wave) velocity of liquid Fe-N alloy up to 99 GPa and 2600 K based on the inelastic X-ray scattering (IXS) measurements in a laser-heated diamond-anvil cell (LH-DAC).

We carried out IXS measurements at the RIKEN Quantum NanoDynamics beamline BL43LXU of SPring-8 [4]. A $Fe_{80}N_{20}$ (Fe_4N) foil was used as the starting specimen and single-crystal Al_2O_3 discs were used as the thermal- and chemical-insulator. The liquid state of the sample was confirmed before and after each IXS measurement based on X-ray diffraction measurements. The IXS spectra were collected in a momentum transfer range of 3-5.7 nm^{-1} with an energy resolution of ~2.8 meV at 17.94 keV. The P-wave velocity of liquid $Fe_{80}N_{20}$ was determined from the dispersion relation of the longitudinal acoustic phonon mode of the liquid. We constructed an equation of state (EoS) for liquid $Fe_{80}N_{20}$ from the pressure and velocity data. Compared with pure Fe [5], the P-wave velocity of liquid $Fe_{80}N_{20}$ is faster by ~10% in the present experimental conditions. By extrapolating the present results to the Earth' s outer core conditions with the present EoS and then comparing with seismological observations, we found that the upper limit of nitrogen is ~3.8 wt% in the outer core.

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Keywords: Earth's core, Liquid Fe-N, Sound velocity, IXS, High pressure

Density and Sound Velocity of Liquid Fe and FeO at High Pressure

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The Earth's core is almost molten. While the dominant component of the core is believed to be iron, a large amount of lighter impurities can be dissolved into the core. Oxygen is a possible candidate for the light impurity in the liquid outer core. Seismological observations exhibit the presence of a low-velocity layer (LVL) at the top of the Earth's core, which might be attributed to the enrichment of oxygen [1,2]. Furthermore, the enrichment of the FeO component and/or partial melting are considered to be the origin of the ultra-low velocity zone (ULVZ) at the base of the lower mantle (e.g. [3]). Therefore, the density (ρ) and longitudinal sound velocity (V_P) of Fe-O liquids under relevant high-pressure and -temperature conditions are of great importance to understand those seismological anomalies. Here we present those elastic properties of liquid Fe and FeO under high-pressure and -temperature (*P*-*T*) conditions.

We have determined the ρ of liquid Fe up to 116 GPa based on in-situ x-ray diffraction measurements at BL10XU, SPring-8, using a laser-heated diamond-anvil cell (LH-DAC) [4]. The V_P of liquid Fe was obtained up to 45 GPa by inelastic x-ray scattering (IXS) measurements in the LH-DAC at BL43LXU, SPring-8 [5]. From these results combined with previous shock-wave data, we obtained the P–T–ρ–V_P–γ relation for the Earth's entire outer core conditions [6]. Also, we determined the V_P of liquid FeO up to 82 GPa using the IXS technique. The present results show that the V_P of liquid FeO is faster than that of liquid Fe by ~15% at the condition of the Earth's core-mantle boundary (CMB). Since the FeO component increases the P-wave velocity of liquid iron alloy, the enrichment of FeO cannot be the origin of the low-velocity anomaly at the top of the outer core. On the other hand, the V_P of liquid FeO is slower by ~35% relative to lower mantle minerals at the base of the lower mantle, so that the ULVZ can be attributed to a tiny amount of liquid FeO component.

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Keywords: liquid, density, sound velocity, high-pressure, core

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

Sat. Jun 5, 2021 9:00 AM - 10:30 AM JST | Sat. Jun 5, 2021 12:00 AM - 1:30 AM UTC | Ch.23 Zoom Room 23

[S-IT20] MAGMA, FLUID TRANSPORT, AND SEISMICITY IN THE EARTH'S INTERIOR

convener:Eiji Ohtani(Department of Earth and Planetary Materials Science, Graduate School of Science, Tohoku University), Saeko Kita(International Institute of Seismology and Earthquake Engineering, BRI), Michihiko Nakamura(Division of Earth and Planetary Materials Science, Department of Earth Science, Graduate School of Science, Tohoku University), Bjorn Mysen(Geophysical Laboratory, Carnegie Inst. Washington), Chairperson:Bjorn Mysen(Geophysical Laboratory, Carnegie Inst. Washington), Michihiko Nakamura(Division of Earth and Planetary Materials Science, Department of Earth Science, Graduate School of Science, Tohoku University)

The mass transfer depends on properties of the Earth's materials and geodynamic processes including cold slab subduction and magmatism due to hot plume activity. The mass transfer processes are imaged by geophysical observations such as seismic tomography and electrical conductivity profiles. One of the most important processes to transport volatiles is the slab subduction. The degree of hydration and dehydration in the slab is essential to evaluate amounts of volatiles transported into the deep mantle. Hydration and dehydration in the slab directly related to slab earthquakes, deformation of the slabs, and the arc magmatism. The fate of the fluid dehydrated in the deep slab is also a debated issue since permeability at the depth may be small, and the fluid might be trapped in the slabs and transported in the deep earth's interior at that depths without escaping to the mantle wedge. Recent seismic tomographic studies of the slab revealed direct observations of hydration and dehydration sites in the slabs. There exists growing evidence for alteration and hydration of the old lithosphere due to fracturing and Putit spot volcanisms which affect the volatile transport into the deep mantle due to slab subduction. The mass transfer to the surface can also be observed as the volcanic eruption in which phase separation of magma and fluid, and crystallization during the magma ascent controls the type of eruptions. The proposed session will focus on those phenomena including laboratory experiments, numerical modeling, and geophysical and geochemical observations including physical and chemical properties of magma and fluid, and geophysical imaging of various scales including seismic tomography of the descending slabs, and monitoring of near surface processes of volcanic eruptions. Contributions to any of these subjects are encouraged. We also encourage papers stimulating an interdisciplinary collaboration relating to establishment of the SEDI-Japan community.

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

[SIT20-07] HDAC experiments on silica solubility and speciation in Na_2CO_3–H_2O fluids at high pressure and temperature

*Naoko Takahashi[1], Tatsuki Tsujimori[1,2], Seiji Kamada[1,3], Michihiko Nakamura[1] (1.Department of Earth Science, Graduate School of Science, Tohoku University, 2.Center for Northeast Asian Studies, Tohoku University, 3.Frontier Research Institute for Interdisciplinary Sciences, Tohoku University)

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

[SIT20-08] Permeability determination from multi-anvil experiments: Implications for the fluid flux in subduction zones

★Invited Papers

*Lisa Eberhard[1], Philipp Eichheimer[1], Marcel Thielmann[1], Michihiko Nakamura[2], Gregor Golabek[1], Dan Frost[1] (1.Bayerisches Geoinstitut, University of Bayreuth, Germany, 2.Departement of Earth Science, Tohoku University, Japan)

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

[SIT20-09] Fluid segregation and chemical compaction through efficient solute transport along wet grain boundaries

*Wakana Fujita[1], Michihiko Nakamura[1], Kentaro Uesugi[2] (1.Graduate School of Science, Tohoku University, 2.Synchrotron Radiation Research Institute (JASRI/SPring-8))

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

[SIT20-10] Coupling between fluid flux and dynamical permeability evolution in the middle-lower crust, an example from Sør Rondane Mountains (SRM), East Antarctica.

*Diana Mindaleva[1], Masaoki Uno[1], Atsushi Okamoto[1], Noriyoshi Tsuchiya[1] (1.Graduate school of environmental studies, Tohoku University)

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

[SIT20-11] Attenuation contrast in mantle wedge across the volcanic front of NE Japan that controls propagations of high-frequency S-wave later phases

*Takahiro Shiina[1], Kei Katsumata[2], Kiyoshi Yomogida[2], Aitaro Kato[3] (1.National Institute of Advanced Industrial Science and Technology (AIST), 2.Graduate School of Science, Hokkaido University, 3.Earthquake Research Institute, the University of Tokyo)

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

[SIT20-12] The effect of water on energy dispersion of olivine and its implications for the origin of the sharp contrast of seismic observation at the lithosphere-asthenosphere boundary

*Chao Liu[1], Takashi Yoshino[1] (1.Institute for Planetary Materials, Okayama University)

HDAC experiments on silica solubility and speciation in Na_2CO_3–H_2O fluids at high pressure and temperature

*Naoko Takahashi[1], Tatsuki Tsujimori[1,2], Seiji Kamada[1,3], Michihiko Nakamura[1]

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Silica is the most dominant solute in subduction-zone fluids. Recent thermodynamic models predict the presence of deprotonated monomer, $SiO(OH)_3^-$(aq), the monomers, $Si(OH)_4$(aq), and the dimers, $Si_2O(OH)_6$(aq), as primary silica species in the alkaline fluids equilibrated with subducted silicate rocks [1]. However, the silica speciation in alkaline fluids at high *P*–*T* conditions remains unclear due to the complexities of equilibrium constants among silica species. Aranovich et al. [2] reported the higher silica solubility in Na_2CO_3 solutions at 500–700°C and 0.4–0.5 GPa than that expected solely from the known species in the extended Deep Earth Water (DEW) model [3], suggesting the possible presence of deprotonated dimer, $Si_2O(OH)_6^-$(aq). To confirm the speciation of silica in Na_2CO_3 solutions at high *P*–*T* conditions, we conducted a Raman spectroscopic study on silica speciation in pure H_2O and Na_2CO_3 solutions (0.5 and 1.0 *m* [mol/kg H_2O]) up to 750°C and 2 GPa using a hydrothermal diamond anvil cell. Moreover, we measured the solubility of quartz by direct observation of dissolving quartz grains.

The measured Raman spectra showed an asymmetric and broad band at ~770 cm^{-1}, which can be assigned to symmetric Si–OH stretching of the monomeric species $SiO(OH)_3^-$(aq) and $Si(OH)_4$(aq). Besides, we newly detected the intense broad bands at ~600 cm^{-1} consisting of at least three components, which represent the bending vibrations of bridging oxygen Si–O–Si of several oligomers. The lowest frequency component at ~530 cm^{-1} was interpreted as the asymmetric breathing mode of ring trimer. While the uncertainty remains in assigning the broad bands at ~1080 cm^{-1} to a single species, we presume the main contributions from deprotonated or oligomeric species. The ratio of the oligomer band area at ~600 cm^{-1} to the monomer band area at ~770 cm^{-1} of each experimental spectrum increases according to the increase pressure and temperature at quartz-saturated conditions.

The determined quartz solubility in pure H_2O at 718°C and 1.0 GPa fell in the range of 0.62 to 0.82 *m*, which is almost consistent with the value of 0.72 *m* calculated by the DEW model. On the other hand, the silica solubility in the Na_2CO_3 solutions at experimental conditions increased to the range of 1.5 to 3.0 *m* with increasing Na_2CO_3concentration and temperature. A preliminary comparison among our experimental results and thermodynamic models has led the following conclusions. (1) the silica solubility in the Na_2CO_3 solutions of the present experiments was several times higher than the value calculated based on the thermodynamic properties of aqueous silica species in the DEW model. (2) Although the addition of thermodynamic parameters of deprotonated dimer $Si_2O(OH)_6^-$(aq) can readily explain the high solubility of silica in the Na_2CO_3 solutions, our Raman spectroscopic data suggest the presence of several other oligomeric species that contributed to the high silica solubility. Therefore, additional oligomeric silica species should be considered in the estimation of silica solubility in alkaline fluids at deep-crust and upper mantle conditions.

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Keywords: hydrothermal diamond anvil cell, Raman spectroscopy, silica species, solubility

Permeability determination from multi-anvil experiments: Implications for the fluid flux in subduction zones

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Dehydration of hydrous minerals and the subsequent transport of the released fluids are important for a number of subduction zone processes. The fluids carry dissolved element and are responsible for metasomatism of the overlying mantle wedge, which is an important stage in the geochemical cycle of many trace and volatile elements. Within the mantle wedge fluids raise the degree of melting. Furthermore, subduction zone fluids are often linked to the origin of deep focused earthquakes. These processes necessitate a significant fluid flux between serpentine layers, which are likely to be the main source of water in subduction zones, and the overlying mantle, which requires fluid permeability to be sufficiently high.

Shear deformation in subduction zones most likely causes strong foliation and preferred orientation of serpentine minerals. Previous experiments at low pressures (100 MPa) indicate the occurrence of permeability anisotropy in foliated serpentinites. Accordingly, fluids may preferentially migrate parallel to the foliation but then become channelized into deep-rooted fault zones.

However, so far permeability measurements were limited to low pressures (<0.5 GPa). Based on pressure-dependent changes in volumes of both solids and liquids it becomes questionable as to whether the results of such permeability measurements can be extrapolated to the significantly higher conditions of subduction zone dehydration.

We report a new experimental method, which allows the permeability in dehydrating mineral assemblages to be determined through the analysis of recovered samples. For this purpose, we performed high pressure multi-anvil experiments. Our assembly consists of an orientated serpentinite drill core embedded in an MgO sleeve. At 2 - 5 GPa antigorite dehydrates over a temperature interval of approximately 100 °C at temperatures <700 °C. The released fluid migrates into the MgO and reacts to form brucite. The fluid can leave the serpentine sample in a direction either parallel or perpendicular to the initial serpentine foliation. The analysis of the location and proportion of brucite formed allows the fluid discharge at the experimental conditions to be calculated over the experimental run time. We combined these results with numerical simulations and μCT-scans to estimate the porosity.

Our results show that serpentinites in subduction zones are expected to form an essentially impermeable layer prior to dehydration. As progressive dehydration occurs at temperatures exceeding 550 °C the permeability increases by 2 orders of magnitude. We also show that the dehydration reaction causes in a change in texture, so that fluid flow becomes isotropic. This should favour pervasive fluid flow rather than channelized flow.

Keywords: serpentinite, multi-anvil, permeability

Fluid segregation and chemical compaction through efficient solute transport along wet grain boundaries

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Segregation of geological fluids such as supercritical aqueous fluids and silicate melts is an essential elementary process for volatile cycles in subduction zones. To explain the mechanism of fluid segregation, various processes have been examined including matrix deformation[1, 2], interfacial tension driven fluid redistribution[3, 4, 5] and melt rock reaction[6, 7]. A common feature in these processes is that fluid migrates through interconnected networks along the grain boundaries and channels. In this presentation, we will report a model of efficient fluid segregation which occurs without fluid interconnections.

The CHO fluid-bearing quartz aggregates were synthesized with nominal fluid fractions between 0 and 0.18 from powdered mixture of Arkansus quartz and amorphous silica prepared by sol-gel method. The mixture was hot-pressing in a piston–cylinder apparatus at 900℃ and 1.0 GPa for 24–382 hours for X_{CO2} = 0–0.44. The recovered run products were imaged with synchrotron X-ray microtomography and the porosity was measured. The quartzites with high initially added fluid fraction (ϕ_{add} > 0.056) tend to consist of fluid rich section and fluid poor section, which irrelevantly locate to top and bottom of the run products. The fluid poor sections retained very small fluid fractions (< 0.01) regardless of the high added fluid fraction. Partially deformed platinum sleeves and nickel capsules demonstrate that fluids were squeezed out from this region at the initial stage of the segregation. This deformation-assisted fluid segregation would continue until the fluid interconnection was pinched off. The pinch-off fluid fractions of our samples were 0.031–0.037 for X_{CO2} = 0 and 0.044–0.048 for X_{CO2} = 0.28–0.44, implying the occurrence of the second stage fluid segregation to form the very dense section of quartzite after the deformation. We calculated diffusive flux of the dissolved SiO_2 driven by the difference in the fluid pressure between the fluid rich section and the fluid poor section that lacks fluid interconnection considering the matrix viscosity. We found that the silica flux from the fluid poor to rich sections was 10^5 times larger than that expected from the reported grain boundary diffusivity. Our results imply that efficiency of the fluid segregation through silica redistribution along the wet or transient grain boundaries is comparable to the fluid segregation along interconnected fluid networks driven by interfacial tension[8] and deformation[9] when the spatial scale is less than ~0.1 meter.

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Keywords: fluid segregation, chemical compaction, quartzite

Coupling between fluid flux and dynamical permeability evolution in the middle-lower crust, an example from Sør Rondane Mountains (SRM), East Antarctica.

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Fluid flow causes hydration reactions, which induce mass transport, and changes rheology of rocks. Permeability increases due to fluid pressure rise cause rock fracturing and provide fluid infiltration. Such fluid activity is related to earthquake generation, tremors, and slow slip events. It was suggested that H_2O released due to dehydration reactions increases fluid pressure, causes fracturing, and induce tremors (e.g., Abers et al., 2009; Katsumata and Kamaya, 2003; Obara et al., 2004). However, quantitative constraints on fluid fluxes and crustal permeability are limited, particularly with regards to its temporal evolution. Therefore, it is important to constrain amount of fluid fluxes to understand roles of fluids in seismic events, permeability evolution, and water-rock interaction in the crust. Here, based on metamorphic fluid-rock reaction zones, we constrain fluid fluxes through the fractured crust by thermodynamic modeling of fluid chemistry and observed fracture geometry, and discuss the relation of fluid flux, their duration, and size of fractures that possibly related to seismic events.

We investigated fluid-rock reaction zones in hydrated metamorphic rocks samples from the Mefjell and Brattnipene Sør Rondane Mountains (SRM), East Antarctica. Amphibolite-facies planar fractures and millimeter-scale hydration zones around them provide unique information on duration and hydraulic parameters of fluid infiltration. Based on reactive-transport analysis of trace elements, in our previous study (Mindaleva et al., 2020) we have investigated timescales of fluid infiltration and estimated permeability evolution. The timescales are constrained to tens of hours. The permeability of the wall rock and fractures were estimated to be 10^{-20}–10^{-22} and 10^{-8}–10^{-9} m^2, respectively. We used these estimations to calculate fluid fluxes in the reaction zones and through the fracture.

To understand amount of fluids transported through the single fracture, we estimated fluid fluxes through the fractures and through the reaction zones. Fluid fluxes through the reaction zone were estimated by two ways: total amount of H_2O added to reaction zone ($Q_{RZ}H_2O$) and modelled fluid flux required for chlorine transport ($Q_{RZ}Cl$). Fluid fluxes through the fracture were estimated by two different approaches. First method utilizes permeability of the fracture, pressure gradient, and timescales of the fluid infiltration, constrained for each sample ($Q_{FR}Hyd$). Second method is based on the advective reaction-transport equation applied to fluid speciation phase equilibrium modelling results ($Q_{FR}Si$). We also measured seismic moment and magnitude from the fluid flux volumes and provide insights about possible seismic events.

Fluid fluxes through the reaction zone log $Q_{RZ}H_2O$ range -4.2– -3.3 m, flux required for Cl transport log $Q_{RZ}Cl$ is same order, ranges -4.7– -3.5 m. Fluid flux through the fracture log $Q_{FR}Hyd$ ranges 1.6– 3.8 m, and fluid flux estimated by thermodynamic modeling of fluid chemistry log $Q_{FR}Si$ ranges 2.1– 2.9 m, respectively.

Magnitude of the possible seismic even estimated from the fluid fluxes by two different approaches ranges -1– 2.6. First method based on the McGarr,1976 equation suggesting relationship between seismic moment and fluid flux. Second method is based on the fault geometry, we used cross-section area as

5–30 ×5–30 m, and slip displacement ranges 1–0.1 mm. Magnitude estimated by McGarr’s equation ranges 2.0– 2.6, while second approach provides ranges -1– 0. We compared our estimations to the results of fluid injection experiments (e.g., Baisch et al., 2006; Baisch et al., 2009; Häring et al., 2008; Deichmann et al., 2014). Moment magnitude estimated by first approach is the maximum magnitude observed in series of fluid injection experiments in the shallow crust. However, first approach is not tested for deep crustal conditions and at very low fluid fluxes. Second approach possibly provides more realistic results for our conditions, incorporating geological observations, low fluid fluxes and middle-lower crustal conditions.

Our results show that much amount of fluids are transported by fractures rather than to be stored in the reaction zones. Such fluid infiltration can possibly induce fracturing and low magnitude seismic events in the crust.

Keywords: Fluid flux , Hydration, Fluids activity, Permeability , Reaction zones, Timescales

Attenuation contrast in mantle wedge across the volcanic front of NE Japan that controls propagations of high-frequency S-wave later phases

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Distinct later phases of waves containing high-frequency (>8 Hz) components were observed for intraslab earthquakes that occurred at intermediate depths, particularly at depths exceeding 100 km, in the NE Japan subduction zone. These high-frequency later phases showed anomalously large peak-amplitude delays, up to ~50 s after direct S-wave arrivals at stations in the backarc region. Using a source-scanning algorithm, we investigated the locations of passing points affecting the propagation of high-frequency later phases. The passing points were estimated to be in the forearc region in the entire NE Japan, indicating that high-frequency later phases are scattered waves that pass through the forearc region. The propagating high-frequency later phases seem to bypass the backarc mantle wedge, as a consequence of the distinct attenuation contrast in the mantle wedge across the volcanic front in NE Japan. These high-frequency later phase observations suggest that the high-attenuation zone in the backarc mantle wedge controls propagations of the high-frequency waves of intraslab earthquakes, in addition to the scatterers possibly locate in the forearc region.

Keywords: Later phase, Intraslab earthquake, S-wave attenuation, Scattering

The effect of water on energy dispersion of olivine and its implications for the origin of the sharp contrast of seismic observation at the lithosphere-asthenosphere boundary

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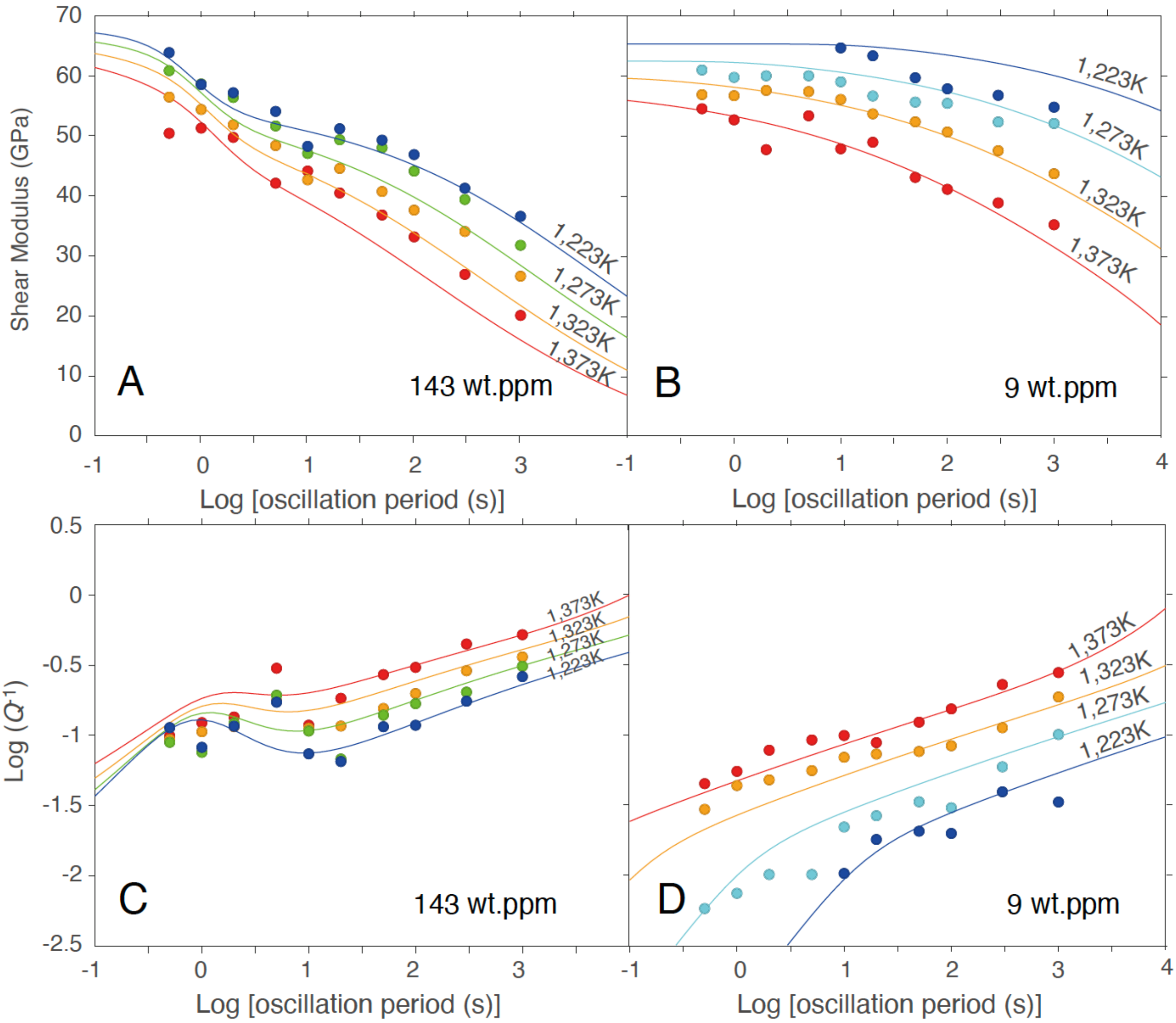
Seismic observations have shown a sharp drop of shear wave velocity at the lithosphere-asthenosphere boundary (LAB) (Kawakatsu et al., 2010) and strong attenuation in the asthenosphere. The temperature difference itself was difficult to explain such sharp change (Karato et al., 2015). Such as presence of partial melt, deduced grain size, or increased water content in asthenosphere have been considered as the possible origins for those anomalies (e.g., Anderson and Sammis, 1970; Hirth and Kohlstedt, 1996; Faul and Jackson, 2005; Yoshino et al., 2006; Jackson et al., 2010; Karato, 2012). Considering the thermal structure and sharp drop of velocity in the old oceanic upper mantle (100 Myr), those anomalies could not be explained by partial melting (Hirschmann, 2010) or reduced grain size (Karato, 2018). Seismic attenuation is a useful tool to figure out this origin. Although recently Cline et al. (2018) showed a small effect of water content on energy dispersion of olivine aggregates, they measured attenuated properties for Ti-related H defects, which is stable at the low pressure they conducted. Because the actual H substitution mechanism in the upper mantle is related to Mg or Si vacancies, thus we need to measure anelastic properties at relatively higher pressure at which these substitution mechanisms become dominant.

