Sun. Jun 6, 2021

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

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

[P-PS04] Small Solar System Bodies: A New Insight from Hayabusa2, OSIRIS-REx and Other Space Missions

convener:Tatsuaki Okada(Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency), Taishi Nakamoto(Tokyo Institute of Technology), Daisuke Kuroda(Kyoto University), Chairperson:Tatsuaki Okada(Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency), Taishi Nakamoto(Tokyo Institute of Technology), YACHEN YANG(Center for Space and Remote Sensing Research)

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

[PPS04-01] Introduction

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

[PPS04-02] Interdisiplinary Science of Hayabusa2 Mission

*Sei-ichiro WATANABE[1], Hikaru Yabuta[2], Koji Wada[3], Naru Hirata[4], Naoyuki Hirata[5], Yuri Shimaki[7], Rina Noguchi[7], Seiji Sugita[6], Kohei Kitazato[4], Tatsuaki Okada[7], Noriyuki Namiki[8], Shogo Tachibana[6,7], Masahiko Arakawa[5], Satoshi Tanaka[7] (1.Nagoya University, 2.Hiroshima University, 3.Chiba Institute of Technology, 4.University of Aizu, 5.Kobe University, 6.University of Tokyo, 7.JAXA/ISAS, 8.National Astronomical Observatory)

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

[PPS04-03] Progress report of initial description of the C-type asteroid Ryugu samples returned by Hayabusa2

*Toru Yada[1], Masanao Abe[1], Aiko Nakato[1], Kasumi Yogata[1], Akiko Miyazaki[1], Kazuya Kumagai[2], Kentaro Hatakeda[2], Tatsuaki Okada[1], Masahiro Nishimura[1], Shizuho Furuya[1], Yoshitake Miwa[1], Ayako Iwamae[2], Lucie Liu[1], Lionel Lourit[3], Cedric Pilorget[3], Vincent Hamm[3], Jean-Pierre Bibring[3], Yuichiro Cho[4], Koki Yumoto[4], Yuna Yabe[4], Seiji Sugita[4], Shogo Tachibana[4], Hirotaka Sawada[1], Sakamoto Kanako[1], Tasuku Hayashi[1], Daiki Yamamoto[1], Ryota Fukai[1], Haruna Sugahara[1], Hisayoshi Yurimoto[5], Tomohiro Usui[1], Sei-ichiro WATANABE[6], Yuichi Tsuda[1] (1.Japan Aerospace Exploration Agency, 2.Marine Works Japan, 3.Institut D'Astrophysique Spatiale, 4.University of Tokyo, 5.Hokkaido University, 6.Nagoya University)

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

[PPS04-04] EXPERIMENTAL STUDY ON IMPACT CRATERS FORMED ON MOUNTAIN-LIKE SURFACE TOPOGRAPHY OF ASTEROIDS

*Yusaku Yokota[1], Masahiko Arakawa[1], Minami Yasui[1], Yuya Yamamoto[1], Sunao Hasegawa[2], Hatsune Okawa[1] (1.Graduate School of Science, Kobe University, 2.Japan Aerospace Exploration Agency)

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

[PPS04-05] The collisional history in the Main Belt

★Invited Papers

*Hiroshi Kobayashi[1] (1.Department of Physics, Nagoya University)

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

[PPS04-06] Internal structure of pebble-pile comets inferred from thermal and mechanical properties of dust aggregates

★Invited Papers

*Sota ARAKAWA[1] (1.National Astronomical Observatory of Japan)

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

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

[P-PS04] Small Solar System Bodies: A New Insight from Hayabusa2, OSIRIS-REx and Other Space Missions

convener:Tatsuaki Okada(Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency), Taishi Nakamoto(Tokyo Institute of Technology), Daisuke Kuroda(Kyoto University), Chairperson:Tatsuaki Okada(Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency), Taishi Nakamoto(Tokyo Institute of Technology), YACHEN YANG(Center for Space and Remote Sensing Research)

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

[PPS04-07] Predicted strength, microporosity, thermal conductivity and grain density of Ryugu rock samples

*Jens Biele[1], Matthias Grott[2], Patrick Michel[3], Tatsuaki Okada[4], Seiji Sugita[5], Naoya Sakatani[6], Wladimir Neumann[2,7], Shingo Kameda[6], Tatsuhiro Michikami[8], Chikatoshi Honda[9] (1.German Aerospace Center, Cologne, Germany, 2.German Aerospace Center, Berlin, Germany, 3.Université Côte d'Azur, Observatoire de la Côte d'Azur, CNRS, Laboratoire Lagrange, Nice, France , 4.Japan Aerospace Exploration Agency, ISAS, Sagamihara, Japan, 5.University of Tokyo, Tokyo, Japan, 6.Rikkyo University, Tokyo, Japan, 7.Klaus-Tschira-Labor für Kosmochemie, Institut für Geowissenschaften, Universität Heidelberg, Heidelberg, Germany, 8.Kindai University, Hiroshima, Japan, 9.University of Aizu, Aizu-Wakamatsu, Japan)

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

[PPS04-08] Analysis of the temperature distributions of boulders on C-type asteroid 162173 Ryugu observed in low altitude operation of the asteroid explorer Hayabusa2

*Ayumu Ohsugi[1,2], Naoya Sakatani[3], Yuri Shimaki[2], Hiroki Senshu[4], Takehiko Arai[5], Hirohide Demura[6], Toru Kouyama[7], Tomohiko Sekiguchi[8], Satoshi Tanaka[2], Tetsuya Fukuhara[3], Tatsuaki Okada[1,2] (1.Graduate School of Science, The University of Tokyo, 2.Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency, 3.Department of Physics, College of Science, Rikkyo University, 4.Planetary Exploration Research Center, Chiba Institute of Technology, 5.Faculty of Engineering, Department of Innovative Engineering, Division of Systems and Information Engineering,Ashikaga University, 6.Department of Computer Science and Engineering, University of Aizu, 7.National Institute of Advanced Industrial Science and Technology, 8.Hokkaido University of Education)

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

[PPS04-09] Surface Age of Ryugu's Boulders Based on Small Crater Statistics

*Yudai Takai[1], Tomokatsu Morota[1], Koki Yumoto[1], Rie Honda[2], Shingo Kameda[3], Eri Tatsumi[1,4], Yuichiro Cho[1], Kazuo Yoshioka[1], Hirotaka Sawada[5], Yasuhiro Yokota[2,5], Naoya Sakatani[3], Masahiko Hayakawa[5], Moe Matsuoka[5], Manabu Yamada[6], Toru Kouyama[7], Hidehiko Suzuki[8], Chikatoshi Honda[9], Kazunori Ogawa[5,10], Seiji Sugita[1] (1.University of Tokyo, 2.Kochi University, 3.Rikkyo University, 4.Instituto de Astrofísica de Canarias, 5.JAXA, 6.Chiba Institute of Technology, 7.National Institute of Advanced Industrial Science and Technology, 8.Meiji University, 9.The University of Aizu, 10.Kobe University)

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

[PPS04-10] Space weathering of bright boulders inferred from the spectral comparison between SCI crater and blue regions on Ryugu

*Minami Aoki[1], Chiho Sugimoto[1], Koki Yumoto[1], Naofumi Takaki[1], ERI TATSUMI[2,1], Tomokatsu Morota[1], Yasuhiro Yokota[3], Masahiko Arakawa[4], Seiji Sugita[1] (1.Department of Earth and Planetary Science, Graduate School of Science, The University of Tokyo, 2.Instituto de Astrofísica de Canarias, 3.JAXA/ISAS, 4.Kobe University)

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

[PPS04-11] Estimation of space weathering timescale using the number of mottles on the boulder in Hayabusa/AMICA images

*Sunho Jin[1], Masateru Ishiguro[1] (1.Seoul National University)

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

[PPS04-12] The Chemical Composition of Interstellar Dust in Light of the DESTINY$^+$ Mission: A Novel Tool to Measure the Elemental Abundances and Ionization of the Local Interstellar Cloud

*Hiroshi Kimura[1], Masanori Kobayashi[1], Tomoko Arai[1], DDA Team / DESTINY+ (1.Planetary Exploration Research Center, Chiba Institute of Technology)

[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-PS04] Small Solar System Bodies: A New Insight from Hayabusa2, OSIRIS-REx and Other Space Missions

convener:Tatsuaki Okada(Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency), Taishi Nakamoto(Tokyo Institute of Technology), Daisuke Kuroda(Kyoto University), Chairperson:Tatsuaki Okada(Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency), Taishi Nakamoto(Tokyo Institute of Technology), YACHEN YANG(Center for Space and Remote Sensing Research)

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

[PPS04-13] Regional photometric properties on asteroid Ryugu in visible wavelength

*Yasuhiro Yokota[1], Rie Honda[2], Eri Tatsumi[3], Deborah Domingue[4], Stefanus E. Schröder[5], Moe Matsuoka[1], Lucie Riu[1], Seiji Sugita[6], Tomokatsu Morota[6], Naoya Sakatani[7], Chikatoshi Honda[8], Yuichiro Cho[6], Shingo Kameda[7], Toru Kouyama[9], Manabu Yamada[10], Masahiko Hayakawa[1], Hiroki Senshu[10], Hidehiko Suzuki[11], Kazuo Yoshioka[6], Hirotaka Sawada[1], Kazunori Ogawa[1] (1.ISAS/JAXA, Japan, 2.Kochi Univ., Japan, 3.Instituto de Astrofisica de Canarias, Univ. of La Laguna, Spain, 4.Planetary Science Institute, USA, 5.DLR, Germany, 6.Univ. of Tokyo, Japan, 7.Rikkyo Univ., Japan, 8.Univ. of Aizu, Japan, 9.AIST, Japan, 10.Chiba Inst. Tech, Japan, 11.Meiji Univ., Japan)

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

[PPS04-14] Spectrophotometric behavior of Ryugu's surface as inferred from the Hayabusa2/NIRS3 data

*Andrea Longobardo[1], Ernesto Palomba[1,2], Anna Galiano[1], Fabrizio Dirri[1], Angelo Zinzi[2], Mario D'Amore[3], Deborah Domingue[4], Kohei Kitazato[5], Takahiro Iwata[6], Moe Matsuoka[6], Takahiro Hiroi[7], Driss Takir[8], Tomoki Nakamura[9], Masanao Abe[5], Makiko Ohtake[5], Shuji Matsuura[10], Sei-ichiro WATANABE[6,11], Makoto Yoshikawa[6], Takanao Saiki[6], Tatsuaki Okada[6], Yukio Yamamoto[6], Yoh Takei[6], Kei Shirai[6], Naru Hirata[5], Naoyuki Hirata[12], Koji Matsumoto[13], Yuichi Tsuda[6] (1.Istituto Nazionale di Astrofisica - Istituto di Astrofisica e Planetologia Spaziali, Rome, Italy, 2.ASI-SSDC, Rome, Italy, 3.German Aerospace Center, Institute of Planetary Research, Berlin, Germany, 4.PSI, Tucson, AZ, USA, 5.University of Aizu, Aizu-Wakamatsu 965-8580, Fukushima, Japan, 6.ISAS-JAXA, Japan, 7.Department of Earth, Environmental and Planetary Sciences, Brown University, Providence, RI 02912, USA, 8.Jacobs/NASA Johnson Space Center, USA, 9.Tohoku University, Miyagi, Japan, 10.Kwansei Gakuin University, Hyogo, Japan, 11.Nagoya University, Nagoya 464-8601, Japan, 12.Kobe University, Kobe 657-8501, Japan, 13.National Astronomical Observatory of Japan, Mitaka 181-8588, Japan)

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

[PPS04-15] Laboratory spectral constraints on the composition and origin of Phobos: Reconciling the Vis-NIR/Mid-IR contradictions

*Matthew Izawa[1], Sandra Potin[2], Edward Cloutis[2] (1.Institute for Planetary Materials, 2.University of Winnipeg)

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

[PPS04-16] UNSUPERVISED LEARNING OF NIRS3 DATA: RYUGU SPECTRAL SURFACE REGIONS CLASSIFICATION

*Mario D'Amore[1], E. Palomba[2,3], A. Galiano[2], A. Zinzi[3], F. Dirri[2], A. Longobardo[2], K. Kitazato[4], T. Iwata[5], M. Matsuoka[5], T. Hiroi[6], D. Takir[7], T. Nakamura[8], M. Abe[5], M.y Ohtake[5], S. Matsuura[9], S. Watanabe[10], M. Yoshikawa[5], T. Saiki[5], S. Tanaka[5], T. Okada[5], Y. Yamamoto[5], Y. Taikei[5], K. Shirai[5], N. Hirata[11,4], K. Matsumoto[12], Y. Tsuda[5] (1.German Aerospace Center, Institute of Planetary Research, Berlin, Germany, 2.INAF-IAPS, Rome, Italy, 3.SSDC-ASI, Rome, Italy, 4.University of Aizu, Aizu-Wakamatsu 965-8580, Fukushima, Japan, 5.Institute of Space and Astronautical Science (ISAS), Japan Aerospace Exploration Agency, Sagamihara, 252-5210, Japan, 6.Department of Earth, Environmental and Planetary Sciences, Brown University, Providence, RI 02912, USA, 7.Jacobs/NASA Johnson Space Center, USA, 8.Tohoku University, Miyagi, Japan, 9.Kwansei Gakuin University, Hyogo, Japan, 10.Nagoya University, Nagoya 464-8601, 11.Kobe University, Kobe 657-8501, Japan, 12.National Astronomical Observatory of Japan, Mitaka 181-8588, Japan.)

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

[PPS04-17] Quantitative analysis of spectral evolution of craters, boulders, and regolith on Ryugu and Bennu

*Koki Yumoto[1], Eri Tatsumi[2,1], Tatsuki Ebihara[1], DellaGiustina Daniella[3], Naofumi Takaki[1], Tomokatsu Morota[1], Yuichiro Cho[1], Golish Dathon[3], Rie Honda[4], Shingo Kameda[5], Yasuhiro Yokota[6], Naoya Sakatani[5], Toru Kouyama[7], Sawada Hirotaka[6], Masahiko Hayakawa[6], Matsuoka Moe[6], Manabu Yamada[8], Hidehiko Suzuki[9], Chikatoshi Honda[10], Kazunori Ogawa[11,12], Kazuo Yoshioka[1], Seiji Sugita[1] (1.University of Tokyo, 2.Instituto de Astrofísica de Canarias,

3.Lunar and Planetary Laboratory, Univ. of Arizona, 4.Kochi Univ., 5.Rikkyo Univ., 6.ISAS/JAXA, 7.Inst. of Adv. Ind. Sci. and Tech., 8.Chiba Inst. of Tech., 9.Meiji Univ., 10.Univ. of Aizu, 11.JSEC/JAXA, 12.Kobe Univ.)

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

[PPS04-18] Bennu's Global Geologic Map Reveals the Last Epoch of Resurfacing

*Erica R Jawin[1], Timothy J McCoy[1], Kevin John Walsh[2], Harold C Connolly[3], Ronald L Ballouz[4], Andrew Joseph Ryan[4], Maurizio Pajola[5], Olivier S Barnouin[6], Hannah H kaplan[7], Vicky E Hamilton[2], Josh P Emery[8], Daniella N Dellagiustina[4], Daniel Jay Scheeres[9], Michael G Daly[10], Carina A Bennett[4], Dathon R Golish[4], Mark Perry[6], R Terik Daly[6], E Beau Bierhaus[11], Michael C Nolan[4], Heather L Enos[4], Dante S Lauretta[4] (1.Smithsonian National Museum of Natural History, 2.Southwest Research Institute, 3.Rowan University, 4.University of Arizona, 5.INAF-Astronomical Observatory of Padova, 6.Johns Hopkins University Applied Physics Laboratory, 7.Goddard Space Flight Research Center, 8.Northern Arizona University, 9.University of Colorado, Boulder, 10.York University, 11.Lockheed Martin Space)

[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-PS04] Small Solar System Bodies: A New Insight from Hayabusa2, OSIRIS-REx and Other Space Missions

convener:Tatsuaki Okada(Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency), Taishi Nakamoto(Tokyo Institute of Technology), Daisuke Kuroda(Kyoto University), Chairperson:Tatsuaki Okada(Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency), Taishi Nakamoto(Tokyo Institute of Technology), YACHEN YANG(Center for Space and Remote Sensing Research)

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

[PPS04-19] Impact histories inferred from exogenic boulders on asteroids Ryugu and Bennu

★Invited Papers

*ERI TATSUMI[1,2], Chiho Sugimoto[2], Seiji Sugita[2], Marcel Popescu[4], Humberto Campins[11], Julia de León[3], Amy A. Simon[5], Hannah H. Kaplan[6], Yuichiro Cho[2], Tomokatsu Morota[2], Rie Honda[7], Shingo Kameda[8], Yasuhiro Yokota[3], Koki Yumoto[2], Minami Aoki[2], Daniella N. DellaGiustina[10], Dathon R. Golish[10], Javier Licandro[1], Juan Luis Rizos[1], Takahiro Hiroi[12], Deborah Domingue[13], Michel Patrick[14], Dante S. Lauretta[10], Manabu Yamada[15], Naoya Sakatani[8], Toru Kouyama[9], Chikatoshi Honda[16], Masahiko Hayakawa[3], Moe Matsuoka[3], Hidehiko Suzuki[17], Kazunori Ogawa[3], Hirotaka Sawada[3] (1.Instituto de Astrofisica de Canarias, 2.Univ. of Tokyo, 3.ISAS/JAXA, 4.Astronomical Institute of the Romanian Academy, 5.NASA Goddard Space Flight Center, 6.Southwest Research Institute, 7.Kochi Univ., 8.Rikkyo Univ., 9.AIST, 10.Univ. of Arizona, 11.Univ. of Central Florida, 12.Brown Univ., 13.Planetary Science Institute, 14.Observatoire de la Côte d'Azur, 15.Chiba Institute of Tech., 16.Univ. of Aizu, 17.Meiji Uni.)

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

[PPS04-20] The ESA Hera mission: rendezvous with a binary asteroid, planetary defense and science

★Invited Papers

*Patrick Michel[1], Michael Kueppers[2], Alan Fitzsimmons[3], Simon F. Green[4], Monica Lazzarin[5], Stephan Ulamec[6], Ian Carnelli[7], Paolo Martino[7] (1.Universite Côte D'Azur, Observatoire De La Côte D'Azur, CNRS, Laboratoire Lagrange, 2.ESA-European Space Astronomy Centre, 3.Queen's University Belfast, 4.The Open University, 5.Padova University, 6.DLR RB-MUSC, 7.ESA-ESTEC)

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

[PPS04-21] Hayabusa2 Extended Mission to rendezvous with Asteroid 1998 KY26: Investigations of an extremely small fast rotator for planetary defense

*Masatoshi Hirabayashi[1], Y. Mimasu[2], N. Sakatani[3], S. Watanabe[4], Y. Tsuda[2], T. Saiki[2], S. Kikuchi[2], T. Kouyama[5], M. Yoshikawa[2], S. Tanaka[2], S. Nakazawa[2], Y. Takei[2], F. Terui[2], H. Takeuchi[2], A. Fujii[2], T. Iwata[2], K. Tsumura[6], S. Matsuura[7], Y. Shimaki[2], S. Urakawa[8], Y. Ishibashi[9], S. Hasegawa[2], M. Ishiguro[10], D. Kuroda[11], S. Okumura[8], S. Sugita[12], T. Okada[2], S. Kameda[3], S. Kamata[13], A. Higuchi[14], H. Senshu[15], H. Noda[16], K. Matsumoto[16], R. Suetsugu[17], T. Hirai[15], K. Kitazato[18] (1.Auburn University, 2.Japan Aerospace Exploration Agency, 3.Rikkyo University, 4.Nagoya University, 5.National Institute of Advanced Industrial Science and Technology, 6.Tokyo City University, 7.Kwansei Gakuin University, 8.Japan Spaceguard Association, 9.Hosei University, 10.Seoul National University, 11.Kyoto University, 12.University of Tokyo, 13.Hokkaido University, 14.University of Occupational and Environmental Health, 15.Chiba Institute of Technology, 16.National Astronomical Observatory of Japan, 17.National Institute of Technology, 18.University of Aizu)

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

[PPS04-22] **Highly Time-Resolved Photometric Observations of Tiny Near Earth Objects with the Tomo-e Gozen Camera**

*Jin Beniyama[1], Shigeyuki Sako[1], Ryou Ohsawa[1], Satoshi Takita[1], Naoto Kobayashi[1], Shin-ichiro Okumura[2], Seitaro Urakawa[2], Fumihiko Usui[3], Fumi Yoshida[4,5], Makoto Yoshikawa[3] (1.Institute of Astronomy, Graduate School of Science, The University of Tokyo, 2.Japan Spaceguard Association, 3.Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency, 4.University of Occupational and Environmental Health, 5.Planetary Exploration Research Center, Chiba Institute of Technology)

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

[PPS04-23] Color and size distributions of main belt asteroids obtained by the Subaru/Hyper Suprime-Cam

*Natsuho Maeda[1], Tsuyoshi Terai[2], Keiji Ohtsuki[1], Fumi Yoshida[3,4], Kosuke Ishihara[1,2,5], Takuto Deyama[1,6] (1.Graduate school of science, Kobe University , 2.National Astronomical Observatory of Japan, 3.Chiba Institute of

Technology, 4.University of Occupational and Environmental Health, 5.The Graduate University for Advanced Studies, 6.NTT Data MSE Corporation)

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

[PPS04-24] Discussion

[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-EM09] Dynamics of Magnetosphere and Ionosphere

convener:Akiko Fujimoto(Kyushu Institute of Technology), Mitsunori Ozaki(Faculty of Electrical and Computer Engineering, Institute of Science and Engineering, Kanazawa University), Yuka Sato(Nippon Institute of Technology), Aoi Nakamizo(Applied Electromagnetic Research Institute, National Institute of Information and Communications Technology), Chairperson:Hiroshi Hasegawa(Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency), Masaki N Nishino(Japan Aerospace Exploration Agency, Institute of Space and Astronautical Science)

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

[PEM09-01] Introduction

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

[PEM09-02] Magnetic Reconnection in a Sheared Magnetic Flux Tube: Slippage versus Tearing

*Hidetaka Kuniyoshi[1], Michael Hesse[2], Cecilia Nogren[3], Paul Tenfjord[3], Norah Kaggwa Kwagala[3] (1.The University of Tokyo, Department of Earth and Planetary Science, 2.NASA Ames Research Center, 3.University of Bergen, Space Plasma Physics Group)

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

[PEM09-03] Fast Magnetic-Field Annihilation in Electron-scale Current Sheet in Earth's Magnetotail

*Hiroshi Hasegawa[1], Richard E. Denton[2], Kevin J. Genestreti[3], Takuma Nakamura[4], Tai D. Phan[5], Rumi Nakamura[4], Kyoung-Joo Hwang[6], Narges Ahmadi[7], Quanqi Shi[8], Michael Hesse[9], James L. Burch[6], James M. Webster[6], Roy B. Torbert[10], Barbara L. Giles[11], Dan J. Gershman[11], Christopher T. Russell[12], Robert J. Strangeway[12], Hanying Wei[12], Per-Arne Lindqvist[13], Yuri V. Khotyaintsev[14], Robert E. Ergun[15], Yoshifumi Saito[1] (1.Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency, 2.Department of Physics and Astronomy, Dartmouth College, 3.Southwest Research Institute, Durham, 4.Space Research Institute, Austrian Academy of Sciences, 5.Space Sciences Laboratory, University of California, Berkeley, 6.Southwest Research Institute, San Antonio, 7.Laboratory for Atmospheric and Space Physics, University of Colorado, 8.Shandong Provincial Key Laboratory of Optical Astronomy and Solar-Terrestrial Environment, Institute of Space Sciences, Shandong University, 9.Space Plasma Physics Group, University of Bergen, 10.Physics Department, University of New Hampshire, 11.NASA Goddard Space Flight Center, 12.Department of Earth, Planetary, and Space Sciences, University of California, Los Angeles, 13.Royal Institute of Technology, Stockholm, 14.Swedish Institute of Space Physics, 15.Department of Astrophysical and Planetary Sciences, University of Colorado)

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

[PEM09-04] Energy dependence of field-aligned anisotropy of electrons during dipolarization at Earth's tailside

*Kaiti Wang[1], Ching-Huei Lin[2], Zhuo-Ren Lang[3], Tohru Hada[4], Toshi Nishimura[5] (1.Tamkang Univ., 2.Chien-Hsin Univ. of Sci. & Tech., 3.National Cheng Kung Univ., 4.Kyushu Univ., 5.Boston Univ.)

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

[PEM09-05] On the origin of cold-dense plasmas in the dusk magnetotail plasma sheet: MMS and Geotail observations

*Masaki N Nishino[1], Yoshifumi Saito[1], Hiroshi Hasegawa[1], Naritoshi Kitamura[2], Yukinaga Miyashita[3,4], Tsugunobu Nagai[1], Shoichiro Yokota[5], Daniel J Gershman[6], Christopher T Russell[7], Barbara L Giles[6] (1.Japan Aerospace Exploration Agency, Institute of Space and Astronautical Science, 2.Graduate School of Science, The University of Tokyo, 3.Korea Astronomy and Space Science Institute, South Korea, 4.Korea University of Science and Technology, South Korea, 5.Graduate School of Science, Osaka University, 6.Goddard Space Flight Center, NASA, 7.University of California, Los Angeles)

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

[PEM09-06] **Substorm-like events related to magnetosheath plasma jets**

*ALEXEI DMITRIEV[1,2], ALLA SUVOROVA[2] (1.Institute of Space Science, National Central University, Jungli City, Taiwan, 2.Skobeltsyn Institute of Nuclear Physics, Lomonosov Moscow State University, Moscow, Russia)

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

[PEM09-07] Discussion

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

10:45 AM - 12:15 PM JST | 1:45 AM - 3:15 AM UTC | Ch.05 Zoom Room 05

[P-EM09] Dynamics of Magnetosphere and Ionosphere

convener:Akiko Fujimoto(Kyushu Institute of Technology), Mitsunori Ozaki(Faculty of Electrical and Computer Engineering, Institute of Science and Engineering, Kanazawa University), Yuka Sato(Nippon Institute of Technology), Aoi Nakamizo(Applied Electromagnetic Research Institute, National Institute of Information and Communications Technology), Chairperson:Hiroshi Hasegawa(Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency), Masaki N Nishino(Japan Aerospace Exploration Agency, Institute of Space and Astronautical Science)

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

[PEM09-08] A Case Study of Transversely Heated Low-Energy Helium Ions by EMIC Waves in the Plasmasphere

★Invited Papers

*Khan-Hyuk Kim[1] (1.School of Space Research, Kyung Hee University)

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

[PEM09-09] CIR- and CME-driven magnetic storm effects on ion upflows in the low-altitude polar ionosphere

*Masayoshi Takada[1], Kanako Seki[1], Yasunobu Ogawa[2], Kunihiro Keika[1] (1.Tokyo University, 2.National Institute of Polar Research)

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

[PEM09-10] Science Objectives of FACTORS mission

*Yoshizumi Miyoshi[1], Naritoshi Kitamura[2], Kazushi Asamura[3], Takeshi Sakanoi[4], Takanori Nishiyama[6], Hirotsugu Kojima[5], Masahito Nose[1], Yuto Katoh[4], Kunihiro Keika[2], Atsuki Shinbori[4,1], Mizuki Fukizawa[4], Kiyoka Murase[6], Miki Kawamura[4] (1.Institute for Space-Earth Environmental Research, Nagoya University, 2.University of Tokyo, 3.JAXA, 4.Tohoku University, 5.Kyoto University, 6.NIPR)

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

[PEM09-11] **Development of a novel method for extracting the geometrical properties of the magnetic vector fields towards the era of multi-point satellite observations**

*Akimasa Yoshikawa[1], Tsubasa Hashimoto[2], Aoi Nakamizo[4], Shinichi Ohtani[3] (1.Department of Earth and Planetary Sciences, Kyushu University, 2.Gradient school of Earth and Planetary Sciences, Kyushu University, 3.JHU/APL, 4.NICT)

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

[PEM09-12] Dawn-dusk asymmetry in the mesoscale field-aligned currents embedded in the diminished large-scale Region 1 current

*Yoshihiro Yokoyama[1], Satoshi Taguchi[1], Toshihiko Iyemori[2] (1.Department of Geopysics, Graduate School of Science, Kyoto University, 2.Kyoto University)

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

[PEM09-13] Discussion

[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-EM09] Dynamics of Magnetosphere and Ionosphere

convener:Akiko Fujimoto(Kyushu Institute of Technology), Mitsunori Ozaki(Faculty of Electrical and Computer Engineering, Institute of Science and Engineering, Kanazawa University), Yuka Sato(Nippon Institute of Technology), Aoi Nakamizo(Applied Electromagnetic Research Institute, National Institute of Information and Communications Technology), Chairperson:Yuki Obana(Department of Engineering Science, Faculty of Engineering, Osaka Electro-Communication University), Yoshihiro Yokoyama(Department of Earth and Planetary Sciences, Graduate School of Science, Kyoto University)

1:45 PM - 2:10 PM JST | 4:45 AM - 5:10 AM UTC

[PEM09-14] Current and future perspectives on 3D analysis of aurora

★Invited Papers

*Yoshimasa Tanaka[1,2,3], Yasunobu Ogawa[1,2,3], Akira Kadokura[1,2,3], Bjorn Gustavsson[4], Kirsti Kauristie[5], Enell Carl-fredrik[6], Urban Brandstrom[7], Tima Sergienko[7], Alexander Kozlovsky[8], Tero Raita[8], Mizuki Fukizawa[9], Takeshi Sakanoi[9], Keisuke Hosokawa[10] (1.National Institute of Polar Research, 2.Polar Environment Data Science Center, Joint Support-Center for Data Science Research, Research Organization of Information and Systems, 3.The Graduate University for Advanced Studies, SOKENDAI, 4.The Arctic University of Norway, 5.Finnish Meteorological Institute, 6.EISCAT Scientific Association, 7.Swedish Institute of Space Physics, 8.Sodankyla Geophysical Observatory, 9.Planetary Plasma and Atmospheric Research Center, Graduate School of Science, Tohoku University, 10.Department of Communication Engineering and Informatics, University of Electro-Communications)

2:10 PM - 2:25 PM JST | 5:10 AM - 5:25 AM UTC

[PEM09-15] Reconstruction of the three-dimensional structure and precipitating electrons of pulsating auroral patches by Aurora Computed Tomography

*Mizuki Fukizawa[1], Takeshi Sakanoi[1], Yoshimasa Tanaka[2], Yasunobu Ogawa[2], Björn Gustavsson[3], Kirsti Kauristie[4], Carl-Fredrik Enell[5], Alexander Kozlovsky[6], Tero Raita[6], Urban Brändström[7], Tima Sergienko[7] (1.Planetary Plasma and Atmospheric Research Center, Graduate School of Science, Tohoku University, 2.National Institute of Polar Research, 3.University of Tromsø - The Arctic University of Norway, 4.Finnish Meteorological Institute, 5.EISCAT Scientific Association, 6.Sodankylä Geophysical Observatory, University of Oulu, 7.Swedish Institute of Space Physics)

2:25 PM - 2:40 PM JST | 5:25 AM - 5:40 AM UTC

[PEM09-16] A generation process of “Great Wall” aurora seen from ISS

*Sota Nanjo[1], Morio Tanaka[2], Natsuo Sato[3], Yuta Hozumi[1], Keisuke Hosokawa[1], Ryuho Kataoka[3,4], Yoshizumi Miyoshi[5], Shin-ichiro Oyama[3,5,6], Mitsunori Ozaki[7], Kazuo Shiokawa[5], Satoshi Kurita[2] (1.The University of Electro-Communications, 2.Kyoto University, 3.National Institute of Polar Research, 4.SOKENDAI, the Graduate University for Advanced Studies, 5.ISEE, Nagoya University, 6.University of Oulu, 7.Kanazawa University)

2:40 PM - 2:55 PM JST | 5:40 AM - 5:55 AM UTC

[PEM09-17] Exploring the Electron Acceleration Mechanism in the Poleward Boundary Intensification

*Hayato Higuchi[1], Akimasa Yoshikawa[2] (1.Department of Earth and Planetary Sciences, Graduate School of Science, Kyushu University, 2.Department of Earth and Planetary Sciences, Faculty of Science, Kyushu University)

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

[PEM09-18] **Antarctic large area network observation of auroral phenomena using unmanned system: Current status of project as of early 2021**

*Akira Kadokura[1], Yasunobu Ogawa[1], Yoshimasa Tanaka[1], Hisao Yamagishi[1], Masaki Okada[1], Ryuho Kataoka[1], Herbert Akihito Uchida[4], Yuichi Otsuka[2], Tetsuo Motoba[3], Natsuo Sato[1], Henri Robert[5], Ashwini K. Sinha[6], Jean Rasson[7] (1.National Institute of Polar Research, 2.Nagoya University, 3.Johns Hopkins University, Applied Physics Laboratory, 4.SOKENDAI, 5.International Polar Foundation, 6.Indian Institute of Geomagnetism, 7.Royal Meteorological Institute of Belgium)

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

[PEM09-19] Discussion

[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-EM09] Dynamics of Magnetosphere and Ionosphere

convener:Akiko Fujimoto(Kyushu Institute of Technology), Mitsunori Ozaki(Faculty of Electrical and Computer Engineering, Institute of Science and Engineering, Kanazawa University), Yuka Sato(Nippon Institute of Technology), Aoi Nakamizo(Applied Electromagnetic Research Institute, National Institute of Information and Communications Technology), Chairperson:Yuki Obana(Department of Engineering Science, Faculty of Engineering, Osaka Electro-Communication University), Yoshihiro Yokoyama(Department of Earth and Planetary Sciences, Graduate School of Science, Kyoto University)

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

[PEM09-20] Seasonal dependence of dusk-side equatorial IHFACs polarity during solar cycle 23-24

Manjula Ranasinghe[2], *Akiko Fujimoto[1], Akimasa Yoshikawa[3], Chandana Jayaratne[2] (1.Kyushu Institute of Technology, 2.University of Colombo, 3.Kyushu University)

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

[PEM09-21] Development of the imaging receiver system for the SuperDARN Hokkaido East radar

*Nozomu Nishitani[1], Tomoaki Hori[1], Yoshiyuki Hamaguchi[1] (1.Institute for Space-Earth Environmental Research, Nagoya University)

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

[PEM09-22] Seasonal and longitudinal dependence of the Sub-Auroral Polarization Streams occurrence observed by the SuperDARN radars

Kento Oya[1], *Nozomu Nishitani[1], Tomoaki Hori[1], John Mike Ruohoniemi[2], William A. Bristow[3], Simon G. Shepherd[4], Bharat Kunduri[2] (1.Institute for Space-Earth Environmental Research, Nagoya University, 2.Virginia Tech Department of Electrical and Computer Engineering, 3.The Pennsylvania State University , 4.Thayer School of Engineering, Dartmouth College)

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

[PEM09-23] Investigation of the mid-latitude ionospheric response during substorm based on magnetic and electric field observations

*Moe Hayashi[1], Akimasa Yoshikawa[1], Akiko Fujimoto[2], Shinichi Ohtani[3] (1.Kyushu University, 2.Kyushu Institute of Technology , 3.The Johns Hopkins University Applied Physics Laboratory)

4:30 PM - 4:55 PM JST | 7:30 AM - 7:55 AM UTC

[PEM09-24] New results of auroral hiss observations on the ground at L=5.5 in Northern Europe

★Invited Papers

*Jyrki Manninen[1], Natalia G. Kleimenova[2,3], Yury Fedorenko[4], Olga Lebed[4], Alexander Kozlovsky[1], Alexander Nikitenko[4], Liudmila Gromova[5] (1.Sodankyla Geophysical Observatory, University of Oulu, Sodankylä, Finland, 2.Schmidt Institute of Physics of the Earth RAN, Moscow, Russia, 3.Space Research Institute RAN, Moscow, Russia, 4.Polar Geophysical Institute, Apatity, Russia, 5.Pushkov Institute of Terrestrial Magnetism, Ionosphere and Radio Wave Propagation RAN, Moscow, Russia)

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

[PEM09-25] Discussion

[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-EM10] Frontiers in solar physics

convener:Takaaki Yokoyama(School of Science, University of Tokyo), Shinsuke Imada(Institute for Space-Earth Environmental Research, Nagoya University), Shin Toriumi(Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency), Alphonse Sterling(NASA/MSFC), Chairperson:Shin Toriumi(Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency)

9:00 AM - 9:01 AM JST | 12:00 AM - 12:01 AM UTC

[PEM10-01] Introduction

9:01 AM - 9:23 AM JST | 12:01 AM - 12:23 AM UTC

[PEM10-02] Sun-to-Earth MHD Simulations of Geo-Effective CMEs

★Invited Papers

*Tibor Torok[1] (1.Predictive Science Inc.)

9:23 AM - 9:45 AM JST | 12:23 AM - 12:45 AM UTC

[PEM10-03] How To Trigger the Solar Flares?

★Invited Papers

*Yumi Bamba[1] (1.Nagoya University)

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

[PEM10-04] The Source Locations of Major Flares and CMEs in the Emerging Active Regions

*Liu Lijuan[1], Wang Yuming[2], Zhou Zhenjun[1] (1.School of Atmospheric Sciences, Sun Yat-sen University, Zhuhai, Guangdong, 519082, China, 2.Department of Geophysics and Planetary Sciences, University of Science and Technology of China, Hefei, Anhui, 230026, China)

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

[PEM10-05] Evaluation of horizontal flow velocity at the solar surface with machine learning and numerical simulation

*Hiroyuki Masaki[1], Hideyuki Hotta[2] (1.Graduate School of Science and Engineering, Chiba University, 2.Chiba University)

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

[PEM10-06] Satellite mission: *PhoENiX* (Physics of Energetic and Non-thermal plasmas in the X (= magnetic reconnection) region)

*Noriyuki Narukage[1], Mitsuo Oka[2], Yasushi Fukazawa[3], Keiichi Matsuzaki[4], Shin Watanabe[4], Taro Sakao[4], Kouichi Hagino[5], Ikuyuki Mitsuishi[6], Tsunefumi Mizuno[3], Iku Shinohara[4], Masumi Shimojo[1], Shinsuke Takasao[7], Tomoko Kawate[8], Takafumi Kaneko[6], Hiroshi Tanabe[9], Munetaka UENO[4], Tadayuki Takahashi[10], Takeshi Takashima[4], Masayuki Ohta[4] (1.National Astronomical Observatory of Japan, 2.University of California, Berkeley, 3.Hiroshima University, 4.Japan Aerospace Exploration Agency, 5.Tokyo University of Science, 6.Nagoya University, 7.Osaka University, 8.National Institute for Fusion Science, 9.The University of Tokyo, 10.Kavli Institute for the Physics and Mathematics of the Universe)

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

10:45 AM - 12:14 PM JST | 1:45 AM - 3:14 AM UTC | Ch.06 Zoom Room 06

[P-EM10] Frontiers in solar physics

convener:Takaaki Yokoyama(School of Science, University of Tokyo), Shinsuke Imada(Institute for Space-Earth Environmental Research, Nagoya University), Shin Toriumi(Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency), Alphonse Sterling(NASA/MSFC), Chairperson:Takaaki Yokoyama(School of Science, University of Tokyo)

10:45 AM - 11:07 AM JST | 1:45 AM - 2:07 AM UTC

[PEM10-07] Spectroscopic and photometric observations of superflares and filament eruption on cool stars

★Invited Papers

*Kosuke Namekata[1,2], Hiroyuki Maehara[2], Ryo Sasaki[3], Hiroki Kawai[3], Yuta Notsu[4], Adam F. Kowalski[4], Joel C. Allred[5], Wataru Iwakiri[3], Yohko Tsuboi[3], Satoshi Honda[6], Soshi Okamoto[1], Kiyoshi Ichimoto[1], Daisaku Nogami[1], Kazunari Shibata[1], Katsuhiro L. Murata[7], Masafumi Niwano[7], Kazuki Shiraishi[7], Ryo Adachi[7], Kota Iida[7], Motoki Oeda[7], Miyako Tozuka[6], Noriyuki Katoh[6], Hiroki Onozuka[6], Keizuke Isogai[1], Mariko Kimura[8], Naoto Kojiguchi[1], Yasuyuki Wakamatsu[1], Yusuke Tampo[1], Futa Ogawa[7], Jun Takahashi[6], Takako T. Ishii[1], Masaki Takayama[6], Tomohito Ohshima[6], Tomoki Saito[6] (1.Kyoto Univ., 2.NAOJ, 3.Chuo Univ., 4.Colorado Univ., 5.NASA, 6.Univ. of Hyogo, 7.Tokyo Institute of Technology, 8.RIKEN)

11:07 AM - 11:29 AM JST | 2:07 AM - 2:29 AM UTC

[PEM10-08] The Solar Orbiter mission – Exploring the Sun and heliosphere

★Invited Papers

*Daniel Mueller[1] (1.European Space Agency)

11:29 AM - 11:44 AM JST | 2:29 AM - 2:44 AM UTC

[PEM10-09] Current Status of the Solar-C_EUVST Mission

*Shinsuke Imada[1], Toshifumi Shimizu[2], Tomoko Kawate[2], Shin Toriumi[2], Yukio Katsukawa[3], Masahito Kubo[3], Hirohisa Hara[3], Yoshinori Suematsu[3], Kiyoshi Ichimoto[4], Ayumi Asai[4], Kyoko Watanabe[6], Takaaki Yokoyama[5], Akiko Tei[2], Harry Warren[7], David Long[8], Louise Harra[8], Luca Teriaca[9], Sarah Matthews[8], Vincenzo Andrette[10], Frederic Auchere[11] (1.Institute for Space-Earth Environmental Research, Nagoya University, 2.ISAS, 3.NAOJ, 4.Kyoto University, 5.University of Tokyo, 6.NDA, 7.NRL, 8.UCL, 9.MPS, 10.Istituto Nazionale di Astrofisica,, 11.IAS)

11:44 AM - 11:59 AM JST | 2:44 AM - 2:59 AM UTC

[PEM10-10] Solar-C(EUVST)/SoSpIM development status and scientific studies

*Kyoko Watanabe[1], Louise Harra[2], Shinsuke Imada[3], Tomoko Kawate[4], Hirohisa Hara[5], Toshifumi Shimizu[6], Yoshizumi Miyoshi[3], Nozomu Nishitani[3], Tomoaki Hori[3], Akimasa Ieda[3], Toshiki Kawai[3], Hidekatsu Jin[7], Chihiro Tao[7], Shohei Nishimoto[1] (1.National Defense Academy of Japan, 2.Physical Meteorological Observatory in Davos, World Radiation Center, 3.Institute for Space-Earth Environmental Research, Nagoya University, 4.National Institute for Fusion Science, National Institutes of Natural Sciences, 5.National Astronomical Observatory of Japan, National Institutes of Natural Sciences, 6.Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency, 7.National Institute of Information and Communications Technology)

11:59 AM - 12:14 PM JST | 2:59 AM - 3:14 AM UTC

[PEM10-11] Cross-disciplinary study on heating, transport, and turbulence dynamics in solar/astrophysical and fusion/laboratory plasmas: SoLaBo-X

*Motoki Nakata[1], Ryohtaroh T Ishikawa[4], Yukio Katsukawa[2], Yohei Masada[5], Tatsuya Kobayashi[1], Munehito Shoda[2], Shinsuke Imada[3], Shin Toriumi[6], Kenichi Nagaoka[1], SoLaBo-X project[1,2] (1.National Institute for Fusion Science , 2.National Astronomical Observatory of Japan, 3.Institute for Space-Earth Environmental Research , 4.The Graduate University for Advanced Studies, 5.Aichi University of Education, 6.Japan Aerospace Exploration Agency Institute of Space and Astronautical Science)

[E] Oral | P (Space and Planetary Sciences)：P-AE Astronomy & Extrasolar Bodies

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

[P-AE16] Exoplanets

convener:Masahiro Ikoma(Division of Science, National Astronomical Observatory of Japan), Norio Narita(The University of Tokyo), Yuka Fujii(National Astronomical Observatory of Japan), Chairperson:Yuka Fujii(National Astronomical Observatory of Japan)

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

[PAE16-01] Exploring New Worlds: An Integrative, Probabilistic Analysis of Nearby Exoplanets and Exoplanetary Systems

★Invited Papers

*Daniel Apai[1] (1.The University of Arizona)

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

[PAE16-02] Global climate modeling of TRAPPIST-1e using MIROC for the model intercomparison

*Takeshi Kuroda[1], Yujie Zou[1,2], Arihiro Kamada[1], Takanori Kodama[2], Naoki Terada[1] (1.Department of Geophysics, Tohoku University, 2.Komaba Institute for Science, The University of Tokyo)

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

[PAE16-03] Global Mapping of the Surface Composition on an Exo-Earth using Sparse Modeling

*Atsuki Kuwata[1], Hajime Kawahara[1], Masataka Aizawa[2], Takayuki Kotani[3,4,5], Motohide Tamura[1,3,4] (1.The University of Tokyo, 2.Tsung-Dao Lee Institute, 3.Astrobiology center, 4.National Astronomical Observatory of Japan, 5.University for Advanced Studies (SOKENDAI))

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

[PAE16-04] Search for Extra-terrestrial Mother Planets Catalogue for influence of stellar activities on the extraplanetary system.

*Yosuke Alexandre Yamashiki[1], Hiroyuki Maehara[2], Vladimir Airapetian[3], Yuta Notsu[6], Kosuke Namekata[4], Riko Shimizu[5], Nami Kimura[1], Tatsuhiko Sato[7], Takanori Sasaki[4] (1.Earth & Planetary Water Resources Assessment Laboratory Graduate School of Advanced Integrated Studies in Human Survivability Kyoto University, 2.National Astronomical Observatory of Japan, 3.NASA's Goddard Space Flight Center, 4.Graduate School of Science, Kyoto University, 5.Faculty of Science, Kyoto University, 6.University of Colorado, 7.Japan Atomic Energy Agency)

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

[PAE16-05] Observational implications of atmospheric and orbital evolution of super-Earths

*Naho Fujita[1], Yasunori Hori[2,3], Takanori Sasaki[1] (1.Kyoto University, 2.Astrobiology Center, 3.National Astronomical Observatory of Japan)

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

[PAE16-06] Effects of H_2 pumping on hot Jupiter's atmospheric escape

*Hiroto Mitani[1], Riouhei Nakatani[2], Naoki Yoshida[1] (1.The University of Tokyo, 2.RIKEN)

[E] Oral | P (Space and Planetary Sciences)：P-AE Astronomy & Extrasolar Bodies

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

[P-AE16] Exoplanets

convener:Masahiro Ikoma(Division of Science, National Astronomical Observatory of Japan), Norio Narita(The University of Tokyo), Yuka Fujii(National Astronomical Observatory of Japan), Chairperson:Norio Narita(The University of Tokyo)

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

[PAE16-07] TESS legacy: the brightest, closest transiting planets for atmospheric studies.

★Invited Papers

*Rafael Luque[1] (1.Instituto de Astrofisica de Andalucia)

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

[PAE16-08] Development of multiband imager MuSCAT3 and its first results on followup observations of TESS transiting planets

*Akihiko Fukui[1], Norio Narita[1,2], Masahiro Ikoma[1], Keisuke Isogai[4], Kiyoe Kawauchi[1], Takanori Kodama[1], Seiya Kurita[1], Nobuhiko Kusakabe[2], Jerome Pitogo de Leon[1], John Livingston[1], Mayuko Mori[1], Taku Nishiumi[3], Motohide Tamura[1,2], Noriharu Watanabe[3], Tomoyasu Yamamuro[5], Daniel Harbeck[6], Mark Bowman[6], Mark Elphick[6], Jon Nation[6], James Armstrong[7], Jacqueline Han[7], Matt Daily[6] (1.The University of Tokyo, 2.Astrobiology Center, 3.SOKENDAI, 4.Kyoto University, 5.OptCraft, 6.Las Cumbres Observatory Global Telescope Network, 7.University of Hawaii)

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

[PAE16-09] New Validated Planets in Overlapping K2 Campaigns

*Jerome Pitogo de Leon[1], John Livingston[1], Michael Endl[4], William Cochran[5,4], Teruyuki Hirano[18], Masayuki Kuzuhara[15,14], Rafael Garcia[11], Savita Mathur[6,7], Fei Dai[10,9], Alessandro Trani[2], Judith Korth[6,7], Kristine Lam[8], Enrique Diez Alonzo[17], Amadeo Castro Gonzalez[17], Malcolm Fridlund[12,13], Akihiko Fukui[3], Rafa Luque[6,7], Norio Narita[16,2,15,14], Enric Palle[6,7], Motohide Tamura[1,14,15], KESPRINT team (1.Department of Astronomy, University of Tokyo, 7-3-1 Hongo, Bunkyo-ku, Tokyo 113-0033, Japan, 2.Department of Earth Science and Astronomy, College of Arts and Sciences, The University of Tokyo, 3-8-1 Komaba, Meguro-ku, Tokyo 153-8902, Japan, 3.Department of Earth and Planetary Science, University of Tokyo, 7-3-1 Hongo, Bunkyo-ky, Tokyo 113-0033, Japan, 4.Department of Astronomy and McDonald Observatory, University of Texas at Austin, 2515 Speedway, Stop C1400, Austin, TX 78712, USA, 5.Center for Planetary Systems Habitability, The University of Texas at Austin, Austin TX USA, 6.Instituto de Astrofisica de Canarias (IAC), 38205 La Laguna, Tenerife, Spain, 7.Departamento de Astrofisica, Universidad de La Laguna, 38206 La Laguna, Tenerife, Spain, 8.Center for Astronomy and Astrophysics, Technical University Berlin, Hardenbergstr. 36, 10623 Berlin, Germany, 9.Division of Geological and Planetary Sciences, California Institute of Technology, 1200 East California Blvd, Pasadena CA 91125, 10.Department of Astrophysical Sciences, Princeton University, 4 Ivy Lane, Princeton, NJ 08544, USA, 11.AIM, CEA, CNRS, Universite Paris-Saclay, Universite Paris Diderot, Sorbonne Paris Cité, F-91191 Gif-sur-Yvette, France, 12.Leiden Observatory, Leiden University, 2333CA Leiden, The Netherlands, 13.Department of Space, Earth and Environment, Chalmers University of Technology, Onsala Space Observatory, SE-439 92 Onsala, Sweden, 14.Astrobiology Center, NINS, 2-21-1 Osawa, Mitaka, Tokyo 181-8588, Japan, 15.National Astronomical Observatory of Japan, NINS, 2-21-1 Osawa, Mitaka, Tokyo 181-8588, Japan, 16.JST, PRESTO, 3-8-1 Komaba, Meguro, Tokyo 153-8902, Japan , 17.Instituto Universitario de Ciencias y Tecnologias Espaciales de Asturias (ICTEA), C.Independencia 13, E-33004 Oviedo, Spain, 18.Department of Earth and Planetary Sciences, Tokyo Institute of Technology, 2-12-1 Ookayama, Meguro-ku, Tokyo 152-8551, Japan)

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

[PAE16-10] Spitzer and ground-based follow-up of the young transiting multi-planet system V1298 Tau

*John Livingston[1], Trevor David[2], Gudmundur Stefansson[3], Elisabeth Newton[4], Allyson Bieryla[5], Shreyas Vissapragada[6], Samuel Hadden[5], Erik Petigura[7], Eric Mamajek[8], Lynne Hillenbrand[6], David Ciardi[6], Charles Beichman[6], Luisa Rebull[6], John Stauffer[6], Varoujan Gorjian[6], Heather Knutson[6], Akihiko Fukui[1], Norio Narita[1], Motohide Tamura[1] (1.University of Tokyo, 2.Flatiron Institute, 3.Princeton University, 4.Dartmouth College, 5.Harvard-Smithsonian, 6.California Institute of Technology, 7.University of California, Los Angeles, 8.Jet Propulsion Laboratory)

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

[PAE16-11] **Twinkle: a low-Earth orbit, visible and infrared observatory for exoplanet and solar system spectroscopy**

*Billy Edwards[1] (1.Blue Skies Space Ltd)

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

[PAE16-12] Multi-planetary systems deduced from the observed ALMA disks: initial conditions and evolutionary outcomes

*Shijie Wang[1], Kazuhiro D Kanagawa[1,2], Toshinori Hayashi[1], Yasushi Suto[1] (1.University of Tokyo, 2.Ibaraki University)

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

9:00 AM - 10:30 AM JST | 12:00 AM - 1:30 AM UTC | Ch.07 Zoom Room 07

[A-AS02] Extreme Events: Observations and Modeling

convener:Sridhara Nayak(Disaster Prevention Research Institute, Kyoto University), Tetsuya Takemi(Disaster Prevention Research Institute, Kyoto University), Satoshi Iizuka(National Research Institute for Earth Science and Disaster Resilience), Chairperson:Satoshi Iizuka(National Research Institute for Earth Science and Disaster Resilience), Sridhara Nayak(Disaster Prevention Research Institute, Kyoto University), Tetsuya Takemi(Disaster Prevention Research Institute, Kyoto University)

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

[AAS02-01] Introduction

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

[AAS02-02] Assessing the Impacts of Extreme Weather on Local-Scale Hazards under Climate Change

★Invited Papers

*Tetsuya Takemi[1] (1.Disaster Prevention Research Institute, Kyoto University)

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

[AAS02-03] **Estimation of moisture sources within an explosive cyclone over the Sea of Japan using an isotopic regional spectral model**

★Invited Papers

*Xiaoyang Li[1], Ryuichi Kawamura[1], Atsuko Sugimoto[2,3], Kei Yoshimura[4,5] (1.Department of Earth and Planetary Science, Faculty of Science, Kyushu University, 2.Arctic Research Center, Hokkaido University, 3.Graduate School of Environmental Science, Hokkaido University, 4.Atmosphere and Ocean Research Institute, The University of Tokyo, 5.Institute of Industrial Science, The University of Tokyo)

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

[AAS02-04] Influence of Warm SST in the Oyashio Region on Rainfall Distribution of Typhoon Hagibis (2019)

*Satoshi Iizuka[1], Ryuichi Kawamura[2], Hisashi Nakamura[3], Toru Miyama[4] (1.National Research Institute for Earth Science and Disaster Resilience, 2.Department of Earth and Planetary Sciences, Kyushu University, 3.Research Center for Advanced Science and Technology, University of Tokyo, 4.Japan Agency for Marine-Earth Science and Technology,)

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

[AAS02-05] Simulation of typhoon-induced heavy precipitation over the Philippines using the Multi-scale Kain-Fritsch Cumulus Scheme in WRF

*Jose Angelo Hokson[1], Shinjiro Kanae[1], Rie Seto[1] (1.School of Environment and Society, Tokyo Institute of Technology)

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

[AAS02-06] **Attribution of atmospheric circulation variations associated with winter temperature whiplash events over Northeast China**

*Zhen Liao[1], Panmao Zhai[1], Yang Chen[1] (1.LaSW, CAMS, China)

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

10:45 AM - 12:15 PM JST | 1:45 AM - 3:15 AM UTC | Ch.07 Zoom Room 07

[A-AS02] Extreme Events: Observations and Modeling

convener:Sridhara Nayak(Disaster Prevention Research Institute, Kyoto University), Tetsuya Takemi(Disaster Prevention Research Institute, Kyoto University), Satoshi Iizuka(National Research Institute for Earth Science and Disaster Resilience), Chairperson:Tetsuya Takemi(Disaster Prevention Research Institute, Kyoto University), Sridhara Nayak(Disaster Prevention Research Institute, Kyoto University), Satoshi Iizuka(National Research Institute for Earth Science and Disaster Resilience)

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

[AAS02-07] Introduction

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

[AAS02-08] Observations and simulations of Typhoon Faxai over the Kanto area

★Invited Papers

*Woosub Roh[1], Masaki Satoh[1] (1.AORI, the university of Tokyo)

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

[AAS02-09] River discharge estimation of ungauged mountainous river basin using NIED Hi-net data

★Invited Papers

*Shakti P.C.[1], Kaoru Sawazaki[1] (1.National Research institute for Earth Science and Disaster Resilience (NIED))

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

[AAS02-10] **Increase in the strength of typhoons to Taiwan due to global warming**

*Ravi Shankar Pandey[1], Yuei-An Liou[1] (1.National Central University)

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

[AAS02-11] Investigation of Uncertainties in Regional Climate Information

*Saurabh Kelkar[1] (1.University of Tsukuba)

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

[AAS02-12] **Precipitation patterns in landfalling typhoons over Japan**

*Sridhara Nayak[1], Tetsuya Takemi[1] (1.Disaster Prevention Research Institute, Kyoto University)

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

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

[H-TT14] Geographic Information Systems and Cartography

convener:Takashi Oguchi(Center for Spatial Information Science, The University of Tokyo), Yoshiki Wakabayashi(Graduate School of Urban Environmental Sciences, Tokyo Metropolitan University), Yuei-An Liou(National Central University), C. Ronald Estoque(National Institute for Environmental Studies, Japan), Chairperson:Takashi Oguchi(Center for Spatial Information Science, The University of Tokyo), Yoshiki Wakabayashi(Graduate School of Urban Environmental Sciences, Tokyo Metropolitan University)

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

[HTT14-01] A GIS-based study on accessibility of public bus system in Sapporo

*ZITONG XU[1], Yuichi S. Hayakawa[2,3] (1.Graduate School of Environmental Science, Hokkaido University, 2.Faculty of Environmental Earth Science, Hokkaido University., 3.Center for Spatial Information Science, The University of Tokyo.)

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

[HTT14-02] **Comparative study of visitors' perceptions of places by analyzing visual content of photographs in Shinjuku, Tokyo**

*Bochra Bettaieb[1], Yoshiki Wakabayashi[1] (1.Tokyo Metropolitan University)

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

[HTT14-03] **Geo-phenomenology: A Qualitative GIS Approach for Understanding People's Lived Experiences**

★Invited Papers

*Yuki Iwai[1] (1.Graduate School, University of Tsukuba)

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

[HTT14-04] UAS Surveys for Identifying Vacant Houses using Night Light and Thermal Information

★Invited Papers

*Kotaro Iizuka[1], Yuki Akiyama[1,2], Nobuyuki Imafuku[3], Satoru Sugita[4] (1.Center for Spatial Information Science, University of Tokyo, 2.Graduate School of Integrative Science and Engineering, Tokyo City University, 3.Urban Development Dept., Building and Housing Division, Omuta City, 4.International Digital Earth Applied Science Research Center, Chubu University)

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

[HTT14-05] Impacts of urbanization on the ecosystem services of the Muthurajawela Marsh and Negombo Lagoon, Sri Lanka

*SUMUDU DARSHANA ATHUKORALA ARACHCHIGE[1], Yuji Murayama[2], Bunkei Matsushita[2], Ronald C. Estoque[3] (1.Graduate School of Life and Environmental Sciences, University of Tsukuba, Tsukuba, Ibaraki, Japan, 2. Faculty of Life and Environmental Sciences, University of Tsukuba, Tsukuba, Ibaraki, Japan, 3.National Institute for Environmental Studies, Tsukuba City, Ibaraki, Japan)

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

[HTT14-06] **Evaluating land use change with urban development and its impact on habitat quality**

*BINGYU WANG[1], Takashi Oguchi[1,2], Kotaro Iizuka[2], Xun Liang[3] (1.Department of Natural Environment Studies, The University of Tokyo, 2.Center for Spatial Information Science, The University of Tokyo, 3.School of Geography and Information Engineering, China University of Geosciences)

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

3:30 PM - 5:00 PM JST | 6:30 AM - 8:00 AM UTC | Ch.14 Zoom Room 14

[H-TT14] Geographic Information Systems and Cartography

convener:Takashi Oguchi(Center for Spatial Information Science, The University of Tokyo), Yoshiki Wakabayashi(Graduate School of Urban Environmental Sciences, Tokyo Metropolitan University), Yuei-An Liou(National Central University), C. Ronald Estoque(National Institute for Environmental Studies, Japan), Chairperson:Yuei-An Liou(National Central University), Ronald C. Estoque(National Institute for Environmental Studies, Japan)

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

[HTT14-07] Assessing the effect of landscape composition on land surface temperature in Tsukuba city, Japan

★Invited Papers

*RUCI WANG[1], Yuji Murayama[1], Takehiro Morimoto[1] (1.University of Tsukuba)

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

[HTT14-08] **Spatiotemporal Characterization and Evolution of Surface Urban Heat Islands in Tokyo: A Perspective from Land Cover/Use Layouts and Variations**

*Fei LIU[1] (1.University of Tsukuba)

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

[HTT14-09] Microclimate simulation of Doshisha University Kyotanabe campus with ENVI-met model

★Invited Papers

*XINGYU WANG[1] (1. Department of Environmental Systems Science, Doshisha University)

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

[HTT14-10] **Recent LULC change in Vietnamese Mekong Delta and its relation to land subsidence after implementation of the Resolution No.120/NQ-CP**

*Kim-Anh Nguyen[1], Yuei-An Liou[1], Phan Duong Cao[2], Philip Mindehoud[3] (1.National Central University, 2.University of Tsukuba, 3.University of Padova)

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

[HTT14-11] Locations of historical and archaeological sites in Japan and China in relation to geography

*Yuan Wang[1], Takashi Oguchi[1] (1.The University of Tokyo)

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

[HTT14-12] **Online Education of Disaster Risk Reduction using Web GIS: Applications to Chinese Secondary Schools**

*Jiali Song[1], Takashi Oguchi[2] (1.Graduate School of Frontier Sciences, The University of Tokyo, 2.Center for Spatial Information Science, The University of Tokyo)

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

9:00 AM - 10:30 AM JST | 12:00 AM - 1:30 AM UTC | Ch.21 Zoom Room 21

[S-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:Satoshi Ide(Department of Earth an Planetary Science, University of Tokyo)

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

[SCG39-19] Systematics and heterogeneity of deep and shallow slow earthquakes

*Kazushige Obara[1] (1.Earthquake Research Institute, The University of Tokyo)

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

[SCG39-20] Extraction of fine space-time structures in deep low-frequency tremor using the Hough transform

*Kodai Sagae[1], Hisashi Nakahara[1], Takeshi Nishimura[1], Kazutoshi Imanishi[2] (1.Solid Earth Physics Laboratory,Department of Geophysics,Graduate School of Science,Tohoku University, 2.National Institute of Advanced Industrial Science and Technology (AIST))

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

[SCG39-21] Comprehensive detection of tremor migration using multiple time windows beneath Kii Peninsula

*Takuya Maeda[1], Kazushige Obara[1], Akiko Takeo[1], Takanori Matsuzawa[2] (1. Earthquake Research Institute, The University of Tokyo, 2.National Research Institute for Earth Science and Disaster Resilience)

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

[SCG39-22] Focal mechanism and radiated energy from shallow tremors in the Guerrero seismic gap.

*Raymundo Omar Plata Martinez[1], Yoshihiro Ito[2], Kazuaki Ohta[4], Masanao Shinohara[5], Satoshi Ide[3] (1.Graduate School of Science, Kyoto University, 2.Disaster Prevention Research Institute, Kyoto University, 3.Department of Earth and Planetary Science, University of Tokyo, 4.National Research Institute for Earth Science and Disaster Resilience, 5.Earthquake Research Institute, University of Tokyo)

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

[SCG39-23] Seismicity around the subducted seamount in the trench-trench junction, southern off Hokkaido, by a broadband OBS array

*Ryosuke Azuma[1], Susumu Kawakubo[1], Hidenobu Takahashi[1], Ryota Hino[1], Yusaku Ohta[1], Ryota Takagi[1], Syuichi Suzuki[1], Makiko Sato[1], Tanaka Shinichi[2], Masanao Shinohara[2] (1.Recearch Center for Prediction of Earthquake and Volcanic Eruption, Graduate School of Science, Tohoku University, 2.Earthquake Research Institute, University of Tokyo)

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

[SCG39-24] 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:Kimihiro Mochizuki(Earthquake Prediction Research Center, Earthquake Research Institute, University of Tokyo)

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

[SCG39-25] Spatio-temporal variation of fluid migration associated with slow earthquakes in the shallow Nankai subduction zone

*Takashi Tonegawa[1], Shunsuke Takemura[2] (1.Japan Agency for Marine-Earth Science and Technology, 2.Earthquake Research Institute, The University of Tokyo)

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

[SCG39-26] Land and marine long-term magnetotelluric observations around the western Nankai slow slip area

*Hiroshi Ichihara[1,2], Makoto Uyeshima[3], Hayato Nakamura[1], Maki Hata[3], Tada-nori Goto[4], Noriko Tada[2], Tetsuo Matsuno[5], Shinya Sato[6], Yoshiya Usui[3], Ryokei Yoshimura[7], Koki Aizawa[8] (1.Graduate school of Environmental Studies, Nagoya University, 2.JAMSTEC, 3.ERI, University of Tokyo, 4.University of Hyogo, 5.KOBEC, Kobe University, 6.Graduate school of Engineering, Kyoto University, 7.DPRI, Kyoto University, 8.Graduate school of Science, Kyushu Univeristy)

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

[SCG39-27] Active source seismic experiment investigating structural characteristics associated with slow earthquake activities in the Hyuga-nada, southwestern Japan

*Seiichi Miura[1], Kimihiro Mochizuki[2], Ryuta Arai[1], Yasuyuki Nakamura[1], Yuka Kaiho[1], Gou Fujie[1], Shuichi Kodaira[1], Rie Nakata[2], Yanxue Ma[2], Masataka Kinoshita[2], Yoshitaka Hashimoto[3], Yohei Hamada[1] (1.Japan Agency for Marine-Earth Science and Technology, 2.Earthquake Research Institute, University of Tokyo, 3.Kochi University)

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

[SCG39-28] Seismic characteristics of the northern Hikurangi subduction zone revealed by offshore seismic observations

*Kimihiro Mochizuki[1], Yusuke Yamashita[2], Emily Warren-Smith[3], Martha K Savage[4], Laura M Wallace[3], Stuart Henrys[3] (1.Earthquake Prediction Research Center, Earthquake Research Institute, University of Tokyo, 2.Disaster Prevention Research Institute, Kyoto University, 3.GNS Science, 4.Victoria University of Wellington)

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

[SCG39-29] **Temporal velocity variations in the northern Hikurangi margin and their relation to slow slip**

*Weiwei Wang[1], Martha Savage[1], Alec Yates[1,2], Hubert Zal[1], Carolyn Boulton[1], Megan Kortink[3], Tim Stern[1], Bill Fry[3], Kimihiro Mochizuki[4], Spahr Webb[5], Wallace Laura[3] (1.Victoria University of Wellington, 2.Université Grenoble Alpes, Université Savoie Mont Blanc, 3.GNS Science, 4.Earthquake Research Institute, University of Tokyo, 5.Lamont-Doherty Earth Observatory, Columbia University)

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

[SCG39-30] 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.24 Zoom Room 24

[S-CG40] Active Tectonics and Seismic Hazards in the Himalayan Region

convener:Kazuki Koketsu(Earthquake Research Institute, University of Tokyo), Nath Soma Sapkota(Nepal Geological Society), Srinagesh Davuluri(CSIR-National Geophysical Research Institute), Chairperson:Kazuki Koketsu(Earthquake Research Institute, University of Tokyo), Hiroe Miyake(Earthquake Research Institute, University of Tokyo)

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

[SCG40-01] Seismic Hazard Assessment Studies in Uttarakhand Himalaya

*Srinagesh Davuluri[1], Suresh Gudapati[1], Srinivas Dakuri[1] (1.CSIR-National Geophysical Research Institute)

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

[SCG40-02] **Active Tectonics & Seismological Research in Nepal Himalaya: Preliminary results from SATREPS project**

*Soma Nath Sapkota[1], Kazuki Koketsu[2], Hiroe Miyake[3], Koji Okumura[4], Prakash Pokhrel[5] (1.Retired Director General, Department of Mines and Geology, Kathmandu Nepal, 2.Professor, Earthquake Research Institute, University of Tokyo, Tokyo Japan, 3.Associate Professor, Earthquake Research Institute, University of Tokyo, Tokyo Japan, 4.Professor, Graduate School of Humanities and Social Sciences, Hiroshima University, Japan, 5.Geologist, Department of Mines and Geology, Kathmandu Nepal)

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

[SCG40-03] Interseismic coupling on the Main Himalayan Thrust in Nepal derived from GNSS displacement rate field

*Takao Tabei[1], Mako Ohzono[2], Bishow Raj Silwal[3], Rajendra Bhandari[3], Janak B. Cahnd[3], Soma Nath Sapkota[4], Hiroe Miyake[2], Kazuki Koketsu[2] (1.Faculty of Science and Technology, Kochi University, 2.Earthquake Research Institute, University of Tokyo, 3.Department Mines and Geology, Nepal, 4.Nepal Geological Society)

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

[SCG40-04] Geodetic Observation for Evaluation of Earthquake Generation Potential in Nepal after the 2015 Gorkha Earthquake

*Bishow Raj Silwal[1], Rajendra Prasad Bhandari[1], Janak Bahadur Chand[1], Mako Ohzono[2], Takao Tabei[3] (1.Department of Mines and Geology, Nepal, 2.Earthquake Research Institute, University of Tokyo, Japan, 3.Kochi University, Kochi, Japan)

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

[SCG40-05] Rupture History of the Himalayan Frontal Thrust near Bagmati River crossing in Central Nepal

*Koji Okumura[1], Prakash Pokhrel[3], Hisao Kondo[2], Tomoru Yamanaka[1], Soma Nath Sapkota[3] (1.Graduate School of Letters, Hiroshima University, 2.Research Institute of Earthquake and Volcano Geology, GSJ, AIST, 3.Department of Mines and Geology, Nepal)

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

[SCG40-06] Strong Motion Observation Network for Earthquake Disaster Mitigation in the Kathmandu Valley, Nepal

*Nobuo Takai[1], Michiko Shigefuji[2], Hiroe Miyake[3], Kazuki Koketsu[3], Mukunda Bhattarai[4], Chintan Timsina[4], Shova Singh[4], Subeg Bijukchhen[5] (1.Hokkaido University, 2.Kyushu University, 3.University of Tokyo, 4.Department of Mines and Geology, Nepal, 5.Khwopa Engineering College, Nepal)

[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.24 Zoom Room 24

[S-CG40] Active Tectonics and Seismic Hazards in the Himalayan Region

convener:Kazuki Koketsu(Earthquake Research Institute, University of Tokyo), Nath Soma Sapkota(Nepal Geological Society), Srinagesh Davuluri(CSIR-National Geophysical Research Institute), Chairperson:Hiroe Miyake(Earthquake Research Institute, University of Tokyo), Kazuki Koketsu(Earthquake Research Institute, University of Tokyo)

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

[SCG40-07] 2D FDM simulation of seismic ground motions and inversion of velocity structure models in the Kathmandu Valley, Nepal

*Hongqi Diao[1], Kazuki Koketsu[1], Kazuhito Hikima[2] (1.Earthquake Research Institute, University of Tokyo, 2.Tokyo Electric Power Company Holdings)

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

[SCG40-08] Microtremor observation in the Kathmandu valley, Nepal: Past, Present, and Future perspectives

*Mukunda Bhattarai[1], Rajesh Sharma[3], Sunita Bhattarai[2], Tara Pokrarel[1], Chintan Timsina[1], Suresh Shrestha[2], Dinesh Nepali[2], Manoj Nakarmi[4], Prakirna Tuladhar[4], Takumi Hayashida[5], Toshiaki Yokoi[5], Hiroe Miyake[6], Koichi Kusunoki[6] (1.National Earthquake Monitoring and Research Center, Department of Mines and Geology, Nepal, 2.Department of Mines and Geology, Nepal, 3.Seismological Center Surkhet, Department of Mines and Geology, Nepal, 4.Department of Urban Development and Building Construction, Nepal, 5.International Institute of Seismology and Earthquake Engineering, Building Research Institute,Japan, 6.Earthquake Research Institute, The University of Tokyo, Japan)

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

[SCG40-09] **BROADBAND MICROTREMOR ARRAY EXPLORATION IN THE KATHMANDU VALLEY, NEPAL**

*Toshiaki Yokoi[1], Takumi Hayasida[1], Mukunda Bhattarai[3], Tara Pokharel[2], Suresh Shrestha[2], Chintan Timsina[3], Sunita Bhattarai[2], Rajesh Sharma[3], Dinesh Nepali[2] (1.International Institute of Seismology and Earthquake Engineering, Building Research Institute, Japan, 2.Department of Mines and Geology, Nepal, 3.National Earthquake Monitoring and Research Centre, NEMRC/DMG, Nepal)

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

[SCG40-10] **Seismic observation and automatic hypocenter location system in Nepal**

*Shigeki Horiuchi[1], Masumi Yamada[3], Koji MIYAKAWA[2], Hiroe Miyake[2], Tadashi Yamashina[4], Chintan Timsina[5], Mukunda Bhattarai[5], Bharat Prasad Koirala[5], Monika Jha[5], Lok Bijaya Adhikari[5] (1.Home Seismometer Corporation, 2.ERI, 3.DPRI, 4.Kochi University, 5.DMG, Nepal)

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

[SCG40-11] Upper-Crustal Structure of Central Nepal inferred from Local Earthquake Tomography

*Chintan Timsina[1], James Mori[2], Masumi Yamada[2] (1.Graduate School of Science, Kyoto University, 2.Disaster Prevention Research Institute, Kyoto University)

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

[SCG40-12] Towards the Further Development of the Education and Research on Earthquakes in Nepal

*Mai Suzuki[1], Binil Aryal[2], Kazuki Koketsu[1] (1.Earthquake Research Institute, The University of Tokyo, 2.Central Department of Physics, Tribhuvan University)

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

9:00 AM - 10:30 AM JST | 12:00 AM - 1:30 AM UTC | Ch.19 Zoom Room 19

[S-CG41] Hard-Rock Drilling Science: From Continental to Deep Sea Drilling, and Oman Project

convener:Eiichi TAKAZAWA(Department of Geology, Faculty of Science, Niigata University), Katsuyoshi Michibayashi(Department of Earth and Planetary Sciences, Nagoya University), Keishi Okazaki(Japan Agency for Marine-Earth Science and Technology), Chairperson:Keishi Okazaki(Japan Agency for Marine-Earth Science and Technology), Sayantani Chatterjee(Niigata University, Department of Geology, Faculty of Science)

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

[SCG41-01] The structure of magma chamber below a fast-spreading ridge based on field and core analyses of the Oman ICDP drilling

*Susumu Umino[1], Yuki Kusano[3], Osamu Ishizuka[3], Takahiro Fudai[4], Akihiro Tamura[1], Tomoaki Morishita[1,2] (1.Department of Earth Sciences, Kanazawa University, 2.JAMSTEC, 3.GSJ-AIST, 4.Taiheiyo Cement Corrperation)

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

[SCG41-02] **Oxidation controlled symplectitic formation in olivine gabbros from Oman ophiolite, Oman Drilling Project, Hole GT2A**

*Sayantani Chatterjee[1], Debaditya Bandyopadhyay[2,3], Eiichi Takazawa[1,4], Katsuyoshi Michibayashi[5] (1.Department of Geology, Faculty of Science, Niigata University, Niigata 950–2181, Japan, 2.Department of Geology, University of North Bengal, Darjeeling 734013, India, 3.Department of Geology, University of Calcutta, Kolkata 700019, India, 4.Japan Agency for Marine–earth Science and Technology, Yokosuka 237–0061, Japan, 5.Graduate School of Environmental Studies, Nagoya University, Nagoya 464–8602, Japan)

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

[SCG41-03] Effect of pore geometry on ultrasonic velocity of epidosites collected from the Oman Drilling Project

*Kumpei Nagase[1], Ikuo Katayama[1], Kohei Hatakeyama[1], Keishi Okazaki[2] (1.Earth and Planetary Systems Science Program, Graduate School of Advanced Science and Engineering, Hiroshima University, 2.Kochi Institute for Core Sample Research, Japan Agency for Marine-Earth Science and Technology)

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

[SCG41-04] Mineral mode of listvenite from ICDP Oman Drilling Project Hole BT1B inferred from X-ray CT core images

*Keishi Okazaki[1], Katsuyoshi Michibayashi[2], Kohei Hatakeyama[3], Natsue Abe[4], Kevin Johnson[5], Peter B Kelemen[6] (1.Kochi Institute for Core Sample Research, Japan Agency for Marine-Earth Science and Technology, 2.Department of Earth and Planetary Sciences, Nagoya University, 3.Department of Earth and Planetary Systems Sciences, Hiroshima University, 4.Mantle Drilling Promotion Office, Japan Agency for Marine-Earth Science and Technology, 5.Department of Earth Sciences, University of Hawai‘i at Mānoa, 6.Lamont Doherty Earth Observatory, Columbia University)

10:00 AM - 10:30 AM JST | 1:00 AM - 1:30 AM UTC

[SCG41-05] Serpentinization and Fe(III) distribution along the crust-mantle section of the oceanic lithosphere: insights from the Oman Drilling CM1A site

★Invited Papers

*Atsushi Okamoto[1], Kazuki Yoshida[1], Ryosuke Oyanagi[2], Yasuhiro Niwa[3], Yasuo Takeichi[3], Masao Kimura[3] (1.Graduate School of Environmental Studies, Tohoku University, 2.Japan Agency For Marine-Earth Science and Technology, 3.High Energy Accelerator Research Organization (KEK))

[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.19 Zoom Room 19

[S-CG41] Hard-Rock Drilling Science: From Continental to Deep Sea Drilling, and Oman Project

convener:Eiichi TAKAZAWA(Department of Geology, Faculty of Science, Niigata University), Katsuyoshi Michibayashi(Department of Earth and Planetary Sciences, Nagoya University), Keishi Okazaki(Japan Agency for Marine-Earth Science and Technology), Chairperson:Katsuyoshi Michibayashi(Department of Earth and Planetary Sciences, Nagoya University), Eiichi TAKAZAWA(Department of Geology, Faculty of Science, Niigata University)

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

[SCG41-06] Heterogeneity in the mantle section of the Oman ophiolite in terms of spinel and clinopyroxene compositions

*Eiichi TAKAZAWA[1,2] (1.Department of Geology, Faculty of Science, Niigata University, 2.Japan Agency for Marine-Earth Science and Technology)

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

[SCG41-07] Systematics of minor and trace element chemistry of olivine in peridotites

*Ikuya Nishio[1], Tomoaki Morishita[1], Keita Itano[1], Akihiro Tamura[1], Asyraf Muhamad[1] (1.Kanazawa University)

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

[SCG41-08] **ICDP DSeis project: compilation of borehole logging and recovered core information at the seismogenic zone of the M5.5 Orkney earthquake with lower crustal intrusives**

*Hiroshi Ogasawara[1], Shunsuke Yoshida[2], Mitsuya Higashi[2], Kensuke Sakaguchi[1], Yuki Yokoyama[4], Yasuo Yabe[3], Tetsuro Hirono[4], Dakalo Ligaraba[5], Nandipha Masondo[5], Yuhji Yamamoto[6], Team ICDP DSeis (1.College of Science and Engineering, Ritsumeikan University, 2.Graduate School of Science and Engineering, Ritsumeikan University, 3.Graduate School of Science, Tohoku University, 4.Graduate School of Science, Osaka University, 5.Graduate School of Geoscience, University of the Witwatersrand, 6.Kochi Core Center, Kochi University)

11:30 AM - 12:00 PM JST | 2:30 AM - 3:00 AM UTC

[SCG41-09] Volcanism along the eastern margin of the Ontong Java Plateau: More reasons to test the Ontong Java Nui hypothesis by scientific ocean drilling

★Invited Papers

*Maria Luisa Tejada[1], Takashi Sano[2], Takeshi Hanyu[1], Anthony A. P. Koppers[3], Masao Nakanishi[4], Akira Ishikawa[5], Takashi Miyazaki[1], Kenichiro Tani[2], Shoka Shimizu[6], Qing Chang[1], Bogdan Stefanov Vaglarov[1] (1.Volcano and Earth Interior Research Center, Institute for Marine Geodynamics, Japan Agency for Marine-Earth Science and Technology, 2-15 Natsushima, Yokosuka 237-0061, Japan, 2.Department of Geology and Paleontology, National Museum of Nature and Science, Amakubo 1-1-1, Tsukuba, Ibaraki 305-0005, Japan, 3.College of Earth, Ocean and Atmospheric Sciences, Oregon State University, Corvallis, OR 97331, U.S.A., 4.Graduate School of Science, Chiba University, Chiba 263-8522, Japan, 5.Department of Earth and Planetary Sciences, Tokyo Institute of Technology, 2-12-1 Ookayama, Meguro, Tokyo 152-8550, Japan , 6.Graduate School of Science and Engineering, Chiba University, Chiba 263-8522, Japan)

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

[SCG41-10] New Developments in Hard Rock Drilling Project: Horoman and Forearc Mantle drilling

*Katsuyoshi Michibayashi[1], Eiichi Takazawa[2], Tomoaki Morishita[3], Mikiya Yamashita[4,5], Gou Fujie[4], Shigeaki Ono[4] (1.Nagoya University, 2.Niigata University, 3.Kanazawa University, 4.JAMSTEC, 5.AIST)

[E] Oral | B (Biogeosciences) : B-PT Paleontology

1:45 PM - 3:15 PM JST | 4:45 AM - 6:15 AM UTC | Ch.26 Zoom Room 26

[B-PT01] Biomineralization and Geochemistry of Proxies

convener:Takashi Toyofuku(Japan Agency for Marine-Earth Science and Technology (JAMSTEC)), Hiroshi Kitazato(Tokyo University of Marine Science and Technology (TUMSAT)), Jelle Bijma(Alfred-Wegener-Institut Helmholtz-Zentrum für Polar- und Meeresforschung), Kotaro Hirose(Faculty of Science and Engineering, Waseda University), Chairperson:Takashi Toyofuku(Japan Agency for Marine-Earth Science and Technology (JAMSTEC)), Hiroshi Kitazato(Tokyo University of Marine Science and Technology (TUMSAT)), Kotaro Hirose(Faculty of Science and Engineering, Waseda University), Jelle Bijma(Alfred-Wegener-Institut Helmholtz-Zentrum für Polar- und Meeresforschung)

1:45 PM - 1:48 PM JST | 4:45 AM - 4:48 AM UTC

[BPT01-01] Introduction

1:48 PM - 2:03 PM JST | 4:48 AM - 5:03 AM UTC

[BPT01-02] Seascape ecological view as a new insight of benthic foraminiferal community

*Hiroshi Kitazato[1] (1.Tokyo University of Marine Science and Technology (TUMSAT))

2:03 PM - 2:21 PM JST | 5:03 AM - 5:21 AM UTC

[BPT01-03] Macromolecular analysis of modern aquatic palynomorphs using micro-Raman spectroscopy

*Takuto Ando[1], Tatsuyuki Yamamoto[2], Mika Ishigaki[3], Kazumi Matsuoka[4] (1.Estuary Research Center, Shimane University, 2.Faculty of Life and Environmental Sciences, Shimane University, 3.Center for Promotion of Project Research. Shimane University, 4.Institute for East China Sea Research, Nagasaki University, Japan)

2:21 PM - 2:39 PM JST | 5:21 AM - 5:39 AM UTC

[BPT01-04] **The spatial distribution and the origin of heavy metals in bottom sediments from Lake Shinji and Nakaumi**

*Hanye ZHANG[1], Kotaro Hirose[1], Kazuo Kamura[1], Minami Aoki[1], Koji Seto[2] (1.Faculty of Science and Engineering, Waseda University, 2.Estuary Research Center, Shimane University)

2:39 PM - 2:57 PM JST | 5:39 AM - 5:57 AM UTC

[BPT01-05] Sedimentary geochemical record of human-induced environmental changes in the estuarine lake Nakaumi, southwest Japan

*Kotaro Hirose[1], Minami Aoki[4], Akira Tsujimoto[3], Koji Seto[2], Kazuo Kamura[1] (1.Faculty of Science and Engineering, Waseda University, 2.Estuary Research Center, Shimane University, 3.Faculty of Education, Shimane Universit, 4.Faculty of Science and Engineering, Waseda University (currently Seikei Gakuen))

2:57 PM - 3:15 PM JST | 5:57 AM - 6:15 AM UTC

[BPT01-06] Calcification depths of planktic foraminifers constrained using geochemical signatures in the sediment trap samples collected from the Bay of Bengal

*Ayumi Maeda[1], Azumi Kuroyanagi[2], Toshihiro Yoshimura[3], Birgit Gaye[4], Tim Rixen[5], Atsushi Suzuki[1], Hodaka Kawahata[6] (1.National Institute of Advanced Industrial Science and Technology, 2.Tohoku University Museum, The Center for Academic Resources and Archives, Tohoku University, 3.Japan Agency for Marine-Earth Science and Technology, 4.Institute for Geology, Universität Hamburg, 5.Leibniz Centre for Tropical Marine Research, 6.Atmosphere and Ocean Research Institute, The University of Tokyo)

[E] Oral | B (Biogeosciences) : B-PT Paleontology

3:30 PM - 5:00 PM JST | 6:30 AM - 8:00 AM UTC | Ch.26 Zoom Room 26

[B-PT01] Biomineralization and Geochemistry of Proxies

convener:Takashi Toyofuku(Japan Agency for Marine-Earth Science and Technology (JAMSTEC)), Hiroshi Kitazato(Tokyo University of Marine Science and Technology (TUMSAT)), Jelle Bijma(Alfred-Wegener-Institut Helmholtz-Zentrum für Polar- und Meeresforschung), Kotaro Hirose(Faculty of Science and Engineering, Waseda University), Chairperson:Hiroshi Kitazato(Tokyo University of Marine Science and Technology (TUMSAT)), Kotaro Hirose(Faculty of Science and Engineering, Waseda University), Takashi Toyofuku(Japan Agency for Marine-Earth Science and Technology (JAMSTEC)), Jelle Bijma(Alfred-Wegener-Institut Helmholtz-Zentrum für Polar- und Meeresforschung)

3:30 PM - 3:48 PM JST | 6:30 AM - 6:48 AM UTC

[BPT01-07] Long term size changes of the Middle Miocene planktonic foraminifera in the western equatorial Pacific

*Takuma Suzuki[1], Hiroki Hayashi[1] (1.Shimane University)

3:48 PM - 4:06 PM JST | 6:48 AM - 7:06 AM UTC

[BPT01-08] High-resolution minor element concentration records in modern brachiopod *Pictothyris picta* shells and their controlling factors

*Kazuma Oikawa[1], Hideko Takayanagi[1], Ryuichi Shinjo[2], Kazuyoshi Endo[3], Masa-aki Yoshida[4], Yasufumi Iryu[1] (1. Institute of Geology and Paleontology Graduate School of Science Tohoku University, 2.Department of Physics and Earth Sciences, University of the Ryukyus, 3.Department of Earth and Planetary Science, Tokyo University, 4.Shimane University Faculty of Life and Environmental Science)

4:06 PM - 4:24 PM JST | 7:06 AM - 7:24 AM UTC

[BPT01-09] Evolution of Mg transporters and their possible effects on coral skeletal proxies in geochemistry

*Tomoko Bell[1], Akira Iguchi[2], Kazuhiko Sakai[3], Yusuke Yokoyama[4] (1.WERI, Univ. of Guam, 2.AIST, 3.TBRC, Univ. of Ryukyus, 4.AORI, Univ. of Tokyo)

4:24 PM - 4:42 PM JST | 7:24 AM - 7:42 AM UTC

[BPT01-10] **The coral reef-dwelling *Peneroplis* spp. shows calcification resilience to ocean acidification conditions - results from culture experiments**

*Laurie Charrieau[1], Katsunori Kimoto[1], Delphine Dissard[2], Beatrice Below[2,3], Kazuhiko Fujita[4], Yukiko Nagai[1,5], Takashi Toyofuku[1,6] (1.Jamstec, 2.IRD/UMR LOCEAN, 3.UMR CR2P, 4.University of the Ryukyus, 5.Yokohama National University, 6.TUMSAT)

4:42 PM - 4:57 PM JST | 7:42 AM - 7:57 AM UTC

[BPT01-11] Can Irregular Observations Provide the Next Clue for the Ecology of Foraminifera?

*Takashi Toyofuku[1,2], Yukiko Nagai[1,3] (1.Japan Agency for Marine-Earth Science and Technology (JAMSTEC), 2.Tokyo University of Marine Science and Technology (TUMSAT), 3.National Museum of Nature and Science,Tokyo)

4:57 PM - 5:00 PM JST | 7:57 AM - 8:00 AM UTC

[BPT01-12] Discussion

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

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

[M-IS01] Environmental, socio-economic, and climatic changes in Northern Eurasia

convener:Pavel Groisman(NC State University Research Scholar at NOAA National Centers for Environmental Information, Asheville, North Carolina, USA), Shamil Maksyutov(National Institute for Environmental Studies), A Dmitry Streletskiy(George Washington University), Yoshihiro Iijima(Graduate School of Bioresources, Mie University), Chairperson:Pavel Groisman(NC State University Research Scholar at NOAA National Centers for Environmental Information, Asheville, North Carolina, USA), Yoshihiro Iijima(Graduate School of Bioresources, Mie University), Shamil Maksyutov(National Institute for Environmental Studies)

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

[MIS01-01] Evaluation of a revised global high-resolution inverse model with CO_2 observations over Siberia.

