2019年5月29日(水)

[E] 口頭発表 | セッション記号 P (宇宙惑星科学)：P-PS 惑星科学

13:45 ~ 15:15 | A01 東京ベイ幕張ホール

[P-PS02] Regolith Science

コンビーナ:和田 浩二(千葉工業大学惑星探査研究センター)、中村 昭子(神戸大学大学院理学研究科地球惑星科学専攻)、Patrick Michel(Observatoire De La Cote D'Azur)、Kevin John Walsh(Southwest Research Institute Boulder)、座長:和田 浩二(千葉工業大学惑星探査研究センター)

13:45 ~ 14:00

[PPS02-01] Moganite in a lunar meteorite as a trace of H_2O ice in the lunar regolith

★Invited Papers

*鹿山 雅裕[1] (1.東北大学)

14:00 ~ 14:15

[PPS02-02] Simulating the Lunar Soil: a Japanese Lunar Soil Simulant FJS-1 and Its Properties

★Invited Papers

*鵜山 尚大[1]、金森 洋史[1]、青木 滋[1] (1.清水建設株式会社)

14:15 ~ 14:30

[PPS02-03] Experimental estimation of regolith scattering behavior when a space lander touches on a planetary body

★Invited Papers

*馬場 満久[1]、Ronald Ballouz[2]、大槻 真嗣[1] (1.国立研究開発法人宇宙航空研究開発機構、2.アリゾナ大学)

14:30 ~ 14:45

[PPS02-04] Ray systems in granular cratering

*Tapan Sabuwala[1]、Christian Butcher[1]、Gustavo Gioia[1]、Pinaki Chakraborty[1] (1.Okinawa Institute of Science and Technology Graduate University)

14:45 ~ 15:00

[PPS02-05] Scaling of oblique impact cratering onto inclined granular layer

滝澤 真太[1]、*桂木 洋光[1] (1.名古屋大学大学院環境学研究科)

15:00 ~ 15:15

[PPS02-06] Experimental study on gravitational effects on crater size formed by low-velocity impacts into granular media

*木内 真人[1]、中村 昭子[2]、和田 浩二[3] (1.国立研究開発法人宇宙航空研究開発機構宇宙科学研究所、2.神戸大学大学院理学研究科、3.千葉工業大学惑星探査センター)

[E] 口頭発表 | セッション記号 P (宇宙惑星科学)：P-PS 惑星科学

15:30 ~ 17:00 | A01 東京ベイ幕張ホール

[P-PS02] Regolith Science

コンビーナ:和田 浩二(千葉工業大学惑星探査研究センター)、中村 昭子(神戸大学大学院理学研究科地球惑星科学専攻)、Patrick Michel(Observatoire De La Cote D'Azur)、Kevin John Walsh(Southwest Research Institute Boulder)、座長:中村 昭子(Graduate School of Science, Kobe University)

15:30 ~ 15:45

[PPS02-07] **Impact Ejecta Environment of an Eccentric Asteroid: 3200 Phaethon**

*Jamey Szalay[1]、Peter Pokorny[2]、Mihaly Horanyi[3]、Diego Janches[2]、Menelaos Sarantos[2]、Ralf Srama[4] (1.Princeton University、2.NASA/GSFC、3.University of Colorado Boulder、4.University of Stuttgart)

15:45 ~ 16:00

[PPS02-08] On the Detection of an Ejecta Dust Cloud Around Asteroid (3200) Phaethon by the DESTINY$^+$ Dust Analyzer

*Hiroshi Kimura[1]、Masanori Kobayashi[1]、Koji Wada[1]、Tomoko Arai[1]、Hiroki Senshu[1]、Masateru Ishiguro[2]、Hidekazu Hanayama[3]、Ko Ishibashi[1]、Takayuki Hirai[1]、Fumi Yoshida[1]、Peng Hong[1] (1.Planetary Exploration Research Center、2.Seoul National University、3.Ishigakijima Astronomical Observatory)

16:00 ~ 16:15

[PPS02-09] Close-up thermal and optical observation of asteroid Ryugu

★Invited Papers

*坂谷 尚哉[1]、岡田 達明[1]、田中 智[1]、千秋 博紀[2]、嶌生 有理[1]、荒井 武彦[3]、神山 徹[5]、出村 裕英[6]、須古 健太郎[6]、関口 朋彦[4]、滝田 隼[15]、福原 哲哉[4]、田口 真[4]、Thomas Müller[7]、Axel Hargermann[8]、Jens Biele[9]、Matthias Grott[9]、Marco Delbo[10]、杉田 精司[13]、本田 理恵[12]、諸田 智克[11]、山田 学[2]、亀田 真吾[4]、巽 瑛理[13]、横田 康弘[1]、鈴木 秀彦[14]、本田 親寿[6]、小川 和律[16]、早川 雅彦[1]、松岡 萌[1]、長 勇一郎[13]、澤田 弘崇[1] (1.宇宙航空研究開発機構 宇宙科学研究所、2.千葉工業大学、3.足利大学、4.立教大学、5.産業技術総合研究所、6.会津大学、7.Max-Planck Institute for Extraterrestrial Physics、8.University of Stirling、9.German Aerospace Center、10.Observatoire de la Côte d'Azur, CNRS、11.名古屋大学、12.高知大学、13.東京大学、14.明治大学、15.北海道教育大学、16.神戸大学)

16:15 ~ 16:30

[PPS02-10] **In-Situ Investigation of Asteroid (162173) Ryugu by the Hayabusa2 MASCOT Lander**

★招待講演

*矢野 創[1]、Ho Tra-Mi[2]、Jaumann Ralf[3]、Bibring Jean-Pierre[4]、 Glassmeier Karl-Heinz[5]、Grott Matthias [3]、Hercik David [5]、Biele Jens [6]、Hamm Maximilian [3]、Schmitz Nicole [3]、 Schröder Stefanus[3]、Otto Katharina[3]、Krause Christian[6]、Lorda Laurence [7]、Moussi-Soffys Aurelie [7]、Pilorget Cedric [4]、Hamm Vincent [4]、Riu Lucie [1]、Okada Tatsuaki[1]、Sakatani Naoya[1]、Reill Josef [8]、Sasaki Kaname [2]、Schlotterer Markus [2]、Tsuda Yuichi [1]、Ulamec Stephan [6]、Wolff Friederike [8]、Michel Patrick[9]、Delbo Marco [9]、Ogawa Kazunori[10]、Senshu Hiroki[11]、Yoshimitsu Tetsuo [1]、Preusker Frank [3]、Scholten Frank [3]、Elgner Stephan[3]、Mottola Stefano[3]、Kührt Ekkehard[3]、Saiki Takanao[1]、Mimasu Yuya [1] (1.Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency, Sagamihara, Japan, 、2.German Aerospace Center DLR Bremen, Bremen, Germany、3.German Aerospace Center, Berlin, Germany、4.Univ. de Paris Sud-Orsay, IAS, Orsay, France、5.TU Braunschweig, Braunschweig, Germany、6.German Aerospace Center DLR Cologne, Cologne, Germany、7.National Centre for Space Studies, CNES, Toulouse, France、8.German Aerospace Center, DLR, Oberpfaffenhofen, Germany、9.Université Côte d'Azur, Observatoire de la Côte d'Azur, CNRS, Laboratoire Lagrange, Nice, France、10.Department of Planetology, Graduate School of Science, Kobe University, Kobe, Japan、11.Planetary Exploration Research Center, Chiba Institute of Technology, Narashino, Japan)

16:30 ~ 16:45

[PPS02-11] Evidence of Mass Movement and Boulder Transport on Bennu from NASA's OSIRIS-REx Space Mission

★Invited Papers

*Erica R Jawin[1]、Kevin J Walsh[2]、Tim McCoy[1]、Harold C Connolly[3]、Dante S Lauretta[4]、Ron L Ballouz[4]、Jamie L Molaro[5]、Olivier S Barnouin[6]、Mike Nolan[4] (1.Smithsonian National Institute, Washington, DC, USA、2.Southwest Research Institute, Boulder, CO, USA、3.Dept. of Geology, Rowan University, Glassboro, NJ, USA、4.Lunar and Planetary Laboratory, University of Arizona, Tucson, AZ, USA 、5.Planetary Science Institute, Tucson, AZ, USA、6.The Applied Physics Laboratory, Johns Hopkins University, Laurel, MD, USA)

16:45 ~ 17:00

[PPS02-12] Resurfacing processes on small asteroids constrained by crater size distributions on Ryugu, Itokawa, and Eros

*高木 直史[1]、長 勇一郎[1]、諸田 智克[3]、巽 瑛理[1]、吉岡 和夫[1]、澤田 弘崇[5]、横田 康弘[2,5]、坂谷 尚哉[5]、早川 雅彦[5]、松岡 萌[5]、本田 理恵[2]、亀田 真吾[4]、山田 学[6]、神山 徹[8]、鈴木 秀彦[10]、本田 親寿[7]、小川 和律[9]、宮本 英昭[1]、Olivier Barnouin[11]、Patrick Michel[12]、Carolyn Ernst[11]、杉田 精司[1,6] (1.東京大学、2.高知大学、3.名古屋大学、4.立教大学、5.宇宙航空研究開発機構 宇宙科学研究所、6.千葉工業大学 惑星探査センター、7.会津大学、8.産総研、9.神戸大学、10.明治大学、11.ジョンズホプキンス大学 応用物理学研究所、12.ニース天文台)

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9:00 ~ 10:30 | A01 東京ベイ幕張ホール

[P-PS03] Solar System Small Bodies: A New Frontier Arising Hayabusa 2, OSIRIS-REx and Other Projects

コンビーナ:石黒 正晃(ソウル大学物理天文学科)、中本 泰史(東京工業大学)、安部 正真(宇宙航空研究開発機構宇宙科学研究所)、Olivier S Barnouin(Johns Hopkins University Applied Physics Laboratory)、座長:Taishi Nakamoto(東京工業大学)

9:00 ~ 9:15

[PPS03-19] The shape of Bennu: Implications for internal structure.

★Invited Papers

*Olivier S Barnouin[1]、Micheal G. Daly[2]、Eric E Palmer[3]、Robert W Gaskell[3]、John R. Weirich[3]、Catherine L Johnson[4]、Manar Al Asad[4]、James H Roberts[1]、Mark E. Perry[1]、Hannah C.M. Sursorney[4]、R. Terik Daly[1]、Edward B. Bierhaus[5]、Jeff A Seabrook[2]、Raymond C. Espiritu[1]、A. Hari Nair[1]、Lilian Nguyen[1]、Gregory A Neumann[6]、Carolyn M Ernst[1]、William V Boynton[7]、Micheal C. Nolan[7]、Coralie D. Adams[9]、Micheal C. Moreau[6]、Bashar Rizk[7]、Christian Drouet D'Aubigny[7]、Erica R. Jawin[8]、Kevin J Walsh[10]、Patrick Michel[11]、Stephen R. Schwartz[7]、Ronald L. Ballouz[7]、Erwan M Mazarico[6]、Daniel J. Scheeres[12]、Jay W. McMahon[12]、W Bottke[10]、Seiji Sugita[13]、Naru Hirata[14]、Noayuki Hirata[15]、Sei-ichiro Watanbe[16]、Keara N. Burke[7]、Daniella N. DellaGuistina[7]、Carinna A. Bennet[7]、Dante Lauretta[7] (1.Johns Hopkins University Applied Physics Laboratory、2.The Centre for Research in Earth and Space Science, York University, Toronto, Ontario, Canada.、3.Planetary Science Institute, Tucson, AZ, USA、4.Department of Earth, Ocean and Atmospheric Sciences, University of British Columbia, Vancouver, Canada.、5.Lockheed Martin Space Systems Company, Denver, CO, USA.、6.NASA Goddard Space Flight Center, Greenbelt, MD, USA.、7.Lunar Planetary Laboratory, University of Arizona, Tucson, AZ, USA.、8.Smithsonian Institution National Museum of Natural History, Washington, DC, USA.、9.KinetX Aerospace, Inc. Simi Valley, CA, USA、10.Southwest Research Institute, Boulder, CO, USA.、11.Université Côte d'Azur, Observatoire de la Côte d'Azur, CNRS, Laboratoire Lagrange, Nice, France.、12.Department of Aerospace Engineering Sciences, University of Colorado, Boulder, CO, USA.、13.University of Tokyo, Tokyo, Japan.、14.Aizu University, Aizu-Wakamatsu, Japan.、15.Kobe University, Kobe, Japan.、16.Nagoya University, Nagoya, Japan.)

9:15 ~ 9:30

[PPS03-20] Global Geology of Bennu from NASA's OSIRIS-REx Space Mission

★Invited Papers

*Erica R Jawin[1]、Kevin J Walsh[2]、Tim McCoy[1]、Harold C Connolly[3]、Dante S Lauretta[4]、Ron L Ballouz[4]、Olivier S Barnouin[5]、C Beddingfield[6]、Carina A Bennett[4]、Edward B Bierhaus[7]、Keara N Burke[4]、Ben Clark[8]、Michael G Daly[9]、Marco Delbo[10]、Daniella DellaGiustina[4]、Jason P Dworkin[11]、Christine Hartzell[12]、John Marshall[6]、Patrick Michel[10]、Jamie L. Molaro[13]、Mike Nolan[4]、Maurizio Pajola[14]、Mark Perry[5]、Bashar Rizk[4]、Scott Sandford[15]、Dan J Scheeres[16]、Stephen R Schwartz[4]、David Trang[17] (1.Smithsonian National Institute, Washington, DC, USA、2.Southwest Research Institute, Boulder, CO, USA、3.Dept. of Geology, Rowan University, Glassboro, NJ, USA、4.Lunar and Planetary Laboratory, University of Arizona, Tucson, AZ, USA 、5.The Applied Physics Laboratory, Johns Hopkins University, Laurel, MD, USA、6.SETI Institute, Mountain View, CA, USA、7.Lockheed Martin Space Systems Company, USA、8.Space Science Institute, Boulder CO, USA、9.York University, Canada、10.Laboratoire Lagrange, Université Côte d'Azur, Observatoire de la Côte d'Azur, CNRS, Laboratoire Lagrange, Nice, France、11.NASA Goddard Space Flight Center, Greenbelt, MD, USA、12.Department of Aerospace Engineering, University of Maryland, College Park MD, USA、13.Planetary Science Institute, Tucson, AZ, USA、14.INAF - Astronomical Observatory of Padova, Italy、15.NASA Ames Research Center, USA、16.Dept. of Aerospace Engineering Sciences, University of Colorado, Boulder, CO, USA、17.HIGP/University of Hawaii at Manoa, USA)

9:30 ~ 9:45

[PPS03-21] Modeling surface mobility mechanisms on a top-shaped near-Earth asteroid

★Invited Papers

*Ronald Ballouz[1]、Nicola Baresi[2]、Olivier S Barnouin[3]、Carina A Bennet[1]、Edward B Bierhaus[4]、Keara N Burke[1]、Harold C Connolly[5]、Sarah T Crites[2]、Daniella DellaGiustitna[1]、Erica Jawin[6]、Dante S Lauretta[1]、Patrick Michel[7]、Derek C Richardson[8]、Dan J Scheeres[9]、Stephen Schwartz[1]、Seiji Sugita[10]、Eri Tatsumi[10]、Florian Thuillet[7]、Kevin Walsh[11] (1.Lunar and Planetary Lab, University of Arizona, Tucson, AZ, USA、2.Institute of Space and Astronautical Science, Sagamihara, Japan、3.The Applied Physics Laboratory, Johns Hopkins University, Laurel, MD, USA、4.Lockheed Martin, Boulder, CO, USA、5.Department of Geology, Rowan University, Glassboro, NJ, USA、6.Smithsonian National Museum of Natural History, Washington, DC, USA、7.UCA-OCA-CNRS, Lagrange Laboratory, Nice, France、8.Dept. of Astronomy, University of Maryland, College Park, MD, USA、9.Dept. of Aerospace Engineering Sciences, University of Colorado, Boulder, CO, USA、10.University of Tokyo, Tokyo, Japan、11.Southwest Research Institute, Boulder, CO, USA)

9:45 ~ 10:00

[PPS03-22] **Visualization and Analysis of Solar System Small Bodies with NASA's Solar System Treks Project**

*Brian Hamilton Day[1]、Emily Law[2] (1.NASA Solar System Exploration Research Virtual Institute, NASA Ames Research Center、2.NASA Jet Propulsion Laboratory, California Institute of Technology)

10:00 ~ 10:15

[PPS03-23] Density Distribution within Small Solar System Bodies Based on Smooth Terrain Shape: Asteroid 25143 Itokawa and Comet 67P/Churyumov-Gerasimenko

*金丸 仁明[1]、佐々木 晶[1]、Mark Wieczorek[2] (1.大阪大学、2.コートダジュール天文台)

10:15 ~ 10:30

[PPS03-24] 彗星探査計画CAESARに向けた非晶質珪酸塩の低温水質変成実験

*瀧川 晶[1,4]、木村 勇気[1]、古川 善博[2]、中村 智樹[3] (1.京都大学大学院理学研究科、2.北海道大学低温科学研究所、3.東北大学大学院理学研究科、4.京都大学白眉センター)

[E] 口頭発表 | セッション記号 P (宇宙惑星科学)：P-PS 惑星科学

10:45 ~ 12:15 | A01 東京ベイ幕張ホール

[P-PS03] Solar System Small Bodies: A New Frontier Arising Hayabusa 2, OSIRIS-REx and Other Projects

コンビーナ:石黒 正晃(ソウル大学物理天文学科)、中本 泰史(東京工業大学)、安部 正真(宇宙航空研究開発機構宇宙科学研究所)、Olivier S Barnouin(Johns Hopkins University Applied Physics Laboratory)、座長:Masateru Ishiguro(Seoul National University)

10:45 ~ 11:00

[PPS03-25] Overview and current status of DESTINY^{+} mission

★Invited Papers

*荒井 朋子[1]、小林 正規[1]、石橋 高[1]、吉田 二美[1]、木村 宏[1]、平井 隆之[1]、洪 鵬[1]、山田 学[1]、千秋 博紀[1]、和田 浩二[1]、スラマ ラルフ[2]、クルーガー ハラルド[3]、渡部 潤一[4]、伊藤 孝士[4]、石黒 正晃[5]、中村 智樹[6]、薮田 ひかる[7]、橘 省吾[8]、三河内 岳[8]、阿部 新助[9]、大塚 勝仁[10]、浦川 聖太郎[11]、中村メッセンジャー 圭子[12]、小松 睦美[13]、亀田 真吾[14]、鍵谷 将人[6]、平田 成[15]、出村 裕英[15]、佐々木 晶[16]、廣井 隆弘[17]、小松 吾郎[18]、金田 英宏[19]、稲守 孝哉[19]、岡本 尚也[20]、柳沢 俊史[20]、吉川 真[20]、矢野 創[20]、岡田 達明[20]、岩田 隆浩[20]、大坪 貴文[20]、川勝 康弘[20]、豊田 裕之[20]、西山 和孝[20]、高島 健[20] (1.千葉工業大学惑星探査研究センター、2.シュツットガルト大学、3.マックスプランク研究所、4.国立天文台、5.ソウル大学、6.東北大学、7.広島大学、8.東京大学、9.日本大学、10.東京流星観測網、11.日本スペースガード協会、12.NASA、13.総合研究院大学、14.立教大学、15.会津大学、16.大阪大学、17.ブラウン大学、18.ダヌンツィオ大学、19.名古屋大学、20.宇宙航空研究開発機構)

11:00 ~ 11:15

[PPS03-26] Observational campaign of (3200) Phaethon and (155140) 2005UD in 2017-2018

*吉田 二美[1]、Arai Tomoko[1]、Ishibashi Ko[1]、Hong Peng[1]、Ishimaru Ryo[1]、International observation collaborators DESTINY+ (1.Planetary Exploration Research Center, Chiba Institute of Technology)

11:15 ~ 11:30

[PPS03-27] Rotationally-resolved spectroscopic observations of Phaethon - 2005 UD, and their fragments detected by lunar impact flashes.

*阿部 新助[1]、Moskovitz Nicholas[2]、吉田 二美[3]、大塚 勝仁[4]、伊藤 孝士[5]、布施 綾太[1]、柳澤 正久[6]、山田 竜平[7] (1.日本大学理工学部 航空宇宙工学科、2.ローウェル天文台、3.千葉工業大学 惑星探査研究センター、4.東京流星ネットワーク、5.国立天文台、6.電気通信大学 情報理工学研究科、7.会津大学 コンピュータ理工学部)

11:30 ~ 11:45

[PPS03-28] Thermal Radiation Pressure Force on Regolith Particles of Atmosphereless Bodies

*Yoonsoo P. Bach[1]、Masateru Ishiguro[1] (1.Department of Physics and Astronomy, Seoul National University)

11:45 ~ 12:00

[PPS03-29] A kilometre-sized Kuiper belt object revealed by OASES stellar occultation observations

*有松 亘[1,2]、津村 耕司[3]、臼井 文彦[4]、新中 善晴[5]、市川 幸平[3,6,7]、大坪 貴文[8]、小谷 隆行[2,9]、和田 武彦[8]、長勢 晃一[8]、渡部 潤一[2] (1.京都大学 付属天文台、2.国立天文台、3.東北大学 学際科学フロンティア研究所、4.神戸大学大学院 理学研究科 惑星科学研究センター、5.京都産業大学、6.コロンビア大学、7.テキサス大学サンアントニオ校、8.宇宙航空研究開発機構　宇宙科学研究所、9.アストロバイオロジーセンター)

12:00 ~ 12:15

[PPS03-30] AKARI/IRC near-infrared asteroid spectroscopic survey: AcuA-spec

*臼井 文彦[1]、長谷川 直[2]、大坪 貴文[2]、尾中 敬[3,4] (1.神戸大学大学院 理学研究科 惑星科学研究センター、2.宇宙航空研究開発機構 宇宙科学研究所、3.東京大学大学院理学系研究科 天文学専攻、4.明星大学理工学部 総合理工学科)

[E] 口頭発表 | セッション記号 P (宇宙惑星科学)：P-EM 太陽地球系科学・宇宙電磁気学・宇宙環境

13:45 ~ 15:15 | A03 東京ベイ幕張ホール

[P-EM09] Vertical coupling in the atmosphere and Ionosphere

コンビーナ:Liu Huixin(九州大学理学研究院地球惑星科学専攻 九州大学宙空環境研究センター)、Chang Loren(Institute of Space Science, National Central University)、大塚 雄一(名古屋大学宇宙地球環境研究所)、座長:Patrick Espy(Norwegian University of Science and Technology)、Astrid Maute(National Center for Atmospheric Research, US)

13:45 ~ 14:05

[PEM09-01] **Vertical Coupling from the Atmosphere to Geospace at Arrival Heights in Antarctica**

★Invited Papers

*Xinzhao Chu[1] (1.University of Colorado Boulder)

14:05 ~ 14:20

[PEM09-02] Vertical structure of terdiurnal tides in the Antarctic MLT region: 15 years observation over Syowa

*Liu Huixin[1]、堤 雅基[2]、Liu Hanli[3] (1.九州大学理学研究院地球惑星科学専攻 、2.National Institute for Polar Research、3.National Center for Atmospheric Research)

14:20 ~ 14:35

[PEM09-03] **3D Investigation of gravity waves propagation by Continuous Doppler sounding**

*Jaroslav Chum[1]、Katerina Podolska[1] (1.Institute of Atmospheric Physics of the Czech Academy of Sciences)

14:35 ~ 14:55

[PEM09-04] **Observations of MLT dynamics using meteor radars and meteor radar networks**

★Invited Papers

*Gunter Stober[1]、Vivien Matthias[2]、Sven Wilhelm[1]、Dimitry Pokhotelov[1]、Alexander Kozlovsky[3]、Evgenia Belova[4]、Johan Kero[4]、Chris Hall[5]、Masaki Tsutsumi[6] (1.Leibniz Institute of Atmospheric Physics、2.Potsdam Institute for Climate Impact Research, Earth System Analysis - Research Domain 1, Potsdam, Germany、3.Sodankylä Geophysical Observatory, Sodankylä, FIN-99600, Finland、4.Swedish Institute of Space Physics, Box 812, 98128 Kiruna, Sweden、5.Tromsø Geophysical Observatory UiT-the Arctic University of Norway, Tromsø, Norway、6.National Institute of Polar Research, Tokyo, Japan)

14:55 ~ 15:15

[PEM09-05] Ionospheric Variability Associated with the Quasi-6-day Planetary Wave

★Invited Papers

*山崎 洋介[1] (1.ドイツ地球科学研究センター)

[E] 口頭発表 | セッション記号 P (宇宙惑星科学)：P-EM 太陽地球系科学・宇宙電磁気学・宇宙環境

15:30 ~ 17:00 | A03 東京ベイ幕張ホール

[P-EM09] Vertical coupling in the atmosphere and Ionosphere

コンビーナ:Liu Huixin(九州大学理学研究院地球惑星科学専攻 九州大学宇宙空環境研究センター)、Chang Loren(Institute of Space Science, National Central University)、大塚 雄一(名古屋大学宇宙地球環境研究所)、座長:大塚 雄一、Yosuke Yosuke Yamazaki(GFZ Potsdam, Germany)

15:30 ~ 15:50

[PEM09-06] Results of FORMOSAT-3/COSMIC to the most recent developments on FORMOSAT-7/COSMIC-2

★Invited Papers

*JANN-YENQ Liu[1] (1.Center for Astronautical Physics and Engineering; Graduate Institute of Space Science, National Central University, Taiwan)

15:50 ~ 16:05

[PEM09-07] A morphological study on the relationship between electron density fluctuations and magnetic fluctuations observed by low altitude satellites in low and middle latitudes

*家森 俊彦[1]、青山 忠司[1]、横山 佳弘[1] (1.京都大学)

16:05 ~ 16:25

[PEM09-08] Observations of the Thermosphere and Ionosphere by the NASA GOLD Mission

★Invited Papers

*Stanley C Solomon[1]、Alan G. Burns[1]、Richard W. Eastes[2]、William E. McClintock[2] (1.National Center for Atmospheric Research、2.University of Colorado)

16:25 ~ 16:40

[PEM09-09] 全球TECに見られる磁気嵐時の中低緯度域における電子密度増大の時間・空間発展

*新堀 淳樹[1]、惣宇利 卓也[1]、大塚 雄一[1]、津川 卓也[2]、西岡 未知[2] (1.名古屋大学宇宙地球環境研究所、2.情報通信研究機構)

16:40 ~ 16:55

[PEM09-10] Tidal Forcing Effects on the Zonal Variation of Solstice Equatorial Plasma Bubbles

*Loren Chang[1]、Jude Salinas[1]、Yi-Chung Chiu[1]、Pei-yun Chiu[1]、Charles Lin[2] (1.Institute of Space Science and Engineering, Center for Astronautical Physics and Engineering, National Central University, Taiwan、2.Department of Earth Science, National Cheng Kung University, Taiwan)

[E] 口頭発表 | セッション記号 P (宇宙惑星科学)：P-EM 太陽地球系科学・宇宙電磁気学・宇宙環境

15:30 ~ 17:00 | A04 東京ベイ幕張ホール

[P-EM11] Dynamics of Magnetosphere and Ionosphere

コンビーナ:中溝 葵(情報通信研究機構　電磁波研究所)、尾崎 光紀(金沢大学理工研究域電子情報学系)、藤本 晶子(九州工業大学)、堀 智昭(名古屋大学宇宙地球環境研究所)、座長:長谷川 洋(宇宙航空研究開発機構 宇宙科学研究所)

15:30 ~ 15:45

[PEM11-01] **A Case Study Based on Ground Observations of the Conjugate Ionospheric Response to Interplanetary Shock in Polar Regions**

*He Fang[1]、Zejun HU[1]、Hongqiao HU[1] (1.Polar Research Institute of China)

15:45 ~ 16:00

[PEM11-02] **Effects of Solar Illumination on the Auroral Electrojet Intensity**

*Shinichi Ohtani[1]、Jesper W Gjerloev[1] (1.The Johns Hopkins University Applied Physics Laboratory)

16:00 ~ 16:15

[PEM11-03] Quasi-persistent multiple mesoscale field-aligned currents in the duskside auroral oval

*横山 佳弘[1]、田口 聡[1]、家森 俊彦[2]、細川 敬祐[3] (1.京都大学大学院理学研究科地球惑星科学専攻地球物理学教室、2.京都大学、3.電気通信大学大学院情報理工学研究科)

16:15 ~ 16:30

[PEM11-04] Generation of dispersive Alfvenic turbulence in magnetosphere-ionosphere feedback coupling

*渡邉 智彦[1]、兼山 将寿[1]、前山 伸也[1] (1.名古屋大学大学院理学研究科)

16:30 ~ 16:45

[PEM11-05] Aspects of simulating magnetosphere-ionosphere coupling via field-aligned current

*Astrid I Maute[1]、Arthur D Richmond[1]、Gang Lu[1] (1.High Altitude Observatory, National Center for Atmospheric Research, Boulder CO, 80301, USA)

16:45 ~ 17:00

[PEM11-06] **Revisiting the energy conversion process of Birkeland current generation**

*吉川 顕正[1] (1.九州大学大学院理学研究院地球惑星科学部門)

[E] 口頭発表 | セッション記号 P (宇宙惑星科学)：P-EM 太陽地球系科学・宇宙電磁気学・宇宙環境

9:00 ~ 10:30 | A04 東京ベイ幕張ホール

[P-EM13] 内部磁気圏

コンビーナ:海老原 祐輔(京都大学生存圏研究所)、Danny Summers(Memorial University of Newfoundland)、三好 由純(名古屋大学宇宙地球環境研究所)、齊藤 慎司(名古屋大学　大学院理学研究科)、座長:Shinji Saito(ISEE, Nagoya University)、海老原 祐輔(京都大学生存圏研究所)

9:00 ~ 9:15

[PEM13-11] Nonlinear Damping of Oblique Whistler Mode Waves Via Landau Resonance

*謝 怡凱[1]、大村 善治[1] (1.京都大学生存圏研究所)

9:15 ~ 9:30

[PEM13-12] Instantaneous Frequency Analysis on Nonlinear EMIC Emissions: Arase Observation

*小路 真史[1]、三好 由純[1]、大村 善治[2]、Kistler Lynn[1,3]、笠羽 康正[4]、松田 昇也[5]、笠原 禎也[6]、松岡 彩子[5]、野村 麗子[7]、石坂 圭吾[8]、熊本 篤志[4]、土屋 史紀[4]、八木谷 聡[6]、寺本 万里子[1]、浅村 和史[5]、高島 健[5]、篠原 育[5] (1.名古屋大学宇宙地球環境研究所、2.京都大学生存圏研究所、3.Institute for the Study of Earth Oceans and Space, University of New Hampshire、4.東北大学、5.宇宙科学研究所、6.金沢大学、7.国立天文台、8.富山県立大学)

9:30 ~ 9:45

[PEM13-13] Rapid Precipitation by EMIC Rising-tone Emissions of Relativistic Electrons Observed by the Van Allen Probes Mission

*中村 紗都子[1]、大村 善治[1]、Craig Kletzing[2]、Daniel Baker[3] (1.京都大学生存圏研究所、2.Department of Physics and Astronomy University of Iowa 、3.The Laboratory for Atmospheric and Space Physics (LASP) at the University of Colorado)

9:45 ~ 10:00

[PEM13-14] Plasmaspheric EMIC waves excited through mode conversion from equatorial noise under existence of M/Q=2 ions

*三好 由純[1]、松田 昇也[2]、栗田 怜[1]、野村 浩司[1]、桂華 邦裕[3]、小路 真史[1]、北村 成寿[3]、笠原 禎也[4]、松岡 彩子[2]、篠原 育[2]、塩川 和夫[1]、町田 忍[1]、Santolik Ondrej[5]、Boardsen Scott[6]、Horne Richard[7]、John Wygant [8] (1.名古屋大学宇宙地球環境研究所、2.宇宙航空研究開発機構、3.東京大学、4.金沢大学、5.チェコ科学アカデミー、6.NASA、7.British Antarctic Survey、8.ミネソタ大学)

10:00 ~ 10:15

[PEM13-15] Generation Mechanism of Non-thermal Continuum Radiation

*大村 善治[1]、Horky Miroslav[1,2] (1.京都大学生存圏研究所、2.Department of Space Physics, Institute of Atmospheric Physics, Czech Academy of Sciences)

10:15 ~ 10:30

[PEM13-16] Influence of kappa distributions on the sweep rate of whistler mode chorus waves

*Danny Summers[1] (1.Memorial University of Newfoundland)

[E] 口頭発表 | セッション記号 P (宇宙惑星科学)：P-EM 太陽地球系科学・宇宙電磁気学・宇宙環境

10:45 ~ 12:15 | A04 東京ベイ幕張ホール

[P-EM13] 内部磁気圏

コンビーナ:海老原 祐輔(京都大学生存圏研究所)、Danny Summers(Memorial University of Newfoundland)、三好 由純(名古屋大学宇宙地球環境研究所)、齊藤 慎司(名古屋大学　大学院理学研究科)、座長:海老原 祐輔(京都大学生存圏研究所)、Shinji Saito(ISEE, Nagoya University)

10:45 ~ 11:05

[PEM13-17] The Impacts of Substorms on the Ring Current

★Invited Papers

*Jasmine Kaur Sandhu[1]、I. J. Rae[1]、M. Gkioulidou[2]、C. Forsyth[1]、G. D. Reeves[3]、M. P. Freeman[4]、K. R. Murphy[5]、M.-T. Walach[6]、H. E. Spence[7] (1.Mullard Space Science Laboratory, University College London, UK.、2.Applied Physics Laboratory, John Hopkins University, USA.、3.Los Alamos National Laboratory, USA.、4.British Antarctic Survey, UK.、5.University of Maryland, USA.、6.Lancaster University, UK.、7.University of New Hampshire, USA.)

11:05 ~ 11:25

[PEM13-18] Dipolarization in the Inner Magnetosphere: Comparison between Geosynchronous Orbit and Further Inside

★Invited Papers

*Shinichi Ohtani[1]、Tetsuo Motoba[1]、Matina Gkioulidou[1]、Kazue Takahashi[1] (1.The Johns Hopkins University Applied Physics Laboratory)

11:25 ~ 11:40

[PEM13-19] **Substorm-associated particle injection near/at geosynchronous orbit: Observations from ERG and GOES**

*Tzu-Fang Chang[1,2]、Chio-Zong Cheng[2]、Sunny Wing-Yee Tam[2]、Chih-Yu Chiang[2]、Yoshizumi Miyoshi[1]、Tomoaki Hori[1]、Takefumi Mitani[3]、Takeshi Takashima[3]、Ayako Matsuoka[3]、Mariko Teramoto[1]、Iku Shinohara[3] (1.Institute for Space-Earth Environmental Research, Nagoya University, Japan、2.Institute of Space and Plasma Sciences, National Cheng Kung University, Tainan, Taiwan、3.Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency, Japan)

11:40 ~ 11:55

[PEM13-20] Substorm -like energetic electron injection observed at the plasma sheet boundary in the inner magnetosphere

*篠原 育[1]、長井 嗣信[1]、三谷 烈史[1]、東尾 奈々[2]、笠原 慧[3]、風間 洋一[4]、Wang Shiang-Yu[4]、Tam Sunny[5]、松岡 彩子[1]、浅村 和史[1]、横田 勝一郎[6]、高島 健[1]、三好 由純[7] (1.宇宙航空研究開発機構／宇宙科学研究所、2.宇宙航空研究開発機構、3.東京大学、4.ASIAA、5.国立成功大学、6.大阪大学、7.名古屋大学／宇宙地球環境研究所)

11:55 ~ 12:10

[PEM13-21] Magnetic field disturbances associated with the magnetic dipolarization observed by Arase (ERG) in the inner magnetosphere

*松岡 彩子[1]、能勢 正仁[2]、三好 由純[2]、篠原 育[1]、寺本 万里子[2]、野村 麗子[3]、藤本 晶子[4]、田中 良昌[5]、篠原 学[6]、笠原 禎也[7]、笠羽 康正[8]、石坂 圭吾[9]、松田 昇也[1]、小路 真史[2]、中川 朋子[10]、Kazama Yoichi[11]、Wang Shiang-Yu[11]、笠原 慧[12]、横田 勝一郎[13]、三谷 烈史[1] (1.宇宙航空研究開発機構　宇宙科学研究所、2.名古屋大学　宇宙地球環境研究所、3.国立天文台　RISE月惑星探査検討室、4.九州工業大学　情報工学部、5.国立極地研究所、6.鹿児島工業高等専門学校、7.金沢大学　総合メディア基盤センター、8.東北大学　惑星プラズマ・大気研究センター、9.富山県立大学 工学部、10.東北工業大学　工学部、11.台湾中央研究院、12.東京大学　大学院理学系研究科、13.大阪大学　大学院理学研究科)

[E] 口頭発表 | セッション記号 P (宇宙惑星科学)：P-EM 太陽地球系科学・宇宙電磁気学・宇宙環境

13:45 ~ 15:15 | A04 東京ベイ幕張ホール

[P-EM13] 内部磁気圏

コンビーナ:海老原 祐輔(京都大学生存圏研究所)、Danny Summers(Memorial University of Newfoundland)、三好 由純(名古屋大学宇宙地球環境研究所)、齊藤 慎司(名古屋大学　大学院理学研究科)、座長:三好 由純(名古屋大学宇宙地球環境研究所)、海老原 祐輔(京都大学生存圏研究所)

13:45 ~ 14:05

[PEM13-22] Statistical Property of Long Lasting Poloidal Pc 4-5 Waves and Relation with Particle Dynamics in the Inner Magnetosphere: Van Allen Probes Observations

★Invited Papers

*山本 和弘[1]、能勢 正仁[2]、桂華 邦裕[3]、Charles Smith[4]、Robert MacDowall[5]、Donald Mitchell[6]、Hyomin Kim[7]、John Wygant[8] (1.京都大学大学院理学研究科、2.名古屋大学宇宙地球環境研究所、3.東京大学理学系研究科、4.Institute for the Study of Earth, Oceans, and Space, University of New Hampshire、5.Solar System Exploration Division, Goddard Space Flight Center、6.The Johns Hopkins University Applied Physics Laboratory、7.Center for Solar‐Terrestrial Research, New Jersey Institute of Technology、8.School of Physics and Astronomy, University of Minnesota)

14:05 ~ 14:25

[PEM13-23] Subauroral Polarization Streams: Indication of Magnetosphere–Ionosphere Coupling

★Invited Papers

*Fei He[1,2,3]、Xiao-Xin Zhang[4]、Wenbin Wang[5]、Zhonghua Yao[1,2,3]、Yong Wei[1,2,3]、Zhi-Peng Ren[1,2,3]、Xinan Yue[1,2,3]、Weixing Wan[1,2,3] (1.Institute of Geology & Geophysics, CAS、2.Institutions of Earth Science, CAS、3.College of Earth and Planetary Sciences, UCAS、4.National Center for Space Weather, CMA、5.High Altitude Observatory, NCAR)

14:25 ~ 14:40

[PEM13-24] Simultaneous Arase-ground observations of a purple and green auroral arc

*塩川 和夫[1]、能勢 正仁[1]、土屋 智[1]、高木 佑基[1]、今城 峻[1]、田中 良昌[2]、三好 由純[1]、細川 敬祐[3]、風間 洋一[4]、Shiang-Yu Wang[4]、Sunny W. Y. Tam[4]、浅村 和史[5]、笠原 慧[6]、横田 勝一郎[7]、堀 智昭[1]、桂華 邦裕[6]、松岡 彩子[5] (1.名古屋大学宇宙地球環境研究所、2.国立極地研究所、3.電気通信大学、4.国立成功大学、5.JAXA宇宙科学研究所、6.東京大学、7.大阪大学)

14:40 ~ 14:55

[PEM13-25] Multiple Satellite Observations of Oxygen Torus in the Inner Magnetosphere

*能勢 正仁[1]、松岡 彩子[2]、熊本 篤志[3]、笠原 禎也[4]、Goldstein J[5,6]、寺本 万里子[1]、土屋 史紀[3]、松田 昇也[2]、小路 真史[1]、今城 峻[1]、生松 聡[7]、山本 和弘[7]、尾花 由紀[8]、野村 麗子[9]、藤本 晶子[10]、篠原 育[2]、三好 由純[1]、Kurth S[11]、Kletzing C[11]、Smith C[12]、MacDowall R[13] (1.名古屋大学宇宙地球環境研究所、2.宇宙航空研究開発機構宇宙科学研究所、3.東北大学大学院理学研究科、4.金沢大学総合メディア基盤センター、5.Space Science and Engineering Division, Southwest Research Institute、6.University of Texas at San Antonio、7.京都大学大学院理学研究科、8.大阪電気通信大学工学部、9.国立天文台、10.九州工業大学、11.Department of Physics and Astronomy, University of Iowa、12.Institute for the Study of Earth, Oceans, and Space, University of New Hampshire、13.Solar System Exploration Division, Goddard Space Flight Center)

14:55 ~ 15:10

[PEM13-26] Study of characteristics of storm-time Pc5 ULF waves excited by the drift-bounce resonance with ring current ions based on the global drift-kinetic simulation

*山川 智嗣[1]、関 華奈子[1]、天野 孝伸[1]、三好 由純[2]、高橋 直子[1] (1.東京大学理学系研究科地球惑星科学専攻、2.名古屋大学宇宙地球環境研究所)

[E] 口頭発表 | セッション記号 A (大気水圏科学)：A-AS 大気科学・気象学・大気環境

9:00 ~ 10:30 | 104 1F

[A-AS01] 高性能スーパーコンピュータを用いた最新の大気科学

コンビーナ:瀬古 弘(気象研究所)、三好 建正(理化学研究所)、小玉 知央(独立行政法人海洋研究開発機構)、滝川 雅之(独立行政法人海洋研究開発機構)、座長:瀬古 弘(気象研究所)、小玉 知央 (国立研究開発法人 海洋研究開発機構)

9:00 ~ 9:15

[AAS01-01] Data Assimilation Studies using Big Observation Data in the Projects of Post K and BDA

*瀬古 弘[1]、國井 勝[2]、澤田 洋平[1]、岡本 幸三[1]、横田 祥[1]、伊藤 耕介[3]、下地 和希[2] (1.気象研究所、2.気象庁、3.琉球大学)

9:15 ~ 9:30

[AAS01-02] **High-resolution Numerical Weather Simulation with a Large Domain for Extreme Heavy Rainfall Events**

*大泉 伝[1,2]、斉藤 和雄[4,3]、le duc[1]、伊藤 純至[3] (1.国立研究開発法人海洋研究開発機構、2.気象研究所、3.東京大学大気海洋研究所、4.気象業務支援センター)

9:30 ~ 9:45

[AAS01-03] Quasi-liner convective systemによって生じた竜巻の数値シミュレーション

★招待講演

*栃本 英伍[1]、新野 宏[1] (1.東京大学大気海洋研究所)

9:45 ~ 10:00

[AAS01-04] Improving the observation operator for Phased Array Weather Radar in the SCALE-LETKF system

*雨宮 新[1]、本田 匠[1]、三好 建正[1] (1.理化学研究所　計算科学研究センター)

10:00 ~ 10:15

[AAS01-05] Data assimilation and forecast experiments for the record-breaking rainfall event in Japan in July 2018 with NICAM-LETKF at 112-km and 28-km resolution

*寺崎 康児[1]、三好 建正[1] (1.理化学研究所計算科学研究センター)

10:15 ~ 10:30

[AAS01-06] Model Parameter Estimation with Data Assimilation Using NICAM-LETKF

★Invited Papers

*小槻 峻司[1]、佐藤 陽祐[2]、寺崎 康児[1]、八代 尚[1]、富田 浩文[1]、佐藤 正樹[3]、三好 建正[1] (1.国立研究開発法人　理化学研究所　計算科学研究センター、2.名古屋大学大学院　工学研究科、3.東京大学　大気海洋研究所)

[E] 口頭発表 | セッション記号 A (大気水圏科学)：A-AS 大気科学・気象学・大気環境

10:45 ~ 12:15 | 104 1F

[A-AS01] 高性能スーパーコンピュータを用いた最新の大気科学

コンビーナ:瀬古 弘(気象研究所)、三好 建正(理化学研究所)、小玉 知央(独立行政法人海洋研究開発機構)、滝川 雅之(独立行政法人海洋研究開発機構)、座長:滝川 雅之(国立研究開発法人 海洋研究開発機構)、三好 建正(理化学研究所計算科学研究機構)

10:45 ~ 11:00

[AAS01-07] 3D debris flow simulations by using smoothed particle hydrodynamics (SPH) method

*上田 翔士[1]、細野 七月[2]、山敷 庸亮[1] (1.京都大学、2.JAMSTEC)

11:00 ~ 11:15

[AAS01-08] **Regional atmospheric data assimilation coupled with an ocean mixed layer model: a case of typhoon Soudelor (2015)**

*高玉 孝平[1]、本田 匠[1]、三好 建正[1] (1.理化学研究所)

11:15 ~ 11:30

[AAS01-09] Effective Radiative Forcing and Climate Response to Short-Lived Climate Pollutants Under Different Scenarios

Hua Zhang[1]、*Bing Xie[1]、Zhili Wang[1] (1.China Meteorological Administration)

11:30 ~ 11:45

[AAS01-10] **The NICAM–SPRINTARS simulation of the long-range transport of black carbon using the K computer**

★Invited Papers

*山下 陽介[1]、滝川 雅之[1]、五藤 大輔[2]、八代 尚[3]、佐藤 正樹[4,1]、金谷 有剛[1]、竹谷 文一[1]、宮川 拓真[1] (1.海洋研究開発機構、2.国立環境研究所、3.理研計算科学、4.東京大学大気海洋研究所)

11:45 ~ 12:00

[AAS01-11] High-resolution, ensemble simulations of intense tropical cyclones and their stochasticity during the El Niños of 1997 and 2015

*山田 洋平[1]、小玉 知央[1]、佐藤 正樹[1,2]、中野 満寿男[1]、那須野 智江[1]、杉 正人[3] (1.海洋研究開発機構、2.東京大学大気海洋研究所、3.気象庁気象研究所)

12:00 ~ 12:15

[AAS01-12] **NICAM results of the project DYAMOND for global storm-resolving model intercomparison**

★Invited Papers

*佐藤 正樹[1]、澁谷 亮輔[2]、小玉 知央[2] (1.東京大学大気海洋研究所、2.海洋研究開発機構)

[E] 口頭発表 | セッション記号 A (大気水圏科学)：A-OS 海洋科学・海洋環境

13:45 ~ 15:15 | 105 1F

[A-OS08] ECS-Kuroshio and Ryukyu Current System -Observation, modeling and theory-

コンビーナ:中村 啓彦(鹿児島大学　水産学部)、Xiao-Hua Zhu(Second Institute of Oceanography)、座長:中村 啓彦(鹿児島大学)、Jae-Hun Park(Inha University)

13:50 ~ 14:10

[AOS08-01] Downstream Evolution of the Kuroshio Velocity Structure and Transport

★Invited Papers

*Magdalena Andres[1]、Sen Jan[2] (1.Woods Hole Oceanographic Institution、2.National Taiwan University)

14:10 ~ 14:25

[AOS08-02] **Non-seasonal variability of the Kuroshio shelf intrusion and its associated changes in the ocean environment over the East China Sea during 1993-2017**

*Jiwon Kang[1]、Hanna Na[1] (1.School of Earth and Environmental Sciences, Seoul National University, Republic of Korea)

14:25 ~ 14:40

[AOS08-03] The temporal and spatial variability of the Kuroshio in the East China Sea and its associated mechanisms

*Yanzhou Wei[1] (1.State Key Laboratory of Satellite Ocean Environment Dynamics, Second Institute of Oceanography, Ministry of Natural Resources, Hangzhou, China)

14:40 ~ 14:55

[AOS08-04] The Joint Kuroshio–Ryukyu Current System Study and a rapid report about mooring observations southeast of Miyakojima

*Xiao-Hua Zhu[1]、Hirohiko Nakamura[2]、Jae-Hun Park[3]、Ruixiang Zhao[1]、Ayako Nishina[2]、Chuanzheng Zhang[1]、Chanhyung Jeon[4]、Hanna Na[5]、Ze-Nan Zhu[1]、Hong Sik Min[6] (1.State Key Laboratory of Satellite Ocean Environment Dynamics, Second Institute of Oceanography, Ministry of Natural Resources, Hangzhou, China、2.Faculty of Fisheries, Kagoshima University, Kagoshima, Japan、3.Department of Ocean Sciences, Inha University, Incheon, South Korea、4.Department of Marine Science and Biological Engineering, Inha University, Incheon, Korea、5.School of Earth and Environmental Sciences, Seoul National University, Seoul, Korea、6.Ocean Circulation and Climate Research Center, Korea Institute of Ocean Science and Technology, Busan, Korea)

14:55 ~ 15:10

[AOS08-05] Relationship of the Kuroshio with the current fields in the East China Sea from observations and model results

*Hong Sik Min[1]、Chorong Hwang[1]、Dong Guk Kim[1]、Hirohiko Nakamura[2]、Ayako Nishina[2]、Xiao-Hua Zhu[3]、Jae-Hun Park[4]、Chanhyung Jeon[4]、Hanna Na[5]、Naoki Hirose[6] (1.Korea Institute of Ocean Science & Technology、2.Kagoshima University、3.Second Institute of Oceanography、4.Inha University、5.Seoul National University、6.Kyushu University)

[E] 口頭発表 | セッション記号 A (大気水圏科学)：A-OS 海洋科学・海洋環境

15:30 ~ 17:00 | 105 1F

[A-OS08] ECS-Kuroshio and Ryukyu Current System -Observation, modeling and theory-

コンビーナ:中村 啓彦(鹿児島大学　水産学部)、Xiao-Hua Zhu(Second Institute of Oceanography)、座長:Jae-Hun Park(Inha University)、中村 啓彦(鹿児島大学)

15:35 ~ 15:55

[AOS08-06] Separating Small-Scale Oceanic Internal Waves and Vortical Motions

★Invited Papers

*Ren-Chieh Lien[1] (1.University of Washington, Seattle, WA, USA)

15:55 ~ 16:10

[AOS08-07] Structure and variability of the Kuroshio current in the Tokara Strait

*劉 昭君[1]、中村 啓彦[2]、朱 小華[1]、仁科 文子[2]、郭 新宇[3]、Menghong Dong[1] (1.Second Institute of Oceanography, China、2.Kagoshima University, Japan、3.Ehime University, Japan)

16:10 ~ 16:25

[AOS08-08] **Near-inertial waves advected by the Kuroshio from observation and simulation**

*CHANHYUNG JEON[1]、Jae-Hun Park[1]、Hirohiko Nakamura[2]、Ayako Nishina[2]、Xiao-Hua Zhu[3]、Dong Guk Kim[4]、Hong Sik Min[4]、Sok Kuh Kang[4]、Hanna Na[5]、Naoki Hirose[6]、Youngseok Choi[1] (1.Inha University、2.Kagoshima University、3.Second Institute of Oceanography、4.Korea Institute of Ocean Science and Technology、5.Seoul National University、6.Kyushu University)

16:25 ~ 16:40

[AOS08-09] Turbulent mixing and near-inertial internal waves induced by the Kuroshio over seamounts in the Tokara Strait

*長井 健容[1]、長谷川 大介[2]、堤 英輔[3]、中村 啓彦[4]、仁科 文子[4]、千手 智晴[3]、遠藤 貴洋[3]、松野 健[3]、井上 龍一郎[5]、Amit Tandon[6] (1.東京海洋大学 海洋環境科学部門、2.東北区水産研究所・国立研究開発法人水産研究・教育機構、3.九州大学応用力学研究所、4.鹿児島大学　水産学部、5.海洋研究開発機構、6.マサチューセッツ大学ダートマス校)

16:40 ~ 16:55

[AOS08-10] Microstructure and mooring observations of enhanced mixing in the Kerama Gap

*井上 龍一郎[1]、中村 啓彦[2]、田中 雄大[3]、藤尾 伸三[4]、柳本 大吾[4]、安田 一郎[4] (1.国立研究開発法人海洋研究開発機構、2.鹿児島大学水産学部、3.国立研究開発法人水産研究・教育機構東北区水産研究所 、4.東京大学大気海洋研究所)

[E] 口頭発表 | セッション記号 A (大気水圏科学)：A-OS 海洋科学・海洋環境

9:00 ~ 10:30 | 301A 3F

[A-OS11] 陸域海洋相互作用-惑星スケール物質循環

コンビーナ:山敷 庸亮(京都大学大学院総合生存学館)、升本 順夫(東京大学大学院理学系研究科)、Behera Swadhin(Climate Variation Predictability and Applicability Research Group, Application Laboratory, JAMSTEC, 3173-25 Showa-machi, Yokohama 236-0001)、佐々木 貴教(京都大学 大学院理学研究科 宇宙物理学教室)、座長:升本 順夫、Swadhin Behera(海洋研究開発機構)

9:00 ~ 9:15

[AOS11-01] Explorations and current understandings for subsurface ocean of icy bodies

★Invited Papers

*木村 淳[1] (1.大阪大学)

9:15 ~ 9:30

[AOS11-02] Climate predictability for societal applications including AI/ML

*Swadhin Behera[1]、Manali Pal[2]、J.V. Ratnam[1]、Rajib Maity[2]、Takeshi Doi[1]、Yushi Morioka[1]、Masami Nonaka[1] (1.Application Laboratory, JAMSTEC, 3173-25 Showa-machi, Yokohama 236-0001、2.Indian Institute of Technology, Kharagpur, India)

9:30 ~ 9:45

[AOS11-03] Re-entry of giant-impact fragments and early evolution of the Earth's ocean

*佐々木 貴教[1] (1.京都大学 大学院理学研究科 宇宙物理学教室)

9:45 ~ 10:00

[AOS11-04] Modeling of Extreme Freshwater Discharge and influence from Japanese First-Class Rivers to Coastal zones

*黒木 龍介、山敷 庸亮[1]、Varlamov Sergey[2]、宮澤 泰正[2]、Racault Marie[3]、Hoshin Gupta[4] (1.京都大学、2.Application Laboratory, Japan Agency for Marine-Earth Science and Technology, Japan、3.Plymouth Marine Laboratory, Plymouth, United Kingdom、4.University of Arizona)

10:00 ~ 10:15

[AOS11-05] Establishment of new curriculum at Biosphere 2

*三木 健司[1]、土井 隆雄[2]、山敷 庸亮[3]、寺田 昌弘[2] (1.京都大学大学院農学研究科、2.京都大学宇宙総合学研究ユニット、3.京都大学総合生存学館)

10:15 ~ 10:30

[AOS11-06] Development of the highly precise high-speed photometry technique with the photometer mounted with PIRKA telescope

*木村 なみ[1] (1.北海道大学)

[E] 口頭発表 | セッション記号 A (大気水圏科学)：A-OS 海洋科学・海洋環境

10:45 ~ 12:15 | 301A 3F

[A-OS11] 陸域海洋相互作用-惑星スケール物質循環

コンビーナ:山敷 庸亮(京都大学大学院総合生存学館)、升本 順夫(東京大学大学院理学系研究科)、Behera Swadhin(Climate Variation Predictability and Applicability Research Group, Application Laboratory, JAMSTEC, 3173-25 Showa-machi, Yokohama 236-0001)、佐々木 貴教(京都大学 大学院理学研究科 宇宙物理学教室)、座長:山敷 庸亮(京都大学大学院総合生存学館)、佐々木 貴教(京都大学大学院理学研究科宇宙物理学教室)

10:45 ~ 11:00

[AOS11-07] **The Drivers of early Archean Earth's Hydrology: Resolving the Faint Young Sun's Paradox**

★Invited Papers

*Vladimir Airapetian[1]、Guillaume Gronoff[2]、Michael Way[3]、Meng Jin[4] (1.NASA Goddard Space Flight Center/SEEC and American University、2.NASA LaRC/SSAI、3.NASA GISS/SEEC、4.SETI)

11:00 ~ 11:15

[AOS11-08] Experimental study on elementary hydrological process of rainfall in a forested continental hinterland

*村上 茂樹[1] (1.国立研究開発法人　森林研究・整備機構　森林総合研究所　九州支所)

11:15 ~ 11:30

[AOS11-09] Radiological Assessment of Martian and Terrestrial Surface during Young Sun

*山敷 庸亮[1]、前原 裕之[6]、野津 湧太[3]、佐藤 達彦[2]、アイラペディアン ウラジミール[7]、野津 翔太[3]、黒木 龍介[1]、村嶋 慶哉[5]、佐藤 啓明[4]、坂東 日菜[5]、行方 宏介[3]、佐々木 貴教[3]、スコット トーマス[8]、野上 大作[3]、柴田 一成[9] (1.京都大学大学院総合生存学館、2.日本原子力機構、3.京都大学大学院理学研究科、4.京都大学工学部、5.京都大学理学部、6.国立天文台、7.NASAゴダード宇宙飛行センター、8.ブリストル大学、9.京都大学理学部附属花山天文台)

11:30 ~ 11:45

[AOS11-10] **Evaluation of scintillator detection materials for application within environmental radiation monitoring**

*Peter George Martin[1]、D. Connor[1]、M. Lowden[1]、T. B. Scott[1] (1.School of Physics, University of Bristol, Bristol, UK)

11:45 ~ 12:00

[AOS11-11] The important factors for future human space activity in terms of space medicine

*寺田 昌弘[1]、山敷 庸亮[1]、三木 健司[1]、辻廣 智子[1]、土井 隆雄[1] (1.京都大学　宇宙総合学研究ユニット)

12:00 ~ 12:15

[AOS11-12] Storm Surge Response to Freshwater Outflow from Typhoons on the Ibaraki Coast

*Josko Troselj[1]、Nobuhito Mori[1] (1.Coastal Engineering Laboratory, Disaster Prevention Research Institute, Kyoto University)

[E] 口頭発表 | セッション記号 A (大気水圏科学)：A-HW 水文・陸水・地下水学・水環境

15:30 ~ 17:00 | 201B 2F

[A-HW22] 流域の物質輸送と栄養塩循環ー源流域から沿岸海域までー

コンビーナ:小林 政広(国立研究開発法人森林研究・整備機構　森林総合研究所)、吉川 省子(農業・食品産業技術総合研究機構　農業環境変動研究センター)、安元 純(琉球大学　農学部　地域農業工学科)、Adina Paytan(University of California Santa Cruz)、座長:奥田 昇(総合地球環境学研究所)

15:40 ~ 16:00

[AHW22-01] **Coral Skeleton $\delta^{15}N$ as a Tracer of Historic Nutrient Loading to a Coral Reef in Maui, Hawaii**

★Invited Papers

*Adina Paytan[1] (1.University of California Santa Cruz)

16:00 ~ 16:15

[AHW22-02] **The Use of Ammonium and Trace Metals in Identifying Low Redox Environment Zone at Indonesian Coastal Alluvial Groundwater**

*Anna Fadliah Rusydi[1,4]、Mitsuyo - Saito[2]、Seiichiro - Ioka[3]、Shin-ichi - Onodera[1] (1.Graduate School of Integrated Arts and Sciences, Hiroshima University, Japan、2.Graduate School of Environmental and Life Sciences, Okayama University, Japan、3.Institute of Regional Innovation, Hirosaki University, Japan、4.Research Center for Geotechnology, Indonesian Institute of Sciences, Indonesia)

16:15 ~ 16:30

[AHW22-03] Spatial and temporal variation in submarine groundwater discharge (SGD) on a beach scale in a temperate coastal island: a multi-tracer approach

*齋藤 光代[1]、小野寺 真一[2]、友澤 裕介[2]、浅井 和由[3] (1.岡山大学大学院環境生命科学研究科、2.広島大学大学院総合科学研究科、3.地球科学研究所)

16:30 ~ 16:45

[AHW22-04] **Phosphorus discharge via groundwater into the lake, based on lacustrine groundwater discharge (LGD) and alluvial plain sediment**

*小野寺 真一[1]、齋藤 光代[2]、金 广哲[3]、Anna Rusydi[1]、友澤 裕介[1]、王 昆陽[1]、伴 修平[4]、奥田 昇[5] (1.広島大学大学院総合科学研究科、2.岡山大学、3.Guangdong Ocean University、4.滋賀県立大学、5.総合地球環境学研究所)

16:45 ~ 17:00

[AHW22-05] **Geochemical controls and health implications of water chemistry in Benoue River Basin, North Cameroon: Insights from Major ions**

*Sharon Bih Kimbi[1,2]、Wilson Y Fantong[3]、Samuel N Ayonghe[2]、Robert Kringel[4]、Shin-ichi Onodera[1] (1.Graduate School of Integrate Arts and Sciences, Hiroshima University、2.Department of Environmental Science, Faculty of science, University of Buea、3.Institute of Mining and Geological Research (IRGM)、4.Federal Institute for Geoscience and Natural Resources Bundesanstalt fur Geowissenschaften und Rohstoffe (BGR) PRESS NO & SW)

[E] 口頭発表 | セッション記号 A (大気水圏科学)：A-HW 水文・陸水・地下水学・水環境

9:00 ~ 10:30 | 103 1F

[A-HW23] 水循環・水環境

コンビーナ:町田 功(産業技術総合研究所地質調査総合センター)、山崎 大(東京大学生産技術研究所)、林 武司(秋田大学教育文化学部)、福士 圭介(金沢大学環日本海域環境研究センター)、座長:林 武司(秋田大学教育文化学部)

9:00 ~ 9:15

[AHW23-12] Drought Analysis based on Copulas and Poisson Process

*Pei-Yu Wu[1]、Gene Jiing-yun You[1] (1.National Taiwan University, Department of Civil Engineering)

9:15 ~ 9:30

[AHW23-13] **Snow melt dynamics in snowfall dominated mountain regions in Shonai**

*Alexander Brandt[1,3]、Muhammad Fraz Ismail[2]、Larry Maximo Lopez Caceres[1]、Wolfgang Bogacki[2] (1.Yamagata University、2.Hochschule Koblenz、3.UGAS)

9:30 ~ 9:45

[AHW23-14] Study on transport of particulate organic matter in a small river with forest and paddy filed by using carbon isotopes ($\delta^{13}C$ and $\Delta^{14}C$)

*長尾 誠也[1]、田原 龍之介[2]、落合 伸也[1]、後藤 晶子[3]、長谷川 卓[3] (1.金沢大学環日本海域環境研究センター、2.金沢大学大学院自然科学研究科、3.金沢大学理工学域地球社会基盤学系)

9:45 ~ 10:00

[AHW23-15] **Sources of Shallow Groundwater Salinity in the Ganges Delta of Bangladesh**

*Masudur Rahman[1,2]、Tomochika Tokunaga[1] (1.Department of Environment Systems, Graduate School of Frontier Sciences, The University of Tokyo, 5-1-5, Kashiwa-no-ha, Kashiwa-shi, Chiba 277-8563, Japan、2.Environmental Science Discipline, Life Science School, Khulna University, Khulna 9208, Bangladesh)

10:00 ~ 10:15

[AHW23-16] **Groundwater chemistry in the Gunii Khooloi basin, Southern Gobi Region of Mongolia using multivariate analysis**

*Batdemberel BAYANZUL[1,2]、Isao Machida[3]、Kengo Nakamura[2]、Noriaki Watanabe[2]、Takeshi Komai[2] (1.School of Geology and Mining Engineering, Mongolian University of Science and Technology、2.Graduate School of Environmental Studies, Tohoku University、3.Groundwater research group, Advanced Industrial Science and Technology)

10:15 ~ 10:30

[AHW23-17] **Temporal observation of molybdenum concentrations in rivers from Erdenet mining area, Mongolia**