To investigate the effect of water on anelastic property of mantle materials, we measured the energy dispersion and Young's modulus of olivine aggregates, which is the most dominant mineral in the upper mantle, in various oscillation periods (0.5 -1000 s) at 1373 K and 3 GPa (70 km depth in the Earth). The newly built short-period cyclic loading system in situ X-ray observation was used in our experimental procedures (Yoshino et al., 2016).

The experimental results show that the energy dispersion increases with increasing period of oscillation, decreasing grain size, and increasing the water content of olivine, while the energy dispersion reduces its Young's modulus. When water content increases, an attenuation peak appears at the short period (5~10 s). The modified generalized Burger's model was used to acquire the effect of water content and grain size on attenuation and velocity of seismic wave quantitatively (Jackson et al., 2005). The fitting results show that there are two contributions from the high-temperature background (diffusion accommodated grain boundary sliding, DGBS) and attenuation peak to the energy dispersion. The characteristic relaxation time for DGBS showed a mild frequency dependence (0.33), which is consistent with the results of the previous study. The water could enhance the relaxation time with an exponent factor of 2.5(0.1) for DGBS. For the attenuation peak, water could enhance the peak height with an exponent factor of 1.2(1).

Takeuchi et al. (2017) found little frequency-dependent attenuation beneath the old oceanic floor, which is consistent with the attenuation behavior of hydrous samples showing an attenuation peak at a short period. The present results demonstrate that the old lithosphere with less than 1 wt.ppm H_2O overlying hydrous asthenosphere (100 wt. ppm H_2O) can produce the observed velocity drop (5-10 %). The difference of seismic properties between the asthenosphere and the old oceanic lithosphere can be explained by a remarkable difference in water content between them.

Keywords: energy dispersion, water, upper mantle, attenuation, velocity, lithosphere and asthenosphere boundary



[E] Oral | S (Solid Earth Sciences) : S-MP Mineralogy & Petrology

Sat. Jun 5, 2021 1:45 PM - 3:15 PM JST | Sat. Jun 5, 2021 4:45 AM - 6:15 AM UTC | Ch.20 Zoom Room 20

[S-MP24] Supercontinents and Crustal Evolution

convener:Tomokazu Hokada(National Institute of Polar Research), Tetsuo Kawakami(Graduate School of Science, Kyoto University), Krishnan Sajeev(Centre for Earth Sciences, Indian Institute of Science), Madhusoodhan Satish-Kumar(Department of Geology, Faculty of Science, Niigata University), Chairperson:Tomokazu Hokada(National Institute of Polar Research), Madhusoodhan Satish-Kumar(Department of Geology, Faculty of Science, Niigata University)

Supercontinent formation and dispersion has been enigmatic in the Earth's history. Eurasia is one such current supercontinent and incredible progress in the understanding of its geological evolution has been achieved in the past decade. Earlier supercontinents in the Earth's history such as Gondwana (0.5 Ga), Rodinia (1.0 Ga), Columbia/Nuna (2.0 Ga), Kenorland (2.5 Ga) and Vaalbara (3.1 Ga), have been the focus of several studies, however limited information on older supercontinents has restricted an understanding their tectonic evolution. Several important unsolved issues remain, such as how, when and where these supercontinents formed and how long they remained as such before breaking apart. Additional questions arise on the processes that triggered the fragmentation and unification of continents. In this session, we invite authors around the world to present original new data as well as review results on the continental scale crustal processes and tectonic evolution that are associated with supercontinent formation events in Earth's history. The well-studied Eurasia and Gondwana supercontinents are of particular focus. Topics of interest include, but not restricted to, extremes in metamorphism, P-T-d-t evolution, magmatism, and the role of fluids. We hope to provide a platform for scientific discussions that will enlighten our understanding of the physical and chemical processes in the continental crust that records episodes of orogenesis that contributed to the formation and evolution of supercontinents.

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

[SMP24-01] Decompression *P-T* evolution recorded in a pelitic gneiss from Tangarden, Sør Rondane Mountains, East Antarctica

*Tetsuo Kawakami[1], Fumiko Higashino[2], Tatsuro ADACHI[3], Masaoki Uno[4] (1.Graduate School of Science, Kyoto University, 2.Okayama University of Science, 3.Advanced Asian Archaeological Research Center, Kyushu University, 4.Graduate School of Environmental Studies, Tohoku University)

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

[SMP24-02] Post-peak Cl- and CO_2-bearing fluids in a Grt-Sil-Bt gneiss from southern Perlebandet, Sør Rondane Mountains, East Antarctica

*Fumiko Higashino[1], Tetsuo Kawakami[2], Tatsuro ADACHI[3], Masaoki Uno[4] (1.Faculty of Science, Okayama University of Science, 2.Kyoto University, 3.Kyushu University, 4.Tohoku University)

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

[SMP24-03] **Contrasting chemical reactions and fluid transport by melt and aqueous fluids during middle crustal fracturing (Sør Rondane Mountains, East Antarctica)**

*Masaoki Uno[1], Tetsuo Kawakami[2], Tatsuro Adachi[3], Fumiko Higashino[4], Noriyoshi Tsuchiya[1] (1.Tohoku University, 2.Kyoto University, 3.Kyushu University, 4.Okayama University of Science)

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

[SMP24-04] Geochemical characterization of zircon for U-Pb age determination in Fyfe Hills of the Napier Complex, East Antarctica

*Mami Takehara[1], Kenji Horie[1,2], Tomokazu Hokada[1,2] (1.National Institute of Polar Research, 2.The Graduate University for Advanced Studies, SOKENDAI)

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

[SMP24-05] Petrology, metamorphic conditions, and monazite dating of metapelites of the Zambezi Belt supracrustal sequence, Zambia

*Kabangu Grace Sakuwaha[1], Toshiaki Tsunogae[1] (1.University of Tsukuba)

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

[SMP24-06] Petro-tectonic setting of the Karagwe–Ankole Belt (Rwanda) and implications for the amalgamation of Rodinia

*Claude Nambaje[1], Madhusoodhan Satish-Kumar[2], Ian S. Williams[3], Toshiro Takahashi[2], Krishnan Sajeev[1] (1.Indian Institute of Science, 2.Niigata University, 3.Australian National University)

Decompression *P-T* evolution recorded in a pelitic gneiss from Tangarden, Sør Rondane Mountains, East Antarctica

*Tetsuo Kawakami[1], Fumiko Higashino[2], Tatsuro ADACHI[3], Masaoki Uno[4]

1. Graduate School of Science, Kyoto University, 2. Okayama University of Science, 3. Advanced Asian Archaeological Research Center, Kyushu University, 4. Graduate School of Environmental Studies, Tohoku University

The Sør Rondane Mountains (SRM), East Antarctica exposes a collision zone lower to middle crust recording tectono- and plutono-metamorphic events at ca. 650-500 Ma that possibly correspond to the EAAO and Kuunga orogeny. The SRM is divided into the NE and SW terranes bounded by the Main Tectonic Boundary (MTB), along which the NE terrane is considered to have thrusted up onto the SW terrane (Osanai et al., 2013). This model was built on the observation that the metamorphic rocks of the NE terrane (with inherited zircons >1200 Ma present) record clockwise *P-T* paths whereas the SW terrane rocks (without inherited zircons >1200 Ma) record counter-clockwise *P-T* paths. However, this tectonic model is only build on small number of *P-T* path constraints and needs to be tested from more *P-T* path constraints from wide area of the SRM. This study aims to constrain the *P-T* path from Tangarden located in the SW terrane.

In Tangarden, intercalations of intermediate, mafic, calcsilicate and pelitic gneisses are dominated. Mylonite is developed parallel to the gneissose structure. Where mylonitization is weak, mafic and calcsilicate gneisses are boudinaged to form lenses within the host gneisses. The sample used in this study is a garnet-sillimanite-biotite gneiss (sample TK2020010101H) collected from the intercalation dominated by mafic, felsic and intermediate bulk compositions. Pelitic lithology is locally affected by retrograde hydration that replaced garnet with Ti-poor green biotite aggregate, but the sample TK2020010101H is only weakly affected by this hydration. In this sample, biotite (mostly TiO_2 > 0.5 wt%) and sillimanite are arranged along the gneissosity, which is overgrown by cordierite. Garnet (X_{Mg} = 0.21-0.38) commonly include biotite (mostly TiO_2 > 1.0 wt%) throughout the grain, and rarely includes sillimanite at the rim. Garnet is partly surrounded by cordierite (X_{Mg} = 0.76-0.81) and Ti-poor biotite (mostly TiO_2 < 0.5 wt%), and these minerals also form pressure shadows developed on garnet. Isolated cordierite in the matrix (X_{Mg} = 0.77-0.80) exhibit elongated shape with biotite inclusions arranged parallel to the gneissosity. Cordierite (X_{Mg} = 0.79) and hercynite (X_{Mg} = 0.28-0.31, ZnO = 3.5-3.7 wt%) are formed between garnet and sillimanite. This sillimanite grain is most likely a former inclusion enclosed in the garnet rim before the development of cordierite + spinel between garnet and the sillimanite grain. Cracks developed in garnet are filled with cordierite + biotite ±quartz. Anthophyllite (X_{Mg} = 0.60-0.68) is common in the cracks developed in garnet, and is intergrown with crack-filling cordierite. These pieces of observation suggest that following reactions took place:

(1) Bt + Sil + Qtz = Grt +Kfs + melt
(2) Bt + Sil + Qtz = Grt + Crd + Kfs + melt
(3) Grt+ Kfs + melt/H_2O = Crd + Bt
(4) Grt + Sil = Crd + Spl
(5) Grt + Qtz + H_2O = Ath + Crd

Based on petrogenetic grid for the NaKFMASH system (Spear et al., 1999), reaction sequence from (1) to (4) suggests nearly isothermal decompression *P-T* path from ˜7 kbar, 800 °C to ˜3 kbar, 750°C. This result is not consistent with the shape of counter-clockwise *P-T* paths reported from the SRM, and rather mimics to clockwise *P-T* paths. More examples of *P-T* paths from wide area of the SRM are needed to understand the tectonic history of the SRM.

Keywords: Continental collision zone, Metamorphism, Antarctica, Pressure-temperature path

Post-peak Cl- and CO_2-bearing fluids in a Grt-Sil-Bt gneiss from southern Perlebandet, Sør Rondane Mountains, East Antarctica

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1. Faculty of Science, Okayama University of Science, 2. Kyoto University, 3. Kyushu University, 4. Tohoku University

Low H_2O activity fluids (e.g., CO_2-, NaCl-, and KCl-bearing fluids) are often recognized in the middle to lower crust (e.g., Newton et al., 1998; Touret and Huizenga, 2011). CO_2-rich fluid in high-grade metamorphic rocks is usually observed as fluid inclusions, whereas Cl-bearing fluid is presumed by high-Cl concentration in hydrous minerals. In addition, some metamorphic minerals, such as cordierite, can incorporate molecular CO_2 and H_2O in the channel-cavities. In the H_2O-CO_2-NaCl ternary system, CO_2 - and NaCl-bearing fluids are extremely immiscible even at high-temperature (Shmulovich and Graham, 2004). In order to understand the metamorphic fluid evolution, therefore, it is important to examine whether both fluids coexisted simultaneously or not when both fluid compositions are presumed from a single sample.

In the Sør Rondane Mountains (SRM), East Antarctica, Late Proterozoic to Cambrian granulites are widely exposed (e.g., Jacobs and Thomas, 2004; Shiraishi et al., 2008; Osanai et al., 2013). Perlebandet is ~10 km long nunataks located at the westernmost part of the SRM. Perlebandet was categorized into NE-terrane which exhibits a clockwise *P-T* path, whereas SW-terrane exhibits a counter-clockwise *P-T* path (Osanai et al., 2013). However, Mieth et al. (2014) interpreted that Parlebandet is part of the SW-terrane on the basis of magnetic survey. The counter-clockwise *P-T* path estimated by Kawakami et al. (2017) supports this interpretation. So far, all previous studies in Perlebandet reporting the *P-T* conditions, zircon U-Pb ages, and CHIME ages in monazite dealt with samples from northern part of the nunataks (Asami et al., 2005; Shiraishi et al., 2008; Kawakami et al., 2017). This study deals with a Grt-Sil-Bt gneiss collected from the southern part of nunataks in Perlebandet.

The studied sample (sample FH19123001Q) mainly comprises garnet, sillimanite, biotite, cordierite, plagioclase, K-feldspar, and quartz. Black cracks filled by Cl-rich biotite (~0.5 wt% Cl) cut the gneissose structure. Cordierite is exclusively present as biotite-cordierite intergrowth around garnet porphyroblasts, suggesting the garnet breakdown reaction during retrograde metamorphism. Since sillimanite is included in cordierite within the intergrowth microstructure in rare cases, garnet breakdown reaction probably occurred under sillimanite stability field. Therefore, the reaction

Grt + Kfs + H_2O --> Bt + Crd (1)

is likely to have occurred. Within the biotite-cordierite intergrowth microstructure, biotite has ~0.2-0.3 wt% Cl, whereas the CO_2 and H_2O peaks were obtained from cordierite by Raman spectrometer. Since both minerals within the intergrowth were formed simultaneously, the H_2O-CO_2-Cl^- fluid infiltration is suggested to be triggered the reaction (1). The *P-T* conditions when the reaction (1) occurred are considered to be ~730 ºC, ~0.4 GPa in NaKFMASH system, because X_{Fe} value of garnet is ~0.8 (Spear et al., 1999). The dehydration reaction line and wet solidus shift to low-temperature and high-temperature side, respectively, due to the low H_2O activity fluid (cf. Johannes and Holtz, 1996). This means that the isopleth of reaction (1) possibly shifts to high-temperature side, although H_2O activity of the H_2O-CO_2-Cl^- fluid is not estimated.

Further information is needed to constrain whether the reaction (1) is a part of counter-clockwise *P-T* path or not. The undated granite bodies are mapped in the southern part of nunataks in Perlebandet. Post-peak granitic intrusion can be a heat source and then the reaction (1) can occur, even following the counter-clockwise *P-T* path. To constrain the *P-T* path helps understand the origin and evolution of the H_2O-CO_2-Cl^- fluid.

Keywords: metamorphic fluid, high-temperature metamorphic rock, Antarctica

Contrasting chemical reactions and fluid transport by melt and aqueous fluids during middle crustal fracturing (Sør Rondane Mountains, East Antarctica)

*Masaoki Uno[1], Tetsuo Kawakami[2], Tatsuro Adachi[3], Fumiko Higashino[4], Noriyoshi Tsuchiya[1]

1. Tohoku University, 2. Kyoto University, 3. Kyushu University, 4. Okayama University of Science

Fluids in the deep crust promote heat and mass transport, control rock rheology and fracturing, and play essential roles on the dynamics of plate boundaries. Although fluid activities are geophysically recognized as migrations of hypocenters and seismic velocity anomalies (e.g., Hasegawa et al., 2005; Yoshida et al., 2018), roles of melt and aqueous fluids in deep crustal fracturing are not always clear, due to limitations in distinguishing melt or aqueous fluids in geophysical observations. Exceptionally well-exposed crust-fluid reaction zones in the Sør Rondane Mountains (SRM), East Antarctica provides an ideal opportunity to evaluate the fluid flow in the deep crust from mm to km-scale (e.g., Adachi et al., 2010; Osanai, et al., 2013; Higashino et al., 2013, 2019; Kawakami et al., 2017; Uno et al., 2017; Mindaleva et al., 2020). Here we examine the amphibolite-facies melt–rock and aqueous fluid–rock reaction zones of hosted in felsic gneiss (so called “bleached” zones) that are widely distributed in the SRM, and discuss the contrasting modes of chemical transport between melt and aqueous fluids during crustal fracturing.

We have analyzed amphibolite-facies melt/aqueous fluid–rock reaction zones, Mefjell area, SRM. Orthopyroxene-bearing felsic gneiss are crosscut by numerous granitic veins and biotite veins (m to 100s m in length) and are associated with cm– to decimeter–scale whitish reaction zones composed of hornblende-biotite-bearing felsic gneiss, showing “bleached” zones. The bleached zones are characterized by complete hydration of orthopyroxene and clinopyroxene to grunerite, hornblende and biotite, representing fluid infiltration at 0.40–0.55 GPa, 600–670°C (Uno et al., 2020). Mineralogy, mineral chemistry and temperature conditions of bleached zones around granitic veins and biotite veins are essentially identical, except for characteristic minor element profiles described below.

Bleached zones associated with granitic vein (“granitic vein-bleached zones”) are characterized by relatively high MnO contents at the vein wall (hornblende 2.0 wt%; biotite 0.6 wt%; ilmenite 6.0 wt%) and they gradually decrease towards the host rock within ~15 mm length (≅ bleached zone width). Similar gradual profiles are observed for Be, Ga, Zn, Sn, Rb, Cs and Pb in biotite and/or hornblende. TiO_2 in biotite are within the range of host rock (3.9–4.5 wt%). The Cl contents in biotite and hornblende are low (<0.08wt%). Contrarily, in bleached zones associated with biotite vein (“biotite vein-bleached zones”), the Cl contents in hornblende and biotite are relatively high and constant within the middle of the bleached zones (0.40–0.52 wt%; ~7 mm length from the vein wall) and sharply decrease towards the host rock (<0.04 wt%; ~15 mm length). MnO in biotite and hornblende are low (<0.4 wt%), and TiO_2 contents in biotite are depleted in bleached zone (~2 wt%) compared to those in the host rock (~4 wt%).

Reactive-transport analysis of MnO and Cl in the bleached zone show that transports from the vein wall to the host rock are diffusion-dominant (P_e = 0) in granitic vein-bleached zone, whereas those in biotite vein-bleached zone are advection dominant (P_e ~300). The MnO, TiO_2 enriched, Cl-depleted nature of the granitic vein-bleached zone is likely to be explained by infiltration of granitic melt, whereas Cl-enriched, MnO, TiO_2 depleted nature of the biotite vein-bleached zone is affected by infiltration of Cl-bearing aqueous fluids. Assuming near lithostatic fluid pressure of the veins, the differences of the modes of chemical transport (diffusional vs. advectional) of the two bleached zones suggest contrasting viscosity of the granitic melt and aqueous fluids during infiltration from the veins to the host rock.

The results of this study indicate that both viscous granitic melt and Cl-bearing aqueous fluids contribute to fracturing at middle crustal conditions (0.40–0.55 GPa, 600–670°C). Further reactive-transport analyses of these reaction zones would reveal timescales of fluids infiltration and associated hydraulic parameters operated during middle crustal fracturing.

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Keywords: Fluid-rock reactions, Reactive-transport model, Amphibolite- and granulite-facies, Sør Rondane Mountains, East Antarctica, Chlorine

Geochemical characterization of zircon for U-Pb age determination in Fyfe Hills of the Napier Complex, East Antarctica

*Mami Takehara[1], Kenji Horie[1,2], Tomokazu Hokada[1,2]

1. National Institute of Polar Research, 2. The Graduate University for Advanced Studies, SOKENDAI

Ultra-high temperature (UHT) metamorphism is critical to understanding the large-scale tectonic processes affecting the deep crust and lithosphere throughout Earth's history. The Napier Complex in East Antarctica is the location where the regional UHT metamorphism was first recognized (Dallwitz, 1968) and experienced extremely high temperatures (>1100 ˚C) based on the mineral assemblage of sapphirine + quartz (Harley, 2016 and reference therein). The thermal history of the Napier Complex is essential for unraveling the Earth's crustal evolution, including deep crust; however, geochronological constraints, such as the timing and duration of the metamorphic events, are still debated. Two hypotheses for the timing are proposed in previous studies: (i) the UHT metamorphism occurred no earlier than 2840 Ma and possibly from 2590 to 2550 Ma (e.g., Harley et al., 2001), (ii) it occurred from around 2500 to 2450 Ma (e.g., Carson et al., 2002).
In this study, U–Pb zircon geochronology integrated with rare earth element (REE) and oxygen isotope was applied to a garnet-bearing quartzo-feldspathic gneiss to confirm the timing of UHT metamorphism in Fyfe Hills in the western part of the Napier Complex. The quartzo-feldspathic gneiss is mainly composed of garnet + mesoperthite (ternary feldspar) + quartz, with small amounts of zircon and opaque minerals (Horie et al., 2012).
The zircons collected from the quartzo-feldspathic gneiss are observed in backscattered electron (BSE) and cathodoluminescence (CL) images obtained using the low-vacuum mode of a scanning electron microscope (JEOL JSM-5900LV) with a Gatan mini CL detector at National Institute of Polar Research, Japan (NIPR). The zircons were analyzed using a sensitive high-resolution ion microprobe (SHRIMP) at National Institute of Polar Research. After the all SHRIMP analysis, true color CL images of the grain mount were obtained using a Gatan ChromaCL2 system installed with a field emission SEM (FE-SEM; JEOL JSM-7100F) at the NIPR. The CL observation and U–Pb ages allowed us to classify the analytical domains into three types: inherited domains, metamorphic domains, and U–Pb system disturbed domains. The REE patterns of metamorphic domains are characterized by a weak fractionation between the middle REE and heavy REE, which reinforces the classification based on the CL observation and the U–Pb ages. The $^{207}Pb/^{206}Pb$ ages of metamorphic domains have an age peak at 2501 Ma, therefore, the gneiss experienced high-temperature metamorphism at 2501 Ma. The $\delta^{18}O$ of zircons are homogeneous among the three groups (5.53 ±0.11‰, 5.51 ±0.14‰, and 5.53 ±0.23‰), which suggests the oxygen isotope compositions in zircon were re-equilibrated after the metamorphism at ca. 2501Ma under dry UHT conditions.

Keywords: zircon, U-Pb age, Napier Complex

Petrology, metamorphic conditions, and monazite dating of metapelites of the Zambezi Belt supracrustal sequence, Zambia

*Kabangu Grace Sakuwaha[1], Toshiaki Tsunogae[1]

1. University of Tsukuba

The Zambezi Belt located in southern Zambia forms part of E-W trending late Pan-African Kuunga orogen associated with assembly of Gondwana supercontinent. Lithologic units of the belt include Neoarchean to Neoproterozoic granitic basement, unconformably overlain by supracrustal sequences, consisting of meta-pelites, psammites, calc-silicates, marbles, and magmatic rocks with NE-SW shortening. Several studies have been conducted to determine the metamorphic conditions of separate localities within this region but data on the textural context to directly link metamorphic paragenesis to geochronological data is limited. We present the first texture-based age determinations of the metamorphism of the metapelite sequence located between the Mpande and Ngoma basement terrains. The data presented includes petrology, metamorphic *P-T* conditions and geochronological data obtained by in-situ microprobe techniques on monazite to link metamorphic paragenesis to key tectonic events in the Pan-African orogeny. The studied rocks exhibit penetrative foliations with mineral assemblages consisting of garnet, biotite, quartz, kyanite, ±staurolite, muscovite, and chlorite or kyanite, biotite, muscovite, chlorite and quartz with accessory rutile, ilmenite, tourmaline, and monazite. Application of garnet-biotite geothermometers on appropriate samples yields peak metamorphic *P-T* conditions of 572 - 627°C and 4 - 6.2 ±1.3 kbar. Application of CHIME age calculations on monazites identifies two age populations which potentially represent long-lived metamorphism from ca. 630 and 573 Ma. These ages are also nearly consistent with previously reported ages from other localities within the belt which have been interpreted to correspond to collisional orogenesis and closure of the Mozambique ocean, followed by burial metamorphism prior to exhumation and erosion.