*Shamil Maksyutov[1], Motoki Sasakawa[1], Toshinobu Machida[1], Tomohiro Oda[2], Jiye Zeng[1], Tsuneo Matsunaga[1], Johannes W Kaiser[3], Mikhail Arshinov[4], Boris Belan[4], Ed Dlugokencky[5] (1.National Institute for Environmental Studies, 2.Universities Space Research Association, 3.Deutscher Wetterdienst, 4.Inst. Atmospheric Optics, 5.Global Monitoring Laboratory, NOAA)

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

[MIS01-02] Co-production of environmental education material "Permafrost and Culture"

*Yoshihiro Iijima[1], Hiroki Takakura[2], Vanda Ignatyeva[3], Aleksandr Fedorov[4], Masanori Goto[5], Toshikazu Tanaka[6] (1.Graduate School of Bioresources, Mie University, 2.Center for Northeast Asian Studies, Tohoku University, 3.Institute of Humanities and Indigenous Studies of the North, SB RAS, 4.Melnikov Permafrost Institute, SB RAS, 5.Slavic-Eurasian Research Center, Hokkaido University, 6.Faculty of Economics, Ryukoku University)

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

[MIS01-03] Permafrost Degradation Threatens Arctic Communities and Infrastructure

*Dmitry A Streletskiy[1], Nikolay I Shiklomanov[1], Kelsey Nyland[1] (1.George Washington University)

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

[MIS01-04] Monthly precipitations for South Siberia derived from bias-corrected reanalysis

Nadezhda Voropay[1,2], *Anna Ryazanova[1], Egor Dyukarev[1,3] (1.Institute of Monitoring of Climatic and Ecological Systems of the Siberian Branch of the Russian Academy of Sciences, 2.V B Sochava Institute of Geography of the Siberian Branch of the Russian Academy of Sciences, 3.Yugra State University)

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

[MIS01-05] Fuel load mapping in central Siberia

★Invited Papers

*Elena Kukavskaya[1], Ludmila Buryak[2], Evgeny Shvetsov[1], Sergey Zhila[1] (1.V.N. Sukachev Institute of Forest of the Siberian Branch of the Russian Academy of Sciences - separate subdivision of the FRC KSC SB RAS, 2.The Branch of FBU VNIILM “Center of Forest Pyrology”)

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

[MIS01-06] New data on the state and changes of glaciers in mountain and Polar Regions of Russia

*Tatiana Khromova[1], Gennady Nosenko, Andrey Glazovsky, Stanislav Nikitin, Anton Muraviev, Ivan Lavrentiev (1.Institute of Geography Russian Academy of Sciences)

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

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

[M-IS01] Environmental, socio-economic, and climatic changes in Northern Eurasia

convener:Pavel Groisman(NC State University Research Scholar at NOAA National Centers for Environmental Information, Asheville, North Carolina, USA), Shamil Maksyutov(National Institute for Environmental Studies), A Dmitry Streletskiy(George Washington University), Yoshihiro Iijima(Graduate School of Bioresources, Mie University), Chairperson:Yoshihiro Iijima(Graduate School of Bioresources, Mie University), Shamil Maksyutov(National Institute for Environmental Studies), Pavel Groisman(NC State University Research Scholar at NOAA National Centers for Environmental Information, Asheville, North Carolina, USA)

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

[MIS01-07] Quantification of the water vapor transport between the northern Eurasia and Arctic ocean considering the water vapor origin

*Tomonori Sato[1], Tetsu Nakamura[1], Yoshihiro Iijima[2], Tetsuya Hiyama[3] (1.Hokkaido University, 2.Mie University, 3.Nagoya University)

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

[MIS01-08] The hydrological cycle over the three great Siberian rivers from reanalyses and observations

*Ambroise Dufour[1], Martin Wegmann[2], Olga Zolina[3,1], Sergey Gulev[1] (1.P.P. Shirshov Institute of Oceanology, Russian Academy of Science, 2.Oeschger Centre for Climate Change Research, University of Bern, 3.Institut des Géosciences de l'Environnement, Université Grenoble Alpes)

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

[MIS01-09] Dark conifer forests dieback at mid-to-highlands in the southern Siberia's mountains is not caused by drought stress

*Nadezhda Tchebakova[1], Elena I. Parfenova[1], Elena V. Bazhina[1], Amber J. Soja[2], Pavel Groisman[3] (1.Institute of Forests of FRC KSC, Siberian Branch, Russian Academy of Sciences, 2.National Institute of Aerospace, NASA Langley Research Center, Hampton, VA, USA , 3.NC State University Research Scholar at National Centers for Environment Information Federal Building, 151 Patton Avenue Asheville, NC 28801, USA)

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

[MIS01-10] Changing climate of the Western Siberia and socio-economic risks

*Daria Aleksandrovna Konstantinova[1], Valentina Petrovna Gorbatenko[1], Olga Vladimirovna Nosyreva[1], Marina Aleksandrovna Volkova[1], Irina Valer'evna Kuzhevskaia[1] (1.Tomsk State University)

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

[MIS01-11] Long-term temporal trends in water chemistry of lakes in response to decreases in acidic deposition and climate warming of the Kola arctic region

★Invited Papers

Tatyana I Moiseenko[1], *Marina I Dinu[1], Maria M Bazova[1] (1.Russian Institute of Geochemistry and Analytical Chemistry RAS)

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

[MIS01-12] Wildfires in boreal eastern Siberia: Reconstructing the past to predict the future

*Ramesh Glueckler[1], Stefan Kruse°[1], Ulrike Herzschuh[1,2,3], Elisabeth Dietze°[1] (1.Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research, Potsdam, Germany , 2.Institute for Environmental Science and Geography, University of Potsdam, Potsdam, Germany, 3.Institute for Biochemistry and Biology, University of Potsdam, Potsdam, Germany)

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

9:00 AM - 10:30 AM JST | 12:00 AM - 1:30 AM UTC | Ch.26 Zoom Room 26

[M-IS04] Evolution and variability of the Asian Monsoon and Indo-Pacific climate during the Cenozoic Era

convener:Takuya Sagawa(Institute of Science and Engineering, Kanazawa University), Kenji Matsuzaki(Atmosphere and Ocean Research Institute, The university of Tokyo), Chairperson:Takuya Sagawa(Institute of Science and Engineering, Kanazawa University), Kenji Matsuzaki(Atmosphere and Ocean Research Institute, The university of Tokyo)

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

[MIS04-01] Orbital- to millennial-scale variability of the East Asian monsoon and the Kuroshio Current during periods of low orbital eccentricity and precessional change in the Pleistocene

★Invited Papers

*Yoshimi Kubota[1], Yuki Haneda[2], Koji Kameo[3], Takuya Itaki[2], Hiroki Hayashi[4], Kizuku Shikoku[4], Kentaro Izumi[5], Martin J Head[6], Yusuke Suganuma[7], Makoto Okada[8] (1.National Museum of Nature and Science, 2.Geological Survey of Japan, AIST, 3. Department of Earth Sciences, Faculty of Science, Chiba University, 4.Interdisciplinary Faculty of Science and Engineering, Shimane University, 5. Faculty & Graduate School of Education, Chiba University, 6.Brock University, 7.National Institute of Polar Research, 8.Department of Earth Sciences, Ibaraki University)

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

[MIS04-02] **Effect of orbitally-driven insolation changes on East Asian monsoon rainfall over the past 450,000 years**

*Taiga Matsushita[1], Mariko Harada[1], Hiroaki Ueda[1], Takeshi Nakagawa[2], Yoshimi Kubota[3], Yoshiaki Suzuki[4] (1.University of Tsukuba, 2.Ritsumeikan University, 3.National Museum of Nature and Science, 4.National Institute of Advanced Industrial Science and Technology)

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

[MIS04-03] Quantification of Asian dust multi-source contributions to silt and clay fractions in the Japan Sea sediments at IODP Site U1425 since 10 Ma by the Parallel Factor (PARAFAC) end-member modelling

*Mui Fa Alison Lee[1], Airi Maruyama[1], Tomohisa Irino[2] (1.Graduate School of Environmental Science, Hokkaido University, 2.Faculty of Environmental Earth Science, Hokkaido University)

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

[MIS04-04] Cyclostratigraphy and orbitally-paced paleo-productivity records of the Miocene Onnagawa Formation in Akita Prefecture, Northern Japan

*Jumpei Yoshioka[1,2], Junichiro Kuroda[2], Kenji Matsuzaki[2], Ryuji Tada[1,3,4] (1.Department of Earth and Planetary Science, the University of Tokyo, 2.Atmosphere and Ocean Research Institute, the University of Tokyo, 3.Yunnan University, 4.Chiba Institute of Technology)

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

[MIS04-05] Sedimentary features and isotope records of the upper Eocene travertine-lacustrin carbonate in the SE Tibet and implication for hte monsoon climate

★Invited Papers

*Aki Sakuma[1], Akihiro Kano[1], Yoshihiro Kakizaki[1], Ryuji Tada[2,3], Hongbo Zheng[3] (1.Department of Earth and Planetary Science, School of Science, the University of Tokyo, 2.Institute for Geo-Cosmology, Chiba Institute of Technology, 3.Yunnan Key Laboratory of Earth System Science, Yunnan University)

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

[MIS04-06] Impact of long-term monsoon dynamics on Cenozoic-Mesozoic climate and ecosystems

*Masayuki Ikeda[1], Kazumi Ozaki[2], LEGRAND Julien[3] (1.University of Tokyo, 2.Toho University, 3.Shizuoka University)

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

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

[M-IS05] Global climate change driven by the Southern Ocean and the Antarctic Ice Sheet

convener:Osamu Seki(Institute of Low Temperature Science, Hokkaido University), Yoshifumi Nogi(National Institute of Polar Research), Akira Oka(Atmosphere and Ocean Research Institute, The University of Tokyo), Yusuke Suganuma(National institute of Polar Research), Chairperson:Takashi Obase(Atmosphere and Ocean Research Institute, the University of Tokyo)

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

[MIS05-01] Modelling the Stability of Antarctic ice sheet for investigating the link between the past and future

★Invited Papers

*Ayako Abe-Ouchi[1], Kaho Harada[1], Takashi Obase[1], Fuyuki SAITO[2], Ralf Greve[3], Christopher Chambers[3], Osamu Seki[3], Kenji Kawamura[4], Jun'ichi Okuno[4] (1.Atmosphere and Ocean Research Institute, The University of Tokyo, 2.JAMSTEC, 3.Hokkaido University, 4.NIPR)

11:05 AM - 11:25 AM JST | 2:05 AM - 2:25 AM UTC

[MIS05-02] Carbon and nutrient cycles in and around the Cape Darnley polynya

★Invited Papers

*Michiyo Yamamoto-Kawai[1], Yoshihiko Ohashi[1] (1.Graduate School of Marine Science and Technology, Tokyo University of Marine Science and Technology)

11:25 AM - 11:45 AM JST | 2:25 AM - 2:45 AM UTC

[MIS05-03] MONACA: The hot explorer under ice

★Invited Papers

*Toshihiro Maki[1], Hirokazu Yamagata[1], Hiroshi Yoshida[2], Yoshifumi Nogi[3] (1.The University of Tokyo, 2.Japan Agency for Marine-Earth Science and Technology, 3.National Institute of Polar Research)

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

[MIS05-04] **Development of the Under Ice AUV “MONACA”**
- Autonomous Navigation Trial in Under Ice Environment -

*Hirokazu Yamagata[1], Shuma Kochii[1], Hiroshi Yoshida[2], Yoshifumi Nogi[3], Toshihiro Maki[1] (1.Institute of Industrial Science, The University of Tokyo, 2.Japan Marine Science and Technology Center, 3.National Institute of Polar Research)

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

[MIS05-05] Long-term future projections for the Antarctic ice sheet with the model SICOPOLIS

*Christopher Chambers[1], Ralf Greve[2,1], Takashi Obase[3], Fuyuki SAITO[4], Kaho Harada[3], Ayako Abe-Ouchi[3] (1.Institute of Low Temperature Science, Hokkaido University, 2.Arctic Research Center, Hokkaido University, 3.Atmosphere and Ocean Research Institute, University of Tokyo, 4.Japan Agency for Marine-Earth Science and Technology)

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

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

[M-IS05] Global climate change driven by the Southern Ocean and the Antarctic Ice Sheet

convener:Osamu Seki(Institute of Low Temperature Science, Hokkaido University), Yoshifumi Nogi(National Institute of Polar Research), Akira Oka(Atmosphere and Ocean Research Institute, The University of Tokyo), Yusuke Suganuma(National institute of Polar Research), Chairperson:Hiroki Matsui(Graduate School of International Resource Sciences, Akita University), Takeshige Ishiwa(National Institute of Polar Research)

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

[MIS05-06] Beryllium isotope records from sectors of the West and East Antarctic Ice sheet reveal Holocene melting related to the incursion of Circumpolar Deep Water

*Adam David Sproson[1,2], Yusuke Yokoyama[1,2], Yoshinori Takano[2], Rebecca Minzoni[3], Bethany Behrens[1], Yosuke Miyairi[1], Takahiro Aze[1] (1.Atmosphere and Ocean Research Institute, University of Tokyo, 5-1-5 Kashiwanoha, Kashiwa, Chiba 277-8564, Japan. , 2.Department of Biogeochemistry, Japan Agency for Marine-Earth Science and Technology, 2-15 Natsushima, Yokosuka, Kanagawa 237-0061, Japan. , 3.Department of Geological Sciences, The University of Alabama, USA.)

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

[MIS05-07] Abrupt Holocene ice-sheet retreat in Lutzow-Holm Bay, East Antarctica

*Yusuke Suganuma[1,2], Yuki Haneda[3], Takuya Itaki[3], Osamu Seki[4], Takeshige Ishiwa[1], Moto Kawamata[2], Masakazu Fujii[1,2], Kazuya Kusahara[8], Daisuke Hirano[4], Masao Iwai[9], Yuji Kato[9], Hiroki Matsui[6], Atsuko Amano[3], Kota Katsuki[5], Takayuki Omori[7], Motohiro Hirabayashi[1], Hiroyuki Matsuzaki[7], Takeyasu Yamagata[7], Masato Ito[8], Shin Sugiyama[4], Naohisa Nishida[10], Jun'ichi Okuno[1,2], Minoru Ikehara[9], Hideki Miura[1,2] (1.National institute of Polar Research, 2.The Graduate University for Advanced Studies (SOKENDAI), 3.Geological Survey of Japan, AIST, 4.Hokkaido University, 5.Shimane University, 6.Akita University, 7.University of Tokyo, 8.JAMSTEC, 9.Center for Advanced Marine Core Research, Kochi University, 10.Tokyo Gakugei University)

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

[MIS05-08] Paleoenvironmental reconstruction using lake sediment cores from Lake Nurume in Lützow Holm Bay

*Takeshige Ishiwa[1], Yuki Tokuda[2], Takuya Itaki[3], Satoshi Sasaki[4], Kota Katsuki[4], Yusuke Suganuma[1,5] (1.National Institute of Polar Research, 2.Tottori University of Environmental Studies, 3.National Institute of Advanced Industrial Science and Technology, 4.Shimane University, 5.The Graduate University for Advanced Studies (SOKENDAI))

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

[MIS05-09] Assessing dust-magnetic correlation in the Indian sector of the Southern Ocean

*Hiroki Matsui[1], Minoru Ikehara[2], Yusuke Suganuma[3,4], Osamu Seki[5], Ikumi Oyabu[3], Kenji Kawamura[3,4] (1.Graduate School of International Resource Sciences, Akita University, 2.Center for Advanced Marine Core Research, Kochi University, 3.National Institute of Polar Research, Research Organization of Information and Systems, 4.Department of Polar Science, School of Multidisciplinary Sciences, The Graduate University for Advanced Studies (SOKENDAI), 5.Institute of Low Temperature Science, Hokkaido University)

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

[MIS05-10] Antarctic warmth in the last interglacial driven by Northern insolation and deglaciation

*Takashi Obase[1], Ayako Abe-Ouchi[1,2], Fuyuki SAITO[3] (1.Atmosphere and Ocean Research Institute, the University of Tokyo, 2.National Institute of Polar Research, Japan, 3.Japan Agency for Marine-Earth Science and Technology)

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

[MIS05-11] Modeling the ocean carbon cycle during the last deglaciation

*Hidetaka Kobayashi[1], Akira Oka[1], Takashi Obase[1], Ayako Abe-Ouchi[1] (1.Atmosphere and Ocean Research Institute, The University of Tokyo)

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

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

[M-IS05] Global climate change driven by the Southern Ocean and the Antarctic Ice Sheet

convener:Osamu Seki(Institute of Low Temperature Science, Hokkaido University), Yoshifumi Nogi(National Institute of Polar Research), Akira Oka(Atmosphere and Ocean Research Institute, The University of Tokyo), Yusuke Suganuma(National institute of Polar Research), Chairperson:Hidetaka Kobayashi(Atmosphere and Ocean Research Institute, The University of Tokyo)

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

[MIS05-12] **Last Glacial Maximum Antarctic sea ice linked with global mean ocean temperature: evidence from PMIP3, PMIP4 and MIROC-4m simulations**

*Tristan Vadsaria[1], Sam Sherriff-Tadano[2,1], Ayako Abe-Ouchi[1], Takashi Obase[1], Wing-Le Chan[1], Xavier Crosta[3] (1.Atmosphere and Ocean Research Institute, The University of Tokyo, Japan, 2.School of Earth and Environment, The University of Leeds, Leeds, UK, 3.Environnements et Paléoenvironnements Océanique et Continentaux, Pessac, France)

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

[MIS05-13] **Antarctic Slope Current modulates warm ocean heat intrusions towards Totten Glacier**

*Yoshihiro Nakayama[1], Chad A Greene[2], Fernando S Paolo[2], Vigan Mensah[1], Hong Zhang[2], Haruhiko Kashiwase[3], Daisuke Simizu[3], Jamin S Greenbaum[4], Donald D Blankenship[5], Ayako Abe-Ouchi[6], Shigeru Aoki[1] (1.Institute of Low Temperature Science, Hokkaido University, Japan, 2.NASA Jet Propulsion Laboratory, California, USA, 3.National Institute of Polar Research, Tokyo, Japan, 4.Scripps Institution of Oceanography, University of California, California USA, 5.Institute for Geophysics, University of Texas at Austin, Texas, USA, 6.Atmosphere and Ocean Research Institute, The University of Tokyo, Tokyo, Japan.)

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

[MIS05-14] Sea Ice Variations in Coastal Amundsen Sea Affected by Ice Shelf Meltwater

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

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

[MIS05-15] Observation of plagic system using a drifter off Wilkes land during sea ice melting season

*Ryosuke Makabe[1,5,2], Keigo Takahashi[2], Shintaro Takao[3], Ryo Matsuda[4], Masayoshi Sano[1], Kohei Mizobata[5], Norio Kurosawa[4], Masato Moteki[5,1], Tsuneo Odate[1,2] (1.National Institute of Polar Research, 2.The Graduate University for Advanced Studies (SOKENDAI), 3.National Institute for Environmental Studies, 4.Soka University, 5.Tokyo University of Marine Science and Technology)

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

[MIS05-16] Primary production and carbon export related to sub-surface chlorophyll maximum off Wilkes land during post bloom season

*Norio Kurosawa[1], Ayuko Kagesawaa[2], Ryosuke Makabe[3,2,4], Shintaro Takao[5], Masayoshi Sano[3], Kohei Mizobata[4], Masato Moteki[4,3], Tsuneo Odate[2,3] (1.Soka University, 2.The Graduate University for Advanced Studies (SOKENDAI), 3.National Institute of Polar Research, 4.Tokyo University of Marine Science and Technology, 5.National Institute for Environmental Studies)

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

[MIS05-17] Contribution of fecal pellet-like dinoflagellates to the carbon sequestration in the seasonal ice zone of the Southern Ocean

*Ryo Matsuda[1], Jaekyeng Han[1], Shinya Okano[1], Masayoshi Sano[2], Shintaro Takao[3], Ryosuke Makabe[2,4,5], Masato Moteki[4,5], Tsuneo Odate[2,4], Norio Kurosawa[1] (1.Soka University, 2.National Institute of Polar Research, 3.National Institute for Environmental Studies, 4.The Graduate University for Advanced Studies (SOKENDAI), 5.Tokyo University of Marine Science and Technology)

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

10:45 AM - 12:15 PM JST | 1:45 AM - 3:15 AM UTC | Ch.22 Zoom Room 22

[M-IS08] Interdisciplinary studies on pre-earthquake processes

convener:Katsumi Hattori(Department of Earth Sciences, Graduate School of Science, Chiba University), Dimitar Ouzounov(Center of Excellence in Earth Systems Modeling & Observations (CEESMO) , Schmid College of Science & Technology Chapman University, Orange, California, USA), Jann-Yenq LIU(Department of Space Science and Engineering, National Central University, Taiwan), Qinghua Huang(Peking University), Chairperson:Katsumi Hattori(Department of Earth Sciences, Graduate School of Science, Chiba University), Dimitar Ouzounov(Center of Excellence in Earth Systems Modeling & Observations (CEESMO) , Schmid College of Science & Technology Chapman University, Orange, California, USA)

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

[MIS08-01] The spatiotemporal evolution of pre-earthquake anomalies and their association with the activation zone

*Dimitar Ouzounov[1], Sergey Pulinets[2], J.Y Liu[3], Katsumi Hattori[4], Patrick Taylor[5] (1.Center of Excellence in Earth Systems Modeling & Observations (CEESMO) , Schmid College of Science & Technology Chapman University, Orange, California, USA, 2.Space Research Institute, Russian Academy of Sciences, Moscow, Russia, 3.Center for Space and Remote Sensing Research, National Central University, Taoyuan, Taiwan, 4.Department of Earth Sciences, Graduate School of Science, Chiba University, Chiba, Japan, 5.NASA GSFC, Greenbelt, MD, USA)

11:00 AM - 11:20 AM JST | 2:00 AM - 2:20 AM UTC

[MIS08-02] The multi observations on electromagnetic emissions and plasma perturbations around Yutian Earthquakes in China

★Invited Papers

*Xuemin Zhang[1], Jing Liu[1], Angelo De Santis[2], Loredana Perrone[2], Xuhui Shen[3], Jianping Huang[3] (1.Institute of Earthquake Forecasting, China Earthquake Administration, 2.Istituto Nazionale di Geofisica e Vulcanologia, 3.Institute of Crustal Dynamics, China Earthquake Administration)

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

[MIS08-03] Bizarre “earthquake weather” immediately before and after the 1995 Kobe earthquake

*Yuji Enomoto[1], Tsuneaki Yamabe[1], Shigeki Sugiura[2], Hitoshi Kondo[2] (1.Shinshu Univeristy, Ueda Campus Fii, 2.Genesis Research Institute Inc.)

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

[MIS08-04] A system of the Monitoring Vibrations and Propagations in the Lithosphere, Atmosphere, and Ionosphere

*Chieh-Hung Chen[1], Yang-Yi Sun[1], Kai Lin[1], Huaizhong Yu[2] (1.Institute of Geophysics and Geomatics, China University of Geosciences, Wuhan, Hubei, China, 2.China Earthquake Networks Center, Beijing, China)

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

[MIS08-05] Assessing the potential earthquake precursory information in ULF magnetic data recorded in Kanto, Japan during 2000 – 2010: distance and magnitude dependences

★Invited Papers

*Peng Han[1], Jiancang Zhuang[2], Katsumi Hattori[3], Chieh-Hung Chen[4], Febty Febriani[5], Hongyan Chen[1] (1.Southern University of Science and Technology, Shenzhen, China, 2.The Institute of Statistical Mathematics, Tokyo, Japan, 3.Graduate School of Science, Chiba University, Chiba, Japan, 4.Institute of Geophysics and Geomatics, China University of Geosciences, Wuhan 430074, China, 5.Research Center for Physics, Indonesian Institute of Sciences, Tangerang, Banten, Indonesia)

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

[MIS08-06] Discussion

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

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

[M-IS08] Interdisciplinary studies on pre-earthquake processes

convener:Katsumi Hattori(Department of Earth Sciences, Graduate School of Science, Chiba University), Dimitar Ouzounov(Center of Excellence in Earth Systems Modeling & Observations (CEESMO) , Schmid College of Science & Technology Chapman University, Orange, California, USA), Jann-Yenq LIU(Department of Space Science and Engineering, National Central University, Taiwan), Qinghua Huang(Peking University), Chairperson:Peng Han(Southern University of Science and Technology, Shenzhen, China), Xuemin Zhang(Institute of Earthquake Forecasting, China Earthquake Administration)

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

[MIS08-07] Seismo-ionospheric anomalies before the 11 March 2011 M9.0 Tohoku Earthquake

*Jann-Yenq LIU[1,2,3], FU-YUAN CHANG[1], I-Te Lee[4], Katsumi Hattori[5], Yuh-Ing Chen[6] (1.Center for Astronautical Physics and Engineering, National Central University, Taoyuan, TAIWAN, 2.Department of Space Science and Engineering, National Central University, TAIWAN, 3.Center for Space and Remote Sensing Research, National Central University, Taoyuan, TAIWAN, 4.Center Weather Bureau, Taipei, TAIWAN, 5.Department of Earth Sciences, Graduate School of Science, Chiba University, Chiba, JAPAN, 6.Institute of Statistics, National Central University, Taoyuan, TAIWAN)

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

[MIS08-08] 3D Tomography of the Ionospheric Anomalies Before the 2010 Maule Earthquake, Chile: Comparison with the 2011 Tohoku-oki and 2015 Illapel Earthquakes

*Ihsan Naufal Muafiry[1], Kosuke Heki[1] (1.Hokkaido University, Japan)

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

[MIS08-09] Spatiotemporal Distribution Characteristics of Conductivity Anomalies before Ms > 6 Earthquakes in the North-South Seismic Belt of China during 2014 – 2019

*Zhiqiang Mao[1], Chieh-Hung Chen[1], Suqin Zhang[2], Qi Li[2], Aisa Yisimayili[3] (1.China University of Geosciences (Wuhan), 2.Institute of Geophysics, China Earthquake Administration, 3.Earthquake Agency of Xinjiang Uygur Autonomous Region)

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

[MIS08-10] **Possible stimulation of seismic activity by geomagnetically induced currents generated by ionizing radiation of solar flare in the illuminated hemisphere**

*Victor A. Novikov[1], Valery M. Sorokin[2], Alexey K. Yaschenko[2], Georgy Yu. Mushkarev[2] (1.Joint Institute for High Temperatures of Russian Academy of Sciences, 2.Pushkov Institute of Terrestrial Magnetism, Ionosphere and Radio Wave Propagation of Russian Academy of Sciences)

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

[MIS08-11] **Detecting the ionospheric disturbances in Japan using the three-dimensional computerized tomography**

*Rui Song[1], Katsumi Hattori[1], Xuemin Zhang[2] (1.Graduate School of Science and Engeering, Chiba University, 2.Institute of Earthquake Forecasting, China Earthquake Administration)

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

[MIS08-12] A Statistical Study of the Correlation Between Geomagnetic Storms and M>7.0 Global Earthquakes During 1957–2020

*Hongyan Chen[1], Rui Wang[1], Miao Miao[1], Xiaocan Liu[2], Yonghui Ma[3], Katsumi Hattori[4], Peng Han[1] (1.Southern University of Science and Technology, Shenzhen, China, 2.The Institute of Geophysics China Earthquake Administration, Beijing, China, 3.School of Science, Harbin Institute of Technology, Shenzhen, China, 4.Graduate School of Science, Chiba University, Chiba, Japan)

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

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

[M-IS08] Interdisciplinary studies on pre-earthquake processes

convener:Katsumi Hattori(Department of Earth Sciences, Graduate School of Science, Chiba University), Dimitar Ouzounov(Center of Excellence in Earth Systems Modeling & Observations (CEESMO) , Schmid College of Science & Technology Chapman University, Orange, California, USA), Jann-Yenq LIU(Department of Space Science and Engineering, National Central University, Taiwan), Qinghua Huang(Peking University), Chairperson:Jann-Yenq LIU(Department of Space Science and Engineering, National Central University, Taiwan), Qinghua Huang(Peking University)

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

[MIS08-13] Italian contribution to the CSES satellite mission

★Invited Papers

*Livio Conti[1], Group the CSES-Limadou Collaboration (1.Uninettuno University)

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

[MIS08-14] A focus on the capability of the RST-based satellite TIR anomalies for the short-term seismic hazard assessment in Japan

★Invited Papers

*Nicola Genzano[1], Roberto Colonna[1], Carolina Filizzola[2], Katsumi Hattori[3,4], Mariano Lisi[2], Nicola Pergola[2], Valerio Tramutoli[1] (1.School of Engineering, University of Basilicata, Via dell' Ateneo Lucano, 10, 85100 Potenza, Italy, 2.National Research Council, Institute of Methodologies for Environmental Analysis, C. da S. Loja, 85050 Tito Scalo (Pz), Italy, 3.Graduate School of Science, Chiba University, Yayoi 1-33, Inage, Chiba, 263-8522, Japan, 4.Center for Environmental Remote Sensing, Chiba University, Yayoi 1-33, Inage, Chiba, 263-8522, Japan)

4:10 PM - 4:30 PM JST | 7:10 AM - 7:30 AM UTC

[MIS08-15] Radon Monitoring in the Gulf of Corinth, Greece

★Invited Papers

*VASSILIOS KARASTATHIS[1], G Elefteriou[1], M. Kafatos[2], K. Tsinganos[3], G Tselentis[1], D. Ouzounov[2], E Mouzakiotis[1] (1.National Observatory of Athens, 2.Chapman University, 3.National and Kapodistrian University of Athens)

4:30 PM - 4:50 PM JST | 7:30 AM - 7:50 AM UTC

[MIS08-16] Earth's crust as a new element of the LAIC model within the Global Electric Circuit concept

★Invited Papers

*Sergey A Pulinets[1], V. Gavrilov[2], V. Bogdanov[3], N. Blaustein[4] (1.Space Research Institute of the Russian Academy of Sciences, 2.Institute of Volcanology and Seismology, Far-East Branch of the Russian Academy of Sciences, 3.Institute of Cosmophysical Research and Radio Wave Propagation, Far-East Branch of the Russian Academy of Sciences, 4.Ben-Gurion University of the Negev, Israel)

4:50 PM - 5:00 PM JST | 7:50 AM - 8:00 AM UTC

[MIS08-17] Discussion

[E] Oral | M (Multidisciplinary and Interdisciplinary) : M-AG Applied Geosciences

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

[M-AG37] CTBT IMS Technologies for Detecting Nuclear Explosion and Their Applications to Earth Science

convener:Nurcan Meral Ozel(Comprehensive Nuclear-Test-Ban Treaty Organization), Hiroyuki Matsumoto(Japan Agency for Marine-Earth Science and Technology), Dirk Metz(Japan Agency for Marine-Earth Science and Technology), Yosuke Naoi(Japan Atomic Energy Agency), Chairperson:Nurcan Meral Ozel(Comprehensive Nuclear-Test-Ban Treaty Organization), Hiroyuki Matsumoto(Japan Agency for Marine-Earth Science and Technology), Dirk Metz(Japan Agency for Marine-Earth Science and Technology)

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

[MAG37-01] **IMS Network Resilience and Business Continuity During Lockdown**

*Nurcan Meral Ozel[1] (1.Comprehensive Nuclear-Test-Ban Treaty Organization)

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

[MAG37-02] I30JP station repair following damage by typhoon “FAXAI”

*Takanari Fujii[1], Takayuki Otsu[1], Makiko Iwakuni[1], Masashi Motohashi[1] (1.Japan Weather Association)

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

[MAG37-03] Long-range acoustic measurements of the 2004 submarine eruption near Nightingale Island: Insights from hydrophone triplet array data recorded at IMS station H01W, Cape Leeuwin

*Dirk Metz[1], Julien Vergoz[2], Ingo Grevemeyer[3] (1.JAMSTEC, 2.CEA, 3.GEOMAR)

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

[MAG37-04] Operation of IMS radionuclide stations in Japan

*Yutaka Tomita[1], Yuichi Kijima[1], Akiko FURUNO[1], Yoichi Yamamoto[1] (1.Japan Atomic Energy Agency)

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

[MAG37-05] Atmospheric dispersion analysis for source term estimation of Xe-133 high-concentration detection events observed at the noble gas monitoring station in Takasaki regarding CTBT and two temporary experimental systems

*Akiko FURUNO[1], Yuichi Kijima[1], Yutaka Tomita[1], Yoichi Yamamoto[1] (1.Japan Atomic Energy Agency)

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

[MAG37-06] Discussion on how the CTBT IMS contributes to Earth and environmental sciences

Nurcan Meral Ozel[1], *Hiroyuki Matsumoto[2], Dirk Metz[2], Yosuke Naoi[3] (1.Comprehensive Nuclear-Test-Ban Treaty Organization, 2.Japan Agency for Marine-Earth Science and Technology, 3.Japan Atomic Energy Agency)

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

Sun. Jun 6, 2021 9:00 AM - 10:30 AM JST | Sun. Jun 6, 2021 12:00 AM - 1:30 AM UTC | Ch.04 Zoom Room 04

[P-PS04] Small Solar System Bodies: A New Insight from Hayabusa2, OSIRIS-REx and Other Space Missions

convener:Tatsuaki Okada(Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency), Taishi Nakamoto(Tokyo Institute of Technology), Daisuke Kuroda(Kyoto University), Chairperson:Tatsuaki Okada(Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency), Taishi Nakamoto(Tokyo Institute of Technology), YACHEN YANG(Center for Space and Remote Sensing Research)

Small Solar System bodies, including asteroids, comets, satellites, and interplanetary dust particles, are notably important for understanding the origin and evolution of our Solar System, as well as investigating the sources of building blocks of life. Many new discoveries on small bodies have been carried out by observations from ground-based and space-based observatories, and explorations by spacecraft rendezvous and flyby. New perspectives on solar system evolution have been paved by analyses of extraterrestrial materials such as meteorites, IDPs, and return samples by space missions. Numerical and laboratory simulation studies have helped interpretations for those results and proposed new insights on these topics. In this session, new results of scientific studies and new ideas of methodology for investigating small solar system bodies are highly welcome, especially the topics on the remote sensing, surface experiments, and analysis of return sample in the Hayabusa2 and OSIRIS-REx missions, as well as the expectations and preparations for future missions including MMX, Destiny+, Hera, Comet Interceptor, and Hayabusa2-Extended missions.

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

[PPS04-01] Introduction

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

[PPS04-02] Interdisiplinary Science of Hayabusa2 Mission

*Sei-ichiro WATANABE[1], Hikaru Yabuta[2], Koji Wada[3], Naru Hirata[4], Naoyuki Hirata[5], Yuri Shimaki[7], Rina Noguchi[7], Seiji Sugita[6], Kohei Kitazato[4], Tatsuaki Okada[7], Noriyuki Namiki[8], Shogo Tachibana[6,7], Masahiko Arakawa[5], Satoshi Tanaka[7] (1.Nagoya University, 2.Hiroshima University, 3.Chiba Institute of Technology, 4.University of Aizu, 5.Kobe University, 6.University of Tokyo, 7.JAXA/ISAS, 8.National Astronomical Observatory)

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

[PPS04-03] Progress report of initial description of the C-type asteroid Ryugu samples returned by Hayabusa2

*Toru Yada[1], Masanao Abe[1], Aiko Nakato[1], Kasumi Yogata[1], Akiko Miyazaki[1], Kazuya Kumagai[2], Kentaro Hatakeda[2], Tatsuaki Okada[1], Masahiro Nishimura[1], Shizuho Furuya[1], Yoshitake Miwa[1], Ayako Iwamae[2], Lucie Liu[1], Lionel Lourit[3], Cedric Pilorget[3], Vincent Hamm[3], Jean-Pierre Bibring[3], Yuichiro Cho[4], Koki Yumoto[4], Yuna Yabe[4], Seiji Sugita[4], Shogo Tachibana[4], Hirotaka Sawada[1], Sakamoto Kanako[1], Tasuku Hayashi[1], Daiki Yamamoto[1], Ryota Fukai[1], Haruna Sugahara[1], Hisayoshi Yurimoto[5], Tomohiro Usui[1], Sei-ichiro WATANABE[6], Yuichi Tsuda[1] (1.Japan Aerospace Exploration Agency, 2.Marine Works Japan, 3.Institut D'Astrophysique Spatiale, 4.University of Tokyo, 5.Hokkaido University, 6.Nagoya University)

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

[PPS04-04] EXPERIMENTAL STUDY ON IMPACT CRATERS FORMED ON MOUNTAIN-LIKE SURFACE TOPOGRAPHY OF ASTEROIDS

*Yusaku Yokota[1], Masahiko Arakawa[1], Minami Yasui[1], Yuya Yamamoto[1], Sunao Hasegawa[2], Hatsune Okawa[1] (1.Graduate School of Science, Kobe University, 2.Japan Aerospace Exploration Agency)

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

[PPS04-05] The collisional history in the Main Belt
★Invited Papers

*Hiroshi Kobayashi[1] (1.Department of Physics, Nagoya University)

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

[PPS04-06] Internal structure of pebble-pile comets inferred from thermal and mechanical properties of dust aggregates
★Invited Papers

*Sota ARAKAWA[1] (1.National Astronomical Observatory of Japan)

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

[P-PS04] Small Solar System Bodies: A New Insight from Hayabusa2, OSIRIS-REx and Other Space Missions

convener:Tatsuaki Okada(Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency), Taishi Nakamoto(Tokyo Institute of Technology), Daisuke Kuroda(Kyoto University), Chairperson:Tatsuaki Okada(Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency), Taishi Nakamoto(Tokyo Institute of Technology), YACHEN YANG(Center for Space and Remote Sensing Research)

Sun. Jun 6, 2021 9:00 AM - 10:30 AM Ch.04 (Zoom Room 04)

Small Solar System bodies, including asteroids, comets, satellites, and interplanetary dust particles, are notably important for understanding the origin and evolution of our Solar System, as well as investigating the sources of building blocks of life. Many new discoveries on small bodies have been carried out by observations from ground-based and space-based observatories, and explorations by spacecraft rendezvous and flyby. New perspectives on solar system evolution have been paved by analyses of extraterrestrial materials such as meteorites, IDPs, and return samples by space missions. Numerical and laboratory simulation studies have helped interpretations for those results and proposed new insights on these topics. In this session, new results of scientific studies and new ideas of methodology for investigating small solar system bodies are highly welcome, especially the topics on the remote sensing, surface experiments, and analysis of return sample in the Hayabusa2 and OSIRIS-REx missions, as well as the expectations and preparations for future missions including MMX, Destiny+, Hera, Comet Interceptor, and Hayabusa2-Extended missions.

9:00 AM - 9:05 AM

[PPS04-01]Introduction

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Interdisiplinary Science of Hayabusa2 Mission

*Sei-ichiro WATANABE[1], Hikaru Yabuta[2], Koji Wada[3], Naru Hirata[4], Naoyuki Hirata[5], Yuri Shimaki[7], Rina Noguchi[7], Seiji Sugita[6], Kohei Kitazato[4], Tatsuaki Okada[7], Noriyuki Namiki[8], Shogo Tachibana[6,7], Masahiko Arakawa[5], Satoshi Tanaka[7]

1. Nagoya University, 2. Hiroshima University, 3. Chiba Institute of Technology, 4. University of Aizu, 5. Kobe University, 6. University of Tokyo, 7. JAXA/ISAS, 8. National Astronomical Observatory

Asteroid explorer *Hayabusa2* completed its proximity operation around C-type asteroid Ryugu and returned to Earth with surface sample. More than 5 g of the particles in the sample catchers were successfully retrieved and wait for analyses. We will review the interdisciplinary science of *Hayabusa2* mission based on the proximity observations through visible and thermal IR imaging, NIR spectrometer, LIDAR, and the Small Carry-on Impactor (SCI) experiment, which will give a strategy of the return sample analyses. The SCI experiment reveals crater-to-impactor size ratio on Ryugu is more than 60 [1], contrast to the lower value of 10 derived from the size-frequency distributions of the main-belt asteroids and craters on the asteroids already explored [2]. This will change the chronology of the material transport process from the main asteroid belt to the Earth region. Based on the SCI scaling law, the surface age of Ryugu is estimated to be ~16 Ma, which is much shorter than the estimated ages (100 Ma to 1 Ga) of the candidate source collisional families in the inner asteroidal belt. This suggests that Ryugu is a product of a higher generation of the parent body disruption [3] or global resurfacing due to YORP induced past rapid rotation [4]. Visible color variations on Ryugu suggest the reddening of surface material by solar heating and/or space weathering under a temporal excursion near the Sun [5]. These hypotheses based on remote-sensing observations and the SCI experiment will be confirmed through return sample analyses.

Another important issue is the reconstruction of the properties of the parent body. Proximity observations using NIRS3 reveals the presence of global OH bearing minerals on Ryugu [6], whereas the amount is relatively small compared with hydrated carbonaceous chondrites and Bennu [7]. Both partial dehydration and incipient aqueous alteration will produce the weak OH absorption [3], which will be distinguished by return sample analyses. High porosity of Ryugu could be ascribed to loss of water ice during or after the formation of the rubble pile, if its parent body was an icy asteroid [4]. Water-rock ratio of the parent planetesimal with ^{26}Al heating will determine the set of coexisting minerals, which will also be determined by return sample analyses. Size-frequency distribution of surface particles as well as aggregate's constituent particles are important for identifying what kind of dust grains planetesimals are consist of. We will discuss the vision of exploration-based reconstruction of planetesimals.

[1] Arakawa et al. (2020), *Science* **368**, 268; [2] Bottke et al. (2020), *Astron. J.* **160**, 14; [3] Sugita et al. (2019), *Science* **364**, eaaw0422, [4] Watanabe et al. *Science* **364**, 268; [5] Morota et al. (2020), *Science* **368**, 654; [6] Kitazato et al. (2019) *Science* **364**, 272; [7] Hamilton et al. (2019), *Nature Astron.* **3**, 332.

Keywords: planetary exploration, material transport in the Solar System, planetary accretion process, planetesimals

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Progress report of initial description of the C-type asteroid Ryugu samples returned by Hayabusa2

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The Hayabusa2 spacecraft reached the C-type near-Earth asteroid 162173 Ryugu in June 2018 and observed the asteroid with onboard instruments and from the landers [1-8], and accomplished two touchdown samplings on 22 Feb. and 12 Jul. 2019 [9]. After the 2nd touchdown, the sample catcher which contains samples was transferred into its reentry capsule. The spacecraft left the asteroid in Nov. 2019 and returned the capsule to the Woomera Prohibited Area in South Australia on 6 Dec. 2020. The handling processes for the capsule and the sample container in it after its landing have been detailed in a previous report [10].

The clean chambers in the Extraterrestrial Sample Curation Center of JAXA Sagamihara campus are composed of five chambers; CC3-1~3 and CC4-1~2 [12]. The container was installed into CC3-1 on 11 Dec. 2020 and opened after evacuated to high vacuum. The sample catcher was extracted from the container, and transported to CC3-2. The catcher is composed of three small chambers A, B and C. The chambers A and C contain sample obtained by the 1st and 2nd touchdowns, respectively. As the cover of the chamber A was opened in vacuum in CC3-2, a large number of black particles were observed inside the chamber A, as shown in the Fig. 1. Two particles inside the chamber A were picked up and placed on a quartz glass dish for future science. The catcher with the greater part of samples was transferred to CC3-3, and the gate valve between CC3-2 and CC3-3 was closed. Then, CC3-3 was slowly purged with purified nitrogen gas to the atmospheric pressure, in which the catcher was handled with Viton-coated butyl gloves.

The catcher containing samples was transferred to CC4-2 and its bulk weight was measured with an electronic balance. The total weight of the samples inside the catcher is 5.4g, subtracting the designed weight of the catcher and a tare weight of an attached jig. The catcher was then dismantled to extract samples from the chambers A, B and C to sapphire glass dishes in CC4-1. The bulk samples held in the dishes were photographed with an optical microscope installed above CC4-2. The same microscope was used to take images of the samples with illumination through five filters (0.40 μm (ul), 0.48 μm (b), 0.55 μm (v), 0.59 μm (Na), and 0.70 μm (w)) matched to the ONC-T camera of Hayabusa2 [2]. The weight of each dish was measured with the balance in CC4-2. The bulk samples in the dishes were measured with the FT-IR (JASCO VIR-300) installed to CC4-2 for their average spectra from 1 to 5 μm and were also measured with MicrOmega installed to CC3-3, a noncontact version of the hyperspectral microscope onboard the MASCOT lander [11], to investigate spectral features from 0.99 to 3.65 μm of the samples. After the bulk initial description, individual particles >1mm in size are handpicked one by one with a vacuum tweezer to be enclosed into individual particle containers. They are to be characterized in the

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same manner as the bulk samples.

The sample distribution plan was detailed in [12]. JAXA plans to release the announcement of opportunity for the Hayabusa2 samples to the international science community with the sample catalog after 18 months from their return to the Earth.

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Figure 1. A photograph of the sample catcher of Hayabusa2 after opening its chamber A in CC3-2. A large number of black particles are observed inside the chamber. An outer diameter of the catcher is 48mm.

Keywords: Hayabusa2, Ryugu, asteroid, return samples, carbonaceous chondrite, C-type asteroid

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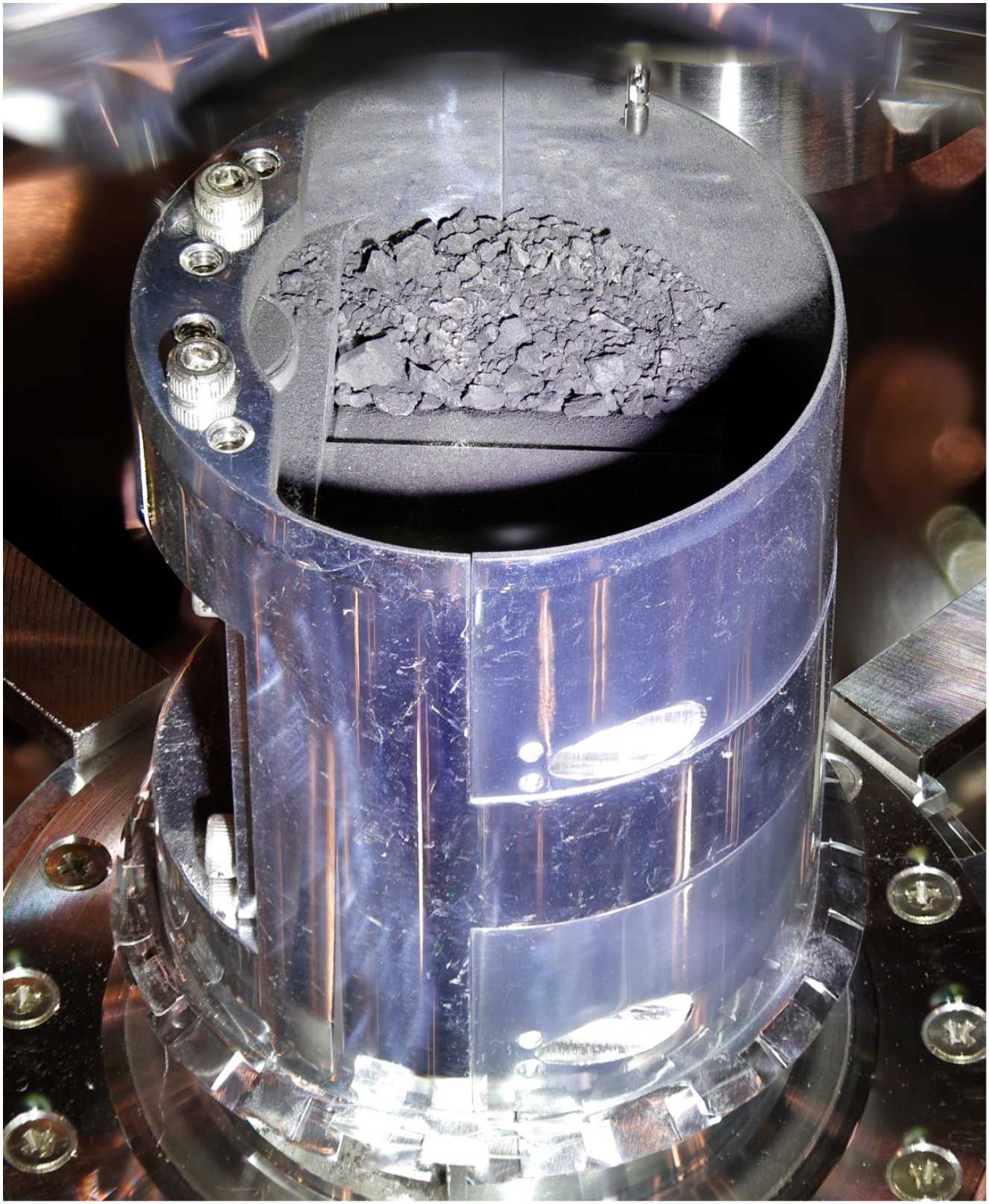

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EXPERIMENTAL STUDY ON IMPACT CRATERS FORMED ON MOUNTAIN-LIKE SURFACE TOPOGRAPHY OF ASTEROIDS

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Impact craters are one of the major geological features on solid bodies such as asteroids and satellites. A crater formed on a flat surface is observed to be a circle but a crater formed on a slope is ellipse. In particular, various topographic features such as slope, bulge, and canyon have been observed on asteroids and small satellites. Recently, Hayabusa2 and OSIRIS-REx revealed that Ryugu and Bennu have a large bulge on their equatorial regions. Furthermore, some craters with asymmetric profiles were found on the bulge of Ryugu. However, the conventional crater scaling laws based on the results of laboratory experiments conducted on the targets having the flat surface. In order to apply the scaling laws to the cratering process on the mountain-like surface topography of asteroids, it is necessary to improve the crater scaling laws including the effect of the surface topography. In this study, we conducted the impact cratering experiments on granular targets simulating the mountain-like surface topography of asteroids, and we investigated the effects of the surface topography on the crater size scaling law and the ejecta growth process.

We prepared two types of targets to simulate the surface topography of asteroids: they are granular targets having the shape of a mountain range and a cone. The inclination (θ) of the mountain range target was set to be 20° and 30°, and that of the cone target was ~30°. We also prepared the target having the flat surface (that is, $\theta = 0°$). We changed the impact point d for the mountain range target; the d was defined as the horizontal distance between the impact point and the summit. In the case of the cone target, we changed the foot width of the target w.

We conducted impact experiments by using a one-stage vertical gas gun at Kobe University and a two-stage vertical gas gun at ISAS. The impact velocities ranged from 69 to 202 m/s for the mountain range target, and from 41 m/s to 4.21 km/s for the cone target. In order to analyze the crater morphology, we constructed the 3D shape model by using the software of PhotoScan Pro.

For the mountain range target, we observed that the crater had an elliptical shape: the width of the crater on the ridge direction (major axis) was always larger than that on the slope direction (minor axis). Furthermore, the elevated crater rim was observed on the ridge direction but it was not observed on the slope direction. The asymmetry of the crater shape strongly depends on the d. Now, the crater asymmetry is shown by the aspect ratio defined as the ratio of major axis length to minor axis length. We found that the aspect ratio increases with the increase of the major axis length at the constant d value, and furthermore, it increases more rapidly with the decrease of d. These characteristics were also found on the target with the slope of $\theta = 20°$ but the aspect ratio for the target with the slope of $\theta = 30°$ was larger than that of $\theta = 20°$ at the same d and the major axis length. Also, we constructed the crater size scaling law described by π-scaling for the mountain range target. The normalized crater radius, π_R, clearly depends on the slope θ, that is, they are ~1.3 times larger than that of the flat surface, $\theta = 0°$.

For the cone target, we observed the ratio of the initial target height to the impacted target height. We investigated the relationship between the height ratio and the v^* at different impact velocities. The v^* is defined as the velocity derived from the projectile momentum divided by the cone mass. At $v^* < 0.5$ m/s, the height ratio decreases exponentially with the increase of the v^*, irrespective of the impact velocity. This means that the height ratio could be controlled by the projectile momentum. At $v^* > 0.5$ m/s, most of the cone was excavated so the height ratio was almost zero. We also measured the crater diameter formed

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on the cone target and it was almost the same as that formed on the flat surface at the same projectile kinetic energy.

Keywords: crater

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The collisional history in the Main Belt

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Asteroids in the Main Belt Mean collisional velocity between them is estimated to be about 5 km/s so that collisions lead to fragmentation. The collisional timescale for 100 km-sized or larger asteroids is estimated to be much longer than the age of the Solar System, while smaller asteroids are expected to have experience of catastrophic disruption. This estimate is consistent with the fraction of asteroids in collisional families. Therefore, such large asteroids may have formed in the planet formation era. The mass distribution of 100km-sized or larger main belt asteroids is explained by the onset of runaway growth of planetesimals. On the other hand, smaller bodies are
fragmented into still smaller bodies. The mass distribution of 10km-sized or smaller asteroids is in the quasi steady state of the collisional cascade. However, the collisional lifetimes of such small asteroids highly depend on collisional outcome models. According to the collisional theory, we may discuss the possible histories of
kilometer sized asteroids.

Keywords: Asteroids, planetesimals, Collisions

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Internal structure of pebble-pile comets inferred from thermal and mechanical properties of dust aggregates

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The *Rosetta* mission has provided new data to better understand what comets are made of. The weak tensile strength of the cometary surface materials suggests that comet 67P/Churyumov–Gerasimenko is a hierarchical dust aggregate formed through gravitational collapse of a bound clump of small dust aggregates so-called `pebbles' in the gaseous solar nebula. Recently, we calculated the thermal inertias and thermal skin depths as functions of the size of pebbles (Arakawa & Ohno 2020). We found that the thermal properties of the comet are consistent with the hierarchical aggregate of cm- to dm-sized pebbles. This estimate is also consistent with the mechanical strength of the nucleus. In addition, we reanalyzed the stickiness of icy dust particles using a viscoelastic contact model. Our results indicate that not only H_2O ice but also CO_2 ice particles could easily grow into cm-sized large pebbles in the solar nebula (Arakawa & Krijt 2021), and this size estimate may be consistent with that from thermal and mechanical analyses on comet 67P.

Keywords: Comet, Thermal inertia, Dust growth

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

Sun. Jun 6, 2021 10:45 AM - 12:15 PM JST | Sun. Jun 6, 2021 1:45 AM - 3:15 AM UTC | Ch.04 Zoom Room 04

[P-PS04] Small Solar System Bodies: A New Insight from Hayabusa2, OSIRIS-REx and Other Space Missions

convener:Tatsuaki Okada(Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency), Taishi Nakamoto(Tokyo Institute of Technology), Daisuke Kuroda(Kyoto University), Chairperson:Tatsuaki Okada(Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency), Taishi Nakamoto(Tokyo Institute of Technology), YACHEN YANG(Center for Space and Remote Sensing Research)

Small Solar System bodies, including asteroids, comets, satellites, and interplanetary dust particles, are notably important for understanding the origin and evolution of our Solar System, as well as investigating the sources of building blocks of life. Many new discoveries on small bodies have been carried out by observations from ground-based and space-based observatories, and explorations by spacecraft rendezvous and flyby. New perspectives on solar system evolution have been paved by analyses of extraterrestrial materials such as meteorites, IDPs, and return samples by space missions. Numerical and laboratory simulation studies have helped interpretations for those results and proposed new insights on these topics. In this session, new results of scientific studies and new ideas of methodology for investigating small solar system bodies are highly welcome, especially the topics on the remote sensing, surface experiments, and analysis of return sample in the Hayabusa2 and OSIRIS-REx missions, as well as the expectations and preparations for future missions including MMX, Destiny+, Hera, Comet Interceptor, and Hayabusa2-Extended missions.

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

[PPS04-07] Predicted strength, microporosity, thermal conductivity and grain density of Ryugu rock samples

*Jens Biele[1], Matthias Grott[2], Patrick Michel[3], Tatsuaki Okada[4], Seiji Sugita[5], Naoya Sakatani[6], Wladimir Neumann[2,7], Shingo Kameda[6], Tatsuhiro Michikami[8], Chikatoshi Honda[9] (1.German Aerospace Center, Cologne, Germany, 2.German Aerospace Center, Berlin, Germany, 3.Université Côte d'Azur, Observatoire de la Côte d'Azur, CNRS, Laboratoire Lagrange, Nice, France , 4.Japan Aerospace Exploration Agency, ISAS, Sagamihara, Japan, 5.University of Tokyo, Tokyo, Japan, 6.Rikkyo University, Tokyo, Japan, 7.Klaus-Tschira-Labor für Kosmochemie, Institut für Geowissenschaften, Universität Heidelberg, Heidelberg, Germany, 8.Kindai University, Hiroshima, Japan, 9.University of Aizu, Aizu-Wakamatsu, Japan)

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

[PPS04-08] Analysis of the temperature distributions of boulders on C-type asteroid 162173 Ryugu observed in low altitude operation of the asteroid explorer Hayabusa2

*Ayumu Ohsugi[1,2], Naoya Sakatani[3], Yuri Shimaki[2], Hiroki Senshu[4], Takehiko Arai[5], Hirohide Demura[6], Toru Kouyama[7], Tomohiko Sekiguchi[8], Satoshi Tanaka[2], Tetsuya Fukuhara[3], Tatsuaki Okada[1,2] (1.Graduate School of Science, The University of Tokyo, 2.Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency, 3.Department of Physics, College of Science, Rikkyo University, 4.Planetary Exploration Research Center, Chiba Institute of Technology, 5.Faculty of Engineering, Department of Innovative Engineering, Division of Systems and Information Engineering,Ashikaga University, 6.Department of Computer Science and Engineering, University of Aizu, 7.National Institute of Advanced Industrial Science and Technology, 8.Hokkaido University of Education)

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

[PPS04-09] Surface Age of Ryugu's Boulders Based on Small Crater Statistics

*Yudai Takai[1], Tomokatsu Morota[1], Koki Yumoto[1], Rie Honda[2], Shingo Kameda[3], Eri Tatsumi[1,4], Yuichiro Cho[1], Kazuo Yoshioka[1], Hirotaka Sawada[5], Yasuhiro Yokota[2,5], Naoya Sakatani[3], Masahiko Hayakawa[5], Moe Matsuoka[5], Manabu Yamada[6], Toru Kouyama[7], Hidehiko Suzuki[8], Chikatoshi Honda[9], Kazunori Ogawa[5,10], Seiji Sugita[1] (1.University of Tokyo, 2.Kochi University, 3.Rikkyo University, 4.Instituto de

Astrofísica de Canarias, 5.JAXA, 6.Chiba Institute of Technology, 7.National Institute of Advanced Industrial Science and Technology, 8.Meiji University, 9.The University of Aizu, 10.Kobe University)

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

[PPS04-10] Space weathering of bright boulders inferred from the spectral comparison between SCI crater and blue regions on Ryugu

*Minami Aoki[1], Chiho Sugimoto[1], Koki Yumoto[1], Naofumi Takaki[1], ERI TATSUMI[2,1], Tomokatsu Morota[1], Yasuhiro Yokota[3], Masahiko Arakawa[4], Seiji Sugita[1] (1.Department of Earth and Planetary Science, Graduate School of Science, The University of Tokyo, 2.Instituto de Astrofísica de Canarias, 3.JAXA/ISAS, 4.Kobe University)

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

[PPS04-11] Estimation of space weathering timescale using the number of mottles on the boulder in Hayabusa/AMICA images

*Sunho Jin[1], Masateru Ishiguro[1] (1.Seoul National University)

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

[PPS04-12] The Chemical Composition of Interstellar Dust in Light of the DESTINY^{+} Mission: A Novel Tool to Measure the Elemental Abundances and Ionization of the Local Interstellar Cloud

*Hiroshi Kimura[1], Masanori Kobayashi[1], Tomoko Arai[1], DDA Team / DESTINY+ (1.Planetary Exploration Research Center, Chiba Institute of Technology)

Predicted strength, microporosity, thermal conductivity and grain density of Ryugu rock samples

*Jens Biele[1], Matthias Grott[2], Patrick Michel[3], Tatsuaki Okada[4], Seiji Sugita[5], Naoya Sakatani[6], Wladimir Neumann[2,7], Shingo Kameda[6], Tatsuhiro Michikami[8], Chikatoshi Honda[9]

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In this presentation, we summarize the findings and interpretations of the physical and thermophysical properties of C-type asteroid 162173 Ryugu obtained from Hayabusa2 remote sensing as well as from MASCOT radiometer (MARA) data. For a typical rock on Ryugu's surface, we find a thermal inertia of 295 ± 18 $Jm^{-2}K^{-1}s^{-1/2}$ (Hamm+ 2020), a microporosity of 50 ±3% (Grott+ 2020, Hamm+, 2020), and assuming a CM chondrite composition and thus an inferred specific heat capacity of cp=890 J/kg/K (±10%, at an average temperature of 277K), we estimate a thermal conductivity of 0.069 ±0.012 J/m/K at ~277 K. These estimates are based on MARA surface brightness temperature measurements of an arguably (Biele et al, 2019) dust-free boulder at MASCOT's landing site obtained over a full diurnal cycle. Those values are consistent with the TIR instrument's global findings (Okada+ 2020). The very high deduced microporosity lets us reasonably estimate the tensile strength of those abundant "cauliflower rocks" (Jaumann+ 2019), ~200-280 kPa (Grott+, 2019).

Furthermore, also from orbital data (ONC imaging and counting, plus radiometric data for GM), we have estimated the macroporosity of Ryugu, assumed to be a homogeneous rubble pile, based on granular mixing theory and the size-frequency distribution of boulders ranging from ~0.1 m to ~100 m diameter. We find (Grott+, 2020) that the macroporosity of Ryugu is very low, 16 ±3% and that if the underlying homogeneity assumption is true, taken together with Ryugu's bulk density and the average microporosity of its boulders, the average grain density can be estimated as 2.85 ±0.15 g/cm^3, consistent with the mineralogy of CM meteorites or the ungrouped carbonaceous chondrite Tagish Lake.

It will now be extremely exciting to compare these values with actual laboratory measurements of the returned samples. For example, if our values for Ryugu's macroporosity and rock microporosity (and/or grain density) do not agree with what is found from the samples, the assumption of homogeneity might be wrong. This would mean that the surface of Ryugu has a significantly different boulder SFD than its interior. Or, simpler, the assumed relationship between rock porosity and thermal conductivity is incorrect.

As for the strength of rock pieces, besides possible size (scale) dependencies and sampling bias, a higher strength than predicted here would have to be reconciled with the very low thermal conductivity of Ryugu's blocks, which dictates rather small grain-to-grain (sinter or volatile condensate or 'salt') neck diameters.

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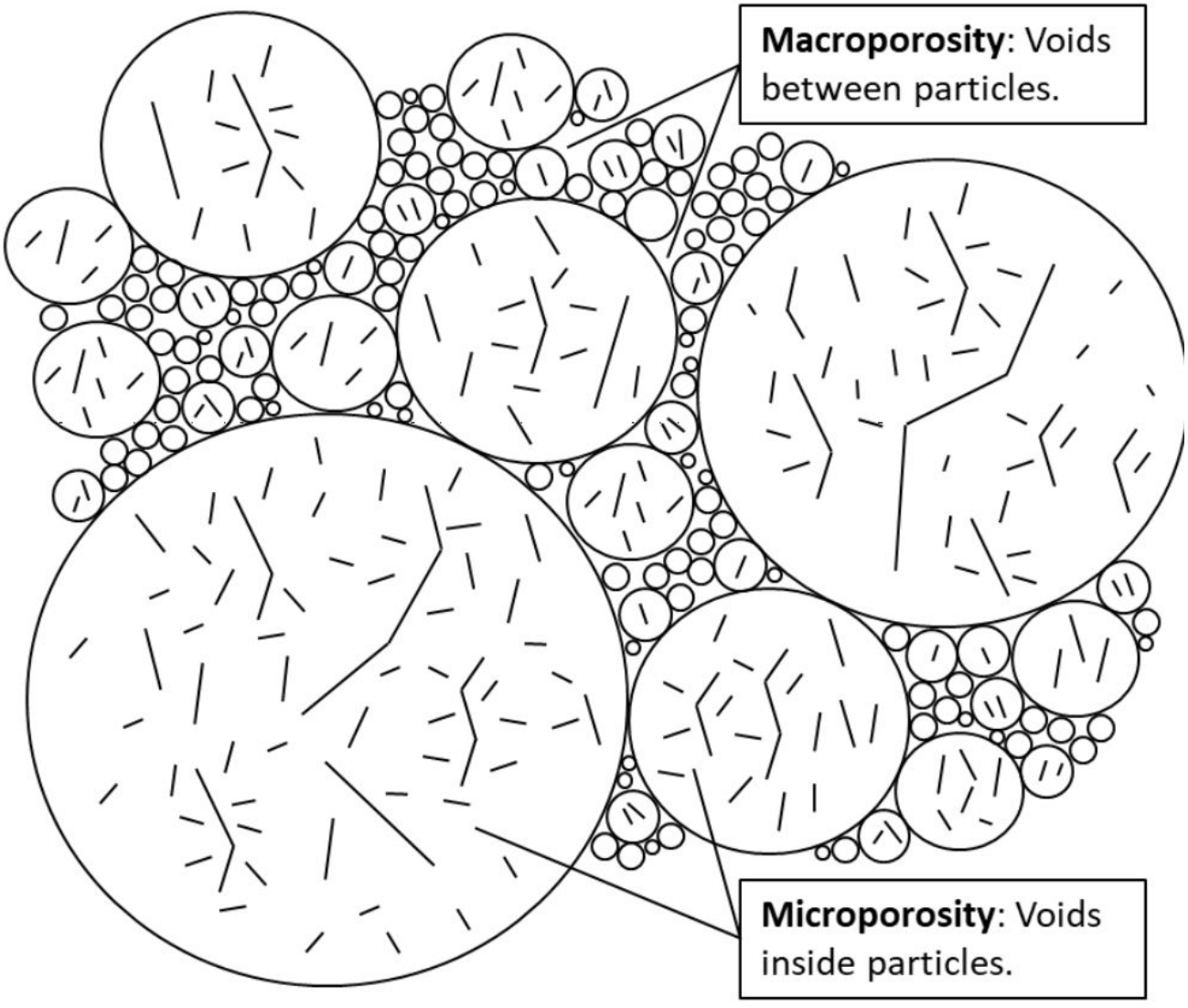
Keywords: rubble pile asteroid, Ryugu, material properties



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Analysis of the temperature distributions of boulders on C-type asteroid 162173 Ryugu observed in low altitude operation of the asteroid explorer Hayabusa2

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The asteroid explorer Hayabusa2 [1] has the Thermal Infrared Imager (TIR) [2,3] which obtains the digital thermal images to indicate the thermal radiation from C-type asteroid 162173 Ryugu. In this study, to obtain detailed thermal properties of boulders at Ryugu, we analyzed TIR images taken below the altitude of 500 m and investigated temperature variations of boulders and their physical state in the specific regions.
TIR has a field of view (FOV) of 16.7˚×12.7˚ and the effective pixels of the detector of 328×248, resulting in the spatial resolution about of 0.051˚ per pixel [2]. The temperature range which TIR covers is 150 to 460 K and the well-calibrated temperature range is 230 to 420 K. We used TIR images taken during the release paths for the MINERVA rover (MNRV) and the MASCOT lander (MSCT). We identified boulders taken with more than 100 pixels and calculated the temperatures. The total numbers of detected boulders were 355 (MNRV) and 312 (MSCT), and the detection errors were obtained as ±5.2 % and ±5.5 % by Wald inequality [4]. In MNRV, the averages and the standard deviations of minimum, average, and maximum temperatures were 286 ±11.2 K, 314 ±5.65 K, and 332 ±5.74 K, respectively. In MSCT, the averages and the standard deviations of minimum, average, and maximum temperatures were 287 ±11.0 K, 313 ±5.53 K, and 332 ±5.99 K, respectively. From the normal Q-Q plots, where the x-axis is the observed value and the y-axis is the expected value which is assumed the detected value follows a normal distribution, the temperatures could follow the normal distribution. The YORP effect [1,5] might lead to the normality of the temperature distributions. Furthermore, the calculated slopes of the size-frequency distributions (SFD) divided by measured altitudes were in the range of 0.30 to 4.0 and these values were consistent with those investigated by Michikami T et al., (2019) [6], who suggested the existence of boulders formed when Ryugu's parent body was destroyed and those covered with regolith layers. Moreover, the range of thermal inertias [7] was calculated as low as 34.6-385 J m^{-2} $s^{-0.5}$ K^{-1} (hereafter, tiu) with the one-dimensional heat diffusion equation [8]. Our results are consistent with that of the global average estimated as 225 ±45 tiu by Shimaki et al. (2020) [9]. In this study, we assumed that the surfaces of boulders were confronted to the images so that further detailed study considering the surface local slopes is needed to estimate more accurately.
In summary, the total numbers of detected boulders were 355 (MNRV) and 312 (MSCT) and the normal Q-Q plots suggested that the average temperature distributions of boulders were close to the normal distribution. Moreover, the values of slopes of SFD and thermal inertias suggested the existence of boulders formed when Ryugu's parent body was destroyed, boulders covered with regolith layers, and porous and fluffy boulders. In the future, we will investigate other areas taken at low-altitudes.

Acknowledgments

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Keywords: Hayabusa2, Temperature, boulder, Ryugu

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Surface Age of Ryugu's Boulders Based on Small Crater Statistics

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The Hayabusa2 spacecraft arrived at the asteroid Ryugu on June, 2018. Detailed observations by Hayabusa2 have revealed a large number of boulders on Ryugu's surface and its low bulk density of 1,190 kg/m^3, suggesting its "rubble-pile" structure [Watanabe et al., 2019; Michikami et al., 2019; Hirabayashi et al., 2019]. Unraveling the lifetime of boulders is important for understanding the surface processes, such as thermal fatigue, impacts and surface flow, and its timescale on Ryugu's surface.

During two touchdown rehearsal operations on October 15 and 25, 2018 (Japan Standard Time) before the first touchdown operation, the Optical Navigation Camera (ONC) onboard the Hayabusa2 spacecraft [Sugita et al., 2019; Kameda et al., 2017; Suzuki et al., 2018; Tatsumi et al., 2019], which took multiple high-resolution images (~1 cm/pixel). Moreover, during the touchdown operations on February 22, 2019 and July 11, 2019, the ONC took even higher-resolution images (~0.1 cm/pixel), showing topographic features of Ryugu's surface on the scale of a few centimeters. Because the characteristic size of the Ryugu's boulder is estimated to be 3 m [Sugita et al., 2019], low-altitude imaging allowed us to observe small craters on the boulder surface.

Using these high-resolution images of Ryugu's surface, we investigated 2,152 boulders and identified 22 several-centimeter-sized circular depressions on the boulder surfaces that are candidates for small impact craters. We also built a cratering chronology model of small craters on Ryugu's boulders, based on the Pi-group crater scaling law under the strength regime [Holsapple, 1993] and the size-frequency distribution model of near-Earth object population [Brown et al., 2002; Suggs et al., 2014].

Based on the size-frequency distributions of small crater candidates and the cratering chronology model for Ryugu's small craters, the surface age of Ryugu's boulders was estimated to 0.01 to 1 Myr, younger than the global surface age of Ryugu (~8 Myr) [Sugita et al., 2019; Morota et al., 2020; Cho et al., submitted]. Moreover, Ryugu's boulders have lower crater density than Bennu's boulders, whose surface age was estimated to be 1.75 ±0.75 Myr [Ballouz et al., 2020]. We will discuss the disruption and resurfacing processes of boulders, based on the estimated survival time of boulders and comparisons with the crater densities of large craters on Ryugu and mini craters on boulder surface of asteroid Bennu.

Keywords: Ryugu, Hayabusa2, crater, boulder

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Space weathering of bright boulders inferred from the spectral comparison between SCI crater and blue regions on Ryugu

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Boulders with reflectance ≧1.5 times the surrounding background have been discovered on Ryugu [1-4]. These are called bright boulders (BBs). Based on spectral features, they are classified into S-type and C-type BBs. The former is likely exogenous, and the latter is likely endogenous [2-4]. Detailed spectral analysis using principal component analysis have revealed that S-type boulders on Ryugu experienced different degrees of space weathering. However, the degrees and patterns of space weathering of C-type bright boulders on Ryugu have not been understood well yet. Because Hayabusa2 collected samples near the SCI crater, which excavated fresh materials from depth that is not intensively influenced by either space weathering or solar heating [5], optical navigation camera telescope (ONC-T) have captured many high-resolution images of fresh materials. Analysis of 13 BBs inside the SCI crater indicate that all these 13 turned to be C-type BBs [6]. In this study, we extend our analysis of C-type BBs inside the SCI crater to understand the nature of space weathering on these C-type materials.

First, we compared the spectra of C-type BBs inside and outside the SCI crater with those of the heated carbonaceous chondrites [7, 8] in v-x slope/ul-index space. Results showed that the distribution of BBs inside the SCI crater is generally consistent with that of BBs outside the SCI crater. Also found is that the spectral trend of C-type BBs in v-x slope/ul-index space is generally similar to the trend formed by heating experiments with carbonaceous chondrites (CCs). However, there is significant difference between C-type BB trend and that of heated CCs; some BBs inside the SCI crater have a high ul-index value that is not found in BBs outside the SCI crater. Thus, this spectral feature may be lost due to space weathering.

Second, we further investigated whether the new spectral shape (e.g., excess ul-index) not seen in BBs outside the SCI crater is unique to BBs that have not undergone space weathering. Previous studies have found that Ryugu surface have both reddish and blueish regions [1]. Results of geologic analysis have shown that the reddish regions may have been exposed for a long time and experienced solar heating and/or solar wind irradiation [9]. Blueish regions are stratigraphically younger than reddish regions; they probably experienced some kind of resurfacing relatively recently [1, 9]. Thus, BBs in blue regions may be less affected by space weathering than those in reddish regions. Then, we have three different stages of solar heating and/or space weathering on Ryugu. Comparison of spectral properties of C-type BBs in these three different regions would give us important clue for understanding space weathering on C-type BBs. Preliminary analysis results suggest that C-type bright boulders on bluish regions, whose surface exposure ages are estimated to be ~0.3 to ~8 Myr [9], do not exhibit statistically significant excess ul-index. Thus, if the decrease in ul-index excess is caused by space weathering, then this mode of space weathering may occur at such short timescales. In the presentation, we will present the up-to-date results of our analyses of this comparison.

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Keywords: asteroid, SCI Crater, Bright Boulder

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Estimation of space weathering timescale using the number of mottles on the boulder in Hayabusa/AMICA images

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The remote-sensing images of the Hayabusa mission target asteroid (25143) Itokawa (Sq-type) indicates the coexistence of both matured terrains by space weathering and fresh regions with newly exposed materials. Several resurfacing mechanisms (e.g., tidal interaction with terrestrial planets) [1] are proposed to explain the formation of these regions. The estimation of space weathering timescale is essential to constrain the possible mechanisms to rejuvenate the asteroid.

Note that there is an unignorable discrepancy between the timescale derived from different techniques. The timescale estimated from the solar flare track density and the weathered rim thickness of regolith samples acquired by Hayabusa spacecraft range from 10^2 to 10^4 years [2][3], while those estimated from laboratory simulations range from 10^4 to 10^6 years [4][5]. Besides, there are inherent insufficiencies of these age estimation methods. Since evidence of regolith migration is found on the surface of Itokawa [6], particles on the very surface would be rejuvenated by granular convection. Meanwhile, laboratory experiments are indirect stimulations of the space weathering process, which would have possibilities to be different from the actual process present in the asteroid. Thus, we focus on estimating the surface exposure age using bright mottles on the large boulders, where the materials are insusceptible to the regolith migration. These mottles are expected to be formed by impacts of mm to cm-sized interplanetary particles.

In this work, we used three AMICA (Asteroid Multi-band Imaging Camera) v-band images. These images were taken on November 12th, 2005, during the close approach to the asteroid. First, we masked boulders large enough to detect mottles. Then, we determined the size distribution of these mottles. We also derived theoretical size distribution with various timescales of space weathering with the well-known size distribution of interplanetary dust particles (e.g., Grün, 1985 [7]). By comparing these two distributions, we estimated the time needed to form mottles before becoming dark again by space weathering.

As a result, we found surface exposure timescales of these boulders are an order of 10^3 –10^4 years, consistent with those previously estimated from laboratory simulation with light ions, such as Hydrogen and Helium. We also plan to discuss possible resurfacing scenarios to expose fresh materials during such short time intervals at this meeting.

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Keywords: Asteroids, Space Weathering, Itokawa, Hayabusa

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The Chemical Composition of Interstellar Dust in Light of the DESTINY+ Mission: A Novel Tool to Measure the Elemental Abundances and Ionization of the Local Interstellar Cloud

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The chemical composition of interstellar dust is directly linked to the depletion of elements in the gas phase of the interstellar medium (ISM), owing to the complementarity of elements in the solid and gas phases of the ISM. It has, therefore, been common practice to derive the elemental abundance of interstellar dust from the measured depletion of dust-forming elements in the gas phase of the ISM. The chemical composition of both solid and gas phases in the ISM would be a crucial factor for the evolution of the presolar molecular cloud, from which the Sun and the Solar System formed about 4.5 billion years ago. In particular, the organic and rocky components of interstellar dust would provide seeds for the origin of life and habitable planets.

On the one hand, the determination of elemental abundances in the solid and gas phases of the ISM is not a straightforward task if partially ionized, unless the ionization fractions of every elements are known a priori. This is exactly the case for the Local Interstellar Cloud (LIC) around the Sun, which is known to be a partially ionized warm cloud with an extension of several parsecs. On the other hand, recent technological advances in space missions have provided us direct information on the chemical composition of dust in the LIC by means of laboratory analyses (Stardust) and in situ measurements (Cassini).

The DESTINY$^+$ Dust Analyzer (DDA) onboard DESTINY$^+$ is a successor of Cassini’s Cosmic Dust Analyzer (CDA) equipped with an impact ionization detector and a time-of-flight mass spectrometer. The DDA will measure the chemical composition of interstellar dust streaming into the inner Solar System from the LIC, similar to the CDA, but with an elevated performance in terms of mass resolution and sensitive area. We have analyzed astronomical deta on the depletion of elements in the gas phase of the LIC and the ionization states of the elements, derived the elemental abundances of dust in the LIC from the depletion, and compared them with space mission data. We found that DDA’s data on the chemical composition of interstellar dust will constrain the gas-phase abundances and ionization states of elements undetectable by remote astronomical observations. In this talk, we will demonstrate that the DDA is a novel tool to measure the composition and ionization of the LIC.

Keywords: DESTINY+, interstellar dust, in-situ analysis, chemical composition, Local Interstellar Cloud, ionization state

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

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

[P-PS04] Small Solar System Bodies: A New Insight from Hayabusa2, OSIRIS-REx and Other Space Missions

convener:Tatsuaki Okada(Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency), Taishi Nakamoto(Tokyo Institute of Technology), Daisuke Kuroda(Kyoto University), Chairperson:Tatsuaki Okada(Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency), Taishi Nakamoto(Tokyo Institute of Technology), YACHEN YANG(Center for Space and Remote Sensing Research)

Small Solar System bodies, including asteroids, comets, satellites, and interplanetary dust particles, are notably important for understanding the origin and evolution of our Solar System, as well as investigating the sources of building blocks of life. Many new discoveries on small bodies have been carried out by observations from ground-based and space-based observatories, and explorations by spacecraft rendezvous and flyby. New perspectives on solar system evolution have been paved by analyses of extraterrestrial materials such as meteorites, IDPs, and return samples by space missions. Numerical and laboratory simulation studies have helped interpretations for those results and proposed new insights on these topics. In this session, new results of scientific studies and new ideas of methodology for investigating small solar system bodies are highly welcome, especially the topics on the remote sensing, surface experiments, and analysis of return sample in the Hayabusa2 and OSIRIS-REx missions, as well as the expectations and preparations for future missions including MMX, Destiny+, Hera, Comet Interceptor, and Hayabusa2-Extended missions.

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

[PPS04-13] Regional photometric properties on asteroid Ryugu in visible wavelength

*Yasuhiro Yokota[1], Rie Honda[2], Eri Tatsumi[3], Deborah Domingue[4], Stefanus E. Schröder[5], Moe Matsuoka[1], Lucie Riu[1], Seiji Sugita[6], Tomokatsu Morota[6], Naoya Sakatani[7], Chikatoshi Honda[8], Yuichiro Cho[6], Shingo Kameda[7], Toru Kouyama[9], Manabu Yamada[10], Masahiko Hayakawa[1], Hiroki Senshu[10], Hidehiko Suzuki[11], Kazuo Yoshioka[6], Hirotaka Sawada[1], Kazunori Ogawa[1] (1.ISAS/JAXA, Japan, 2.Kochi Univ., Japan, 3.Instituto de Astrofisica de Canarias, Univ. of La Laguna, Spain, 4.Planetary Science Institute, USA, 5.DLR, Germany, 6.Univ. of Tokyo, Japan, 7.Rikkyo Univ., Japan, 8.Univ. of Aizu, Japan, 9.AIST, Japan, 10.Chiba Inst. Tech, Japan, 11.Meiji Univ., Japan)

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

[PPS04-14] Spectrophotometric behavior of Ryugu's surface as inferred from the Hayabusa2/NIRS3 data

*Andrea Longobardo[1], Ernesto Palomba[1,2], Anna Galiano[1], Fabrizio Dirri[1], Angelo Zinzi[2], Mario D'Amore[3], Deborah Domingue[4], Kohei Kitazato[5], Takahiro Iwata[6], Moe Matsuoka[6], Takahiro Hiroi[7], Driss Takir[8], Tomoki Nakamura[9], Masanao Abe[5], Makiko Ohtake[5], Shuji Matsuura[10], Sei-ichiro WATANABE[6,11], Makoto Yoshikawa[6], Takanao Saiki[6], Tatsuaki Okada[6], Yukio Yamamoto[6], Yoh Takei[6], Kei Shirai[6], Naru Hirata[5], Naoyuki Hirata[12], Koji Matsumoto[13], Yuichi Tsuda[6] (1.Istituto Nazionale di Astrofisica - Istituto di Astrofisica e Planetologia Spaziali, Rome, Italy, 2.ASI-SSDC, Rome, Italy, 3.German Aerospace Center, Institute of Planetary Research, Berlin, Germany, 4.PSI, Tucson, AZ, USA, 5.University of Aizu, Aizu-Wakamatsu 965-8580, Fukushima, Japan, 6.ISAS-JAXA, Japan, 7.Department of Earth, Environmental and Planetary Sciences, Brown University, Providence, RI 02912, USA, 8.Jacobs/NASA Johnson Space Center, USA, 9.Tohoku University, Miyagi, Japan, 10.Kwansei Gakuin University, Hyogo, Japan, 11.Nagoya University, Nagoya 464-8601, Japan, 12.Kobe University, Kobe 657-8501, Japan, 13.National Astronomical Observatory of Japan, Mitaka 181-8588, Japan)

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

[PPS04-15] Laboratory spectral constraints on the composition and origin of Phobos: Reconciling the Vis-NIR/Mid-IR contradictions

*Matthew Izawa[1], Sandra Potin[2], Edward Cloutis[2] (1.Institute for Planetary Materials, 2.University of Winnipeg)

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

[PPS04-16] UNSUPERVISED LEARNING OF NIRS3 DATA: RYUGU SPECTRAL SURFACE REGIONS CLASSIFICATION

*Mario D'Amore[1], E. Palomba[2,3], A. Galiano[2], A. Zinzi[3], F. Dirri[2], A. Longobardo[2], K. Kitazato[4], T. Iwata[5], M. Matsuoka[5], T. Hiroi[6], D. Takir[7], T. Nakamura[8], M. Abe[5], M.y Ohtake[5], S. Matsuura[9], S. Watanabe[10], M. Yoshikawa[5], T. Saiki[5], S. Tanaka[5], T. Okada[5], Y. Yamamoto[5], Y. Taikei[5], K. Shirai[5], N. Hirata[11,4], K. Matsumoto[12], Y. Tsuda[5] (1.German Aerospace Center, Institute of Planetary Research, Berlin, Germany, 2.INAF-IAPS, Rome, Italy, 3.SSDC-ASI, Rome, Italy, 4.University of Aizu, Aizu-Wakamatsu 965-8580, Fukushima, Japan, 5.Institute of Space and Astronautical Science (ISAS), Japan Aerospace Exploration Agency, Sagamihara, 252-5210, Japan, 6.Department of Earth, Environmental and Planetary Sciences, Brown University, Providence, RI 02912, USA, 7.Jacobs/NASA Johnson Space Center, USA, 8.Tohoku University, Miyagi, Japan, 9.Kwansei Gakuin University, Hyogo, Japan, 10.Nagoya University, Nagoya 464-8601, 11.Kobe University, Kobe 657-8501, Japan, 12.National Astronomical Observatory of Japan, Mitaka 181-8588, Japan.)

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

[PPS04-17] Quantitative analysis of spectral evolution of craters, boulders, and regolith on Ryugu and Bennu

*Koki Yumoto[1], Eri Tatsumi[2,1], Tatsuki Ebihara[1], DellaGiustina Daniella[3], Naofumi Takaki[1], Tomokatsu Morota[1], Yuichiro Cho[1], Golish Dathon[3], Rie Honda[4], Shingo Kameda[5], Yasuhiro Yokota[6], Naoya Sakatani[5], Toru Kouyama[7], Sawada Hirotaka[6], Masahiko Hayakawa[6], Matsuoka Moe[6], Manabu Yamada[8], Hidehiko Suzuki[9], Chikatoshi Honda[10], Kazunori Ogawa[11,12], Kazuo Yoshioka[1], Seiji Sugita[1] (1.University of Tokyo, 2.Instituto de Astrofísica de Canarias, 3.Lunar and Planetary Laboratory, Univ. of Arizona, 4.Kochi Univ., 5.Rikkyo Univ., 6.ISAS/JAXA, 7.Inst. of Adv. Ind. Sci. and Tech., 8.Chiba Inst. of Tech., 9.Meiji Univ., 10.Univ. of Aizu, 11.JSEC/JAXA, 12.Kobe Univ.)

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

[PPS04-18] Bennu's Global Geologic Map Reveals the Last Epoch of Resurfacing

*Erica R Jawin[1], Timothy J McCoy[1], Kevin John Walsh[2], Harold C Connolly[3], Ronald L Ballouz[4], Andrew Joseph Ryan[4], Maurizio Pajola[5], Olivier S Barnouin[6], Hannah H kaplan[7], Vicky E Hamilton[2], Josh P Emery[8], Daniella N Dellagiustina[4], Daniel Jay Scheeres[9], Michael G Daly[10], Carina A Bennett[4], Dathon R Golish[4], Mark Perry[6], R Terik Daly[6], E Beau Bierhaus[11], Michael C Nolan[4], Heather L Enos[4], Dante S Lauretta[4] (1.Smithsonian National Museum of Natural History, 2.Southwest Research Institute, 3.Rowan University, 4.University of Arizona, 5.INAF-Astronomical Observatory of Padova, 6.Johns Hopkins University Applied Physics Laboratory, 7.Goddard Space Flight Research Center, 8.Northern Arizona University, 9.University of Colorado, Boulder, 10.York University, 11.Lockheed Martin Space)

Regional photometric properties on asteroid Ryugu in visible wavelength

*Yasuhiro Yokota[1], Rie Honda[2], Eri Tatsumi[3], Deborah Domingue[4], Stefanus E. Schröder[5], Moe Matsuoka[1], Lucie Riu[1], Seiji Sugita[6], Tomokatsu Morota[6], Naoya Sakatani[7], Chikatoshi Honda[8], Yuichiro Cho[6], Shingo Kameda[7], Toru Kouyama[9], Manabu Yamada[10], Masahiko Hayakawa[1], Hiroki Senshu[10], Hidehiko Suzuki[11], Kazuo Yoshioka[6], Hirotaka Sawada[1], Kazunori Ogawa[1]

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Introduction: Hayabusa2 revealed the detailed shape of the Cb-type asteroid 162173 Ryugu. The surface of Ryugu is divided into east and west regions by a trough [1,2,3]. The western region (160 - 290˚E) is called the Western bulge, and the wider eastern region is called the Eastern Hemisphere. Ryugu has an equatorial ridge, and the ridge spans across both east and west regions [1,2,3]. A model for the evolution of the ridge has been proposed, in which pebbles/regolith from the ridge have migrated towards the mid-latitudes [4]. The Western bulge has fewer craters [5] and fewer boulders (D>5 m) [6] than the Eastern hemisphere. The photometric analysis of Hayabusa2 Telescopic Onboard Navigation Camera (ONC-T) data reported that the Western bulge has a slightly higher v-band (0.55 μm) reflectance than the Eastern hemisphere when observed at a solar phase angle of 19˚ [2]. However, the ONC-T opposition observations (zero phase angle observations) show a similar range of values in both regions for the normal albedo [7]. We therefore hypothesize that this difference in optical properties between the east and west regions may be due to surface properties other than the albedo of the surface materials. To help understand the evolutionary history of these regions (Eastern hemisphere, Western bulge, and Equatorial ridge), we conducted a regional photometric analysis of the ONC-T data using the Hapke photometric model [8,9].

Data and method: We used seven sets of Ryugu global observations (2.1 m/pixel) acquired in the ONC-T v-band. The phase angles of the observations ranged from 0 to 42˚. In order to reduce the number of free parameters, we fixed three of the five parameters of the Hapke photometric model [8,9]. The fixed parameters were: opposition surge strength B_0 = 0.98, opposition surge width h = 0.075, and phase function parameter b = 0.388. These values are the global averages from a recent photometric study [10]. The two free parameters were the single scattering albedo, w, and the macroscopic roughness, θ-bar. A 32 x 32 m (4x4˚) mesh was defined on the Ryugu surface, and values of the radiance factor (I/F) and photometric angles (incident (i), emission (e), and phase (α) angles) were collected from the ONC images from the pixels within each mesh. Averaging binning was used to mitigate the bias of the data distribution in the three dimensional photometric angle space (Binning width: $\Delta i = \Delta e = 1$˚; $\Delta \alpha = 0.1$˚ for α = 0-2˚, $\Delta \alpha = 0.2$˚ for α = 2-5˚, and $\Delta \alpha = 1$˚ for α >5˚). Finally, Hapke model fitting (Levenberg-Marquardt method) was performed for each mesh to determine w and θ-bar.

Results: The spatial distribution of w appears similar to that of the normal albedo. On the other hand, the spatial distribution of θ-bar was similar to the reflectance map in [2], which was made from observations at α=19˚. This suggests that a difference in surface roughness/texture at small scales (cm to μm order) may exist between the east and west regions. We also found that the ridge has smaller θ-bar values than the Eastern hemisphere. This feature is consistent with the pebbles/regolith migration hypothesis [4]. The present analysis shows that the regional differences in photometric properties can be detected in the

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ONC-T data. Further investigation of the history of the Eastern hemisphere, Western bulge, and ridge will require comparison with other roughness-related studies (e.g., densities of crater/boulder, thermal infrared data, and LIDAR data).

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Keywords: Asteroid, Ryugu, Photometry

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Spectrophotometric behavior of Ryugu’s surface as inferred from the Hayabusa2/NIRS3 data

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We studied the photometric behavior of the main spectral parameters describing the Ryugu near-infrared spectrum as measured by the Hayabusa2/NIRS3 spectrometer with a focus on albedo at 1.9 um, the band depths at 2.7 um, band depth at 2.8 um, spectral slope between 1.2 and 1.9 um.

We applied the same empirical model used to examine the surfaces of other small bodies such as Vesta, Lutetia. Ceres, Churyumov-Gerasimenko (Longobardo et al., 2014, 2016, 2017, 2019). The model methodology involves removing the topographic influence by dividing the radiance factor by a disk function and deriving the phase function by means of a statistical analysis approach.

In the following we summarize the results.

Albedo. Due to the small phase angle coverage (15˚-40˚), we approximated the phase function as a straight line and compared its slope with the slope of the phase function of other asteroids retrieved in the infrared range. We found a similarity between Ceres and Ryugu and flatter phase functions for Eros and Vesta, confirming the well known anti-correlation between albedo and phase function steepness.

Band depths. Band depths are observed to decrease with increasing phase angle. This is a unique behavior that has not been observed on any other small body visited by a space mission. This behavior can be ascribed to Ryugu’s very dark surface (~2% of incident light is reflected from the surface, Sugita et al., 2019; Kitazato et al., 2019), in which the role of multiple scattering is negligible and the large absorption properties of the surface reduces the radiation reflected at larger phase angles.

Infrared slope. A small phase reddening is observed, very similar to that observed by the ONC camera in the visible range (Tastumi et al., 2020), suggesting a constant particle phase function between visible and near-infrared and/or microscopically smooth particles.

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Keywords: Hayabusa2, Ryugu Asteroid, Photometry, Spectroscopy

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Laboratory spectral constraints on the composition and origin of Phobos: Reconciling the Vis-NIR/Mid-IR contradictions

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The origin and compositional makeup of Phobos, the larger and innermost satellite of Mars, remains uncertain. Phobos will be targeted by the Mars Moon eXplorer mission currently scheduled for a 2024 launch. In preparation for the upcoming exploration of Phobos, we have undertaken an investigation of various proposed spectral and compositional analogues of Phobos surface material. Fundamentally, Phobos presents a contradiction in that at visible and near-infrared wavelengths, Phobos is spectrally similar to D-type asteroids –possibly represented by meteorites like Tagish Lake –but at longer wavelengths, Phobos is more consistent with anhydrous silicate mixtures similar to basalts. Each wavelength range is therefore suggestive of different formation mechanisms: gravitational capture versus reaccretion of Martian ejecta. By investigating mixtures of various analogue materials, we are attempting to determine if any plausible mixtures of known components such as Martian regolith breccia, Tagish Lake carbonaceous chondrite, or their constituent phases, can reproduce the spectrum of Phobos over both the visible-near infrared and mid-infrared wavelength ranges.

Keywords: Phobos, Reflectance spectroscopy

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UNSUPERVISED LEARNING OF NIRS3 DATA: RYUGU SPECTRAL SURFACE REGIONS CLASSIFICATION

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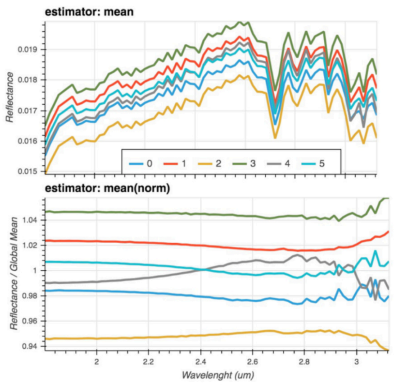
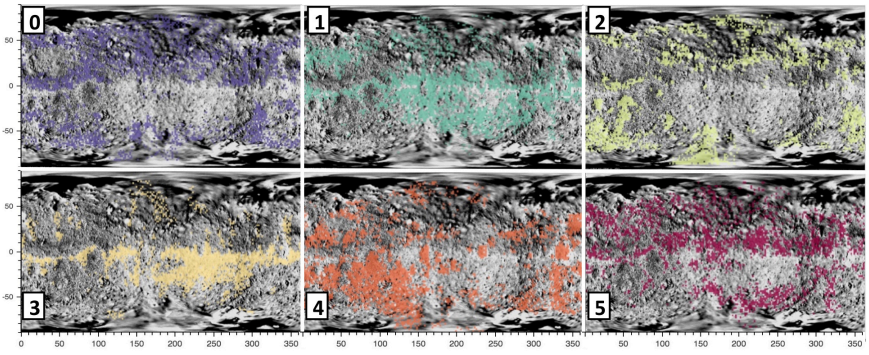
The 27th of June 2018 the Japanese Hayabusa2 spacecraft approached the C-type Near Earth asteroid 162173 Ryugu. Hayabusa2 is equipped with three remote sensing instruments such i.e. as the Thermal Infrared Imager TIR, the NIRS 3 spectrometer and the Optical Navigation Camera-Telescopic (ONC-T) with a wideband and seven narrow band filters. A Lidar instrument allowed to reconstruct the shape model of the asteroid and to measure the altimetry, in order to perform a precise touchdown in sampling the asteroidal regolith. Additionally, by using the robotic landers Minerva-II and Mascot, Hayabusa 2 has conducted in situ surface experiments. Ryugu is a top-shaped Cb type asteroid and is covered by a large number of boulders. It is one of the darkest object in our Solar System with a quite homogenous composition, including OH-rich materials. In conclusion, we find an automated approach to extract spatially coherent region on Ryugu surface based only on spectral data using almost the whole NIRS3 spectral range. Those classes show a significant spatial correlation with geomorphological feature and different spectral trends.

Keywords: unspuervised, machine learning , spectral surface regions



Classes average (top) and normalized to global mean.



Classes distribution on the surface of Ryugu

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Quantitative analysis of spectral evolution of craters, boulders, and regolith on Ryugu and Bennu

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Spectral evolution of C-complex asteroids [1] needs to be identified to understand the implications for parent-body materials from telescopic observations. Spectroscopy of near-Earth C-complex asteroids Ryugu and Bennu provide data to identify the predominant weathering effects on the respective asteroids, which could be potentially extrapolated to main belt C-complex bodies. For instance, the spectral change of craters with increasing size showed a darkening/reddening effect for Ryugu [2, 3], whereas brightening/bluing was derived for Bennu [4]. In this study, we quantify the spectral evolution tracks of craters, boulders, and regolith to further constrain the weathering effects on Ryugu and Bennu.

Evidence of boulder breakdown on the surfaces of Ryugu and Bennu [5, 6] suggests a shorter lifetime for smaller boulders. Thus, a size-dependent spectral trend among boulders may reflect their spectral/physical evolution. For regolith, dependence on geopotential height should represent spectral evolution since regolith can migrate in the direction of local downslopes [7]. Moreover, for all geologic features, spectral evolution could be further deduced from latitude-dependent trends [8, 9]. To quantify the trends, we established spectral catalogues of craters and boulders on Ryugu based on images acquired by the Optical Navigation Camera [10]. For Bennu, we analyzed the catalogue based on images acquired by the mid-field multispectral imager MapCam [11] established in [4].

The trends we find from spectral analysis of both craters and regolith showed darkening/reddening on Ryugu and brightening/bluing on Bennu. Their significance was confirmed by t-tests with p-value <.01. The spectral evolution of these asteroids exhibits diverging tracks in spectral feature space. The rates of spectral change were estimated by combining the size-dependency of craters and their model ages with spectral measurements [12]. The weathering rate (/$\log_{10}$ time; time range ~10^3–10^7 yr) of albedo was quantified to be $-2.9(5)\times10^{-4}$ for Ryugu and $+3.5(6)\times10^{-4}$ for Bennu. As for the 480-to-850 nm spectral slope, the weathering rate (/um/$\log_{10}$ time; time range ~10^3–10^7 yr) was +0.006(2) for Ryugu and −0.009(2) for Bennu. The observed bluing rate on Bennu is smaller than that estimated from main-belt asteroids [13] by an order of magnitude. These rates provide observational constraints for weathering experiments of returned samples. Also, comparison of the magnitude of the maturation between craters and regolith shows that weathering heterogeneity on the surface is produced mainly by surface migrations on Ryugu, and crater formations on Bennu.

However, boulder color trends show significant darkening/reddening for both asteroids. Although size-dependent trends of boulders may be due to the difference in material properties, the consistency with latitude-dependent trends supports the association with weathering processes. The possible difference in spectral evolution of boulders compared with that of regolith is consistent with the presence

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of fine particles, which may be produced by thermal disaggregation of boulder surfaces [3, 14]. Possible spectral alteration of boulders by the presence/absence of fines could be tested with reflectance measurements of returned samples.

[1] Lantz et al., 2018, *Icarus*, *302*, 10-17. [2] Sugita et al, 2019, *Science*, *364*(6437), eaaw0422. [3] Morota et al., 2020, *Science*, *368*(6491), 654-659, aaz6306. [4] DellaGiustina et al., 2020, *Science*, *370* (6517), eabc3660. [5] Molaro et al., 2020, *Nat. Commun.*, *11*(1), 2913. [6] Ballouz et al., 2020, *Nature*, *587*(7833), 205-209. [7] Jawin et al., 2020, *JGR: Planets*, *125*(9). [8] Hemingway et al., 2015, *Icarus*, 261, 66-79. [9] Sen et al., 2021, LPSC, #2548. [10] Kameda et al., 2017, *SSR*, *208*(1), 17-3. [11] Rizk et al., 2018, *SSR*, *214*(1), 26. [12] Takaki et al., submitted to *Icarus.* [13] Nesvorný et al., 2005, *Icarus*, *173*(1), 132-152. [14] Johnson & Fanale, 1973, *J. Geophys. Res. 78*, 8507–8518.

Keywords: Space weathering, Asteroids

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Bennu's Global Geologic Map Reveals the Last Epoch of Resurfacing

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Asteroid (101955) Bennu, the target of NASA’s OSIRIS-REx mission, is a rubble-pile asteroid with a surface dominated by boulders. We mapped its global geology to better understand its global characteristics and surface evolution. Our global geologic map of Bennu will facilitate future analyses of the asteroid and will contextualize the returned sample. We present the results of our analysis and the implications for the heterogeneous evolution of Bennu’s surface.

Bennu’s small size and rubble-pile nature have led to subdued topography with few distinct stratigraphic contacts. As such, our mapping methodology included first mapping major topographic features, geologic features, and surface texture variation, and then integrating these three products to define geologic units.

Bennu’s topographic features include two dominant structures: the equatorial bulge, between approximately 20°N and S latitude, and four longitudinal ridges (dorsa) and adjacent troughs (fossae) that span both hemispheres and the equator. The geologic features of Bennu that we mapped include craters >10 m in diameter, boulders >20 m in diameter, lineaments, particle ejection source regions, and morphologies associated with mass movement (e.g., imbricated or buried boulders). Craters are abundant on the equatorial bulge, which suggests that the bulge is an old feature. There are more large boulders in the southern hemisphere than the northern hemisphere or the equatorial region. Mass movement features appear to be spatially correlated with large boulders (many large boulders are partly buried) and are concentrated in fossae bound by lineaments. Bennu’s surface texture variation is controlled by the abundance of boulders. The surface can be divided into two dominant morphologies: (1) smooth or knobby with few boulders, and (2) rugged with abundant boulders.