*Solongo Tsetsgee[1]、Keisuke Fukushi[1]、Altansukh Ochir[2]、 Takahashi Yoshio[3]、Ariuntungalag Yunden[2]、Enkhjin Odgerel[2]、Noriko Hasebe[1] (1.Kanazawa University、2.National University of Mongolia、3.The University of Toyko)

[E] 口頭発表 | セッション記号 A (大気水圏科学)：A-HW 水文・陸水・地下水学・水環境

10:45 ~ 12:15 | 103 1F

[A-HW23] 水循環・水環境

コンビーナ:町田 功(産業技術総合研究所地質調査総合センター)、山崎 大(東京大学生産技術研究所)、林 武司(秋田大学教育文化学部)、福士 圭介(金沢大学環日本海域環境研究センター)、座長:福士 圭介

10:45 ~ 11:05

[AHW23-18] 琵琶湖湖底近傍におけるマンガン・ヒ素の水-鉱物相互作用　―過去40年間での湖内分布の変化に対する考察ー

★招待講演

*板井 啓明[1]、名取 幸花[1] (1.東京大学大学院理学系研究科　地球惑星科学専攻)

11:05 ~ 11:20

[AHW23-19] **Sources, pathways and treatment of contaminants in surface water: Applicability in developing countries**

*Mst. Shamsun Nahar[1] (1.Earth Consultant Co. Ltd, Toyama, Japan)

11:20 ~ 11:35

[AHW23-20] **Numerical simulations (COMSOL) of γ-Fe_2O_3 nanohybrids for transport (3D) and arsenic removal in homogeneous porous media**

*Ajay Kumar[1]、Himanshu Joshi[1]、Anil Kumar[1] (1.INDIAN INSTITUTE OF TECHNOLOGY ROORKEE, INDIA)

11:35 ~ 11:50

[AHW23-21] **Transport processes of suspended solids in the Kumaki River inferred from atmospheric radionuclides**

*落合 伸也[1]、田原 龍之介[2]、松中 哲也[1]、長尾 誠也[1] (1.金沢大学 環日本海域環境研究センター、2.金沢大学 自然科学研究科)

11:50 ~ 12:05

[AHW23-22] Using tritium in Japanese precipitation for tritium-tracer transit time studies across Asia

*Maksym Gusyev[1]、Yoshito Kikumori[1]、Terumasa Nishihara[2]、Takeshi Hayashi[3]、Kimpei Ichiyanagi[4]、Naofumi Akata[5]、Tomoki Oda[6]、Uwe Morgenstern[7]、Michael Stewart[7] (1.International Centre for Water Hazard and Risk Management (ICHARM), Public Works Research Institute (PWRI)、2.Civil Engineering Research Institute for Cold Region, PWRI、3.Akita University、4.Kumamoto University、5.National Institute for Fusion Science (NIFS)、6.University of Tokyo、7.GNS Science, New Zealand)

[E] 口頭発表 | セッション記号 A (大気水圏科学)：A-CG 大気海洋・環境科学複合領域・一般

15:30 ~ 17:00 | 302 3F

[A-CG34] 衛星による地球環境観測

コンビーナ:沖 理子(宇宙航空研究開発機構)、本多 嘉明(千葉大学環境リモートセンシング研究センター)、高薮 縁(東京大学 大気海洋研究所)、松永 恒雄(国立環境研究所地球環境研究センター／衛星観測センター)、座長:可知 美佐子(宇宙航空研究開発機構　地球観測研究センター)

15:30 ~ 15:45

[ACG34-01] 水循環変動観測衛星「しずく」と高性能マイクロ波放射計2（AMSR2）の現状と将来計画

*可知 美佐子[1]、前田 崇[1]、小野 温[1]、藤井 秀幸[1]、笠原 希仁[1]、江淵 直人[1,2] (1.宇宙航空研究開発機構　地球観測研究センター、2.北海道大学　低温科学研究所)

15:45 ~ 16:00

[ACG34-02] Testing and Evaluation for JPSS-1 Algorithms using Algorithm Development Library Block 2.1

*Bigyani Das[1,2]、Weizhong Chen[1,2]、Thomas S King[1,2]、Walter Wolf[2] (1.IMSG、2.STAR/NESDIS/NOAA)

16:00 ~ 16:15

[ACG34-03] Remote Sensing of Atmospheric and Surface Properties using Hyperspectral satellite Sensors

*Xu Liu[1] (1.NASA Langley Research Center)

16:15 ~ 16:30

[ACG34-04] RADIOMETRIC UNIFORMITY AND STABILITY OF GROUND SITE CHARACTERIZATION FOR INSAT-3D

*Shailesh Parihar[1]、R. Bhatla[1]、A. K. Mitra[2] (1.Banaras Hindu University, Varanasi, India、2.India Meteorological Department, New Delhi, India)

16:30 ~ 16:45

[ACG34-05] 地球環境観測のためのASTER熱赤外放射計に対する代替校正活動

*山本 聡[1]、外岡 秀行[2]、加藤 創史[3]、鮎澤 一樹[2]、松永 恒雄[4] (1.宇宙システム開発利用推進機構、2.茨城大学、3.リモート・センシング技術センター、4.国立環境研究所)

16:45 ~ 17:00

[ACG34-06] 植生ライダMOLIの概要

★招待講演

*下田 陽久[1]、木村 俊義[2]、三橋 怜[2]、室岡 純平[2]、境沢 大介[2]、今井 正[2]、浅井 和宏[3] (1.東海大学、2.日本宇宙航空開発研究機構、3.東北工業大学)

[E] 口頭発表 | セッション記号 A (大気水圏科学)：A-CG 大気海洋・環境科学複合領域・一般

13:45 ~ 15:15 | 303 3F

[A-CG35] 地球規模環境変化の予測と検出

コンビーナ:河宮 未知生(海洋研究開発機構)、建部 洋晶(海洋研究開発機構)、立入 郁(海洋研究開発機構)、座長:建部 洋晶

13:45 ~ 14:00

[ACG35-01] **Sour and anoxic Sea of Japan in the near future**

*Chen-Tung Arthur Chen[1]、Hon-Kit Lui[1]、Masao Ishii[2] (1.National Sun Yat Sen University、2.Japan Meteorological Agency)

14:00 ~ 14:15

[ACG35-02] **Decadal predictions of the variable ocean carbon uptake**

★Invited Papers

*Hongmei Li[1]、Tatiana Ilyina[1]、Wolfgang A. Müller[1,2]、Peter Landschützer[1] (1.Max Planck Institute for Meteorology, Bundesstraße 53, 20146 Hamburg, Germany、2.Deutscher Wetterdienst, Bernhard-Nocht-Straße 76, 20359 Hamburg, Germany)

14:15 ~ 14:30

[ACG35-03] Air-sea CO_2 flux variations in the tropical Pacific simulated with two ESMs embedded an ocean data assimilation system

*渡辺 路生[1]、建部 洋晶[1]、小山 博司[1]、羽島 知洋[1]、渡部 雅浩[2]、河宮 未知生[1] (1.海洋研究開発機構、2.東京大学大気海洋研究所)

14:30 ~ 14:45

[ACG35-04] **A Study of Decadal Ocean Deoxygenation and Heat Uptake from a suite of OMIP Simulations**

*Takano Yohei[1]、Tjiputra Jerry[2]、Schwinger Jörg[2]、Gröger Matthias[3]、Berthet Sarah[4]、Séférian Roland[4]、Yool Andrew[5]、Palmieri Julien[5]、渡辺 路生[6]、Stemmler Irene[1]、Ilyina Tatiana[1] (1.Max Planck Institute for Meteorology、2.Norwegian Research Centre、3.Swedish Meteorological and Hydrological Institute、4.Centre National de Recherche Météorologique, Unite mixte de recherche 3589 Météo-France/CNRS、5. National Oceanography Centre、6.Japan Agency for Marine-Earth Science and Technology)

14:45 ~ 15:00

[ACG35-05] **Role of large-scale environmental variability in changing storm climate**

*Nilima Aditya Natoo[1] (1.University of Bremen, Germany)

15:00 ~ 15:15

[ACG35-06] The forced response of the climate system: The case of climatic teleconnections

*Tamas Bodai[1]、Matyas Herein[2]、Gabor Drotos[3] (1.University of Reading、2.Eotvos University Budapest、3.Universitat de les Illes Balears)

[E] 口頭発表 | セッション記号 A (大気水圏科学)：A-CG 大気海洋・環境科学複合領域・一般

15:30 ~ 17:00 | 303 3F

[A-CG35] 地球規模環境変化の予測と検出

コンビーナ:河宮 未知生(海洋研究開発機構)、建部 洋晶(海洋研究開発機構)、立入 郁(海洋研究開発機構)、座長:立入 郁(海洋研究開発機構)、河宮 未知生(海洋研究開発機構)

15:30 ~ 15:45

[ACG35-07] Guiding Mother Earth: taking stock of progress to a long-term temperature goal

★Invited Papers

*Myles Robert Allen[1] (1.Environmental Change Institute, School of Geography and the Environment and Department of Physics, University of Oxford)

15:45 ~ 16:00

[ACG35-08] **Uneven distributions of four hazard indicators of climate change with the Paris Agreement's goals**

*塩竈 秀夫[1] (1.国立環境研究所地球環境研究センター)

16:00 ~ 16:15

[ACG35-09] Understanding the centennial-scale human-natural interactions using an integrated terrestrial model MIROC-INTEG under ISIMIP2 project

*佐藤 雄亮[1]、Julien Boulange[1]、花崎 直太[1]、高田 久美子[1]、Yadu Pokhrel[3]、Ted Veldkamp[2,4]、Peter Burek[2]、横畠 徳太[1] (1.国立研究開発法人国立環境研究所、2.国際応用システム研究所、3.ミシガン州立大学、4.アムステルダム自由大学)

16:15 ~ 16:30

[ACG35-10] Radiative forcing of the physiological CO_2 response

*Victor Brovkin[1]、Veronika Gayler[1]、Sonia I Seneviratne[2]、Pierre Gentine[3] (1.Max Planck Institute for Meteorology, Hamburg, Germany、2.ETH, Institute for Atmospheric and Climate Science, Zurich, Switzerland、3.Columbia University, Earth and Environmental Engineering, New York, USA)

16:30 ~ 16:45

[ACG35-11] Progress of MIROC-ES2 simulations in CMIP6 and the analysis of the biogeochemical feedbacks

*羽島 知洋[1]、渡辺 真吾[1]、河宮 未知生[1]、立入 郁[1]、建部 洋晶[1]、伊藤 昭彦[2]、高田 久美子[2]、渡辺 路生[1]、野口 真希[1]、山本 彬友[1]、伊藤 彰記[1]、阿部 学[1]、大垣内 るみ[1]、山崎 大[3] (1.独立行政法人 海洋研究開発機構、2.国立環境研究所、3.東京大学生産技術研究所)

16:45 ~ 17:00

[ACG35-12] The impact of long-term historical warming on the global terrestrial gross primary production

*Irina Melnikova[1]、Takahiro Sasai[1] (1.Tohoku University)

[E] 口頭発表 | セッション記号 H (地球人間圏科学)：H-GM 地形学

13:45 ~ 15:15 | 101 1F

[H-GM03] Geomorphology

コンビーナ:八反地 剛(筑波大学生命環境系)、瀬戸 真之(福島大学うつくしま福島未来支援センター)、座長:Thomas Parkner、八反地 剛

13:45 ~ 14:00

[HGM03-01] Surface structure as a control for gully complex development in the Mackey`s block, North Island, New Zealand

*Thomas Parkner[1] (1.University of Tsukuba, Graduate School of Life and Environmental Sciences)

14:00 ~ 14:15

[HGM03-02] Model Linking Landslides and River Evolution of Incisional Channel Created by River Erosion

*Chia-Ting Kao[1]、Gene Jiing-yun You[1] (1.National Taiwan University)

14:15 ~ 14:30

[HGM03-03] **A semi-automated method for extracting channels and channel profiles from LiDAR-derived digital elevation models**

*Pinliang Dong[1] (1.University of North Texas)

14:30 ~ 14:45

[HGM03-04] Laboratory experiments on the landform development

*大内 俊二[1] (1.中央大学理工学部)

14:45 ~ 15:00

[HGM03-05] Characteristics of lake sediment from southern part of Mongolia and comparison to meteorological data

*Uyangaa Udaanjargal[1]、Noriko Hasebe[1]、Keisuke Fukushi[1]、Tanaka Yukiya[2]、Davaadorj Davaasuren[4]、Makoto Sambo[1]、Baasansuren Gankhurel[1]、Nagayoshi Katsuta[3]、Shinya Ochiai[1]、Tuvshin Gerelmaa[4] (1.Kanazawa University、2.Kyunghee University、3.Gifu University、4.National University of Mongolia)

15:00 ~ 15:15

[HGM03-06] **Evaluation of geomorphological changes on Kujukuri beach based on UAV SfM**

*Mergen Kungaa[1]、Toshihiko Sugai[1]、Natsuki Sasaki[1]、Taiga Kimori[1]、Taro Funatsu (1.Tokyo University, Graduate School of Frontier Sciences, Department of Natural Environmental Studies)

[E] 口頭発表 | セッション記号 H (地球人間圏科学)：H-DS 防災地球科学

9:00 ~ 10:30 | 304 3F

[H-DS10] Natural hazards impacts on human society, economics and technological systems

コンビーナ:PETROVA ELENA(Lomonosov Moscow State University, Faculty of Geography)、松島 肇(北海道大学大学院農学研究院)、座長:Elena Petrova、Hajime Matsushima

9:00 ~ 9:15

[HDS10-01] 海岸砂丘の生態系サービスを活用した人々の暮らし

★招待講演

*金子 是久[1] (1.北総生き物研究会)

9:15 ~ 9:30

[HDS10-02] Survey on the Impact of Sea wall on the Vegetation of Coastal sand dune

*鐘 向梅[1]、松島 肇[2]、鈴木 玲[3]、平吹 喜彦[4]、木村 浩二[5] (1.北海道大学大学院農学院、2.北海道大学大学院農学研究院、3.北の里浜 花のかけはしネットワーク、4.東北学院大学教養部、5.雪印種苗株式会社)

9:30 ~ 9:45

[HDS10-03] Greening on the seawall: challenge to conversion from gray to green infrastructure.

★Invited Papers

*松島 肇[1]、鈴木 玲[2]、木村 浩二[4]、鐘 向梅[5]、平吹 喜彦[3] (1.北海道大学大学院農学研究院、2.北の里浜花のかけはしネットワーク、3.東北学院大学教養部、4.雪印種苗株式会社、5.北海道大学大学院農学院)

9:45 ~ 10:00

[HDS10-04] Distribution Characteristics of Informal Green Space and Its Extension of perspective into Green Infrastructure

*minseo kim[1]、Katsunori Furuya[1] (1.Chiba University Graduate School of Horticulture)

10:00 ~ 10:15

[HDS10-05] **DISASTER ANALYSIS OF LIGHTNING STRIKE DENSITY BASED ON LANDFORM FOR REDUCING VICTIMS IN WONOSOBO, INDONESIA**

*Astry Zulky Permatasari[1]、Gagad Nur Ridho[1]、Yan Abdi Rahmanu[1]、Emilya Nurjani[1] (1.Gadjah Mada University)

10:15 ~ 10:30

[HDS10-06] Development of Cost Competitive Unmanned Aerial Vehicle for Search and Rescue

*Aditya Keshav Natoo

[E] 口頭発表 | セッション記号 H (地球人間圏科学)：H-DS 防災地球科学

13:45 ~ 15:15 | 301B 3F

[H-DS10] Natural hazards impacts on human society, economics and technological systems

コンビーナ:PETROVA ELENA(Lomonosov Moscow State University, Faculty of Geography)、松島 肇(北海道大学大学院農学研究院)、座長:Hajime Matsushima、Elena Petrova

13:45 ~ 14:00

[HDS10-07] **Seasonal variations of atmospheric hazard impacts on infrastructure**

★Invited Papers

*ELENA PETROVA[1] (1.Lomonosov Moscow State University, Faculty of Geography)

14:00 ~ 14:15

[HDS10-08] 大地震によって引き起こされる化学物質流出事故後の浄水場機能に対する影響と対策オプション評価

*伊藤 理彩[1]、中久保 豊彦[2]、小島 直也[1]、東海 明宏[1] (1.大阪大学 大学院工学研究科、2.お茶の水女子大学 基幹研究院)

14:15 ~ 14:30

[HDS10-09] Development of disaster risk management plan of a thermal power plant: Spearheading the paradigm shift from disaster management to disaster risk management of NATECH in India

*Repaul Kanji[1]、Madan Mohan Rout[2]、Ankur Srivastava[3] (1.Gujarat Institute of Disaster Management, Gandhinagar, Gujarat, India、2.Institute of Seismological Research, Gandhinagar, India、3.Indian Institute of Technology Delhi, India)

14:30 ~ 14:45

[HDS10-10] **Applying Transfer Learning to Improve Machine Learning Impact Model at Extremes**

*Peter Lawrence Watson[1]、Manos Anagnostou[1]、David Wanik[1] (1.University of Connecticut)

14:45 ~ 15:00

[HDS10-11] rescEU, the European Union Civil Protection System UCPM and the future role of Geosciences in natural disaster reduction

*Andreas Nikolaus Kueppers[1] (1.GFZ - Deutsches Geoforschungszentrum - Helmholtz Zentrum Potsdam)

15:00 ~ 15:15

[HDS10-12] The Probability of Satellite Anomalies by a Disastrous Solar Flare

*関 大吉[1,2,3] (1.京都大学大学院総合生存学館、2.ケンブリッジ大学極端リスク研究センター、3.京都大学大学院理学研究科附属天文台)

[E] 口頭発表 | セッション記号 H (地球人間圏科学)：H-DS 防災地球科学

15:30 ~ 17:00 | 301B 3F

[H-DS10] Natural hazards impacts on human society, economics and technological systems

コンビーナ:PETROVA ELENA(Lomonosov Moscow State University, Faculty of Geography)、松島 肇(北海道大学大学院農学研究院)、座長:Elena Petrova、Hajime Matsushima

15:30 ~ 15:50

[HDS10-13] 東京都における防災公園の維持管理について

★招待講演

*菊池 正芳[1] (1.公益財団法人東京都公園協会)

15:50 ~ 16:05

[HDS10-14] Rebuilding Tourism after the Great East Japan Earthquake and Examining Post-Disaster Tourism in Kamaishi City

*佐々木 啓[1]、山本 清龍[2]、佐々木 薫子[3] (1.岩手大学、2.東京大学、3.北海道大学)

16:05 ~ 16:20

[HDS10-15] Population Change in Ishinomaki City, Miyagi Prefecture, with a Focus on the Area around the Earthquake Ruins

*西坂 涼[1]、古谷 勝則[1] (1.千葉大学)

16:20 ~ 16:35

[HDS10-16] The Way of Seeing the Atomic Bomb Dome and the Relationship with Viewers' Attributes

*安原 有紗[1]、山本 清龍[1]、下村 彰男[1] (1.東京大学大学院農学生命科学研究科)

16:35 ~ 16:50

[HDS10-17] スリランカ国ラトゥナプラ市における洪水リスク分析

*土田 亮[1]、寶 馨[1] (1.京都大学大学院総合生存学館)

[E] 口頭発表 | セッション記号 H (地球人間圏科学)：H-TT 計測技術・研究手法

15:30 ~ 17:00 | 101 1F

[H-TT21] 石造文化財に応用可能な非破壊分析

コンビーナ:小口 千明(埼玉大学大学院理工学研究科)、Celine Elise Thomachot-Schneider(Groupe d'etude des environnements naturels, anthropiques et archeologiques - Universite de Reims-Champagne-Ardenne (France))、宋 苑瑞(早稲田大学)、Miguel Gomez-Heras(Universidad Autonoma de Madrid)、座長:宋 苑瑞、小口 千明

15:30 ~ 15:45

[HTT21-01] Study on creation of 3D model by SfM photogrammetry: An example of Taya Cave

清水 きさら[1]、*小口 千明[1]、田村 裕彦[2]、早川 裕弋[3]、小倉 拓郎[4]、緒方 啓介[5] (1.埼玉大学大学院理工学研究科、2.田谷の洞窟保存実行委員会、3.北海道大学地球環境科学院、4.東京大学大学院新領域創成科学研究科社会文化環境学専攻、5.鶴見大学)

15:45 ~ 16:00

[HTT21-02] **人工洞窟における地上レーザ測量データと3Dプリントの地盤工学的および教育的活用**

*早川 裕弋[1,2]、小倉 拓郎[4,5]、田村 裕彦[2]、小口 千明[3]、清水 きさら[3] (1.北海道大学地球環境科学研究院、2.東京大学空間情報科学研究センター、3.埼玉大学、4.東京大学新領域創成科学研究科、5.北海道大学大学院環境科学院)

16:00 ~ 16:15

[HTT21-03] 沖縄県の世界遺産，園比屋武御嶽石門の保存修復ー モルタルによる穴埋めとシリコーン樹脂塗布から30年経過後の現状

*宋 苑瑞[1]、西浦 忠輝[2]、小口 千明[3] (1.早稲田大学、2.国士舘大学、3.埼玉大学)

16:15 ~ 16:30

[HTT21-04] 高知県沿岸部の海底石造物の起源推定のためのポータブルXRFの活用

★招待講演

*谷川 亘[1]、浦本 豪一郎[2]、村山 雅史[2]、濱田 洋平[1]、山本 裕二[2]、多田井 修[3] (1.国立研究開発法人海洋研究開発機構高知コア研究所、2.高知大学　海洋コア総合研究センター、3.マリン・ワーク・ジャパン)

16:30 ~ 16:45

[HTT21-05] pXRF analyses on Assyrain sculptures

★Invited Papers

*安間 了[1]、SHIN Ki-Cheol[2]、渡辺 千香子[3]、辻 彰洋[4] (1.徳島大学大学院社会産業理工学研究部、2.総合地球環境学研究所、3.大阪学院大学国際学部、4.国立科学博物館植物研究部)

16:45 ~ 17:00

[HTT21-06] Discussion

*小口 千明[1] (1.埼玉大学大学院理工学研究科)

[E] 口頭発表 | セッション記号 S (固体地球科学)：S-IT 地球内部科学・地球惑星テクトニクス

13:45 ~ 15:15 | A09 東京ベイ幕張ホール

[S-IT26] New perspectives on the geodynamics of East Asia

コンビーナ:Timothy B Byrne(University of Connecticut)、山口 飛鳥(東京大学大気海洋研究所)、Jonny Wu(University of Houston)、沖野 郷子(東京大学大気海洋研究所)、座長:Jonny Wu、Okino Kyoko

13:45 ~ 14:00

[SIT26-01] How to solve controversies in Cenozoic tectonics in western Pacific margin

*木村 学[1] (1.東京海洋大学・海洋資源環境学部)

14:00 ~ 14:15

[SIT26-02] Plio-Pleistocene plate interactions associated the Philippine Sea Plate

*Timothy B Byrne[1]、Gaku Kimura[3]、Jonny Wu[2] (1.University of Connecticut、2.University of Houston、3.Tokyo University of Science and Technology)

14:15 ~ 14:30

[SIT26-03] A regional mylonite zone between the Mesozoic metamorphic basement and the subducted Miocene covered schists in eastern Range of Taiwan: A possible Plio-Pleistocene transform fault between Eurasia and the Philippine Sea plate

*Gong-Ruei Ho[1]、Jian-Cheng Lee[1]、Timothy B Byrne[2]、En-Chao Yeh[3] (1.Institute of Earth Sciences, Academia Sinica、2.Department of Geography, University of Connecticut、3.Department of Earth Sciences, National Taiwan Normal University)

14:30 ~ 14:45

[SIT26-04] **Coeval exhumation or subduction channel extrusion of the high pressure Yuli belt? Insights from the Shoufeng fault in eastern Taiwan**

*Jian-Cheng Lee[1,5]、Gong-Ruei Ho[1,5]、Timothy B Byrne[2]、Yuan Hsi Lee[3,5]、En-Chao Yeh[4,5] (1.Academia Sinica、2.Univerity of Connecticut、3.National Chung Cheng University、4.National Taiwan Normal University、5.The Yuli Exhumation Study team (YES Team))

14:45 ~ 15:00

[SIT26-05] Metamorphic temperature variation across the Yuli belt: a clue about exhumation of high-pressure rocks?

*Chin-Ho Tsai[1]、Chih-Ying Yeh[1]、Yui Kouketsu[2]、Masaki Enami[3] (1.Department of Natural Resources & Environmental Studies, National Dong Hwa Univ.、2.Department of Earth & Planetary Sciences, Nagoya Univ.、3.Institute for Space-Earth Environmental Research, Nagoya Univ.)

15:00 ~ 15:15

[SIT26-06] **三次元モデリングによるマリアンナ沈み込み帯の温度構造、スラブ変成作用と境界面地震**

*季 顕鋒[1,2,3]、吉岡 祥一[3,4] (1.中国科学院チベット高原地球科学卓越創新センター、2.中国科学院チベット高原研究所、3.神戸大学都市安全研究センター、4.神戸大学大学院 理学研究科)

[E] 口頭発表 | セッション記号 S (固体地球科学)：S-IT 地球内部科学・地球惑星テクトニクス

15:30 ~ 17:00 | A09 東京ベイ幕張ホール

[S-IT26] New perspectives on the geodynamics of East Asia

コンビーナ:Timothy B Byrne(University of Connecticut)、山口 飛鳥(東京大学大気海洋研究所)、Jonny Wu(University of Houston)、沖野 郷子(東京大学大気海洋研究所)、座長:山口 飛鳥(東京大学大気海洋研究所)、Tim Byrne

15:30 ~ 15:45

[SIT26-07] **A tomography-led plate reconstruction of NE Asia during the late Cretaceous**

*Jonny Wu[1]、Yi-An Lin[1]、Nicolas Flament[2]、Tsung-Jui Wu[1]、Yiduo Liu[1] (1.University of Houston、2.University of Wollongong)

15:45 ~ 16:00

[SIT26-08] Geodynamic models of late Mesozoic intraoceanic subduction offshore NE Asia caused by growing Izanagi plate

*Lorenzo Colli[1]、Jonny Wu[1]、Yi-An Lin[1] (1.University of Houston)

16:00 ~ 16:15

[SIT26-09] **Early Cretaceous to Paleocene magmatism in the Sikhote-Alin area and their implications for Paleo-Pacific plate subduction and continental evolution**

*Tsung-Jui Wu[1]、Jonny Wu[1]、Igor Alexandrov[2]、Thomas Lapen[1] (1.Department of Earth and Atmospheric sciences, University of Houston, Houston, U.S.、2.Far East Geological Institute, Russian Academy of Sciences, Vladivostok, Russia)

16:15 ~ 16:30

[SIT26-10] Processes of subduction initiation revealed by P-T paths of amphibolite and blueschist tectonic blocks in serpentinite mélange: An example from the Kamuikotan high-P/T metamorphic rocks in Hokkaido, northern Japan

*竹下 徹[1]、岡本 あゆみ、シン ウォンジ[1]、安藤 瑞帆[1] (1.北海道大学大学院理学院自然史科学専攻)

16:30 ~ 16:50

[SIT26-11] Metamorphism in the Sanbagawa belt of SW Japan as a record of subduction processes

★Invited Papers

*ウォリス サイモン[1] (1.東京大学)

16:50 ~ 17:00

[SIT26-12] Subduction and exhumation of the high pressure metamorphic rocks: What we know and what we need to know.

*Timothy B Byrne[1] (1.University of Connecticut)

[E] 口頭発表 | セッション記号 S (固体地球科学)：S-GC 固体地球化学

13:45 ~ 15:15 | A10 東京ベイ幕張ホール

[S-GC40] Volatile Cycles in the Deep Earth - from Subduction Zone to Hot Spot

コンビーナ:角野 浩史(東京大学大学院総合文化研究科広域科学専攻相関基礎科学系)、羽生 毅(海洋研究開発機構 地球内部物質循環研究分野)、佐野 有司(東京大学大気海洋研究所海洋地球システム研究系)、Gray E Bebout(Lehigh University)、座長:羽生 毅、Gray Bebout(Lehigh University)、佐野 有司、角野 浩史

13:45 ~ 14:15

[SGC40-01] Continental growth, crustal recycling, and global water cycle

★Invited Papers

*是永 淳[1] (1.イェール大学地球科学科)

14:15 ~ 14:30

[SGC40-02] マントルプルーム内部でマグマ形成に果たす揮発成分の役割

*高橋 栄一[1]、王 錦団[1]、李 立[1] (1.中国科学院広州地球化学研究所)

14:30 ~ 14:45

[SGC40-03] DH partitioning experiment among high-pressure polymorph of olivine

*佐野 亜沙美[1]、伊藤 正一[2]、井上 徹[3]、野田 昌道[3] (1.日本原子力研究開発機構 J-PARCセンター、2.京都大学、3.広島大学)

14:45 ~ 15:00

[SGC40-04] **Formation of Fe-rich volatile-bearing phases in the deep lower mantle and the implications for deep Earth volatile cycles**

*Li Zhang[1]、Hongsheng Yuan[1]、Eiji Ohtani[2]、Lianjie Man[1]、Duck Young Kim[1]、Dmitry Popov[3]、Yue Meng[3]、Eran Greenberg[4]、Vitali Prakapenka[4] (1.Center for High Pressure Science and Technology Advanced Research (HPSTAR)、2.Department of Earth Science, Graduate School of Science, Tohoku University、3.HPCAT, X-ray Science Division, Argonne National Laboratory、4.GeoSoilEnviroCARS, University of Chicago)

15:00 ~ 15:15

[SGC40-05] Estimation of the origin of Pitcairn Island OIB by Independent Component Analysis

*小澤 恭弘[1]、岩森 光[1,2,3]、羽生 毅[2]、浜田 盛久[2]、清水 健二[4]、牛久保 孝之[4]、木村 純一[2]、常 青[2]、中村 仁美[5]、伊藤 元雄[4] (1.東京工業大学、2.海洋研究開発機構　地球内部物質循環研究分野、3.東京大学　地震研究所、4.海洋研究開発機構　高知コア研究所、5.国立研究開発法人産業技術総合研究所・地質調査総合センター)

[E] 口頭発表 | セッション記号 S (固体地球科学)：S-GC 固体地球化学

15:30 ~ 17:00 | A10 東京ベイ幕張ホール

[S-GC40] Volatile Cycles in the Deep Earth - from Subduction Zone to Hot Spot

コンビーナ:角野 浩史(東京大学大学院総合文化研究科広域科学専攻相関基礎科学系)、羽生 毅(海洋研究開発機構 地球内部物質循環研究分野)、佐野 有司(東京大学大気海洋研究所海洋地球システム研究系)、Gray E Bebout(Lehigh University)、座長:羽生 毅、Gray Bebout(Lehigh University)、佐野 有司、角野 浩史

15:30 ~ 16:00

[SGC40-06] Tracing recycled volatiles in MORB with halogens

★Invited Papers

*Ray Burgess[1]、Lorraine Ruzie-Hamilton[1]、Patricia Clay[1]、Bastian Joachim[2]、Christopher Ballentine[3] (1.School of Earth and Environmental Sciences, University of Manchester, Manchester, M13 9PL UK、2.Institute for Mineralogy and Petrography, University of Innsbruck, Innrain, 52A-6020, Innsbruck, Austria、3.Department of Earth Sciences, University of Oxford, South Parks Road, Oxford, OX1 3AN UK)

16:00 ~ 16:15

[SGC40-07] Volatile composition in ocean island basalts

*羽生 毅[1] (1.海洋研究開発機構 地球内部物質循環研究分野)

16:15 ~ 16:30

[SGC40-08] Halogen heterogeneity in the subcontinental lithospheric mantle

*角野 浩史[1]、小林 真大[2]、Ray Burgess[3]、Chris Ballentine[4] (1.東京大学大学院総合文化研究科広域科学専攻、2.東京都立産業技術研究センター、3.マンチェスター大学地球環境学教室、4.オックスフォード大学地球科学科)

16:30 ~ 16:45

[SGC40-09] Efficiency of Deep Carbon Subduction: Input, Metamorphic Records, and Bearing on Estimated Sources of Arc Volcanic Gases

*Gray E Bebout[1,2]、Gabe S Epstein[2]、Brian M House[3] (1.Institute for Planetary Materials, Okayama University、2.Lehigh University、3.University of California, San Diego)

16:45 ~ 17:00

[SGC40-10] Helium isotope variations in subduction-type volcanic hydrothermal systems

*佐野 有司[1]、鹿児島 渉悟[1]、高畑 直人[1]、尾上 哲治[2]、柴田 智郎[3]、Tobias Fischer[4] (1.東京大学大気海洋研究所海洋地球システム研究系、2.熊本大学先端科学研究部基礎科学部門地球環境科学講座、3.京都大学地球熱学研究施設、4.ニューメキシコ大学地球惑星科学教室)

[E] 口頭発表 | セッション記号 S (固体地球科学)：S-CG 固体地球科学複合領域・一般

9:00 ~ 10:30 | 国際会議室 2F

[S-CG48] Science of slow earthquakes: Toward unified understandings of whole earthquake process

コンビーナ:井出 哲(東京大学大学院理学系研究科地球惑星科学専攻)、廣瀬 仁(神戸大学都市安全研究センター)、氏家 恒太郎(筑波大学生命環境系)、波多野 恭弘(東京大学地震研究所)、座長:廣瀬 仁、田中 愛幸

9:00 ~ 9:30

[SCG48-01] Variability of the space-time evolution of slow slip events off the Boso Peninsula, central Japan, from 1996 to 2018

★Invited Papers

*福田 淳一[1] (1.東京大学地震研究所)

9:30 ~ 9:45

[SCG48-02] Cumulative slip distribution of short-term slow slip events in the western Shikoku area, southwest Japan based on tilt change measurements

*廣瀬 仁[1,2]、田村 和華子[2]、木村 武志[3] (1.神戸大学都市安全研究センター、2.神戸大学大学院理学研究科惑星学専攻、3.防災科学技術研究所)

9:45 ~ 10:00

[SCG48-03] Shallow undersea SSEs off the western Japan monitored by the GNSS-A

*横田 裕輔[1]、石川 直史[2] (1.東京大学生産技術研究所、2.海上保安庁海洋情報部)

10:00 ~ 10:15

[SCG48-04] Co- and Post-seismic deformation due to the 2016 moderate earthquake sequence at the Chaman fault

*松本 史子[1]、古屋 正人[1] (1.北海道大学)

10:15 ~ 10:30

[SCG48-05] GNSSと重力データを用いたスロースリップ中における流体移動の定量化の試み　第一報

*梅宮 悠輔[1]、田中 愛幸[1] (1.東京大学理学部)

[E] 口頭発表 | セッション記号 S (固体地球科学)：S-CG 固体地球科学複合領域・一般

13:45 ~ 15:15 | コンベンションホールA 2F

[S-CG48] Science of slow earthquakes: Toward unified understandings of whole earthquake process

コンビーナ:井出 哲(東京大学大学院理学系研究科地球惑星科学専攻)、廣瀬 仁(神戸大学都市安全研究センター)、氏家 恒太郎(筑波大学生命環境系)、波多野 恭弘(東京大学地震研究所)、座長:小原 一成(東京大学地震研究所)、加藤 愛太郎(東京大学地震研究所)

13:45 ~ 14:00

[SCG48-06] Interplay between long-term SSE and ETS facilitated by different underground environment

*小原 一成[1] (1.東京大学地震研究所)

14:00 ~ 14:15

[SCG48-07] **Determination of sVLFE epicenters around the subducted Kyushu-Palau Ridge from coda interferometry**

*利根川 貴志[1]、山下 裕亮[2]、伊藤 亜妃[1]、篠原 雅尚[3]、末次 大輔[1]、高橋 努[1]、石原 靖[1]、小平 秀一[1]、金田 義行[4] (1.海洋研究開発機構、2.京都大学防災研究所、3.東京大学地震研究所、4.香川大学)

14:15 ~ 14:30

[SCG48-08] Detection of slow earthquakes in the microseism frequency band (0.05–1.0 Hz) by large-scale waveform stacking

*増田 滉己[1]、井出 哲[1]、太田 和晃[2] (1.東京大学大学院理学系研究科地球惑星科学専攻、2.京都大学防災研究所)

14:30 ~ 14:45

[SCG48-09] Source characteristics of low-frequency earthquakes in Nankai subduction zone inferred from analysis of large event dataset

*Natalia Poiata[1]、Mariano Supino[1,2]、Gaetano Festa[2]、Jean-Pierre Vilotte[1]、Kazushige Obara[3] (1.Institut de Physique du Globe de Paris、2.Università degli Studi di Napoli “ Federico II ”, Napoli, Italy、3.Earthquake Research Institute, University of Tokyo, Japan)

14:45 ~ 15:00

[SCG48-10] **High-frequency radiation prior to semi-volcanic low-frequency earthquake in Eastern Shimane, SW Japan, illuminated by “0.1 manten” Hyper Dense Seismic Observation**

*加藤 愛太郎[1]、酒井 慎一[1]、松本 聡[2]、飯尾 能久[3] (1.東京大学地震研究所、2.九州大学、3.京都大学防災研究所)

15:00 ~ 15:15

[SCG48-11] Variation of Focal Mechanisms of Low Frequency Earthquakes in Parkfield

*麻生 未季[1,3]、麻生 尚文[2]、井出 哲[1] (1.東京大学大学院理学系研究科、2.東京工業大学理学院、3.応用アール・エム・エス株式会社)

[E] 口頭発表 | セッション記号 S (固体地球科学)：S-CG 固体地球科学複合領域・一般

15:30 ~ 17:00 | コンベンションホールA 2F

[S-CG48] Science of slow earthquakes: Toward unified understandings of whole earthquake process

コンビーナ:井出 哲(東京大学大学院理学系研究科地球惑星科学専攻)、廣瀬 仁(神戸大学都市安全研究センター)、氏家 恒太郎(筑波大学生命環境系)、波多野 恭弘(東京大学地震研究所)、座長:井出 哲(東京大学大学院理学系研究科)、太田 和晃

15:30 ~ 16:00

[SCG48-12] Mapping seismic data to slow slip using machine learning

★Invited Papers

*Bertrand Rouet-Leduc[1]、Claudia Hulbert[2]、Ian McBrearty[1]、Paul Johnson[1] (1.Los Alamos National Laboratory, USA、2.Ecole Normale Superieure, France)

16:00 ~ 16:15

[SCG48-13] Revealing the slow earthquake activity in the Japan Trench and its relation to the 2011 Tohoku-Oki earthquake

*西川 友章[1]、松澤 孝紀[2]、太田 和晃[1]、内田 直希[3]、西村 卓也[1]、井出 哲[4] (1.京都大学防災研究所、2.防災科学技術研究所、3.東北大学大学院理学研究科、4.東京大学大学院理学系研究科)

16:15 ~ 16:30

[SCG48-14] Tremor and slow slip associated with afterslip of the 2011 Tohoku earthquake

*太田 和晃[1]、伊藤 喜宏[1]、日野 亮太[2]、大柳 修慧[1]、松澤 孝紀[3]、篠原 雅尚[4]、塩原 肇[4] (1.京都大学防災研究所、2.東北大学大学院理学研究科、3.防災科学技術研究所、4.東京大学地震研究所)

16:30 ~ 16:45

[SCG48-15] High definition imaging of the Japan Trench by OBS Array of Arrays: Does shallow tectonic tremor occur in the plate interface?

*大柳 修慧[1]、太田 和晃[2]、伊藤 喜宏[2]、日野 亮太[3]、太田 雄策[3]、東 龍介[3]、篠原 雅尚[4]、望月 公廣[4]、佐藤 利典[5]、村井 芳夫[6] (1.京都大学理学研究科、2.京都大学防災研究所、3.東北大学、4.東京大学地震研究所、5.千葉大学、6.北海道大学)

16:45 ~ 17:00

[SCG48-16] 東北地方太平洋沖地震後の繰り返し地震活動：海陸地震観測網による検討

*内田 直希[1]、高木 涼太[1]、平原 聡[1]、中山 貴史[1]、松澤 暢[1]、田中 佐千子[2]、浅野 陽一[2] (1.東北大学大学院理学研究科附属地震・噴火予知研究観測センター、2.防災科学技術研究所)

[E] 口頭発表 | セッション記号 M (領域外・複数領域)：M-IS ジョイント

15:30 ~ 17:00 | 201A 2F

[M-IS07] アストロバイオロジー

コンビーナ:薮田 ひかる(広島大学大学院理学研究科地球惑星システム学専攻)、杉田 精司(東京大学大学院理学系研究科地球惑星科学専攻)、深川 美里(国立天文台)、藤島 皓介(東京工業大学地球生命研究所)、座長:深川 美里(名古屋大学大学院 理学研究科)、藤島 皓介(ELSI 地球生命研究所)

15:35 ~ 15:50

[MIS07-01] METEOROID AND DEBRIS IMPACT FLUX IN LOW EARTH ORBIT WITNESSED BY THE TANPOPO CAPTURE PANELS ONBOARD THE ISS IN 2015-2017

*Hajime Yano[1]、K. Yamamoto[2]、E. Minakami[2]、M. Eitel[1,3]、S. Sasaki[4]、J. Imani[5]、K. Okudaira[6]、M. Higashide[7]、E. Imai[8]、Y. Kawaguchi[9]、Yoko Kebukawa[10]、H. Mita[11]、M. Nishi[12]、T. Noguchi[13]、Makoto Tabata[14]、A. Tsuchiyama[12]、Hikaru Yabuta[15]、K. Arai[8]、H. Hashimoto[1]、Kensei Kobayashi[10]、A. Yamagishi[16] (1.Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency、2.Hosei University、3.University of Stuttgart、4.Tokyo University of Technology、5.Yuki Seimitsu, Co. Ltd.、6.University of Aizu、7.JAXA/Aerospace Research and Development Directorate、8.Nagaoka University of Technology、9.Chiba Institute of Technology、10.Yokohama National University、11.Fukuoka Institute of Technology、12.Kyoto University、13.Kyushu University、14.Chiba University、15.Hiroshima University、16.Tokyo University of Pharmacy and Life Science)

15:50 ~ 16:10

[MIS07-02] Growth and transport of dust, ice, and organics in the inner part of protoplanetary disks

★Invited Papers

*奥住 聡[1] (1.東京工業大学地球惑星科学系)

16:10 ~ 16:25

[MIS07-03] Model Prediction of Complex Organic Molecules in Protoplanetary Disks

*野村 英子[1]、Catherine Walsh[2]、Tom Millar[3] (1.東京工業大学理学院地球惑星科学系、2.リーズ大学、3.クィーンズ大学ベルファスト)

16:25 ~ 16:40

[MIS07-04] Abiotic synthesis of organic matters in environments simulating asteroids and the catalytic effect of minerals on amino acid formation

*Walaa Elmasry[1]、Yoko Kebukawa[1]、Kensei Kobayashi[1] (1.Yokohama National University)

16:40 ~ 16:55

[MIS07-05] 模擬海底熱水系環境下でのアミノ酸前駆体からのペプチド生成

*小林 憲正[1]、内藤 敬介[1]、内藤 弘毅[1]、倉本 想士[1]、今井 栄一[2]、三田 肇[3]、癸生川 陽子[1] (1.横浜国立大学、2.長岡技術科学大学、3.福岡工業大学)

[E] 口頭発表 | セッション記号 M (領域外・複数領域)：M-GI 地球科学一般・情報地球科学

13:45 ~ 15:15 | 104 1F

[M-GI30] Data assimilation: A fundamental approach in geosciences

コンビーナ:中野 慎也(情報・システム研究機構　統計数理研究所)、藤井 陽介(気象庁気象研究所)、宮崎 真一(京都大学理学研究科)、三好 建正(理化学研究所)、座長:三好 建正(理化学研究所計算科学研究機構)、中野 慎也(情報・システム研究機構 統計数理研究所)

13:45 ~ 14:00

[MGI30-01] Recent progresses and applications of geomagnetic data assimilation

★Invited Papers

*Julien Aubert[1]、Vincent Lesur[1]、Alexandre Fournier[1]、Gauthier Hulot[1] (1.Institut de Physique du Globe de Paris, France)

14:00 ~ 14:15

[MGI30-02] Accounting for non-locality of vertical error correlation within ETKF through eigen-spectral localization

★Invited Papers

*堀田 大介[1] (1.気象庁気象研究所)

14:15 ~ 14:30

[MGI30-03] Data assimilation experiments with MODIS LAI observations and the dynamic global vegetation model SEIB-DGVM over Siberia

★Invited Papers

*荒木田 葉月[1]、小槻 峻司[1]、大塚 成徳[1]、澤田 洋平[1,2]、三好 建正[1] (1.理化学研究所 計算科学研究センター、2.気象庁気象研究所)

14:30 ~ 14:45

[MGI30-04] アジョイント法による定常トレーサー分布から海洋鉛直拡散係数分布を推定する試み

★招待講演

*岡 顕[1] (1.東京大学大気海洋研究所)

14:45 ~ 15:00

[MGI30-05] Nonlinear data assimilation with 4DEnVar using iterative weather forecast model

*横田 祥[1]、小泉 耕[1]、國井 勝[2,1]、伊藤 耕介[3,1] (1.気象庁気象研究所、2.気象庁予報部数値予報課、3.琉球大学)

15:00 ~ 15:15

[MGI30-06] Development of Data Assimilation System for Atmospheric Density to Improve Satellite's Orbit Prediction Accuracy

*加藤 博司[1]、日南川 英明[1]、秋山 恭平[1]、秋山 祐貴[1]、中野 将弥[2]、大日向 大地[2]、中村 信一[1] (1.宇宙航空研究開発機構、2.富士通株式会社)

[E] 口頭発表 | セッション記号 M (領域外・複数領域)：M-GI 地球科学一般・情報地球科学

15:30 ~ 17:00 | 104 1F

[M-GI30] Data assimilation: A fundamental approach in geosciences

コンビーナ:中野 慎也(情報・システム研究機構　統計数理研究所)、藤井 陽介(気象庁気象研究所)、宮崎 真一(京都大学理学研究科)、三好 建正(理化学研究所)、座長:宮崎 真一(京都大学)、藤井 陽介

15:30 ~ 15:45

[MGI30-07] An LETKF-based ocean reanalysis for the Asia-Oceania region using Himawari-8 SSTs and SMOS/SMAP SSS

★Invited Papers

*大石 俊[1]、日原 勉[2]、相木 秀則[1]、石坂 丞二[1]、宮澤 泰正[2]、可知 美佐子[3] (1.名古屋大学、2.JAMSTEC、3.JAXA)

15:45 ~ 16:00

[MGI30-08] Validation of JCOPE-T DA ocean assimilation product

*日原 勉[1]、Varlamov Sergey[1]、宮澤 泰正[1]、美山 透[1]、可知 美佐子[2]、村上 浩[2] (1.国立研究開発法人海洋研究開発機構、2.国立研究開発法人宇宙航空研究開発機構)

16:00 ~ 16:15

[MGI30-09] **Do surface lateral flows matter for land data assimilation?: Implication for hyper-resolution land modeling and observation**

*澤田 洋平[1] (1.気象庁気象研究所)

16:15 ~ 16:30

[MGI30-10] Geodynamo data assimilation for candidate models of IGRF13-SV from Japan team

*南 拓人[1]、中野 慎也[2]、高橋 太[3]、松島 政貴[4]、清水 久芳[1]、藤 浩明[5] (1.東京大学地震研究所海半球観測研究センター、2.統計数理研究所、3.九州大学大学院理学研究院、4.東京工業大学理学院地球惑星科学系、5.京都大学大学院理学研究科)

16:30 ~ 16:45

[MGI30-11] A pilot study of geomagnetic data assimilation into a geodynamo model

*中野 慎也[1]、南 拓人[2]、高橋 太[3]、松島 政貴[4]、藤 浩明[5]、清水 久芳[2] (1.情報・システム研究機構　統計数理研究所、2.東京大学地震研究所、3.九州大学大学院理学研究院、4.東京工業大学理学院、5.京都大学大学院理学研究科附属地磁気世界資料解析センター)

16:45 ~ 17:00

[MGI30-12] Bayesian parameter estimation of a physics-based model of postseismic crustal deformation

★Invited Papers

*福田 淳一[1]、Johnson Kaj[2] (1.東京大学地震研究所、2.Department of Earth and Atmospheric Sciences, Indiana University)

[E] 口頭発表 | セッション記号 P (宇宙惑星科学)：P-PS 惑星科学

2019年5月29日(水) 13:45 ~ 15:15 | A01 東京ベイ幕張ホール

[P-PS02] Regolith Science

コンビーナ:和田 浩二(千葉工業大学惑星探査研究センター)、中村 昭子(神戸大学大学院理学研究科地球惑星科学専攻)、Patrick Michel(Observatoire De La Cote D'Azur)、Kevin John Walsh(Southwest Research Institute Boulder)、座長:和田 浩二(千葉工業大学惑星探査研究センター)

Recent planetary explorations have revealed that almost all solid bodies in the solar system are covered with small particles, called regolith. The surface geology, especially regolith behavior on the surfaces of solid bodies, becomes increasingly more important as represented by Hayabusa mission and other on-going and planned sample-return missions such as Hayabusa2, OSIRIS-REx, and MMX.

For fully understanding the regolith science, it is required to know and compare the regolith conditions on various celestial bodies, from asteroids to planets, with various methods.

Therefore, this session welcomes broad topics related to regolith on various celestial bodies, such as asteroids, comets, the Moon, the martian moons, Mars, etc. Papers on the formation, evolution, and alteration processes of regolith particles and regolith systems on the surface of planetary bodies, remote and in-situ observational results and techniques, analyses and results of returned samples, and laboratory, numerical, and theoretical studies on the fundamental physical and chemical processes are all welcome.

Note that what we call regolith is not just fine grains: all kinds of materials (more or less loose) that lie on the surface, from cobbles to finer grains, are our targets.

13:45 ~ 14:00

[PPS02-01] Moganite in a lunar meteorite as a trace of H_2O ice in the lunar regolith

★Invited Papers

*鹿山 雅裕[1] (1.東北大学)

14:00 ~ 14:15

[PPS02-02] Simulating the Lunar Soil: a Japanese Lunar Soil Simulant FJS-1 and Its Properties

★Invited Papers

*鵜山 尚大[1]、金森 洋史[1]、青木 滋[1] (1.清水建設株式会社)

14:15 ~ 14:30

[PPS02-03] Experimental estimation of regolith scattering behavior when a space lander touches on a planetary body

★Invited Papers

*馬場 満久[1]、Ronald Ballouz[2]、大槻 真嗣[1] (1.国立研究開発法人宇宙航空研究開発機構、2.アリゾナ大学)

14:30 ~ 14:45

[PPS02-04] Ray systems in granular cratering

*Tapan Sabuwala[1]、Christian Butcher[1]、Gustavo Gioia[1]、Pinaki Chakraborty[1] (1.Okinawa Institute of Science and Technology Graduate University)

14:45 ~ 15:00

[PPS02-05] Scaling of oblique impact cratering onto inclined granular layer

滝澤 真太[1]、*桂木 洋光[1] (1.名古屋大学大学院環境学研究科)

15:00 ~ 15:15

[PPS02-06] Experimental study on gravitational effects on crater size formed by low-velocity impacts into granular media

*木内 真人[1]、中村 昭子[2]、和田 浩二[3] (1.国立研究開発法人宇宙航空研究開発機構宇宙科学研究所、2.神戸大学大学院理学研究科、3.千葉工業大学惑星探査センター)

Moganite in a lunar meteorite as a trace of H_2O ice in the lunar regolith

*鹿山 雅裕[1]
*Masahiro KAYAMA[1]

1. 東北大学
1. Tohoku University

A large amount of H_2O ice has been observed on the regolith surface near the lunar poles by remote sensing spacecraft. However, only sparse evidence for H_2O ice beneath the top few millimeters of the regolith exists because neutron spectrometers cannot distinguish forms of H and near-infrared spectrometers are only sensitive to the optical surface. Furthermore, traces of H_2O ice have not yet been found from the lunar samples. Here, 13 different lunar meteorites with various lithologies have been investigated using micro-Raman spectrometry, electron microscopy, and synchrotron angle-dispersive x-ray diffraction (SR-XRD) to find a trace of H_2O ice in the subsurface. Consequently, moganite has been discovered from the KREEP (high potassium, rare-earth element, and phosphorous)-like gabbroic-basaltic brecciated meteorite NWA 2727 that may originate from the local crater sites within the Procellarum terranes.

Moganite (monoclinic SiO_2 phase that belongs to the *I2/a* space group) coexisting with coesite and stishovite (high-pressure SiO_2 polymorphs) was discovered only in NWA2727 by the micro-Raman spectrometry. NWA 2727 is mainly composed of gabbroic and basaltic clasts containing their breccia matrix, where only the breccia matrix contain moganite-bearing silica micrograins (2 to 13 mm in radius) between the constituent minerals (olivine, pyroxene and plagioclase). The SR-XRD analyses of these silica micrograins in the breccia matrix indicate a characteristic diffraction pattern that is in good agreement with the structure of moganite. However, no moganite was discovered from the basaltic and gabbroic clasts of NWA 2727 as well as in the other lunar meteorites selected here. Transmission electron microscopy of the silica micrograins demonstrates the aggregates of numerous euhedral or subhedral moganite nanoparticles (average radius of 4.5 nm).

Moganite was discovered in only one of those 13 samples. If terrestrial weathering had produced moganite in the lunar meteorites, there should be moganite present in all the samples, especially lunar meteorites fell to Earth around the same time (NWA 2977, 3333, and 6950 as measured here), but this was not the case. Furthermore, many previous researches on natural occurrences and laboratory experiments conclude that moganite is restricted to formation by precipitating from alkaline silicic acid (H_4SiO_4) water under high-pressure consolidation at >100 MPa, which is distinctly different environment from the desert that NWA 2727 found. A part of the moganite had changed into the coesite and stishovite, indicating their formation through heavy impact collisions on the Moon. These facts confirm our theory that it could not have formed in the desert.

Formation of lunar moganite can be interpreted based on the present and previous works as follows. Alkaline water-bearing carbonaceous chondrite collisions delivered abundant alkaline water to the lunar surface at <2.67 Ga. After the collisions, the delivered water was captured as fluid inside the breccia during the shock-induced consolidation. On the sunlit surface, lunar moganite precipitated from this captured alkaline water. Simultaneously, such captured water got cold-trapped at the lunar regolith in the subsurface and may still remain as ice underneath the local crater sites within the Procellarum terranes.

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Lunar moganite coexists with coesite and stishovite, thereby implying that a trace of the subsurface water ice was brought from the Moon by the recent impact at <1–30 Ma. Our moganite-precipitation simulation modeling concludes a subsurface H_2O concentration higher than the estimated bulk content of 0.6 wt % is expected to still remain as ice. This value is in excellent agreement with the concentrations of H_2O ice on the poles by remote sensing spacecraft observation. Thus, the subsurface is expected to be the abundant and available water resource for future lunar explorations.

キーワード：モガナイト、月隕石、氷、レゴリス
Keywords: Moganite, Lunar meteorite, H2O ice, Regolith

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Simulating the Lunar Soil: a Japanese Lunar Soil Simulant FJS-1 and Its Properties

*鵜山 尚大[1]、金森 洋史[1]、青木 滋[1]
*Naohiro Uyama[1], Hiroshi Kanamori[1], Shigeru Aoki[1]

1. 清水建設株式会社
1. Shimizu Corporation

Going back to the Moon is a world-wide trend of space exploration based on the international cooperation as the Global Exploration Roadmap (GER3) stated. JAXA also proposed future human exploration missions around 2030 within the international cooperation. All scenarios have their bases on the scientific observation that a plenty of water (hydrogen) is trapped in the polar regions, especially inside the craters of permanent shadow. In order to investigate those water and other existing volatiles, however, many engineering challenges wait for human and robotic missions even only from the view of lunar soil, such as traversing the soft soil, drilling and/or excavating the soil, and handling the soil for desired sample collections and scientific processes, and more for the in-situ resource utilization and human missions. Thus, the ground tests prior to launches are of great importance to increase the possibility of mission success.

In order to offer opportunities for the community to perform ground tests, we have manufactured a lunar soil simulant, called FJS-1. The investigation of FJS-1 shows that many properties of FJS-1 lies close to the data collected from Apollo samples. For instance, the particle size distribution lies below 2 [mm]; the median particle size is between 70 and 75 [micro-m]; the shear strength, i.e. cohesion c, is 0 to 10 [kN/m2]; and the internal friction angle, phi, is 30 to 50 [deg]. The chemical composition is also close to Apollo samples with slight difference that FJS-1 contains more ferric oxide and Alkaline components than Apollo samples.

In addition to the basic properties, we started investigating the strength of frozen lunar soil using FJS-1. Determining the optimized configuration of a sampler such as a drill or an excavator needs the information of actual lunar soil; however, nobody knows the actual state, in other words, the ground truth of lunar water/ice yet. We therefore decided to investigate the strength of frozen soil, utilizing FJS-1, for the future use for drill or excavator designs. The qualitative observation from our first experiment is that the frozen FJS-1 at temperature below 0 [degC] became slightly loose when FJS-1 contained 0.5 to 1.0 [wt%] of water, and that the strength drastically increased above 2 [wt%]. We will conduct more experiments to collect a set of frozen soil strength to offer the estimates of the strength of lunar soil for future lunar exploration missions.

キーワード：月土壌、模擬土壌、FJS-1、模擬土壌特性、凍結土壌
Keywords: Lunar soil, Soil simulant, FJS-1, Soil simulant properties, Frozen soil

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Experimental estimation of regolith scattering behavior when a space lander touches on a planetary body

*馬場 満久[1]、Ronald Ballouz[2]、大槻 真嗣[1]
*Mitsuhisa Baba[1], Ronald Louis Ballouz[2], Masatsugu Otsuki[1]

1. 国立研究開発法人宇宙航空研究開発機構、2. アリゾナ大学
1. Japan Aerospace Exploration Agency, 2. The University of Arizona

A planetary lander, which needs to land on and lift up from a planetary surface, needs to be concerned with levitated regolith. Regolith scattered by the landing foot pad might attach to or damage on-board instruments, such as the spacecraft’ s camera suite. To design the landing probe, it is necessary to estimate the expected area of the regolith that the probe may scatter. Here we show an experimental approach that was developed to study the behavior of scattered regolith under a vacuum environment. For the probe design, it is necessary to precisely measure the initial ejection angle, ejection velocity, and the amount of regolith that the landing foot pad scatters.

In order to characterize scattered-particle behavior, drop tests in a large vacuum chamber were conducted. A cylindrical mass projectile, mimicking the lander foot pad, fell freely from various heights in the vacuum chamber. The mass lands in a sandbox filled with silica sand and forms a crater with scattered sand particles. During silica sand scattering, a high-speed camera detected particle highlighted by a line laser. Initial ejection velocities and the ejection angles were estimated by processing the images of the impact site, captured by the high-speed camera.

The result of our study revealed that the ejection angle of scattered grains is not sensitive to the impact kinetic energy of the projectile. Our results are consistent with previous studies that showed a similar relationship between impact kinetic energy and ejection angle, but for lower impact energies. Moreover, we find that for impact speeds of ~ 4 m/s, the initial ejection velocity of a majority of the silica sand particle is distributed around 1 m/s.

Our experimental approach can be applied to various kinds of planetary regolith, such as Phobos simulant for the Martian Moons eXploration(MMX). These results help us to understand how to determine the optimal design conditions for a landing probe. Further studies that account for the effect of microgravity and changes to the bulk density and porosity of the regolith need to be undertaken based on drop tower test and numerical simulation.

キーワード：レゴリス、室内実験、着陸装置
Keywords: Regolith, Laboratory Experiment, Landing Gear

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Ray systems in granular cratering

*Tapan Sabuwala[1], Christian Butcher[1], Gustavo Gioia[1], Pinaki Chakraborty[1]

1. Okinawa Institute of Science and Technology Graduate University

In classical experiments of granular cratering, a ball dropped on a smooth bed of grains ends up within a crater surrounded by a uniform blanket of ejecta. We show that such a uniform blanket of ejecta changes to a ray system, or set of radial streaks of ejecta, where the surface of the granular bed includes undulations. By carrying out numerous experiments and computational simulations thereof, we ascertain that the number of rays in a ray system $\propto D/\lambda$, where D is the diameter of the ball and λ the wavelength of the undulations. Further, we show that the ejecta in a ray system originates from valleys located in a narrow annulus of diameter D with center at the site of impact. The impacting ball creates a hemispherical shockwave, whose interaction with the surficial valleys engenders the ray system. Our findings may help shed light on the enigmatic ray systems that ring many impact craters on the Moon and other planetary bodies.

Keywords: impact crater, crater rays, granular cratering

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Scaling of oblique impact cratering onto inclined granular layer

滝澤 真太[1]、*桂木 洋光[1]
Shinta Takizawa[1], *Hiroaki Katsuragi[1]

1. 名古屋大学大学院環境学研究科
1. Graduate School of Environmental Studies, Nagoya University

Empirical (Pi-group) scaling laws for craters created on an inclined granular layer by an oblique impact of a spherical projectile were experimentally obtained. In the experiment, inclination angle and incident angle were systematically (and independently) varied in the ranges of 0 to 33 degree and 10 to 170 degree, respectively. A spherical projectile (diameter 6 mm) was impacted onto a surface of inclined granular layer with an impact speed 10 - 100 m/s. Two high-speed cameras and laser profilometry system were used to measure the impact speed, angle, and final crater shape. From the experimental results, we found following behaviors. When the incident angle is small, almost symmetric craters were observed. However, the collapse of the upper crater wall was triggered when the inclination angle is large enough. The scale of the collapse grows as the inclination angle is increased. In addition, the crater volume strongly depends on inclination angle. By combining these experimental findings, we developed the empirical scaling for crater dimensions and aspect ratios. The obtained scaling is consistent with previous works on the normal impact to horizontal granular surface with high impact speed. We also discuss a possible way to evaluate the impact conditions from the actual astronomical impact craters.

キーワード：斜め衝突、傾斜粉体層
Keywords: oblique impact , inclined granular layer

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Experimental study on gravitational effects on crater size formed by low-velocity impacts into granular media

*木内 真人[1]、中村 昭子[2]、和田 浩二[3]
*Masato Kiuchi[1], Akiko M Nakamura[2], Koji Wada[3]

1. 国立研究開発法人宇宙航空研究開発機構宇宙科学研究所、2. 神戸大学大学院理学研究科、3. 千葉工業大学惑星探査センター
1. Japan aerospace exploration agency, Institute of space and astronautical science, 2. Department of Planetology, Kobe University, 3. Planetary Exploration Research Center, Chiba Institute of Technology

Craters on regolith surface can be formed at various impact velocities. When secondary craters form on the surface of small bodies, such as asteroids and comets, the impactors have very low-velocities of several m s^{-1} or less due to the small escape velocity of the bodies. These secondary collisions can increase the number of small craters on the surface and will affect the surface topography of small bodies. Therefore, it is important to investigate low-velocity impacts on granular materials that simulate regolith particles to understand the low-velocity cratering process on the surface of small bodies.

Low-velocity impact experiments with velocities in the range of several m s^{-1} and granular targets have been conducted to investigate crater size and develop empirical relationships between impact conditions and crater size under 1 G (e.g., Uehara et al., 2003; Walsh et al., 2003). However, it was found that the impact velocity dependence of crater diameter was inconsistent between the hypervelocity impact experiments conducted at low and high-gravity conditions (Gault and Wedekind, 1977; Schmidt and Housen, 1987) and the low-velocity impact experiments conducted under 1 G (Kiuchi et al., 2018, JpGU meeting).