Keywords: Zambezi Belt, Zambia, Metamorphic P-T, Monazite dating

Petro-tectonic setting of the Karagwe–Ankole Belt (Rwanda) and implications for the amalgamation of Rodinia

*Claude Nambaje[1], Madhusoodhan Satish-Kumar[2], Ian S. Williams[3], Toshiro Takahashi[2], Krishnan Sajeev[1]

1. Indian Institute of Science, 2. Niigata University, 3. Australian National University

Petrological, geochemical and geochronological studies of granitic rocks from the Karagwe–Ankole Belt (KAB) have helped to establish the tectonic setting of the orogenic belt and the implications for Rodinia assembly. Four categories of granitic rocks have been recognised, providing constraints on the geodynamic evolution of the KAB.
Anorogenic (A-type) garnet-biotite granite was emplaced at 1368 ±5 Ma. Its major, trace and rare earth element composition, Nd TDM model age of up to 2.33–1.96 Ga, high initial 87Sr/86Sr (0.7119–0.7216) and negative ε Nd (-1.9 to -4.0), indicates derivation from a much older mafic source, probably asthenospheric or lower continental lithospheric mantle contaminated by crustal material. Ascent of the magma was aided by a localised crustal-scale zone of weakness within Archean crust underlying both the Eastern and Western Domains of the KAB. The rest of the granites have S-type orogenic characteristics. Large batholiths of two-mica granite emplaced at 1369 ±5 Ma have major, trace and rare earth element compositions, high initial 87Sr/86Sr (0.7081–0.7329), strongly negative ε Nd (-9.4 to -10.1) and a Nd TDM model age of 2.82–2.40 Ga, consistent with derivation by partial melting of a pelitic source containing Paleoproterozoic and Archean components, possibly with a minor contribution from magma derived from the lower crust. The magmatism occurred in a convergent setting between the Congo and Tanzania cratons during an early stage of Rodinia amalgamation. Muscovite granite and leucogranite resulting from fluid-fluxed partial melting of metapelites were emplaced at ca. 1011–976 Ma in a late to post-collisional setting of Rodinia. Their high initial 87Sr/86Sr (0.7289–0.7446) and strongly negative ε Nd (-6.8 to -12.4) indicate a supracrustal source. One younger S-type leucogranite (614 ±9 Ma) was emplaced in a volcanic-arc setting, possibly during the West Gondwana Orogeny. The combined available evidence points to evolution of the Mesoproterozoic KAB during accretion-collisional tectonism.

[E] Oral | S (Solid Earth Sciences) : S-MP Mineralogy & Petrology

Sat. Jun 5, 2021 3:30 PM - 5:00 PM JST | Sat. Jun 5, 2021 6:30 AM - 8:00 AM UTC | Ch.20 Zoom Room 20

[S-MP24] Supercontinents and Crustal Evolution

convener:Tomokazu Hokada(National Institute of Polar Research), Tetsuo Kawakami(Graduate School of Science, Kyoto University), Krishnan Sajeev(Centre for Earth Sciences, Indian Institute of Science), Madhusoodhan Satish-Kumar(Department of Geology, Faculty of Science, Niigata University), Chairperson:Krishnan Sajeev(Centre for Earth Sciences, Indian Institute of Science), Tetsuo Kawakami(Graduate School of Science, Kyoto University)

Supercontinent formation and dispersion has been enigmatic in the Earth's history. Eurasia is one such current supercontinent and incredible progress in the understanding of its geological evolution has been achieved in the past decade. Earlier supercontinents in the Earth's history such as Gondwana (0.5 Ga), Rodinia (1.0 Ga), Columbia/Nuna (2.0 Ga), Kenorland (2.5 Ga) and Vaalbara (3.1 Ga), have been the focus of several studies, however limited information on older supercontinents has restricted an understanding their tectonic evolution. Several important unsolved issues remain, such as how, when and where these supercontinents formed and how long they remained as such before breaking apart. Additional questions arise on the processes that triggered the fragmentation and unification of continents. In this session, we invite authors around the world to present original new data as well as review results on the continental scale crustal processes and tectonic evolution that are associated with supercontinent formation events in Earth's history. The well-studied Eurasia and Gondwana supercontinents are of particular focus. Topics of interest include, but not restricted to, extremes in metamorphism, P-T-d-t evolution, magmatism, and the role of fluids. We hope to provide a platform for scientific discussions that will enlighten our understanding of the physical and chemical processes in the continental crust that records episodes of orogenesis that contributed to the formation and evolution of supercontinents.

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

[SMP24-07] **A comparison between carbon isotope thermometry and Raman spectra of carbonaceous material (RSCM) thermometry in low-medium grade carbonate rocks from the Chitradurga Schist Belt, Dharwar Craton**

*Kiran Sasidharan[1], Madhusoodhan Satish-Kumar[1], Yoshihiro Nakamura[2], Hiroaki Ohfuji[3] (1.Niigata University, 2.Geological Survey of Japan, AIST, 3.Tohoku University)

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

[SMP24-08] Insights into failed rift processes in the Archean, evidence from the Western Dharwar Craton, southern India.

*Sreehari Lakshmanan[1], Tsuyoshi Toyoshima[2], Madhusoodhan Satish-Kumar[2] (1.Graduate School of Science and Technology, Niigata University, Niigata, Japan, 2.Department of Geology, Niigata University, Niigata, Japan)

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

[SMP24-09] **Trace and rare earth element geochemistry of the clinopyroxene of dolerite dykes from Western Dharwar craton, southern India**

*Silpa Ammini Sasidharan[1], Madhusoodhan Satish-Kumar[1], Eiichi TAKAZAWA[1], Krishnan Sajeev[2] (1.Faculty of Science Niigata University, 2.Indian Institute of Science, Bangalore, India)

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

[SMP24-10] Evidence of carbonic crustal fluid during deep to shallow crustal evolution of the interior of Eastern Ghats Belt India: Grenvillian to Kuunga orogenies

*Kaushik Das[1,6], Sankar Bose[2,6], Junji Torimoto[3], Yasutaka Hayasaka[1,6], Daniel Dunkley[4,5] (1.Hiroshima University, 2.Presidency University, 3.JAMSTEC, Yokotsuka, 4.NIPR, Tokyo, 5.IG-PAS, Poland, 6.HiPeR, Japan)

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

[SMP24-11] **Metasomatic Corundum-Sapphirine-Spinel-Clinozoisite assemblage Indications for Ca-Al rich fluid**

*Krishnan Sajeev[1], S Veni[1] (1.Centre for Earth Sciences, Indian Institute of Science)

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

[SMP24-12] A geochemical perspective on tectonic setting and depositional environment of Precambrian metacarbonate rocks in collisional orogenic belts

*Madhusoodhan Satish-Kumar[1] (1.Department of Geology, Faculty of Science, Niigata University)

A comparison between carbon isotope thermometry and Raman spectra of carbonaceous material (RSCM) thermometry in low-medium grade carbonate rocks from the Chitradurga Schist Belt, Dharwar Craton

*Kiran Sasidharan[1], Madhusoodhan Satish-Kumar[1], Yoshihiro Nakamura[2], Hiroaki Ohfuji[3]

1. Niigata University, 2. Geological Survey of Japan, AIST, 3. Tohoku University

The Dharwar Craton (DC), southern India, is a much-discussed Archean terrain that encompasses rocks spanning from approximately Meso to Neoarchean. Generally, the DC is divided into the Western Dharwar Craton (WDC) and Eastern Dharwar Craton (EDC) based on the abundance of greenstone belts, volume of granitoids and grade of metamorphism (Swami Nath and Ramakrishnan, 1981; Chadwick et al., 2000). The major lithological units are the Basement Gneiss (Tonalite Tronjhemite Granodiorite gneiss), two set of volcano-sedimentary sequences and younger granitic intrusions (Jayananda et al., 2018). The oldest stratigraphic unit in the DC, the Sargur Group, occurs as enclaves in Basement Gneiss. The younger volcano-sedimentary sequence is the Dharwar Supergroup consists of lower Bababudan Group and upper Chitradurga Group. The Chitradurga Schist Belt (CSB) in the WDC is one of the granite-greenstone belts that preserves an almost complete stratigraphic section of the DC and undergone low to medium grade metamorphism. However, the metamorphic temperature within CSB using mineral thermometry (Hokada et al., 2013) is not well established due to low grade conditions. To resolve this issue, we attempted to estimate the regional-scale metamorphic temperature conditions of the CSB using carbon isotope thermometry and Raman spectra of carbonaceous material (RSCM) in the meta-carbonate rocks.

The weakly metamorphosed organic materials included in sedimentary rocks are termed as Carbonaceous Material (CM). The CM undergoes thermal maturation and subsequent recrystallisation during metamorphism is known as graphitization. The irreversible and progressive graphitization with increasing temperature forms the basis for metamorphic geothermometer such as carbon isotope thermometry in carbonate rocks and RSCM in metapelitic rocks (Beyssac et al., 2002). Exchange of isotopes between the lighter carbon (^{12}C) from CM and heavier carbon (^{13}C) from carbonate minerals during prograde metamorphism in equilibrium condition is the basis of carbon isotope thermometry (Satish-Kumar et al., 2002). Moreover, RSCM exhibits a systematic change in the crystallinity with metamorphic grade (Wopenka & Pasteris, 1993) and metamorphic temperature can be obtained using spectral features such as intensity (height) ratio R1, area (integrated intensity) ratio R2, and width (full width at half maximum; FWHM) between several prominent peaks (D1 and G peaks).

The CMs are found mainly in associated with carbonate minerals as well as in quartz as inclusions. The CM which are isolated by the silica phase were avoided for isotopic analysis, since they were not in isotopic equilibrium with the carbonate minerals. The carbon isotope thermometry results yield a metamorphic temperature of range from 340 - 560˚C estimated by using Wada and Suzuki (1983). Meanwhile, RSCM gave a temperature range from 400 - 570˚C estimated using R2 ratio (area ratio) following the calibration by Beyssac et al., (2002). Both thermometric results are corresponding to each other and observed a progression in the metamorphic temperature from upper green schist facies to lower amphibolite facies from north to south of CSB respectively. We compare the morphological, Raman spectral and carbon isotopic characteristics of CMs in low grade metamorphic rocks to evaluate the lower limit of temperature estimation using RSCM and carbon isotope thermometry. This study also provides the first report of regional metamorphic temperature gradient in the Chitradurga Schist Belt, in the Western Dharwar Craton.

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Keywords: Chitradurga Schist Belt, Carbon isotope thermometry, Raman Spectra of Carbonaceous Material thermometry

Insights into failed rift processes in the Archean, evidence from the Western Dharwar Craton, southern India.

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Field and structural geological information from different schist belts within Western Dharwar Craton (WDC), Dharwar Craton (DC), southern India are collected. Volcanic and sedimentary rocks of the WDC show characteristics evolved in a shallow-marine, narrow basin identical to a failed rift zone developed by the fracturing of basement rocks. 'Rift debris' type poorly sorted conglomerates are preserved in the boundary between Basement Gneiss and schist belts. Folded sequences of volcanic, volcanoclastic, and sedimentary rocks squeezed in between thrust/reverse faults summarizes the major structural association in the study area. This association is identical to a neotectonic inverted failed rift structure. Regional-scale strike-slip faults are also identified from the study area which is either associated with sinistral transpression or independent tectonic activity.
Geochemical signatures preserved in volcanic and volcaniclastic rocks also point to an intracratonic mafic to intermediate volcanism. The variation in the geochemical pattern can be attributed to the degree of crustal contamination during volcanism.
Field relations, structural association, and geochemical characteristics of WDC are pointing to the presence of well-preserved aborted rifts in the Archean DC. Post-3.0 Ga crustal growth throughout the Western Dharwar Craton is therefore initiated by similar failed rifting events. Multiple events of failed rifting and later basin inversion events associated with regional-scale shortening resulted in the current fold-and-thrust belt architecture of WDC. This shortening probably connected to the collision between Western Dharwar Craton and Eastern Dharwar Craton.

Keywords: Archean, Failed rift, Basin tectonics

Trace and rare earth element geochemistry of the clinopyroxene of dolerite dykes from Western Dharwar craton, southern India

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The late Archean to early Proterozoic mafic dyke swarms of the Western Dharwar craton (WDC) are significant as they represent the nature and composition of Sub-continental Lithospheric Mantle (SCLM). They provide key information regarding the mantle dynamics during the Precambrian and helps to understand the tectonic evolution of the Dharwar craton. Major and trace element zoning of the minerals like clinopyroxenes from these mantle-derived rocks are indicators of magmatic processes like fractional crystallization or magma mixing, melt extraction and compositional evolution [1, 2]. Furthermore, the rare earth element concentrations help to identify the origin and evolution of the mafic igneous rocks.

The major and trace element characteristics of the clinopyroxene from two generations of dolerite and olivine dolerite dykes of Western Dharwar Craton have been investigated by using electron microprobe and LA-ICPMS. The clinopyroxene in dolerite dykes show compositional zoning that are considered to be primary in nature. The major element analysis of the dolerite shows significant differences in Cr concentrations within the clinopyroxene grain. The core is rich in Cr_2O_3 (0.538 wt%) and the rim is poor in Cr_2O_3 (0.007 wt%). There is also a concomitant decrease in Mg# from the core (85) to the rim (51) and Cr_2O_3 content decreases towards the rim. The trace and rare earth element pattern of the core shows a depleted pattern compared to the rim. The dolerites and olivine dolerites are formed from different source magmas and the dolerites have a different fractional crystallization history. The melt composition in equilibrium with clinopyroxene was estimated and they are consistent with the bulk rock geochemical characteristics reported previously [3]. The clinopyroxene in the olivine dolerites, although doesn't show any zoning, is compositionally more primitive than the dolerites as observed by the general trace element and REE concentrations. In the case of dolerites, the Cr-rich clinopyroxene cores preserve the original melt composition prior to fractional crystallization and the trace elements and rare earth element compositions indicate the influence of subducted materials on the mantle source.

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Keywords: LA-ICPMS,, Clinopyroxene, , Dolerite dykes , Western Dharwar craton

Evidence of carbonic crustal fluid during deep to shallow crustal evolution of the interior of Eastern Ghats Belt India: Grenvillian to Kuunga orogenies

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We report an occurrence of aluminous granulite and associated gneiss metamorphosed in ultra-high temperature conditions at the continental deep crust at the Eastern Ghats Belt (EGB), India. The detailed pressure-temperature-time-fluid history is retrieved from this suite of aluminous granulite and associated gneisses from a single exposure, which were injected by granitic aplite veins at a high angle at a ductile depth of the host gneissic rocks. The sapphirine-spinel-quartz-bearing aluminous granulite reveals a peak metamorphic condition of ~1000 °C at ~8 kbar at ~990 Ma (U-Pb zircon SHRIMP age). Porphyroblastic garnet and quartz in the peak assemblage have mono-phase, high-density, CO_2-rich primary fluid inclusions (~1 g/cm^3). Secondary fluid inclusions in quartz grains of the retrograde cooled and/or decompressed assemblages of the same aluminous granulite have the signature of bi-phase CO_2-H_2O fluids with a comparatively low estimated density (0.8 g/cm^3). The CO_2 isochore plots suggest a pressure drop from 7-8 kbar to 4-5 kbar (simultaneous or after the cooling from 1000 ºC to 800 ºC). While the late aplite dykes were emplaced at an high angle with asymmetrically bent foliation of the surrounding gneiss at 492$\pm$3 Ma (monazite U-Th-total Pb EPMA age). This aplite dyke also contain numerous primary and pseudosecondary fluid inclusions in the quartz grains (CO_2 monophase to biphase at room temperature). The calculated density is in the range of 0.71-0.82 g/cm^3, suggesting the entrapment of this stage at < 3 kbar. This is the only occurrence known so far from the "orogenic interior" of the EGB that preserves the evidence of carbonic fluid presence during the evolution of UHT metamorphosed deep crust till its exhumation to shallow crust in a period encompassing the Grenvillian orogeny and the Kuunga orogeny, the later one being the age of the final cratonization of the EGB.

Keywords: Eastern Ghats Province, UHT metamorphic rocks, Zircon and monazite age dating, C-O-H fluid

Metasomatic Corundum-Sapphirine-Spinel-Clinozoisite assemblage Indications for Ca-Al rich fluid

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Sapphirine-spinel assemblage is typical in Mg-Al rich silica undersaturated ultrahigh temperature granulites. However, clinozoisite is an epidote series mineral with low to medium grade regional metamorphic or in contact metamorphic region. Corundum is usually present in silica undersaturated highly aluminous rocks. Hence it is difficult to form these minerals together unless in typical conditions or settings.
Here we report a Corundum-Sapphirine-Spinel-Clinozoisite vein with or without Ti-free högbomite from Manavadi near the Palghat-Cauvery-Shear zone in southern India. Sapphirine is identified as inclusions only within the spinel. Spinel grains are porphyroblasic and associated with clinozoisite-plagioclase assemblage along the fracture boundary associated with the host amphibolite. Högbomite is present as a later phase associated with spinel grain boundary. Spinel and clinozoisite form a partial rim around the corundum. In few other domains of the same rock consist of spinel corona over corundum and spinel growth along the amphibole grain boundaries associated with a calcite vein.
The spinel is Fe-Mg rich with slightly rich in Mg (XMg = 0.67) composition. Sapphirine is peraluminous with a composition near to 7:9:3 or even more aluminous. Sapphirine present in garnet-orthopyroxene or quartz-bearing Mg-Al rich granulite is more silica-rich. The host amphibolite is a calcium-rich sample with only clino-amphibole and plagioclase as mineral assemblage.
Based on the textural association, P-T estimates, and fluid composition, we demonstrate that sapphirine bearing assemblage formed through metasomatic reactions between a Ca-Al rich fluid and the host amphibolite. The corollary of our observation also indicates the immobile elements like aluminum can dissolve as salt in aqueous fluids and become mobile to form unique mineral assemblages. The present study also caution that many of the UHT assemblages may be resulted from metasomatic reactions that lead to misinterpretation.

Keywords: Metasomatism, Sapphirine, Al-Ca fluid

A geochemical perspective on tectonic setting and depositional environment of Precambrian metacarbonate rocks in collisional orogenic belts

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Carbonate rocks are the remnants of chemically precipitated sediments that preserve important records of paleo-oceanic continental margins, especially in Precambrian time. Although vulnerable to post-depositional alterations, pure carbonate rocks preserve geochemical proxies for understanding the depositional age and environment, and tectonic setting. A review of geochemical and isotopic characteristics is presented here to prove the versatility of metamorphosed carbonate rocks in deducing the premetamorphic signatures. The examples considered here are from East Antarctica, Sri Lanka, India, Madagascar and Africa that formed the part of the East African-Antarctic Orogen.

A comprehensive screening procedure involving field relations, C–O isotopic compositions, trace element distribution, and REE + Y patterns helped in selecting samples that preserve pre-metamorphic information. Shale-normalized REE patterns in most metacarbonate layers have typical signatures of open ocean deposition in a passive continental margin with variable fluvial input. In comparison to Phanerozoic equivalents, the absence of a Ce anomaly is most significant, whereas other REE variables such as $(La/Sm)_{SN}$, $(Sm/Yb)_{SN}$ and $(La/Yn)_{SN}$ show positive and characteristic correlations with carbon and oxygen isotopes, Sri, epsilon Nd values and Nd model ages. Each depositional basin has distinctive geochemical parameters, especially those adjacent to preexisting continents and island arcs. From a compilation of the geochemical proxies of metacarbonate rocks from different terrains in the East Gondwana supercontinent, we can identify the paleogeographic distribution of carbonate rocks with respect to their apparent depositional age and their proximity to continents. The carbonate sedimentation progressed in a wide span across what is now the East African-Antarctic Orogenic Belt probably from the early Proterozoic to the Cryogenian. In summary, extracting trace and rare earth element characteristics and comparing them with carbon, oxygen, sulfur, strontium, neodymium and lead isotopes in carefully screened unaltered metacarbonate rocks in collisional orogenic belts can help in understanding the variations in the environment of deposition, age of deposition and the tectonic setting in which they were deposited, and in decoding the history of the lost oceans.

Keywords: Metacarbonate rocks, East African Antarctic Orogen, Trace and rare earth element geochemistry, C, O, S, Sr, Nd and Pb isotope geochemistry

[E] Oral | S (Solid Earth Sciences) : S-GC Geochemistry

Sat. Jun 5, 2021 10:45 AM - 12:15 PM JST | Sat. Jun 5, 2021 1:45 AM - 3:15 AM UTC | Ch.23 Zoom Room 23

[S-GC32] Volatiles in the Earth - from Surface to Deep Mantle

convener:Takeshi Hanyu(Japan Agency for Marine-Earth Science and Technology, Research Institute for Marine Geodynamics), E Gray Bebout(Lehigh University), Yuji Sano(Division of Ocean and Earth Systems, Atmosphere and Ocean Research Institute, University of Tokyo), Hirochika Sumino(Department of General Systems Studies, Graduate School of Arts and Sciences, The University of Tokyo), Chairperson:Gray E Bebout(Lehigh University), Hirochika Sumino(Department of General Systems Studies, Graduate School of Arts and Sciences, The University of Tokyo)

Volatiles play an important role in the dynamical and chemical processes in the Earth. The presence of volatiles drastically changes mineral stability and rheological behavior of the rocks. Chemical fractionation, such as partial melting, hydration, and dehydration are controlled by volatiles in the rocks. Volatiles enhance the production of magmas and drive their ascent and volcanic eruption. The atmosphere and hydrosphere have been generated by variety of degassing events from the mantle through volcanism. Some volatiles in the Earth's surface have been suggested to be recycled back into the mantle beyond subduction zones. Although the significance of volatiles in the Earth's evolution has been recognized, each of these processes is poorly constrained. We therefore welcome contributions from experimental, observational, and modeling studies that help shed light on the behavior, chemical/physical characteristic, and flux/budget of volatiles, such as hydrogen, carbon, nitrogen, noble gases, halogens, and sulfur. We encourage studies linking the behavior of multiple volatile elements and their isotopic compositions. Studies investigating the linkage between volatile and solid geochemical tracers, the phase equilibria of volatile-bearing mantle assemblages, and the effect of volatiles on the physical properties of the mantle are also welcome.

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

[SGC32-01] Helium isotope analyses of volcanic gases and HESJ standard gas using a multi-turn time-of-flight mass spectrometer

*Yuki Hattori[1], Yoshihide Akiyama[1], Hirochika Sumino[1] (1.Graduate School of Arts and Science, The University of Tokyo)

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

[SGC32-02] Systematic depth variation of water in the lithosphere-asthenosphere boundary beneath Ichinomegata, NE Japan

*Yuto Sato[1], Eiichi Takahashi[1], Kazuhito Ozawa[2] (1.State Key Labolatory of Isotope Geochemistry, Guangzhou Institute of Geochemistry, CAS, 2.Department of Earth and Planetary Science, Graduate School of Science, The University of Tokyo)

11:15 AM - 11:45 AM JST | 2:15 AM - 2:45 AM UTC

[SGC32-03] **Impact of mantle hydration on the global carbon cycle**

★Invited Papers

*Ikuo Katayama[1] (1.Department of Earth and Planetary Systems Science, Hiroshima University)

11:45 AM - 12:15 PM JST | 2:45 AM - 3:15 AM UTC

[SGC32-04] **The story of Earth's volatile accretion and evolution**

★Invited Papers

*Sujoy Mukhopadhyay[1], Sandrine Peron[1] (1.Department of Earth and Planetary Sciences, University of California Davis, Davis, CA, USA)

Helium isotope analyses of volcanic gases and HESJ standard gas using a multi-turn time-of-flight mass spectrometer

*Yuki Hattori[1], Yoshihide Akiyama[1], Hirochika Sumino[1]

1. Graduate School of Arts and Science, The University of Tokyo

Helium isotope ratio ($^3He/^4He$ ratio) shows different values in geochemical reservoirs such as the atmosphere, crust, and mantle, depending on relative contributions of primordial and radiogenic helium. $^3He/^4He$ ratios of volcanic gases vary between magmatic (up to 1.1×10^{-5} or lower) and crustal (less than 1×10^{-7}) values. When magma becomes active, $^3He/^4He$ ratio of volcanic gas may increase due to the increased contribution of magmatic helium. Therefore, $^3He/^4He$ ratio of volcanic gas has the potential as a monitoring tool of volcanic activity. Such $^3He/^4He$ ratio increases preceding volcanic eruptions have been reported for El Hierro, Canary Islands[1], Mt. Etna, Italy[2], and Ontake, Japan[3].

Although continuous analysis of volcanic gas is necessary to monitor volcanic activity, it is difficult because a magnet-sector type mass spectrometer equipped with a massive electromagnet is currently used to analyze helium isotopes. There are two reasons why a magnet-sector type mass spectrometer is necessary. One is that adequate mass resolution is required to distinguish $^3He^+$ from HD^+, and the other is that high sensitivity is required to detect trace amounts of ^3He. For these reasons, helium isotope analysis is limited to suitable laboratory and on-site, real-time measurement of $^3He/^4He$ ratio around a volcano is almost impossible.

We have been developing a new technique of noble gas analysis using the "infiTOF" (MSI TOKYO, Inc.), which is a portable mass spectrometer derived from the multi-turn time-of-flight mass spectrometer MULTUM-S II[4, 5]. The high mass resolution achieved by an infiTOF is more than enough to distinguish $^3He^+$ from HD^+. However, the sensitivity of a normal infiTOF was far lower than the requirement to analyze noble gases in volcanic gas because most of noble gas molecules admitted to the spectrometer were pumped out by vacuum pumps directly connected to the spectrometer before ionized by an electron ionization source. Therefore, we installed valves between the spectrometer and the vacuum pumps to operate the mass spectrometer while it is isolated from the pumps. Getter pumps, which absorb active gases but not noble gases, were also installed to keep high vacuum in the spectrometer during the operation. In addition, we introduced the ion counting method for signal processing of the secondary electron multiplier to detect weak signals of ^3He ions.