To define geologic units, we integrated the maps of topographic features, geologic features, and surface texture variation, resulting in two geologic units we refer to as the “Smooth Unit” and the “Rugged Unit”. The Smooth Unit contains few large boulders or mass movement features and can occur on both dorsa and fossae. The mission’s sample collection site (Nightingale) and several particle ejection source regions are located in the Smooth Unit. The Rugged Unit contains 89% of the mapped large boulders and 85% of mass movement features, which are mostly located in fossae. The surface of Bennu can therefore be effectively characterized by only two geologic units that represent end-member characteristics. The two units are also distinct in other global maps of Bennu, including surface roughness, slopes, and certain spectral maps.

The relative concentration of mass movement features in the Rugged Unit, which likely formed in the last few hundred thousand years, suggests that resurfacing may have been more concentrated in the Rugged

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Unit than the Smooth Unit. In addition, the distribution of the reddest (believed to be the youngest) craters on Bennu shows that the Rugged Unit contains fewer red craters, by a factor of ~3 per unit area relative to the Smooth Unit. This difference suggests the Rugged Unit may have experienced more resurfacing in the recent past (~500,000 years) relative to the Smooth Unit, which may have been less active.

The equatorial bulge, dorsa, and fossae appear to be the oldest features on Bennu due to their crater abundance. Both geologic units cross the equatorial bulge, suggesting that it has not greatly affected Bennu's surface evolution. Large boulders are abundant in fossae and may be linked to their evolution, but some large boulders are also present on dorsa, which suggests that topography is not the only control on the boulder distribution. Surface modification in the form of impact cratering, mass movement, and particle ejection continued after the formation of the equatorial bulge, dorsa, and fossae, and over time, enhanced resurfacing in certain regions led to the formation of the Rugged Unit.

Keywords: Bennu, OSIRIS-REx, Resurfacing, Geology, Mapping

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

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

[P-PS04] Small Solar System Bodies: A New Insight from Hayabusa2, OSIRIS-REx and Other Space Missions

convener:Tatsuaki Okada(Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency), Taishi Nakamoto(Tokyo Institute of Technology), Daisuke Kuroda(Kyoto University), Chairperson:Tatsuaki Okada(Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency), Taishi Nakamoto(Tokyo Institute of Technology), YACHEN YANG(Center for Space and Remote Sensing Research)

Small Solar System bodies, including asteroids, comets, satellites, and interplanetary dust particles, are notably important for understanding the origin and evolution of our Solar System, as well as investigating the sources of building blocks of life. Many new discoveries on small bodies have been carried out by observations from ground-based and space-based observatories, and explorations by spacecraft rendezvous and flyby. New perspectives on solar system evolution have been paved by analyses of extraterrestrial materials such as meteorites, IDPs, and return samples by space missions. Numerical and laboratory simulation studies have helped interpretations for those results and proposed new insights on these topics. In this session, new results of scientific studies and new ideas of methodology for investigating small solar system bodies are highly welcome, especially the topics on the remote sensing, surface experiments, and analysis of return sample in the Hayabusa2 and OSIRIS-REx missions, as well as the expectations and preparations for future missions including MMX, Destiny+, Hera, Comet Interceptor, and Hayabusa2-Extended missions.

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

[PPS04-19] Impact histories inferred from exogenic boulders on asteroids Ryugu and Bennu

★Invited Papers

*ERI TATSUMI[1,2], Chiho Sugimoto[2], Seiji Sugita[2], Marcel Popescu[4], Humberto Campins[11], Julia de León[3], Amy A. Simon[5], Hannah H. Kaplan[6], Yuichiro Cho[2], Tomokatsu Morota[2], Rie Honda[7], Shingo Kameda[8], Yasuhiro Yokota[3], Koki Yumoto[2], Minami Aoki[2], Daniella N. DellaGiustina[10], Dathon R. Golish[10], Javier Licandro[1], Juan Luis Rizos[1], Takahiro Hiroi[12], Deborah Domingue[13], Michel Patrick[14], Dante S. Lauretta[10], Manabu Yamada[15], Naoya Sakatani[8], Toru Kouyama[9], Chikatoshi Honda[16], Masahiko Hayakawa[3], Moe Matsuoka[3], Hidehiko Suzuki[17], Kazunori Ogawa[3], Hirotaka Sawada[3] (1.Instituto de Astrofisica de Canarias, 2.Univ. of Tokyo, 3.ISAS/JAXA, 4.Astronomical Institute of the Romanian Academy, 5.NASA Goddard Space Flight Center, 6.Southwest Research Institute, 7.Kochi Univ., 8.Rikkyo Univ., 9.AIST, 10.Univ. of Arizona, 11.Univ. of Central Florida, 12.Brown Univ., 13.Planetary Science Institute, 14.Observatoire de la Côte d'Azur, 15.Chiba Institute of Tech., 16.Univ. of Aizu, 17.Meiji Uni.)

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

[PPS04-20] The ESA Hera mission: rendezvous with a binary asteroid, planetary defense and science

★Invited Papers

*Patrick Michel[1], Michael Kueppers[2], Alan Fitzsimmons[3], Simon F. Green[4], Monica Lazzarin[5], Stephan Ulamec[6], Ian Carnelli[7], Paolo Martino[7] (1.Universite Côte D'Azur, Observatoire De La Côte D'Azur, CNRS, Laboratoire Lagrange, 2.ESA-European Space Astronomy Centre, 3.Queen's University Belfast, 4.The Open University, 5.Padova University, 6.DLR RB-MUSC, 7.ESA-ESTEC)

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

[PPS04-21] Hayabusa2 Extended Mission to rendezvous with Asteroid 1998 KY26: Investigations of an extremely small fast rotator for planetary defense

*Masatoshi Hirabayashi[1], Y. Mimasu[2], N. Sakatani[3], S. Watanabe[4], Y. Tsuda[2], T. Saiki[2], S. Kikuchi[2], T. Kouyama[5], M. Yoshikawa[2], S. Tanaka[2], S. Nakazawa[2], Y. Takei[2], F. Terui[2], H. Takeuchi[2], A. Fujii[2], T. Iwata[2], K. Tsumura[6], S. Matsuura[7], Y. Shimaki[2], S. Urakawa[8], Y. Ishibashi[9], S. Hasegawa[2], M. Ishiguro[10], D. Kuroda[11], S. Okumura[8], S. Sugita[12], T. Okada[2], S. Kameda[3], S. Kamata[13], A. Higuchi[14], H. Senshu[15], H.

Noda[16], K. Matsumoto[16], R. Suetsugu[17], T. Hirai[15], K. Kitazato[18] (1.Auburn University, 2.Japan Aerospace Exploration Agency, 3.Rikkyo University, 4.Nagoya University, 5.National Institute of Advanced Industrial Science and Technology, 6.Tokyo City University, 7.Kwansei Gakuin University, 8.Japan Spaceguard Association, 9.Hosei University, 10.Seoul National University, 11.Kyoto University, 12.University of Tokyo, 13.Hokkaido University, 14.University of Occupational and Environmental Health, 15.Chiba Institute of Technology, 16.National Astronomical Observatory of Japan, 17.National Institute of Technology, 18.University of Aizu)

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

[PPS04-22] **Highly Time-Resolved Photometric Observations of Tiny Near Earth Objects with the Tomo-e Gozen Camera**

*Jin Beniyama[1], Shigeyuki Sako[1], Ryou Ohsawa[1], Satoshi Takita[1], Naoto Kobayashi[1], Shin-ichiro Okumura[2], Seitaro Urakawa[2], Fumihiko Usui[3], Fumi Yoshida[4,5], Makoto Yoshikawa[3] (1.Institute of Astronomy, Graduate School of Science, The University of Tokyo, 2.Japan Spaceguard Association, 3.Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency, 4.University of Occupational and Environmental Health, 5.Planetary Exploration Research Center, Chiba Institute of Technology)

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

[PPS04-23] Color and size distributions of main belt asteroids obtained by the Subaru/Hyper Suprime-Cam

*Natsuho Maeda[1], Tsuyoshi Terai[2], Keiji Ohtsuki[1], Fumi Yoshida[3,4], Kosuke Ishihara[1,2,5], Takuto Deyama[1,6] (1.Graduate school of science, Kobe University , 2.National Astronomical Observatory of Japan, 3.Chiba Institute of Technology, 4.University of Occupational and Environmental Health, 5.The Graduate University for Advanced Studies, 6.NTT Data MSE Corporation)

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

[PPS04-24] Discussion

Impact histories inferred from exogenic boulders on asteroids Ryugu and Bennu

*ERI TATSUMI[1,2], Chiho Sugimoto[2], Seiji Sugita[2], Marcel Popescu[4], Humberto Campins[11], Julia de León[3], Amy A. Simon[5], Hannah H. Kaplan[6], Yuichiro Cho[2], Tomokatsu Morota[2], Rie Honda[7], Shingo Kameda[8], Yasuhiro Yokota[3], Koki Yumoto[2], Minami Aoki[2], Daniella N. DellaGiustina[10], Dathon R. Golish[10], Javier Licandro[1], Juan Luis Rizos[1], Takahiro Hiroi[12], Deborah Domingue[13], Michel Patrick[14], Dante S. Lauretta[10], Manabu Yamada[15], Naoya Sakatani[8], Toru Kouyama[9], Chikatoshi Honda[16], Masahiko Hayakawa[3], Moe Matsuoka[3], Hidehiko Suzuki[17], Kazunori Ogawa[3], Hirotaka Sawada[3]

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Rubble-pile asteroids, such as (162173) Ryugu and (101955) Bennu, are formed as a result of catastrophic disruption of a parent body and re-accumulation of the fragments by self-gravity Michel and Ballouz et al. 2020). Therefore, reaccumulated rubble piles could include mixtures of materials from both the parent body and its catastrophic impactor, as they did in the case of 2008 TC_3 and the Almahata Sitta meteorites (Jenniskens et al. 2009). Indeed, six unusually bright, basaltic, meter-scale boulders were recently identified on Bennu's dark surface (DellaGiustina et al. 2021), and their close spectral matches to the Howardite-Eucrite-Diogenite (HED) meteorites and Vesta family members indicate that they originated from asteroid (4) Vesta. In parallel, bright exogenic anhydrous-silicate–rich materials were found on Ryugu (Tatsumi et al. 2021). The bright boulders on Ryugu are consistent with ordinary chondrite meteorites, based on their albedo and the weak or even absent absorption band at 2 μm. These exogenous materials on the surfaces of rubble-pile asteroids could be a key to constraining their specific impact conditions and collisional evolution.

In this study, we report further study of the visible spectrophotometry and morphology of exogenic boulders on Ryugu and Bennu using two multi-band cameras: the telescopic Optical Navigation Camera (ONC-T) onboard the Hayabusa2 spacecraft, and MapCam onboard the Origins, Spectral Interpretation, Resource Identification, and Security–Regolith Explorer (OSIRIS-REx) spacecraft, respectively.

For Ryugu, we first detected objects with peak reflectance brighter by a factor of >1.5 than the surrounding area. Tatsumi et al. (2021) found two spectral groups among the bright boulders: S-type with an absorption near 1 μm and C/X-type with a flat spectrum. That study found 6 S-types and 15 C/X-types, and here we report the additional finding of two S-types and ~70 C/X-types. We found that S-type bright boulders follow two parallel trends consistent with space weathering of ordinary chondrites. Fragments from projectiles suggest that Ryugu may not have formed directly from the original parent body, i.e., it is from a second or higher generation of collisional descendants (Sugimoto et al. in revision).

For Bennu, we directly surveyed the absorption near 1 μm, which is indicative of anhydrous silicates. We propose 77 objects of exogenic origin including 6 boulders previously reported by DellaGiustina et al. (2021). We find that proposed exogenic objects follow two mixing trends with respect to the average spectrum of Bennu (Tatsumi and Popescu et al. submitted). One trend can be explained by mixing with HEDs, as discussed in DellaGiustina et al. (2021), and the other trend can be explained by mixing with

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another, of olivine-rich composition. Near-infrared spectra also support the possibility of multiple compositions among exogenic objects on Bennu. Le Corre et al. (submitted) also reached to the similar conclusion with a different methodology. Thus, similar to Ryugu, Bennu could represent a second or higher generation collisional fragment.

Using high-resolution images, we found that more than half of the exogenic objects that we identified on Bennu have breccia-like or inclusion-like morphologies. We do not observe a correlation between morphology and spectral shape.

Direct comparison of reflectance spectra of exogenic ,materials between Ryugu and Bennu suggests a compositional difference. Furthermore, the number density of exogenic objects > 0.5 m on Bennu is ˜40 times that on Ryugu (Tatsumi and Popescu et al. submitted). Bennu exhibits much more contamination from exogenic materials than Ryugu, which likely reflects differences in impact conditions, such as impact velocity and impactor size.

Michel and Ballouz et al. (2020) Nat. Commun. 11, 2655
Jenniskins et al. (2009) Nature 458, 485-488.
DellaGiustina et al. (2021) Nat. Astron. 5, 31-38.
Tatsumi et al. (2021) Nat. Astron. 5, 39-45.
Sugimoto et al. (in revision) Icarus.
Tatsumi and Popescu et al. (submitted) MNRAS.
Le Corre et al. (submitted) PSJ.

Keywords: Asteroids, Hayabusa2, OSIRIS-REx, Ryugu, Bennu

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The ESA Hera mission: rendezvous with a binary asteroid, planetary defense and science

*Patrick Michel[1], Michael Kueppers[2], Alan Fitzsimmons[3], Simon F. Green[4], Monica Lazzarin[5], Stephan Ulamec[6], Ian Carnelli[7], Paolo Martino[7]

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The Hera mission is in Phase C for launch in 2024 in the ESA Space Safety Programme. Hera will contribute to the first deflection test of an asteroid, in the framework of the international Asteroid Impact and Deflection Assessment (AIDA) collaboration, supported by NASA and ESA

Hera will rendezvous for the first time with a binary asteroid, (65803) Didymos, and take particular emphasis on its
secondary, Dimorphos, of only 160 m in diameter. So far, no mission has visited such a small rock in space. Moreover, for the first time, internal and subsurface properties will be directly measured. As a crucial contribution to planetary defense, Hera will perform the measurements necessary to understand the effect of the NASA DART impact on Didymos' secondary in 2022, in particular its mass, its internal structure, the direct determination of the momentum transfer and the detailed characterization of the crater left by DART.

How do binaries form? What does a 160 m-size rock in space look like? What is the surface composition? What are its internal properties? What are the surface structure and regolith mobility on both Didymos and Dimorphos? What are the surface geophysical properties of two objects of different size and surface gravity, which probably formed from the same material? And what will be the size and the morphology of the crater left by DART, which will provide the first impact experiment at full asteroid scale using an impact speed close to the average speed between asteroids? What will be the exact momentum transferred by DART, which needs the precise measurement of the mass of the target by Hera? These questions and many others will be addressed by Hera as a natural outcome of its investigations focused on planetary defense.

The measurements performed by Hera will thus provide unique information on many current issues in asteroid science and therefore, the scientic legacy of the Hera mission will extend far beyond the core aims of planetary defense. Hera is, thus, the main European contribution to the current international asteroid exploration era.

Acknowledgement: Funding support from ESA and from the European Union's Horizon 2020 research and innovation programme under grant agreement No 870377 (project NEO-MAPP) is acknowledged.

Keywords: Asteroids, Binary Asteroids, Impact Physics, Planetary defense, Cubesat, Space mission

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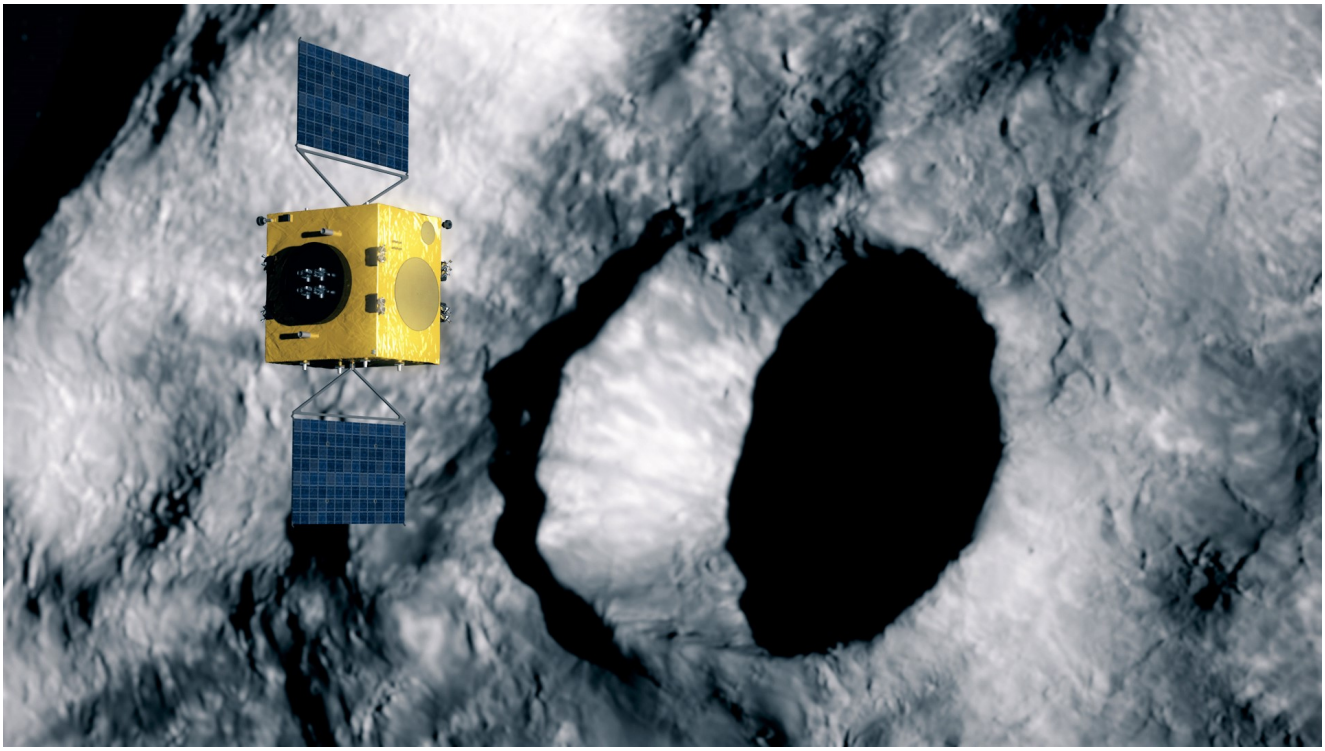

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Hayabusa2 Extended Mission to rendezvous with Asteroid 1998 KY26: Investigations of an extremely small fast rotator for planetary defense

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Hayabusa2, led by the Japan Aerospace Exploration Agency (JAXA), brought material samples from asteroid Ryugu back to Earth. On December 6, 2020, the Hayabusa2 team successfully collected the re-entry capsule, while the spacecraft departed from Earth, again. As of January 2021, the spacecraft is reported to have no critical issues.

Based on the spacecraft’s healthy condition and remaining fuel, the Hayabusa2 extended mission development team has evaluated the feasibility of an additional mission. Here, we introduce an extended mission in which the spacecraft will explore Asteroid 1998 KY26, a ~30 m - ~40 m in diameter asteroid rotating at a spin period of ~10 m, after a ~10-year cruise phase. Rendezvous operations are planned to detail the physical properties and surrounding environments of this target, one of the smallest elements of small planetary bodies.

In the planned mission schedule, the spacecraft will rendezvous with 1998 KY26 in late 2031. During this cruise phase, the spacecraft may fly by 2001 CC21 in middle 2026. It will approach the asteroid at high speed (~ 5 km/sec) during the flyby, and thus sophisticated guidance, navigation, and control technologies will be necessary. We also plan to conduct long-term monitoring of the zodiacal light and the transits of exoplanets. After two Earth swing-by operations in late 2027 and early 2028, the spacecraft will arrive at the target asteroid. The planned trajectory will need an additional delta-V of 1.09 km/sec, given the 2,900-sec Isp. The distance from the sun is ~1 AU when the spacecraft arrives at this asteroid.

There are key challenges that need to be resolved in Planetary Defense.
Extremely small bodies (especially smaller than 100 m in diameter) are the most common in the solar system and may have a high probability to influence our societies. Ground- and space-based-telescopes still have technical difficulties in observing these asteroids. Therefore, the physical properties of these objects are poorly understood. Successful planetary defense strategies strongly depend on the physical conditions of asteroids. Extremely small asteroids, which may be the largest pieces within rubble pile asteroid elements, will strongly constrain these conditions.
Given the planned observations, the Hayabusa2 extended mission will significantly contribute to advancing science and engineering knowledge about Planetary Defense by exploring an extremely small body.

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Finally, we note that the Hayabusa2 extended mission was approved by the science-engineering space exploration mission assessment committee in Japan, which evaluated the scientific and engineering significance of the mission, and is currently waiting for official approval by the government for budgeting. Also, this abstract is also presented at the Planetary Defense Conference in 2021.

Keywords: Asteroids, Planetary defense, Space exploration mission

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Highly Time-Resolved Photometric Observations of Tiny Near Earth Objects with the Tomo-e Gozen Camera

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Near Earth Objects (NEO) are solar system bodies whose perihelion distances are smaller than 1.3 au. NEOs are thought to have their origin in the main-belt region between Mars and Jupiter. In addition to the gravitational interaction with the Sun and planets, nongravitational effect which arise from solar radiation plays an important role in their dynamical evolution. YORP effect is one of the nongravitational effects that affects the spin state of an asteroid. YORP effect strongly changes the rotation periods of tiny asteroids (smaller than 100 m in diameter) on a shorter timescale than that of the orbital evolution. Fast rotators suffer from strong centrifugal force and may experience deformation or rotational fission when its rotation period reaches the critical value by YORP spin-up. Therefore the strength of tiny bodies could be inferred using rotation periods of tiny NEOs. Recently, large survey projects have discovered 2,000–3,000 NEOs per year and some fast rotators with rotation periods below a minute have been discovered. Highly time-resolved observations are needed to accurately detect fast rotation because the lower-limit of rotation period which can be detected depends on the overhead time of the instrument. Since the past instruments did not have enought time-resolution, the distribution of rotation periods of NEOs with periods below a minute is still unclear.

We obtained highly time-resolved light curves of 37 tiny NEOs whose diameters are 3–86 m using Tomo-e Gozen camera equipped with 105 cm Schmidt telescope at Kiso Observatory, the University of Tokyo. The observation cadence was 2 fps. We derived the rotation periods of 22 NEOs, of which 5 NEOs show the rotation periods shorter than 20 seconds. The shortest rotation period of our NEOs was about 11 seconds. In spite of high-cadence observations, we found no asteroid rotating shorter than 10 seconds. The lack of tiny fast rotating NEOs has never been reported before our systematic highly time-resolved observation. We discuss the diameter-rotation period relation derived from our observation in terms of YORP spin-up. The observed rotation period distribution is consistent with the senario that the strength of tiny NEOs are weaker than those of meteorites. We also discuss another possible senario that most tiny NEOs are newly-formed in the near-earth region instead of the main-belt.

Keywords: asteroid, near earth objects, solar system, light curve, YORP effect

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Color and size distributions of main belt asteroids obtained by the Subaru/Hyper Suprime-Cam

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S-type and C-type asteroids are two of the most major types in the main asteroid belt (e.g., DeMeo & Carry 2014). S-type asteroids are thought to have a stony composition, while C-type asteroids are characterized by carbonaceous composition and hydrous minerals (e.g, DeMeo et al. 2015; Usui et al. 2019). Although S-type asteroids and C-type asteroids are thought to have different compositions and origins in this way, their evolution paths are still not well understood.

The size distribution of a population of asteroids strongly reflects the process of their collisional evolution (e.g., Bottke et al. 2015). In the collision equilibrium, the size distribution is primarily determined by the size dependence of impact strength (O’ Brien & Greenberg 2003). Therefore, by comparing size distributions of asteroids with different spectral types, we can obtain information about the relation between their type and their impact strength. This is essential information to reveal their collisional evolution. Although some previous observational works studied size distributions of asteroids with different spectral types (Ivezić et al. 2001; Yoshida & Nakamura 2007), the understanding is still far from complete.

In this work, we performed a survey observation of small main-belt asteroids with the wide-field camera, Hyper Suprime-Cam installed on the 8.2 m Subaru Telescope. Using data acquired with two types of filters, *g*-band (0.40-0.55 μm wavelength) and *r*-band (0.55-0.70 μm wavelength), we measured *g-r* color for 3459 main-belt asteroids detected in 14 deg^2 of the sky. From the asteroids we obtained above, we selected a statistical sample consisting of 1814 asteroids with absolute magnitude brighter than 20.3 mag to remove a detection bias. We classified them into two groups, i.e., reddish “S-like” asteroids and bluish “C-like” asteroids based on the boundary color derived from the previous survey data (The fourth release of Sloan Digital Sky Survey Moving Object Catalog, Ivezić et al. 2010). We converted the absolute magnitude of each sample into a diameter assuming an albedo of 0.21 for S-like and 0.07 for C-like asteroids, respectively, which are the mean values of the S- and C-type main-belt asteroids measured by the infrared astronomical satellite AKARI (Usui et al. 2013). We found that the shapes of the size distributions of the S-like and C-like samples agree well with each other within statistical errors for the diameter range from 0.4 km to 1.5 km. The similarity between the size distributions of the S-like and C-like asteroids indicates that their size dependences of impact strength are also similar at least in the size range from several hundred meters to several kilometers. Namely, the impact strength of asteroids in this size range is likely to be dominated by any other factors rather than their compositions. On the other hand, spin periods of most asteroids in this size range have an upper limit of 2.2 hours, the so-called “spin-barrier” (e.g., Chang et al. 2015). This is interpreted as showing that the asteroids in this size range are rubble-piles, i.e., they consist of numerous pieces of components held together by their self-gravity. The similarity of the size distributions between the S-like and C-like asteroids seems to support the view that most of them have a rubble-pile structure. Also, Itokawa and Ryugu, which were explored by Hayabusa/Hayabusa2, are both several hundred meters in diameter and are considered to

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have a rubble-pile structure (Fujiwara et al. 2006; Watanabe et al. 2019). Our result is also consistent with this view.

Keywords: asteroids, survey, size distributions

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

[P-PS04] Small Solar System Bodies: A New Insight from Hayabusa2, OSIRIS-REx and Other Space Missions

convener:Tatsuaki Okada(Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency), Taishi Nakamoto(Tokyo Institute of Technology), Daisuke Kuroda(Kyoto University), Chairperson:Tatsuaki Okada(Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency), Taishi Nakamoto(Tokyo Institute of Technology), YACHEN YANG(Center for Space and Remote Sensing Research)

Sun. Jun 6, 2021 3:30 PM - 5:00 PM Ch.04 (Zoom Room 04)

Small Solar System bodies, including asteroids, comets, satellites, and interplanetary dust particles, are notably important for understanding the origin and evolution of our Solar System, as well as investigating the sources of building blocks of life. Many new discoveries on small bodies have been carried out by observations from ground-based and space-based observatories, and explorations by spacecraft rendezvous and flyby. New perspectives on solar system evolution have been paved by analyses of extraterrestrial materials such as meteorites, IDPs, and return samples by space missions. Numerical and laboratory simulation studies have helped interpretations for those results and proposed new insights on these topics. In this session, new results of scientific studies and new ideas of methodology for investigating small solar system bodies are highly welcome, especially the topics on the remote sensing, surface experiments, and analysis of return sample in the Hayabusa2 and OSIRIS-REx missions, as well as the expectations and preparations for future missions including MMX, Destiny+, Hera, Comet Interceptor, and Hayabusa2-Extended missions.

4:55 PM - 5:00 PM

[PPS04-24]Discussion

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

Sun. Jun 6, 2021 9:00 AM - 10:30 AM JST | Sun. Jun 6, 2021 12:00 AM - 1:30 AM UTC | Ch.05 Zoom Room 05

[P-EM09] Dynamics of Magnetosphere and Ionosphere

convener:Akiko Fujimoto(Kyushu Institute of Technology), Mitsunori Ozaki(Faculty of Electrical and Computer Engineering, Institute of Science and Engineering, Kanazawa University), Yuka Sato(Nippon Institute of Technology), Aoi Nakamizo(Applied Electromagnetic Research Institute, National Institute of Information and Communications Technology), Chairperson:Hiroshi Hasegawa(Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency), Masaki N Nishino(Japan Aerospace Exploration Agency, Institute of Space and Astronautical Science)

This session provides an opportunity to present recent results from satellite and ground-based observations and theoretical and simulation studies on the magnetosphere, ionosphere, and their coupling processes. We invite talks and posters discussing various phenomena related to the magnetosphere-ionosphere system: solar wind-magnetosphere interaction, magnetosphere-ionosphere convection, field-aligned current, magnetic storms/substorms, neutral-plasma interaction, ionospheric ion inflow and outflow, aurora phenomena, and so forth. Discussions on planetary and satellite ionospheres and magnetospheres, future missions and instrument developments are also welcome.

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

[PEM09-01] Introduction

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

[PEM09-02] Magnetic Reconnection in a Sheared Magnetic Flux Tube: Slippage versus Tearing

*Hidetaka Kuniyoshi[1], Michael Hesse[2], Cecilia Nogren[3], Paul Tenfjord[3], Norah Kaggwa Kwagala[3] (1.The University of Tokyo, Department of Earth and Planetary Science, 2.NASA Ames Research Center, 3.University of Bergen, Space Plasma Physics Group)

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

[PEM09-03] Fast Magnetic-Field Annihilation in Electron-scale Current Sheet in Earth's Magnetotail

*Hiroshi Hasegawa[1], Richard E. Denton[2], Kevin J. Genestreti[3], Takuma Nakamura[4], Tai D. Phan[5], Rumi Nakamura[4], Kyoung-Joo Hwang[6], Narges Ahmadi[7], Quanqi Shi[8], Michael Hesse[9], James L. Burch[6], James M. Webster[6], Roy B. Torbert[10], Barbara L. Giles[11], Dan J. Gershman[11], Christopher T. Russell[12], Robert J. Strangeway[12], Hanying Wei[12], Per-Arne Lindqvist[13], Yuri V. Khotyaintsev[14], Robert E. Ergun[15], Yoshifumi Saito[1] (1.Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency, 2.Department of Physics and Astronomy, Dartmouth College, 3.Southwest Research Institute, Durham, 4.Space Research Institute, Austrian Academy of Sciences, 5.Space Sciences Laboratory, University of California, Berkeley, 6.Southwest Research Institute, San Antonio, 7.Laboratory for Atmospheric and Space Physics, University of Colorado, 8.Shandong Provincial Key Laboratory of Optical Astronomy and Solar-Terrestrial Environment, Institute of Space Sciences, Shandong University, 9.Space Plasma Physics Group, University of Bergen, 10.Physics Department, University of New Hampshire, 11.NASA Goddard Space Flight Center, 12.Department of Earth, Planetary, and Space Sciences, University of California, Los Angeles, 13.Royal Institute of Technology, Stockholm, 14.Swedish Institute of Space Physics, 15.Department of Astrophysical and Planetary Sciences, University of Colorado)

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

[PEM09-04] Energy dependence of field-aligned anisotropy of electrons during dipolarization at Earth's tailside

*Kaiti Wang[1], Ching-Huei Lin[2], Zhuo-Ren Lang[3], Tohru Hada[4], Toshi Nishimura[5] (1.Tamkang Univ., 2.Chien-Hsin Univ. of Sci. & Tech., 3.National Cheng Kung Univ., 4.Kyushu Univ., 5.Boston Univ.)

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

[PEM09-05] On the origin of cold-dense plasmas in the dusk magnetotail plasma sheet: MMS and Geotail observations

*Masaki N Nishino[1], Yoshifumi Saito[1], Hiroshi Hasegawa[1], Naritoshi Kitamura[2], Yukinaga Miyashita[3,4], Tsugunobu Nagai[1], Shoichiro Yokota[5], Daniel J Gershman[6], Christopher T Russell[7], Barbara L Giles[6] (1.Japan Aerospace Exploration Agency, Institute of Space and Astronautical Science, 2.Graduate School of Science, The University of Tokyo, 3.Korea Astronomy and Space Science Institute, South Korea, 4.Korea University of Science and Technology, South Korea, 5.Graduate School of Science, Osaka University, 6.Goddard Space Flight Center, NASA, 7.University of California, Los Angeles)

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

[PEM09-06] **Substorm-like events related to magnetosheath plasma jets**

*ALEXEI DMITRIEV[1,2], ALLA SUVOROVA[2] (1.Institute of Space Science, National Central University, Jungli City, Taiwan, 2.Skobeltsyn Institute of Nuclear Physics, Lomonosov Moscow State University, Moscow, Russia)

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

[PEM09-07] Discussion

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

[P-EM09] Dynamics of Magnetosphere and Ionosphere

convener:Akiko Fujimoto(Kyushu Institute of Technology), Mitsunori Ozaki(Faculty of Electrical and Computer Engineering, Institute of Science and Engineering, Kanazawa University), Yuka Sato(Nippon Institute of Technology), Aoi Nakamizo(Applied Electromagnetic Research Institute, National Institute of Information and Communications Technology), Chairperson:Hiroshi Hasegawa(Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency), Masaki N Nishino(Japan Aerospace Exploration Agency, Institute of Space and Astronautical Science)

Sun. Jun 6, 2021 9:00 AM - 10:30 AM Ch.05 (Zoom Room 05)

This session provides an opportunity to present recent results from satellite and ground-based observations and theoretical and simulation studies on the magnetosphere, ionosphere, and their coupling processes. We invite talks and posters discussing various phenomena related to the magnetosphere-ionosphere system: solar wind-magnetosphere interaction, magnetosphere-ionosphere convection, field-aligned current, magnetic storms/substorms, neutral-plasma interaction, ionospheric ion inflow and outflow, aurora phenomena, and so forth. Discussions on planetary and satellite ionospheres and magnetospheres, future missions and instrument developments are also welcome.

9:00 AM - 9:05 AM

[PEM09-01]Introduction

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Magnetic Reconnection in a Sheared Magnetic Flux Tube: Slippage versus Tearing

*Hidetaka Kuniyoshi[1], Michael Hesse[2], Cecilia Nogren[3], Paul Tenfjord[3], Norah Kaggwa Kwagala[3]

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Although it still remains controversial whether auroral acceleration is, in fact, a manifestation of a reconnection process, discussions of a different type of reconnection in this context began with 'reconnection type II' by Haerendel (Haerendel, 2007, 2011), which recognized early on that auroral acceleration may be a form of magnetic reconnection. According to the author, the reconnection process enhances the auroral acceleration by reducing the flux tubes' shear magnetic stress of field aligned current sheets. The process of magnetic reconnection in a flux tube can occur in a time-stationary fashion as slippage reconnection or in a time-dependent manner, for example, tearing instability. However, it is not well known how a system can be set up to sustain slippage reconnection, whether there is a combination of slippage reconnection and time-dependent reconnection. To investigate this question, using a 3D MHD simulation, we model a twisted flux tube, adding a spatially localized resistive region in the center of the simulation box. As a result, firstly, the Poynting flux injected at the boundary propagates to the resistive region and dissipates there. Secondly, tearing instability occurs with slippage reconnection in the resistive region when the resistivity is strong enough and the cross section of the flux tube is elliptical enough, otherwise only slippage reconnection occurs. Finally, magnetic field generated by tearing instability propagates to both ends of the flux tube.

Keywords: Magnetic Reconnection, Auroral acceleration, Magnetohydrodynamics

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Fast Magnetic-Field Annihilation in Electron-scale Current Sheet in Earth's Magnetotail

*Hiroshi Hasegawa[1], Richard E. Denton[2], Kevin J. Genestreti[3], Takuma Nakamura[4], Tai D. Phan[5], Rumi Nakamura[4], Kyoung-Joo Hwang[6], Narges Ahmadi[7], Quanqi Shi[8], Michael Hesse[9], James L. Burch[6], James M. Webster[6], Roy B. Torbert[10], Barbara L. Giles[11], Dan J. Gershman[11], Christopher T. Russell[12], Robert J. Strangeway[12], Hanying Wei[12], Per-Arne Lindqvist[13], Yuri V. Khotyaintsev[14], Robert E. Ergun[15], Yoshifumi Saito[1]

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Magnetic reconnection in current sheets is the key to fast release of magnetic energy in many space and astrophysical plasma systems, such as during magnetospheric substorms, but observations to understand exactly how magnetic-to-electron energy conversion occurs in electron-scale diffusion regions (EDRs), where magnetic topology changes, have been lacking. It is generally believed that EDR has an X-type magnetic-field geometry around which the energy of anti-parallel magnetic fields is mostly converted to the bulk-flow energy of electrons by magnetic tension of reconnected field-lines. We present state-of-the-art analysis of multi-spacecraft observations in Earth's magnetotail of an electron-scale current sheet, which demonstrates that contrary to the standard model of reconnection with an X-type EDR geometry, the fast energy conversion in the detected EDR was caused mostly by magnetic-field annihilation, rather than reconnection. The experimental discovery of the annihilation-dominated EDR reveals a new form of energy conversion in the reconnection process that can occur when the EDR has evolved from the X-type to planar geometry.

Keywords: magnetic reconnection, magnetotail, magnetic field annihilation

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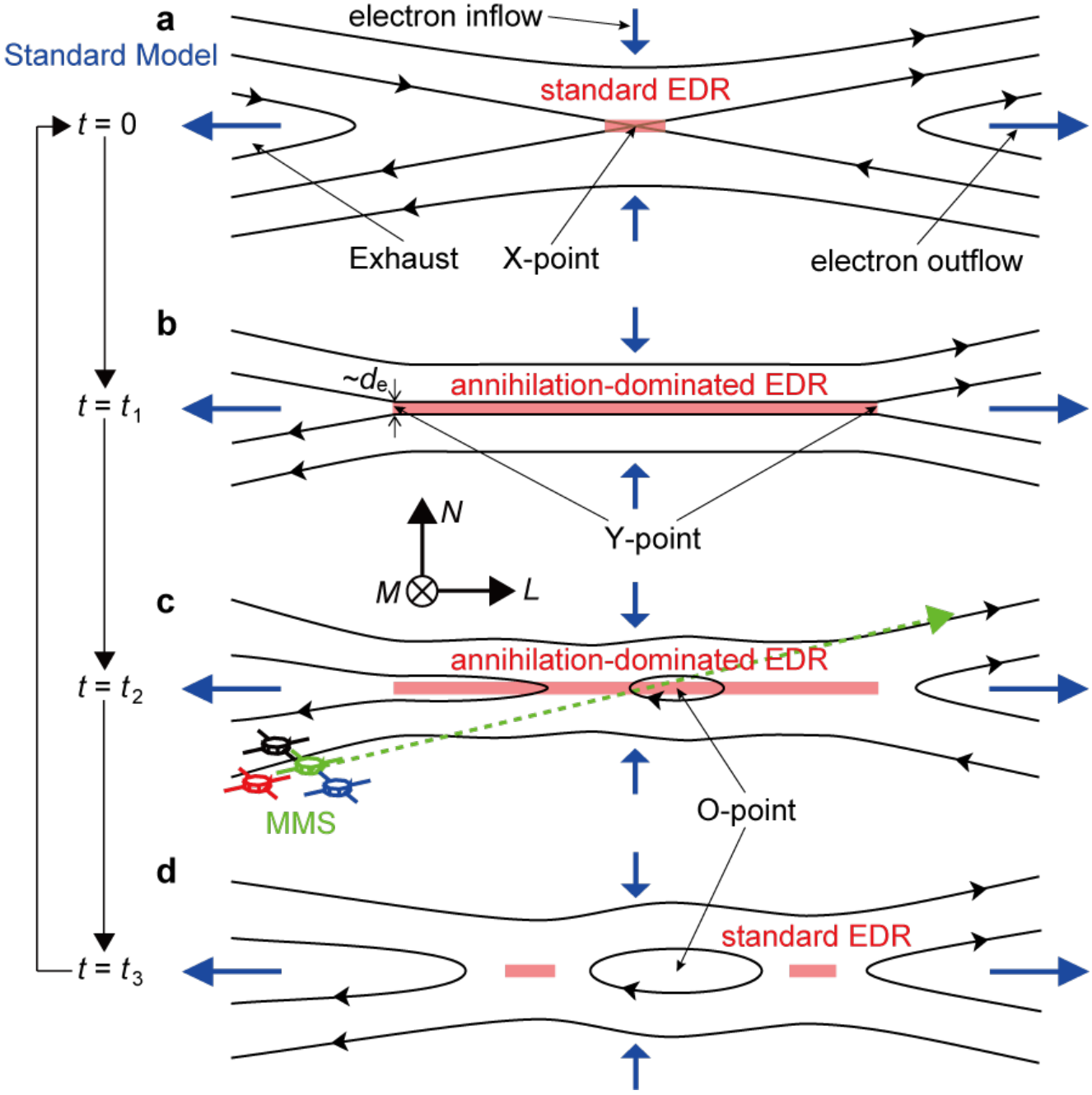

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Energy dependence of field-aligned anisotropy of electrons during dipolarization at Earth's tailside

*Kaiti Wang[1], Ching-Huei Lin[2], Zhuo-Ren Lang[3], Tohru Hada[4], Toshi Nishimura[5]

1. Tamkang Univ., 2. Chien-Hsin Univ. of Sci. & Tech., 3. National Cheng Kung Univ., 4. Kyushu Univ., 5. Boston Univ.

A specific pattern on energy-dependence of variations in field-aligned anisotropy (η) of electrons was found from hundreds of eV to thousands of eV during dipolarization time around 10 Earth radii near magnetic equator in the inner plasmasheet at tailside based on measurements of the instrument ESA (ElectroStatic Analyzer) onboard of THEMIS Mission. More exactly, in the beginning of dipolarization, η peaks at a lower energy and it shifts to a higher energy but with a smaller value when the dipolarization angle reaches maximum [*Wang et al.*, 2019]. In this study, by further analyzing the field-aligned anisotropies of electrons in both northward and southward directions at 62 dipolarization sites from the year of 2008 to 2011, we find that electrons observed at about two-thirds of these sites exhibit such a pattern and the energy range is largely associated with the ratio of bounce time to the dipolarization time. Furthermore, we find that this pattern hardly exists when the minimum AL index is less than -190nT or the maximum of y-component of electric field (E_y) measured by the onboard instrument EFI (Electric Field Instrument) is higher than 20mV/m during the dipolarization time analyzed. Hence, mechanisms affecting electron motions associated with the values of AL index and E_y as well as their influences on this energy-dependence will be assessed and discussed.

*References

Wang, K., Z. R. Lang, C. H. Lin, T. Hada, T. Nishimura (2019), Analysis on anisotropy variations for pitch angle distributions of electrons with various parameters at dipolarization sites in the inner plasma sheet, Paper No. PEM11-14, JpGU Meeting 2019, Chiba, Japan.

Keywords: dipolarizations in the inner plasmasheet, field-aligned anisotropy of electrons, energy-dependence, AL index, electric fields, observations of THEMIS mission

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On the origin of cold-dense plasmas in the dusk magnetotail plasma sheet: MMS and Geotail observations

*Masaki N Nishino[1], Yoshifumi Saito[1], Hiroshi Hasegawa[1], Naritoshi Kitamura[2], Yukinaga Miyashita[3,4], Tsugunobu Nagai[1], Shoichiro Yokota[5], Daniel J Gershman[6], Christopher T Russell[7], Barbara L Giles[6]

1. Japan Aerospace Exploration Agency, Institute of Space and Astronautical Science, 2. Graduate School of Science, The University of Tokyo, 3. Korea Astronomy and Space Science Institute, South Korea, 4. Korea University of Science and Technology, South Korea, 5. Graduate School of Science, Osaka University, 6. Goddard Space Flight Center, NASA, 7. University of California, Los Angeles

The near-Earth plasma sheet becomes cold and dense under the northward interplanetary magnetic field (IMF) condition, which suggests entry of solar wind plasma into the magnetosphere across the magnetopause. The cold and dense characteristics of the plasma sheet are more evident in the magnetotail flank regions that are interface between cold solar wind plasma and hot magnetospheric plasma. Several physical mechanisms have been proposed to explain the entry of solar wind plasma across the magnetopause and resultant formation of the cold-dense plasma sheet (CDPS) in the tail flank regions. However, transport path of the cold-dense plasma inside the magnetotail has not been understood yet. Here we present a case study of the CDPS in the dusk magnetotail by Magnetospheric Multiscale (MMS) spacecraft under the conditions of the strongly northward IMF and the high-density solar wind. The ion distribution function consists of high- and low-energy components, and the low-energy one intermittently shows energy dispersion in the directions parallel and anti-parallel to the local magnetic field. Considering the time-of-flight effect of the energy-dispersed low-energy ions, we infer that these ions originate in the region down the tail, and move along the magnetic field toward the ionosphere and then come back to the magnetotail by the mirror reflection. The pitch-angle dispersion analysis gives consistent results on the travelling time and path length of the energy-dispersed ions. Interestingly, Geotail spacecraft detected large magnetic field fluctuations in the low-latitude boundary layer near the dusk terminator, which may be attributed to Kelvin-Helmholtz instability due to the velocity shear between the magnetosheath and the plasma sheet. Based on these observations, we discuss possible generation mechanisms of the energy-dispersed structure of the low-energy ions during the northward IMF.

Keywords: Magnetotail plasma sheet, Plasma transport, Northward IMF, Low-latitude boundary layer (LLBL), Magnetospheric Multiscale (MMS) spacecraft, Geotail spacecraft

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Substorm-like events related to magnetosheath plasma jets

*ALEXEI DMITRIEV[1,2], ALLA SUVOROVA[2]

1. Institute of Space Science, National Central University, Jungli City, Taiwan, 2. Skobeltsyn Institute of Nuclear Physics, Lomonosov Moscow State University, Moscow, Russia

Fast and dense streams of magnetosheath plasma, so-called jets, can hit the dayside magnetopause. The interaction results in a localized compression of the magnetosphere and sometimes penetration of the magnetosheath plasma inside the magnetosphere. These effects produce intensification of the geomagnetic activity at high-latitudes on dayside with further propagation of the disturbances toward night side. These, so-called substorm-like events can occur even during quite geomagnetic conditions under northward orientation of interplanetary magnetic field. We present examples of substorm-like events under various conditions.

Keywords: substorms, auroral activity, magnetosheath plasma jets

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

[P-EM09] Dynamics of Magnetosphere and Ionosphere

convener:Akiko Fujimoto(Kyushu Institute of Technology), Mitsunori Ozaki(Faculty of Electrical and Computer Engineering, Institute of Science and Engineering, Kanazawa University), Yuka Sato(Nippon Institute of Technology), Aoi Nakamizo(Applied Electromagnetic Research Institute, National Institute of Information and Communications Technology), Chairperson:Hiroshi Hasegawa(Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency), Masaki N Nishino(Japan Aerospace Exploration Agency, Institute of Space and Astronautical Science)

Sun. Jun 6, 2021 9:00 AM - 10:30 AM Ch.05 (Zoom Room 05)

This session provides an opportunity to present recent results from satellite and ground-based observations and theoretical and simulation studies on the magnetosphere, ionosphere, and their coupling processes. We invite talks and posters discussing various phenomena related to the magnetosphere-ionosphere system: solar wind-magnetosphere interaction, magnetosphere-ionosphere convection, field-aligned current, magnetic storms/substorms, neutral-plasma interaction, ionospheric ion inflow and outflow, aurora phenomena, and so forth. Discussions on planetary and satellite ionospheres and magnetospheres, future missions and instrument developments are also welcome.

10:20 AM - 10:30 AM

[PEM09-07]Discussion

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

Sun. Jun 6, 2021 10:45 AM - 12:15 PM JST | Sun. Jun 6, 2021 1:45 AM - 3:15 AM UTC | Ch.05 Zoom Room 05

[P-EM09] Dynamics of Magnetosphere and Ionosphere

convener:Akiko Fujimoto(Kyushu Institute of Technology), Mitsunori Ozaki(Faculty of Electrical and Computer Engineering, Institute of Science and Engineering, Kanazawa University), Yuka Sato(Nippon Institute of Technology), Aoi Nakamizo(Applied Electromagnetic Research Institute, National Institute of Information and Communications Technology), Chairperson:Hiroshi Hasegawa(Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency), Masaki N Nishino(Japan Aerospace Exploration Agency, Institute of Space and Astronautical Science)

This session provides an opportunity to present recent results from satellite and ground-based observations and theoretical and simulation studies on the magnetosphere, ionosphere, and their coupling processes. We invite talks and posters discussing various phenomena related to the magnetosphere-ionosphere system: solar wind-magnetosphere interaction, magnetosphere-ionosphere convection, field-aligned current, magnetic storms/substorms, neutral-plasma interaction, ionospheric ion inflow and outflow, aurora phenomena, and so forth. Discussions on planetary and satellite ionospheres and magnetospheres, future missions and instrument developments are also welcome.

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

[PEM09-08] A Case Study of Transversely Heated Low-Energy Helium Ions by EMIC Waves in the Plasmasphere

★Invited Papers

*Khan-Hyuk Kim[1] (1.School of Space Research, Kyung Hee University)

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

[PEM09-09] CIR- and CME-driven magnetic storm effects on ion upflows in the low-altitude polar ionosphere

*Masayoshi Takada[1], Kanako Seki[1], Yasunobu Ogawa[2], Kunihiro Keika[1] (1.Tokyo University, 2.National Institute of Polar Research)

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

[PEM09-10] Science Objectives of FACTORS mission

*Yoshizumi Miyoshi[1], Naritoshi Kitamura[2], Kazushi Asamura[3], Takeshi Sakanoi[4], Takanori Nishiyama[6], Hirotsugu Kojima[5], Masahito Nose[1], Yuto Katoh[4], Kunihiro Keika[2], Atsuki Shinbori[4,1], Mizuki Fukizawa[4], Kiyoka Murase[6], Miki Kawamura[4] (1.Institute for Space-Earth Environmental Research, Nagoya University, 2.University of Tokyo, 3.JAXA, 4.Tohoku University, 5.Kyoto University, 6.NIPR)

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

[PEM09-11] **Development of a novel method for extracting the geometrical properties of the magnetic vector fields towards the era of multi-point satellite observations**

*Akimasa Yoshikawa[1], Tsubasa Hashimoto[2], Aoi Nakamizo[4], Shinichi Ohtani[3] (1.Department of Earth and Planetary Sciences, Kyushu University, 2.Gradient school of Earth and Planetary Sciences, Kyushu University, 3.JHU/APL, 4.NICT)

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

[PEM09-12] Dawn-dusk asymmetry in the mesoscale field-aligned currents embedded in the diminished large-scale Region 1 current

*Yoshihiro Yokoyama[1], Satoshi Taguchi[1], Toshihiko Iyemori[2] (1.Department of Geopysics, Graduate School of Science, Kyoto University, 2.Kyoto University)

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

[PEM09-13] Discussion

A Case Study of Transversely Heated Low-Energy Helium Ions by EMIC Waves in the Plasmasphere

*Khan-Hyuk Kim[1]

1. School of Space Research, Kyung Hee University

The Van Allen Probe A spacecraft observed strong ~0.5-Hz helium (He^+) band and weak ~0.8-Hz hydrogen (H^+) band EMIC waves on 17 April 2018, at L = ~4.5-5.2, in the dawn sector, near the magnetic equator, and close to the plasmapause. We examined low-energy ion fluxes observed by the Helium Oxygen Proton and Electron (HOPE) instrument onboard Van Allen Probe A during the wave interval and found that low-energy He^+ flux (< 10 eV) enhancements occur nearly simultaneously with He-band and H-band EMIC wave power enhancements in a direction mostly perpendicular to the background magnetic field without significant low-energy H^+ and O^+ flux variations. We suggest that cold He^+ ions (<1 eV) are preferentially and transversely heated up 10 eV through the interaction with EMIC waves inside the plasmasphere. The low-Earth orbit spacecraft observed localized precipitations of energetic protons in the upper ionosphere at subauroral latitudes near the magnetic field footprint of Van Allen Probe A. Our observations provide a clear evidence that EMIC waves play an important role in the overall dynamics in the inner magnetosphere, contributing to the high-energy particle loss and low-energy particle energization.

Keywords: EMIC waves, Low-energy ion heating, Plasmasphere

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CIR- and CME-driven magnetic storm effects on ion upflows in the low-altitude polar ionosphere

*Masayoshi Takada[1], Kanako Seki[1], Yasunobu Ogawa[2], Kunihiro Keika[1]

1. Tokyo University, 2. National Institute of Polar Research

Molecular ions ($O_2^+/NO^+/N_2^+$) in the ring current of the terrestrial magnetosphere have been observed during the magnetic storms [e.g., Klecker et al., 1986; Seki et al., 2019]. These ions originate from the low-altitude ionosphere. In the ionosphere, upward ion transports (upflows) supply sources of the ions outflowing to the magnetosphere. Since the molecular ions usually exist in the low-altitude (< 300 km) ionosphere and can be affected by neutral winds, the generation mechanisms and properties of ion upflows to transport molecular ions are different from those of O^+ [e.g., Ogawa et al., 2010; Yamazaki et al., 2017]. In particular, their dependence on solar activities is one of the important properties to understand formation mechanisms of the ion upflows. In a previous study by Ogawa et al. [2019], the characteristics of O^+ ion upflows in the polar ionosphere were investigated during CIR- and CME-driven magnetic storms by using EISCAT radars. They reported that the upflows during CIR- and CME-driven storms have different dependence on magnetic local time. For the CIR-driven storms, upward ion flux around noon was pronounced, while it was enhanced around midnight during the CME-driven storms. Their study focused on the ion upflows in the altitude range between 400 and 500 km, where O^+ is the dominant species, and responses of the ion upflows to the different type of magnetic storms in the low-altitude ionosphere, where molecular ions exist, are far from understood. The purpose of this study is thus to understand effects of CIR- and CME-driven magnetic storms on ion upflows in the low-altitude ionosphere based on long-term observations of the EISCAT radars.

We used data from the EISCAT UHF radar at Tromsø and Svalbard radar at Longyearbyen from January 1, 1996 to January 1, 2016 and surveyed statistical properties of ion upflows and ionospheric conditions during CIR- and CME-driven magnetic storms. We used 1-minute time resolution data when the radar was looking along the local magnetic field line. The ionospheric parameters such as electron density, ion velocity, and ion and electron temperatures were averaged over three altitude range, i.e., 250-350, 300-400, and 400-500 km, respectively. We screened data to exclude unrealistic values with the following criteria: Absolute value of ion velocity was less than 1500 m/s, ion and electron temperatures were less than 10000 K, and electron density was more than 10^{10} m^{-3} and less than 10^{13} m^{-3}. To understand the similarity and difference between low and high altitude upflows, we compared data at different altitude ranges. The results show that the upward velocity in the nightside at Tromsø increased with increasing altitude in the main phase of both CIR- and CME-driven magnetic storms. On the other hand, the upward flux in the nightside at Longyearbyen was not enhanced at any altitude after CIR-driven storms, whereas it increased from the low-altitude region after CME-driven storms. It was also confirmed that any effect of the magnetic storms that was remarkable at the higher altitudes reported in the previous study [Ogawa et al., 2019] was not seen in the dayside low-altitude ionosphere at Longyearbyen.

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[1] B. Klecker et al., Discovery of energetic molecular ions (NO+ and O2+) in the storm time ring current, *Geophys. Res. Lett.*, 13, 632-635, 1986

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[4] Y. Yamazaki et al., Average field-aligned ion velocity over the EISCAT radars, *J. Geophys. Res. Space Physics,*122, 5630-5642, 2017
[5] Y. Ogawa et al., Characteristics of CME- and CIR-driven ion upflows in the polar ionosphere, *J. Geophys. Res. Space Physics*, 124, 3637–3649, 2019

Keywords: ion upflow, corotating interaction region (CIR), coronal mass ejection (CME), magnetic stroms, polar ionosphere, EISCAT radars

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Science Objectives of FACTORS mission

*Yoshizumi Miyoshi[1], Naritoshi Kitamura[2], Kazushi Asamura[3], Takeshi Sakanoi[4], Takanori Nishiyama[6], Hirotsugu Kojima[5], Masahito Nose[1], Yuto Katoh[4], Kunihiro Keika[2], Atsuki Shinbori[4,1], Mizuki Fukizawa[4], Kiyoka Murase[6], Miki Kawamura[4]

1. Institute for Space-Earth Environmental Research, Nagoya University, 2. University of Tokyo, 3. JAXA, 4. Tohoku University, 5. Kyoto University, 6. NIPR

FACTORS (Frontiers of Formation, Acceleration, Coupling and Transport Mechanisms Observed by the Outer Space Research System) is a future polar orbiting satellite mission to understand coupling processes between space and Earth’ s atmosphere including energy inputs from magnetosphere associated with aurora and ion outflow from ionosphere. FACTORS is a next-generation multi-satellite formation flight mission, and comprehensive plasma/particle and fields/waves instruments as well as visible/FUV imagers are installed. Major science objectives are 1) energy transport in the magnetosphere-ionosphere coupling system and their relationship to small-scale aurora phenomena, 2) particle transport in the magnetosphere-ionosphere system by ion outflow. In particular, we focus on the acceleration and/or heating of ions by plasma waves to the escaping energies. The team is now working for discussions about the science strategy. Moreover, the team conducts several simulation studies about orbit and measurements of waves. In this presentation, we report the science objectives and possible observation strategies.

Keywords: polar ionosphere/magnetosphere, future mission

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Development of a novel method for extracting the geometrical properties of the magnetic vector fields towards the era of multi-point satellite observations

*Akimasa Yoshikawa[1], Tsubasa Hashimoto[2], Aoi Nakamizo[4], Shinichi Ohtani[3]

1. Department of Earth and Planetary Sciences, Kyushu University, 2. Gradient school of Earth and Planetary Sciences, Kyushu University, 3. JHU/APL, 4. NICT

We propose a new method for analyzing the evolution of a geomagnetic fields that enables us to extract the geometrical properties of the magnetic vector fields towards the era of multi-point satellite observations

In general, geometrical properties of magnetic fields (B-fields) can be represented by divergence and/or convergence of magnetic flux tube, gradient of magnetic flux density, curvature, and twist of magnetic field lines. Such geometries can be reconstructed from a dyadic tensor of B-field gradients that represents various spatial gradients of magnetic field components in a three-dimensional space. Furthermore, change of B-field can be characterized by a change of magnetic flux-density and a change of direction of B-field.

When a satellite cruse in space with finite velocity in the rest frame, the time-hysteresis of measured magnetic fields by this satellite includes contribution from a Euler differentiation of B-field at the satellite position in the rest frame and the change of B-field when the satellite moves across an inhomogeneous B-field region. In general, it is impossible to separate these two contributions from single satellite observation. To successfully measure the spatial gradients of B-field, we need an appropriate formation fright composed of multiple satellites. A formation flight composed of 4-satellites have already realized in the Cluster and the MMS missions and is a minimum configuration that enable to deduce a spatial gradient of B-field in the 3D system.

In this paper, we provide a methodology that derive the dyadic tensor of B-field in the triangular cone formed by 4-satellites, of which components describe averaged characteristic of spatial gradients of B-field. By using this methodology, we can extract the Euler differentiation of B-field at the centroid position of formation flight. This technique can be easily applied to formation flights of more than four satellites.

We also derive a novel expression of B-field development equation under any Ohm’ s law, which explicitly describes what type of plasma motion causes B-field development in the parallel and perpendicular direction to B-field. The former part corresponds to the development of magnetic flux density and the latter part corresponds to the changing ratio of B-field direction. By comparing extracted Euler differentiation of B-field from observational data and results deduced from new formulation, we can identify cause and results of B-field development under an arbitrary Ohm’ s law. Application to the MHD’ s Ohm’ s law will be discussed in the presentation.

Keywords: formation flight of satellites, Multi-point observation of magnetic field, magnetic gradient tensor

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Dawn-dusk asymmetry in the mesoscale field-aligned currents embedded in the diminished large-scale Region 1 current

*Yoshihiro Yokoyama[1], Satoshi Taguchi[1], Toshihiko Iyemori[2]

1. Department of Geopysics, Graduate School of Science, Kyoto University, 2. Kyoto University

Irregular magnetic perturbations embedded in the diminished large-scale Region 1 current are observed in almost all MLT except for the near noon region during prolonged northward IMF conditions. Our recent statistical study for the dusk side sector has revealed that the mesoscale field-aligned currents that produce these irregular magnetic perturbations tend to occur under the northward IMF conditions and are possibly generated in the low-latitude boundary layer. Our study has also shown that the current density of the mesoscale field-aligned currents tends to increase as the solar wind proton density increases. To clarify whether or not there exist asymmetries in the mesoscale field-aligned currents between the dawn and dusk sector, by utilizing magnetic data obtained by Swarm satellites during the period from May 2014 to May 2017, we investigated the dependence of the dawn side field-aligned currents on the solar zenith angle, the IMF, and solar wind plasma parameters, and compared the results with those from the dusk side sector. We found that the occurrence ratio of the mesoscale field-aligned current in the dawn sector also shows a strong dependence on the northward IMF condition. Besides, we found that there are weak dawn-dusk asymmetries in the occurrence ratio against the Y component of IMF, and in the current density. From our proposed mechanism of the generation for the mesoscale field-aligned currents, which is associated with the cold dense ion regions in the low-latitude boundary layer, we interpret those dawn-dusk asymmetries.

Keywords: field-aligned currents, northward IMF

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

[P-EM09] Dynamics of Magnetosphere and Ionosphere

convener:Akiko Fujimoto(Kyushu Institute of Technology), Mitsunori Ozaki(Faculty of Electrical and Computer Engineering, Institute of Science and Engineering, Kanazawa University), Yuka Sato(Nippon Institute of Technology), Aoi Nakamizo(Applied Electromagnetic Research Institute, National Institute of Information and Communications Technology), Chairperson:Hiroshi Hasegawa(Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency), Masaki N Nishino(Japan Aerospace Exploration Agency, Institute of Space and Astronautical Science)

Sun. Jun 6, 2021 10:45 AM - 12:15 PM Ch.05 (Zoom Room 05)

This session provides an opportunity to present recent results from satellite and ground-based observations and theoretical and simulation studies on the magnetosphere, ionosphere, and their coupling processes. We invite talks and posters discussing various phenomena related to the magnetosphere-ionosphere system: solar wind-magnetosphere interaction, magnetosphere-ionosphere convection, field-aligned current, magnetic storms/substorms, neutral-plasma interaction, ionospheric ion inflow and outflow, aurora phenomena, and so forth. Discussions on planetary and satellite ionospheres and magnetospheres, future missions and instrument developments are also welcome.

12:10 PM - 12:15 PM

[PEM09-13]Discussion

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

Sun. Jun 6, 2021 1:45 PM - 3:15 PM JST | Sun. Jun 6, 2021 4:45 AM - 6:15 AM UTC | Ch.05 Zoom Room 05

[P-EM09] Dynamics of Magnetosphere and Ionosphere

convener:Akiko Fujimoto(Kyushu Institute of Technology), Mitsunori Ozaki(Faculty of Electrical and Computer Engineering, Institute of Science and Engineering, Kanazawa University), Yuka Sato(Nippon Institute of Technology), Aoi Nakamizo(Applied Electromagnetic Research Institute, National Institute of Information and Communications Technology), Chairperson:Yuki Obana(Department of Engineering Science, Faculty of Engineering, Osaka Electro-Communication University), Yoshihiro Yokoyama(Department of Earth and Planetary Sciences, Graduate School of Science, Kyoto University)

This session provides an opportunity to present recent results from satellite and ground-based observations and theoretical and simulation studies on the magnetosphere, ionosphere, and their coupling processes. We invite talks and posters discussing various phenomena related to the magnetosphere-ionosphere system: solar wind-magnetosphere interaction, magnetosphere-ionosphere convection, field-aligned current, magnetic storms/substorms, neutral-plasma interaction, ionospheric ion inflow and outflow, aurora phenomena, and so forth. Discussions on planetary and satellite ionospheres and magnetospheres, future missions and instrument developments are also welcome.

1:45 PM - 2:10 PM JST | 4:45 AM - 5:10 AM UTC

[PEM09-14] Current and future perspectives on 3D analysis of aurora

★Invited Papers

*Yoshimasa Tanaka[1,2,3], Yasunobu Ogawa[1,2,3], Akira Kadokura[1,2,3], Bjorn Gustavsson[4], Kirsti Kauristie[5], Enell Carl-fredrik[6], Urban Brandstrom[7], Tima Sergienko[7], Alexander Kozlovsky[8], Tero Raita[8], Mizuki Fukizawa[9], Takeshi Sakanoi[9], Keisuke Hosokawa[10] (1.National Institute of Polar Research, 2.Polar Environment Data Science Center, Joint Support-Center for Data Science Research, Research Organization of Information and Systems, 3.The Graduate University for Advanced Studies, SOKENDAI, 4.The Arctic University of Norway, 5.Finnish Meteorological Institute, 6.EISCAT Scientific Association, 7.Swedish Institute of Space Physics, 8.Sodankyla Geophysical Observatory, 9.Planetary Plasma and Atmospheric Research Center, Graduate School of Science, Tohoku University, 10.Department of Communication Engineering and Informatics, University of Electro-Communications)

2:10 PM - 2:25 PM JST | 5:10 AM - 5:25 AM UTC

[PEM09-15] Reconstruction of the three-dimensional structure and precipitating electrons of pulsating auroral patches by Aurora Computed Tomography

*Mizuki Fukizawa[1], Takeshi Sakanoi[1], Yoshimasa Tanaka[2], Yasunobu Ogawa[2], Björn Gustavsson[3], Kirsti Kauristie[4], Carl-Fredrik Enell[5], Alexander Kozlovsky[6], Tero Raita[6], Urban Brändström[7], Tima Sergienko[7] (1.Planetary Plasma and Atmospheric Research Center, Graduate School of Science, Tohoku University, 2.National Institute of Polar Research, 3.University of Tromsø - The Arctic University of Norway, 4.Finnish Meteorological Institute, 5.EISCAT Scientific Association, 6.Sodankylä Geophysical Observatory, University of Oulu, 7.Swedish Institute of Space Physics)

2:25 PM - 2:40 PM JST | 5:25 AM - 5:40 AM UTC

[PEM09-16] A generation process of “Great Wall” aurora seen from ISS

*Sota Nanjo[1], Morio Tanaka[2], Natsuo Sato[3], Yuta Hozumi[1], Keisuke Hosokawa[1], Ryuho Kataoka[3,4], Yoshizumi Miyoshi[5], Shin-ichiro Oyama[3,5,6], Mitsunori Ozaki[7], Kazuo Shiokawa[5], Satoshi Kurita[2] (1.The University of Electro-Communications, 2.Kyoto University, 3.National Institute of Polar Research, 4.SOKENDAI, the Graduate University for Advanced Studies, 5.ISEE, Nagoya University, 6.University of Oulu, 7.Kanazawa University)

2:40 PM - 2:55 PM JST | 5:40 AM - 5:55 AM UTC

[PEM09-17] Exploring the Electron Acceleration Mechanism in the Poleward Boundary Intensification

*Hayato Higuchi[1], Akimasa Yoshikawa[2] (1.Department of Earth and Planetary Sciences, Graduate School of Science, Kyushu University, 2.Department of Earth and Planetary Sciences, Faculty of Science, Kyushu University)

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

[PEM09-18] **Antarctic large area network observation of auroral phenomena using unmanned system: Current status of project as of early 2021**

*Akira Kadokura[1], Yasunobu Ogawa[1], Yoshimasa Tanaka[1], Hisao Yamagishi[1], Masaki Okada[1], Ryuho Kataoka[1], Herbert Akihito Uchida[4], Yuichi Otsuka[2], Tetsuo Motoba[3], Natsuo Sato[1], Henri Robert[5], Ashwini K. Sinha[6], Jean Rasson[7] (1.National Institute of Polar Research, 2.Nagoya University, 3.Johns Hopkins University, Applied Physics Laboratory, 4.SOKENDAI, 5.International Polar Foundation, 6.Indian Institute of Geomagnetism, 7.Royal Meteorological Institute of Belgium)

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

[PEM09-19] Discussion

Current and future perspectives on 3D analysis of aurora

*Yoshimasa Tanaka[1,2,3], Yasunobu Ogawa[1,2,3], Akira Kadokura[1,2,3], Bjorn Gustavsson[4], Kirsti Kauristie[5], Enell Carl-fredrik[6], Urban Brandstrom[7], Tima Sergienko[7], Alexander Kozlovsky[8], Tero Raita[8], Mizuki Fukizawa[9], Takeshi Sakanoi[9], Keisuke Hosokawa[10]

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Aurora Computed Tomography (ACT) is an analysis method to reconstruct three-dimensional (3D) structure of auroral luminosity from monochromatic auroral images simultaneously taken by multi-point imager network on the ground. The ACT method enables us to derive the altitude profile of the auroral luminosity, corresponding to the energy distribution of precipitating electrons from the magnetosphere. Another advantage of the ACT is the capability to derive the 3D distribution of the electron density, resulting in the electrical conductivity, in the ionospheric E and F regions at high-time resolution. The auroras are the electromagnetic phenomena generated by the magnetosphere-ionosphere (M-I) coupling process, so it is essential to understand the 3D current system in the M-I system. The 3D current system can be estimated by using the ionospheric conductivity obtained from the ACT analysis, with the ionospheric electric field from the radars or the ionospheric equivalent current from the magnetometers. So far, we have applied the ACT analysis to several discrete aurora events to reconstruct the 3D distribution of the optical emission and the energy distribution of the precipitating electrons. It was demonstated that the altitude profile of the optical emission at the wavelength of 427.8 nm obtained by the ACT method is similar to the ionospheric density profile simultaneously observed with the EISCAT radar. Recently, we also succeeded in the 3D reconstruction of the pulsating auroral patches. In these case studies, the ionospheric electron density converted from the optical emission using the theoretical and empirical models was underestimated compared with that observed by the EISCAT radar. The radars and optical imagers are complementary to each other, because the radars have a high range resolution, while the imagers have a high angular resolution. In order to combine these different kinds of data effectively, we have developed the Generalized - Aurora Computed Tomography (G-ACT) method, which is capable of retrieving the differential number flux of precipitating electrons from multi-instrument data, such as the monochromatic images from the multiple imagers, the ionospheric electron density from the radars, and cosmic noise absorption from the imaging riometers. This method enables more accurate reconstruction of 3D aurora, even in case it is difficult to reconstruct by the optical data only. In particular, it is expected that the G-ACT method will be useful for the research on the auroral 3D structure by the EISCAT_3D, which is a multiple-site phased-array incoherent scatter radar system that is planned to be operated in 2022. We are planning to apply the G-ACT technique to data obtained from both the EISCAT_3D radar and the imager networks, which are being constructed by the international collaboration, to extract the 3D current system accompanied by various auroral phenomena.

Keywords: aurora, tomography analysis, discrete aurora, pulsating aurora, energy distribution of precipitating electrons, EISCAT_3D

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Reconstruction of the three-dimensional structure and precipitating electrons of pulsating auroral patches by Aurora Computed Tomography

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Aurora Computed Tomography (ACT) is an inversion problem analysis method to reconstruct the auroral three-dimensional (3-D) structure from monochromatic auroral images obtained with multiple ground-based optical instruments which have common field of view by applying the Computed Tomography method (e.g., Aso et al., 1990). In addition, Generalized-Aurora Computed Tomography (G-ACT) is the analysis method developed from ACT to reconstruct the energy and spatial distribution of precipitating electrons by combining ionospheric electron density data observed by an Incoherent Scatter radar (Aso et al., 2008; Tanaka et al., 2011). These methods have been applied to discrete auroras whose structures have discrete boundaries such as auroral arcs. On the other hand, it is relatively difficult to reconstruct the 3-D structure of pulsating aurora (PsA) by ACT since the structure boundaries of PsA is generally blurred. Therefore, ACT and G-ACT have not been applied to PsA yet.

In this study, we evaluate the possibility applying ACT and G-ACT to the PsA patch and will finally investigate the temporal changes of the 3-D structure and precipitating electrons of PsA patches. We used monochromatic auroral images obtained with three all-sky images in Scandinavia (Skibotn (69.35˚N, 18.82˚E), Kilpisjärvi (69.05˚N, 20.36˚E), Abisko (68.36˚N, 18.82˚E)) during the substorm recovery phase in 0 –2 UT on 18 February 2018. The observation wavelength is 427.8 nm and temporal resolution is 2 s. We selected the isolated PsA patch observed by the three all-sky imagers to make the problem simple though PsA patches often occur in close proximity to each other. Then, we carried out to reconstruct its 3-D structure from only auroral images by ACT. The background diffuse auroral emission was subtracted from the auroral images as uniform emission to reduce noises before conducting ACT.

As a result, we obtained the auroral 3-D structure whose widths in the east-west, north-south, and altitude directions were 60 km, 42 km, and 14 km respectively. The accuracy of the reconstruction was evaluated by using a model aurora. We compared the auroral 3-D structure reconstructed from the pseudo images obtained by integrating model 3-D aurora in the line-of-sight directions to the model auroral 3-D structure and found that the peak altitude was correctly reconstructed but the peak value and altitude width of the reconstructed aurora were respectively ~18 % smaller and ~33 % larger than those of the model aurora. These errors would be caused by the horizontally wide structure of PsA patch which makes ambiguity in determining the lower- and upper-limit altitude from auroral images.

Next, we examined the events that a PsA patch was observed at the observation point of the EISCAT UHF radar in Tromsø (69.58˚N, 19.23˚E) and reconstructed the auroral 3-D structures from the three auroral images. The reconstructed 3-D volume emission rates were converted to electron densities to compare

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with the altitude profiles of electron densities observed by the EISCAT UHF radar. As a result, the maximum values of reconstructed electron densities were ~32 –40 % smaller than those of observed ones. These errors might be caused by the subtraction of the background diffuse auroral emission from auroral images before conducting ACT, the error of reconstructing the 3-D volume emission rate by ACT, and the errors of the effective recombination coefficient and neutral atmospheric model which used to convert the volume emission rate to electron density.
We give the talk on the reconstruction of 3-D structure of PsA patches by G-ACT, and evaluate their accuracy. We also show the results on the temporal changes of 3-D structure and energy distribution of precipitating electrons that cause PsA patches.

Keywords: Pulsating aurora, Computed Tomography

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A generation process of “Great Wall” aurora seen from ISS

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By analyzing observations of the digital single-lens reflex cameras onboard the International Space Station, we have reported the morphology of the "Great Wall" aurora, which is a structure, embedded within the omega-band aurora, having wide distributions in the latitudinal and altitudinal directions and a narrow extent in the longitudinal direction. By studying the two case examples from both hemispheres, we found that the Great Wall auroras appeared in the western flank of the torch structure of the omega-band. We also showed the detailed structure of the Great Wall aurora at the JpGU-AGU meeting last year. However, we have not yet discussed their generation process in detail. To better understand the generation process of the Great Wall aurora, it is important to discuss the current system in the vicinity of the omega-band. Vanhamäki et al. (2009) derived the current system in the vicinity of the omega-band by combining model calculations with observations using optical instruments, a riometer, and magnetometers. Their results suggest that there is an upward field-aligned current (FAC) in the western flank of the torch structure due to the negative divergence of the electric field. The existence of the upward FAC is consistent with the appearance of the Great Wall aurora, but they did not discuss how the optical aurora forms in that region as a manifestation of FAC. In this study, we focus on the gradient of the conductance of the torch structure and discuss the possible generation process of the Great Wall aurora. Within the hole structure, a dark region between the consecutive torches, conductance is lower as compared to that in the torch structure; thus, the positive (negative) charges are accumulated along the western (eastern) flank to keep the westward flowing Hall current continuous. The positive potential along the western flank can increase the electron precipitation and drives the upward FAC, which can introduce the generation of Great Wall aurora. In the presentation, we will discuss the validity of this scenario by analyzing observations from the low-Earth orbiting satellites.

Keywords: Omega band, Field-Aligned Current, Magnetosphere-Ionosphere coupling

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Exploring the Electron Acceleration Mechanism in the Poleward Boundary Intensification

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The auroral oval poleward boundary auroral intensification (PBI) had been regarded the result of “distant neutral line reconnection” effects in the ionosphere. On the other hand, Ohtani and Yoshikawa., [2016] proposed a model in which PBI is the result of polarization process caused by plasma flows due to “dayside reconnection” approaching the conductivity gradient region of auroral oval. This model is an application of the theory of ionospheric polarization-field-aligned current (FAC) proposed by Yoshikawa et al., [2013]. According to Ohtani and Yoshikawa., [2016], Alfven waves upwelling from the ionosphere to the magnetosphere accelerate electrons downward and generating explosive auroral intensification. This is a new concept of the auroral process that has never existed in magnetospheric physics before. To simulate above mentioned process, it is essential to consider the ionosphere-magnetosphere coupling via Alfven waves and kinetic effects based on wave-particle interactions, which can explain "how upward Alfven waves rising from the cold ionosphere as a result of ionospheric polarization can trigger explosive downward electron acceleration?.”
In this research, in order to reproduce the aurora acceleration process associated with "ionospheric polarization PBI", we try to develop a "3D Vlasov-PIC-Fluid electron acceleration simulation". This simulation scheme has advantages such as maximum kinetic effect and reduced computational cost in reproducing the electron acceleration process by Alfven waves of ionospheric origin.
In this presentation, we will introduce new model of PBI, and explain basic concept of our developing Vlasov-PIC-Fluid code.

Keywords: Poleward Boundary Intensification, Auroral electron acceleration mechanism, Kinetic effect, Vlasov simulation, M-I coupling system, Wave particle interaction

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Antarctic large area network observation of auroral phenomena using unmanned system: Current status of project as of early 2021

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Space and upper atmospheric sciences group in the National Institute of Polar Research (NIPR) is now planning to construct an observation network for auroral phenomena along the coast of the Dronning Maud Land in the Antarctica including Japanese Syowa Station, and has developed a Unmanned Auroral Observation system (UAO), which is equipped with a 3-axis fluxgate magnetometer, all-sky auroral imager, GNSS/TEC receiver, and a data communication system using the Inmarsat satellite data link with a low power consumption. The first UAO (UAO-1) had been installed at Amundsen Bay area, which is located about 500 km eastward from Syowa Station, in February, 2017 in the summer operation of the 58th Japanese Antarctic Research Expedition (JARE-58). The second UAO (UAO-2) had been installed at Belgium Princess Elisabeth Antarctica (PEA) Station in January, 2020. Electric power of the UAO-1 is supplied by a hybrid natural energy electric generation system which consists of three sets of 192W wind generators and 8 sets of 62W solar panels, while that of the UAO-2 is supplied from the AC power source of the PEA Station which is generated by a power generation system of the station using nine big wind generators and solar panels. For the UAO, observed magnetometer data (1 sec resolution), GNSS BINEX data (30 sec resolution), daily Keogram and sample image data of the auroral imager, and House Keeping data (temperatures and power voltages) (1 min resolution) are transmitted at every 1 hour via the satellite link system to a server in Japan by FTP, and auroral image data of 1 sec resolution are stored in a memory card of the video encoder in the system. Sample interval and pixel resolution of the transmitted auroral image data are 1 hour (5 minutes) and 640x480 (160x120) for the UAO-1 (UAO-2), respectively. UAO-2 has the other USB memory in the system which can store auroral still image of 1 sec resolution with 640x480 pixel resolution and GNSS BINEX data of 1 sec resolution. PEA Station is maintained during summer season, and becomes an unmanned station during winter season, while the electric power to all the instruments at the station is supplied continuously all through the season. In January, 2020, we had also installed an auroral imager system at Indian Maitri Station, which consists of four sets of all-sky imager using Watec cameras: 1) Panchromatic (color) ; 2) Panchromatic (black&white); 3) filtered at 560nm (FWHM:10nm); 4) filtered at 632nm (FWHM:10nm), respectively. Maitri is a year-round station. The auroral imager system is run autonomously. We ask expedition members at Maitri to send daily summary files via E-mail to us. In our presentation, we will talk about current status of the project as of early 2021.

Keywords: aurora, network observation, Antarctic

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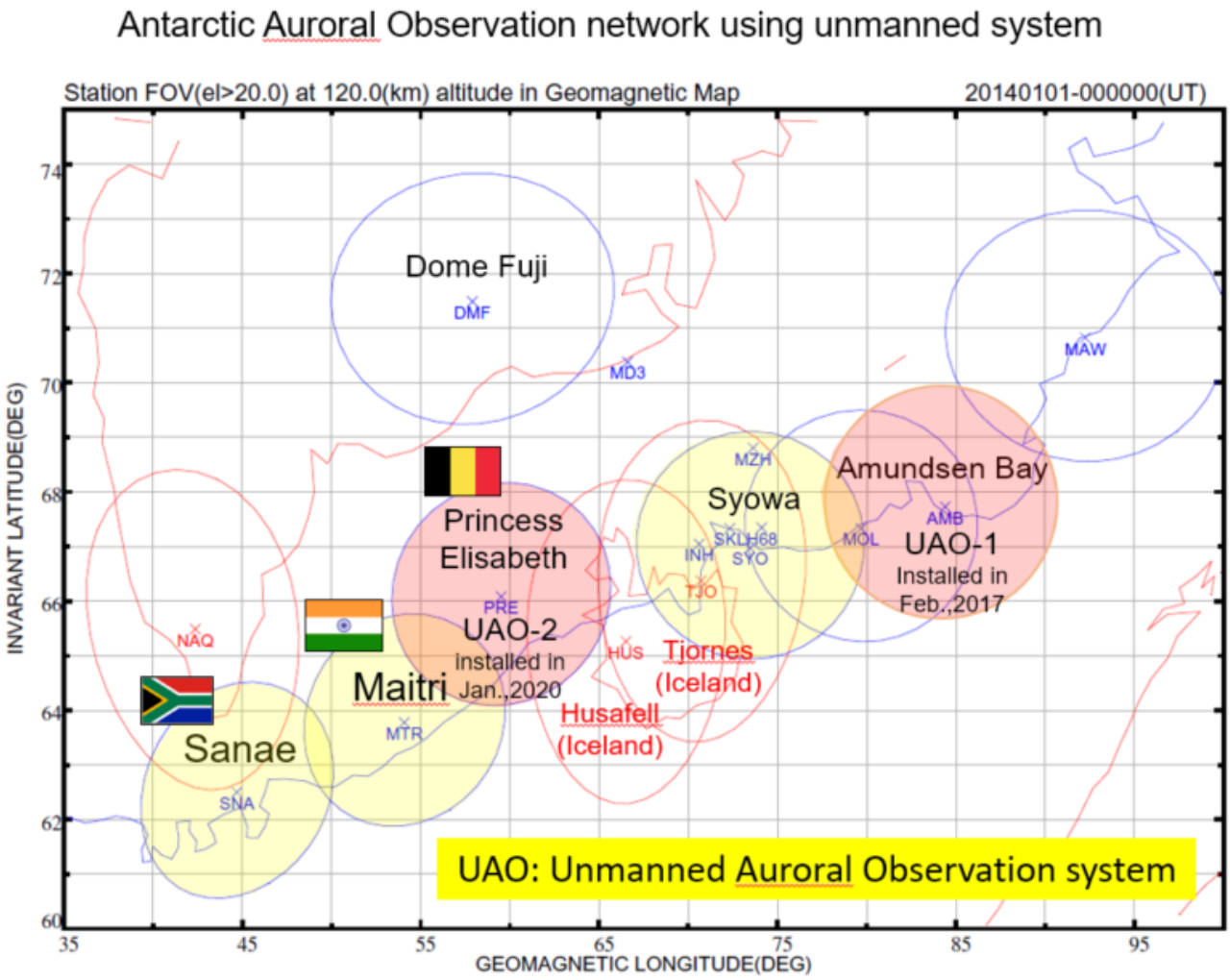

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[E] Oral | P (Space and Planetary Sciences) | P-EM Solar-Terrestrial Sciences, Space Electromagnetism & Space Environment

[P-EM09] Dynamics of Magnetosphere and Ionosphere

convener:Akiko Fujimoto(Kyushu Institute of Technology), Mitsunori Ozaki(Faculty of Electrical and Computer Engineering, Institute of Science and Engineering, Kanazawa University), Yuka Sato(Nippon Institute of Technology), Aoi Nakamizo(Applied Electromagnetic Research Institute, National Institute of Information and Communications Technology), Chairperson:Yuki Obana(Department of Engineering Science, Faculty of Engineering, Osaka Electro-Communication University), Yoshihiro Yokoyama(Department of Earth and Planetary Sciences, Graduate School of Science, Kyoto University)
Sun. Jun 6, 2021 1:45 PM - 3:15 PM Ch.05 (Zoom Room 05)

This session provides an opportunity to present recent results from satellite and ground-based observations and theoretical and simulation studies on the magnetosphere, ionosphere, and their coupling processes. We invite talks and posters discussing various phenomena related to the magnetosphere-ionosphere system: solar wind-magnetosphere interaction, magnetosphere-ionosphere convection, field-aligned current, magnetic storms/substorms, neutral-plasma interaction, ionospheric ion inflow and outflow, aurora phenomena, and so forth. Discussions on planetary and satellite ionospheres and magnetospheres, future missions and instrument developments are also welcome.

3:10 PM - 3:15 PM

[PEM09-19]Discussion

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

Sun. Jun 6, 2021 3:30 PM - 5:00 PM JST | Sun. Jun 6, 2021 6:30 AM - 8:00 AM UTC | Ch.05 Zoom Room 05

[P-EM09] Dynamics of Magnetosphere and Ionosphere

convener:Akiko Fujimoto(Kyushu Institute of Technology), Mitsunori Ozaki(Faculty of Electrical and Computer Engineering, Institute of Science and Engineering, Kanazawa University), Yuka Sato(Nippon Institute of Technology), Aoi Nakamizo(Applied Electromagnetic Research Institute, National Institute of Information and Communications Technology), Chairperson:Yuki Obana(Department of Engineering Science, Faculty of Engineering, Osaka Electro-Communication University), Yoshihiro Yokoyama(Department of Earth and Planetary Sciences, Graduate School of Science, Kyoto University)

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

[PEM09-20] Seasonal dependence of dusk-side equatorial IHFACs polarity during solar cycle 23-24

Manjula Ranasinghe[2], *Akiko Fujimoto[1], Akimasa Yoshikawa[3], Chandana Jayaratne[2] (1.Kyushu Institute of Technology, 2.University of Colombo, 3.Kyushu University)

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

[PEM09-21] Development of the imaging receiver system for the SuperDARN Hokkaido East radar

*Nozomu Nishitani[1], Tomoaki Hori[1], Yoshiyuki Hamaguchi[1] (1.Institute for Space-Earth Environmental Research, Nagoya University)

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

[PEM09-22] Seasonal and longitudinal dependence of the Sub-Auroral Polarization Streams occurrence observed by the SuperDARN radars

Kento Oya[1], *Nozomu Nishitani[1], Tomoaki Hori[1], John Mike Ruohoniemi[2], William A. Bristow[3], Simon G. Shepherd[4], Bharat Kunduri[2] (1.Institute for Space-Earth Environmental Research, Nagoya University, 2.Virginia Tech Department of Electrical and Computer Engineering, 3.The Pennsylvania State University , 4.Thayer School of Engineering, Dartmouth College)

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

[PEM09-23] Investigation of the mid-latitude ionospheric response during substorm based on magnetic and electric field observations

*Moe Hayashi[1], Akimasa Yoshikawa[1], Akiko Fujimoto[2], Shinichi Ohtani[3] (1.Kyushu University, 2.Kyushu Institute of Technology , 3.The Johns Hopkins University Applied Physics Laboratory)

4:30 PM - 4:55 PM JST | 7:30 AM - 7:55 AM UTC

[PEM09-24] New results of auroral hiss observations on the ground at L=5.5 in Northern Europe

★Invited Papers

*Jyrki Manninen[1], Natalia G. Kleimenova[2,3], Yury Fedorenko[4], Olga Lebed[4], Alexander Kozlovsky[1], Alexander Nikitenko[4], Liudmila Gromova[5] (1.Sodankyla Geophysical Observatory, University of Oulu, Sodankylä, Finland, 2.Schmidt Institute of Physics of the Earth RAN, Moscow, Russia, 3.Space Research

Institute RAN, Moscow, Russia, 4.Polar Geophysical Institute, Apatity, Russia, 5.Pushkov Institute of Terrestrial Magnetism, Ionosphere and Radio Wave Propagation RAN, Moscow, Russia)

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

[PEM09-25] Discussion

Seasonal dependence of dusk-side equatorial IHFACs polarity during solar cycle 23-24

Manjula Ranasinghe[2], *Akiko Fujimoto[1], Akimasa Yoshikawa[3], Chandana Jayaratne[2]

1. Kyushu Institute of Technology, 2. University of Colombo, 3. Kyushu University

The east-west ward variation of MAGDAS/CPMN magnetometer 1-hour time resolution data at Davao (Philippines) station operated by International Center for Space Weather Science and Education, Kyushu University from August 1998 to July 2020 are used to investigate the characteristics of the long-term Inter-hemispheric field-aligned currents (IHFACs). The recent in-situ satellite and ground-based observations have reported the dusk-side current polarity of IHFACs are often inconsistent with the Fukushima’ s IHFACs model. We investigated whether the dusk-side IHFACs polarity is consistent or not with the current direction predicted by Fukushima’ s IHFACs model, by analyzing the time-series data of IHFACs variations. We confirmed that the solstices dusk IHFACs flow the same direction of noon IHFACs and the equinoxes dusk IHFACs disagree with Fukushima’ s model. Seasonal IHFACs variations exhibited remarkable asymmetry in both dawn and noon sectors. By contrast, the profile of dusk-side IHFACs intensity was symmetry. The difference between noon and dusk IHFACs intensity might be strongly related to the seasonal dependence of the dusk IHFACs polarity. In addition, we presented that solar cycle dependence can be seen in the peak-to-peak amplitude, monthly average and yearly integral intensity of IHFACs. In contrast to annual variations of IHFACs polarity in the dawn/noon sectors, there were multiple periodicities in the dusk sector: annual variation during the declining phase of solar cycle and semiannual or terannual variations during the increasing and maximum phase. The dusk-side IHFACs modulations were more related with F10.7 variability compared with the dawn and noon sectors. It suggests that the dusk IHFACs is affected by the solar cycle activities.

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Development of the imaging receiver system for the SuperDARN Hokkaido East radar

*Nozomu Nishitani[1], Tomoaki Hori[1], Yoshiyuki Hamaguchi[1]

1. Institute for Space-Earth Environmental Research, Nagoya University

The Super Dual Auroral Radar Network (SuperDARN) is a network of High-Frequency (HF) radars located in the high- and mid-latitude regions of both hemispheres, operating continuously with a typical temporal resolution of 1 to 2 minutes. This resolution corresponds to the Nyquist frequency range of 4 to 8 mHz. In order to monitor any variations shorter than 1 min, such as Pc3 pulsations, the radar should choose a special beam scanning mode at the cost of the 1-min scanning period for the whole field of view.

In order to overcome this problem, several solutions have been proposed. One of them is the radar with imaging capability, which enables to sample data for multiple beam directions simultaneously. Several radars have adopted this method since 10 years ago. Meanwhile, traditional-style imaging radars adopted a costly A/D board so that the cost of building the radar system was high.

Software-Defined Radio (SDR), using a much less expensive A/D unit than the traditional A/D boards, is useful for the radar receiver system. A few imaging radars with the Universal Software Radio Peripheral (USRP), i.e., one of the SDR, are operating in the high latitude regions such as in Canada. In contrast, there is no imaging radar with the USRP in the mid-latitude region yet.

In this paper, we report on the present status and the future perspectives of an imaging receiver system that we plan to install for the SuperDARN Hokkaido East radar. We have developed a prototype (4-ch subset out of 20-ch array) of the SuperDARN imaging receiver system consisting mainly of USRP receiver units. This prototype set was attached to the SuperDARN Hokkaido East radar for testing in June-July 2020. With this 4-ch subset system, we succeeded in obtaining the data consistent with the preexisting receiver’ s data. Installation of the imaging receivers can significantly improve the spatial-temporal resolution of the radar data, and make it possible to examine several phenomena such as SAPS wave structures, Pc3 pulsations, and coseismic ionospheric disturbances, which have not been captured with sufficient spatial-temporal resolution by the preexisting receiver set.

Keywords: SuperDARN, imaging receiver

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Seasonal and longitudinal dependence of the Sub-Auroral Polarization Streams occurrence observed by the SuperDARN radars

Kento Oya[1], *Nozomu Nishitani[1], Tomoaki Hori[1], John Mike Ruohoniemi[2], William A. Bristow[3], Simon G. Shepherd[4], Bharat Kunduri[2]

1. Institute for Space-Earth Environmental Research, Nagoya University, 2. Virginia Tech Department of Electrical and Computer Engineering, 3. The Pennsylvania State University , 4. Thayer School of Engineering, Dartmouth College

We conduct a statistical study on occurrence characteristics of Sub-Auroral Polarization Streams (SAPS), using the Super Dual Auroral Radar Network (SuperDARN) data. We use six years of mid-latitude SuperDARN data and study the seasonal dependence of SAPS type flows. We identify the equatorward auroral oval boundary using the precipitating energy flux data of the National Oceanic and Atmospheric Administration (NOAA) Polar Orbiting Environmental Satellites (POES) satellites. We use only ionospheric echoes sampled in the region equatorward of this boundary. We set the following criteria to identify SAPS events: 1. the flow speed should exceed 150 m/s [Nagano et al., 2015]. 2. the flow should be directed westward (-45 deg $< \Delta \theta <$ +45 deg).

Some past studies suggested the seasonal dependence of SAPS, e.g., SAPS-like high velocity flows occur over a larger magnetic local time (MLT) extent during winter months [Koustov et al., 2006], lower velocity flows are observed more often in the summer Northern Hemisphere than in the winter Southern Hemisphere [Kunduri et al., 2012]. These results are in slight disagreement with another interhemispheric study [Parkinson et al., 2005], which showed that summer Southern Hemisphere velocities are slightly higher than in the winter Northern Hemisphere. Nevertheless, there have been few comprehensive studies on the statistics of seasonal dependence.

One of the remarkable SAPS characteristics found in the present study is that the occurrence rate in spring and autumn are generally larger than other seasons for each radar, which can be interpreted in terms of the Russel-McPherron effect (Russell & McPherron, 1973). On the other hand, we see no consistent tendency among the radars regarding the summer-winter difference of the SAPS occurrence, but the peak MLT of SAPS occurrence in summer and winter depends on the radar's location. These results are interpreted in terms of the differences in the dipole tilt angle (DTA). To the best of our knowledge, this is the first result of the SAPS occurrence rate discussed as a function of the dipole tilt angle in addition to the solar zenith angle.

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Keywords: SuperDARN, Sub-Auroral Polarization Streams (SAPS), longitudinal dependence

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Investigation of the mid-latitude ionospheric response during substorm based on magnetic and electric field observations

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Investigation of the mid-latitude ionospheric response during substorm based on magnetic and electric field observations
The purpose of this study is to obtain a more comprehensive view and understanding of the formation process of global three-dimensional current system during auroral substorms.
It is known that there are two types of current systems in the polar ionosphere: the R1-current linked to the magnetospheric convection system and the R2-current linked to the pressure gradient region in the inner magnetosphere [Iijima and Potemra, 1976, 1978]. Substorms are caused by strong plasma injection in the near-earth region. The plasma vorticities that grow at the flow edge of the plasma injection forms a substorm current wedge (SCW) system of which current closure structure is the same of the R1 current system. At the lower latitude of the SCW system, the R2-type current system develops due to the increase in plasma pressure in the inner magnetosphere. Growth of the R2-type system and the SCW system don't always match. The R2-type current system causes not only a shielding effect that weakens the ionospheric current reaching low latitudes and equatorial regions due to the growth of the SCW system, but also an over-shielding effect that sometimes causes the growth of current systems in the opposite direction. (Kikuchi et al [1996]; Nishida [1968]).
The ground magnetic field disturbances observed during substorms are not only generated by the ionospheric currents, but also by the field-aligned currents (FACs) accompanied by the growth of the SCW. In the mid- and low-latitude regions, where this composite effect is particularly large, it is difficult to determine from the magnetic field data alone whether the magnetic field variation during substorms is due to the formation of the ionospheric current system or to the remote field effect of the current wedge current system. A direct comparison of ionospheric electric and magnetic field data is essential for a better understanding of the causes of magnetic disturbances.
In this presentation, we report the results of a study of mid-latitude ionospheric variability during auroral substorm using electric field data from the HF Doppler radar and magnetic field data from SuperMag and MAGDAS installed by Kyushu University in Palatunka, Russia. The analysis period was from October 2006 to May 2007, and the number of events was 100. As an initial result, two patterns of magnetic and electric field variations were identified in the mid-latitude night side. (i) A westward electric field was observed for 30 minutes to 1 hour after the magnetic and electric field fluctuation onset on the evening side of the SCW (14 out of 20 events). (ii) W-shaped oscillations and then westward electric field fluctuations were observed for 10 minutes before and after the SCW center magnetic field fluctuation and electric field fluctuation onset (4 out of 6 events). This may indicate the growth and extinction of the FAC pat of the SCW associated with the substorm. We report the results of a detailed global verification of this fact.