We collected data of crater diameter on granular materials with impact velocities ranging from 1 to 4.6 m s^{-1} under a gravity range of 0.20 to 1 G to investigate the effects of gravity on crater diameter using a drop system developed for reduced gravity impact experiments (Kiuchi and Nakamura, 2015 JPGU meeting). Most of our experiments were conducted under 10^5 Pa for comparison with the low-velocity experiments under 1 G reported in previous studies, but we also conducted several experiments under 7 Pa according to the atmosphere-less condition of small bodies.

This time we newly organized our experimental results in which the gravity was changed using the atmospheric pressure dependence. As a result, the exponent values of gravity became close to that obtained by the high-velocity experiment (Gault and Wedekind, 1977). We compared our results with high-velocity experiments reported in previous studies. Our results for the glass projectile and the sand target almost agreed with the previous high-velocity crater-size scaling- law (Housen and Holsapple, 2011) when the atmospheric effect was taken into account, but the crater diameter for the steel projectile and the sand target was lower than that for the glass projectile. This result shows that the crater-size scaling- law obtained for high-velocity impact can be applied to low-velocity impacts of several m s^{-1} under reduced pressure when the density ratio of the projectile to the target is close to unity. The same scaling applies over a very wide range of impact velocities.

キーワード：低速度衝突実験、クレーターサイズの重力依存性
Keywords: Impact experiments at low-velocity, Gravitational effects on crater size

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[E] 口頭発表 | セッション記号 P (宇宙惑星科学)：P-PS 惑星科学

2019年5月29日(水) 15:30 ~ 17:00 | A01 東京ベイ幕張ホール

[P-PS02] Regolith Science

コンビーナ:和田 浩二(千葉工業大学惑星探査研究センター)、中村 昭子(神戸大学大学院理学研究科地球惑星科学専攻)、Patrick Michel(Observatoire De La Cote D'Azur)、Kevin John Walsh(Southwest Research Institute Boulder)、座長:中村 昭子(Graduate School of Science, Kobe University)

Recent planetary explorations have revealed that almost all solid bodies in the solar system are covered with small particles, called regolith. The surface geology, especially regolith behavior on the surfaces of solid bodies, becomes increasingly more important as represented by Hayabusa mission and other on-going and planned sample-return missions such as Hayabusa2, OSIRIS-REx, and MMX.

For fully understanding the regolith science, it is required to know and compare the regolith conditions on various celestial bodies, from asteroids to planets, with various methods.

Therefore, this session welcomes broad topics related to regolith on various celestial bodies, such as asteroids, comets, the Moon, the martian moons, Mars, etc. Papers on the formation, evolution, and alteration processes of regolith particles and regolith systems on the surface of planetary bodies, remote and in-situ observational results and techniques, analyses and results of returned samples, and laboratory, numerical, and theoretical studies on the fundamental physical and chemical processes are all welcome.

Note that what we call regolith is not just fine grains: all kinds of materials (more or less loose) that lie on the surface, from cobbles to finer grains, are our targets.

15:30 ~ 15:45

[PPS02-07] Impact Ejecta Environment of an Eccentric Asteroid: 3200 Phaethon

*Jamey Szalay[1]、Peter Pokorny[2]、Mihaly Horanyi[3]、Diego Janches[2]、Menelaos Sarantos[2]、Ralf Srama[4] (1.Princeton University、2.NASA/GSFC、3.University of Colorado Boulder、4.University of Stuttgart)

15:45 ~ 16:00

[PPS02-08] On the Detection of an Ejecta Dust Cloud Around Asteroid (3200) Phaethon by the DESTINY$^+$ Dust Analyzer

*Hiroshi Kimura[1]、Masanori Kobayashi[1]、Koji Wada[1]、Tomoko Arai[1]、Hiroki Senshu[1]、Masateru Ishiguro[2]、Hidekazu Hanayama[3]、Ko Ishibashi[1]、Takayuki Hirai[1]、Fumi Yoshida[1]、Peng Hong[1] (1.Planetary Exploration Research Center、2.Seoul National University、3.Ishigakijima Astronomical Observatory)

16:00 ~ 16:15

[PPS02-09] Close-up thermal and optical observation of asteroid Ryugu

★Invited Papers

*坂谷 尚哉[1]、岡田 達明[1]、田中 智[1]、千秋 博紀[2]、嶌生 有理[1]、荒井 武彦[3]、神山 徹[5]、出村 裕英[6]、須古 健太郎[6]、関口 朋彦[4]、滝田 隼[15]、福原 哲哉[4]、田口 真[4]、Thomas Müller[7]、Axel Hargermann[8]、Jens Biele[9]、Matthias Grott[9]、Marco Delbo[10]、杉田 精司[13]、本田 理恵[12]、諸田 智克[11]、山田 学[2]、亀田 真吾[4]、巽 瑛理[13]、横田 康弘[1]、鈴木 秀彦[14]、本田 親寿[6]、小川 和律[16]、早川 雅彦[1]、松岡 萌[1]、長 勇一郎[13]、澤田 弘崇[1] (1.宇宙航空研究開発機構 宇宙科学研究所、2.千葉工業大学、3.足利大学、4.立教大学、5.産業技術総合研究所、6.会津大学、7.Max-Planck Institute for Extraterrestrial Physics、8.University of Stirling、9.German Aerospace Center、10.Observatoire de la Côte d'Azur, CNRS、11.名古屋大学、12.高知大学、13.東京大学、14.明治大学、15.北海道教育大学、16.神戸大学)

16:15 ~ 16:30

[PPS02-10] In-Situ Investigation of Asteroid (162173) Ryugu by the Hayabusa2 MASCOT Lander

★招待講演

*矢野 創[1]、Ho Tra-Mi[2]、Jaumann Ralf[3]、Bibring Jean-Pierre[4]、 Glassmeier Karl-Heinz[5]、Grott Matthias[3]、Hercik David[5]、Biele Jens[6]、Hamm Maximilian[3]、Schmitz Nicole[3]、 Schröder Stefanus[3]、Otto Katharina[3]、Krause Christian[6]、Lorda Laurence[7]、Moussi-Soffys Aurelie[7]、Pilorget Cedric[4]、Hamm Vincent[4]、Riu Lucie[1]、Okada Tatsuaki[1]、Sakatani Naoya[1]、Reill Josef[8]、Sasaki Kaname[2]、Schlotterer

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16:30 ~ 16:45

[PPS02-11] Evidence of Mass Movement and Boulder Transport on Bennu from NASA's OSIRIS-REx Space Mission

★Invited Papers

*Erica R Jawin[1]、Kevin J Walsh[2]、Tim McCoy[1]、Harold C Connolly[3]、Dante S Lauretta[4]、Ron L Ballouz[4]、Jamie L Molaro[5]、Olivier S Barnouin[6]、Mike Nolan[4] (1.Smithsonian National Institute, Washington, DC, USA、2.Southwest Research Institute, Boulder, CO, USA、3.Dept. of Geology, Rowan University, Glassboro, NJ, USA、4.Lunar and Planetary Laboratory, University of Arizona, Tucson, AZ, USA、5.Planetary Science Institute, Tucson, AZ, USA、6.The Applied Physics Laboratory, Johns Hopkins University, Laurel, MD, USA)

16:45 ~ 17:00

[PPS02-12] Resurfacing processes on small asteroids constrained by crater size distributions on Ryugu, Itokawa, and Eros

*高木 直史[1]、長 勇一郎[1]、諸田 智克[3]、巽 瑛理[1]、吉岡 和夫[1]、澤田 弘崇[5]、横田 康弘[2,5]、坂谷 尚哉[5]、早川 雅彦[5]、松岡 萌[5]、本田 理恵[2]、亀田 真吾[4]、山田 学[6]、神山 徹[8]、鈴木 秀彦[10]、本田 親寿[7]、小川 和律[9]、宮本 英昭[1]、Olivier Barnouin[11]、Patrick Michel[12]、Carolyn Ernst[11]、杉田 精司[1,6] (1.東京大学、2.高知大学、3.名古屋大学、4.立教大学、5.宇宙航空研究開発機構 宇宙科学研究所、6.千葉工業大学 惑星探査センター、7.会津大学、8.産総研、9.神戸大学、10.明治大学、11.ジョンズホプキンス大学 応用物理学研究所、12.ニース天文台)

Impact Ejecta Environment of an Eccentric Asteroid: 3200 Phaethon

*Jamey Szalay[1], Peter Pokorny[2], Mihaly Horanyi[3], Diego Janches[2], Menelaos Sarantos[2], Ralf Srama[4]

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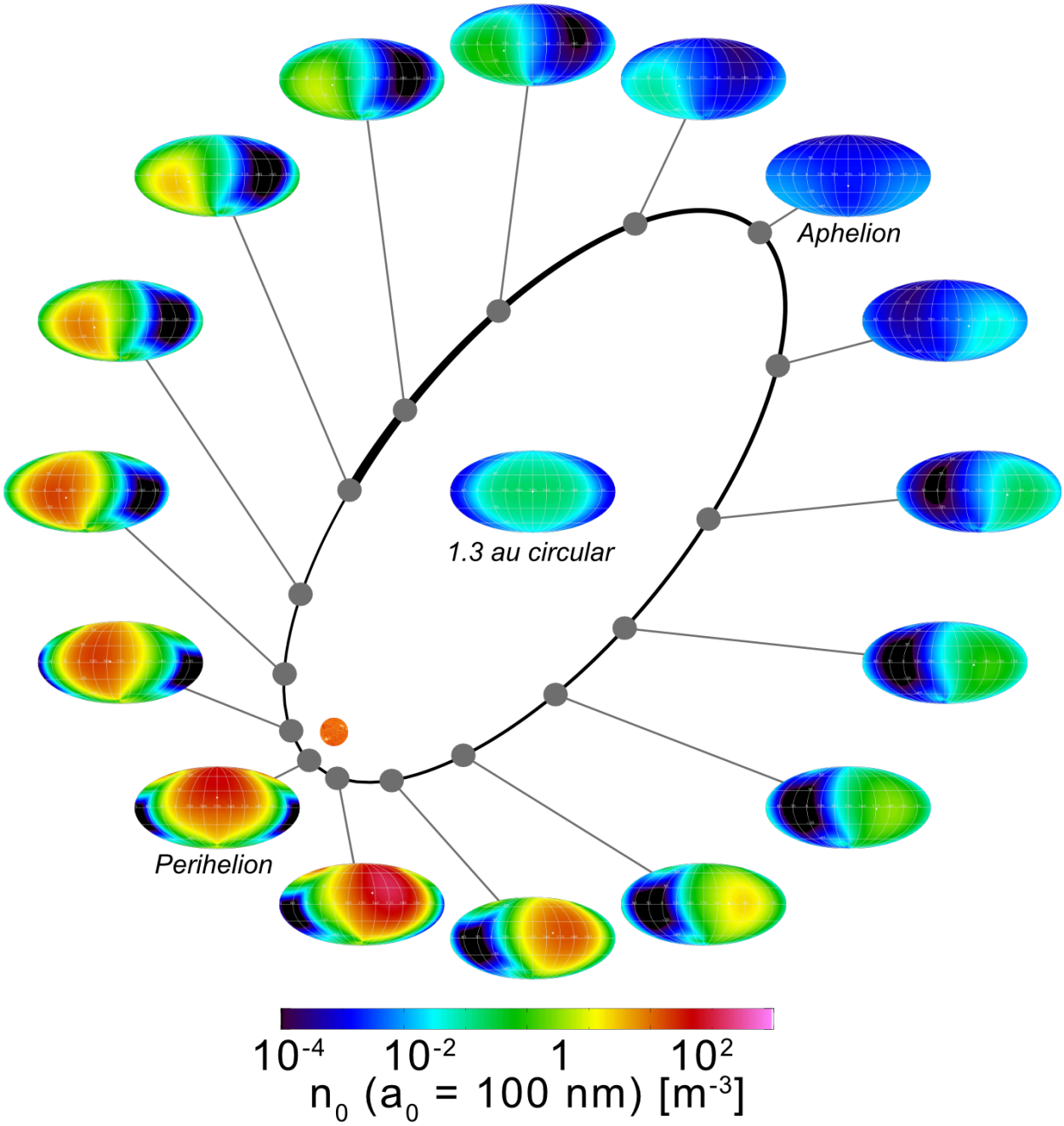
Airless regolith bodies in the solar system are continually bombarded by meteoroids, modifying their surfaces and sustaining impact ejecta clouds. While large bodies like the Moon retain a significant fraction of ejected regolith, small asteroids shed this material into the interplanetary dust complex. Measurements of the lunar impact ejecta cloud found it was sustained by the known sporadic meteoroid sources. Here, we extend lunar ejecta measurements using a model of the meteoroid environment at 1 au to investigate the structure of an ejecta cloud at an eccentric airless body, asteroid 3200 Phaethon: the target of JAXA’ s DESTINY+ mission.

Due to Phaethon's large eccentricity, Phaethon's peak ejecta density at 1 au is approximately 30 times higher compared to a body in a circular orbit at 1 au, largely due to enhanced ejecta production from meteoroids shed from Jupiter Family Comets. Such asymmetric ejecta production suggests Phaethon experiences significantly different meteoroid-specific space weathering processes than a body with a similar semi-major axis on a circular orbit. We estimate impact ejecta processes at Phaethon shed approximately 1 ton per year, which is not sufficient to appreciably contribute to the Geminids meteoroid complex, yet provides ample ejecta densities to measure with an in-situ dust detector aboard DESTINY+. These results suggest eccentric asteroids shed more material than those on near-circular orbits, and are suitable candidates for in-situ dust detection and chemical characterization due to their amplified asymmetric ejecta production.

In this presentation, we will summarize recent efforts to constrain the evolution and ejection of asteroid regolith for 3200 Phaethon. We will present predicted impact counts for a dust detector on close flybys of Phaethon in preparation for JAXA’ s DESTINY+ mission and discuss how such measurements would provide critical insight into Phaethon’ s origin and evolution in a manner unique to dust detection data.

Keywords: Ejecta, Meteoroids, Regolith

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On the Detection of an Ejecta Dust Cloud Around Asteroid (3200) Phaethon by the DESTINY$^+$ Dust Analyzer

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We will provide the most recent report on the detectability of an ejecta cloud around Asteroid (3200) Phaethon by the DESTINY$^+$ Dust Analyzer (DDA), based on a model of dust dynamics in the cloud. We demonstrate that solar radiation pressure plays a vital role in shaping the spatial distribution of dust particles in Phaethon's ejecta cloud, because small particles, albeit the majority, are expelled from the sunward direction. We find that the DDA will have an opportunity of detecting dust particles in the ejecta cloud of Phaethon during a flyby, depending on the closest approach to the asteroid, heliocentric distance, and the initial velocity of ejecta. There are no hazard from impacts of 100 μm-sized ejecta particles that potentially could make tiny holes on the surface of the spacecraft during a flyby.

Keywords: Asteroid (3200) Phaethon, ejecta dust cloud, DESTINY+

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Close-up thermal and optical observation of asteroid Ryugu

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In 2018, the Hayabusa2 spacecraft successfully carried out four descend operations toward Ryugu’s surface. During these operations, we acquired highly resolved optical and thermal images from altitudes below several hundred meters, using Hayabusa2’s Optical Navigation Camera (ONC-T) and Thermal Infrared Imager (TIR), respectively. Close-up thermal images by TIR indicate thermophysical properties of the surface materials and its regional difference, which cannot be resolved by higher altitude observations (e.g., home-position observations from 20 km altitude). The temperature depends mainly on the thermal inertia of the observed medium; higher thermal inertia materials have lower daytime temperatures. Optical images by ONC-T show detailed physical conditions of the surface materials, such as particle size distribution of pebbles, surface morphology of small boulders and craters. At the spacecraft altitude of 100 m, for example, TIR and ONC-T have pixel resolutions of 8.9 cm/pix and 1.1 cm/pix, respectively. In this study, we report on a comparison of TIR and ONC images, especially for boulders and craters.

BOULDERS: TIR close-up observations showed various boulders with different daytime temperatures, or different thermal inertia. Typical thermal inertia of boulders is about 300 J m^{-2} K^{-1} $s^{-0.5}$, but there are a few boulders with thermal inertia up to 1000 J m^{-2} K^{-1} $s^{-0.5}$. The thermal inertia of rocks is mainly controlled by porosity, and porous rock has lower thermal inertia. Therefore, TIR observations show that the porosity of boulders is variable. Furthermore, boulders with high thermal inertia (low porosity) observed by ONC-T were found to be relatively brighter and had a smooth surface. Such variation in porosity, optical brightness, and surface morphology of boulders on Ryugu’s surface might reflect the degree of thermal metamorphism (depth of the source) in the parent body. If the constituents of Ryugu originate from variable depths inside the parent body, this supports the idea of a rubble pile formation of Ryugu after the catastrophic disruption of the parent body. This will place important constraints on the thermal evolution of the parent body.

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CRATERS: During the MINERVA descend operations at 21st Sep., we acquired highly resolved images of two craters with diameter of less than 35 m by TIR, but both craters exhibit different thermal characteristics. One crater has a hot spot close to the center of crater, where the thermal inertia is estimated to be less than 150 J m^{-2} K^{-1} $s^{-0.5}$. On the other hand, there seems to be no hot spot in the other crater. The difference in thermophysical properties between these craters might be attributed to formation age or original surface conditions. Our finding of a hot spot with low thermal inertia indicates the presence of a fine-particle deposit in the crater and regolith generation related to the cratering process on this low-gravity asteroid.

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In-Situ Investigation of Asteroid (162173) Ryugu by the Hayabusa2 MASCOT Lander

In-Situ Investigation of Asteroid (162173) Ryugu by the Hayabusa2 MASCOT Lander

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After a journey of almost four years to the C-type asteroid (162173) Ryugu, the MASCOT lander of the Hayabusa2 mission was delivered to the asteroid’s surface on October 3rd in 2018 and successfully performed in situ investigations. MASCOT was released from the mother spacecraft at an altitude of 41 m and came to rest on the surface at a site located at 22.31±0.05˚S, 317.16±0.05˚E. MASCOT observed the surface for a full day-night cycle using its four science instruments until batteries ran out after 17h and 7min. The payload consisting of a wide angle camera (MASCAM), an imaging IR spectrometer (MicrOmega), a multi-channel radiometer (MARA), and a magnetometer (MasMAG) provided a wealth of data which helped to characterize the asteroid’s surface down to millimeter scale. MasCAM images revealed a surface dominated by rocks and boulders without showing fine-grained material. Boulders appeared either bright with smooth faces and sharp edges or dark with cauliflower-like crumbly surfaces.

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Inclusions observed in high-resolution images showed that rocks had strong similarities with carbonaceous chondrites. Temperatures of a ~60 cm diameter rock that have been measured in situ, were found to be consistent with a thermal inertia of 282(+93, -35) J m^{-2} K^{-1} $s^{-1/2}$, much lower than anticipated when compared to samples in our meteorite collections. This indicated that rocks on Ryugu were highly porous and likely very friable. The remnant magnetization of Ryugu's surface material on scales larger than 1 m was estimated to be lower than $3{\cdot}10^{-6}$ Am^2/kg (the measurement limit of MasMAG). A preliminary analysis of the induction effect in Ryugu caused by the variation in the solar wind magnetic field revealed significantly high electrical conductivity (of the order 1 S/m).

キーワード：Ryugu、Hayabusa2、Asteroid Surface、Lander、Carbonaceous Chondrites、High Porosity
Keywords: Ryugu, Hayabusa2, Asteroid Surface, Lander, Carbonaceous Chondrites, High Porosity

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Evidence of Mass Movement and Boulder Transport on Bennu from NASA's OSIRIS-REx Space Mission

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The near-Earth Asteroid (101955) Bennu is currently being studied by the NASA OSIRIS-REx mission. This small, top-shaped asteroid has evidence of a diverse suite of geologic units, including impact craters, linear features, and abundant boulders at a range of sizes, geometric albedos, and morphologies. The surface of the asteroid appears to be old; however localized evidence of mass movement has been detected in various locations that suggests the surface is dynamic. The abundance of boulders on the surface varies widely with location, with concentrations of boulders located in local topographic lows (e.g. the interior of candidate impact craters, between linear ridges), suggesting that boulders travelled across the surface to result in these concentrations. Several locations that are abundant in boulders show evidence of imbrication in the local downslope direction, but evidence of imbrication is more localized than on other asteroids such as Itokawa. Evidence of mass movement at smaller particles sizes is also evident by burial of boulders: evidence of largescale W-E movement of material and burial of rocks has been identified, as well as pileup of boulders at locations downslope of scarps. In addition, the largest boulder on Bennu (~95 m diameter) appears to be partly buried, with a portion of the boulder of unknown size remaining in the subsurface. This boulder has an exposed face that extends vertically off the surface by ~20 m, suggesting that several tens of meters of finer-grained material could have accumulated to bury part of the boulder. The direction that material would have traveled to bury this boulder follows the regional slopes. As a comparison, the second largest boulder on Bennu (~50 m diameter) that is nearby albeit at a slightly higher latitude (45 S latitude, versus the buried boulder at 25 S latitude) is not buried –rather, this boulder appears to be perched on the surface. The variation in very large boulder burial suggests the surface of Bennu has potentially experienced large-scale material transport.

Keywords: OSIRIS-REx, Bennu, Mass-movement, Asteroid, Regolith

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Resurfacing processes on small asteroids constrained by crater size distributions on Ryugu, Itokawa, and Eros

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Recent ion irradiation experiments in laboratories suggest that space weathering may take place very rapidly [1], but telescopic observations of asteroids support much slower space weathering [2]. The spectral rejuvenation process on asteroid surfaces may hold a key for bridging the gap between the two opposite conclusions [3]. However, the nature of the spectral rejuvenation process has not been understood well yet. One approach for understanding the spectral rejuvenation process is to constrain the depth-age relation of surface layers on asteroids. In fact, imaging observations by Hayabusa2 revealed that smaller craters are highly depleted on the surface of the asteroid Ryugu [4], strongly suggesting that resurfacing is acting efficiently on near-surface layers. This depletion was already observed on Eros and Itokawa [5]. In this study, we analyze this depletion in small craters to constrain the resurfacing mechanism on small asteroids, such as Ryugu, Itokawa, and Eros. More specifically, we estimate the resurfacing age of Ryugu, Itokawa and Eros based on crater counting and crater production functions. Then we compare the analysis results with theoretical models for resurfacing mechanisms on such small asteroids.

Crater retention age can be estimated by using both the crater size frequency distribution (CSFD) and the crater production function (CPF). The CSFD on Ryugu shows that the large craters distribution (≧100m in diameter) is close to saturation level, but the number density of small craters (~10 m) is reduced by a factor of 100 [4]. Similar depletion in small craters is also observed on Itokawa [5]. We calculated crater retention ages for different size craters and derived the relation between crater retention ages and excavation depth of craters.

The CPFs on Ryugu, Itokawa, and Eros are estimated based on a classical main belt collisional evolution model and a scaling relation for crater formation. We used a scaling relation including armoring effect [6] for Ryugu and Itokawa to account for the high abundance of boulders on them. In this analysis, we used

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larger craters than ~10m in diameter. Finally, we derived the relation between crater retention age, *t*, and depth, *d*, of crater, $t \sim d^a$, where *a* is found to be 1.8±0.4 on Ryugu, 1.1±0.3 on Itokawa, and 1.9±0.3 on Eros, respectively. If crater degradation is controlled by a diffusion process, the relation between crater retention age *t* is proportional to the square of crater depth *d*, i.e.,$t \sim d^2$. Ryugu's and Eros's power-law indices (*a* ~1.8-1.9) are consistent with diffusion (*a* = 2), which is not the case of Itokawa's power-law index. However, Itokawa's power-law index *a* increase to 1.9 if we include smaller craters than ~10m in diameter in this analysis. This value is consistent with diffusion (*a* = 2). Actually, Michel et al. 2009 suggests that the depletion of small craters on Itokawa is reproduced by a seismic shaking model without taking an armoring effect into account [7]. The efficiency of an armoring effect for small craters on asteroids is uncertain, but an armoring effect may change the interpretation of CSFDs. In order to understand crater scaling for smaller craters, Small Carry-on Impactor (SCI) experiment on Hayabusa2 is important.

[1] Lantz+2018, Icarus, **302**, 10–17

[2] Lazzarin+2009 AA, **498**, 307-311

[3] Shestopalov+2013, Icarus, **225**, 781-798

[4] Sugita+2019, Science in revision

[5] Hirata+2009, Icarus, **200**, 486-502

[6] Tatsumi & Sugita 2018, Icarus, **300**, 227-248

[7] Michel+2009, Icarus, **200**, 503-513

キーワード：小惑星、クレーター、表面更新、リュウグウ、イトカワ、はやぶさ2
Keywords: asteroid, crater, resurfacing, Ryugu, Itokawa, Hayabusa2

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[E] 口頭発表 | セッション記号 P (宇宙惑星科学)：P-PS 惑星科学

2019年5月29日(水) 9:00 ~ 10:30 | A01 東京ベイ幕張ホール

[P-PS03] Solar System Small Bodies: A New Frontier Arising Hayabusa 2, OSIRIS-REx and Other Projects

コンビーナ:石黒 正晃(ソウル大学物理天文学科)、中本 泰史(東京工業大学)、安部 正真(宇宙航空研究開発機構宇宙科学研究所)、Olivier S Barnouin(Johns Hopkins University Applied Physics Laboratory)、座長:Taishi Nakamoto(東京工業大学)

2018年6月、小惑星探査機「はやぶさ2」が約3年半の航海を経て、目的地リュウグウに到着した。また、別の小惑星探査機「OSIRIS-REx」も探査天体Bennuに間もなく到着しようとしている。これらの探査によって、太陽系小天体研究は、今まさに新しい局面を迎えようとしている。本セッションは、2012年から開催されてきたもので、これまでに実験、観測、探査、理論、さらにサンプル分析の観点から太陽系小天体の研究に関して議論を行ってきた。特に今回は、はやぶさ2とOSIRIS-RExの初期成果を中心に太陽系小天体に関する最新研究を持ち寄り、今後の展望を議論することを目的とする。はやぶさ2、OSIRIS-REx以外の研究成果発表も歓迎する。

9:00 ~ 9:15

[PPS03-19] The shape of Bennu: Implications for internal structure.

★Invited Papers

*Olivier S Barnouin[1]、Micheal G. Daly[2]、Eric E Palmer[3]、Robert W Gaskell[3]、John R. Weirich[3]、Catherine L Johnson[4]、Manar Al Asad[4]、James H Roberts[1]、Mark E. Perry[1]、Hannah C.M. Sursorney[4]、R. Terik Daly[1]、Edward B. Bierhaus[5]、Jeff A Seabrook[2]、Raymond C. Espiritu[1]、A. Hari Nair[1]、Lilian Nguyen[1]、Gregory A Neumann[6]、Carolyn M Ernst[1]、William V Boynton[7]、Micheal C. Nolan[7]、Coralie D. Adams[9]、Micheal C. Moreau[6]、Bashar Rizk[7]、Christian Drouet D'Aubigny[7]、Erica R. Jawin[8]、Kevin J Walsh[10]、Patrick Michel[11]、Stephen R. Schwartz[7]、Ronald L. Ballouz[7]、Erwan M Mazarico[6]、Daniel J. Scheeres[12]、Jay W. McMahon[12]、W Bottke[10]、Seiji Sugita[13]、Naru Hirata[14]、Noayuki Hirata[15]、Sei-ichiro Watanbe[16]、Keara N. Burke[7]、Daniella N. DellaGuistina[7]、Carinna A. Bennet[7]、Dante Lauretta[7] (1.Johns Hopkins University Applied Physics Laboratory、2.The Centre for Research in Earth and Space Science, York University, Toronto, Ontario, Canada.、3.Planetary Science Institute, Tucson, AZ, USA、4.Department of Earth, Ocean and Atmospheric Sciences, University of British Columbia, Vancouver, Canada.、5.Lockheed Martin Space Systems Company, Denver, CO, USA.、6.NASA Goddard Space Flight Center, Greenbelt, MD, USA.、7.Lunar Planetary Laboratory, University of Arizona, Tucson, AZ, USA.、8.Smithsonian Institution National Museum of Natural History, Washington, DC, USA.、9.KinetX Aerospace, Inc. Simi Valley, CA, USA、10.Southwest Research Institute, Boulder, CO, USA.、11.Université Côte d'Azur, Observatoire de la Côte d'Azur, CNRS, Laboratoire Lagrange, Nice, France.、12.Department of Aerospace Engineering Sciences, University of Colorado, Boulder, CO, USA.、13.University of Tokyo, Tokyo, Japan.、14.Aizu University, Aizu-Wakamatsu, Japan.、15.Kobe University, Kobe, Japan.、16.Nagoya University, Nagoya, Japan.)

9:15 ~ 9:30

[PPS03-20] Global Geology of Bennu from NASA's OSIRIS-REx Space Mission

★Invited Papers

*Erica R Jawin[1]、Kevin J Walsh[2]、Tim McCoy[1]、Harold C Connolly[3]、Dante S Lauretta[4]、Ron L Ballouz[4]、Olivier S Barnouin[5]、C Beddingfield[6]、Carina A Bennett[4]、Edward B Bierhaus[7]、Keara N Burke[4]、Ben Clark[8]、Michael G Daly[9]、Marco Delbo[10]、Daniella DellaGiustina[4]、Jason P Dworkin[11]、Christine Hartzell[12]、John Marshall[6]、Patrick Michel[10]、Jamie L. Molaro[13]、Mike Nolan[4]、Maurizio Pajola[14]、Mark Perry[5]、Bashar Rizk[4]、Scott Sandford[15]、Dan J Scheeres[16]、Stephen R Schwartz[4]、David Trang[17] (1.Smithsonian National Institute, Washington, DC, USA、2.Southwest Research Institute, Boulder, CO, USA、3.Dept. of Geology, Rowan University, Glassboro, NJ, USA、4.Lunar and Planetary Laboratory, University of Arizona, Tucson, AZ, USA 、5.The Applied Physics Laboratory, Johns Hopkins University, Laurel, MD, USA、6.SETI Institute, Mountain View, CA, USA、7.Lockheed Martin Space Systems Company, USA、8.Space Science Institute, Boulder CO, USA、9.York University, Canada、10.Laboratoire Lagrange, Université Côte d'Azur, Observatoire de la Côte d'Azur, CNRS, Laboratoire Lagrange, Nice, France、11.NASA Goddard Space Flight Center, Greenbelt, MD, USA、12.Department of

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9:30 ~ 9:45

[PPS03-21] Modeling surface mobility mechanisms on a top-shaped near-Earth asteroid

★Invited Papers

*Ronald Ballouz[1]、Nicola Baresi[2]、Olivier S Barnouin[3]、Carina A Bennet[1]、Edward B Bierhaus[4]、Keara N Burke[1]、Harold C Connolly[5]、Sarah T Crites[2]、Daniella DellaGiustitna[1]、Erica Jawin[6]、Dante S Lauretta[1]、Patrick Michel[7]、Derek C Richardson[8]、Dan J Scheeres[9]、Stephen Schwartz[1]、Seiji Sugita[10]、Eri Tatsumi[10]、Florian Thuillet[7]、Kevin Walsh[11] (1.Lunar and Planetary Lab, University of Arizona, Tucson, AZ, USA、2.Institute of Space and Astronautical Science, Sagamihara, Japan、3.The Applied Physics Laboratory, Johns Hopkins University, Laurel, MD, USA、4.Lockheed Martin, Boulder, CO, USA、5.Department of Geology, Rowan University, Glassboro, NJ, USA、6.Smithsonian National Museum of Natural History, Washington, DC, USA、7.UCA-OCA-CNRS, Lagrange Laboratory, Nice, France、8.Dept. of Astronomy, University of Maryland, College Park, MD, USA、9.Dept. of Aerospace Engineering Sciences, University of Colorado, Boulder, CO, USA、10.University of Tokyo, Tokyo, Japan、11.Southwest Research Institute, Boulder, CO, USA)

9:45 ~ 10:00

[PPS03-22] **Visualization and Analysis of Solar System Small Bodies with NASA's Solar System Treks Project**

*Brian Hamilton Day[1]、Emily Law[2] (1.NASA Solar System Exploration Research Virtual Institute, NASA Ames Research Center、2.NASA Jet Propulsion Laboratory, California Institute of Technology)

10:00 ~ 10:15

[PPS03-23] Density Distribution within Small Solar System Bodies Based on Smooth Terrain Shape: Asteroid 25143 Itokawa and Comet 67P/Churyumov-Gerasimenko

*金丸 仁明[1]、佐々木 晶[1]、Mark Wieczorek[2] (1.大阪大学、2.コートダジュール天文台)

10:15 ~ 10:30

[PPS03-24] 彗星探査計画CAESARに向けた非晶質珪酸塩の低温水質変成実験

*瀧川 晶[1,4]、木村 勇気[1]、古川 善博[2]、中村 智樹[3] (1.京都大学大学院理学研究科、2.北海道大学低温科学研究所、3.東北大学大学院理学研究科、4.京都大学白眉センター)

The shape of Bennu: Implications for internal structure.

*Olivier S Barnouin[1], Micheal G. Daly[2], Eric E Palmer[3], Robert W Gaskell[3], John R. Weirich[3], Catherine L Johnson[4], Manar Al Asad[4], James H Roberts[1], Mark E. Perry[1], Hannah C.M. Sursorney[4], R. Terik Daly[1], Edward B. Bierhaus[5], Jeff A Seabrook[2], Raymond C. Espiritu[1], A. Hari Nair[1], Lilian Nguyen[1], Gregory A Neumann[6], Carolyn M Ernst[1], William V Boynton[7], Micheal C. Nolan[7], Coralie D. Adams[9], Micheal C. Moreau[6], Bashar Rizk[7], Christian Drouet D'Aubigny[7], Erica R. Jawin[8], Kevin J Walsh[10], Patrick Michel[11], Stephen R. Schwartz[7], Ronald L. Ballouz[7], Erwan M Mazarico[6], Daniel J. Scheeres[12], Jay W. McMahon[12], W Bottke[10], Seiji Sugita[13], Naru Hirata[14], Noayuki Hirata[15], Sei-ichiro Watanbe[16], Keara N. Burke[7], Daniella N. DellaGuistina[7], Carinna A. Bennet[7], Dante Lauretta[7]

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Introduction: We used data collected by the Origins, Spectral Interpretation, Resource Identification, and Security–Regolith Explorer (OSIRIS-REx) spacecraft since November 1, 2018 to develop a global digital terrain model (DTM) of Bennu. The DTM is developed from images collected by the OSIRIS-REx Camera Suite using stereophotoclinometry (SPC). We validated the DTM independently using limb data and by the identification of keypoints between actual images and synthetic images rendered from the DTM. The results are also compared to an independent model derived from range measurements collected by the OSIRIS-REx Laser Altimeter (OLA). While developing the global model, we also refine the pole orientation and rotational state of the asteroid. The characteristics of the resulting global digital terrain model provide constraints on the factors responsible for the origin and evolution of Bennu’s shape and surface.

Digital Terrain Model Construction from Imaging: About 1500 OCAMS images with ground sample distance ranging from 30 to 200 m were used to develop the global DTM of Bennu. We used distant limb data of Bennu to construct an initial DTM of Bennu. Then a combination of geometric stereo data and surface lighting conditions (or photoclinometry) modeled small patches (or maplets) of terrain across the asteroid. Geometric stereo typically defines the location of the center of each maplet, while the surface tilts across the maplet are estimated by best fitting the brightness variations of images that contain some portion of the maplet. These maplets are then combined to build a global model. The model increases in detail, accuracy, and precision as higher-resolution images and images with different viewing conditions are incorporated.

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Digital Terrain Model Construction from Laser Altimetry: We collated several six-hour linear scans obtained by OLA during orbit around Bennu to make an independent shape model of Bennu at a resolution equivalent to the one derived from imaging. This DTM is improved relative to the SPC-derived model because OLA better resolves the heights, and extent of 1 to 3m boulders across the surface of the asteroid.

Bennu’s Geomorphological and Structural Properties: The evaluation of the both models shows that the average size of the asteroid is 490.06 ±0.16 m.

The model shows the presence of several features:
-An equatorial ridge that is muted, and is diamond-shaped when viewed from the pole;
-Topographic north-south ridges that extend in some instances from pole to pole. The ridges influence the distribution of boulders, which are frequently concentrated between the ridges;
-Large craters that influence some of the attributes of the shape, primarily along the equator;
-A few large protruding boulders >40 m in diameter and >10 m high, mostly in the southern hemisphere;
-Grooves, scarps, and troughs that in some instances extend several 10s to 100s of meters, with depths ranging from 2–10 m.

Conclusion: The initial shape characteristics suggest that Bennu has some interior stiffness. Considering past modeling efforts investigating deformation due to spin-up, the lack of a circular equatorial ridge with a pronounced bulge, and the presence of high standing north-south ridges indicate that in spite of an abundance of evidence for material moving towards the equator, Bennu has interior structure that resists deformation.

Keywords: (101955) Bennu, Asteroids, OSIRIS-REx mission

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Global Geology of Bennu from NASA's OSIRIS-REx Space Mission

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NASA’s OSIRIS-REx sample return mission has been observing the near-Earth Asteroid (101955) Bennu since December 2018 and will be collecting a sample of the surface in the summer of 2020, to be returned to Earth in 2023. Preliminary and ongoing observations have yielded much information about Bennu’s formation, evolution, and ongoing geologic activity. Here we report on the global geology of Bennu based on analyses of images combined with shape, mass, and slope measurements. Initial results suggest that Bennu is a rubble-pile asteroid, formed from a parent body that was collisionally disrupted and reaccumulated. The asteroid has a “top” shape which is spherical with an equatorial bulge, similar to other near-Earth asteroids including Ryugu as observed by the Hayabusa2 sample return space mission. Candidate impact craters have been observed at a range of diameters between ~10-150 m across the surface of Bennu, leading to a crater retention age of 100 million to 1 billion years. An apparent concentration of large crater candidates at low latitudes suggest that the equatorial ridge is stratigraphically old, and may have formed early in Bennu’s history or been inherited from the reaccumulation event which created the asteroid. Several linear features have been identified on Bennu, the largest of which are topographic highs that extend longitudinally from the northern polar regions to the equator. Boulders are concentrated between several of these linear ridges, as well as in the interior of large candidate craters. Boulders on Bennu appear to be geologically diverse. Boulder sizes range from < 3 m to ~95 m in diameter with large variations in geometric albedo, morphology, degree of burial, and state of degradation. Fractured boulders have been identified with various numbers, orientations, and widths of fractures. Distinct clasts within several boulders indicate they may be breccias, while piles of boulders may represent disaggregated polymict or brecciated boulders. Current imaging resolution cannot resolve centimeter-sized particles, so direct detections of regolith or other sub-cm sized particles have not been made. However, several small candidate craters (< 20 m diameter) have a significant lack of boulders relative to the surrounding terrain, and additional datasets suggest the presence of a component of fine-grained particles. Improved image resolution will aid in the identification of regolith deposits on Bennu.

Keywords: OSIRIS-REx, Bennu, Asteroid, Geology

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Modeling surface mobility mechanisms on a top-shaped near-Earth asteroid

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The advent of near-Earth asteroid (NEA) encounters with spacecraft has provided a view of planetary surfaces evolving on the smallest objects yet explored. The arrival of OSIRIS-REx and Hayabusa2 at their target asteroids (101955) Bennu, with average diameter (d) = 0.49 km, and (162173) Ryugu (d = 0.90 km), revealed cratered top-shaped worlds with signs of surface mobility [1, 2]. Compared to larger planetary bodies, Bennu and Ryugu’s small sizes and gravities challenge the conventional understanding of surface modification mechanisms, such as the redistribution of boulders on the surface or the erasure of craters.

On the larger NEA (433) Eros (d = 16.8 km), boulders were spatially correlated with impact craters, which degrade through impact-induced seismic shaking [3]. However, our poor understanding of rubble-pile interiors [4], combined with processes that operate more efficiently on smaller NEAs (such as thermal re-radiation torques, i.e., the YORP effect [5]), introduces new complexities to understanding surface mobility on Bennu and Ryugu.

Here, we first present evidence of a dynamic surface on Bennu and Ryugu. Then, we present an analysis of the dynamical processes that may dominate the surface modification of small top-shaped NEAs. We model the redistribution of material on the surface due to different input energy sources: i) impact-induced seismic shaking, ii) YORP spin-up, iii) impact cratering, and iv) planetary encounters. We use a combination of techniques that allows us to approach the problem at multiple length and time scales. The first step models the global effect of the energy sources using analytical techniques. In the second step, we model the fine grain scale interactions in a microgravity environment in short timescales using a particle dynamics code [6,7]. Finally, we propagate the accumulated effect of the fine-scale interactions by integrating individual surface modifications over the typical timescale of each individual process. The results are used to assess which of the above listed mechanisms are the most effective at transforming small NEA surfaces.

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Acknowledgements:

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Keywords: Near Earth Asteroids, OSIRIS-REx, Hayabusa2

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Visualization and Analysis of Solar System Small Bodies with NASA's Solar System Treks Project

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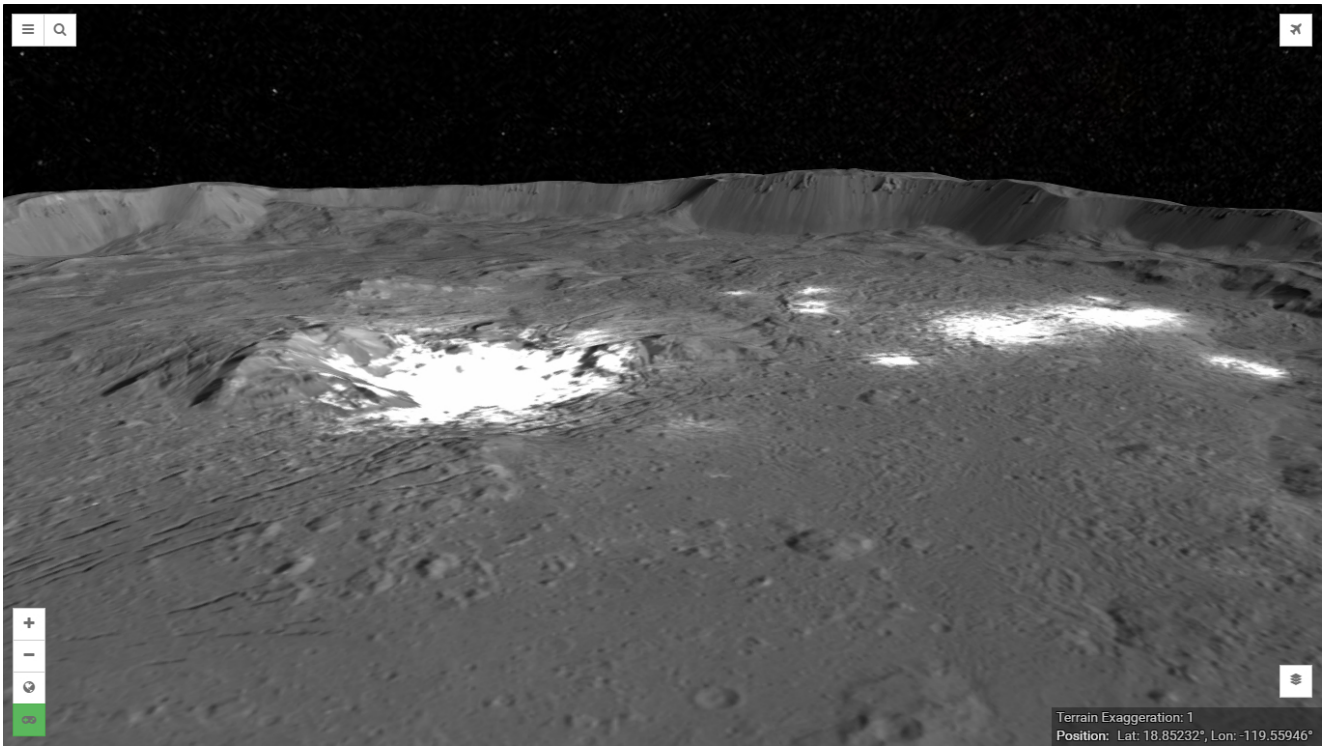
In its investigations of Vesta and Ceres, NASA's Dawn mission has returned spectacular data detailing the surfaces of these two prominent small bodies in our Solar System's asteroid belt. In order to greatly facilitate dissemination, visualization, and analysis of this data, and public understanding of the mission, the Dawn mission has partnered with NASA's Solar System Treks Project (SSTP). SSTP has recently released an update to the Vesta Trek online portal (https://trek.nasa.gov/vesta/) and has released a new Ceres Trek portal (https://trek.nasa.gov/ceres/).

This presentation will showcase the use of the Ceres Trek and Vesta Trek portals and demonstrate how they can be used to visualize and analyze particularly interesting landforms such as the pitted terrain on Vesta and relic cryovolcanoes on Ceres. We will also demonstrate the new VR capability that has been added to the portals, allowing users to generate their own virtual reality flyovers for any user-defined paths along the bodies' surfaces. In addition to highlighting the portals for Ceres and Vesta, the presentation will preview additional portals being planned/developed for other small bodies. NASA and JAXA have requested the development of a portal for the asteroid Ryugu to facilitate dissemination, visualization, and analysis of data from Japan's Hayabusa2 mission, and a portal for Mars' moon Phobos in support of mission planning for Japan's MMX mission. We are also planning a portal for the asteroid Bennu with data from the OSIRIS-Rex mission.

All of these products are efforts in the NASA Solar System Treks Project (SSTP), available at https://trek.nasa.gov. NASA's Solar System Trek online portals provide web-based suites of interactive data visualization and analysis tools to enable mission planners, planetary scientists, students, and the general public to access mapped data products from past and current missions for a growing number of planetary bodies including the Moon, Mars, Vesta, etc. These portals are being used for site selection and analysis by NASA and a number of its international partners, supporting upcoming missions. In addition to demonstrating the capabilities of selected portals in this presentation, we will solicit input from the community for ideas for future enhancements to the portals.

Keywords: Ceres, Vesta

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Density Distribution within Small Solar System Bodies Based on Smooth Terrain Shape: Asteroid 25143 Itokawa and Comet 67P/Churyumov-Gerasimenko

*金丸 仁明[1]、佐々木 晶[1]、Mark Wieczorek[2]
*Masanori Kanamaru[1], Sho Sasaki[1], Mark Wieczorek[2]

1. 大阪大学、2. コートダジュール天文台
1. Osaka University, 2. Côte d'Azur Observatory

Small solar system bodies are the remnants of the early stage of the solar system formation. Shapes and interior structures of small bodies tell us about how they formed and evolved. Particularly, the interior density distribution of small bodies is an important clue for better understanding of planetesimal collisions and subsequent accumulation processes. However, we have much less information about their interiors than their surface properties, partly because it is difficult to measure the exterior gravity precisely in a small body mission. We have investigated a method to estimate density distribution within a small body based on combining spacecraft imagery and the simulated gravity field on the surface of the small body (Kanamaru and Sasaki, 2019; Kanamaru, Sasaki and Wieczorek, in prep.).

If a small body possesses loose regolith sufficiently, over geologic time, impact-induced seismic shaking or cometary activity may have triggered mass movement from a high standing region to a low standing region (Richardson and Bowling, 2014). Our inversion of density distribution assumes that a very flat region on a small body, which is covered with fine gravels and associated with the low standing area in gravitational potential, might approximate an equi-potential surface. Therefore, the inversion processes include (1) mapping a smooth terrain on a 3D shape model of the small body using the Small Body Mapping Tool, and (2) computing dynamic elevations above a reference potential surface given ununiform density distribution (as shown in the upper left panel in Figure). As a criteria for mapping the smooth terrain, we also used a surface roughness defined as the standard deviation of the dynamic elevations within a circle of a specific scale (upper right panel in Figure). The misfit between the smooth terrains and the equi-potential surface is characterized by the standard deviation of the surface elevations within the flat region. On the above assumption of the topographic erosion process, the minimum misfit gives a best fitting density. We applied this method to asteroid Itokawa and comet 67P/Churyumov-Gerasimenko to investigate whether each of their lobes has a different density from the other or not.

There exists three major smooth terrains on Itokawa, named MUSES-C Regio, Sagamihara Regio and Uchinoura Regio. Given different densities to the two lobes of Itokawa (the head and body), the misfit for the smooth terrains is minimized where the head of Itokawa has a higher density than the mean bulk density. Based on the consideration of the systematic errors that arise from the uncertainty of the shape model itself and the calculation error of the gravity field, the allowable range of the head density is estimated to be 2,450 (2,220-2,670) kg/m^3 in contrast to the body density of 1,930 (1,976-1,879) kg/m^3 . Such a great contrast in density between the two lobes is consistent with the independent estimate of the center-of-mass/center-of-figure offset of Itokawa based on the YORP spin-up observation (Lowry et al., 2014).

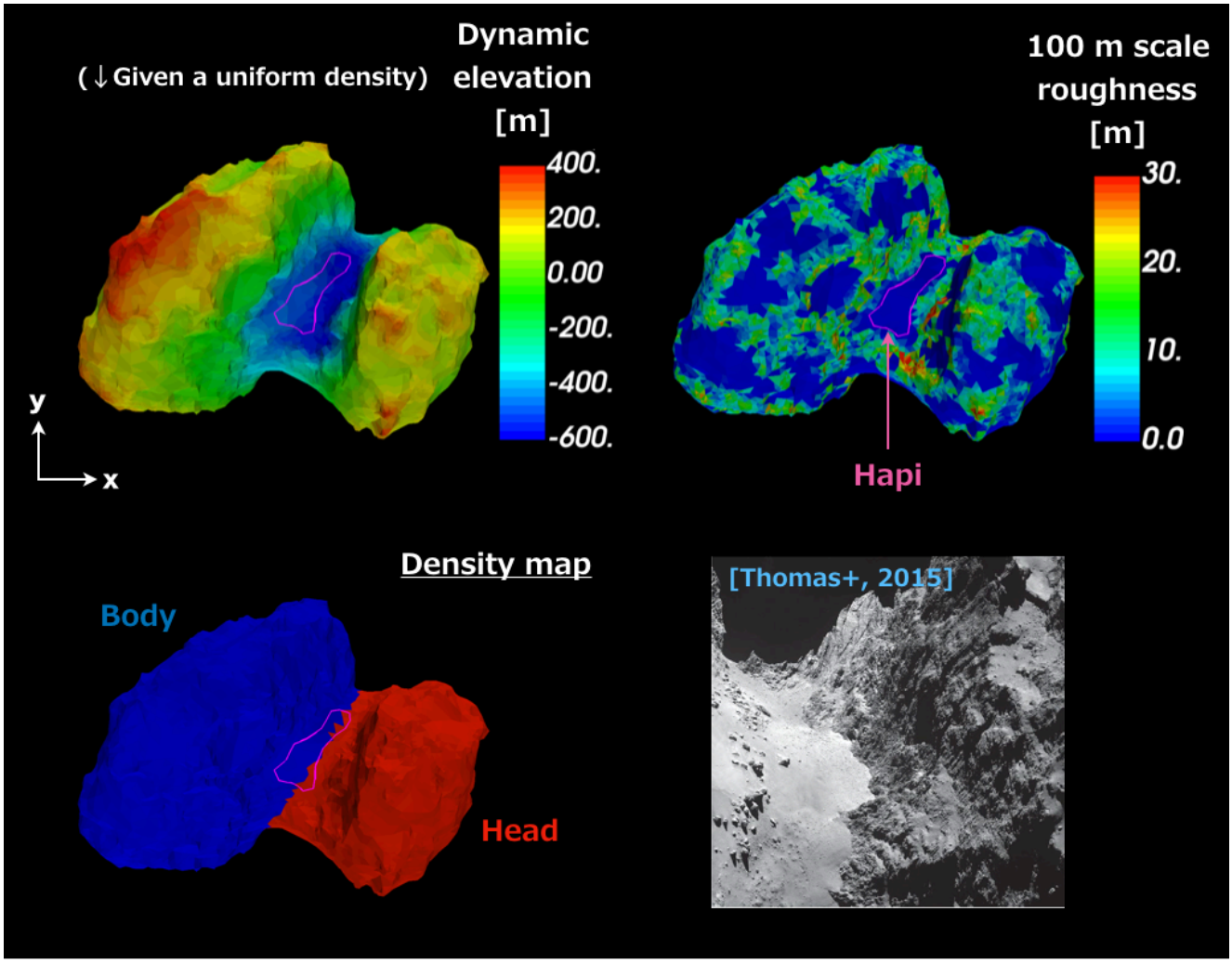
The comet nucleus of 67P also has a smooth terrain called Hapi, which is likely to be covered with particles falling from other regions. In the density inversion for the two lobes of 67P, the head and body

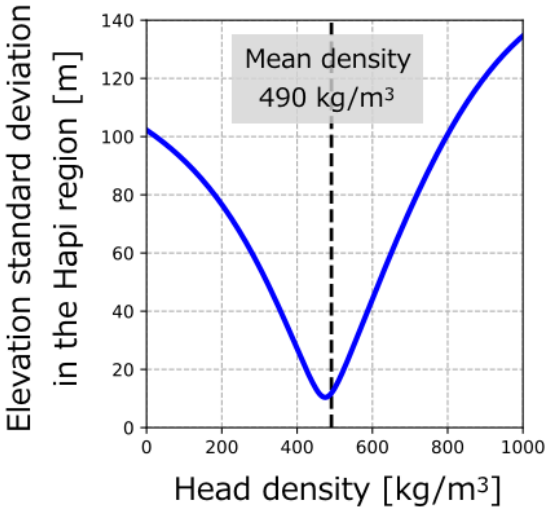
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(see the middle left panel in Figure), the best fitting density of the head is similar to the mean bulk density unlike the case of Itokawa (lower panel in Figure). This result indicates a global scaled homogeneity of 67P, which is consistent with the gravity measurement by Patzold et al. (2016). If the bi-lobed shape of the comet was formed by a sub-catastrophic disruption of its parent body and merger of two main fragments (Jutzi and Benz, 2017), it is possible for the two lobes to have the same density.

キーワード：太陽系小天体、小惑星25143イトカワ、チュリモフ・ゲラシメンコ彗星、内部密度分布構造、重力場
Keywords: Small solar system body, Asteroid 25143 Itokawa, Comet 67P/Churyumov-Gerasimenko, Interior density distribution, Gravity field

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彗星探査計画CAESARに向けた非晶質珪酸塩の低温水質変成実験
Low temperature hydration experiments of cometary analog materials towards the Comet Astrobiology Exploration Sample Return (CAESAR) mission

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*Aki Takigawa[1,4], Yuki Kimura[1], Yoshihiro Furukawa[2], Tomoki Nakamura[3]

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1. Graduate School of Science, Kyoto University, 2. Institute of Low Temperature Science, 3. Graduate School of Science, Tohoku University, 4. The Hakubi Center for Advanced Research

The Comet Astrobiology Exploration Sample Return (CAESAR) mission is a final candidate for selection as the fourth mission in NASA’s New Frontiers Program. CAESARaims to acquire and return to Earth for laboratory analysis a minimum of 80 g of surface material from the nucleus of comet 67P/Churyumov-Gerasimenko (67P) (Squyres et al. 2018).Near-infrared spectra of a short-period comet 67P taken by the spectrometer onboard Rosseta spacecraft also indicate the absence of phyllosilicates in this comet (Capaccioni et al. 2015). In order to return anhydrated samples from 67P, optimal conditions for sampling should be determined because cometary dust particles especially amorphous silicates are highly reactive. Hydration process of anhydrous crystalline silicates such as olivine is already well-characterized, whereas reaction of water vapor or ice with amorphous silicates and organic matters at temperatures below H_2O freezing points has been poorly understood. In this study, we performed incubation experiments of amorphous silicates and organic matters under low temperature conditions with ice or vapor of D_2O/NH_3.

Amorphous silicate nanoparticles with three different chemical compositions and textures (S1, S2, and S3), and commercial glycine and ribose powder were used in the experiments. S1 is composed of ~100 nm particles having $MgSi_2O_5$composition prepared with sol-gel processing. S2 and S3 are condensates from high temperature gases. S2 is amorphous Mg_2SiO_4nanoparticles of ~80 nm in size synthesized in a Radio Frequency plasma system (Koike et al. 2010). S3 is 30-100 nm sized amorphous silicate with Mg/Si~0.93 embedded with metallic Fe-Ni particles condensed from a high temperature vapor of the CI chondritic ratios of Mg, Al, Ca, Fe, and Nito Si in an induction thermal plasma system (Kim et al. 2017).

Two types of ice were used in the experiments to evaluate the effects of corrosive gases in 67P; (A) Pure D_2O ice (99.90% purity) and (B) Mixture D_2O ice with 0.3% H_2O and 0.15% NH_3. Experiments with different ices were performed in different vacuum containers placed in a cryogenic box. About 5 mg of three silicate and glycine samples were put in different open-top glass bottles (2 ml). Approximately 50 mg of chipped ice fragments were put in the glass bottles and directly contact with the silicate and glycine samples. Roughly ~500 mg of the same ice fragments were put in the vacuum containers as a vapor source. The temperature of the cryogenic box sets at -17 or -27˚C. The samples were exposed with saturated vapor of ices for 10-120 days. As a comparison, exposure experiments of amorphous silicate samples (S1, S2, and S3) to H_2O vapor were also conducted at 25 and 50˚C for 10 days.

The exposed silicate samples were analyzed with a powder X-ray diffraction (XRD, Rigaku SmartLab) and Fourier-transform infrared spectroscopy (FT-IR; JASCO MFT-680, Thermo Nicolet iS5). The recovery rate of glycine (i.e., molar ratio of recovered glycine over starting glycine) and ribose were obtained by liquid

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chromatography tandem mass spectrometer (LC/MSMS; Shimadzu LCMS-8040).

No clear change of the XRD patterns and FT-IR spectra for S1, S2, and S3 was confirmed after the experiments for <120 days at -17 and -27˚C. The recovery of glycine exposed to D_2O ice and NH_3 -containing D_2O ice for 10 days was 108±8 mol% and 105±8 mol%, respectively. The recovery of ribose exposed to D_2O ice and NH_3-containing D_2O ice for 10 days was 108±12 mol% and 105±12 mol%, respectively. Bicause the ice sublimation timescale is very short at the exoerimental temperatures, the present results indicate that cometary silicates at <-20˚C in comets are pristine even if they have high surface to volume ratio and amorphous structures as GEMS grains in anhydrous CP-IDPs.

キーワード：彗星、探査計画、水質変成実験
Keywords: comet, space exploration, hydration experiment

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[E] 口頭発表 | セッション記号 P (宇宙惑星科学)：P-PS 惑星科学

2019年5月29日(水) 10:45 ~ 12:15 | A01 東京ベイ幕張ホール

[P-PS03] Solar System Small Bodies: A New Frontier Arising Hayabusa 2, OSIRIS-REx and Other Projects

コンビーナ:石黒 正晃(ソウル大学物理天文学科)、中本 泰史(東京工業大学)、安部 正真(宇宙航空研究開発機構宇宙科学研究所)、Olivier S Barnouin(Johns Hopkins University Applied Physics Laboratory)、座長:Masateru Ishiguro(Seoul National University)

2018年6月、小惑星探査機「はやぶさ2」が約3年半の航海を経て、目的地リュウグウに到着した。また、別の小惑星探査機「OSIRIS-REx」も探査天体Bennuに間もなく到着しようとしている。これらの探査によって、太陽系小天体研究は、今まさに新しい局面を迎えようとしている。本セッションは、2012年から開催されてきたもので、これまでに実験、観測、探査、理論、さらにサンプル分析の観点から太陽系小天体の研究に関して議論を行ってきた。特に今回は、はやぶさ2とOSIRIS-RExの初期成果を中心に太陽系小天体に関する最新研究を持ち寄り、今後の展望を議論することを目的とする。はやぶさ2、OSIRIS-REx以外の研究成果発表も歓迎する。

10:45 ~ 11:00

[PPS03-25] Overview and current status of DESTINY$^+$ mission

★Invited Papers

*荒井 朋子[1]、小林 正規[1]、石橋 高[1]、吉田 二美[1]、木村 宏[1]、平井 隆之[1]、洪 鵬[1]、山田 学[1]、千秋 博紀[1]、和田 浩二[1]、スラマ ラルフ[2]、クルーガー ハラルド[3]、渡部 潤一[4]、伊藤 孝士[4]、石黒 正晃[5]、中村 智樹[6]、薮田 ひかる[7]、橘 省吾[8]、三河内 岳[8]、阿部 新助[9]、大塚 勝仁[10]、浦川 聖太郎[11]、中村メッセンジャー 圭子[12]、小松 睦美[13]、亀田 真吾[14]、鍵谷 将人[6]、平田 成[15]、出村 裕英[15]、佐々木 晶[16]、廣井 隆弘[17]、小松 吾郎[18]、金田 英宏[19]、稲守 孝哉[19]、岡本 尚也[20]、柳沢 俊史[20]、吉川 真[20]、矢野 創[20]、岡田 達明[20]、岩田 隆浩[20]、大坪 貴文[20]、川勝 康弘[20]、豊田 裕之[20]、西山 和孝[20]、高島 健[20] (1.千葉工業大学惑星探査研究センター、2.シュツットガルト大学、3.マックスプランク研究所、4.国立天文台、5.ソウル大学、6.東北大学、7.広島大学、8.東京大学、9.日本大学、10.東京流星観測網、11.日本スペースガード協会、12.NASA、13.総合研究院大学、14.立教大学、15.会津大学、16.大阪大学、17.ブラウン大学、18.ダヌンツィオ大学、19.名古屋大学、20.宇宙航空研究開発機構)

11:00 ~ 11:15

[PPS03-26] Observational campaign of (3200) Phaethon and (155140) 2005UD in 2017-2018

*吉田 二美[1]、Arai Tomoko[1]、Ishibashi Ko[1]、Hong Peng[1]、Ishimaru Ryo[1]、International observation collaborators DESTINY+ (1.Planetary Exploration Research Center, Chiba Institute of Technology)

11:15 ~ 11:30

[PPS03-27] Rotationally-resolved spectroscopic observations of Phaethon - 2005 UD, and their fragments detected by lunar impact flashes.