As a result, it has become possible to detect a significant number of ^3He ions during analyses of volcanic gas samples. The $^3He/^4He$ ratios of samples were calibrated by comparing with the analysis of the helium standard gas (HESJ) with a known $^3He/^4He$ ratio[6]. Besides, we investigated the pressure conditions, which enable accurate measurement of $^3He/^4He$ ratios, from the stability of observed $^3He/^4He$ ratios versus the pressure of sample gas admitted to the spectrometer. It was finally demonstrated that $^3He/^4He$ ratios of volcanic gas samples, which were measured under optimized conditions and calibrated with HESJ, were consistent with those measured with a magnet-sector type mass spectrometer within analytical errors.

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[6] J. Matsuda *et al.*, *Geochem. J.*, 36(2), 191–195 (2002).

Keywords: mass spectrometry, isotope ratio, helium isotope, volcanic gas, ion counting

Systematic depth variation of water in the lithosphere-asthenosphere boundary beneath Ichinomegata, NE Japan

*Yuto Sato[1], Eiichi Takahashi[1], Kazuhito Ozawa[2]

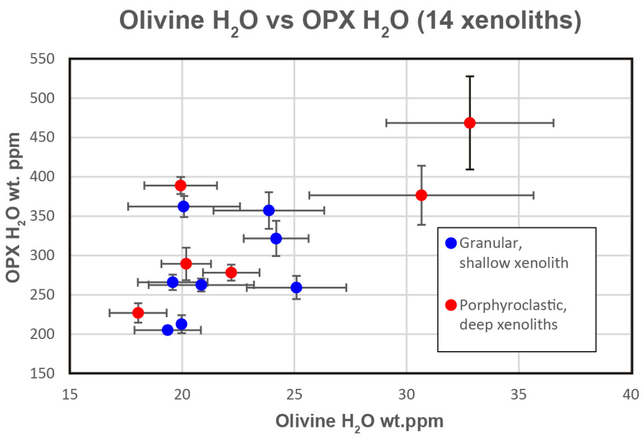
1. State Key Labolatory of Isotope Geochemistry, Guangzhou Institute of Geochemistry, CAS, 2. Department of Earth and Planetary Science, Graduate School of Science, The University of Tokyo

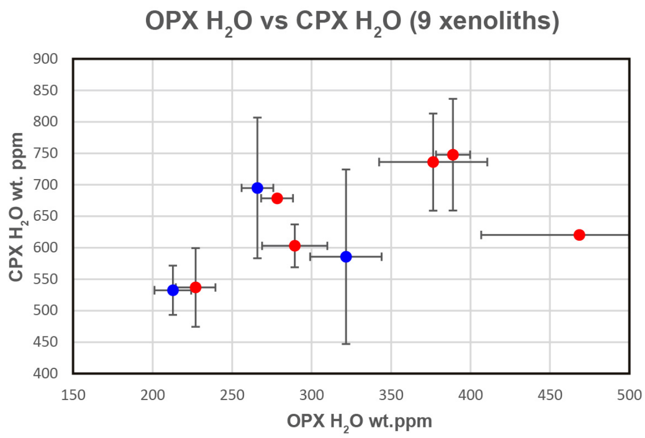
Mantle xenoliths are fragments of mantle materials rapidly brought by alkali-basalt and kimberlite magmas. They are source of information for better understanding dynamics operated in the lithosphere, asthenosphere, and their boundary. Water is one of the most important components because it significantly affects the solidus temperature (e.g., Kushiro et al, 1968) and rheological properties such as viscosity (e.g., Mei & Kohlstedt, 2000) and deformation mechanism (e.g., Jun et al., 2006). For instance, the chemical stratification of water has been considered as one of the key factors for defining lithosphere-asthenosphere boundary (LAB) (e.g., Hirth and Kohlstedt, 1996; Lee et al., 2005). In this study, we examined the role of water in defining LAB in the arc settings by analysis of water contents of minerals in mantle xenoliths from Ichinomegata maar in NE Japan, where thermal and petrologic structures of the upper mantle are constrained by our geothermobarometry (Sato & Ozawa, 2019). The mantle beneath Ichinomegata is granular, amphibole- and plagioclase-bearing, and subsolidus at the depth of 28-32 km and porphyroclastic, amphibole- and plagioclase-free, and partially molten in the depth range of 41-55 km. They correlated the former to the lithospheric mantle and the latter to the LAB-zone.

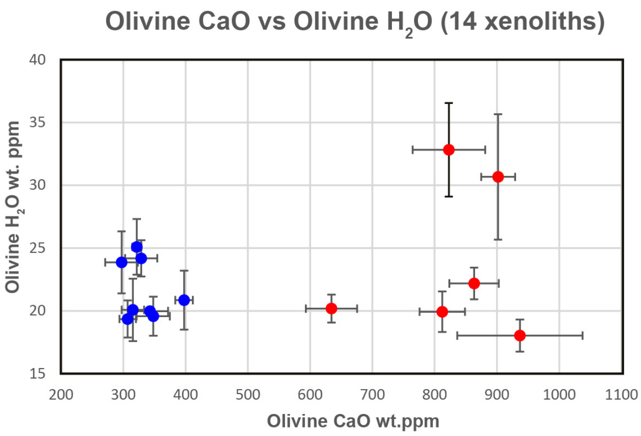
We analyzed water contents of 57 olivine, 71 orthopyroxene, and 33 clinopyroxene grains hand-picked from 14 peridotite xenoliths (2-7 grains for each mineral in each xenolith). IR spectra of three random but orthogonal sections of each grain were measured using polarized light to determine total absorbance (Libowitzky & Rossman, 1996) with a Jasco FTIR-6100 spectrometer with a Jasco IRT-5000 microscope in GIGCAS. The calibration factors determined by Bell et al., (1995; 2003) were used. The obtained water contents of olivine, orthopyroxene, and clinopyroxene range 16.8-37.0, 198-547, 477-886 wt. ppm, respectively. The error (1SD) for each grain is ~3% and that for each mineral in each xenolith is ~8%. Satsukawa et al. (2017) measured water contents of olivine and pyroxenes in peridotite xenoliths from the shallow depths. Their water contents are consistently lower than our results probably due to the selection of samples or underestimation caused by the methods. The water contents of olivine are higher than those reported from spinel peridotites (Demouchy & Bolfan-Casanova, 2016). The range of clinopyroxene is comparable to the reported range, but the highest water content of orthopyroxene exceeds the reported highest values from the world xenolith localities. These water contents in the Ichinomegata xenoliths reflect high water contents in the wedge mantle above subducting slab.

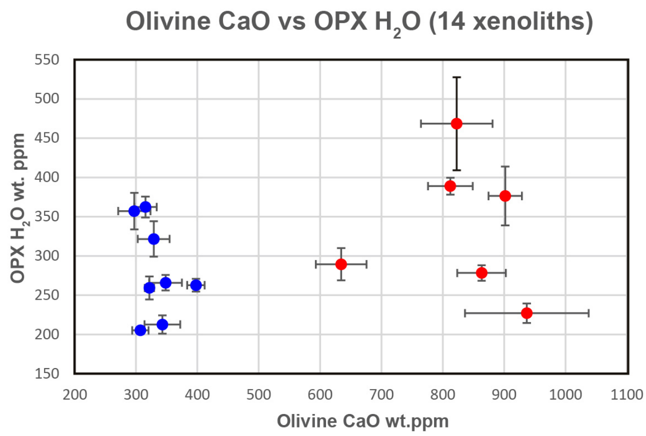
We conducted chemical analysis of olivine using EPMA (JEOL JXA-8230 in GIGCAS) to estimate the derivation depths and temperatures by combining pyroxene geothermobarometry. The CaO contents in olivine range 297-937 wt. ppm, which split into two clusters corresponding to the 8 granular samples (297-398 ppm) and 6 porphyroclastic samples (634-937 ppm). Their estimated depths range 25-48 km and temperature of 820-1055 ˚C. There are depth variations in the water contents. The water contents of olivine and pyroxenes in the granular samples are quite variable and high in the maximum and mean water contents. By contrast, those in the shallow samples are less variable and low in the maximum and mean water contents. The xenolith registering the highest water contents underwent partial melting and the deformation featuring porphyroclastic texture when it stayed at 45 km and 1024 ˚C. The estimated water contents in minerals are consistent with experimentally determined water solubility of minerals coexisting with basaltic melts containing ~5 wt.% of H_2O at 1.2 GPa and 1200 °C (Hauri et al., 2006). These suggest that water was supplied into the deeper levels corresponding to the LAB zone beneath Ichinomegata from underlying asthenospheric mantle through heterogenous paths.

Keywords: Water in Nominally Anhydrous Minerals, Subduction zone, Lithosphere-Asthenosphere Boundary, Fourier-transform infrared spectroscopy, Geothermobarometry









Impact of mantle hydration on the global carbon cycle

*Ikuo Katayama[1]

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The long-term stabilization of the Earth's surface environment is likely controlled by the global carbon cycle through the negative feedback system. The oceanic plate can capture carbon dioxide from seawater through water-rock interactions in the crust and mantle, in addition to carbonates and organic matter deposited on the seafloor, which is responsible for carbon transport to the Earth's interior. In the uppermost part of the oceanic crust, carbonates are precipitated in the volcanic rocks, filling the fractures and voids, and the carbon content tends to increase with the age of oceanic plates (e.g., Alt and Teagle 1999). On the other hand, although the amount of carbon uptake in the deep crust and mantle is not well known, if seawater penetrates along faults, carbonates are likely to be precipitated by water-rock interactions. In particular, alteration of mantle rocks can promote carbonate precipitation via increasing pH of the aqueous fluids. Extensive carbonation of peridotites is evident in the Oman ophiolite; for example, listvenite is widespread in the lower part of the ophiolite, where serpentine is completely replaced by carbonate due to metamorphic sole-derived fluids (Kelemen et al. 2013). Mantle hydration has recently been suggested along the outer-rise faults that develop in the relatively old plate subduction, such as the Japan Trench, where seawater infiltrates to mantle and extensive serpentinization is expected to occur (e.g., Fujie et al. 2013). In such case, carbonation process may have occurred during the mantle hydration, and the amount of carbon uptake in the oceanic lithosphere may have increased significantly. Although the negative feedback system of carbon cycle has contributed to the stabilization of the surface environment throughout the geological history, the extensive mantle carbonation may break the feedback system and result in global cooling. We hope that the upcoming deep drilling project at off Hawaii (Umino et al. 2020) provides a clue to understand the carbon uptake process in the deep crust and mantle.

Keywords: Carbon cycle, Mantle hydration

The story of Earth’s volatile accretion and evolution

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The geochemistry of mantle-derived lavas requires long-term differences to be preserved between different regions of the Earth’s mantle, and between the mantle and the atmosphere. Reading this history has required developing higher precision measurement techniques, which has provided a wealth of information regarding volatile accretion. Often this information has come from mantle noble gases that have recorded events during Earth’s earliest history. Being chemically inert, the evolution of noble gas isotopic and elemental ratios trace physical processes during accretion, such as magma ocean degassing, early mantle degassing and atmospheric loss. Furthermore, there are large differences in the primordial isotopic ratios of noble gases between different volatile sources, allowing one to infer the sources that contributed volatiles to Earth during accretion.

The primordial neon isotopic ratio ($^{20}Ne/^{22}Ne$) of mantle plumes, which sample material from near the core-mantle boundary and separated from the mid-ocean ridge basalt source within the first 90 Ma, is dramatically different from the atmospheric and chondritic values, but close to values of the nebular gas [1]. This observation requires early acquisition of solar neon and likely reveals the growth of the proto-Earth in the presence of a gas disk [1]. These same deep mantle materials, however, also carry the fingerprint of chondritic krypton [2,3]. This surprising observation requires concomitant acquisition of solar as well as chondritic volatiles during the early phase of Earth’s formation; chondritic volatiles, including water, were therefore added not just late in Earth’s formation.

A careful characterization of the solid Earth’s noble gas fingerprint reveals that the atmospheric noble gases cannot be related to the solid Earth noble gases through any combination of mantle outgassing and atmospheric escape. The distinct signature of the atmospheric noble gases requires their derivation from sources different from those that contributed to solid Earth after the last major interior-atmosphere equilibration –the Moon forming giant impact. While the nature of these volatile sources to the atmosphere is not entirely clear, they include comets [4.5]. Additionally, the distinct noble gas signatures of the atmosphere and mantle place constraints on the rate of volatile exchange between the interior and the surface over 4.5 Ga. In particular, the Xe isotopic composition of modern day lavas and the observation of increasing Xe isotopic mass fractionation in the Archean atmosphere indicates efficient Xe subduction into the mantle occurred after 3.0-2.5 Ga [6,7].

[1] Williams and Mukhopadhyay, Nature 565, 2018 [2] Broadley M. et al. PNAS 117, 2020. [3] Peron et al. in review. [4] Marty B. et al Science 356, 2017. [5] Bekaert D. et al., Scientific Reports 10, 2020. [6] Parai and Mukhopadhyay, Nature 560, 2018. [7] Peron and Moreira GPL 9, 2018.

Keywords: volatiles, accretion, atmosphere, giant impacts, early Earth, subduction

[E] Oral | S (Solid Earth Sciences) : S-GC Geochemistry

Sat. Jun 5, 2021 1:45 PM - 3:15 PM JST | Sat. Jun 5, 2021 4:45 AM - 6:15 AM UTC | Ch.23 Zoom Room 23

[S-GC32] Volatiles in the Earth - from Surface to Deep Mantle

convener:Takeshi Hanyu(Japan Agency for Marine-Earth Science and Technology, Research Institute for Marine Geodynamics), E Gray Bebout(Lehigh University), Yuji Sano(Division of Ocean and Earth Systems, Atmosphere and Ocean Research Institute, University of Tokyo), Hirochika Sumino(Department of General Systems Studies, Graduate School of Arts and Sciences, The University of Tokyo), Chairperson:Yuji Sano(Center for Advanced Marine Core Research, Kochi University), Takeshi Hanyu(Japan Agency for Marine-Earth Science and Technology, Research Institute for Marine Geodynamics)

Volatiles play an important role in the dynamical and chemical processes in the Earth. The presence of volatiles drastically changes mineral stability and rheological behavior of the rocks. Chemical fractionation, such as partial melting, hydration, and dehydration are controlled by volatiles in the rocks. Volatiles enhance the production of magmas and drive their ascent and volcanic eruption. The atmosphere and hydrosphere have been generated by variety of degassing events from the mantle through volcanism. Some volatiles in the Earth's surface have been suggested to be recycled back into the mantle beyond subduction zones. Although the significance of volatiles in the Earth's evolution has been recognized, each of these processes is poorly constrained. We therefore welcome contributions from experimental, observational, and modeling studies that help shed light on the behavior, chemical/physical characteristic, and flux/budget of volatiles, such as hydrogen, carbon, nitrogen, noble gases, halogens, and sulfur. We encourage studies linking the behavior of multiple volatile elements and their isotopic compositions. Studies investigating the linkage between volatile and solid geochemical tracers, the phase equilibria of volatile-bearing mantle assemblages, and the effect of volatiles on the physical properties of the mantle are also welcome.

1:45 PM - 2:15 PM JST | 4:45 AM - 5:15 AM UTC

[SGC32-05] H/D partitioning between forsterite, wadsleyite and ringwoodite : ab initio free energy calculation

★Invited Papers

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

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

[SGC32-06] **Volatile characteristics of Central American geothermal fluids**8.6.0

★Invited Papers

*Peter H Barry[1], David V Bekaert[1], J M de Moor[2], Jabrane Labidi[3], Esteban Gazel[4], M Nakagawa[5], Donato Giovannelli[6], Matt Schrenk[7], Karen G Lloyd[8] (1.Woods Hole Oceanographic Institution, 2.Observatorio Volcanológico y Sismológico de Costa Rica (OVSICORI), Universidad Nacional, Costa Rica, 3.Université de Paris, Institut de physique du globe de Paris, CNRS, Paris, France, 4.Department of Earth and Atmospheric Sciences, Cornell University, Ithaca, New York 14853, USA, 5.Earth-Life Science Institute, Tokyo Institute for Technology, Tokyo, Japan, 6.Department of Biology, University of Naples “Federico II”, Naples, Italy, 7.Department of Earth and Environmental Sciences, Michigan State University, MI, USA, 8.Department of Microbiology, University of Tennessee, TN, USA)

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

[SGC32-07] Halogen and noble gas compositions of mantle wedge and subducted sediment, recorded in metamorphic rocks from the Sanbagawa belt

*JIE REN[1], Hirochika Sumino[1], Yui Kouketsu[2], Simon Richard Wallis[3] (1.Graduate School of Arts and Sciences, The University of Tokyo , 2.Graduate School of Environmental Studies, Nagoya University, 3.Graduate School Sciences, The University of Tokyo)

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

[SGC32-08] Discussion

H/D partitioning between forsterite, wadsleyite and ringwoodite : ab initio free energy calculation

*Jun Tsuchiya[1], Taku Tsuchiya[1]

1. Geodynamics Research Center, Ehime University

Deuterium is the heavy stable isotope of hydrogen. The D/H ratio shows large variation in various astronomical bodies such as protosolar nebula ($2x10^{-5}$), Earth (SMOW= 1.5×10^{-4}, average seawater), Venus ($1.6x10^{-2}$) and carbonaceous chondrites (~$2x10^{-4}$) (e.g. Saal et al. 2013). Many studies are conducted to determine the D/H ratio in various rocks with different origins of the Earth, since this may be the key to understand the evolutional history and the origin of water of the Earth.
Many studies suggest that hydrous minerals in subducting cold slabs can transport water into deep Earth’s interiors. There is a possibility that several times of sea water exist in the transition zone at depth between 410km and 660 km if the constituent minerals are largely hydrated (e.g. Smyth 1994). Recently, hydrous ringwoodite with 1 wt%H_2O has been found in natural diamond, suggesting that the transition zone is at least locally hydrated (Pearson et al. 2014). Therefore, the D/H ratio may be changed by the partitioning behaviors of D and H among these mantle minerals by the circulation of water in deep interiors.
In this study, we determined the free energy of D and H bearing forsterite, wadsleyite and ringwoodite by ab initio calculation in order to determine the equilibrium constants of D and H isotopic exchange reactions between them. First, we determined the stable structures of hydrous forsterite, wadsleyite and ringwoodite with Mg vacancy with two hydrogen atoms or Si vacancy with four hydrogen atoms by first principles calculation based on density functional theory. Then, the phonon frequencies are calculated based on density functional perturbation theory (Baroni et al. 2001) and also by the finite displacement method (Parlinski et al. 1997, Togo and Tanaka 2015). Then, we used quasi-harmonic approximation to calculate the Gibbs free energy of H and D baring phases. In this presentation, we report the Gibbs free energy of isotopic exchange reaction between forsterite and wadsleyite, and also between wadsleyite and ringwoodite.

Keywords: ab initio calculation, high pressure, H/D partitioning

Volatile characteristics of Central American geothermal fluids8.6.0

*Peter H Barry[1], David V Bekaert[1], J M de Moor[2], Jabrane Labidi[3], Esteban Gazel[4], M Nakagawa[5], Donato Giovannelli[6], Matt Schrenk[7], Karen G Lloyd[8]

1. Woods Hole Oceanographic Institution, 2. Observatorio Volcanológico y Sismológico de Costa Rica (OVSICORI), Universidad Nacional, Costa Rica, 3. Université de Paris, Institut de physique du globe de Paris, CNRS, Paris, France, 4. Department of Earth and Atmospheric Sciences, Cornell University, Ithaca, New York 14853, USA, 5. Earth-Life Science Institute, Tokyo Institute for Technology, Tokyo, Japan, 6. Department of Biology, University of Naples "Federico II", Naples, Italy, 7. Department of Earth and Environmental Sciences, Michigan State University, MI, USA, 8. Department of Microbiology, University of Tennessee, TN, USA

Earth's various mantle reservoirs (e.g., depleted mid ocean ridge basalt (MORB) mantle, plume mantle source) retain distinct volatile geochemical features that inform our understanding of planetary accretion, mantle convection and mixing, as well as subduction-driven recycling processes. At subduction zones, volatile elements (e.g., helium, carbon, nitrogen) are actively cycled between terrestrial reservoirs by plate tectonics. The efficiency of volatile transfers between Earth's interior (crust and mantle) and exterior (atmosphere and oceans) controls Earth's redox conditions, mantle heterogeneities and atmospheric evolution. The distribution of terrestrial volatiles, which is controlled by the long-term balance between volcanism and recycling, has enabled conditions favorable for life on Earth. Despite the importance of volatile elements on a global scale, their fluxes and sources (slab vs. mantle), and sinks however remain under-constrained, particularly in subduction-related fluids.

The Central America Volcanic Arc (CAVA), is one of the best studied[1,2,3] arc segments globally. However, relatively few studies have focused on constraining volatile fluxes throughout the southern segment of the CAVA due to the lack of active volcanism in the region. This area is tectonically unique, as the border between Costa Rica and Panama represents the transition between the orthogonal subduction of the Cocos Plate and the oblique subduction of the Nazca Plate relative to the Caribbean Plate. Here, we present unpublished He, CO_2 and N_2 isotope and relative abundance data from geothermal fluids in southern Costa Rica and western Panama. In total, isotope data are reported for 65 deeply sourced wells, seeps and springs, as well as gas samples. These data reveal a clear southeastward increase in $^3He/^4He$, from typical volcanic arc values (about 7 times the atmospheric ratio, R_A) in Costa Rica, up to MORB-like values (8 plus/minus1 R_A) in the volcanically-dormant region of western Panama. Remarkably, "cold" seeps in Panama display $^3He/^4He$ up to 8.9 R_A, equivalent to the highest values ever reported for active volcanic arc settings worldwide. These data suggest contribution from a ^3He-rich mantle source under western Panama, potentially associated with the Galapagos plume. $d^{13}C$ vary from −29.7‰ to +6.7‰ vs. PDVB, suggesting CO_2 loss due to calcite precipitation, as it has been recently shown in Costa Rica's Nicoya Peninsula[4]. N isotopes and clumped N isotopologues[5] in CAVA samples cluster around +5‰ vs. air, suggesting N is mainly derived from sediments. Flux considerations suggest that subducting N may be quantitatively recycled into the arc, although uncertainties on fluxes allow up to 63% of slab-N to be transported into the mantle past the arc melting region, which is consistent with previous studies[6,7]. In summary, we show evidence for 1) the existence of a pervasive (plume) mantle component in southern CAVA samples, and 2) extensive CO2 fractionation during low temperature C sequestration as calcite in the forearc region and 3) strong N sediment signatures in arc fluids.

By combining these findings with other geochemical tracers (clumped N-isotopes, Pb isotopes, Ce/Pb[8]) and high-resolution simulations of global mantle flow around the Galapagos plume[9], we conclude that there may be an asthenospheric "pipeline" connecting the Galapagos plume to a slab window that formed via subduction of a spreading ridge under western Panama[10,11]. This finding is globally significant, as the lateral entrainment and dispersal of plume material by large-scale asthenospheric mantle winds provides a straightforward explanation for the worldwide observation of OIB-like geochemical signatures in mantle domains that are remote from plume sources.

[1] Shaw et al., 2003.

[2] De Leeuw et al., 2007.

[3] de Moor et al., 2017.

[4] Barry et al., 2019.

[5] Labidi et al., 2021 (In Review - EPSL).

[6] Busigny et al. (2019)

[7] Bekaert et al., 2021.

[8] Gazel et al. 2011.

[9] Conrad and Behn 2010.

[10] Herrstrom et al. 1995.

[11] Abratis and Wörner 2001. 8.6.0

Keywords: Carbon, Helium, Nitrogen, Central America, Costa Rica, Panama

Halogen and noble gas compositions of mantle wedge and subducted sediment, recorded in metamorphic rocks from the Sanbagawa belt

*JIE REN[1], Hirochika Sumino[1], Yui Kouketsu[2], Simon Richard Wallis[3]

1. Graduate School of Arts and Sciences, The University of Tokyo , 2. Graduate School of Environmental Studies, Nagoya University, 3. Graduate School Sciences, The University of Tokyo

Subduction of crustal rocks results in transportation of volatiles into the mantle, which can have a major effect on the chemical and physical properties of constituent rocks. Volatile transport also plays an important role in arc volcanism and seismicity. However, the details of volatile cycling process remain debated. The distinct elemental and/or isotopic compositions of halogens and noble gases in different reservoirs (e.g. MORB-source mantle, seawater, subducted sediments and igneous rocks) make them good tracers for fluid origin in subduction zones. We analyzed the halogen and noble gas compositions in a series of metamorphic rocks that recorded a paleo slab-mantle wedge boundary *(Kawahara et al, 2016)*. Analyzed samples are ultramafic serpentinite (derive from the mantle wedge) and schist (derive from subducted sediment) located in the Mt. Shiraga region of the Sanbagawa belt in central Shikoku.

In order to determine the trace amounts of halogens, especially those contained in fluid inclusions, a portion of each sample was neutron-irradiated in the Kyoto University Research Reactor to convert halogens (^{37}Cl, ^{79}Br and ^{127}I) to noble gas isotopes (^{38}Ar, ^{80}Kr,^{128}Xe), which have lower detection limits than direct analyses of halogens with other methods. Stepwise crushing and heating processes were conducted in order to extract volatiles contained in different sites of the rocks. The irradiated and un-irradiated portions were analyzed by noble gas mass spectrometry at the University of Tokyo, to determine halogen and noble gas compositions respectively.