Keywords: Substorm, Field aligned current, current wedge, ionospheric current

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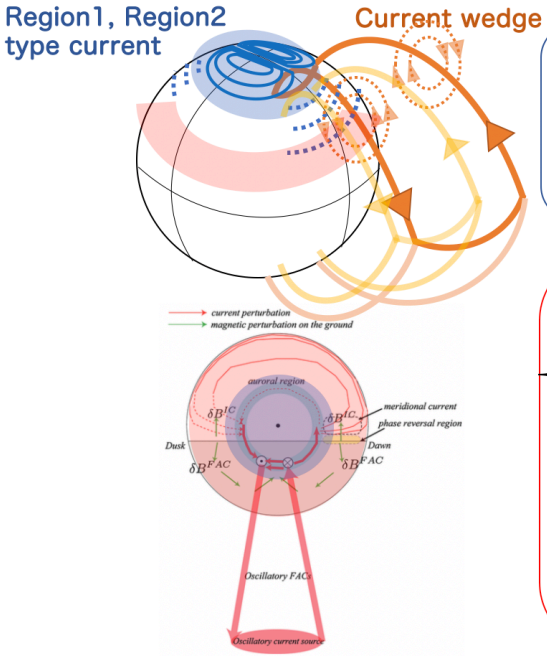
1. Magnetic field variations in polar and mid-low latitudes



@ Magnetic field variations in the polar regions

・ Just below the ionosphere electric field
・ Region 1 and Region 2 types of ionospheric currents mainly cause magnetic field variations

@ Magnetic Field Fluctuations at Mid and Low Latitudes
Ionospheric currents of Region 1 and Region 2 types
＋
Substorm current wedge

These two things complicate the magnetic field fluctuations.
→During substorms, it is difficult to isolate the magnetic field variability given by the two from the magnetic field data alone.
→I want to compare magnetic and electric field data and distinguish between the two effects.

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New results of auroral hiss observations on the ground at L=5.5 in Northern Europe

*Jyrki Manninen[1], Natalia G. Kleimenova[2,3], Yury Fedorenko[4], Olga Lebed[4], Alexander Kozlovsky[1], Alexander Nikitenko[4], Liudmila Gromova[5]

1. Sodankyla Geophysical Observatory, University of Oulu, Sodankylä, Finland, 2. Schmidt Institute of Physics of the Earth RAN, Moscow, Russia, 3. Space Research Institute RAN, Moscow, Russia, 4. Polar Geophysical Institute, Apatity, Russia, 5. Pushkov Institute of Terrestrial Magnetism, Ionosphere and Radio Wave Propagation RAN, Moscow, Russia

Auroral hiss is a well-known type of nighttime natural VLF emission with a noise-like structure generated by the Cherenkov instability of precipitating soft electrons above the ionosphere. Auroral hiss occurrence up to 39 kHz was studied in the equatorward region of the auroral oval at the Finnish station Kannuslehto (KAN, MLAT = 64.2˚N) during 11 winter months in 2015-2018. During this time interval, 98 isolated and rather powerful magnetic substorms were recorded over Scandinavia. In 93% of the substorms studied, an auroral VLF hiss was recorded at the same time as enhancement of field-aligned currents (FACs). FACs are caused by soft electron precipitation which could be a plausible source of the auroral VLF hiss generation. For the first time, it was found that auroral VLF hiss occurrence in the equatorward region of the auroral oval is a typical signature of the substorm growth phase.

Also a few examples of simultaneous auroral hiss observations at Lovozero, Russia (LOZ, MLAT = 64.2˚N) will be shown. LOZ is located at the same magnetic latitude as KAN, but 400 km to east from KAN. Simultaneous observations can be used for direction finding of auroral hiss events.

Figure presents a survey of the auroral hiss event on 23 December 2016 at 17-19 UT. From top to bottom: a) the auroral hiss spectrogram; b) the auroral keogram from Abisko; c) the auroral keogram from Sodankyla; d) the IL indicator of magnetic activity; and e) the south-west quarters of the global map (in geomagbnetic coordinate´s) of the field-aligned currents (FACs) according to the AMPERE data. Blue arrows point the time of these map of auroral hiss at KAN was accompanied by the upward FAC increasing in the premidnight sector constructions. The upward FACs are marked by red and the downward FACs, by blue. The small circles indicate the location of KAN.

Keywords: Auroral hiss, substorm, growth phase

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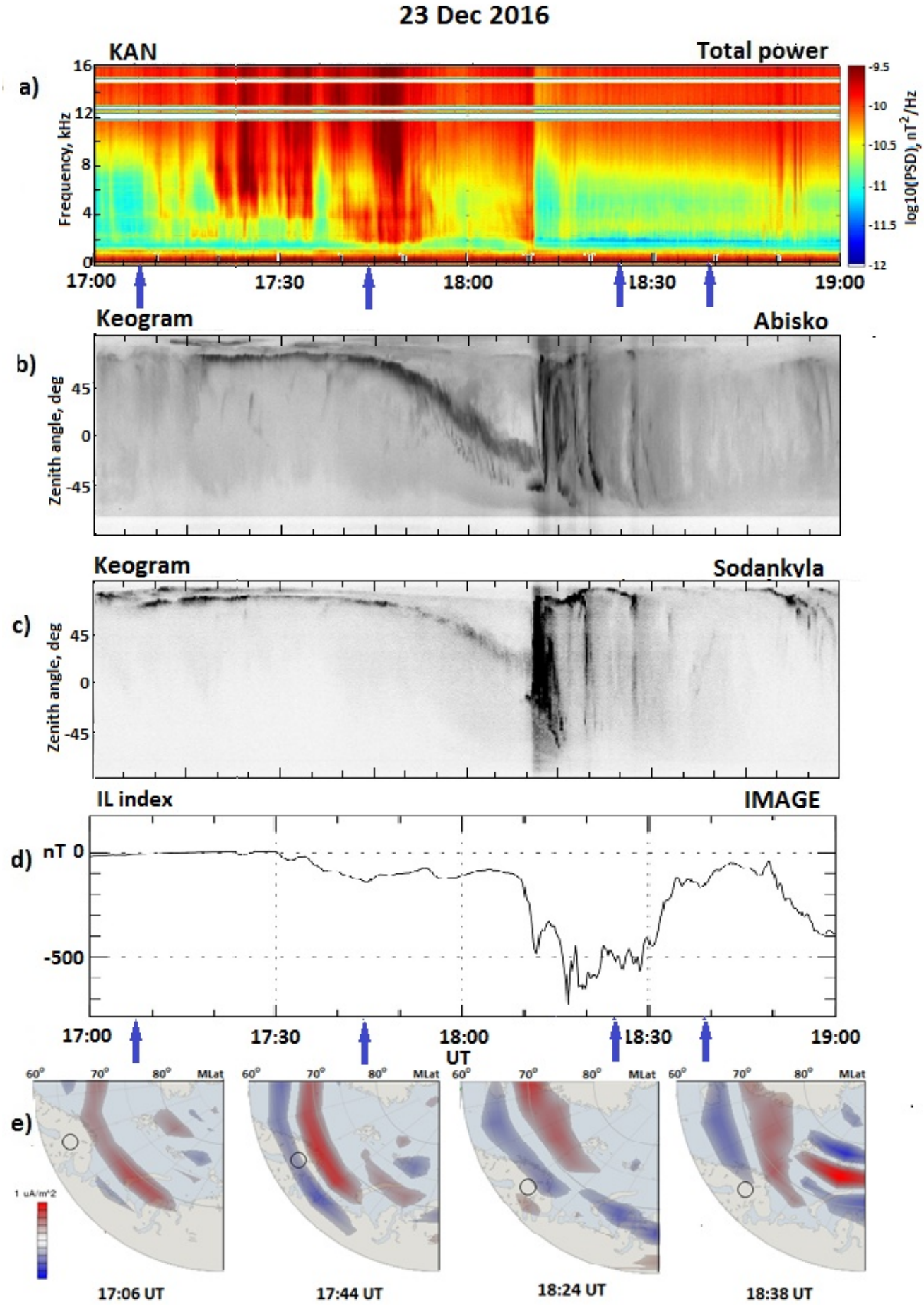

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[E] Oral | P (Space and Planetary Sciences) | P-EM Solar-Terrestrial Sciences, Space Electromagnetism & Space Environment

[P-EM09] Dynamics of Magnetosphere and Ionosphere

convener:Akiko Fujimoto(Kyushu Institute of Technology), Mitsunori Ozaki(Faculty of Electrical and Computer Engineering, Institute of Science and Engineering, Kanazawa University), Yuka Sato(Nippon Institute of Technology), Aoi Nakamizo(Applied Electromagnetic Research Institute, National Institute of Information and Communications Technology), Chairperson:Yuki Obana(Department of Engineering Science, Faculty of Engineering, Osaka Electro-Communication University), Yoshihiro Yokoyama(Department of Earth and Planetary Sciences, Graduate School of Science, Kyoto University)
Sun. Jun 6, 2021 3:30 PM - 5:00 PM Ch.05 (Zoom Room 05)

This session provides an opportunity to present recent results from satellite and ground-based observations and theoretical and simulation studies on the magnetosphere, ionosphere, and their coupling processes. We invite talks and posters discussing various phenomena related to the magnetosphere-ionosphere system: solar wind-magnetosphere interaction, magnetosphere-ionosphere convection, field-aligned current, magnetic storms/substorms, neutral-plasma interaction, ionospheric ion inflow and outflow, aurora phenomena, and so forth. Discussions on planetary and satellite ionospheres and magnetospheres, future missions and instrument developments are also welcome.

4:55 PM - 5:00 PM

[PEM09-25]Discussion

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

Sun. Jun 6, 2021 9:00 AM - 10:30 AM JST | Sun. Jun 6, 2021 12:00 AM - 1:30 AM UTC | Ch.06 Zoom Room 06

[P-EM10] Frontiers in solar physics

convener:Takaaki Yokoyama(School of Science, University of Tokyo), Shinsuke Imada(Institute for Space-Earth Environmental Research, Nagoya University), Shin Toriumi(Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency), Alphonse Sterling(NASA/MSFC), Chairperson:Shin Toriumi(Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency)

This session is for discussions on recent progress in solar and heliospheric physics, and related fields (including plasma physics and planetary physics). In 2020, we had several important milestones in this area. The Daniel K. Inouye Solar Telescope (DKIST operated by NSO) has taken its first image and its call for proposals in observation cycle 1 was announced. The Solar Orbiter was launched by ESAunder collaboration with NASA and released the first data to the public. In Japan, SOLAR-C(EUVST) was selected at ISAS/JAXA as 4th competitively-chosen middle-class mission. We will discuss what observational and theoretical studies achieved in the recent years and what should be addressed next in the coming mid-2020s. We welcome contributions not only by solar researchers but also those from related fields on observations, theories, numerical works, and experiments.

9:00 AM - 9:01 AM JST | 12:00 AM - 12:01 AM UTC

[PEM10-01] Introduction

9:01 AM - 9:23 AM JST | 12:01 AM - 12:23 AM UTC

[PEM10-02] Sun-to-Earth MHD Simulations of Geo-Effective CMEs

★Invited Papers

*Tibor Torok[1] (1.Predictive Science Inc.)

9:23 AM - 9:45 AM JST | 12:23 AM - 12:45 AM UTC

[PEM10-03] How To Trigger the Solar Flares?

★Invited Papers

*Yumi Bamba[1] (1.Nagoya University)

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

[PEM10-04] The Source Locations of Major Flares and CMEs in the Emerging Active Regions

*Liu Lijuan[1], Wang Yuming[2], Zhou Zhenjun[1] (1.School of Atmospheric Sciences, Sun Yat-sen University, Zhuhai, Guangdong, 519082, China, 2.Department of Geophysics and Planetary Sciences, University of Science and Technology of China, Hefei, Anhui, 230026, China)

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

[PEM10-05] Evaluation of horizontal flow velocity at the solar surface with machine learning and numerical simulation

*Hiroyuki Masaki[1], Hideyuki Hotta[2] (1.Graduate School of Science and Engineering, Chiba University, 2.Chiba University)

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

[PEM10-06] Satellite mission: *PhoENiX* (Physics of Energetic and Non-thermal plasmas in the X (= magnetic reconnection) region)

*Noriyuki Narukage[1], Mitsuo Oka[2], Yasushi Fukazawa[3], Keiichi Matsuzaki[4], Shin Watanabe[4], Taro Sakao[4], Kouichi Hagino[5], Ikuyuki Mitsuishi[6], Tsunefumi Mizuno[3], Iku Shinohara[4], Masumi Shimojo[1], Shinsuke Takasao[7], Tomoko Kawate[8], Takafumi Kaneko[6], Hiroshi Tanabe[9], Munetaka UENO[4], Tadayuki Takahashi[10], Takeshi Takashima[4], Masayuki Ohta[4] (1.National Astronomical Observatory of Japan, 2.University of California, Berkeley, 3.Hiroshima University, 4.Japan Aerospace Exploration Agency,

5.Tokyo University of Science, 6.Nagoya University, 7.Osaka University, 8.National Institute for Fusion Science, 9.The University of Tokyo, 10.Kavli Institute for the Physics and Mathematics of the Universe)

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

[P-EM10] Frontiers in solar physics

convener:Takaaki Yokoyama(School of Science, University of Tokyo), Shinsuke Imada(Institute for Space-Earth Environmental Research, Nagoya University), Shin Toriumi(Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency), Alphonse Sterling(NASA/MSFC), Chairperson:Shin Toriumi(Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency)
Sun. Jun 6, 2021 9:00 AM - 10:30 AM Ch.06 (Zoom Room 06)
This session is for discussions on recent progress in solar and heliospheric physics, and related fields (including plasma physics and planetary physics). In 2020, we had several important milestones in this area. The Daniel K. Inouye Solar Telescope (DKIST operated by NSO) has taken its first image and its call for proposals in observation cycle 1 was announced. The Solar Orbiter was launched by ESAunder collaboration with NASA and released the first data to the public. In Japan, SOLAR-C(EUVST) was selected at ISAS/JAXA as 4th competitively-chosen middle-class mission. We will discuss what observational and theoretical studies achieved in the recent years and what should be addressed next in the coming mid-2020s. We welcome contributions not only by solar researchers but also those from related fields on observations, theories, numerical works, and experiments.

9:00 AM - 9:01 AM

[PEM10-01]Introduction

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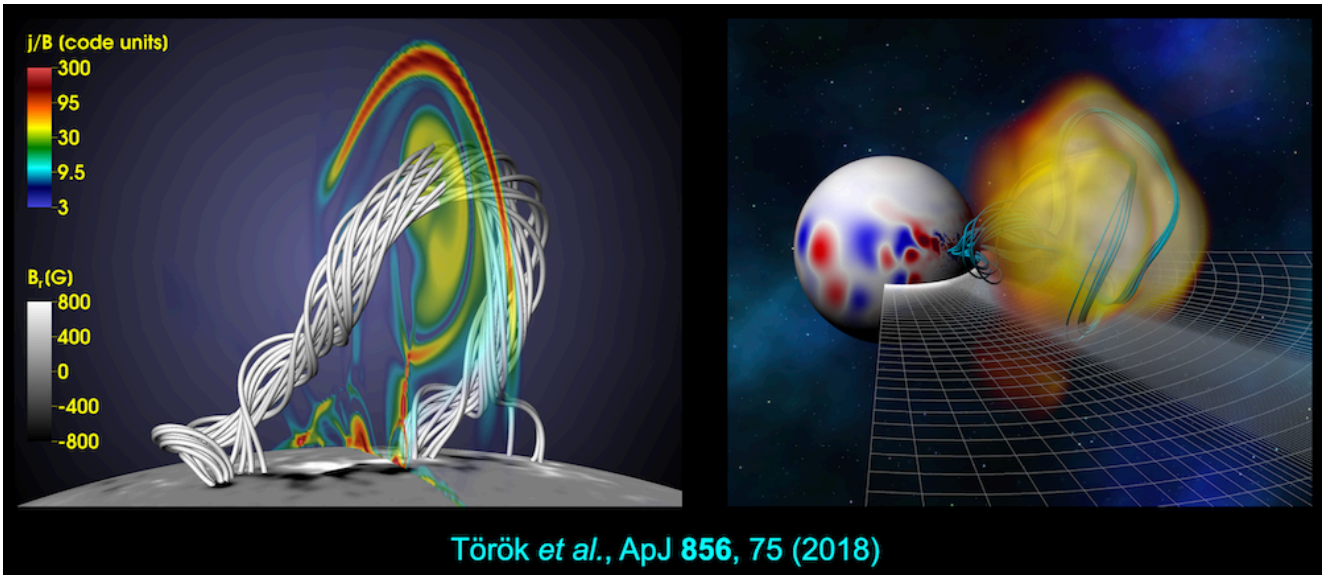
Sun-to-Earth MHD Simulations of Geo-Effective CMEs

*Tibor Torok[1]

1. Predictive Science Inc.

Coronal mass ejections (CMEs) are the main driver of space-weather disturbances in the terrestrial magnetosphere. Predicting the impact of CMEs before they arrive at Earth is one of the main challenges of solar and heliospheric physics. A candidate tool for this purpose are numerical simulations. State-of-the-art magnetohydrodynamic (MHD) simulations are capable of modeling CMEs all the way from Sun to Earth but computationally still too demanding to be used for real-time modeling. Presently, only a simplified model (WAS-ENLIL) is used for operational space-weather forecast. However, given the continuous increase of computing power, more sophisticated models may become available for this purpose in the near future, and first attempts are currently made to prepare such models for operational use. A specific task at hand is to evaluate their accuracy in reproducing in-situ measurements at Earth. In this presentation, I will discuss the predictive capabilities and limitations of state-of-the-art CME simulations. As an example, I will present a Sun-to-Earth simulation of the well-known 14 July 2000 "Bastille-Day" event, which produced a very strong geomagnetic storm. I will also briefly discuss a recent application of the simulation for a modeling of the solar particle event (SPE) associated with the eruption.

Keywords: Sun, Coronal Mass Ejections, Space Weather, Numerical Simulations, Magnetohydrodynamics



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How To Trigger the Solar Flares?

*Yumi Bamba[1]

1. Nagoya University

Solar flares and coronal mass ejections, the largest energy-releasing events in the current solar system, are an excellent manifestation of ceaseless magnetohydrodynamic activity of the Sun. In particular, the question of when the flares occur and how they are triggered is not only crucial from the viewpoint of scientific curiosity but also directly linked to the space-weather forecasting, which is now increasingly demanded in tandem with ever-growing reliance of the modern society on information technology. To challenge this conundrum, it is of paramount importance to leverage state-of-the-art observational capabilities, such as spectroscopy in a variety of wavelength domains and polarimetry to derive the detailed magnetic information, and combine the observables with cutting-edge theoretical models that allow for exploration of coronal evolutions including the nonlinear force-free field extrapolations. In the last decade, we have seen a substantial improvement in understanding of flare-triggering mechanisms, facilitated by the development in the realm of both observation and theory. In this review, we first provide an overview of the status quo of flare-related studies. Then, we cast a spotlight on recent advancements by presenting some of our achievements, focusing especially on the series of analysis of the representative flares in Cycle 24 that unveil the physical mechanisms behind the photospheric evolution of the triggering field and its atmospheric response. Finally, the review concludes with discussing the future perspective.

Keywords: Solar flares, Coronal mass ejections, Magnetic fields

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The Source Locations of Major Flares and CMEs in the Emerging Active Regions

*Liu Lijuan[1], Wang Yuming[2], Zhou Zhenjun[1]

1. School of Atmospheric Sciences, Sun Yat-sen University, Zhuhai, Guangdong, 519082, China, 2. Department of Geophysics and Planetary Sciences, University of Science and Technology of China, Hefei, Anhui, 230026, China

Major flares and coronal mass ejections (CMEs) tend to originate from the compact polarity inversion lines (PILs) in the solar active regions (ARs). Recently, a scenario named as "collisional shearing" is proposed by Chintzoglou, et. al, 2019 to explain the phenomenon, which suggests that the collision between different emerging bipoles is able to form the compact PIL, driving the shearing and flux cancellation that are responsible to the subsequent large activities. In this work, through tracking the evolution of 19 emerging ARs from their birth until they produce the first major flares or CMEs, we investigated the source PILs of the activities, i.e., the active PILs, to explore the generality of "collisional shearing". We find that none of the active PILs is the self PIL (sPIL) of a single bipole. We further find that 11 eruptions originate from the collisional PILs (cPILs) formed due to the collision between different bipoles, 6 from the conjoined systems of sPIL and cPIL, and 2 from the conjoined systems of sPIL and ePIL (external PIL between the AR and the nearby preexisting polarities). Collision accompanied by shearing and flux cancellation is found developing at all PILs prior to the eruptions, with 84% (16/19) cases having collisional length longer than 18~Mm. Moreover, we find that the magnitude of the flares is positively correlated with the collisional length of the active PILs, indicating that the intenser activities tend to originate from the PILs with severer collision. The results suggest that the "collisional shearing", i.e., bipole-bipole interaction during the flux emergence is a common process in driving the major activities in emerging ARs.

Keywords: Sun, Solar magnetic field, Solar active region, Flare, Coronal mass ejections

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Evaluation of horizontal flow velocity at the solar surface with machine learning and numerical simulation

*Hiroyuki Masaki[1], Hideyuki Hotta[2]

1. Graduate School of Science and Engineering, Chiba University, 2. Chiba University

We develop a method to predict the horizontal velocity on the solar surface from snapshots of solar radiative intensity and vertical velocity using neural networks. The motion of solar plasma is related to many phenomena such as sunspot formation and flares. We can observe the line-of-sight (LOS) velocity field with the Doppler effect. In contrast, the velocity perpendicular to LOS is difficult to observe. Some methods estimate the horizontal velocity field by tracking the displacement of features on the solar surface, which require several images. Methods with a neural network for extracting the displacement are also proposed, but these methods also require images at two different times.

On the other hand, many numerical magnetohydrodynamic (MHD) simulations are carried out to explore the solar convection and magnetic field. They can reproduce the phenomena inside the sun with high accuracy thanks to recent improvements in computer performance. In this study, we develop a code for predicting the horizontal velocity field from the corresponding intensity and vertical velocity field by combining numerical MHD simulation and neural networks. We train the neural network using the results of our own MHD simulations. The networks output two components of the horizontal velocity field with the input of corresponding intensity and the vertical velocity field. The network is trained efficiently since we only use the convolutional neural network. As a result, the networks achieve a high correlation coefficient of 0.9 between the predicted and simulated velocity field. The horizontal velocity field can also be predicted from the image with any number of pixels.

Keywords: granulation

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Satellite mission: *PhoENiX* (Physics of Energetic and Non-thermal plasmas in the X (= magnetic reconnection) region)

*Noriyuki Narukage[1], Mitsuo Oka[2], Yasushi Fukazawa[3], Keiichi Matsuzaki[4], Shin Watanabe[4], Taro Sakao[4], Kouichi Hagino[5], Ikuyuki Mitsuishi[6], Tsunefumi Mizuno[3], Iku Shinohara[4], Masumi Shimojo[1], Shinsuke Takasao[7], Tomoko Kawate[8], Takafumi Kaneko[6], Hiroshi Tanabe[9], Munetaka UENO[4], Tadayuki Takahashi[10], Takeshi Takashima[4], Masayuki Ohta[4]

1. National Astronomical Observatory of Japan, 2. University of California, Berkeley, 3. Hiroshima University, 4. Japan Aerospace Exploration Agency, 5. Tokyo University of Science, 6. Nagoya University, 7. Osaka University, 8. National Institute for Fusion Science, 9. The University of Tokyo, 10. Kavli Institute for the Physics and Mathematics of the Universe

We are planning a new solar satellite mission, "*PhoENiX*", for understanding of particle acceleration during magnetic reconnection. The main observation targets of this mission are solar flares. The scientific objectives of this mission are (1) to identify particle acceleration sites, (2) to investigate temporal evolution of particle acceleration, and (3) to characterize properties of accelerated particles, during solar flares. In order to achieve these science objectives, the *PhoENiX* satellite will obtain the information about individual X-ray and gamma-ray photons (i.e., position, time, energy and polarization) with three instruments of (1) photon-counting type Soft X-ray focusing Imaging-Spectrometer (SXIS; up to ~10 keV), (2) photon-counting type Hard X-ray focusing Imaging-Spectrometer (HXIS; up to ~30 keV), and (3) Soft Gamma-ray Spectro-Polarimeter (SGSP; spectroscopy is available in the energy range of from > 20 keV to < 600 keV; spectropolarimetry is available from >60 keV to < 600 keV). We plan to realize *PhoENiX* satellite in the Solar Cycle 26 (in 2030s). We emphasize that, thanks to above new observational approach for solar flares, *PhoENiX* is the first mission that can survey "accelerating" particles in the magnetic reconnection system. To maximize the scientific outputs from the new observations by *PhoENiX*, we are also promoting the sounding rocket project *FOXSI-4* (that aims to observe a solar flare in 2024) as a demonstration of *PhoENiX* and developing sophisticated numerical approach and interdisciplinary approach. In this presentation, we will introduce the *PhoENiX* mission and our trinity (observational, numerical, and interdisciplinary) approaches.

Keywords: particle acceleration, magnetic reconnection, solar flare, imaging spectroscopy in X-rays, PhoENiX, FOXSI-4

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

Sun. Jun 6, 2021 10:45 AM - 12:14 PM JST | Sun. Jun 6, 2021 1:45 AM - 3:14 AM UTC | Ch.06 Zoom Room 06

[P-EM10] Frontiers in solar physics

convener:Takaaki Yokoyama(School of Science, University of Tokyo), Shinsuke Imada(Institute for Space-Earth Environmental Research, Nagoya University), Shin Toriumi(Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency), Alphonse Sterling(NASA/MSFC), Chairperson:Takaaki Yokoyama(School of Science, University of Tokyo)

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10:45 AM - 11:07 AM JST | 1:45 AM - 2:07 AM UTC

[PEM10-07] Spectroscopic and photometric observations of superflares and filament eruption on cool stars

★Invited Papers

*Kosuke Namekata[1,2], Hiroyuki Maehara[2], Ryo Sasaki[3], Hiroki Kawai[3], Yuta Notsu[4], Adam F. Kowalski[4], Joel C. Allred[5], Wataru Iwakiri[3], Yohko Tsuboi[3], Satoshi Honda[6], Soshi Okamoto[1], Kiyoshi Ichimoto[1], Daisaku Nogami[1], Kazunari Shibata[1], Katsuhiro L. Murata[7], Masafumi Niwano[7], Kazuki Shiraishi[7], Ryo Adachi[7], Kota Iida[7], Motoki Oeda[7], Miyako Tozuka[6], Noriyuki Katoh[6], Hiroki Onozuka[6], Keizuke Isogai[1], Mariko Kimura[8], Naoto Kojiguchi[1], Yasuyuki Wakamatsu[1], Yusuke Tampo[1], Futa Ogawa[7], Jun Takahashi[6], Takako T. Ishii[1], Masaki Takayama[6], Tomohito Ohshima[6], Tomoki Saito[6] (1.Kyoto Univ., 2.NAOJ, 3.Chuo Univ., 4.Colorado Univ., 5.NASA, 6.Univ. of Hyogo, 7.Tokyo Institute of Technology, 8.RIKEN)

11:07 AM - 11:29 AM JST | 2:07 AM - 2:29 AM UTC

[PEM10-08] The Solar Orbiter mission – Exploring the Sun and heliosphere

★Invited Papers

*Daniel Mueller[1] (1.European Space Agency)

11:29 AM - 11:44 AM JST | 2:29 AM - 2:44 AM UTC

[PEM10-09] Current Status of the Solar-C_EUVST Mission

*Shinsuke Imada[1], Toshifumi Shimizu[2], Tomoko Kawate[2], Shin Toriumi[2], Yukio Katsukawa[3], Masahito Kubo[3], Hirohisa Hara[3], Yoshinori Suematsu[3], Kiyoshi Ichimoto[4], Ayumi Asai[4], Kyoko Watanabe[6], Takaaki Yokoyama[5], Akiko Tei[2], Harry Warren[7], David Long[8], Louise Harra[8], Luca Teriaca[9], Sarah Matthews[8], Vincenzo Andrette[10], Frederic Auchere[11] (1.Institute for Space-Earth Environmental Research, Nagoya University, 2.ISAS, 3.NAOJ, 4.Kyoto University, 5.University of Tokyo, 6.NDA, 7.NRL, 8.UCL, 9.MPS, 10.Istituto Nazionale di Astrofisica,, 11.IAS)

11:44 AM - 11:59 AM JST | 2:44 AM - 2:59 AM UTC

[PEM10-10] Solar-C(EUVST)/SoSpIM development status and scientific studies

*Kyoko Watanabe[1], Louise Harra[2], Shinsuke Imada[3], Tomoko Kawate[4], Hirohisa Hara[5], Toshifumi Shimizu[6], Yoshizumi Miyoshi[3], Nozomu Nishitani[3], Tomoaki Hori[3], Akimasa Ieda[3], Toshiki Kawai[3], Hidekatsu Jin[7], Chihiro Tao[7], Shohei Nishimoto[1] (1.National Defense Academy of Japan, 2.Physical Meteorological Observatory in Davos, World Radiation Center, 3.Institute for Space-Earth Environmental Research, Nagoya University, 4.National Institute for Fusion Science, National Institutes of Natural

Sciences, 5.National Astronomical Observatory of Japan, National Institutes of Natural Sciences, 6.Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency, 7.National Institute of Information and Communications Technology)

11:59 AM - 12:14 PM JST | 2:59 AM - 3:14 AM UTC

[PEM10-11] Cross-disciplinary study on heating, transport, and turbulence dynamics in solar/astrophysical and fusion/laboratory plasmas: SoLaBo-X

*Motoki Nakata[1], Ryohtaroh T Ishikawa[4], Yukio Katsukawa[2], Yohei Masada[5], Tatsuya Kobayashi[1], Munehito Shoda[2], Shinsuke Imada[3], Shin Toriumi[6], Kenichi Nagaoka[1], SoLaBo-X project[1,2] (1.National Institute for Fusion Science , 2.National Astronomical Observatory of Japan, 3.Institute for Space-Earth Environmental Research , 4.The Graduate University for Advanced Studies, 5.Aichi University of Education, 6.Japan Aerospace Exploration Agency Institute of Space and Astronautical Science)

Spectroscopic and photometric observations of superflares and filament eruption on cool stars

*Kosuke Namekata[1,2], Hiroyuki Maehara[2], Ryo Sasaki[3], Hiroki Kawai[3], Yuta Notsu[4], Adam F. Kowalski[4], Joel C. Allred[5], Wataru Iwakiri[3], Yohko Tsuboi[3], Satoshi Honda[6], Soshi Okamoto[1], Kiyoshi Ichimoto[1], Daisaku Nogami[1], Kazunari Shibata[1], Katsuhiro L. Murata[7], Masafumi Niwano[7], Kazuki Shiraishi[7], Ryo Adachi[7], Kota Iida[7], Motoki Oeda[7], Miyako Tozuka[6], Noriyuki Katoh[6], Hiroki Onozuka[6], Keizuke Isogai[1], Mariko Kimura[8], Naoto Kojiguchi[1], Yasuyuki Wakamatsu[1], Yusuke Tampo[1], Futa Ogawa[7], Jun Takahashi[6], Takako T. Ishii[1], Masaki Takayama[6], Tomohito Ohshima[6], Tomoki Saito[6]

1. Kyoto Univ., 2. NAOJ, 3. Chuo Univ., 4. Colorado Univ., 5. NASA, 6. Univ. of Hyogo, 7. Tokyo Institute of Technology, 8. RIKEN

Solar and stellar flares are caused by the release of magnetic energy on the surfaces. Solar flares produce strong emissions from radio to X-rays and mass ejections (known as filament eruptions or coronal mass ejections), which often affect the Earth's environment. In the case of stars other than the Sun, very large flares called `superflares' (more than 10 times the most energetic solar flares) have been observed not only on M-dwarfs and binaries but also on solar-type stars (G-type main-sequence stars). These can produce much larger X-ray/UV emission and huge mass ejection than those of solar flares, severely affecting the exoplanet habitability. Therefore, stellar superflares are getting more and more attention in terms of the exoplanet habitability as well as possible extreme space weather events on the current Sun (Maehara et al. 2012, Airapetian et al. 2020). The gigantic superflares are expected to share the same physics as solar flares, but the properties are not well known mostly because of the difficulty in observations.

Recently, we have started monitoring observations of stellar flares with our new 3.8m Seimei Telescope at Okayama Observatory in Japan (the largest optical and infrared telescope in East Asia), simultaneously with space/ground optical photometry (e.g. TESS). In this talk, I introduce interesting properties of the observed superflares on a solar-type star (G-dwarf) and an M-dwarf. First, we detected two superflares on an active young solar-type star named EK Draconis. Interestingly, one of them shows clear evidence for a stellar filament eruption associated with a superflare. After the superflare with radiated energy of 2.0×10^{33} erg, a blue-shifted Hα absorption component with a velocity of -510 km s^{-1} appeared. The temporal changes in the spectra greatly resemble those of solar filament eruptions and the erupted mass of 1.1×10^{18} g corresponds to those predicted from solar flare-energy/CME-mass relation. These discoveries imply that a huge stellar filament eruption occurred possibly in the same way as solar ones (Namekata et al. submitted). This fast eruption can lead to a coronal mass ejection, which enables further studies to estimate its impacts on planets and stellar mass loss.

We also detected one superflare on an active M-dwarf named AD Leonis. The time-resolved Hα line of the superflare shows symmetric line broadenings of 14 Åin association with the large white-light flare (2.0×10^{33} erg). The line broadening indicates very high electron density in the flaring chromosphere (cf. pressure or opacity broadening). The dense regions can be generated by flare heating of non-thermal high-energy particles that can penetrate into the lower chromosphere. We modeled the flaring M-dwarf atmosphere with the RADYN code (e.g. Kowalski et al. 2017) and found that the energy injection of high-energy particles with the flux of 10^{12} erg/s/cm^2 can well reproduce the observed Hα spectra (Namekata et al. 2020b, PASJ). The energy flux is much higher than the solar ones, which indicates the very efficient particle acceleration in the superflare. On the other hand, the superflare on M-dwarf and

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another superflare on G-dwarf did not show any evidence of stellar filament eruptions. This may indicate the flare/mass-eruption association rates are not 100 % in stellar flares, although it should be noted that our detection is limited to the line-of-sight motions. Our studies provided how to investigate stellar mass eruption and high energy particles on stellar flares with the help of solar physics, and further solar-stellar connection will deepen our understanding of extreme events not only on active stars but also on the Sun.

Keywords: stellar flares, superflares, stellar mass ejection, Seimei telescope, optical spectroscopic observations

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The Solar Orbiter mission –Exploring the Sun and heliosphere

*Daniel Mueller[1]

1. European Space Agency

Solar Orbiter, launched on 10 February 2020, is a space mission of international collaboration between ESA and NASA. It is exploring the linkage between the Sun and the heliosphere and has started to collect unique data at solar distances down to 0.49 au. By ultimately approaching as close as 0.28 au, Solar Orbiter will view the Sun with very high spatial resolution and combine this with in-situ measurements of the surrounding heliosphere. Over the course of the mission, the highly elliptical orbit will get progressively more inclined to the ecliptic plane. Thanks to this new perspective, Solar Orbiter will deliver images and comprehensive data of the unexplored Sun’ s polar regions and the side of the Sun not visible from Earth. This talk will highlight first science results from Solar Orbiter and provide a mission status update.

Keywords: the Sun, space mission

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Current Status of the Solar-C_EUVST Mission

*Shinsuke Imada[1], Toshifumi Shimizu[2], Tomoko Kawate[2], Shin Toriumi[2], Yukio Katsukawa[3], Masahito Kubo[3], Hirohisa Hara[3], Yoshinori Suematsu[3], Kiyoshi Ichimoto[4], Ayumi Asai[4], Kyoko Watanabe[6], Takaaki Yokoyama[5], Akiko Tei[2], Harry Warren[7], David Long[8], Louise Harra[8], Luca Teriaca[9], Sarah Matthews[8], Vincenzo Andrette[10], Frederic Auchere[11]

1. Institute for Space-Earth Environmental Research, Nagoya University, 2. ISAS, 3. NAOJ, 4. Kyoto University, 5. University of Tokyo, 6. NDA, 7. NRL, 8. UCL, 9. MPS, 10. Istituto Nazionale di Astrofisica,, 11. IAS

Solar-C_EUVST (EUV High-Throughput Spectroscopic Telescope) is designed to comprehensively understand the energy and mass transfer from the solar surface to the solar corona and interplanetary space, and to investigate the elementary processes that take place universally in cosmic plasmas. As a fundamental step towards answering how the plasma universe is created and evolves, and how the Sun influences the Earth and other planets in our solar system, the proposed mission is designed to comprehensively understand how mass and energy are transferred throughout the solar atmosphere. Understanding the solar atmosphere, which connects to the heliosphere via radiation, the solar wind and coronal mass ejections, and energetic particles is pivotal for establishing the conditions for life and habitability in the solar system.

The two primary science objectives for Solar-C_EUVST are : I) Understand how fundamental processes lead to the formation of the solar atmosphere and the solar wind, II) Understand how the solar atmosphere becomes unstable, releasing the energy that drives solar flares and eruptions. Solar-C_EUVST will, A) seamlessly observe all the temperature regimes of the solar atmosphere from the chromosphere to the corona at the same time, B) resolve elemental structures of the solar atmosphere with high spatial resolution and cadence to track their evolution, and C) obtain spectroscopic information on the dynamics of elementary processes taking place in the solar atmosphere.

In this talk, we will first discuss the science target of the Solar-C_EUVST, and then discuss the current status of the Solar-C_EUVST mission.

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Solar-C(EUVST)/SoSpIM development status and scientific studies

*Kyoko Watanabe[1], Louise Harra[2], Shinsuke Imada[3], Tomoko Kawate[4], Hirohisa Hara[5], Toshifumi Shimizu[6], Yoshizumi Miyoshi[3], Nozomu Nishitani[3], Tomoaki Hori[3], Akimasa Ieda[3], Toshiki Kawai[3], Hidekatsu Jin[7], Chihiro Tao[7], Shohei Nishimoto[1]

1. National Defense Academy of Japan, 2. Physical Meteorological Observatory in Davos, World Radiation Center, 3. Institute for Space-Earth Environmental Research, Nagoya University, 4. National Institute for Fusion Science, National Institutes of Natural Sciences, 5. National Astronomical Observatory of Japan, National Institutes of Natural Sciences, 6. Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency, 7. National Institute of Information and Communications Technology

The Solar Spectral Irradiance Monitor (SoSpIM) has been developed by the Physical Meteorological Observatory in Davos World Radiation Center (PMOD/WRC) in Switzerland to be installed on the Solar-C(EUVST), the next solar observation satellite.

SoSpIM has two observation wavelength bands (170-215Å, 1115-1275Å) that are also covered by Solar-C(EUVST). By having a redundant system with three independent channels for each wavelength band, the instrument can monitor the degradation and contamination of Solar-C(EUVST). SoSpIM is expected to be used for calibration of the Solar-C(EUVST).

The extreme ultraviolet (EUV) emissions observed by SoSpIM play a main role in controlling the composition of the Earth's upper atmosphere. Both wavelength bands are mainly absorbed in the thermosphere and ionosphere, which are usually formed at altitudes > 80 km, and are thought to change the composition of the Earth's atmosphere around this altitude. In particular, it is known that sudden fluctuations in EUV emissions due to solar flares greatly change the composition and height profile of the ionosphere, causing space weather phenomena such as communication failures. Therefore, we set up the SoSpIM science team to study not only solar flare physics, but also discuss what kind of space weather research is feasible using SoSpIM data.

In this presentation, we will report on the current development status of SoSpIM and the scientific topics considered to be contributed by SoSpIM data.

Keywords: Solar-C(EUVST), Irradiance Monitor, Space Weather

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Cross-disciplinary study on heating, transport, and turbulence dynamics in solar/astrophysical and fusion/laboratory plasmas: SoLaBo-X

*Motoki Nakata[1], Ryohtaroh T Ishikawa[4], Yukio Katsukawa[2], Yohei Masada[5], Tatsuya Kobayashi[1], Munehito Shoda[2], Shinsuke Imada[3], Shin Toriumi[6], Kenichi Nagaoka[1], SoLaBo-X project[1,2]

1. National Institute for Fusion Science , 2. National Astronomical Observatory of Japan, 3. Institute for Space-Earth Environmental Research , 4. The Graduate University for Advanced Studies, 5. Aichi University of Education, 6. Japan Aerospace Exploration Agency Institute of Space and Astronautical Science

A cross-disciplinary research activity for solar/astrophysical and fusion/laboratory plasmas “SoLaBo-X (Solar + Laboratory + Cross-disciplinary)” is presented. Multi-scale interactions and the energy transfer processes among the microscopic fluctuations and the macroscopic structures are key ingredients to elucidate long-standing issues, e.g., solar coronal heating, solar wind accelerations, and turbulence suppressions by spontaneously generated zonal flows in fusion plasmas. Beyond large difference of the mean plasma parameters, our joint-study project focuses on the turbulence dynamics and associated heating and transport processes in solar and magnetically confined plasmas. Two major directions have been specified, i.e., (1)Energy transfer analyses based on the higher order turbulence correlations in multi-component turbulent fields, and (2)Deep-learning-assisted fast and accurate evaluations/predictions of the spatio-temporal structures in the turbulent fields. In these directions, several research topics have been addressed: (i)Visualization experiments and the image analysis of electrically-driven turbulent convections in relevance to the dynamics in the solar tachocline, (ii)Statistical analysis and modeling of entropy-gradient-driven(local) and cooling-driven(nonlocal) turbulence in the solar convection zone, (iii)Multi-scale convolutional neural network modeling for the fast predictions of hardly-observable turbulence fields(e.g., horizontal velocity and/or magnetic fields, etc.) from the observables(e.g., continuum intensity and/or vertical velocity, etc.), and (iv)Extended modeling of the electron parallel energy transport and the experimental verification in a linear plasma device with the direct measurement of the electron energy distribution function.

Keywords: turbulence , solar plasmas , fusion plasmas , cross-disciplinary study

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[E] Oral | P (Space and Planetary Sciences)：P-AE Astronomy & Extrasolar Bodies

Sun. Jun 6, 2021 1:45 PM - 3:15 PM JST | Sun. Jun 6, 2021 4:45 AM - 6:15 AM UTC | Ch.06 Zoom Room 06

[P-AE16] Exoplanets

convener:Masahiro Ikoma(Division of Science, National Astronomical Observatory of Japan), Norio Narita(The University of Tokyo), Yuka Fujii(National Astronomical Observatory of Japan), Chairperson:Yuka Fujii(National Astronomical Observatory of Japan)

Exoplanetary science, which began with the discovery of a hot Jupiter in 1995, reached a significant turning point by the detection of countless super-Earths by the Kepler space telescope. In 2018, the new space telescope TESS was launched to conduct an extensive survey of exoplanets orbiting nearby bright stars, opening a new era of characterization of exoplanet atmospheres. Moreover, recent observations have identified a growing number of terrestrial planets in the so-called habitable zone. While exoplanets have been targeted mainly for astronomy until recently, it would be fair to say that Earth and planetary science is finally becoming a research field to make a central contribution. This session aims at allowing participants to share their research results and new ideas regarding exoplanets and also inform the current status of their projects. Exoplanet science is a growing, interdisciplinary research field. We welcome participants from various fields.

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

[PAE16-01] Exploring New Worlds: An Integrative, Probabilistic Analysis of Nearby Exoplanets and Exoplanetary Systems

★Invited Papers

*Daniel Apai[1] (1.The University of Arizona)

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

[PAE16-02] Global climate modeling of TRAPPIST-1e using MIROC for the model intercomparison

*Takeshi Kuroda[1], Yujie Zou[1,2], Arihiro Kamada[1], Takanori Kodama[2], Naoki Terada[1] (1.Department of Geophysics, Tohoku University, 2.Komaba Institute for Science, The University of Tokyo)

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

[PAE16-03] Global Mapping of the Surface Composition on an Exo-Earth using Sparse Modeling

*Atsuki Kuwata[1], Hajime Kawahara[1], Masataka Aizawa[2], Takayuki Kotani[3,4,5], Motohide Tamura[1,3,4] (1.The University of Tokyo, 2.Tsung-Dao Lee Institute, 3.Astrobiology center, 4.National Astronomical Observatory of Japan, 5.University for Advanced Studies (SOKENDAI))

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

[PAE16-04] Search for Extra-terrestrial Mother Planets Catalogue for influence of stellar activities on the extraplanetary system.

*Yosuke Alexandre Yamashiki[1], Hiroyuki Maehara[2], Vladimir Airapetian[3], Yuta Notsu[6], Kosuke Namekata[4], Riko Shimizu[5], Nami Kimura[1], Tatsuhiko Sato[7], Takanori Sasaki[4] (1.Earth & Planetary Water Resources Assessment Laboratory Graduate School of Advanced Integrated Studies in Human Survivability Kyoto University, 2.National Astronomical Observatory of Japan, 3.NASA's Goddard Space Flight Center, 4.Graduate School of Science, Kyoto University, 5.Faculty of Science, Kyoto University, 6.University of Colorado, 7.Japan Atomic Energy Agency)

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

[PAE16-05] Observational implications of atmospheric and orbital evolution of super-Earths

*Naho Fujita[1], Yasunori Hori[2,3], Takanori Sasaki[1] (1.Kyoto University, 2.Astrobiology Center, 3.National Astronomical Observatory of Japan)

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

[PAE16-06] Effects of H_2 pumping on hot Jupiter's atmospheric escape

*Hiroto Mitani[1], Riouhei Nakatani[2], Naoki Yoshida[1] (1.The University of Tokyo, 2.RIKEN)

Exploring New Worlds: An Integrative, Probabilistic Analysis of Nearby Exoplanets and Exoplanetary Systems

*Daniel Apai[1]

1. The University of Arizona

The number of known exoplanets is growing rapidly, opening a new era in astronomy, planetary science, and astrobiology. Yet, the detailed characterization of individual —and likely very complex —worlds will remain challenging: Even with future, ambitious space missions only limited information can be gained about a modest number of parameters. Some properties that likely impact the potential for habitability will remain not directly observable. While measurements of individual exoplanets and systems will be incomplete and will often carry significant uncertainties, our understanding of the exoplanet population and planet formation/evolution pathways deepens, opening an opportunity to enhance our interpretation of measurements of individual planets and systems.

In this talk I will describe a statistical framework that combines necessarily incomplete and somewhat uncertain measurements of individual planets and planetary systems with population-level statistical information (from exoplanet demographics and planet formation/evolution models), to provide a statistical, probabilistic assessment of nearby planetary systems. I will show how this approach can successfully predict the presence and properties of yet-undiscovered worlds in nearby multi-planet systems, such as tau Ceti, and how it can enhance the efficiency of next-generation, space-based direct imaging survey missions in their quest to characterize habitable worlds and identify biosignatures.

Keywords: Exoplanets

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Global climate modeling of TRAPPIST-1e using MIROC for the model intercomparison

*Takeshi Kuroda[1], Yujie Zou[1,2], Arihiro Kamada[1], Takanori Kodama[2], Naoki Terada[1]

1. Department of Geophysics, Tohoku University, 2. Komaba Institute for Science, The University of Tokyo

TRAPPIST-1 is an ultra-cool red dwarf star (M-dwarf) with the size of slightly larger than Jupiter, located at about 40 light-years away from our Sun. It has been found that at least seven rocky planets are orbiting the star within the semi-major axis of ~0.06 AU, receiving the comparable irradiation to the terrestrial planets of our Solar System. Especially, the planet TRAPPIST-1e, whose size is estimated to be ~92% of the Earth orbiting with the semi-major axis of ~0.028 AU and the period of ~6.1 days (Gillon et al., 2017), would be favorable to keep the warm temperature which the surface liquid water may stably exist, with the estimated irradiation of ~900 W m^{-2} (~66% of the Earth). Also, it is highly probable that TRAPPIST-1e has a synchronous (tidally-locked with the same periods of rotation and revolution) orbit against TRAPPIST-1, like Ganymede against Jupiter with the similar size and positional relationship.

If TRAPPIST-1e has a suitable atmosphere, it is expected that its environment would be habitable, i.e. suitable for the existence of life. Several studies using global climate models (GCMs) have investigated the possible habitable climate of TRAPPIST-1e (Wolf, 2017; Turbet et al., 2018; Fauchez et al., 2019), and a model intercomparison project with several kinds of conditions is also ongoing (Fauchez et al., 2019, 2020). On this context, we also started GCM simulations of TRAPPIST-1e using MIROC (Model for Interdisciplinary Research on Climate), which has been developed in the Atmosphere and Ocean Research Institute of The University of Tokyo, National Institute for Environmental Studies and Japan Agency for Marine-Earth Science and Technology, to join the intercomparison project for the robust validation and understanding of the habitability of the extrasolar planet.

We have performed the simulations of the possible climate of TRAPPIST-1e with four kinds of ideal conditions with the surface pressure of 1 bar along with Fauchez et al. (2020): 1) Ben1: a dry land planet with a N_2 atmosphere including 400 ppm CO_2, 2) Ben2: a dry land planet with a pure CO_2 atmosphere, 3) Hab1: a slab ocean planet with a N_2 atmosphere including 400 ppm CO_2, and 4) Hab2: a slab ocean planet with a pure CO_2 atmosphere, and got preliminary results for each condition. In the presentation, we are showing the results and discussions in comparisons with other GCMs joining the intercomparison project (LMDG: the Laboratoire de Météorologie Dynamique Generic model, ROCKE-3D: the Resolving Orbital and Climate Keys of Earth and Extraterrestrial Environments with Dynamics, ExoCAM: the Exoplanet Community Atmospheric Model, and the Met Office Unified Model) for the validations of MIROC to adapt to tidally-locked exoplanets and the habitability of TRAPPIST-1e.

Keywords: Extrasolar planet, TRAPPIST-1, Global climate model

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Global Mapping of the Surface Composition on an Exo-Earth using Sparse Modeling

*Atsuki Kuwata[1], Hajime Kawahara[1], Masataka Aizawa[2], Takayuki Kotani[3,4,5], Motohide Tamura[1,3,4]

1. The University of Tokyo, 2. Tsung-Dao Lee Institute, 3. Astrobiology center, 4. National Astronomical Observatory of Japan, 5. University for Advanced Studies (SOKENDAI)

In the exploration of extraterrestrial life, the characterization of exoplanets has been studied. Direct imaging is one of the fundamental observation methods for characterization. However, even for close terrestrial exoplanets from the solar system, a resolution of a few microarcseconds is required for spatially resolved observations, and even if direct imaging becomes possible, it will only be possible to observe point sources. Kawahara & Fujii (2010, 2011) proposed Spin-Orbit Tomography (SOT) to obtain the two-dimensional spatial distribution of a planet's surface from the temporal variation of observed reflected light without spatial resolution. Recently, Aizawa et al. (2020) obtained highly accurate spatial distribution maps by introducing sparse modeling to SOT.

In addition to the above methods, we focused on Spin-Orbit Unmixing (SOU), which was developed by introducing Spectral Unmixing, a remote sensing method, to SOT. SOU enables us to obtain the spatial distribution of the planet's surface and the reflection spectrum from the luminosity variations at multiple wavelengths (Kawahara 2020). In this study, we introduced sparse modeling to SOU. In SOU, we placed sparsity-inducing constraints and reformulated the solution into an appropriate form to use the proximal gradient method, one of the optimization algorithms. As a result, we obtain highly accurate and more sparse planetary surface distributions and reflection spectra. In this talk, we describe this method and show the results of tests using Earth data.

Keywords: Exoplanets, Mapping, Sparse Modeling

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Search for Extra-terrestrial Mother Planets Catalogue for influence of stellar activities on the extraplanetary system.

*Yosuke Alexandre Yamashiki[1], Hiroyuki Maehara[2], Vladimir Airapetian[3], Yuta Notsu[6], Kosuke Namekata[4], Riko Shimizu[5], Nami Kimura[1], Tatsuhiko Sato[7], Takanori Sasaki[4]

1. Earth & Planetary Water Resources Assessment Laboratory Graduate School of Advanced Integrated Studies in Human Survivability Kyoto University, 2. National Astronomical Observatory of Japan, 3. NASA's Goddard Space Flight Center, 4. Graduate School of Science, Kyoto University, 5. Faculty of Science, Kyoto University, 6. University of Colorado, 7. Japan Atomic Energy Agency

The Search for Extra-terrestrial Mother Planets Catalogue will be used to search for potentially habitable mother planets and to derive data on stellar activity of their host stars. The ultimate goal of the survey is to accomplish creating a full and original data catalogue of exoplanets at Kyoto University, based on the Exokyoto catalogue, while paying special attention to characterization of stellar activity of planet hosts. We presented the first quantitative impact evaluation system of stellar flares on the habitability factors with an emphasis on the impact of stellar proton events. We derive the maximum flare energy from stellar star spot sizes and examine the impacts of flare-associated ionizing radiation on CO_2, H_2, and N_2+ O_2-rich atmospheres of a number of well-characterized terrestrial type exoplanets. Our simulations based on the Particle and Heavy Ion Transport code System suggest that the estimated ground-level dose for each planet in the case of terrestrial-level atmospheric pressure (1 bar) for each exoplanet does not exceed the critical dose for complex (multicellular) life to persist, even for the planetary surface of Proxima Centauri b, Ross-128 b, and TRAPPIST-1 e. We re-conduct numerical simulation based on newely obtained spectra for the possible CME occurred in those planetary system, revailing higher and harder spectra may induce significant damage even for those "habitable"planets. Some thick atmosphere and hydrosphere may protect their habitability reducing exposure impact for those planet. Together with the observation for H-alpha for host stars we also are attempt to conduct developing database for those risk for potentially habitable planetary system.
In this presentation we will introduce how the energy spectra of potential CME may affect entire estimation of the possible dose at the surface environment of extrasolar planets with preliminary classification by stellar impact among "habitable" planets situated CHZ based on the conventional classification theory. According to our estimation, some planets with hardest energy spectra and higher atmospheric escape rate the surface environment become severe for terrestrial-type life system.

Keywords: extrasolar planetary catalogue, Stellar Energetic Particles, Mother planet

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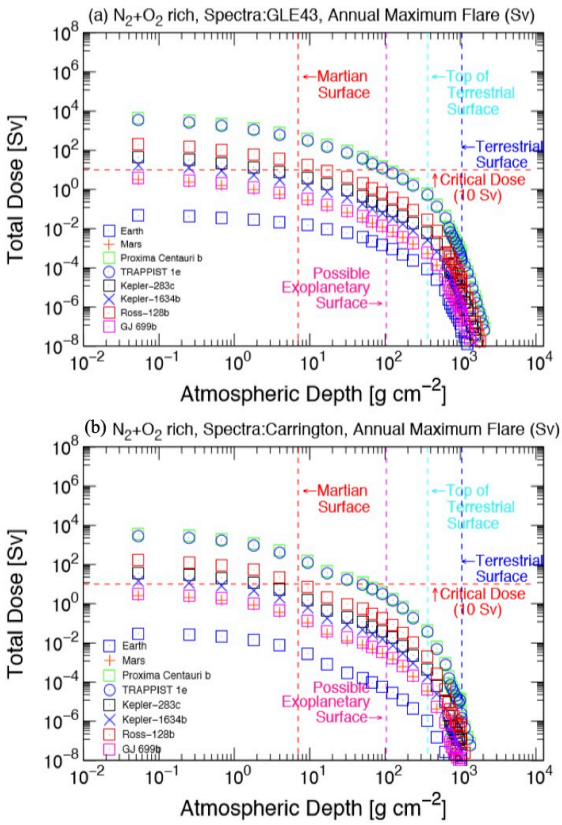

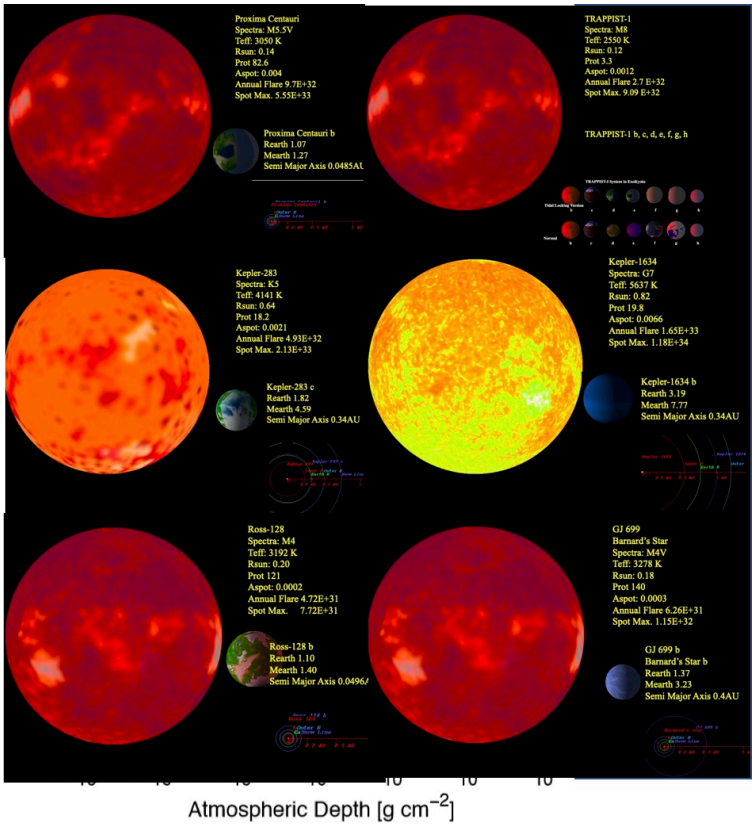

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Observational implications of atmospheric and orbital evolution of super-Earths

*Naho Fujita[1], Yasunori Hori[2,3], Takanori Sasaki[1]

1. Kyoto University, 2. Astrobiology Center, 3. National Astronomical Observatory of Japan

There is a scarcity of close-in small planets with 1.5 to 2.0 times Earth radii and the orbital period of < 100 days in the radius distribution of Kepler planets around FGK stars (Fulton & Petigura 2018) and M dwarfs (Hirano et al. 2018). The so-called “radius gap” is considered as the radius boundary between planets with atmospheres and those without atmospheres. The atmospheric escape of small planets by photoevaporation can explain the origin of the observed radius gap (e.g., Owen & Wu 2017). Previous studies, however, assumed that evaporating planets stay in situ. Planets that undergo mass loss should move outward while conserving the total angular momentum of the star-planet system. In this study, we calculated the orbital evolution of close-in super-Earths that undergo hydrodynamic escape of their atmospheres driven by stellar X-ray and UV irradiations. We found that a radius gap, as seen in observations, appears in the orbital period-radius distribution of close-in super-Earths. Our results also suggest that the atmospheric escape of planets strongly affects the final orbital configuration of the planetary systems. More super-Earths orbiting M dwarfs are expected to be discovered by ongoing near-infrared doppler surveys, such as CFHT/SPIRou, Subaru/IRD, and VLT/CRIRES. Therefore, our theoretical study on the orbital evolution of close-in super-Earths helps understand their formation history and dynamical evolution.

Keywords: Exoplanets, Super-Earths, Atmospheric escape, Orbital evolution, Exoplanet observation, M dwarfs

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Effects of H_2 pumping on hot Jupiter's atmospheric escape

*Hiroto Mitani[1], Riouhei Nakatani[2], Naoki Yoshida[1]

1. The University of Tokyo, 2. RIKEN

Observations have revealed atmospheric escape of hot Jupiters around various-type stars. Classically, extreme-ultraviolet (EUV; >13.6eV) radiation of the host stars is considered to be responsible for the atmospheric escape.
EUV radiation is particularly strong for low-mass young stars, while intermediate-mass stars are less luminous in EUV but have an intense far-ultraviolet (FUV; <13.6eV) radiation instead. Therefore, compared to EUV heating, FUV-associated heating can be relatively effective for hot jupiters around intermediate-mass stars. The Lyman-Werner photons can excite molecular hydrogen to upper vibrational states (so-called H_2 pumping), and subsequent collisional de-excitation can result in substantial heating to the gas. Recent observations have discovered planets around A-stars, which have FUV luminosity about five orders of magnitude higher than the solar value. It is expected that H_2 pumping is effective to drive atmospheric escape for such planets.
In this study, we investigate the heating effects on the dynamics of hot Jupiter's atmosphere, performing radiation hydrodynamic simulations with self-consistent thermochemistry. We found that H_2 pumping can yield a mass-loss rate of ~ 10^{13} g/s around hot A-stars, which is orders of magnitude larger than typical mass-loss rates for EUV-driven escape (~10^{10} g/s). We discuss the effect of H_2 pumping heating on the atmospheric escape process of hot Jupiters around various host stars.

Keywords: Exoplanet, Hot Jupiter, Atmospheric escape

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[E] Oral | P (Space and Planetary Sciences)：P-AE Astronomy & Extrasolar Bodies

Sun. Jun 6, 2021 3:30 PM - 5:00 PM JST | Sun. Jun 6, 2021 6:30 AM - 8:00 AM UTC | Ch.06 Zoom Room 06

[P-AE16] Exoplanets

convener:Masahiro Ikoma(Division of Science, National Astronomical Observatory of Japan), Norio Narita(The University of Tokyo), Yuka Fujii(National Astronomical Observatory of Japan), Chairperson:Norio Narita(The University of Tokyo)

Exoplanetary science, which began with the discovery of a hot Jupiter in 1995, reached a significant turning point by the detection of countless super-Earths by the Kepler space telescope. In 2018, the new space telescope TESS was launched to conduct an extensive survey of exoplanets orbiting nearby bright stars, opening a new era of characterization of exoplanet atmospheres. Moreover, recent observations have identified a growing number of terrestrial planets in the so-called habitable zone. While exoplanets have been targeted mainly for astronomy until recently, it would be fair to say that Earth and planetary science is finally becoming a research field to make a central contribution. This session aims at allowing participants to share their research results and new ideas regarding exoplanets and also inform the current status of their projects. Exoplanet science is a growing, interdisciplinary research field. We welcome participants from various fields.

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

[PAE16-07] TESS legacy: the brightest, closest transiting planets for atmospheric studies.

★Invited Papers

*Rafael Luque[1] (1.Instituto de Astrofisica de Andalucia)

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

[PAE16-08] Development of multiband imager MuSCAT3 and its first results on followup observations of TESS transiting planets

*Akihiko Fukui[1], Norio Narita[1,2], Masahiro Ikoma[1], Keisuke Isogai[4], Kiyoe Kawauchi[1], Takanori Kodama[1], Seiya Kurita[1], Nobuhiko Kusakabe[2], Jerome Pitogo de Leon[1], John Livingston[1], Mayuko Mori[1], Taku Nishiumi[3], Motohide Tamura[1,2], Noriharu Watanabe[3], Tomoyasu Yamamuro[5], Daniel Harbeck[6], Mark Bowman[6], Mark Elphick[6], Jon Nation[6], James Armstrong[7], Jacqueline Han[7], Matt Daily[6] (1.The University of Tokyo, 2.Astrobiology Center, 3.SOKENDAI, 4.Kyoto University, 5.OptCraft, 6.Las Cumbres Observatory Global Telescope Network, 7.University of Hawaii)

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

[PAE16-09] New Validated Planets in Overlapping K2 Campaigns

*Jerome Pitogo de Leon[1], John Livingston[1], Michael Endl[4], William Cochran[5,4], Teruyuki Hirano[18], Masayuki Kuzuhara[15,14], Rafael Garcia[11], Savita Mathur[6,7], Fei Dai[10,9], Alessandro Trani[2], Judith Korth[6,7], Kristine Lam[8], Enrique Diez Alonzo[17], Amadeo Castro Gonzalez[17], Malcolm Fridlund[12,13], Akihiko Fukui[3], Rafa Luque[6,7], Norio Narita[16,2,15,14], Enric Palle[6,7], Motohide Tamura[1,14,15], KESPRINT team (1.Department of Astronomy, University of Tokyo, 7-3-1 Hongo, Bunkyo-ku, Tokyo 113-0033, Japan, 2.Department of Earth Science and Astronomy, College of Arts and Sciences, The University of Tokyo, 3-8-1 Komaba, Meguro-ku, Tokyo 153-8902, Japan, 3.Department of Earth and Planetary Science, University of Tokyo, 7-3-1 Hongo, Bunkyo-ky, Tokyo 113-0033, Japan, 4.Department of Astronomy and McDonald Observatory, University of Texas at Austin, 2515 Speedway, Stop C1400, Austin, TX 78712, USA, 5.Center for Planetary Systems Habitability, The University of Texas at Austin, Austin TX USA, 6.Instituto de Astrofisica de Canarias (IAC), 38205 La Laguna, Tenerife, Spain, 7.Departamento de Astrofisica, Universidad de La Laguna, 38206 La Laguna, Tenerife, Spain, 8.Center for Astronomy and Astrophysics, Technical University Berlin, Hardenbergstr. 36, 10623 Berlin, Germany, 9.Division of Geological and Planetary Sciences, California Institute of Technology, 1200 East California Blvd, Pasadena CA 91125, 10.Department of Astrophysical Sciences, Princeton University, 4 Ivy Lane, Princeton, NJ 08544, USA, 11.AIM, CEA, CNRS, Universite Paris-Saclay, Universite Paris Diderot, Sorbonne Paris Cité, F-91191 Gif-sur-Yvette, France, 12.Leiden Observatory, Leiden University, 2333CA Leiden, The Netherlands, 13.Department of Space, Earth and Environment, Chalmers University of Technology, Onsala Space Observatory, SE-439 92 Onsala,

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

[PAE16-10] Spitzer and ground-based follow-up of the young transiting multi-planet system V1298 Tau

*John Livingston[1], Trevor David[2], Gudmundur Stefansson[3], Elisabeth Newton[4], Allyson Bieryla[5], Shreyas Vissapragada[6], Samuel Hadden[5], Erik Petigura[7], Eric Mamajek[8], Lynne Hillenbrand[6], David Ciardi[6], Charles Beichman[6], Luisa Rebull[6], John Stauffer[6], Varoujan Gorjian[6], Heather Knutson[6], Akihiko Fukui[1], Norio Narita[1], Motohide Tamura[1] (1.University of Tokyo, 2.Flatiron Institute, 3.Princeton University, 4.Dartmouth College, 5.Harvard-Smithsonian, 6.California Institute of Technology, 7.University of California, Los Angeles, 8.Jet Propulsion Laboratory)

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

[PAE16-11] **Twinkle: a low-Earth orbit, visible and infrared observatory for exoplanet and solar system spectroscopy**

*Billy Edwards[1] (1.Blue Skies Space Ltd)

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

[PAE16-12] Multi-planetary systems deduced from the observed ALMA disks: initial conditions and evolutionary outcomes

*Shijie Wang[1], Kazuhiro D Kanagawa[1,2], Toshinori Hayashi[1], Yasushi Suto[1] (1.University of Tokyo, 2.Ibaraki University)

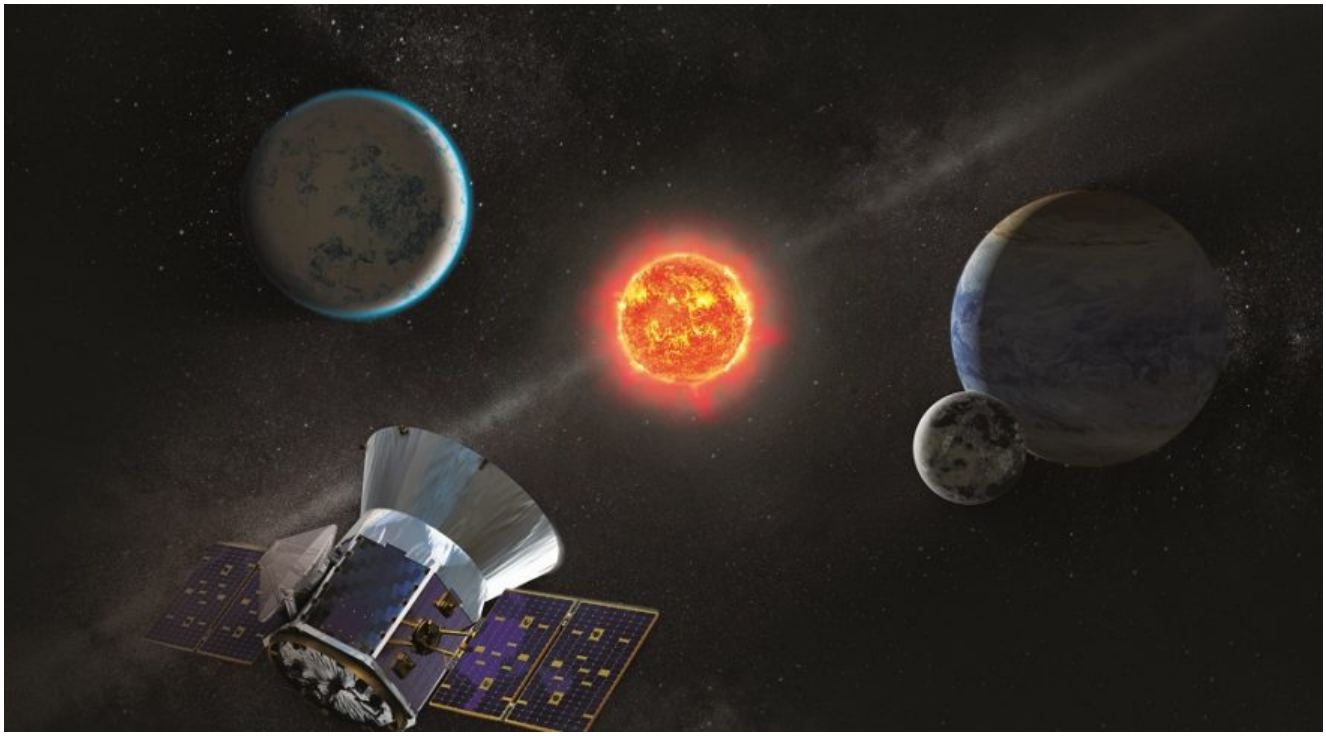
TESS legacy: the brightest, closest transiting planets for atmospheric studies.

*Rafael Luque[1]

1. Instituto de Astrofisica de Andalucia

Successfully launched in April 2018, NASA’s Transiting Exoplanet Survey Satellite (TESS) is well on its way to discovering thousands of exoplanets in orbit around the brightest stars in the sky. During its initial two-year survey mission, TESS has monitored more than 200,000 targeted bright stars in the solar neighborhood for drops in brightness caused by planetary transits, discovering more than a hundred planets already and with thousands of candidates pending confirmation. The brightness of TESS host stars makes TESS planets far easier to characterize with follow-up observations than planets from prior missions. TESS follow-up observations have already enabled measurements of the masses, sizes, densities, orbits, and atmospheres of a large cohort of small planets, including habitable zone rocky worlds. In this talk, I will review the ground-based efforts to perform those observations, the facilities and teams involved, and the prospects for atmospheric studies of the most promising targets with the new generation of ground- and space-based facilities such as the GSMTs and JWST.

Keywords: exoplanets, exoplanet atmospheres, radial velocity, transit, TESS



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Development of multiband imager MuSCAT3 and its first results on followup observations of TESS transiting planets

*Akihiko Fukui[1], Norio Narita[1,2], Masahiro Ikoma[1], Keisuke Isogai[4], Kiyoe Kawauchi[1], Takanori Kodama[1], Seiya Kurita[1], Nobuhiko Kusakabe[2], Jerome Pitogo de Leon[1], John Livingston[1], Mayuko Mori[1], Taku Nishiumi[3], Motohide Tamura[1,2], Noriharu Watanabe[3], Tomoyasu Yamamuro[5], Daniel Harbeck[6], Mark Bowman[6], Mark Elphick[6], Jon Nation[6], James Armstrong[7], Jacqueline Han[7], Matt Daily[6]

1. The University of Tokyo, 2. Astrobiology Center, 3. SOKENDAI, 4. Kyoto University, 5. OptCraft, 6. Las Cumbres Observatory Global Telescope Network, 7. University of Hawaii

The successor of the Kepler space telescope, TESS, has been surveying ~80% of the entire sky to search for small planets transiting nearby stars, which can be prime targets for future atmospheric characterizasions. However, a large fraction of planetary candidates that TESS has been discovering are actually false positives, and ground-based followup observations are essential to identify true transiting planets. To validate such planetary candidates and further characterize them in detail, we have developed a new optical four-band imager MuSCAT3 for a 2m telescope at Haleakala Observatory in Hawaii. The first light of MuSCAT3 has scceeded in September 2020, and its science operation has started in November 2020. In this talk, we will introduce the characteristics of MuSCAT3, and show some scientific results obtained with this instrument, in coordination with two precedent instruments of MuSCAT in Japan and MuSCAT2 in Spain, for followup observations of TESS planetary candidates.

Keywords: transiting planet, TESS, multiband photometry

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New Validated Planets in Overlapping K2 Campaigns

*Jerome Pitogo de Leon[1], John Livingston[1], Michael Endl[4], William Cochran[5,4], Teruyuki Hirano[18], Masayuki Kuzuhara[15,14], Rafael Garcia[11], Savita Mathur[6,7], Fei Dai[10,9], Alessandro Trani[2], Judith Korth[6,7], Kristine Lam[8], Enrique Diez Alonzo[17], Amadeo Castro Gonzalez[17], Malcolm Fridlund[12,13], Akihiko Fukui[3], Rafa Luque[6,7], Norio Narita[16,2,15,14], Enric Palle[6,7], Motohide Tamura[1,14,15], KESPRINT team

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We analysed 72 candidate planetary systems first identified during Campaigns 5 and 6 (C5 and C6) of the NASA K2 Mission. We set out to validate these systems using a suite of follow-up observations including adaptive optics, speckle imaging, and reconnaissance spectroscopy. The overlap between C5 with C16 and C18, and C6 with C17, yields light curves with longer baselines that allow us to measure the transit ephemeris very precisely, revisit single transit candidates identified in earlier campaigns, and search for additional transiting planets with longer periods not detected in previous works. Using vespa, we compute false positive probabilities less than 1% for 35 candidates and hence statistically validate them as planets. These planets have a typical size of 2.2R⊕ and orbital periods between 1.99 and 52.71 days. We highlight interesting systems including a sub-Neptune with the longest period with more than two transits detected from K2, sub-Saturns around F stars, and several multi-planetary systems in a variety of architectures, four of which are new discoveries. These results show that a wealth of planetary systems still remain in the K2 data, many ofwhich can be validated using minimal follow-up observations and taking advantage of analyses presented in previous catalogs.

Keywords: exoplanet, transit, imaging

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Spitzer and ground-based follow-up of the young transiting multi-planet system V1298 Tau

*John Livingston[1], Trevor David[2], Gudmundur Stefansson[3], Elisabeth Newton[4], Allyson Bieryla[5], Shreyas Vissapragada[6], Samuel Hadden[5], Erik Petigura[7], Eric Mamajek[8], Lynne Hillenbrand[6], David Ciardi[6], Charles Beichman[6], Luisa Rebull[6], John Stauffer[6], Varoujan Gorjian[6], Heather Knutson[6], Akihiko Fukui[1], Norio Narita[1], Motohide Tamura[1]

1. University of Tokyo, 2. Flatiron Institute, 3. Princeton University, 4. Dartmouth College, 5. Harvard-Smithsonian, 6. California Institute of Technology, 7. University of California, Los Angeles, 8. Jet Propulsion Laboratory

We report on Spitzer IRAC2 and ground-based transit observations of the young (23 Myr) transiting multi-planet system V1298 Tau in the foreground of the Taurus-Auriga star-forming region. We find the transit depths at 4.5 microns of planets b, c, and d are consistent to within ~1-sigma of that measured at 0.42-0.90 microns from Kepler observations acquired during Campaign 4 of the K2 mission. The K2 data were acquired in early 2015 and were affected by a data gap as well as likely spot-crossings. We see no evidence for spot-crossings in the Spitzer light curves, consistent with the expectation of a lower spot-to-photosphere contrast at mid-IR wavelengths relative to the optical. Our revised ephemerides shrink the transit midpoint uncertainties from hours to minutes in mid-2021, when observations with JWST might be obtained. Our observations provide the first multi-wavelength view of the V1298 Tau system, an important benchmark for investigating the atmospheric properties of a moderately irradiated giant exoplanet shortly after its formation. Additionally, we publish individual transit times from K2, Spitzer, and our ground-based observations, along with dynamical investigations of transit timing variations. We measure very low dynamical masses consistent with the picture of low density young planets still undergoing significant radial contraction.

Keywords: Exoplanets, Young associations, Multi-planet systems, Transit photometry

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Twinkle: a low-Earth orbit, visible and infrared observatory for exoplanet and solar system spectroscopy

*Billy Edwards[1]

1. Blue Skies Space Ltd

The Twinkle Space Mission is a space-based observatory that has been conceived to measure the atmospheric composition of exoplanets as well as characterising stars and solar system objects. The satellite is based on a high-heritage platform and will carry a 0.45 m telescope with a visible and infrared spectrograph providing simultaneous wavelength coverage from 0.5 - 4.5 μm. The spacecraft will be launched into a Sun-synchronous low-Earth polar orbit and will operate in this highly stable thermal environment for a baseline lifetime of seven years.

Twinkle will have the capability to provide high-quality infrared spectroscopic characterisation of the atmospheres of hundreds of bright exoplanets, covering a wide range of planetary types. It will also be capable of providing phase curves for hot, short-period planets around bright stars targets and of providing ultra-precise photometric light curves to accurately constrain orbital parameters, including ephemerides and TTVs/TDVs present in multi-planet systems.

Twinkle is available for researchers around the globe in two ways:

1) joining its collaborative multi-year survey programme, which will observe hundreds of exoplanets and solar system objects; and
2) accessing dedicated telescope time on the spacecraft, which they can schedule for any combination of science cases.

I will present an overview of Twinkle’s capabilities and discuss some example exoplanet surveys to highlight the broad range of targets the mission could observe, demonstrating the huge scientific potential of the spacecraft.

Keywords: Exoplanet atmospheres, Visible and near-infrared spectroscopy, Space-based telescope

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Multi-planetary systems deduced from the observed ALMA disks: initial conditions and evolutionary outcomes

*Shijie Wang[1], Kazuhiro D Kanagawa[1,2], Toshinori Hayashi[1], Yasushi Suto[1]

1. University of Tokyo, 2. Ibaraki University

Since the discovery of the ring/gap substructure of the HL Tau disk in 2015, recent high-resolution ALMA/DSHARP observations have resolved more similar substructures on nearby protoplanetary disks. Theories have predicted that a massive planet can carve a gap in the disk as it grows, therefore these substructures were promisingly related to the planetary origin. Following this interpretation, it is possible to constrain the semi-major axis and even planetary mass from the morphology of the gaps. In Wang et al. 2020, we carried out N-body simulations to evolve the HL Tau planetary system from the current configuration up to 10 Gyrs after the disk dispersal, with implementation of both planetary migration and gas accretion schemes coupled with the the disk profile. By varying the disk parameters, we produced a variety of widely-separated planetary systems consisting of three super-Jupiters at the end of the disk dispersal. Most of the systems are found to be stable for at least 10 Gyr in a marginal resonance state. Our recent work expands the targets to other ALMA disks and considers alternative initial planetary mass estimates based on the dust-gap-only and gas-gap scenarios. We show it is possible to break the degeneracy for some gaps by considering the consistency of the predicted mass with the planetary formation model.

Keywords: Protoplanetary disks, Planet formation

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

Sun. Jun 6, 2021 9:00 AM - 10:30 AM JST | Sun. Jun 6, 2021 12:00 AM - 1:30 AM UTC | Ch.07 Zoom Room 07

[A-AS02] Extreme Events: Observations and Modeling

convener:Sridhara Nayak(Disaster Prevention Research Institute, Kyoto University), Tetsuya Takemi(Disaster Prevention Research Institute, Kyoto University), Satoshi Iizuka(National Research Institute for Earth Science and Disaster Resilience), Chairperson:Satoshi Iizuka(National Research Institute for Earth Science and Disaster Resilience), Sridhara Nayak(Disaster Prevention Research Institute, Kyoto University), Tetsuya Takemi(Disaster Prevention Research Institute, Kyoto University)

The frequencies and intensities of extreme events such as heavy rainfall, flash floods, droughts, heat waves, tropical cyclones etc. have increased in many regions across the globe and are of serious concern due to their socio-economic and climate change connections. Thus, understanding of the patterns of such events and particularly their characteristics have been the focus of many recent studies. This session invites abstracts on observational and numerical modeling studies to enhance the understanding of the spatial and temporal characteristics and predictability of the extreme events. In particular, abstracts are encouraged on regional analysis of the extreme events in past years and in near or far future (30-100 years), which would assist the policy makers to build potentially more resilient societies to face the extreme event related disasters. This session also welcomes the submissions on model simulations and evaluations to advance the understanding of the physics and dynamics associated with the extreme events.

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

[AAS02-01] Introduction

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

[AAS02-02] Assessing the Impacts of Extreme Weather on Local-Scale Hazards under Climate Change

★Invited Papers

*Tetsuya Takemi[1] (1.Disaster Prevention Research Institute, Kyoto University)

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

[AAS02-03] **Estimation of moisture sources within an explosive cyclone over the Sea of Japan using an isotopic regional spectral model**

★Invited Papers

*Xiaoyang Li[1], Ryuichi Kawamura[1], Atsuko Sugimoto[2,3], Kei Yoshimura[4,5] (1.Department of Earth and Planetary Science, Faculty of Science, Kyushu University, 2.Arctic Research Center, Hokkaido University, 3.Graduate School of Environmental Science, Hokkaido University, 4.Atmosphere and Ocean Research Institute, The University of Tokyo, 5.Institute of Industrial Science, The University of Tokyo)

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

[AAS02-04] Influence of Warm SST in the Oyashio Region on Rainfall Distribution of Typhoon Hagibis (2019)

*Satoshi Iizuka[1], Ryuichi Kawamura[2], Hisashi Nakamura[3], Toru Miyama[4] (1.National Research Institute for Earth Science and Disaster Resilience, 2.Department of Earth and Planetary Sciences, Kyushu University, 3.Research Center for Advanced Science and Technology, University of Tokyo, 4.Japan Agency for Marine-Earth Science and Technology,)

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

[AAS02-05] Simulation of typhoon-induced heavy precipitation over the Philippines using the Multi-scale Kain-Fritsch Cumulus Scheme in WRF

*Jose Angelo Hokson[1], Shinjiro Kanae[1], Rie Seto[1] (1.School of Environment and Society, Tokyo Institute of Technology)

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

[AAS02-06] **Attribution of atmospheric circulation variations associated with winter temperature whiplash events over Northeast China**

*Zhen Liao[1], Panmao Zhai[1], Yang Chen[1] (1.LaSW, CAMS, China)

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

[A-AS02] Extreme Events: Observations and Modeling

convener:Sridhara Nayak(Disaster Prevention Research Institute, Kyoto University), Tetsuya Takemi(Disaster Prevention Research Institute, Kyoto University), Satoshi Iizuka(National Research Institute for Earth Science and Disaster Resilience), Chairperson:Satoshi Iizuka(National Research Institute for Earth Science and Disaster Resilience), Sridhara Nayak(Disaster Prevention Research Institute, Kyoto University), Tetsuya Takemi(Disaster Prevention Research Institute, Kyoto University)

Sun. Jun 6, 2021 9:00 AM - 10:30 AM Ch.07 (Zoom Room 07)

The frequencies and intensities of extreme events such as heavy rainfall, flash floods, droughts, heat waves, tropical cyclones etc. have increased in many regions across the globe and are of serious concern due to their socio-economic and climate change connections. Thus, understanding of the patterns of such events and particularly their characteristics have been the focus of many recent studies. This session invites abstracts on observational and numerical modeling studies to enhance the understanding of the spatial and temporal characteristics and predictability of the extreme events. In particular, abstracts are encouraged on regional analysis of the extreme events in past years and in near or far future (30-100 years), which would assist the policy makers to build potentially more resilient societies to face the extreme event related disasters. This session also welcomes the submissions on model simulations and evaluations to advance the understanding of the physics and dynamics associated with the extreme events.

9:00 AM - 9:05 AM

[AAS02-01]Introduction

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Assessing the Impacts of Extreme Weather on Local-Scale Hazards under Climate Change

*Tetsuya Takemi[1]

1. Disaster Prevention Research Institute, Kyoto University

Understanding hazards and risks due to extreme weather phenomena is critically important in order to consider disaster risk reduction under climate change. Quantitative representations of meteorological hazards are critically important in order to assess the impacts of such hazards not only for past disastrous events but also as for anticipated extreme events under future global warming. Furthermore, hazard information at local-scales is required because the resulting phenomena occur depending on their local geographic features. Since the Innovative Program of Climate Change Projection for the 21st Century (KAKUSHIN Program, FY2007-2012) funded by the Japanese Government, we have been studying the impacts of extreme weather under future global warming under the subsequent Program for Risk Information on Climate Change (SOUSEI Program, FY2012-2017) and the latest Integrated Research Program for Advancing Climate Models (TOUGOU Program FY2017-). Meteorological hazards such as heavy rainfalls, strong winds, and tropical cyclones were quantitatively examined as case studies. In this presentation, we will talk about how the quantitative representation of meteorological hazards helps to assess the impacts of the hazards for climate change adaptation and disaster risk reduction. We will focus on tropical cyclones and heavy rainfalls as extreme weather and use a dynamical downscaling technique with the Weather Research and Forecasting (WRF) model for the impact assessment studies. Past extreme weather that caused severe disaster can be regarded as a baseline to consider local-scale hazards. The impacts of climate change are investigated with the use of pseudo-global warming technique in which warming increments are added to past meteorological fields. The results from case studies on tropical cyclones and heavy rainfalls are demonstrated in this presentation. Furthermore, the analysis of airflows downscaling to urban districts with the use of a building-resolving large-eddy simulation model is demonstrated. Strong wind hazards are quantitatively assessed by the building-resolving modelling technique.

Keywords: extreme weather, dynamical downscaling, climate change impact, urban disaster risk, global warming

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Estimation of moisture sources within an explosive cyclone over the Sea of Japan using an isotopic regional spectral model

*Xiaoyang Li[1], Ryuichi Kawamura[1], Atsuko Sugimoto[2,3], Kei Yoshimura[4,5]

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In this study, we identified water origins and clarified moisture transport processes within the explosive cyclone migrating poleward across the Sea of Japan (SJ) on November 30, 2014, by using an isotopic regional spectral model. Regarding the total precipitable water and condensation in the vicinity of the cyclone center, a replacement of water origins occurred during the cyclone development, resulting from a shift of the moisture transport from the warm conveyor belt (WCB) to the cold conveyor belt (CCB) and dry intrusion (DI). At the early stage, the WCB transported large amounts of moisture from the East China Sea and Kuroshio (ECS & KS) into the cyclone’ s inner region. While at the rapidly developing stage, the CCB and DI conveyed more moisture from the Northwest Pacific Ocean (NWP) and SJ, respectively, to the cyclone center area. Compared with the local moisture, the contribution of remote moisture was dominant in the vicinity of the cyclone center. With respect to the water origins of condensation within the cyclone frontal system at the rapidly developing stage, the NWP vapors, principally transported by the CCB, contributed 35.5% of the condensation in the western warm front. The ECS & KS moisture, conveyed by the WCB, accounted for 32.4% of the condensation in the cold and eastern warm fronts. In addition, condensation from the SJ, which was mainly triggered by the DI and induced by the topography, occurred on the west coast of the mainland of Japan and near the cyclone center. The spatial distribution of the isotopic composition in condensation also supports the water origin results. These results point the way toward better understanding of where the moisture is evaporated, how the moisture is transported, and where the moisture is condensed. The findings can be used for weather forecasting, disaster preparedness, and allocation of water and energy resources in association with extratropical cyclones.

Keywords: explosive cyclone, water origins, warm conveyor belt, cold conveyor belt, isotopic regional spectral model, stable water isotopes

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Influence of Warm SST in the Oyashio Region on Rainfall Distribution of Typhoon Hagibis (2019)

*Satoshi Iizuka[1], Ryuichi Kawamura[2], Hisashi Nakamura[3], Toru Miyama[4]

1. National Research Institute for Earth Science and Disaster Resilience, 2. Department of Earth and Planetary Sciences, Kyushu University, 3. Research Center for Advanced Science and Technology, University of Tokyo, 4. Japan Agency for Marine-Earth Science and Technology,

Typhoon Hagibis (2019) caused widespread flooding and damage over eastern Japan. The associated rainfall maxima were primarily observed on the windward mountain slopes along with the west of the leading edge of a low-level front. Concomitantly, a significant positive value in sea surface temperature anomalies (SSTAs) was observed in association with an ocean eddy over the Oyashio region, together with anomalous warmth over the entire western North Pacific. The present study examines the role of the SSTAs in the rainfall distribution associated with Hagibis, to deepen our understanding of the influence of the midlatitude ocean on tropical cyclones and associated rainfall. Our sensitivity experiments demonstrate that the observed warm SSTAs had the potential to displace the rainfall caused by Hagibis inland and thereby acted to increase precipitation along the Pacific coast of northeastern Japan. Our results suggest that midlatitude SSTAs on ocean-eddy scales can also influence the synoptic-scale atmospheric front and associated heavy rainfall.

Keywords: Typhoon, Rainfall, Sea Surface Temperature, Oyashio

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Simulation of typhoon-induced heavy precipitation over the Philippines using the Multi-scale Kain-Fritsch Cumulus Scheme in WRF

*Jose Angelo Hokson[1], Shinjiro Kanae[1], Rie Seto[1]

1. School of Environment and Society, Tokyo Institute of Technology

Cumulus parameterization schemes, which handle convection processes such as those involving moisture and precipitation, have been indispensable in simulations using numerical weather prediction models such as the Weather Research and Forecasting (WRF) model. The Kain-Fritsch (KF) is one of the most-used schemes in WRF. An improved and scale-aware version of this scheme, called Multi-scale KF (MSKF), was produced to address overestimations of precipitation by KF. Studies in the Himalayas and the United States have proven that using MSKF brings improvement to the simulated precipitation values. However, the applicability and performance of MSKF over the Philippines in simulating precipitation, especially heavy precipitation, is yet to be verified. Herein, we examined these by simulating Typhoon Koppu and comparing the hourly and daily results with those of two other cumulus schemes –KF and Grell-Freitas (GF). Six simulations were conducted –three use cumulus schemes in high resolution (5 km, innermost domain), and three do not. Based on the results, the MSKF is applicable for use in simulating precipitations, including heavy precipitations, over the Philippines. It is best used when a typhoon is at its strongest but underperforms when the typhoon is weak and nearing dissipation. However, GF performs best among the three schemes. Additionally, the results show that using cumulus schemes in high resolution (5 km, using nests) does not always improve, sometimes even deteriorate, the performance of simulations in producing accurate precipitation values. Further investigations should be conducted regarding the performance of MSKF in simulating heavy precipitations over the Philippines and neighboring areas.

Keywords: typhoon-induced heavy precipitation, multi-scale Kain-Fritsch cumulus scheme, WRF, Typhoon Koppu, Philippines

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Attribution of atmospheric circulation variations associated with winter temperature whiplash events over Northeast China

*Zhen Liao[1], Panmao Zhai[1], Yang Chen[1]

1. LaSW, CAMS, China

Based on the daily meteorological observations, reanalysis and model datasets, this study investigated the evolution and the causes of the extreme cold events in Northeast China via a ‘temperature whiplash’ index over 1980-2018 from the perspective of the temperature variability and associated circulation. Results indicate that winters in Northeast China have become increasingly volatile during 1980-2018 based on the interdiurnal temperature variation. Such enhanced volatility has a strong expression in significant increases in whiplash events, which characterizes rapid and drastic switches between warm and cold extremes within several days. And cold extremes in these areas are more likely to occur in the form of the whiplash events under global warming background. At the same time, the increased whiplash events in Northeast China have a good relationship with the enhanced winter 500 hPa geopotential height variance over the Sea of Okhotsk. Further, the attribution analysis of the associated circulation variance by using HadGEM3-A-N216 ensembles shows that the observed changes in the winter 500 hPa geopotential height variance over the Sea of Okhotsk can attribute to the anthropogenic forcing, implying that the anthropogenic forcing has an impact on the associated circulation and thus lead to the increased the whiplash events in Northeast China.

Keywords: attribution, compound event, circulation

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

Sun. Jun 6, 2021 10:45 AM - 12:15 PM JST | Sun. Jun 6, 2021 1:45 AM - 3:15 AM UTC | Ch.07 Zoom Room 07

[A-AS02] Extreme Events: Observations and Modeling

convener:Sridhara Nayak(Disaster Prevention Research Institute, Kyoto University), Tetsuya Takemi(Disaster Prevention Research Institute, Kyoto University), Satoshi Iizuka(National Research Institute for Earth Science and Disaster Resilience), Chairperson:Tetsuya Takemi(Disaster Prevention Research Institute, Kyoto University), Sridhara Nayak(Disaster Prevention Research Institute, Kyoto University), Satoshi Iizuka(National Research Institute for Earth Science and Disaster Resilience)

The frequencies and intensities of extreme events such as heavy rainfall, flash floods, droughts, heat waves, tropical cyclones etc. have increased in many regions across the globe and are of serious concern due to their socio-economic and climate change connections. Thus, understanding of the patterns of such events and particularly their characteristics have been the focus of many recent studies. This session invites abstracts on observational and numerical modeling studies to enhance the understanding of the spatial and temporal characteristics and predictability of the extreme events. In particular, abstracts are encouraged on regional analysis of the extreme events in past years and in near or far future (30-100 years), which would assist the policy makers to build potentially more resilient societies to face the extreme event related disasters. This session also welcomes the submissions on model simulations and evaluations to advance the understanding of the physics and dynamics associated with the extreme events.