*阿部 新助[1]、Moskovitz Nicholas[2]、吉田 二美[3]、大塚 勝仁[4]、伊藤 孝士[5]、布施 綾太[1]、柳澤 正久[6]、山田 竜平[7] (1.日本大学理工学部 航空宇宙工学科、2.ローウェル天文台、3.千葉工業大学 惑星探査研究センター、4.東京流星ネットワーク、5.国立天文台、6.電気通信大学 情報理工学研究科、7.会津大学 コンピュータ理工学部)

11:30 ~ 11:45

[PPS03-28] Thermal Radiation Pressure Force on Regolith Particles of Atmosphereless Bodies

*Yoonsoo P. Bach[1]、Masateru Ishiguro[1] (1.Department of Physics and Astronomy, Seoul National University)

11:45 ~ 12:00

[PPS03-29] A kilometre-sized Kuiper belt object revealed by OASES stellar occultation observations

*有松 亘[1,2]、津村 耕司[3]、臼井 文彦[4]、新中 善晴[5]、市川 幸平[3,6,7]、大坪 貴文[8]、小谷 隆行[2,9]、和田 武彦[8]、長勢 晃一[8]、渡部 潤一[2] (1.京都大学 付属天文台、2.国立天文台、3.東北大学 学際科学フロンティア研究所、4.神

戸大学大学院 理学研究科 惑星科学研究センター、5.京都産業大学、6.コロンビア大学、7.テキサス大学サンアントニオ校、8.宇宙航空研究開発機構　宇宙科学研究所、9.アストロバイオロジーセンター)

12:00 ~ 12:15

[PPS03-30] AKARI/IRC near-infrared asteroid spectroscopic survey: AcuA-spec

*臼井 文彦[1]、長谷川 直[2]、大坪 貴文[2]、尾中 敬[3,4] (1.神戸大学大学院 理学研究科 惑星科学研究センター、2.宇宙航空研究開発機構 宇宙科学研究所、3.東京大学大学院理学系研究科 天文学専攻、4.明星大学理工学部 総合理工学科)

Overview and current status of DESTINY$^+$ mission

*荒井 朋子[1]、小林 正規[1]、石橋 高[1]、吉田 二美[1]、木村 宏[1]、平井 隆之[1]、洪 鵬[1]、山田 学[1]、千秋 博紀[1]、和田 浩二[1]、スラマ ラルフ[2]、クルーガー ハラルド[3]、渡部 潤一[4]、伊藤 孝士[4]、石黒 正晃[5]、中村 智樹[6]、薮田 ひかる[7]、橘 省吾[8]、三河内 岳[8]、阿部 新助[9]、大塚 勝仁[10]、浦川 聖太郎[11]、中村 メッセンジャー 圭子[12]、小松 睦美[13]、亀田 真吾[14]、鍵谷 将人[6]、平田 成[15]、出村 裕英[15]、佐々木 晶[16]、廣井 隆弘[17]、小松 吾郎[18]、金田 英宏[19]、稲守 孝哉[19]、岡本 尚也[20]、柳沢 俊史[20]、吉川 真[20]、矢野 創[20]、岡田 達明[20]、岩田 隆浩[20]、大坪 貴文[20]、川勝 康弘[20]、豊田 裕之[20]、西山 和孝[20]、高島 健[20]
*Tomoko Arai[1], Masanori Kobayashi[1], Ko Ishibashi[1], Fumi Yoshida[1], Hiroshi Kimura[1], Takayuki Hirai[1], Hong Peng[1], Manabu Yamada[1], Hiroki Senshu[1], Koji Wada[1], Ralf Srama[2], Harald Kruger[3], Jun-ichi Watanabe[4], Takashi Ito[4], Masateru Ishiguro[5], Tomoki Nakamura[6], Hikaru Yabuta[7], Shogo Tachibana[8], Takashi Mikouchi[8], Shinsuke Abe[9], Katsuhito Ohtsuka[10], Seitaro Urakawa[11], Keiko Nakamura-Messenger[12], Mutsumi Komatsu[13], Shingo Kameda[14], Masato Kagitani[6], Naru Hirata[15], Hirohide Demura[15], Sho Sasaki[16], Takahiro Hiroi[17], Goro Komatsu[18], Hidehiro Kaneda[19], Takaya Inamori[19], Takaya Okamoto[20], Toshifumi Yanagisawa[20], Makoto Yoshikawa[20], Hajime Yano[20], Tatsuaki Okada[20], Takahiro Iwata[20], Takafumi Ootsubo[20], Yasuhiro Kawakatsu[20], Hiroyuki Toyota[20], Kazutaka Nishiyama[20], Takeshi Takashima[20]

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DESTINY$^+$ (Demonstration and Experiment of Space Technology for INterplanetary voYage, Phaethon fLyby and dUst Science) was selected in 2017 as a mission for JAXA/ISAS small-class program. It is a joint mission of technology demonstration and scientific observation. It will test high performance electric propelled vehicle technology and high-speed flyby of asteroid (3200) Phaethon and possibly asteroid 2005UD, which a break-up body from Phaethon as an extended mission. Engineering challenges include an up-close encounter at a distance of 500 km from Phaethon with radio-optical hybrid navigation guidance and control, and autonomous imaging based on optical information for target tracking during a high-speed flyby of 33km/sec. The science goal is to understand the nature and origin of cosmic dust brought onto the Earth, in the context of exogenous contribution of carbon and organics for possible prebiotic seeds of the terrestrial life. Phaethon is a parent body of Geminid meteor shower, and thus a known source to periodically provide dust to the Earth, via the dust stream. The science objectives are two folded: (1) in-situ analyses of velocity, arrival direction, mass and chemical composition of interplanetary and interstellar dust particles around 1 au, the dust trail, and nearby Phaethon, and (2) flyby imaging of Phaethon to study its geology, for understanding dust ejection mechanism of active asteroid and the surface compositional variation. High-spatial-resolution images of less than 5 meter per pixel are obtained with Telescopic camera (TCAP), and VIS-NIR spectral images of less than 100 meter per pixel are taken with multiband camera (MCAP). Mass, speed, arrival direction and chemical composition for each dust particle are analyzed with dust analyzer (DDA). Here, we present an overview and the current status of DESTINY$^+$ mission.

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キーワード：デスティニープラス、フェートン、フライバイ、ふたご座流星群、惑星間塵
Keywords: DESTINY+, Phaethon, Flyby, Geminid meteor shower, IDP

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Observational campaign of (3200) Phaethon and (155140) 2005UD in 2017-2018

Observational campaign of (3200) Phaethon and (155140) 2005UD in 2017-2018

*吉田 二美[1]、Arai Tomoko[1]、Ishibashi Ko[1]、Hong Peng[1]、Ishimaru Ryo[1]、International observation collaborators DESTINY+
*Fumi Yoshida[1], Tomoko Arai[1], Ko Ishibashi[1], Peng Hong[1], Ryo Ishimaru[1], DESTINY+ International observation collaborators

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1. Planetary Exploration Research Center, Chiba Institute of Technology

(3200) Phaethon is the flyby target and (155140) 2005UD is a second flyby candidate of the DESTINY+ mission. Each asteroid approached to the Earth and became bright in 2017-2018. We utilize this opportunity and organized an observation campaign for both asteroids with international collaborators. The following people participated to the observational campaign : F. Yoshida, R. Ishimaru, K. Ishibashi, P. Hong, T. Arai (PERC/ChiTech), R. Okazaki, T. Sekiguchi, H. Naito, M. Imai, T. Ono (Hokkaido University of Education), S. Urakawa (Japan Spaceguard Association, Bisei Spaceguard Center), Y. Shinnaka (Kyoto Sanyo Univ.), T. Tanigawa (Sumoto high school), T. Yanagisawa, H. Kurosaki (JAXA), S. Abe, R. Kato (Nihon Univ.), N. Natira, T. Nishiumi (Univ. of Tokyo), M. Ishiguro (Seoul National University), M.-J. Kim, Y.-J. Choi, H.-K. Moon (KASI), D.-H. Kim, H.-J. Lee, S.-M. Lee (Chungbuk National University), Zhong-Yi Lin (Institute of Astronomy, National Central University), Xiaobin Wang (Yunnan Observatories, CAS), A. Serebryanskiy, M. Krugov, I. Reva (Fesenkov Astrophysical Institute), O. Burkhonov, E. Kamoliddin (UBAI), A. Peyrot, J-P. Teng (Les Makes Observatory), Y. Krugly (Institute of Astronomy of V.N. Karazin Kharkiv National University), I. M. Volkov (SAI MSU, INASAN), I. V. Nikolenko, S. I. Barabanov (INASAN), M. Kaplan, O. Erece (Akdeniz university), A. Sonka, S. Anghel (Astronomical Institute of Romanian Academy, Bucharest University), M. Birlan, F. Vachier, J. Berthier (Observatoire de Paris, IMCCE, CNRS), A. Klotz (CNRS-OMP-IRAP), P. Thierry (Auragne Observatory), O. Ivanova, M. Husarik (Astronomical Institute of the Slovak Academy of Sciences), E. Kuznetsov, D. Glamazda, G. Kaiser, E. Koren, V. Krushinsky, A. Popov, A. Shagabutdinov, Y. Vibe (Ural Federal University), M. Lazzarin, V. Petropoulou, I. Bertini, F. La Forgia (University of Padova), E. Palomba, E. D'aversa, A. Migliorini (INAF-IAPS), J. Vaubaillon (Observatoire de Paris), T. G. Wilson (University College London, Isaac Newton Group), O. Vaduvescu (Isaac Newton Group, Instituto de Astrofísica de Canarias), M. Popescu, Julia de Leon (Instituto de Astrofísica de Canarias), V. Lorenzi (Fundación Galileo Galilei - INAF, Instituto de Astrofísica de Canarias), M. Granvik (University of Helsinki / Luleå University of Technology), A. Penttilä (University of Helsinki), K. O. Muinonen (University of Helsinki / National Land Survey of Finland), T. Kareta, V. Reddy, D. S. Lauretta, B. Sharkey, C. Hergenrother (LPL, University of Arizona), J. A. Sanchez (PSI), T. Linder (Astronomical Research Institute), O. Kuhn, A. Conrad (Large Binocular Telescope Observatory), N. Moskovitz (Lowell Observatory), J. Masiero, A. Mainzer, L. Benner, M. Brozovic, S. Naidu, J. Giorgini (NASA JPL), E.L. Wright, D. Jewitt (UCLA), P. Taylor, E. Rivera-Valentin, S. Bhiravarasu, B. Aponte-Hernandez (Lunar and Planetary Institute), S. Marshall, F. Venditti, A. Virkki, L. Zambrano-Marin (Arecibo Observatory & University of Central Florida), C. R. Sanchez-Vahamonde (University of Western Ontario) (in the order from east to west in Fig.1).

Most of results obtained from the campaign were presented in IDP2019, which was held at Tokyo Skytree Town Campus of CIT, Japan, on February 12-14, 2019 (Fig. 2). So far, for both asteroids, rotation period,

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average colors, absolute magnitudes, spectra (0.4-2.5 μm) were obtained by photometry and spectroscopy during this observation campaign. Radar observation were done for Phaethon, and polarimetric observations were done for both asteroids. As preliminary results, the following properties were reported. Rotation periods: 5.2 hr (or 7.85 hr) for 2005UD, 3.6hr for Phaethon. Average colors : B-V=0.71, V-R=0.37, V-I=0.32 for 2005UD, B-V=0.73, V-R=0.36 for Phaethon. Absolute magnitude is 17.25 mag for 2005UD. No significant variation of rotationally resolved VIS-NIR spectra were seen for both asteroids. However, a slight variation of visual spectra of Phaethon taken in 2017 was reported. Both asteroids are in C-complex. Interestingly, in the NIR spectra, both asteroids show totally different spectra each other: concave-up and blue for Phaethon, linear and red for 2005UD. The results from polarimetric observation show both asteroids are very similar. As for Phaethon, rotational variation in polarization was reported. Lightcurve observations revealed Phethon has top shape. Radar observation estimated the Phaethon's diameter is about 6km, and revealed no coma, no satellite. Possible craters (D>1km below 30 deg latitude, D=1.5km near equator), 600m wide dark spot (likely a flattened region) were discovered.

キーワード：Asteroids、(3200) Phaethon、(155140) 2005UD
Keywords: Asteroids, (3200) Phaethon, (155140) 2005UD

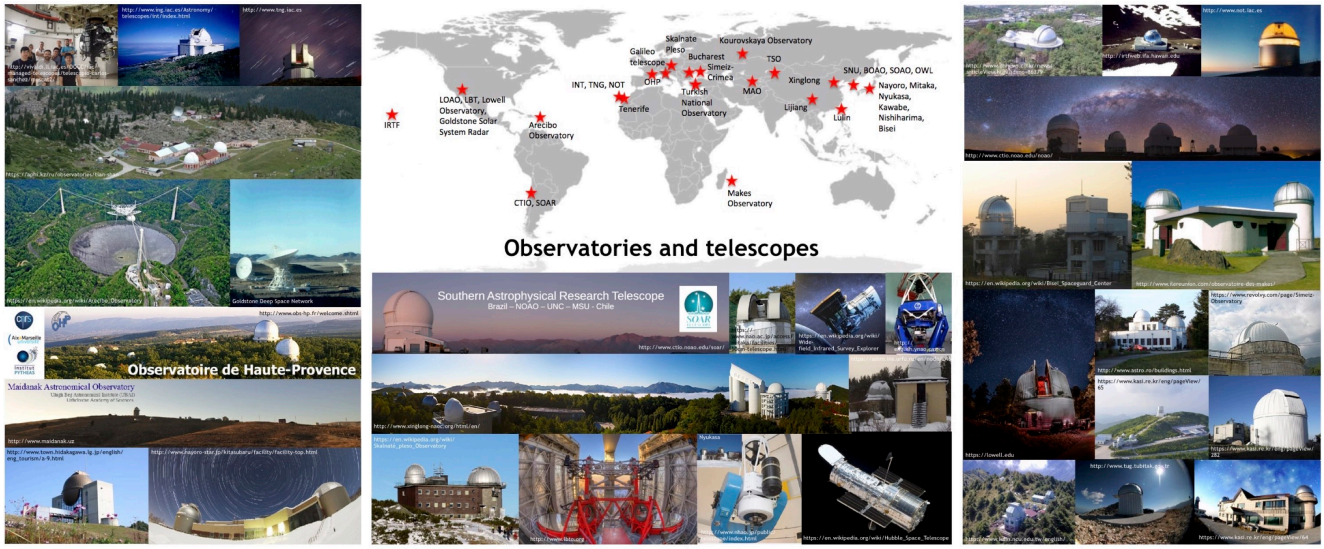


Fig1. Observatories and telescopes participating to the observation campaign of Phaethon and 2005UD in 2017 and 2018.


Fig2. IDP2019 held at Tokyo Skytree Town Campus of CIT, Chiba, Japan, on February 12–14, 2019.

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Rotationally-resolved spectroscopic observations of Phaethon - 2005 UD, and their fragments detected by lunar impact flashes.

Rotationally-resolved spectroscopic observations of Phaethon - 2005 UD, and their fragments detected by lunar impact flashes.

*阿部 新助[1]、Moskovitz Nicholas[2]、吉田 二美[3]、大塚 勝仁[4]、伊藤 孝士[5]、布施 綾太[1]、柳澤 正久[6]、山田 竜平[7]
*Shinsuke Abe[1], Nicholas Moskovitz[2], Fumi Yoshida[3], Katsutoshi Ohtsuka[4], Ito Takashi[5], Ryota Fuse[1], Masahisa Yanagisawa[6], Ryuhei Yamada[7]

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3200 Phaethon is an Apollo type near-Earth asteroid (NEA) categorized as a B-type asteroid which has been associated with the most intense meteor shower, Geminids. Cometary activity of Phaethon has been observed during its perihelion passage, ~0.140 AU, that motivates us to do direct exploration by the spacecraft, DESTINY+. It is also suggested that (155140) 2005 UD is a break-up pair of Phaethon because of dynamically similarity and same B-type spectrum type which is only ~5 % in NEA population. We examined the spectral properties of this asteroid pair to find the surface heterogeneity. Rotationally-resolved spectroscopic observations of Phaethon were carried out using 1.0-m telescopes at Lulin/Taiwan, and Kawabe/Wakayama, observatories in 2007 and 2017 apparitions, respectively. While Rotationally-resolved spectroscopic observation of 2005 UD was performed by using 4.1-m SOAR telescope at Cerro Tololo, Chili in 2018. It is presumably revealed that the surface heterogeneity, C-type like red slope surface area, of Phaethon was clearly seen from 2017 data, while no-existing surface heterogeneity was observed for 2005 UD.

When a meteoroid impacts the moon at several 10s of km/s, a brilliant flash at the point of impact can be observed as a flash in visible and near-infrared light. Lunar impact monitoring has a great advantage to detect large meteoroids in the mass range between 10s of grams and few kilograms corresponding to centimeters and tens of centimeters, which is as a bridge between visual meteors and small asteroids. We observed lunar impact flashes during Geminids maximum in 2018. 11 events were simultaneously detected from 2 locations at Nihon university and UEC, suggesting existence of relativity large fragments, several cm to several tens of cm in diameter, in the Geminid meteor stream.

In order to understand the Phaethon-Geminid stream Complex (PGC), ground-based telescopic observations of Geminids meteoroids and its parent splitting-bodies will be presented.

キーワード：小惑星、彗星、流星、月面衝突閃光
Keywords: Asteroids, Comets, Meteoroids, Lunar impact flash

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Thermal Radiation Pressure Force on Regolith Particles of Atmosphereless Bodies

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1. Department of Physics and Astronomy, Seoul National University

It is suggested that thermal fracture near the perihelion is a possible mechanism to produce the dust trail of the near-Earth asteroid, (3200) Phaethon (Jewitt and Li, 2013, ApJ 771, L36). For this scenario to be true, generated dust particles should have been ejected from the surface before its next apparition to show the detectable activities (Li and Jewitt, 2013, ApJ, 145, 154). It is, however, not well understood how these particles were escalated from the regolith against the asteroid's gravity. In this study, we hypothesize that the thermal radiation pressure around the perihelion passage would exert substantial force on dust grains to be lifted up and contributes the dust tail formation with further help of solar radiation pressure. As a result, we find that roughly ~1-10 micron size dust grains can be ejected from Phaethon by the mechanism, while a detailed model of gravitational field is required for accurate range of the particle sizes. Our idea is not necessarily limited to Phaethon case, but is applicable to any atmosphereless bodies. We will explain how the thermal radiation pressure is effective at different distances from the sun.

Keywords: asteroids, regolith, thermal radiation

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A kilometre-sized Kuiper belt object revealed by OASES stellar occultation observations

*有松 亘[1,2]、津村 耕司[3]、臼井 文彦[4]、新中 善晴[5]、市川 幸平[3,6,7]、大坪 貴文[8]、小谷 隆行[2,9]、和田 武彦[8]、長勢 晃一[8]、渡部 潤一[2]
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We will report the first detection of a single stellar occultation event candidate by a kilometer-sized (radius= 1-10 km) Kuiper belt object (KBO). Since the kilometer-sized KBOs are too faint to be detected directly, the monitoring of stellar occultation events is one possible way to discover them. With the aim of detecting the stellar occultation events, we launched an optical observation project named Organized Autotelescopes for Serendipitous Event Survey (OASES). We installed two low-cost OASES observation systems in different positions on the rooftop of the Miyako open-air school on Miyako Island, Miyakojima-shi, Okinawa Prefecture, Japan, and monitored up to 2000 stars simultaneously with a sampling cadence of 15.4Hz. In the 60-hour dataset obtained with the two-year OASES observations, we discovered one occultation candidate event by a KBO with a radius of approximately 1.3 km. Our present detection yields a surface number density of KBOs with radii exceeding 1.2 km is approximately 6×10^{5} deg^{-2}. This surface number density favors a theoretical size distribution model with an excess signature at a radius of 1–2 km. The present results suggest that planetesimals before their runaway growth phase grew into kilometer-sized objects in the primordial outer Solar System and remain as one of the major populations in the present-day Kuiper belt.

キーワード：太陽系外縁天体、カイパーベルト、可視望遠鏡による地上観測
Keywords: trans-Neptunian objects, Kuiper belt , ground based observations by optical telescopes

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AKARI/IRC near-infrared asteroid spectroscopic survey: AcuA-spec

AKARI/IRC near-infrared asteroid spectroscopic survey: AcuA-spec

*臼井 文彦[1]、長谷川 直[2]、大坪 貴文[2]、尾中 敬[3,4]
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1. Kobe University, 2. ISAS/JAXA, 3. The University of Tokyo, 4. Meisei University

Water is found in various forms in our solar system and is one of the most important ingredients in the origin of life. It provides evidence for the evolution of the solar system, especially its thermal history. Hydrated minerals are formed in environments where anhydrous rock and liquid water exist together, resulting from aqueous alteration. Because hydrated minerals are stable even above the sublimation temperature of water ice, they become an important reservoir to trace the water present in the history of the solar system unless they were reset by a temperature change after formation. Asteroids are considered to record the initial conditions of our solar nebula of 4.6 Ga ago. To explore the existence of water in the present solar system, it is indispensable to investigate the presence of hydrated minerals and water ice on various types of asteroids. Hydrated minerals and water ice exhibit diagnostic absorption features in the so-called 3 micron band (approximately 2.5-3.5 micron wavelength range). Many spectroscopic surveys have been conducted in the 3 micron band using ground-based observatories, which are severely affected by telluric absorption at around 2.8 micron. Space-borne observations, free from the effect, therefore, offer an excellent opportunity to study and identify the mineral species in asteroids.

The Infrared Camera (IRC) on board the AKARI satellite has a unique spectroscopic capability covering 2.5-5 microns continuously with a spectral resolution of R~100, which provides valuable data thanks to its high sensitivity and unique wavelength coverage. We conducted a spectroscopic survey of asteroids in the 3 micron band using IRC. In the warm mission period of AKARI, 147 pointed observations were performed for 66 asteroids in the grism mode in 2.5-5 microns. According to our observations, it is found that most C-complex asteroids, especially all Ch-, Cgh-, B-, and Cb-type asteroids, have obvious absorption features in the reflectance spectra at around 2.75 micron, which is attributed to OH-stretch in hydrated minerals. The peak wavelength of the 2.7 micron band feature is concentrated at around 2.75 micron: in particular, there is a correlation between the peak wavelength and the band depth among 13 C-complex asteroids. This trend can be understood in terms of the process where hydrated minerals are being heated up and gradually losing water, that is, the dehydration process.

In this talk, we present the spectroscopic survey of asteroids with AKARI for detecting the 2.7 micron absorption features and discuss scenarios for the formation and evolution of C-complex asteroids.

キーワード：小惑星、含水鉱物、近赤外線分光観測
Keywords: asteroids, hydrated minerals, near-infrared spectroscopy

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[E] 口頭発表 | セッション記号 P (宇宙惑星科学)：P-EM 太陽地球系科学・宇宙電磁気学・宇宙環境

2019年5月29日(水) 13:45 ~ 15:15 | A03 東京ベイ幕張ホール

[P-EM09] Vertical coupling in the atmosphere and Ionosphere

コンビーナ:Liu Huixin(九州大学理学研究院地球惑星科学専攻 九州大学宙空環境研究センター)、Chang Loren(Institute of Space Science, National Central University)、大塚 雄一(名古屋大学宇宙地球環境研究所)、座長:Patrick Espy(Norwegian University of Science and Technology)、Astrid Maute(National Center for Atmospheric Research, US)

Vertical coupling mechanisms throughout the whole atmosphere are critical to understanding the near Earth space environment, as well as its sensitivity to the solar, geomagnetic, and atmospheric drivers. This international session focuses on physical/chemical processes occurring in the mesosphere, thermosphere, and ionosphere (MTI). Both quiet and disturbed states in response to lower atmospheric forcing or solar forcing are important for understanding the MTI system and its coupling to other regions. We invite presentations of observations and observational concepts with ground-based and/or space-borne instruments, theoretical studies, numerical simulations, and development of data analysis systems for various kinds of temporal and spatial variations in atmosphere-ionosphere coupled system.

13:45 ~ 14:05

[PEM09-01] **Vertical Coupling from the Atmosphere to Geospace at Arrival Heights in Antarctica**
★Invited Papers

*Xinzhao Chu[1] (1.University of Colorado Boulder)

14:05 ~ 14:20

[PEM09-02] Vertical structure of terdiurnal tides in the Antarctic MLT region: 15 years observation over Syowa

*Liu Huixin[1]、堤 雅基[2]、Liu Hanli[3] (1.九州大学理学研究院地球惑星科学専攻 、2.National Institute for Polar Research、3.National Center for Atmospheric Research)

14:20 ~ 14:35

[PEM09-03] **3D Investigation of gravity waves propagation by Continuous Doppler sounding**

*Jaroslav Chum[1]、Katerina Podolska[1] (1.Institute of Atmospheric Physics of the Czech Academy of Sciences)

14:35 ~ 14:55

[PEM09-04] **Observations of MLT dynamics using meteor radars and meteor radar networks**
★Invited Papers

*Gunter Stober[1]、Vivien Matthias[2]、Sven Wilhelm[1]、Dimitry Pokhotelov[1]、Alexander Kozlovsky[3]、Evgenia Belova[4]、Johan Kero[4]、Chris Hall[5]、Masaki Tsutsumi[6] (1.Leibniz Institute of Atmospheric Physics、2.Potsdam Institute for Climate Impact Research, Earth System Analysis - Research Domain 1, Potsdam, Germany、3.Sodankylä Geophysical Observatory, Sodankylä, FIN-99600, Finland、4.Swedish Institute of Space Physics, Box 812, 98128 Kiruna, Sweden、5.Tromsø Geophysical Observatory UiT-the Arctic University of Norway, Tromsø, Norway、6.National Institute of Polar Research, Tokyo, Japan)

14:55 ~ 15:15

[PEM09-05] Ionospheric Variability Associated with the Quasi-6-day Planetary Wave
★Invited Papers

*山崎 洋介[1] (1.ドイツ地球科学研究センター)

Vertical Coupling from the Atmosphere to Geospace at Arrival Heights in Antarctica

*Xinzhao Chu[1]

1. University of Colorado Boulder

The observational campaign with Fe Boltzmann and Na Doppler lidars has entered its 9th year at Arrival Heights near McMurdo (77.8S, 166.7E), Antarctica. The unique datasets have opened an exceptional window for exploration in the vertical coupling from the lower atmosphere to the thermosphere, and vertical coupling among the neutral atmosphere, ionosphere, and magnetosphere. Collaborating with theoreticians and modelers, we are attempting to establish a vertical picture of gravity waves in Antarctica from near the surface to the thermosphere, and a key concept is the secondary gravity wave generation initially hypothesized by Dr. Sharon Vadas. Combining observations with numerical modeling, we are also trying to understand how metal layers with cosmic dust origins are formed high in the thermosphere and ionosphere F-region via a complex atmosphere-ionosphere-magnetosphere (AIM) coupling and even correlating with solar wind activity. In this paper we will report a few studies that may be intriguing for advancing the understandings of vertical coupling from the atmosphere to the geospace at Arrival Heights that is a gravity-wave hotspot and by the edge of polar cap and auroral zone.

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Vertical structure of terdiurnal tides in the Antarctic MLT region: 15 years observation over Syowa

Vertical structure of terdiurnal tides in the Antarctic MLT region: 15 years observation over Syowa

*Liu Huixin[1]、堤 雅基[2]、Liu Hanli[3]
*Huixin Liu[1], Masaki Tsutsumi[2], Hanli Liu[3]

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1. Earth and Planetary Science Division, Kyushu University, Japan, 2. National Institute for Polar Research, Japan, 3. National Center for Atmospheric Research, US

The terdiurnal tide (TDT) in the Antarctica mesosphere and lower thermosphere (MLT) region is poorly known. In this study, we examine its characteristics using long-term neutral wind observations at Syowa (69S, 39E) between January 2004 and July 2018. The analysis reveals TDT being a significant tidal component in the Antarctica with distinct vertical structures and seasonal evolution. (1) It shows a prominent height-dependent seasonal variation, being in opposite phase above and below 94 km altitude, with peak amplitude in June –July at altitudes below 94 km, but in November –December above it. (2) The zonal wind component is 90 phase shifted from the meridional, with its amplitude of comparable or larger values than the meridional in all seasons except for November –December. (3) The vertical wavelength is shortest (50 –65 km) in local summer (Nov.–Jan.) and longes (80 –110 km) in local winter (Jun.–Aug.). Most of these features differ from those reported in the Arctic, indicating hemispheric asymmetry. Furthermore, the phase structure reveals a dominant upward propagating mode in local summer, but superposition of more than one mode in other seasons. Especially in local winter, a downward propagating mode above 95 km suggests Joule heating/ion drag as likely tidal sources from above, in addition to those from lower atmosphere. The nearly 15 years Syowa observations provide new constrains and benchmark for model simulations that seek to understan terdiurnal tidal forcing mechanisms in polar regions.

キーワード：Terdiurnal tide、Antarctica、vertical coupling
Keywords: Terdiurnal tide, Antarctica, vertical coupling

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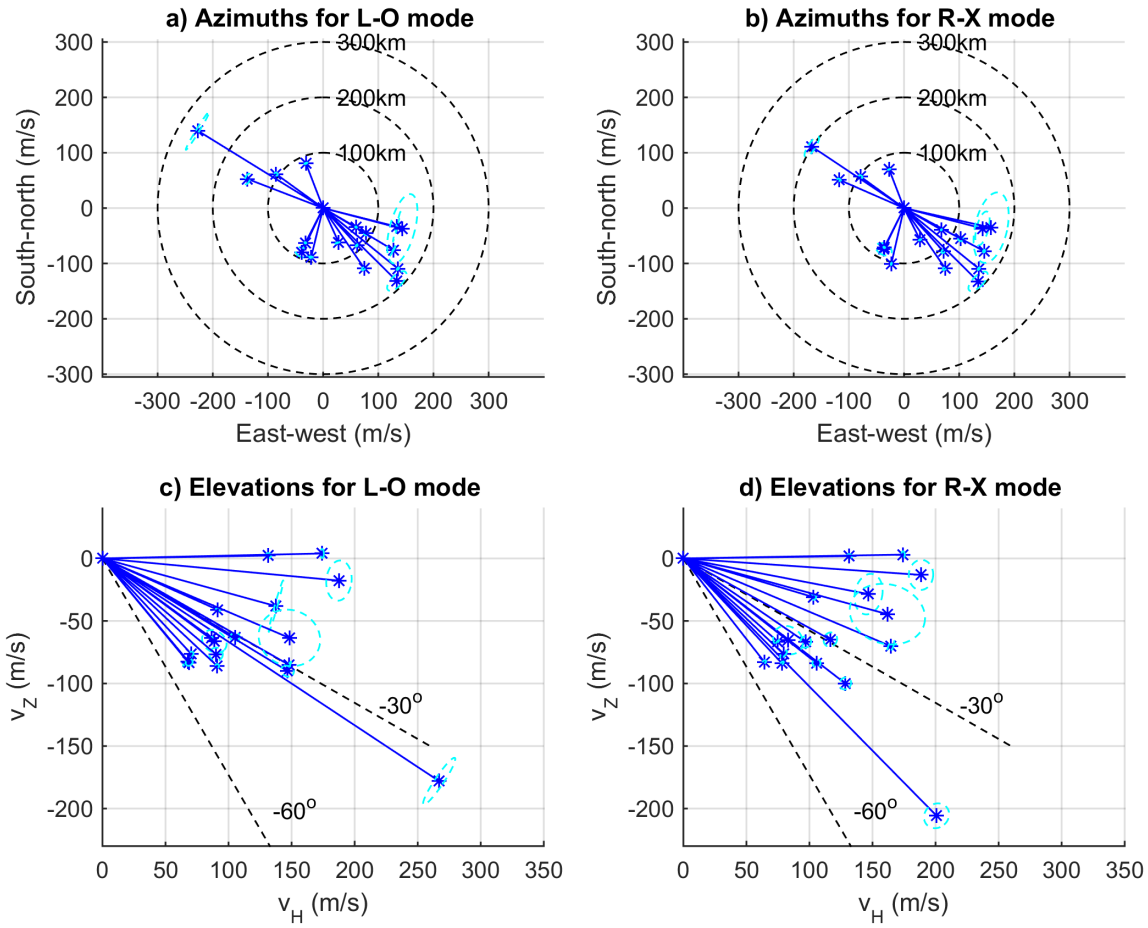
3D Investigation of gravity waves propagation by Continuous Doppler sounding

*Jaroslav Chum[1], Katerina Podolska[1]

1. Institute of Atmospheric Physics of the Czech Academy of Sciences

Multi-point continuous Doppler sounding is a useful tool to investigate short-time fluctuations in the ionosphere. We present analysis of GW propagation in the upper atmosphere and ionosphere in 3D. It is based on multi-point continuous Doppler sounding at three different frequencies; sounding radio waves of various frequencies reflect at different altitudes. The advantage of this analysis is information about the GW propagation in 3D and about the attenuation of wave power with height. The disadvantage is a relatively small number of events that can be analyzed as critical frequency of the ionosphere foF2 has to be larger than the highest sounding frequency and also significant cross-correlation between signals reflecting at different altitudes is necessary.

Keywords: atmospheric internal gravity waves, ionosphere , Doppler sounding, 3D analysis, Attenuation



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Observations of MLT dynamics using meteor radars and meteor radar networks

*Gunter Stober[1], Vivien Matthias[2], Sven Wilhelm[1], Dimitry Pokhotelov[1], Alexander Kozlovsky[3], Evgenia Belova[4], Johan Kero[4], Chris Hall[5], Masaki Tsutsumi[6]

1. Leibniz Institute of Atmospheric Physics, 2. Potsdam Institute for Climate Impact Research, Earth System Analysis - Research Domain 1, Potsdam, Germany, 3. Sodankylä Geophysical Observatory, Sodankylä, FIN-99600, Finland, 4. Swedish Institute of Space Physics, Box 812, 98128 Kiruna, Sweden, 5. Tromsø Geophysical Observatory UiT-the Arctic University of Norway, Tromsø, Norway, 6. National Institute of Polar Research, Tokyo, Japan

The winter 2015/16 was characterized by an unusually strong polar vortex with values up to 2 standard deviations guiding the mid-latitude planetary waves into the subtropical mesosphere. This exceptionally strong wave activity in the subtropical mesosphere led to a regionally reversed meridional temperature gradient resulting in a zonal wind reversal between 70 and 80 km at polar latitudes due to the thermal wind relation. This regional wind reversal changes the propagation conditions for waves propagating upward from the mesosphere into the thermosphere/ionosphere. The variability of the thermosphere/ionosphere is influenced by forcing from below and thus by gravity waves and atmospheric tides propagating upward from the mesosphere into the thermosphere.
To investigate the change in propagation characteristics of gravity waves and tides in the upper mesosphere/ lower thermosphere (MLT) during this unusual zonal wind reversal in winter 2015/16 we use data from a meteor radar network in Scandinavia. With this network we are able to apply tomographic wind field analysis obtaining horizontally resolved wind fields and horizontal wavelength spectra. Further, we are able to assess the spatial and temporal day-to-day variability of tides.

Keywords: meteor radar, horizontally resolved winds, planetary waves, atmospheric tides and gravity waves, vertical coupling

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Ionospheric Variability Associated with the Quasi-6-day Planetary Wave

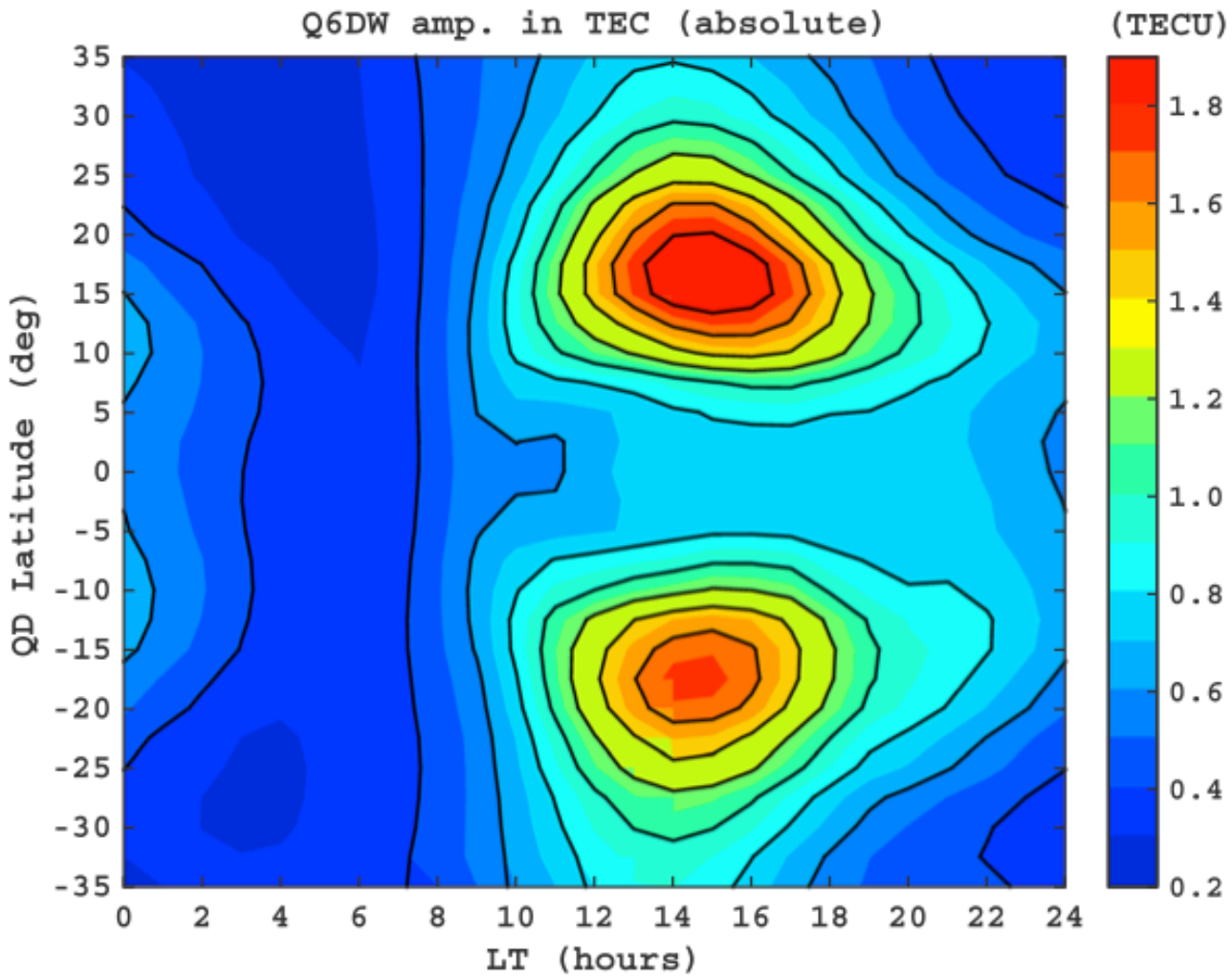
*山崎 洋介[1]
*Yosuke Yamazaki[1]

1. ドイツ地球科学研究センター
1. GFZ German Research Centre for Geosciences

The state of the ionosphere varies from day to day. This is partly due to atmospheric waves that propagate to the upper atmosphere from below. The present study investigates the ionospheric variability associated with the quasi-6-day wave (Q6DW), which is a westward-traveling planetary wave with zonal wave number s=1 and period around t=6d. First, the Q6DW effect on the equatorial ionospheric electric field is examined using the equatorial electrojet measurements from CHAMP and Swarm satellites, as well as ground-based magnetometer and radar observations. Case studies are presented where westward-propagating disturbances with s=1 and t~6d are observed in the daytime equatorial ionospheric electric field. Geopotential height measurements from the Aura satellite confirm the presence of the Q6DW in the lower thermosphere during those events. Next, the impact of the Q6DW on the equatorial ionization anomaly (EIA) is assessed using global maps of total electron content (TEC) from Global Positioning System data. It is shown that the amplitude of the Q6DW in TEC is largest at the EIA crest latitudes and its intra-annual variability closely follows the Q6DW variability in the lower thermosphere.

キーワード：電離圏/熱圏、準6日波、赤道域
Keywords: ionosphere/thermosphere, quasi-6-day wave, equatorial region

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2019年5月29日(水) 15:30 ~ 17:00 | A03 東京ベイ幕張ホール

[P-EM09] Vertical coupling in the atmosphere and Ionosphere

コンビーナ:Liu Huixin(九州大学理学研究院地球惑星科学専攻 九州大学宙空環境研究センター)、Chang Loren(Institute of Space Science, National Central University)、大塚 雄一(名古屋大学宇宙地球環境研究所)、座長:大塚 雄一、Yosuke Yosuke Yamazaki(GFZ Potsdam, Germany)

Vertical coupling mechanisms throughout the whole atmosphere are critical to understanding the near Earth space environment, as well as its sensitivity to the solar, geomagnetic, and atmospheric drivers. This international session focuses on physical/chemical processes occurring in the mesosphere, thermosphere, and ionosphere (MTI). Both quiet and disturbed states in response to lower atmospheric forcing or solar forcing are important for understanding the MTI system and its coupling to other regions. We invite presentations of observations and observational concepts with ground-based and/or space-borne instruments, theoretical studies, numerical simulations, and development of data analysis systems for various kinds of temporal and spatial variations in atmosphere-ionosphere coupled system.

15:30 ~ 15:50

[PEM09-06] Results of FORMOSAT-3/COSMIC to the most recent developments on FORMOSAT-7/COSMIC-2

★Invited Papers

*JANN-YENQ Liu[1] (1.Center for Astronautical Physics and Engineering; Graduate Institute of Space Science, National Central University, Taiwan)

15:50 ~ 16:05

[PEM09-07] A morphological study on the relationship between electron density fluctuations and magnetic fluctuations observed by low altitude satellites in low and middle latitudes

*家森 俊彦[1]、青山 忠司[1]、横山 佳弘[1] (1.京都大学)

16:05 ~ 16:25

[PEM09-08] Observations of the Thermosphere and Ionosphere by the NASA GOLD Mission

★Invited Papers

*Stanley C Solomon[1]、Alan G. Burns[1]、Richard W. Eastes[2]、William E. McClintock[2] (1.National Center for Atmospheric Research、2.University of Colorado)

16:25 ~ 16:40

[PEM09-09] 全球TECに見られる磁気嵐時の中低緯度域における電子密度増大の時間・空間発展

*新堀 淳樹[1]、惣宇利 卓也[1]、大塚 雄一[1]、津川 卓也[2]、西岡 未知[2] (1.名古屋大学宇宙地球環境研究所、2.情報通信研究機構)

16:40 ~ 16:55

[PEM09-10] Tidal Forcing Effects on the Zonal Variation of Solstice Equatorial Plasma Bubbles

*Loren Chang[1]、Jude Salinas[1]、Yi-Chung Chiu[1]、Pei-yun Chiu[1]、Charles Lin[2] (1.Institute of Space Science and Engineering, Center for Astronautical Physics and Engineering, National Central University, Taiwan、2.Department of Earth Science, National Cheng Kung University, Taiwan)

16:55 ~ 17:00

Discussion

Results of FORMOSAT-3/COSMIC to the most recent developments on FORMOSAT-7/COSMIC-2

*JANN-YENQ Liu[1]

1. Center for Astronautical Physics and Engineering; Graduate Institute of Space Science, National Central University, Taiwan

The FORMOSAT-3 Project is also named Constellation Observing System for Meteorology, Ionosphere and Climate (COSMIC), or FORMOSAT-3/COSMIC (F3/C) for short. The project is targeted to place six micro-satellites into six different orbits with 72-deg inclination at 700~800 kilometer above the earth ground. These satellites orbit around the earth to form a low-earth-orbit constellation that conduct radio occultation (RO) by receiving signals transmitted by the 24 US GPS satellites. The satellite observation covers the entire global ionosphere, providing over 2,500 global RO sounding data (electron density and S4 scintillation profiles) per day since 15 April 2006. This for the first time allows scientists observing the 3D ionospheric electron density structure and dynamics. Simultaneous F3/C RO observations and ground-based receiver measurements of International GNSS (global navigation satellite system) Service (IGS) further initiate constructing three different models for monitoring (near real-time), nowcasting (few minutes to hours), and forecasting (few hours to days) the ionospheric weather resulted from the space weather (solar disturbances, solar winds, magnetic storms, etc.); the atmospheric severe weathers (typhoons, fronts, volcano eruptions, etc.); and the lithosphere weather (earthquakes, tsunami, etc.). The monitoring model is combining the total electron content (TEC) or the GNSS satellite signal scintillations of F3/C and ground-based IGS observations to construct an advanced GIM (global ionospheric map) to report the ionospheric bias and develop L-band scintillation models for communication, positioning, and navigation applications. The nowcast model is a global 3D ionospheric data assimilation model based on the Gauss-Markov Kalman filter with an existing background model to assimilate the TEC observations from the ground-based IGS receivers and space-based F3/C to output the global electron density for coming few minutes to hours. On the other hand, to carry out a long-term forecast, the neutral compositions in the atmosphere should be taken into consideration. Therefore, to develop a forecast model assimilating the observations of F3/C and IGS ground-based receivers into a neutral-ion coupled model. Following the F3/C, FORMOSAT-7/COSMIC (F7/C2) consists of six small-satellites with 24-deg inclination and about 500 km altitude will be launched in 2019. The developed models with F7/C2 RO by receiving signals transmitted by the GPS/GLONASS satellites and IVM (ionospheric velocity meter) plasma measurements as well as ground-based IGS GNSS data shall significantly improve the space weather monitoring/nowcast/forecast in the near future.

Keywords: ionospheric space weather, FORMOSAT-3/COSMIC, FORMOSAT-7/COSMIC, Kalman filter

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A morphological study on the relationship between electron density fluctuations and magnetic fluctuations observed by low altitude satellites in low and middle latitudes

*家森 俊彦[1]、青山 忠司[1]、横山 佳弘[1]
*Toshihiko Iyemori[1], Tadashi Aoyama[1], Yoshihiro Yokoyama[1]

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1. Kyoto University

Polar orbiting low-altitude satellites such as the Swarm satellites observe magnetic and electron density fluctuations in low and middle latitudes along satellite orbit. The magnetic fluctuations typically have the period about 10-30seconds along satellite orbit and they are mostly small-scale field-aligned current effects and named as 'magnetic ripples'. They are supposed to be generated in lower ionosphere by dynamo mechanism caused by neutral atmospheric waves from lower atmosphere. On the nightside, they still exist with smaller amplitude because of lower ionospheric conductivity. Plasma bubbles also exist on the nightside and they normally accompany magnetic fluctuations to keep pressure balance. If we trace down to the dynamo layer around 120km altitude from magnetic ripples and compare the electron density fluctuations, they correspond better than the correspondence on the orbit. This indicates vertical propagation of atmospheric waves which causes both magnetic ripples and electron density fluctuations. On the other hand, in well-developed plasma bubbles, plasma density fluctuation and magnetic fluctuation occur at the same location on the orbit. In this study, we present morphological relationship between the two phenomena. That is, we investigate how magnetic ripples relate to plasma bubbles.

キーワード：磁気リップル、電離層電子密度、プラズマバブル
Keywords: magnetic ripples, ionospheric electron density, plasma bubbles

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Observations of the Thermosphere and Ionosphere by the NASA GOLD Mission

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1. National Center for Atmospheric Research, 2. University of Colorado

The new Global-scale Observations of the Limb and Disk (GOLD) mission is an imaging spectrograph deployed in geostationary orbit on the SES-14 communications satellite. GOLD measures airglow emitted by the Earth in the far-ultraviolet region of the spectrum from 132 to 164 nm, notably including the 135.6 nm doublet of atomic oxygen (O), and most of the LBH bands of molecular nitrogen (N_2). During the day, the ratios of the oxygen to nitrogen emissions indicate the relative column densities of O and N_2, and temperature can be inferred from the spectral shape of the LBH bands. During the night, radiative recombination emissions by the O doublet indicate the density of the ionosphere, particularly the equatorial ionization anomalies and the structured instabilities that form within them. GOLD also measures exospheric temperatures on the limb, it infers molecular oxygen densities from stellar occultations, and it can also see northern hemisphere aurora. SES-14 was launched in January 2018, the satellite achieved geostationary orbit in, and GOLD observations commenced in October. We will give an overview of the GOLD mission and show preliminary results from its first months of operations. Despite the recent quiet conditions with low solar activity, composition images reveal daily and seasonal variations, indicative of global vertical wind patterns. The equatorial ionization anomalies are seen to be surprisingly variable and dynamic, with instabilities forming on most nights, even at solar minimum. We will compare GOLD results with global general circulation models and airglow emissions modeling, and discuss how these data could be used in assimilation models of the upper atmosphere and ionosphere.

Keywords: Thermosphere, Ionosphere, Ultraviolet Imaging

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全球TECに見られる磁気嵐時の中低緯度域における電子密度増大の時間・空間発展

Temporal and spatial evolutions of storm enhanced density in the mid- and low-latitude regions as seen in the variation of global total electron content

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The global electron density distribution in the ionosphere depends strongly on geographical latitude, longitude, and local time. The structure changes severely from the high-latitude to the equatorial regions associated with geomagnetic storms. The storm-time prominent ionospheric phenomena are tongue of ionization (TOI), storm-enhanced density (SED), and equatorial ionization anomaly (EIA). These phenomena are very dynamic because ionospheric electric fields and particle precipitation from the magnetosphere vary significantly during the development and decay of the geomagnetic storms. The generation mechanism of SED has been thought as local upward **E**x**B** drifts [e.g., Huang et al., 2005, Liu et al., 2016], westward plasma transportation from the nightside to the dayside by sub-auroral polarization stream (SAPS) [Foster et al., 2007], equatorward neutral winds [Anderson, 1976], and latitudinal expansion of the EIA [e.g., Kelley et al., 2004]. However, since such different mechanisms of the formation of SED have been proposed by many researchers, a comprehensive understanding of the cause of SED formation has not yet been done. In this study, we investigate the temporal and spatial evolutions of SED during the development and decay of geomagnetic storms using Global Navigation Satellite System (GNSS) Total Electron Content (TEC) data with high time and spatial resolutions, to identify the main mechanism responsible for SED. We also use solar wind data and geomagnetic indices to see the interplanetary condition and geomagnetic activity during geomagnetic storms. In the present analysis, we first calculate the average absolute TEC (ATEC) of 10 geomagnetically quiet days every month, referring to the list of quiet and disturbed days provided by GFZ. Next, we subtract the storm-time ATEC from the average ATEC and create global maps of the difference ATEC in geographical and geomagnetic coordinates. Several hours after the onset of the main phase of the geomagnetic storms, the enhanced TEC region with a narrow latitudinal width (5-10 degrees) appears at high latitudes (60-70 degrees in geomagnetic latitude (GMLAT)) of the afternoon sector (12-16 h, MLT: magnetic local time). The enhanced TEC region is located at a lower latitude of the equatorward wall of the midlatitude trough. As the geomagnetic storms grow, the enhanced TEC region expands to the nightside (~20 h, MLT) within a time scale of 20-30 minutes, and the region moves equatorward within several hours. After that, apart from the midlatitude enhanced TEC phenomena, another TEC enhancement takes place in the low-latitude region (15-30 degrees, GMLAT) on both sides of the dip equator. This observational fact cannot be explained by the latitudinal expansion of the EIA and westward transportation of a part of the higher latitude EIA by SAPS [Kelley et al., 2004; Foster et al., 2007]. As already proposed by Liu et al. [2016], the midlatitude enhanced TEC signature may be caused by upward **E**x**B** drifts that lift the ionosphere in the sunlit region to higher altitudes. In future study, we verify the effect of the localized **E**x**B** drifts on the formation of SED from a comparison between the global TEC and ionospheric plasma flow

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observed by the SuperDARN radars.

キーワード：磁気嵐、電離圏、磁気嵐時の電子密度増大、赤道異常、中緯度、対流電場
Keywords: Geomagnetic storm, Ionosphere, Storm enhanced density, Equatorial ionization anomaly, Midlatitude, Convection electric field

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Tidal Forcing Effects on the Zonal Variation of Solstice Equatorial Plasma Bubbles

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1. Institute of Space Science and Engineering, Center for Astronautical Physics and Engineering, National Central University, Taiwan, 2. Department of Earth Science, National Cheng Kung University, Taiwan

Equatorial plasma bubbles are elongated plasma depletions that can occur in the nighttime ionospheric F region, causing scintillation in satellite navigation and communications signals, and manifesting in ionograms as spread F. Equatorial plasma bubbles are believed to be Rayleigh-Taylor instabilities seeded by vertically propagating gravity waves. A necessary pre-condition for plasma bubble formation is believed to be a threshold vertical ion drift from the E region, which is required to produce the vertical plasma gradients conducive to such an instability. Factors affecting the zonal and seasonal variation of equatorial plasma bubbles therefore include magnetic declination, as well as the strength of the equatorial electojet, and neutral winds in the lower thermosphere controlling vertical plasma drifts via the wind dynamo. In most longitude zones, the above factors result in elevated occurrence rates of equatorial plasma bubbles during the equinoxes. The notable exception is over the central Pacific and African sectors, where equatorial plasma bubble activity maximizes during solstice. As the zonal separation of the two sectors is roughly half the Earth’ s circumference, *Tsunoda et al.* (2015) hypothesized that the solstice maxima in these two sectors could be driven by a zonal wavenumber 2 atmospheric tidal component in the mesosphere and lower thermosphere (MLT). In this study, we find that the post-sunset electron density observed by FORMOSAT-3/COSMIC during the boreal summer does indeed exhibit a wave-2 zonal distribution in both the equatorial and northern mid latitude regions. The equatorial wave-2 is consistent with results expected from elevated vertical ion drift over the Central Pacific and African sectors, while the mid- latitude wave-2 is consistent with the Mid-Summer Nighttime Anomaly. Using COSMIC, the seasonal, longitudinal, and local time variation of ionospheric tidal and stationary planetary wave (SPW) components that produce zonal wavenumber 2 disturbances when viewed in a constant local time frame is examined. Numerical experiments are also carried out using the Thermosphere Ionosphere Electrodynamics General Circulation Model (TIE-GCM) to determine the effect of the aforementioned tidal and SPW components on vertical ion drift, showing a clear wave-2 modulation of vertical ion drift when subject to forcing from wave-2 atmospheric tidal components in the mesosphere and lower thermosphere. The aforementioned results are consistent with the solstice maxima hypothesis.

Keywords: Ionosphere, Scintillation, Tides

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2019年5月29日(水) 15:30 ~ 17:00 | A04 東京ベイ幕張ホール

[P-EM11] Dynamics of Magnetosphere and Ionosphere

コンビーナ:中溝 葵(情報通信研究機構　電磁波研究所)、尾崎 光紀(金沢大学理工研究域電子情報学系)、藤本 晶子(九州工業大学)、堀 智昭(名古屋大学宇宙地球環境研究所)、座長:長谷川 洋(宇宙航空研究開発機構 宇宙科学研究所)

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 ionosphere and magnetospheres, future missions and instrument developments are also welcome.

15:30 ~ 15:45

[PEM11-01] **A Case Study Based on Ground Observations of the Conjugate Ionospheric Response to Interplanetary Shock in Polar Regions**

*He Fang[1]、Zejun HU[1]、Hongqiao HU[1] (1.Polar Research Institute of China)

15:45 ~ 16:00

[PEM11-02] **Effects of Solar Illumination on the Auroral Electrojet Intensity**

*Shinichi Ohtani[1]、Jesper W Gjerloev[1] (1.The Johns Hopkins University Applied Physics Laboratory)

16:00 ~ 16:15

[PEM11-03] Quasi-persistent multiple mesoscale field-aligned currents in the duskside auroral oval

*横山 佳弘[1]、田口 聡[1]、家森 俊彦[2]、細川 敬祐[3] (1.京都大学大学院理学研究科地球惑星科学専攻地球物理学教室、2.京都大学、3.電気通信大学大学院情報理工学研究科)

16:15 ~ 16:30

[PEM11-04] Generation of dispersive Alfvenic turbulence in magnetosphere-ionosphere feedback coupling

*渡邉 智彦[1]、兼山 将寿[1]、前山 伸也[1] (1.名古屋大学大学院理学研究科)

16:30 ~ 16:45

[PEM11-05] Aspects of simulating magnetosphere-ionosphere coupling via field-aligned current

*Astrid I Maute[1]、Arthur D Richmond[1]、Gang Lu[1] (1.High Altitude Observatory, National Center for Atmospheric Research, Boulder CO, 80301, USA)

16:45 ~ 17:00

[PEM11-06] **Revisiting the energy conversion process of Birkeland current generation**

*吉川 顕正[1] (1.九州大学大学院理学研究院地球惑星科学部門)

A Case Study Based on Ground Observations of the Conjugate Ionospheric Response to Interplanetary Shock in Polar Regions

*He Fang[1], Zejun HU[1], Hongqiao HU[1]

1. Polar Research Institute of China

This study uses data acquired by an imaging riometer, an ionosphere total electron content (TEC) monitor, and three specific wavelength auroral imagers at the conjugate Antarctic Zhongshan (ZHS) and Arctic Yellow River (YRS) stations to investigate the response of the polar ionosphere to a space weather event induced by solar flare activity on July 14, 2012. After the geomagnetic storm suddenly commenced and a magnetospheric substorm was triggered by the arrival of an interplanetary shock wave and its interaction with the magnetosphere at 18:10 UT, significantly enhanced auroral activity was observed by the auroral imagers at the ZHS. Meanwhile, the polar conjugate observation stations in the two hemispheres recorded notable growth of the two-dimensional cosmic noise adsorption and similar motion tendencies. According to our analysis and comparison of the ionospheric TEC data acquired by the conjugate stations, the TEC at both locations presented a considerable growth tendency after the interplanetary shock wave arrived, although the two stations experienced different sunlight conditions (polar night in the Antarctic region and polar day in the Arctic region). However, a comparison with high-frequency radar data demonstrated that different sources were responsible for the electron density enhancement of the ionosphere. In the Arctic polar day region, the increased electron density may have been caused by anti-sunward convection of the plasma irregularity, whereas in the Antarctic polar night region, the increased electron density may have been caused by energetic particle precipitation at the magnetospheric tail. Different physical processes might be the cause of the differential responses of the ionosphere at the two studied geomagnetic conjugate stations in the same solar activity event due to different local photoionization conditions.

Keywords: polar ionosphere, conjugate, substorm, response, irregularity

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Effects of Solar Illumination on the Auroral Electrojet Intensity

*Shinichi Ohtani[1], Jesper W Gjerloev[1]

1. The Johns Hopkins University Applied Physics Laboratory

The present study investigates the dependence of the local auroral electrojet (AEJ) intensity on the solar illumination by statistically examining the northward geomagnetic disturbance in terms of the solar zenith angle (SZA) χ. It is found that on the day side, both westward and eastward electrojets (WEJ and EEJ) are more intense for smaller χ suggesting that the solar EUV-induced conductance is the dominant factor for the AEJ intensity. On the night side, in contrast, the χ dependence of the AEJ intensity, if sorted solely by the magnetic local time (MLT), is apparently different for stations at different longitudes and in different hemispheres. However, if additionally sorted by the dipole tilt angle ϕ, a consistent pattern emerges. It is therefore suggested that although ϕ and χ are correlated, the dipole tilt angle and SZA have physically different effects on the local AEJ intensity. The nightside AEJ, especially the WEJ, tends to be more intense for small $|\phi|$. Moreover, whereas the WEJ is statistically more intense when the ionosphere is dark, the EEJ is more intense when sunlit. The preference of the WEJ for the dark ionosphere extends widely in MLT from premidnight to dawn, and therefore, it cannot be linked exclusively with the substorms or be attributed to the previously proposed processes of the preferred auroral precipitation in the dark ionosphere. Instead, it may be explained at least morphologically in terms of the conductance enhancement due to the diffuse auroral precipitation, which is also prevalent from premidnight to dawn and is more intense in the dark hemisphere.

Keywords: Auroral electrojets, Solar illumination, Ionospheric conductance, Dipole tilt, Solar zenith angle, Diffuse aurora

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Quasi-persistent multiple mesoscale field-aligned currents in the duskside auroral oval

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*Yoshihiro Yokoyama[1], Satoshi Taguchi[1], Toshihiko Iyemori[2], Keisuke Hosokawa[3]

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1. Department of Geophysics, Graduate School of Science, Kyoto University, 2. Kyoto University, 3. Department of Communication Engineering and Informatics, University of Electro-Communications

Within a large-scale field-aligned current, whose latitudinal width is a few hundred kilometers in the ionosphere, smaller-scale current structures are often embedded. Previous studies have shown that a mesoscale upward field-aligned current with widths of order 10 km generally agree with auroral arcs. However, we still do not understand how this relation forms. In this study, using multispacecraft Swarm data and aurora data from a ground-based all-sky imager at Longyearbyen, Svalbard, we have examined mesoscale features of the field-aligned current and auroral arcs in the duskside auroral oval. We focused on the situation when the large-scale Region 1 current diminishes so that mesoscale features can stand out. Through the cross-correlation analysis of the magnetic perturbations observed by Swarm A and Swarm C, we took events in which the observed magnetic perturbations represent the spatial structure of multiple pairs of upward/downward mesoscale field-aligned currents, not Alfven wave. Conjugate observations between Swarm satellites and the all-sky imager have shown that auroral arcs actually occur in the region of the upward field-aligned current. The result of the analysis of the all-sky image data obtained before and after the conjunction event has shown that the auroral arcs have quasi-persistent features, and also indicated when the auroral arcs appear and disappear. From these results, we discuss how the mesoscale field-aligned current can form.

キーワード：沿磁力線電流、Postnoonオーロラ、Swarm衛星
Keywords: Field-aligned current, Postnoon aurora, Swarm satellites

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Generation of dispersive Alfvenic turbulence in magnetosphere-ionosphere feedback coupling

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*Tomo-Hiko Watanabe[1], Masatoshi Kaneyama[1], Shinya Maeyama[1]

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1. Graduate School of Science, Nagoya University

Magnetosphere-ionosphere (M-I) feedback coupling is considered to provide possible explanations to self-excitatation of auroral arc structures with enhancements of the ionospheric density and the field-aligned current. Recent theoretical and numerical studies have revealed generation of Alfvenic turbulence in the nonlinear evolution of the feedback instability, following the Kelvin-Helmholtz instability accompanied with curl structures of the ionospheric density.
Our recent study has extented to include effects of the electron intertia in the magnetospheric dynamics, where the dispersive Alfven waves with the parallel electric field play a key role in the M-I coupling. The linear stability analysis incuding the electron inertia term has shown the stabilization effect while the mean parallel acceleration of electrons is self-consistently included in the model of auroral arc growth. Nonlinear simulations of the feedback instability have also demonstrated generation of the Alfvenic turbulence with finite parallel electric fields, where a power law energy spectra are obtained for the parallel and perpendicular wavenumbers. The physical picture of Alfvenic turbulence obtained in the persent study is consistent to FAST spacecraft observations of the dispersive Alfven waves and the electron acceleration in the Alfvenic aurora.

キーワード：オーロラ、磁気圏-電離圏結合、乱流、電子加速、アルヴェン波
Keywords: aurora, magnetosphere-ionosphere coupling, turbulence, electron acceleration, Alfven waves

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Aspects of simulating magnetosphere-ionosphere coupling via field-aligned current

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Magnetosphere-ionosphere (MI) coupling is crucial in modeling the thermosphere-ionosphere (TI) response to geomagnetic activity. In general circulation models (GCMs) the MI coupling is frequently realized by specifying the ion convection and auroral particle precipitation patterns from, e.g., empirical models or assimilative models. Using assimilative models, such as the Assimilative Model of Ionospheric Electrodynamics (AMIE), has the advantage that the ion convection and auroral particle precipitation patterns are self-consistent and based on available observations. However, assimilating data can be time consuming and requires expert knowledge, and therefore it is so far not the standard way of MI coupling in GCMs. With the availability of AMPERE data, there is an increased interest of employing field-aligned currents (FAC) in GCMs to represent the MI coupling. The FAC from AMPERE captures interhemispheric differences in the MI coupling not represented by empirical ion convection models. However, since GCMs mostly employ prescribed high latitude ion convection patterns little is known about differences in the TI response to high latitude forcing by prescribed FACs.

In this study, we will compare with the help of a simulated geomagnetic storm the different MI coupling methods, i.e., AMIE, empirical ion convection and AMPERE field-aligned current. We illustrate the sensitivity of the Joule heating and low latitude electric field with respect of the spatial distribution of the aurora and ion convection for the different cases. The influence of interhemispheric differences in the MI coupling on the middle and low latitude thermosphere-ionosphere system will be examined.