The halogen compositions of fluids obtained by crush extraction show relatively high I/Cl ratios with stable Br/Cl ratios compared with halogens in MORB-mantle or seawater. These features are similar to the data for the nearby Higashi-akaishi mantle wedge peridotite exhumed from ~100 km depth *(Sumino et al, 2010)*, which are considered to partially preserve the signals of sedimentary pore fluids. In addition, the serpentinite body shows overall decreasing I/Cl ratios with increasing distance from the subduction boundary. This supports the idea that the original high I/Cl fluids were transported along the subduction interface and penetrated upward into the mantle wedge.

The isotopic data of the noble gases are complex. Neon and Argon isotopic compositions are almost overwhelmed by the seawater/atmosphere component. Helium shows distinct and diverse ^{3}He/^{4}He ratios, which is likely to be strongly influenced by the cosmic ray, producing ^{3}He preferentially. Nevertheless, a radiogenic ^{3}He/^{4}He component possibly derived from subducted crust/sediment was identified in the fluids extracted from the serpentinite body, which is similar to slab-derived fluids preserved in the Higashi-akaishi peridotite *(Sumino et al, 2010)*. This adds support to the idea that the shallow part of mantle wedge has been influenced by addition of volatiles from the subducted slab.

Keywords: Mantle wedge, Sanbagawa belt, Halogen, Noble gas

[E] Oral | S (Solid Earth Sciences) | S-GC Geochemistry

[S-GC32] Volatiles in the Earth - from Surface to Deep Mantle

convener:Takeshi Hanyu(Japan Agency for Marine-Earth Science and Technology, Research Institute for Marine Geodynamics), E Gray Bebout(Lehigh University), Yuji Sano(Division of Ocean and Earth Systems, Atmosphere and Ocean Research Institute, University of Tokyo), Hirochika Sumino(Department of General Systems Studies, Graduate School of Arts and Sciences, The University of Tokyo), Chairperson:Yuji Sano(Center for Advanced Marine Core Research, Kochi University), Takeshi Hanyu(Japan Agency for Marine-Earth Science and Technology, Research Institute for Marine Geodynamics)

Sat. Jun 5, 2021 1:45 PM - 3:15 PM Ch.23 (Zoom Room 23)

Volatiles play an important role in the dynamical and chemical processes in the Earth. The presence of volatiles drastically changes mineral stability and rheological behavior of the rocks. Chemical fractionation, such as partial melting, hydration, and dehydration are controlled by volatiles in the rocks. Volatiles enhance the production of magmas and drive their ascent and volcanic eruption. The atmosphere and hydrosphere have been generated by variety of degassing events from the mantle through volcanism. Some volatiles in the Earth's surface have been suggested to be recycled back into the mantle beyond subduction zones. Although the significance of volatiles in the Earth's evolution has been recognized, each of these processes is poorly constrained. We therefore welcome contributions from experimental, observational, and modeling studies that help shed light on the behavior, chemical/physical characteristic, and flux/budget of volatiles, such as hydrogen, carbon, nitrogen, noble gases, halogens, and sulfur. We encourage studies linking the behavior of multiple volatile elements and their isotopic compositions. Studies investigating the linkage between volatile and solid geochemical tracers, the phase equilibria of volatile-bearing mantle assemblages, and the effect of volatiles on the physical properties of the mantle are also welcome.

3:00 PM - 3:15 PM

[SGC32-08]Discussion

[E] Oral | S (Solid Earth Sciences) : S-CG Complex & General

Sat. Jun 5, 2021 10:45 AM - 12:15 PM JST | Sat. Jun 5, 2021 1:45 AM - 3:15 AM UTC | Ch.21 Zoom Room 21

[S-CG39] Science of slow earthquakes: Toward unified understandings of whole earthquake process

convener:Satoshi Ide(Department of Earth an Planetary Science, University of Tokyo), Hitoshi Hirose(Research Center for Urban Safety and Security, Kobe University), Kohtaro Ujiie(Faculty of Life and Environmental Sciences, University of Tsukuba), Takahiro Hatano(Department of Earth and Space Science, Osaka University), Chairperson:Kohtaro Ujiie(Faculty of Life and Environmental Sciences, University of Tsukuba)

Accumulating observational studies on various types of slow deformation events, such as tectonic tremors, very low frequency events, and slow slip events, portrays some universal characteristics in generally complex behavior, including interaction among events and influence by various outer loading. Some of these phenomena seem to have causal relation with the occurrence of very large earthquakes. A unified understanding of these slow and fast earthquake processes requires an approach integrating geophysics, seismology, geodesy, geology, and non-equilibrium statistical physics. We welcome presentations based on, but not limited to, geophysical observation, data analysis, analytical theory, numerical simulation, field study, and laboratory experiments.

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

[SCG39-01] The stabilizing effect of pore-fluid pressure along subduction megathrust faults: Evidence from experiments on Nankai Trough sediments

*John D Bedford[1,2], Daniel R Faulkner[2], Michael J Allen[2], Takehiro Hirose[1] (1.JAMSTEC, 2.Univ. of Liverpool)

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

[SCG39-02] **Depth-dependent deep-slow earthquakes controlled by temperature dependence of brittle-ductile transitional rheology**

*Ryosuke Ando[1], Kohtaro Ujiie[2], Naoki Nishiyama[2], Yasushi Mori[3] (1.Graduate School of Science, University of Tokyo, 2.Graduate School of Life and Environmental Sciences, University of Tsukuba, 3.Kitakyushu Museum of Natural History and Human History)

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

[SCG39-03] **Localized megathrust slip controlled by chemical reactions in subduction mélanges**

*Kohtaro Ujiie[1], Kazuya Noro[2], Norio Shigematsu[3], Ake Fagereng[4], Naoki Nishiyama[1], Christopher Tulley[4], Haruna Masuyama[2], Yasushi Mori[5] (1.Faculty of Life and Environmental Sciences, University of Tsukuba, 2.Graduate School of Life and Environmental Sciences, University of Tsukuba, 3.Geological Survey of Japan, National Institute of Advanced Industrial Science and Technology, 4.School of Earth and Environmental Sciences, Cardiff University, 5.Kitakyushu Museum of Natural History and Human Histor)

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

[SCG39-04] Lithological heterogeneity and fluid flow related to seamount subduction: an exhumed example from Amami-Oshima Island

*Madison Frank[1], Ginta Motohashi[1], Kohtaro Ujiie[2] (1.Graduate School of Life and Environmental Sciences, University of Tsukuba, 2.Faculty of Life and Environmental Sciences, University of Tsukuba)

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

[SCG39-05] Constraints on silica transport along subduction boundaries based on volume change estimates of metamorphic rocks

*Shogo Soejima[1], Simon Richard Wallis[1] (1.Department of Earth and Planetary Science, Graduate School of Science, The University of Tokyo)

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

[SCG39-06] Discussion

The stabilizing effect of pore-fluid pressure along subduction megathrust faults: Evidence from experiments on Nankai Trough sediments

*John D Bedford[1,2], Daniel R Faulkner[2], Michael J Allen[2], Takehiro Hirose[1]

1. JAMSTEC, 2. Univ. of Liverpool

Pore-fluid pressure is an important parameter in controlling fault mechanics as it lowers the effective normal stress allowing fault slip at lower shear stress. It is also thought to influence the nature of fault slip, particularly in subduction zones where the occurrence of slow-slip has been linked to areas of elevated pore-fluid pressure. Despite the importance of pore-fluid pressure on fault mechanics, its role on controlling fault stability, which is determined by the friction rate parameter (a-b), is poorly constrained, particularly for fault materials from subduction zones. In the winter of 2018-19 the accretionary complex overlying Nankai Trough subduction zone (SW Japan) was drilled as part of Integrated Ocean Drilling Program (IODP) Expedition 358. Here we test the frictional stability of the accretionary sediments recovered during the expedition by performing a series of velocity-stepping experiments on simulated fault gouges while systematically varying the pore-fluid pressure and effective normal stress conditions. The Nankai gouges are strongly rate-strengthening and exhibit negative values for the rate-and-state parameter b. We find that for experiments where the effective normal stress is held constant and the pore-fluid pressure is varied the Nankai gouges become more rate-strengthening, and thus more stable, at higher pore-fluid pressures. In contrast, when the pore-fluid pressure is held constant and the effective normal stress is varied, there is minimal effect on the frictional stability of the gouge. The increase in frictional stability of the gouge at elevated pore-fluid pressure is caused by an evolution in the rate-and-state parameter b, which becomes more negative at high pore-fluid pressure. These results have important implications for understanding the nature of slip in subduction zones and suggest the stabilizing effect of pore-fluid pressure could promote slow-slip or aseismic creep on areas of the subduction interface that might otherwise experience earthquake rupture.

Keywords: Slow slip, Pore-fluid pressure, Nankai Trough, Fault friction

Depth-dependent deep-slow earthquakes controlled by temperature dependence of brittle-ductile transitional rheology

*Ryosuke Ando[1], Kohtaro Ujiie[2], Naoki Nishiyama[2], Yasushi Mori[3]

1. Graduate School of Science, University of Tokyo, 2. Graduate School of Life and Environmental Sciences, University of Tsukuba, 3. Kitakyushu Museum of Natural History and Human History

Recent geophysical observations have classified the deep-slow earthquakes, down-dip the seismogenic zone, into Long-term Slow Slip Events (L-SSEs), Short-term Slow Slip Events (S-SSEs), and Low-frequency earthquakes (LFEs) and tremor in the order from slow to fast. The same ordering has also become recognized as converted from the shallow to the deep in the source depths, apparently contradicting the well-established transitional behavior from the shallower brittle/fast regime to the deeper ductile/slow regime, as described by the "seismogenic inversion layer". Here we propose a new mechanical model that can consistently explain these two, only by considering the competitive temperature-dependent effects on the fraction of the brittle material, *Rb*, and the viscosity of the ductile material, η, in fault zones. Our model is geologically motivated and is an extension of the previous physical model with the brittle-ductile heterogeneity on faults. The key to understanding the enigmatic depth dependencies is that the reduction of η is more significant than the reduction of *Rb* as increasing temperature. Our results highlight the importance of rock plasticity, rather than friction, and rheological heterogeneity as universal mechanisms of deep-slow earthquakes independent of tectonic environments.

Keywords: Rheology, Fault rocks, Mathematical model, SSEs, LFEs, Heterogeneity

Localized megathrust slip controlled by chemical reactions in subduction mélanges

*Kohtaro Ujiie[1], Kazuya Noro[2], Norio Shigematsu[3], Ake Fagereng[4], Naoki Nishiyama[1], Christopher Tulley[4], Haruna Masuyama[2], Yasushi Mori[5]

1. Faculty of Life and Environmental Sciences, University of Tsukuba, 2. Graduate School of Life and Environmental Sciences, University of Tsukuba, 3. Geological Survey of Japan, National Institute of Advanced Industrial Science and Technology, 4. School of Earth and Environmental Sciences, Cardiff University, 5. Kitakyushu Museum of Natural History and Human Histor

Megathrust slip down-dip of the seismogenic zone is accommodated by either steady creep or episodic slow slip events (SSEs). However, the geological conditions defining the rheology of megathrust slip remain elusive. Field observation and laboratory analyses show that subduction mélanges deformed at ~370–500 °C in warm-slab environments record fluid release and viscous shear localization associated with chemical reactions between juxtaposed metapelitic and metabasaltic rocks. In the mélange deformed near the base of the seismogenic zone, very fine-grained reaction products facilitated grain boundary diffusion creep at lower shear stresses than surroundings, whereas in the mélange deformed near the mantle wedge corner, chemical reactions led to viscous shear at two orders of magnitude faster strain rate than surroundings. We suggest that chemical reactions facilitate localized changes in megathrust slip mode with depth, potentially providing a mechanism for change from viscous creep to SSEs.

Lithological heterogeneity and fluid flow related to seamount subduction: an exhumed example from Amami-Oshima Island

*Madison Frank[1], Ginta Motohashi[1], Kohtaro Ujiie[2]

1. Graduate School of Life and Environmental Sciences, University of Tsukuba, 2. Faculty of Life and Environmental Sciences, University of Tsukuba

Recent geophysical surveys and deep ocean drilling revealed that shallow slow earthquakes have been spatially and temporally correlated to lithological heterogeneity associated with the subduction of seamounts. Furthermore, it has been proposed that the rise in fluid pressure and fluid flow on the leading edge of the seamount during subduction results in tectonic tremor. However, geological perspective of shallow slow earthquakes related to seamount subduction remains elusive. Our preliminary geologic investigations conducted on an exhumed accretionary complex exposed in Amami-Oshima Island, Ryukyu Arc reveal a section containing mélange sequences related to subduction of a seamount. Outcrops include altered basalt, a sequence of variable limestone and low grade basaltic sediments, and a mudstone dominated sequence showing a block-in-matrix fabric. A complex quartz vein network is present in the mudstone dominated mélange where extensional fractures have formed in competent blocks. Viscous shear was accommodated along the mixed rocks composed of limestone and basaltic materials, which is consistent with lithological heterogeneity inferred for the shallow slow slip source region. The quartz-filled fracture network in the mudstone dominated mélange may represent tremorgenic fluid flow along brittle fractures that occurred near the subducting seamount. We suggest that the exhumed section at Amami-Oshima Island is representative of the source conditions under which shallow slow earthquakes occur during seamount subduction.

Keywords: seamount, subduction, slow earthquakes, mélange, lithological heterogeneity, Amami-Oshima Island

Constraints on silica transport along subduction boundaries based on volume change estimates of metamorphic rocks

*Shogo Soejima[1], Simon Richard Wallis[1]

1. Department of Earth and Planetary Science, Graduate School of Science, The University of Tokyo

Transport of significant quantities of SiO2 along subduction boundaries has been highlighted as important in processes such as silicification of the lower crust that may influence the time scales of slow earthquakes and the formation of a broad antigorite-rich domain along the base of the wedge mantle. The source of such silica is thought to be subducted quartz-rich sediments and water-rich fluids transported along the subduction boundary have the potential to transport silica over large distances. However, there are few studies that can help place bounds of the amount of silica that has been transported in subducted rocks. The removal of silica from one domain and its redeposition in another should be related to large changes in rock volume. The changes in volume that are important are those that take place at depth where the metamorphic temperature is the greatest and where the rocks are influenced by deep-sourced fluids. Previously proposed methods to estimate the volume change of rocks can be broadly classified into two categories: geometric methods based on strain estimates including absolute stretching, and chemical methods based on the bulk chemical compositions. However, application of the geometric methods to slate belts generally indicates large volume decreases not recognized by chemical methods. Possible reasons for this discrepancy are: uncertainties associated with assumptions about the original composition and the nature of immobile elements may and lack of good methods to assess the contribution of grain boundary sliding to bulk rock deformation. This study examines how orientations and deformation types of deformed mineral vein sets can be used to estimate volume change. This possibility of using this approach has been previously recognized but its practical application has been little studied. The deformed vein set analysis method is potentially more reliable than other geometric approaches because veins develop on scales much larger than individual grains and should record the otherwise hidden contribution to deformation by grain boundary sliding. In this study we developed a new approach that incorporates a statistical analysis to evaluate appropriate uncertainties. The newly developed approach was applied to analyze deformed metagreywacke in the Del Puerto canyon of the Franciscan belt. The analysis allows constraints to be placed on all three components of finite deformation: strain, mean vorticity number and volume change. The results are compatible with negligible volume change but also allow for significant volume increase. The results are not compatible with previously estimated significant amounts of volume reduction in the same region based on grain-scale analysis. The lack of prominent overgrowths around individual grains suggests that any volume increase is limited. Strain analysis using the Rf / ϕ method applied to individual grains showed maximum shortening was about 50%, implying that about 10% of strain was provided by grain boundary sliding. Furthermore, comparing the results of the Rf / ϕ method with those of the deformed vein sets method, it is suggested that the deformation during subduction is negligible compared to that developed during exhumation. The lack of volume change implies a lack of large-scale silica transport in the region either due to a limited fluid flux and/or silica saturation. This implies that there is not sufficient silica to form antigorite domains with kilometer-scale thicknesses or forming major silicification of the lower crust. Our data suggest that zones of antigorite-rich domains along the base of the mantle wedge will be more limited than generally thought and processes other than silica deposition may control time scales of slow earthquakes.

Keywords: Volume change, Deformed vein, Slow earthquakes, Silica transport

[E] Oral | S (Solid Earth Sciences) | S-CG Complex & General

[S-CG39] Science of slow earthquakes: Toward unified understandings of whole earthquake process

convener:Satoshi Ide(Department of Earth an Planetary Science, University of Tokyo), Hitoshi Hirose(Research Center for Urban Safety and Security, Kobe University), Kohtaro Ujiie(Faculty of Life and Environmental Sciences, University of Tsukuba), Takahiro Hatano(Department of Earth and Space Science, Osaka University), Chairperson:Kohtaro Ujiie(Faculty of Life and Environmental Sciences, University of Tsukuba)

Sat. Jun 5, 2021 10:45 AM - 12:15 PM Ch.21 (Zoom Room 21)

Accumulating observational studies on various types of slow deformation events, such as tectonic tremors, very low frequency events, and slow slip events, portrays some universal characteristics in generally complex behavior, including interaction among events and influence by various outer loading. Some of these phenomena seem to have causal relation with the occurrence of very large earthquakes. A unified understanding of these slow and fast earthquake processes requires an approach integrating geophysics, seismology, geodesy, geology, and non-equilibrium statistical physics. We welcome presentations based on, but not limited to, geophysical observation, data analysis, analytical theory, numerical simulation, field study, and laboratory experiments.

12:00 PM - 12:15 PM

[SCG39-06]Discussion

[E] Oral | S (Solid Earth Sciences) : S-CG Complex & General

Sat. Jun 5, 2021 1:45 PM - 3:15 PM JST | Sat. Jun 5, 2021 4:45 AM - 6:15 AM UTC | Ch.21 Zoom Room 21

[S-CG39] Science of slow earthquakes: Toward unified understandings of whole earthquake process

convener:Satoshi Ide(Department of Earth an Planetary Science, University of Tokyo), Hitoshi Hirose(Research Center for Urban Safety and Security, Kobe University), Kohtaro Ujiie(Faculty of Life and Environmental Sciences, University of Tsukuba), Takahiro Hatano(Department of Earth and Space Science, Osaka University), Chairperson:Takahiro Hatano(Department of Earth and Space Science, Osaka University)

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

[SCG39-07] Systematic understanding of the slip-front-propagation velocity in terms of Linear Marginal Stability Hypothesis

*Takehito Suzuki[1] (1.Department of Physics and Mathematics, Aoyama Gakuin University)

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

[SCG39-08] Effects of periodic stress perturbations on earthquake nucleation

*Takuya Saito[1], Takahiro Hatano[2] (1.Aoyama Gakuin University, 2.Osaka University)

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

[SCG39-09] Feasibility of periodic solution in Rate-State friction Law

*Ryo Mizushima[1], Takahiro Hatano[1] (1.Department of Earth and Space Science, Osaka University)

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

[SCG39-10] **Slow earthquake signatures in the ratio between acoustic and internal gravity wave amplitudes in coseismic ionospheric disturbances**

*Kosuke Heki[1], Yuki Takasaka [1] (1.Department of Earth and Planetary Sciences, Faculty of Science, Hokkaido University)

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

[SCG39-11] Observation of shallow slow slip event propagating updip to the trough in the Nankai Trough.

*Eiichiro Araki[1], Takeshi Iinuma[1], Yojiro Yamamoto[1], Toshinori Kimura[1], Yuya Machida[1], Ryoichiro Agata[1], Keisuke Ariyoshi[1], Tsuyoshi Ichimura[2], Takane Hori[1], Shuichi Kodaira[1] (1.Japan Agency for Marine-Earth Science and Technology, 2.Earthquake Research Insitute, the University of Tokyo)

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

[SCG39-12] Discussion

Systematic understanding of the slip-front-propagation velocity in terms of Linear Marginal Stability Hypothesis

*Takehito Suzuki[1]

1. Department of Physics and Mathematics, Aoyama Gakuin University

Slip-front-propagation on an interface between two media has attracted interests of many researchers in scientific and industrial fields. In particular, the slip-front-propagation velocity has been obtained using some friction laws such as the slip-velocity-dependent law. Notably, to obtain the propagation velocity, Linear Marginal Stability Hypothesis (LMSH) has been widely employed. First, LMSH assumes the plane wave solution for the slip profile near the slip front, i.e., u~exp(i (k x-omega t)), where u is the slip and k and omega are the complex wave number and frequency, respectively. The imaginary parts of k and omega are written as k_i and $omega_i$, respectively, and the slip-front-propagation velocity is given by $v=omega_i/k_i$. We consider the friction law depending on both the slip and slip velocity, leading to two model parameters in the governing equation. We therefore assume that the terms C_1 u and C_2 \dot{u}, where C_1 and C_2 are the constants, emerge in the governing equation for u. We have obtained the cubic equation for $omega_i$ using LMSH, and found that the numbers of the solutions for $omega_i$ can be categorized into 12 regions on the C_1-C_2 phase space. Here, we aim to categorize the slip-front-propagation velocity on the C_1-C_2 phase space, and give some implications associated with slow earthquakes.

We should emphasize that the slip front has two forms: the intruding and extruding fronts (see details in Suzuki and Matsukawa, 2019). Actually, we have obtained the analytical solutions for $omega_i$, and they are called $omega^{in}_1$, $omega^{in}_2$, and $omega^{in}_3$ for the intruding front, and $omega^{ex}_1$, $omega^{ex}_2$, and $omega^{ex}_3$ for the extruding front. Using these values and the relationship between k_i and $omega_i$, we have also obtained the analytical forms of k_i, which are called k^{in}_1, k^{in}_2, and k^{in}_3 for the intruding front, and k^{ex}_1, k^{ex}_2, and k^{ex}_3 for the extruding front. Therefore, we can write analytical forms for the intruding and extruding slip-front-propagation velocities, $v^{in}_j=omega^{in}_j/k^{in}_j$ and $v^{ex}_j=omega^{ex}_j/k^{ex}_j$ (j=1,2,3), respectively.

In terms of the solutions of v^{in}_j and v^{ex}_j, the C_1-C_2 phase space is divided into 7 regions. They are the regions with (A) v^{in}_1, (B) v^{ex}_1, (C) v^{in}_1 and v^{ex}_2, (D) v^{ex}_1 and v^{ex}_3, (E) v^{in}_1, v^{ex}_2, and v^{in}_3, (F) v^{in}_1, v^{ex}_2, and v^{ex}_3, and (G) no propagation velocity. In particular, we emphasize that there exists the region where v^{in}_j or v^{ex}_j does not exist. This region cannot generate the steady slip-front-propagation, and may imply the generation of slow earthquakes from seismological viewpoint.

Keywords: slip-front-propagation velocity, friction law, Linear Marginal Stability Hypothesis

Effects of periodic stress perturbations on earthquake nucleation

*Takuya Saito[1], Takahiro Hatano[2]

1. Aoyama Gakuin University, 2. Osaka University

One of the crucial methods to discover underlying physics is to investigate a mechanical response. This idea is inherent not only in laboratory scale, but applicable to a kilometer-scale fault [1]. Recent studies have been showing a high susceptibility of tremors in slow earthquake [2], which may be sorted into an issue of the mechanical response. This study numerically investigates effects on earthquake nucleation growths of periodic stress perturbations like ocean tides. By assuming the rate- and state-dependent friction law on a flat fault embedded in an elastic continuum, we compute the earthquake occurrence rate as a function of the stress or the phase of stress perturbation.

The remarkable points in the results are as follows:
(1) The phase distributions do not show a large phase shift.
(2) The earthquake occurrence is defined as the moment when the slip velocity exceeds a given threshold value. The occurrence rate is one-to-one mapped onto the shear or the normal stress at the moment of occurrence. This implies an instantaneous response.
(3) The dependences of occurrence rate on the shear or the normal stress appear to be exponential. This indicates existence of a characteristic stress.
(4) Variation of the normal stress additionally alters a frictional state on the interface according to the rock experiments performed by Linker and Dieterich [3], but this Linker-Dietrich effect on the stress response has not been well understood yet. As a result of numerical simulation, the Linker-Dieterich effect is found to suppress a difference in value of the phase distributions. Eventually, if the effect is very large, we observe even antiphase distribution (see fig. 1).

[1] T. J. Ader, N. Lapusta, J.-P. Avouac, and J.-P. Ampuero, Geophys. J. Int. 198, 385 (2014).
[2] S. Ide and Y. Tanaka, Geophys. Res. Lett. 41, 3842 (2014); S. Ide, S. Yabe, H.-J. Tai, and K. H. Chen, Geophys. Res. Lett., 42, 3248 (2015).
[3] M. F. Linker, J. H. Dieterich, J. Geophys. Res. 97 4923 (1992).