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

[AAS02-07] Introduction

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

[AAS02-08] Observations and simulations of Typhoon Faxai over the Kanto area

★Invited Papers

*Woosub Roh[1], Masaki Satoh[1] (1.AORI, the university of Tokyo)

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

[AAS02-09] River discharge estimation of ungauged mountainous river basin using NIED Hi-net data

★Invited Papers

*Shakti P.C.[1], Kaoru Sawazaki[1] (1.National Research institute for Earth Science and Disaster Resilience (NIED))

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

[AAS02-10] **Increase in the strength of typhoons to Taiwan due to global warming**

*Ravi Shankar Pandey[1], Yuei-An Liou[1] (1.National Central University)

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

[AAS02-11] Investigation of Uncertainties in Regional Climate Information

*Saurabh Kelkar[1] (1.University of Tsukuba)

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

[AAS02-12] **Precipitation patterns in landfalling typhoons over Japan**

*Sridhara Nayak[1], Tetsuya Takemi[1] (1.Disaster Prevention Research Institute, Kyoto University)

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

[A-AS02] Extreme Events: Observations and Modeling

convener:Sridhara Nayak(Disaster Prevention Research Institute, Kyoto University), Tetsuya Takemi(Disaster Prevention Research Institute, Kyoto University), Satoshi Iizuka(National Research Institute for Earth Science and Disaster Resilience), Chairperson:Tetsuya Takemi(Disaster Prevention Research Institute, Kyoto University), Sridhara Nayak(Disaster Prevention Research Institute, Kyoto University), Satoshi Iizuka(National Research Institute for Earth Science and Disaster Resilience)
Sun. Jun 6, 2021 10:45 AM - 12:15 PM Ch.07 (Zoom Room 07)

The frequencies and intensities of extreme events such as heavy rainfall, flash floods, droughts, heat waves, tropical cyclones etc. have increased in many regions across the globe and are of serious concern due to their socio-economic and climate change connections. Thus, understanding of the patterns of such events and particularly their characteristics have been the focus of many recent studies. This session invites abstracts on observational and numerical modeling studies to enhance the understanding of the spatial and temporal characteristics and predictability of the extreme events. In particular, abstracts are encouraged on regional analysis of the extreme events in past years and in near or far future (30-100 years), which would assist the policy makers to build potentially more resilient societies to face the extreme event related disasters. This session also welcomes the submissions on model simulations and evaluations to advance the understanding of the physics and dynamics associated with the extreme events.

10:45 AM - 10:50 AM

[AAS02-07]Introduction

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Observations and simulations of Typhoon Faxai over the Kanto area

*Woosub Roh[1], Masaki Satoh[1]

1. AORI, the university of Tokyo

A tropical cyclone is one of the extreme events to make heavy rainfall and strong winds. The typhoon Faxai generated in 1st Sep. 2019 and launched the Kanto area on 8th Sep. 2019. There are intensive observation stations over the Kanto area, whose domain size is 100 km×100 km. For example, the High Spectral Resolution Lidar (HSRL, 355 nm), Doppler lidar, and the Cloud Profiling Radar (CPR, 94 GHz) are located in Tokyo. Several polarimetric radars are available like C-band radar in two airports, X-band phased array radar in Saitama University, Ka-band radar in Tsukuba. The WInd profiler Network and Data Acquisition System (WINDAS) data is available in Kawaguchiko, Mito, and Kumagaya. The ULTIMATE (ULTra sIte for Measuring Atmosphere of Tokyo metropolitan Environment) is proposed to verify and improve high-resolution numerical simulations based on these observation data. The typhoon Faxai is one of the targets in the ULTIMATE project.

In this study, we analyzed these intensive observation data about the typhoon Faxai. We simulated typhoon Faxai using the Nonhydrostatic ICosahedral Atmospheric Model (NICAM, Satoh et al. 2014). We evaluate the performances of NICAM using a Joint simulator (Hashino et al. 2013) and discuss how to improve the microphysics in NICAM using the observation data.

Keywords: NICAM , Tropical cyclone , ULTIMATE, Joint simulator

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River discharge estimation of ungauged mountainous river basin using NIED Hi-net data

*Shakti P.C.[1], Kaoru Sawazaki[1]

1. National Research institute for Earth Science and Disaster Resilience (NIED)

In Japan, flood events in mountainous river basins in recent years have resulted in significant loss of life and damage to infrastructure. Estimation of peak streamflow of rivers during flood events can be a good reference for flood disaster prevention and management. However, because there are no streamflow data for many of the small mountainous river basins in Japan –known as ungauged river basins –it takes considerably more effort to predict and estimate water-related disasters in such areas. To understand the flow rate of ungauged river basins during the extreme rain event, there are several direct and indirect approaches that have been applied and tested to estimate river discharge particularly during the period of an extreme rain event.
In this study, we considered High sensitivity seismograph network (Hi-net) observation to recognize the time and peak discharge during a heavy rain event. Hi-net is a nationwide high-sensitivity seismograph network, Japan, comprised of more than 800 seismograph stations distributed by approximately 20 km distance interval. They are also located in the mountainous region to measure earthquakes. Two Hi-net stations are located in a mountainous sub-basin of the Mogami River Basin, located in Yamagata prefecture of Japan. After validating the simulated discharge data of the Mogami River Basin with gauged data for the selected two past rain events (10-23 July 2004 and 7-16 September 2015), simulated discharge of a river was compared with noise data of the Hi-net stations. It was found that the noise data of those stations at a high-frequency level were followed a similar trend with the time series of simulated discharge at those two points for the selected events.

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Increase in the strength of typhoons to Taiwan due to global warming

*Ravi Shankar Pandey[1], Yuei-An Liou[1]

1. National Central University

Detailed investigation on the tracks and cyclogenesis locations of all 77 typhoons that hit Taiwan in the last 40 years (1977 to 2016) during typhoon season (May to November) is carried out. Ten pathways of all typhoons that hit Taiwan are detected and statistical analysis is carried out on fundamental typhoon parameters, including the direction to enter Taiwan, ocean of cyclogenesis, and phases of El Niño Southern Oscillation (ENSO) at cyclogenesis. The majority (> half, 53 %) of typhoons strike Taiwan from the East direction, typically (78%) from the Philippine Sea. They are on average stronger than the rest two other directional (West, South) typhoons. Yet, typhoons from the West uniquely survive the longest hours with the highest curvy tracks, often (59%) from just bordering the ocean i.e., the South China Sea. They are on average relatively weaker. Further statistical analysis on relationships among all typhoon parameters through Fisher' s Exact and Chi-square (χ 2) tests supports the above crucial finding and reveals that the curvy nature of tracks of typhoons is more responsible for the longer survival of typhoons (r = 0.67) than its strength. 26% more cyclogenesis is detected during the warm phase of ENSO than the cold phase. In the last 4 decades during the warm phase of ENSO, the number of cyclogenesis is also observed slowly increasing. A significant rise in the Sea Surface Temperature (SST) by 0.4 ~ 0.7 ˚C is measured using decadal, 5-yearly, yearly, ENSO phase, and monthly-wise SST Anomalies (SSTA) for the whole typhoon season (May-November) during the last 40 years in comparison to base years (1941-1970) over the entire global ocean, North Pacific Ocean, Philippine Sea, South China sea, and Eastern China Sea. A 35% crucial increase in decadal-averaged strength of typhoons is observed by 0.4 ~ 0.7 ˚C rise in the SST in all study oceans that originate typhoons to hit Taiwan during the last 40 years (1977 to 2016). The role of El-Niño epochs is found very crucial for the major SSTA changes during the typhoon season. The climatological analysis is fully consistent with statistical findings and leads to global warming as the major cause of the rising strength of typhoons that hit Taiwan during the study period. The maximum SST change in the Eastern China Sea during the study period is potentially due to its proximity from mainland China. This fact opens new research opportunities for the future.

Keywords: Cyclogenesis, El Niño Southern Oscillation, Sea Surface Temperature, Sea Surface Temperature Anomaly

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Investigation of Uncertainties in Regional Climate Information

*Saurabh Kelkar[1]

1. University of Tsukuba

Climate change is the change in the frequency, intensity, spatial extent, duration, and timing of extreme weather and climate events (IPCC, 2013). Its impacts have already been visible across the globe. People in coastal regions, high mountains as well as lower-income and other marginalised communities, have less capacity to prepare for and cope with the extreme events and thus experience a more significant impact. However, in order to respond to climate change, reliable climate information and projections are necessary. These projections are estimated with the help of global and regional climate models. Projecting the climate scenarios involves uncertainties such as systematic errors associated with structural differences in models and inconsistencies between observations. Addressing these is as crucial as responding to global warming. In this study, we attempt to explore the uncertainties involved in climate information on a regional scale. We use an ensemble of GCM and RCM to obtain regional climate information of Japan, and investigate the possible uncertainties by comparing the ensemble simulations with the statistical metrics. With the result of this research, we hope to contribute to existing knowledge on climate uncertainties.

Keywords: Regional Climate Modelling, Added Values, Ensemble

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Precipitation patterns in landfalling typhoons over Japan

*Sridhara Nayak[1], Tetsuya Takemi[1]

1. Disaster Prevention Research Institute, Kyoto University

Typhoons are one of the most dangerous weather events in the world and some of them bring extensive precipitation, and cause widespread flooding on the regions along their track. Thus understanding the precipitation patterns in landfalling typhoons has a focus in many previous studies. In this study, the precipitation patterns in 120 landfalling typhoons around Japan during 2006-2019 are extensively analyzed. The best track data from the Regional Specialized Meteorological Center (RSMC) Tokyo are used to identify the typhoon tracks and the precipitation datasets from the Radar Automated Meteorological Data Acquisition System (Radar-AMeDAS) are used to analyze the precipitation patterns. The probabilities of the different spell durations of precipitation intensities over different regions of Japan with various radii from the typhoon center starting from 10 km to 300 km shows that the occurrence of typhoon induced heavier precipitations is higher compared to the typhoon induced lighter precipitations. The heavier precipitations last up to a day, while the lighter precipitations last about 12 hours. The long-lived precipitations are also noticed that last up to 2 days, but they don’ t occur so frequently. The results also indicate that the pattern of spell durations are mostly same over all the regions within 300 km radius.

Keywords: Precipitation pattern, Typhoon, Spell duration

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

Sun. Jun 6, 2021 1:45 PM - 3:15 PM JST | Sun. Jun 6, 2021 4:45 AM - 6:15 AM UTC | Ch.14 Zoom Room 14

[H-TT14] Geographic Information Systems and Cartography

convener:Takashi Oguchi(Center for Spatial Information Science, The University of Tokyo), Yoshiki Wakabayashi(Graduate School of Urban Environmental Sciences, Tokyo Metropolitan University), Yuei-An Liou(National Central University), C. Ronald Estoque(National Institute for Environmental Studies, Japan), Chairperson:Takashi Oguchi(Center for Spatial Information Science, The University of Tokyo), Yoshiki Wakabayashi(Graduate School of Urban Environmental Sciences, Tokyo Metropolitan University)

This session discusses various methods which acquire, store, analyze and visualize geospatial data, and presents the outcomes of empirical studies using GIS or mapping methods. The session also deals with applications of digital data, and GIS, and mapping to various fields of earth and planetary science and human society. All presentations and discussion of this session are made in English.

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

[HTT14-01] A GIS-based study on accessibility of public bus system in Sapporo

*ZITONG XU[1], Yuichi S. Hayakawa[2,3] (1.Graduate School of Environmental Science, Hokkaido University, 2.Faculty of Environmental Earth Science, Hokkaido University., 3.Center for Spatial Information Science, The University of Tokyo.)

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

[HTT14-02] **Comparative study of visitors' perceptions of places by analyzing visual content of photographs in Shinjuku, Tokyo**

*Bochra Bettaieb[1], Yoshiki Wakabayashi[1] (1.Tokyo Metropolitan University)

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

[HTT14-03] **Geo-phenomenology: A Qualitative GIS Approach for Understanding People's Lived Experiences**

★Invited Papers

*Yuki Iwai[1] (1.Graduate School, University of Tsukuba)

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

[HTT14-04] UAS Surveys for Identifying Vacant Houses using Night Light and Thermal Information

★Invited Papers

*Kotaro Iizuka[1], Yuki Akiyama[1,2], Nobuyuki Imafuku[3], Satoru Sugita[4] (1.Center for Spatial Information Science, University of Tokyo, 2.Graduate School of Integrative Science and Engineering, Tokyo City University, 3.Urban Development Dept., Building and Housing Division, Omuta City, 4.International Digital Earth Applied Science Research Center, Chubu University)

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

[HTT14-05] Impacts of urbanization on the ecosystem services of the Muthurajawela Marsh and Negombo Lagoon, Sri Lanka

*SUMUDU DARSHANA ATHUKORALA ARACHCHIGE[1], Yuji Murayama[2], Bunkei Matsushita[2], Ronald C. Estoque[3] (1.Graduate School of Life and Environmental Sciences, University of Tsukuba, Tsukuba, Ibaraki, Japan, 2. Faculty of Life and Environmental Sciences, University of Tsukuba, Tsukuba, Ibaraki, Japan, 3.National Institute for Environmental Studies, Tsukuba City, Ibaraki, Japan)

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

[HTT14-06] **Evaluating land use change with urban development and its impact on habitat quality**

*BINGYU WANG[1], Takashi Oguchi[1,2], Kotaro Iizuka[2], Xun Liang[3] (1.Department of Natural Environment Studies, The University of Tokyo, 2.Center for Spatial Information Science, The University of Tokyo, 3.School of Geography and Information Engineering, China University of Geosciences)

A GIS-based study on accessibility of public bus system in Sapporo

*ZITONG XU[1], Yuichi S. Hayakawa[2,3]

1. Graduate School of Environmental Science, Hokkaido University, 2. Faculty of Environmental Earth Science, Hokkaido University., 3. Center for Spatial Information Science, The University of Tokyo.

It is commonly known that one of the most important keys to realize a compact city is to develop convenient urban public transportation. According to the second Sapporo city planning master plan in March, 2016, there is a trend of population decreasing, super-aged society, and the shrinkage of the productive age population in Sapporo. With this background, it is desired to have thorough assessments of accessibility covering the residential areas for the sustainable development of the city. This study focuses on the accessibility in Sapporo city with a particular interest in the public bus system and its spatial relationships to the population and point of interest (POI) data. For this purpose, the specific population in every block is estimated and the POI index is obtained. More specifically, by analyzing the population and POI distribution around the bus system (every stop and route), we evaluate the accessibility of the bus system in Sapporo. The network analysis and spatial analysis are performed to provide the objective assessment of the accessibility which will be supportive information for the future urban planning.

Keywords: Sapporo, Population, Point of interest, Spatial analysis, Accessibility

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Comparative study of visitors' perceptions of places by analyzing visual content of photographs in Shinjuku, Tokyo

*Bochra Bettaieb[1], Yoshiki Wakabayashi[1]

1. Tokyo Metropolitan University

Photographs taken by tourists have the potential to play an important role in understanding visitors' behaviors and perceptions in tourist destinations. The authors had analyzed geocoded photographs taken in central Tokyo to compare the behavior patterns of foreign visitors. However, our previous study could not identify the contents of photographs. To resolve this issue, the present study employed a machine learning method to analyze the visual contents of photographs. The data obtained were geocoded photos in 2018, taken within 1 km from Shinjuku. We analyzed 1,940 photos taken by visitors from four major countries (e.g., USA, UK, Taiwan and Singapore) to Shinjuku who posted their pictures on Flickr. The images of photographs were analyzed by using Google Cloud' s Vision API that enables us to assign labels to images and automatically classify them into predefined categories. Based on the labels assigned to the photographs, we manually classified them into 8 categories. By employing the locational information of Flickr data, each photograph was geocoded as an input to GIS. The spatial distribution of photographs by category was compared between visitors' home countries to capture the variation in perception and behavior of visitors. The results indicated that the visitors' perceptions of Shinjuku varied with home countries of visitors. While all visitors showed a common perception of Shinjuku characterized by urbanism, some differences were observed among the other categories. Analysis of the spatial distribution of photos revealed that the photos categorized as urbanism widely distributed in and around Shinjuku station, whereas the photos categorized as culture concentrated at the east or south side of the station.

Keywords: Flickr, photo image, machine learning, GIS

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Geo-phenomenology: A Qualitative GIS Approach for Understanding People’ s Lived Experiences

*Yuki Iwai[1]

1. Graduate School, University of Tsukuba

Ⅰ. Introduction

Although geographic information systems (GIS) were used worldwide, there has been remarkably little debate about an applicability to understanding qualitative aspects of geographical phenomena. The aim of this study is to contribute methodological advances in GIS at the intersection of quantitative methods and qualitative analysis. The approach to GIS-based phenomenology developed in this study, called "Geo-phenomenology," is based on the integration of spatial analysis and interpretation to understand participants' lived experiences. The three central elements of this approach are (1) go-along interviews to obtain the lived experiences of participants; (2) spatial analysis and exploratory spatial data analysis (ESDA) in GIS; (3) interpretative phenomenological analysis as a qualitative approach. A case study of the commuting route of a female graduate student, Ms. J, attending a national university in Japan, is used to illustrate the approach.

Ⅱ. Research Method

Ms. J was asked to speak spontaneously about her memories and impressions on the way to school. The semi-structured interview is known as an appropriate method for interpretative phenomenological analysis because the participants narrate their experiences from their perspective. The survey was conducted over two consecutive days. On the first day, an overview of the survey was given, and we conducted the go-along interview from her school building to her house in the evening. The second day's survey was conducted in the morning, and the go-along interview was conducted from Ms. J's home to her school building along the same route as last night. During go-along interviews, the GPS (10-second intervals) and voice recorder were used.

Ⅲ. Results and Discussion

Combing the obtained narratives with locational information, Ms. J’ s lived experiences could be visualized spatially and temporally. From the quantitative point of view, the number of words was interpreted for where she was interacting with locations. Conversely, what content of narratives changed where was shown by ESDA in the qualitative perspective. Removing previous geographic knowledge and preconceptions (i.e., Epoché), the relationship between J's narratives and the environment on the way to school was analyzed. As a result, the number of words was highly distributed around the waterfront and the park. Focusing on the content in narratives, Ms. J recognized the area around the university as a rich natural environment. Moreover, an overall discussion of Ms. J's responses, the central theme of her experiences on the commuting route was closely related to youth. Geo-phenomenology makes it possible to find spatiotemporal patterns and rules of his (her) world regarding the way he (she) interacts with the various facilities, natural environments, people, and places. In addition, the method of this approach allows various spatiotemporal analyses because the narrative data is directly combined with the attribute table of the vector data. This is one of contributes that the development of analytical methods for qualitative GIS that is relying on visualization. Previous GIS research has been dominated by objective analysis using large amounts of data. In contrast, geo-phenomenology proves that using GIS is also useful even when the sample size is N=1.

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Keywords: phenomenological analysis, qualitative data analysis, exploratory spatial data analysis (ESDA), qualitative GIS

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UAS Surveys for Identifying Vacant Houses using Night Light and Thermal Information

*Kotaro Iizuka[1], Yuki Akiyama[1,2], Nobuyuki Imafuku[3], Satoru Sugita[4]

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Changes of the social environment such as the population decline has led to the increasing number of vacant houses in Japan. According to the Housing and Land Survey conducted by the Ministry of Internal Affairs and Communications, approximately 13.6 % of total housing units are vacant across Japan. Japanese government has enforced a new law, regarding the special law about the promotion of vacant houses. The law encourages the local governments to identify and record the situation of the vacant houses. However, the current situation of the identification method relies only on direct observation of the houses, estimating if it is vacant or not. The approach takes massive time and labor costs, which is inefficient to conduct such survey for the whole city and frequently. Situation always changes for house rents, people’ s activity, movements, etc., and difficulty rises to grasp the condition up to date.

This work considers the utilization of the Unmanned Aerial Systems (UAS) or hereafter drones, to spatially survey the necessary sites and identify the houses if they are vacant or not. Multiple aerial imageries were collected at different time of the day with a RGB camera. The Structure from Motion technique develops the 3D model of the residential areas which can be used to check through the 3D space. Nighttime flight was also conducted to collect the aerial imageries at nights. The data is processed to spatially identify the night lights that is observed from each home, which can be a direct measurement to identify the human activity. Finally, the thermal information simultaneously collected through the aerial survey was also image processed to observe the heat emission of each home, which also can be an indicator for human activities, hence, it would imply that vacant houses should have less heat transfer. We would like to present and discuss our proposed method for collecting the data and interpreting the developed data for understanding the situation.

Keywords: UAV, thermal, night light, remote sensing, vacant house

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Impacts of urbanization on the ecosystem services of the Muthurajawela Marsh and Negombo Lagoon, Sri Lanka

*SUMUDU DARSHANA ATHUKORALA ARACHCHIGE[1], Yuji Murayama[2], Bunkei Matsushita[2], Ronald C. Estoque[3]

1. Graduate School of Life and Environmental Sciences, University of Tsukuba, Tsukuba, Ibaraki, Japan, 2. Faculty of Life and Environmental Sciences, University of Tsukuba, Tsukuba, Ibaraki, Japan, 3. National Institute for Environmental Studies, Tsukuba City, Ibaraki, Japan

This study examines the impacts of urbanization on the ecosystem services of the Muthurajawela Marsh and Negombo Lagoon (MMNL), a critical urban wetland ecosystem (UWE) in Sri Lanka. We developed a framework to estimate the changes in the ecosystem service value (ESV) of the MMNL based on land use/cover (LUC) changes in the area from 1997 to 2017. This framework encompasses various sub-disciplines, including environmental history, urban ecology, wetland science, GIScience, and remote sensing. Considering a business as usual scenario (BAU) and an ecological protection scenario (EPS) and using a set of spatial variables (driving factors of LUC changes), we simulated the future LUC changes (2017-2030) in the MMNL and examined the consequent projected future changes in its ESV. The results showed that the total ESV of the MMNL has decreased by LKR 7,005.85 million, or about 66%, from 1997 to 2017, in which about 98% was due to the loss of marshlands and mangroves. The scenario analysis revealed that if the current LUC change pattern continued, marshlands would continue to decrease by 2030 under the BAU scenario. However, under the EPS scenario, the marshland would increase. The scenario analysis also revealed that the total ESV of the MMNL would also continue to decrease by LKR 3570 million under the BAU scenario. However, under the EPS scenario, there would only be about a decrease of LKR 2120 million. In this study, LUC management strategies and environmental engineering measures are discussed to provide scientific guidance for improving the ecosystem services of MMNL and other UWEs in the country.

Keywords: Wetland ecosystem service, Muthurajawela Marsh, Negombo Lagoon, Socio-ecological scenarios, Land Change Modeler, Urban ecology

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Evaluating land use change with urban development and its impact on habitat quality

*BINGYU WANG[1], Takashi Oguchi[1,2], Kotaro Iizuka[2], Xun Liang[3]

1. Department of Natural Environment Studies, The University of Tokyo, 2. Center for Spatial Information Science, The University of Tokyo, 3. School of Geography and Information Engineering, China University of Geosciences

Land use/and Cover Change (LUCC) is the core topic of the global environment, which significantly influences the structure and function of the ecosystem, including biodiversity, natural habitats, and resource usage. Accompanied by rapid population growth and socio-economic development, the world has undergone large-scale urban expansion. Therefore, seeking sustainable urban planning is essential to balance urban growth and environmental conservation. The concept of a compact city has been proposed globally as a critical strategy to establish sustainable urban forms. Whether a compact city is compelling for preserving the natural environment under urban development needs should be carefully examined considering regional differences.

Existing research has recognized the influences of landscape change on habitat quality by integrating ecosystem assessment tools and land use information. The Integrated Valuation of Ecosystem Services and Trade-offs model (InVEST) with intuitive spatial virtualization and less prior knowledge can improve the understanding and interpretation of ecosystem functioning. Spatiotemporal land use modeling is effective and reproducible for analyzing both causes and consequences of landscape dynamics. A growing body of land use simulation approaches with future scenarios such as the Cellular Automata (CA) model, which has been widely applied to illustrate landscape dynamics, with the fundamental expression of geospatial processes through cell states and their neighborhood space.

This research has adopted a patch-generating land-use simulation model (PLUS), which couples the CA model with a Random Forest algorithm of data mining technology, considering driving factors including topography and climate conditions, locational factors and traffic networks, and distribution of protected areas. This study proposes a framework to explore different urban patterns and their impact on habitat quality by incorporating the PLUS and InVEST models. Two coastal areas with urban agglomerations are selected for different urbanization levels, the National Capital Region (NCR) in the Tokyo Metropolitan Area of Japan and the Guangdong-Hong Kong-Macao Greater Bay Area (GBA) of China. Three future compact city scenarios with the urban layout evolution of high-compact cities, medium-compact cities, and low-compact cities are designed along with the corresponding habitat quality evaluation.

The results imply that under the scenario of high-compact cities, both significant improvement and degradation of habitat quality are observed within the study areas, and the total decline in habitat quality across each area is the largest. The scenario of low-compact cities depicts scattered urban growth with mixed land use patterns and have the least habitat quality variation in both areas. The scenario of medium-compact cities improves habitat quality more than that of low-compact cities in the NCR, and habitat quality decline is less than the scenario of high-compact cities. Therefore, conserving green space with medium-compact cities could be sustainable urban planning in the NCR. In the GBA, the scenario of medium-compact cities has average habitat quality variation compared with other scenarios. Here, macro-control of land use demand to prevent excessive urban growth and over-dense urban structure should be considered for long-term strategy.

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Keywords: land use change, habitat quality, compact city, urban simulation, future scenarios

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

Sun. Jun 6, 2021 3:30 PM - 5:00 PM JST | Sun. Jun 6, 2021 6:30 AM - 8:00 AM UTC | Ch.14 Zoom Room 14

[H-TT14] Geographic Information Systems and Cartography

convener:Takashi Oguchi(Center for Spatial Information Science, The University of Tokyo), Yoshiki Wakabayashi(Graduate School of Urban Environmental Sciences, Tokyo Metropolitan University), Yuei-An Liou(National Central University), C. Ronald Estoque(National Institute for Environmental Studies, Japan), Chairperson:Yuei-An Liou(National Central University), Ronald C. Estoque(National Institute for Environmental Studies, Japan)

This session discusses various methods which acquire, store, analyze and visualize geospatial data, and presents the outcomes of empirical studies using GIS or mapping methods. The session also deals with applications of digital data, and GIS, and mapping to various fields of earth and planetary science and human society. All presentations and discussion of this session are made in English.

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

[HTT14-07] Assessing the effect of landscape composition on land surface temperature in Tsukuba city, Japan

★Invited Papers

*RUCI WANG[1], Yuji Murayama[1], Takehiro Morimoto[1] (1.University of Tsukuba)

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

[HTT14-08] **Spatiotemporal Characterization and Evolution of Surface Urban Heat Islands in Tokyo: A Perspective from Land Cover/Use Layouts and Variations**

*Fei LIU[1] (1.University of Tsukuba)

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

[HTT14-09] Microclimate simulation of Doshisha University Kyotanabe campus with ENVI-met model

★Invited Papers

*XINGYU WANG[1] (1. Department of Environmental Systems Science, Doshisha University)

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

[HTT14-10] **Recent LULC change in Vietnamese Mekong Delta and its relation to land subsidence after implementation of the Resolution No.120/NQ-CP**

*Kim-Anh Nguyen[1], Yuei-An Liou[1], Phan Duong Cao[2], Philip Mindehoud[3] (1.National Central University, 2.University of Tsukuba, 3.University of Padova)

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

[HTT14-11] Locations of historical and archaeological sites in Japan and China in relation to geography

*Yuan Wang[1], Takashi Oguchi[1] (1.The University of Tokyo)

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

[HTT14-12] **Online Education of Disaster Risk Reduction using Web GIS: Applications to Chinese Secondary Schools**

*Jiali Song[1], Takashi Oguchi[2] (1.Graduate School of Frontier Sciences, The University of Tokyo, 2.Center for Spatial Information Science, The University of Tokyo)

Assessing the effect of landscape composition on land surface temperature in Tsukuba city, Japan

*RUCI WANG[1], Yuji Murayama[1], Takehiro Morimoto[1]

1. University of Tsukuba

In recent years, Urban Heat Island (UHI) phenomenon, which causes excessive energy consumption, environmental deterioration, and health damage, has become prevalent in many cities. Urban planners have been challenging to reduce UHI by effective city planning and policies. However, because of the complicated nature of causes in the urban environment changes, it is still challenging to measure their effectiveness on the UHI reduction. Therefore, this study takes Tsukuba city, a planned city, as an example, to assess the effect of landscape composition on Land Surface Temperature (LST) and evaluates the distribution of building height (3D) and functions (e.g., residential, commercial) on LST. This study uses Esri City Engine and ArcGIS software to conduct spatial analysis using remote sensing data, open street map data, and Zenrin data. The regression analysis examines the relationships between LST and land use/cover, building height, building function, and other variables (e.g., distance to the road). Our results show that green space management and control could be significant to harmonize demand growth, environment protection, economic development, and healthy urban establishment. The enhanced theoretical underpinning on sustainable cities can further promote city dwellers' environmental awareness and help the city make an orderly urban development.

Keywords: Geographical information science, Urban heat island, Land surface temperature, Land use/cover, Tsukuba city

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Spatiotemporal Characterization and Evolution of Surface Urban Heat Islands in Tokyo: A Perspective from Land Cover/Use Layouts and Variations

*Fei LIU[1]

1. University of Tsukuba

The surface urban heat islands (SUHI) phenomenon in the urban context has gained considerable attention due to the climate crisis and environmental health issues. Targeting Tokyo Metropolitan Area (TMA) as a critical case, this study profiled and clarified the spatial variations, relationships, and trends between land surface temperature (LST) and land cover/use from 2001 to 2015 based on multi-source spatial data. Toward an in-depth understanding of SUHI dynamics in TMA for mitigation solutions and appropriate urban policies, this study conducted an integrative investigation by examining the spatiotemporal evolution of thermal gradients between the urban and non-urban fabric areas and delineating the layouts of thermal cores in TMA. The spatial interconnections between SUHI and its potential driving forces were explored and identified by incorporating spatial regression analysis. Results indicate that Tokyo was recognized as a polynucleated-structure metropolitan area distributing multiple intense thermal island clusters over space. Thermal islands densely emerged in the compact low/middle-rise residential quarters and renovating regions, rather than in the central business districts of TMA. High-rise buildings shielding solar radiation, the contributions of large-scale water bodies and urban afforestation, and sea breezes' impacts might result in this phenomenon. In light of this, this study suggests that the local authorities consider delineating the thermal cores areas, alleviating the magnitude of persistent thermal islands area, and controlling the emergence and formation of new thermal cores, coupled with partitioned or location-specified landscape-designing and green measures. Findings from this study can strive to tackle the urban climate issues and contribute to broader planning considerations on future sustainable development.

Keywords: Land Cover/Use, Land Surface Temperature, Tokyo Metropolitan Area, Urban Sustainability, Surface Urban Heat Island

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Microclimate simulation of Doshisha University Kyotanabe campus with ENVI-met model

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Microclimate refers to small-scale meteorology, ranging from a few meters to a few kilometers, and directly affects our daily activities. The microclimate formed in a certain place is strongly influenced by the surrounding environment, such as topography, land-use, and type of vegetation, which are provided within standard GIS datasets. Recently, the microclimate simulations have been performed with the boundary conditions generated from GIS datasets to get the information on local climate, such as daily maximum/minimum temperature, humidity, and wind speed. One of the microclimate models used in the world is ENVI-met, which calculates mass, momentum, and energy budgets in a 3-dimensional space through the Eulerian approach, developed by Michael Bruse (Bruse 1999; see www.envi-met.com). Many researchers have studied the simulation capabilities of ENVI-met (e.g., Crank et al., 2018; Lopez-Cabeza et al., 2018), and compared ENVI-met with other models (e.g., Paas and Schneider, 2016; Liu et al., 2020; Gal and Kantor, 2020). It has been found that the ENVI-met simulations are relatively precise, while there are situations where it cannot highlight the difference of solar radiation in space and time (Liu et al., 2020; Gal and Kantor, 2020). This research focuses on the verification of the numerical stability of ENVI-met model through the microclimate simulation of Doshisha University Kyotanabe campus, and explores the capability of ENVI-met to produce the useful information on the local climate and the impact of different environment layout on the microclimate.

Microclimate simulations of Kyotanabe campus for a period from 0:00 to 24:00 on December 1, 2020 are conducted with ENVI-met model. The simulation area is 300 m×170 m×73.29 m, and grid number 300×170×28. The locations and heights of buildings come from KML data generated by Google Earth. The vegetation types are selected from the ENVI-met database, according to the actual vegetation. The soil moisture and temperature are based on the observations by Kyoto-city (2018) and Kinouchi and Yoshitani (2001). Meteorological conditions for the simulations, including surface air temperature, wind speed, and wind direction, are provided by the observations at Kyotanabe AMeDAS of Japan Meteorological Agency. We compare the meteorological observations on the lawn in Kyotanabe campus with the ENVI-met simulations, and explore the relationship between the simulated microclimate and the surrounding environment.

Simulated surface air temperature shows the daily variations similar to those of the observed temperature, although the simulated temperature is about 2 degrees lower than the observed temperature in the daytime. This may be due to the setting of excessive cloud cover, resulting in less solar radiation. Simulated relative humidity is lower than the observed relative humidity in the nighttime, and opposite in the daytime. Simulated wind speed fluctuates little and is much larger than the observed wind speed. The deviation may be caused by inappropriate model settings. The simulated air temperature and wind speed show the dependence on the degree of closed environment by buildings and trees. The enclosure degree affects the flow of air and the amount of received solar radiation and lost heat. It is found that the closed

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environment has better heat conservation capability. The ENVI-met is basically good at microclimate simulations, and shows a significant impact of different environments on the microclimate. The enclosure degree of environment has a negative correlation with wind speed and relative humidity, and a positive correlation with air temperature.

Keywords: Microclimate, Urban environment, Numerical simulation

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Recent LULC change in Vietnamese Mekong Delta and its relation to land subsidence after implementation of the Resolution No.120/NQ-CP

*Kim-Anh Nguyen[1], Yuei-An Liou[1], Phan Duong Cao[2], Philip Mindehoud[3]

1. National Central University, 2. University of Tsukuba, 3. University of Padova

Vietnamese Mekong Delta (VMD) is known as the second largest granary in the world, while its rice paddy yield has been seriously threatened by the alarmingly enhanced extreme weathers and human intervention in the upstream. After serious drought in 2016, the Vietnamese government enforced the Resolution No.120/NQ-CP on 17/11/2017 and Directive No. 04/CT-TTg on 4/2/2016 aiming for sustainable development of the Mekong Delta to adapt to climate change. These introduced strategies with new visions and strategic directions that lead the economic development of VMD focusing on aquaculture, fruit, and rice products, corresponding to transformation in land use and land cover (LULC). Consequently, LULC change in the Mekong Delta from paddy rice field to aquaculture has been observed significant, and LULC change has been found to accelerate the subsidence over aquaculture lands and wetlands. This paper presents the LULC change in the VMD, land subsidence and their relationship in the timeframe from 2014 to 2019. Land subsidence map and its value were generated from Sentinel-1 imagery from ESA (European Space Agency), LULC maps were created from the Landsat data time series. The accuracy of the LULC classification is 95% with Kappa coefficient 0.94. The land subsidence was validated with measured data. Results show that significant land subsidence generally occurred in aquaculture land, open water and mangrove wetland, which were significantly increased in terms of areas from the LULC change analysis. LULC change and its relationship with land subsidence in the VMD were also discussed. Results of the study provide useful information for the authorities to design plans to mitigate human impacts and reduce the risk while dealing with climate change.

Keywords: land subsidence;, land use, land cover; , Mekong Delta , Sentinel-1, Landsat

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Recent LULC change in Vietnamese Mekong Delta and its relation to land subsidence after implementation of the Resolution No.120/NQ-CP

Kim-Anh Nguyen[1,2], Yuei-An Liou*[1], and Phan Duong Cao[3] and Philip Mindehoud[4]

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Abstract:

Vietnamese Mekong Delta (VMD) is known as the second largest granary in the world, while its rice paddy yield has been seriously threatened by the alarmingly enhanced extreme weathers and human intervention in the upstream. After serious drought in 2016, the Vietnamese government enforced the Resolution No.120/NQ-CP on 17/11/2017 and Directive No. 04/CT-TTg on 4/2/2016 aiming for sustainable development of the Mekong Delta to adapt to climate change. These introduced strategies with new visions and strategic directions that lead the economic development of VMD focusing on aquaculture, fruit, and rice products, corresponding to transformation in land use and land cover (LULC). Consequently, LULC change in the Mekong Delta from paddy rice field to aquaculture has been observed significant, and LULC change has been found to accelerate the subsidence over aquaculture lands and wetlands. This paper presents the LULC change in the VMD, land subsidence and their relationship in the timeframe from 2014 to 2019. Land subsidence map and its value were generated from Sentinel-1 imagery from ESA (European Space Agency), LULC maps were created from the Landsat data time series. The accuracy of the LULC classification is 95% with Kappa coefficient 0.94. The land subsidence was validated with measured data. Results show that significant land subsidence generally occurred in aquaculture land, open water and mangrove wetland, which were significantly increased in terms of areas from the LULC change analysis. LULC change and its relationship with land subsidence in the VMD were also discussed. Results of the study provide useful information for the authorities to design plans to mitigate human impacts and reduce the risk while dealing with climate change.

Keywords: land subsidence; land use/land cover; Landsat data; Sentinel-1; Mekong Delta; Vietnam

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Locations of historical and archaeological sites in Japan and China in relation to geography

*Yuan Wang[1], Takashi Oguchi[1]

1. The University of Tokyo

The remains of historical/archaeological sites exist all over the world. Their existence provides the basis of researches for many disciplines such as Archaeology, History, and Geography, as they can reflect activities and thinking of ancient people who built them as well as related environmental factors. In previous studies about the relationship between ancient sites and their surroundings, local topography is considered to be one of the most important factors that determine what kind of features to build, and several topographic factors such as elevation, slope and aspect have been analyzed. However, such research is still uncomprehensive, and the quantitative expression of relationships between the ancient sites and related topographic factors needs to be explored further. Therefore, this research utilizes GIS and DEMs (Digital Elevation Models) to investigate topographic factors more comprehensively as well as surface hydrological conditions in relation to historical and archaeological sites in Japan and China. It employs machine learning methods for quantitative analyses and compare the results from the two countries. The results were interpreted based on geographical, historical, and archaeological knowledge. It was found that the ancient sites in different study areas are sensitive to different topographic factors, and the distance between the ancient sites and major rivers also influence their distribution. Finally predictive maps of historical/archaeological sites were produced according to the obtained quantitative results.

Keywords: GIS, Topographic factors, Ancient sites

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Online Education of Disaster Risk Reduction using Web GIS: Applications to Chinese Secondary Schools

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Use of Web GIS for DRR (Disaster Risk Reduction) has received attention in recent years. In 2022, a new subject of geography will become compulsory in Japanese high schools, and the guideline for the subject was provided by the Ministry of Education, Culture, Sports, Science, and Technology. The guideline shows that the new subject focuses on maps, GIS, ESD (Education for Sustainable Development), international understanding, regional surveys, and DRR. Introducing Web GIS to DRR education in school classrooms will be essential for students to develop knowledge and skills of DRR. There have been Web GIS systems for school education in Japan. For example, ESRI Japan provides the ArcGIS Online service to Japanese schools for learning geography with GIS technology. As a disaster-prone country, Japan puts emphasis on pre-DRR actions, and has relatively strong DRR countermeasures. Therefore, the United Nations Development Programme (UNDP) has allowed Japan to share the lessons learned from past earthquakes and other disasters. However, even in Japan, there are still no well-established guidelines for teaching DRR in schools, and it is still unknown whether students can understand DRR and improve their ability of DRR thinking by using GIS. Therefore, this study utilizes Web GIS technology to support geospatial thinking of students, and investigates factors influencing the learning effects of students. For this purpose, we developed materials for systematic DRR education and designed curricula to utilize the material effectively. This approach was implemented multiple times for students in Chinese secondary schools as online courses during the COVID-19 pandemic. Questionnaire surveys were also conducted during the courses to collect information useful for evaluating the educational effects of our educational materials and curricula. Important findings from the questionnaire surveys are: 1) students who can pay more attention to disaster information tend to feel easier to learn DRR, whereas the past learning experience of Web hazard maps is only weakly related; 2) experience of using Web maps makes students easier to learn about hazard maps; and 3) ability of using electronic products helps students learn GIS.

Keywords: Disaster risk reduction education, Web GIS, Learning effects

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

Sun. Jun 6, 2021 9:00 AM - 10:30 AM JST | Sun. Jun 6, 2021 12:00 AM - 1:30 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:Satoshi Ide(Department of Earth an Planetary Science, University of Tokyo)

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.

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

[SCG39-19] Systematics and heterogeneity of deep and shallow slow earthquakes

*Kazushige Obara[1] (1.Earthquake Research Institute, The University of Tokyo)

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

[SCG39-20] Extraction of fine space-time structures in deep low-frequency tremor using the Hough transform

*Kodai Sagae[1], Hisashi Nakahara[1], Takeshi Nishimura[1], Kazutoshi Imanishi[2] (1.Solid Earth Physics Laboratory,Department of Geophysics,Graduate School of Science,Tohoku University, 2.National Institute of Advanced Industrial Science and Technology (AIST))

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

[SCG39-21] Comprehensive detection of tremor migration using multiple time windows beneath Kii Peninsula

*Takuya Maeda[1], Kazushige Obara[1], Akiko Takeo[1], Takanori Matsuzawa[2] (1. Earthquake Research Institute, The University of Tokyo, 2.National Research Institute for Earth Science and Disaster Resilience)

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

[SCG39-22] Focal mechanism and radiated energy from shallow tremors in the Guerrero seismic gap.

*Raymundo Omar Plata Martinez[1], Yoshihiro Ito[2], Kazuaki Ohta[4], Masanao Shinohara[5], Satoshi Ide[3] (1.Graduate School of Science, Kyoto University, 2.Disaster Prevention Research Institute, Kyoto University, 3.Department of Earth and Planetary Science, University of Tokyo, 4.National Research Institute for Earth Science and Disaster Resilience, 5.Earthquake Research Institute, University of Tokyo)

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

[SCG39-23] Seismicity around the subducted seamount in the trench-trench junction, southern off Hokkaido, by a broadband OBS array

*Ryosuke Azuma[1], Susumu Kawakubo[1], Hidenobu Takahashi[1], Ryota Hino[1], Yusaku Ohta[1], Ryota Takagi[1], Syuichi Suzuki[1], Makiko Sato[1], Tanaka Shinichi[2], Masanao Shinohara[2] (1.Recearch Center for Prediction of Earthquake and Volcanic Eruption, Graduate School of Science, Tohoku University, 2.Earthquake Research Institute, University of Tokyo)

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

[SCG39-24] Discussion

Systematics and heterogeneity of deep and shallow slow earthquakes

*Kazushige Obara[1]

1. Earthquake Research Institute, The University of Tokyo

During the last two decades from the first discovery of slow earthquakes in southwest Japan around 2000, many types of slow earthquakes associated with different source depths and time scales have been discovered in such a way to fill gaps in space and spectral domains because of deployment of observation networks, continuous monitoring, and development of analyzing technology. As a result, composition of slow earthquakes in shallow and deep parts became common at present although different at the beginning. On the other hand, more quantitative and comprehensive analyses revealed more heterogeneous activity pattern of slow earthquakes rather than homogeneous. In this presentation, I would like to review the slow earthquake activity from points of view on systematics and heterogeneity.

Slow earthquakes in the Nankai trough region are separated into shallow and deep sides of the huge earthquake seismogenic zone along the subducting Philippine Sea plate interface. Deep slow earthquakes are systematically separated into Episodic Tremor and Slip (ETS), which is composed of tremor, very low frequency earthquake (VLF), and short-term slow slip event (SSE) at the deepest part and long-term SSE in between ETS and locked zones. Long-term SSEs have been detected in some places in this intervened zone as to fill the spatial gap recently although originally detected at two limited areas. These deep slow earthquakes are distributed at their own depths along-strike horizontally separated into some segments with different spatiotemporal pattern. This suggests that the type of slow earthquakes is systematically controlled by the environment as a function of depth.

On the other hand, the distribution pattern of shallow slow earthquakes is different from those of deep slow earthquakes. Although shallow VLF were originally detected at some spatiotemporal clusters along the Nankai trough, very recently shallow SSE, VLF and tremor has been detected simultaneously southeast off Kii Peninsula. This is an evidence for the occurrence of ETS in shallow side. Moreover, a long-term SSE was detected by acoustic GNSS measurement system near the Nankai trough. As a result, we have a common set of slow earthquakes in both shallow and deep sides; however, detail distribution pattern is different. Near the Nankai trough, shallow ETS and long-term SSE are aligned along-strike on the same depth contour line of the subducting plate. This indicates along-strike strong heterogeneity including different types of slow earthquakes and also strong/weak coupling portions. This along-strike heterogeneity is similar to the Japan trench.

Regarding spatiotemporal activity of slow earthquakes, there are two characteristic properties: migration and recurrence. Migration of ETS including slow speed main front migration and Rapid Tremor Reversal is common for shallow and deep sides. On the other hand, recurrence property is different. Deep ETS indicates beautiful periodic pattern at each segment; however, there is no clear periodicity in shallow ETS activity. This might be interpreted that shallow strong heterogeneity affects interaction between different neighboring phenomena and disturbs regular recurrence behavior. However, migration indicating rupture propagation of slow slip event is interpreted as a common process after initiation in both shallow and deep sides.

Keywords: Slow earthquake, tremor, very low frequency earthquake, slow slip event

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Extraction of fine space-time structures in deep low-frequency tremor using the Hough transform

*Kodai Sagae[1], Hisashi Nakahara[1], Takeshi Nishimura[1], Kazutoshi Imanishi[2]

1. Solid Earth Physics Laboratory,Department of Geophysics,Graduate School of Science,Tohoku University, 2. National Institute of Advanced Industrial Science and Technology (AIST)

Tremor migration is one of the important features of deep low-frequency tremors. The characteristics of the tremor migration are classified into the following three types: (1) Long-term migration (Obara, 2010) for which tremor propagates along the strike of a subducting plate at approximately 10 km/day in synchronization with a slow slip event (SSE); (2) Rapid tremor reversal (RTR) for which tremor propagates along the strike into the reverse direction to the long-term migration with a speed of approximately 200 km/day (Houston et al., 2011); (3) Tremor streak which is a migration of tremor along the dip at approximately 1000 km/day (Ghosh et al., 2010). We usually investigate the temporal evolution of tremors by projecting tremor locations into an axis (Obara, 2010; Sagae et al., 2021, GJI). Therefore, it is necessary to study the three-dimensional behavior of tremors from the epicentral distribution and the time of occurrence. In the field of astronomy, Morii (2019) performed a detection of straight lines using the 3-D Hough transform (2D in space and 1D in time) to investigate movements of celestial bodies in the observed images. We called the method as “space-time Hough transform” to distinguish it from the conventional 3-D Hough transform in 3D spatial dimensions. As a previous study which applied Hough transform in seismology, Uchide and Imanishi (2017, SSJ) detected fault planes using hypocenter locations and focal mechanism information based on the conventional Hough transform. In this study, by slightly modifying the space-time Hough transform, we extract fine space-time structures in tremor migrations.

In this study, straight lines (tremor migrations) are detected in the three-dimensional space of the epicentral distribution and time. We set the positive x-axis, y-axis, and z-axis in the east, north, and time direction, respectively. Any straight line in the three-dimensional space is represented as $\rho = x(-\sin\phi \sin\psi + \cos\theta \cos\phi \cos\psi) + y(\sin\phi \cos\psi + \cos\theta \cos\phi \sin\psi) - z(\sin\theta \cos\phi)$, where ρ is the distance from the origin to the straight line, θ is the zenith angle, ϕ is the azimuth, and ψ is the rotation angle, respectively. In particular, $\tan\theta$ represents the migration speed, and the vector $(\cos\psi, \sin\psi)$ represents the direction vector in the x-y plane. In this study, the direction vector of a straight line is taken in the radial direction, whereas in Morii (2019), that is taken in a direction perpendicular to the radial direction. We set a “bin” for each parameter of $(\rho, \theta, \phi, \psi)$. Then, we calculate ρ while changing (θ, ϕ, ψ) for each event, and perform a “vote” to the corresponding “bin”. Finally, the “bin” $(\rho, \theta, \phi, \psi)$ with the largest number of votes is the best straight line that represents event data best. Furthermore, even if there are multiple straight lines in the space, these straight lines can be detected separately using the Hough transform because votes for different lines are cast on different “bins”. This enables to relax a constraint of one migration in one time-window used in previous studies (Obara et al., 2012; Maeda et al., 2020 SSJ). Our method has a potential to detect multiple migrations within a time window.

We analyzed a tremor catalog in which tremor epicenters were determined using a dense seismic array beneath the Kii Peninsula (Sagae et al., 2021, GJI). This catalog is suitable for investigating details of tremor migrations because it determined approximately 2.2 times more tremors than a catalog determined by the envelope correlation method (Obara, 2002). The analyzed period is from July 2012 to July 2014. We used every one hour time-window to detect migrations. The parameters “bins” were set

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in increments of 10 degrees for ϕ and ψ, in the range of 1–40 km/hr for θ, and in an increment of 5 km for ρ in consideration of uncertainties in the tremor locations. The Hough transform was applied when the time-window contained more than 10 events, and a straight line with the largest number of votes was detected. Then, after removing events composing the straight lines already detected, other straight lines were detected iteratively until the number of unvoted events was less than 10 events.

As a result, we found that predominant directions of migrations differ depending on locations. In the place where along-strike migrations were predominant, we found a feature that tremor migrated into the opposite direction to the long-term migration. Moreover, locations of RTR and Tremor streak reported in Sagae et al. (2021, GJI) were similar to locations where migrations were predominant in the strike and dip directions, respectively. This result suggests that RTR and Tremor streak may occur repeatedly in the same locations.

Keywords: Deep low-frequency tremor,, Hough transform, Migration, Kii Peninsula

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Comprehensive detection of tremor migration using multiple time windows beneath Kii Peninsula

*Takuya Maeda[1], Kazushige Obara[1], Akiko Takeo[1], Takanori Matsuzawa[2]

1. Earthquake Research Institute, The University of Tokyo, 2. National Research Institute for Earth Science and Disaster Resilience

Deep low-frequency tremors occur downdip of seismogenic zone along the subducting plate interface. Together with short-term slow slip events (SSEs), tremors constitute the Episodic Tremor and Slip (ETS; Rogers and Dragert, 2003). Tremors are known to migrate in the along-strike direction at a velocity of ~10 km/day. After main slip front associated with the ETS passes, relatively small-scale and high-velocity migrations like as Rapid Tremor Reversal (RTR ; Houston et al., 2011) and streak (Ghosh et al., 2010) are often observed. RTR propagates in the direction opposite to that of the ETS main front at a velocity of ~100 km/day, and streak propagates in the along-dip direction at a velocity of ~1000 km/day. Bletery et al. (2017) interpreted these migrations of tremors to represent secondary slip fronts (SSFs) and detected SSFs with wide timescales in Cascadia. In this study, we comprehensively detect SSFs using multiple time windows and estimate migration parameters beneath the Kii Peninsula, southwest Japan.

We use a tremor catalog derived by using the hybrid method based on the envelope correlation considering the spatial distribution of amplitude (Maeda and Obara, 2009). We analyze tremors included in not only major ETS but also minor episodes beneath the Kii Peninsula during 2001 to 2020. In order to detect various SSFs, we use seven different time windows (1 h, 2 h, 4 h, 8 h, 16 h, 32 h,64 h). In this analysis, we assume that all tremor sources in a SSF migrate in one direction in each fixed time window and the migration front extends perpendicularly to the migration direction. First, we estimate the direction of migration as follows: (i) remove spatial outliers from the tremors included in the time window, (ii) calculate the correlation coefficient between time and distance along temporary migration direction, (iii) find a direction which gives the maximum correlation coefficient by a grid search. Next, we estimate the velocity of migration as follows: (i) remove spatiotemporal outliers by the linear regression of space–time plot projected on the direction of migration, (ii) find the slope of the regression line of remaining points. Finally, assuming that SSF area is a rectangle here, we estimate the spatial dimension of SSF as follows: (i) calculate the migration length from the product of migration velocity and duration, (ii) locate the spatial center of SSF in each time window, (iii) calculate standard deviation (σ) of distance between the tremor sources and a straight line in the migration direction through the center, (iv) define the perpendicular width of SSF as 6σ.

As a result, the distribution of direction is isotropic in shorter time windows and is dominated in the along-strike direction as the time window becomes longer. This result is consistent with previous studies in the sense that SSF in the strike direction is dominant in longer time windows (Bletery et al., 2017; Ide, 2012; Obara et al., 2012). The velocity of SSFs becomes slower as the time window increases. For example, average velocity is 270 and 9 km/day for the time window of 1 and 64 h, respectively. Regarding the shape of the SSF, the perpendicular width is longer than the migration length in most of the SSFs. The area of SSFs does not change significantly in shorter time windows. The isotropic distribution of direction in shorter time windows suggest that short timescale migrations occur in a random direction. The along-strike direction in longer time window is interpreted to represent the main slip front. The result that most of the SSF migrates with a spread in the perpendicular direction to the migration direction suggests that migration is two-dimensional phenomena rather than one- dimensional phenomena like as streak.

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Keywords: slow earhquake, tremor, migration

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Focal mechanism and radiated energy from shallow tremors in the Guerrero seismic gap.

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Thanks to the recent development of offshore seismic networks monitoring shallow slow earthquakes have been reported in different subductions zones, such as the case of the Japan trench, New Zealand and most recently the Guerrero seismic gap at the Mexican subduction. In Guerrero, a good understanding of deep slow earthquakes has already been acquired, on the contrary, shallow slow earthquakes in Guerrero have been scarcely explored. A better knowledge of the shallow slow earthquakes in the Guerrero seismic gap is necessary to characterize the seismogenic zone at the shallow plate interface. Shallow tremors in the Guerrero seismic gap were observed using data from an array of ocean bottom seismometers (OBS). We analyzed this data to estimate source parameters, such as focal mechanisms and radiated seismic energies of shallow tremors. OBS data includes attenuation and site effects, predominantly from an offshore environment, which needs to be understood to unmask source properties of seismic events recorded. After correcting horizontal orientation of OBS, focal mechanism of shallow tremors and regular earthquakes were calculated by inverting observed S-wave polarization angles. Focal mechanisms for both shallow tremors and regular earthquakes trend to follow the subducting plate motion with a low thrust angle. Additionally, spectral inversion with regular earthquakes was done to estimate site effects and attenuation for the OBS region. By removing these two effects, source spectrum of shallow tremors will be available for comparison with regular earthquakes in the region. Describing shallow tremors in the Guerrero the seismic gap will bring a new perspective of the seismic behavior of the Guerrero seismic gap.

Keywords: Shallow tremor, Guerrero gap, Slow earthquakes, Focal mechanism, Seismic energy

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Seismicity around the subducted seamount in the trench-trench junction, southern off Hokkaido, by a broadband OBS array

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Many shallow very-low-frequency earthquakes (sVLFE) have been observed in the Kuril and Japan trench-trench junction, southern off Erimo, Hokkaido, by the inland F-net (Asano et al., 2008). In this region, many tectonic tremors have been also discovered by the S-net after 2016 (Tanaka et al., 2019; Nishikawa et al., 2019) and the long-term offline ocean bottom seismometer (OBS) network between 2006 and 2007 (Kawakubo et al., 2020). These studies reported simultaneous occasion of sVLFE and tremors. Kawakubo et al. additionally indicated that intervals of activities and epicenters distribution are roughly consistent with that before and the 2011 Tohoku-oki earthquake. However, there is no broad-band observatory above sVLFEs, and known hypocenters only by F-net are less accurate. Therefore, a spatial comparison of sVLFEs with tremors and regular earthquakes is difficult. In addition, because a spatial relation between a seamount subduction from the junction (Tsuru et al., 2005; Makino, 2005) and sVLFE occasion is expected, a near-field observatory providing precise spatio-temporal distribution of earthquakes is essential for understanding a state of the slow earthquake activities. From above backgrounds, we aim to investigate a seismicity of slow and regular earthquakes by deploying a near-field broad-band OBSs array.

This study uses seismograms recorded by one broad-band (120 seconds) OBS and four shot-period (1 Hz) OBSs deployed around the subducted seamount during July 6th, 2019 to October 8th, 2020. The deployment and recovery of OBSs were operated by the R/V Shinsei-maru (KS19-12 and KS20-16 cruises), the Japan Agency for Marin-Earth Science and Technology, and the R/V Ryoufu-maru (RF20-07), the Japan Meteorological Agency. Seismograms were recorded by a recorder featuring a 24-bit A/D converter with a 200 Hz sampling rate.

To investigate sVLFE, we firstly search tremors occurring simultaneously with sVLFEs by an envelope correlation method (Ide, 2010) which calculates correlation between station pairs and estimates hypocenters by using residuals of arrival times between pairs with maximum correlation coefficient over an optional value. We calculated envelopes from three components of seismograms between 2–8 Hz, took the squared sum of components, low-pass filtered below 0.5 Hz, and finally resampled at 1 Hz. We then took cross correlation for each 120 s window with 60 s overlap and adopted events with a maximum correlation coefficient over 0.6 at all pairs of stations. Finally, we extracted reliable events in accordance with a hypocenter error < 5 km, and arrival time residual < 3 s.

As a preliminary result, we obtained 378 events satisfying thresholds for errors, and 176 of them have a duration over 20 seconds, identified as tremors referring to Ohta et al. (2019). Followings are of interest in our result.

(1) A time series of all events projected along the seismic survey line (Tsuru et al., 2005; Makino et al., 2005) shows a highly activating period accompanied by long duration events on middle February, 2020, so that simultaneous sVLFE occasion is expected. We will process a waveform analysis for this period as a

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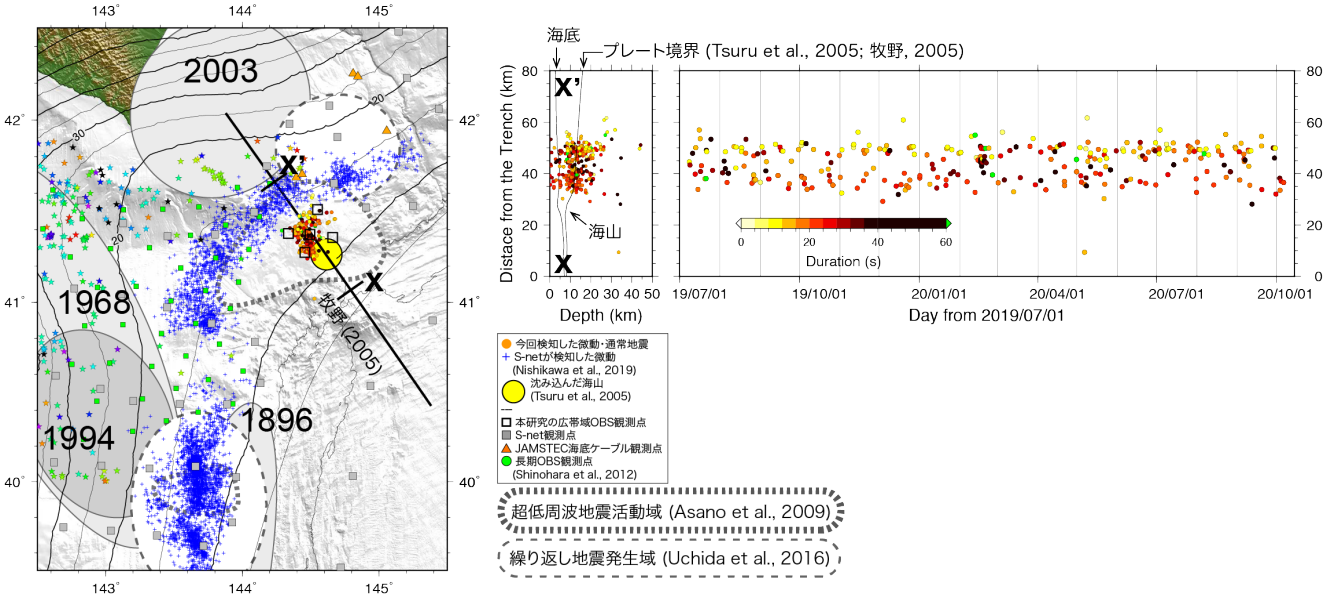
first step of sVLFE investigation.

(2) Most of determined events locate at the west half of the array, that is down-dip side of the subducted seamount. This may indicate a stress accumulation by the forearc–seamount collision.

(3) The resultant epicenter distribution seems to be isolated from that by previous works (Nishikawa et al., 2019; Kawakubo et al. 2020). Such a state of the seismic gap would be apparent related with a limit of detectable area of S-net and our arrays. Therefore, to discuss the isolation, the analysis with S-net data to expand the detectable area would be effective.

As future tasks, careful investigation of accuracy of hypocenter and duration, and confirmation of events on seismograms would bring an understanding of the state of seismic activity and the relationship with the subducted seamount.

Keywords: Shallow VLFEs and tremors around the Kuril and Japan trench-trench junction, Broadband ocean bottom seismometer array observation, Subducted seamount



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[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:Satoshi Ide(Department of Earth an Planetary Science, University of Tokyo)

Sun. Jun 6, 2021 9:00 AM - 10:30 AM 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.

10:15 AM - 10:30 AM

[SCG39-24]Discussion

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

Sun. Jun 6, 2021 10:45 AM - 12:15 PM JST | Sun. Jun 6, 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

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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

[SCG39-25] Spatio-temporal variation of fluid migration associated with slow earthquakes in the shallow Nankai subduction zone

*Takashi Tonegawa[1], Shunsuke Takemura[2] (1.Japan Agency for Marine-Earth Science and Technology, 2.Earthquake Research Institute, The University of Tokyo)

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

[SCG39-26] Land and marine long-term magnetotelluric observations around the western Nankai slow slip area

*Hiroshi Ichihara[1,2], Makoto Uyeshima[3], Hayato Nakamura[1], Maki Hata[3], Tada-nori Goto[4], Noriko Tada[2], Tetsuo Matsuno[5], Shinya Sato[6], Yoshiya Usui[3], Ryokei Yoshimura[7], Koki Aizawa[8] (1.Graduate school of Environmental Studies, Nagoya University, 2.JAMSTEC, 3.ERI, University of Tokyo, 4.University of Hyogo, 5.KOBEC, Kobe University, 6.Graduate school of Engineering, Kyoto University, 7.DPRI, Kyoto University, 8.Graduate school of Science, Kyushu Univeristy)

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

[SCG39-27] Active source seismic experiment investigating structural characteristics associated with slow earthquake activities in the Hyuga-nada, southwestern Japan

*Seiichi Miura[1], Kimihiro Mochizuki[2], Ryuta Arai[1], Yasuyuki Nakamura[1], Yuka Kaiho[1], Gou Fujie[1], Shuichi Kodaira[1], Rie Nakata[2], Yanxue Ma[2], Masataka Kinoshita[2], Yoshitaka Hashimoto[3], Yohei Hamada[1] (1.Japan Agency for Marine-Earth Science and Technology, 2.Earthquake Research Institute, University of Tokyo, 3.Kochi University)

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

[SCG39-28] Seismic characteristics of the northern Hikurangi subduction zone revealed by offshore seismic observations

*Kimihiro Mochizuki[1], Yusuke Yamashita[2], Emily Warren-Smith[3], Martha K Savage[4], Laura M Wallace[3], Stuart Henrys[3] (1.Earthquake Prediction Research Center, Earthquake Research Institute, University of Tokyo, 2.Disaster Prevention Research Institute, Kyoto University, 3.GNS Science, 4.Victoria University of Wellington)

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

[SCG39-29] **Temporal velocity variations in the northern Hikurangi margin and their relation to slow slip**

*Weiwei Wang[1], Martha Savage[1], Alec Yates[1,2], Hubert Zal[1], Carolyn Boulton[1], Megan Kortink[3], Tim Stern[1], Bill Fry[3], Kimihiro Mochizuki[4], Spahr Webb[5], Wallace Laura[3] (1.Victoria University of Wellington, 2.Université Grenoble Alpes, Université Savoie Mont Blanc, 3.GNS Science, 4.Earthquake Research Institute, University of Tokyo, 5.Lamont-Doherty Earth Observatory, Columbia University)

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

[SCG39-30] Discussion

Spatio-temporal variation of fluid migration associated with slow earthquakes in the shallow Nankai subduction zone

*Takashi Tonegawa[1], Shunsuke Takemura[2]

1. Japan Agency for Marine-Earth Science and Technology, 2. Earthquake Research Institute, The University of Tokyo

Slow earthquakes in the subduction zones are potentially linked to fluids, and such observations have been recently reported in the shallow Nankai subduction zone through heterogeneous variations of seismic structure (Tonegawa et al. 2020, JpGU, AGU). However, the region of fluid migration has not been precisely identified yet. Because those studies have reported that fluid migration may occur before shallow slow earthquakes, the identification of the region of fluid migration is important to investigate the characteristics of shallow slow earthquakes. In this study, we estimated two-dimensional maps of the scattering coefficient by seismic heterogeneous variations through a non-linear inversion, i.e., simulated annealing, and investigated the relationship between the scattering coefficient changes, which reflects fluid migration, and slow earthquakes. Here, this technique was confirmed by synthetic waveforms calculated with a three-dimensional velocity structure incorporating heterogeneous structure and random sources at the sea surface.

In the numerical simulations, we set a region with a velocity reduction, and estimated scattering coefficient by using synthetic waveforms with and without the velocity reduction. We performed this test twice by changing the region of velocity reduction, and these tests showed that the anomalies of the scattering coefficient were suitably estimated at the regions of the velocity reductions.

We applied this technique to the following observed data. We calculated cross-correlation functions (CCFs) from ambient noise records in the vertical component observed at the DONET stations, and the stacked CCFs show ocean-acoustically coupled Rayleigh (ACR) waves at frequency band of 0.5–2.0 Hz. We further calculated cross correlation coefficients (CCs) between the reference CCF and individual CCF, which was corrected by temporal change in seismic velocity. Here, dCC is defined by the difference of the CCs (CCs) between the stable period and the period with a reduction. The dCCs for all of the station pairs were the observed data, and such dCCs were observed multiple times.
As a result, the anomaly of the scattering coefficient was estimated to be surrounding and partly overlapped with the region of slow earthquakes including slow slip event (SSE) observed by borehole pore pressure measurements and very low frequency earthquakes (VLFEs). Figure 1 shows an example of dCC occurred in 2012, and the anomaly region was estimated at the southern part of and around the SSE region estimated by Araki et al. (2017). This observation may indicate that a leakage of fluids around the edges of the source region of slow earthquakes is observed.

Keywords: Fluid migration, Spatial mapping, Slow earthquake, Scattering coefficient

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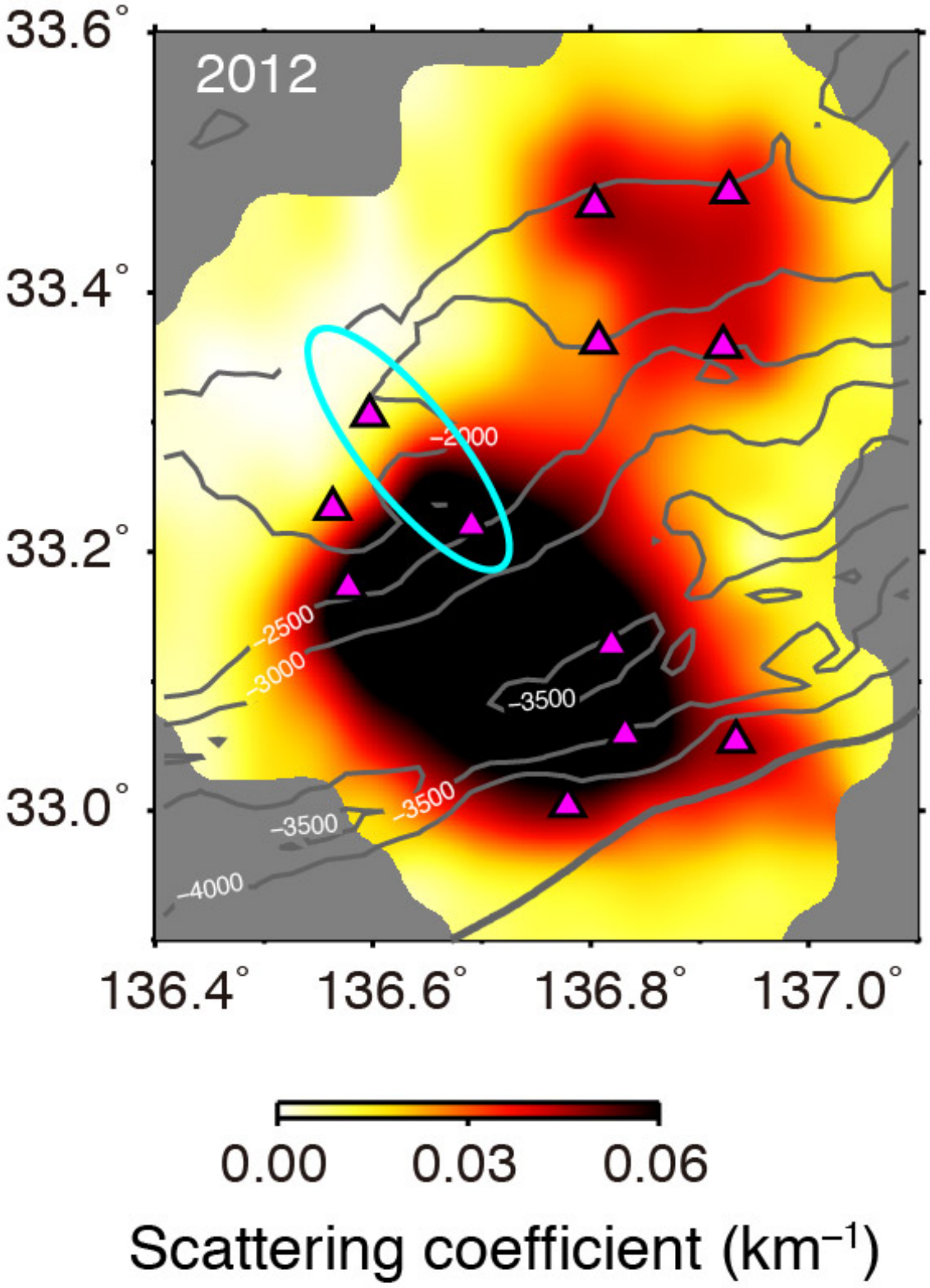

Figure 1. The anomaly of the scattering coefficient around the nodes of KMB, KMC and KMD of DONET for a case of dCC observed in 2012. Blue box roughly indicates the region of SSE detected by Araki et al. (2017).

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Land and marine long-term magnetotelluric observations around the western Nankai slow slip area

*Hiroshi Ichihara[1,2], Makoto Uyeshima[3], Hayato Nakamura[1], Maki Hata[3], Tada-nori Goto[4], Noriko Tada[2], Tetsuo Matsuno[5], Shinya Sato[6], Yoshiya Usui[3], Ryokei Yoshimura[7], Koki Aizawa[8]

1. Graduate school of Environmental Studies, Nagoya University, 2. JAMSTEC, 3. ERI, University of Tokyo, 4. University of Hyogo, 5. KOBEC, Kobe University, 6. Graduate school of Engineering, Kyoto University, 7. DPRI, Kyoto University, 8. Graduate school of Science, Kyushu Univeristy

Imaging of resistivity distribution gives us fundamental information about fluid and lithological feature around focal area of slow earthquakes because it depends on the pore-fluid distribution, salinity, connectivity of fluid-filled rock pores, and clay minerals the crust and upper-most mantle. Resistivity distribution of the crust-mantle scale can be estimated based on long period magnetotelluric (MT) observations. In this study, we introduce results of long period MT observations around the slow earthquake zones in the western Nankai trough mainly conducted by the JSPS KAKENHI project "Science of Slow Earthquakes". The observations were carried out by the two research teams for marine and land MT surveys.

Marine MT surveys were conducted between 2017 and 2020 at fifteen sites around the off-Miyazaki and off-Kochi area, Japan, based on Ocean Bottom Electro-Magnetometers (OBEMs). The observation periods of each OBEM were between 5 and 12 months. The training ship “Fukae-maru” and research vessel “Kairei” owned by Kobe University and JAMSTEC, respectively, cooperated for deployment and recovery of OBEMs. The OBEMs also acquired absolute pressure in three sites to detect SSEs. Based on the observed electromagnetic data, we estimated magnetotelluric impedances using BIRRP code (Chave and Thomson, 2004). The estimated MT impedances showed strong coastal effect due to complicated bathymetry in the western Nanakai Trough area. Based on the impedances at the twelve OBEM site in middle and eastern side of study area, we conducted forward resistivity modeling to evaluate the coastal effect using the 3-D modelling code (Tada et al., 2012). A simple optimum model consisting of seawater, seabed conductive layer and underneath background area can explain the coastal effect. In addition, the forward modeling implied heterogenous resistivity structure in the background area. Thus we applied 3-D inversion using the forward model as initial model. The inverted model mostly explained observed MT impedances. The model showed resistive anomaly around the ruptured area of the 1968 Hyuga-nada earthquake (M7.5) (Yagi et al., 1998). The resistivity model also shows conductive area in the western area part of the study area. It may relate to structural heterogeneity dure to subducting Kyushu-Palao ridge.

The network-MT surveys have been carried out in the western part of Shikoku Island and eastern part of Kyushu Island since April, 2016 to discuss resistivity distribution and its time variation in the long-term slow slip events (L-SSE) area beneath the Bungo channel. We used metallic telephone line network of the Nippon Telegraph and Telephone (NTT) Corp. to measure the electrical potential difference with long baselines over several kilometers. The electrical potential differences measured in this way are known to be less affected by small scale near-surface lateral resistivity heterogeneities (e.g. Uyeshima, 2007). We also measure the geomagnetic field at two stations in the target region. We estimated the frequency-domain response functions in the western Shikoku area of good quality with the aid of the BIRRP code. After applying the 3-D DASOCC inversion code (Siripunvaraporn et al., 2004), which directly inverted the Network-MT response and obtain the 3-D resistivity structure in the western Shikoku area.

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Remarkable low resistivity anomalies were detected in the middle crust of the hanging wall above the subducting Philippine Sea slab. However, no remarkable conductive anomaly was shown around the area of L-SSE in the Bungo channel region. Thus we also examined how the Network-MT responses are sensitive to temporal resistivity change along the slab because the L-SSE repeatedly occurred about every 6 or 7 years. In a test model, 10 km thick conductive layer is assigned just beneath the top surface of the slab. When the resistivity is set to be 20 Ohm-m (thus 500 S anomaly), RMS misfit was significantly increased from the best fit model. It indicates that temporal change could be detected due to current Network-MT survey.

We successfully obtained long-period MT impedances and preliminary resistivity distributions around western Nankai slow earthquake area based on the land and marine MT observations. Thus we plan to integrate the marine and land MT data in this study and past network-MT data in Kyushu Island (e.g. Hata et al., 2015) and estimate reliable 3-D resistivity structure covering the slow EQ areas in the western Nankai subduction zone.

Figure: Locations of OBEM sites and baselines of network-MT

Keywords: Slow earthquake, Bungo Channel, magnetotelluric, OBEM, Network-MT, 3-D resistivity

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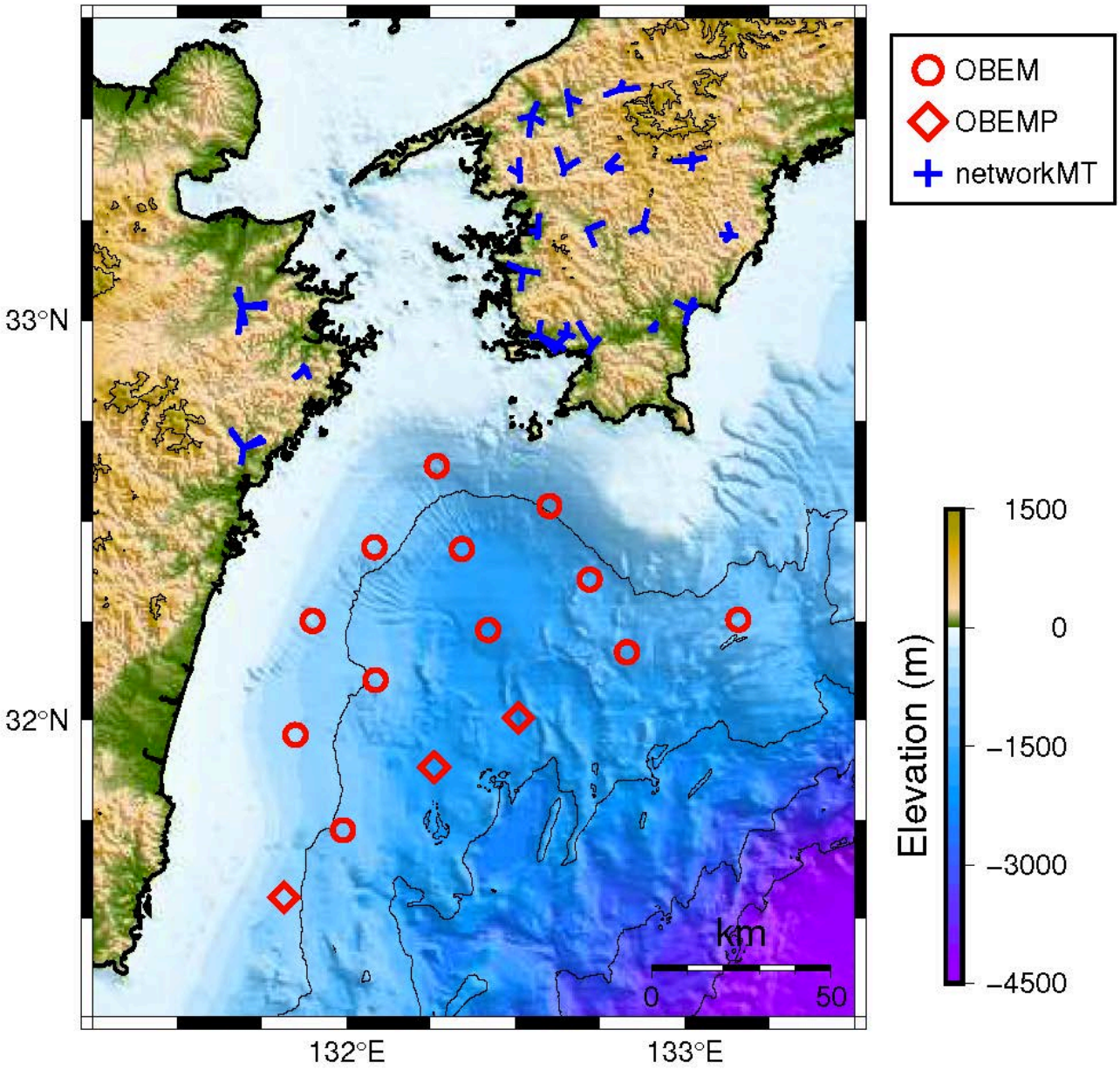

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Active source seismic experiment investigating structural characteristics associated with slow earthquake activities in the Hyuga-nada, southwestern Japan

*Seiichi Miura[1], Kimihiro Mochizuki[2], Ryuta Arai[1], Yasuyuki Nakamura[1], Yuka Kaiho[1], Gou Fujie[1], Shuichi Kodaira[1], Rie Nakata[2], Yanxue Ma[2], Masataka Kinoshita[2], Yoshitaka Hashimoto[3], Yohei Hamada[1]

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The Hyuga-nada is located in the westernmost part of the Nankai subduction zone, connecting to the Ryukyu Trench toward southwest. The Kyushu-Palau Ridge in the Philippine Sea Plate is now subducting in the Hyuga-nada region where the seafloor topography is very rough (e.g., Yamamoto et al. 2013). Magnitude (M) seven class large earthquakes have occurred in the Hyuga-nada such as 1961 (M7.0), 1968 (M7.5), and 1984 (M7.1), whereas no earthquake greater than M8 has occurred. Frequent slow slip events (SSE) are detected in the shallow part of the Hyuga-nada as well as low frequency tremors and very low-frequency earthquakes that exhibit spatial migration (e.g. Yamashita et al., 2015; Tonegawa et al., 2020; Yokota and Ishikawa, 2020).

To investigate the structural characteristics associated with the slow earthquake activity in the Hyuga-nada, we conducted two seismic cruises using R/Vs Kaimei and Kairei of Japan Agency for Marine-Earth Science and Technology (JAMSTEC) from August to September, 2020. These cruises are partly supported by KAKENHI “Science of Slow Earthquakes”, and also a part of site survey for IODP drilling proposal in Hyuga-nada. The seismic source was an airgun array with total volume of 10600 cu. in. of R/V Kaimei. Multi-channel seismic (MCS) hydrophone streamer cable with 6-km length was also towed by the R/V Kaimei to acquire seismic reflection profiles along the four seismic lines crossing tremor area (Yamashita et al, 2015): NE-SW (HYU01), WNW-ESE (HYU02), and two NW-SE (HYU18 and 22) directions. One hundred ocean bottom seismometers (OBS) were deployed by R/V Kaimei along two seismic lines (HYU01 and HYU02) with 2-km spacing to record wide-angle reflection and refraction signals and retrieved by R/V Kairei .

In our presentation, we will show the detail of the active source experiments, acquired MCS and OBS data, and preliminary processing results.

Keywords: Slow earthquake, Hyuga-nada, MCS, OBS

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Seismic characteristics of the northern Hikurangi subduction zone revealed by offshore seismic observations

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Since 2012, we conducted marine seismic observations in the northern part of the Hikurangi subduction zone, where slow slip events have occurred regularly at an interval of 1.5 ~ 2 years. Owing to the shallow subduction of the Pacific Plate beneath the Australian Plate, the structural features of the plate interface have been well identified from seismic reflection sections and magnetic anomaly maps. Such structural features include subducted seamounts and high seismic reflectivity of the plate interface attributable to an abundance of fluid (Bell et al., 2010; Barker et al., 2018).

We started offshore seismic observations by deploying four ocean bottom seismometers (OBSs) for a year-long observation from April 2012 to March 2013. We successfully determined hypocenters of mostly offshore earthquakes and subsurface seismic velocity structures down to ~30 km depth and imaged detailed velocity variations (Mochizuki et al., 2021). We found that the seismicity is mainly distributed around a core of high Vp/Vs bodies within the subducted oceanic crust of ~12 km thickness and we interpreted those high Vp/Vs values representing abundance of fluid that has been produced by dehydration reactions during subduction of the oceanic crust. The seismically highly reflective plate interface is found to be located above such high Vp/Vs bodies, which is consistent with our interpretation. Therefore, the seismicity around the high Vp/Vs bodies coincides with the peripheries of the highly reflective plate interface.

During a 2014-15 observation period and through international collaboration, we captured for the first time offshore tectonic tremor activity accompanying a large SSE (Wallace et al., 2016; Todd et al., 2018). The tremors appear to be activated near the end of the SSE and continued for about two weeks. The envelope correlation method revealed that a total of 120 tremors were only distributed around one of the subducted seamounts.

Another deployment was undertaken between 2018 and 2019, during which a large SSE occurred in the same region as the 2014 SSE event (Woods et al., 2020). We also observed tremor activity over the subducted seamount, and it showed the same temporal relationship with the SSE occurrence as the 2014 activity (Yamashita et al., 2020).

These observations strongly suggest the involvement of cyclic fluid transfer around the plate interface in concordance with the occurrences of SSE and tremors. Indeed, the spatio-temoral distribution of focal mechanisms as well as changing seismic velocity and anisotropy, suggests the systematic changes of fluid pressure within the subducting oceanic crust (Warren-Smith et al., 2019; Zal et al., 2020; Wang et al., in preparation). Therefore, the fluid production rate within the subducting oceanic crust is possibly a major factor that controls the seismic behavior at the northern Hikurangi margin. Rolling ocean bottom seismograph deployments are improving our ability to evaluate seismic potential, by accounting for the influence of slow slip events.

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Keywords: Slow slip events, Fluid transfer, High Vp/Vs bodies

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Temporal velocity variations in the northern Hikurangi margin and their relation to slow slip

*Weiwei Wang[1], Martha Savage[1], Alec Yates[1,2], Hubert Zal[1], Carolyn Boulton[1], Megan Kortink[3], Tim Stern[1], Bill Fry[3], Kimihiro Mochizuki[4], Spahr Webb[5], Wallace Laura[3]

1. Victoria University of Wellington, 2. Université Grenoble Alpes, Université Savoie Mont Blanc, 3. GNS Science, 4. Earthquake Research Institute, University of Tokyo, 5. Lamont-Doherty Earth Observatory, Columbia University

Slow Slip Events (SSE) have been studied in increasing detail over the last 20 years, improving our understanding of subduction zone behavior. Although the relationship between SSEs and the physical properties of their surrounding materials is still not well-understood, the northern Hikurangi margin in New Zealand is the site of relatively shallow (<10 km deep), frequent SSEs, providing excellent opportunities for near-field investigations. From September to October 2014, an SSE occurred with more than 250 mm slip, and was recorded successfully by the Hikurangi Ocean Bottom Investigation of Tremor and Slow Slip (HOBITSS) deployment. This study applies coda wave interferometry to the ambient noise data acquired by nine HOBITSS ocean bottom seismometers (OBS) to study the seismic velocity variations related to the SSE. Single station cross-component correlations are computed and a period band of 2.5-14 s is used to calculate velocity variations, which focuses on the upper plate in our study region. The average velocity variations display a velocity decrease of approximate 0.05% during the SSE, followed by a velocity increase of approximate 0.05% afterward. We suggest that two possibilities exist to explain this: The first possibility is the velocity changes are related to changes in crustal strain during the slow slip cycle, whereby elastic strain accumulates prior to the SSE causing contraction and reduction of porosity above the SSE source (seismic velocity increase between SSEs). During the SSE the upper plate goes into extension as the elastic strain is released, which results in dilation and a porosity increase (seismic velocity reduction). After the SSE, stress and strain accumulate again, causing a porosity decrease and a velocity increase. The second possibility, which has been suggested by other seismological observations is that fluid migration into the upper plate during the SSE, due to breakage of a low-permeability seal on the plate boundary caused by the SSE, explains the seismic velocity decrease during the SSE. Under this model, after the SSE, the fluids in the upper plate diffuse gradually and the velocity increases again.

Keywords: slow slip event, the Hikurangi subduction zone, seismic velocity variations, ambient noise

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[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:Kimihiro Mochizuki(Earthquake Prediction Research Center, Earthquake Research Institute, University of Tokyo)

Sun. Jun 6, 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

[SCG39-30]Discussion

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

Sun. Jun 6, 2021 1:45 PM - 3:15 PM JST | Sun. Jun 6, 2021 4:45 AM - 6:15 AM UTC | Ch.24 Zoom Room 24

[S-CG40] Active Tectonics and Seismic Hazards in the Himalayan Region

convener:Kazuki Koketsu(Earthquake Research Institute, University of Tokyo), Nath Soma Sapkota(Nepal Geological Society), Srinagesh Davuluri(CSIR-National Geophysical Research Institute), Chairperson:Kazuki Koketsu(Earthquake Research Institute, University of Tokyo), Hiroe Miyake(Earthquake Research Institute, University of Tokyo)

In the Himalayan region, the Indian and Eurasian plates collide, and the Indian lithosphere underthrusts beneath the Eurasian plate from the Main Frontal Thrust with a convergence rate of approximately 18 mm/year. This has historically caused large earthquakes such as the 1934 Bihar-Nepal earthquake, and seismic hazards in the region remain high. On April 25, 2015 (UTC), the Mw 7.8 Gorkha earthquake occurred along the plate boundary, and this affected the Main Frontal Thrust increasing the stress in possible source areas of future large earthquakes. Therefore, even after the Gorkha earthquake, studies on active tectonics and seismic hazards are still necessary in the Himalayan region. All kinds of studies on them are welcome for this session.

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

[SCG40-01] Seismic Hazard Assessment Studies in Uttarakhand Himalaya

*Srinagesh Davuluri[1], Suresh Gudapati[1], Srinivas Dakuri[1] (1.CSIR-National Geophysical Research Institute)

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

[SCG40-02] Active Tectonics & Seismological Research in Nepal Himalaya: Preliminary results from SATREPS project

*Soma Nath Sapkota[1], Kazuki Koketsu[2], Hiroe Miyake[3], Koji Okumura[4], Prakash Pokhrel[5] (1.Retired Director General, Department of Mines and Geology, Kathmandu Nepal, 2.Professor, Earthquake Research Institute, University of Tokyo, Tokyo Japan, 3.Associate Professor, Earthquake Research Institute, University of Tokyo, Tokyo Japan, 4.Professor, Graduate School of Humanities and Social Sciences, Hiroshima University, Japan, 5.Geologist, Department of Mines and Geology, Kathmandu Nepal)

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

[SCG40-03] Interseismic coupling on the Main Himalayan Thrust in Nepal derived from GNSS displacement rate field

*Takao Tabei[1], Mako Ohzono[2], Bishow Raj Silwal[3], Rajendra Bhandari[3], Janak B. Cahnd[3], Soma Nath Sapkota[4], Hiroe Miyake[2], Kazuki Koketsu[2] (1.Faculty of Science and Technology, Kochi University, 2.Earthquake Research Institute, University of Tokyo, 3.Department Mines and Geology, Nepal, 4.Nepal Geological Society)

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

[SCG40-04] Geodetic Observation for Evaluation of Earthquake Generation Potential in Nepal after the 2015 Gorkha Earthquake

*Bishow Raj Silwal[1], Rajendra Prasad Bhandari[1], Janak Bahadur Chand[1], Mako Ohzono[2], Takao Tabei[3] (1.Department of Mines and Geology, Nepal, 2.Earthquake Research Institute, University of Tokyo, Japan, 3.Kochi University, Kochi, Japan)

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

[SCG40-05] Rupture History of the Himalayan Frontal Thrust near Bagmati River crossing in Central Nepal

*Koji Okumura[1], Prakash Pokhrel[3], Hisao Kondo[2], Tomoru Yamanaka[1], Soma Nath Sapkota[3] (1.Graduate School of Letters, Hiroshima University, 2.Research Institute of Earthquake and Volcano Geology, GSJ, AIST, 3.Department of Mines and Geology, Nepal)

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

[SCG40-06] Strong Motion Observation Network for Earthquake Disaster Mitigation in the Kathmandu Valley, Nepal

*Nobuo Takai[1], Michiko Shigefuji[2], Hiroe Miyake[3], Kazuki Koketsu[3], Mukunda Bhattarai[4], Chintan Timsina[4], Shova Singh[4], Subeg Bijukchhen[5] (1.Hokkaido University, 2.Kyushu University, 3.University of Tokyo, 4.Department of Mines and Geology, Nepal, 5.Khwopa Engineering College, Nepal)

Seismic Hazard Assessment Studies in Uttarakhand Himalaya

*Srinagesh Davuluri[1], Suresh Gudapati[1], Srinivas Dakuri[1]

1. CSIR-National Geophysical Research Institute

The seismic Hazard Assessment studies in the Uttarakhand region has been undertaken with the installation of seismological network comprising of 53 Broad band seismographs, 32 Strong Motion Accelerometers and 4 Strong Motion Velocity meters to constrain the seismicity and characterize with the major tectonic features, record ground motion accelerations to characterize the ground motions in Uttarakhand both in terms of the Amplitude, Frequency and compare with the BIS Response spectra. During February 2017 –November 2020, around 700 earthquakes of magnitude ranging from 0.8 to 5.5 have been located. The main features of the seismicity patterns show they cluster both in space and depth. Majority of the earthquakes are coinciding with the Main Himalayan thrust, the interface between the Eurasian and Indian Plates was the locale for the past large earthquakes. Further, the strong motion and Broad band seismograph data past and present has contributed in the deriving the ground motion Prediction equations for this region which is the first of the kind for the continental continental plate collision.

Keywords: Uttarakhand Himalaya, Seismicity, Ground Motion Prediction Equations

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Active Tectonics & Seismological Research in Nepal Himalaya: Preliminary results from SATREPS project

*Soma Nath Sapkota[1], Kazuki Koketsu[2], Hiroe Miyake[3], Koji Okumura[4], Prakash Pokhrel[5]

1. Retired Director General, Department of Mines and Geology, Kathmandu Nepal, 2. Professor, Earthquake Research Institute, University of Tokyo, Tokyo Japan, 3. Associate Professor, Earthquake Research Institute, University of Tokyo, Tokyo Japan, 4. Professor, Graduate School of Humanities and Social Sciences, Hiroshima University, Japan, 5. Geologist, Department of Mines and Geology, Kathmandu Nepal

Knowing the return period and possible impact of great and megaquake in Nepal Himalaya is key to mitigate impending seismic risk in this region. To understand and evaluate seismic risk, Deapartment of Mineas and Geology (DMG), Urban Development and Building Construction (DUDBC), and Tribhuwan University (TU) in collaboration with Japan International Cooperation Agency (JICA), Japan Science and Technology (JST) and Earthquake Research Institute (ERI) of Tokyo University are collaborating through Science and Technology Research Partnership for Sustainable Development (SATREPS) project for Seismic Hazard assessment of Kathmandu valley and quantifying central Himalayan seismic gap between 2015 Gorkha Earthquake and 1905 Kangra earthquake.

Many geological and geophysical survey are conducted in Kathmandu valley to calculate and predict the different parameter of thick sediment (approx. 600m) of Kathmandu valley during impending big earthquake. Permanent eight GNSS station of Global Positioning System and eight seismic stations are installed which are now connected to the national network and will enhance the monitoring capacity of Nepalese network. This will ultimately improve the location accuracy to report earthquake parameter to the government authority. Paeloseismological trenching is also conducted in Butwal, Tribeni, Bagmati and Kathmandu valley preliminary promising results are coming from different Geophysical campaign experiment in Kathmandu valley, Geomorphological and paleoseismological trenching in Himalayan front which will be discussed.

Keywords: Central Himalayan Seismic Gap , Return Period, Paleoseismology, GNSS stations

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Interseismic coupling on the Main Himalayan Thrust in Nepal derived from GNSS displacement rate field

*Takao Tabei[1], Mako Ohzono[2], Bishow Raj Silwal[3], Rajendra Bhandari[3], Janak B. Cahnd[3], Soma Nath Sapkota[4], Hiroe Miyake[2], Kazuki Koketsu[2]

1. Faculty of Science and Technology, Kochi University, 2. Earthquake Research Institute, University of Tokyo, 3. Department Mines and Geology, Nepal, 4. Nepal Geological Society

Most of the land in Nepal is located on the hanging wall of the Indian-Eurasian plate convergent zone. We have deployed 10 continuous GNSS stations in central and mid-western Nepal since 2016 under the SATREPS/NERDiM project to enhance spatial resolution of geodetic observation network and better estimate earthquake generation potential in the Himalayan Frontal Zone (Silwal et al., 2021; this meeting). We focus especially on the “Central Seismic Gap” where no destructive event has been recorded for centuries. Data collected at each SATREPS/NERDiM GNSS site are transmitted to Kathmandu on a semi-daily basis via domestic cell phone network and then processed together with data from the pre-existing domestic GNSS stations and IGS reference stations. Highly automated data acquisition and baseline analysis system is implemented in a processing server.

As a preliminary analysis, we collect all available GNSS data in Nepal since 1995 through UNAVCO DAI v2 and process them using PPP-AR method of GIPSY/OASIS II ver.6.4. The result shows that the north-south contraction in Nepal is roughly 10-15 mm/yr, equivalent to a strain rate of 0.1 ppm/yr, implying that about 30-40% of the relative Indian-Eurasian plate motion (36-37 mm/yr) is taken up in crustal shortening across the Himalayan Frontal Zone. Next we estimate interseismic coupling on the Indian-Eurasian plate boundary using TDEFNODE (McCaffrey, 2009) and GNSS site displacement rates. Two plate boundary models are checked, the first one is characterized by down-dip variation of gently dipping fault planes and steeper ramps (Hubbard et al., 2016) and the second by rather flatter surface (Hayes, 2018). We constrain the lower limit of the plate interface to 35 km in depth and place nodes on the interface with a lateral spacing of 30-40 km along depth contours every 5 km. Then slip deficit rates are estimated on the interface. Plate coupling ratio (normalized slip deficit rate) seems corelate with structure of the interface, i.e., strong coupling on the gently dipping fault planes and week or null coupling on the steeper ramps. This pattern is in contrast with the previous result that shows coupling ratios nearly monotonously decreasing with depth on the flatter interface (e.g. Stevens and Avouac, 2015). Further investigation is needed to clarify current state of plate coupling on the Himalayan Frontal Zone.