Keywords: Magnetosphere-ionosphere coupling via field-aligned current, Interhemispheric assymetries, Middle and low latitude effects

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Revisiting the energy conversion process of Birkeland current generation

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As shown by Vasyliunas [1970], the magnetospheric diamagnetic current has a finite divergece when it crosses the region with a finite B gradient and connects to the Field-Aligned Current (FAC). A pressure gradient force, the origin of the diamagnetic current in a force balance to the Ampere force, never twists plasma flow. While for the development of magnetic shear, which corresponds to FAC, combination of Ampere’s law , Faraday’s induction law and MHD Ohm’s law require the gradient of plasma vortex along B-field. In other words, for the existence of a quasi-steady FAC in the MHD scheme, the plasma vorticity along the B-field is inevitably required.

Of course, for the development of plasma vorticity, we need a dynamical process that twists the plasma. What is the dynamical process that twists the plasma as FACs are generated due to the divergence of the diamagnetic current? A conventional answer to this question is a mode conversion between the compressional mode and the Alfven mode when the diamagnetic current is growing (in inductive process). However, in principle, the magnetosphere-ionosphere coupling system forms a dissipative structure in the open solar-terrestrial system. Therefore, even in a macroscopic quasi-steady system, the constant conversion from the thermal energy to the magnetic energy and the internal mode conversion from magnetic compression to the magnetic shear should continuously take place. In this sense, we need to revisit the dynamical process of FAC. In this presentation, we will discuss what is the dynamical process and what is the quasi-steady state of FACs in a dissipative structure of the open magnetosphere-ionosphere system.

キーワード：沿磁力線電流、磁気圏電離圏結合、エネルギー変換
Keywords: Birkeland Current, Magnetosphere-Ionosphere Coupling, Energy Conversion

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2019年5月29日(水) 9:00 ~ 10:30 | A04 東京ベイ幕張ホール

[P-EM13] 内部磁気圏

コンビーナ:海老原 祐輔(京都大学生存圏研究所)、Danny Summers(Memorial University of Newfoundland)、三好 由純(名古屋大学宇宙地球環境研究所)、齊藤 慎司(名古屋大学　大学院理学研究科)、座長:Shinji Saito(ISEE, Nagoya University)、海老原 祐輔(京都大学生存圏研究所)

The inner magnetosphere is characterized by the dominance of intrinsic dipolar Earth's magnetic field. The dipolar magnetic field traps charged particles, resulting in the formation of unique particle environment known as the plasmasphere, the ring current, and the radiation belt. The inner magnetosphere is always changing because of incoming energy from the outer magnetosphere and the ionosphere in the forms of particles and electromagnetic fields. In the inner magnetosphere, the particle energy is transferred to the field energy, and vice versa. The mutual coupling between particles and fields also makes the inner magnetosphere unique. The outgoing energy to these regions is also known to be significant, such as precipitation into the upper atmosphere and sub-auroral disturbances. A number of satellites (e.g., DMSP, NOAA, Geotail, Cluster, THEMIS, Van Allen Probes, MMS, and Arase), ground-based instruments (e.g., SuperDARN and EISCAT radars, magnetometers, and cameras), and numerical simulations (e.g., global particle simulation, PIC simulation, and hybrid simulation) have successfully surveyed the inner magnetosphere, which deepen our knowledge significantly. USAF DSX, UCLA Elfin and NASA CeRES will be launched soon, being expected to provide important information. We solicit papers describing recent results on the inner magnetosphere and/or its coupling with the other regions, including the ionosphere and the outer magnetosphere.

9:00 ~ 9:15

[PEM13-11] Nonlinear Damping of Oblique Whistler Mode Waves Via Landau Resonance

*謝 怡凱[1]、大村 善治[1] (1.京都大学生存圏研究所)

9:15 ~ 9:30

[PEM13-12] Instantaneous Frequency Analysis on Nonlinear EMIC Emissions: Arase Observation

*小路 真史[1]、三好 由純[1]、大村 善治[2]、Kistler Lynn[1,3]、笠羽 康正[4]、松田 昇也[5]、笠原 禎也[6]、松岡 彩子[5]、野村 麗子[7]、石坂 圭吾[8]、熊本 篤志[4]、土屋 史紀[4]、八木谷 聡[6]、寺本 万里子[1]、浅村 和史[5]、高島 健[5]、篠原 育[5] (1.名古屋大学宇宙地球環境研究所、2.京都大学生存圏研究所、3.Institute for the Study of Earth Oceans and Space, University of New Hampshire、4.東北大学、5.宇宙科学研究所、6.金沢大学、7.国立天文台、8.富山県立大学)

9:30 ~ 9:45

[PEM13-13] Rapid Precipitation by EMIC Rising-tone Emissions of Relativistic Electrons Observed by the Van Allen Probes Mission

*中村 紗都子[1]、大村 善治[1]、Craig Kletzing[2]、Daniel Baker[3] (1.京都大学生存圏研究所、2.Department of Physics and Astronomy University of Iowa 、3.The Laboratory for Atmospheric and Space Physics (LASP) at the University of Colorado)

9:45 ~ 10:00

[PEM13-14] Plasmaspheric EMIC waves excited through mode conversion from equatorial noise under existence of M/Q=2 ions

*三好 由純[1]、松田 昇也[2]、栗田 怜[1]、野村 浩司[1]、桂華 邦裕[3]、小路 真史[1]、北村 成寿[3]、笠原 禎也[4]、松岡 彩子[2]、篠原 育[2]、塩川 和夫[1]、町田 忍[1]、Santolik Ondrej[5]、Boardsen Scott[6]、Horne Richard[7]、John Wygant[8] (1.名古屋大学宇宙地球環境研究所、2.宇宙航空研究開発機構、3.東京大学、4.金沢大学、5.チェコ科学アカデミー、6.NASA、7.British Antarctic Survey、8.ミネソタ大学)

10:00 ~ 10:15

[PEM13-15] Generation Mechanism of Non-thermal Continuum Radiation

*大村 善治[1]、Horky Miroslav[1,2] (1.京都大学生存圏研究所、2.Department of Space Physics, Institute of Atmospheric Physics, Czech Academy of Sciences)

10:15 ~ 10:30

[PEM13-16] Influence of kappa distributions on the sweep rate of whistler mode chorus waves

*Danny Summers[1] (1.Memorial University of Newfoundland)

Nonlinear Damping of Oblique Whistler Mode Waves Via Landau Resonance

*謝 怡凱[1]、大村 善治[1]
*Yikai HSIEH[1], Yoshiharu Omura[1]

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Nonlinear trapping of electrons via Landau resonance is an important mechanism of oblique whistler mode wave-particle interactions. Electrons trapped by Landau resonance gain energies from waves. The Landau resonance velocity becomes very close to the group velocity of nearly parallel whistler mode waves at frequencies around half the electron gyrofrequency, resulting in a long interaction time and possible wave damping. We perform test particle simulations with parameters at L = 5 and a small wave normal angle 10 degrees to study the wave-particle interactions via the Landau resonance. Analyzing the wave electric fields and the resonant currents formed by electrons undergoing Landau and cyclotron resonances, we show that effective wave damping occurs near half the electron gyrofrequency. This nonlinear wave damping is contributed by Landau resonance rather than cyclotron resonance. Furthermore, we confirm that this damping is dominated by perpendicular components of the wave electric field and perpendicular resonant currents. The simulation results indicate that nonlinear damping via Landau resonance is one of the mechanisms dividing chorus emissions into the upper band and the lower band.

キーワード：ホイッスラーモード波、波動粒子相互作用、相対論的電子、ランダウ共鳴
Keywords: whistler mode waves, wave-particle interaction, relativistic electrons, Landau resonance

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Instantaneous Frequency Analysis on Nonlinear EMIC Emissions: Arase Observation

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In the inner magnetosphere, the Arase spacecraft has observed electromagnetic ion cyclotron (EMIC) emissions with both rising and falling frequencies. The instantaneous frequency analyses on the electromagnetic fields of the EMIC rising tone emission have been performed by the Hilbert-Huang transform. The time variation of the instantaneous frequency shows a good agreement with the nonlinear theory for the frequency evolutions. Rapid instantaneous frequency modulation is also found during the rising tone emission. We estimate the peak-to-peak time of the fluctuation in the frequency and find that the fluctuation is caused around a half of the particle trapping time. From the motion of the phase-bunched particle around the resonant velocity, it is expected that the nonlinear resonant current, which induces the falling frequency is formed in half the trapping time.

キーワード：非線形波動粒子相互作用、あらせ衛星
Keywords: nonlinear wave particle interaction, Arase spacecraft

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Rapid Precipitation by EMIC Rising-tone Emissions of Relativistic Electrons Observed by the Van Allen Probes Mission

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On 23 February 2014, Van Allen Probes sensors observed quite strong electromagnetic ion cyclotron waves (EMIC) in the outer dayside magnetosphere. The maximum amplitude was more than 14 nT, comparable to 7 % of the magnitude of the ambient magnetic field. The EMIC waves consisted of a series of coherent rising tone emissions. Rising tones are excited sporadically by energetic protons. At the same time, the probes detected drastic fluctuations in fluxes of MeV electrons. It was found that the electron fluxes decreased by more than 30 % during the one minute following the observation of each EMIC rising tone emissions. Furthermore, it is concluded that the flux reduction is a non-adiabatic (irreversible) process since holes in the particle flux levels appear as drift echoes with energy dispersion. We examine the process of the electron pitch angle scattering by nonlinear wave trapping due to anomalous cyclotron resonance with EMIC rising tone emissions. The energy range of precipitated electrons corresponds to the presumed energy for the threshold amplitude for nonlinear wave trapping. This is the first report of rapid precipitation by this mechanism of relativistic electrons by EMIC rising tone emissions and their drift echoes in time observed by spacecraft.

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Plasmaspheric EMIC waves excited through mode conversion from equatorial noise under existence of M/Q=2 ions

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Equatorial noise (EN, and referred to as magnetosonic mode waves) emissions are observed inside and outside the plasmapause and propagate across the magnetic field. In this study, we found the mode conversion from EN to EMIC waves in the plasmasphere using the plasma wave data from Van Allen Probes and Arase. When EN propagates into the earthward across the field line toward the Earth, EN splits into different waves modes; EN, and EMIC waves with the existence of M/Q=2 ions (deuteron or alpha particles) in the deep plasmasphere and the topside ionosphere. The oblique EMIC waves are excited through this mode conversion process, which are different characteristics of the propagation directions from EMIC waves generated from other processes. This mode conversion contributes to an origin of the plasmaspheric EMIC waves, especially at L<2.

キーワード：あらせ、プラズマ圏EMIC、M/Q=2イオン
Keywords: Arase, Plasmaspheric EMIC waves, M/Q=2 ions

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Generation Mechanism of Non-thermal Continuum Radiation

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We study a possible nonlinear mechanism which could be responsible for generation of the non-thermal continuum radiation. We propose a theoretical model and perform numerical simulations using a 2-D electromagnetic particle code (KEMPO2) [1] to verify the mechanism [2]. In the simulation system, we have density gradient and ring beam electrons in the dense region as a source of electrostatic waves through ring-beam instability. These electrostatic waves cause non-gyrotropy of the ring velocity distribution which is necessary for generation of the harmonic waves. Velocity component V_y together with magnetic field B_z of the generated Z-mode waves creates Lorentz force in the x-direction (along the magnetic field). Hence, oscillating energetic electrons work as an anntenna emiting O-mode waves to the low density region. Electromagnetic O-mode waves are emitted at harmonics of the cyclotron frequency up to the maximal plasma frequency of the high density region, and they are observed as non-thermal continuum radiation in the low density region.

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[1] M. Horky, Y. Omura, and O. Santolik, Particle simulation of electromagnetic emissions from electrostatic instability driven by an electron ring beam on the density gradient, Physics of Plasmas 25, 042905, doi: 10.1063/1.5025912, 2018.
[2] M. Horky, and Y. Omura, Novel nonlinear mechanism of the generation of non-thermal continuum radiation, Physics of Plasmas 26, 2019.

キーワード：波動粒子相互作用、非線形過程、プラズマポーズ
Keywords: wave-particle interaction, nonlinear process, plasma_pause

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Influence of kappa distributions on the sweep rate of whistler mode chorus waves

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Kappa particle distributions typically possess a high-energy power-law tail characterized by a spectral index kappa. Here we consider the bi-kappa and kappa-loss-cone distributions. The influence of kappa distributions on the linear growth rate of whistler-mode waves is mediated by the electron anisotropy. The linear growth rate corresponding to kappa distributions (for kappa=2) exceeds that for a bi-Maxwellian distribution for electron anisotropies less than a critical value; for anisotropies greater than the critical value the opposite applies. The influence of kappa distributions on the threshold wave amplitude for nonlinear growth depends on the wave frequency, the electron anisotropy and the temperature of the (hot) energetic electrons that generate the waves. We construct time profiles of the amplitude and frequency of chorus wave elements for various sets of parameters. We examine how the sweep (chirp) rate of the waves depends on the kappa index. Nonlinear growth of whistler mode waves can be enhanced or inhibited by kappa distributions,dependent on the values of the parameters of the background plasma and the properties of the injected energetic electron population that generates the waves.

Keywords: kappa distributions, whistler mode waves, chorus sweep rates

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[E] 口頭発表 | セッション記号 P (宇宙惑星科学)：P-EM 太陽地球系科学・宇宙電磁気学・宇宙環境

2019年5月29日(水) 10:45 ~ 12:15 | A04 東京ベイ幕張ホール

[P-EM13] 内部磁気圏

コンビーナ:海老原 祐輔(京都大学生存圏研究所)、Danny Summers(Memorial University of Newfoundland)、三好 由純(名古屋大学宇宙地球環境研究所)、齊藤 慎司(名古屋大学　大学院理学研究科)、座長:海老原 祐輔(京都大学生存圏研究所)、Shinji Saito(ISEE, Nagoya University)

The inner magnetosphere is characterized by the dominance of intrinsic dipolar Earth's magnetic field. The dipolar magnetic field traps charged particles, resulting in the formation of unique particle environment known as the plasmasphere, the ring current, and the radiation belt. The inner magnetosphere is always changing because of incoming energy from the outer magnetosphere and the ionosphere in the forms of particles and electromagnetic fields. In the inner magnetosphere, the particle energy is transferred to the field energy, and vice versa. The mutual coupling between particles and fields also makes the inner magnetosphere unique. The outgoing energy to these regions is also known to be significant, such as precipitation into the upper atmosphere and sub-auroral disturbances. A number of satellites (e.g., DMSP, NOAA, Geotail, Cluster, THEMIS, Van Allen Probes, MMS, and Arase), ground-based instruments (e.g., SuperDARN and EISCAT radars, magnetometers, and cameras), and numerical simulations (e.g., global particle simulation, PIC simulation, and hybrid simulation) have successfully surveyed the inner magnetosphere, which deepen our knowledge significantly. USAF DSX, UCLA Elfin and NASA CeRES will be launched soon, being expected to provide important information. We solicit papers describing recent results on the inner magnetosphere and/or its coupling with the other regions, including the ionosphere and the outer magnetosphere.

10:45 ~ 11:05

[PEM13-17] The Impacts of Substorms on the Ring Current

★Invited Papers

*Jasmine Kaur Sandhu[1]、I. J. Rae[1]、M. Gkioulidou[2]、C. Forsyth[1]、G. D. Reeves[3]、M. P. Freeman[4]、K. R. Murphy[5]、M.-T. Walach[6]、H. E. Spence[7] (1.Mullard Space Science Laboratory, University College London, UK.、2.Applied Physics Laboratory, John Hopkins University, USA.、3.Los Alamos National Laboratory, USA.、4.British Antarctic Survey, UK.、5.University of Maryland, USA.、6.Lancaster University, UK.、7.University of New Hampshire, USA.)

11:05 ~ 11:25

[PEM13-18] Dipolarization in the Inner Magnetosphere: Comparison between Geosynchronous Orbit and Further Inside

★Invited Papers

*Shinichi Ohtani[1]、Tetsuo Motoba[1]、Matina Gkioulidou[1]、Kazue Takahashi[1] (1.The Johns Hopkins University Applied Physics Laboratory)

11:25 ~ 11:40

[PEM13-19] Substorm-associated particle injection near/at geosynchronous orbit: Observations from ERG and GOES

*Tzu-Fang Chang[1,2]、Chio-Zong Cheng[2]、Sunny Wing-Yee Tam[2]、Chih-Yu Chiang[2]、Yoshizumi Miyoshi[1]、Tomoaki Hori[1]、Takefumi Mitani[3]、Takeshi Takashima[3]、Ayako Matsuoka[3]、Mariko Teramoto[1]、Iku Shinohara[3] (1.Institute for Space-Earth Environmental Research, Nagoya University, Japan、2.Institute of Space and Plasma Sciences, National Cheng Kung University, Tainan, Taiwan、3.Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency, Japan)

11:40 ~ 11:55

[PEM13-20] Substorm -like energetic electron injection observed at the plasma sheet boundary in the inner magnetosphere

*篠原 育[1]、長井 嗣信[1]、三谷 烈史[1]、東尾 奈々[2]、笠原 慧[3]、風間 洋一[4]、Wang Shiang-Yu[4]、Tam Sunny[5]、松岡 彩子[1]、浅村 和史[1]、横田 勝一郎[6]、高島 健[1]、三好 由純[7] (1.宇宙航空研究開発機構／宇宙科学研究所、2.宇

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11:55 ~ 12:10

[PEM13-21] Magnetic field disturbances associated with the magnetic dipolarization observed by Arase (ERG) in the inner magnetosphere

*松岡 彩子[1]、能勢 正仁[2]、三好 由純[2]、篠原 育[1]、寺本 万里子[2]、野村 麗子[3]、藤本 晶子[4]、田中 良昌[5]、篠原 学[6]、笠原 禎也[7]、笠羽 康正[8]、石坂 圭吾[9]、松田 昇也[1]、小路 真史[2]、中川 朋子[10]、Kazama Yoichi[11]、Wang Shiang-Yu[11]、笠原 慧[12]、横田 勝一郎[13]、三谷 烈史[1] (1.宇宙航空研究開発機構　宇宙科学研究所、2.名古屋大学　宇宙地球環境研究所、3.国立天文台　RISE月惑星探査検討室、4.九州工業大学　情報工学部、5.国立極地研究所、6.鹿児島工業高等専門学校、7.金沢大学　総合メディア基盤センター、8.東北大学　惑星プラズマ・大気研究センター、9.富山県立大学 工学部、10.東北工業大学　工学部、11.台湾中央研究院、12.東京大学　大学院理学系研究科、13.大阪大学　大学院理学研究科)

12:10 ~ 12:15

Discussion

The Impacts of Substorms on the Ring Current

*Jasmine Kaur Sandhu[1], I. J. Rae[1], M. Gkioulidou[2], C. Forsyth[1], G. D. Reeves[3], M. P. Freeman[4], K. R. Murphy[5], M.-T. Walach[6], H. E. Spence[7]

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Substorms are a highly dynamic process that result in the global redistribution of energy within the magnetosphere. The occurrence of a substorm can provide the inner magnetosphere with hot ions and consequently intensify the ring current population. However, substorms are a highly variable phenomenon that can occur as an isolated event or as part of a sequence. In this study we determine the extent to which substorms enhance the ring current energy content and compare how the energy enhancement varies with substorm type.

Using ion observations (H^+, O^+, and He^+) from the RBSPICE and HOPE instruments onboard the Van Allen Probes, we quantify how the total ring current energy content changes during the substorm process. A statistical analysis demonstrates the impact of a typical substorm on the ring current region. We find that ~ 5% of the total energy released at substorm onset is transferred into the ring current population, and energises the ring current by 12% on average. The features of the energy enhancement correlate well with the expected properties of particle injections into the inner magnetosphere, and large enhancements in the O^+ contribution to the energy content suggest important compositional variations.

Analysis also reveals that the ring current response to substorms is strongly dependent upon the type of substorm activity. The results show that substorms followed by a series of successive substorms are associated with significantly different ring current conditions and enhancements compared to isolated substorms. We present clear magnitude and local time differences that illustrate the complexity and variability of the substorm-ring current coupling, along with an interpretation of the details of this relationship.

Keywords: Ring Current, Substorms, Van Allen Probes, Magnetosphere

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Dipolarization in the Inner Magnetosphere: Comparison between Geosynchronous Orbit and Further Inside

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1. The Johns Hopkins University Applied Physics Laboratory

The present study addresses the current system associated with dipolarization in the inner magnetosphere. *Ohtani et al.* [2018] examined dipolarization events observed by the Van Allen Probes (RBSP) satellites within 5.8 R_E from Earth, and by statistically comparing signatures at nearby RBSP or GOES satellites, they found that dipolarization signatures are often highly correlated (c.c. > 0.8) within 1 hr in MLT and 1 R_E in R_{XY}, and the dipolarization region expands earthward as well as azimuthally. In the present study we use, as a reference, the GOES geosynchronous satellites instead, and we examine how the magnetic field at the RBSP position changes responding to sharp dipolarizations at geosynchronous orbit. As expected from the aforementioned result, the two spacecraft occasionally observe similar dipolarization signatures with some time delay. It is, however, also found that in some events the magnetic field changes far less systematically at the RBSP probes, and in other events it barely changes or changes very gradually even if the RBSP probes are located very close to the GOES location in longitude (DMLT = 0.0 ~ 0.5 hr in MLT). By examining such variability with respect to the radial distance and magnetic latitude of the RBSP probes, we address the spatial structure of the associated current system. We also examine the variation of particle fluxes at the RBSP probes for each type of the magnetic response, and discuss the result in terms of the enhancement of local plasma pressure and the formation of a R2-sense field-aligned current system, which we suggest coexists along with the conventional substorm wedge current system.

Reference:

Ohtani, S., Motoba, T., Gkioulidou, M., Takahashi, K., & Singer, H. J. (2018). Spatial development of the dipolarization region in the inner magnetosphere. Journal of Geophysical Research: Space Physics, 123, 5452–5463. https://doi.org/10.1029/2018JA025443.

Keywords: Dipolarization, Inner magnetosphere, Substorms, Field-aligned currents

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Substorm-associated particle injection near/at geosynchronous orbit: Observations from ERG and GOES

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The injection of electrons during the substorm event, occurring on Apr. 5, 2017, was observed by the ERG (Arase), GOES-15 and GOES-13 spacecraft near/at geosynchronous orbit. The ERG satellite observed the nearly-dispersionless injection and the subsequent drift echoes while the GOES-15 and GOES-13 captured the drift echoes with dispersion. The multipoint observations provide constraints for us to simulate the substorm-associated injection. We improve an existing model in the literature to study the substorm injection event. Since the electron energies of interest are comparable to the rest mass energy, our work further provides the relativistic form of the previous model and employs a semi-empirical model instead of a dipole-based one in the previous study. Our simulations successfully reproduce the key features of the nearly-dispersionless injection and the drift echoes. The periods of drift echoes show a better fit to the spacecraft observations when relativistic effects are taken into account. The substorm-associated injection event can be better simulated by the further-developed model shown in this study.

Keywords: ERG, Arase, substorm injection, drift echoes, relativistic effects

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Substorm -like energetic electron injection observed at the plasma sheet boundary in the inner magnetosphere

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The Arase (ERG) satellite is possible to observe higher L-value plasma sheet close to the plasma sheet boundary because of its characteristic orbit, and, actually, Arase has observed several lobe entry events just outside of the outer radiation belt. In some of these events, we found that energetic electron bursts up to (sometimes, over) 300 keV appear at the plasma sheet boundary. The purpose of this study is to address where do the energetic electron bursts at higher latitude come from and what is the contribution of magnetotail reconnection and its associated acceleration process to the generation of the energetic electron bursts.

However, the observed energetic electron bursts look quite similar to typical dispersionless substorm injection events. If the observed electron bursts are due to the substorm injection, the observation cannot be explained by the standard understanding of the injection because (1) the injection occurs associated with local magnetic field dipolarizations in downstream of the magnetotail reconnection jets (in deep inside of the plasma sheet) and (2) energetic electrons observed at the plasma sheet boundary are thought to be directly accelerated from magnetotail reconnection sites. Since the pitch angle distribution of 100-200 keV electron shows enhancement both of parallel and perpendicular fluxes, the observed results suggest the coexistence of (1) and (2). In this presentation, we will discuss the physical meanings of the observed electron bursts. The discussion is important to address the relationship between magnetotail reconnection and injections, and the results might contribute to a better understanding of electron acceleration processes and energy input to the inner magnetosphere.

キーワード：energetic electron injection、substorm
Keywords: plasma sheet boundary, electron acceleration

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Magnetic field disturbances associated with the magnetic dipolarization observed by Arase (ERG) in the inner magnetosphere

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The magneto-hydrodynamic waves propagating in the plasma sheet are recognized to transport substantial energies in the magnetosphere. We investigated magnetic field disturbances of the Alfven waves observed by the Arase spacecraft at about 5 earth-radii distance in the midnight. In the inner plasma sheet Alfven waves were often accompanied by the magnetic dipolarization.
We examined the magnetic disturbances in the plane perpendicular to the ambient magnetic field. In the two events examined in our study, the magnetic field disturbances were linearly polarized and the polarization direction gradually rotated 180 degrees in 200 seconds. It is well interpreted that Arase traversed a magnetic flux tube where torsional Alfven waves propagated. The change of the polarization direction reflected the change of observation location in the flux tube. Torsional-mode is significantly common and natural as the parallel-propagating Alfven wave. It is known that large-scale energy transfer and dissipation of the torsional Alfven waves take place on the solar surface.
Meanwhile, in the boundary plasma sheet adjacent to the lobe, the magnetic field disturbances were linearly polarized again and confined to the dawn-dusk direction. They are interpreted as plane Alfven waves having uniformity in the dawn-dusk direction and propagating obliquely. The kinetic effect of the Alfven waves has been often discussed in previous works in association with the auroral emission at the ionospheric altitude.

キーワード：あらせ、磁場、双極子化、アルフベン波
Keywords: Arase, magnetic field, dipolarization, Alfven wave

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[E] 口頭発表 | セッション記号 P (宇宙惑星科学)：P-EM 太陽地球系科学・宇宙電磁気学・宇宙環境

2019年5月29日(水) 13:45 ~ 15:15 | A04 東京ベイ幕張ホール

[P-EM13] 内部磁気圏

コンビーナ:海老原 祐輔(京都大学生存圏研究所)、Danny Summers(Memorial University of Newfoundland)、三好 由純(名古屋大学宇宙地球環境研究所)、齊藤 慎司(名古屋大学　大学院理学研究科)、座長:三好 由純(名古屋大学宇宙地球環境研究所)、海老原 祐輔(京都大学生存圏研究所)

The inner magnetosphere is characterized by the dominance of intrinsic dipolar Earth's magnetic field. The dipolar magnetic field traps charged particles, resulting in the formation of unique particle environment known as the plasmasphere, the ring current, and the radiation belt. The inner magnetosphere is always changing because of incoming energy from the outer magnetosphere and the ionosphere in the forms of particles and electromagnetic fields. In the inner magnetosphere, the particle energy is transferred to the field energy, and vice versa. The mutual coupling between particles and fields also makes the inner magnetosphere unique. The outgoing energy to these regions is also known to be significant, such as precipitation into the upper atmosphere and sub-auroral disturbances. A number of satellites (e.g., DMSP, NOAA, Geotail, Cluster, THEMIS, Van Allen Probes, MMS, and Arase), ground-based instruments (e.g., SuperDARN and EISCAT radars, magnetometers, and cameras), and numerical simulations (e.g., global particle simulation, PIC simulation, and hybrid simulation) have successfully surveyed the inner magnetosphere, which deepen our knowledge significantly. USAF DSX, UCLA Elfin and NASA CeRES will be launched soon, being expected to provide important information. We solicit papers describing recent results on the inner magnetosphere and/or its coupling with the other regions, including the ionosphere and the outer magnetosphere.

13:45 ~ 14:05

[PEM13-22] Statistical Property of Long Lasting Poloidal Pc 4-5 Waves and Relation with Particle Dynamics in the Inner Magnetosphere: Van Allen Probes Observations

★Invited Papers

*山本 和弘[1]、能勢 正仁[2]、桂華 邦裕[3]、Charles Smith[4]、Robert MacDowall[5]、Donald Mitchell[6]、Hyomin Kim[7]、John Wygant[8] (1.京都大学大学院理学研究科、2.名古屋大学宇宙地球環境研究所、3.東京大学理学系研究科、4.Institute for the Study of Earth, Oceans, and Space, University of New Hampshire、5.Solar System Exploration Division, Goddard Space Flight Center、6.The Johns Hopkins University Applied Physics Laboratory、7.Center for Solar‐Terrestrial Research, New Jersey Institute of Technology、8.School of Physics and Astronomy, University of Minnesota)

14:05 ~ 14:25

[PEM13-23] Subauroral Polarization Streams: Indication of Magnetosphere–Ionosphere Coupling

★Invited Papers

*Fei He[1,2,3]、Xiao-Xin Zhang[4]、Wenbin Wang[5]、Zhonghua Yao[1,2,3]、Yong Wei[1,2,3]、Zhi-Peng Ren[1,2,3]、Xinan Yue[1,2,3]、Weixing Wan[1,2,3] (1.Institute of Geology & Geophysics, CAS、2.Institutions of Earth Science, CAS、3.College of Earth and Planetary Sciences, UCAS、4.National Center for Space Weather, CMA、5.High Altitude Observatory, NCAR)

14:25 ~ 14:40

[PEM13-24] Simultaneous Arase-ground observations of a purple and green auroral arc

*塩川 和夫[1]、能勢 正仁[1]、土屋 智[1]、高木 佑基[1]、今城 峻[1]、田中 良昌[2]、三好 由純[1]、細川 敬祐[3]、風間 洋一[4]、Shiang-Yu Wang[4]、Sunny W. Y. Tam[4]、浅村 和史[5]、笠原 慧[6]、横田 勝一郎[7]、堀 智昭[1]、桂華 邦裕[6]、松岡 彩子[5] (1.名古屋大学宇宙地球環境研究所、2.国立極地研究所、3.電気通信大学、4.国立成功大学、5.JAXA宇宙科学研究所、6.東京大学、7.大阪大学)

14:40 ~ 14:55

[PEM13-25] Multiple Satellite Observations of Oxygen Torus in the Inner Magnetosphere

*能勢 正仁[1]、松岡 彩子[2]、熊本 篤志[3]、笠原 禎也[4]、Goldstein J[5,6]、寺本 万里子[1]、土屋 史紀[3]、松田 昇也[2]、小路 真史[1]、今城 峻[1]、生松 聡[7]、山本 和弘[7]、尾花 由紀[8]、野村 麗子[9]、藤本 晶子[10]、篠原 育[2]、三好 由純[1]、

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14:55 ~ 15:10

[PEM13-26] Study of characteristics of storm-time Pc5 ULF waves excited by the drift-bounce resonance with ring current ions based on the global drift-kinetic simulation

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15:10 ~ 15:15

Discussion

Statistical Property of Long Lasting Poloidal Pc 4-5 Waves and Relation with Particle Dynamics in the Inner Magnetosphere: Van Allen Probes Observations

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Poloidal ULF waves in the inner magnetosphere have been attracting many attentions because they can interact with plasma particles. A lot of event analysis of the drift-bounce resonance, the bounce resonance, and the drift resonance have been conducted (e.g., *Hughes et al.*, 1978; *Takahashi et al.*, 1990, 2018; *Liu et al.*, 2013; *Dai et al.*, 2013; *Min et al.*, 2017; *Oimatsu et al.*, 2018; *Rubtsov* et al., 2018). However, the statistical relation between the poloidal mode waves and particles is rarely reported, and the phase relation between poloidal oscillations and resonance particles is only studied by *Ren et al.* (2018).

To reveal the importance of a poloidal ULF wave in the dynamics of the inner magnetosphere, we statistically analyzed 91 events of the poloidal waves detected by Van Allen Probes with duration time larger than 2 hr, because significant wave particle interaction is expected for such long lasting waves. We calculated eigen-frequencies of the selected waves using the Tsyganenko 89 model (*Tsyganenko*, 1989), and found that most of them are second harmonic mode waves. The cross phase between the radial magnetic field and the azimuthal electric field also supports this result. Using the ion sounding technique (*Su et al.*, 1977; *Min et al.*, 2017; *Yamamoto et al.*, 2018), we estimated the azimuthal wave number (*m* number) for 47 events from RBSPICE observation. Most of the 47 events have *m* = -120 to -200 (i.e., westward propagation). These high-*m* waves can be excited by wave-particle interaction.

Relation between the high-*m* poloidal waves and the plasmasphere was investigated. When the poloidal waves were observed, cold electron density increased by a factor of ~2. When the electron density decreased to the original state, the poloidal waves disappeared. This implies that the poloidal waves are excited in the structured high electron density region like plasma plume. The scenario of wave excitation through bounce resonance proposed by *Liu et al.* (2013) can explain the density variations during wave appearance.

We will also discuss the variations of proton flux around resonance energy and evaluate the importance of poloidal ULF waves in the dynamics of the inner magnetosphere. During quiet period (|Dst| < 10 nT), the proton flux at energy of (0.3-1)W_{res} (W_{res}: resonance energy) was slightly smaller than that on the orbit just

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before the wave onset. The decrease of resonance particle flux may be caused by wave-particle interaction.

キーワード：poloidal ULF 波動、リングカレント、プラズマ圏、波動粒子相互作用、Van Allen Probes (RBSP)
Keywords: poloidal ULF waves, ring current, plasmasphere, wave particle interaction, Van Allen Probes (RBSP)

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Subauroral Polarization Streams: Indication of Magnetosphere–Ionosphere Coupling

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Subauroral polarization streams, or SAPS, are narrow channels of strong westward ion flows in both the subauroral ionosphere and the conjugated inner magnetosphere in the nightside during geomagnetic storms and substorms. The SAPS are closely related with ionospheric conductivity and region–2 field–aligned currents. Many characteristics of SAPS have been determined from space–based measurements of electric fields and ion drifts in the ionosphere and the magnetosphere, and ground–based radar observations, such as the global occurrence based on the statistics of many individual event, long term variabilities, hemispheric asymmetries, electromagnetic wave structures, double peak signatures, and evolution patterns during intense storms and quiet time substorms. Multisatellite observations during a geomagnetic storm indicated that the SAPS were first initiated around the dusk sector and then expanded toward the midnight, moved to low latitudes and formed a wedge-shaped structure during the main phase. More recently, multisatellite observations during a severe storm revealed that strong oscillations occurred in the SAPS channel when IMF By changed from positive to negative. The SAPS oscillations were first observed in the pre–midnight sector and propagated towards the dusk sector. The oscillations may be related to the waves generated by the interaction between the fast–flowing energetic plasma sheet ions and the cold plasmasphere. The new features of SAPS provide new insights in to the coupling dynamics in the magnetosphere.

Keywords: SAPS, Large-scale structure, Oscillations, plasma sheet, storm

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Simultaneous Arase-ground observations of a purple and green auroral arc

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The purple auroral emission at a wavelength of 427.8nm is often caused by resonant scattering of sunlight by nitrogen molecular ions at the high-latitude part of auroral arcs, and can be a manifestation of ion upflow in the auroral ionosphere. We report the first particle observation for the source region of a purple/green auroral arc in the inner magnetosphere, which was made by the Arase satellite. The auroral arc appeared and expanded equatorward from ~0310 UT (midnight in local time) on September 11, 2018 at Nain, Canada, in association with the expansion phase of a substorm that occurred during the arrival of a corotating interaction region (CIR) in the solar wind. The auroral arc is characterized by purple and green emissions at the top and bottom parts, respectively, suggesting resonant-scattering of sunlight by auroral nitrogen molecular ions. Bi-directional field-aligned electrons with energies of ~keV were observed by the LEP-e onboard the Arase satellite during the arc crossing at L ~ 6.4, while source electrons become isotropic in the diffuse aurora afterwards. Electrons at energies of ~20 keV measured by the MEP-e of Arase also show a bi-directional (nearly) field-aligned distribution, while electron loss cone was identified at the arc crossing. The low-energy protons measured by LEP-i of Arase show time-pitch-angle dispersion from anti-earthward (180 degree) to earthward (0 degree) during the arc crossing. Based on these observations, we discuss physical mechanisms that cause these particle features and the observed purple/green auroral arc.

キーワード：紫のオーロラアーク、衛星ー地上同時観測、沿磁力線電子降り込み
Keywords: purple auroral arc, simultaneous satellite-ground observation, field-aligned electron precipitation

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Multiple Satellite Observations of Oxygen Torus in the Inner Magnetosphere

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A recent study employing the Arase and Van Allen Probes A satellites at different MLT revealed an event in which the inner magnetospheric O^+ density enhancement (know as the dense oxygen torus) does not extend over all MLT. Rather, the torus is skewed toward the dawn sector, being described more precisely as a crescent-shaped torus or a pinched torus [Nosé et al., 2018]. In the reported event of 24 April 2017, Arase flying in the morning sector detected an enhancement of the average plasma mass up to ~3.5 amu around L=4.9–5.2, while Van Allen Probe A flying in the afternoon sector observed no clear enhancements in the average plasma mass. In the present study, we focus on simultaneous observations of the magnetic field and plasma waves made by the Arase and Van Allen Probes A and B satellites on 12 September 2017. For this event the orbital configuration of the satellites is opposite to that in the study by Nosé et al. [2018]; that is, Arase is in the afternoon and the Van Allen Probes are in the morning. It is found that only Probe B observed a clear enhancement in the average plasma mass up to ~4 amu around L=3.5 and MLT=9.0 hr. This result demonstrates that the crescent-shaped O^+ torus is not a unique (single-event) occurrence, and thus may be a general feature of the density enhancement in the inner magnetosphere.

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Study of characteristics of storm-time Pc5 ULF waves excited by the drift-bounce resonance with ring current ions based on the global drift-kinetic simulation

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Storm-time Pc5 waves are electromagnetic fluctuations in the inner magnetosphere with the frequency of 1.67-6.67 mHz, and are considered to be generated by ring current ions associated with the injection from the magnetotail during substorms. The excitation mechanism and global distribution of Pc5 waves are keys to understand dynamic variation of the outer radiation belt, since Pc5 waves are considered to contribute to the radial diffusion of radiation belt electrons [e.g. Elkington et al., 2003]. Promising candidates of excitation mechanism of the storm-time Pc5 waves are the drift or drift-bounce resonance [Southwood, 1976]. Although previous spacecraft observations suggest the resonant excitation [e.g., Dai et al., 2013; Yeoman and Wright., 2001], there are other possibilities such as periodic pressure inhomogeneity formed by time-dependent injections. Theoretically, Yamakawa et al. [2019] confirmed the drift resonance excitation of storm-time Pc5 waves in 3D dipole structure based on the drift-kinetic simulation. However, in what kind of situation the drift resonance is switched to the drift-bounce resonance is far from understood.

In order to simulate the excitation of the storm-time Pc5 waves, we perform a kinetic simulation for ring current particles using GEMSIS-RC model [Amano et al., 2011], in which five-dimensional drift-kinetic equation for the phase space density (PSD) of ring current ions and Maxwell equations are solved self-consistently under assumption that the first adiabatic invariant is conserved. In order to simulate consequence of ion injection from the plasma sheet, we set a localized high-pressure region around midnight consisting of H+ ions. We compare two cases of the initial velocity distribution; the Maxwellian velocity distribution with the isotropic temperature of 16 keV (Case a) and the velocity distribution with the phase bunching in the southern hemisphere due to the bounce motion of ions in addition to the background Maxwellian distribution (Case b). For the Case b, we changed the strength of the initial phase bunching to investigate the conditions for drift-bounce resonance to be dominant.In Case a, the simulation results show the drift resonance excitation of both poloidal and toroidal mode waves in Pc5 frequency range in the dayside dusk sector. These waves are fundamental mode waves with azimuthal wave number m ~ - 20 propagating westward. Global distribution of the excited Pc5 waves indicates that they are excited where the local growth rate resultant from the positive PSD gradient in energy is positive. In Case b, excitation of the second harmonic poloidal-mode Pc4 ULF waves due to the drift-bounce resonance was identified in the dayside dusk sector in the strong bunching case. We will also report on characteristics of excited ULF waves and their dependence on the initial bunching strength of injected ions with a focus of the relative contribution of the drift and drift-bounce resonances.

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キーワード：リングカレント、Pc5 ULF、ドリフトバウンス共鳴、ドリフト運動シミュレーション、磁気嵐
Keywords: ring current, Pc5 ULF, drift-bounce resonance, drift-kinetic simulation, magnetic storm

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2019年5月29日(水) 9:00 ~ 10:30 | 104 1F

[A-AS01] 高性能スーパーコンピュータを用いた最新の大気科学

コンビーナ:瀬古 弘(気象研究所)、三好 建正(理化学研究所)、小玉 知央(独立行政法人海洋研究開発機構)、滝川 雅之(独立行政法人海洋研究開発機構)、座長:瀬古 弘(気象研究所)、小玉 知央 (国立研究開発法人 海洋研究開発機構)

気象学を含む様々な分野において、「京」コンピュータや地球シミュレータ等の高性能スーパーコンピュータを用いて、最先端のシミュレーション研究が行われている。高性能スーパーコンピュータにより、解像度やアンサンブル数等において従来より桁で上回る計算や、これまでにない高頻度高密度な観測ビッグデータを用いたデータ同化が可能になり、気象学の新たな展開が生まれつつある。また、「京」の後継機であるポスト「京」スーパーコンピュータを稼働させるべく開発が進められており、これに向けた研究もスタートしている。「スパコンによる大気科学」では、2019年大会において、気象・気候・環境科学の最先端のシミュレーション研究をテーマとし、「京」や他のスーパーコンピュータを用いた最新の成果や新たなシミュレーション研究の展開に関する発表を募集する。

9:00 ~ 9:15

[AAS01-01] Data Assimilation Studies using Big Observation Data in the Projects of Post K and BDA

*瀬古 弘[1]、國井 勝[2]、澤田 洋平[1]、岡本 幸三[1]、横田 祥[1]、伊藤 耕介[3]、下地 和希[2] (1.気象研究所、2.気象庁、3.琉球大学)

9:15 ~ 9:30

[AAS01-02] **High-resolution Numerical Weather Simulation with a Large Domain for Extreme Heavy Rainfall Events**

*大泉 伝[1,2]、斉藤 和雄[4,3]、le duc[1]、伊藤 純至[3] (1.国立研究開発法人海洋研究開発機構、2.気象研究所、3.東京大学大気海洋研究所、4.気象業務支援センター)

9:30 ~ 9:45

[AAS01-03] Quasi-liner convective systemによって生じた竜巻の数値シミュレーション

★招待講演

*栃本 英伍[1]、新野 宏[1] (1.東京大学大気海洋研究所)

9:45 ~ 10:00

[AAS01-04] Improving the observation operator for Phased Array Weather Radar in the SCALE-LETKF system

*雨宮 新[1]、本田 匠[1]、三好 建正[1] (1.理化学研究所　計算科学研究センター)

10:00 ~ 10:15

[AAS01-05] Data assimilation and forecast experiments for the record-breaking rainfall event in Japan in July 2018 with NICAM-LETKF at 112-km and 28-km resolution

*寺崎 康児[1]、三好 建正[1] (1.理化学研究所計算科学研究センター)

10:15 ~ 10:30

[AAS01-06] Model Parameter Estimation with Data Assimilation Using NICAM-LETKF

★Invited Papers

*小槻 峻司[1]、佐藤 陽祐[2]、寺崎 康児[1]、八代 尚[1]、富田 浩文[1]、佐藤 正樹[3]、三好 建正[1] (1.国立研究開発法人理化学研究所　計算科学研究センター、2.名古屋大学大学院　工学研究科、3.東京大学　大気海洋研究所)

Data Assimilation Studies using Big Observation Data in the Projects of Post K and BDA

*瀬古 弘[1]、國井 勝[2]、澤田 洋平[1]、岡本 幸三[1]、横田 祥[1]、伊藤 耕介[3]、下地 和希[2]
*Hiromu Seko[1], Masaru Kunii[2], Yohei Sawada[1], Kozo Okamoto[1], Sho Yokota[1], Kosuke Ito[3], Kazuki Shimoji[2]

1. 気象研究所、2. 気象庁、3. 琉球大学
1. Meteorological Research Institute, 2. Japan Meteorological Agency, 3. University of the Ryukyus

In the projects of 'Advancement of meteorological and global environmental predictions utilizing observational Big Data' of 'The post K computer development plan of the FLAGSHIP2020 Project' and 'Innovating "Big Data Assimilation" Technology for Revolutionizing Very-short-range Severe Weather Prediction', the data assimilation techniques including the coupling with the ocean model have been developed to improve the prediction accuracy of heavy rainfalls, typhoons and tornadoes, and to obtain the longer leading time (the time from the prediction to the occurrences of severe phenomena). The most of these studies were conducted by using the super computer 'K' and Big Observation Data. In this presentation, the impacts of rapid scan'atmospheric motion vector' and sea surface temperature of Himawari-8 on the Typhoon intensity and track predictions and on the rainfall predictions of heavy rainfalls, the assimilation results of all-sky radiance data in the convection scale prediction, and the reproduction of rainfall system that caused tornadoes by the data of Polarization radar and dense surface observation network will be presented.

キーワード：データ同化、観測ビッグデータ
Keywords: Data Assimilation, Big Observation Data

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High-resolution Numerical Weather Simulation with a Large Domain for Extreme Heavy Rainfall Events

*大泉 伝[1,2]、斉藤 和雄[4,3]、le duc[1]、伊藤 純至[3]
*Tsutao OIZUMI[1,2], Kazuo Saito[4,3], le duc[1], Junshi Ito[3]

1. 国立研究開発法人海洋研究開発機構、2. 気象研究所、3. 東京大学大気海洋研究所、4. 気象業務支援センター
1. Japan Agency for Marine-Earth Science and Technology, 2. Meteorological Research Institute, 3. The Atmosphere and Ocean Research Institute, 4. Japan Meteorological Business Support Center

In Japan, heavy rainfall occasionally causes disasters such as debris flows. For example, debris flows induced severe societal damages in Izu Oshima Island on 15-16 October 2013 and in Hiroshima City on 19-20 August 2014, western Japan on July 5th –8th 2018. To mitigate these disasters damage and evacuate residents in a timely fashion, an accurate numerical weather prediction (NWP) system is important.
In this study, we conducted an ultra-high resolution NWP simulations (grid spacing is 5 km to 150 m) with a large and small domain area to above heavy rainfall events. Several important model factors (grid spacing, PBL scheme model domain size) influencing heavy rainfall forecasting in NWP models were investigated. The model was an optimized version of the Japan Meteorological Agency Non-Hydrostatic Model for the supercomputer “K”.
The result showed the 2-km grid spacing models showed better precipitation performance than 5-km resolution models. And the 500-m resolution models showed better precipitation performance than 2-km grid spacing models. The 2-km and 500-m grid spacing models with the large model domain show better performance than those with the small domain. Overall, the results indicated that using a high-resolution model (500-m grid spacing) with the large model domain area provides an advantage for simulating heavy rain events.

キーワード：集中豪雨、高解像度実験、気象庁非静力学モデル
Keywords: heavy rainfall, high resolution simulation, JMA-NHM

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Quasi-liner convective systemによって生じた竜巻の数値シミュレーション
A Numerical Case Study on a Tornado that Formed in a Quasi Linear Convective System

*栃本 英伍[1]、新野 宏[1]
*Eigo Tochimoto[1], Hiroshi Niino[1]

1. 東京大学大気海洋研究所
1. Atmosphere and Ocean Research Institute, The University of Tokyo

Tornadoes are mainly classified into three groups based on different types of convective systems: supercells, quasi-linear convective systems (QLCSs), and non-supercells. In the United States, it is estimated that 18% of all tornadoes are spawned by QLCSs. In Japan, although tornadoes associated QLCSs also occur and cause severe damages, the detailed features and formation mechanism of tornadoes have not been well under stood. Thus, we performed a high-resolution numerical simulation to reproduce and examine the formation process of a tornado that formed in a quasi linear convective system at Chiyoda-town, Ibaraki prefecture, Japan on 8 December 1992.

A quadruple-nested simulation using Japanese Meteorological Agency non-hydrostatic model was performed. A simulation with horizontal scale of 2km successfully reproduced the QLCS, which propagated eastward quickly and reached around Chiyoda-town at 0830 JST. A cold pool and its associated downdrafts existed behind the convection region with strong updrafts (>10m/s). A simulation with the finest horizontal scale of 50m successfully reproduced the tornado in the QLCS. The vertical vorticity and horizontal velocity exceeded 0.7 $s^{-1}$and 47m/s, respectively. At around 500m height, a low-level mesocyclone, which was accompanied by strong updrafts (>20m/s), formed and developed around the location of tornadogenesis. Near the surface, at 1 or 2 minutes before the tornadogenesis, strong rear-inflow jet (RIJ) accompanied by relatively cold air developed, and then tornado formed in the north of the RIJ. Thus, it is suggested that the RIJ play some roles in the formation and development of the tornado.

キーワード：竜巻、対流
Keywords: Tornado, Convection

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Improving the observation operator for Phased Array Weather Radar in the SCALE-LETKF system

*雨宮 新[1]、本田 匠[1]、三好 建正[1]
*Arata Amemiya[1], Takumi Honda[1], Takemasa Miyoshi[1]

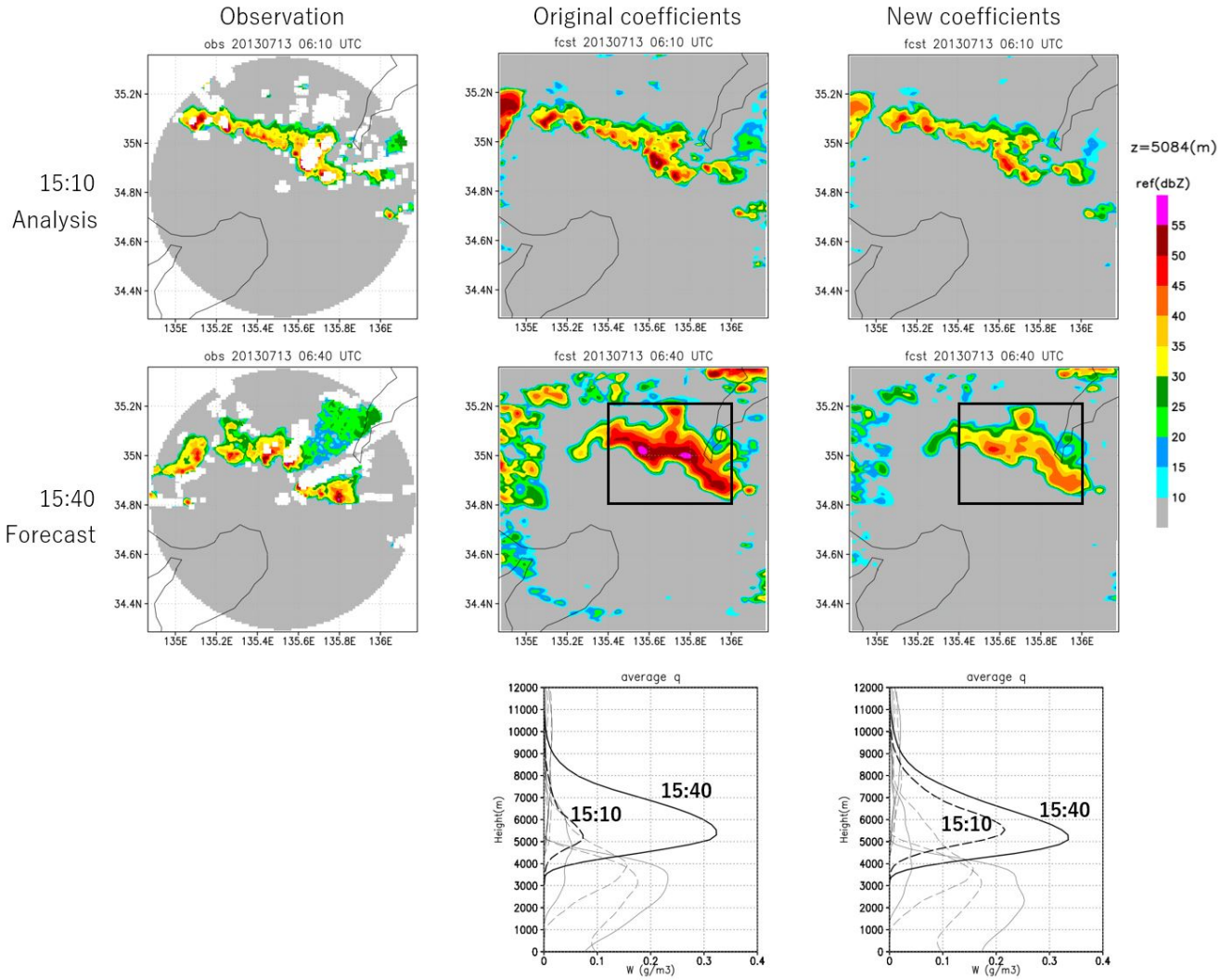
1. 理化学研究所　計算科学研究センター
1. RIKEN Center for Computational Science

The observation operator of Phased Array Weather Radar (PAWR; Ushio et al. 2014; Yoshikawa et al. 2013) in the SCALE-LETKF data assimilation system (Lien et al., 2017) is revisited, and the impact of improving the observation operator on the analysis is examined.
Previous studies (Miyoshi et al., 2016, *IEEE*; Miyoshi et al., 2016, *BAMS*) have shown that the three-dimensional fine-scale structure of radar signals observed by PAWR can be successfully assimilated to produce a high-resolution analysis using a regional model SCALE-RM and the local ensemble transformed Kalman filter (LETKF). Forecasts using a high-resolution regional model from the analysis field has a potential to provide reliable precipitation forecasts for longer period of time than a simple nowcasting technique based on an advection scheme, since the explicit physical processes would allow us to capture the development of new convective cells. However, even with an analysis field incorporating such detailed observational data, accurate forecasting of localized convection systems is generally a challenging issue. In the previous studies mentioned above, there was a known problem that the area of strong radar echo calculated from the forecast field starts to expand unrealistically even within several minutes. Along with systematic model biases and imbalance, the observation operator could be the cause of this misrepresentation. Therefore, the observation operator of PAWR is revisited in this study.
The observation operator calculates equivalent radar reflectivity factor (Z_e [mm6/m3]) from hydrometeor mass density of each particle categories (W [g/m^2]). The cloud microphysics scheme in SCALE-RM (Tomita et al., 2008) is a 1-moment 6-caterogy scheme. They include 3 categories for precipitation particles, namely, rain, snow, and graupel. The relation between Z_e and each of W is obtained by an offline numerical calculation of Mie scattering and approximated in the form of an exponential function.
$Z_e = \alpha_r \exp(\beta_r) + \alpha_s \exp(\beta s) + \alpha_g \exp(\beta_g)$
Previous studies used values from a literature (Xue et al., 2009) for the coefficients. However, the coefficients used for graupel (α_g and β_g) has been originally calculated using assumptions about the particle size distribution different from those in SCALE-RM. In particular, a multiplicative factor of the particle size distribution of graupel in SCALE-RM is much smaller in their calculation ($N_0 = 3 \times 10^4$ m^{-4}) than that in SCALE-RM ($N_0 = 4 \times 10^6$ m^{-4}). This leads to an underestimation in sensitivity of graupel mass to observed radar reflectivity factor.
The new coefficients for graupel are chosen to be consistent with the SCALE-RM cloud microphysics scheme using the Joint-Simulator developed by Japan Aerospace Exploration Agency (JAXA). The results are $\alpha_g = 5.54 \times 10^3$, $\beta_g = 1.70$, where the original values from the literature are $\alpha_g = 8.18 \times 10^4$, $\beta_g = 1.50$.
The case study of PAWR assimilation on the localized short-duration heavy rain event on July 13, 2013 is performed again using the new coefficients and compared to previous results (Miyoshi et al., 2016, *IEEE*; Miyoshi et al., 2016, *BAMS*).
The results are shown in Fig. 1. With the new set of coefficients in PAWR observation operator, the evolution for the 30-minute forecast period is closer to the observation than that with the original coefficients. The rapidly-growing unrealistic spread of a large reflectivity area are significantly suppressed. The difference is also clear in the vertical profiles of area-averaged graupel mass. The rapid increase of graupel in the middle troposphere in the conventional forecast experiment implies the recovery from the

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imbalance by inconsistency between the observation operator and cloud microphysics scheme. The new coefficients lead to improve hte imbalance and provide physically more consistent analysis fields. To further improve PAWR assimilation, this modification to the observation operator allows us to focus on other factors such as a model error treatment as the next step.

キーワード：データ同化、気象予報、降水レーダー
Keywords: Data Assimilation, Weather forecasting, Precipitation radar



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Data assimilation and forecast experiments for the record-breaking rainfall event in Japan in July 2018 with NICAM-LETKF at 112-km and 28-km resolution

*寺崎 康児[1]、三好 建正[1]
*Koji Terasaki[1], Takemasa Miyoshi[1]

1. 理化学研究所計算科学研究センター
1. RIKEN Center for Computational Science

In July 2018, an active Baiu front caused record-breaking rainfalls and disasters in broad areas in western Japan. This study performs data assimilation and forecast experiments using the NICAM-LETKF system (Terasaki et al. 2015, Terasaki et al. 2017) at 112-km and 28-km resolution with 32 ensemble members. The computational efficiency is essential to run the high-resolution data assimilation cycle. Yashiro et al. (2016) developed a new NICAM-LETKF system to reduce the computational cost of the LETKF part by considering a throughput-aware framework. Data assimilation experiments are performed with conventional observations and advanced microwave sounding unit-A (AMSU-A) satellite radiances for one month starting at 0000 UTC 10 June 2018. Next, forecast experiments are initialized every day at 0000 UTC on 1-5 July 2018. The results show that the 28-km resolution experiment outperforms the 112-km resolution experiment for the location and intensity of the heavy rainfall, although the precipitation amount is significantly underestimated compared with the observation. The locations of the Pacific and Okhotsk highs determine the location of the Baiu front. The 112-km resolution may be too coarse to resolve these phenomena sufficiently.
More than a half of the computational time of the LETKF was occupied by file I/O in the previous NICAM-LETKF system. The new NICAM-LETKF system successfully accelerated by reducing the I/O time to be about 20% of the computational time of the LETKF.

キーワード：データ同化、数値予報、NICAM-LETKF、集中豪雨
Keywords: Data assimilation, Numerical weather prediction, NICAM-LETKF, Heavy rainfall

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Model Parameter Estimation with Data Assimilation Using NICAM-LETKF

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*Shunji Kotsuki[1], Yousuke Sato[2], Koji Terasaki[1], Hasashi Yashiro[1], Hirofumi Tomita[1], Masaki Satoh[3], Takemasa Miyoshi[1]

1. 国立研究開発法人　理化学研究所　計算科学研究センター、2. 名古屋大学大学院　工学研究科、3. 東京大学　大気海洋研究所
1. RIKEN Center for Computational Science, 2. Graduate School of Engineering, Nagoya University, 3. Atmosphere and Ocean Research Institute, the University of Tokyo

This study aims to improve forecasts of numerical weather prediction (NWP) models by optimizing model parameters with data assimilation. Kotsuki et al. (2018a, JGR) succeeded in improving global precipitation forecasts at 112-km-resolution NICAM (Nonhydrostatic ICosahedral Atmospheric Model) by estimating a parameter called B1 of Berry (1967)’s large-scale condensation scheme using satellite-observed precipitation data and the Local Ensemble Transform Kalman Filter (LETKF).

Extending the previous study, this study explores to improve the forecasts further using other satellite observations. This study estimates the parameter B1 as a global-constant parameter with cloud liquid water (CLW) data observed by GCOM-W/AMSR2. The parameter estimation successfully reduces excessive bias in CLW although precipitation forecasts are degraded. In addition, this study extends to estimate spatial distributions of the B1 parameter. The spatially-varying B1 parameter shows the best agreement to the spatial pattern of observed LWP. This presentation will include the most recent progress up to the time of the meeting.

キーワード：モデルパラメータ推定、大規模凝結、アンサンブルカルマンフィルタ、雲水量、放射収支、NICAM-LETKF
Keywords: Model Parameter Estimation, Large Scale Condensation, Ensemble Kalman Filter, Liquid Water Path, Radiation Budget, NICAM-LETKF

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[E] 口頭発表 | セッション記号 A (大気水圏科学)：A-AS 大気科学・気象学・大気環境

2019年5月29日(水) 10:45 ~ 12:15 | 104 1F

[A-AS01] 高性能スーパーコンピュータを用いた最新の大気科学

コンビーナ:瀬古 弘(気象研究所)、三好 建正(理化学研究所)、小玉 知央(独立行政法人海洋研究開発機構)、滝川 雅之(独立行政法人海洋研究開発機構)、座長:滝川 雅之(国立研究開発法人 海洋研究開発機構)、三好 建正(理化学研究所計算科学研究機構)

気象学を含む様々な分野において、「京」コンピュータや地球シミュレータ等の高性能スーパーコンピュータを用いて、最先端のシミュレーション研究が行われている。高性能スーパーコンピュータにより、解像度やアンサンブル数等において従来より桁で上回る計算や、これまでにない高頻度高密度な観測ビッグデータを用いたデータ同化が可能になり、気象学の新たな展開が生まれつつある。また、「京」の後継機であるポスト「京」スーパーコンピュータを稼働させるべく開発が進められており、これに向けた研究もスタートしている。「スパコンによる大気科学」では、2019年大会において、気象・気候・環境科学の最先端のシミュレーション研究をテーマとし、「京」や他のスーパーコンピュータを用いた最新の成果や新たなシミュレーション研究の展開に関する発表を募集する。

10:45 ~ 11:00

[AAS01-07] 3D debris flow simulations by using smoothed particle hydrodynamics (SPH) method

*上田 翔士[1]、細野 七月[2]、山敷 庸亮[1] (1.京都大学、2.JAMSTEC)

11:00 ~ 11:15

[AAS01-08] **Regional atmospheric data assimilation coupled with an ocean mixed layer model: a case of typhoon Soudelor (2015)**

*高玉 孝平[1]、本田 匠[1]、三好 建正[1] (1.理化学研究所)

11:15 ~ 11:30

[AAS01-09] Effective Radiative Forcing and Climate Response to Short-Lived Climate Pollutants Under Different Scenarios

Hua Zhang[1]、*Bing Xie[1]、Zhili Wang[1] (1.China Meteorological Administration)

11:30 ~ 11:45

[AAS01-10] **The NICAM–SPRINTARS simulation of the long-range transport of black carbon using the K computer**

★Invited Papers

*山下 陽介[1]、滝川 雅之[1]、五藤 大輔[2]、八代 尚[3]、佐藤 正樹[4,1]、金谷 有剛[1]、竹谷 文一[1]、宮川 拓真[1] (1.海洋研究開発機構、2.国立環境研究所、3.理研計算科学、4.東京大学大気海洋研究所)

11:45 ~ 12:00

[AAS01-11] High-resolution, ensemble simulations of intense tropical cyclones and their stochasticity during the El Niños of 1997 and 2015

*山田 洋平[1]、小玉 知央[1]、佐藤 正樹[1,2]、中野 満寿男[1]、那須野 智江[1]、杉 正人[3] (1.海洋研究開発機構、2.東京大学大気海洋研究所、3.気象庁気象研究所)

12:00 ~ 12:15

[AAS01-12] **NICAM results of the project DYAMOND for global storm-resolving model intercomparison**

★Invited Papers

*佐藤 正樹[1]、澁谷 亮輔[2]、小玉 知央[2] (1.東京大学大気海洋研究所、2.海洋研究開発機構)

3D debris flow simulations by using smoothed particle hydrodynamics (SPH) method

*上田 翔士[1]、細野 七月[2]、山敷 庸亮[1]
*Shoji Ueta[1], Natsuki Hosono[2], Yosuke Alexandre Yamashiki[1]

1. 京都大学、2. JAMSTEC
1. Kyoto University, 2. JAMSTEC

Yamashiki et al. (2012) and Yamashiki et al. (2013) perform laboratory experiments that represent a debris flow. We use smoothed particle hydrodynamics (SPH), Lagrangian numerical hydrodynamics method, and reproduce the experiments by 2D simulations. We find that water does not erode rock by using same size particles between water and rock, but that water can erode rock by using smaller size water particles than rock particle. We could extend this 2D simulation to 3D one and reproduce more realistic results.
Also, debris flows include not only rock and water but also mud. We developed a 3D SPH code that includes the solid-liquid mutual interaction with fully SPH manner to deal with multiphase flow well. We compare the results of the code with the results of a land slide experiment and some simulations in Igarashi et al. (2012) and find that we can get the results similar to those of experiments. We also try to perform more realistic debris flow simulationsin Hiroshima in 2014’s cases.