Keywords: slow earthquake, nonequilibrium statistical physics, nucleation, stress perturbation

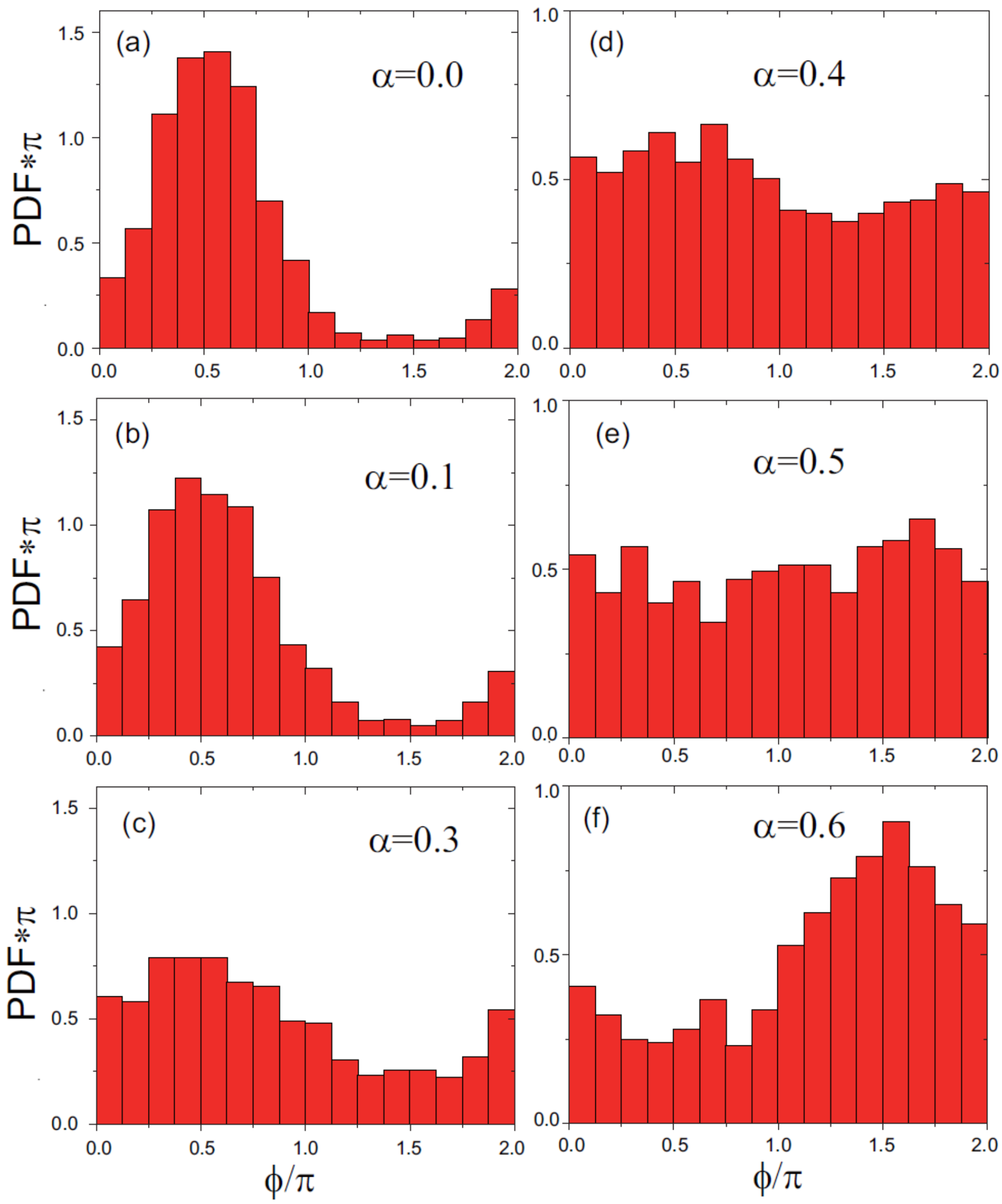

FIG. 1: Distributions of the normal-stress phase at the earthquake occurrence. As an increase of the Linker-Dieterich parameter α, a difference in value of the phase distribution becomes small, and eventually the phase distribution is inverted.

Feasibility of periodic solution in Rate-State friction Law

*Ryo Mizushima[1], Takahiro Hatano[1]

1. Department of Earth and Space Science, Osaka University

Slow earthquakes are phenomena with a wide range of time scales and a variety of characteristics. Among them, slow slip event (SSE) has a remarkable feature of periodic motion. For example, off the coast of Tohoku, the subduction rate fluctuates with a period of about three years. In addition to that, interestingly, relatively large earthquakes have occurred at the timing of accelerated slip (Uchida et al., 2016).

Since the mechanism of periodic occurrence of SSE is not clear, various models have been proposed. As a quasi-static model, the "fault patch model" has been used in many studies. In this model, a patchy sliding region is considered to exist on the fault plane. The sliding behavior is determined by considering the balance between elastic forces and friction (determined by the Rate-State friction law) on the patch region. However, there is a problem with this model. When the sliding behavior is examined numerically, the solution diverges. To prevent divergence, the effect of elastic wave radiation (radiation damping) is conventionally used (Rice 1993). However, since this model is quasi-static, elastic waves are not generated. Also, if elastic waves do occur, the model cannot be used as an SSE. Therefore, radiation damping is not a solution to the problem.

First, in this study, we reconsider what kind of behavior appears after the slip becomes unstable without radiation damping. For this calculation, we use a nonlinear analysis method called Dulac's criterion. Using this method, the nonlinearity of friction is rigorously taken into account to determine the feasibility of the periodic solutions. As a result, it is shown that there are no periodic solutions and the solution diverges when the aging law, slip law, and Nagata's law (Nagata et al., 2012) is used.

In this study, we further devise a new evolution law that avoids divergence. Considering the wear effect, we create a new evolution law. By applying this law to the model, we show that it is possible to realize periodic solutions without divergence. We also confirm that the velocity dependence of the friction coefficient in steady-state is similar in the granite experiment (Kilgore et al., 1993). Finally, the period of the sliding behavior derived from the new law is discussed. Then, we consider what values of the parameters are suitable for SSE.

Keywords: Rate-State friction law, Nonlinear analysis

Slow earthquake signatures in the ratio between acoustic and internal gravity wave amplitudes in coseismic ionospheric disturbances

*Kosuke Heki[1], Yuki Takasaka [1]

1. Department of Earth and Planetary Sciences, Faculty of Science, Hokkaido University

Frequency spectra of seismic waves from a fault rupture reflects the size of the faults, i.e. larger amplitudes of long period waves are excited by larger magnitude earthquakes. Anomalies in rise times of the fault movements would also influence the spectra. For example, earthquakes characterized by slow faulting, known as tsunami earthquakes, excite large tsunamis for the amplitudes of short-period seismic waves. In this study, we compare amplitudes of long- and short-period atmospheric waves excited by vertical crustal movements associated with earthquake faulting. Such atmospheric waves often reach the ionospheric F region and cause coseismic ionospheric disturbances (CID) observed as oscillations in ionospheric total electron content (TEC), with ground Global Navigation Satellite System (GNSS) receivers. CID often includes long-period internal gravity wave (IGW) components in addition to short period acoustic wave (AW) components. The latter has a period of ˜4 minutes and propagate by 0.8-1.0 km/s, while the former has a period of ˜12 minutes and propagate as fast as 0.2-0.3 km/s. Here we compare amplitudes of these two different waves for five earthquakes, 2011 Tohoku-oki (Mw9.0), 2010 Maule (Mw8.8), 1994 Hokkaido-Toho-Oki (Mw8.3), 2003 Tokachi-oki (Mw8.0), and the 2010 Mentawai (Mw7.9) earthquakes, using data from regional dense GNSS networks. We found two important features, i.e. (1) larger earthquakes show larger IGW/AW amplitude ratios, and (2) the Mentawai earthquake, a typical tsunami earthquake, exhibits abnormally large IGW amplitudes relative to AW amplitudes. These findings demonstrate that earthquakes with longer durations for faulting, take longer times for vertical crustal movements, and excite longer period atmospheric waves such as IGW more efficiently.

Keywords: slow earthquake, ionospheric disturbance, GNSS-TEC

Observation of shallow slow slip event propagating updip to the trough in the Nankai Trough.

*Eiichiro Araki[1], Takeshi Iinuma[1], Yojiro Yamamoto[1], Toshinori Kimura[1], Yuya Machida[1], Ryoichiro Agata[1], Keisuke Ariyoshi[1], Tsuyoshi Ichimura[2], Takane Hori[1], Shuichi Kodaira[1]

1. Japan Agency for Marine-Earth Science and Technology, 2. Earthquake Research Insitute, the University of Tokyo

We report observation of shallow slow slip in Kumano-nada, the Nankai Trough, south of Japan in December 2020 to January 2021 period from nearby seafloor and seafloor borehole observations. We investigated long-term pore-fluid pressure, and tilt data at three seafloor borehole stations (IODP C0002, C0010, C0006), a seafloor tilt station data (BMS1), as well as 13 DONET seafloor pressure station data, to identify slow crustal deformation. Seafloor broadband seismic data were also analyzed to identify low frequency earthquakes (LFT) and very low frequency earthquakes (VLFE) activity.

The observed episodic slow event is hereby reported in several stages (Stage A-D).

Stage A (Dec. 3-13): The slow event was first observed at Dec. 3, 2020 by the seafloor tilt station (BMS1) in DONET1-B Node with no accompanied LFT and VLFE activity, with firstly southward tilting and then turned to northward tilting, through stagnant period in Dec. 6-11 when active burst of LFT and VLFE activity started.

Stage B (Dec. 13-29): After two days in Dec. 13, slow change also started at borehole stations in the south-western side. Observed pore-fluid pressure change were trending continuously negative for C0002 (-8.7 kPa) and C0010 (-9.2kPa) and positive for C0006 (nearest to the trough in Node C, 15.4kPa). These changes were much larger than past episodes reported (Araki et al., 2017 and Ariyoshi et al., 2021). The seafloor and borehole tilt data also responded with large tilt change as large as 1.9 (BMS1) ~9 (C0010) and ~90 microradians (C0006) respectively. Seafloor pressure data between nearby stations in Nodes B, C and D also showed significant relative differences with slow transition, such as +1hPa (KMD06 and KMD07-KMD05), +2hPa (KMC11 and KMC12-KMC09). Pressure KMC12-KMC09 went through notable negative polarity change of ~ -1 hPa in +2 hPa change in overall, suggesting crustal deformation migrated beneath KMC09 site during the period. LFT and VLFE activity during the stage was active.

Stage C (Dec. 29-Jan. 10, 2021): While C0002 and C0010 pore-fluid pressure data continues to trend negatively, C0006 changed its trend from positive to negative after Dec. 29, suggesting the source of observed crustal deformation migrated from north to south beyond C0006 located within 10 km from the trough. Seafloor pressure between KMC11(at the trough axis)-KMC09 exhibited significant change of −1.3 hPa during the period, also suggests crustal deformation migration reached to the trough.

Stage D (Jan. 10-29): Intermittent slow changes in pore-fluid pressure were observed in C0010 and C0006 accompanying local LFT activity.

We performed slip fault modeling to account observed tilt and pore-fluid pressure change in the stages to understand what caused observed crustal deformation, using grid search of best fit Okada models for fault geometry and slip. Modeling was performed in time segments in these stages, first assuming the fault on the subducting plate boundary, and model with higher fault dipping angle to check validity of the assumption. In Dec. 16-21 period in the stage B, the best fit model was Mw 6.1 slip located in south of

DONET1-B node, where LFT activity was concentrated. Mechanisms of VLFE events during the period was also analyzed to give pronounced low angle reverse fault solutions. Therefore, we consider the observed event in the period was slow slip in the shallow subducting plate interface, probably initiated downdip in Kumano Basin, propagating updip on the subducting Philippine Sea plate interface toward the trough.

The borehole pore-fluid trend polarity change observed at C0006 (< 10km from the trough axis) in the stage C to D as well as seafloor pressure change at KMC11, strongly suggests crustal deformation took place very close to the trough axis where the plate subduction interface originated. From these direct observations in the seafloor above the plate interface, we argue that the slow slip event reached to the trough.

Keywords: Slow slip event, the Nankai Trough, seafloor observation, slow earthquakes, seafloor borehole observation

[E] Oral | S (Solid Earth Sciences) | S-CG Complex & General

[S-CG39] Science of slow earthquakes: Toward unified understandings of whole earthquake process

convener:Satoshi Ide(Department of Earth an Planetary Science, University of Tokyo), Hitoshi Hirose(Research Center for Urban Safety and Security, Kobe University), Kohtaro Ujiie(Faculty of Life and Environmental Sciences, University of Tsukuba), Takahiro Hatano(Department of Earth and Space Science, Osaka University), Chairperson:Takahiro Hatano(Department of Earth and Space Science, Osaka University)

Sat. Jun 5, 2021 1:45 PM - 3:15 PM Ch.21 (Zoom Room 21)

Accumulating observational studies on various types of slow deformation events, such as tectonic tremors, very low frequency events, and slow slip events, portrays some universal characteristics in generally complex behavior, including interaction among events and influence by various outer loading. Some of these phenomena seem to have causal relation with the occurrence of very large earthquakes. A unified understanding of these slow and fast earthquake processes requires an approach integrating geophysics, seismology, geodesy, geology, and non-equilibrium statistical physics. We welcome presentations based on, but not limited to, geophysical observation, data analysis, analytical theory, numerical simulation, field study, and laboratory experiments.

3:00 PM - 3:15 PM

[SCG39-12]Discussion

[E] Oral | S (Solid Earth Sciences) : S-CG Complex & General

Sat. Jun 5, 2021 3:30 PM - 5:00 PM JST | Sat. Jun 5, 2021 6:30 AM - 8:00 AM UTC | Ch.21 Zoom Room 21

[S-CG39] Science of slow earthquakes: Toward unified understandings of whole earthquake process

convener:Satoshi Ide(Department of Earth an Planetary Science, University of Tokyo), Hitoshi Hirose(Research Center for Urban Safety and Security, Kobe University), Kohtaro Ujiie(Faculty of Life and Environmental Sciences, University of Tsukuba), Takahiro Hatano(Department of Earth and Space Science, Osaka University), Chairperson:Hitoshi Hirose(Research Center for Urban Safety and Security, Kobe University)

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

[SCG39-13] Development of the detection method for short-term slow slip events using GNSS data and its application to the Nankai subduction zone

*Yutaro Okada[1], Takuya Nishimura[2], Takao Tabei[3], Takeshi Matsushima[4], Hitoshi Hirose[5] (1.Graduate School of Science, Kyoto University, 2.Disaster Prevention Research Institute, Kyoto University, 3.Faculty of Science and Technology, Kochi University, 4.Faculty of Science, Kyushu University, 5.Research Center for Urban Safety and Security, Kobe University)

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

[SCG39-14] Spatiotemporal slip distributions of the 2018-2019 Bungo Channel long-term slow slip event

*Yukinari Seshimo[1], Shoichi Yoshioka[2,1] (1.Department of Planetology, Graduate School of Science, Kobe University, 2.Research Center for Urban Safety and Security, Kobe University)

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

[SCG39-15] What controls along-strike variations in Long term SSE recurrence intervals in the Western Nankaui Subduction Zone?

*Takanari Ohata[1], SHINICHI MIYAZAKI[1], Kazuro Hirahara[2] (1.KYOTO UNIVERSITY, 2.KAGAWA UNIVERSITY)

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

[SCG39-16] Post-seismic to Co-seismic Moment Ratio: a Case Study of the 2016 Moderate Earthquakes along Chaman Fault Inferred from Sentinel-1 InSAR Time-Series

*Masato Furuya[1], Fumiko Matsumoto[2] (1.Department of Earth and Planetary Sciences Hokkaido University, 2.PASCO)

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

[SCG39-17] The moment release rate of short-term slow slip events in the northern Kii Peninsula from 2002 to 2015 based on NIED Hi-net tilt data

*Naoya Chujo[1], Hitoshi Hirose[2,1,3], Takeshi Kimura[3] (1.Department of Planetology, Graduate School of Science, Kobe University, 2.Research Center for Urban Safety and Security, Kobe University, 3.National Research Institute for Earth Science and Disaster Resilience)

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

[SCG39-18] Discussion

Development of the detection method for short-term slow slip events using GNSS data and its application to the Nankai subduction zone

*Yutaro Okada[1], Takuya Nishimura[2], Takao Tabei[3], Takeshi Matsushima[4], Hitoshi Hirose[5]

1. Graduate School of Science, Kyoto University, 2. Disaster Prevention Research Institute, Kyoto University, 3. Faculty of Science and Technology, Kochi University, 4. Faculty of Science, Kyushu University, 5. Research Center for Urban Safety and Security, Kobe University

Slow slip events (SSEs), which are kinds of slow earthquakes, are observed in a geodetic time domain and are categorized by their duration into long-term SSEs lasting several months to years and short-term SSEs (S-SSEs) lasting several days to weeks. S-SSEs east of the Bungo Channel have been systematically detected by using tiltmeters [Sekine et al., 2010] and GNSS [Nishimura et al., 2013] and their duration has been determined by tiltmeters based on corresponding low-frequency tremors [e.g., Sekine et al., 2010]. However, it is important to estimate the duration of S-SSEs by using only geodetic measurements because S-SSEs do not always accompany tremors. On the other hand, S-SSEs in the Kyushu region have been detected by only using GNSS data [Nishimura, 2014] and their duration has never been estimated objectively. Therefore, we developed a new S-SSE detection method which can estimate their source parameters including duration and applied it to 23-year-long GNSS data in the whole Nankai subduction zone from the Kyushu to the Tokai regions.

In this study, we use 734 GNSS stations in the period from February 1, 1997, to January 31, 2020. These coordinates were estimated using GIPSY/OASIS version 6.4 software with a strategy of precise point positioning-ambiguity resolution. As preprocessing of GNSS data, we remove post-seismic deformation, co-seismic displacements, long-terms trend including seasonal oscillation, and common-mode error. Firstly, we compute correlation coefficients between a synthetic template representing a time evolution of an S-SSE and 121-day-coordinates of GNSS data for each horizontal component at all stations. Secondly, we average the correlation coefficients weighted by the synthetic displacements predicted from the sub-faults. In this study, we assumed 429 sub-faults on the Philippine Sea plate interface [Iwasaki et al., 2015] and computed synthetic displacements with an elastic half-space dislocation model [Okada, 1992]. We then detected dates and locations of the candidate events by applying thresholds to the weighted average of correlation coefficients. Thirdly, we estimate a rectangular fault model of the events [Matsu’ura and Hasegawa, 1987] by using observed displacements of the candidate event. Fourthly, we stack 121-day-long GNSS coordinates weighted by the displacements predicted from the estimated fault model. Then, we estimate a duration of the candidate event by extracting a maximum correlation coefficient between stacked coordinates and a synthetic template. Finally, we detect S-SSEs by applying the criteria to the fault model and duration estimation result of the candidate events.

In our preliminary result, we detected 280 S-SSEs in the Nankai subduction zone during the analyzed period. Their typical moment magnitude is approximately 6.0, and their duration mainly distributes from 1 to 10 days. Some of S-SSEs detected in offshore Kyushu roughly correspond to repeating earthquakes [Uchida et al., 2020] and very low-frequency earthquakes [Baba et al., 2020]. This is the first geodetic evidence of the synchronization between S-SSEs and other phenomena in offshore Kyushu.

Estimation of slip amount and duration in the developed method enables us to clarify the spatial variation of slip rates of S-SSEs in the Nankai subduction zone. The average slip rate of S-SSEs, which is computed by dividing the cumulative slip by the cumulative duration, shows some regional characteristics (Figure 1). The average slip rate in western Shikoku is about twice larger than that of eastern Shikoku, and the average slip rate in Kyushu is the smallest among the Nankai subduction zone. These differences are statistically significant and possibly relate to the geometry of the subducting Philippine Sea plate.

Acknowledgments
We thank the Geospatial Information Authority of Japan, Japan Coast Guard, Japan Crustal Activity Science Consortium, and International GNSS Service for providing GNSS RINEX data. This research was supported by JSPS KAKENHI Grant Number JP16H06474 in Scientific Research on Innovative Areas “Science of Slow Earthquakes”, the MEXT of Japan under its "The Second Earthquake and Volcano Hazards Observation and Research Program", and ERI under its "Joint Usage/Research Program 2020-A-03".

Keywords: Slow slip event, Nankai subduction zone, GNSS

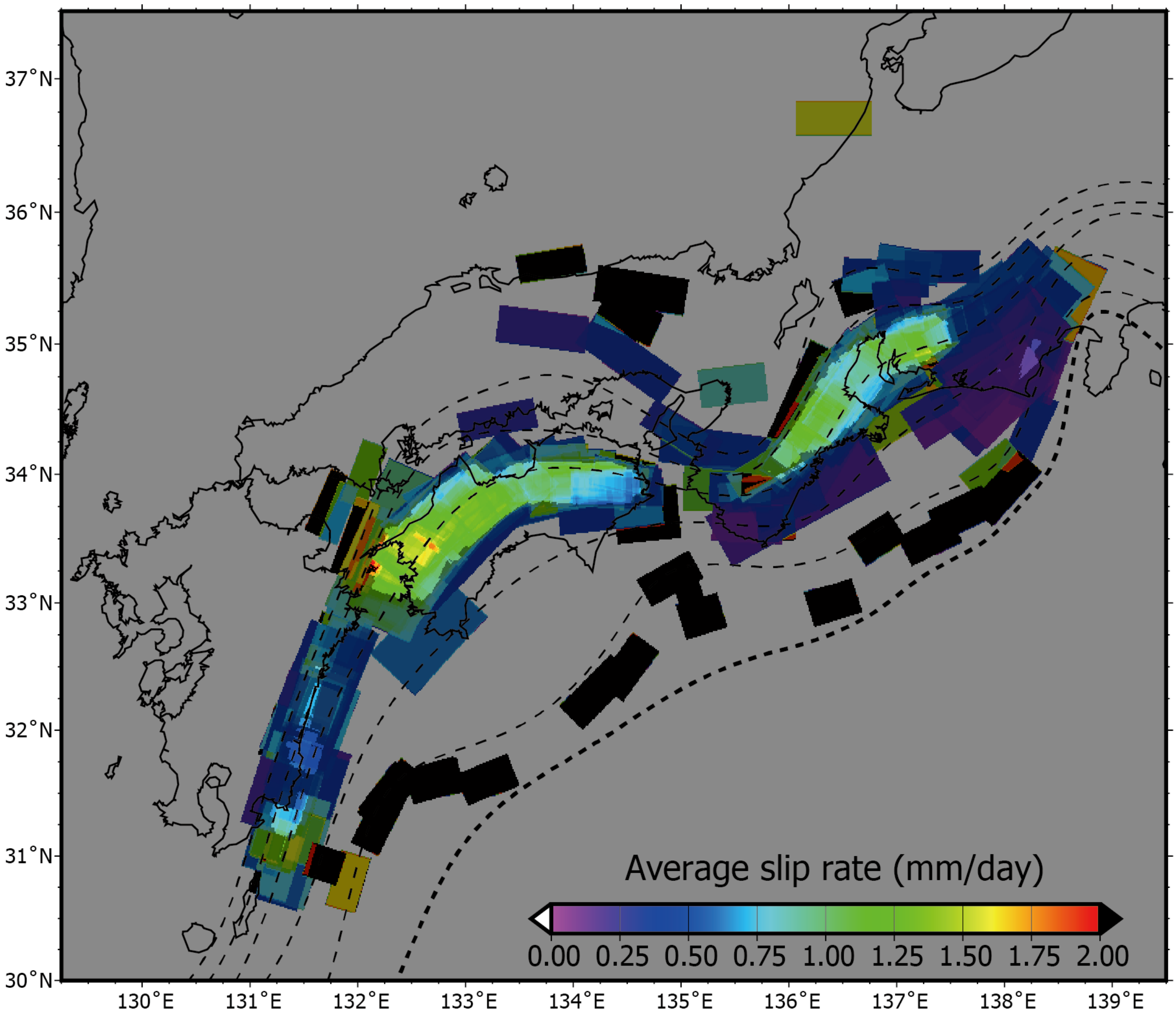

Figure 1. Average slip rates of S-SSE for 23 years. Note that the grid points that underwent less than 10 SSEs are shaded.