Keywords: Nepal, GNSS, NERDiM

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Geodetic Observation for Evaluation of Earthquake Generation Potential in Nepal after the 2015 Gorkha Earthquake

*Bishow Raj Silwal[1], Rajendra Prasad Bhandari[1], Janak Bahadur Chand[1], Mako Ohzono[2], Takao Tabei[3]

1. Department of Mines and Geology, Nepal, 2. Earthquake Research Institute, University of Tokyo, Japan, 3. Kochi University, Kochi, Japan

Nepal is prone to devastating earthquake disaster because it is located in the active collision zone between the Eurasian and Indian tectonic plates. Immediately after the 2015 Gorkha earthquake, Integrated Research on Great Earthquakes and Disaster Mitigation in Nepal Himalaya, SATREPS/NERDiM, was initiated under the collaboration of Nepalese and Japanese governments. One of the project teams is working with an objective of evaluating earthquake generation potential in central Nepal by means of geodetic data collected from Global Navigation Satellite System (GNSS) network, which is able to monitor 3-D site displacements caused by the plate interaction at a high precision of a few millimeters per year. Spatial and temporal variation of displacement field and converted strain accumulation pattern will be useful to reveal physical processes ongoing on the plate interface. Our new GNSS network, composed of ten permanent stations deployed in central and mid-western Nepal covering about 100 km north to south and 400 km east to west, have greatly improved detectability of crustal deformation in the plate convergent region. In addition, we have installed an automated GNSS data processing and archiving system in Kathmandu. Preliminary result shows that the north-south contraction in Nepal is as large as 10-15 mm/yr, equivalent to the strain rate of 0.1 ppm/yr. As the next step, we are preparing estimation of plate locking distribution using the latest plate boundary model. Strain build-up monitored by our system, in conjunction with data from other pre-existing GNSS stations in and around Nepal, will provide very fundamental and important information for evaluating earthquake generation potential in the near future.

Keywords: GNSS, Earthquake, Geodetic, Nepal

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Rupture History of the Himalayan Frontal Thrust near Bagmati River crossing in Central Nepal

*Koji Okumura[1], Prakash Pokhrel[3], Hisao Kondo[2], Tomoru Yamanaka[1], Soma Nath Sapkota[3]

1. Graduate School of Letters, Hiroshima University, 2. Research Institute of Earthquake and Volcano Geology, GSJ, AIST, 3. Department of Mines and Geology, Nepal

The 2015 Golkha earthquake raised concern about the future large earthquake occurring in south of the 2015 source area. The 2015 earthquake ruptured 10 to 20 km deep portion of the plate boundary interface ~50 km away from the surface trace of the frontal thrust. It is necessary to evaluate the earthquake potential of the shallowest part of the Himalayan Frontal Thrust in central Nepal. After 5 years of intensive studies on the rupture history, now there are important questions about three large past earthquakes of 1934, 1344, and 1255 (or 13 century). They are, (1) the existence and extent of 1934 surface rupture, (2) the existence and extent of 1344 rupture, and (3) the extent and exact timing of 1255 (or 13th century) event. As to the 1934 surface rupture, Rizza et al. (2019) as well as Sapkota et al. (2012) demonstrated ruptures on fault exposures against Wesnousky et al. (2018) in Bardibas area. However, the west terminations of the 1255 and 1934 rupture have not been defined yet. We excavated two trenches on the Himalayan front in east and in west of Bagmati river to examine the terminations and to know the rupture history. At the Dumachaur Khola site 4 km east of Bagmati river, 3 or 4 events in 3500 years are excavated. The timing of the last event here is in the earlier half of the 2nd millennium C.E.. At the Gopalkoti-Dandatol site, 0.7 km west of Bagmati river, 2 or 3 events between 3rd and 14th century C.E. are recognized. 1934 ruptures do not appear in both trenches. This study is a part of the JICA-JST SATREPS project: Integrated Research on Great Earthquakes and Disaster Mitigation in Nepal Himalaya.

Keywords: Himalayan Frontal Thrust, paleoseismology, surface rupture

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Strong Motion Observation Network for Earthquake Disaster Mitigation in the Kathmandu Valley, Nepal

*Nobuo Takai[1], Michiko Shigefuji[2], Hiroe Miyake[3], Kazuki Koketsu[3], Mukunda Bhattarai[4], Chintan Timsina[4], Shova Singh[4], Subeg Bijukchhen[5]

1. Hokkaido University, 2. Kyushu University, 3. University of Tokyo, 4. Department of Mines and Geology, Nepal, 5. Khwopa Engineering College, Nepal

The Himalayan continental collision zone of the Indian plate and the Eurasian plate have been causing many devastating earthquakes in the past. The Kathmandu Valley in Nepal is filled with soft soil of Plio-Pleistocene origin the thickness of the sediments is more than 600 m in the central part of the valley. Because of the site amplification of this sediment structure, many damages occurred not only by the near earthquakes (e.g., the 2015 Gorkha Nepal earthquake) but also by the far earthquakes (e.g., the 1934 Bihar-Nepal, the 2011 Taplejung-Sikkim earthquakes).

Moreover, the residential area in the Kathmandu Valley has been spread quickly in recent years by the explosive population growth. By this seismological and social environment, the earthquake damage risk of this metropolitan area in the valley is increasing. This risk must be reduced by a high precision prediction for the next great earthquake which has the potential to occur in the Central Seismic Gap of the Main Frontal Thrust in Nepal Himalaya.

There were six known seismic observation sites in the valley: one station by USGS, one station by the Department of Mines and Geology, Ministry of Industry, Commerce, and Supplies and four stations by the collaborative observation of Hokkaido University and Tribhuvan University (Takai et al., 2016). However, the density of these former stations was too low to know the site amplification variation in the valley whose diameter is about 25 km in detail.

“Integrated Research on Great Earthquake and Disaster Mitigation in Nepal Himalaya” is a project of the Science and Technology Research Partnership for Sustainable Development program supported by JST and JICA (SATREPS NERDiM, 2016-2021, Principal Investigator: Kazuki Koketsu). By this NERDiM project, in order to accumulate the strong motion data, the strong motion observation network was installed with ten strong-ground motion seismometers in Nov. 2016- May 2018. There was only one rock site station (Kirtipur) in the valley, therefore, we installed the instruments to north, west, and east rock site stations. Moreover, we selected the heavily damaged area (Balaju) during the 2015 Gorkha Nepal earthquake and the low-density observation area as observation sites.

Even the small amount of accumulated important data can show the difference of the amplification factor at each station in the valley. The north rock site Jhor and the east rock site Sanga have predominant periods in 0.25 - 0.3 s, on the other hand, other sedimentary sites have those in 1.2 - 5 s (2018 JpGU, 2019 SSJ). We have constructed the 1-D and 3-D deep sedimentary velocity structure models in the Kathmandu Valley (Bijukchhen et al., 2017, Bijukchhen, 2018) by using aftershock records of the 2015 Gorkha earthquake of existing stations. After installing these observation sites, we could compare the observed receiver function with the theoretical one (2020 JpGU, 2020 WCEE). In this comparison, the observed receiver functions agreed with the theoretical ones in most stations except stations on the center and marginal part of the valley, which is not used by the construction of that velocity model. Also, we made the correction term of the ground motion prediction equation (GMPE) for velocity response

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spectra for this valley using aftershock records and depth to seismic bedrock of the valley (2020 SDEE). This will be a powerful tool for making the design spectrum for a long period of ground motion for high-rise buildings increasing in the valley.

The accumulation of the strong motion data by this new network will be able to upgrade this GMPE and the underground structure to contribute to the disaster mitigation planning for the Kathmandu metropolitan area, in the future.

Acknowledgments: A part of this research was supported by SATREPS of JST-JICA Grant Number JPMJSA1511, and JSPS KAKENHI.

Keywords: Strong Motion Observation Network, Nepal Himalaya, Kathmandu Valley

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

Sun. Jun 6, 2021 3:30 PM - 5:00 PM JST | Sun. Jun 6, 2021 6:30 AM - 8:00 AM UTC | Ch.24 Zoom Room 24

[S-CG40] Active Tectonics and Seismic Hazards in the Himalayan Region

convener:Kazuki Koketsu(Earthquake Research Institute, University of Tokyo), Nath Soma Sapkota(Nepal Geological Society), Srinagesh Davuluri(CSIR-National Geophysical Research Institute), Chairperson:Hiroe Miyake(Earthquake Research Institute, University of Tokyo), Kazuki Koketsu(Earthquake Research Institute, University of Tokyo)

In the Himalayan region, the Indian and Eurasian plates collide, and the Indian lithosphere underthrusts beneath the Eurasian plate from the Main Frontal Thrust with a convergence rate of approximately 18 mm/year. This has historically caused large earthquakes such as the 1934 Bihar-Nepal earthquake, and seismic hazards in the region remain high. On April 25, 2015 (UTC), the Mw 7.8 Gorkha earthquake occurred along the plate boundary, and this affected the Main Frontal Thrust increasing the stress in possible source areas of future large earthquakes. Therefore, even after the Gorkha earthquake, studies on active tectonics and seismic hazards are still necessary in the Himalayan region. All kinds of studies on them are welcome for this session.

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

[SCG40-07] 2D FDM simulation of seismic ground motions and inversion of velocity structure models in the Kathmandu Valley, Nepal

*Hongqi Diao[1], Kazuki Koketsu[1], Kazuhito Hikima[2] (1.Earthquake Research Institute, University of Tokyo, 2.Tokyo Electric Power Company Holdings)

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

[SCG40-08] Microtremor observation in the Kathmandu valley, Nepal: Past, Present, and Future perspectives

*Mukunda Bhattarai[1], Rajesh Sharma[3], Sunita Bhattarai[2], Tara Pokrarel[1], Chintan Timsina[1], Suresh Shrestha[2], Dinesh Nepali[2], Manoj Nakarmi[4], Prakirna Tuladhar[4], Takumi Hayashida[5], Toshiaki Yokoi[5], Hiroe Miyake[6], Koichi Kusunoki[6] (1.National Earthquake Monitoring and Research Center, Department of Mines and Geology, Nepal, 2.Department of Mines and Geology, Nepal, 3.Seismological Center Surkhet, Department of Mines and Geology, Nepal, 4.Department of Urban Development and Building Construction, Nepal, 5.International Institute of Seismology and Earthquake Engineering, Building Research Institute,Japan, 6.Earthquake Research Institute, The University of Tokyo, Japan)

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

[SCG40-09] BROADBAND MICROTREMOR ARRAY EXPLORATION IN THE KATHMANDU VALLEY, NEPAL

*Toshiaki Yokoi[1], Takumi Hayasida[1], Mukunda Bhattarai[3], Tara Pokharel[2], Suresh Shrestha[2], Chintan Timsina[3], Sunita Bhattarai[2], Rajesh Sharma[3], Dinesh Nepali[2] (1.International Institute of Seismology and Earthquake Engineering, Building Research Institute, Japan, 2.Department of Mines and Geology, Nepal, 3.National Earthquake Monitoring and Research Centre, NEMRC/DMG, Nepal)

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

[SCG40-10] Seismic observation and automatic hypocenter location system in Nepal

*Shigeki Horiuchi[1], Masumi Yamada[3], Koji MIYAKAWA[2], Hiroe Miyake[2], Tadashi Yamashina[4], Chintan Timsina[5], Mukunda Bhattarai[5], Bharat Prasad Koirala[5], Monika Jha[5], Lok Bijaya Adhikari[5] (1.Home Seismometer Corporation, 2.ERI, 3.DPRI, 4.Kochi University, 5.DMG, Nepal)

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

[SCG40-11] Upper-Crustal Structure of Central Nepal inferred from Local Earthquake Tomography

*Chintan Timsina[1], James Mori[2], Masumi Yamada[2] (1.Graduate School of Science, Kyoto University, 2.Disaster Prevention Research Institute, Kyoto University)

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

[SCG40-12] Towards the Further Development of the Education and Research on Earthquakes in Nepal

*Mai Suzuki[1], Binil Aryal[2], Kazuki Koketsu[1] (1.Earthquake Research Institute, The University of Tokyo, 2.Central Department of Physics, Tribhuvan University)

2D FDM simulation of seismic ground motions and inversion of velocity structure models in the Kathmandu Valley, Nepal

*Hongqi Diao[1], Kazuki Koketsu[1], Kazuhito Hikima[2]

1. Earthquake Research Institute, University of Tokyo, 2. Tokyo Electric Power Company Holdings

Great and disastrous earthquakes have repeatedly occurred at the subduction interface along the Himalayan arc in the past and would continue to occur in the future due to the continuous collision between the Indian Plate and Eurasian Plate. And a recent example was the 2015 Mw7.8 Gorkha earthquake, which induced serious seismic disasters in the Kathmandu Valley, Nepal. The Kathmandu Valley sits on an ancient lake bed zone with irregular soft sedimentary layers of several hundred meters depth in the deep part. Previous studies of the tomography of the Kathmandu valley demonstrated that the velocity structure model in the Kathmandu Valley is highly spatially variable, with obvious difference of thickness of soft sedimentary layers within short distances. The gravity survey and seismic reflection experiment conducted in the Kathmandu Valley in latest years by the joint research team between Japan and Nepal has confirmed the high thickness gradients of sediments and obtained a preliminary 3D velocity structure model. Because seismic ground motions especially long-period ground motions that can be significantly amplified and reverberated due to the basin effect within the valley can pose a serious threat to the buildings and infrastructures in the Kathmandu Valley, it’s necessary to investigate the propagation effect and the amplification effect of seismic ground motions in the valley and to refine the preliminary velocity structure model for the strong ground motion simulations for seismic hazard assessment.

A collaboration between Japan and Nepal has begun since 2011 to study the strong motion characteristics in the Kathmandu Valley and several strong motion accelerometers have been installed within the valley since then. Three-component strong motions of several moderate regional and local earthquakes and small local earthquakes have been recorded by these strong motion stations. In this study, we performed 2D FDM simulations of seismic ground motions at the strong motion station sites in the Kathmandu Valley using the preliminary velocity structure model and compared with other researcher’s 3D FDM simulation results and the observation data for a moderate regional earthquake. The results showed that the source size effect of the moderate regional earthquake could not be ignored, and that the 2D FDM simulation could reproduce the early phases of the propagation effect but could not reproduce the later phases of the large surface waves generated in the deep part of the Kathmandu Basin. Due to the limited number of strong motion records accumulated in the Kathmandu Valley, we perform inversion of 2D velocity structure models based on the preliminary 3D model in the valley. To avoid the source size effect of the moderate regional or local earthquakes, we choose to use small local earthquakes which occurred near the Kathmandu Valley to perform inversion of 2D velocity structure models. The 2D velocity structure models along the lines connecting the epicenter of the small local earthquake and different strong motion station sites are inverted. The 2D FDM simulations of strong ground motions using the inverted velocity structure models in the Kathmandu Valley could reproduce the amplitudes of the main phases of the observation data. Our study on the strong motion simulations and inversion of velocity structure models in the Kathmandu Valley provides a basis for the seismic hazard assessment in this area.

Keywords: Kathmandu Valley, strong ground motion, 2D FDM simulation, inversion, velocity structure model

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Microtremor observation in the Kathmandu valley, Nepal: Past, Present, and Future perspectives

*Mukunda Bhattarai[1], Rajesh Sharma[3], Sunita Bhattarai[2], Tara Pokrarel[1], Chintan Timsina[1], Suresh Shrestha[2], Dinesh Nepali[2], Manoj Nakarmi[4], Prakirna Tuladhar[4], Takumi Hayashida[5], Toshiaki Yokoi[5], Hiroe Miyake[6], Koichi Kusunoki[6]

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Kathmandu valley falls in the Lesser Himalaya of central Nepal and is one of the largest intermontane basins of Nepal. It is prone to earthquake disasters due to its tectonic environment and local site conditions. Furthermore, accumulated piles of thick sediment above the basement rock, steep topography in basin outskirts, unplanned land use/settlements, rapid urbanization, and poor earthquake-resistant constructions have made this region highly vulnerable to earthquake disaster. These factors emphasize the need for subsurface structure studies and their applications to damage evaluation of Reinforced Concrete (RC) buildings. Not only the evaluation of site-specific seismic hazard where the dwelling is located using passive surface waves but also surveys inside the building itself is of great concern for the evaluation of future seismic risk, where about 3 million agglomerates are residing.

Passive microtremor measurement has been performed in the Kathmandu valley before the Gorkha earthquake using a single tri-axial seismometer (Pandey et al., 1996, Paudel et al., 2010, Bhandary et al, 2014). After the Gorkha earthquake, there exist few studies in the Kathmandu valley for the site-specific studies using microtremor (JICA, 2016, Poovarodom et al., 2017, Molnar et al., 2017). These studies also have the limitation of revealing the deep shear wave velocity structures up to the basin basement.

The project for “Integrated Research on Great Earthquakes and Disaster Mitigation in Nepal Himalaya” is a multidisciplinary research project (FY:2016-2021) in Nepal supported by Japan Science and Technology Agency (JST) and Japan International Cooperation Agency (JICA). The main objective of this project is to provide an advanced seismic risk assessment of the Kathmandu valley by subsurface explorations and establishing seismic observation networks targeting around the central seismic gap along the Main Himalayan Thrust (MHT) to contribute to disaster risk reduction of Nepal by utilizing data acquired from explorations/observations and their research findings.

There are five working groups in this project, group 3 (G3) where most of the authors belong is mainly involved in subsurface explorations of the Kathmandu valley, whereas group 5 (G5) which reflects the overall output of the project is mainly based on inputs from G1 to G4. Few outcomes of microtremor explorations have already been documented for e.g., Bhattarai et al., 2017a; 2017b, Yokoi et al., 2018; 19, Hayashida et al.,2018; 2019. However, most of these studies could not obtain the dispersion curve and consequently velocity structures in the frequency range from 0.1 to 0.2 Hz.

In this meeting, I will discuss the period verification of Nepalese RC buildings revealed from microtremor observations in some sampled RC buildings with the building codes and explain the application of shear wave velocity structures to building damage analysis as a potential output of (G5) and also emphasizes its importance on the future disaster mitigation of the Kathmandu valley.

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Acknowledgments:

This research was supported by Science and Technology Research Partnership for Sustainable Development (SATREPS) from Japan Science and Technology Agency (JST) and Japan International Cooperation Agency (JICA). I highly acknowledge the Director General of the Department of Mines and Geology (DMG) for providing me an opportunity to join this scientific gathering remotely.

Keywords: Array deployment, Kathmandu valley, Shear wave velocity structure, Gorkha earthquake, RC buildings

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BROADBAND MICROTREMOR ARRAY EXPLORATION IN THE KATHMANDU VALLEY, NEPAL

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Strong ground motion of long duration and long predominant period around four seconds were observed during the 2015 Gorkha earthquake at the central part of the Kathmandu Valley (KTV), Nepal (e.g., [1], [2]). KTV is a tectonic basin formed during the Himalayan orogeny due to the collision of the Indian plate to the Eurasian plate (e.g., [3]). The research group to which the authors belong (Group3, SATREPS) has conducted the deep exploration using microtremor from Dec. 2016 to May 2019, with the aim to reveal the cause of the mentioned phenomena to make use it for bettering the seismic hazard assessment. In JPGU2019, we presented a partial report of the activities until Dec. 2018 ([4]). We will report the summary of the activities in JPGU2021.

We conducted the field observation of microtremor in KTV using four broadband seismographs to estimate mainly Vs structure of deep sediments. We used also short period seismometers, land geophones and multi-channel data logger for shallow exploration [4]. Due to the difficulty to set up a large regular polygon arrays in the densely built-up city, we had to deploy large irregular quadrilateral ones based on confirmation of the isotropic nature of coherence function of microtremor, whereas equilateral triangular ones for middle and small sizes. The maximum inter-station distances of each sites were about 900m, and at maximum 1,400 m. Recording duration was one night or longer per deployment. Then we applied 2ST-SPAC analysis to the records of these arrays in a combined way to estimate the dispersion curves.

We, however, had to take countermeasures to extend the analyzable frequency range. To fix the problem supposed to be caused by the insufficient power of microtremor in the frequency range lower than 0.2 Hz, we have combined the phase velocity of Rayleigh waves that was determined by [5] using surface waves components of tectonic earthquake records in the frequency range from 0.01 Hz to 0.13 Hz. To cover highest frequency range we have conducted shallow exploration using different methods, MASW, CCA of mini hexagon array, L-Shape SPAC, etc., using short period seismometers and geophones: from about 5 Hz to higher than 10 Hz.

Besides we filled the gap of dispersion curves appeared in some sites between 0.2 Hz and the lowest analyzable frequency of 2ST-SPAC, i.e., around 0.3 Hz, by applying CCA to the records of scalene triangle arrays extracted from the quadrilateral ones. However, the gap from 0.13 Hz to 0.2 Hz remained unfilled for all sites. We also filled other gaps at a few sites in higher frequency ranges, but lower than 1 Hz, using auxiliary the phase velocities calculated from zero crosses of the SPAC coefficient curves.

We, then, applied the inversion of Vs structure from the determined dispersion curves. The estimated Vs structure showed a sharp discontinuity at a depth of about 600 m at the central part of KTV. In addition, another Vs discontinuity was observed at a depth of about 400 m. According to the information from a few deep drilling in KTV, The former can be interpreted as the seismic bedrock, and the latter is speculated to be a buried terrace formed in an era of discharge of the paleo-Kathmandu lake.

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We could show a sufficient efficacy and usefulness of irregular shape arrays, and a comparison of various methods for shallow exploration as a show case, based on these observational activities.

Acknowledgement: This study was supported by JST and JICA under SATREPS: “Integrated Research on Great Earthquakes and Disaster Mitigation in Nepal Himalaya (FY2016-2021)”.

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Keywords: Microtremor Array Exploration, Irregular Shape Array, Deep Sedimentary layers, Kathmandu Valley

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Seismic observation and automatic hypocenter location system in Nepal

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1. Introduction

SATREPS program of Integrated Research on Great Earthquake and Disaster Mitigation in Nepal was started in 2015. One of the objectives of this project is to enhance the eismic observation system in Nepal. Our group installed eight seismic stations in the area called central Himalayan seismic gaps. Seismic waveform data are collected in near real-time. We developed an automatic location system, which determines hypocenter locations, magnitude, and seismic intensity distribution within a few minutes after the felt earthquake occurrence. The computed earthquake parameters are disclosed on a website for the damage reduction by a larger earthquake. We present our group activity and scientific results from this subject.

2. Seismic observation system

We installed 8 seismic stations with three-component velocity and acceleration sensors. Broadband velocity seismometers were installed at four stations and 1 Hz seismometers were installed at remaining four stations. A modem with a SIM card was installed in the seismic observation device and continuous waveform data is transmitted every minute to a server at the Department of Mines & Geology (DMG) in Kathmandu. The observation device operates with a solar panel and a built-in battery. There is a function to update the software remotely from the cental server.

3. Automatic processing system

Since the seismic stations were installed in the area of central Himalayan earthquake gap, seismicityinside and around the seismic network is relatively low. For security reasons, we need to install seismometers inside the public facilities, such as schools and parks. Therefore, the noise level during the daytime is relatively high for most of the stations. We found that the events created by noise are several ten times larger than seismic events without a noise filter. The low seismicity and high noise level require a good algorithm of noise signal discrimination.

Since the seismic stations are located on the premises of schools, etc., the main source of noises is human activity. The noise durations are mostly 1-2 seconds or less and high-frequency components are dominant. We set the following criteria for the noise-signal discrimination and removed noise events after hypocenter location.

The event is classified as noise if:

(1) Standard error of arrival time residual > 2.0 seconds.

(2) No P-wave readings at the closest 3 stations if the number of P-wave readings (Np) < 5.

(3) No P wave reading at the closest station if Np < 4.

(4) Nerr>Np, where Nerr is the number of the inappropriate stations with (a) (f-P) time <(S-P) time and (b) predominant period(Tp) and epicentral distance(D) are following combinations; Tp>1.2 and D>100km, Tp>0.7 and D<100km, Tp>0.3 and D<50km. These parameters are set empirically by checking noise events and seismic events to eliminate noise events.

4. Result

Hypocenters are located automatically when more than three P-wave arrival times are observed. Many noise events are included in events, which are located by three P wave arrivals.However, if the number of P wave readings is 4 or more, the event is most likely an earthquake and accurate location can be

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determined. The processing results can be monitored on the website. When an earthquake with a magnitude > 4.5 occurs, our system displays the distribution of the MMI seismic intensity calculated from the epicenter location and magnitude.
In addition to the SATREPS seismic stations, DMG collects continuous waveform data from seismic stations installed by France, China, and RIMES in a mini-seed format. Currently, we are developing an automatic hypocenter location system using all the data.

Keywords: SATREPS Nepal, Seismic Observation, Automatic hypocenter location

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Upper-Crustal Structure of Central Nepal inferred from Local Earthquake Tomography

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Central Nepal is one of the most studied sections of the Himalayas. Multiple geological and geophysical campaigns in central Nepal have proposed a variety of models for seismo-tectonics and geometries of the Main Himalayan Thrust (MHT). However, most of them focused on the two-dimensional model across the MHT. After the 2015 Gorkha earthquake (Mw 7.8), several studies have suggested considerable lateral variation on the crustal structure in both cross-strike and along-strike directions. In this study, we utilize the recordings of numerous local events by the dense network focusing on (1) imaging 3D physical heterogeneities of the upper crust in central Nepal and (2) its role in controlling the rupture of the 2015 earthquake.

We used manually picked P- and S- arrivals from around 1700 events of the Gorkha earthquake sequence for a simultaneous inversion of the seismic velocities and hypocenters using the local earthquake tomography technique. These events were recorded in central Nepal by a temporary network of 42 broadband and short-period stations from June 2015 to April 2016. We applied a gradational approach starting with inversion of a 1D velocity model and progressively updated to a detailed 3D model in several steps. This allows us to have a reasonable model even in areas where we have lower resolution. Moreover, we also obtained a Qp model of the region using vertical-component waveforms of relocated earthquakes and the Vp model. Our results not only provide a detailed velocity structure and aftershock distribution within the source region of the Gorkha earthquake but also are useful for other applications such as numerical simulations.

Preliminary results of our velocity model show three main domains. (1) Zone of low Vp and low Vs in the southern part of the area at shallow depth (<10 km). This zone is spatially well-correlated with sedimentary rocks of the sub-Himalaya. (2) A zone of remarkably low Vp/Vs ratio (<1.65) in the central-northern part of the area from surface to the depth of 10 km. This anomalously low ratio may represent bodies of felsic (quartz-rich) rocks as mapped at the surface. (3) A region of high Vp, at the depth of the Gorkha Earthquake rupture, coincides with the area of large (>4 m) co-seismic slip. This high-velocity zone may represent an asperity on the fault which possibly controlled the rupture of the mainshock.

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Towards the Further Development of the Education and Research on Earthquakes in Nepal

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In order to mitigate the earthquake disaster, it is important to promote the public understanding of earthquakes and to foster an expert on earthquakes, and the various educational institutions provide the diverse curriculums related to earthquakes. In Nepal, where the latest large earthquake hit in 2015 and the risk of future big earthquakes is still high, the different types of earthquake related education and research are provided from the elementary education institutions to the higher education institutions. These curriculums contribute to nurturing people who have the precise knowledge on earthquakes and have the skills on disaster preparedness, however, there are still problems. Based on the interview and literature research at the educational institutions and the government agencies in Nepal, this presentation discusses the actual circumstances of the education and research on earthquakes in Nepal and suggests what is needed for the further development of it.

In Nepal, the primary and secondary schools provide the education on the earthquake disaster mitigation (e.g. how to evacuate in the event of an earthquake) and the higher education institutions offer the courses in geology, engineering, and social sciences related to earthquakes. In addition, the national ministries and NGOs provide training and advice to the builders on how to construct the earthquake-resistant buildings. While these various efforts are being made to mitigate the future earthquake damage, it is revealed that the earthquake-related education and research in the educational institutions mainly focuses on the general knowledge about earthquakes and hardly deals with the specific cases in Nepal, and that the course of seismology, one of the most important earthquake-related academic fields, is hardly provided in Nepal. These problems are shared by those involved in the earthquake education and research in Nepal, and in order to solve these problems, it is necessary to develop the educational curriculum for seismology that incorporates the examples of Nepal.

This research was supported by Science and Technology Research Partnership for Sustainable Development (SATREPS), Japan Science and Technology Agency (JST, JPMJSA1511) / Japan International Cooperation Agency (JICA).

Keywords: Seismology, Higher education, Nepal

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

Sun. Jun 6, 2021 9:00 AM - 10:30 AM JST | Sun. Jun 6, 2021 12:00 AM - 1:30 AM UTC | Ch.19 Zoom Room 19

[S-CG41] Hard-Rock Drilling Science: From Continental to Deep Sea Drilling, and Oman Project

convener:Eiichi TAKAZAWA(Department of Geology, Faculty of Science, Niigata University), Katsuyoshi Michibayashi(Department of Earth and Planetary Sciences, Nagoya University), Keishi Okazaki(Japan Agency for Marine-Earth Science and Technology), Chairperson:Keishi Okazaki(Japan Agency for Marine-Earth Science and Technology), Sayantani Chatterjee(Niigata University, Department of Geology, Faculty of Science)

The IODP and ICDP have decided to launch a new international science framework, and hard rock drilling science is about to enter the preparatory period for the next phase. Therefore, drilling proposals from a new perspective and the production of scientific results based on existing drilling projects are expected. In this session, we invite presentations on the scientific results of hard-rock drilling. We also invite related studies of on-land geological investigations of Oman ophiolites and experimental studies. The session is intended to be interdisciplinary, including the fields of geophysics, geochemistry, petrology, engineering, and biology. This session is co-hosted with the focus group of hard rock drilling science.

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

[SCG41-01] The structure of magma chamber below a fast-spreading ridge based on field and core analyses of the Oman ICDP drilling

*Susumu Umino[1], Yuki Kusano[3], Osamu Ishizuka[3], Takahiro Fudai[4], Akihiro Tamura[1], Tomoaki Morishita[1,2] (1.Department of Earth Sciences, Kanazawa University, 2.JAMSTEC, 3.GSJ-AIST, 4.Taiheiyo Cement Corrperation)

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

[SCG41-02] Oxidation controlled symplectitic formation in olivine gabbros from Oman ophiolite, Oman Drilling Project, Hole GT2A

*Sayantani Chatterjee[1], Debaditya Bandyopadhyay[2,3], Eiichi Takazawa[1,4], Katsuyoshi Michibayashi[5] (1.Department of Geology, Faculty of Science, Niigata University, Niigata 950–2181, Japan, 2.Department of Geology, University of North Bengal, Darjeeling 734013, India, 3.Department of Geology, University of Calcutta, Kolkata 700019, India, 4.Japan Agency for Marine–earth Science and Technology, Yokosuka 237–0061, Japan, 5.Graduate School of Environmental Studies, Nagoya University, Nagoya 464–8602, Japan)

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

[SCG41-03] Effect of pore geometry on ultrasonic velocity of epidosites collected from the Oman Drilling Project

*Kumpei Nagase[1], Ikuo Katayama[1], Kohei Hatakeyama[1], Keishi Okazaki[2] (1.Earth and Planetary Systems Science Program, Graduate School of Advanced Science and Engineering, Hiroshima University, 2.Kochi Institute for Core Sample Research, Japan Agency for Marine-Earth Science and Technology)

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

[SCG41-04] Mineral mode of listvenite from ICDP Oman Drilling Project Hole BT1B inferred from X-ray CT core images

*Keishi Okazaki[1], Katsuyoshi Michibayashi[2], Kohei Hatakeyama[3], Natsue Abe[4], Kevin Johnson[5], Peter B Kelemen[6] (1.Kochi Institute for Core Sample Research, Japan Agency for Marine-Earth Science and Technology, 2.Department of Earth and Planetary Sciences, Nagoya University, 3.Department of Earth and Planetary Systems Sciences, Hiroshima University, 4.Mantle Drilling Promotion Office, Japan Agency for Marine-Earth Science and Technology, 5.Department of Earth Sciences, University of Hawai‘i at Mānoa, 6.Lamont Doherty Earth Observatory, Columbia University)

10:00 AM - 10:30 AM JST | 1:00 AM - 1:30 AM UTC

[SCG41-05] Serpentinization and Fe(III) distribution along the crust-mantle section of the oceanic lithosphere: insights from the Oman Drilling CM1A site

★Invited Papers

*Atsushi Okamoto[1], Kazuki Yoshida[1], Ryosuke Oyanagi[2], Yasuhiro Niwa[3], Yasuo Takeichi[3], Masao Kimura[3] (1.Graduate School of Environmental Studies, Tohoku University, 2.Japan Agency For Marine-Earth Science and Technology, 3.High Energy Accelerator Research Organization (KEK))

The structure of magma chamber below a fast-spreading ridge based on field and core analyses of the Oman ICDP drilling

*Susumu Umino[1], Yuki Kusano[3], Osamu Ishizuka[3], Takahiro Fudai[4], Akihiro Tamura[1], Tomoaki Morishita[1,2]

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The ICDP Oman Drilling Project drilled the lower crustal section of the Oman Ophiolite in Wadi Gideah, north of Ibra and recovered 400 m long cores each from Hole GT1A and GT2A. We report field observations of the lower crustal section along Wadi Gideah and reconstructed the vertical stratigraphy in reference to the Moho and describe the microstructures and major and trace element compositions of the whole rocks and constituent minerals. These observations enable us to estimate the amount of trapped melt in the lower crustal gabbro and discuss the conditions of magmatic and hypersolidus deformation that operated in the lower crustal magma chamber beneath the Oman paleoridge axis.

The lower crust attains 3.5 km in thickness, among which GT1A and GT2A holes range in stratigraphic height above the Moho from 0.4 to 0.8 km and from 2.0 to 1.6 km, respectively. Foliation and hypersolidus deformation structures are ubiquitous. Modal layering is locally present but is much less common. Well developed modal layering is present in the lowermost 125 m thick gabbro above the Moho.

Cored samples are predominantly olivine gabbros with deformed olivine aggregates and clinopyroxene with quarter structures embedded in granoblastic plagioclase and large euhedral plagioclases with resorbed turbid cores. These textures suggest deformation under the presence of melt, which assisted complete recovery of strain through recrystallization of fine-grained plagioclase and overgrowth of euhedral rims around magmatic plagioclase cores. Poikilitic and ophitic clinopyroxene occur sporadically throughout the holes, which are commonly present in the upper gabbros. Hypersolidus deformation structures are present irrespective to depth.

The lower GT1A and higher GT2A sections range in whole-rock Mg#s of 72-83 and 68-79, respectively. The lowest Mg#s overlap those of the sheeted dikes above. The whole-rock compositions are mainly controlled by accumulation of plagioclase, olivine, clinopyroxene and interstitial melts. The lower whole-rock Mg# and higher REEs and HFSEs of GT2A suggest larger amounts of trapped melt at stratigraphically higher levels. The amounts of trapped melt were estimated by LREE concentrations in the clinopyroxene cores, and by assuming LREE abundance in trapped melts to be equivalent to that of the sheeted dikes. Mass balance calculations yield the amount of trapped melt in gabbros to be 5 to 10 mass% in general and 25 mass% at most.

The drilled cores have common hypersolidus deformation with foliation but only limited modal layering, ubiquitous zoned cumulus minerals and common ophitic clinopyroxenes as well as the amount of trapped melt >5 mass% are all characteristics of foliated gabbros. In addition to this, field observations of the gabbros in Wadi Gideah show poorly develop modal layering but foliation defined by shape-preferred orientation of clinopyroxenes in the stratigraphic levels including both GT1A and GT2A holes. We concluded that both GT1A and GT2A holes sampled the thick foliated gabbros in Wadi Gideah section, which crystallized on the axial melt lens floor and were transported downward in the lower crust.

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Keywords: Oman ICDP, lower oceanic crust, magma chamber, fast-spreading ridge, upper gabbro, layered gabbro

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Oxidation controlled symplectitic formation in olivine gabbros from Oman ophiolite, Oman Drilling Project, Hole GT2A

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Symplectites are vermicular intergrowth of two or more mineral phases that inferred to be formed via melt-rock reaction, solid-state transformation, oxidation, or during different stages of magmatic crystallization. Here we report orthopyroxene-magnetite symplectitic intergrowth partly surrounding olivine within lower crustal olivine gabbros from Oman ophiolite recovered during Oman drilling project at Hole GT2A. The symplectites are found to be only associated with olivine and typically characterized by orthopyroxene groundmass hosting magnetite lamella. The width of the homogeneous grain of orthopyroxene ranges up to 300 μm whereas the width of vermicular intergrowth of magnetite within orthopyroxene ranges between 20-30 μm. The intergrowth of fine-grained magnetite rods is sometimes typified by the perpendicular arrangement with respect to the contact of adjacent olivine. Further, fine-grained lamella of magnetite within orthopyroxene generally grades away into irregular coarser-grained variety with increasing distance from olivine. From closer petrographic observation and previously inferred depth of formation of the sample (i.e., ~1kbar) we conclude this texture does not involve reaction (or significant material transfer) between two minerals (e.g., olivine and plagioclase). We thus infer such vermicular intergrowth is formed via olivine oxidation involving the reaction

Olivine + O_2 →Orthopyroxene + Magnetite

In order to test this hypothesis, we have adapted the equilibrium phase equilibria approach and computed several Temperature –Composition diagrams in a fixed pressure (1 kbar) to observe the oxidation effects in different olivine compositions. Our experiments predict the coexistence of olivine with Fo_{75-76} and Fo_{71} with the orthopyroxene (En_{79} and En_{76}) respectively; which is remarkably similar to the obtained mineral chemistry. Our result suggests the symplectite growth may have occurred between 600-1000˚C via subsolidus olivine oxidation and/or reaction with oxidizing melt.

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Keywords: Olivine gabbro, Orthopyroxene-magnetite symplectite, Lower crust, Oman ophiolite

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Effect of pore geometry on ultrasonic velocity of epidosites collected from the Oman Drilling Project

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Geophysical survey suggests a large amount of pore water exists in crack at the upper oceanic crust where seismic wave velocity is slow. However, anomalous low Vp/Vs ratio observed in central ridge and young oceanic crust (Spudich and Orcutt 1980; Kim et al., 2019), and such low Vp/Vs structure can't be explained by crack alone. Theorical model predict that crack with small aspect ratio increase Vp/Vs of rocks. On the other hand, pore with large aspect ratio decrease Vp/Vs (Kuster and Toksoz, 1974). Therefore, these anomalies can be explained by thick pore with large aspect ratio (shearer 1988). In this study, we focused on epidosite suggested to form on the hydrothermal alteration process of oceanic crust (Schiffman et al., 1987). We measured physical properties of epidosite and diabase collected from the Oman ophiolite, and we investigate pore aspect ratio from simultaneous measurement of velocity and porosity.

We developed simultaneous measurement system of ultrasonic velocity and porosity under hydrostatic pressure, using Intra-vessel deformation and fluid flow apparatus at Hiroshima University (Shimamoto et al., 2006). Ultrasonic velocity and porosity were measured under confining pressure up to 200 MPa at water-saturated condition. Pore pressure was fixed at 1 MPa. Ultrasonic velocity was measured by a pulse transmission method using both P- and S-wave piezoelectric transducers with a resonant frequency of 2 MHz. Porosity was calculated by initial porosity measured by pycnometer before compaction, and volume change of pore water after compaction using syringe pump. After each experiment, the measurement specimens were cored (10 mm in length, 6 mm in diameter) to perform X-ray microtomography in order to obtain 3D images of the pore shape. Microtomography analyses were performed using Xradia 410 Versa at Kochi Core Center. We used epidosite and diabase collected from gabbro-dike transition sections at Hole GT3A on the Oman Drilling project.

The experimental result shows that both P-wave and S-wave velocities increase with decreasing of porosity due to closing of pore. Diabase shows an increasing of Vp/Vs with increasing porosity whereas, sample with epidosite shows a decreasing of Vp/Vs with porosity. The microstructure of the measurement specimen showed that diabase is consisted crack-like pore shape, while the epidosite showed a porous pore shape.

We investigate pore aspect ratio from measured velocities and porosities based on application of effective medium theory by Kuster and Toksoz (1974). As a result, this implies that different aspect ratio in diabase and epidosite, pore aspect ratio is more than an order of magnitude higher in epidosite. This implies that there is possibility that anomalous low Vp/Vs observed in the central ridge and young oceanic crust might be explained by the effect of pore water in epidosite.

Keywords: Epidosite, Pore geometry, Vp/Vs, Aspect ratio

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Mineral mode of listvenite from ICDP Oman Drilling Project Hole BT1B inferred from X-ray CT core images

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To understand the global cycle of fluid flow from the surface to the deep of the Earth, it is important to constrain how and how much fluid is captured and released by metamorphic reactions following hydration/dehydration and carbonation/decarbonation. In the Oman Ophiolite, a fossil of an oceanic plate is widely exposed. Continuous drilling from the bottom of the ophiolite through the basal thrust to the footwall metamorphic sole was conducted in Hole BT1B by the ICDP Oman Drilling Project. Listvenite, completely carbonated former peridotite, is the main lithology in Hole BT1B also found in other ophiolite bodies. Listvenite is mainly composed of magnesite, quartz, dolomite and Fe-hydroxide with minor chromian spinel and chromian mica (fuchsite). Two serpentinite and ophicarbonate intervals were also found above the basal thrust. Below the basal thrust, the metamorphic sole composed by the greenschist/greenstone is the main lithology.

We evaluated the mineral mode of listvenite in BT1B from the X-ray Computed Tomography (XCT) images. XCT images was continuously obtained with a spacing of 0.625 mm along the Z-axis on all 401 whole-round core sections recovered from Hole BT1B. The X-Y resolution of XCT image is 0.125mm and an intensity of X-ray attenuation, “XCT number”, are computed for each voxel. The XCT number of a material depends on several factors such as density, element (e.g., atomic number), porosity, sample shape and sample volume. All listvenite and serpentinite core sections are nearly the same dimensions (~63.5 mm in diameter) and thus same volume, therefore, the XCT number provides information of physical and chemical properties of the core samples.

Each XCT number in XCT images and chemical mapping data of Mg, Si, Ca and Fe from the XRF core scanner in the same location as XCT images are compared for 27 sections including 9289 data points for each element. Multiple linear regression for XCT number and XRF quantified that XCT numbers of pure magnesite ($MgCO_3$), quartz (SiO_2), and dolomite ($CaMg(CO_3)_2$) grains in the cores are 3106, 2974 and 3415, respectively. Using these values, histograms of XCT number of each slice in each section is fitted assuming that the CT histogram (CT number >2500) of a slice is composed of three peaks with Gaussian distribution.

In most core sections, XCT data indicates that the matrix of listvenite is mainly composed of magnesite and quartz, and minor dolomite, consistent with discrete XRD and XRF data. Veins usually show high CT number (~3400), while the CT number in veins is fitted well with dolomite. Dolomite abundance in each core section is highly dependent on the intensity of veins. Dolomite abundance in most core sections within 15 m from the basal thrust is higher than 50%. This is consistent with higher vein intensity close to the basal thrust and could indicate that significant amounts of Ca were supplied from Ca- and CO_2-rich fluids along the basal thrust. Total MgO/SiO_2 ratio in BT1B is ~1.2. This value is slightly smaller than that

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from onboard XRF data of listvenite (~1.3) and smaller than that estimated from the geochemical analysis of the Oman peridotite (~1.5). This suggest that Si enrichment or Mg loss during carbonation and/or following serpentinization of the ophiolite. Fe contents may also have significant effect on evaluating the modal abundance of minerals in listvenite and further investigation of compositional effects, especially Fe solid solutions in carbonate and hematite on the XCT number would be needed for an accurate assessment of the mineralogy in listvenite.

Keywords: Ophiolite, Mantle, Oceanic crust, Listvenite, Serpentinite, X-ray CT

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Serpentinization and Fe(III) distribution along the crust-mantle section of the oceanic lithosphere: insights from the Oman Drilling CM1A site

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Serpentinization of mantle peridotite causes the production of hydrogen and hydrocarbon, which provides energy for sustaining the microbial activities within the oceanic lithosphere. The total production of hydrogen energy depends on the extent of serpentinization and its reaction pathway. During serpentinization, Fe(II) in olivine or orthopyroxene is commonly oxidized to form magnetite Fe_3O_4, which is coupled with H_2O reduction to produce H_2. In contrast, the Fe(II)-rich brucite is often reported as a precursor of magnetite+serpentine, and Fe(III) can exist within serpentine minerals. Due to variable occurrences of iron-bearing minerals, the magnetic sustainability of the serpentinized peridotite within the oceanic lithosphere is not always linear relationship with the extent of serpentinization. The CM1site of the Oman Drilling Project provides us a good opportunity to understand where and how much amount of hydrogen produces within the oceanic lithosphere from the lower crust to upper mantle section. In this study, we reported the depth variation of serpentinization and the Fe(III)/Fe(II) ratios along the crust-mantle section, and the spatial and temporal variations on Fe(III), meaning that the hydrogen production. We conducted bulk measurement of Fe(III)/total Fe along the borehole, and micro XANES mapping at Photon Factory, KEK.

The CM1A site shows the complete continuous core with length of 404.15 m, from the lower crust composed of olivine gabbros and troctolite, crust-mantle transition zone composed of dunite, and mantle section mainly composed of harzburgite. All the core samples are highly serpentinized, but it has a variation along the depth. In the olivine gabbros, the extent of the serpentinization is relatively low (11-69%; Yoshida et al., 2021), but serpentinization of olivine grains with mesh texture are observed as black network veins. In the transition zone, dunite is almost 100% serpentinized, and the onboard X-ray CT images reveals that the network of distinct “bright (magnetite-rich)” vein networks. In the upper mantle section, olivine shows mesh texture and bastite formed around the Opx and 70-90% serpentinized. The serpentine minerals in the gabbroic rocks, dunite and hurzburgite are mostly lizardite and associated with brucite, but we found that blight vein network is composed of antigorite.

The bulk Fe(III)/total Fe ratio ranges from 0.21 to 0.66. we found two clear trends, and the ratio is higher in dunite and harzburgite than gabbroic crust, reflecting the extent of serpentinization. In the harzburgite, the local Fe(III)/total Fe ratio is higher in the mesh rim around the olivine, whereas it is low in bastite. Magnetite also preferentially occurs in olivine mesh texture, and it is absent around olivine, due to the difference in silica activity. This indicates that the olivine has higher potential of oxidation of iron to produce hydrogen. The other feature is that antigorite veins in dunite parts shows (1) magnetite was dissolved and reprecipitated at the margin of the veins, (2) the antigorite is high XMg value, and (3) high Fe(III)/total Fe ratio than the other lizardite. These features indicate that the low-temperature alteration characterized by lizardite + brucite occurred pervasively at the earlier stage to produce hydrogen, and the high-temperature oxidizing fluids would have infiltrated along the fracture networks from the deeper parts, probably related to the later obduction/subduction stage.

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References: Yoshida, K., Okamoto, A., Oyanagi, R., Shimizu, H., Tsuchiya, N., Oman Drilling Project Science Party II, 2020. Journal of Geophysical Research, 125, e2020JB020268

Keywords: Oman ophiolite, Fe(III)/Fe(II) distribution, serpentinite, antigorite, magnetite, crust-mantle transition zone

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

Sun. Jun 6, 2021 10:45 AM - 12:15 PM JST | Sun. Jun 6, 2021 1:45 AM - 3:15 AM UTC | Ch.19 Zoom Room 19

[S-CG41] Hard-Rock Drilling Science: From Continental to Deep Sea Drilling, and Oman Project

convener:Eiichi TAKAZAWA(Department of Geology, Faculty of Science, Niigata University), Katsuyoshi Michibayashi(Department of Earth and Planetary Sciences, Nagoya University), Keishi Okazaki(Japan Agency for Marine-Earth Science and Technology), Chairperson:Katsuyoshi Michibayashi(Department of Earth and Planetary Sciences, Nagoya University), Eiichi TAKAZAWA(Department of Geology, Faculty of Science, Niigata University)

The IODP and ICDP have decided to launch a new international science framework, and hard rock drilling science is about to enter the preparatory period for the next phase. Therefore, drilling proposals from a new perspective and the production of scientific results based on existing drilling projects are expected. In this session, we invite presentations on the scientific results of hard-rock drilling. We also invite related studies of on-land geological investigations of Oman ophiolites and experimental studies. The session is intended to be interdisciplinary, including the fields of geophysics, geochemistry, petrology, engineering, and biology. This session is co-hosted with the focus group of hard rock drilling science.

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

[SCG41-06] Heterogeneity in the mantle section of the Oman ophiolite in terms of spinel and clinopyroxene compositions

*Eiichi TAKAZAWA[1,2] (1.Department of Geology, Faculty of Science, Niigata University, 2.Japan Agency for Marine-Earth Science and Technology)

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

[SCG41-07] Systematics of minor and trace element chemistry of olivine in peridotites

*Ikuya Nishio[1], Tomoaki Morishita[1], Keita Itano[1], Akihiro Tamura[1], Asyraf Muhamad[1] (1.Kanazawa University)

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

[SCG41-08] **ICDP DSeis project: compilation of borehole logging and recovered core information at the seismogenic zone of the M5.5 Orkney earthquake with lower crustal intrusives**

*Hiroshi Ogasawara[1], Shunsuke Yoshida[2], Mitsuya Higashi[2], Kensuke Sakaguchi[1], Yuki Yokoyama[4], Yasuo Yabe[3], Tetsuro Hirono[4], Dakalo Ligaraba[5], Nandipha Masondo[5], Yuhji Yamamoto[6], Team ICDP DSeis (1.College of Science and Engineering, Ritsumeikan University, 2.Graduate School of Science and Engineering, Ritsumeikan University, 3.Graduate School of Science, Tohoku University, 4.Graduate School of Science, Osaka University, 5.Graduate School of Geoscience, University of the Witwatersrand, 6.Kochi Core Center, Kochi University)

11:30 AM - 12:00 PM JST | 2:30 AM - 3:00 AM UTC

[SCG41-09] Volcanism along the eastern margin of the Ontong Java Plateau: More reasons to test the Ontong Java Nui hypothesis by scientific ocean drilling

★Invited Papers

*Maria Luisa Tejada[1], Takashi Sano[2], Takeshi Hanyu[1], Anthony A. P. Koppers[3], Masao Nakanishi[4], Akira Ishikawa[5], Takashi Miyazaki[1], Kenichiro Tani[2], Shoka Shimizu[6], Qing Chang[1], Bogdan Stefanov Vaglarov[1] (1.Volcano and Earth Interior Research Center, Institute for Marine Geodynamics, Japan Agency for Marine-Earth Science and Technology, 2-15 Natsushima, Yokosuka 237-0061, Japan, 2.Department of Geology and Paleontology, National Museum of Nature and Science, Amakubo 1-1-1, Tsukuba, Ibaraki 305-0005, Japan, 3.College of Earth, Ocean and Atmospheric Sciences, Oregon State University, Corvallis, OR 97331, U.S.A., 4.Graduate School of Science, Chiba University, Chiba 263-8522, Japan, 5.Department of

Earth and Planetary Sciences, Tokyo Institute of Technology, 2-12-1 Ookayama, Meguro, Tokyo 152-8550, Japan , 6.Graduate School of Science and Engineering, Chiba University, Chiba 263-8522, Japan)

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

[SCG41-10] New Developments in Hard Rock Drilling Project: Horoman and Forearc Mantle drilling

*Katsuyoshi Michibayashi[1], Eiichi Takazawa[2], Tomoaki Morishita[3], Mikiya Yamashita[4,5], Gou Fujie[4], Shigeaki Ono[4] (1.Nagoya University, 2.Niigata University, 3.Kanazawa University, 4.JAMSTEC, 5.AIST)

Heterogeneity in the mantle section of the Oman ophiolite in terms of spinel and clinopyroxene compositions

*Eiichi TAKAZAWA[1,2]

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The tectonic environment during the formation of Oman ophiolite is still debated, but it becomes consensus that ridge spreading worked in the early stage [1, 2]. The age of the volcanic and plutonic rocks in the crustal section formed by the spreading ridge is 96-95 Ma, which is close to the oldest age (~ 95-94 Ma) of the metamorphic sole, indicating that the thrusting of ophiolite had started during or immediately after the formation of the crustal section [3, 4]. It is important to clarify the compositional modification that the residual mantle peridotite have received during thrusting/subduction following the partial melting in the spreading ridge. In this talk, I will summarize what has been clarified at this time.

Spinel's Cr# (= Cr/[Cr+Al] atomic ratio) and abundance of heavy rare earth elements in clinopyroxene (e.g., Yb) are used as an indicator to estimate the depletion of peridotites with upper mantle origin [5, 6, 7]. Research team at Niigata University has examined spatial compositional heterogeneity in the mantle section of the Oman ophiolite. The study area has been focused in the Fizh and Salahi massifs from the northern part and the Wadi Tayin massif from the southern part of the Oman ophiolite.

In the Fizh and Salahi massifs, the Cr# of spinels in harzburgite falls within the composition range of abyssal peridotites except for some areas. Areas where Cr# is higher than the composition range of abyssal peridotites exist locally as the "high refractory harzburgite zone" [8] in the northern part of the Fizh mantle section and as the ultramafic complex of the Salahi mantle section [9]. In the Wadi Tayin mantle section in the southern part of Oman ophiolite, Cr# of harzbergite spinel is mostly within the composition range of abyssal peridotite.

On the other hand, the Cr# of dunite spinel has a wide range from abyssal peridotite to forearc peridotite, and spinel with a high value of 0.7 or more widely distributed in the Fizh and Sarahi mantle section. The high Cr# region of the dunite spinel spreads finger-like in the mantle section, suggesting a reaction with melts (island arc tholeiite and boninite) derived from highly refractory peridotite. Even in the Wadi Tayin mantle section in the southern part of Oman ophiolite, some of the dunite spinel have high Cr#, and their distribution is limited to the shear zone and the vicinity of the basal thrust.

The rare earth element pattern of Cpx in the peridotites in the mantle section of the Oman ophiolite tends to change with the coexisting spinel Cr#. That is, as the Cr# of spinel increases, the Ce/Yb ratio of Cpx increases. There is a difference in the correlation between the northern part and the southern part of Oman ophiolite, and when comparing the peridotites with the same Cr# of spinel, the Ce/Yb ratio of Cpx is higher in the southern part. This is thought to represent a difference in the composition of the melt that reacted with harzburgite to form dunite, and while boninite melt was involved in the north, it is possible that MORB may be an island arc tholeiite in the south. The former is characterized by a higher amount of Cr and a lower abundance of rare earth elements than the latter.

References: [1] Nicolas et al., 1988, Tectonophysics, 151, 87–105; [2] Umino, 1995, Journal of Geography (Chigaku Zasshi), 104, 321–349; [3] Rioux et al., 2012, JGR, 117, B07201,

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Keywords: Oman ophiolite, upper mantle, spreading ridge, thrusting, mantle-melt reaction

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Systematics of minor and trace element chemistry of olivine in peridotites

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1. Kanazawa University

Upper mantle consists of mostly peridotites consisting mostly of olivine. Minor and trace element chemistry of olivine has received attention to understand mantle heterogeneity (Sobolev et al., 2007) and element mobility in subducted oceanic mantle (Scambelluri et al., 2004). Therefore, minor and trace element chemistry of olivine has been lately investigated for volcanic rocks (Foley et al., 2013), garnet-peridotite (De Hoog et al., 2010), deserpentinized peridotite (Garrido et al., 2005). However, those of residual spinel-peridotite after partial melting have not been well studied compared to those peridotites and also systematics of olivine minor and trace element chemistry is not well established. Therefore, a comprehensive study on minor and trace element chemistry of olivine from various origins is important as an indicator of constraining the origin of peridotite and understanding elements input/output during the secondary process such as metasomatism and serpentinization/deserpentinization.

We make a systematic inquiry into olivine trace elements of residual peridotites, cumulus ultramafic rocks, metasomatized and deserpentinized ultramafic rocks. We used previously well-studied samples for the trace element analyses: abyssal peridotites from the Atlantis Massif, the Central Indian Ridge, and Southwest Indian Ridge (Tamura et al., 2008; Morishita et al., 2007, 2009) and forearc peridotite from Izu-Bonin-Mariana arc (Morishita et al., 2011) for residual peridotite samples, and ultramafic xenolith from Takashima in the southwest Japan arc (Muroi and Arai, 2014), banded-dunite-harzburgite from Horoman peridotite complex (Matsufuji et al., 2006), and hornblende peridotite from Hakusan area for cumulative samples, respectively. Minor and trace elements in olivine of other origins such as lower dunite recovered by Oman Drilling Project, and metasomatized and/or deserpentinized ultramafic rocks from SW Greenland were analyzed to understand the secondary process.

The minor and trace element abundance in olivine was obtained by LA-ICP-MS analysis. The analysis was performed by an ablating spot of 100 μm in diameter and a repetition rate of 6-10 Hz. Each analysis consisted of 30 s measurement of gas bland and 30 s ablation. The following isotopes were measured: ^{7}Li, ^{11}B, ^{23}Na, ^{27}Al, ^{29}Si, ^{31}P, ^{43}Ca, ^{45}Sc, ^{49}Ti, ^{51}V, ^{53}Cr, ^{59}Co, ^{62}Ni, ^{63}Cu, ^{66}Zn, ^{75}As, ^{85}Rb, ^{88}Sr, ^{89}Y, ^{90}Zr, ^{93}Nb, ^{95}Mo, ^{118}Sn, ^{121}Sb, ^{137}Ba, ^{140}Ce, ^{181}Ta, ^{208}Pb, ^{209}Bi, ^{232}Th, and ^{238}U. Signals of certain elements such as B, Ba, Sr, Ba, Pb, Al, and Cr, which indicate the presence of cracks or inclusions such as serpentine and spinel, were carefully monitored. In this study, we did not obtain rare earth elements abundance because they are mostly the below detection limit.

The minor and trace element abundances in olivine primarily depend on the degree of depletion. However, the results suggest that Ca, Ti, Y, B, and Li can be used as proxies to discriminate the origin of ultramafic rocks. Those elements tend to be higher in olivine of cumulus, metasomatized and deserpentinized ultramafic rocks than in olivine of residual peridotites. Y concentration in olivine of residual peridotite presents good correlations with the degree of partial melting estimated by REE concentration in clinopyroxene and Cr# of spinel. We emphasize that the minor and trace element chemistry of olivine has the potential as an indicator of the mantle process.

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Keywords: Olivine, Mantle, Peridotite, Trace element

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ICDP DSeis project: compilation of borehole logging and recovered core information at the seismogenic zone of the M5.5 Orkney earthquake with lower crustal intrusives

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The ICDP DSeis project (ICDP, 2019, The Thrill to Drill) has accomplished a full core recovery with a total of 1.6 km length drilled from 2.9 km underground, probing the upper margin of the aftershock zone of the M5.5 Orkney sinistral earthquake (Ogasawara et al. Deep Mining 2019). It was known before drilling that the host rocks of this seismogenic zone were Archean metamorphosed sedimentary rocks (2.9 billion years old; West Rand group, including quartzite and etc.).

This presentation will report the results of the compilation of down-hole logging (gamma-rays, density, elastic wave velocity, magnetic susceptibility, water temperature and conductivity) performed in 2017-2018 and non-destructive analysis (e.g., MSCL) of a hundred-plus meter-long core imported to the Kochi Core Center in 2019.

Drilling and logging in 2017-2018 revealed not only that the densities and Vp of the metamorphosed sedimentary rocks of the West Rand group (Roodepoort, Crown, Babrosco formations) are comparable to the upper crust, but also that dolerite sills with densities and seismic velocities were comparable to the lower crust.

Lamprophyre dyke and fault gouge and breccia were recovered from the intersection with the aftershock zone of the M5.5 sinistral earthquake (Ogasawara et al. Deep Mining 2019), and talc was also detected (Yokoyama 2020 MSc thesis, Osaka University). Because the borehole collapsed and blocked at the intersection with the aftershock zone, it was not possible to conduct borehole logging at the intersection and beyond it. This section was imported to the Kochi Core Center for MSCL and X-ray CT in FY 2019.

In FY2020, these were compiled. As a result, the density of the intact part of the lamprophyre dyke intersected at the aftershock zone is significantly larger than that of the dolerite sill, and the magnetic susceptibility increases rapidly and Vp decreases sharply when approaching the fault zone.

At the other intersection of the dolerite sill and another mafic dyke, Wiersberg et al. (2019 EGU), Rusley et al. (2018 AGU), Nisson et al. (2019 AGU), Warr et al. (2020 AGU) also found hypersaline brine fissure and gases (similar to those near hydrothermal vents on oceanic ridges?) rich in dissolved organic hydrocarbons of non-meteoric or non-biogenic origins. Aftershock activity consists of several streaks, with direction in line with the intersection line between the aftershock plane and the dolerite sills (Tadokoro MSc thesis Ritsumeikan). Since it is well known that mafic intrusives affect the subsurface fluid flow, an integrated analysis of all of these will kick off discussions on the relationship between material, water, and rupture at a seismogenic zone.

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The ICDP team consists of researchers from Japan, South Africa, USA, Germany, Switzerland, India, Israel, Australia, and practitioners from the mining industry in South Africa. The core members include Y. Yabe and T. Ito (Tohoku Univ.), J. Mori (Kyoto Univ.), T. Hirono (Osaka Univ.), Y. Yamamoto (Kochi Univ.), B. Liebenberg (Moab Khotsong mine), T.C. Onsott (Princeton Univ.), T.L. Kieft (New Mexico Tech), T. Wiersberg (GFZ), R.J. Durrheim (Wits Univ.). Durrheim (Wits Univ.), J. Castillo (Free State Univ.), M. Ziegler (ETH, Zurich), and their students.

This drilling program was built on the projects supported by JST-JICA SATREPS and JSPS Kakenhi. It is currently supported by AngloGold Ashanti, Harmony, Sibanye Stillwater, ICDP, JSPS Core-to-Core Program, JSPS-SA NRF bilateral Program, Ritsumeikan University, Kochi Core Center, Collaborative Research Program for Seismic Volcanic Observations to Mitigate Hazards, US NSF, German DFG, South African NRF, CSIR and CGS.

Keywords: Seismogenic zone, ICDP scientific drilling, Deep goold mines in South Africa, Altered intrusives as dense as lower crustal material

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Volcanism along the eastern margin of the Ontong Java Plateau: More reasons to test the Ontong Java Nui hypothesis by scientific ocean drilling

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The Ontong Java Nui hypothesis, which states that three Pacific oceanic plateaus, Ontong Java, Manihiki and Hikurangi, once formed a single super plateau has been around for more than a decade now. However, there are critical pieces of the Ontong Java Nui puzzle that either do not fit or are sorely missing. Two of the outstanding inconsistencies are the contrasting crustal thickness between Manihiki Plateau (MP) and Ontong Java Plateau (OJP) and the rather distinct geochemical composition of the former which is not found on the latter so far. During the R/V Kairei KR16-04 cruise, we conducted geological surveys and dredging on the ridges protruding from the eastern margin of the OJP, as well as from the capping seamounts. We found that the dredged rocks have a variety of chemical composition ranging from tholeiitic to transitional to alkalic affinities. The tholeiites show similar middle to heavy rare earth abundances to OJP tholeiites but have elevated highly incompatible element (Rb, Th, Nb, Ta) contents, somewhat forming U-shaped trace element patterns that resemble those of Danger Island Trough basalts. Alkalic basalt composition mimics the trace element patterns of the 44 Ma, 65 Ma, and 90 Ma transitional to strongly alkalic basalts from the Solomon Islands and the Lyra Basin that form the southern and western margins of the OJP, respectively. Indicative older ~96-116 Ma ^{40}Ar-^{39}Ar ages of the ridge samples dredged near or below the base of the seamounts contrast with the 67-68 Ma plateau ages of samples from a seamount atop one of the ridges. These ages indicate later formation of the ridges compared to the main OJP (~122 Ma) but match with those of dated samples from Rapuhia Scarp on the northern margin of Hikurangi Plateau. Isotope and trace element data provide the missing compositional link while the new age data tie together the younger ages among Ontong Java, Manihiki and Hikurangi plateau volcanism. These findings support but add complexity to the Ontong Java Nui jigsaw fit. Thus, drilling the basement around the Eastern Salient of the OJP is required to further probe the extent or existence of the Ontong Java Nui super plateau.

Keywords: Ontong Java Nui, Ontong Java Plateau, Manihiki Plateau, Hikurangi Plateau

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New Developments in Hard Rock Drilling Project: Horoman and Forearc Mantle drilling

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1. Nagoya University, 2. Niigata University, 3. Kanazawa University, 4. JAMSTEC, 5. AIST

Plate tectonics, which is the paradigm of modern earth science, has been based on the assumption of a homogeneous and dry oceanic plate. However, rapid progress in ocean bottom exploration in the last 20 years strongly suggests that oceanic plates are diverse and quite wet (water-bearing). The Oman Drilling Expedition (2016-2018) has clearly demonstrated that the oceanic plate is not only poorly understood, but also that a major feature of the oceanic plate is that it can be far more hydrous than currently thought. However, while the Oman drilling experiment is revealing the full picture of the wet oceanic plate, our understanding of the dry case is still lacking. The Horoman peridotite body, located near Cape Erimo in the southernmost part of the Hidaka Mountains in Hokkaido, Japan, is one of the rare dry oceanic plate fragments in the world. We are now planning to carry out Horoman peridotite drilling experiments to recover continuous samples of dry oceanic plate material. We will compare our results with those of the recent Oman ophiolite drilling experiments to develop a new lithostratigraphic model that accounts for the entire oceanic plate, taking into account magma production and water content. In addition, the results of the geophysical survey of the Ogasawara Trench performed on December 19, 2020 will be briefly presented for the forearc Mantle drilling project.

Keywords: Horoman Peridotite, Oman ophiolite, Forearc Mantle Drilling

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[E] Oral | B (Biogeosciences)：B-PT Paleontology

Sun. Jun 6, 2021 1:45 PM - 3:15 PM JST | Sun. Jun 6, 2021 4:45 AM - 6:15 AM UTC | Ch.26 Zoom Room 26

[B-PT01] Biomineralization and Geochemistry of Proxies

convener:Takashi Toyofuku(Japan Agency for Marine-Earth Science and Technology (JAMSTEC)), Hiroshi Kitazato(Tokyo University of Marine Science and Technology (TUMSAT)), Jelle Bijma(Alfred-Wegener-Institut Helmholtz-Zentrum für Polar- und Meeresforschung), Kotaro Hirose(Faculty of Science and Engineering, Waseda University), Chairperson:Takashi Toyofuku(Japan Agency for Marine-Earth Science and Technology (JAMSTEC)), Hiroshi Kitazato(Tokyo University of Marine Science and Technology (TUMSAT)), Kotaro Hirose(Faculty of Science and Engineering, Waseda University), Jelle Bijma(Alfred-Wegener-Institut Helmholtz-Zentrum für Polar- und Meeresforschung)

In order to reconstruct the Earth climate system, marine paleoclimatologists resort to transfer functions or geochemical proxies, which are produced or affected by organisms. The relationships used for reconstructions are generally based on field calibrations or derived from laboratory experiments. The danger of these so-called empirical relationships is that they may be valid only within the restricted parameter space of their calibration. Application of proxy relationships to very different environmental settings (e.g. high vs. low latitude or glacial vs. interglacial) requires a mechanistic understanding of these relationships. Much progress can be expected by a better understanding of the biomineralization mechanisms and the incorporation of proxy signals.
In this session we facilitate contributions related to the biomineralization, calibration and validation of marine proxies from field study, laboratory culture experiment and paleo-environmental reconstruction.

1:45 PM - 1:48 PM JST | 4:45 AM - 4:48 AM UTC

[BPT01-01] Introduction

1:48 PM - 2:03 PM JST | 4:48 AM - 5:03 AM UTC

[BPT01-02] Seascape ecological view as a new insight of benthic foraminiferal community

*Hiroshi Kitazato[1] (1.Tokyo University of Marine Science and Technology (TUMSAT))

2:03 PM - 2:21 PM JST | 5:03 AM - 5:21 AM UTC

[BPT01-03] Macromolecular analysis of modern aquatic palynomorphs using micro-Raman spectroscopy

*Takuto Ando[1], Tatsuyuki Yamamoto[2], Mika Ishigaki[3], Kazumi Matsuoka[4] (1.Estuary Research Center, Shimane University, 2.Faculty of Life and Environmental Sciences, Shimane University, 3.Center for Promotion of Project Research. Shimane University, 4.Institute for East China Sea Research, Nagasaki University, Japan)

2:21 PM - 2:39 PM JST | 5:21 AM - 5:39 AM UTC

[BPT01-04] **The spatial distribution and the origin of heavy metals in bottom sediments from Lake Shinji and Nakaumi**

*Hanye ZHANG[1], Kotaro Hirose[1], Kazuo Kamura[1], Minami Aoki[1], Koji Seto[2] (1.Faculty of Science and Engineering, Waseda University, 2.Estuary Research Center, Shimane University)

2:39 PM - 2:57 PM JST | 5:39 AM - 5:57 AM UTC

[BPT01-05] Sedimentary geochemical record of human-induced environmental changes in the estuarine lake Nakaumi, southwest Japan

*Kotaro Hirose[1], Minami Aoki[4], Akira Tsujimoto[3], Koji Seto[2], Kazuo Kamura[1] (1.Faculty of Science and Engineering, Waseda University, 2.Estuary Research Center, Shimane University, 3.Faculty of Education, Shimane Universit, 4.Faculty of Science and Engineering, Waseda University (currently Seikei Gakuen))

2:57 PM - 3:15 PM JST | 5:57 AM - 6:15 AM UTC

[BPT01-06] Calcification depths of planktic foraminifers constrained using geochemical signatures in the sediment trap samples collected from the Bay of Bengal

*Ayumi Maeda[1], Azumi Kuroyanagi[2], Toshihiro Yoshimura[3], Birgit Gaye[4], Tim Rixen[5], Atsushi Suzuki[1], Hodaka Kawahata[6] (1.National Institute of Advanced Industrial Science and Technology, 2.Tohoku University Museum, The Center for Academic Resources and Archives, Tohoku University, 3.Japan Agency for Marine-Earth Science and Technology, 4.Institute for Geology, Universität Hamburg, 5.Leibniz Centre for Tropical Marine Research, 6.Atmosphere and Ocean Research Institute, The University of Tokyo)

[E] Oral | B (Biogeosciences) | B-PT Paleontology

[B-PT01] Biomineralization and Geochemistry of Proxies

convener:Takashi Toyofuku(Japan Agency for Marine-Earth Science and Technology (JAMSTEC)), Hiroshi Kitazato(Tokyo University of Marine Science and Technology (TUMSAT)), Jelle Bijma(Alfred-Wegener-Institut Helmholtz-Zentrum für Polar- und Meeresforschung), Kotaro Hirose(Faculty of Science and Engineering, Waseda University), Chairperson:Takashi Toyofuku(Japan Agency for Marine-Earth Science and Technology (JAMSTEC)), Hiroshi Kitazato(Tokyo University of Marine Science and Technology (TUMSAT)), Kotaro Hirose(Faculty of Science and Engineering, Waseda University), Jelle Bijma(Alfred-Wegener-Institut Helmholtz-Zentrum für Polar- und Meeresforschung)

Sun. Jun 6, 2021 1:45 PM - 3:15 PM Ch.26 (Zoom Room 26)

In order to reconstruct the Earth climate system, marine paleoclimatologists resort to transfer functions or geochemical proxies, which are produced or affected by organisms. The relationships used for reconstructions are generally based on field calibrations or derived from laboratory experiments. The danger of these so-called empirical relationships is that they may be valid only within the restricted parameter space of their calibration. Application of proxy relationships to very different environmental settings (e.g. high vs. low latitude or glacial vs. interglacial) requires a mechanistic understanding of these relationships. Much progress can be expected by a better understanding of the biomineralization mechanisms and the incorporation of proxy signals.

In this session we facilitate contributions related to the biomineralization, calibration and validation of marine proxies from field study, laboratory culture experiment and paleo-environmental reconstruction.

1:45 PM - 1:48 PM

[BPT01-01]Introduction

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Seascape ecological view as a new insight of benthic foraminiferal community

*Hiroshi Kitazato[1]

1. Tokyo University of Marine Science and Technology (TUMSAT)

Foraminifers secrete various chemicals for chamber walls. They are calcium carbonates such as calcite, aragonite, Mg-calcite, organic compounds for agglutinated chambers and/or organic cemented test walls. Foraminiferal test walls basically form according to genetic information. However, same test group is tended to gather at specific microenvironments. For instance, turf shaped algal microhabitat such as coralline algae at rocky shore is composed of both frond and thallus parts as microhabitat. Frond part is open space where fresh seawater moves inbetween one frond and to the other. *Elphidium crispum*, *Pararotalia nipponica* and *Patellina corrugate* and other calcareous foraminifers dwell at frondal surface. In contrast, thallus part is muddy and high concentration of organic matters. The thallus part shows less oxygenated than frondal part as the space is close. Microbial cascades are developed at thallus part. Minor elements such as Mg or Sr are relatively high in sediment. Soft-shelled forms such as *Allogromia*, gromiid, agglutinated forms and miliolids groups with high magnesian calcite tests flourish at the thallus part. Most of foraminifers dwelled at muddy environments are mobile mode of life.
Microhabitat segregation and microenvironmental differences may cause similar biomineralization of benthic foraminiferal tests. I would like to stress that micro-seascape should be important to characterize benthic foraminiferal communities.

Keywords: Seascape ecology, microhabitat, benthic foraminifers, biodiversity, biomineralization

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Macromolecular analysis of modern aquatic palynomorphs using micro-Raman spectroscopy

*Takuto Ando[1], Tatsuyuki Yamamoto[2], Mika Ishigaki[3], Kazumi Matsuoka[4]

1. Estuary Research Center, Shimane University, 2. Faculty of Life and Environmental Sciences, Shimane University, 3. Center for Promotion of Project Research. Shimane University, 4. Institute for East China Sea Research, Nagasaki University, Japan

Palynomorphs are composed of resistant biomacromolecules and preserved partly in sedimentary rocks. Aquatic palynomorphs have great potential to reconstruct ecosystem or community composition of aquatic organisms in the past due to that they include several taxa with different ecological roles. For example, dinoflagellate cysts, ciliate cysts/loricas, foraminiferal linings, raphidophycean cysts, prasinophycean phycomata, flagments/eggs of zooplanktons, and acritarchs including *Micrhystridium ariakense* are deposited as aquatic palynomorphs in the sediments of Nakaumi Lagoon and Lake Shinji. However, production, preservation and distribution of these aquatic palynomorphs are not fully understood. Macromolecular analysis using micro-FTIR is common technique to know preservation/decomposition process of palynomorphs. In fact, we used micro-FTIR for chemotaxonomy and understanding preservation bias of several aquatic palynomorphs, and showed the results in this session at the last JpGU-AGU Meeting. Raman microscopy is another spectroscopic method to observe macromolecular structure and can analyze the area with micron- or submicron size. However, it is difficult to get good spectra due to emission of autofluorescence from targeted palynomorphs under the light with low wavelength (e.g., 532nm laser). In this presentation, we would like to introduce the results of micro-Raman analysis for aquatic palynomorphs succeeded by using the laser with higher wavelength (785 nm).

We analyzed authentic standards (e.g., cellulose and chitin) to compare with macromolecular structures of aquatic palynomorphs. IR spectra of polysaccharides are characterized by a dominant absorption band between 1200-1000 cm^{-1} (fingerprint region) related to the stretching vibration of C-O bond. On the other hand, Raman spectra of polysaccharides are more sharp and smaller number of peaks in the same region. The data using authentic standards suggested that IR and Raman spectra are sensitive to differences in the position of glycosidic bond (e.g., α-/β- and 1,3-/1,4-/1,6-) and the type of functional groups in fingerprint region, respectively. In fact, a shift in the Raman spectra around fingerprint region of chitin with acetamide groups was observed as compared with those of cellulose with hydroxyl groups. *Alexandrium catenella/pacificum* is one of causative dinoflagellates for paralytic shellfish poisoning and forms a translucent ellipsoidal cyst. The highest peak of IR spectra around fingerprint region in the cyst of *A. catenella/pacificum* is at ~1033cm^{-1} and lower than for cellulose (~1059cm^{-1}). On the other hand, there is no change in Raman spectra of cellulose and *A. catenella/pacificum* in fingerprint region. However, Raman spectra of the cyst wall in *A. catenella/pacificum* included the higher peaks around 1500-1200 cm^{-1} region characterized by polysaccharides with α-glucoside bond and mainly related to the scissoring vibration of C-H bond. We suggested the macromolecules in cyst wall of *A. catenella/pacificum* is possibly composed of polysaccharides with β-glucoside bonds including smaller number of α-glucoside bonds. The cysts of *A. catenella/pacificum* are more labile than the dinoflagellate cysts for degradation in the sediments, which might be resulted from higher α-/β-glucoside bonds ratio in macromolecule of cyst wall.

Keywords: micro-Raman, palynomorph, biomacromolecule, polysaccharide

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The spatial distribution and the origin of heavy metals in bottom sediments from Lake Shinji and Nakaumi

*Hanye ZHANG[1], Kotaro Hirose[1], Kazuo Kamura[1], Minami Aoki[1], Koji Seto[2]

1. Faculty of Science and Engineering, Waseda University, 2. Estuary Research Center, Shimane University

The elemental composition of the surface sediment of the Hii River system estuary (Lake Shinji / Nakaumi), which straddles Shimane and Tottori prefectures, was clarified. Based on the results, mainly targeting the heavy metal elements, the spatial distribution and factors were investigated.

Using an Ekman-Birge grab, the surface sediment samples were collected from the bottom of Lake Shinji and Nakaumi and the related water systems during August and September 2016. The surface layers of the samples were separated by 2.3 cm square cube for the following analysis. Afterwards, the homogenized samples were lyophilized in order to be acid-decomposed with nitric acid and hydrochloric acid. Ultimately, the element concentration was measured by an Agilent 7700x ICP mass spectrometer.

Most of the surveyed elements show that it tends to be distributed at relatively high concentrations near the center of Lake Shinji and Nakaumi. On the contrary, low concentrations appear near the Ohashi River and its estuary and the Sakai Channel. This result has a good inverse correlation with the sand content of the sediment and is consistent with the research result by Matsumoto (2009). This tendency is thought to be due to the fact that debris brought from the catchment areas was separated according to particle size and specific gravity by the deposition process, and then particles containing each element accumulated near the center of the lake.

The spatial distribution of heavy metals in the surface sediments of the Lake Nakaumi obtained in this research is compared to the vertical change of the core sediments excavated in the center of the Lake Nakaumi (Aoki, 2019) and the spatial distribution in previous studies (Nakao et al., 1971; Kondo et al., 1986, etc.). Most of the heavy metal elements reflect the load of former mining activities, which were brought through the Ohashi and Iu rivers. Compared to the past results, the concentrations of heavy metals have been declining in recent decades, but still show a relatively high level in the western part of the Nakaumi. On the other hand, the sample of Yonago Bay in the eastern part of Nakaumi retains a relatively high concentration, among which the concentration of Mo is particularly remarkable. It is considered that Mo remains in the sediment as sulfide deposition. Possible causes include the effects of organic matter due to production activities and waste water from daily life around Yonago Bay, as well as the reducing environment caused by the obstruction of the bay and the depressions after dredging. Moreover, Mn shows a relatively high concentration from the central part of Lake Nakaumi to the area around Daikonshima and Ejima, and a relatively low concentration in Yonago Bay. It is considered that the reason why Mn is concentrated in the center of the lake rather than fixed in the sediment is probably that Mn does not form sparingly soluble sulfide.

Keywords: Lake Shinji and Nakaumi water system, surface sediment, heavy metals, spatial distribution, anthropogenic pollution, accumulation process

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Sedimentary geochemical record of human-induced environmental changes in the estuarine lake Nakaumi, southwest Japan

*Kotaro Hirose[1], Minami Aoki[4], Akira Tsujimoto[3], Koji Seto[2], Kazuo Kamura[1]

1. Faculty of Science and Engineering, Waseda University, 2. Estuary Research Center, Shimane University, 3. Faculty of Education, Shimane Universit, 4. Faculty of Science and Engineering, Waseda University (currently Seikei Gakuen)

We investigated the distribution of organic- and abiotic- geochemical records in sediment from brackish lake Nakaumi to put the consequences of natural and artificial environmental factors affecting the lake environment into a larger context.

The eastern part of the Shimane Prefecture is a region of intense human activities since ancient times, and these activities are well documented in historical records. Lake Nakaumi is a brackish lagoon, which is located at the estuary of the Hii River system in the lower reaches of Lake Shinji-ko and is isolated from the Japan Sea by the Yumigahama peninsula. So, this maritime lake with geography enclosed setting is recording the effects of human activities in the lake sediments with a high temporal resolution.

We established the stratigraphy of bottom sediments at site Nk-3C in Lake Nakaumi based on three sediment cores using lithofacies, soft X-ray photography and CNS elemental analysis. Using the age model inferred from ^{137}Cs, ^{210}Pb and ^{14}C dating, the sediment is estimated to be deposited for the past 600 years, and the sedimentation rates ranges between 0.24 and 0.38 cm/yr.

The C/N, which follows a generally increasing trend in the 18th century, indicating a relative increase of terrestrial organic materials. We suggest that a displacement in river course of the Hii and/or Iinashi rivers in the middle 17th century and resulting progradation of their deltas enhanced the dilution effect on C and N due to an increase in sedimentation rate at the core site. The sharp rise of C, N, and S after late 19th century reflects the eutrophication of Lake Nakaumi, caused by an array of anthropogenic impacts, such as the rapid increase of nutrient inputs due to industrialization and population growth, and the semi-enclosure of the lake due to land reclamation in the Sakai Strait, the outlet of Lake Nakaumi.

We also investigated the vertical distribution of abiotic elements mainly heavy metals by using XRF analyzer and ICP-MS. There, we found a significant trend in Cu and Mo, which can be the distinct time indicators for the bottom sediment in Lake Nakaumi. Cu sharply increased from the 19th century, which is earlier than initiation of heavy metal increase in common sediments from Japanese urban bays (e.g. Yasuhara et al., 2007) due to industrial development at the beginning of 20th century. It reflects the Cu loads to the lake through the River Iu from Homan-zan copper mine which started in middle 19th century and reached their peak in early 20th century. Mo displayed three peaks in the early 1900s, 1940-50 and 1960-70, which indicated remarkable correspondence with the changes in domestic demand for molybdenum. Molybdenum, which was used as an additive element in steel, was mined in the Daito mine from 1912 to 1985 on the upper reaches of the Hii River. This mine accounted for most of the Mo supply in Japan at that period. Accordingly, these trends in Mo is considered to be reflected by the load from this mine.

The pollution in Lake Nakaumi can be linked to copper mining activity in the catchment area from the 18th century. Interestingly, the clear trend in heavy metal pollution (Cu, Pb, Zn and As) predates eutrophication and also nationwide trends of heavy metals. Most of the metals peaked around 1970 CE

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and decreased in general due to the decline of industrial activities after the rapid economic growth and emission regulations, but Pb, Zn, As and In displays recent increasing trends. In our presentation we will also discuss the trends of other heavy metals, including the possibility of long-distance transport from Asian continents.

Reference:
Yasuhara, M. et al. (2007) Limnology and Oceanography, 52: 1633–1644.

Keywords: estuarine lake, bottom sediment, human induced pollution, CNS, heavy metals, Lake Nakaumi

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Calcification depths of planktic foraminifers constrained using geochemical signatures in the sediment trap samples collected from the Bay of Bengal

*Ayumi Maeda[1], Azumi Kuroyanagi[2], Toshihiro Yoshimura[3], Birgit Gaye[4], Tim Rixen[5], Atsushi Suzuki[1], Hodaka Kawahata[6]

1. National Institute of Advanced Industrial Science and Technology, 2. Tohoku University Museum, The Center for Academic Resources and Archives, Tohoku University, 3. Japan Agency for Marine-Earth Science and Technology, 4. Institute for Geology, Universität Hamburg, 5. Leibniz Centre for Tropical Marine Research, 6. Atmosphere and Ocean Research Institute, The University of Tokyo

Mg/Ca and oxygen isotope ratios (δ^{18}O) of planktic foraminifers revealed the hydrological conditions from the surface to thermocline using multiple species. Knowledge of apparent calcification depth (ACD) of planktic foraminifers plays a key role in reconstructing past environment, while the ACDs showed seasonal variations and are different at regional scale. We pursued revealing ACDs of *Globigerinoides ruber*, *Trilobatus sacculifer*, and *Neogloboquadrina dutertrei* in the Bay of Bengal using multiyear sediment trap samples collected approximately 900 m depth. The sediment traps were moored in the southwestern Bay of Bengal at ~950 m depth and 17-42 days intervals. The estimated temperature using δ^{18}O and Mg/Ca patterns of *G. ruber*, *T. sacculifer* and *N. dutertrei* showed that *G. ruber* reflect the temperature within the surface mixed layer, whereas *N. dutertrei* precipitated tests in the upper thermocline and *T. sacculifer* calcify between them. The rapidly attenuating photosynthetically active radiation constrained living depth of the symbiont-bearing species within the euphotic zone of the upper 60 m in the southern Bay of Bengal. The flux-weighed δ^{18}O values of each species corresponded to the mean annual δ^{18}O values of respective species. Seasonal variations in species-specific test fluxes can be averaged out due to the recuring flux peaks in the NEM and the SWM.

Keywords: planktic foraminifera, Bay of Bengal, oxygen isotope ratio

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[E] Oral | B (Biogeosciences) : B-PT Paleontology

Sun. Jun 6, 2021 3:30 PM - 5:00 PM JST | Sun. Jun 6, 2021 6:30 AM - 8:00 AM UTC | Ch.26 Zoom Room 26

[B-PT01] Biomineralization and Geochemistry of Proxies

convener:Takashi Toyofuku(Japan Agency for Marine-Earth Science and Technology (JAMSTEC)), Hiroshi Kitazato(Tokyo University of Marine Science and Technology (TUMSAT)), Jelle Bijma(Alfred-Wegener-Institut Helmholtz-Zentrum für Polar- und Meeresforschung), Kotaro Hirose(Faculty of Science and Engineering, Waseda University), Chairperson:Hiroshi Kitazato(Tokyo University of Marine Science and Technology (TUMSAT)), Kotaro Hirose(Faculty of Science and Engineering, Waseda University), Takashi Toyofuku(Japan Agency for Marine-Earth Science and Technology (JAMSTEC)), Jelle Bijma(Alfred-Wegener-Institut Helmholtz-Zentrum für Polar- und Meeresforschung)

In order to reconstruct the Earth climate system, marine paleoclimatologists resort to transfer functions or geochemical proxies, which are produced or affected by organisms. The relationships used for reconstructions are generally based on field calibrations or derived from laboratory experiments. The danger of these so-called empirical relationships is that they may be valid only within the restricted parameter space of their calibration. Application of proxy relationships to very different environmental settings (e.g. high vs. low latitude or glacial vs. interglacial) requires a mechanistic understanding of these relationships. Much progress can be expected by a better understanding of the biomineralization mechanisms and the incorporation of proxy signals.
In this session we facilitate contributions related to the biomineralization, calibration and validation of marine proxies from field study, laboratory culture experiment and paleo-environmental reconstruction.

3:30 PM - 3:48 PM JST | 6:30 AM - 6:48 AM UTC

[BPT01-07] Long term size changes of the Middle Miocene planktonic foraminifera in the western equatorial Pacific

*Takuma Suzuki[1], Hiroki Hayashi[1] (1.Shimane University)

3:48 PM - 4:06 PM JST | 6:48 AM - 7:06 AM UTC

[BPT01-08] High-resolution minor element concentration records in modern brachiopod *Pictothyris picta* shells and their controlling factors

*Kazuma Oikawa[1], Hideko Takayanagi[1], Ryuichi Shinjo[2], Kazuyoshi Endo[3], Masa-aki Yoshida[4], Yasufumi Iryu[1] (1. Institute of Geology and Paleontology Graduate School of Science Tohoku University, 2.Department of Physics and Earth Sciences, University of the Ryukyus, 3.Department of Earth and Planetary Science, Tokyo University, 4.Shimane University Faculty of Life and Environmental Science)

4:06 PM - 4:24 PM JST | 7:06 AM - 7:24 AM UTC

[BPT01-09] Evolution of Mg transporters and their possible effects on coral skeletal proxies in geochemistry

*Tomoko Bell[1], Akira Iguchi[2], Kazuhiko Sakai[3], Yusuke Yokoyama[4] (1.WERI, Univ. of Guam, 2.AIST, 3.TBRC, Univ. of Ryukyus, 4.AORI, Univ. of Tokyo)

4:24 PM - 4:42 PM JST | 7:24 AM - 7:42 AM UTC

[BPT01-10] **The coral reef-dwelling *Peneroplis* spp. shows calcification resilience to ocean acidification conditions - results from culture experiments**

*Laurie Charrieau[1], Katsunori Kimoto[1], Delphine Dissard[2], Beatrice Below[2,3], Kazuhiko Fujita[4], Yukiko Nagai[1,5], Takashi Toyofuku[1,6] (1.Jamstec, 2.IRD/UMR LOCEAN, 3.UMR CR2P, 4.University of the Ryukyus, 5.Yokohama National University, 6.TUMSAT)

4:42 PM - 4:57 PM JST | 7:42 AM - 7:57 AM UTC

[BPT01-11] Can Irregular Observations Provide the Next Clue for the Ecology of Foraminifera?

*Takashi Toyofuku[1,2], Yukiko Nagai[1,3] (1.Japan Agency for Marine-Earth Science and Technology (JAMSTEC), 2.Tokyo University of Marine Science and Technology (TUMSAT), 3.National Museum of

Nature and Science,Tokyo)

4:57 PM - 5:00 PM JST | 7:57 AM - 8:00 AM UTC

[BPT01-12] Discussion

Long term size changes of the Middle Miocene planktonic foraminifera in the western equatorial Pacific

*Takuma Suzuki[1], Hiroki Hayashi[1]

1. Shimane University

Planktonic foraminifera is an oceanic free-floating single celled protozoa. In the modern ocean, it is classified into approximately 50 species. The oldest planktonic foraminiferal fossil records are appeared from the Jurassic. Carbonate shells of planktonic foraminifera are well preserved into marine sediments especially from ocean drilled cores. The successive and rich appearance of the fossils provide good paleoenvironmental proxies with high special-temporal resolution by chemical and morphological analyses.

In this study, we focused “size” of planktonic foraminiferal shell to consider evolution models about size such as “Lilliput Effect” and “Giantism”. These models have a potential to make clear what the relationship between organism response and environmental fluctuation. The size analysis of planktonic foraminifera has a significant potential for investigation of “Lilliput Effect” and “Giantism” because a size analysis to investigate these evolution models require a lot of individuals of single taxon. Another reason should be pointed out that planktonic foraminifera shows accretion growth by adding a new chamber on its penultimate chamber, therefore the size of planktonic foraminifera well reflects the ontogenic pattern.

Our study is composed of two parts as described bellow:

1. This study aims to reconstruct the temporal size change of *Paragloborotalia siakensis* (LeRoy) during Middle Miocene in the western equatorial Pacific. The core samples we used in this study were drilled at ODP Site 807. The successive sediments well preserved foraminiferal shells, and recorded the transition from the relatively warm face (MMCO: Mid-Miocene Climatic Optimum) to the colder mode Mi-3 with the expansion of the Eastern Antarctica Ice Sheet.

2. In order to consider the model about “Dwarfing” and “Giantism” of *P. siakensis* in equatorial Pacific, we compared the size change at ODP Site 807 with those of IODP Sites U1337 and U1338 drilled at the eastern equatorial Pacific.

Keywords: body size, planktonic foraminifera, Lilliput Effect, Cope’s rule, Middle Miocene

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High-resolution minor element concentration records in modern brachiopod *Pictothyris picta* shells and their controlling factors

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Carbon ($\delta^{13}C$) and oxygen ($\delta^{18}O$) isotope composition of Rhynchonelliformea brachiopods (hereafter, called 'brachiopods') have been regarded as useful paleoenvironmental indicators throughout the Phanerozoic. However, variations of minor element concentrations in modern brachiopod shells and their relationships with environmental factors (e.g., temperature, salinity, and pH) and biological controls are not well understood. In this study, we measured $\delta^{13}C$ and $\delta^{18}O$ values and minor element concentrations of the primary (PL) and secondary (SL) layers of three *Pictothyris picta* shells (one male and two female individuals) collected at a water depth of 61 m off Okinoshima to clarify the factors controlling the isotopic and elemental variations. We obtained ontogenetic-series $\delta^{13}C$, $\delta^{18}O$, and minor element (i.e., Mg/Ca, Mn/Ca, Fe/Ca, and Sr/Ca) profiles from the PL (PL-Ont) and the uppermost SL (SL-Ont) at the sampling resolution of 3 days to 8 months per sample. We also obtained minor element concentrations as well as $\delta^{13}C$ and $\delta^{18}O$ from the innermost SL (SL-In). The SL-Ont was precipitated in oxygen isotopic equilibrium with ambient seawater regardless of the growth stage and the seasonal changes at the growth site. Mg/Ca profiles of the PL- and SL-Ont showed that the Mg uptake into the *P. picta* shells is related to the shell growth stages. This relationship likely indicates that Mg removal mechanism works during brachiopod shell precipitation, and the extent of the Mg removal varies with the growth stages. Consequently, we identified three growth stages (sectors 1 to 3) based on differences in Mg/Ca values between PL- and SL-Ont. A significant positive correlation between Sr/Ca and $\delta^{13}C$ values was found in the sectors 1 and 2 of PL- and SL-Ont profiles of the three shells. This correlation implies that the shell precipitation rate is likely to be influenced by the metabolic effect affecting the $\delta^{13}C$ values. The shell Mn and Fe concentrations were low and constant throughout the shells, respectively, except for Mn/Ca values from sectors 2 and 3 of the PL-Ont.

Keywords: brachiopod, carbon and oxygen isotope, minor element concentrations, calcification, vital effect

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Evolution of Mg transporters and their possible effects on coral skeletal proxies in geochemistry

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1. WERI, Univ. of Guam, 2. AIST, 3. TBRC, Univ. of Ryukyus, 4. AORI, Univ. of Tokyo

Corals have been used as geochemical proxies since the 1970's and they play prominent roles in paleoclimatology. However, it has not been well elucidated how minerals in seawater are transported and precipitated in aragonite coral skeleton. There are no foundational methods to differentiate and quantify biogenic and abiogenic effects during skeletal formation, thus it hampers corals from being fully reliable environmental proxies. To address these uncertainties, in this study, we attempt to evaluate biological complexity by investigating how coral genes evolved over geologic time scales (e.g. million years). In coral skeletons, Mg is an abundant element of coral skeleton (1000-2100ppm), and Mg can be concentrated by almost double that of modern seawater. Therefore, we decided to focus on coral Mg transporters of five coral species (*Acropora digitifera, Acropora hyacinthus, Acropora millepora, Acropora palmate* and *Acropora tenuis*) and investigated how Mg transporters have been evolving. Our preliminary result indicated that Mg transporter of *Acropora digitifera*, *Acropora hyacinthus and Acropora millepora* showed high similarity to Mg transporter of Japanese rice fish. On the other hand, *Acropora palmate* and *Acropora tenuis* did not show such a trend. According to the Coral Trait database, the three types of corals that showed high similarity to rice fish appeared on the earth less than 1 million years ago while the other two species showed ages older than 3 million years ago. Such difference could be possibly triggered by an environmental change such as the availability of Mg ion in seawater (seawater [Mg]). There have been continuous increases in seawater [Mg] from 5 Ma to present: from 50 mmol/L to 55 mmol/L. This increase (about 10%) of seawater [Mg] could potentially facilitate coral Mg transport systems to respond to the seawater chemistry change and evolve to develop more Mg specific transporters. Our result indicated a strong biogenic response and control (Mg transporter) to abiotic factors (seawater [Mg]). That is to say, using Mg ratio in coral skeletons might not be ideal due to vital effect. We suggest our approach to investigate gene evolution may guide us to identify the geochemical proxies with possible strong vital effects thus help us identify robust proxies.