キーワード：土石流、SPH
Keywords: debris flow, smoothed particle hydrodynamics

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Regional atmospheric data assimilation coupled with an ocean mixed layer model: a case of typhoon Soudelor (2015)

*高玉 孝平[1]、本田 匠[1]、三好 建正[1]
*Kohei Takatama[1], Takumi Honda[1], Takemasa Miyoshi[1]

1. 理化学研究所
1. RIKEN

This study investigates the effect of atmosphere-ocean coupling in a regional atmospheric data assimilation system for a case of Typhoon Soudelor (2015). A simple ocean mixed layer model, known as the Price-Weller-Pinkel (PWP) model, has been implemented into a regional atmospheric data assimilation system SCALE-LETKF.

The results show that the PWP model produced reasonable sea surface temperature (SST) fields in response to the atmospheric flow, particularly, dropping SST associated with the typhoon’s mixing the ocean upper layers. However, the analyzed track and intensity of the typhoon were not improved by coupling the PWP model. This can be explained by lower SSTs and by smaller ensemble spread of near surface atmospheric temperature. In the atmosphere-ocean coupling system, the stronger a typhoon, the cooler the SSTs via heat releases from the ocean surface and via vertical mixing of the upper ocean. These processes induce negative feedback for the typhoon development, so that the typhoon growth rates are suppressed (enhanced) in ensemble members with strong (weak) typhoon. This results in more similar typhoon intensities among ensemble members. Therefore, the coupled system reduces the ensemble spreads in the atmospheric fields associated with typhoon. The presentation will include the most up-to-date results at the time of the conference.

キーワード：データ同化、台風、大気海洋相互作用
Keywords: Data Assimilation, Typhoon, Air-Sea Interaction

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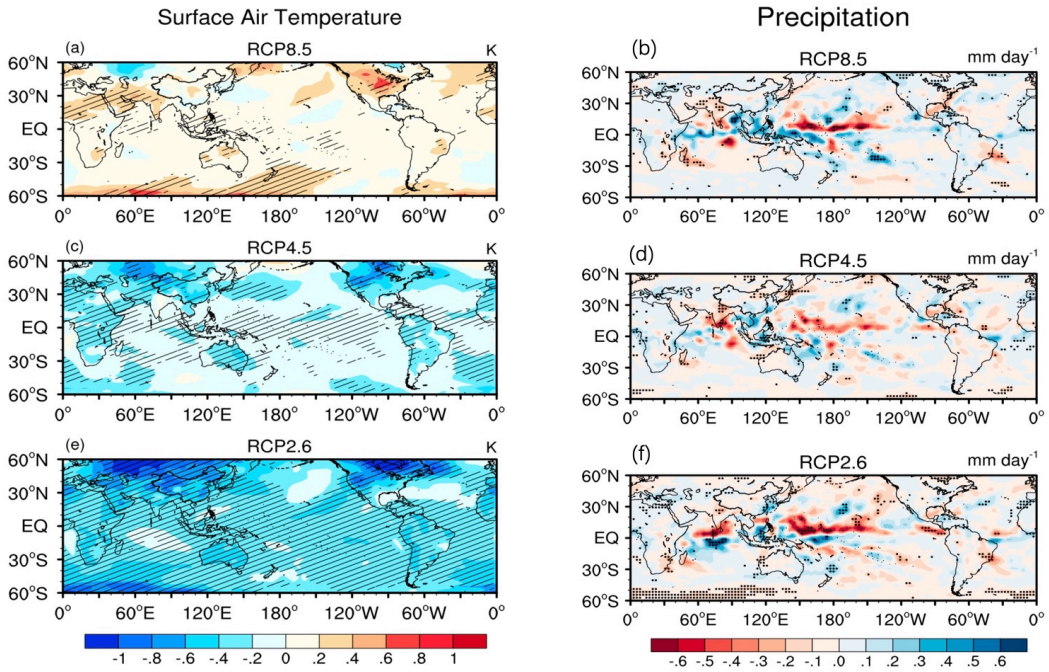
Effective Radiative Forcing and Climate Response to Short-Lived Climate Pollutants Under Different Scenarios

Hua Zhang[1], *Bing Xie[1], Zhili Wang[1]

1. China Meteorological Administration

We used an online aerosol-climate model (BCC_AGCM2.0_CUACE/Aero) to simulate effective radiative forcing and climate response to changes in the concentrations of short-lived climatic pollutants (SLCPs), including methane, tropospheric ozone, and black carbon, for the period 2010–2050 under Representative Concentration Pathway scenarios (RCPs) 8.5, 4.5, and 2.6. Under these three scenarios, the global annual mean effective radiative forcing were 0.1, 0.3, and 0.5 W m^{-2}, respectively. Under RCP 8.5, the change in SLCPs caused significant increases in surface air temperature (SAT) in middle and high latitudes of the Northern Hemisphere and significant decreases in precipitation in the Indian Peninsula and equatorial Pacific. Global mean SAT and precipitation increased by 0.13 K and 0.02 mm d^{-1}, respectively. The reduction in SLCPs from 2010 to 2050 under RCPs 4.5 and 2.6 led to significant decreases in SAT at high latitudes in the Northern Hemisphere. Precipitation increased slightly in most continental regions, and the Intertropical Convergence Zone moved southward under both of these mitigation scenarios. Global mean SAT decreased by 0.20 and 0.44 K, and global averaged precipitation decreased by 0.02 and 0.03 mm d^{-1}under RCPs 4.5 and 2.6, respectively.

Keywords: SLCP/SLCF, ERF, Climate response



The spatial distribution of (left column) surface air temperature and (right column) precipitation resulting from changes of SLCPs, from 2010 to 2050, in (a and b) Representative Concentration Pathway 8.5 (RCP8.5), (c and d) RCP4.5, and (e and f) RCP2.6. The areas with “・” and “/” passed the 95% significance test.

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The NICAM-SPRINTARS simulation of the long-range transport of black carbon using the K computer

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*Yousuke Yamashita[1], Masayuki Takigawa[1], Daisuke Goto[2], Hisashi Yashiro[3], Masaki Satoh[4,1], Yugo Kanaya[1], Fumikazu Taketani[1], Takuma Miyakawa[1]

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1. Japan Agency for Marine-Earth Science and Technology, 2. National Institute for Environmental Studies, 3. RIKEN Advanced Institute for Computational Science (AICS), 4. Atmosphere and Ocean Research Institute, The University of Tokyo

The Nonhydrostatic Icosahedral Atmospheric Model (NICAM)-SPRINTARS is the global aerosol transport model, which has been developed to calculate global aerosol transport and its influences on radiation and precipitation incorporated with the NICAM. The latest model is developed to include the forest fire emission with daily time-scales and has fine horizontal resolution with 56 km, which is capable of simulating fine scales transport processes of aerosols such as the accumulation of black carbon (BC) behind the cold front, and the wetdeposition process around the low-pressure system.
The large and continuous forest fire emission occurred around Lake Baikal of Siberia in September 2016. The observation of BC was performed from August to October by observational cruise of R/V Mirai (MR16-06) possessed by Japan Agency for Marine-Earth Science and Technology (JAMSTEC), and the maximum BC concentration was detected in 25-26 September around Aleutian Islands. These results imply the long-range transport of BC from Lake Baikal to Aleutian Islands, however, possibility of detection of anthropogenic BC emitted in Asia is not ruled out.
To analyze the origin and transport pathway of observed BC by R/V Mirai observation, we performed the experiments of the NICAM-SPRINTARS with anthropogenic and forest fire emission (Ant+Fire simulation) using the K computer. To estimate anthropogenic BC impact, the simulation without fire emission was performed (Ant simulation). Without fire emission, the BC concentration in 25-26 September is much smaller than observation, indicating small impact of anthropogenic BC on this event. In this event the BC is trapped behind the cold front and beyond the warm front to indicate high concentration peak (about 300 ng/m^3) of surface BC with sharp temporal change. This high concentration event is well simulated by the latest 56-km model, however, the low horizontal resolution experiments about 220-km show relatively low concentration peak (about 100-150 ng/m^3) with roughly temporal change.
We also estimate the BC transport to Arctic. The 56-km model simulation with Siberian forest fire emission (Ant+FireSb simulation) indicates a larger increase in Arctic column BC from 22 to 27 September than the Ant simulation, however, the 220-km model simulations indicate no significant difference of the Arctic column BC level to the Ant simulation.
These results indicate that one noticeable impact of latest model development is achieved by replacing the model's horizontal resolution being 56-km, which is capable of simulating the fine structure of long-range BC transport to impact on the low human activity area such as Arctic and ocean.

キーワード：黒色炭素、エアロゾル輸送モデル、「京」コンピューター
Keywords: black carbon, aerosol transport model, K computer

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High-resolution, ensemble simulations of intense tropical cyclones and their stochasticity during the El Niños of 1997 and 2015

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*Yohei Yamada[1], Chihiro Kodama[1], Masaki Satoh[1,2], Masuo Nakano[1], Tomoe Nasuno[1], Masato Sugi[3]

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1. Japan Agency for Marine-Earth Science and Technology, 2. Atmosphere and Ocean Research Institute, The university of Tokyo, 3. Meteorological Research Institute, Japan Meteorological Agency

Extreme El Niño events affect the number of intense tropical cyclones (ITCs) over the western North Pacific (e.g., Camargo and Sobel, 2005; Chan 2007). Extreme El Niño events were observed in 1997 and 2015. In the both years, the number of ITC were above normal in the western North Pacific. In order to clarify how, and to what extent, sea surface temperature (SST) anomaly distributions control the ITCs genesis, we conducted 50-member ensemble simulations for boreal summer in 1997 and 2015 using a global nonhydrostatic model called NICAM (Satoh et al. 2014) with a horizontal grid interval of 14 km. Clouds were explicitly calculated using a single-moment bulk microphysics scheme without cumulus convection scheme. The sea surface temperature was nudged toward observed SST data using a slab ocean model.
We found no robust control of ITCs by a prescribed SST distribution. These simulations showed that, even if the same SST was used as the boundary condition for each ensemble simulation, the number of ITCs varied substantially among members. This means that uncertainty remains large for seasonal forecasts of ITC activity. However, the ensemble simulations showed a clear relationship between the number of ITCs and their genesis locations in the western North Pacific. We compared environmental conditions between ensemble members. We found that the simulated numbers of ITCs in the western North Pacific were also closely related to the strength of the monsoon trough, which stochastically varies under given SST conditions. This indicates that reliable seasonal forecasting of ITCs depends on our ability to accurately reproduce the monsoon trough, whose strength is modulated mainly by internal atmospheric variability as well as SST.

キーワード：強い台風、モンスーントラフ、エルニーニョ、高解像度全球非静力学モデル、アンサンブルシミュレーション
Keywords: intense tropical cyclone, monsoon trough, El Niño, high resolution global nonhydrostatic model, ensemble simulation

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NICAM results of the project DYAMOND for global storm-resolving model intercomparison

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*Masaki Satoh[1], Ryosuke Shibuya[2], Chihiro Kodama[2]

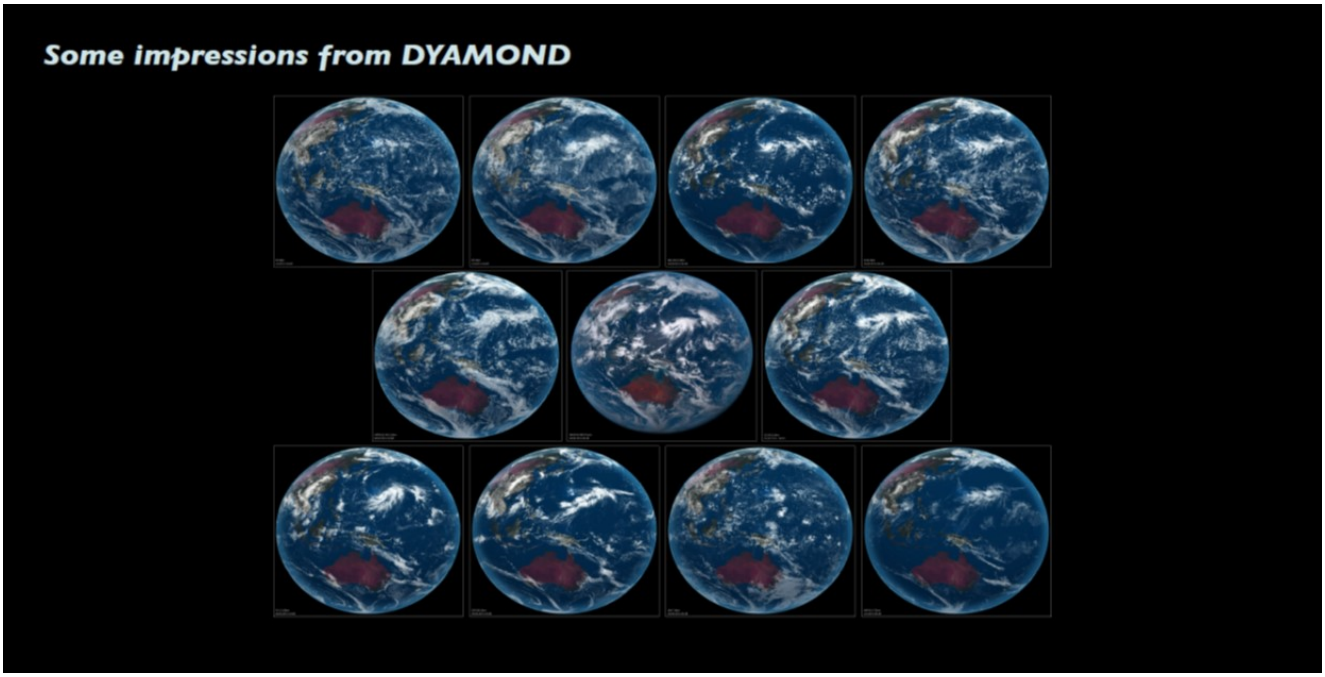
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Project DYAMOND (DYnamics of the Atmospheric general circulation Modeled On Non-hydrostatic Domains; https://www.esiwace.eu/services/dyamond) describes a framework for the intercomparison of an emerging class of atmospheric circulations model that, through their resolution of the major modes of atmospheric heat transport, endeavor to represent the most important scales of the full three-dimensional fluid dynamics of the atmospheric circulation.

Nine models submitted simulations of the forty day intercomparison period. Eight of these employed a tiling of the sphere that was uniformly less than 5km. At these scales vertical accelerations that are non-hydrostatic become important, and convective storms in the tropics can be resolved by the underlying equations of motion. The models and some basic characteristics of their output are described in more detail, as is the availability and planned use of this output for future scientific study.

In this presentation, I will show some results of the DYAMOND simulations with NICAM and current status of DYAMOND with a list of possible participants, together with diagnostics considered.

キーワード：全球非静力学モデル、NICAM、DYAMOND、全球ストーム解像モデル
Keywords: Global nonhydrostatic model, NICAM, DYAMOND, global storm-resolving model



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[E] 口頭発表 | セッション記号 A (大気水圏科学)：A-OS 海洋科学・海洋環境

2019年5月29日(水) 13:45 ~ 15:15 | 105 1F

[A-OS08] ECS-Kuroshio and Ryukyu Current System -Observation, modeling and theory-

コンビーナ:中村 啓彦(鹿児島大学　水産学部)、Xiao-Hua Zhu(Second Institute of Oceanography)、座長:中村 啓彦(鹿児島大学)、Jae-Hun Park(Inha University)

The East China Sea (ECS) is separated from the North Pacific basin by the Ryukyu Islands. On each side of the Ryukyu Islands, there lies two western boundary currents -the Kuroshio on the northwest and the Ryukyu Current on the southeast. These two currents play an important role in the global substance cycle and have a remarkable impact on the climate and adjacent marginal seas. Our knowledge of the Kuroshio and the Ryukyu Current's dynamics, variability, and impact has advanced significantly over the last decade, because of recent international collaborative field programs, improvement in satellite measurements, and advancement in high-resolution numerical models. This session seeks contributions from ECS-Kuroshio and Ryukyu Current studies and will cover a wide range of topics of observation, modeling and theory. The dynamics of the Kuroshio and the Ryukyu Current's variability at all spatio-temporal scales, the influence of the Kuroshio on typhoons and climate, the interactions among the Kuroshio, Ryukyu Current and eddies, internal waves including near-internal waves and their interactions with background currents, and the water mass exchanges through the gaps between the Ryukyu Islands are welcome to be discussed in this session.

13:45 ~ 13:50

Introduction

13:50 ~ 14:10

[AOS08-01] Downstream Evolution of the Kuroshio Velocity Structure and Transport

★Invited Papers

*Magdalena Andres[1]、Sen Jan[2] (1.Woods Hole Oceanographic Institution、2.National Taiwan University)

14:10 ~ 14:25

[AOS08-02] **Non-seasonal variability of the Kuroshio shelf intrusion and its associated changes in the ocean environment over the East China Sea during 1993-2017**

*Jiwon Kang[1]、Hanna Na[1] (1.School of Earth and Environmental Sciences, Seoul National University, Republic of Korea)

14:25 ~ 14:40

[AOS08-03] The temporal and spatial variability of the Kuroshio in the East China Sea and its associated mechanisms

*Yanzhou Wei[1] (1.State Key Laboratory of Satellite Ocean Environment Dynamics, Second Institute of Oceanography, Ministry of Natural Resources, Hangzhou, China)

14:40 ~ 14:55

[AOS08-04] The Joint Kuroshio–Ryukyu Current System Study and a rapid report about mooring observations southeast of Miyakojima

*Xiao-Hua Zhu[1]、Hirohiko Nakamura[2]、Jae-Hun Park[3]、Ruixiang Zhao[1]、Ayako Nishina[2]、Chuanzheng Zhang[1]、Chanhyung Jeon[4]、Hanna Na[5]、Ze-Nan Zhu[1]、Hong Sik Min[6] (1.State Key Laboratory of Satellite Ocean Environment Dynamics, Second Institute of Oceanography, Ministry of Natural Resources, Hangzhou, China、2.Faculty of Fisheries, Kagoshima University, Kagoshima, Japan、3.Department of Ocean Sciences, Inha University, Incheon, South Korea、4.Department of Marine Science and Biological Engineering, Inha University, Incheon, Korea、5.School of Earth and Environmental Sciences, Seoul National University, Seoul, Korea、6.Ocean Circulation and Climate Research Center, Korea Institute of Ocean Science and Technology, Busan, Korea)

14:55 ~ 15:10

[AOS08-05] Relationship of the Kuroshio with the current fields in the East China Sea from observations and model results

*Hong Sik Min[1]、Chorong Hwang[1]、Dong Guk Kim[1]、Hirohiko Nakamura[2]、Ayako Nishina[2]、Xiao-Hua Zhu[3]、Jae-Hun Park[4]、Chanhyung Jeon[4]、Hanna Na[5]、Naoki Hirose[6] (1.Korea Institute of Ocean Science & Technology、2.Kagoshima University、3.Second Institute of Oceanography、4.Inha University、5.Seoul National University、6.Kyushu University)

15:10 ~ 15:15

Discussion

Downstream Evolution of the Kuroshio Velocity Structure and Transport

*Magdalena Andres[1], Sen Jan[2]

1. Woods Hole Oceanographic Institution, 2. National Taiwan University

The Kuroshio flows along the North Pacific western boundary carrying heat, mass and momentum poleward. Along this route, the Kuroshio’ s strength and vertical structure undergo significant temporal and spatial variability. Recent observational studies have examined the Kuroshio between Luzon and Taiwan, just before the Kuroshio flows into the East China Sea and upstream of the beginning of the Ryukyu Current (a subsurface-intensified current that carries part of the total poleward western boundary current flow). These observations were part of the recent US Origins of the Kuroshio and Mindanao Currents (OKMC) and Taiwan Observations of Kuroshio Transport Variability (OKTV) and Study of the Kuroshio II (SK-II) observational programs. These studies, together with previous observational efforts, build a comprehensive picture of the Kuroshio on its route from its origins near Luzon to southeastern Japan, where the current finally transitions from a western boundary current into the Kuroshio Extension, a vigorously meandering free jet. Through the joint OKMC/OKTV efforts, Kuroshio strength and velocity structure were measured between June 2012 and November 2014 with pressure-sensor equipped inverted echo sounders (PIESs) and upward- looking acoustic Doppler current profilers (ADCPs) deployed across the current northeast of Luzon, Philippines, and east of Taiwan with an 8 month overlap in the two arrays’ deployment periods. The time-mean net (i.e., integrated from the surface to the bottom) absolute transport increases downstream and the observed downstream increase is consistent with the return flow predicted by the simple Sverdrup relation and the mean wind stress curl field over the North Pacific (despite the complicated bathymetry and gaps along the North Pacific western boundary). Northeast of Luzon, the Kuroshio is shallower than 750 dbar, while east of Taiwan areas of positive flow reach to the seafloor (3000 m). A similar deepening of the subtropical western boundary current is observed in the North Atlantic in the region where the Gulf Stream leaves Cape Hatteras. In addition, there is a deep counterflow beneath the poleward-flowing Kuroshio. Time-varying transports and velocities indicate the strong influence at both sections of westward propagating eddies from the ocean interior. Topography associated with the ridges east of Taiwan also influences the mean and time-varying velocity structure there. By comparison, in the North Atlantic there is also a deep counterflow beneath the Gulf Stream at Cape Hatteras, however, this is likely due to different processes than those at play in the North Pacific, due to the presence of the Deep Western Boundary Current there which carries equatorward flow in the Atlantic Meridional Overturning Circulation (AMOC) cold limb flow.

Keywords: Kuroshio, mesoscale eddies, PIES, ADCP

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Non-seasonal variability of the Kuroshio shelf intrusion and its associated changes in the ocean environment over the East China Sea during 1993-2017

*Jiwon Kang[1], Hanna Na[1]

1. School of Earth and Environmental Sciences, Seoul National University, Republic of Korea

The Kuroshio in the East China Sea (ECS) exhibits strong variability over the northeast of Taiwan; weakening of the Kuroshio has been understood to be associated with shelf-ward shift of the Kuroshio axis, which induces shelf intrusion of the Kuroshio water. The Kuroshio intrusion plays an important role for understanding the characteristics of water masses over the shelf region that, in turn, influences ocean environment in the marginal seas. In this study, non-seasonal variability of the intrusion, which was reported to be more significant in comparison with its seasonal variability, is examined during 1993-2017.

The Kuroshio intrusion index was defined based on the Empirical Orthogonal Function analysis of satellite-altimetry-derived geostrophic velocity data. The composite analysis of oceanic and atmospheric variables according to the intrusion index reveals that strong Kuroshio intrusion is associated with increase of sea surface temperature and eddy kinetic energy, strengthening of northwesterly wind and upward surface heat flux in the continental shelf region. The strong Kuroshio intrusion would also be related to sub-mesoscale eddy variability inside the ECS, and its relationship is discussed by examining surface drifter data over the region.

Keywords: Kuroshio, shelf intrusion, East China Sea, sub-mesoscale eddy

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The temporal and spatial variability of the Kuroshio in the East China Sea and its associated mechanisms

*Yanzhou Wei[1]

1. State Key Laboratory of Satellite Ocean Environment Dynamics, Second Institute of Oceanography, Ministry of Natural Resources, Hangzhou, China

The Kuroshio is a strong western boundary current of the North Pacific subtropical gyre. It transports huge amounts of heat and nutrients poleward, and has a profound effect on the hydrography, fisheries, and climate of countries surrounding the Northwestern Pacific. As such, the temporal and spatial variability of the Kuroshio on multiple scales is of wide interest to the oceanographic and climate communities. In this study, we examine the temporal and spatial variability of the Kuroshio based on long term hydrographic observation and satellite data, and discuss the associated mechanisms.

Keywords: Kuroshio, East China Sea

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The Joint Kuroshio–Ryukyu Current System Study and a rapid report about mooring observations southeast of Miyakojima

*Xiao-Hua Zhu[1], Hirohiko Nakamura[2], Jae-Hun Park[3], Ruixiang Zhao[1], Ayako Nishina[2], Chuanzheng Zhang[1], Chanhyung Jeon[4], Hanna Na[5], Ze-Nan Zhu[1], Hong Sik Min[6]

1. State Key Laboratory of Satellite Ocean Environment Dynamics, Second Institute of Oceanography, Ministry of Natural Resources, Hangzhou, China, 2. Faculty of Fisheries, Kagoshima University, Kagoshima, Japan, 3. Department of Ocean Sciences, Inha University, Incheon, South Korea, 4. Department of Marine Science and Biological Engineering, Inha University, Incheon, Korea, 5. School of Earth and Environmental Sciences, Seoul National University, Seoul, Korea, 6. Ocean Circulation and Climate Research Center, Korea Institute of Ocean Science and Technology, Busan, Korea

From June 2015 to June 2017, an international cooperative research project called “Joint Kuroshio-Ryukyu Current System Study” (JKRYCSS) was conducted by scientists from Japan, China, and South Korea. Tall moorings with current meters (CMs) and upward-looking acoustic Doppler current profilers (ADCPs), and current and pressure-recording inverted echo sounders (CPIESs) were deployed on northwestern and southeastern sides of Miyakojima Island to observe the Kuroshio and the Ryukyu Current, simultaneously. These mooring sites lay along the altimeter track used by TOPEX/Poseidon and Jason-1/2/3, which is roughly perpendicular to the isobath of the continental shelf break.

In this talk, we will illustrate the velocity structure and variability of the Ryukyu Current by analyzing the 2-year record from a mooring array southeast of Miyakojima Island. The results showed that the shoreward intensified currents flowed northeastward. The subsurface core of the Ryukyu Current was located near the 1000 m isobath, with a maximum of 19.4 cm/s at 500 m. The observed velocity structure was reproduced well by the HYCOM reanalysis, except that the observed current core was stronger and shallower. The mean estimated volume transport across the observation section was 9.0 Sv with a standard deviation of 8.7 Sv, with a near 100-day variability dominant in the upper layer but absent in the deep layer.

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Relationship of the Kuroshio with the current fields in the East China Sea from observations and model results

*Hong Sik Min[1], Chorong Hwang[1], Dong Guk Kim[1], Hirohiko Nakamura[2], Ayako Nishina[2], Xiao-Hua Zhu[3], Jae-Hun Park[4], Chanhyung Jeon[4], Hanna Na[5], Naoki Hirose[6]

1. Korea Institute of Ocean Science & Technology, 2. Kagoshima University, 3. Second Institute of Oceanography, 4. Inha University, 5. Seoul National University, 6. Kyushu University

We investigated relationship between variations of the Kuroshio in the southern East China Sea (ECS) and the current structure across the Korea/Tsushima Strait (KTS) using observational data and numerical simulation results. Variability of the Kuroshio in the southern ECS was obtained from moored current measurements located near the Kuroshio axis for 2 years (June 2015-June 2017), while current pattern across the KTS was obtained from acoustic Doppler current profiler (ADCP) measurements by a ferryboat between Hakata and Pusan. Comparisons between the two time series of observations reveal a significant relationship : when the Kuroshio in the southern ECS was strengthened the current in the western channel of KTS was also strengthened with a shift of the Tsushima Current (TC) to the coast. This correlated feature was also seen in the data-assimilated HYCOM, confirming that the HYCOM can reasonably reproduce the current field in the ECS. Further investigations using 25-year-long HYCOM outputs exhibit that the Kuroshio can vary the TC in the KTS. This presentation will show the connectivity of current fields in the northern ECS to the Kuroshio in the southern ECS.

Keywords: Kuroshio, East China Sea, observation

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[E] 口頭発表 | セッション記号 A (大気水圏科学)：A-OS 海洋科学・海洋環境

2019年5月29日(水) 15:30 ~ 17:00 | 105 1F

[A-OS08] ECS-Kuroshio and Ryukyu Current System -Observation, modeling and theory-

コンビーナ:中村 啓彦(鹿児島大学　水産学部)、Xiao-Hua Zhu(Second Institute of Oceanography)、座長:Jae-Hun Park(Inha University)、中村 啓彦(鹿児島大学)

The East China Sea (ECS) is separated from the North Pacific basin by the Ryukyu Islands. On each side of the Ryukyu Islands, there lies two western boundary currents -the Kuroshio on the northwest and the Ryukyu Current on the southeast. These two currents play an important role in the global substance cycle and have a remarkable impact on the climate and adjacent marginal seas. Our knowledge of the Kuroshio and the Ryukyu Current's dynamics, variability, and impact has advanced significantly over the last decade, because of recent international collaborative field programs, improvement in satellite measurements, and advancement in high-resolution numerical models. This session seeks contributions from ECS-Kuroshio and Ryukyu Current studies and will cover a wide range of topics of observation, modeling and theory. The dynamics of the Kuroshio and the Ryukyu Current's variability at all spatio-temporal scales, the influence of the Kuroshio on typhoons and climate, the interactions among the Kuroshio, Ryukyu Current and eddies, internal waves including near-internal waves and their interactions with background currents, and the water mass exchanges through the gaps between the Ryukyu Islands are welcome to be discussed in this session.

15:30 ~ 15:35

Introduction

15:35 ~ 15:55

[AOS08-06] Separating Small-Scale Oceanic Internal Waves and Vortical Motions

★Invited Papers

*Ren-Chieh Lien[1] (1.University of Washington, Seattle, WA, USA)

15:55 ~ 16:10

[AOS08-07] Structure and variability of the Kuroshio current in the Tokara Strait

*劉 昭君[1]、中村 啓彦[2]、朱 小華[1]、仁科 文子[2]、郭 新宇[3]、Menghong Dong[1] (1.Second Institute of Oceanography, China、2.Kagoshima University, Japan、3.Ehime University, Japan)

16:10 ~ 16:25

[AOS08-08] **Near-inertial waves advected by the Kuroshio from observation and simulation**

*CHANHYUNG JEON[1]、Jae-Hun Park[1]、Hirohiko Nakamura[2]、Ayako Nishina[2]、Xiao-Hua Zhu[3]、Dong Guk Kim[4]、Hong Sik Min[4]、Sok Kuh Kang[4]、Hanna Na[5]、Naoki Hirose[6]、Youngseok Choi[1] (1.Inha University、2.Kagoshima University、3.Second Institute of Oceanography、4.Korea Institute of Ocean Science and Technology、5.Seoul National University、6.Kyushu University)

16:25 ~ 16:40

[AOS08-09] Turbulent mixing and near-inertial internal waves induced by the Kuroshio over seamounts in the Tokara Strait

*長井 健容[1]、長谷川 大介[2]、堤 英輔[3]、中村 啓彦[4]、仁科 文子[4]、千手 智晴[3]、遠藤 貴洋[3]、松野 健[3]、井上 龍一郎[5]、Amit Tandon[6] (1.東京海洋大学 海洋環境科学部門、2.東北区水産研究所・国立研究開発法人水産研究・教育機構、3.九州大学応用力学研究所、4.鹿児島大学　水産学部、5.海洋研究開発機構、6.マサチューセッツ大学ダートマス校)

16:40 ~ 16:55

[AOS08-10] Microstructure and mooring observations of enhanced mixing in the Kerama Gap

*井上 龍一郎[1]、中村 啓彦[2]、田中 雄大[3]、藤尾 伸三[4]、柳本 大吾[4]、安田 一郎[4] (1.国立研究開発法人海洋研究開発機構 、2.鹿児島大学水産学部、3.国立研究開発法人水産研究・教育機構東北区水産研究所 、4.東京大学大気海洋研究所)

16:55 ~ 17:00
Discussion

Separating Small-Scale Oceanic Internal Waves and Vortical Motions

*Ren-Chieh Lien[1]

1. University of Washington, Seattle, WA, USA

Internal waves and vortical motions coexist in the ocean, sometimes at same temporal and spatial scales. Observations taken by 20 EM-APEX floats in the upper ocean thermocline of the summer Sargasso Sea capture the temporal and vertical variations of Ertel potential vorticity (PV) in 7–70 m vertical scale, averaged over horizontal scales of *O*(4–8 km). PV is dominated by its linear components —vertical vorticity and vortex stretching, each with rms value of ~0.15 *f*. In the internal wave frequency band, they are coherent and in phase, expected for linear internal waves. Packets of strong vertical vorticity and vortex stretching, > 0.2 *f*, balance each other closely such that the rms PV ~0.03 *f*. PV is dominant at frequencies less than 1.4 *f* and peaks at vertical wavenumber *<~0.1* cpm , our highest resolvable vertical wavenumber. PV frequency spectrum plateaus at subinertial frequencies and has a −1 spectral slope in the internal wave frequencies with a small peak at inertial frequency. The PV at near-inertial frequency is likely attributed to the differential advection of background PV by near inertial waves. Measurement errors might also contribute to PV in the internal wave frequency band. Vertical vorticity and vortex stretching are separated into linear vortical mode and internal wave components following the normal mode decomposition. The theoretical prediction of a negative correlation between vertical vorticity and vortex stretching for the linear vortical mode, i.e., reinforcing PV, is confirmed at subinertial frequencies. The Burger number of the vortical mode is ~0.84, implying HKE/APE of ~0.7. The vortical mode frequency and vertical wavenumber spectra are 1-2 decades less than internal wave components. A joint experiment will be conducted in Tokara Strait in the next 3 years to study Kuroshio interaction with seamounts in Tokara Strait. We will discuss the importance of separating internal lee waves and vortical motions behind the seamount on quantifying turbulence mixing and watermass transformation.

Keywords: Internal Lee Waves, Vortical Motions, Turbulence, Kuroshio, Tokara Strait

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Structure and variability of the Kuroshio current in the Tokara Strait

Structure and variability of the Kuroshio current in the Tokara Strait

*劉 昭君[1]、中村 啓彦[2]、朱 小華[1]、仁科 文子[2]、郭 新宇[3]、Menghong Dong[1]
*Zhao-Jun Liu[1], Hirohiko Nakamura[2], Xiao-Hua Zhu[1], Ayako Nishina[2], Xinyu Guo[3], Menghong Dong[1]

1. Second Institute of Oceanography, China、2. Kagoshima University, Japan、3. Ehime University, Japan
1. Second Institute of Oceanography, China, 2. Kagoshima University, Japan, 3. Ehime University, Japan

Transverse-vertical structure and temporal variability of the Kuroshio current across the Tokara Strait during 2003–2012 measured by ferryboat acoustic Doppler current profiler (ADCP) with a 2-km horizontal resolution and a 2-day interval are presented. The Kuroshio passing through the Tokara Strait exhibits a nearly permanent multicore velocity structure. The mean eastward Kuroshio transport is 25.84 Sv (1 Sv ≡10^6 m^3 s^{-1}) and the net baroclinic transport relative to 700 m is 19.57 Sv. The seasonal variation of the Kuroshio transport via the Tokara Strait is a “W”-shaped curve with a maximum in July and a second maximum in December–January. The baroclinic transport shows seasonal variation similar to that of the undecomposed transport, with a maximum in July. However, the barotropic transport displays a reversed seasonal variation—a “V”-shaped distribution—with a maximum in December. In the empirical orthogonal function (EOF) analyses of the cross-sectional velocity, with the exception of the well-known meander (EOF1: 41.1%) and transport (EOF2: 26.3%) modes, the third mode (EOF3: 19.2%) is first observed. The EOF3 mode exhibits a band-like structure, with a smaller horizontal scale than the first two EOF modes; such a band-like structure may be related to the wakes in the lee of the Tokara Islands. Additional analysis based on high-resolution JCOPE-T reanalysis data revealed that (1) many vortexes were generated around the Tokara Strait due to the strong flow-topography interaction; (2) the intensities of the island-induced wakes depend on the Kuroshio path position around the Tokara Strait.

キーワード：Tempo-spatial variations、Kuroshio、Tokara Strait
Keywords: Tempo-spatial variations, Kuroshio, Tokara Strait

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Near-inertial waves advected by the Kuroshio from observation and simulation

*CHANHYUNG JEON[1], Jae-Hun Park[1], Hirohiko Nakamura[2], Ayako Nishina[2], Xiao-Hua Zhu[3], Dong Guk Kim[4], Hong Sik Min[4], Sok Kuh Kang[4], Hanna Na[5], Naoki Hirose[6], Youngseok Choi[1]

1. Inha University, 2. Kagoshima University, 3. Second Institute of Oceanography, 4. Korea Institute of Ocean Science and Technology, 5. Seoul National University, 6. Kyushu University

Advection of near-inertial waves (NIWs) by background currents has been predicted using numerical simulations, while supporting in-situ observations were rare. A pair of tall current moorings, deployed around 26˚N and 125˚E in Okinawa Trough from June 2015 to June 2016, provides a clear evidence exhibiting NIWs advected by the Kuroshio. Energetic NIWs are observed after two-typhoon passages in early August and late September 2015. Both typhoon passages occurred across the Kuroshio east of Taiwan upstream of the observation sites about 250-km southwest with a difference of about 2-degree in latitude. One site (KCM1), relatively close to the center of the Kuroshio axis, exhibits more energetic NIWs than near the edge of the Kuroshio (KCM2), ~32 km away from KCM1. The frequency of NIWs shifts to the lower band from the local inertial frequency (0.91*f*), inferring propagation from the south. The data-assimilative three-dimensional numerical model forced by 6-hourly atmospheric forcings including tides and oceanic circulation demonstrates local NIW generation is weak at observation sites during and after typhoon passages, while its generation upstream of observation sites is quite energetic. Current patterns and frequency shifts of NIWs between observation and simulation agree well at observation sites. Analyses of simulation provide that negative relative vorticity region works like a waveguide for NIW propagation, and the strong Kuroshio current advects the waves poleward with a speed ~85% of the local current.

Keywords: Near-inertial waves, Advection, Kuroshio, observation, simulation

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Turbulent mixing and near-inertial internal waves induced by the Kuroshio over seamounts in the Tokara Strait

*長井 健容[1]、長谷川 大介[2]、堤 英輔[3]、中村 啓彦[4]、仁科 文子[4]、千手 智晴[3]、遠藤 貴洋[3]、松野 健[3]、井上 龍一郎[5]、Amit Tandon[6]
*Takeyoshi Nagai[1], Daisuke Hasegawa[2], Eisuke Tsutsumi[3], Hirohiko Nakamura[4], Ayako Nishina[4], Tomoharu Senjyu[3], Takahiro Endoh[3], Takeshi Matsuno[3], Ryuichiro Inoue[5], Amit Tandon[6]

1. 東京海洋大学 海洋環境科学部門、2. 東北区水産研究所・国立研究開発法人水産研究・教育機構、3. 九州大学応用力学研究所、4. 鹿児島大学　水産学部、5. 海洋研究開発機構、6. マサチューセッツ大学ダートマス校
1. Department of Ocean Sciences, Tokyo University of Marine Science and Technology, 2. Tohoku National Fisheries Research Institute, Japan Fisheries Research and Education Agency, 3. Kyushu University, Research Institute for Applied Mechanics, 4. Faculty of Fisheries Kagoshima University, 5. Ocean Circulation Research Group, Japan Agency for Marine-Earth Science and Technology, 6. Mechanical Engineering Department & SMAST, University of Massachusetts Dartmouth

Recent observations in the upstream side of the Tokara Strait during November 2016, where the Kuroshio south of Kyushu flows over a number of seamounts, show banded structures of large amplitude high vertical wavenumber shear roughly along isopycnal, which are suggestive of near-inertial internal waves. The measured vertical section of laterally high resolution (~1 km) tow-yo microstructure measurements show the banded layers of large turbulent kinetic energy dissipation rates clearly associated with the near inertial shear banding. In this study, the results from the similar tow-yo microstructure surveys during November 2017 and June 2018 cruise, which are extended further downstream side of the Tokara Strait in the Kuroshio are analyzed. It is found that the high vertical wavenumber near-inertial shear is amplified near the seamounts in the Kuroshio, and that turbulent kinetic energy dissipation rates are elevated near the seamounts over 100 km along the Kuroshio axis by a factor of 100-1000. This length scale, over 100 km, is much larger than that of the hydraulically controlled isopycnal displacements with large Froude number in close proximity to the seamounts ~5km. In the presentation, mechanisms of the amplified near-inertial shear and elevated turbulence over such a wide length scale are discussed with the results from June 2018 cruise and using numerical simulations with and without tide.

キーワード：黒潮、近慣性内部波、乱流
Keywords: Kuroshio, Near-inertial internal waves, Turbulence

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Microstructure and mooring observations of enhanced mixing in the Kerama Gap

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*Ryuichiro Inoue[1], Hirohiko Nakamura[2], Takahiro Tanaka[3], Shinzou Fujio[4], Daigo Yanagimoto[4], Ichiro Yasuda[4]

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1. Japan Agency for Marine-Earth Science and Technology, 2. Kagoshima University, Faculy of Fisheries, 3. Tohoku National Fisheries Research Institute, Japan Fisheries Research and Education Agency, 4. The University of Tokyo, Atmosphere and Ocean Research Institute

Microstructure and mooring observations were conducted around the Kerama Gap, near the midpoint of the Ryukyu Island chain, in December 2016. We observed the enhanced mixing near the topography, with vertical diffusivities of 10^{-2}~10^{-1} m^2 s^{-1} and found that tides are important to drive the enhanced mixing at the sill. To understand tidal processes, we conducted two-dimensional numerical simulations. The numerical simulation indicated that hydraulic jump or lee wave breaking are important for the enhanced mixing behind the sill. It also indicated that there are interferences between M2 internal tides radiated from entrance and exit of the Kerama Gap, which may correspond to observed enhanced vertical shear and mixing at a bottom of the North Pacific Intermediate Water in the Kerama Gap. These results suggest that enhanced mixing around Kerama Gap is important for ventilating deep water as well as renewal of the North Pacific Intermediate Water in the Okinawa Trough.

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[E] 口頭発表 | セッション記号 A (大気水圏科学)：A-OS 海洋科学・海洋環境

2019年5月29日(水) 9:00 ~ 10:30 | 301A 3F

[A-OS11] 陸域海洋相互作用-惑星スケール物質循環

コンビーナ:山敷 庸亮(京都大学大学院総合生存学館)、升本 順夫(東京大学大学院理学系研究科)、Behera Swadhin(Climate Variation Predictability and Applicability Research Group, Application Laboratory, JAMSTEC, 3173-25 Showa-machi, Yokohama 236-0001)、佐々木 貴教(京都大学 大学院理学研究科 宇宙物理学教室)、座長:升本 順夫、Swadhin Behera(海洋研究開発機構)

本セッションは2010年大会から2018年大会まで9回にわたって開催してきた。初期はENSO/IODと河川流出について、中期は特に原発事故による河川流出に注力した。いずれのテーマも今日まで継続しており、研究成果と発表を経ている。例年宇宙分野との連携を探って来た。昨年度より、特に地球惑星システムと、他の惑星における水循環についての話題に地球惑星科学全体で「海洋」に関する関心は高く、特に木星衛星（エウロパなど）の内部海、古火星の海、そして太陽系外惑星の海などがある。これらの全てにおいて、陸域（固相）・海洋（液相）の関連が重要となっている。今年度のテーマは、地球における陸域・海洋におけるモデリング・リモートセンシングによる計算・観測技術と、それらを火星などの惑星観測とモデリングにおいてどのように応用可能であるかの視点について議論を進める。

9:00 ~ 9:15

[AOS11-01] Explorations and current understandings for subsurface ocean of icy bodies

★Invited Papers

*木村 淳[1] (1.大阪大学)

9:15 ~ 9:30

[AOS11-02] Climate predictability for societal applications including AI/ML

*Swadhin Behera[1]、Manali Pal[2]、J.V. Ratnam[1]、Rajib Maity[2]、Takeshi Doi[1]、Yushi Morioka[1]、Masami Nonaka[1] (1.Application Laboratory, JAMSTEC, 3173-25 Showa-machi, Yokohama 236-0001、2.Indian Institute of Technology, Kharagpur, India)

9:30 ~ 9:45

[AOS11-03] Re-entry of giant-impact fragments and early evolution of the Earth's ocean

*佐々木 貴教[1] (1.京都大学 大学院理学研究科 宇宙物理学教室)

9:45 ~ 10:00

[AOS11-04] Modeling of Extreme Freshwater Discharge and influence from Japanese First-Class Rivers to Coastal zones

*黒木 龍介、山敷 庸亮[1]、Varlamov Sergey[2]、宮澤 泰正[2]、Racault Marie[3]、Hoshin Gupta[4] (1.京都大学、2.Application Laboratory, Japan Agency for Marine-Earth Science and Technology, Japan、3.Plymouth Marine Laboratory, Plymouth, United Kingdom、4.University of Arizona)

10:00 ~ 10:15

[AOS11-05] Establishment of new curriculum at Biosphere 2

*三木 健司[1]、土井 隆雄[2]、山敷 庸亮[3]、寺田 昌弘[2] (1.京都大学大学院農学研究科、2.京都大学宇宙総合学研究ユニット、3.京都大学総合生存学館)

10:15 ~ 10:30

[AOS11-06] Development of the highly precise high-speed photometry technique with the photometer mounted with PIRKA telescope

*木村 なみ[1] (1.北海道大学)

Explorations and current understandings for subsurface ocean of icy bodies

*木村 淳[1]
*Jun Kimura[1]

1. 大阪大学
1. Osaka University

Most of solid bodies in the outer solar system, around Jupiter's orbit and beyond, are covered with ice on its surface, which are called as "Icy bodies".
In these icy bodies, e.g., Jovian moon Europa and Saturnian moon Enceladus, existence of the global liquid water ocean under the icy crust, called as "subsurface ocean", has been strongly suggested through the past remote sensing (mainly by geodetic and electromagnetic measurement) and theoretical modelling.
In this talk, I introduce the results of previous observations and theoretical calculations, and summarize the current
understandings focusing on the geophysical knowledge about the subsurface ocean of icy bodies.

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Climate predictability for societal applications including AI/ML

*Swadhin Behera[1], Manali Pal[2], J.V. Ratnam[1], Rajib Maity[2], Takeshi Doi[1], Yushi Morioka[1], Masami Nonaka[1]

1. Application Laboratory, JAMSTEC, 3173-25 Showa-machi, Yokohama 236-0001, 2. Indian Institute of Technology, Kharagpur, India

The tropical Indo-Pacific domain is important for global climate. Particularly, the warm pool region rooted in both basins plays an important role in the modulation of ocean and atmosphere variability on several spatio-temporal scales. While both basins share the extended warm pool, each of the two basins has its own modes of ocean and climate variations. Tropical Pacific Ocean is well-known for the El Niñ o/Southern Oscillation (ENSO) phenomenon, the influence of which is seen world-wide during ENSO occurrence years. Recently, another mode of climate variability called the ENSO Modoki is discovered in the tropical Pacific Ocean. The ENSO Modoki is distinct from ENSO in terms of its characteristics and global impacts. Therefore, predictability of ENSO and ENSO Modoki is important for reducing their impacts on the society. Coupled models like SINTEX-F has been predicting the ENSO Modokis quite well. Here an attempt is made to compare those predictabilities using predictions from an AI/ML based statistical approach.

Keywords: ENSO , ENSO Modoki, Prediction

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Re-entry of giant-impact fragments and early evolution of the Earth's ocean

*佐々木 貴教[1]
*Takanori Sasaki[1]

1. 京都大学 大学院理学研究科 宇宙物理学教室
1. Department of Astronomy, Kyoto University

The late stages of Earth's formation remain a mystery. No building blocks remain in Earth's orbit and no geological evidence is available for the first 700 million years Earth's history. Herein we propose that protoplanetary fragments produced by the giant impacts during terrestrial planet formation may give some important clues to the era. Iron-bearing giant impact fragments provide significant reducing agent that could transform primitive CO2–H2O atmosphere and ocean into more reducing H2-bearing atmosphere. Re-entry of the giant-impact fragments into eary Earth would be important for the origin of Earth’ s life and its early evolution.

キーワード：地球、海洋、巨大衝突
Keywords: Earth, ocean, giant impact

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Modeling of Extreme Freshwater Discharge and influence from Japanese First-Class Rivers to Coastal zones

Modeling of Extreme Freshwater Discharge and influence from Japanese First-Class Rivers to Coastal zones

*黒木 龍介、山敷 庸亮[1]、Varlamov Sergey[2]、宮澤 泰正[2]、Racault Marie[3]、Hoshin Gupta[4]
*Ryusuke Kuroki, Yosuke Alexandre Yamashiki[1], Sergey Varlamov[2], Yasumasa Miyazawa[2], Racault Fanny Marie[3], Hoshin Vijai Gupta[4]

1. 京都大学、2. Application Laboratory, Japan Agency for Marine-Earth Science and Technology, Japan、3. Plymouth Marine Laboratory, Plymouth, United Kingdom、4. University of Arizona
1. Kyoto University, 2. Application Laboratory, Japan Agency for Marine-Earth Science and Technology, Japan, 3. Plymouth Marine Laboratory, Plymouth, United Kingdom, 4. University of Arizona

We estimated the effects of extreme fresh water discharge from Japanese first-class rivers to coastal zones of the Japanese coast. Our targeted event was a typhoon Etau from 06/09/2015 to 12/09/2015, a week, and we could success to optimize 5 parameters, soil roughness coefficient, river roughness coefficient, effective porosity, saturated hydraulic conductivity, and effective rainfall by using Shuffled Complex Evolution method developed by University of Arizona (SCE-UA method), that is one of the optimization method for hydrologic model during this week. In addition to this, we made a set of hourly simulated river outflow data of almost all of Japanese first-class rivers from these basins to the Pacific Ocean and the Sea of Japan during the period by using our model “Cell Distributed Runoff Model Version 3.1.1 (CDRMV3.1.1)”. After the simulation, we used these calculated discharge data with a coupled hydrological-oceanographic model JCOPE-T for estimation of sea surface salinity distribution (SSS) in Japanese coastal zones. And simulated SSS results were verified by comparison with Chlorophyll-a distribution, observed by satellite re-mote sensing. Therefore we successfully reproduced peak discharge prediction of extreme typhoon events on river mouth and the coastal oceanic circulation.

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Establishment of new curriculum at Biosphere 2

*三木 健司[1]、土井 隆雄[2]、山敷 庸亮[3]、寺田 昌弘[2]
*Kenji Miki[1], Takao Doi[2], Yosuke Yamashiki[3], Masahiro Terada[2]

1. 京都大学大学院農学研究科、2. 京都大学宇宙総合学研究ユニット、3. 京都大学総合生存学館
1. Kyoto University Graduate School of Agriculture, 2. Kyoto University Unit of Synergetic Studies for Space, 3. Graduate School of Advanced Integrated Studies in Human Survivability

We are currently planning to start up a new practical training programme at Biosphere 2 under a contract between Kyoto University and Arizona State University.
Biosphere 2 was established in1991 and was designed to produce a closed-complete ecosystem in the institute. Although the ecosystem-establishment was not fully successful, the institute still has been used for various research such as ecology, terraforming, and closed-environental impact to human health.
Our practical training programme will include hands-on training for exoplanet observation, and lectures about water-cycle and atmospheric science.
Although the programme is going to be carried out in August 2019, the pilot programme were put into practice with ten participants including lecturers and students from the states and Japan.
At the conference, we would give a presentation about the detailed programme schedule and expected educational and academic results from this programme.

キーワード：Biosphere 2、エコシステム
Keywords: Biosphere 2, ecosystem

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Development of the highly precise high-speed photometry technique with the photometer mounted with PIRKA telescope

*木村 なみ[1]
*Nami Kimura[1]

1. 北海道大学
1. Hokkaido University

There is a few striped pattern on Jupiter when we observe by visible light, and we can see white bands called " belt” and dark band called " zone". The cloud top altitude is high at zone, low at belt by infrared observation.Various models are proposed to figure out, but we cannot elucidate the mechanism of this large scale structure.The Galileo datas tell us that the zonal jets are located on boundaries between the belts and zones, with the westward jets on the poleward edges of belts and the eastward jets on the poleward edges of zones.It is still not clear that the wind occurs by sun light in atmospheric layer or internal heat source makes the global structure including the wind.One of the mechanism making zonal wind is that small eddies combine each other and make eddy flow, but it is not sufficiently to observe the cumulonimbus the source of small eddies. In the case of thunders of the earth, the study of the activity of cumulonimbus such a strong upward current and thunder storms makes progress. Upward current can help hydrologic cycle. There is a relationship of frequency of thunders and the altitude go the cumulonimbus on the earth, and the CMC is known to be proportion to brightness of the thunder, too. I developed a photometer equipped to PIRKA telescope to arrest the time change and the frequency of thunder lightning in the Jupiter.First I estimated the time of the duration and freqency and spatial distribution of lightnings of Jupiter by using parameters of lightnings on the earth and observation data of satellites.Then it is necessary to divide into 10 to observe lightning activity which continue 1ms and to focus on one cumulonimbus and to get high signal-noise ratio. I designed the equipment which can achieve these numerical goal and examined observation methods for example exposure time and field of view.

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[E] 口頭発表 | セッション記号 A (大気水圏科学)：A-OS 海洋科学・海洋環境

2019年5月29日(水) 10:45 ~ 12:15 | 301A 3F

[A-OS11] 陸域海洋相互作用-惑星スケール物質循環

コンビーナ:山敷 庸亮(京都大学大学院総合生存学館)、升本 順夫(東京大学大学院理学系研究科)、Behera Swadhin(Climate Variation Predictability and Applicability Research Group, Application Laboratory, JAMSTEC, 3173-25 Showa-machi, Yokohama 236-0001)、佐々木 貴教(京都大学 大学院理学研究科 宇宙物理学教室)、座長:山敷 庸亮(京都大学大学院総合生存学館)、佐々木 貴教(京都大学大学院理学研究科宇宙物理学教室)

本セッションは2010年大会から2018年大会まで9回にわたって開催してきた。初期はENSO/IODと河川流出について、中期は特に原発事故による河川流出に注力した。いずれのテーマも今日まで継続しており、研究成果と発表を経ている。例年宇宙分野との連携を探って来た。昨年度より、特に地球惑星システムと、他の惑星における水循環についての話題に地球惑星科学全体で「海洋」に関する関心は高く、特に木星衛星（エウロパなど）の内部海、古火星の海、そして太陽系外惑星の海などがある。これらの全てにおいて、陸域（固相）・海洋（液相）の関連が重要となっている。今年度のテーマは、地球における陸域・海洋におけるモデリング・リモートセンシングによる計算・観測技術と、それらを火星などの惑星観測とモデリングにおいてどのように応用可能であるかの視点について議論を進める。

10:45 ~ 11:00

[AOS11-07] The Drivers of early Archean Earth’s Hydrology: Resolving the Faint Young Sun's Paradox

★Invited Papers

*Vladimir Airapetian[1]、Guillaume Gronoff[2]、Michael Way[3]、Meng Jin[4] (1.NASA Goddard Space Flight Center/SEEC and American University、2.NASA LaRC/SSAI、3.NASA GISS/SEEC、4.SETI)

11:00 ~ 11:15

[AOS11-08] Experimental study on elementary hydrological process of rainfall in a forested continental hinterland

*村上 茂樹[1] (1.国立研究開発法人　森林研究・整備機構　森林総合研究所　九州支所)

11:15 ~ 11:30

[AOS11-09] Radiological Assessment of Martian and Terrestrial Surface during Young Sun

*山敷 庸亮[1]、前原 裕之[6]、野津 湧太[3]、佐藤 達彦[2]、アイラペディアン ウラジミール[7]、野津 翔太[3]、黒木 龍介[1]、村嶋 慶哉[5]、佐藤 啓明[4]、坂東 日菜[5]、行方 宏介[3]、佐々木 貴教[3]、スコット トーマス[8]、野上 大作[3]、柴田 一成[9] (1.京都大学大学院総合生存学館、2.日本原子力機構、3.京都大学大学院理学研究科、4.京都大学工学部、5.京都大学理学部、6.国立天文台、7.NASAゴダード宇宙飛行センター、8.ブリストル大学、9.京都大学理学部附属花山天文台)

11:30 ~ 11:45

[AOS11-10] Evaluation of scintillator detection materials for application within environmental radiation monitoring

*Peter George Martin[1]、D. Connor[1]、M. Lowden[1]、T. B. Scott[1] (1.School of Physics, University of Bristol, Bristol, UK)

11:45 ~ 12:00

[AOS11-11] The important factors for future human space activity in terms of space medicine

*寺田 昌弘[1]、山敷 庸亮[1]、三木 健司[1]、辻廣 智子[1]、土井 隆雄[1] (1.京都大学　宇宙総合学研究ユニット)

12:00 ~ 12:15

[AOS11-12] Storm Surge Response to Freshwater Outflow from Typhoons on the Ibaraki Coast

*Josko Troselj[1]、Nobuhito Mori[1] (1.Coastal Engineering Laboratory, Disaster Prevention Research Institute, Kyoto University)

The Drivers of early Archean Earth’ s Hydrology: Resolving the Faint Young Sun's Paradox

*Vladimir Airapetian[1], Guillaume Gronoff[2], Michael Way[3], Meng Jin[4]

1. NASA Goddard Space Flight Center/SEEC and American University, 2. NASA LaRC/SSAI, 3. NASA GISS/SEEC, 4. SETI

Understanding how the early Archean Earth supported standing bodies of liquid surface water under the faint young Sun is one of the greatest challenges of modern science. Can this problem be resolved as a part of the puzzle of understanding of the origin of building blocks of life on early Earth? Here, we present a new concept of how these two pieces of the mystery of life can be reconciled if we reconstruct the eruptive history of space weather from the young Sun at the time when life started on Earth. Our three-dimensional (3D) magnetohydrodynamic model of the young Sun suggests that energetic protons can be accelerated in shock waves driven by frequent and powerful Coronal Mass Ejection events and Corotating Interacting Regions produced by the young Sun's wind. Accelerated protons at energies > 300 MeV penetrated into the nitrogen-rich weakly reducing atmosphere and initiated the reactive chemistry by breaking molecular nitrogen, carbon dioxide, and methane, producing nitrous oxide, the potent greenhouse gas, and hydrogen cyanide, an essential feedstock molecule of life. Our Global Climate Model, ROCKE-3D, suggests that at 4(1000) ppmv of nitrous oxide produced in a 1(0.5) bar atmospheres outputs the mean annualized Earth’ s temperature of +16(5.2)C, and thus may provide a resolution of the FYS paradox and explain the presence of early oceans.

Keywords: Earth, Sun, climate, chemistry

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Experimental study on elementary hydrological process of rainfall in a forested continental hinterland

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There is an observational fact that a rainfall amount is constant or increases with increasing the distance from the coast (x) in a forest covered continent up to a few thousands kilometers, e.g. Amazon and Yenisei river basins. However, it contradicts the basic law of hydrology as shown in Fig 1a; rainfall (P) is partitioned into evapotranspiration (ET) and discharge (Q) that means P_0 at $x = x_0$ is larger than P_1 at $x = x_1$ ($x_0 < x_1$), because $P_0 = ET_0 + Q_0$ and $P_1 =< ET_0$. The contradiction is solved by Makarieva and Gorshkov (2007, hereafter refer to MG 2007) in which they proposed Biotic Pump of Atmospheric Moisture (BP) as illustrated in Fig. 1b. The principle of BP is that ET from forests (ET(F)) is greater than that from the ocean (ET(O)) that is the driving force to transport moisture from the ocean to a forested continental hinterland.

Nonetheless, MG (2007) and their series of studies did not explicitly mention the reason of large ET from forests. It is great in forests because evaporation of canopy interception (hereafter refer to interception; typically some 20% of rainfall) at the time of rainfall is larger than that from any other vegetative surfaces, though the amount of transpiration is similar independent of vegetation types under a certain climate condition.

Some studies showed that interception is proportional to the rainfall amount on an hourly basis. For example Hashino et al. (2012) observed evaporation rate of more than 10 mm/hour during rainfall that requires latent heat of five times as large as the solar constant. To explain such huge amount of evaporation during rainfall Murakami (2006) proposed splash droplet evaporation mechanism. I believe it is the only explanation of enormous evaporation because small droplets can evaporate and disappear quickly even under very high humidity based on the theory and experiments of cloud physics. On top of that, latent heat is supplied from clouds upon condensation of water vaper. However, splash droplet evaporation along with BP is still a hypothesis.

To prove the splash droplet evaporation hypothesis stable isotope of water is used. Over 1000 of rainwater samples were collected on an hourly basis both under the forest canopy and at the opening simultaneously (Fig. 2). The isotopic ratios are measured and are being analyzed in combine with the meteorological data. The outline of the methodology is presented at the meeting.

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キーワード：Biotic Pump of Atmospheric Moisture、canopy interception、splash droplet evaporation、stable isotope of water
Keywords: Biotic Pump of Atmospheric Moisture, canopy interception, splash droplet evaporation, stable isotope of water

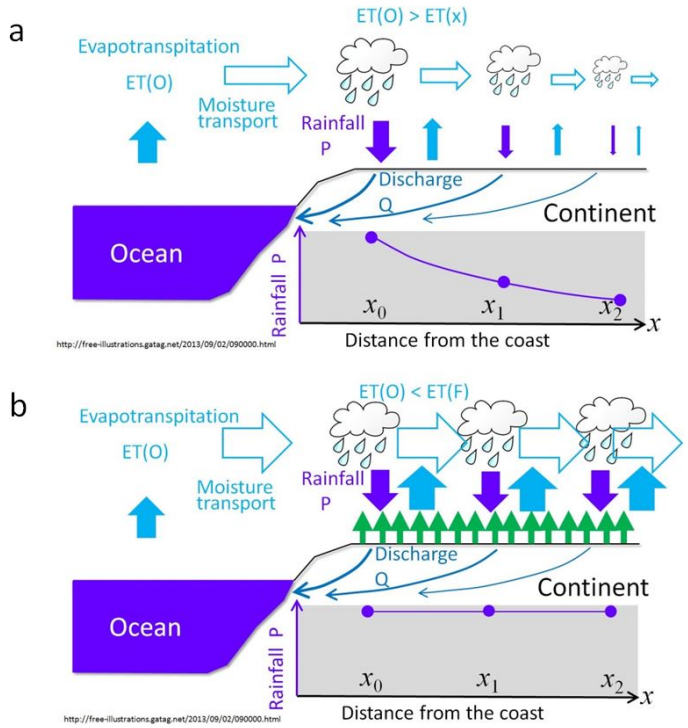


Fig. 1

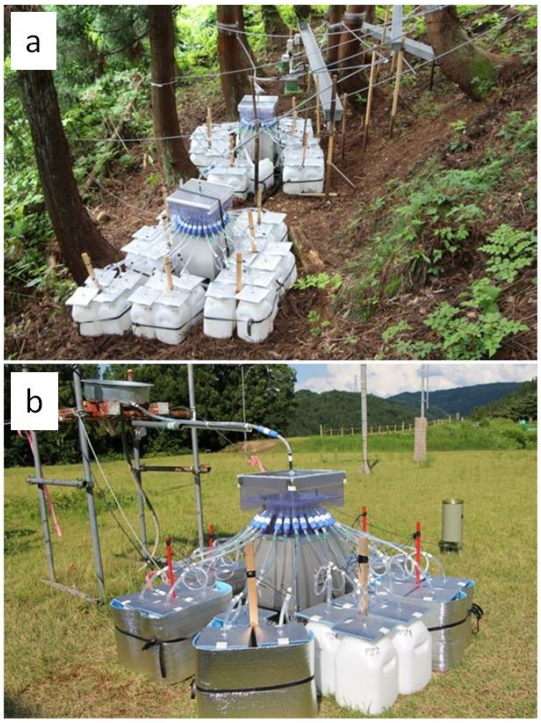


Fig. 2

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Radiological Assessment of Martian and Terrestrial Surface during Young Sun

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For a terrestrial planetary system, during the initiation period of planetary formation, the activity of a young Sun is extremely important in order to comprehend the atmospheric behavior of the planet. Relatively lower luminosity associated with lower surface temperature of the young Sun brings the planets a cooler surface environment. Terrestrial and Martian surfaces become icy cold in this environment without considering extensive GHG formation. Within such environments, the dose from SEP from a young Sun might play an important role in primordial atmospheric composition.