Spatiotemporal slip distributions of the 2018-2019 Bungo Channel long-term slow slip event

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We estimated the spatiotemporal slip distributions of the long-term slow slip event (L-SSE) that occurred beneath the Bungo Channel from 2018 to 2019, by using the GNSS time series data operated by Geospatial Information Authority of Japan.
In this region, the Philippine Sea plate is subducting beneath the Amurian plate in the northwest direction at a rate of about 6.5 cm/yr. At the plate boundary beneath the Bungo Channel, aseismic interplate long-term slow slip events, which are hereafter referred to as L-SSEs, have occurred repeatedly with durations of several months to a couple of years. From previous studies, L-SSEs beneath the Bungo Channel have been identified to take place at intervals of about 6 years such as the events that occurred during the periods from 1997 to 1998, from 2002 to 2004, and from 2009 to 2011.
We used the daily coordinate values (F3 solutions) of GEONET and 114 GNSS observation stations in western Shikoku and eastern Kyushu for the period between January 1, 2016 and June 30, 2020. We set six stations as reference stations located in the northern Chugoku district, which were not affected by crustal deformations associated with the L-SSE. The GNSS time series data include coseismic steps, steps caused by antenna exchange, common-mode errors, and annual and semi-annual components. We removed these components to investigate crustal deformation associated with the L-SSE. We approximated tectonic deformation associated with plate motion as a liner function and removed its trend. The data period used for its calculation was taken from January 1, 2016 to December 31, 2017. After that, we employed an inversion method with three prior constraints: the spatial slip distribution was smooth to some extent, the slip directions were mostly oriented in the direction of plate convergence, and the temporal change in slip was smooth to some extent (Yoshioka et al., 2015). The data period used for the inversion analysis was taken from January 1, 2018 to December 31, 2019. We divided the time series into an equal time span of 0.1 yr.
As a result of the inversion analysis, the maximum slip of about 27 cm, the moment release of 3.7×10^{19} Nm, and equivalent moment magnitude of 7.0 were estimated. The slips can be divided into two slip stages. The first slip occurred on the southwest side of the Bungo Channel from 2018.3 to 2018.7. The maximum slip, moment release and equivalent moment magnitude were estimated to be about 10 cm, 8.9×10^{18} Nm, and 6.6, respectively. The maximum slip velocity was estimated to be about 36 cm/yr during the period from 2018.5 to 2018.6. The second slip took place beneath the Bungo Channel from 2018.8 to 2019.4. The maximum slip, moment release and equivalent moment magnitude were estimated to be about 19 cm, 2.0×10^{19} Nm, and 6.8, respectively. The maximum slip velocity was estimated to be about 53 cm/yr during the period from 2019.1 to 2019.2. After the second slip, slight slip occurred beneath the Bungo Channel from 2019. 5 to 2019.7.
Tectonic tremors appear to have been activated on the downdip side of the L-SSE occurrence region when large slow slips occurred beneath the Bungo Channel.
As described above, the first slip occurred on the southwest side of the Bungo Channel, and the second slip took place near the center of the Bungo Channel. Compared to the L-SSEs that occurred beneath the Bungo Channel in the past, this spatiotemporal slip pattern was similar to that of the L-SSE that occurred from 2002 to 2004. However, the difference is that the interval between the first slip and the second slip was shorter, and that the slip expanded in the northeast-southwest direction in the latter half of the

second slip. The moment release was almost the same, but the maximum slip and the maximum slip velocity were larger. This may be related to a slight increase in the interval from the last L-SSE occurrence.

Keywords: Bungo Channel, 2018-2019, long-term slow slip event, spatiotemporal slip distribution

What controls along-strike variations in Long term SSE recurrence intervals in the Western Nankaui Subduction Zone?

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There have been observed a variety of slow earthquakes. Recent simulation studies based on rate and state friction (RSF) laws have showed that these activities can be changed before occurrence of megaquakes (e.g., Matsuzawa et al., 2010). In this respect, it is important to understand frictional properties controlling slip evolution of these slow earthquakes in relation to megaquake forecasting. Here we focus on Long-term Slow Slip Events (L-SSEs) among these slow earthquakes. SSE simulations have so far been executed by trial-and-error assignments of RSF parameters. In these situations, Hirahara and Nishikiori (2019) executed numerical twin experiments of a simple Bungo channel L-SSE patch with Ensemble Kalman Filter (EnKF) to show a potential of determining frictional parameters from synthetic GNSS data. Further, Fujita (2020) showed a capability of short-term forecasting L-SSE activity using the slip rate data on the SSE fault inverted from actual GNSS data. However, it was also found that we need quite good pairs of initial parameters to obtain converged parameters even with EnKF.

Recent study revealed along-strike variations of recurrence interval (Tr) of L-SSE in the Western Nankai Subduction Zone; in the Southern Hyuga-nada, 2-3 years, the Bungo channel, 3 years, and the Northern Hyuga-nada and Western Shikoku, 5-6 years. Takagi et al. (2019) proposed that the up-dip locked region controls these variations. That is, at the down-dip of the locked region, Tr of L-SSE tends to be longer because of the low accumulation of the stress. To confirm this idea, we make a numerical model with the actual 3-D geometry of PHS slab to simulate such L-SSE behaviors. In our model, we set kinematically slip deficiency rate in the locked zone, and RSF parameters in the depth-dependent SSE zone and creep zone where slip evolution is quasi-dynamically simulated. We found that along-strike Tr variations cannot be fully explained only by the along-strike difference of slip deficiency rate. Thus, we need to consider another model.

In our RSF model without cut-off velocities, slip instability of a L-SSE zone with velocity weakening frictional property is basically controlled by the ratio of the width of the L-SSE zone and the critical nucleation size (W/h*) (e.g., Liu and Rice, 2007). Other parameters, however, possibly control SSE slip behaviors (e.g., Ampuero, 2019). Therefore, it is necessary to understand which parameters control the observed along-strike Tr variations and the physical meanings. First, we make a simple dipping plain model composing three zones of locked, SSE and creep in the down-dip direction, each of which has uniform parameters. Then, we execute experiments by changing parameters to examine produced Tr, maximum SSE velocity (Vmx) and duration (Td). These simulations showed that almost all parameters, such as frictional parameters, effective normal stress, width of the L-SSE zone, and slip deficiency of the locked region, make effects on Tr by roughly the same weight. Especially, we note that simulations with a constant W/h* produce considerable different slip behaviors. Second, we construct a plane model including several SSE zones with different parameters to reveal the along-strike interactions. We found that the heterogeneous distribution of parameters, such as width of the SSE zone and effective normal stress, can produce along-strike variations of Tr, Vmx and Td. It was also recognized that the boundary conditions assigned in the both sides of SSE zones affect slip behaviors such as along-strike slip propagations.

Keywords: SSE, Rate and State Friction Law, Recurrence interval, Nankai Subduction Zone

Post-seismic to Co-seismic Moment Ratio: a Case Study of the 2016 Moderate Earthquakes along Chaman Fault Inferred from Sentinel-1 InSAR Time-Series

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1. Department of Earth and Planetary Sciences Hokkaido University, 2. PASCO

Postseismic-to-co-seismic moment ratios for large earthquakes greater than M7 are roughly around 0.3 or less, but those for moderate to even smaller earthquakes could be greater than 1 or more (Chen and Lapsta, 2009; Alwahedi and Hawthorne, 2018). However, there have been limited estimates on those ratios for moderate earthquakes. Of those limited estimates on postseismic-to-co-seismic moment ratio, the one reported by Furuya and Satyabala (2008) is exceptionally large, reaching nearly 6, in which a long-lasting afterslip due to an M5.0 earthquake in 2005 along Chaman Fault was detected. Chaman Fault is the western transform plate boundary between Indian and Eurasian plates and is well known for its low seismicity, which was interpreted as either a long-recurrent interval of large earthquakes or steady creep. Meanwhile, on May 13 and July 10, 2016, moderate earthquakes occurred along the Chaman fault, and are the largest earthquakes since the 2005 M5.0 event but located ~150 km further to the south. The USGS reports that the 1st event on May 13 consists of the triplet at almost the same hypocenter with Mw 5.2, 4.7, and 5.5 and that the 2nd event ~20 km to the north-east was mb 4.7 (body-wave magnitude). Our goals are to check if the Chaman Fault is anomalous in terms of its frictional properties and/or if the post-seismic to co-seismic moment ratio for moderate earthquakes will always get larger, compared to those for larger earthquakes. To estimate the post- to co-seismic moment ratios for these events, we examine the surface deformation associated with these moderate earthquakes, using 75 Sentinel-1A SAR images from October 2014 to August 2018 to generate 428 interferograms. We perform InSAR time-series analysis, using the LiCSBAS package by Morishita et al (2020). Below are our findings so far:

- The post-seismic to co-seismic moment ratio for the smaller mb 4.7 earthquake was ~10, whereas that for the larger Mw5-class events to the south was ~2.

- Slips on the fault for the mb4.7 earthquake reached the surface, whereas those for the Mw5 events did not.

-The apparent seasonality for the post-seismic moment release for the larger Mw5 earthquakes is probably caused because the areas are ~20 km distant from the reference area.

- No clear secular creep signals were detected before the earthquakes. Although we could notice possible triggered slip signals before the mb4.7 earthquake, their LOS changes are at most 5 mm and the estimated slip-patches for the mb4.7 earthquake were clearly distant from those for the possible triggered slip.

- Significant gap in the slip patches between the M5-class events and the mb4.7 event is located in the fault-bending zone that also coincides with the ruptured area by the 1892 M6.6 earthquake.

- Slip velocities and stress drops estimated for the mb4.7 event are smaller than those of the M5-class events.

Keywords: Chaman Fault, Afterslip, moderate earthquake, InSAR

The moment release rate of short-term slow slip events in the northern Kii Peninsula from 2002 to 2015 based on NIED Hi-net tilt data

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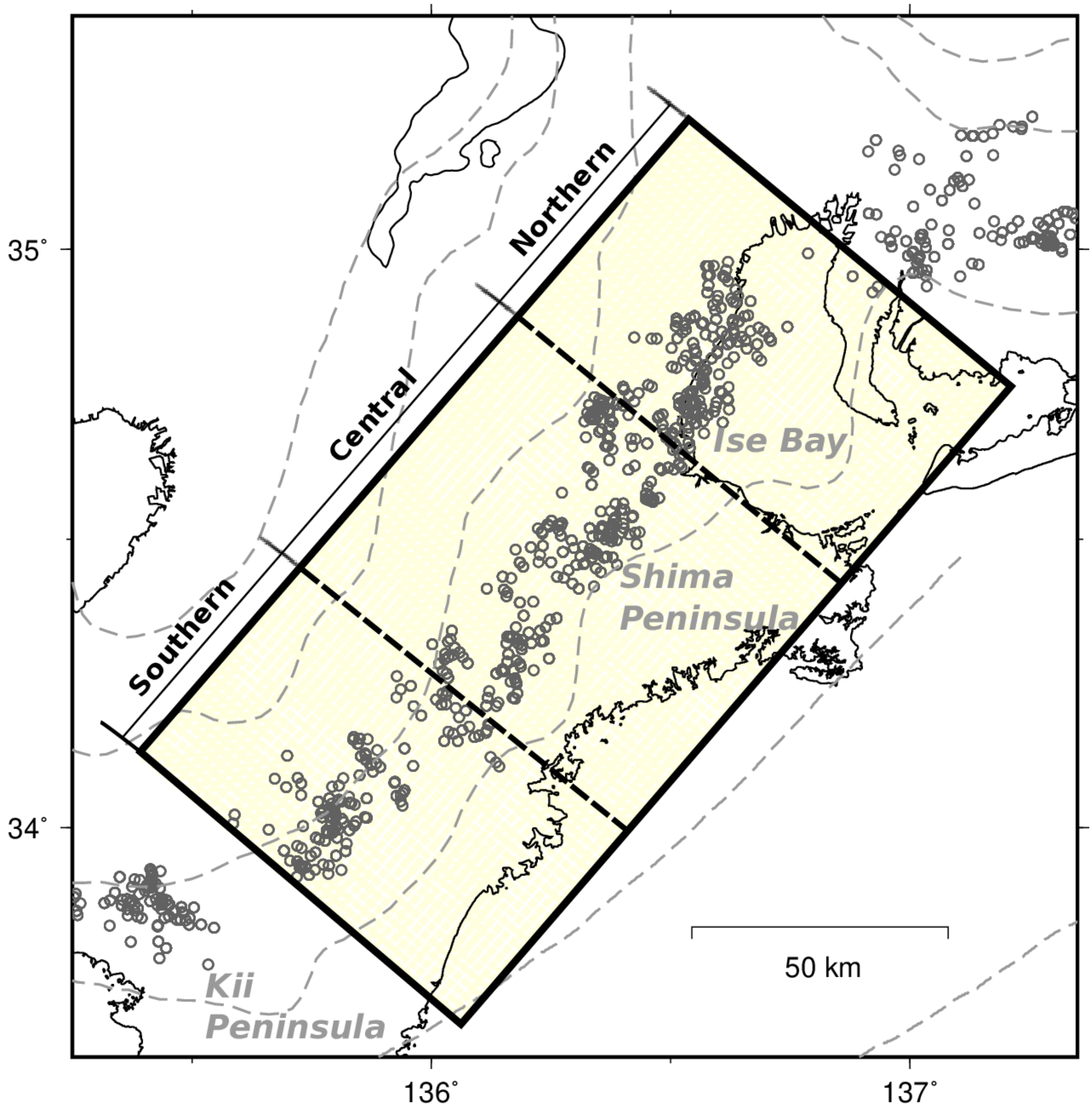
1. Department of Planetology, Graduate School of Science, Kobe University, 2. Research Center for Urban Safety and Security, Kobe University, 3. National Research Institute for Earth Science and Disaster Resilience

In the southwest Japan subduction zone, short-term slow slip events (S-SSEs) with nonvolcanic tremor (Episodic Tremor and Slip: ETS, Rogers and Dragert, 2003) which last for several days to weeks occur repeatedly (e.g., Obara et al., 2004). Because the S-SSEs occur at the downdip extension of a megathrust earthquake rupture zone, the SSEs are one of the key factors for stress buildup processes of the megathrust earthquakes (e.g., Obara and Kato, 2016). Therefore, detailed slip distributions of S-SSEs are important for understanding the strain accumulation and release at the ETS zone. In the northern Kii Peninsula, S-SSEs have been detected (e.g., Hirose and Obara, 2006). In addition, previous studies examine the moment release rate by S-SSEs in this area (Sekine et al., 2010; Nishimura et al., 2013). For example, Nishimura et al. (2013) show the long-term moment release rate is roughly constant for nearly 16 years (1996-2012). Since we obtained more recent data, it is important to explore longer-term moment release history as S-SSEs.
Here we apply an inversion method (Hirose and Kimura, 2020) which can express a spatial slip distribution to tilt offset measurements in the northern Kii Peninsula and estimate detailed slip distributions of 52 S-SSEs from March 2002 to October 2015. We also calculate the long-term moment release rate of S-SSEs over a more recent period than the previous studies, and discuss regional differences of S-SSEs activity in the northern Kii Peninsula.
We used time-series records of a high-sensitivity accelerometer (tiltmeter) installed at NIED Hi-net stations located in the Kii Peninsula and Tokai areas. We applied the BAYTAP-G (Tamura et al., 1991) program together with atmospheric pressure records observed at the Tsu Local Meteorological Observatory to the tilt records in order to remove tidal components and an atmospheric pressure response. First, we checked the tremor activity in the northern Kii Peninsula based on the NIED tremor catalog (Maeda and Obara, 2009; Obara et al., 2010) to find out “active episodes”. Next, We try to identify a corresponding tilt transient to an active episode of tremor, then we define the event duration of the SSE from the tilt transient if it is identified. We measured a tilt offset due to an SSE from a detrended tilt record as a difference in tilt just before and after the SSE. We estimated a slip distribution that explains the tilt offset dataset for an SSE by a conventional inversion method by Hirose and Kimura (2020).
We successfully identified and estimated 52 S-SSEs in the study area in 13 years. The estimated moment magnitudes of the 52 SSEs range from 5.4 to 6.2. The cumulative seismic moment in the entire modeled region (the rectangle with the solid line in Fig.) indicates the moment release rate is mostly constant (~ 4E+18 Nm/year) through the study period. Then, we divide the modeled region into three segments (southern, central, northern; separated by dashed lines in Fig.) based on the slip distributions of S-SSEs. We find that the long-term moment release rate in the central and northern segments (corresponding to the Shima Peninsula and Ise Bay part of the ETS zone) is higher than that in the southern segment (corresponding to the southern Nara Prefecture in the ETS zone), indicating the regionality of S-SSEs activity in the northern Kii Peninsula. In addition, in the central and northern segments, the moment release rate decreases around 2011, suggesting a possible effect of the crustal deformations caused by the 2011 Tohoku earthquake.

Acknowledgments: This work was supported by JSPS KAKENHI Grant Number JP16H06474.

Meteorological data were provided by Japan Meteorological Agency.



[E] Oral | S (Solid Earth Sciences) | S-CG Complex & General

[S-CG39] Science of slow earthquakes: Toward unified understandings of whole earthquake process

convener:Satoshi Ide(Department of Earth an Planetary Science, University of Tokyo), Hitoshi Hirose(Research Center for Urban Safety and Security, Kobe University), Kohtaro Ujiie(Faculty of Life and Environmental Sciences, University of Tsukuba), Takahiro Hatano(Department of Earth and Space Science, Osaka University), Chairperson:Hitoshi Hirose(Research Center for Urban Safety and Security, Kobe University)

Sat. Jun 5, 2021 3:30 PM - 5:00 PM Ch.21 (Zoom Room 21)

Accumulating observational studies on various types of slow deformation events, such as tectonic tremors, very low frequency events, and slow slip events, portrays some universal characteristics in generally complex behavior, including interaction among events and influence by various outer loading. Some of these phenomena seem to have causal relation with the occurrence of very large earthquakes. A unified understanding of these slow and fast earthquake processes requires an approach integrating geophysics, seismology, geodesy, geology, and non-equilibrium statistical physics. We welcome presentations based on, but not limited to, geophysical observation, data analysis, analytical theory, numerical simulation, field study, and laboratory experiments.

4:45 PM - 5:00 PM

[SCG39-18]Discussion

[E] Oral | M (Multidisciplinary and Interdisciplinary) : M-IS Intersection

Sat. Jun 5, 2021 10:45 AM - 12:15 PM JST | Sat. Jun 5, 2021 1:45 AM - 3:15 AM UTC | Ch.03 Zoom Room 03

[M-IS07] Effects of lightning, severe weather and tropical storms

convener:Mitsuteru Sato(Department of Cosmoscience, Hokkaido University), Hisayuki Kubota(Hokkaido University), C. Glenn Vincent Lopez(- - -), Purwadi Purwadi(Department of Cosmosciences, Hokkaido University, Sapporo 0600810, Japan), Chairperson:Mitsuteru Sato(Department of Cosmoscience, Hokkaido University), Hisayuki Kubota(Hokkaido University)

Thunderstorms are markers of deep convection and severe weather, producing heavy precipitation, hail and strong winds that lead to significant natural hazards, especially in coastal and urban areas. Huge economic damages and loss of human lives often result from such events. As the intensity and frequency of thunderstorms is projected to increase in the future - when the atmosphere and oceans become warmer - the need for detecting and nowcasting thunderstorms and lightning on local and regional scales becomes crucial.
We invite contributions dealing with thunderstorms and lightning and their atmospheric effects. We seek contributions focusing on convective storm evolution, forecasting of thunderstorms and lightning using local, regional and global detection networks as well as other sensors. Also, works on global lightning patterns in an era of climate change, satellite-based studies of thunderstorms and other remote-sensing technologies, as well as urban effects on lightning and public safety from lightning danger.

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

[MIS07-01] Current status and prospects of ULAT/SATREPS

*Yukihiro Takahashi[1,2], Mitsuteru Sato[1,2], Hisayuki Kubota[1,2], Tetsuro Ishida[1,2], Ellison Castro[3], Loren Jay Estrebillo[3], Purwadi Purwadi[4], Meryl Algodon[1], Gay Perez[3], Joel Marciano[5], Jun Matsumoto[6], Jun-Ichi Hamada[6] (1.Department of Cosmosciences, Graduate School of Science, Hokkaido University, 2.Department of Earth and Planetary Sciences, Faculty of Science, Hokkaido University, 3.University of the Philippines, Diliman, 4.BPPT, Indonesia, 5.PhilSA, Phlippines, 6.Tokyo Metropolitan University)

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

[MIS07-02] **The relationship between CG lightning detected by AVON V-POTEKA and thunderstorm parameters**

*Purwadi Purwadi[1], Yukihiro Takahashi[2], Mitsuteru Sato[2], Hisayuki Kubota[2], Kozo Yamashita[3] (1.Agency for Assessment and Application for Technology, Jakarta 10340, Indonesia, 2.Faculty of Science, Hokkaido University, Sapporo 0600810, Japan, 3.Department of Electrical Engineering, Salesian Polytechnic, Tokyo, Japan)

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

[MIS07-03] Machine Learning Prediction of Precipitation in Metro Manila, Philippines

★Invited Papers

*Akira Noda[1], Yukihiro Takahashi[2], Hisayuki Kubota[2], Ken-ichi Fukui[3], Mitsuteru Sato[2] (1.Department of Earth and Planetary Sciences, School of Science, Hokkaido University., 2.Department of Cosmosciences, Graduate School of Science, Hokkaido University, 3.The Institute of Scientific and Industrial Research, Osaka University)

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

[MIS07-04] **3D Reconstruction of Typhoon Trami Eye Using Airborne Camera**

★Invited Papers

*Meryl Regine Llenaresas Algodon[1], Yukihiro Takahashi[2], Mitsuteru Sato[2], Hisayuki Kubota[3], Tetsuro Ishida[3], Kozo Yamashita[4], Ellison Caparas Castro[5], Gay Jane Perez[6], Joel Joseph Marciano[7], Jun Matsumoto[8], Jun-Ichi Hamada[9], Kazuhisa Tsuboki[10], Hiroyuki Yamada[11] (1.Hokkaido University, Graduate School of Science, 2.Hokkaido University, 3.Hokkaido University, Faculty of Science, 4.Ashikaga University, 5.University of the Philippines Quezon City (Philippines), 6.NASA Goddard Space Flight Center

Earth Science Division Greenbelt MD 20771-0000 (United States), 7.Advanced Science and Technology Institute Quezon City (Philippines), 8.Tokyo Metropolitan University Tokyo 192, 9.Tokyo Metropolitan University Hachioji, 10.Nagoya University, Institute for Space–Earth Environmental Research Nagoya 464, 11.University of the Ryukyus Nishihara)

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

[MIS07-05] Successive observation of atmospheric electric observation at Kakioka Geomagnetic Observatory

*Masashi Kamogawa[1], Tomoyuki Suzuki[1], Toshiyasu Nagao[3], Yasuhiro Minamoto[2] (1.Global Center for Asian and Regional Research, University of Shizuoka, 2.Laboratory for Environmental Research at Mount Fuji, 3.Institute of Oceanic Research and Development, Tokai University)

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

[MIS07-06] Observation of Elves and Transient Luminous Events from the International Space Station with the Mini-EUSO telescope

*Marco Casolino[1], Toshikazu Ebisuzaki[1], Yoshiyuki Takizawa[1], Naoto Sakaki[1], Satoshi Wada[1] (1.Riken)

Current status and prospects of ULAT/SATREPS

*Yukihiro Takahashi[1,2], Mitsuteru Sato[1,2], Hisayuki Kubota[1,2], Tetsuro Ishida[1,2], Ellison Castro[3], Loren Jay Estrebillo[3], Purwadi Purwadi[4], Meryl Algodon[1], Gay Perez[3], Joel Marciano[5], Jun Matsumoto[6], Jun-Ichi Hamada[6]

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Our projects of a SATREPS “ULAT” is to realize precise real-time monitoring and issuing alert for extreme weather, such as torrential rainfall or typhoon. We have been developing a ground observation network with lightning sensors and trying to establish semi real-time operation of micro-satellites to capture the typhoon and thunderstorms. In these projects, we apply two new technologies, that is, the lightning activity estimated by the ground-based lightning networks with 12 sites for VLF radio wave measurement in nation-wide of Philippines and with 50 sites for electrostatic field measurement in Metro Manila together with infrasound sensor and automated weather station, and the 3 dimensional capturing of thunderstorms by the on-demand operation of 50-kg micro-satellites, including the Philippine-developed satellites. We started ULAT project in 2017 and completed the installation of the ground lightning observation station with automated weather station about 70 percent of the original plan and started continuous recording of the data. Although, due to COVID-19, now the installation of ground station is stopping, we plan to carry out the work remotely making use of the latest IT devices. As for the satellite observation, we succeeded in reconstructing detailed 3-D cloud structure near the center of typhoon Maysak 2020 with camera onboard DIWATA-1. In this presentation we update the recent progress of the projects.
This research was supported by Science and Technology Research Partnership for Sustainable Development (SATREPS), Japan Science and Technology Agency (JST) / Japan International Cooperation Agency (JICA).

Keywords: ULAT, SATREPS, microsatellite, lightning, extreme weather, monitoring

The relationship between CG lightning detected by AVON V-POTEKA and thunderstorm parameters

*Purwadi Purwadi[1], Yukihiro Takahashi[2], Mitsuteru Sato[2], Hisayuki Kubota[2], Kozo Yamashita[3]

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Cloud to ground (CG) lightning observation networks, namely AVON V-POTEKA, have been established using a 1-40 kHz very low frequency (VLF) receiver. It has been deployed and operated to cover East and South East Asia since 2017. In this study, the CG lightning geolocation estimation of AVON V-POTEKA data is estimated using the time of arrival method and found the best accuracy of ~30 km. The relationship between lightning and thunderstorm cloud parameters over the maritime continent (MC) can be conducted with additional data of the Himawari 8 band 15 (12.4 μm) to provide cloud top temperature (CTT), radiosonde archived data, and the Global Satellite Mapping of Precipitation with gauge adjusted (GSMaP_Gauge) standard V7. Using the statistical method and grid size 0.5° x 0.5º, the relationship between CG lightning and thunderstorm clouds parameters is found in this study. Moreover, the CTT of thunderstorm clouds is found to be less than -30ºC to produce at least 1 CG lightning, which can be detected by AVON V-POTEKA. Both CTT and cloud top height (CTH) shows a logarithmic relationship with the CG lightning with R^2=0.95. On the other hand, the relationship between CG lightning and rainfall shows a power relationship with R^2=0.92. The relationship between CG lightning and precipitation water area is estimated to be a power relationship.