Keywords: Coral, Evolution, Skeletal proxy, Mg transporter

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The coral reef-dwelling *Peneroplis* spp. shows calcification resilience to ocean acidification conditions - results from culture experiments

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1. Jamstec, 2. IRD/UMR LOCEAN, 3. UMR CR2P, 4. University of the Ryukyus, 5. Yokohama National University, 6. TUMSAT

Ocean acidification is a consequence of the current climate changes, driven by anthropogenic activities. The concomitant decrease in pH and carbonate ion concentration in sea water may have severe impacts on marine life, and especially on calcifying organisms. Coral reefs were among the first ecosystems to be recognized as vulnerable to ocean acidification. Within coral reefs, large benthic foraminifera (LBF) are major calcium carbonate producers.

The aim of this work was to evaluate the impacts of varying pH on survival and calcification of the symbiont-bearing LBF species *Peneroplis* spp. We performed culture experiments to first study their resistance to ocean acidification conditions, and then their resilience once placed back under open ocean pH.

After three days, small signs of test decalcification were observed on specimens kept at pH 7.4, and severe test decalcification was observed on specimens kept at pH 6.9, with the inner organic lining clearly appearing. Similar strongly decalcified specimens were observed after 32 days under pH 7.4. All the specimens were alive at the end of the experiment. These results demonstrate the resistance of *P eneroplis* spp. to an acidified pH, at least on a short period of time.

After being partially decalcified, some of the living specimens were placed back at pH 7.9 (in situ value). After one month, the majority of the specimens showed recalcification features, mainly by addition of new chambers. The trace elements concentrations of the newly formed chambers were analysed by LA-ICPMS. Interestingly, more chambers were added when food was given, which highlights the crucial role of energy source in the recalcification process. Moreover, the newly formed chambers were most of the time abnormal, and the general structure of the tests was altered. These abnormalities have potential impacts on reproduction capacities and in situ survival of *Peneroplis* spp. In conclusion, if symbiont-bearing LBF show some resistance and resilience to lowered pH conditions, they will remain strongly affected by ocean acidification.

Keywords: Ocean acidification, Large Benthic Foraminifera, Culture experiments, Calcification process

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Can Irregular Observations Provide the Next Clue for the Ecology of Foraminifera?

*Takashi Toyofuku[1,2], Yukiko Nagai[1,3]

1. Japan Agency for Marine-Earth Science and Technology (JAMSTEC), 2. Tokyo University of Marine Science and Technology (TUMSAT), 3. National Museum of Nature and Science,Tokyo

Calcareous foraminifera is major producers of carbonates in the ocean. By extracting foraminifera from sediments, analyzing their assemblages, and analyzing their elemental compositions, we can reconstruct the geologic time's past environment. The carbonate shells, called tests, deposited by foraminifera play a central role in paleoenvironmental reconstructions. Therefore, it is one of the centers of interest how the calcareous test is formed. This carbonate test is known to form intermittently as the foraminifera cell grows. As the foraminifera collect food and increase the volume of their cytoplasm, they repeatedly build the next chamber before the last one is full. In this process, new chambers are built using the existing chambers as footholds. The angle and size of the new chamber determine the overall shape of the test e.g., biserial, triserial, spiral, and others. Behind the scenes, the pseudopods, which control the foraminifera's locomotion, have been found to play a very diverse and important role in chamber formation. This is due to the repeated and detailed observation of the chamber formation process and the observation of its ultrastructure by electron microscopy. In our laboratory, we controlled the feeding conditions of foraminifera to derive the conditions that induce chamber formation. Therefore, we can control the timing of shell formation to some extent and prepare a system for reliable observation. The process of shell formation can be documented by, for example, time-lapse observation, recording foraminifera chamber formation, and the order in which they form (and sometimes reproduction to observe the birth of new offspring in detail). We can also use fluorescent indicators to label calcium, pH, and other intracellular organelles and observe how they are distributed during chamber formation and the rest of ecology.

On the other hand, if such observations are made for too long and too often, the observation may fail. For example, an individual may stop and run away when it seems to be forming a chamber, or it may return to a single cell even though it is dividing during reproduction. These observations are difficult to explain straight forward, so it is not easy to publish them in a paper very much. However, there are many interesting observations, and it would be a shame to keep them in storage, so we would like to introduce them to this opportunity.

Keywords: foraminifera, time-lapse microscopy, biomineralization, laboratory culture, fulorescnet obseervation, null negative

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[E] Oral | B (Biogeosciences) | B-PT Paleontology

[B-PT01] Biomineralization and Geochemistry of Proxies

convener:Takashi Toyofuku(Japan Agency for Marine-Earth Science and Technology (JAMSTEC)), Hiroshi Kitazato(Tokyo University of Marine Science and Technology (TUMSAT)), Jelle Bijma(Alfred-Wegener-Institut Helmholtz-Zentrum für Polar- und Meeresforschung), Kotaro Hirose(Faculty of Science and Engineering, Waseda University), Chairperson:Hiroshi Kitazato(Tokyo University of Marine Science and Technology (TUMSAT)), Kotaro Hirose(Faculty of Science and Engineering, Waseda University), Takashi Toyofuku(Japan Agency for Marine-Earth Science and Technology (JAMSTEC)), Jelle Bijma(Alfred-Wegener-Institut Helmholtz-Zentrum für Polar- und Meeresforschung)

Sun. Jun 6, 2021 3:30 PM - 5:00 PM Ch.26 (Zoom Room 26)

In order to reconstruct the Earth climate system, marine paleoclimatologists resort to transfer functions or geochemical proxies, which are produced or affected by organisms. The relationships used for reconstructions are generally based on field calibrations or derived from laboratory experiments. The danger of these so-called empirical relationships is that they may be valid only within the restricted parameter space of their calibration. Application of proxy relationships to very different environmental settings (e.g. high vs. low latitude or glacial vs. interglacial) requires a mechanistic understanding of these relationships. Much progress can be expected by a better understanding of the biomineralization mechanisms and the incorporation of proxy signals.

In this session we facilitate contributions related to the biomineralization, calibration and validation of marine proxies from field study, laboratory culture experiment and paleo-environmental reconstruction.

4:57 PM - 5:00 PM

[BPT01-12]Discussion

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

Sun. Jun 6, 2021 9:00 AM - 10:30 AM JST | Sun. Jun 6, 2021 12:00 AM - 1:30 AM UTC | Ch.13 Zoom Room 13

[M-IS01] Environmental, socio-economic, and climatic changes in Northern Eurasia

convener:Pavel Groisman(NC State University Research Scholar at NOAA National Centers for Environmental Information, Asheville, North Carolina, USA), Shamil Maksyutov(National Institute for Environmental Studies), A Dmitry Streletskiy(George Washington University), Yoshihiro Iijima(Graduate School of Bioresources, Mie University), Chairperson:Pavel Groisman(NC State University Research Scholar at NOAA National Centers for Environmental Information, Asheville, North Carolina, USA), Yoshihiro Iijima(Graduate School of Bioresources, Mie University), Shamil Maksyutov(National Institute for Environmental Studies)

We invite presentations on the biogeochemical cycles, the surface energy budget and water cycle, and climate and ecosystem interactions in Northern Eurasia (land-cover/land-use change, atmospheric aerosols, soil, and permafrost changes that affect and are being affected by climate and ecosystem change), "human dimension", and tools to address the Northern Eurasia studies.

In environmental studies, our Session foci are on the permafrost changes in Siberia, Asian Mountains, and the Arctic coastal regions and on the carbon cycle of Northern Eurasia.

In the regional water cycle studies, our Session foci are on the changing distribution of precipitation intensity, frequency, form (solid versus liquid) and on the pattern and seasonal cycle changes of runoff.

In the "human dimension" studies, our Session foci are on assessments of impact of the ongoing environmental changes in Northern Eurasia on the human well-being and on mitigation strategies development in response to harmful consequences of these changes.

The particular foci of this Session will be the studies of changes that impacts regional sustainable development in the Arctic, Boreal zone, and the Drylands of Northern Eurasia.

We invite also early career scientists associated with (or interested in) the Northern Eurasia Earth Science Partnership Initiative and its continuation, Northern Eurasia Future Initiative (http://nefi-neespi.org/NEFI-WhitePaper.pdf).

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

[MIS01-01] Evaluation of a revised global high-resolution inverse model with CO_2 observations over Siberia.

*Shamil Maksyutov[1], Motoki Sasakawa[1], Toshinobu Machida[1], Tomohiro Oda[2], Jiye Zeng[1], Tsuneo Matsunaga[1], Johannes W Kaiser[3], Mikhail Arshinov[4], Boris Belan[4], Ed Dlugokencky[5] (1.National Institute for Environmental Studies, 2.Universities Space Research Association, 3.Deutscher Wetterdienst, 4.Inst. Atmospheric Optics, 5.Global Monitoring Laboratory, NOAA)

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

[MIS01-02] Co-production of environmental education material "Permafrost and Culture"

*Yoshihiro Iijima[1], Hiroki Takakura[2], Vanda Ignatyeva[3], Aleksandr Fedorov[4], Masanori Goto[5], Toshikazu Tanaka[6] (1.Graduate School of Bioresources, Mie University, 2.Center for Northeast Asian Studies, Tohoku University, 3.Institute of Humanities and Indigenous Studies of the North, SB RAS, 4.Melnikov Permafrost Institute, SB RAS, 5.Slavic-Eurasian Research Center, Hokkaido University, 6.Faculty of Economics, Ryukoku University)

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

[MIS01-03] Permafrost Degradation Threatens Arctic Communities and Infrastructure

*Dmitry A Streletskiy[1], Nikolay I Shiklomanov[1], Kelsey Nyland[1] (1.George Washington University)

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

[MIS01-04] Monthly precipitations for South Siberia derived from bias-corrected reanalysis

Nadezhda Voropay[1,2], *Anna Ryazanova[1], Egor Dyukarev[1,3] (1.Institute of Monitoring of Climatic and Ecological Systems of the Siberian Branch of the Russian Academy of Sciences, 2.V B Sochava Institute of Geography of the Siberian Branch of the Russian Academy of Sciences, 3.Yugra State University)

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

[MIS01-05] Fuel load mapping in central Siberia

★Invited Papers

*Elena Kukavskaya[1], Ludmila Buryak[2], Evgeny Shvetsov[1], Sergey Zhila[1] (1.V.N. Sukachev Institute of Forest of the Siberian Branch of the Russian Academy of Sciences - separate subdivision of the FRC KSC SB RAS, 2.The Branch of FBU VNIILM “Center of Forest Pyrology”)

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

[MIS01-06] New data on the state and changes of glaciers in mountain and Polar Regions of Russia

*Tatiana Khromova[1], Gennady Nosenko, Andrey Glazovsky, Stanislav Nikitin, Anton Muraviev, Ivan Lavrentiev (1.Institute of Geography Russian Academy of Sciences)

Evaluation of a revised global high-resolution inverse model with CO_2 observations over Siberia.

*Shamil Maksyutov[1], Motoki Sasakawa[1], Toshinobu Machida[1], Tomohiro Oda[2], Jiye Zeng[1], Tsuneo Matsunaga[1], Johannes W Kaiser[3], Mikhail Arshinov[4], Boris Belan[4], Ed Dlugokencky[5]

1. National Institute for Environmental Studies, 2. Universities Space Research Association, 3. Deutscher Wetterdienst, 4. Inst. Atmospheric Optics, 5. Global Monitoring Laboratory, NOAA

We apply a revised version of the global inverse model NTFVAR (NIES-TM-FLEXPART-variational) to make top-down estimates of regional carbon dioxide fluxes based on data from the Japan-Russia Siberian tall tower inland observation network (JR-STATION) in Siberia and NOAA's global monitoring network for 2008-2017. In the revised coupled modeling system, the global tracer transport model NIES-TM uses ERA-5 reanalysis winds interpolated to 42 hybrid-pressure levels with a horizontal resolution of 2.5 and 3.75 degrees, while the FLEXPART model uses 0.1-degree resolution and includes a diurnal cycle. Simulation of advection in the transport model and its adjoint was revised to a 3rd order upwind scheme. The land biosphere fluxes are provided by the global upscaling product based on tower flux data at a resolution of 0.1 degrees (Zeng et al. 2020). Fossil emissions are provided by ODIAC, fire emissions by GFAS, and oceanic fluxes by the upscaling product based on surface ocean pCO_2 observations (Landschü tzer et al. 2015). The diurnal cycle of biospheric CO_2 exchange is simulated by combining data for gross ecosystem production and ecosystem respiration. The respiration and oceanic fluxes are scaled to match the global CO_2 growth rate. Corrections to the prior fluxes are estimated on a bi-weekly time step for two sets of observational data, one includes only background observation sites of the global network and another adds JR-STATION data to it by taking afternoon averaged data once a day for each site. Flux optimization with the global background network results in a good match and strong correlation with JR-STATION data over West Siberia, demonstrating that the combination of accurate transport and prior fluxes make background observations useful for constraining large scale fluxes. Addition of the Siberian observations further reduces the bias of the CO_2 simulations at the sites and improves the match in the cold season. The comparison shows the importance of adding regional observations for improving regional carbon dioxide flux estimates.

Landschützer, P., et al. The reinvigoration of the Southern Ocean carbon sink, Science, 349, 1221-1224, 2015.
Zeng, J., et al. Global terrestrial carbon fluxes of 1999–2019 estimated by upscaling eddy covariance data with a random forest. Sci Data 7, 313, 2020.

Keywords: carbon dioxide, inverse modeling, Siberia

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Co-production of environmental education material "Permafrost and Culture"

*Yoshihiro Iijima[1], Hiroki Takakura[2], Vanda Ignatyeva[3], Aleksandr Fedorov[4], Masanori Goto[5], Toshikazu Tanaka[6]

1. Graduate School of Bioresources, Mie University, 2. Center for Northeast Asian Studies, Tohoku University, 3. Institute of Humanities and Indigenous Studies of the North, SB RAS, 4. Melnikov Permafrost Institute, SB RAS, 5. Slavic-Eurasian Research Center, Hokkaido University, 6. Faculty of Economics, Ryukoku University

Co-production of environmental education material "Permafrost and Culture"

Iijima, Y., H. Takakura, V. Ignatieva, A.N. Fedorov, M. Goto, T. Tanaka

The Arctic has been facing enhanced climate change with intensified warming trend for the recent decades. Understanding the impact of the climate change on human societies in the Arctic/North emerges urgent importance from the standpoint of sustainability of the local population and indigenous culture. Based on the long-term collaborative researches between Japan and Arctic countries, in particular Siberia in Russia, interdisciplinary outcomes combining between natural sciences and social/humanitarian sciences have potential importance to introduce structured knowledges on present situation and future direction of environmental changes in the Arctic to local population. As for this challenge, the new collaboration has been conducted to compile an educational textbook entitled “Permafrost and Culture”. In this book, particular attention is paid to the Sakha (Yakut) people living in the Republic of Sakha (Yakutia), Russia. The life of the Sakha people is closely connected with permafrost. Scientific data clearly show that permafrost thawing resulting from climate change causes acute issues on a pan-Arctic scale. Although many published scientific papers confirm what is really happening in local communities inhabiting permafrost zones, the general public receives insufficient information on this. While climate change is a global phenomenon, it often manifests itself in regional and local natural disasters, so it is extremely important to consider it from a regional perspective. Focusing on regions and conducting a detailed study of individual specific situations allows us to discover the interconnections and attain a more accurate global picture of the changes that are occurring. This book was originally published in Russia under the same title and has been translated into English to expand the readership. The content is based on results of two international research projects, ArCS: Arctic Challenge for Sustainability (September 2015 to March 2020) and ArCS II:Arctic Challenge for Sustainability II (June 2020 to March 2025), which were jointly supported by the Ministry of Education, Culture, Sports, Science and Technology of Japan. In addition, this activity is supported by JSPS KAKENHI Grant Number JP19H00556 “Co-production of permafrost degradation impact assessment for permafrost environmental utilization and conservation” and Joint Russia and Japan bilateral project in JST-SICORPS (2019-2021) “ARCTIC Hydrological Cycle CHanges: Impacts on environment sustainability and natural resources (ARCTIC-CHI)”

Keywords: Arctic, climate change, permafrost, local population, interdisciplinary research

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Permafrost Degradation Threatens Arctic Communities and Infrastructure

*Dmitry A Streletskiy[1], Nikolay I Shiklomanov[1], Kelsey Nyland[1]

1. George Washington University

Active layer thickness (ALT) is one of the essential climatic variables and is important for understanding many natural processes in the cold regions. ALT is also a required variable for land-use planning and construction on permafrost. The Circumpolar Active Layer Monitoring (CALM) program, part of Global Terrestrial Network for Permafrost (GTN-P), is the primary global archive of ALT data worldwide with more than 250 sites located in polar and high altitude permafrost environments. Some of the CALM sites go back to early 1970th, however the majority of sites were established in either in mid-1990s of after the fourth international polar year (2008). Three main measurement methods are employed by the CALM program include mechanical probing at the at grids ranging from 10 to 1000 square meters, thaw tubes, and shallow temperature boreholes, where ALT is obtained by interpolation of maximum depth of zero degree C isotherm. Using CALM data we temporal variability of ALT across circumpolar permafrost regions that have more than 10 years of data and were active over the last 5 years. The results show that absolute majority of CALM sites have increasing ALT trends over the last 20 years. The median rate is about 5 cm/decade, with majority of sites experiencing 2 to 8 cm/decade increase. Sites located in continuous permafrost generally show less changes relative to sites in discontinuous permafrost. Northern Eurasia regions, including Russian European North and North of Central Siberia were found to have highest regional rates of change. Changes in permafrost have negative impacts on communities and industrial facilities of the Northern Eurasia. Enhanced permafrost monitoring is urgently needed to address challenges associated with permafrost degradation in Northern Eurasia.

Keywords: permafrost, active layer, monitoring, climate change

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Monthly precipitations for South Siberia derived from bias-corrected reanalysis

Nadezhda Voropay[1,2], *Anna Ryazanova[1], Egor Dyukarev[1,3]

1. Institute of Monitoring of Climatic and Ecological Systems of the Siberian Branch of the Russian Academy of Sciences, 2. V B Sochava Institute of Geography of the Siberian Branch of the Russian Academy of Sciences, 3. Yugra State University

The accuracy of global hydrometeorological data is important for regional and global climate studies. We compared the ERA5 reanalysis monthly precipitation data of the European Centre for Medium-range Weather Forecasts over South Siberia against observed precipitation data records from 132 ground weather stations for 1979–2015. The ERA5 reanalysis provides detailed fields reasonably reproducing features of mesoscale precipitation structures related to topography and synoptic-scale patterns. The linear correlation coefficients between reanalysis and weather station data are high but mean values are biased. The mean absolute error varies from -23 mm to 90 mm. A bias correction procedure was suggested to improve the precipitation data quality and reduce mean values error. The linear scaling coefficient for each month and weather station were calculated and extrapolated to the study area using the ordinary kriging method.

Finally, the maps of the Bias-**C**orrected **P**recipitation data for **S**outh **S**iberia (**CPSS**) were created and annual sums of precipitation were calculated. Multiply validation of bias correction was performed on the control test sets. The CPSS data fit the observation data very well. The mean error does not exceed 7 mm, the mean absolute error maximal value is 44 mm, and the mean relative error is less than 23%. The maximal biases are typical for mountain areas.

After bias correction for all months, in most cases, there is a decrease in monthly precipitation compared to the original ERA5 dataset. The precipitation decreases slightly in the winter months and significantly (by 10–13 mm) in the summer. The standard deviation also decreases for all months, but the changes are more pronounced in summer. The correction procedure almost eliminated the average error, the rest of the statistical characteristics also showed an improvement in the data quality.

The suggested approach of bias correction and downscaling is based on a combination of the physical-based high-resolution precipitation data field obtained in ERA5 reanalysis and spatially-irregular statistical correction using high-quality ground observation data. Taking into account the assessment of the scaling efficiency, the described approach can be recommended for correcting the monthly precipitation in territories with continental and sharply continental climates at territories with similar physical and geographical conditions.

Accordingly, this work forms part of a long-term effort to produce high-quality precipitation datasets across this region. High-resolution bias-corrected gridded precipitation data sets provide important information regarding precipitation conditions over different regions, especially for regions with very sparse meteorological stations. The dataset obtained could be useful for large-scale hydrological streamflow simulations, for studies of long-term precipitation variations at a higher scale, and analysis of droughts and water-logging events. The data is available for download from Zenodo in Network Common Data Form (NetCDF) format (https://zenodo.org/record/4472614).

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The study was carried out with the financial support of the RFBR in the framework of scientific project 18-45-700015.

Keywords: precipitations, reanalysis, South Siberia, bias correction, downscaling

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Fuel load mapping in central Siberia

*Elena Kukavskaya[1], Ludmila Buryak[2], Evgeny Shvetsov[1], Sergey Zhila[1]

1. V.N. Sukachev Institute of Forest of the Siberian Branch of the Russian Academy of Sciences - separate subdivision of the FRC KSC SB RAS, 2. The Branch of FBU VNIILM “Center of Forest Pyrology”

Fuel load and structure are fundamental drivers of fire behavior and are critical elements for strategic fire management interventions. Moreover, data on fuel loads are of high importance to accurately estimate wildland fire emissions and their contribution to the regional and global carbon balances. We have developed fuel loads maps for the Krasnoyarsk region, central Siberia by integrating satellite and ground-based data with respect to the forest-growing conditions and the disturbance of the territory by anthropogenic and natural factors (fires, loggings, insects). The maps obtained could be used to timely prepare and minimize the possible damage from fires ensuring the functional stability of forest ecosystems. The research was funded by the RFBR/KRFC Grant #20-44-242004.

Keywords: fuel load, Siberia, fire, logging

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New data on the state and changes of glaciers in mountain and Polar Regions of Russia

*Tatiana Khromova[1], Gennady Nosenko, Andrey Glazovsky, Stanislav Nikitin, Anton Muraviev, Ivan Lavrentiev

1. Institute of Geography Russian Academy of Sciences

The new glacier inventory created recently at the Institute of Geography of the Russian Academy of Sciences is based on Sentinel 2 images obtained mainly in 2016-2019. This data made it possible to study the current state and recent changes of glaciers in Russia, where now there are 22 glacial systems. Glaciers are located on islands and archipelagoes of Russian Arctic and in mountain regions of continental part of the country and currently cover the area of 54,531 km2.

The largest glacial systems are located on archipelagoes of Russian Arctic. The next in area

glacial systems are located in the mountains of the temperate zone: the Caucasus, Kamchatka and Altai. The most numerous group is small glacial systems, the area of which does not exceed 100 km2. They are located in different glaciological zones. The De Long Islands and the Urals are in polar region. The Putorana Plateau, the Byranga Mountains, the Chersky Ridge, the Chukotka Upland, Northeast of the Koryak highlands are in subpolar area. Kodar Ridge and Eastern Sayan are in the temperate zone. Some glacier systems are very small. There area is less than 10 km2. Despite their small size, these glacial systems are important from indicative point of view, fixing the zone of spatial distribution of glaciation. They indicate the growth points in the event of a change in climatic conditions according to a scenario favorable for glaciers.

The glacier area has decreased since the compilation of the USSR glacier Inventory (1965-1982) by 5603.9 km2 or 9.3%. The area of polar glaciers has decreased less than glaciers in mountainous regions. Values range from 5.44% (Novaya Zemlya) to 19.11% (De Longa Islands). Small glaciers were not found in the Khibiny. Glaciers in the Urals have reduced their area by 63%. The subpolar glacier systems of the Orulgan (46.6%), Chersky (44.4%), and Suntar-Khayata (34%) ridges reduced the area a little less. Reduction in the area of glacial systems in the temperate zone ranges from 57% (Eastern Sayan) to 13% (Kodar). The largest glacial systems in the Caucasus, Kamchatka and Altai have reduced their areas by 25, 22 and 39 percent, respectively.

The results of our studies confirm the tendencies for the reduction of the glacier area throughout Russia. The exception is the glaciers of the volcanic regions of Kamchatka, which increased their size or remained stationary. The magnitude and rate of changes depend on the local climatic and orographic features.
The presentation includes the results obtained in the framework of the following research projects: №. 0148-2019-0004 of the Research Plan of the Institute of Geography of RAS, №. 18-05-60067 supported by RFBR.

Keywords: glaciers, climate change, Northern Eurasia

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

Sun. Jun 6, 2021 10:45 AM - 12:15 PM JST | Sun. Jun 6, 2021 1:45 AM - 3:15 AM UTC | Ch.13 Zoom Room 13

[M-IS01] Environmental, socio-economic, and climatic changes in Northern Eurasia

convener:Pavel Groisman(NC State University Research Scholar at NOAA National Centers for Environmental Information, Asheville, North Carolina, USA), Shamil Maksyutov(National Institute for Environmental Studies), A Dmitry Streletskiy(George Washington University), Yoshihiro Iijima(Graduate School of Bioresources, Mie University), Chairperson:Yoshihiro Iijima(Graduate School of Bioresources, Mie University), Shamil Maksyutov(National Institute for Environmental Studies), Pavel Groisman(NC State University Research Scholar at NOAA National Centers for Environmental Information, Asheville, North Carolina, USA)

We invite presentations on the biogeochemical cycles, the surface energy budget and water cycle, and climate and ecosystem interactions in Northern Eurasia (land-cover/land-use change, atmospheric aerosols, soil, and permafrost changes that affect and are being affected by climate and ecosystem change), "human dimension", and tools to address the Northern Eurasia studies.

In environmental studies, our Session foci are on the permafrost changes in Siberia, Asian Mountains, and the Arctic coastal regions and on the carbon cycle of Northern Eurasia.

In the regional water cycle studies, our Session foci are on the changing distribution of precipitation intensity, frequency, form (solid versus liquid) and on the pattern and seasonal cycle changes of runoff.

In the "human dimension" studies, our Session foci are on assessments of impact of the ongoing environmental changes in Northern Eurasia on the human well-being and on mitigation strategies development in response to harmful consequences of these changes.

The particular foci of this Session will be the studies of changes that impacts regional sustainable development in the Arctic, Boreal zone, and the Drylands of Northern Eurasia.

We invite also early career scientists associated with (or interested in) the Northern Eurasia Earth Science Partnership Initiative and its continuation, Northern Eurasia Future Initiative (http://nefi-neespi.org/NEFI-WhitePaper.pdf).

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

[MIS01-07] Quantification of the water vapor transport between the northern Eurasia and Arctic ocean considering the water vapor origin

*Tomonori Sato[1], Tetsu Nakamura[1], Yoshihiro Iijima[2], Tetsuya Hiyama[3] (1.Hokkaido University, 2.Mie University, 3.Nagoya University)

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

[MIS01-08] The hydrological cycle over the three great Siberian rivers from reanalyses and observations

*Ambroise Dufour[1], Martin Wegmann[2], Olga Zolina[3,1], Sergey Gulev[1] (1.P.P. Shirshov Institute of Oceanology, Russian Academy of Science, 2.Oeschger Centre for Climate Change Research, University of Bern, 3.Institut des Géosciences de l'Environnement, Université Grenoble Alpes)

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

[MIS01-09] Dark conifer forests dieback at mid-to-highlands in the southern Siberia's mountains is not caused by drought stress

*Nadezhda Tchebakova[1], Elena I. Parfenova[1], Elena V. Bazhina[1], Amber J. Soja[2], Pavel Groisman[3] (1.Institute of Forests of FRC KSC, Siberian Branch, Russian Academy of Sciences, 2.National Institute of Aerospace, NASA Langley Research Center, Hampton, VA, USA , 3.NC State University Research Scholar at National Centers for Environment Information Federal Building, 151 Patton Avenue Asheville, NC 28801, USA)

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

[MIS01-10] Changing climate of the Western Siberia and socio-economic risks

*Daria Aleksandrovna Konstantinova[1], Valentina Petrovna Gorbatenko[1], Olga Vladimirovna Nosyreva[1], Marina Aleksandrovna Volkova[1], Irina Valer'evna Kuzhevskaia[1] (1.Tomsk State University)

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

[MIS01-11] Long-term temporal trends in water chemistry of lakes in response to decreases in acidic deposition and climate warming of the Kola arctic region

★Invited Papers

Tatyana I Moiseenko[1], *Marina I Dinu[1], Maria M Bazova[1] (1.Russian Institute of Geochemistry and Analytical Chemistry RAS)

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

[MIS01-12] **Wildfires in boreal eastern Siberia: Reconstructing the past to predict the future**

*Ramesh Glueckler[1], Stefan Kruse°[1], Ulrike Herzschuh[1,2,3], Elisabeth Dietze°[1] (1.Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research, Potsdam, Germany , 2.Institute for Environmental Science and Geography, University of Potsdam, Potsdam, Germany, 3.Institute for Biochemistry and Biology, University of Potsdam, Potsdam, Germany)

Quantification of the water vapor transport between the northern Eurasia and Arctic ocean considering the water vapor origin

*Tomonori Sato[1], Tetsu Nakamura[1], Yoshihiro Iijima[2], Tetsuya Hiyama[3]

1. Hokkaido University, 2. Mie University, 3. Nagoya University

Arctic warming has been a pronounced feature of the recent climate change. Related changes in meridional thermal gradient and surface evaporation from the Arctic ocean could modulate the horizontal water vapor transport which may further affect the continental precipitation variability. The study develops the atmospheric water vapor transport model in which the spatiotemporal variation of water vapor fraction originated from the evaporation at the designated land and ocean surface areas is predicted. The model experiment driven by JRA-55 reanalysis dataset with bias correction reveals that the water vapor originated from the Arctic ocean can be transported southward, penetrating the northern coastal regions of the Eurasian continent. The monthly mean fraction of Arctic-originated water vapor relative to total precipitable water vapor becomes as high as 20% in northern Eurasia. The higher fraction of Arctic water vapor is partly attributable to the enhanced evaporation from the Arctic ocean in the low sea ice years. Besides that, the atmospheric circulation pattern is found to be an important factor for the high fraction because the high Arctic fraction is likely to occur in the area where monthly mean southward moisture flux is strong, like western Siberia in September 2017 and eastern Siberia in September 2011.

Keywords: Atmospheric water vapor, Water vapor transport model, Arctic

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The hydrological cycle over the three great Siberian rivers from reanalyses and observations

*Ambroise Dufour[1], Martin Wegmann[2], Olga Zolina[3,1], Sergey Gulev[1]

1. P.P. Shirshov Institute of Oceanology, Russian Academy of Science, 2. Oeschger Centre for Climate Change Research, University of Bern, 3. Institut des Géosciences de l’ Environnement, Université Grenoble Alpes

The basins of the three great Siberian rivers –Ob, Yenisei, Lena –have come under scrutiny as symptomatic of the effects of Arctic amplification on regional water cycles. As the air moistens, Zhang et al. (2013) report more vapour convergence and greater discharges into the Arctic Ocean. The thawing permafrost is also extremely relevant. However, the warming signal can display counterintuitive patterns (Wegmann et al., 2018) and the consequences on moisture fluxes are not straightforward (Dufour et al., 2016).

This study draws on several reanalyses including ERA-5 (Hersbach et al., 2019) and discharge data (Shiklomanov et al., 2018).

We replicate the significant moisture convergence trend found in Zhang et al., 2013 for the extended 1948-2018 period. However, the trend breaks down for the shorter 1979-2018 time windows and in other reanalyses except MERRA-2 over 1980-2018. The discharge observations summed over the mouths of all three rivers are significantly increasing in the long run but not during the satellite era. The weak increasing trend in convergence and discharge is indeed due to moister air but it is superimposed on strong atmospheric variability.

Nearly all reanalyses exhibit significant negative net precipitation trend over the satellite era with the exception of NCEP NCAR R1 and MERRA-2. Further analysis indicates that these trends are due to a decrease in precipitation rather than an increase in evaporation. The decrease in precipitation occurred mainly in summer and is absent in GPCP and CRU TS4 data. The conflicting trends between convergence and net precipitation indicate a severe unbalance of moisture budgets over Siberia.

Over the Siberian river basins, there are weak long-term increasing trends of moisture convergence and river discharge. The reanalyses show perplexing negative precipitation trends in contradiction with the increasing/constant moisture transport. The causes of either tendencies are likely atmospheric variability and non-stationary analysis increments.

Keywords: water cycle, Siberia, reanalyses

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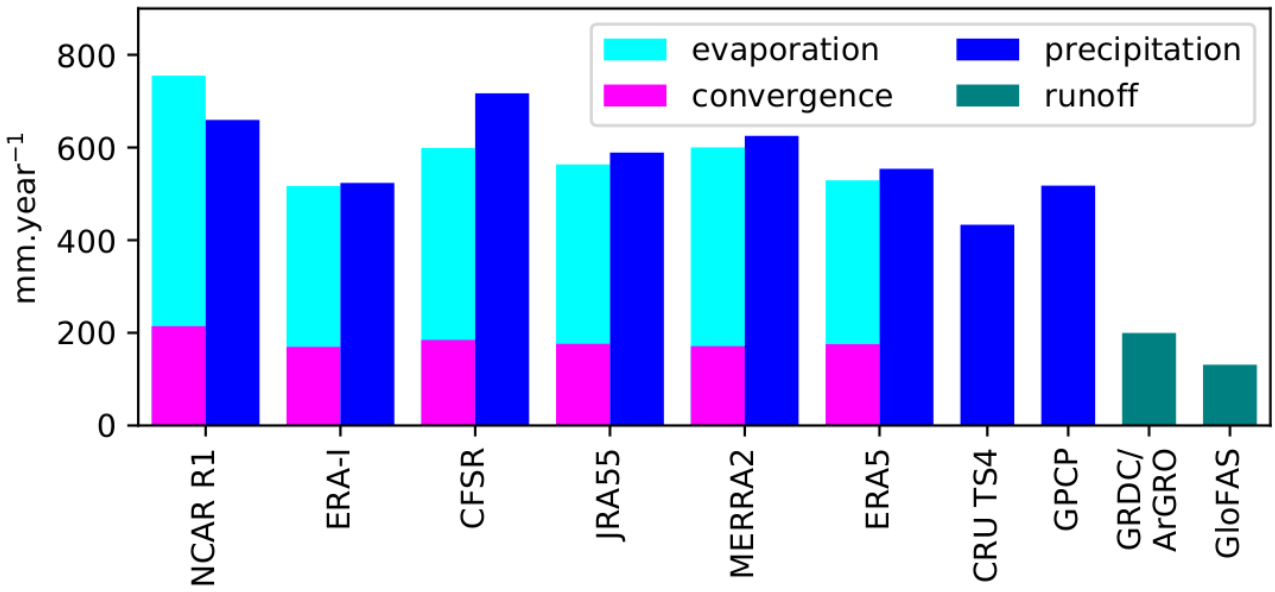

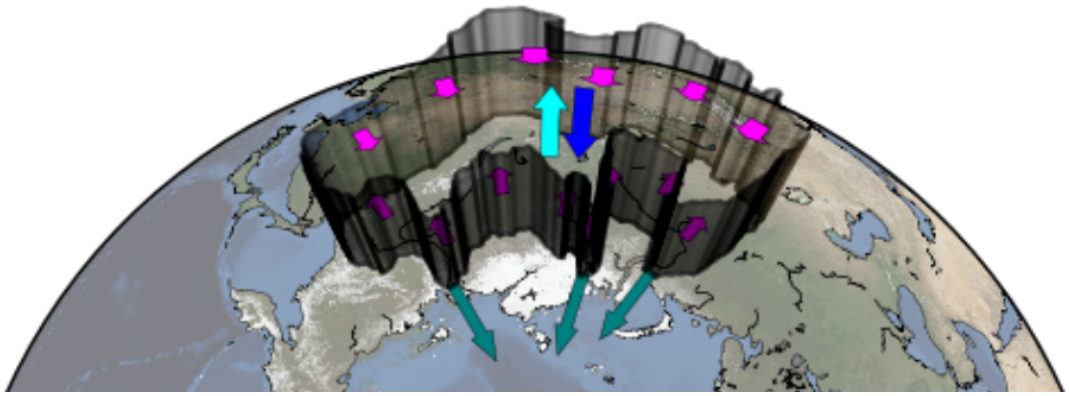

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Dark conifer forests dieback at mid-to-highlands in the southern Siberia’s mountains is not caused by drought stress

*Nadezhda Tchebakova[1], Elena I. Parfenova[1], Elena V. Bazhina[1], Amber J. Soja[2], Pavel Groisman[3]

1. Institute of Forests of FRC KSC, Siberian Branch, Russian Academy of Sciences, 2. National Institute of Aerospace, NASA Langley Research Center, Hampton, VA, USA , 3. NC State University Research Scholar at National Centers for Environment Information Federal Building, 151 Patton Avenue Asheville, NC 28801, USA

Foresters and ecologists of the world register dieback of dark conifer (shade-tolerant, water-loving *Pinus sibirica, Abies sibirica* and *Picea obovata*) forests across the boreal zone since the 1960-x. This issue has become urgent since the 1970s across the southern Siberia’s mountains (west-east: Altai, Kuznetsky Alatau, West and East Sayans and southern Transbaikalia) in the most productive dark conifer forests. The damage was expressed through: necroses of branches with generative organs that cause microsporogenesis and pollen development irregularities followed by low pollen and seed vitality; chloroses and premature needle falls; the occurrence of stem rot; the linear and radial increment decrease etc.

To date, there are several hypotheses to explain dieback of dark conifers within the 50-56° N latitudes across Northern Eurasia associated with:

1. climate aridization supposedly taking place under global warming;

2. anthropogenic environmental pollution (various gas emissions, acid rainfall).;

3. phytopathogens (Armillaria mellea, Heterobasidion annosum, etc;

4. invasive insect pests;

5. increased hard ultraviolet radiation (UV-- caused by the troposphere ozone depletion and additionally amplified by the increased ozone concentration in the near-surface air layer).

Our goal was to concentrate only on one Hypothesis #1 and accept/reject that: 1. Has the climate across the southern Siberia’s Mts been drying for the last 60 years; 2. If the current climate is drying then whether it may cause dieback of dark conifer trees as referred in the literature. Finally, would be climate change predicted from the CMIP5 projections (AR5) dry enough to cause dieback hotspots within the range of climax dark conifer forests by the end of the 21st century.

To achieve our goals we investigated climate change trends of annual precipitation, summer monthly temperatures and aridity/moisture indices (annual moisture index, AMI, and standardized precipitation evapotranspiration index, SPEI) for 1961-2019; and modeled dark conifer forest distributions and their shifts in a changing climate using our mountain bioclimatic vegetation model.

Our examinations of damaged trees in dark conifer forests along four mountain transects in each mountain system across the southern Siberia’s Mts showed that most dieback was found in the mid-elevation taiga at 700-900 m and up to 1400 m in highland taiga. To identify whether those events were associated with climate droughts AMI, SAMI (standardized AMI) and water balance (precipitation

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minus evapotranspiration), SPEI, were calculated for nine weather stations located in various ecosystem types (Fig. 1) and interpolated then for the lower border of decline/dieback occurrences. Climate trends for 1961-2019 demonstrated that moisture conditions have not changed much at these dieback sites and remained sufficient for dark conifer forests. Given the AMI limit for the lower/southern border of dark conifer forests was 2.25, AMI varied between 0.8-0.2 at 800-1200 m that indicated very wet conditions. Modeled moisture conditions would still remain satisfactory for dark conifers at the 2080s even for the extreme dry scenario RCP 8.5. Given the SPEI values <-1.5 were characteristic of extreme droughts, such moisture conditions occurred only 3-4 times for 1961-2019 (Fig. 1). Trees are known to survive occasional 1-2 drought years and then successfully recover. To state on a drought event for an ecosystem based only on SPEI is not ecologically sufficient. Dark conifers grow under positive annual water balance > 150 mm and true steppe –under negative. However, SPEI in these ecosystems varied within the same range ±2 (Fig. 1).

We conclude that Siberian pine and fir dieback observed mainly at the mid-to-high elevations were caused by reasons other than the drought stress as cited in the literature (Kharuk et al. 2020 et seq.). Other hypotheses are to be investigated to explain the phenomena.

Supported by RFBR grant 20-05-00540

Keywords: forest ecosystems, annual moisture index, SPEI, die-back, dark-needled species

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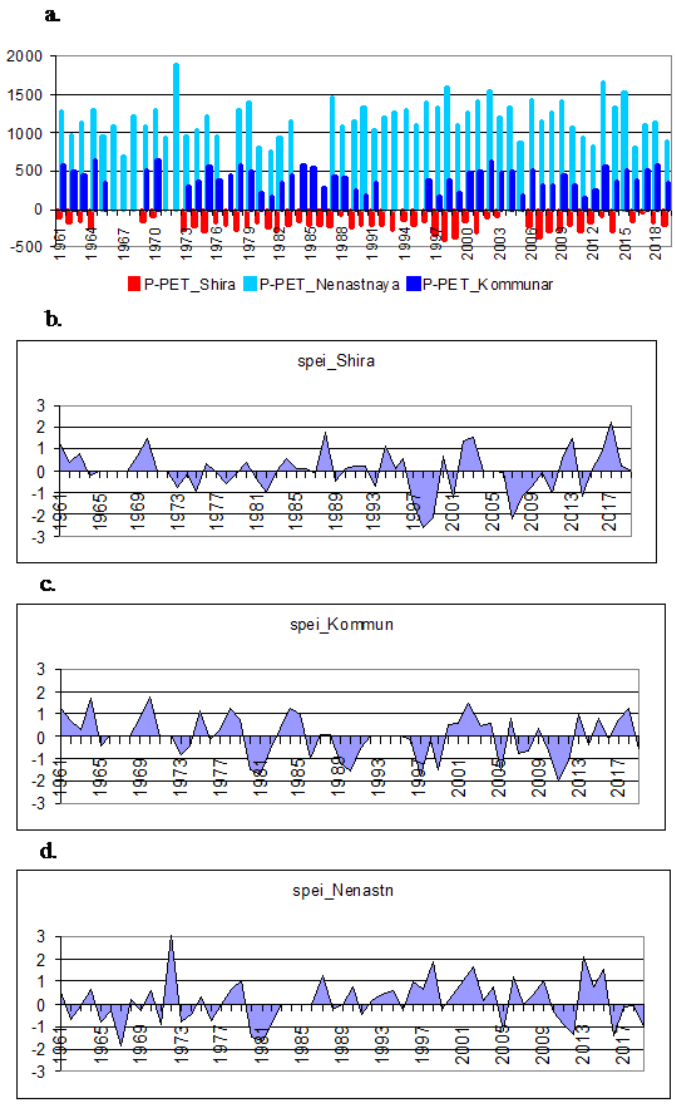

Fig. 1. Annual water balance (precipitation minus evapotranspiration, a) and SPEI (b, c, d) in different ecosystem types for 1961–2019: steppe (b), mountain dark conifer taiga (c), subalpine open taiga (d)

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Changing climate of the Western Siberia and socio-economic risks

*Daria Aleksandrovna Konstantinova[1], Valentina Petrovna Gorbatenko[1], Olga Vladimirovna Nosyreva[1], Marina Aleksandrovna Volkova[1], Irina Valer'evna Kuzhevskaia[1]

1. Tomsk State University

Western Siberia belongs to the regions with the highest rate of climate warming. Despite the positive factor for the inhabitants of the region, such changes can cause significant socio-economic consequences. The sectors of the economy particularly dependent on meteorological conditions include agriculture complex, construction design, the electric power complex, and the transport sector. The aim of the paper is a comprehensive analysis of specialized climatic indicators of the most populated part of Western Siberia, necessary for the development of the economy sectors in the presence of global climate change. Indicators based on the values of air temperature, precipitation and include the frequency of thunderstorms, hail, and convective instability. In addition, the peculiarities of snow cover, blizzard and glaze-rime phenomena were analyzed for the cold period of the year, the duration of which is considerable in the investigated territory. Data of daily weather station observations of air temperature, precipitation and atmospheric phenomena from the RIHMI-WDC information database from 1961 to 2020 were analyzed for the research.
First of all, global warming is reflected in the values of climatic conditions used in applied calculations. The dates of the steady transition of the mean daily air temperature through 0 ˚C moved to an earlier date by 4-6 days, through 5 ˚C by 6-9 days. There is an increase in the extreme temperature of the cold half-year period in the south of Western Siberia. The “low temperatures” events observed more often. Withal, the “high temperatures” events conduct itself similarly during the warm half-year period, against the background of the most conspicuous warming and relatively moderate warming cycle. Studying of the precipitation regime has showed that in most of the territory, the number of days is increasing, both with continuous rainfall and without rainfall. The maximum continuous dry periods are generally greater than the duration of wet periods and increases at a rate of up to 0.8 days per decade. The duration of snow cover is on average 180 days. A decrease in the occurrence duration over the last 30 years is observed, which is due to a change in snow occurrence time and destruction of the snow cover. Over the past three decades, in both the number of days with a blizzard and the average duration of blizzards declined by 2-3 times. To study the frequency of glaze-rime phenomena, the numbers of days with an event and the sum of cases per year have been calculated. The intra-annual, diurnal courses and continuous duration of glaze-rime phenomena were considered. The frequent phenomenon –rime –is 84% of all cases of studied phenomena. The prevalent continuous duration of rime ranges from 7 to 12 hours, glaze and wet snow –within 6 hours. As a result of the study of meteorological conditions for the formation of ice covering on road surface have been determined that the number of anti-icing treatment with deicing materials used in practice is insufficient to ensure the required level of road maintenance and traffic safety on the road network of the northern regions. The number of cycles of anti-icing treatment applied on roads should be expanded by almost 1.5 times. Convective instability of the atmosphere over Western Siberia, evaluated by the temperature-humidity characteristics of the atmosphere in the layer to 500 hPa, has increased in the recent decade. The boundary of the zones of active convection has been gradually moving to the north. The duration of the thunderstorm season and number of days with a hail and thunderstorm have increased. Numbers of days with durable hail as well as with large hail have doubled. The range of values of climatic characteristics taken into account in the construction design, the development and operation of the highways network, housing and utilities sector, the agricultural complex of the region has changed against the global background of climate change.

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Keywords: climate risks, socio-economic risks, changing climate

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Long-term temporal trends in water chemistry of lakes in response to decreases in acidic deposition and climate warming of the Kola arctic region

Tatyana I Moiseenko[1], *Marina I Dinu[1], Maria M Bazova[1]

1. Russian Institute of Geochemistry and Analytical Chemistry RAS

Acidification of waters had been identified in acid-sensitive areas of many countries by the 1960s because of regional and global emissions of acid-forming gases. Although the emission of SO_2 and NO_x had notably diminished by the 1990s, the problem of water acidification remains pressing: the anticipated recovery of water chemistry does not occur in some lakes because of the effects of associated factors and climate warming. We studied the long-term response of water chemistry to reduced acid deposition and climate warming in the northern Kola part of Russia, based on the monitoring data on 75 lakes. The monitoring was carried out once every 4–5 years in 1990–2018, with analysis for major anions an cations, dissolved organic carbon (DOC), and heavy metals (Ni and Cu). Analysis of archive data on the weather allowed us to reliably identify trends toward a systematic temperature increase over the past 28 years (when our studies were carried out). The population of the lakes under study was proved to generally show a decrease in concentrations of anthropogenic sulfates and strengthening of the acid-neutralizing capacity (ANC) of the waters during this period of time. The lakes were analyzed in six subareas depending on the bedrock geology of the catchment areas and distances from the emission sources. The water chemistry of the lakes responded notably differently to a decrease in the influx of acids: in the most acid-sensitive areas, whose catchment bedrocks are granite and quartz sand, ANC did not increase, and acidification continued to develop. The concentrations of both DOC and nutrients in the lake waters were determined to increase. Simultaneously the P_{tot}/PO_4^{3-} and N_{tot}/NO_3^- ratios systematically increased, which indicates that bioavailable forms of nutrients are successively utilized in the ecosystems, which means that the lakes are eutotrophied. This phenomenon can be explained by the following two mechanisms: a decrease in the deposition of strong acids and climate warming. We suggest that the effects of multiple factors on the surface waters results in an irreversible evolution of the lakes, and hence, the term *recovery* does not adequately reflect the processes occurring in this industrially well-developed part of the Arctic.

The research was carried out with the financial support of the Russian Foundation for Basic Research 18-05-60012

Keywords: Acidification , Metals, Climate change

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Wildfires in boreal eastern Siberia: Reconstructing the past to predict the future

*Ramesh Glueckler[1], Stefan Kruse°[1], Ulrike Herzschuh[1,2,3], Elisabeth Dietze°[1]

1. Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research, Potsdam, Germany , 2. Institute for Environmental Science and Geography, University of Potsdam, Potsdam, Germany, 3. Institute for Biochemistry and Biology, University of Potsdam, Potsdam, Germany

Recent extreme fire seasons in many parts of the world have raised concern: How will wildfire activity change with a warming climate? And which consequences could this in turn bring to the environment and to society? The boreal forest of Siberia, where wildfires are a key ecological disturbance, experiences rapidly rising temperatures. This affects vegetation dynamics, permafrost stability and the predominant fire regimes. However, due to a lack of long-term data, the relationships between these processes yet remain to be fully understood. With the aim of improving predictions about impacts of future fire regimes in Siberia, this highlights the need for (I) new long-term paleoenvironmental fire reconstructions to assess the impacts of past fire regime changes and (II) a fire-vegetation model capable of reproducing observed and reconstructed fire activity, so that it can eventually be used to reliably predict future changes.

Here, we present the first results of a project that aims at providing new insights for both of those aspects in eastern Siberia. First, new lake-sedimentary macroscopic charcoal records from south-west Yakutia characterize Holocene fire regime changes in larch-dominated boreal forests. Second, a new fire module for the individual-based, spatially explicit vegetation model LAVESI (*Larix* Vegetation Simulator) allows for an evaluation of fine-scale fire-weather-vegetation interactions. The newly available fire reconstructions are a promising opportunity to help inform the model. Ongoing research will be continuing to add data from more sites, as well as looking into ways in which proxy-based fire characterization could be improved. A combination of paleoenvironmental reconstructions and the fire-vegetation model can serve as an important tool in order to more reliably evaluate wildfire risks and impacts in eastern Siberia.

°shared senior-authorships

Keywords: boreal, forest, siberia, yakutia, wildfire, larch

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

Sun. Jun 6, 2021 9:00 AM - 10:30 AM JST | Sun. Jun 6, 2021 12:00 AM - 1:30 AM UTC | Ch.26 Zoom Room 26

[M-IS04] Evolution and variability of the Asian Monsoon and Indo-Pacific climate during the Cenozoic Era

convener:Takuya Sagawa(Institute of Science and Engineering, Kanazawa University), Kenji Matsuzaki(Atmosphere and Ocean Research Institute, The university of Tokyo), Chairperson:Takuya Sagawa(Institute of Science and Engineering, Kanazawa University), Kenji Matsuzaki(Atmosphere and Ocean Research Institute, The university of Tokyo)

The Asian Monsoon (AM) is an inter-hemispheric atmospheric system driven by the thermal contrast between ocean and land and has a significant impact on the global climate. The uplift of Himalaya and Tibetan Plateau (HTP) has been considered to have played a significant role on the establishment and intensification of Asian monsoon, but its importance is still controversial. On the other hand, comparison of AM evolution process with global climatic changes suggests that AM evolution during Cenozoic is significantly affected by global climate changes most likely through pCO2. In addition, oceanic climate condition in areas adjacent to monsoon region is also essential for the land-ocean thermal contrast.
In this session, we promote understanding of AM evolution, variability at multiple time scale (millennial to tectonic time scale) as well as their controlling factors, and their interaction with global climate system. Presentations from various archives such as piston cores, DSDP/ODP/IODP cores as well as land sections relying on a wide panel of paleo-environmental proxy are welcome (e.g. Geochemistry, Geophysics, Sedimentology, Micropaleontology as well as modeling studies). We also welcome presentations from older time periods such as Mesozoic and Paleozoic for better understanding of the evolution of the monsoon system during the Phanerozoic.

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

[MIS04-01] Orbital- to millennial-scale variability of the East Asian monsoon and the Kuroshio Current during periods of low orbital eccentricity and precessional change in the Pleistocene
★Invited Papers

*Yoshimi Kubota[1], Yuki Haneda[2], Koji Kameo[3], Takuya Itaki[2], Hiroki Hayashi[4], Kizuku Shikoku[4], Kentaro Izumi[5], Martin J Head[6], Yusuke Suganuma[7], Makoto Okada[8] (1.National Museum of Nature and Science, 2.Geological Survey of Japan, AIST, 3. Department of Earth Sciences, Faculty of Science, Chiba University, 4.Interdisciplinary Faculty of Science and Engineering, Shimane University, 5. Faculty & Graduate School of Education, Chiba University, 6.Brock University, 7.National Institute of Polar Research, 8.Department of Earth Sciences, Ibaraki University)

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

[MIS04-02] **Effect of orbitally-driven insolation changes on East Asian monsoon rainfall over the past 450,000 years**

*Taiga Matsushita[1], Mariko Harada[1], Hiroaki Ueda[1], Takeshi Nakagawa[2], Yoshimi Kubota[3], Yoshiaki Suzuki[4] (1.University of Tsukuba, 2.Ritsumeikan University, 3.National Museum of Nature and Science, 4.National Institute of Advanced Industrial Science and Technology)

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

[MIS04-03] Quantification of Asian dust multi-source contributions to silt and clay fractions in the Japan Sea sediments at IODP Site U1425 since 10 Ma by the Parallel Factor (PARAFAC) end-member modelling

*Mui Fa Alison Lee[1], Airi Maruyama[1], Tomohisa Irino[2] (1.Graduate School of Environmental Science, Hokkaido University, 2.Faculty of Environmental Earth Science, Hokkaido University)

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

[MIS04-04] Cyclostratigraphy and orbitally-paced paleo-productivity records of the Miocene Onnagawa Formation in Akita Prefecture, Northern Japan

*Jumpei Yoshioka[1,2], Junichiro Kuroda[2], Kenji Matsuzaki[2], Ryuji Tada[1,3,4] (1.Department of Earth and Planetary Science, the University of Tokyo, 2.Atmosphere and Ocean Research Institute, the University of Tokyo, 3.Yunnan University, 4.Chiba Institute of Technology)

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

[MIS04-05] Sedimentary features and isotope records of the upper Eocene travertine-lacustrin carbonate in the SE Tibet and implication for hte monsoon climate

★Invited Papers

*Aki Sakuma[1], Akihiro Kano[1], Yoshihiro Kakizaki[1], Ryuji Tada[2,3], Hongbo Zheng[3] (1.Department of Earth and Planetary Science, School of Science, the University of Tokyo, 2.Institute for Geo-Cosmology, Chiba Institute of Technology, 3.Yunnan Key Laboratory of Earth System Science, Yunnan University)

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

[MIS04-06] Impact of long-term monsoon dynamics on Cenozoic-Mesozoic climate and ecosystems

*Masayuki Ikeda[1], Kazumi Ozaki[2], LEGRAND Julien[3] (1.University of Tokyo, 2.Toho University, 3.Shizuoka University)

Orbital- to millennial-scale variability of the East Asian monsoon and the Kuroshio Current during periods of low orbital eccentricity and precessional change in the Pleistocene

*Yoshimi Kubota[1], Yuki Haneda[2], Koji Kameo[3], Takuya Itaki[2], Hiroki Hayashi[4], Kizuku Shikoku[4], Kentaro Izumi[5], Martin J Head[6], Yusuke Suganuma[7], Makoto Okada[8]

1. National Museum of Nature and Science, 2. Geological Survey of Japan, AIST, 3. Department of Earth Sciences, Faculty of Science, Chiba University, 4. Interdisciplinary Faculty of Science and Engineering, Shimane University, 5. Faculty & Graduate School of Education, Chiba University, 6. Brock University, 7. National Institute of Polar Research, 8. Department of Earth Sciences, Ibaraki University

Marine Isotope Stages (MIS) 20–18, along with MIS 12–10, are the closest astronomical analogues of the present interglacial and last glacial period (MIS 2–1). Comparing MIS 20–18 with MIS 2–1 provides an excellent opportunity to investigate natural climate variability and constrain future climate change predictions in East Asia. A previous study on the Chinese Loess Plateau shows that the grain-size-inferred intensity of the East Asian winter monsoon (EAWM) remains weak during MIS 20 and 18 likely due to the less-severe summer insolation and resulting suppressed snow accumulation and weak Siberian High. Here, we reconstruct the paleoceanography of MIS 20–18 through multiple proxies including microfossil assemblage data, planktonic foraminiferal isotopes (δ^{18}O and δ^{13}C), and foraminiferal Mg/Ca-based temperature records, from the Chiba composite section (CbCS) exposed on the Boso Peninsula, east-central Japan to compare with the East Asian monsoon proxies. The boundary between the warm Kuroshio and cold Oyashio currents is presently situated just east of the Boso Peninsula. The fluctuating position of the boundary between the Kuroshio and Oyashio currents in the mid-latitude western North Pacific affects both heat transport and air–ocean interactions and has significant consequences for the East Asian climate. We use principal component analysis (PCA) to capture dominant patterns of the temporal variation in these marine records, and show that MIS 19b and 19a are represented by millennial-scale stadial/interstadial oscillations. The northerly positions for the gyre boundary during late MIS 19c, early MIS 18, and the interstadials of MIS 19a are inferred from the leading mode, which is consistent with a weak EAWM and consequent mild winter climate in East Asia. Glacial MIS 20 had significantly more mild winters than MIS 2. For the interglacial MIS 19 and following glacial MIS 18, the onset of winter cooling in East Asia lagged the summer/annual climate by 30–40 kyr, which is also seen in the leading mode of the CbCS marine proxies.

Keywords: Asian monsoon, Kuroshio, Chiba composite section, Pleistocene, Millennial-scale, Marine Isotope Stage (MIS) 19

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Effect of orbitally-driven insolation changes on East Asian monsoon rainfall over the past 450,000 years

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1. University of Tsukuba, 2. Ritsumeikan University, 3. National Museum of Nature and Science, 4. National Institute of Advanced Industrial Science and Technology

Understanding orbital-scale changes in East Asian summer monsoon (EASM) precipitation is one of the fundamental issues in paleoclimate research, for determining the response of East Asian monsoon to different climate forcings such as insolation, ice volume, and greenhouse gases. Proxy records suggest that East Asian summer monsoon precipitation over the last hundreds of thousands of years has fluctuated associated with orbitally driven insolation changes and/or changes in global ice volume. However, due to the inconsistency between different proxies, it has been controversial what was the essential driving force for the EASM variability.

In the present study, we aim to evaluate the effect of insolation changes on the EASM based on numerical simulations. Using a climate model (MRI-CGCM 3.2), the global climate under given insolation changes for the past 450,000 years were calculated. The results showed that the summer precipitation in East Asia varies at the periodicities of precession (23 kyr) and obliquity (41 kyr), consistently with insolation changes. The calculated temporal changes in summer precipitation is highly consistent with cave speleothem $d^{18}O$ data in South East China, while the proxy data from North China (Chinese Loess Plateau) and Japan (Lake Biwa) cannot be fully explained by the calculation results. Importantly, the 100-kyr periodicity which dominates the variation in Chinese Loess Plateau was not found in our calculation results. We found a strong positive correlation between insolation and precipitation over the coastal area of China and a negative correlation between insolation and precipitation around Japan, which implies that EASM intensity is strongly affected by insolation intensity and but the effect can vary between regions.

The positive correlation between boreal summer insolation and summer precipitation over China results from the atmosphere-ocean interaction over the Indian Ocean and the western Pacific. Under strong insolation, northern shift of a monsoon front associated with intensification of the North Pacific subtropical high causes the increase in rainfall in the coastal area of China. Intensification of the subtropical high is caused by the integration of local Wind-Evaporation-Sea Surface Temperature (WES) feedback with Kelvin wave response to the warm Indian Ocean (IPOC mode). On the other hand, the correlation between insolation and precipitation around Japan affected by the strength of North Pacific High. Under strong insolation, the North Pacific High intensified, which causes decrease in summer precipitation around Japan.

Keywords: East Asian Summer Monsoon, Insolation, Global Ice Volume, Climate Modeling, Air-Sea Interactions

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Quantification of Asian dust multi-source contributions to silt and clay fractions in the Japan Sea sediments at IODP Site U1425 since 10 Ma by the Parallel Factor (PARAFAC) end-member modelling

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A complete aeolian accumulation rates in silt and clay fractions from the Late Miocene to Pleistocene were reconstructed at the Integrated Ocean Drilling Program (IODP) Site U1425 in the Japan Sea. A total of 180 samples were collected from the Hole 1425D, which had 354 m in length and covered the last 9.76 m.y. Grain size separation was conducted to evaluate the mineral composition in silt (>4 μm) and clay (<4 μm) fractions by X-ray diffractometer (XRD). Mineral composition suggests the source variabilities in silt and clay fractions, which could be interpreted as provenance shifts occurring in 8 and 2.7 Ma.

Parallel factor analysis (PARAFAC) was applied to decompose X-ray diffractograms into individual subcomponents to identify the sources and quantify their contributions. Six-components PARAFAC model was established and 3 Asian dust sources (Taklimakan Desert, Gobi Desert and Ordos Plateau), a riverine source of Japan Island Arc, and 2 biogenic sources of Opal-A and Opal-CT were identified.

In the late Miocene, high riverine flux from Japan Islands reflected strong summer monsoon during 9.7-8 Ma. Provenance shift occurred between 8 and 7 Ma from Japan Islands source to aeolian source for a short period. Flux of materials from Japan decreased to the lowest of 0.2 g/cm^2/kyr in 8 Ma and aeolian flux was higher from 7.5 to 7 Ma. These data implied that Asian aridification was intensified at about 8 Ma coinciding with the late Miocene cooling. During this period, eolian flux was generally low with occasional increases to 1.4 and 1 g/cm^2/kyr in 6.7 and 5.64 Ma, respectively, indicating sporadic aridification of Asian interior and the intensification of the winter monsoon.

Aeolian flux increased dramatically in Pleistocene to the maximum of 4 g/cm^2/kyr, where the Gobi Desert, Taklimakan Desert and Ordos Plateau were the 3 main contributors of the aeolian flux to the Japan Sea since then. The abrupt increases of aeolian flux in Japan Sea were related to the Northern Hemisphere Glaciation (NHG) which established a very cold and dry environment to accelerate sediment erosion in the Central Asia Mountain ranges and strengthened the atmospheric circulation systems in northern hemisphere. However, aeolian flux decreased to 2.8 g/cm^2/kyr during Holocene due to decreasing fluxes from Gobi and Ordos Plateau.

The contribution of Taklimakan source to Japan Sea ranged from 10 to 50% and the dust flux increased gradually in Pleistocene to the highest of 1.74 g/cm^2/kyr at 0.13 Ma. Lower flux occurred in the Late Miocene to Pliocene of <0.6 g/cm^2/kyr. Mass accumulation rate (MAR) of Taklimakan aeolian in silt fraction was generally higher than clay fraction. The contribution of Gobi dust to Japan Sea ranged from 20 to 50% since 10 Ma. The highest MAR of 2.42 g/cm^2/kyr occurred in 1.02 Ma and the lowest in Pliocene. The MAR of Gobi dust in clay fraction was higher than silt fraction from 9.24 to 0.75 Ma. Taklimakan dust showed higher grain size index than Gobi, which could be controlled by the different pathways of westerly jet and winter monsoon from the source regions to the site.

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Keywords: aeolian accumulation rate, Parallel factor analysis , Miocene to Pleistocene, Taklimakan Desert, Gobi Desert, Ordos Plateau

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Cyclostratigraphy and orbitally-paced paleo-productivity records of the Miocene Onnagawa Formation in Akita Prefecture, Northern Japan

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Middle-to-Late Miocene is the time of the global climate transition from a relatively warm climate mode to a more glaciated mode. The global cooling in the earth history is highly related to changes in the Earth system dynamics such as tectonics, ocean circulation, and carbon cycling. During this epoch, diatomaceous sediments were widely deposited in the North Pacific margin and marginal basins including the Japan Sea, and deposition of these formations is supposed to have great influence on the global carbon cycling through the enhanced organic carbon burial that might have resulted in the global cooling. Despite years of efforts to study the role of the organic carbon burial associated with the formations of diatomaceous sediments along the North Pacific margins, a full consensus about their contributions on the Middle-to-Late Miocene cooling has not been reached.
The Onnagawa Formation, which is widely exposed in Akita Prefecture, northern Japan, is one of the representative expressions of the Miocene siliceous (diatomaceous) sediments deposited during Middle-to-Late Miocene, and known for its rhythmical sedimentary cycles in diagenetically recrystallized siliceous rocks. Since silica diagenesis prevents the construction of precise biostratigraphy, the periodicities of the sedimentary cycles have not been clarified.
We have obtained a numerical age of 11.18±0.37 Ma for the middle part of the Onnagawa Formation based on U-Pb dating of zircon grains obtained from volcanic ash layers (Yoshioka et al., submitted to Geochemical Journal). By integrating this age with the radiolarian biostratigraphy, we established the chronostratigraphy of the Onnagawa Formation. Then, we reconstructed the changes in the ratio of detritus to biogenic silica to apply cyclostratigraphic approach. The ratio of detritus to biogenic silica was estimated by using continuous and high-resolution records of mineralogical composition taken by an X-ray diffractometry (XRD) and major element composition taken by X-ray fluorescence (XRF) spectroscopy, and correlated with the short-eccentricity-tuned gamma ray attenuation (GRA) records of the deep-sea sediment cores at Integrated Ocean Drilling Program (IODP) Site U1430 in the Japan Sea. GRA is supposed to reflect the ratio of detritus to biogenic silica in the biosiliceous sediments. Continuous and high-resolution XRD and XRF records enabled not only the application of cyclostratigraphy to the Onnagawa Formation but also the discussion of paleoceanography. The age-tuned XRF data indicate that the cyclicities of outstanding sedimentary cycles derived from the biogenic silica productivity are those of obliquity and precession cycles and that the biogenic productivity was highly related to the supply of nutrients such as silicon and phosphorus. The detailed age model by cyclostratigraphy will promote research on paleoceanography of the Onnagawa basin.

Keywords: cyclostratigraphy, biogenic silica, orbital forcing, XRF, XRD

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Sedimentary features and isotope records of the upper Eocene travertine-lacustrin carbonate in the SE Tibet and implication for hte monsoon climate

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The Asian monsoon is one of the largest climatic systems in the world but estimates of its onset vary from the late Eocene to the Quaternary (e.g. Licht et al., 2014). We investigated the sedimentary environment of the late Eocene Jiuziyan Formation, a terrestrial limestone unit that occurs a few localities in the Jianchuan basin, Yunnan Province in China. Previously, this has been characterized as lacustrine carbonate and the transition to the palustrine deposit was interpreted as the appearance of wetter climate during the late Eocene (Sorrel et al., 2017). Our observations of macro- and microfacies revealed sedimentary fabrics indicating rapid $CaCO_3$ precipitation, such as dendritic calcite and calcified reed stems, which are unlikely to develop in a simple lacustrine setting. These fabrics, together with clearly higher $\delta^{13}C$ values (-0.7 to +6.9 ‰) and lower $\delta^{18}O$ values (-14.6 to -10.5 ‰) than those of lacustrine marlstone of the overlying Shuanghe Formation shown by Wu et al. (2018), indicate that the limestone was at least partly travertine, carbonate formed from thermogenic (endogenic) spring water. In addition, the occurrence of centimeter-scale lamination coupled with cyclic changes in $\delta^{13}C$ and $\delta^{18}O$ is almost identical with the modern travertine reported from Baishuitai in northern Yunnan Province (Sun and Liu, 2010). The centimeter-scale lamination is annual and the cyclic changes in $\delta^{13}C$ and $\delta^{18}O$ imply seasonal temperature and precipitation change, which have comparable amplitude to the record of the modern travertine at Baishuitai. Our results do not contradict late Eocene wetting and additionally suggest the development of a high-CO_2 aquifer in the underground, which was likely associated with a tectonic activity in the southeastern Tibetan Plateau. This might be related to the shift from the dry condition of the Baoxiangsi Fm. underlying the Jiuziyan Fm. to the wet condition of the Shuanghe Fm.

Keywords: late Eocene, travertine, lacustrine carbonate, annual lamination, carbon and oxygen isotopes, Asian monsoon

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Impact of long-term monsoon dynamics on Cenozoic-Mesozoic climate and ecosystems

*Masayuki Ikeda[1], Kazumi Ozaki[2], LEGRAND Julien[3]

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Earth’ s orbital variations on timescales of 10^4 to 10^5 years, known as Milankovitch cycles, have played a critical role in pacing climate change and ecosystem dynamics during the Cenozoic and Mesozoic, through glacial and monsoon dynamics. However, the climatic and biotic consequences of these cycles on much longer 10^7 years timescales remain unclear, due to a lack of long proxy records with precise age constraints.
Here, we show 10 Myr scale variations in Triassic Jurassic records of lake level, desert distribution, biogenic silica burial flux, atmospheric CO2 levels, and sea surface temperature, SST. Their phase relationships, coupled with carbon cycle modeling results, suggest that orbitally paced summer monsoon dynamics modulates changes in terrestrial weatherability, affecting changes in pCO2 of up to 500 to 1000 ppmv and 3 to 7 C SST. We also infer that these 10 Myr scale climatic variations could have been causally linked to biotic turnover, size variations in dinosaur footprints, and tetrapod dispersal, potentially through spatio temporal variations in resource availability and arid hot climatic barriers at low middle latitudes.

Keywords: monsoon

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

Sun. Jun 6, 2021 10:45 AM - 12:15 PM JST | Sun. Jun 6, 2021 1:45 AM - 3:15 AM UTC | Ch.11 Zoom Room 11

[M-IS05] Global climate change driven by the Southern Ocean and the Antarctic Ice Sheet

convener:Osamu Seki(Institute of Low Temperature Science, Hokkaido University), Yoshifumi Nogi(National Institute of Polar Research), Akira Oka(Atmosphere and Ocean Research Institute, The University of Tokyo), Yusuke Suganuma(National institute of Polar Research), Chairperson:Takashi Obase(Atmosphere and Ocean Research Institute, the University of Tokyo)

The Southern Ocean and Antarctic ice sheet, which are the giant reservoirs of heat, water, and materials, have a potential to play central roles in long-term global climate change. This system is composed of the following sub-systems; ice shelf which is a place of the interaction of ice sheet and ocean, flowing iceberg, seasonal sea ice zone, Antarctic bottom water which drives the thermohaline circulation, active biological production and Antarctic Circumpolar Current. These sub-systems are interacted with each other and have significant impact on changes in the global environmental system. This session aim to summarize recent observational and simulation studies from various fields relating to the past and present changes in the Antarctic Ice sheet and Southern Ocean, which are essential elements for unraveling the changes in the global climate system. Further, future science plans for understanding of the environmental changes of the Antarctic Cryosphere is also discussed.

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

[MIS05-01] Modelling the Stability of Antarctic ice sheet for investigating the link between the past and future

★Invited Papers

*Ayako Abe-Ouchi[1], Kaho Harada[1], Takashi Obase[1], Fuyuki SAITO[2], Ralf Greve[3], Christopher Chambers[3], Osamu Seki[3], Kenji Kawamura[4], Jun'ichi Okuno[4] (1.Atmosphere and Ocean Research Institute, The University of Tokyo, 2.JAMSTEC, 3.Hokkaido University, 4.NIPR)

11:05 AM - 11:25 AM JST | 2:05 AM - 2:25 AM UTC

[MIS05-02] Carbon and nutrient cycles in and around the Cape Darnley polynya

★Invited Papers

*Michiyo Yamamoto-Kawai[1], Yoshihiko Ohashi[1] (1.Graduate School of Marine Science and Technology, Tokyo University of Marine Science and Technology)

11:25 AM - 11:45 AM JST | 2:25 AM - 2:45 AM UTC

[MIS05-03] MONACA: The hot explorer under ice

★Invited Papers

*Toshihiro Maki[1], Hirokazu Yamagata[1], Hiroshi Yoshida[2], Yoshifumi Nogi[3] (1.The University of Tokyo, 2.Japan Agency for Marine-Earth Science and Technology, 3.National Institute of Polar Research)

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

[MIS05-04] Development of the Under Ice AUV “MONACA” - Autonomous Navigation Trial in Under Ice Environment -

*Hirokazu Yamagata[1], Shuma Kochii[1], Hiroshi Yoshida[2], Yoshifumi Nogi[3], Toshihiro Maki[1] (1.Institute of Industrial Science, The University of Tokyo, 2.Japan Marine Science and Technology Center, 3.National Institute of Polar Research)

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

[MIS05-05] Long-term future projections for the Antarctic ice sheet with the model SICOPOLIS

*Christopher Chambers[1], Ralf Greve[2,1], Takashi Obase[3], Fuyuki SAITO[4], Kaho Harada[3], Ayako Abe-Ouchi[3] (1.Institute of Low Temperature Science, Hokkaido University, 2.Arctic Research Center, Hokkaido University, 3.Atmosphere and Ocean Research Institute, University of Tokyo, 4.Japan Agency for Marine-Earth Science and Technology)

Modelling the Stability of Antarctic ice sheet for investigating the link between the past and future

*Ayako Abe-Ouchi[1], Kaho Harada[1], Takashi Obase[1], Fuyuki SAITO[2], Ralf Greve[3], Christopher Chambers[3], Osamu Seki[3], Kenji Kawamura[4], Jun'ichi Okuno[4]

1. Atmosphere and Ocean Research Institute, The University of Tokyo, 2. JAMSTEC, 3. Hokkaido University, 4. NIPR

Linking the paleo-ice sheet modelling studies and the future projection is challenging because of its millennial-scale long response time to external forcing which leads to its long commitment. Here in this study, in order to investigate the existence of threshold in the system which characterizes the irreversible behavior under climate changes, we use three-dimensional ice sheet model, SICOPOLIS, to investigate the Antarctic ice sheet response to atmospheric and oceanic warming, systematically. Ice sheet change is calculated for a given anomaly of surface temperature of 1 to 20 degree C as atmosphere forcing and basal melting beneath ice shelves of 1 to 400 m/a as ocean forcing. The response of ice sheet mass balance and volume for different time scales, 100, 1000, 10000 and 100, 000 years are analyzed for different initial conditions. We find that the collapse of West Antarctic ice sheet (WAIS) and the retreat of coastal areas of East Antarctic ice sheet (EAIS) such as Wilkes Subglacial Basin result in sea-level contributions of about 10m within 1kyr if an oceanic melt anomaly were around 5 to 10 m/a. The ice sheet change is little for the first 100 years, partly because of the compensation between the accumulation increase and the ice sheet retreat. Especially, continuous basal melting rate of 2-10m/a leads to Marine ice sheet instability (MISI) in a few hundred years before the major glacial rebound, while it takes much longer time for the recovery after eliminating the melting or warming. Implication for paleoclimate and ice sheet modelling as well as future projection will be further discussed.

Keywords: climate, ice sheet, modelling, Antarctic ice sheet, deglaciation

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Carbon and nutrient cycles in and around the Cape Darnley polynya

*Michiyo Yamamoto-Kawai[1], Yoshihiko Ohashi[1]

1. Graduate School of Marine Science and Technology, Tokyo University of Marine Science and Technology

In polynyas around the Antarctic coast, cold dense shelf water (DSW), the precursor to Antarctic Bottom Water (AABW), is formed by enhanced sea-ice production. The outflow of this DSW into the abyss links biogeochemistry of the upper and deeper oceans. As part of the GRAntarctic project, we have investigated carbon and nutrient cycles in and around the Cape Darnley polynya region, where DSW and AABW are formed. Data of transient tracers CFCs and SF_6 are also used to estimate time-scale of AABW transport from the polynya to the deep ocean.

Ship-based and moored observations have shown large seasonal and interannual changes in carbon and nutrient concentrations in the polynya, due to production and decomposition of organic matter. Estimates of carbon and nutrient budgets in the polynya indicate the net removal of silicate and dissolved inorganic carbon (DIC) on the shelf. As a result, low DIC and silica concentrations characterize the newly formed AABW in this region. CFC and SF_6 showed a rapid transport of well-ventilated AABW from the Cape Darnley polynya region to the north and west. During this rapid transport, the effect of decomposition of organic matter was not evident in DIC or nutrient concentrations. These results revealed that Cape Darnley polynya acts as a significant sink of DIC and silicate, lowering DIC and silicate concentrations of AABW.

Keywords: carbon cylce, nutrient cycle, polynya, Southern Ocean

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MONACA: The hot explorer under ice

*Toshihiro Maki[1], Hirokazu Yamagata[1], Hiroshi Yoshida[2], Yoshifumi Nogi[3]

1. The University of Tokyo, 2. Japan Agency for Marine-Earth Science and Technology, 3. National Institute of Polar Research

Autonomous Underwater Vehicles (AUVs) are now recognized as a convenient and high-performance tool for underwater survey. However, under ice observation is still challenging. Because the surface is packed with ice, AUVs cannot directly surface even in case of emergency. Support vessels cannot stay in close to the vehicle either. The vehicle mostly has to return to a pinpoint open water nearby the ship through long lonely journey home.
The AUV MONACA was developed for under ice survey of Antarctica, supported by JSPS Grant-in-Aid for Scientific Research on Innovative Areas No.4902. MONACA is 2 m long, 230 kg weigh, and it can cruise for about 8 hours. The vehicle is designed to go into ice covered oceans as far as 10 km. Although the survey range is limited compared with large AUVs, it can conduct a highly precise survey with lower costs. Its sensor unit consisting of a multi-beam sonar, an INS (Inertial Navigation System), and a DVL (Doppler Velocity Log) can be flipped upside down, so that the vehicle can survey both the ice and seafloor with minimum modification. In this presentation, the overview of the project is introduced. Results of open water and under ice experiments are also shown.

Keywords: Antarctica, Observation technology, Autonomous Underwater Vehicle

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Development of the Under Ice AUV “MONACA” - Autonomous Navigation Trial in Under Ice Environment -

*Hirokazu Yamagata[1], Shuma Kochii[1], Hiroshi Yoshida[2], Yoshifumi Nogi[3], Toshihiro Maki[1]

1. Institute of Industrial Science, The University of Tokyo, 2. Japan Marine Science and Technology Center, 3. National Institute of Polar Research

This presentation introduces the AUV MONACA (Mobility Oriented Nadir AntarctiC Adventurer) and reports the results of autonomous navigation trials held in Oct. 2020 and Feb. 2021.

The AUV MONACA was developed for under ice survey of Antarctica, supported by JSPS Grant-in-Aid for Scientific Research on Innovative Areas No.4902, to measure the sea ice/shelf ice and seafloor for research of ice sheet-ocean interaction. MONACA is 2 m long, 230 kg weigh, and it can cruise for about 8 hours. Depth rating is 1500m. The vehicle is designed to go into ice covered oceans as far as 10 km. The flat body is filled with buoyancy materials at the top so that the battery units and main unit can be accessed from the side. The vehicle has five degrees of freedom (surge, heave, roll, pitch, and yaw) by 4 vertical thrusters and 2 horizontal thrusters. Although the survey range is limited compared with large AUVs, it can conduct a highly precise survey with lower costs. Its modular design enables the necessary and sufficient compositions for various survey needs. Its sensor unit consisting of a multi-beam sonar, an INS (Inertial Navigation System), and a DVL (Doppler Velocity Log) can be flipped upside down, so that the vehicle can survey both the ice and seafloor with minimum modification.

The first autonomous navigation trial was held in Oct. 2020 at Shimoda Bay, located in Sizuoka. MONACA was deployed, and its basic performance such as waypoint tracking and altitude control were veirfied at the open and calm water. The sensor unit was looking downward. Bathymetry data was also collected by the multibeam sonar. The second autonomous navigation trial is planned in Feb. 2021 at Mombetsu Port, located in Hokkaido and covered by ice. The sensor unit is looking upward to detect floating ice. The performance of ice-relative navigation and ice mapping is evaluated. The results of the trial will be shown in the presentation.

Keywords: Under-ice Survey, AUV

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Long-term future projections for the Antarctic ice sheet with the model SICOPOLIS

*Christopher Chambers[1], Ralf Greve[2,1], Takashi Obase[3], Fuyuki SAITO[4], Kaho Harada[3], Ayako Abe-Ouchi[3]

1. Institute of Low Temperature Science, Hokkaido University, 2. Arctic Research Center, Hokkaido University, 3. Atmosphere and Ocean Research Institute, University of Tokyo, 4. Japan Agency for Marine-Earth Science and Technology

Ice-sheet simulations of extended versions of ISMIP6 (Ice Sheet Model Intercomparison Project for the Coupled Model Intercomparison Project Phase 6) future climate experiments for the Antarctic ice sheet until the year 3000 are used to investigate the long term impacts of 21st century projected warming. The simulations use climate projections from the beginning of 2015 until the end of 2100, after which no further climate trend is applied. Fourteen experiments are for the “unabated warming” pathway, and three are for the “reduced emissions” pathway. For the unabated warming path simulations, a large difference in the vulnerability of east and west Antarctica develops over hundreds of years (Figure 1 bottom), with west Antarctica suffering a much more severe ice loss than east Antarctica. In these cases, the mass loss amounts to a 14-experiment average of ~3.3 m sea-level equivalent by the year 3000 and ~5.3 m for the most sensitive experiment (Figure 1 top). For the reduced emissions pathway, the mean mass loss is ~0.25 m sea-level equivalent. The conclusions are quite different to ISMIP6, which saw only modest losses, or even gains, by the year 2100, demonstrating that the consequences of the unabated warming path are large and long term. Under the unabated 21st century warming scenario the ice sheet progresses through 4 phases, that are defined by differing rates of ice loss. The stages are attributable to how west Antarctica loses mass along the Siple Coast followed later by additional loss from the Thwaites/Pine Island region and an eventual leveling out in the rate of ice sheet loss once the majority of the west Antarctic ice sheet has melted. Simulations with and without bedrock rebound corroborate a negative feedback for ice loss found in previous studies. Limitations to the study, include the lack of accounting for local climatic changes in regions where ice sheet collapse occurs.

Keywords: Antarctica, ice sheet, climate change, cryosphere

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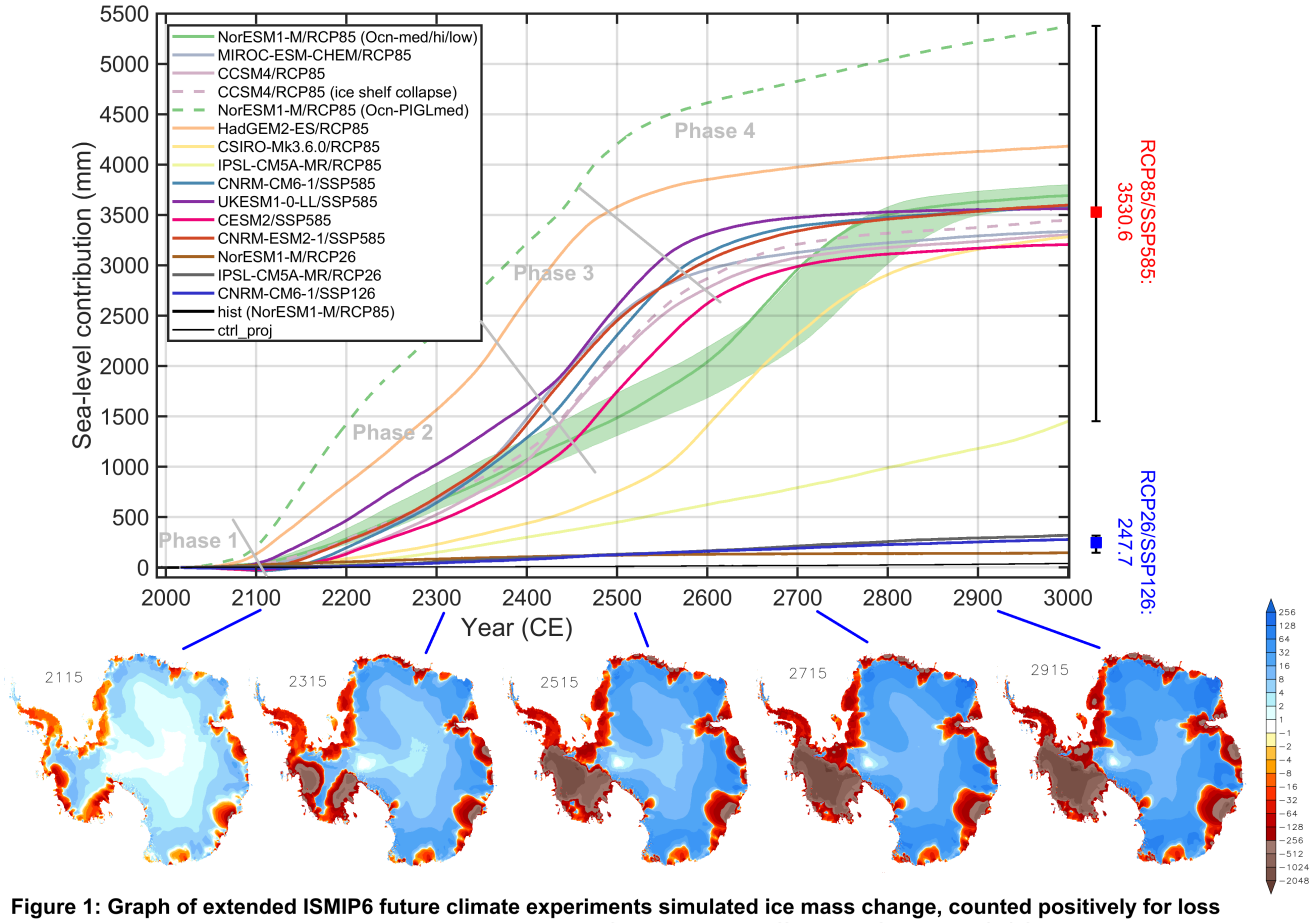

Figure 1: Graph of extended ISMIP6 future climate experiments simulated ice mass change, counted positively for loss and expressed as sea-level contribution. Below are ice surface elevation differences from 2015 (m) for the year indicated for case MIROC-ESM-CHEM/RCP85.

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

Sun. Jun 6, 2021 1:45 PM - 3:15 PM JST | Sun. Jun 6, 2021 4:45 AM - 6:15 AM UTC | Ch.11 Zoom Room 11

[M-IS05] Global climate change driven by the Southern Ocean and the Antarctic Ice Sheet

convener:Osamu Seki(Institute of Low Temperature Science, Hokkaido University), Yoshifumi Nogi(National Institute of Polar Research), Akira Oka(Atmosphere and Ocean Research Institute, The University of Tokyo), Yusuke Suganuma(National institute of Polar Research), Chairperson:Hiroki Matsui(Graduate School of International Resource Sciences, Akita University), Takeshige Ishiwa(National Institute of Polar Research)

The Southern Ocean and Antarctic ice sheet, which are the giant reservoirs of heat, water, and materials, have a potential to play central roles in long-term global climate change. This system is composed of the following sub-systems; ice shelf which is a place of the interaction of ice sheet and ocean, flowing iceberg, seasonal sea ice zone, Antarctic bottom water which drives the thermohaline circulation, active biological production and Antarctic Circumpolar Current. These sub-systems are interacted with each other and have significant impact on changes in the global environmental system. This session aim to summarize recent observational and simulation studies from various fields relating to the past and present changes in the Antarctic Ice sheet and Southern Ocean, which are essential elements for unraveling the changes in the global climate system. Further, future science plans for understanding of the environmental changes of the Antarctic Cryosphere is also discussed.

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

[MIS05-06] Beryllium isotope records from sectors of the West and East Antarctic Ice sheet reveal Holocene melting related to the incursion of Circumpolar Deep Water

*Adam David Sproson[1,2], Yusuke Yokoyama[1,2], Yoshinori Takano[2], Rebecca Minzoni[3], Bethany Behrens[1], Yosuke Miyairi[1], Takahiro Aze[1] (1.Atmosphere and Ocean Research Institute, University of Tokyo, 5-1-5 Kashiwanoha, Kashiwa, Chiba 277-8564, Japan. , 2.Department of Biogeochemistry, Japan Agency for Marine-Earth Science and Technology, 2-15 Natsushima, Yokosuka, Kanagawa 237-0061, Japan. , 3.Department of Geological Sciences, The University of Alabama, USA.)

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

[MIS05-07] Abrupt Holocene ice-sheet retreat in Lutzow-Holm Bay, East Antarctica

*Yusuke Suganuma[1,2], Yuki Haneda[3], Takuya Itaki[3], Osamu Seki[4], Takeshige Ishiwa[1], Moto Kawamata[2], Masakazu Fujii[1,2], Kazuya Kusahara[8], Daisuke Hirano[4], Masao Iwai[9], Yuji Kato[9], Hiroki Matsui[6], Atsuko Amano[3], Kota Katsuki[5], Takayuki Omori[7], Motohiro Hirabayashi[1], Hiroyuki Matsuzaki[7], Takeyasu Yamagata[7], Masato Ito[8], Shin Sugiyama[4], Naohisa Nishida[10], Jun'ichi Okuno[1,2], Minoru Ikehara[9], Hideki Miura[1,2] (1.National institute of Polar Research, 2.The Graduate University for Advanced Studies (SOKENDAI), 3.Geological Survey of Japan, AIST, 4.Hokkaido University, 5.Shimane University, 6.Akita University, 7.University of Tokyo, 8.JAMSTEC, 9.Center for Advanced Marine Core Research, Kochi University, 10.Tokyo Gakugei University)

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

[MIS05-08] Paleoenvironmental reconstruction using lake sediment cores from Lake Nurume in Lützow Holm Bay

*Takeshige Ishiwa[1], Yuki Tokuda[2], Takuya Itaki[3], Satoshi Sasaki[4], Kota Katsuki[4], Yusuke Suganuma[1,5] (1.National Institute of Polar Research, 2.Tottori University of Environmental Studies, 3.National Institute of Advanced Industrial Science and Technology, 4.Shimane University, 5.The Graduate University for Advanced Studies (SOKENDAI))

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

[MIS05-09] Assessing dust-magnetic correlation in the Indian sector of the Southern Ocean

*Hiroki Matsui[1], Minoru Ikehara[2], Yusuke Suganuma[3,4], Osamu Seki[5], Ikumi Oyabu[3], Kenji Kawamura[3,4] (1.Graduate School of International Resource Sciences, Akita University, 2.Center for Advanced Marine Core Research, Kochi University, 3.National Institute of Polar Research, Research Organization of

Information and Systems, 4.Department of Polar Science, School of Multidisciplinary Sciences, The Graduate University for Advanced Studies (SOKENDAI), 5.Institute of Low Temperature Science, Hokkaido University)

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

[MIS05-10] Antarctic warmth in the last interglacial driven by Northern insolation and deglaciation

*Takashi Obase[1], Ayako Abe-Ouchi[1,2], Fuyuki SAITO[3] (1.Atmosphere and Ocean Research Institute, the University of Tokyo, 2.National Institute of Polar Research, Japan, 3.Japan Agency for Marine-Earth Science and Technology)

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

[MIS05-11] Modeling the ocean carbon cycle during the last deglaciation

*Hidetaka Kobayashi[1], Akira Oka[1], Takashi Obase[1], Ayako Abe-Ouchi[1] (1.Atmosphere and Ocean Research Institute, The University of Tokyo)

Beryllium isotope records from sectors of the West and East Antarctic Ice sheet reveal Holocene melting related to the incursion of Circumpolar Deep Water

*Adam David Sproson[1,2], Yusuke Yokoyama[1,2], Yoshinori Takano[2], Rebecca Minzoni[3], Bethany Behrens[1], Yosuke Miyairi[1], Takahiro Aze[1]

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Glaciers and ice sheets in both mountain regions and the poles are losing mass, causing an increase in the rate of mean sea level rise whilst expanding an ever-warming ocean. Sea level rose globally by ~15 cm over the past ~100 years but that rate is currently accelerating, becoming twice as fast (3.6 mm yr^{-1}). Sea level rise could reach around 30 to 60 cm by 2100 if greenhouse gas emissions are sharply reduced and global warming is limited less than 2˚C but could rise to around 60 to 110 cm if greenhouse gas emissions continue to increase [1]. It is therefore imperative for Earth scientists to use the geological record to reconstruct the deglacial history of key regions relevant to sea level rise during past periods of extreme climate [e.g., 2]. This will allow better constraints on numerical models for future climate predictions and a greater understanding of the cryosphere response to future global warming. Here, we present the authigenic Be isotope composition of lake and marine sediments from the Lützow-Holm Bay and the Ferrero Bay, respectively [3-5].

Meteoric ^{10}Be is produced in the atmosphere by cosmic rays and delivered to the Earth and ocean surface via dust and precipitation. In Antarctica, these sources of ^{10}Be become locked up in ice sheets and are subsequently released to the continental shelf during periods of melting and freshwater discharge, where they adhere to suspended particles in the water column and subsequently accumulate on the basin floor [6]. Stable ^{9}Be is present in silicate rocks and is released during subglacial weathering, with little simultaneous release of ^{10}Be, and transported to the oceans via meltwater outflow [7]. When Be is incorporated into the authigenic phase of marine sediments, the $^{10}Be/^{9}Be$ reflects that of the overlying water column [8], which in turn reflects the relative dominance of freshwater flux and/or subglacial weathering.

New Be isotope records from Lakes Maruwan Oike and Lake Skallen, near Lützow-Holm Bay, and Ferrero Bay, the Amundsen Sea Embayment, reveal a large increase in ^{10}Be abundance and $^{10}Be/^{9}Be$ ratios between 4.1 to 3.6 Ka BP and 10 to 6 ka BP, respectively. This suggests widespread meltwater discharge and destabilisation of respective parts of the East and West Antarctic Ice Sheet during the Late and Early Holocene. Such events could be linked to a strengthening of the Southern Hemisphere westerlies which, in turn, would have caused enhanced upwelling of warm Circumpolar Deep Waters (CDW) onto the shelf leading to increased marine ice shelf instability and melting [9, 10] suggesting possible Antarctic contribution to global sea-level rise during the Holocene [11].

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[10] Yokoyama, Y., et al. (2016) *Proceedings of the National Academy of Sciences* **113**(9): p. 2354. [11] Yokoyama, Y., et al. (2019) *Quaternary Science Reviews* **206**: p. 150-161.