Here, we propose a reasonable radiological assssessment of the possible exposure intensity in SEP from a young Sun, by evaluating the possible magnitude and frequency of early solar flares by using possible star spot area, derived from their rotational period. We evaluated annual and maximum flare energy in different cases of solar spot areas for 3 %, 5 % ,and 10 % of solar surfaces. The maximum dose at the Martian TOA reaches 5.86 k Gy (265 Sv) when the solar spot area reaches 10 % of the solar surface. Such higher radiation dose may have influenced significantly atmospheric composition of Early Mars and Young Earth.

キーワード：若い太陽、太陽フレア、放射線環境
Keywords: Young Sun, Solar Flare, Radiological Condition

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Evaluation of scintillator detection materials for application within environmental radiation monitoring

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The last five years has seen the unabated growth in the number of airborne platforms performing radiation mapping –each using various iterations of low-altitude unmanned aerial vehicle (UAV). Alongside the associated advancements in the base airborne system transporting the radiation detection payload, from the earliest radiological analyses performed using gas-filled Geiger-Muller tube detectors, modern radiation mapping platforms are now based near-exclusively on solid-state scintillator (and to a lesser-extent semiconductor) detectors. With numerous types of these light-emitting crystalline materials now in existence, this combined desk and computational modelling study sought to evaluate the best-available detector material compatible with the requirements for low-altitude autonomous radiation mapping –of naturally-occurring but also anthropogenically-derived radionuclides.

Aside from ground-based radiation surveying undertaken by humans; environmental mapping of radiation distribution (resulting from both anthropogenic activities as well as from naturally-occurring radioactive material) has been performed historically using manned, fixed-wing aircraft. In contrast to the more limited detector volumes carried during on-ground operations (due to size and weight practicalities), the systems carried during these extensive spatial extent aerial surveys are typically not less than 33 litres in detector volume. For the gamma-ray measurements of naturally-occurring radionuclides, the key emission peaks are associated with the daughter products of the U (^{214}Bi) and Th (^{208}Tl) decay chains, alongside a strong contribution from radiogenic potassium (^{40}K). In contrast to the higher-energy (>1.0 MeV) gamma-ray emissions characteristic of the aforementioned naturally-occurring radionuclides, the primary anthropogenically-derived radionuclide released into the environment in extensive quantities during an emergency release event (such as at both Fukushima and Chernobyl) is radiocesium –specifically ^{137}Cs (half-life: 30.17 years), which emits a single gamma-ray photon at 0.662 MeV.

While the currently and widely-used NaI and CsI (both of which are Tl-doped) are the mainstays of radiation monitoring, during this study, LaBr scintillator detectors were determined to possess not only a greater sensitivity to incident gamma-radiation, but also a far superior spectral (energy) resolution over existing detector materials. Combined with their current competitive cost, an array of three such composition cylindrical detectors were determined to provide the best means of detecting and discriminating the various incident gamma-rays incident onto the detector owing to both naturally-occurring or anthropogenically-derived sources.
In this talk, we will present the results of multiple GEANT4 simulations that will inform the potential future development of the next generation of radiation detection materials and their optimal configurations for deployment.

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The important factors for future human space activity in terms of space medicine

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When humans stay in space for long term, our body has various phyisiological effects by the specific space environments. Recently, space agency, such as NASA and JAXA, has the plan to send human to Moon or Mars. Therefore, it is very important to understand how we are effected during space staying. For example, our skeletal muscles on the leg become atrophy and bone volume decrease by spaceflight. And, astronauts must spend time in closed environment during human space mission. So, we need to know the mental or emotional changes during space mission.
Now, we have space camps which is simulated for future space misson. In this time, I will present the phyisiological data of mental factors in simulated space camps.

キーワード：宇宙医学、有人宇宙活動、隔離環境
Keywords: Space medicine, Human space activity, Closed environment

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Storm Surge Response to Freshwater Outflow from Typhoons on the Ibaraki Coast

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Introduction and Objective

Collaborative results (Troselj et al., 2017) have permitted for the first time to quantitatively evaluate the influence of extreme freshwater outflow to the coastal ocean due to typhoon passage by combining river and ocean models using hourly time step data and remote-sensing technology. They found that projection of coastal Sea Surface Salinity was improved (up to 10 PSU difference) and became more realistic with included freshwater impact and concluded that extreme events freshwater outflows significantly decrease Sea Surface Salinity distribution in the coastal zone.

With the advance of weather forecasting systems and specific availability of forecasting typhoon trajectory and intensity, the research team aims to be able to apprehend freshwater impacts on the coastal marine environment in advance of typhoon events, and contribute to the comprehensive management and protection of coastal zones.

In our JpGU presentation (2018), we concluded that our findings that the freshwater outflow impact to the storm surge is negligible during the typhoon passage but is important to be considered in evaluating an after-runner storm surge mechanism should be further confirmed in future works by testing the applicability of using the same method with many other typhoon event cases.

A follow up of the previous studies is shown here. As parameters which affect the total sea level are storm surge, tides, waves and freshwater impact, the main objective of the study is to test dependence between storm surge heights and the freshwater impact before and after passing of several typhoons over the Ibaraki Coast, Japan.

Methods

We continued the study from Troselj et al. (2018) with improved downscaling model methodology and extended analyzed period into 7 years (2000-2006). We applied better vertical transformation equation (Vtransform=2, new formulation developed by A. Shchepetkin) and different vertical stretching function (Vstretching=4, where A. Shchepetkin improved double stretching) compared to Troselj et al. (2018). River forcing conditions were applied as observed river temperature and discharge (MLIT, 2017) with constant salinity of 0.5 PSU for Tone, Naka and Kuji rivers.

Discussions

We compared coastal storm surge heights for cases with and without freshwater outflow impact and discussed differences in results, for several typhoons passing over Ibaraki Coast during the analysed period. With new results, our conclusions from JpGU presentation (2018) cannot yet be certainly

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confirmed. The mechanism which we found then, presence of so called after-runner storm surge occurring about 4 days after passage of the event, is occurring in some typhoon cases but not every time. Therefore, its occurrence is function of many parameters occurring simultaneously such as typhoon trajectory, intensity and central pressure, actual state of the ocean (tides, waves), river discharge magnitude and temporal distribution and model conditions.

Summary

Using dynamic downscaling for reanalysis of coastal current system in the Ibaraki Coast, our goal was to test dependence between storm surge heights and the freshwater impact before and after typhoon events. We found that the mechanism found in the previous study is not occurring every time on the same way but is rather function of many other dependent parameters.

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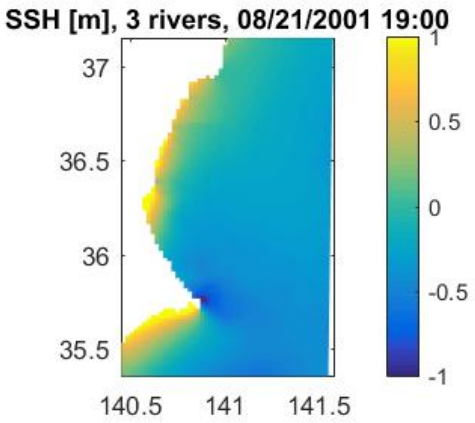
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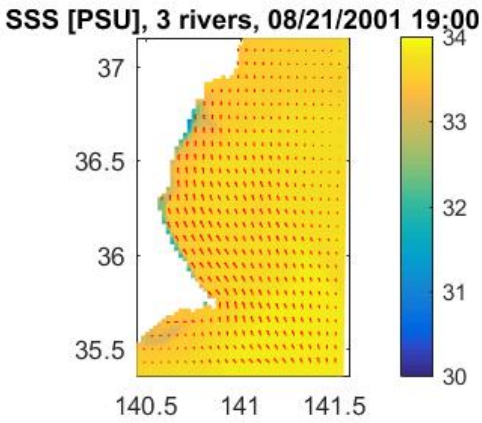
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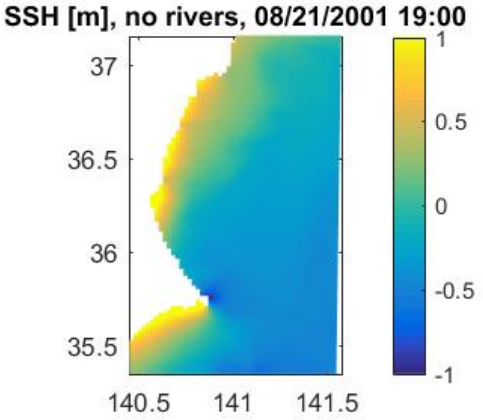
Keywords: storm surge, freshwater impact, typhoon events, downscaling, coastal current, COAWST

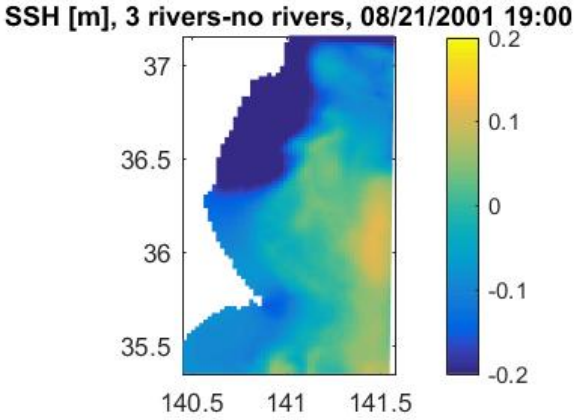
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[E] 口頭発表 | セッション記号 A (大気水圏科学)：A-HW 水文・陸水・地下水学・水環境

2019年5月29日(水) 15:30 ~ 17:00 | 201B 2F

[A-HW22] 流域の物質輸送と栄養塩循環ー源流域から沿岸海域までー

コンビーナ:小林 政広(国立研究開発法人森林研究・整備機構　森林総合研究所)、吉川 省子(農業・食品産業技術総合研究機構　農業環境変動研究センター)、安元 純(琉球大学　農学部　地域農業工学科)、Adina Paytan(University of California Santa Cruz)、座長:奥田 昇(総合地球環境学研究所)

本セッションでは，源流部から沿岸海域を含む流域における物質輸送および栄養塩循環について，幅広い研究分野（陸水学，水文学，地下水学，沿岸海洋学，気象学，土壌学，堆積学，林学，農学，水産学，生態学，社会科学など）からの話題提供を踏まえて，持続可能な流域環境に関する分野横断的な議論を行うことを目的としている．特に，人間活動や気候変動の影響下における複雑で動的な水系における自然現象やその時間変化に主眼をおいた物理，化学，生物学的メカニズムを明瞭にするために，トレーサー技術，分子レベルの技術，水理モデル，古生物学的手法，屋内やフィールドでの試験，生態系サービスや社会ー生態学システムについての社会科学的評価など，流域科学のための新しい手法に基づく研究発表を歓迎する．このセッションを通して，新しい流域科学を創造するために，分野を超えた参加者相互の議論と協力体制作りを目指したい．

15:30 ~ 15:40

Introduction

15:40 ~ 16:00

[AHW22-01] **Coral Skeleton $\delta^{15}N$ as a Tracer of Historic Nutrient Loading to a Coral Reef in Maui, Hawaii**

★Invited Papers

*Adina Paytan[1] (1.University of California Santa Cruz)

16:00 ~ 16:15

[AHW22-02] **The Use of Ammonium and Trace Metals in Identifying Low Redox Environment Zone at Indonesian Coastal Alluvial Groundwater**

*Anna Fadliah Rusydi[1,4]、Mitsuyo - Saito[2]、Seiichiro - Ioka[3]、Shin-ichi - Onodera[1] (1.Graduate School of Integrated Arts and Sciences, Hiroshima University, Japan、2.Graduate School of Environmental and Life Sciences, Okayama University, Japan、3.Institute of Regional Innovation, Hirosaki University, Japan、4.Research Center for Geotechnology, Indonesian Institute of Sciences, Indonesia)

16:15 ~ 16:30

[AHW22-03] Spatial and temporal variation in submarine groundwater discharge (SGD) on a beach scale in a temperate coastal island: a multi-tracer approach

*齋藤 光代[1]、小野寺 真一[2]、友澤 裕介[2]、浅井 和由[3] (1.岡山大学大学院環境生命科学研究科、2.広島大学大学院総合科学研究科、3.地球科学研究所)

16:30 ~ 16:45

[AHW22-04] **Phosphorus discharge via groundwater into the lake, based on lacustrine groundwater discharge (LGD) and alluvial plain sediment**

*小野寺 真一[1]、齋藤 光代[2]、金 広哲[3]、Anna Rusydi[1]、友澤 裕介[1]、王 昆陽[1]、伴 修平[4]、奥田 昇[5] (1.広島大学大学院総合科学研究科、2.岡山大学、3.Guangdong Ocean University、4.滋賀県立大学、5.総合地球環境学研究所)

16:45 ~ 17:00

[AHW22-05] **Geochemical controls and health implications of water chemistry in Benoue River Basin, North Cameroon: Insights from Major ions**

*Sharon Bih Kimbi[1,2]、Wilson Y Fantong[3]、Samuel N Ayonghe[2]、Robert Kringel[4]、Shin-ichi Onodera[1] (1.Graduate School of Integrate Arts and Sciences, Hiroshima University、2.Department of Environmental Science, Faculty of science, University of Buea、3.Institute of Mining and Geological Research (IRGM)、

4.Federal Institute for Geoscience and Natural Resources Bundesanstalt fur Geowissenschaften und Rohstoffe (BGR) PRESS NO & SW)

Coral Skeleton $\delta^{15}N$ as a Tracer of Historic Nutrient Loading to a Coral Reef in Maui, Hawaii

*Adina Paytan[1]

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Excess nutrient loading to nearshore environments has been linked to declining water quality and ecosystem health. Macro-algal blooms, eutrophication, and reduction in coral cover have been observed in West Maui, Hawaii, and linked to nutrient inputs from coastal submarine groundwater seeps. Here, we present a forty-year record of nitrogen isotopes ($\delta^{15}N$) of intra-crystalline coral skeletal organic matter in three coral cores collected at this site and evaluate the record in terms of changes in nitrogen sources. Our results show a dramatic increase in coral $\delta^{15}N$ values after 1995, corresponding with the implementation of biological nutrient removal at the nearby Lahaina Wastewater Reclamation Facility (LWRF). High $\delta^{15}N$ values are known to be strongly indicative of denitrification and sewage effluent, corroborating a previously suggested link between local wastewater injection and degradation of the reef environment. This record demonstrates the power of coral skeletal $\delta^{15}N$ as a tool for evaluating nutrient dynamics within coral reef environments.

Keywords: Nitrogen Isotopes, Corals, Submarine Groundwater Discharge

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The Use of Ammonium and Trace Metals in Identifying Low Redox Environment Zone at Indonesian Coastal Alluvial Groundwater

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Reduction and oxidation (redox) conditions in the aquifer are essential factors; those can determine the behavior of chemicals in the groundwater system. Nowadays, researches concerning the low redox (reduction) environment are growing significantly since some pollutions occur under this condition. The study was taken place in Indramayu, Indonesia. The area is an alluvial plain located on the North Coast of West Java Island. The groundwater in the alluvial area is compelling to study because it has a large aquifer storage capacity but unfortunately vulnerable to contamination. Moreover, the contamination will get severe under reduction environment. The primary objective of this study is to understand groundwater vulnerability by identifying the reduction environmental zone in the study site.

In this research, we used combined chemical parameters: ammonium (NH_4^+-N), dissolve manganese (Mn^{2+}) and ferrous (Fe^{2+}), to trace reduction condition in the groundwater. NH_4^+-N is one form of nitrogen compound that usually arise under reduction condition. Other parameters that arise with the reduction process are Mn^{2+} and Fe^{2+}. Therefore, in this investigation, we assumed the use of NH_4^+-N, combined with the concentrations of Mn^{2+} and Fe^{2+} elements, are able to identify groundwater reduction environment.

Totally, there was ten soil taken from 2 boreholes located at the south and north of the research site and 20 water samples collected from groundwater (18) and river (2). The soil samples were analyzed for NH_4^+-N and C/N ratio parameters. These data were used to explain further about NH_4^+-N presence in groundwater. Additionally, the water samples were analyzed for NH_4^+-N, $Mn^{2+,}$ and Fe^{2+} concentrations. The aquifer materials consist of sandstone, claystone, and sandy claystone. The NH_4^+-N concentrations were ranged from 0.82 until 3.37 mg / L. However; there was no clear relationship between the soil’s depth and compositions with NH_4^+-N concentrations. The soil samples had low C/N ratios, with values of 8.00 to 12.19. This is indicating that N-organic in the soil potentially experiences mineralization, one that produces NH_4^+-N. Furthermore, NH_4^+-N in water samples were detected as the dominant nitrogen form at most sites. Similarly, Mn^{2+} was detected at almost all locations. Moreover, the concentrations of Mn^{2+} were high (> 0.05 mg / L), around 0.07 - 12.8 mg / L, at 16 locations. High concentrations of Fe^{2+} (> 0.3 mg/L), were found in groundwater at 6 locations. The concentrations were ranged from 1.39 to 9.91 mg/L. The presence of NH_4^+-N along with high Mn^{2+} contents indicated that almost all locations experienced reduction condition at a zone of manganese reduction. Moreover, at 6 locations, the reduction process was stronger and lead to becoming ferrous zone. This was shown by NH_4^+-N existence as dominant nitrogen form and high concentrations of Fe^{2+} as well as Mn^{2+}.

Keywords: Ammonium, Manganese, Ferrous, Reduction, Coastal Groundwater, Indramayu

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Spatial and temporal variation in submarine groundwater discharge (SGD) on a beach scale in a temperate coastal island: a multi-tracer approach

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*Mitsuyo Saito[1], Shin-ichi Onodera[2], Yusuke Tomozawa[2], Kazuyoshi Asai[3]

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1. Graduate School of Environmental and Life Science, Okayama University, 2. Graduate School of Integrated Arts and Sciences, Hiroshima University, 3. Geo Science Laboratory

Submarine groundwater discharge (SGD) is defined as subsurface water flow from the seabed to the coastal sea and ocean. Because groundwater often contains higher nutrients than river water, SGD delivers comparatively large quantities of nutrients to coastal ecosystems. However, there are few studies to examine the spatial relation between SGD and coastal ecosystem such as seagrasses and seaweeds. In the present research, we aimed to examine the spatial and temporal variation in SGD on a beach scale in a temperate coastal island.
The study areas are located on Ikuchijima Island in Seto Inland Sea, southern Japan. The regional climate is mild, with an annual mean precipitation of 1,100 mm and temperature of 15.6 ˚C. The whole island is characterized by steep slopes and is widely covered by citrus farms with more than 40% of the island. The previous researches confirmed that SGD can rival or even exceed surface runoff in this island. However, the spatial and temporal variation in SGD on a beach scale was not well examined. We installed piezometers in two beach sites (Gohonmatsu: IKG and Miyabara: IKM) and measured water pressure, water temperature, electric conductivity (EC), and radon (^{222}Rn) concentration in pore water in July and December 2018, and January 2019. In January 2019, SF6 (sulfur hexafluoride) concentration was measured to estimate residence time of pore water. Before the field campaign in July 2018, the study area had an extreme rainfall event. IKG has steeper backland topography than IKM. There is no surface water inflow to IKG, while a small channel inflow to IKM. Main bottom material is sand in both beaches, however, the western part of IKG is covered by coarse gravels. Large spatial variation in hydraulic potential, water temperature, EC and ^{222}Rn concentration in pore water were confirmed in both beaches, with larger variation range in IKG. EC was totally lower and ^{222}Rn was higher in IKG than IKM. These results suggest that higher rate in fresh-SGD in IKG than IKM. In addition, significant low EC and high ^{222}Rn concentration were confirmed in the western part of IKG in July 2018.

キーワード：海底湧水、海浜スケール、時空間変化
Keywords: Submarine groundwater discharge (SGD), Beach scale, Spatial and temporal variation

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Phosphorus discharge via groundwater into the lake, based on lacustrine groundwater discharge (LGD) and alluvial plain sediment

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*Shin-ichi Onodera[1], Mitsuyo Saito[2], Guangzhe Jin[3], Anna Fadliah Rusydi[1], Yusuke Tomozawa[1], Kunyang Wang[1], Syuhei Ban[4], Noboru Okuda[5]

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1. Graduate School of Integrated and Arts Sciences, Hiroshima University, 2. Graduate School of Environmental and Life Science, Okayama University, 3. Guangdong Ocean University, 4. The University of Shiga Prefecture, 5. Research Institute for Humanity and Nature

Groundwater discharge and nutrient flux into a lake has not been confirmed enough in terms of spatial variation including those in deeper zone. Biwa Lake has different characteristics between in northern and southern. In northern, the water depth varies up to 100m, groundwater discharge is also expected not only in beach sides with shallower depth but in deeper zones. We examined to indicate spatial variation of Rn-222 and to compare with the results of seepage observations by Kobayashi (1993).

Radon radioisotope (Rn-222) concentrations were measured by a RAD7 at 500 m interval along the whole shoreline of the northern lake, and surface water samples were coincidently collected. Oxygen stable isotope ratio ($\delta^{18}O$), Chloride anion and nutrients (nitrogen, phosphorus, and silicon) concentrations were measured in the laboratory in order to evaluate inflow of the groundwater into the lake. Those dissolved materials were also measured from the groundwater samples were collected in ca. 20 wells situated along the shore of the lake as well as those in river waters. In the eastern coast (Hikone), artesian groundwater was also collected because of aquiclude at 10m deep under the ground. Lake waters at the surface, middle and bottom layers and interstitial waters in the bottom sediments were collected for measuring Rn-222 concentrations.

At the both sites of Yasu and Takashima, high pressures of groundwater indicated flow of the water to the lake under the ground. Spatial distributions in Rn-222, Cl^- and nutrient concentrations with those in $\delta^{18}O$ along the coasts also indicated discharges of groundwater into the lake. High concentrations of dissolved phosphorus phosphate (> 0.1ppm) were detected from several wells out of 15 ones investigated. Based on the comparative results with the seepage observations, we could confirm good correlation between Rn-222 concentration and seepage observation results.

In addition, Rn-222 concentrations in lake waters were measured in the surface and bottom layers at the 4 stations with different water depths (5m, 10m and 20m) in October 2015 and July 2016. The highest Rn-222 was observed in the bottom layer at 20m-deep site in both periods. The concentration was more than 2-fold of that in the littoral site. It suggests high possibility of deep-LGD from offshore lake floor.

キーワード：リン、地下水、沖積平野、堆積物
Keywords: Phosphorus, groundwater, alluvial plain, semiment

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Geochemical controls and health implications of water chemistry in Benoue River Basin, North Cameroon: Insights from Major ions

*Sharon Bih Kimbi[1,2], Wilson Y Fantong[3], Samuel N Ayonghe[2], Robert Kringel[4], Shin-ichi Onodera[1]

1. Graduate School of Integrate Arts and Sciences, Hiroshima University, 2. Department of Environmental Science, Faculty of science, University of Buea, 3. Institute of Mining and Geological Research (IRGM), 4. Federal Institute for Geoscience and Natural Resources Bundesanstalt fur Geowissenschaften und Rohstoffe (BGR) PRESS NO & SW

Increase population growth in the north region of Cameroon coupled with rapid urbanisation has led to the widespread of informal settlements in urban areas. Multivariate statistics and hydrochemical diagrams were used to investigate the groundwater chemistry, usability and the impact of urbanisation on water resource quality. The purposive random technique was used to sample and collect 86 water samples from 34 boreholes, 37 wells, 14 rivers and 1spring during the month of January, 2017. Major ions were analyzed using an Ion Chromatography. The results revealed that, water pH ranged from slightly acidic to basic meanwhile the water types varied from Ca-Cl in wells, Na-HCO_3 in springs and CaMg-HCO_3 in boreholes and rivers. Water sources did not meet WHO, 2006 quality standard with respect to pH (60.5% <7 & >8.5), EC (58.1%>250 μS/cm) and NO_3^-(60.5%>10mg/l). The Wilcox and USSL diagrams for irrigational uses showed that the water sources are of low to moderate salinity and low alkalinity hazard and thus excellent for use in irrigation. Increase concentrations of NO_3^- and Cl^- from 8.0mg/l to 198.4mg/l and from 2.0mg/l to 59.4mg/l in 1997 and 2017 (20yrs) respectively could be linked to increase population, poor waste disposal and pollution from agricultural fields. While anthropogenic activities are main provenance of NO_3^- and Cl^-, the population is equally affected by fluorosis from lithogenic fluoride and is at risk to nitrate. It is recommended that a monitoring and evaluation system for ground water sources with respect to their quantity and quality be put in place to ensure sustainable management by policy makers.

Keywords: Hydrochemistry, Water resources, Fluorosis, Urbanization, Cameroon

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[E] 口頭発表 | セッション記号 A (大気水圏科学)：A-HW 水文・陸水・地下水学・水環境

2019年5月29日(水) 9:00 ~ 10:30 | 103 1F

[A-HW23] 水循環・水環境

コンビーナ:町田 功(産業技術総合研究所地質調査総合センター)、山崎 大(東京大学生産技術研究所)、林 武司(秋田大学教育文化学部)、福士 圭介(金沢大学環日本海域環境研究センター)、座長:林 武司(秋田大学教育文化学部)

We focus on various issues of water cycle and environment and aim to answer questions of hydrological and earth system sciences including 1) surface, subsurface and evapotranspiration processes of water cycle; 2) natural and anthropogenic hydrothermal systems, 3) environments issues and studies on a watershed or global scale, 4) water-related issues with ecological, environmental, and geochemical aspects, and 5) other issues in hydrological sciences. This session welcomes presentations regarding various kinds of approaches and techniques such as field survey, remote sensing, isotope tracers, numerical simulation, and theoretical analysis.

9:00 ~ 9:15

[AHW23-12] Drought Analysis based on Copulas and Poisson Process

*Pei-Yu Wu[1]、Gene Jiing-yun You[1] (1.National Taiwan University, Department of Civil Engineering)

9:15 ~ 9:30

[AHW23-13] **Snow melt dynamics in snowfall dominated mountain regions in Shonai**

*Alexander Brandt[1,3]、Muhammad Fraz Ismail[2]、Larry Maximo Lopez Caceres[1]、Wolfgang Bogacki[2] (1.Yamagata University、2.Hochschule Koblenz、3.UGAS)

9:30 ~ 9:45

[AHW23-14] Study on transport of particulate organic matter in a small river with forest and paddy filed by using carbon isotopes ($\delta^{13}C$ and $\Delta^{14}C$)

*長尾 誠也[1]、田原 龍之介[2]、落合 伸也[1]、後藤 晶子[3]、長谷川 卓[3] (1.金沢大学環日本海域環境研究センター、2.金沢大学大学院自然科学研究科、3.金沢大学理工学域地球社会基盤学系)

9:45 ~ 10:00

[AHW23-15] **Sources of Shallow Groundwater Salinity in the Ganges Delta of Bangladesh**

*Masudur Rahman[1,2]、Tomochika Tokunaga[1] (1.Department of Environment Systems, Graduate School of Frontier Sciences, The University of Tokyo, 5-1-5, Kashiwa-no-ha, Kashiwa-shi, Chiba 277-8563, Japan、2.Environmental Science Discipline, Life Science School, Khulna University, Khulna 9208, Bangladesh)

10:00 ~ 10:15

[AHW23-16] **Groundwater chemistry in the Gunii Khooloi basin, Southern Gobi Region of Mongolia using multivariate analysis**

*Batdemberel BAYANZUL[1,2]、Isao Machida[3]、Kengo Nakamura[2]、Noriaki Watanabe[2]、Takeshi Komai[2] (1.School of Geology and Mining Engineering, Mongolian University of Science and Technology、2.Graduate School of Environmental Studies, Tohoku University、3.Groundwater research group, Advanced Industrial Science and Technology)

10:15 ~ 10:30

[AHW23-17] **Temporal observation of molybdenum concentrations in rivers from Erdenet mining area, Mongolia**

*Solongo Tsetsgee[1]、Keisuke Fukushi[1]、Altansukh Ochir[2]、 Takahashi Yoshio[3]、Ariuntungalag Yunden[2]、Enkhjin Odgerel[2]、Noriko Hasebe[1] (1.Kanazawa University、2.National University of Mongolia、3.The University of Toyko)

Drought Analysis based on Copulas and Poisson Process

*Pei-Yu Wu[1], Gene Jiing-yun You[1]

1. National Taiwan University, Department of Civil Engineering

Drought is a regular and recurring climatic phenomenon. Because of climate change and the increasing water demand, we have experienced higher drought deficit and severity in recent years. To evaluate the impact of the trend of drought, this study aims to develop an improved framework for streamflow drought analysis and simulation of the future conditions. Based on our proposed framework based on Copulas and Poisson process, this study firstly analyzes historical inflow data to estimate statistical parameters of drought. Secondly, we calculate three defined indices of the drought, drought duration, drought deficit, and interval time between droughts respectively. With statistical test, these three indices are found to be correlated. Following, the marginal distributions of these indices are estimated. Accordingly, this study constructs a stochastic model by three-dimensional Gaussian copulas to simulate the occurrence of drought events. In addition, to more appropriately simulate drought occurrences, a Poisson process is applied in this study to describe the occurrence between drought events. This simulation is based on the stationary assumption in current stage. In the future, we will consider the influence of climate change and simulate drought events under non-stationary condition. The results of this work can be utilized to support the decision or policy making processes in drought management.

Keywords: drought analysis, copulas, poisson process

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Snow melt dynamics in snowfall dominated mountain regions in Shonai

*Alexander Brandt[1,3], Muhammad Fraz Ismail[2], Larry Maximo Lopez Caceres[1], Wolfgang Bogacki[2]

1. Yamagata University, 2. Hochschule Koblenz, 3. UGAS

With a total snowfall of 1500 mm, which is the half of the total annual precipitation, Shonai is one of the snowiest regions of the world (*Asaoka et al, 2013*). Snow depth can reach up to 5.2 meters in March before the snow melt finishes in May. The maximum snow depth as 50-year average is 2.7 m in the Yamagata University Research Forest (YURF), southern of the Shonai plains. The relatively warm air in winter (~ 0˚C) leads to several melting and refreezing processes within the snow column, increasing the snow density to 0.5 g/cm³. This huge amount of snow in Yamagata, Akita and Aomori prefecture is the dominating water source for plants in spring and a good thermal insulation for the soil, which is never freezing in YURF. A change of wind direction in winter is the reason for the high amount of snow. Cold air from Siberia is passing the warm Japanese Sea and faces the central mountains of Tohoku (*Asaoka et al., 2013*). These characteristics are very unique in the world leading to snow accumulations higher than in most areas of the world (*Krasting et al., 2013, Masiokas et al., 2006*).

The thick snow pack with high density results in a high Snow Water Equivalent (SWE). Monitoring and modelling of the snow melt period in spring is essential to confirm river discharges, water infiltration into the soil and to calculate the water balance of Japanese mountain forests. A modelling approach was done with the calculation of Degree-Day Factors (DDF) (*Ismail et al., 2015*). Measurements to determine the snow pack differences of forest covered sites and clear-cut sites are conducted this winter and will be intensified in the snow melting period. We expect results comparable to *Jost et al. (2009)* and *Schelker et al. (2013)*.

Automatic and manual measurements of snow density and snow depth were conducted intensively in the last 7 years in YURF. Together with the DDF we already discovered a significant trend of changing melt dynamics after half of the melting season. Results show furthermore, that the snow cover is not losing water, even in the warm periods during the winter. Soil moisture is measured to identify the start of the snow melt period, river flow discharge measurements will be introduced as soon as the snow melt starts. All these measurements together are parameters for the following calculations of snowmelt runoff. Melting dynamic related to temperature, snow cover and season was discovered and will be compared with river discharge measurements.

Literature:

Asaoka, Yoshihiro, Yuji Kominami (2013): Incorporation of satellite-derived snow-cover area in spatial snowmelt modeling for a large area: determination of a gridded degree-day factor

Ismail, Muhammad Fraz, Habib-ur-Rehman, Wolfgang Bogacki, Noor Muhammad (2015): Degree Day Factor models for forecasting the snowmelt runoff for Naran watershed

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Jost, Georg, R. Dan Moore, Markus Weiler, David R. Gluns, Younes Alila (2009): Use of distributed snow measurements to test and improve a snowmelt model for predicting the effect of forest clear-cutting

Krasting, John P., Anthony J. Broccoli, Keith W. Dixon, John R. Lanzante (2013): Future Changes in Northern Hemisphere Snowfall

Masiokas, Mariano H., Ricardo Villalba, Brian H. Luckman, Carlos Le Quesne, Juan Carlos Aravena (2006): Snowpack Variations in the Central Andes of Argentina and Chile, 1951–2005: Large-Scale Atmospheric Influences and Implications for Water Resources in the Region

Schelker, J., L. Kuglerová, K. Eklöf, K. Bishop, H. Laudon (2013): Hydrological effects of clear-cutting in a boreal forest –Snowpack dynamics, snowmelt and streamflow responses

Keywords: Snow Water Equivalent, Degree-Day Factor, soil moisture, snowmelt, climate data, snow accumulation

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Study on transport of particulate organic matter in a small river with forest and paddy filed by using carbon isotopes ($\delta^{13}C$ and $\Delta^{14}C$)

*長尾 誠也[1]、田原 龍之介[2]、落合 伸也[1]、後藤 晶子[3]、長谷川 卓[3]
*Seiya Nagao[1], Ryunosuke Tahara[2], Shinya Ochiai[1], Akiko Goto[3], Takashi Hasegawa[3]

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1. Institute of Nature and Environmental Technology, Kanazawa University, 2. Graduate School of Natural Science and Technology, Kanazawa University, 3. Institute of Science and Engineering, Kanazawa University

Radioactive and stable isotopes of carbon (^{14}C and ^{13}C) can serve as powerful tools for identifying sources and estimating turnover times of organic matter in aquatic systems. The present study aims to investigate variations in the characteristics of riverine particulate organic matter running through forests and paddy fields, corresponding to a typical Japanese river system. We selected the Kumaki River located in the central part of the Noto Peninsula in Ishikawa Prefecture, Japan. The river research was conducted at a fixed site of the midstream Kumaki River from April 2016 to March 2018.

Total organic carbon and nitrogen content was measured using the elemental analyzer after the 0.1 M HCl treatment to remove inorganic carbonates. ^{14}C measurements were performed by accelerator mass spectrometry. Final ^{14}C activities are reported in $\Delta^{14}C$. $\delta^{13}C$ values were determined for sub-samples of the CO_2 gas generated during graphite production, using an isotope ratio mass spectrometer.

$\delta^{13}C$ and $\Delta^{14}C$ values of organic matter in the riverine POC of Kumaki River show the range of −27.2‰ to −25.1‰, and −130 to +3 ‰, respectively. There are two negative correlations (correlation factor of 0.78) between the $\delta^{13}C$ and $\Delta^{14}C$ values at winter and the other season except for summer in July and August in 2017. The results indicate that particulate organic matter is mixed with two end-members such as surface forest soil and paddy field soil.

キーワード：放射性炭素、炭素安定同位体比、懸濁態有機物
Keywords: Radiocarbon, stable carbon isotope ratio, Particulate organic matter

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Sources of Shallow Groundwater Salinity in the Ganges Delta of Bangladesh

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In Bangladesh, unconsolidated fluvio-deltaic sediments host highly productive aquifer systems that are generally classified as shallow aquifers (depth less than 150 m below ground level, mbgl) and deep aquifers (depth more than 150 mbgl). Elevated groundwater salinity in shallow aquifers underlying the southern deltaic areas, in addition to mass poisoning of arsenic, aggravates freshwater scarcity in the country. However, little is known about the origin of salinity and mechanisms of salinization. Therefore, we analyzed both measured and previously published data on pH (n=585), electrical conductivity (EC, n=737), chloride and bromide (n=120 each), stable isotopes of water (oxygen-18 & deuterium, n=175 each), and radiogenic isotopes (C-14, n=18 & tritium, n=29) to discuss these issues for the upper shallow groundwater (depth around 60 mbgl) in the Ganges delta covering much of the coastal areas of Bangladesh. Stable isotope data from two GNIP (Global Network of Isotopes in Precipitation) stations in the delta were incorporated in this study. A paleo-shoreline, representing the maximum extent of last marine transgression at around 7 ka, was retrieved from a previous study and incorporated as well.
The upper shallow groundwater shows slightly acidic to alkaline in nature (6.1-8.5) over the delta. EC ranges from 210-29,400 microsimens/cm with lower salinity in fluvial area (210-2,000 microsimens/cm) than those in tidal domain (383-29,400 microsimens/cm). Cl^-/Br^- molar ratios are higher in tidal area (160-540,000) than those in fluvial setting (42-2,800). The cross plot between oxygen-18 and deuterium isotopes shows that groundwater data fall on or slightly below the local meteoric water line (Figure 1). Most of the brackish groundwater (n=43, EC>2,000-10,000 microsimens/cm) contains depleted isotope signatures. In EC vs oxygen-18 cross plot, EC mostly increases with almost constant isotopic signatures and this trend does not follow seawater mixing. Tritium concentrations are either low (0.1-2.9 TU, n=6) or below detection limit (<0.3 TU, n=9) in tidal domain, whereas around 57% of data show 0.2-7.2 TU in fluvial area. Radiocarbon (C-14) signatures are also higher in fluvial area (around 50-88 pMC) than those in tidal domain (around 36-86 pMC).
These results indicate that present-day seawater intrusion or connate seawater/estuarine water entrapped within sediments is not a major source of elevated salinity in groundwater. Current seawater intrusion is being occurred probably only in limited areas, i.e., near the coast. Also, it is hypothesized that groundwater salinity was possibly provided through the dissolution of soluble salts in paleosols by paleo-precipitation and concurrent infiltration to aquifers. During the transgression, intertidal environment was dominated in the study area, where evaporites and mud-cracks were likely to be developed during prolonged dry season. Subsequently, the monsoonal precipitation dissolved these evaporite minerals and vertically infiltrated into aquifers through mud-cracks or sediments. The future tasks should concentrate on analyzing whether these processes are occurring currently in the delta as well as reconstruction of paleo-geography for validating the hypothesis.

Keywords: Elevated salinity, Upper shallow groundwater, Electrical conductivity, Isotopes, Intertidal environment, Evaporite minerals

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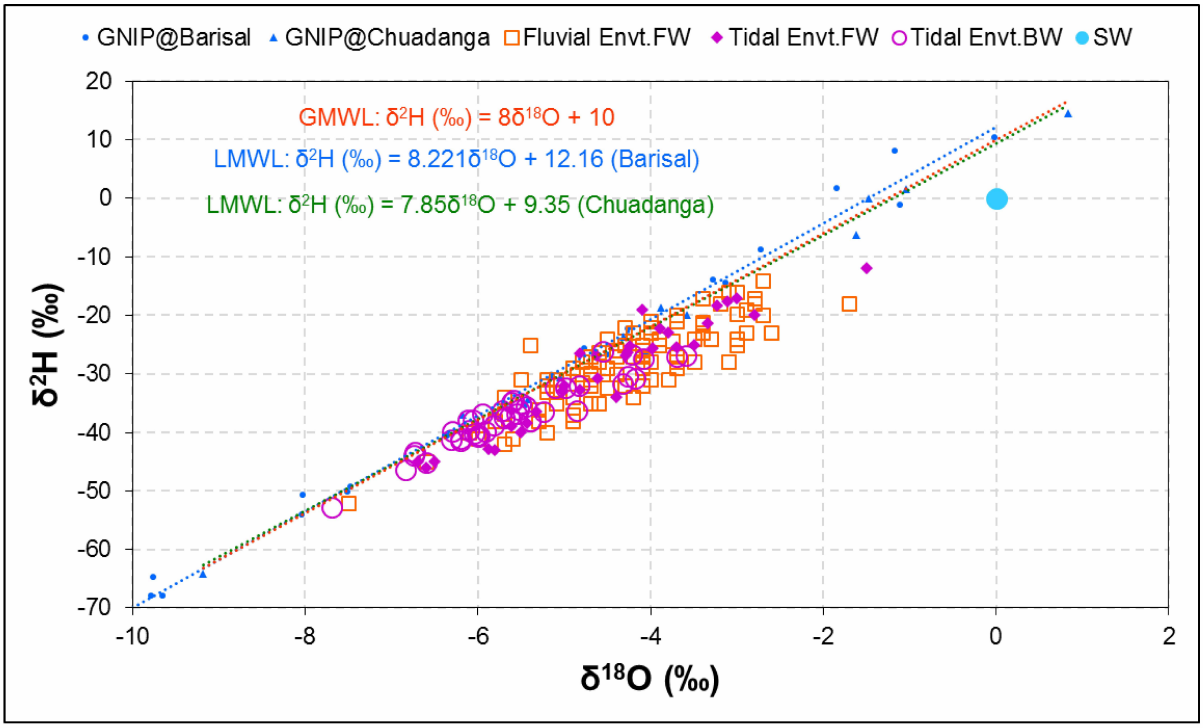


Figure 1: Cross plot between stable oxygen ($\delta^{18}O$) and deuterium ($\delta^{2}H$) isotopes

GNIP: Global Network of Isotopes in Precipitation, Envt.: Environment, FW: Freshwater (≤2000 µS/cm), BW: Brackish water (>2000 µS/cm), SW: Seawater

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Groundwater chemistry in the Gunii Khooloi basin, Southern Gobi Region of Mongolia using multivariate analysis

*Batdemberel BAYANZUL[1,2], Isao Machida[3], Kengo Nakamura[2], Noriaki Watanabe[2], Takeshi Komai[2]

1. School of Geology and Mining Engineering, Mongolian University of Science and Technology, 2. Graduate School of Environmental Studies, Tohoku University, 3. Groundwater research group, Advanced Industrial Science and Technology

Water plays a vital role in the southern part of Mongolia where is climatically classified as an arid and semi-arid region, so called Southern Gobi Region of Mongolia (SGR). Groundwater serves as the only source of water supply and is largely utilized by mining companies such as the Tavan Tolgoi and Oyu Tolgoi Mine located in the SGR. The area is expected to face severe water shortages of mining and drinking water, which may be related to changes in groundwater recharge due to climate change. Understanding the geochemical evolution of groundwater and recharge mechanisms in the Gunii Khooloi basin is thus paramount for water resource management in this region. However, chemical compositions of groundwater in the SGR has not been studied so far.

In this study, the hydrogeochemical approaches have been introduced to characterize hydrogeochemical characteristics and its associated recharge processes in the Gunii Khooloi basin. To investigate this hydrogeochemical study, springs, groundwater in shallow wells and deep wells in the study area were sampled twice (in September 2016, and in June 2017). A total of 95 groundwater samples were collected within these two years for major chemical analysis in order to understand the general hydrogeochemical conditions of the Gunii Khooloi basin.

Here, we will present the groundwater chemical properties and relationship between shallow and deep groundwater in the Gunii Khooloi basin clarified by multivariate statistical analysis, such as principal component analysis (PCA) and hierarchical cluster analysis (HCA).

Keywords: Groundwater chemistry, Principal component analysis, Southern Gobi Region of Mongolia

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Temporal observation of molybdenum concentrations in rivers from Erdenet mining area, Mongolia

*Solongo Tsetsgee[1], Keisuke Fukushi[1], Altansukh Ochir[2], Takahashi Yoshio[3], Ariuntungalag Yunden[2], Enkhjin Odgerel[2], Noriko Hasebe[1]

1. Kanazawa University, 2. National University of Mongolia, 3. The University of Toyko

Erdenet mine is one of the world’ s largest copper–molybdenum mine. This study is conducted the temporal observation of Mo concentrations in river waters. The waters were collected from three rivers, flowing thought Erdenet city, during 9 months in 2018 March to November.
During the summer Mo concentration was increasing with temperature and pH. On the other hand, When the winter was starting low concentration of Mo with low temperature and pH. The Mo concentration is positively correlated with pH and temperature. The tailing pond sample pH slightly lower than rivers due to it couldn’ t be increase of pH in river water. And also, sediment result showed that Mo concentration is lower than water. Therefore, another possibility of reason could be relating to the white dust and it can be increase pH of water.
A huge tailing pond is located in the north of the Erdenet area. It is recognized that the dried precipitates formed by the neutralization of the acidic mine water in the tailing ponds are dispersed widely in the Erdenet area by wind. The dried precipitates (so called white dust) are mainly composed with lime or carbonates containing high amount of Mo. It can be expected that the white dust may dissolve with rainwater. The increase of Mo concentrations associated with the increase of pH may be caused by the dissolution of the white dust at summer rainy season.

Keywords: Molybdenum , pH, Erdenet mine, River water, Temporal observation

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[E] 口頭発表 | セッション記号 A (大気水圏科学)：A-HW 水文・陸水・地下水学・水環境

2019年5月29日(水) 10:45 ~ 12:15 | 103 1F

[A-HW23] 水循環・水環境

コンビーナ:町田 功(産業技術総合研究所地質調査総合センター)、山崎 大(東京大学生産技術研究所)、林 武司(秋田大学教育文化学部)、福士 圭介(金沢大学環日本海域環境研究センター)、座長:福士 圭介

We focus on various issues of water cycle and environment and aim to answer questions of hydrological and earth system sciences including 1) surface, subsurface and evapotranspiration processes of water cycle; 2) natural and anthropogenic hydrothermal systems, 3) environments issues and studies on a watershed or global scale, 4) water-related issues with ecological, environmental, and geochemical aspects, and 5) other issues in hydrological sciences. This session welcomes presentations regarding various kinds of approaches and techniques such as field survey, remote sensing, isotope tracers, numerical simulation, and theoretical analysis.

10:45 ~ 11:05

[AHW23-18] 琵琶湖湖底近傍におけるマンガン・ヒ素の水-鉱物相互作用　―過去40年間での湖内分布の変化に対する考察ー

★招待講演

*板井 啓明[1]、名取 幸花[1] (1.東京大学大学院理学系研究科　地球惑星科学専攻)

11:05 ~ 11:20

[AHW23-19] **Sources, pathways and treatment of contaminants in surface water: Applicability in developing countries**

*Mst. Shamsun Nahar[1] (1.Earth Consultant Co. Ltd, Toyama, Japan)

11:20 ~ 11:35

[AHW23-20] **Numerical simulations (COMSOL) of γ-Fe_2O_3 nanohybrids for transport (3D) and arsenic removal in homogeneous porous media**

*Ajay Kumar[1]、Himanshu Joshi[1]、Anil Kumar[1] (1.INDIAN INSTITUTE OF TECHNOLOGY ROORKEE, INDIA)

11:35 ~ 11:50

[AHW23-21] **Transport processes of suspended solids in the Kumaki River inferred from atmospheric radionuclides**

*落合 伸也[1]、田原 龍之介[2]、松中 哲也[1]、長尾 誠也[1] (1.金沢大学 環日本海域環境研究センター、2.金沢大学 自然科学研究科)

11:50 ~ 12:05

[AHW23-22] Using tritium in Japanese precipitation for tritium-tracer transit time studies across Asia

*Maksym Gusyev[1]、Yoshito Kikumori[1]、Terumasa Nishihara[2]、Takeshi Hayashi[3]、Kimpei Ichiyanagi[4]、Naofumi Akata[5]、Tomoki Oda[6]、Uwe Morgenstern[7]、Michael Stewart[7] (1.International Centre for Water Hazard and Risk Management (ICHARM), Public Works Research Institute (PWRI)、2.Civil Engineering Research Institute for Cold Region, PWRI、3.Akita University、4.Kumamoto University、5.National Institute for Fusion Science (NIFS)、6.University of Tokyo、7.GNS Science, New Zealand)

12:05 ~ 12:15

Discussion

琵琶湖湖底近傍におけるマンガン・ヒ素の水-鉱物相互作用　ー過去40年間での湖内分布の変化に対する考察ー

Solid-water interaction of Mn and As near the bottom of Lake Biwa. –Implications for the spatio-temporal change of these elements for past 40 years-

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Enrichment of Mn and As in the surface of sediment caused by diagenetic process has been reported from various lakes in the world. Lake Biwa is a typical example, in which clear enrichments of Mn (up to 5.7 wt%) and As (up to 900 mg/kg) within thin surface enriched layer (< 2 cm) of sediment were observed. This enrichment is caused by the accumulation of manganese oxide and arsenate both of which show lower mobility than these reducing chemical forms. However, decreasing trend of interannual minimum dissolved oxygen level reported from the lake-bottom can change redox behavior of these elements near the sediment-water interface (Itai et al. 2012, Sohrin et al. 2016, Fukushima et al. 2019). Through the geochemical survey after 2009, some specific scientific questions have been arisen.

(i) The degree of surface enrichment of Mn and As from 7 stations in northern lake were markedly increased in 2009 relative to 1977 (Itai et al., 2012). However, the source of them and process of this change are unclear.

(ii) The temporal increase of As in sediment is particularly significant in southern basin of northern lake (so called “first-basin”). The As accumulated on the surface of sediment is likely by scavenging from water column rather than upward diffusion from buried sediment. Nevertheless, difference between northern and southern basin (so called “second-basin”) is unclear.

(iii) Past study suggest that Mn and As level in sediment can be a unique indicator of palaeo water depth (Takamatsu, 1985). This is plausibly caused by higher enrichment of Mn and As toward deeper part of the lake. We confirmed this trend via measurement of 22 core sediments from northern lake. We hypothesize that this distribution is attributed to the geochemical focusing (Schaller et al., 1997), although scientific evidences are still not enough. Besides, there should be some specific mechanism to keep Mn and As enrichment after buried into deep sediment.

In order to answer these questions, we need comprehensive geochemical survey between water column and sediment with focusing speciation of these metals. In the presentation, we would like to present our dataset of lake water (3 stations, 10 m depth interval, 1 year), sediment core (30-40 cm depth, 22 stations), porewater (30 - 40 cm depth, 7 stations), filtered materials of 1, 3, 5, 7, 9 m from lake bottom (7 stations) characterized by X-ray absorption spectroscopy, micro beam chemical analysis, water chemistry analysis, porous diffusion model, and aqueous speciation calculation. Coupling with available monitoring data after 1950s, we make some constraints for the above questions.

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キーワード：マンガン、ヒ素、形態分析、酸化還元、経時変化、湖底堆積物
Keywords: manganese, arsenic, speciation, redox environment, temporal change, lake sediment

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Sources, pathways and treatment of contaminants in surface water: Applicability in developing countries

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This report presents the contamination degree, occurrence, distribution characteristics in the surface water and sediments from Dhaka Rivers (Buriganga and Shitalakshya River) and the Bay of Bengal coast of Bangladesh. A model water treatment method is developing using Baburail Canal Water linked with Shitalakshya River, a World Bank supported project, under Narayanganj City Corporation, Bangladesh. By evaluating hypoxic to anoxic low dissolve oxygen (DO) (below the 0.85 mg/L critical level) associated with very high concentrations of biological oxygen demands (BOD) (5-10 mg/L) and toxic metals (Cr, As, Pb, Cd etc.) in surface water, a model treatment process is developing by using micro bubbling system for increasing the DO level, Neem leaves and bamboo powder are for heavy metals removal process and finally TiO_2 (P25)/ Fe^{+++} method is for the degradation and coagulation of organic content in treated water. The model method of this study should be applied to future water treatment focused on the potential to improve water quality in urban and surrounding areas in developing countries.

Keywords: Surface Water, Bay of Bengal, Dissolve Oxygen, Micro Bubbling System

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Numerical simulations (COMSOL) of γ-Fe_2O_3 nanohybrids for transport (3D) and arsenic removal in homogeneous porous media

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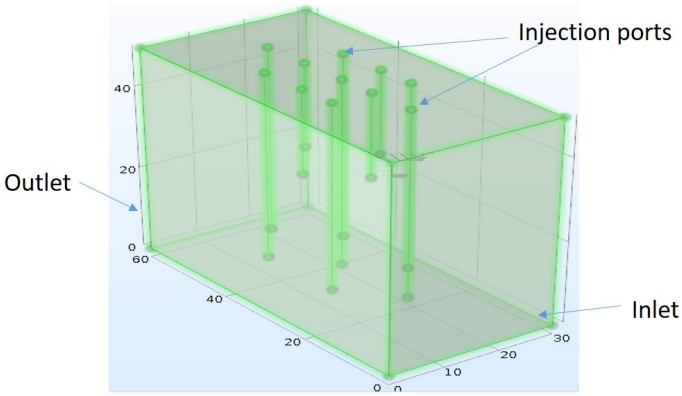
Worldwide, arsenic is a menace among the living communities due to its contamination in groundwater. It leaches moderately into groundwater from earth crust and bedrocks enriched with its ores. The countries like India and Bangladesh are being critically affected due to their densely populated areas. Several nanomaterials have been developed and examined as adsorbents for its removal, which are being utilized in *ex-situ* remediation technique. This technique has the disadvantages in terms of generating highly toxic waste, causes due to its easy mobilization in the living ecosystems. Nowadays, *in-situ* (subterranean) sequestration of arsenic is gaining considerable attention in respect to reduce the chance of its mobilization in living environment.

To this aim, the γ-Fe_2O_3 nanohybrids are developed using a novel approach of synthesis which include the usage of industry waste as one of precursor material. These nanoparticles have been found significantly stable in aqueous solutions representing real world groundwater conditions. The measured zeta (ζ)-potential value of -31.6 mV, indicated their significant colloidal stability. In respect to *in-situ* application, the understanding of transport modeling and retardation of nanomaterials in aquifer systems by simulating through numerical models in complex 3-dimensional scenario are necessary. Therefore, a modeling approach based on modified advection-dispersion-retardation equations has been investigated, considering the coupled influence of head difference and reaction rate of particle transport.

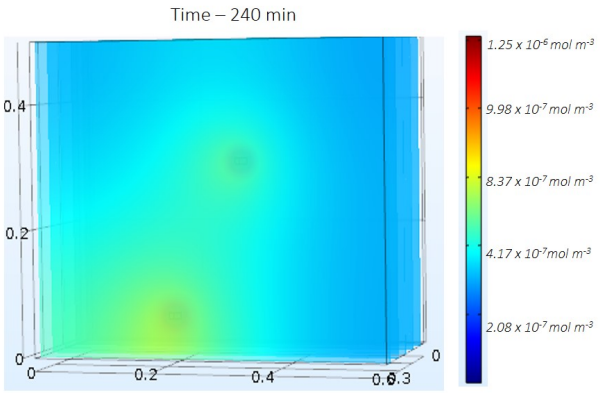
All the experiments were performed in a sand-tank set up (0.6 x 0.3 x 0.50 m) having several injection ports at variable depths. The tank was packed with the porous media (medium size sand) having the grain size (mm), grain density (g cm^{-3}), bulk density (g cm^{-3}) and effective porosity (%) values of 0.5-1.0, 2.33 ± 0.2, 1.55 ±0.09 and 0.34 ±0.1, respectively. The longitudinal and traverse dispersivity of consolidated media were calculated using NaCl as a tracer. The COMSOL Multiphysics model (subsurface module) was investigated for simulation of γ-Fe_2O_3 nanohybrids injection and their transport through porous media. Transport of arsenic and as-synthesized nanomaterial were modelled by considering these as solute and colloid, respectively, under fully saturated homogenous porous media and variable flow rate conditions. After simulation, the colloidal solution of nanoparticles was allowed to inject at the concentration of 1.25 x 10^{-4} mol m^{-3} and flow rate of 1.2 L h^{-1}. The simulation results were matched with the experimental observations which provided estimates of transport parameters. The retardation efficiency utilized to predict the γ-Fe_2O_3 nanohybrids in similar porous media, although the extend of injection pressure, colloid concentration and pumping rate may be underpredicted which require further investigations.

Keywords: Numerical modeling, In-situ arsenic sequestration, Groundwater

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3-Dimesional view of Sand-Tank set up



Transport of nanohybrids (Simulation)

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Transport processes of suspended solids in the Kumaki River inferred from atmospheric radionuclides

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1. Institute of Nature and Environmental Technology, Kanazawa University, 2. Graduate School of Natural Science and Technology, Kanazawa University

The Kumaki River, which drains into the Nanao Bay, is in the central part of the Noto Peninsula. Over recent years, the vegetation in the catchment area of the Kumaki River has changed, and the areas of unmanaged forest and cultivated areas have progressively increased because of plantation activities and decreasing and aging population. These anthropogenic catchment environmental changes may affect the erosion and transport of clastic materials and particulate organic matter to the lower reaches and coastal areas. It is therefore important to clarify the transport processes of these materials to achieve proper management and prediction of environmental changes in river watersheds and coastal areas.
To investigate the transport processes of suspended solids (SS) in the Kumaki River, the atmospheric radionuclides ($^{210}Pb_{ex}$, ^{7}Be, and ^{137}Cs) of SS samples were observed. The SS samples were obtained with a continuous centrifuge of the river water (100 L) collected at the three sampling points (upstream, midstream, and downstream) in Kumaki River every month since April 2016. The concentrations of atmospheric radionuclides in SS samples were measured with a Ge detector. The water discharge was also measured based on cross-sectional profiles of water depth and the flow velocity with a leveling rod and a flow meter at each sampling point.
The $^{7}Be/^{210}Pb_{ex}$ activity ratio of SS sample, which is related to the residence time of these radionuclides in the catchment area, showed clear positive correlation with the water discharge and it was high during winter season with higher precipitation in each sampling point. This result indicates that SS was transported in a shorter time scale during rainfall event and winter season. On the other hand, $^{7}Be/^{210}Pb_{ex}$ ratio exceptionally decreased during heavy rainfall events with the higher water discharge over the threshold value, implying that older stored sediment and subsurface soil were eroded and transported under these conditions. Temporal and spatial changes in ^{137}Cs concentration and $^{137}Cs/^{210}Pb_{ex}$ ratio of SS sample showed different fluctuation in each sampling point, suggesting that changes in discharge amount and source of SS were affected by the subcatchment-scale local hydrological environments and land use conditions.

キーワード：浮遊物質、河川流域、大気由来放射性核種
Keywords: suspended solids, river catchment area, atmospheric radionuclides

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Using tritium in Japanese precipitation for tritium-tracer transit time studies across Asia

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In order to improve management of water resources, water circulation times are estimated with the use of tritium-tracer in catchments across Asia. As an environmental tracer generated in the upper atmosphere, tritium in precipitation is influenced by latitude, season and altitude, and understanding of tritium inputs in water cycle components is needed to estimate mean transit times (MTTs). For future studies, we established the latitude scaling factors to the north and south of the Tokyo area, which has the tritium measurements in monthly precipitation from 1961 to present, by investigating the latitude tritium effect at selected coastal stations in Asia (Gusyev et al., 2016; 2019). In Japan, higher spring tritium was confirmed with winter and spring precipitation samples in 2016 and we observed the altitude effect in March-April snowpack in Hokkaido. The importance of latitude and altitude effects is demonstrated with annual tritium in precipitation at Japanese meteorological stations compared to Tokyo tritium, and with estimated MTTs using 2016 tritium winter and summer baseflow samples at headwater catchments of the Tone and Ishikari River basins, Japan.

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Gusyev M.A., Morgenstern U., Nishihara T., Hayashi T., Akata N., Ichiyanagi K., Sugimoto A., Hasegawa A., Stewart, M.K. (2019). Evaluating anthropogenic and environmental tritium effects using precipitation and Hokkaido snowpack at selected coastal locations in Asia. Science of the Total Environment 659: 1307-1321, doi: 10.1016/j.scitotenv.2018.12.342

Gusyev M.A., Morgenstern U., Stewart M.K., Yamazaki Y., Kashiwaya K., Nishihara T., Kuribayashi D., Sawano H. and Y. Iwami (2016). Application of tritium in precipitation and baseflow in Japan: a case study of groundwater transit times and storage in Hokkaido watersheds. *Hydrol. Earth Syst. Sci.*, 20, 1-16, doi:10.5194/hess-20-1-2016

Keywords: tritium in precipitation, scaling factors, tritium input, mean transit times

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[E] 口頭発表 | セッション記号 A (大気水圏科学)：A-CG 大気海洋・環境科学複合領域・一般

2019年5月29日(水) 15:30 ~ 17:00 | 302 3F

[A-CG34] 衛星による地球環境観測

コンビーナ:沖 理子(宇宙航空研究開発機構)、本多 嘉明(千葉大学環境リモートセンシング研究センター)、高薮 縁(東京大学 大気海洋研究所)、松永 恒雄(国立環境研究所地球環境研究センター／衛星観測センター)、座長:可知 美佐子(宇宙航空研究開発機構　地球観測研究センター)

近年、我々は様々な時空間スケールで起こる地球環境変動の問題を意識せざるを得ない状況下にある。衛星による地球環境観測データは、その問題への対処や解決に向けて必要不可欠な基礎データとなっている。衛星観測の分野は、近年の観測センサ技術とデータ処理技術の進歩により急速な進展を見せつつあり、個々の観測センサデータの精度を吟味する時代から、より高度なデータ利用の時代に入り、ユーザーの裾野も広がっている。また40年以上に渡る観測データの蓄積により、長期変動の解析がもたらす成果に期待が持てるようになり、長期継続観測の重要性が益々増している。利用が複合的になった今日において、大気、海洋、陸域の分野を包含できる本連合大会の大気水圏科学分野のセッションで包括的に取り上げ、関係者の知恵と知識を集結することで地球環境変動の問題に向けた更なる研究と利用の進展、将来の衛星地球観測計画の議論を促進することを目的としてセッション提案を行う。

15:30 ~ 15:45

[ACG34-01] 水循環変動観測衛星「しずく」と高性能マイクロ波放射計2（AMSR2）の現状と将来計画

*可知 美佐子[1]、前田 崇[1]、小野 温[1]、藤井 秀幸[1]、笠原 希仁[1]、江淵 直人[1,2] (1.宇宙航空研究開発機構　地球観測研究センター、2.北海道大学　低温科学研究所)

15:45 ~ 16:00

[ACG34-02] Testing and Evaluation for JPSS-1 Algorithms using Algorithm Development Library Block 2.1

*Bigyani Das[1,2]、Weizhong Chen[1,2]、Thomas S King[1,2]、Walter Wolf[2] (1.IMSG、2.STAR/NESDIS/NOAA)

16:00 ~ 16:15

[ACG34-03] Remote Sensing of Atmospheric and Surface Properties using Hyperspectral satellite Sensors

*Xu Liu[1] (1.NASA Langley Research Center)

16:15 ~ 16:30

[ACG34-04] **RADIOMETRIC UNIFORMITY AND STABILITY OF GROUND SITE CHARACTERIZATION FOR INSAT-3D**

*Shailesh Parihar[1]、R. Bhatla[1]、A. K. Mitra[2] (1.Banaras Hindu University, Varanasi, India、2.India Meteorological Department, New Delhi, India)

16:30 ~ 16:45

[ACG34-05] 地球環境観測のためのASTER熱赤外放射計に対する代替校正活動

*山本 聡[1]、外岡 秀行[2]、加藤 創史[3]、鮎澤 一樹[2]、松永 恒雄[4] (1.宇宙システム開発利用推進機構、2.茨城大学、3.リモート・センシング技術センター、4.国立環境研究所)

16:45 ~ 17:00

[ACG34-06] 植生ライダMOLIの概要

★招待講演

*下田 陽久[1]、木村 俊義[2]、三橋 怜[2]、室岡 純平[2]、境沢 大介[2]、今井 正[2]、浅井 和宏[3] (1.東海大学、2.日本宇宙航空開発研究機構、3.東北工業大学)

水循環変動観測衛星「しずく」と高性能マイクロ波放射計2（AMSR2）の現状と将来計画
Current Status and Future Plan of the Global Change Observation Mission - Water (GCOM-W) and Advanced Microwave Scanning Radiometer 2 (AMSR2)

*可知 美佐子[1]、前田 崇[1]、小野 温[1]、藤井 秀幸[1]、笠原 希仁[1]、江淵 直人[1,2]
*Misako Kachi[1], Takashi Maeda[1], Nodoka Ono[1], Hideyuki Fujii[1], Marehito Kasahara[1], Naoto Ebuchi[1,2]

1. 宇宙航空研究開発機構　地球観測研究センター、2. 北海道大学　低温科学研究所
1. Earth Observation Research Center, Japan Aerospace Exploration Agency, 2. Institute of Low Temperature Science, Hokkaido University

The Global Change Observation Mission (GCOM) –Water (GCOM-W) is one of two medium sized satellites to provide comprehensive information of the Essential Climate Variables (ECV) of atmosphere, ocean, land, cryosphere, and ecosystem. The GCOM-W (Water) or “SHIZUKU” satellite that carries the Advanced Microwave Scanning Radiometer 2 (AMSR2), which was launched on May 2012; and GCOM-C (Climate) or “SHIKISAI” satellite that carries the Second-generation Global Imager (SGLI) and launched in December 2017. Both satellites are currently operating, and their data are distributed through the JAXA G-Portal (https://gportal.jaxa.jp/gpr/).