Keywords: cloud to ground lightning, cloud top temperature, cloud top height, rainfall

Machine Learning Prediction of Precipitation in Metro Manila, Philippines

*Akira Noda[1], Yukihiro Takahashi[2], Hisayuki Kubota[2], Ken-ichi Fukui[3], Mitsuteru Sato[2]

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It is difficult to accurately predict the occurrence and rain volume of torrential rains such as guerrilla rain, rain band with typhoon and linear precipitation zones even in Japan, where meteorological observations from the ground and space and weather forecasts using numerical models are well established. One of the reasons for this is that the spatial narrowness of the rainfall area and the rapid development of these extreme weather events exceed the temporal and spatial resolution of conventional weather observation networks. Furthermore, in Southeast Asia, where the meteorological observation infrastructure is relatively weak, many disasters such as heavy rains and floods caused by monsoons and typhoons occur every year. There is an urgent need to establish the cost-effective weather forecasting technology. In recent years, the development of machine learning technology has been remarkable owing to the increased processing speed of computers and big data. In addition, in the field of meteorology, the researches on the forecasting method development using machine learning have been actively conducted. Our research group has developed an automatic weather and lightning observation system called as P-POTEKA since 2017, and has been deploying it in Metro Manila, Philippines, which is frequently affected by heavy rains and associated flooding. To date, 35 P-POTEKA units have been installed in Metro Manila and continue the acquisition of meteorological data (precipitation, temperature, pressure, humidity, wind speed, wind direction and solar irradiance every minutes). While AMeDAS (The Automated Meteorological Data Acquisition System) in Japan is deployed with the average interval of 17km, P-POTEKA in Metro Manila is deployed with the average interval of 2-3km, making the observation network with the world's highest spatial and temporal resolution suitable for capturing extreme weather events. Using the P-POTEKA rainfall data, RGB image data corresponding to the spatial distribution of rainfall in Metro Manila was created by interpolating the data using the ordinary kriging method. By training these time-series rainfall image data on a machine learning model called ConvLSTM (Convolutional Long-Short Term Memory), we predicted the distribution and rainfall amount from the present to 1-hour later with the 10-minutes intervals using the observation data of the past 1-hour. The root mean squared error (RMSE) of the RGB values of pixels corresponding to the predicted and actual observed precipitation distributions were calculated for untrained rainfalls (40 patterns) to evaluate the performance of our machine learning method. As a result, it was found that the prediction using ConvLSTM is relatively accurate up to 30 minutes from the present, but the prediction accuracy of the spatio-temporal change of prediction becomes significantly worse after 40-60 minutes from the present. In this presentation, the details of the machine learning method model using ConvLSTM and the prediction results of precipitation and precipitation distribution predictions will be explained more in detail.

Keywords: torrential rainfalls, machine learning, mesoscale meteorology

3D Reconstruction of Typhoon Trami Eye Using Airborne Camera

*Meryl Regine Llenaresas Algodon[1], Yukihiro Takahashi[2], Mitsuteru Sato[2], Hisayuki Kubota[3], Tetsuro Ishida[3], Kozo Yamashita[4], Ellison Caparas Castro[5], Gay Jane Perez[6], Joel Joseph Marciano[7], Jun Matsumoto[8], Jun-Ichi Hamada[9], Kazuhisa Tsuboki[10], Hiroyuki Yamada[11]

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Typhoons are extreme weather phenomena that inflict damages and casualties around the globe. These phenomena are difficult to study because of their chaotic behaviour but the capacity to measure their intensity can help mitigate the hazards that they bring. In the past, several attempts have been done to relate typhoon's intensity with the structural evolution of its eye. This suggests the possible relation between the typhoon intensity with typhoon eye altitude. In this research, we visualize Typhoon Trami’s structure by reconstructing the three-dimensional model inside its eye and integrating the information of its cloud top altitude. An experiment was conducted under the SATREPS/ULAT project (SATREPS: Science and Technology Research Partnership for Sustainable Development, ULAT: Understanding Lightning and Thunderstorm) where images of Typhoon Trami were taken from an aircraft last September 26, 2018. Aircraft images were used to reconstruct the 3D model inside the typhoon eye because they provide closer views of the typhoon than that of geostationary satellite images making it easier to reconstruct a 3D model. The 3D reconstruction generated covers approximately 50 km distance from the typhoon eye at 24.3 m/pixel spatial resolution. Three cross-sections of the 3D model were analyzed, and the resulting altitude distribution was compared with the cloud-top altitude estimated by mapping the brightness temperature of the Himawari Thermal Infrared Band 13 with cloud-top height as measured by NOAA sonde data. From the 3D model, the altitude distribution ranges from 5.3 km to 14.3 km while the altitude estimated from the brightness temperature ranges from 5.2 km to 14.6 km. However, regions of altitude difference can also be observed between the two methods. This study shows that a three-dimensional model could be a good mode of typhoon visualization as it shows a more detailed typhoon structure such as the stairstep structures that was detected at some regions within the typhoon eye. This research was supported by SATREPS, funded by Japan Science and Technology Agency (JST) / Japan International Cooperation Agency (JICA).

Keywords: 3D Reconstruction, Typhoon Monitoring

Successive observation of atmospheric electric observation at Kakioka Geomagnetic Observatory

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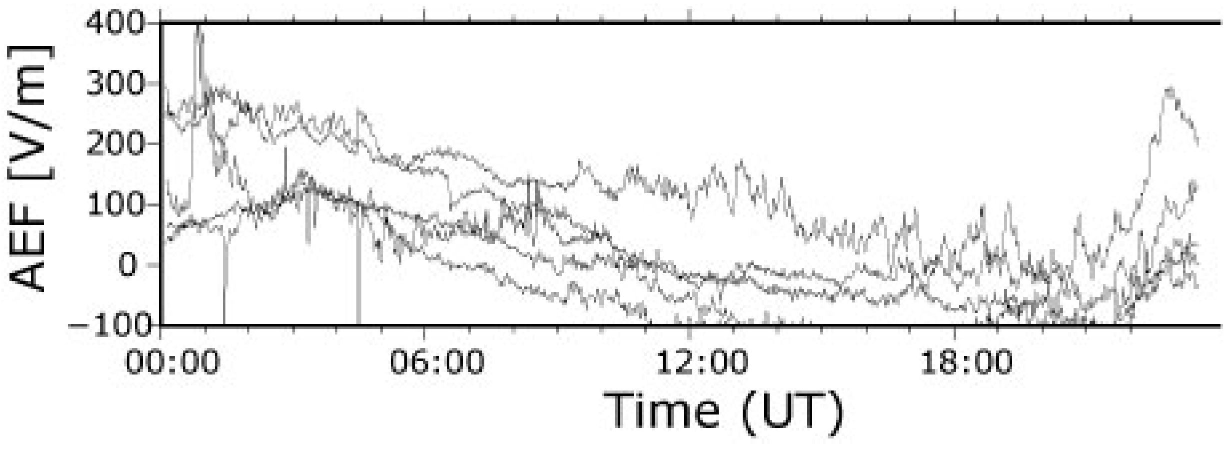
1. Global Center for Asian and Regional Research, University of Shizuoka, 2. Laboratory for Environmental Research at Mount Fuji, 3. Institute of Oceanic Research and Development, Tokai University

The atmospheric electric field (AEF) measurement has been carried out by the Japan Meteorological Agency (JMA) at Kakioka geomagnetic observatory since 1929. The JMA decided that the AEF measurement would terminate at the end of February 2021. Since many researchers have used the AEF data at Kakioka, several research groups such as universities examined whether or not successive observations could be conducted at Kakioka. In our grope, we installed one field mill with board range of intensity developed by Otowa Co. Ltd., sensitive and insensitive field mills developed by Boltek and two all-sky cameras at 18 of Feb., 2021. This observation was available on not only traditional fair-weather study but also the study of severe weather accompanying heavy lightning activities. The sampling of field mills are 20 Hz (Otowa) and 10 Hz (Boltek). The time stamp was synchronized by GPS.

This paper is a preliminary report of the AEF measurement in the vicinity of the current AEF observation operated by our group. This figure shows that the time-series of AEF records (Otowa) from 19 to 23 of Feb. of 2021 in UT.

Keywords: Atmospheric electric field, Potential gradient, Kakioka



Observation of Elves and Transient Luminous Events from the International Space Station with the Mini-EUSO telescope

*Marco Casolino[1], Toshikazu Ebisuzaki[1], Yoshiyuki Takizawa[1], Naoto Sakaki[1], Satoshi Wada[1]

1. Riken

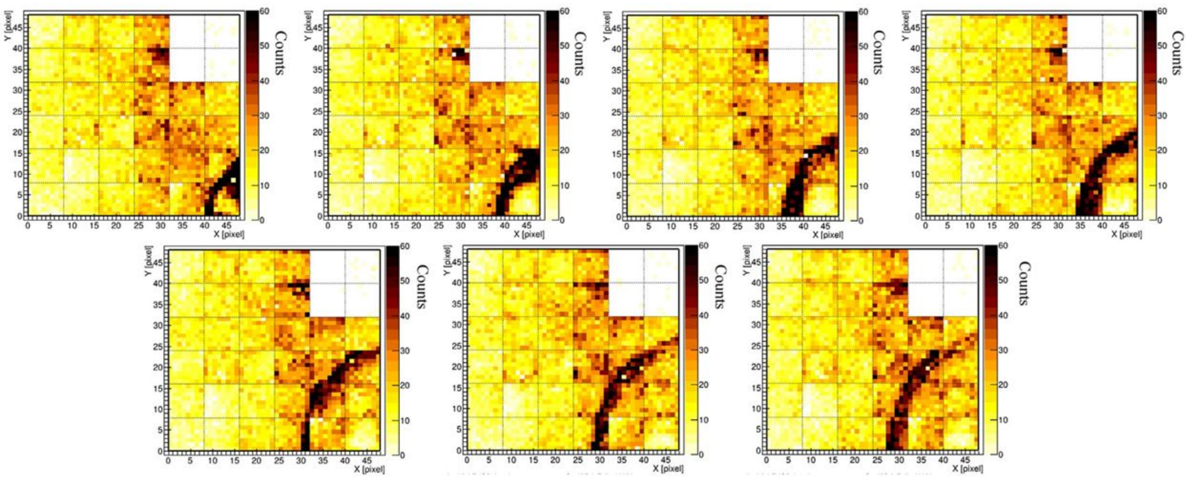
Mini-EUSO is a telescope observing the Earth in the ultraviolet band from a nadir-facing, UV transparent window of the International space station.

The instrument - launched in 2019 - has a field of view of 44degrees, a spatial resolution on the ionosphere of 4.7 km and a sampling rate of 2.5 microseconds. The telescope consists in an optical system with two Fresnel lenses and a focal surface composed of an array of 36 Hamamatsu multi-anode photomultiplier tubes, for a total of 2304 pixels. The telescope also contains two ancillary cameras, in the near infrared and visible ranges, to complement measurements in these bandwidths.

The telescope detects UV emissions of cosmic, atmospheric and terrestrial origin on different time scales, from 2.5 microseconds and above. At the fastest sampling rate, Mini-EUSO is able to observe atmospheric phenomena such as ELVES and other Transient Luminous Events with the imaging camera, allowing to study in detail the expansion and propagation.

In this work we will present the ELVES observations done by Mini-EUSO, discussing their rate of occurrence, location and structure (ring size, speed, shape), in particular the multi-ringed events.

Keywords: TLE, ELVES, International Space Station



[E] Oral | M (Multidisciplinary and Interdisciplinary) : M-IS Intersection

Sat. Jun 5, 2021 1:45 PM - 3:15 PM JST | Sat. Jun 5, 2021 4:45 AM - 6:15 AM UTC | Ch.15 Zoom Room 15

[M-IS09] Weathering and conservation of cultural heritage and geosites

convener:Luigi Germinario(University of Padova, Italy), Chiaki T. Oguchi(Institute for Environmental Science and Technology, Graduate School of Science and Engineering, Saitama University), Akos Torok(Budapest University of Technology and Economics), Tetsuya Waragai(Graduate School of Science and Engineering, Nihon University), Chairperson:Luigi Germinario(University of Padova, Italy), Chiaki T. Oguchi(Institute for Environmental Science and Technology, Graduate School of Science and Engineering, Saitama University)

Cultural heritage (World Heritage Sites, historical structures, archaeological artifacts, etc.) and geoheritage (geosites, geoparks, etc.) are exposed to weathering in the geological and human time scale. The resulting deterioration of the rocks and other geological materials in cultural and natural contexts can be often severe and demands the prompt adoption of conservation measures. The relevant research involves a range of disciplines: mineralogy, geomorphology, geoarchaeology, environmental science, engineering geology, materials science, analytical chemistry, etc. However, our knowledge on many aspects is still limited. This session welcomes contributions presenting original research, case studies, and discussions on damage assessment, experimental techniques, monitoring, predictive models, conservation procedures, documentation, etc. related to geological materials in cultural heritage and geosites.

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

[MIS09-01] Evaluation of the degradation state of dinosaur footprint based on 3D measurement.

*Nobuaki Kuchitsu[1], Shuji SAKAI[2], Masato FUJITA[3] (1.Tokyo National Research Institute for Cultural Properties, 2.Toppan Printing Co., Ltd., 3.Toyama Science Museum)

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

[MIS09-02] Study on relations between deterioration of tuff stone used as exteriors of a historical building and microenvironment factors

*Uno Tomoko[1], Chiemi Iba[2], Masaru Abuku[3] (1.Mukogawa Womens University, 2.Kyouto University, 3.Kinki University)

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

[MIS09-03] Changes in pore-size distribution of rocks induced by thermal cycles of low temperature

*Tetsuya Waragai[1] (1.Graduate School of Science and Engineering, Nihon University)

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

[MIS09-04] **Non-destructive strength tests of heritage buildings: an overview of Schmidt hammer and Duroskop tests**

*Akos Torok[1] (1.Budapest University of Technology and Economics)

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

[MIS09-05] Numerical analysis of heat, moisture, and salt transfer and deformation in porous materials under atmospheric conditions

*Masaru Abuku[1], Koichi Ishii[2] (1.Kindai University, 2.Research Center of Computational Mechanics, Inc.)

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

[MIS09-06] **HYPERION: understanding and quantifying the effects of climate change on cultural heritage**

*Chiara Coletti[1], Luigi Germinario[1], Fabrizio Antonelli[2], Renzo Bertoncello[3], Antonio Galgaro[1], Lara Maritan[1], Matteo Massironi[1], Jacopo Nava[1], Rebecca Piovesan[2], Raffaele Sassi[1], Elena Tesser[2], Claudio Mazzoli[1] (1.Department of Geosciences, University of Padova, Via Gradenigo 6, 35131 Padova, Italy, 2.LAMA - Laboratory for Analysing Materials of Ancient origin, University Iuav of Venice, San Polo 2468/B, 30125 Venice, Italy, 3.Department of Chemical Sciences, University of Padova, Via Marzolo 1, 35131 Padova, Italy)

Evaluation of the degradation state of dinosaur footprint based on 3D measurement.

*Nobuaki Kuchitsu[1], Shuji SAKAI[2], Masato FUJITA[3]

1. Tokyo National Research Institute for Cultural Properties, 2. Toppan Printing Co., Ltd., 3. Toyama Science Museum

Past degradation of footprint fossils of dinosaurs at Oyama Area in Toyama City is discussed through constructing and comparing the past 3D shapes of the fossil. The 3D shapes of the fossil as of the plural in the past were estimated based on the replicas made by taking a mold in the past as well as old photographs taken from various directions as of the plural in the past. The change in the degradation rate in the past was argued by comparing the established 3D shapes in the past. As a result, degradation was detected just after the discovery of a sauropd footprint located in the original outcrop caused by a road construction, but the rate is getting smaller as time passes. On the other hand, the degradation of the ornithopoda footprint, newly found on the one-step lower out crop due to the additional excavation, seems to be getting larger. It will contribute to the discussion of how to conserve such fossils to understand the tendency of the degradation fluctuation in the past.

Keywords: three-dimensional measurement, replica, weathering rate, past shape, Oyama area of Toyama City

Study on relations between deterioration of tuff stone used as exteriors of a historical building and microenvironment factors

*Uno Tomoko[1], Chiemi Iba[2], Masaru Abuku[3]

1. Mukogawa Womens University, 2. Kyouto University, 3. Kinki University

Two types of tuff stone (Nichika Seki, produced in Ishikawa prefecture, and Tatsuyama Ishi produced in Hyogo prefecture) are used as exterior in the former Koshien Hotel, which was built in 1930 and used as the campus building at Mukogawa Women’ s University. According to the condition survey of the stone, we found that the deterioration types in the two stones are different. In addition, even if the stone is in a similar environment, one side is damaged, while the other side is not damaged.

To investigate these factors of the deterioration, we grasped the material properties of these stones; stone structure, pore size distribution of the stones, thermal and moisture conductivity. We also investigated the deterioration condition of the stone and the surrounding microenvironment.

As a result, it was expected that the area and degrees of the stone getting a wetting by rain, the surface temperature changes of the stone exposed by solar and nocturnal radiation were affecting the deterioration. Based on the results of the condition survey, thermal and moisture properties, and boundary conditions, we are planning to analysis the temperature and water content inside the stone.

Keywords: Deterioration Condition, Microenvironment, Conservation of Historical Building

Changes in pore-size distribution of rocks induced by thermal cycles of low temperature

*Tetsuya Waragai[1]

1. Graduate School of Science and Engineering, Nihon University

Many case studies have analyzed the relationship between thermo–mechanical fracture and temperature change induced by the insolation of rocks. However, extracting only thermal effects and discussing fracture in field observations are difficult. Therefore, laboratory experiments in which thermal cycles are applied to rocks are considered to be effective methods for simplifying and analyzing the relationship between fracture and thermal cycles. In particular, this approach is considered effective in measuring the generation of the acoustic emission (AE) and changes in pores to capture the initial stage of microscopic phenomena such as thermal fatigue fracture. Therefore, we experimentally investigated the fracture of rock specimens based on changes in pore-size distribution, ultrasonic propagation velocity, and the occurrence of AE. For the experiment, we used three rock types—granite and marble with a porosity of 2% or less and sandstone with a porosity of approximately 14%, which are often used as stone materials. Thereafter, we repeatedly subjected the prepared specimens from the rock types to temperature changes from 4℃ to 84℃ using a temperature-controlled chamber at a temperature change rate of ±2℃/min, which is the threshold for thermal shock fracture. Consequently, the P-wave velocity decreased by approximately 25%, 7.2%, and 2.5% for the granite, marble, and sandstone, respectively. Furthermore, for granite, the pore-size distribution decreased by approximately 6% in the diameter range of 0.8–0.5 μm and increased by approximately 5% in the diameter range of 0.4–0.1 μm. For the marble, the pore-size distribution decreased by approximately 16% in the diameter range of 0.5–0.1 μm and increased by approximately 16% in the diameter range of 6–0.65 μm. For the sandstone, the variation in pore size was negligible. Moreover, the occurrence of AE was detected in all rock types, but we found that its magnitude for the granite was the largest, followed by the marble and sandstone, respectively. Therefore, a low-temperature thermal cycle causes thermo–mechanical fracture inside rocks.

Keywords: Thermal weathering, Thermo–mechanical fracture, Acoustic emission, Microcrack, Pore size distribution

Non-destructive strength tests of heritage buildings: an overview of Schmidt hammer and Duroskop tests

*Akos Torok[1]

1. Budapest University of Technology and Economics

Strength tests of heritage structures require special care since in most cases, only non-destructive tests are possible to detect the surface strength of materials. The most widely used tool is Schmidt hammer. It has been applied for a few decades to assess the strength of building stones. Another less widely used tool is Duroskop, a non-destructive test device with lower impact strength, and it can detect smaller surface strength than Schimdt hammer. In this paper, the non-destructive strength test results of the faç ades of several buildings are presented. The aim is to assess Schmidt hammer rebound and Duroskop rebound variations representing various states of weathering. The studied buildings were constructed from porous limestone, travertine, non-porous crystalline limestone and sandstone. The Schmidt hammer rebound values and Duroskop rebound values of ashlars were recorded representing various weathering conditions. The large data set of measurements was evaluated using geostatistical methods. The results indicate that besides the lithology, the differences in exposure and air quality alos influences surface strength. The data sets help to outline the weathering-related changes in Schmidt hammer and Duroskop rebound.

Keywords: weathering, surface strenght, Schmidt hammer, Duroskop, non-destructive testing

Numerical analysis of heat, moisture, and salt transfer and deformation in porous materials under atmospheric conditions

*Masaru Abuku[1], Koichi Ishii[2]

1. Kindai University, 2. Research Center of Computational Mechanics, Inc.

Salt weathering of porous materials such as stone, brick, etc. is a phenomenon composed of heat, moisture and salt transfer in porous materials, crystallization and phase change of salt, deformation of porous materials, and so on. Thus far, several numerical models have been developed by researchers for studying such phenomena, in addition to the efforts of measuring physical and chemical data of porous materials, ions, and salt crystals. When a numerical simulation obtained using one of these models is applied to different real-world objects, such as a building wall, stone cultural property, or masonry systems, one has to often deal with complex geometries comprising various materials and boundary conditions. To render such an application of the salt weathering prediction feasible, we have developed a generic finite element method code, namely: PMSolver. This code analyzes non-steady heat, moisture, and salt transfer in porous materials, while examining the deformation of materials from the temperature, salt solution content, and salt crystal content. Further, this code is equipped with a GUI that works on a pre- and postprocessor Femap, and incorporates the input data of geometries, material properties, and initial and boundary conditions into the solver. Furthermore, the transport, phase change, and crystallization/dissolution of a mixture, which is obtained by dissolving two different salts in water, are elucidated in this model while maintaining electrical neutrality. The code includes the data on sodium chloride and sodium sulfate. During the mechanical analysis, the pore liquid pressure, crystallization pressure, and thermal stress are considered, in addition to the stress obtained from a static mechanical analysis; this is aimed at determining the strain field at each time step. The code can also consider different types of atmospheric boundary conditions such as temporally and spatially distributed wind-driven rain with ions, sea spray, atmospheric salt deposition, and seepage water. When the seepage flow is analyzed, two iteration steps are considered.

Keywords: Poromechanics, Finite Element Method, Salt weathering, Salt crystallization, Moisture transfer

HYPERION: understanding and quantifying the effects of climate change on cultural heritage

*Chiara Coletti[1], Luigi Germinario[1], Fabrizio Antonelli[2], Renzo Bertoncello[3], Antonio Galgaro[1], Lara Maritan[1], Matteo Massironi[1], Jacopo Nava[1], Rebecca Piovesan[2], Raffaele Sassi[1], Elena Tesser[2], Claudio Mazzoli[1]

1. Department of Geosciences, University of Padova, Via Gradenigo 6, 35131 Padova, Italy, 2. LAMA - Laboratory for Analysing Materials of Ancient origin, University Iuav of Venice, San Polo 2468/B, 30125 Venice, Italy, 3. Department of Chemical Sciences, University of Padova, Via Marzolo 1, 35131 Padova, Italy

Climate change is one of the most critical global challenges of our time. During the last century, the anthropic activity had a great impact not only on the environment, affecting even the conservation of cultural heritage. This is becoming a mandatory issue to be tackled by international and local administrations and heritage stakeholders.

Stone is the natural materials most utilized in historical monuments. Although stone decay phenomena have been broadly investigated in the past, only few studies are moving towards the understanding and quantification of the short- and long-term effects of climate change. This research direction, however, is essential for supporting sustainable mitigation plans and the city’s resilience management.

The HYPERION project aims to fill this gap, improving the knowledge of measurable material- and climate-based parameters that influence stone decay rate. The project includes simulations of future scenarios and potential effects of changing climate patterns and air quality, extreme climate events, and multi-hazard circumstances in the historical urban context.

In this contribution, we present the preliminary results of the study of selected building stones used in four European demonstration sites, in Italy (Venice), Greece (Rhodes), Spain (Granada), and Norway (Tønsberg). The basic petrographic and physical-mechanical investigation of the stone materials is combined with accelerated ageing tests under different environmental stresses (cycles of salt crystallization and freeze-thaw and interaction with rainwaters with different compositions) and field-exposure tests. The expected results will help refining adequate material-specific models of stone surface recession and support structural and hygrothermal simulations about the future decay of cultural heritage. Data recorded will also be exploited for hypothesize in advance the best conservative treatments of the building stones investigated.

Keywords: Stones, Decay, Salt weathering, Freeze-thaw, Surface recession, Climate change

[E] Oral | EVENT：EVENT

Sat. Jun 5, 2021 9:00 AM - 9:45 AM JST | Sat. Jun 5, 2021 12:00 AM - 12:45 AM UTC | Ch.07 Zoom Room 07

[EV-23] Exhibitors' Seminar

昨年と同じく、出展者様にセミナーを開催していただきます。
地球惑星科学関連の、有用な情報を発信してくださいますので是非ご参加ください。

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

[E-11-23] Latest Application Developments from Picarro

[E] Oral | EVENT | EVENT

[EV-23] Exhibitors' Seminar

Sat. Jun 5, 2021 9:00 AM - 9:45 AM Ch.07 (Zoom Room 07)

昨年と同じく、出展者様にセミナーを開催していただきます。
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9:00 AM - 9:45 AM

[E-11-23]Latest Application Developments from Picarro

Latest Application Developments from Picarro