Keywords: Beryllium isotopes, Holocene, Antarctica, Glacial discharge

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Abrupt Holocene ice-sheet retreat in Lutzow-Holm Bay, East Antarctica

*Yusuke Suganuma[1,2], Yuki Haneda[3], Takuya Itaki[3], Osamu Seki[4], Takeshige Ishiwa[1], Moto Kawamata[2], Masakazu Fujii[1,2], Kazuya Kusahara[8], Daisuke Hirano[4], Masao Iwai[9], Yuji Kato[9], Hiroki Matsui[6], Atsuko Amano[3], Kota Katsuki[5], Takayuki Omori[7], Motohiro Hirabayashi[1], Hiroyuki Matsuzaki[7], Takeyasu Yamagata[7], Masato Ito[8], Shin Sugiyama[4], Naohisa Nishida[10], Jun'ichi Okuno[1,2], Minoru Ikehara[9], Hideki Miura[1,2]

1. National institute of Polar Research, 2. The Graduate University for Advanced Studies (SOKENDAI), 3. Geological Survey of Japan, AIST, 4. Hokkaido University, 5. Shimane University, 6. Akita University, 7. University of Tokyo, 8. JAMSTEC, 9. Center for Advanced Marine Core Research, Kochi University, 10. Tokyo Gakugei University

The Antarctic Ice Sheet (AIS) is one of the most significant potential contributors to future sea-level changes. Recently, the acceleration of AIS’ s mass loss has been reported based on satellite observations, such as radar altimetry, interferometer, and gravity measurements, and shipboard observations coupled with modeling studies. In these studies, the main cause of the modern ice mass loss is thought to be iceberg calving and basal melting due to an inflow of modified Circumpolar Deep Water (mCDW). However, the role of the mCDW for the large-scale deglaciation of the AIS, such as the deglaciation since the Last Glacial Maximum (LGM), remains unclear due to the lack of the geological data-based constraint. Therefore, marine and land-based reconstruction of the deglaciation process of the AIS since the LGM is essential to understand the role of the mCDW for a large-scale ice mass loss, which will be a useful analog to calibrate the climate and ice sheet models and to refine the future ice sheet retreat projection. In this presentation, we show an overview of our recent activities in the Lützow-Holm Bay (LHB), Dronning Maud Land, East Antarctica. Newly obtained sedimentary cores and legacy samples from the LHB are used for detailed lithofacies analysis, authigenic Be-10 measurement, hydrogen isotopic compositions analysis, and benthic foraminiferal assemblage of the sedimentary cores. And also, a hybrid age model is constructed by foraminiferal and calibrated bulk organic carbon AMS C-14 dates. These indicate that the East AIS rapidly retreated since the Early Holocene due to an intensified incision of the mCDW. This retreat propagated from the submarine trough to shallower vicinity and then ceased by the Mid-Holocene coincide with the weakening of the mCDW incision. This phenomenon is consistent with the abrupt ice sheet thinning observed along the eastern coast of the bay (Soya Coast) revealed by surface exposure ages and clear lithofacies change of lake sediments and its AMS C-14 dates. This is the first clear terrestrial and marine-based geological constraint for the large-scale deglaciation of the East AIS, driven by a modulation of the mCDW incision, since the LGM.

Keywords: Antarctica Ice Sheet and Southern Ocean, Giant Reservoirs - Antarctic, Solid Earth

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Paleoenvironmental reconstruction using lake sediment cores from Lake Nurume in Lützow Holm Bay

*Takeshige Ishiwa[1], Yuki Tokuda[2], Takuya Itaki[3], Satoshi Sasaki[4], Kota Katsuki[4], Yusuke Suganuma[1,5]

1. National Institute of Polar Research, 2. Tottori University of Environmental Studies, 3. National Institute of Advanced Industrial Science and Technology, 4. Shimane University, 5. The Graduate University for Advanced Studies (SOKENDAI)

Lake sediment in Antarctica is a useful archive for paleoenvironmental reconstruction as sea-level and ice-sheet change. Various sediment cores have been collected from a large number of lakes in Lützow Holm Bay, East Antarctica (e.g., Takano et al., 2012; Verleryen et al., 2017; Suganuma et al., 2018; Ishiwa et al., 2020). However, the previous studies generally used one core sample for each lake in most cases, and it is necessary to proceed with an analysis of multiple core samples to reconstruct detailed environmental changes in the lake. Lake Nurume at Langhovde, Lützow Holm Bay is isolated from the sea by ~1 m sill, and a perennial snow patch is well developed in the southeast of the lake. In the geomorphological survey of the 61st Japanese Antarctic Research Expedition, we collected four sediment cores in Lake Nurume and also measured water column profiles (e.g., salinity, temperature, and turbidity) and detailed lake bathymetry (Ishiwa et al., in press). We will present preliminary results of these cores, such as radiocarbon dating, XRF, X-ray CT scanning, and microfossils analysis of the cores. Combining geological settings and obtained results in Lake Nurume provides significant insight into paleoenvironmental reconstruction around Lützow Holm Bay. Moreover, the dataset will be a valuable archive of paleoenvironmental studies using lake sediments in Antarctica.

Keywords: East Antarctica, Lake sediments

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Assessing dust-magnetic correlation in the Indian sector of the Southern Ocean

*Hiroki Matsui[1], Minoru Ikehara[2], Yusuke Suganuma[3,4], Osamu Seki[5], Ikumi Oyabu[3], Kenji Kawamura[3,4]

1. Graduate School of International Resource Sciences, Akita University, 2. Center for Advanced Marine Core Research, Kochi University, 3. National Institute of Polar Research, Research Organization of Information and Systems, 4. Department of Polar Science, School of Multidisciplinary Sciences, The Graduate University for Advanced Studies (SOKENDAI), 5. Institute of Low Temperature Science, Hokkaido University

Understanding Antarctic climate change requires integration of marine and ice core records. Recent advances in transfer of ice core chronology to marine core by signal matching will eventually allow direct comparison between marine and ice core records. Dust-magnetic correlation which utilizes great similarity between magnetic susceptibility of marine cores and aeolian dust of ice cores has been increasingly used in the Scotia Sea and the Pacific sector of the Southern Ocean (SO). However, dust-magnetic correlation has rarely been assessed in the Indian sector of the SO, hampering circum-Antarctic application of the method. Here we test dust-magnetic correlation in the Indian sector of the SO through the last 400 kyrs by age-depth model comparison of dust-magnetic correlation, oxygen isotope correlation, and published radiocarbon dates. We discuss potential effect of age-depth errors and bioturbation process to integrate traditional marine core chronologies with ice core chronology.

Keywords: Dust-magnetic correlation, Age-depth model, Southern Ocean

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Antarctic warmth in the last interglacial driven by Northern insolation and deglaciation

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1. Atmosphere and Ocean Research Institute, the University of Tokyo, 2. National Institute of Polar Research, Japan, 3. Japan Agency for Marine-Earth Science and Technology

The global mean sea level in the last interglacial (LIG, about 130,000 to 115,000 years before present) was very likely higher than the present level, driven mainly by mass loss of the Antarctic ice sheet. Some studies have suggested that this mass loss may have been caused by the warmer temperature over the Southern Ocean in the LIG compared with the present interglacial. However, the ultimate cause of the difference in Antarctic warming between the last and current interglacials has not been explained. Here, based on transient simulations of the last deglaciation using a fully coupled ocean–atmosphere model, we show that greater meltwater (by a factor of 1.5 relative to the last deglaciation) during the middle and later stages of the deglaciation could have produced the difference in Antarctic warmth. Northern Hemisphere ice sheet model experiments suggest that the difference in meltwater was caused by slightly smaller orbital eccentricity in our current interglacial than in the LIG, indicating that mass loss of the Antarctic ice sheet is influenced by the preceding northern summer insolation and disintegration of Northern Hemisphere ice sheets.

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Modeling the ocean carbon cycle during the last deglaciation

*Hidetaka Kobayashi[1], Akira Oka[1], Takashi Obase[1], Ayako Abe-Ouchi[1]

1. Atmosphere and Ocean Research Institute, The University of Tokyo

Ice core records show that the atmospheric carbon dioxide concentration (pCO2) varied with an amplitude of about 100 ppm during glacial-interglacial cycles. Although not yet fully understood, it is recognized that the variation of atmospheric pCO2 is mainly due to changes in the ocean carbon cycle (e.g., sea surface temperature, biological carbon pump, ocean circulation, and carbonate inorganic chemistry). Recent studies, including those of the authors, point to the importance of changes in the Southern Ocean for the changes in the ocean carbon cycle. On the other hand, these consequences are mainly derived from comparisons of the carbon cycle under equilibrium climates, and more practically, the mechanisms of the transient responses of the carbon cycle that occur in the context of temporal changes in climate need to be finally clarified. Using the results of our modeling study, in which a complex coupled atmosphere-ocean general circulation model reproduces well the deep ocean circulation and surface temperature changes during the Bolling-Allerod (BA) transition, we investigate the transient response of the ocean carbon cycle during the last deglaciation between 21,000 and 11,000 years ago. We report the preliminary results of the transient simulation. In particular, we focus on the response of the ocean carbon cycle to rapid changes in the Atlantic meridional overturning circulation during the BA transition.

Keywords: ocean carbon cycle, last deglaciation, Atlantic meridional overturning circulation, Southern Ocean

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

Sun. Jun 6, 2021 3:30 PM - 5:00 PM JST | Sun. Jun 6, 2021 6:30 AM - 8:00 AM UTC | Ch.11 Zoom Room 11

[M-IS05] Global climate change driven by the Southern Ocean and the Antarctic Ice Sheet

convener:Osamu Seki(Institute of Low Temperature Science, Hokkaido University), Yoshifumi Nogi(National Institute of Polar Research), Akira Oka(Atmosphere and Ocean Research Institute, The University of Tokyo), Yusuke Suganuma(National institute of Polar Research), Chairperson:Hidetaka Kobayashi(Atmosphere and Ocean Research Institute, The University of Tokyo)

The Southern Ocean and Antarctic ice sheet, which are the giant reservoirs of heat, water, and materials, have a potential to play central roles in long-term global climate change. This system is composed of the following sub-systems; ice shelf which is a place of the interaction of ice sheet and ocean, flowing iceberg, seasonal sea ice zone, Antarctic bottom water which drives the thermohaline circulation, active biological production and Antarctic Circumpolar Current. These sub-systems are interacted with each other and have significant impact on changes in the global environmental system. This session aim to summarize recent observational and simulation studies from various fields relating to the past and present changes in the Antarctic Ice sheet and Southern Ocean, which are essential elements for unraveling the changes in the global climate system. Further, future science plans for understanding of the environmental changes of the Antarctic Cryosphere is also discussed.

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

[MIS05-12] Last Glacial Maximum Antarctic sea ice linked with global mean ocean temperature: evidence from PMIP3, PMIP4 and MIROC-4m simulations

*Tristan Vadsaria[1], Sam Sherriff-Tadano[2,1], Ayako Abe-Ouchi[1], Takashi Obase[1], Wing-Le Chan[1], Xavier Crosta[3] (1.Atmosphere and Ocean Research Institute, The University of Tokyo, Japan, 2.School of Earth and Environment, The University of Leeds, Leeds, UK, 3.Environnements et Paléoenvironnements Océanique et Continentaux, Pessac, France)

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

[MIS05-13] Antarctic Slope Current modulates warm ocean heat intrusions towards Totten Glacier

*Yoshihiro Nakayama[1], Chad A Greene[2], Fernando S Paolo[2], Vigan Mensah[1], Hong Zhang[2], Haruhiko Kashiwase[3], Daisuke Simizu[3], Jamin S Greenbaum[4], Donald D Blankenship[5], Ayako Abe-Ouchi[6], Shigeru Aoki[1] (1.Institute of Low Temperature Science, Hokkaido University, Japan, 2.NASA Jet Propulsion Laboratory, California, USA, 3.National Institute of Polar Research, Tokyo, Japan, 4.Scripps Institution of Oceanography, University of California, California USA, 5.Institute for Geophysics, University of Texas at Austin, Texas, USA, 6.Atmosphere and Ocean Research Institute, The University of Tokyo, Tokyo, Japan.)

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

[MIS05-14] Sea Ice Variations in Coastal Amundsen Sea Affected by Ice Shelf Meltwater

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

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

[MIS05-15] Observation of plagic system using a drifter off Wilkes land during sea ice melting season

*Ryosuke Makabe[1,5,2], Keigo Takahashi[2], Shintaro Takao[3], Ryo Matsuda[4], Masayoshi Sano[1], Kohei Mizobata[5], Norio Kurosawa[4], Masato Moteki[5,1], Tsuneo Odate[1,2] (1.National Institute of Polar Research, 2.The Graduate University for Advanced Studies (SOKENDAI), 3.National Institute for Environmental Studies, 4.Soka University, 5.Tokyo University of Marine Science and Technology)

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

[MIS05-16] Primary production and carbon export related to sub-surface chlorophyll maximum off Wilkes land during post bloom season

*Norio Kurosawa[1], Ayuko Kagesawaa[2], Ryosuke Makabe[3,2,4], Shintaro Takao[5], Masayoshi Sano[3], Kohei Mizobata[4], Masato Moteki[4,3], Tsuneo Odate[2,3] (1.Soka University, 2.The Graduate University for Advanced Studies (SOKENDAI), 3.National Institute of Polar Research, 4.Tokyo University of Marine Science and Technology, 5.National Institute for Environmental Studies)

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

[MIS05-17] Contribution of fecal pellet-like dinoflagellates to the carbon sequestration in the seasonal ice zone of the Southern Ocean

*Ryo Matsuda[1], Jaekyeng Han[1], Shinya Okano[1], Masayoshi Sano[2], Shintaro Takao[3], Ryosuke Makabe[2,4,5], Masato Moteki[4,5], Tsuneo Odate[2,4], Norio Kurosawa[1] (1.Soka University, 2.National Institute of Polar Research, 3.National Institute for Environmental Studies, 4.The Graduate University for Advanced Studies (SOKENDAI), 5.Tokyo University of Marine Science and Technology)

Last Glacial Maximum Antarctic sea ice linked with global mean ocean temperature: evidence from PMIP3, PMIP4 and MIROC-4m simulations

*Tristan Vadsaria[1], Sam Sherriff-Tadano[2,1], Ayako Abe-Ouchi[1], Takashi Obase[1], Wing-Le Chan[1], Xavier Crosta[3]

1. Atmosphere and Ocean Research Institute, The University of Tokyo, Japan, 2. School of Earth and Environment, The University of Leeds, Leeds, UK, 3. Environnements et Paléoenvironnements Océanique et Continentaux, Pessac, France

Southern Ocean sea ice and oceanic fronts are known to play an important role on the climate system, carbon cycles, bottom ocean circulation, and Antarctic ice sheet. However, many models of the previous Past-climate Model Intercomparison Project (PMIP) underestimated sea-ice extent (SIE) for the Last Glacial Maximum (LGM)(Roche et al., 2012; Marzocchi and Jensen, 2017), mainly because of surface bias (Flato et al., 2013) that may have an impact on mean ocean temperature (MOT). Indeed, recent studies further suggest an important link between Southern Ocean sea ice and mean ocean temperature (Ferrari et al., 2014; Bereiter et al., 2018 among others). Misrepresent the Antarctic sea-ice extent could highly impact deep ocean circulation, the heat transport and thus the MOT. In this study, we will stress the relationship between the distribution of Antarctic sea-ice extent and the MOT through the analysis of the PMIP3 and PMIP4 exercise and by using a set of MIROC models. To date, the latest version of MIROC improve its representation of the LGM Antarctic sea-ice extent, affecting the deep circulation and the MOT distribution (Sherriff-Tadano et al., under review).

Our results show that available PMIP4 models have an overall improvement in term of LGM sea-ice extent compared to PMIP3, associated to colder deep and bottom ocean temperature. Focusing on MIROC (4m) models, we show that models accounting for Southern Ocean sea-surface temperature (SST) bias correction reproduce an Antarctic sea-ice extent, 2D-distribution, and seasonal amplitude in good agreement with proxy-based data. Finally, using PMIP-MIROC analyze, we show that it exists a relationship between the maximum SIE and the MOT, modulated by the Antarctic intermediate and bottom waters.

Keywords: Antartic sea-ice, Last Glacial Maximum , Mean Ocen Temperature, MIROC simulations, PMIP3 and PMIP4 simulations

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Antarctic Slope Current modulates warm ocean heat intrusions towards Totten Glacier

*Yoshihiro Nakayama[1], Chad A Greene[2], Fernando S Paolo[2], Vigan Mensah[1], Hong Zhang[2], Haruhiko Kashiwase[3], Daisuke Simizu[3], Jamin S Greenbaum[4], Donald D Blankenship[5], Ayako Abe-Ouchi[6], Shigeru Aoki[1]

1. Institute of Low Temperature Science, Hokkaido University, Japan, 2. NASA Jet Propulsion Laboratory, California, USA, 3. National Institute of Polar Research, Tokyo, Japan, 4. Scripps Institution of Oceanography, University of California, California USA, 5. Institute for Geophysics, University of Texas at Austin, Texas, USA, 6. Atmosphere and Ocean Research Institute, The University of Tokyo, Tokyo, Japan.

The Totten Glacier in East Antarctica has received increasing attention in recent years for its ice loss and warm oceanographic conditions observed at the ice shelf front. Here, we developed satellite estimates of temporally varying Totten Ice Shelf (TIS) melt rates and a high-resolution ocean model. We show that the Antarctic Slope Current (ASC) impedes ocean heat intrusions onto the continental shelf, whereas on-shelf intrusions are enhanced when the ASC weakens. Our findings suggest that atmospheric and oceanic conditions beyond our regional model domain play a greater role than local wind stress curl or other factors in driving interannual variability of the ASC. We further show that heat intrusions towards the TIS are enhanced with coastal freshening, suggesting a positive feedback whereby even freshening due to ice loss in West Antarctica could start a chain reaction, leading to increased melt in East Antarctica, and further coastal freshening.

Keywords: Southern Ocean, Ice shelf-ocean interaction, Circumpolar Deep Water

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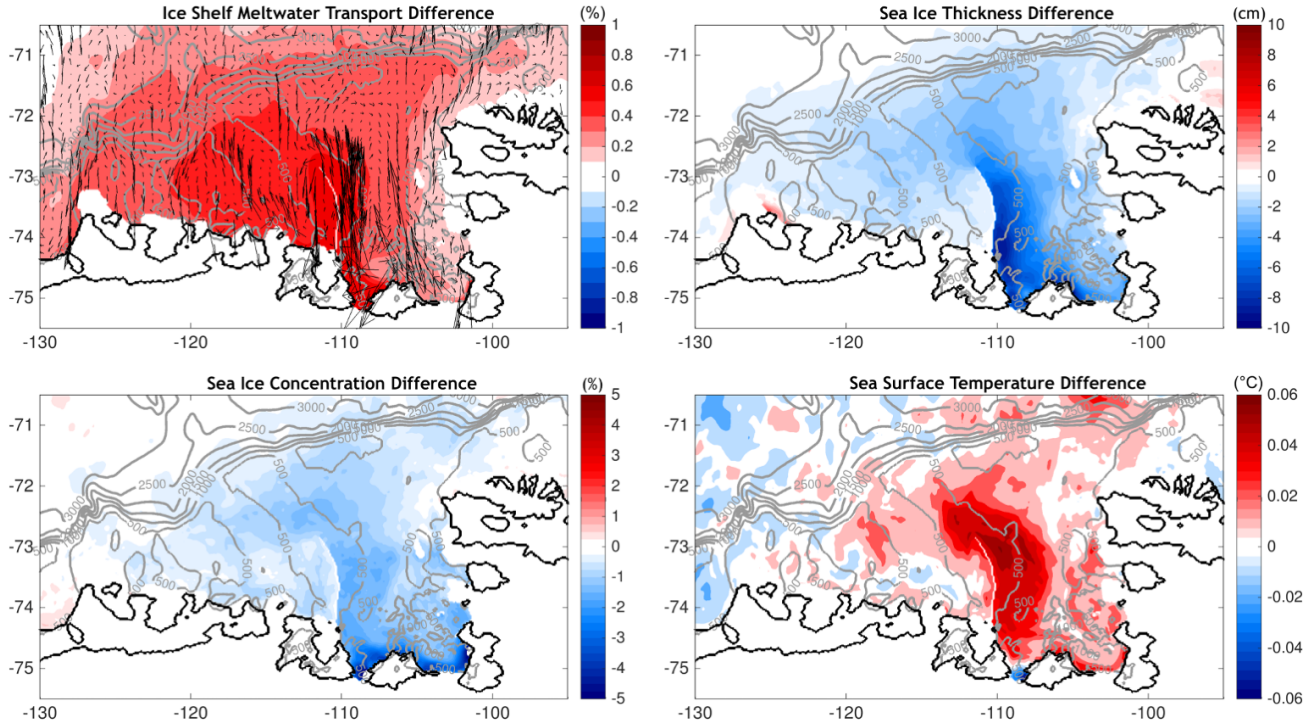
Sea Ice Variations in Coastal Amundsen Sea Affected by Ice Shelf Meltwater

*KOFAN LU[1]

1. Japan Agency for Marine-Earth Science and Technology

Meltwater outflows from Pine Island Embayment become more important in changing the ocean circulations in the coastal Amundsen along with the elevated basal melt of ice shelves. Sea ice variations in Amundsen Sea is modified by a combination of thermodynamic and dynamic processes, while in coastal areas dynamical process determined by ocean circulations is more dominant. A melt rate-controlled model set is developed to study the changes of the surface hydrography and sea ice distributions when double the melt rate (~ +135 Gt/yr in total) of Pine Island and Thwaites Glaciers. The increasing meltwater outflows from Pine Island Embayment transport westward and flush the sea ice drift, leading to both lower sea ice concentration and thickness along the coast. Sea ice concentration drops ~2% in average inthe coastal areas and sea ice thickness reduces ~10 cm in maximum. Due to the declined albedo that follows the lower sea ice concentration, the sea surface temperature increases ~0.06˚C in maximum. Although this surface warming occurs only in the upper layer (~100 m) and would not feedback to the ice shelf melt, the stored surface heat delays the sea ice formation and shorten freezing season. Changes of sea ice seasonal cycle by ice shelf meltwater are further investigated to evaluate the importance of thermodynamic and dynamic processes, which helps to assess the future sea ice trend under the climatological perturbations of surface heat budget in Amundsen Sea.

Keywords: Amundsen Sea sea ice, Pine Island Glacier, Thwaites Glacier, ice shelf meltwater



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Observation of plagic system using a drifter off Wilkes land during sea ice melting season

*Ryosuke Makabe[1,5,2], Keigo Takahashi[2], Shintaro Takao[3], Ryo Matsuda[4], Masayoshi Sano[1], Kohei Mizobata[5], Norio Kurosawa[4], Masato Moteki[5,1], Tsuneo Odate[1,2]

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Ice edge phytoplankton bloom is one of the most important events to regulate primary production, which accelerates biological carbon pump in the seasonal ice zone in the Southern Ocean. Improvement of light condition and iron supply with sea ice melt are thought to be critical factors for development of the ice edge bloom. Thus, relationship between sea ice dynamics and biological activity is essential for understanding not only ecosystem structure and its dynamics but also carbon sequestration. Ice edge blooms were found only in situation with <40% sea ice cover. In that time, amount of sea ice had already melted, i.e. most of materials and algae in sea ice had already been released into water column. Therefore, time-series observation should be started at earlier phase of sea ice melt to understand dynamics of ice edge bloom and related biogeochemical cycles. We designed an ice guard GPS buoy for drifter observation attached with sensor frames and time series sediment traps at various depth to reveal surface condition and export flux during ice melting season.

A drifter observation was conducted in austral summer 2019/2020 during ice breaker *Shirase* cruise under 61st Japanese Antarctic Research Expedition. A drifter was deployed at 64.26˚S, 115.96˚E on 9th Dec., 2019 and retrieved at 64.55˚S, 104.79˚E on 16th Feb., 2020. All instruments, i.e. sensors attached to GPS frame and four sensor frames, two time-series sediment traps and an Acoustic Doppler Current Profiler (ADCP, 300 kHz) worked. At the deployment and retrieval sites, a CTD cast for vertical profiles of physical parameters and water sampling for determination of chlorophyll *a* (chl. *a*), particulate organic carbon/nitrogen (POC/N) and phytoplankton community structure. Three closing net tows for zooplankton analyses were conducted from 200-100, 100-50 and 50-0 m depth layers. Ten sea ice collections for analyzing sea ice components (salinity, chl. *a*, POC/N, taxonomic composition of ice algae) were also obtained at deployment site.
Less variability in depth of all instruments indicates that the drifter array was relatively stable even in dense sea ice situation. Sea ice concentration at deployment site was over 90%, which rapidly decreased from end of December to early January. Chlorophyll fluorescence at 20 m depth increased with decrease of sea ice concentration. However quite rapid increase in the fluorescence in higher (>50%) sea ice concentration. The euphotic layer depth (1% PAR) was still shallower than 20 m at the same time, and an increase in dissolved oxygen at 20 m depth occurred after the fluorescence peak. These suggested that the fluorescence peak at 20 m depth was caused by rather released ice algae than primary production in surface water column. After then, increase in fluorescence was also found at 30 m depth following the increase at 40 m depth. These changes in peak depth of fluorescence means that temporal changes of productive layer, i.e. transition from ice edge bloom to sub-surface chlorophyll maximum. Size composition of chl. *a* and taxonomic composition of algae in sea ice showed dominance of diatom. The abundance in the water column at deployment site was dominated by smaller taxa (<10 μm), and this was replaced by larger taxa (>10 μm) at retrieval site. Macro-nutrients at surface layer decreased indicates amount of diatom production as well as microbial degradation during the study period. We will also discuss zooplankton composition and the vertical migration pattern during ice melting season by using ADCP data.

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Keywords: seasonal ice zone, sea ice melt, pelagic ecosystem

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Primary production and carbon export related to sub-surface chlorophyll maximum off Wilkes land during post bloom season

*Norio Kurosawa[1], Ayuko Kagesawaa[2], Ryosuke Makabe[3,2,4], Shintaro Takao[5], Masayoshi Sano[3], Kohei Mizobata[4], Masato Moteki[4,3], Tsuneo Odate[2,3]

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In the Southern Ocean, ecological studies have mainly focused on ice edge phytoplankton blooms. This bloom is usually decline within 10-14 days, after then, sub-surface chlorophyll maximum (SCM) is often found widespread in the seasonal ice zone in austral summer. Structures and ecological roles of SCM have been reported especially in sub-tropical regions. Less is known in the seasonal ice zone in the Southern Ocean, although the important roles for trophic link and carbon cycling were implied by previous snap shots.

We conducted two time-series survey using a drifter array with series of ship based observation around the drifter to reveal the pelagic environment, net primary production (NPP) and export flux when SCM developed, during Southern Ocean cruises of T/RV Umitaka-maru of Tokyo University of Marine Science and Technology. The experiments were conducted off Vincennes Bay (63.5˚S, 110˚E) from January 17-18, 2017 and January 14-19, 2019. A drifter was composed of GPS buoy, 4 sensor frames (attached with CTD, Chl. sensor and PAR sensor), an upward looking ADCP (300 kHz) and sediment traps. Multiple CTD casts were also conducted to determine vertical profiles of physical parameters and to sample waters for measurements of macro-nutrients, chlorophyll *a* (chl. *a*), particulate organic matters (POC and PON) and phytoplankton abundance.

In 2017, SCM was found at 40-50 m depth with lower chl. *a* of less than 0.4 μg L^{-1}. NPP was vertically even ranged 0.4-5.5 mg C m^{-3}. Standing stock of POC highly decreased during 24 hours due to other than export flux, suggesting high microbial activity which was probably enhanced by small haptophytes dominant food web. On the other hand, marked high SCM, reached 2.0 μg L^{-1} was found in 2019. NPP was 4 times higher at 10 m depth than that at SCM depth, and surface (0-40 m depth) integrated NPP was higher in the latter period than the former. The temporal changes in NPP would be relation to increase in large diatom abundance (e.g. *Chaetoceros* spp.). Standing stock of POC was increased in the upper (0-60 m) layer in the latter period, and, at the same time, production-export (P-E) ratio also increased in the lower layer (60-150 m). Temporal changes in temperature at various depth indicates that nutrient supply by vertical mixing was higher in 2019 than in 2017, which would cause differences in biomass and NPP between two years. Increase in standing stock of silicic acid and low δ^{13}C values in POM at SCM in 2019 also supported strong influence of deeper waters. Southern Annular Mode (SAM) from November to January was positive in 2018/19 and negative in 2016/17, respectively. This might cause the difference in pelagic system in two seasons. By the way, diel vertical migration of meso- to macro-zooplankton detected by an ADCP back-scatter suggested strong relationship between SCM and zooplankton communities in 2019.

We found a bottom up regulation of SCM structures. SCM was mainly formed by accumulation of phytoplankton at thermocline, which would play roles as a hot spot of herbivorous and omnivorous feeding of zooplankton community. Further studies focusing on biogeochemical contribution of SCM with physico-chemical conditions relation to SAM are needed for understanding changing ecosystems with

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climate changes in the Antarctic seasonal ice zone.

Keywords: Southern Ocean, phytoplankton bloom, seasonal ice zone, sub-surface chlorophyll maximum

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Contribution of fecal pellet-like dinoflagellates to the carbon sequestration in the seasonal ice zone of the Southern Ocean

*Ryo Matsuda[1], Jaekyeng Han[1], Shinya Okano[1], Masayoshi Sano[2], Shintaro Takao[3], Ryosuke Makabe[2,4,5], Masato Moteki[4,5], Tsuneo Odate[2,4], Norio Kurosawa[1]

1. Soka University, 2. National Institute of Polar Research, 3. National Institute for Environmental Studies, 4. The Graduate University for Advanced Studies (SOKENDAI), 5. Tokyo University of Marine Science and Technology

Ice edge phytoplankton bloom is an important factor affecting on the food web and the carbon sequestration in the seasonal ice zone of the Southern Ocean. As a sinking particulate organic carbon (POC), zooplankton fecal pellets, marine snow, and phyto-detritus are known as important drivers for export carbon flux from surface layer. To investigate composition of sinking particles and those variability with sea ice melts, sinking particles have been recovered in off Wilkes land since the austral summer in 2016. In the preliminarily observation, we found a large number of fecal pellet (FP)-like dinoflagellates (FLDs) containing phytoplankton in the trap samples at 50 m taken in 2016. The export fluxes in this season would be underestimated to assess FLDs as FP. In the present study, we investigated on FLD's dynamics during the melting of sea ice.

Sediment traps were deployed at 50 m depth (63°52' S, 109°87' E) from December 10, 2016 to January 8, 2017, at 50 m and 80 m (63°29' S, 110°00' E) from January 17-18, 2017, at the 60 m and 150 m (63°29' S, 109°59' E) from January 14 to 19, 2019, at the 60 m and 150 m (64°16' S, 116°58' E) from December 10, 2019 to January 20, 2020. Sinking particle samples were fixed in neutral Lugol's solution (final conc. 5-20%) and stored at 4℃ until analysis. After removing zooplankton swimmers, FLDs and FPs were identified into several groups based on their morphological characteristics. Numbers and lengths of them were counted and measured under the optical microscope. POC fluxes were estimated using numbers and volumes of FLDs and FPs. To reveal the organisms predated by the FLDs, the eukaryotic community structures were analyzed by high throughput sequencing of 18S rRNA gene amplicons (V9 region) using the total DNA of FLDs. Taxonomic affiliations were assigned using PR2 database.

Based on morphological features such as protrusions and grid-like patterns on the cell membrane, FLDs were found in all samples except for short term observation in January 17-18, 2017. As similar cells have been found in the other Antarctic waters, which were tentatively identified to be dinoflagellates, the FLDs was also assumed to be a type of dinoflagellates. FLDs, which were covered by thin membrane were resolved and released ellipsoidal FPs. The POC fluxes of FLDs and its derived ellipsoidal FPs was 5.1 ±5.4 mg C m^{-2} day^{-1} in the spring of 2016 at depth of 50 m and were 1.3 ±0.8 mg C m^{-2} day^{-1} and 0.2 ±0.2 mg C m^{-2} day^{-1} in the summer of 2019 at depths of 60 m and 150 m. These values were almost equal to depths of 60 m and 150 m from the spring of 2019 to the summer of 2020. Those results indicate the melting sea ice season and the dynamics of FLDs are closely, and the FLDs still contribute to the carbon transport even one month after sea ice melting. In the analysis of the eukaryotic community structure of FLDs, 69 ±32% of the total OTU was identified to a dinoflagellate *Gyrodinium rubrum*, which was estimated to be FLDs itself. The remaining OTUs, the contents of the FLDs mainly consisted of other species of *Dinoflagellata* (37 ±25%), *Ochrophyta* (36 ±27%), unidentified Eukaryota (16 ±27%). The eukaryotic communities of the ellipsoidal FPs showed similar structures, suggesting that the ellipsoidal FPs were derived/discharged from FLDs, which is consistent with the microscopic observation as mentioned above. Comparison of the eukaryotic community structure of FLD contents with that in seawater indicated that FLDs were estimated to be an opportunistic feeder.

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In this study, dinoflagellates, which are similar to fecal granules were found, and they contributed to carbon sequestration into the depth layers in conjugation with the occurrence of ice bloom. It is essential to further investigate the physiology and ecology of this species to deeply understand the carbon transport in the Southern Ocean.

Keywords: Southern Ocean, carbon sequestration, fecal pellet-like dinoflagellates, sediment trap, Gyrodinium rubrum

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

Sun. Jun 6, 2021 10:45 AM - 12:15 PM JST | Sun. Jun 6, 2021 1:45 AM - 3:15 AM UTC | Ch.22 Zoom Room 22

[M-IS08] Interdisciplinary studies on pre-earthquake processes

convener:Katsumi Hattori(Department of Earth Sciences, Graduate School of Science, Chiba University), Dimitar Ouzounov(Center of Excellence in Earth Systems Modeling & Observations (CEESMO) , Schmid College of Science & Technology Chapman University, Orange, California, USA), Jann-Yenq LIU(Department of Space Science and Engineering, National Central University, Taiwan), Qinghua Huang(Peking University), Chairperson:Katsumi Hattori(Department of Earth Sciences, Graduate School of Science, Chiba University), Dimitar Ouzounov(Center of Excellence in Earth Systems Modeling & Observations (CEESMO) , Schmid College of Science & Technology Chapman University, Orange, California, USA)

The year 2021 is the memorial year of the 2011 Tohoku Earthquake (M9.0). For the past decade, we have advanced our knowledge of precursors and earthquake preparation processes.
This session expands the interdisciplinary discussions on the preparation process of earthquake and earthquake predictability by presenting the latest progress in studying the physically based pre-earthquake phenomena. New observations from space and ground have provided evidence, enhancing a better understanding of the tectonic activity. The session anticipates talks that include but is not limited to observations and analyses of seismic, electrical, electromagnetic, electro-chemical, and thermodynamic processes related to stress changes in the lithosphere along with their statistical and physical validation. Presentations on the latest observational results associated with major earthquakes obtained by different methodologies are welcomed. The topics of the session are as follows but not limited.

-General discussion on earthquake preparation process and the physics of pre-earthquake signals
- Theory, modeling, laboratory experiments, computational simulation for generation and propagation of pre-earthquake signals and their connection with the seismic cycle
- Multi-parameter observations, detection, and validation of pre-earthquake signals
- Cross-disciplinary studies, practical and technical approaches for better understanding of earthquake preparation processes and their connection with seismicity.

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

[MIS08-01] The spatiotemporal evolution of pre-earthquake anomalies and their association with the activation zone

*Dimitar Ouzounov[1], Sergey Pulinets[2], J.Y Liu[3], Katsumi Hattori[4], Patrick Taylor[5] (1.Center of Excellence in Earth Systems Modeling & Observations (CEESMO) , Schmid College of Science & Technology Chapman University, Orange, California, USA, 2.Space Research Institute, Russian Academy of Sciences, Moscow, Russia, 3.Center for Space and Remote Sensing Research, National Central University, Taoyuan, Taiwan, 4.Department of Earth Sciences, Graduate School of Science, Chiba University, Chiba, Japan, 5.NASA GSFC, Greenbelt, MD, USA)

11:00 AM - 11:20 AM JST | 2:00 AM - 2:20 AM UTC

[MIS08-02] The multi observations on electromagnetic emissions and plasma perturbations around Yutian Earthquakes in China

★Invited Papers

*Xuemin Zhang[1], Jing Liu[1], Angelo De Santis[2], Loredana Perrone[2], Xuhui Shen[3], Jianping Huang[3] (1.Institute of Earthquake Forecasting, China Earthquake Administration, 2.Istituto Nazionale di Geofisica e Vulcanologia, 3.Institute of Crustal Dynamics, China Earthquake Administration)

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

[MIS08-03] Bizarre “earthquake weather” immediately before and after the 1995 Kobe earthquake

*Yuji Enomoto[1], Tsuneaki Yamabe[1], Shigeki Sugiura[2], Hitoshi Kondo[2] (1.Shinshu Univeristy, Ueda Campus Fii, 2.Genesis Research Institute Inc.)

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

[MIS08-04] A system of the Monitoring Vibrations and Propagations in the Lithosphere, Atmosphere, and Ionosphere

*Chieh-Hung Chen[1], Yang-Yi Sun[1], Kai Lin[1], Huaizhong Yu[2] (1.Institute of Geophysics and Geomatics, China University of Geosciences, Wuhan, Hubei, China, 2.China Earthquake Networks Center, Beijing, China)

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

[MIS08-05] Assessing the potential earthquake precursory information in ULF magnetic data recorded in Kanto, Japan during 2000 – 2010: distance and magnitude dependences

★Invited Papers

*Peng Han[1], Jiancang Zhuang[2], Katsumi Hattori[3], Chieh-Hung Chen[4], Febty Febriani[5], Hongyan Chen[1] (1.Southern University of Science and Technology, Shenzhen, China, 2.The Institute of Statistical Mathematics, Tokyo, Japan, 3.Graduate School of Science, Chiba University, Chiba, Japan, 4.Institute of Geophysics and Geomatics, China University of Geosciences, Wuhan 430074, China, 5.Research Center for Physics, Indonesian Institute of Sciences, Tangerang, Banten, Indonesia)

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

[MIS08-06] Discussion

The spatiotemporal evolution of pre-earthquake anomalies and their association with the activation zone

*Dimitar Ouzounov[1], Sergey Pulinets[2], J.Y Liu[3], Katsumi Hattori[4], Patrick Taylor[5]

1. Center of Excellence in Earth Systems Modeling & Observations (CEESMO) , Schmid College of Science & Technology Chapman University, Orange, California, USA, 2. Space Research Institute, Russian Academy of Sciences, Moscow, Russia, 3. Center for Space and Remote Sensing Research, National Central University, Taoyuan, Taiwan, 4. Department of Earth Sciences, Graduate School of Science, Chiba University, Chiba, Japan, 5. NASA GSFC, Greenbelt, MD, USA

We studied the temporal and spatial phenomenon between Thermal Radiation (TRA); Ionospheric total electron content (TEC); and; abnormal patterns of radon data and their relationship with earthquake activation zones (EAZ). For the estimates of each EAZ, we use Dobrovolsky et al. (1979) and Bowman et al. (1998), where the EAZ radius scales exponentially with earthquake magnitude, especially for Mw 6.0 and larger. This gives a broader study of larger magnitudes earthquakes and TRA and TEC anomalies. We analyzed 10 large (M6+) earthquakes (2004-2019) for TRA and TEC anomalies in each of the EAZ zones. Our results show evolutionally patterns in the appearance of pre-earthquake transient effects in the atmosphere and ionosphere, with a short time-lag, from hours up to a few days, and scalable with a magnitude estimate at their unusually far distance from the epicenter (for the M7+ events). The spatial characteristics of pre-earthquake anomalies were associated with the larger area but always inside the preparation-activation region estimated by Dobrovolsky-Bowman. The pre-earthquake pattern of the atmosphere and ionosphere signals, revealed by a simultaneous analysis of satellite, GPS/TEC, Satellite Earth observations, and ground data, all suggesting that these earthquakes follow a global recognizable spatial pattern of TRA and TEC.

Keywords: pre-earthquake, precursor, thermal anomaly, GPS/TEC

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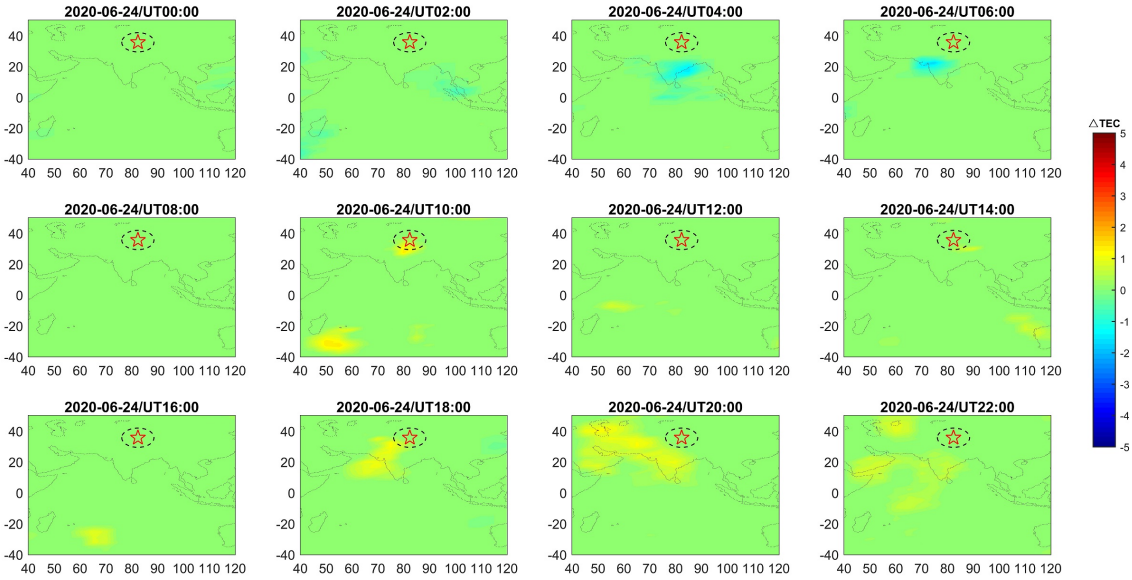
The multi observations on electromagnetic emissions and plasma perturbations around Yutian Earthquakes in China

*Xuemin Zhang[1], Jing Liu[1], Angelo De Santis[2], Loredana Perrone[2], Xuhui Shen[3], Jianping Huang[3]

1. Institute of Earthquake Forecasting, China Earthquake Administration, 2. Istituto Nazionale di Geofisica e Vulcanologia, 3. Institute of Crustal Dynamics, China Earthquake Administration

Based on the multi data of TEC inversed from GPS observations in China mainland, TEC mapping published by JPL, electron density from Zhangheng-1 satellite, electromagnetic data from ground geomagnetic observatories and ZH-1 satellite, the ionospheric perturbations were mainly analyzed around Yutian Ms6.4 earthquake on 26 June 2020, in Xinjiang Uygur Autonomous Region. The plasma perturbations were revealed from peak F2 layer to the topside ionosphere at satellite height about 507km. The electromagnetic emissions were enhanced before the earthquake, but its seasonal variations make it difficult to distinguish those anomalies possibly related to the earthquake. The consistence from ground and space-borne experiments may help to validate the earthquake-associated disturbances. Combined with the results for other three earthquakes in Yutian with magnitude larger than 6.0 during 2008-2020, it is found that the seismo-ionospheric disturbances concentrated 1 week before, mainly with increasing features and local effects, in which some showed simultaneous anomaly at its conjugate region. The comprehensive multi data analysis can improve the distinguishing capability for earthquake-related anomalies, and enhance their reliability. The solar activity and space magnetic disturbances will cause high frequent anomaly occurrence in the global maps, and influence heavily for abstracting the seismo-ionospheric signals. But a case study for solar eclipse on 21 June 2020 induced decreasing TEC anomalies, which is totally different with those related to Yutian earthquake, whatever in region or abnormal state. The LAIC couping process was discussed finally, and the effects from overlapped electric field were simulated by SAMI-2 model in high and low solar activity year.

Keywords: GPS TEC, CSES satellite, Ionospheric perturbation, LAIC model



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Bizarre “earthquake weather” immediately before and after the 1995 Kobe earthquake

*Yuji Enomoto[1], Tsuneaki Yamabe[1], Shigeki Sugiura[2], Hitoshi Kondo[2]

1. Shinshu Univeristy, Ueda Campus Fii, 2. Genesis Research Institute Inc.

In the Kobe earthquake that occurred at 5:46 LT on January 17, 1995, the night sky, which should normally be dark immediately before and after, became bright and changed to bluish purple, white, and red. Among the many eyewitness testimonies (e.g. Sakaguchi, 2007), a series of photographs, taken by N. Yokota (lived in Izumiotsu, Osaka) in the direction of the epicenter[E1] , scientifically support this bizarre earthquake weather. (See Fig. 1). Radon emanation from faults, earthquake lights, and appearance of sporadic E in ionosphere have been reported associated with this earthquake. Based on this information, causal mechanisms of two kinds of the earthquake weather: whitish illuminants with extending streak clouds and bluish/purple- and red-colored clouds, are proposed as follows.

One is the radioluminescence that occurred in the atmosphere above around the epicenter due to emanation of a large amount of ^{222}Rn from the fault, that is, the ionization of nitrogen molecules and water molecules due to the α-ray irradiation during the radon decay, which resulted in EQL, the generation of high-frequency electromagnetic waves and generation of whitish streak clouds due the cloud chamber effect of γ-rays.

Secondly, regarding the origin of the blue-purple clouds and red clouds in the sky, we propose that the Sun light was color-dispersed due to the electro-optical interaction (Pockels/Kerr effect) between the sunlight shining into the ionosphere and the ionospheric electric field.

This is probably the first time in the world that such bizarre earthquake weather has been confirmed.

[E1]

Keywords: 1995Kobe earthquake, Earthquake weather, Radioluminescence, Electro-optical effect

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Fig.1 a) Map, b) photo showing bizarre earthquake weather just after the 1995 Kobe EQ, c) the simulated night sky which should be dark (StellaNavigator ver.5)

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A system of the Monitoring Vibrations and Propagations in the Lithosphere, Atmosphere, and Ionosphere

*Chieh-Hung Chen[1], Yang-Yi Sun[1], Kai Lin[1], Huaizhong Yu[2]

1. Institute of Geophysics and Geomatics, China University of Geosciences, Wuhan, Hubei, China, 2. China Earthquake Networks Center, Beijing, China

Scientists have reported that pre-earthquake anomalous phenomena can be observed in numerous distinct fields. These anomalous phenomena were classified into different groups based on promising relationships from potential mechanisms. However, the promising relationships among distinct parameters in a group are sometimes questionable due to that a certain distance exists between adjacent stations. A novel system was established in Leshan, Sichuan, China to monitor changes and/or waves propagations from the lithosphere to the ionosphere in 2021. The system monitors changes of more than 10 physical parameters at altitudes ranged from -5 meters to ~350 kilometers. A piezometer monitors changes of groundwater levels with a sampling interval of 2 seconds in a well. Variations of temperature and air pressure are continuously observed by utilizing thermometers and barometers in wells with depths of 5, 3 and 1 meters and 0.5 meters above the surface. Two broadband seismometers were set at opposite corners of the station to monitor ground motion with a sampling rate of 50 Hz. A ground-based GNSS receiver routinely receive signals from the BeiDou geosynchronous satellites to study ground vibrations and changes of the total electron content about 350 kilometers above the Earth’ s surface. A Sonic Detection And Ranging (SODAR) system and a Radio Acoustic Sounding System (RASS) were also employed in monitoring changes of temperature and winds from the surface to ~5 kilometers in altitude. To understand the disturbance of the acoustic-gravity waves on clouds, an all-sky camera is installed in the station. Two atmospheric electric field meters are utilized to monitor electric fields around the surface. A flux magnetometer was installed in the surrounded areas with horizontal distance of about 50 meters to study changes of the geomagnetic field and ionospheric current about 100 kilometers above the surface. Furthermore, the VHF coherent scattering radar and the Meteor radar were set about 20 kilometers away from the stations for monitoring changes 80-160 kilometers above the surface. Note that observations from the China Seismo-Electromagnetic Satellite (CSES) and Radio occultation can also be integrated together to sheds light on extending the monitoring upon 500 kilometer above the surface. In short, an MVP-LAI system was established to Monitors Vibrations and Propagations in the Lithosphere, Atmosphere, and Ionosphere and to examines the accuracy of those potential mechanisms.

Keywords: LAI coupling, Pre-earthquake anomalous phenomena

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Assessing the potential earthquake precursory information in ULF magnetic data recorded in Kanto, Japan during 2000 –2010: distance and magnitude dependences

*Peng Han[1], Jiancang Zhuang[2], Katsumi Hattori[3], Chieh-Hung Chen[4], Febty Febriani[5], Hongyan Chen[1]

1. Southern University of Science and Technology, Shenzhen, China, 2. The Institute of Statistical Mathematics, Tokyo, Japan, 3. Graduate School of Science, Chiba University, Chiba, Japan, 4. Institute of Geophysics and Geomatics, China University of Geosciences, Wuhan 430074, China, 5. Research Center for Physics, Indonesian Institute of Sciences, Tangerang, Banten, Indonesia

In order to clarify the ULF seismo-magnetic phenomena, a sensitive geomagnetic network has been installed in Kanto, Japan since 2000. In previous studies, we have verified the correlation between ULF magnetic anomalies and local sizeable earthquakes. In this paper, we use Molchan’s error diagram to evaluate the potential earthquake precursory information in the magnetic data recorded in Kanto, Japan during 2000 –2010. We introduce the probability gain (*PG*) and the probability difference (*D*) to quantify the forecasting performance and to explore the optimal prediction parameters for a given ULF magnetic station. The results show that the earthquake predictions based on magnetic anomalies are significantly better than random guesses, indicating the magnetic data contain potential useful precursory information. Further investigations suggest that the prediction performance depends on the choices of the distance (*R*) and size of the target earthquake events (*Es*). Optimal *R* and *Es* are about (100 km, $10^{8.75}$) and (180 km, $10^{8.75}$) for Seikoshi (SKS) station in Izu and Kiyosumi (KYS) station in Boso, respectively.

Keywords: ULF magnetic data, earthquake precursory information, Molchan’s error diagram, Kanto, Japan

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

[M-IS08] Interdisciplinary studies on pre-earthquake processes

convener:Katsumi Hattori(Department of Earth Sciences, Graduate School of Science, Chiba University), Dimitar Ouzounov(Center of Excellence in Earth Systems Modeling &Observations (CEESMO) , Schmid College of Science &Technology Chapman University, Orange, California, USA), Jann-Yenq LIU(Department of Space Science and Engineering, National Central University, Taiwan), Qinghua Huang(Peking University), Chairperson:Katsumi Hattori(Department of Earth Sciences, Graduate School of Science, Chiba University), Dimitar Ouzounov(Center of Excellence in Earth Systems Modeling &Observations (CEESMO) , Schmid College of Science &Technology Chapman University, Orange, California, USA)

Sun. Jun 6, 2021 10:45 AM - 12:15 PM Ch.22 (Zoom Room 22)

The year 2021 is the memorial year of the 2011 Tohoku Earthquake (M9.0). For the past decade, we have advanced our knowledge of precursors and earthquake preparation processes.
This session expands the interdisciplinary discussions on the preparation process of earthquake and earthquake predictability by presenting the latest progress in studying the physically based pre-earthquake phenomena. New observations from space and ground have provided evidence, enhancing a better understanding of the tectonic activity. The session anticipates talks that include but is not limited to observations and analyses of seismic, electrical, electromagnetic, electro-chemical, and thermodynamic processes related to stress changes in the lithosphere along with their statistical and physical validation. Presentations on the latest observational results associated with major earthquakes obtained by different methodologies are welcomed. The topics of the session are as follows but not limited.

-General discussion on earthquake preparation process and the physics of pre-earthquake signals
- Theory, modeling, laboratory experiments, computational simulation for generation and propagation of pre-earthquake signals and their connection with the seismic cycle
- Multi-parameter observations, detection, and validation of pre-earthquake signals
- Cross-disciplinary studies, practical and technical approaches for better understanding of earthquake preparation processes and their connection with seismicity.

12:10 PM - 12:15 PM

[MIS08-06]Discussion

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

Sun. Jun 6, 2021 1:45 PM - 3:15 PM JST | Sun. Jun 6, 2021 4:45 AM - 6:15 AM UTC | Ch.22 Zoom Room 22

[M-IS08] Interdisciplinary studies on pre-earthquake processes

convener:Katsumi Hattori(Department of Earth Sciences, Graduate School of Science, Chiba University), Dimitar Ouzounov(Center of Excellence in Earth Systems Modeling & Observations (CEESMO) , Schmid College of Science & Technology Chapman University, Orange, California, USA), Jann-Yenq LIU(Department of Space Science and Engineering, National Central University, Taiwan), Qinghua Huang(Peking University), Chairperson:Peng Han(Southern University of Science and Technology, Shenzhen, China), Xuemin Zhang(Institute of Earthquake Forecasting, China Earthquake Administration)

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- Cross-disciplinary studies, practical and technical approaches for better understanding of earthquake preparation processes and their connection with seismicity.

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

[MIS08-07] Seismo-ionospheric anomalies before the 11 March 2011 M9.0 Tohoku Earthquake

*Jann-Yenq LIU[1,2,3], FU-YUAN CHANG[1], I-Te Lee[4], Katsumi Hattori[5], Yuh-Ing Chen[6] (1.Center for Astronautical Physics and Engineering, National Central University, Taoyuan, TAIWAN, 2.Department of Space Science and Engineering, National Central University, TAIWAN, 3.Center for Space and Remote Sensing Research, National Central University, Taoyuan, TAIWAN, 4.Center Weather Bureau, Taipei, TAIWAN, 5.Department of Earth Sciences, Graduate School of Science, Chiba University, Chiba, JAPAN, 6.Institute of Statistics, National Central University, Taoyuan, TAIWAN)

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

[MIS08-08] 3D Tomography of the Ionospheric Anomalies Before the 2010 Maule Earthquake, Chile: Comparison with the 2011 Tohoku-oki and 2015 Illapel Earthquakes

*Ihsan Naufal Muafiry[1], Kosuke Heki[1] (1.Hokkaido University, Japan)

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

[MIS08-09] Spatiotemporal Distribution Characteristics of Conductivity Anomalies before Ms > 6 Earthquakes in the North-South Seismic Belt of China during 2014 – 2019

*Zhiqiang Mao[1], Chieh-Hung Chen[1], Suqin Zhang[2], Qi Li[2], Aisa Yisimayili[3] (1.China University of Geosciences (Wuhan), 2.Institute of Geophysics, China Earthquake Administration, 3.Earthquake Agency of Xinjiang Uygur Autonomous Region)

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

[MIS08-10] **Possible stimulation of seismic activity by geomagnetically induced currents generated by ionizing radiation of solar flare in the illuminated hemisphere**

*Victor A. Novikov[1], Valery M. Sorokin[2], Alexey K. Yaschenko[2], Georgy Yu. Mushkarev[2] (1.Joint Institute for High Temperatures of Russian Academy of Sciences, 2.Pushkov Institute of Terrestrial Magnetism, Ionosphere and Radio Wave Propagation of Russian Academy of Sciences)

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

[MIS08-11] **Detecting the ionospheric disturbances in Japan using the three-dimensional computerized tomography**

*Rui Song[1], Katsumi Hattori[1], Xuemin Zhang[2] (1.Graduate School of Science and Engeering, Chiba University, 2.Institute of Earthquake Forecasting, China Earthquake Administration)

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

[MIS08-12] A Statistical Study of the Correlation Between Geomagnetic Storms and M>7.0 Global Earthquakes During 1957–2020

*Hongyan Chen[1], Rui Wang[1], Miao Miao[1], Xiaocan Liu[2], Yonghui Ma[3], Katsumi Hattori[4], Peng Han[1] (1.Southern University of Science and Technology, Shenzhen, China, 2.The Institute of Geophysics China Earthquake Administration, Beijing, China, 3.School of Science, Harbin Institute of Technology, Shenzhen, China, 4.Graduate School of Science, Chiba University, Chiba, Japan)

Seismo-ionospheric anomalies before the 11 March 2011 M9.0 Tohoku Earthquake

*Jann-Yenq LIU[1,2,3], FU-YUAN CHANG[1], I-Te Lee[4], Katsumi Hattori[5], Yuh-Ing Chen[6]

1. Center for Astronautical Physics and Engineering, National Central University, Taoyuan, TAIWAN, 2. Department of Space Science and Engineering, National Central University, TAIWAN, 3. Center for Space and Remote Sensing Research, National Central University, Taoyuan, TAIWAN, 4. Center Weather Bureau, Taipei, TAIWAN, 5. Department of Earth Sciences, Graduate School of Science, Chiba University, Chiba, JAPAN, 6. Institute of Statistics, National Central University, Taoyuan, TAIWAN

In this paper, observations of the total electron content (TEC) of the global ionosphere map (GIM), radio occultation electron density profiles of FORMOSAT-3/COSMIC, and in situ plasma quantities probed by DMSP satellite are used to study seismo-ionospheric anomalies associated the 11 March 2011 M9.0 Tohoku earthquake, while the Thermosphere Ionosphere Electrodynamics General Circulation Model (TIEGCM) is applied to simulate and understand the observed anomalies. The observation shows that the GIM TEC over the epicenter significantly and continuously enhances on 6-8 March 2011, 4-2 days before the earthquake. The spatial analysis further demonstrates that the enhancement anomaly specifically and persistently appears in the northern epicenter area. Simulation results well agree with the observations, which suggest that the electric potential around the epicenter has been distorted and significantly affects the TEC during the earthquake preparation period.

Keywords: Tohoku Earthquake, GIM TEC, FORMOSAT-3/COSMIC, ionospheric earthquake precursor, TIEGCM, seismo-electric field

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3D Tomography of the Ionospheric Anomalies Before the 2010 Maule Earthquake, Chile: Comparison with the 2011 Tohoku-oki and 2015 Illapel Earthquakes

*Ihsan Naufal Muafiry[1], Kosuke Heki[1]

1. Hokkaido University, Japan

This study compares the 3D structure of ionospheric electron density anomalies immediately before the three megathrust earthquakes, i.e. 2011 Mar. 11 Tohoku-Oki (Muafiry & Heki, JGR 2020), 2015 Sep.16 Illapel (He & Heki, JGR 2018), and the 2010 Feb. 27 Maule, Chile (new study), earthquakes, revealed using slant-TEC residuals as inputs to 3D tomographic inversion. For the Maule earthquake, we used 371 TEC data obtained using 7 satellites and 91 ground GNSS stations mainly in Chile and Argentine. The tomography results showed that the pre-seismic ionospheric anomaly in each case has following similarities; (1) They are composed of pairs of low-altitude positive and high-altitude negative electron density anomalies. (2) They occur above the land area close to the submarine faults. (3) They have clear onsets a few tens of minutes before earthquakes (~40 min before 2011 Tohoku-oki, and Maule, and ~20 minutes before the Illapel earthquakes) and grow with decaying rates. Muafiry & Heki (2020) hypothesized the physical process consistent with such 3D structure. We will also compare strengths and dimensions of the electron density anomalies before these three earthquakes.

Keywords: 3D tomography, GNSS, Pre-seismic Ionospheric Anomaly

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Spatiotemporal Distribution Characteristics of Conductivity Anomalies before Ms > 6 Earthquakes in the North-South Seismic Belt of China during 2014 –2019

*Zhiqiang Mao[1], Chieh-Hung Chen[1], Suqin Zhang[2], Qi Li[2], Aisa Yisimayili[3]

1. China University of Geosciences (Wuhan), 2. Institute of Geophysics, China Earthquake Administration, 3. Earthquake Agency of Xinjiang Uygur Autonomous Region

The North-South Seismic Belt of China is one of the most active seismic areas on the Chinese continent. More than ten strong earthquakes (Ms > 6) have occurred in this region since 2010. However, Earthquake-related conductivity anomalies are rarely reported for those earthquakes. In this study, 3-component geomagnetic data recorded at sixty geomagnetic stations are selected to compute the Parkinson vectors to monitor the changes of conductivity before and after the earthquakes. Considering most fluxgate magnetometer have only been installed since 2014, we concentrate on six Ms > 6 earthquakes occurred during 2014–2019. To mitigate artificial disturbances, low noise data during the 00:00 –5:00 LT are utilized. We compute the background distribution and monitoring distribution using the azimuth of the Parkinson vectors at each station within six years (2014 –2019) and a 15-day moving window, respectively. The background distribution is subtracted from the monitoring distributions to mitigate the influences of underlying inhomogeneous tectonic structures. The obtained difference distributions binned by 10˚ within 400 km from each station are superimposed during 60 days before and after the earthquake to construct integrated maps. To analyze the potential frequency characteristics, we compute the results form low to high frequency band. The results show that for four earthquakes, the conductivity anomalies areas appear near the epicenter 10 to 20 days before earthquakes, while the rest two earthquakes have no anomaly. The conductivity anomalies appear at all study frequency band from 0.0005 Hz to 0.1 Hz, and significantly at 0.001 –0.005 Hz before earthquakes. Meanwhile, we find that the lower frequency band corresponds to larger anomalies area. These results suggest the change of underlying conductivity near the hypocenter is a possible phenomena for strong earthquakes, and the frequency characteristics of the seismo-conductivity anomaly during the earthquake are helpful to understand the pre-earthquake anomalous phenomena.

Keywords: Seismo-conductivity anomalies, Parkinson vector , Geomagnetic, The North-South Seismic Belt of China

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Possible stimulation of seismic activity by geomagnetically induced currents generated by ionizing radiation of solar flare in the illuminated hemisphere

*Victor A. Novikov[1], Valery M. Sorokin[2], Alexey K. Yaschenko[2], Georgy Yu. Mushkarev[2]

1. Joint Institute for High Temperatures of Russian Academy of Sciences, 2. Pushkov Institute of Terrestrial Magnetism, Ionosphere and Radio Wave Propagation of Russian Academy of Sciences

In addition to traditional approach to the short-term earthquake (EQ) prediction based on a search of possible precursors of seismic event, the following steps towards EQ predictability look reasonable [Sobolev, 2011]: a) determination of an unstable area; (b) monitoring the triggering effects and assessment their impact on the unstable area; and (c) estimation of probability of location, time, and magnitude of impending EQ.

It is well-known that external factors like distant strong EQs, underground explosions, fluid injection, etc. can trigger EQ in the crust fault matured for dynamical rupture. Recently it was found that EQ triggering is possible during injection of DC pulses into the Earth crust by statistical analysis of regional seismicity during artificial electromagnetic impact [Tarasov & Tarasova] and laboratory experiments [Sobolev & Ponomarev, 2003; Novikov et al, 2017].

Numerical estimations based on a theoretical model of disturbance of electric filed, electric current, and heat release in lithosphere associated with variation of ionosphere conductivity caused by absorption of ionizing radiation of solar flares [Sorokin et al, 2019] demonstrated that solar flare can generate electric current density in lithosphere over 10^{-6} A/m^2, that is comparable with a current density generated in the Earth crust by artificial pulsed power systems, which provide regional earthquake triggering and spatiotemporal variation of seismic activity. Therefore, EQ triggering is possible not only by man-made pulsed power sources but also by the solar flares. The results obtained were confirmed by sharp increase of global seismicity after the strong solar flare of X9.3 class on September 6, 2017 [Novikov et al, 2020].

For application of the obtained results for EQ alarm immediately after the strong solar flare in the specific seismic-prone zones we need to select the areas, most sensitive to impact of solar flare, where the maximal density of geomagnetically induced currents (GIC) will be generated in the conductive crust faults. We present the numerical model of GIC generation by ionizing radiation of solar flare in the illuminated hemisphere. Calculations of disturbance of electromagnetic field and telluric current were performed for San Andreas fault (California), integral radiant flux density of 0.005 J/m^2, and the time of UTC 15:00 and 18:00 on July 20, 2020. It was found that ionosphere conductivity disturbance is 2 S and 4 S for UTC 15:00 and 18:00, respectively, that provides double increase of telluric current in the fault (1.5×10^{-7} and 3×10^{-7} A/m^2). Duration of the current pulse is about 40-50 s. These parameters are comparable with the DC pulse generated in the EQ sources by artificial power system (MHD generator "Pamir-2": current density 10^{-7} - 10^{-8} A/m^2 at depth of 5-10 km, DC pulse duration up to 10s) resulted in triggering of regional weak seismicity at Northern Tien Shan.

The reported study was funded by RFBR and NSFC, project number 21-55-53053.

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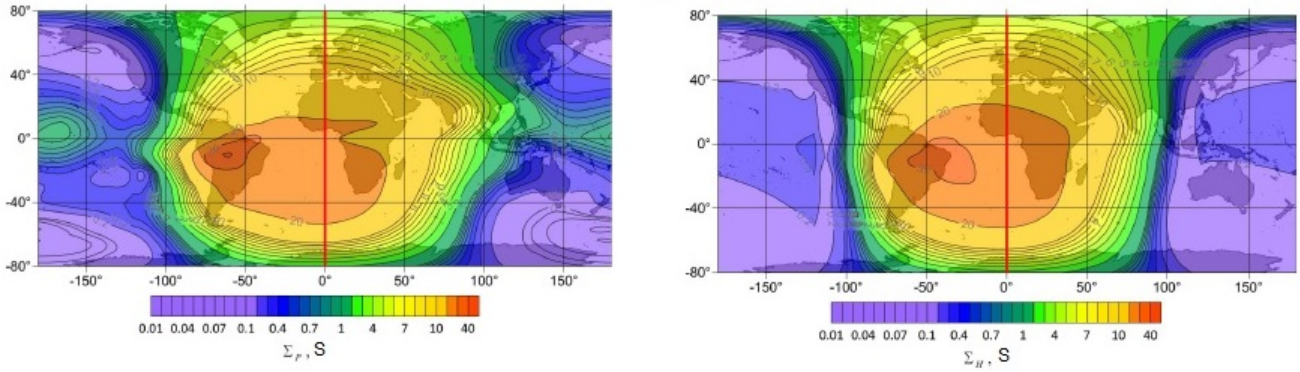
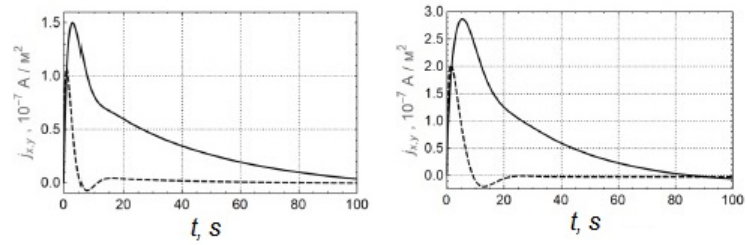
Keywords: solar flare, geomagnetically induced current, earthquake triggering, conductive fault

Spatial distriution of integral Pedersen (left panel) and Hall (right panel) ionosphere conductivities
vertical red line is undersolar meridian





Time dependence of telluric current density

Solid line - jx , dotted line - jy.

UTC 15:00 - left panel
UTC 18:00 - right panel

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Detecting the ionospheric disturbances in Japan using the three-dimensional computerized tomography

*Rui Song[1], Katsumi Hattori[1], Xuemin Zhang[2]

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To reconstruct the 3-D structures related to ionospheric irregularities in Japan, the improved constraint least-square fitting algorithm was adopted. Unlike the conventional least-square fitting, spatial restrictions in horizontal direction were removed for better reproducing the disturbances. Before the performance on imaging ionospheric irregularities was evaluated, common assessments for quiet ionospheric conditions were first implemented. Taking the day of March 22, 2012, as an example, the results indicated that the characteristics of IED could be well retrieved by the improved algorithm. Then, the temporal and spatial IEDs related to plasma depletions and MSTIDs were elaborated, respectively. Especially for the storm-time depletion occurred on July 27, 2004, although it exhibited equatorward propagating characteristic, considering the abrupt fracture of up to 15 TECU imaged by TEC mapping, we speculated it was the abnormal PBs generated by the combing effects from the equatorward TADs and eastward PPEF during an intense storm. However, whether such irregularities being related to PBs or storm-induced LSTIDs is still worth further study and discussion in the future work. Next, Ne reconstruction for the nighttime MSTIDs on June 23, 2012, was conducted. The upward and downward motions of Ne were found to be connected with the negative and positive disturbances. Moreover, the sinusoidal structure concerning such disturbances indicates that an east-west oscillating EF exists in F region, then drives the plasma drift via $\delta \mathbf{E} \times \mathbf{B}$. It is suggested that the electrodynamic process, as expected from the Perkins instability, plays an important role in generating the nighttime MSTIDs.

Keywords: Computerized Ionospheric Tomography, Total Electron Content, Plasma Depletion, Medium-scale Traveling Ionospheric Disturbance

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A Statistical Study of the Correlation Between Geomagnetic Storms and M>7.0 Global Earthquakes During 1957–2020

*Hongyan Chen[1], Rui Wang[1], Miao Miao[1], Xiaocan Liu[2], Yonghui Ma[3], Katsumi Hattori[4], Peng Han[1]

1. Southern University of Science and Technology, Shenzhen, China, 2. The Institute of Geophysics China Earthquake Administration, Beijing, China, 3. School of Science, Harbin Institute of Technology, Shenzhen, China, 4. Graduate School of Science, Chiba University, Chiba, Japan

In order to find out whether the geomagnetic storms and large-mega earthquakes are correlated or not, statistical studies based on Superposed Epoch Analysis (SEA), significance analysis, and Z test have been applied to the Dst index data and M > 7.0 global earthquakes during 1957–2020. The results indicate that before M > 7.0 global earthquakes, there are clearly higher probabilities of geomagnetic storms than after them. Geomagnetic storms are more likely to be related to shallow earthquakes rather than deep ones. Further statistical investigations of the results based on cumulative storm hours show consistency with those based on storm days, suggesting that the high probability of geomagnetic storms prior to large-mega earthquakes is significant and robust. Some possible mechanisms such as a reverse piezoelectric effect and/or electroosmotic flow are discussed to explain the statistical correlation. The result might open new perspectives in the complex process of earthquakes and the Lithosphere-Atmosphere-Ionosphere (LAI) coupling.

Keywords: Statistical study, Geomagnetic storm, Earthquakes, Superposed epoch analysis

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

Sun. Jun 6, 2021 3:30 PM - 5:00 PM JST | Sun. Jun 6, 2021 6:30 AM - 8:00 AM UTC | Ch.22 Zoom Room 22

[M-IS08] Interdisciplinary studies on pre-earthquake processes

convener:Katsumi Hattori(Department of Earth Sciences, Graduate School of Science, Chiba University), Dimitar Ouzounov(Center of Excellence in Earth Systems Modeling & Observations (CEESMO) , Schmid College of Science & Technology Chapman University, Orange, California, USA), Jann-Yenq LIU(Department of Space Science and Engineering, National Central University, Taiwan), Qinghua Huang(Peking University), Chairperson:Jann-Yenq LIU(Department of Space Science and Engineering, National Central University, Taiwan), Qinghua Huang(Peking University)

The year 2021 is the memorial year of the 2011 Tohoku Earthquake (M9.0). For the past decade, we have advanced our knowledge of precursors and earthquake preparation processes.
This session expands the interdisciplinary discussions on the preparation process of earthquake and earthquake predictability by presenting the latest progress in studying the physically based pre-earthquake phenomena. New observations from space and ground have provided evidence, enhancing a better understanding of the tectonic activity. The session anticipates talks that include but is not limited to observations and analyses of seismic, electrical, electromagnetic, electro-chemical, and thermodynamic processes related to stress changes in the lithosphere along with their statistical and physical validation. Presentations on the latest observational results associated with major earthquakes obtained by different methodologies are welcomed. The topics of the session are as follows but not limited.

-General discussion on earthquake preparation process and the physics of pre-earthquake signals
- Theory, modeling, laboratory experiments, computational simulation for generation and propagation of pre-earthquake signals and their connection with the seismic cycle
- Multi-parameter observations, detection, and validation of pre-earthquake signals
- Cross-disciplinary studies, practical and technical approaches for better understanding of earthquake preparation processes and their connection with seismicity.

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

[MIS08-13] Italian contribution to the CSES satellite mission

★Invited Papers

*Livio Conti[1], Group the CSES-Limadou Collaboration (1.Uninettuno University)

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

[MIS08-14] A focus on the capability of the RST-based satellite TIR anomalies for the short-term seismic hazard assessment in Japan

★Invited Papers

*Nicola Genzano[1], Roberto Colonna[1], Carolina Filizzola[2], Katsumi Hattori[3,4], Mariano Lisi[2], Nicola Pergola[2], Valerio Tramutoli[1] (1.School of Engineering, University of Basilicata, Via dell' Ateneo Lucano, 10, 85100 Potenza, Italy, 2.National Research Council, Institute of Methodologies for Environmental Analysis, C. da S. Loja, 85050 Tito Scalo (Pz), Italy, 3.Graduate School of Science, Chiba University, Yayoi 1-33, Inage, Chiba, 263-8522, Japan, 4.Center for Environmental Remote Sensing, Chiba University, Yayoi 1-33, Inage, Chiba, 263-8522, Japan)

4:10 PM - 4:30 PM JST | 7:10 AM - 7:30 AM UTC

[MIS08-15] Radon Monitoring in the Gulf of Corinth, Greece

★Invited Papers

*VASSILIOS KARASTATHIS[1], G Elefteriou[1], M. Kafatos[2], K. Tsinganos[3], G Tselentis[1], D. Ouzounov[2], E Mouzakiotis[1] (1.National Observatory of Athens, 2.Chapman University, 3.National and Kapodistrian University of Athens)

4:30 PM - 4:50 PM JST | 7:30 AM - 7:50 AM UTC

[MIS08-16] Earth's crust as a new element of the LAIC model within the Global Electric Circuit concept

★Invited Papers

*Sergey A Pulinets[1], V. Gavrilov[2], V. Bogdanov[3], N. Blaustein[4] (1.Space Research Institute of the Russian Academy of Sciences, 2.Institute of Volcanology and Seismology, Far-East Branch of the Russian Academy of Sciences, 3.Institute of Cosmophysical Research and Radio Wave Propagation, Far-East Branch of the Russian Academy of Sciences, 4.Ben-Gurion University of the Negev, Israel)

4:50 PM - 5:00 PM JST | 7:50 AM - 8:00 AM UTC

[MIS08-17] Discussion

Italian contribution to the CSES satellite mission

*Livio Conti[1], Group the CSES-Limadou Collaboration

1. Uninettuno University

We present a review of the research activity of the Italian team (Limadou Collaboration) within the CSES-1 mission. CSES-1 is a satellite of the China National Space Administration (CNSA) developed in collaboration with the Italian Space Agency (ASI). The mission is led by the Chinese Earthquake Administration from the Chinese side. The Italian Institute for Nuclear Physics (INFN) leads the Limadou collaboration that includes several other institutes (INGV, INAF-IAPS, CNR-IFAC) and Universities. The satellite - equipped with nine advanced instruments devoted to measure continuously and simultaneously data of electric and magnetic field, charged particles, and plasma parameters –has been designed for studying the near-Earth electromagnetic, plasma and particles environment. The main Italian contribution to the mission is the HEPD detector for measuring high-energy charged particles (O(1 MeV to O(100 MeV)) on board of CSES-1. We have also carried out measurement and validation test sessions of CSES-1 plasma instruments in the INAF-IAPS plasma chamber. CSES-1 aims at investigating the iono-magnetospheric phenomena induced by internal natural sources (such as earthquakes, volcanos, lightning, etc.) and external sources (Sun and cosmic rays) and by artificial emitters including radio emitters). Two case studies of strong earthquakes occurred in 2018 in Indonesia revealed some important anomalies in the electron density, preceding each seismic event occurrence. In addition, a preliminary systematic superposed space and time analysis between CSES-1 electron density data and earthquakes occurred in 2018 and 2019 has shown a significant robust correlation. The CSES-1 mission allows a detailed study of the structure and the dynamic of the topside ionosphere, the coupling mechanisms with the lower and higher plasma layers and the temporal variations of the geomagnetic field, in quiet and disturbed conditions. Data collected by the CSES-1 mission are extremely useful for investigating solar-terrestrial interactions and phenomena of solar physics, namely coronal mass ejections (CMEs), solar flares and cosmic ray solar modulation. CSES-1 is the first of a series of satellites that will be launched - with the same instruments suite and similar orbital parameters - in order to reduce the revisit time between consecutive observations. On board the CSES-2 satellite will be installed a particle detector and an electric field analyzer provided by the Limadou collaboration.

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A focus on the capability of the RST-based satellite TIR anomalies for the short-term seismic hazard assessment in Japan

*Nicola Genzano[1], Roberto Colonna[1], Carolina Filizzola[2], Katsumi Hattori[3,4], Mariano Lisi[2], Nicola Pergola[2], Valerio Tramutoli[1]

1. School of Engineering, University of Basilicata, Via dell' Ateneo Lucano, 10, 85100 Potenza, Italy, 2. National Research Council, Institute of Methodologies for Environmental Analysis, C. da S. Loja, 85050 Tito Scalo (Pz), Italy, 3. Graduate School of Science, Chiba University, Yayoi 1-33, Inage, Chiba, 263-8522, Japan, 4. Center for Environmental Remote Sensing, Chiba University, Yayoi 1-33, Inage, Chiba, 263-8522, Japan

With the aim to evaluate the potentiality of the parameter "RST-based satellite TIR anomalies" in a space-time relation with large earthquakes (M>=6) occurred in Japan from 2005 to 2015, we have performed a long-term statistical correlation analysis (see Genzano et al., 2021).
To accomplish this purpose, we use the Robust Satellite Technique (RST; Tramutoli 1998, 2007), and the Robust Estimator TIR Anomalies (RETIRA; Tramutoli et al., 2005) index, to identify Significant Sequences of TIR Anomalies (SSTAs) over 11 years of night-time satellite images acquired by MTSAT satellites over Japan.
By applying empirical spatial-temporal rules, which are established also taking in account the physical models up to now proposed to explain seismic TIR anomalies appearances, the performed long-term correlation analysis put in relief that a non-casual relation exists between satellite TIR anomalies and the occurrence of the earthquakes.
Here, we summarize the achieved results and discuss them in the perspective of a multi-parameter system, which could improve our present knowledge on the earthquake-related processes and increase our capacity to assess the seismic hazard in the medium-short term (months to days).
Moreover, we will discuss the improvements to the RST approach, recently introduced, aimed to minimize the proliferation of the false positives (i.e. TIR anomalies independent to the seismic sources, but due to other causes, e.g. meteorological factors), as well as the exportation of the RST/RETIRA approach/index on the radiances collected by the next-generation satellite sensor Himawari-8/AHI.

Acknowledgments
This study was partly supported by joint research program of Center for Environmental Remote Sensing of Chiba University (Japan).

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Keywords: Earthquakes, Satellite thermal anomalies, Seismic hazard, Statistical analysis, Multi-parametric system, Japan

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Radon Monitoring in the Gulf of Corinth, Greece

*VASSILIOS KARASTATHIS[1], G Elefteriou[1], M. Kafatos[2], K. Tsinganos[3], G Tselentis[1], D. Ouzounov[2], E Mouzakiotis[1]

1. National Observatory of Athens, 2. Chapman University, 3. National and Kapodistrian University of Athens

Significant new findings on the relation between soil radon variations with the natural seismicity and forthcoming events have been obtained after continuous real-time monitoring of soil radon concentration in the area of the Gulf of Corinth, Greece through a five-year period. The Gulf of Corinth, one of Earth's most active continental rift systems is a high seismic hazard area with many catastrophic earthquakes in its history; however its seismicity rate is not as high comparing to others active tectonic systems such as the Hellenic Arc region. The long quiescent periods between the major seismic events essentially help to establish a safe correlation of possible pre-earthquake radon variations with the seismic events. The Gulf of Corinth has a high rate of crustal extension of up to 1.5 cm/yr at the western part and 0.5 at the eastern one.

Two permanent real-time and continuously operating gamma-ray spectrometers have been installed in the area as a part of a larger network of radon monitoring stations covering South and Western Greece. More specifically, in order to observe pre-earthquake anomalies in radon concentration before strong earthquakes we have installed soil radon concentration monitoring stations at high seismicity areas such as the Hellenic arc in Western Greece and the eastern part of the Gulf of Corinth. The installation of the stations began in May 2016 and in all sites a real-time monitoring was established. The network is currently expanding with new stations at Crete.

The radon network was mainly based on NaI(Tl) scintillation detectors for γ-spectrometry. A full spectrum analysis processing that is applied to the data, provides us with a good energy resolution. At all stations there is detailed information of meteorological parameters that could affect the radon concentration measurements such as temperature, pressure, humidity and wind speed.

The Loutraki station, which is installed at a site close to a large fault with significant hydrothermal flux, provided us with highly interesting insights about the correlation of the seismicity rate with radon level at the area. However, an even more noteworthy observation is that the radon level variations also seem to follow a pattern, related to the stronger events. This station shows a very high consistency in the measurements and is strongly insulated from exogenous factors such as temperature, pressure and humidity.
Our results appear to be compatible with the “dilatancy model” that proposes an inelastic volumetric increase of rocks prior to failure. Before earthquakes there is accumulation of tectonic strain that produces a slow, steady increase of effective stress.

Before the major events there is a steady and slow increase of radon due to the increase of cracks and porosity and/or an increase in the flow rate of pore water. In addition, before strong events there is a significant drop of radon level.
Several seismic events have been associated with soil radon variations in three local radon monitoring stations.

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Keywords: Radon monitoring, pre-earthquake phenomena, earthquake precursors

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Earth’s crust as a new element of the LAIC model within the Global Electric Circuit concept

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Multiparameter analysis (deep borehole measurements, vertical ionospheric sounding, GPS TEC, meteorological parameters) for several strong (M≧7) earthquake in Kamchatka peninsula area demonstrated the self-organizing process characteristic to the critical stage approaching. The most striking fact was the synchronization of variations of the specific resistivity of the earth crust measured at different depths in several boreholes close to Petropavlovsk-Kamchatsky and night-time positive ionospheric variations several days before the mains shock of strong earthquake. The vertical sounding provided by the "Parus" ionosonde at Paratunka (close to Petropavlovsk-Kamchatsky) in addition to variations similar to GPS TEC demonstrated several features in E-region of the ionosphere which usually interpreted as particle precipitation. Increase of the crust resistivity could be interpreted as the serial resistance added to the resistance of the boundary layer in the Global Electric Circuit (GEC) blocking the vertical fair weather current and leading to generation of the vertical electric field, which through the GEC induced the positive anomaly in the ionosphere. For Zhupanovskoye M7.2 earthquake on 30 January 2016 the increase of the apparent resistivity reached 700%. The sporadic E effects could be interpreted as E-layer delamination stimulated by acoustic gravity waves. This delamination was clearly demonstrated at oblique sounding ionograms before earthquakes in Vrancea zone observation. It is assumed that a joint multiparameter analysis of borehole measurement data and monitoring data of the state of the ionosphere will improve the reliability of determining the start of the final stage of earthquake preparation, since significant changes in ionospheric parameters occur, in general, no more than five days before strong Kamchatka earthquakes.

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

[M-IS08] Interdisciplinary studies on pre-earthquake processes

convener:Katsumi Hattori(Department of Earth Sciences, Graduate School of Science, Chiba University), Dimitar Ouzounov(Center of Excellence in Earth Systems Modeling &Observations (CEESMO) , Schmid College of Science &Technology Chapman University, Orange, California, USA), Jann-Yenq LIU(Department of Space Science and Engineering, National Central University, Taiwan), Qinghua Huang(Peking University), Chairperson:Jann-Yenq LIU(Department of Space Science and Engineering, National Central University, Taiwan), Qinghua Huang(Peking University)
Sun. Jun 6, 2021 3:30 PM - 5:00 PM Ch.22 (Zoom Room 22)

The year 2021 is the memorial year of the 2011 Tohoku Earthquake (M9.0). For the past decade, we have advanced our knowledge of precursors and earthquake preparation processes.
This session expands the interdisciplinary discussions on the preparation process of earthquake and earthquake predictability by presenting the latest progress in studying the physically based pre-earthquake phenomena. New observations from space and ground have provided evidence, enhancing a better understanding of the tectonic activity. The session anticipates talks that include but is not limited to observations and analyses of seismic, electrical, electromagnetic, electro-chemical, and thermodynamic processes related to stress changes in the lithosphere along with their statistical and physical validation. Presentations on the latest observational results associated with major earthquakes obtained by different methodologies are welcomed. The topics of the session are as follows but not limited.

-General discussion on earthquake preparation process and the physics of pre-earthquake signals
- Theory, modeling, laboratory experiments, computational simulation for generation and propagation of pre-earthquake signals and their connection with the seismic cycle
- Multi-parameter observations, detection, and validation of pre-earthquake signals
- Cross-disciplinary studies, practical and technical approaches for better understanding of earthquake preparation processes and their connection with seismicity.

4:50 PM - 5:00 PM

[MIS08-17]Discussion

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[E] Oral | M (Multidisciplinary and Interdisciplinary)：M-AG Applied Geosciences

Sun. Jun 6, 2021 3:30 PM - 5:00 PM JST | Sun. Jun 6, 2021 6:30 AM - 8:00 AM UTC | Ch.20 Zoom Room 20

[M-AG37] CTBT IMS Technologies for Detecting Nuclear Explosion and Their Applications to Earth Science

convener:Nurcan Meral Ozel(Comprehensive Nuclear-Test-Ban Treaty Organization), Hiroyuki Matsumoto(Japan Agency for Marine-Earth Science and Technology), Dirk Metz(Japan Agency for Marine-Earth Science and Technology), Yosuke Naoi(Japan Atomic Energy Agency), Chairperson:Nurcan Meral Ozel(Comprehensive Nuclear-Test-Ban Treaty Organization), Hiroyuki Matsumoto(Japan Agency for Marine-Earth Science and Technology), Dirk Metz(Japan Agency for Marine-Earth Science and Technology)

The Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO) was founded in 1996 in response to the adaption of the Treaty in 1996 by the United Nations General Assembly, which bans nuclear explosions on the Earth's surface, in the atmosphere, underwater and underground. The Treaty has a unique and comprehensive verification regime to make sure that nuclear explosion goes detected. The regime is supported by International Monitoring System (IMS) composed of the four state-of-the-art technologies; 1) Seismic, 2) Hydroacoustic, 3) Infrasound, and 4) Radionuclide, by the International Data Centre (IDC), and by the On-Site Inspections (OSI).
IMS will, when complete, consists of 337 facilities worldwide to monitor the planet for signs of nuclear explosion. Around 90 % of the facilities are operational and sending the data to the IDC in Vienna, Austria.
The huge amount of data collected by the IMS network can be used for other purposes such as civil and scientific applications in addition to detecting nuclear explosions. For example, they can provide Tsunami Warning centers with near real-time information about an underwater earthquake. The data could also help better understand of earthquakes, volcanoes, oceans, climate change, and other issues on our planet.
This session will provide the overview of the IMS, the IMS response to the spread of COVID-19, and the scientific and engineering discussions on each technology. The session strongly welcomes young scientists and engineers who are interested in four IMS technologies.

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

[MAG37-01] **IMS Network Resilience and Business Continuity During Lockdown**

*Nurcan Meral Ozel[1] (1.Comprehensive Nuclear-Test-Ban Treaty Organization)

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

[MAG37-02] I30JP station repair following damage by typhoon “FAXAI”

*Takanari Fujii[1], Takayuki Otsu[1], Makiko Iwakuni[1], Masashi Motohashi[1] (1.Japan Weather Association)

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

[MAG37-03] Long-range acoustic measurements of the 2004 submarine eruption near Nightingale Island: Insights from hydrophone triplet array data recorded at IMS station H01W, Cape Leeuwin

*Dirk Metz[1], Julien Vergoz[2], Ingo Grevemeyer[3] (1.JAMSTEC, 2.CEA, 3.GEOMAR)

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

[MAG37-04] Operation of IMS radionuclide stations in Japan

*Yutaka Tomita[1], Yuichi Kijima[1], Akiko FURUNO[1], Yoichi Yamamoto[1] (1.Japan Atomic Energy Agency)

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

[MAG37-05] Atmospheric dispersion analysis for source term estimation of Xe-133 high-concentration detection events observed at the noble gas monitoring station in Takasaki regarding CTBT and two temporary experimental systems

*Akiko FURUNO[1], Yuichi Kijima[1], Yutaka Tomita[1], Yoichi Yamamoto[1] (1.Japan Atomic Energy Agency)

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

[MAG37-06] Discussion on how the CTBT IMS contributes to Earth and environmental sciences

Nurcan Meral Ozel[1], *Hiroyuki Matsumoto[2], Dirk Metz[2], Yosuke Naoi[3] (1.Comprehensive Nuclear-Test-Ban Treaty Organization, 2.Japan Agency for Marine-Earth Science and Technology, 3.Japan Atomic Energy Agency)

IMS Network Resilience and Business Continuity During Lockdown

*Nurcan Meral Ozel[1]

1. Comprehensive Nuclear-Test-Ban Treaty Organization

The COVID-19 pandemic has irrevocably marked the year 2020 and posed unprecedented challenges testing the resilience of the International Monitoring System (IMS) Network. In response, the Provisionary Technical Secretariat (PTS) put in place pragmatic business continuity plans and measures to mitigate the impact of COVID-19 due to travel restrictions across the globe, lockdowns and remote working.

The IMS Network has proven its operational strength and resilience with high data availability and performance throughout the first and second waves of the pandemic in spring and autumn/winter 2020. Furthermore, in the lockdown periods nothing went undetected by the IMS ranging from earthquakes, tsunami, meteorite, fireballs to a variety of seismic activities. A retrospect analysis of the success of PTS business continuity plans crystallizes a number of strategic and operational lessons.

The first lesson is strategic team play between the State Signatories, their Station Operators, National Data Centres and PTS. The IMS performance and state of health monitoring and meetings were intensified immediately prior to the first wave to coordinate preventive, planned and corrective maintenance work with key PTS staff to enhance IMS Operations & Maintenance. An even closer and continuous interaction with station operators and local contractors was sought in parallel. The immediate and seamless transfer of the whole PTS to Home Office and successful maintenance of PTS’ s large-scale IT infrastructure operations enabled this team play.

Operational measures enhanced the resilience of IMS stations to mitigate the impact of COVID-19 lockdown. An emphasis was put on remote troubleshooting and issue resolution along with increased sparing of critical spare parts and frequency of replenishment of consumables, greater use of local purchasing, shipment tracking and re-routing to alternatives.

Global travel restrictions led to delays in some PTS sustainment and station establishment activities. At the same time the right balance was struck between virtual endeavours versus essential on-site presence such as the remote certifications of RN55 Norilsk, Russian Federation in October and IS25 Guadaloupe, France in November 2020. Traditional biennial O&M Workshop an important endeavour for IMS resilience to support network of station operators was conducted virtually.

CTBTO remains vigilant in monitoring, updating and innovating business continuity plans and crisis preparedness as the world navigates the COVID-19 crisis further and carrying the lessons learned into 2021 to further strengthen IMS Network resilience.

Keywords: CTBTO, IMS, COVID-19, Business continuity, Network resilience, Lessons learned

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I30JP station repair following damage by typhoon “FAXAI”

*Takanari Fujii[1], Takayuki Otsu[1], Makiko Iwakuni[1], Masashi Motohashi[1]

1. Japan Weather Association

Tremendous typhoon “FAXAI” attacked Chiba prefecture, where I30JP was installed, on 8th September 2019. It brought strong wind and heavy rainfall widely. Barometric pressure when it landed in Chiba prefecture was 960hPa. It caused tremendous damage around Chiba especially by strong wind. Power outage continued for more than 2 weeks in the vast area of Chiba prefecture.

In I30JP, IMS infrasound station in Japan, although observation data of I30H1 –I30H6 are normally transmitted to IDC miraculously, in each site so many cedar trees were fallen and observation facilities were heavily damaged, such as security fences and pipe array.

The remedial actions have been taken for the typhoon damages as the unscheduled maintenance by October 2020. The surrounding environment has been quite changed at I30H6 site before and after the typhoon. We also analyzed changes in the characteristics of the infrasound waveform data after the station repair.

Keywords: CTBT, National Data Centre, infrasound, waveform analysis, typhoon

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Long-range acoustic measurements of the 2004 submarine eruption near Nightingale Island: Insights from hydrophone triplet array data recorded at IMS station H01W, Cape Leeuwin

*Dirk Metz[1], Julien Vergoz[2], Ingo Grevemeyer[3]

1. JAMSTEC, 2. CEA, 3. GEOMAR

Little is known about active volcanism in the remote regions of the global ocean. Here, we resort to long-range acoustic measurements to study the 2004 eruption at Nightingale Island, Tristan da Cunha. Underwater sound phases associated with the event were recorded at Cape Leeuwin, Western Australia, where a bottom-moored hydrophone array is operated as part of the International Monitoring System (IMS). IMS recordings in combination with local seismic observations suggest that the center of activity is located to the east of Nightingale Island, where a seafloor mapping campaign aboard R/V Maria S Merian (2012MSM20/2) revealed a previously unknown, potentially newly formed stratocone. Signal back azimuth derived from progressive-multi-channel-beamforming differ by more than two degrees from the expected geodesic value, suggesting that low-frequency sound phases may not have traveled along the direct source-receiver path, but were instead reflected off an unnamed seamount located south of Tristan da Cunha. This interpretation is supported by results from transmission loss modeling via the parabolic equation approach, which indicate significant bathymetric obstruction between the volcano and the H01W array in the Southern Ocean. Our study further highlights the potential of the IMS network for the detection and study of future eruptions both at Nightingale Island and elsewhere. Implications for test-ban treaty monitoring and volcano early warning will be discussed.

Keywords: Submarine eruption, Nightingale Island, IMS, CTBTO

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Operation of IMS radionuclide stations in Japan

*Yutaka Tomita[1], Yuichi Kijima[1], Akiko FURUNO[1], Yoichi Yamamoto[1]

1. Japan Atomic Energy Agency

The Japan Atomic Energy Agency (JAEA)has operated two radionuclide stations which are Takasaki radionuclide station (RN38) and Okinawa radionuclide station (RN37) for the CTBT (Comprehensive Nuclear- Test-Ban Treaty) International Monitoring System (IMS). RN38 was built in the Takasaki Advanced Radiation Research Institute of the National Institutes for Quantum and Radiological Science and Technology (QST) in 2002. Radioactivity of particulate radionuclides and radioxenon gases are measured at RN38 by using a Radionuclide Aerosol Sampler / Analyzer (RASA) and a Swedish Automatic Unit for Noble Gas (SAUNA) respectively. It was worthy of special mention that the SAUNA of RN38 detected the radioxenons which were related to the DPRK-3 event in 2013. RN37 was installed in a renovated facility at the Okinawa Tracking and Communication Station of the Japan Aerospace Exploration Agency (JAXA) in 2006. It measures only radioactivity of particulate radionuclides by using a RASA. JAEA contributes to the CTBT international verification regime through these activities. Operation and some monitoring results of both radionuclide stations will be reported in this presentation.

Keywords: CTBT, RN38, RN37, RASA, SAUNA

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Atmospheric dispersion analysis for source term estimation of Xe-133 high-concentration detection events observed at the noble gas monitoring station in Takasaki regarding CTBT and two temporary experimental systems

*Akiko FURUNO[1], Yuichi Kijima[1], Yutaka Tomita[1], Yoichi Yamamoto[1]

1. Japan Atomic Energy Agency

This research aims at source term estimations of high-concentration detection events of Xe-133, which were observed at the CTBT IMS (International Monitoring System) Takasaki radionuclide monitoring station from the viewpoint of atmospheric dispersion analysis. Japan Atomic Energy Agency operates JPX38 in the Takasaki radionuclide station for noble gas monitoring, and conducts temporary measurement project of radioxenon at Horonobe in Hokkaido (JPX81) and Mutsu in Aomori (MUX88) as a part of the noble gas joint measurement project with CTBTO. The high-concentration detection events were frequently occurred not only at the JPX38 but also at the JPX81from the end of 2020 to January 2021. In the presentation, we will describe the source term estimation analysis of these high-concentration detection events, and discuss the relationship of the events between two stations.

Keywords: CTBT, atmospheric dispersion simulation, source term estimation, high-concentration detection events

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Discussion on how the CTBT IMS contributes to Earth and environmental sciences

Nurcan Meral Ozel[1], *Hiroyuki Matsumoto[2], Dirk Metz[2], Yosuke Naoi[3]

1. Comprehensive Nuclear-Test-Ban Treaty Organization, 2. Japan Agency for Marine-Earth Science and Technology, 3. Japan Atomic Energy Agency

Following the all presentations, the conveners provide a discussion time on various scopes related to the CTBT International Monitoring System from the point of view of scientific and technological aspects. We welcome multi-disciplinary discussions to deepen understanding of the Earth as well as suggestions to achieve sustainability of the IMS network from those scientists and engineers who involve four technologies; seismic, hydroacoustic, infrasound and radionuclide monitoring.

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