AMSR2 is multi-frequency, total-power microwave radiometer system with dual polarization channels for all frequency bands, and a successor of JAXA’s Advanced Microwave Scanning Radiometer for EOS (AMSR-E) on the NASA's Aqua satellite. Sensor specification of AMSR2 is almost identical to that of AMSR-E, except larger (2.0 m) antenna, additional 7.3 GHz channels to mitigate Radio Frequency Interference (RFI) and improved internal calibration. Due to its higher spatial resolution, all-weather capability, near-real-time availability and observation stability, AMSR2 data is routinely used in many operational and science applications. To provide consistent dataset between AMSR2 and AMSR-E for long-term water cycle monitoring and climate studies, we applied the latest AMSR2 algorithms and formats to AMSR-E data and have provided products through the G-Portal system. Level 1B and 1R (resampled L1B) products have been released since April 2018, and Level 2 products will be released early summer in 2019. We have also released new AMSR2 research products, Thin Ice Detection (sea ice thinner than 30 cm) and Total Precipitable Water over Land, since January 2019 through the GCOM-W Research Product Data Providing Service (https://suzaku.eorc.jaxa.jp/GCOM_W/research/resdist.html).

The GCOM-W satellite has been in extended mission phase since 2017, and we expect to operate satellite and instrument as long as possible to reduce observation gaps between AMSR2 follow-on mission, which has been in Pre-project Phase (Phase A) since September 2018.

キーワード：衛星リモートセンシング、水循環、マイクロ波放射計
Keywords: satellite remote sensing, water cycle, microwave radiometer

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Testing and Evaluation for JPSS-1 Algorithms using Algorithm Development Library Block 2.1

*Bigyani Das[1,2], Weizhong Chen[1,2], Thomas S King[1,2], Walter Wolf[2]

1. IMSG, 2. STAR/NESDIS/NOAA

The Joint Polar Satellite System 1 (JPSS-1) is the next generation polar-orbiting operational environmental satellite which was launched on November 18, 2017. It carries advanced versions of the instruments Advanced Technology Microwave Sounder (ATMS), Cross-track Infrared Sounder (CrIS), Ozone Mapping and Profiler Suite (OMPS) and Visible Infrared Imaging Radiometer Suite (VIIRS) that are on board of Suomi National Polar-Orbiting Partnership (S-NPP) satellite which was launched on October 28, 2011. All the Sensor Data Record (SDR) algorithms for the instruments are processed in the Interactive Data Processing Segment (IDPS) system designed and maintained by Raytheon. The Algorithm Development Library (ADL) Block 2.1 is an updated offline test system developed by Raytheon to mimic the operational system. Current version of the algorithm has gone through many recent code updates as well as Look-up-Table (LUT) updates for improving product quality. The center for Satellite Applications and Research (STAR) Algorithm Scientific Software Integration and System Transition Team (ASSISTT) uses ADL Block 2.1 to test and integrate updates to JPSS-1 algorithms, both code and the Lookup Tables (LUTs). Weekly updates are made to Dark tables for both OMPS Nadir Mapper (NM) and Nadir Profiler (NP) instruments and for both SNPP and JPSS-1 (J01) satellites. These are tested, integrated and submitted as packages with inputs, outputs and guide documents for further verification by the Data Products Engineering and Services (DPES) team and final integration by Raytheon in the operational system IDPS. Updates are also made to bi-weekly Wavelength and Solar tables for OMPS NP for SNPP satellite. They are tested and submitted in the package for operational implementation. We have created scripts to automate the staging and processing of weekly and bi-weekly updated LUTs in ADL Block 2.1. Details of the process of integration and application of the scripts for testing and integration of LUTs for OMPS as well as other instruments will be discussed.

Keywords: JPSS, Algorithm Integration, STAR ASSISTT, Algorithm Development Library

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Remote Sensing of Atmospheric and Surface Properties using Hyperspectral satellite Sensors

*Xu Liu[1]

1. NASA Langley Research Center

Hyperspectral remote sensors from satellite platforms provide high information content on clouds, atmospheric temperatures, moisture, and trace gases profiles. They also provide surface information. In order to retrieve these information from hyperspectral remote sensing data, a fast and accurate radiative transfer model and a robust inversion algorithm are needed. We will describe a Principal Component-based Radiative Transfer Model (PCRTM) and an associated non-linear inversion algorithm. The PCRTM model can provide fast and accurate top of atmosphere high spectral resolution radiance or reflectance spectra from far infrared spectral region to UV-VIS spectral region. The forward model has been used to analyse hyperspectral data such as AIRS, CrIS, IASI, and SCIAMACHY. Examples of retrieval results from some of these satellite sensors will be given.

Keywords: remote sensing, atmospheric profiles, radiative transfer

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RADIOMETRIC UNIFORMITY AND STABILITY OF GROUND SITE CHARACTERIZATION FOR INSAT-3D

*Shailesh Parihar[1], R. Bhatla[1], A. K. Mitra[2]

1. Banaras Hindu University, Varanasi, India, 2. India Meteorological Department, New Delhi, India

Radiometric phenomena of Earth Observation Satellite sensors vary between ground pre-launch calibration campaign, after launch and over satellite lifetime due to launching vibration, eventual optical element misalignments, generally space harsh environment. One of vicarious calibration methods is the reflectance-based approach that is applied here to radiometric calibration of INSAT-3D visible channel. In-situ vicarious calibration method for radiometric calibration of visible (VIS 550–750 nm) sensor onboard geostationary satellite INSAT-3D has been carried out for characterizing the radiometric uniformity of the site at Bhuj, Gujarat. The measurements of ground reflectance (spectral range of 350–2500 nm), aerosol optical depth (AOD), total column ozone from Spectroradiometer (spectral range of 350–2500 nm), Sunphotometer, Ozonometer respectively and other meteorological variables were obtained from site during the field campaigns and calibration coefficients with bias and relative error for optical sensor of the INSAT-3D satellite is presented. Based on these measurements, simulations of radiance reaching at top of the atmosphere (TOA) were carried out using radiative transfer model 6S (Second Simulation of the Satellite Signal in the Solar Spectrum). The computed TOA radiances when compared with the sensor measured radiances for various dates and sites show an over-estimation of TOA radiance. The analysis suggested that Bhuj site has been preferred for post launch vicarious calibration of optical sensor of INSAT-3D satellite as well as upcoming geostationary INSAT satellite series.

Keywords: INSAT-3D, vicarious calibration, radiative transfer model 6S

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地球環境観測のためのASTER熱赤外放射計に対する代替校正活動
Vicarious calibration activities of ASTER Thermal Infrared Radiometer (TIR) for Earth environmental observation

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1. Japan Space Systems, 2. Ibaraki University, 3. Remote Sensing Technology Center of Japan, 4. National Institute for Environmental Studies

The Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) instrument on the Terra satellite has been retrieving multiband images with 14 spectral bands from the visible through thermal infrared and stereo images over the Earth's surface since 2000. The data set by ASTER has provided the composition and distribution of materials, temperature/emissivity map, and digital elevation topography models (DEM), contributing to a variety of Earth's science applications, i.e., natural resources, agricultural applications, natural disasters, geology, and urban development as well as monitoring global environmental change. In addition, the data of ASTER is being used for space business involved in space-enabled economic activity and service.

In order to establish the ASTER data for high-accuracy applications, radiometric calibration and atmospheric correction are highly important. Since any optical sensor is expected to degrade in space, we need to monitor the performance of the sensor over time based on onboard and vicarious calibrations. One of vicarious calibration approaches characterizes instrument performance based on comparison with the data measured by field campaigns at homogeneous ground areas such as lake and desert sites. The field campaigns for ASTER took place at various test sites such as Railroad Valley Playa, Lunar Lake, and Alkali Lake in Nevada and water sites such as Lake Kasumigaura in Japan during about two decades.

On 30 August through 1 September 2018, as part of annual vicarious calibrations for ASTER Thermal Infrared Radiometer (TIR), we conducted the field campaigns at Railroad Valley playa and Alkali Lake in Nevada. We also made the vicarious calibration at Lone Mountain playa in Nevada, which is a new test site discovered during this campaign. In this presentation, we will report the activity of the 2018's field campaigns at Nevada, and discuss how important the radiometric calibration after launch is to Earth's science applications including assessment of global environmental change based on satellites.

キーワード：マルチペクトルデータ、リモートセンシング、ASTER、地球観測衛星、代替校正
Keywords: multispectral data, remote-sensing, ASTER, Earth observation satellite, vicarious calibration

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植生ライダMOLIの概要
Overview of Vegetation Lidar MOLI

*下田 陽久[1]、木村 俊義[2]、三橋 怜[2]、室岡 純平[2]、境沢 大介[2]、今井 正[2]、浅井 和宏[3]
*Haruhisa Shimoda[1], Toshiyoshi Kimura[2], Rei Mituhashi [2], Junpei Muruoka [2], Daisuke Sakaizawa[2], Tadashi Imai [2], Kazuhiro Asai[3]

1. 東海大学、2. 日本宇宙航空開発研究機構、3. 東北工業大学
1. Tokai University, 2. JAXA, 3. Tohoku Institute of Technology

Under the PARIS AGREEMENT (Adopted at COP 21 in 2015), each country, including developing countries, is obliged to declare its emissions, but an objective verification method was considered necessary from the perspective of credibility and accuracy. It is said that one of the largest errors today is in the evaluation of CO_2 absorption by forests. Regarding the assessment of forests as a CO_2 absorption source, biomass and the change of biomass observed. We propose the use of airborne and satellite-mounted LIDAR as an effective method of directly measuring tree height. JAXA has begun studying the space vegetation LIDAR mission using the Multi-footprint Observation Lidar and Imager (MOLI) in collaboration with scientists. The main objective of this mission is to globally and precisely measure canopy height from space for improving biomass estimation. MOLI is designed to be mounted on the Exposed Facility (EF) of the Japanese Experiment Module on the International Space Station (ISS). The mission requirements for MOLI were set through discussions with scientists, and are listed as follows:

1. MOLI measures canopy height globally with accuracy of ±2 m (for canopy height less than 20 m) or ± 10% (for canopy height above 20 m) so as to generate map data of canopy heights and biomass, combined with imagery data from other satellites. The measurement data are also used as inputs or for validation in carbon cycle models.

2. Simultaneously, MOLI also measures the vegetation index and vegetation phenology for generating more accurate map data of canopy height and biomass.

3. MOLI measures the average amount of carbon per sub-national-scale area (80 km grid) to an uncertainty level of 20% or less (95% confidence interval).

The system requirements for MOLI are set based on the mission requirements. Regarding the waveform generated by the Geoscience Laser Altimeter System (GLAS) installed in the ICESat. However, waveforms with a lower S/N (less than 10) were excluded from analysis, as it greatly reduced the accuracy of canopy height measurement. Based on this result, the S/N requirement of MOLI was set to 10 or more, and the measurement precision of canopy height reached ±2 m or 10 %.

The tilted ground causes significant errors in measuring the canopy height due to the difference in height of the ground in the footprint. MOLI must be able to detect the inclination of the ground in order to estimate the difference in height of the footprint ground. Thus, MOLI must have a multi-footprint to estimate the tilt of the ground surface by detecting the time lag of each footprint.

Since MOLI needs to acquire data on vegetation phenology and vegetation index at the same time as the LIDAR observation to generate map data, it also has an optical imager with multiple bands. Using the imager, MOLI also measures the canopy height to identify the trees observed by MOLI for ground

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verification. The imager GSD is 5m. The imager also has green, red and NIR bands for measuring vegetation phenology and vegetation index.

To realize the sampling design, it is necessary to irradiate two laser beams and receive two reflection signals with the array detector. We considered dividing the laser beam into two laser beams by using an optical system. Based on this method, one laser transmitter is attached and the pulse energy is 40 mJ

キーワード：植生ライダ、MOLI、バイオマス
Keywords: vegetation Lidar, MOLI, biomass

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2019年5月29日(水) 13:45 ~ 15:15 | 303 3F

[A-CG35] 地球規模環境変化の予測と検出

コンビーナ:河宮 未知生(海洋研究開発機構)、建部 洋晶(海洋研究開発機構)、立入 郁(海洋研究開発機構)、座長:建部 洋晶

地球温暖化および関連する人為起源の環境変化により、極端な気象現象の激甚化や海面上昇、海洋酸性化・貧酸素化、そして大規模な生態系変化が生じることが懸念されている。こうした変化を予測するための実験プロトコル(CMIP6)が、2021年公表予定のIPCC第6次報告書に向けて定められ、それに基づいた各国の研究機関での実験結果が得られつつある。CMIP6の他にも、イベントアトリビューションや、環境変化と社会経済の相互作用を取り入れたモデル開発など、様々なタイプの予測研究が盛んになっている。また、環境変化を捉える観測研究や、予測の信頼性検証ための観測データ解析も重要性を増してきている。本セッションでは、地球規模環境変化予測に関する専門的な議論に加え、モデル予測と観測、社会科学との分野横断的な連携も視野に、最新の研究成果報告と討議を行う。なお本セッションは、Future Earth プロジェクト「地球システムの解析・統合・モデリング」AIMES (https://aimesproject.org/) との共同開催である。

13:45 ~ 14:00

[ACG35-01] Sour and anoxic Sea of Japan in the near future

*Chen-Tung Arthur Chen[1]、Hon-Kit Lui[1]、Masao Ishii[2] (1.National Sun Yat Sen University、2.Japan Meteorological Agency)

14:00 ~ 14:15

[ACG35-02] Decadal predictions of the variable ocean carbon uptake

★Invited Papers

*Hongmei Li[1]、Tatiana Ilyina[1]、Wolfgang A. Müller[1,2]、Peter Landschützer[1] (1.Max Planck Institute for Meteorology, Bundesstraße 53, 20146 Hamburg, Germany、2.Deutscher Wetterdienst, Bernhard-Nocht-Straße 76, 20359 Hamburg, Germany)

14:15 ~ 14:30

[ACG35-03] Air-sea CO_2 flux variations in the tropical Pacific simulated with two ESMs embedded an ocean data assimilation system

*渡辺 路生[1]、建部 洋晶[1]、小山 博司[1]、羽島 知洋[1]、渡部 雅浩[2]、河宮 未知生[1] (1.海洋研究開発機構、2.東京大学大気海洋研究所)

14:30 ~ 14:45

[ACG35-04] A Study of Decadal Ocean Deoxygenation and Heat Uptake from a suite of OMIP Simulations

*Takano Yohei[1]、Tjiputra Jerry[2]、Schwinger Jörg[2]、Gröger Matthias[3]、Berthet Sarah[4]、Séférian Roland[4]、Yool Andrew[5]、Palmieri Julien[5]、渡辺 路生[6]、Stemmler Irene[1]、Ilyina Tatiana[1] (1.Max Planck Institute for Meteorology、2.Norwegian Research Centre、3.Swedish Meteorological and Hydrological Institute、4.Centre National de Recherche Météorologique, Unite mixte de recherche 3589 Météo-France/CNRS、5. National Oceanography Centre、6.Japan Agency for Marine-Earth Science and Technology)

14:45 ~ 15:00

[ACG35-05] Role of large-scale environmental variability in changing storm climate

*Nilima Aditya Natoo[1] (1.University of Bremen, Germany)

15:00 ~ 15:15

[ACG35-06] The forced response of the climate system: The case of climatic teleconnections

*Tamas Bodai[1]、Matyas Herein[2]、Gabor Drotos[3] (1.University of Reading、2.Eotvos University Budapest、3.Universitat de les Illes Balears)

Sour and anoxic Sea of Japan in the near future

*Chen-Tung Arthur Chen[1], Hon-Kit Lui[1], Masao Ishii[2]

1. National Sun Yat Sen University, 2. Japan Meteorological Agency

The ocean acidification is frequently related to hypoxia. In the paper "An anoxic Sea of Japan in 2200?" (Chen, Marine Chemistry, 1999) it was suggested that the sea is undergoing rapid de-oxygenation, and that the sea may become anoxic by the year 2200. But, a question mark was used in the title because of large uncertainties. In a recent Nature Climate Change paper (Chen et al., 2017), however, it was further concluded that the deep Sea of Japan has acidified at a faster rate than anywhere else in the world oceans. The conclusion of rapid acidification is in line with the conclusion of de-oxygenation. In addition, adding 20 years of new data confirms that the assessment of 1999 was correct. Likely the Sea of Japan would become sour and anoxic within the next two hundred years, if not sooner, based on nutrients, oxygen and pH data.

Keywords: Sea of Japan, acidification, hypoxia

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Decadal predictions of the variable ocean carbon uptake

*Hongmei Li[1], Tatiana Ilyina[1], Wolfgang A. Müller[1,2], Peter Landschützer[1]

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The global ocean, as a major carbon sink, absorbs about 25% of the contemporary anthropogenic CO_2 emissions; hence the carbon uptake by the ocean largely mitigates the CO_2concentration increase in the atmosphere and hence the global warming. Moreover, the strength of the carbon flux into the ocean, varies substantially from annual to decadal time-scale. Therefore, predicting the variable ocean carbon uptake and global carbon cycle is of essential value of tracing the fate of carbon and the corresponding climate and ecosystem changes.

By assimilating atmosphere and ocean physical observations into the decadal prediction system based on the Max Planck Institute Earth System Model (MPI-ESM), we reproduce the ocean carbon uptake variations in consistent with the data-based estimates. The retrospective predictions starting from the assimilation states show a predictive skill of 2 years in the ocean carbon uptake globally. Regionally the predictive skill is up to 5 years in the Southern Ocean and the North Pacific. To understand the mechanisms in maintaining the predictability of the ocean carbon uptake, we separate the ocean surface pCO_2, which is the main driver of the variability in carbon fluxes, into thermal and non-thermal components. The thermal component is affected by the solubility of CO_2via temperature variations, and the non-thermal component is affected by the ocean circulation and biology, i.e., is not first order affected by the temperature. We find that the thermal component contributes mainly to shorter-term (of <3 years) of predictive skill of the ocean carbon uptake, while the non-thermal component is responsible for longer-term (of >3 years) of predictive skill of the ocean carbon uptake.

Decadal prediction study of the global carbon cycle and corresponding ecosystem based on the ESMs is still at its early stage and facing a number of challenges arising from limited ocean biogeochemical observations and lack of proper initialization strategies. An extension of our predictions in the context of multi-model framework is in progress and this will facilitate deeper understanding of the mechanisms and further improvement of the predictive skill in the global carbon cycle.

Keywords: Decadal predictions, Ocean carbon uptake, Climate variability

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Air-sea CO_2 flux variations in the tropical Pacific simulated with two ESMs embedded an ocean data assimilation system

*渡辺 路生[1]、建部 洋晶[1]、小山 博司[1]、羽島 知洋[1]、渡部 雅浩[2]、河宮 未知生[1]
*Michio Watanabe[1], Hiroaki Tatebe[1], Hiroshi Koyama[1], Tomohiro Hajima[1], Masahiro Watanabe[2], Michio Kawamiya[1]

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1. Japan Agency for Marine-Earth Science and Technology, 2. Atmosphere and Ocean Research Institute, the University of Tokyo

Interannual-to-decadal fluctuations of the global-mean atmospheric CO_2 concentration are observed associated with internal climate variations, and these fluctuations sometimes cancel out and at other times support the centennial increasing trend of the global-mean atmospheric CO_2 concentration due to accumulation of anthropogenic CO_2 emissions. One direct cause of the fluctuations is the oceanic absorption or release of CO_2 through the global air-sea CO_2 flux variations which are mainly dominated by the tropical Pacific. Therefore, deeper understanding of the tropical oceanic processes and properly initializing oceanic states including marine ecosystem are of importance in future predictions of the global CO_2 concentration together with quantification of human-influences. In the present study, we examined the simulated air-sea CO_2 flux variations in the tropical Pacific in two ESMs (MIROC-ES2L and MIROC-ESM) with the same ocean data assimilation system. Although the assimilation procedures are the same, observed anti-correlated relationship between interannual variations of the upward air-sea CO_2 flux and the sea surface temperature (SST) in the tropical Pacific are well captured in MIROC-ES2L, but the relationship is reversed in MIROC-ESM. Tropical climatic-mean state of MIROC-ESM shows significant biases of weaker trade winds as well as more diffuse equatorial thermocline than observations, and simulated amplitude of interannual variations of NINO3-SST is about half as large as observations. When observations are assimilated into the model, these biases lead to non-negligible correction terms on the governing equations of ocean temperature and salinity, which induces an anomalous spurious equatorial upwelling during El-Niño events. The spurious upwelling brings dissolved inorganic carbon rich water in the subsurface layer to the surface mixed layer. Consequently, an anomalous upward air-sea CO_2 flux is occurred during El-Niño, as opposed to observations and MIROC-ES2L. Better modeling physical processes in the tropical climate system is suggested to be essential for better marine ecosystem modeling and reanalysis.

キーワード：地球システムモデル、データ同化、大気海洋CO2フラックス、ENSO
Keywords: Earth system model, data assimilation, air-sea CO2 flux, ENSO

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A Study of Decadal Ocean Deoxygenation and Heat Uptake from a suite of OMIP Simulations

*Takano Yohei[1]、Tjiputra Jerry[2]、Schwinger Jörg[2]、Gröger Matthias[3]、Berthet Sarah[4]、Séférian Roland[4]、Yool Andrew[5]、Palmieri Julien[5]、渡辺 路生[6]、Stemmler Irene[1]、Ilyina Tatiana[1]
*Yohei Takano[1], Jerry Tjiputra[2], Jörg Schwinger[2], Matthias Gröger[3], Sarah Berthet[4], Roland Séférian[4], Andrew Yool[5], Julien Palmieri[5], Michio Watanabe[6], Irene Stemmler[1], Tatiana Ilyina[1]

1. Max Planck Institute for Meteorology、2. Norwegian Research Centre、3. Swedish Meteorological and Hydrological Institute、4. Centre National de Recherche Météorologique, Unite mixte de recherche 3589 Météo-France/CNRS、5. National Oceanography Centre、6. Japan Agency for Marine-Earth Science and Technology
1. Max Planck Institute for Meteorology, 2. Norwegian Research Centre, 3. Swedish Meteorological and Hydrological Institute, 4. Centre National de Recherche Météorologique, Unite mixte de recherche 3589 Météo-France/CNRS, 5. National Oceanography Centre, 6. Japan Agency for Marine-Earth Science and Technology

Observational studies reveal substantial ocean deoxygenation and increased heat uptake in the past decades. These two properties are known to be tightly connected. The Earth System Models (ESMs) struggle to simulate the observed trends in oxygen inventory (O_2-Inv) and the tight global O_2-heat relationship. One possible reason is the role of decadal climate variability.

The past decadal changes in oxygen inventory and tight global O_2-heat relationship cannot be fully explained by changes in solubility alone, indicating the important role of changes in ocean circulation and biology. Climate variability could modulate O_2-Inv and heat uptake on decadal timescales but the observed climate variability is not necessarily simulated in the ESMs historical simulations due to the fact that the models have their own internal climate variability, which vary in magnitude and phase, in the coupled climate system. Here we address the question how the observed decadal climate variability modulates O_2-Inv and heat uptake using a suite of OMIP simulations.

We will present results from the comparison of state-of-the-art ocean model simulations driven by the atmospheric reanalysis forcing. The main focus is to understand decadal changes in global and regional upper ocean O_2-Inv and OHC based on the results from six different model simulations (NorESM-OC, EC-EARTH3.3.0, CNRM-ESM2-1, UKESM1, MIROC-ES2L, and MPI-OM-HAMOCC), and observations. The model structural differences result in different physical and biogeochemical mean states, which lead to different decadal variability of O_2-Inv and OHC. The regional O_2-heat relationship among the models and observations would be presented to discern the biases in the simulated ocean circulations and biological processes. Our study will provide first indications of the importance of decadal climate variability on determining changes in O_2-Inv and OHC. Hence, it will also provide guidance on accuracy and uncertainty of future deoxygenation and warming projected in the ESMs. We aim on stimulating the discussion on near term strategy of how we analyze upcoming OMIP simulations within the context of climate variability and changes in ocean physics and biogeochemistry based on our multi-model analysis.

キーワード：Multi-model comparison、ocean deoxygenation、ocean heat uptake、decadal variability and trend
Keywords: Multi-model comparison, ocean deoxygenation, ocean heat uptake, decadal variability and trend

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Role of large-scale environmental variability in changing storm climate

*Nilima Aditya Natoo[1]

1. University of Bremen, Germany

This paper focusses sequentially on two different aspects: (a) recent changes in observed storms, and (b) its linkages to the changes in large-scale environmental (LSE) variability. The analysis of observed storm show that in spite of an overall reduction in the Southwest Pacific (SWP) storminess over the past four decades, the number of extreme storms corresponding to the mean maximum sustained storm wind speed, has increased. At the same time, a slight reduction in the corresponding mean minimum central pressure is observed. The transition time from category 1 to 3 has also reduced substantially (by ~12 hours). Possible conditions for some of these observed behavioural change in terms of quick intensification and traveling longer distance towards south pole will be discussed.
The second aspect explores the linkages between above changes in storm indices and corresponding variability in LSE variability. The methodology uses multiple linear regression analysis to establish their relationship. This relationship is used to construct scenarios of likely change in future storminess using simulated (RCP8.5 minus historical) differences. The analysis will show how the role of some of the environmental indices when in combination can aid in modulating the Southwest Pacific change in storminess.

Keywords: Southwest Pacific, Storminess, Regression analysis

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The forced response of the climate system: The case of climatic teleconnections

*Tamas Bodai[1], Matyas Herein[2], Gabor Drotos[3]

1. University of Reading, 2. Eotvos University Budapest, 3. Universitat de les Illes Balears

We frame the forced response of the climate system in terms of an ensemble that represents the so-called snapshot/pullback attractor, and explore the implications and power of this approach. Teleconnections as cross-correlations can be defined in the ensemble-based framework by evaluating the correlations over ensemble members. As a specific example, we studied the teleconnection between the El Niño–Southern Oscillation (ENSO) and the Indian summer monsoon in ensemble simulations from state-of-the-art climate models, the Max Planck Institute Earth System Model (MPI-ESM) and the Community Earth System Model (CESM). We detect an increase in the strength of the teleconnection in the MPI-ESM under historical forcing between 1890 and 2005, which is in contrast with scientific consensus. In the MPI-ESM no similar increase is present between 2006 and 2099 under the Representative Concentration Pathway 8.5 (RCP8.5), and in a 110-year-long 1-percent pure CO2 scenario; neither is in the CESM between 1960 and 2100 with historical forcing and RCP8.5. This is also a puzzling result inasmuch as the historical forcing is the weakest. Accordingly, we evaluated that the static susceptibility of the strength of the teleconnection with respect to radiative forcing (assuming an instantaneous and linear response) is at least three times larger in the historical MPI-ESM ensemble than in the others.

Keywords: teleconnection, ENSO, Indian monsoon, forced response, trajectory ensemble

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2019年5月29日(水) 15:30 ~ 17:00 | 303 3F

[A-CG35] 地球規模環境変化の予測と検出

コンビーナ:河宮 未知生(海洋研究開発機構)、建部 洋晶(海洋研究開発機構)、立入 郁(海洋研究開発機構)、座長:立入 郁(海洋研究開発機構)、河宮 未知生(海洋研究開発機構)

地球温暖化および関連する人為起源の環境変化により、極端な気象現象の激甚化や海面上昇、海洋酸性化・貧酸素化、そして大規模な生態系変化が生じることが懸念されている。こうした変化を予測するための実験プロトコル(CMIP6)が、2021年公表予定のIPCC第6次報告書に向けて定められ、それに基づいた各国の研究機関での実験結果が得られつつある。CMIP6の他にも、イベントアトリビューションや、環境変化と社会経済の相互作用を取り入れたモデル開発など、様々なタイプの予測研究が盛んになっている。また、環境変化を捉える観測研究や、予測の信頼性検証ための観測データ解析も重要性を増してきている。本セッションでは、地球規模環境変化予測に関する専門的な議論に加え、モデル予測と観測、社会科学との分野横断的な連携も視野に、最新の研究成果報告と討議を行う。なお本セッションは、Future Earth プロジェクト「地球システムの解析・統合・モデリング」AIMES (https://aimesproject.org/) との共同開催である。

15:30 ~ 15:45

[ACG35-07] Guiding Mother Earth: taking stock of progress to a long-term temperature goal

★Invited Papers

*Myles Robert Allen[1] (1.Environmental Change Institute, School of Geography and the Environment and Department of Physics, University of Oxford)

15:45 ~ 16:00

[ACG35-08] **Uneven distributions of four hazard indicators of climate change with the Paris Agreement's goals**

*塩竈 秀夫[1] (1.国立環境研究所地球環境研究センター)

16:00 ~ 16:15

[ACG35-09] Understanding the centennial-scale human-natural interactions using an integrated terrestrial model MIROC-INTEG under ISIMIP2 project

*佐藤 雄亮[1]、Julien Boulange[1]、花崎 直太[1]、高田 久美子[1]、Yadu Pokhrel[3]、Ted Veldkamp[2,4]、Peter Burek[2]、横畠 徳太[1] (1.国立研究開発法人国立環境研究所、2.国際応用システム研究所、3.ミシガン州立大学、4.アムステルダム自由大学)

16:15 ~ 16:30

[ACG35-10] Radiative forcing of the physiological CO_2 response

*Victor Brovkin[1]、Veronika Gayler[1]、Sonia I Seneviratne[2]、Pierre Gentine[3] (1.Max Planck Institute for Meteorology, Hamburg, Germany、2.ETH, Institute for Atmospheric and Climate Science, Zurich, Switzerland、3.Columbia University, Earth and Environmental Engineering, New York, USA)

16:30 ~ 16:45

[ACG35-11] Progress of MIROC-ES2 simulations in CMIP6 and the analysis of the biogeochemical feedbacks

*羽島 知洋[1]、渡辺 真吾[1]、河宮 未知生[1]、立入 郁[1]、建部 洋晶[1]、伊藤 昭彦[2]、高田 久美子[2]、渡辺 路生[1]、野口 真希[1]、山本 彬友[1]、伊藤 彰記[1]、阿部 学[1]、大垣内 るみ[1]、山崎 大[3] (1.独立行政法人 海洋研究開発機構、2.国立環境研究所、3.東京大学生産技術研究所)

16:45 ~ 17:00

[ACG35-12] The impact of long-term historical warming on the global terrestrial gross primary production

*Irina Melnikova[1]、Takahiro Sasai[1] (1.Tohoku University)

Guiding Mother Earth: taking stock of progress to a long-term temperature goal

*Myles Robert Allen[1]

1. Environmental Change Institute, School of Geography and the Environment and Department of Physics, University of Oxford

The IPCC Special Report on 1.5˚C found that human-induced global warming had reached 1˚C ±0.2˚C, increasing at 0.2˚C per decade, leaving only a few decades for emissions to be reduced to net zero to limit warming to 1.5˚C. The Paris Climate Agreement introduced a regime of periodic stocktakes of progress to the long-term temperature goal of limiting warming to well below 2˚C, pursuing efforts to 1.5˚C. While there is general agreement that these stocktakes are to be informed by science, these is less consensus on how this will be done. I will explain how we can robustly estimate the level of human-induced warming to date, and how this information was used to support a revision in the remaining carbon budget for cumulative future CO_2 emissions consistent with limiting warming to 1.5˚C. CO_2 budgets in the IPCC Special Report were contingent on scenarios for non-CO_2 forcing, but the concept of a carbon budget can be generalised if we recognise how other anthropogenic forcing agents affect climate on different timescales, either expressing them as CO_2-forcing-equivalent emissions, or applying the traditional GWP_{100} metric in a new way. Taken together, these insights provide a simple, transparent, scenario-independent and model-independent method of assessing the implications of current and future emissions for progress towards a long-term temperature goal.

Keywords: Climate change, Greenhouse-gases, Stocktake, Attribution, Metrics, Forcing

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Uneven distributions of four hazard indicators of climate change with the Paris Agreement’ s goals

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Clarifying characteristics of hazards and risks of climate change at 2ºC and 1.5ºC global warming is important for understanding the implications of the Paris Agreement. We perform and analyse large ensembles of 2ºC and 1.5ºC warming simulations. In the 2ºC runs, we find substantial increases in extreme hot days, heavy rainfalls, high streamflow and labor capacity reduction related to heat stress. For example, about half of the world's population will experience a present day 1-in-10 year hot day event every other year at 2ºC warming. The regions with largely increases of these four hazard indicators coincide with countries characterized by small CO_2 emissions, low-income and high vulnerability. Limiting global warming to 1.5ºC, compared to 2ºC, will lower increases in the four hazard indicators especially in those regions.

キーワード：気候変動、パリ協定
Keywords: Climate change, Paris Agreement

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Understanding the centennial-scale human-natural interactions using an integrated terrestrial model MIROC-INTEG under ISIMIP2 project

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*Yusuke Satoh[1], Julien Boulange[1], Naota Hanasaki[1], Kumiko Takata[1], Yadu Pokhrel[3], Ted Veldkamp[2,4], Peter Burek[2], Tokuta Yokohata[1]

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Within the earth system, changing-climate, -human society, and -ecosystems interact mutually. It is crucial to better understand the interconnectedness among such human-natural systems in order to assess the potential impacts of climate and socioeconomic changes on each system and identify sustainable pathways. Although existing earth system models and integrated assessment models are applicable to explore this field, parts of their natural and/or human processes tend to be simplified depending on their scope. Therefore, it still remains a challenge to improve integrated modeling frameworks. For these reasons, a process-based integrated terrestrial model, MIROC INTEGrated terrestrial model (MIROC-INTEG), was developed. The modeling framework is composed of five natural/human subcomponents. At its core is a land surface model (MATSIRO), which is coupled to three human modules; water use (H08), food and biofuel crop production(PRYSBI2) and land use change (TELMO). An ecosystem model (VISIT) calculates the C and N cycles among atmosphere-vegetation-soil. While each sub-model can run independently, MIROC-INTEG dynamically simulates their interactions, embracing the water-food-energy nexus within a system.

The goal of this study is to improve our quantitative understanding on coupled terrestrial systems at the global scale for past and future time-scales. Hence, we have run MIROC-INTEG following the Inter-Sectoral Impact Model Inter-comparison Project phase 2a (ISIMIP2a) and 2b (ISIMIP2b) simulation protocols. Using 3 hourly climate forcing data and considering anthropogenic activities, MIROC-INTEG simulated agro-hydrological condition at a spatial resolution of 0.5°, globally. As its inputs, ISIMIP2a makes use of three reanalysis-base metrological data for historical periods, and ISIMIP2b employs an ensemble of bias-corrected forcing data set of four general circulation models covering preindustrial, historical, and future time-periods under four representative concentration pathways. Furthermore, ISIMIP provides a unique opportunity for validation of simulation skill in comparison with other models' under consistent protocols.
Within this contribution we present the first results of MIROC-INTEG looking specifically at the centennial-scale human-natural interactions over the period 1851-2099 and its consequences for long-term changes in fundamental hydrological variables. The results are presented at global, regional and large-basin scale and are compared against existing ISIMIP runs of other hydrological and land surface models.

キーワード：陸域統合モデル、人間活動、気候変動および社会変化、マルチフォーシング、モデル間相互比較
Keywords: Integrated terrestrial model, Human intervention, climate and socio-economic change, multi-forcing, model inter comparison

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Radiative forcing of the physiological CO_2 response

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Theory and observations indicate that plant stomatal conductance decreases in response to increase in the atmospheric CO_2. This physiological CO_2 response causes reduction in the evapotranspiration and modification of the global hydrological cycle, affecting the global radiative fluxes and climate sensitivity. While this biogeophysical mechanism is included into all comprehensive Earth System Models, its radiative forcing has not been isolated from the other biospheric feedbacks. To evaluate the scale of its radiative forcing, we performed two sensitivity experiments with the CMIP6 version of the MPI Earth system model (MPI-ESM1.2-LR). In addition to the standard 4xCO_2 simulation, in which both climate and carbon cycle respond to an instantaneous 4-fold increase in CO_2, we performed the 4xCO_2rad simulation in which biogeochemistry and plants were not affected by elevated CO_2. We analyse changes in outgoing radiation and surface temperature using the Gregory et al. (2004) approach for radiative forcing, and compare results with- and without physiological CO_2 response. Rescaling to the doubling of the CO_2 concentration, stomatal conductance response increases equilibrium climate sensitivity of the model by ca. 10%, and its radiative feedback is estimated at 0.14 W/m^2/K. This suggest that the magnitude of this positive biogeophysical feedback is comparable with the magnitude of biogeochemical (climate-carbon) feedback.

Keywords: climate feedbacks, vegetation cover, radiative forcing

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Progress of MIROC-ES2 simulations in CMIP6 and the analysis of the biogeochemical feedbacks

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*Tomohiro Hajima[1], Shingo Watanabe[1], Michio Kawamiya[1], Kaoru Tachiiri[1], Hiroaki Tatebe[1], Akihiko Ito[2], Kumiko TAKATA[2], Michio Watanabe[1], Maki Noguchi[1], Akitomo Yamamoto[1], Akinori Ito[1], Manabu Abe[1], Rumi Ohgaito[1], Dai Yamazaki[3]

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In order to reveal how climate-biogeochemical system responds to anthropogenic forcing, a new Earth system model “MIROC-ES2L” has been developed for CMIP6. The physical core of the model is “MIROC5.2”, and the biogeochemical component are updated from that used for CMIP5: the new model has explicit CN interaction in land ecosystem, and ocean component has been improved to include P, Fe, and O in addition to C and N cycles that were already incorporated into that of CMIP5 ver. In the new model, ocean N cycle is opened to other subsystems: N input via biological fixation, deposition and riverine transport are considered, and denitrification process controls N loss from the ocean. This model is used for CMIP6 runs, by participating in endorsed MIPs such as C4MIP, PMIP, OMIP, LUMIP, CDRMIP, ScenarioMIP, VolMIP, etc.
A provisional historical simulation by MIROC-ES2L with CMIP6 official forcing (v6.2.1) clearly showed a global warming trend from 1970’s, which is consistent with observation (HadCRU4). Carbon stored in land ecosystem decreased by responding to the land-use change forcing, and started to increase around 1960 by responding to CO2 increase and increased N input into land (N deposition and fertilizer), in addition to the response to LUC. Ocean continuously store the anthropogenic CO2: the increase during 1850-2005 is about 150PgC, which is almost similar level to the number reported in Global Carbon Budget 2017. In addition to C cycle, the historical simulation showed drastic changes in global N budget, by directly responding to the anthropogenic forcing (LUC and agriculture), and indirectly affected by climate–carbon cycle change. Agriculture increased both land N2O emission (diagnosed) and N leaching, the latter of which impacted on ocean biogeochemistry near river mouths.

キーワード：地球システムモデル、生物地球化学、CMIP6、炭素循環、フィードバック
Keywords: Earth system model, Biogeochemistry, CMIP6, Carbon cycle, Feedback

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The impact of long-term historical warming on the global terrestrial gross primary production

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1. Tohoku University

The recent increase of carbon dioxide in the atmosphere from anthropogenic emissions resulted in the increase of carbon uptake by the global biosphere. The most uncertain contributor to the interannual global uptake variability is land, and the largest and primary land carbon flux is gross primary production (GPP). In this study, we aim to estimate the impact of the long-term (1951–2010) historical warming on the global terrestrial GPP. We use the Biosphere model integrating Eco-physiological And Mechanistic approaches using Satellite data (BEAMS ver.1.3) [*Sasai et al.*, 2016] forced by historical and nonwarming simulation climates of the Database for Policy Decision making for Future climate change (d4PDF) [*Mizuta et al.*, 2017]. This is a pioneer study to apply a diagnostic GPP estimation approach on the large-size ensembles climate data to simulate the long-term global GPP.

First, we evaluated the surface d4PDF climatology in comparison with existing modern datasets, including reanalyses, and discussed the benefits and limitations of the database in the studies of the terrestrial carbon fluxes. Second, we validated the BEAMS GPP forced by d4PDF data against observations and evaluated the BEAMS performance against existing GPP grid-datasets by other approaches (data-driven datasets and process-driven models). Finally, we discussed the impact of the long-term historical warming on the global GPP in terms of decadal trends and density histograms.

We confirmed that d4PDF surface climatology is appropriate for use in the studies of the terrestrial carbon fluxes, and d4PDF historical climate data is comparable to existing modern datasets. BEAMS estimated both the magnitude and decadal trends of the global terrestrial GPP realistically by using the benefits of the diagnostic approach. The global long-term (1951–2010) mean GPP equaled 144.0 ±2.3 GtC $year^{-1}$ for historical and 140.3 ±1.3 GtC $year^{-1}$ for nonwarming climates. The accumulated increase of the historical warming-induced GPP equaled 184.8 ±5.8 GtC for the period of 1951–2010 and accounted for nearly half of all anthropogenic emissions. The GPP increase intensified over time. The density histogram analyses showed that the global GPP distribution in the present (2001–2010) share neither the mean nor spread of GPP in the nonwarming climate.
This study provides the evidence of the impact of long-term historical warming on the global GPP by a novel approach using the benefits of the diagnostic model and large-size ensemble climate data.

Keywords: GPP, climate change, BEAMS, diagnostic approach, large-size ensemble, d4PDF

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[E] 口頭発表 | セッション記号 H (地球人間圏科学)：H-GM 地形学

2019年5月29日(水) 13:45 ~ 15:15 | 101 1F

[H-GM03] Geomorphology

コンビーナ:八反地 剛(筑波大学生命環境系)、瀬戸 真之(福島大学うつくしま福島未来支援センター)、座長:Thomas Parkner、八反地 剛

The main subject of this session is interdisciplinary discussion on the whole range of themes relating to geomorphology, especially geomorphic processes, landform development and its relation to environmental changes, geomorphological hazards and their mitigation, relationships among geomorphic processes, other natural phenomena and human activities, and various techniques of geomorphological measurements and landform classification. All presentations and discussion of this session are made in English.

13:45 ~ 14:00

[HGM03-01] Surface structure as a control for gully complex development in the Mackey`s block, North Island, New Zealand

*Thomas Parkner[1] (1.University of Tsukuba, Graduate School of Life and Environmental Sciences)

14:00 ~ 14:15

[HGM03-02] Model Linking Landslides and River Evolution of Incisional Channel Created by River Erosion

*Chia-Ting Kao[1]、Gene Jiing-yun You[1] (1.National Taiwan University)

14:15 ~ 14:30

[HGM03-03] **A semi-automated method for extracting channels and channel profiles from LiDAR-derived digital elevation models**

*Pinliang Dong[1] (1.University of North Texas)

14:30 ~ 14:45

[HGM03-04] Laboratory experiments on the landform development

*大内 俊二[1] (1.中央大学理工学部)

14:45 ~ 15:00

[HGM03-05] Characteristics of lake sediment from southern part of Mongolia and comparison to meteorological data

*Uyangaa Udaanjargal[1]、Noriko Hasebe[1]、Keisuke Fukushi[1]、Tanaka Yukiya[2]、Davaadorj Davaasuren[4]、Makoto Sambo[1]、Baasansuren Gankhurel[1]、Nagayoshi Katsuta[3]、Shinya Ochiai[1]、Tuvshin Gerelmaa[4] (1.Kanazawa University、2.Kyunghee University、3.Gifu University、4.National University of Mongolia)

15:00 ~ 15:15

[HGM03-06] **Evaluation of geomorphological changes on Kujukuri beach based on UAV SfM**

*Mergen Kungaa[1]、Toshihiko Sugai[1]、Natsuki Sasaki[1]、Taiga Kimori[1]、Taro Funatsu (1.Tokyo University, Graduate School of Frontier Sciences, Department of Natural Environmental Studies)

Surface structure as a control for gully complex development in the Mackey`s block, North Island, New Zealand

*Thomas Parkner[1]

1. University of Tsukuba, Graduate School of Life and Environmental Sciences

Gully erosion occurs on many steep, erosion-prone slopes. While most research focusses on gully formation by water erosion, gullies can also enlarge by mass movement processes. In New Zealand, such process combinations are named gully complexes. While concepts on gully complex development are available, material variability - other than lithology –is not included. In this study, development of gullies and gully complexes is analyzed by focusing on properties of the initial surface into with gullies and gully complexes erode to relate gully orientation and erosion intensity to surface structure.

The study area consists of 12 headwater catchments in the Mackey`s Block, North Island, New Zealand. Bedrock consists of Cretaceous-aged, highly crushed and sheared mudstones and sandstones. Deforestation by European settlers at the beginning of the 20th century for pastoral farming was followed by reforestation for wood production from the 1980s. Sequential aerial photographs from 1939 to 2005 were interpreted to map mass movements and the development of gullies. Digital elevation models were extracted from aerial photography from 1957 to 2002 using ERDAS to relate surface structure to gully orientation and erosion intensity.

Mapping results indicate that prior to a severe gully erosion phase, which started shortly before the first aerial photography in 1939, the surface structure is charaterized by (revegetated) small gullies, deep-seated landsliding with double ridges, and shallow flows. Deep (few meters to 15m) gullies complexes incised at the toe of mass movement bodies and eroded upslope. Such gullies developed oversteepened sidewalls, which in turn initiate extensive mass movements at the gully walls. Erosion intensity increased suddenly, where gullies destabilized mass movement deposits. Above the deep gully complexes, shallow (about 1 -2m deep), hundreds of meter long gully arms extended along boundaries of mass movements. These results indicate that next to morphometric parameters (slope, catchment size), material type, vegetation change, and moisture conditions, the development of gully complexes is also controlled by surface structure.

Keywords: gully, mass movement

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Model Linking Landslides and River Evolution of Incisional Channel Created by River Erosion

*Chia-Ting Kao[1], Gene Jiing-yun You[1]

1. National Taiwan University

Landslides produce enormous volumes of sediment in mountainous watersheds. However, quantifying landslide-derived sediment transported downstream remains a challenge. This study makes effort in determine the amount of landslide-derived sediment that eroded by the water and the ratio of sediment yield of this problem. We try to use a coupled two-dimensional model to investigate the evolution of landslide aggregation influenced by the channel flow.In this study, the shallow water equations consider the two-dimensional distribution flow velocity to estimate the shear stress. In addition, the Exner equation is applied to calculate the sediment transport the landslide aggregation evolution. By assuming constant inflow, the Exner equation can be derived as a diffusion equation. Besides, both of the two equations under a horizontal 2D straight, non-erodible banks, and no secondary flow channel can be derived as our governing equation which has the nonlinear terms, and the analytical method may not work to solve the two equations under the 2D condition. As a result, this study adopts the finite volume method to proceed this work. This proposed model will be able to have a better presentation in estimating the landslide-derived sediment in channel, and these sequences are expected to be useful indicators in the watershed management according to the predicted the upstream of watershed sediment yield .

Keywords: Landslide aggregation, River erosion, Finite volume method, Exner equation, Shallow water equations, Numerical modeling

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A semi-automated method for extracting channels and channel profiles from LiDAR-derived digital elevation models

*Pinliang Dong[1]

1. University of North Texas

Stream channels are an integral part of hydrology, alluvial geomorphology and tectonic geomorphology, and have long been studied qualitatively and quantitatively. With the advent of digital elevation models (DEMs) and geographic information systems (GIS), several methods have been proposed to extract channels from raster DEMs. This presentation introduces a semi-automated method for extracting stream channels from high resolution DEMs. The methodology flowchart includes the following major steps: (1) channel detection, (2) mathematical morphological operation, (3) vectorization, (4) profile generation, and (5) accuracy assessment. The method is implemented as an ArcGIS Python add-in toolbar. The application of the toolbar is demonstrated using a LiDAR-derived DEM in a study area along the San Andreas Fault in California, USA.

Keywords: Stream channel, Digital elevation model, Geographic information system, Light detection and ranging (LiDAR), Python

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Laboratory experiments on the landform development

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Geomorphic experiments with uplift and rainfall erosion are expected to provide some important knowledge to interpret the development of landform, which has left only scarce and hard-to-find evidence. This type of experiments had not been conducted so often, probably because no one had a good idea to scale down the processes of landform development. In recent years, however, laboratory experiments on the development of landform were increasingly conducted for the purpose to verify numerical/analytical models, which have been promoted by the development of computer technology and the spread of DEM, while the fundamental problems of huge scale difference have not been solved yet. Some of these recent experiments demonstrated a certain mechanism or a law governing the experimental landform development, such as the self-organized criticality or the competition between diffusive hill slope transport and advective transport in channels, which was suggested by numerical analyses. This indicates the applicability of numerical models to the experimental landform, but not to the real landform yet, although the authors believed it. Real landforms we see today have developed in the geographical space through the historical time, and inevitably have infinite varieties. We can find landscapes similar to the experimentally formed landscapes somewhere in the world, but this does not mean that mechanisms or laws dominated in the experiment also work on the real landform. The experimental landform develops within a certain setting, which is restricted by the facilities and arranged for the purpose. We still have a lot to do before taking the experiments as a bridge between numerical models and natural landscapes. I have been conducting a series of geomorphic experiments with changing experimental settings (40 runs by now), and I here try to make clear the significance of experiments in the study of geomorphology on the basis of these experiments.
A mixture of fine sand and kaolinite (10:1 by weight) compacted in a square prism-shaped stainless container (ca. 60×60×40cm) is pushed up by the uplift-generating device put under the bottom plate of container. Mist-type rainfall is generated by a pump through spray nozzles. The results of experiments suggested the existence of two thresholds of uplift rate, which is the most important independent controlling factor. Below the lower threshold, fluvial erosion offsets the surface rising by slow uplift, and gentle landforms reflecting the mound erodibility and rainfall intensity appear (Characteristic relief phase). Above the upper threshold, uplift overwhelms and a massive mountain grows until it hits the limit of experimental facilities (Mountain building phase). When the uplift rate is between the lower and upper thresholds, average surface height stops increasing and changes around a certain height depending on the uplift rate, after valley systems develop and slopes grow enough to cause landslides (Steady state phase). This steady state phase is the most common condition through the series of experiments. Rainfall intensity is expected to affect the amount of surface flow; and therefore, the rate of erosion. Low rainfall generates less surface flow, and this reduces erosion and make the surface grow higher. Permeability of the sand mound is considered to have a similar effect concerning the surface flow. However, more permeable material, associated with lower sear strength, promotes slope failures even in the earlier stage. The surface, therefore, becomes lower even with less rainfall. These factors, which relate each other themselves, apparently have complex effects on the development of experimental landform. The relationships among these controlling factors can be compared to those concerning real landform. Revealing these relationships and their effects on the experimental landform is probably the key to make

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geomorphic experiments meaningful in the study of geomorphology.

キーワード：地形実験、隆起、降雨強度、流水侵食、斜面崩壊、透水性
Keywords: geomorphic experiment, uplift, rainfall intensity, fluvial erosion, landslide, permeability

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Characteristics of lake sediment from southern part of Mongolia and comparison to meteorological data

*Uyangaa Udaanjargal[1], Noriko Hasebe[1], Keisuke Fukushi[1], Tanaka Yukiya[2], Davaadorj Davaasuren[4], Makoto Sambo[1], Baasansuren Gankhurel[1], Nagayoshi Katsuta[3], Shinya Ochiai[1], Tuvshin Gerelmaa[4]

1. Kanazawa University, 2. Kyunghee University, 3. Gifu University, 4. National University of Mongolia

Mongolia is located in center of the Central Asia and it provides an important key archive for the research of climate characteristics inside continents. Lake sediments are an excellent archive to study long-term fluctuations of environmental conditions (Gunten et al. 2009). Lake is the subject to a variety of extrinsic and intrinsic forcing variables that regulate the subsequent history of the lake, such as climate, watershed bedrock composition, tectonic and volcanic activity, vegetation, aquatic biota, and human activities (Gierlowski-Kordesch, 2004). To understand how climate system works in Mongolia and how we can extract information from the lake sediments, sediment cores of about 30 cm long from Boontsagaan, Orog and Olgoy lakes are analyzed and compared to the meteorological data (air temperature, precipitation and wind) of Galuut and Baatsagaan stations, Bayanhongor Province. The sedimentary features include whole and mineral grain size, grain density, water, organic matter, carbonate, and amorphous silica contents. Sedimentary ages were estimated by excess 210Pb measurement. According to the comparison between sediment characteristics and climate condition, temperature is correlated to whole grain size in three of lakes.

Further comparison reveals that calcium carbonate concentration, amorphous silica concentration, and mineral grain size correlate to temperature in Boontsagaan and Olgoy lakes. In Orog lake, wetter years with high wind and much rainfall result in fine grain size, while the high amount of $CaCO_3$and organic flux is found during the low precipitation. Some of the major fluctuations may indicate indirect consequence of climate change, for instance, some events such as the earthquake or a permafrost degradation.

Keywords: lakes , sediment characteristics, climate condition

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Evaluation of geomorphological changes on Kujukuri beach based on UAV SfM

*Mergen Kungaa[1], Toshihiko Sugai[1], Natsuki Sasaki[1], Taiga Kimori[1], Taro Funatsu

1. Tokyo University, Graduate School of Frontier Sciences, Department of Natural Environmental Studies

Nowadays, structure from motion (SfM) photogrammetry became a powerful tool in the hands of coastal researchers. During 2018-2019 we conducted 4 aerial survey by UAV on the 4 km long stretch on Kujukuri beach between Nabakigawa and Horikawa rivers, Chiba Prefecture. These 2 rivers separate research area from rest of 60-km long Kujukuri beach, forming separate morpho- and lithodynamical unit. The results of the research were high-resolution digital elevation models (DEM) and orthomosaics for February 2018, June 2018, September 2018 and February 2019. Based on DEM and orhomosaics we were able evaluate geomorphological changes throughout the year. From February 2018 to September 2018 we recorded active accumulation along the entire length of the beach. But accumulation intensity varied in different zones of beach as if foreshore, backshore or dunes. Also, the accumulation processes did not occur evenly for 7 months, but mostly intensified in the summer. From September 2018 to February 2019 erosional processes prevailed having different intensity at various sites. Thus, we were able to record in high resolution the process of transition from the winter profile of the beach to the summer profile and back.

Keywords: Coastal geomorphology, UAV SfM, Kujukuri beach

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[E] 口頭発表 | セッション記号 H (地球人間圏科学)：H-DS 防災地球科学

2019年5月29日(水) 9:00 ~ 10:30 | 304 3F

[H-DS10] Natural hazards impacts on human society, economics and technological systems

コンビーナ:PETROVA ELENA(Lomonosov Moscow State University, Faculty of Geography)、松島 肇(北海道大学大学院農学研究院)、座長:Elena Petrova、Hajime Matsushima

The last decade set a record for the number and scale of natural disasters and demonstrates high vulnerability of human society and technosphere to their impacts. The most serious consequences have the so-called natural-technological disasters in which natural hazards trigger accidents at technology and infrastructure such as nuclear power and chemical plants, oil refineries and pipelines, power supply systems, buildings, and roads. A distinctive feature of natural-technological events, such as of the 2011 Tohoku earthquake, is their multi-hazard and synergistic nature, which creates cascading impacts, resulting in simultaneous occurrences of myriad catastrophes. The main goal of this multidisciplinary session is to summarize case studies of relationships between natural hazards and technological disasters, their social and economic consequences; and to encourage a discussion about tools and methods to prevent disasters and to minimize their consequences, disaster reconstruction, and tourism for reconstruction, Eco-DRR, and green infrastructure.

9:00 ~ 9:15

[HDS10-01] 海岸砂丘の生態系サービスを活用した人々の暮らし

★招待講演

*金子 是久[1] (1.北総生き物研究会)

9:15 ~ 9:30

[HDS10-02] Survey on the Impact of Sea wall on the Vegetation of Coastal sand dune

*鐘 向梅[1]、松島 肇[2]、鈴木 玲[3]、平吹 喜彦[4]、木村 浩二[5] (1.北海道大学大学院農学院、2.北海道大学大学院農学研究院、3.北の里浜 花のかけはしネットワーク、4.東北学院大学教養部、5.雪印種苗株式会社)

9:30 ~ 9:45

[HDS10-03] Greening on the seawall: challenge to conversion from gray to green infrastructure.

★Invited Papers

*松島 肇[1]、鈴木 玲[2]、木村 浩二[4]、鐘 向梅[5]、平吹 喜彦[3] (1.北海道大学大学院農学研究院、2.北の里浜花のかけはしネットワーク、3.東北学院大学教養部、4.雪印種苗株式会社、5.北海道大学大学院農学院)

9:45 ~ 10:00

[HDS10-04] Distribution Characteristics of Informal Green Space and Its Extension of perspective into Green Infrastructure

*minseo kim[1]、Katsunori Furuya[1] (1.Chiba University Graduate School of Horticulture)

10:00 ~ 10:15

[HDS10-05] **DISASTER ANALYSIS OF LIGHTNING STRIKE DENSITY BASED ON LANDFORM FOR REDUCING VICTIMS IN WONOSOBO, INDONESIA**

*Astry Zulky Permatasari[1]、Gagad Nur Ridho[1]、Yan Abdi Rahmanu[1]、Emilya Nurjani[1] (1.Gadjah Mada University)

10:15 ~ 10:30

[HDS10-06] Development of Cost Competitive Unmanned Aerial Vehicle for Search and Rescue

*Aditya Keshav Natoo

海岸砂丘の生態系サービスを活用した人々の暮らし
People's lives utilizing coastal dunes ecosystem service

*金子 是久[1]
*Kaneko Korehisa[1]

1. 北総生き物研究会
1. Hokuso Creature Association

１．はじめに

海岸砂丘は、海と陸地の間の緩衝帯であり、生物多様性の形成、津波等の自然災害を緩和する機能を有している。人々は、古くから海岸砂丘に集落「まち」を形成し、海岸砂丘による生態系サービス（自然の恩恵）を受けていた。しかし、高度経済成長期以降、人口増加、開発の進行により、海岸砂丘は破壊され、人々が自然の恩恵を受ける機会が減少した。今回は、大規模沿岸開発前の海岸砂丘における人々のくらしから海岸砂丘の機能および生態系サービスを評価し、今後の社会情勢変化に伴う海岸砂丘の再生について考える。

２．調査方法

調査地は、千葉県の東京湾側の沿岸都市とした。東京湾側は、昭和30年以降、大規模な沿岸開発が行われたことから、開発前の海岸砂丘を評価する上で有効な場所と判断した。今回、調査地の景観、環境（土壌・地下水）について調べた。

３．調査結果および考察

千葉県は、1993年は自然海岸が23.5%で、約70.0%が人工海岸等であった。調査地の沿岸都市では、昭和初期にて醤油、味噌、酒蔵等の醸造業が存在し、その地域の必需品および嗜好品として支えていた。海岸砂丘の淡水層や海の生物等の生態系サービスを利用した産業であった。主要な沿岸都市の立地環境（土壌・地下水位・水質）を調べた結果、調査地の沿岸都市は、海岸砂丘上（地形分類は砂洲、砂堆・自然堤防、表層地質は砂がち堆積物、砂地）に位置し、井戸の深度も表層下2-10ｍで海岸砂丘の淡水層の水を生活・産業用水として使用していた。また、③ 沿岸都市周辺を含め、海から台地にかけて、砂地と湿地が交互し、海岸砂丘を形成していた。これらのことから、当時の醤油・味噌・酒の醸造場は、海岸砂丘の機能と環境（淡水層）を利用していたと推察される。

４．今後、日本が直面する社会と海岸砂丘のあり方

今後は、① 人口減少、少子高齢化の進行、② 経済の衰退、税収の減少、財政の逼迫、③ インフラ（道路・鉄道等）の老朽化、維持管理の問題であり、社会は大きな転換期を迎えようとしている。特に、沿岸の工業地帯においては、高度経済成長期の工業化社会において世界最大級の都市隣接型の工業地帯として日本の経済発展に大きく貢献したが、現在では、中長期的な国内需要の縮小やグローバル競争の激化により大手製造業の海外への移転で生産設備の休止・停止の企業が増加、遊休地は拡大している。また、施設の老朽化が進行し

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ているが、各企業の現状の財政状況では再整備は困難であるのと、2011年の東日本大震災で発生した液状化現象、津波、高潮からの防災・減災の災害対策が必要であることから、今後の課題は、行政・企業・地域住民・学識者と連携しながら、遊休地を活用した自然海岸砂丘の再生（グリーンインフラ）を取り組めるかである。

キーワード：生態系サービス、海岸砂丘、産業、再生
Keywords: Ecosystem Service, Coastal Sand System, Industry, Regeneration

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Survey on the Impact of Sea wall on the Vegetation of Coastal sand dune

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[Introduction]

In recent years, many extreme events have come out due to climate change such as heavy rain, typhoon, etc. Large amounts of expenses are required for disaster-management measures. However, with the declining of population, the government budget is gradually lessening. On the other hand, people’s interests about disasters risk reduction are increasing. Before the disaster in 2011, at Yuriage district in Miyagi prefecture, coastal sand dune, pine forest and backward wetlands can be seen from the shoreline to the landward. In 2011, it is clear that the tsunami disturbed the organisms that support the coastal ecosystem and the environment which is the foundation of its habitat on a large scale. Since the coastal sand dune ecosystem here was disturbed, it has been restored naturally over time and then as a tsunami protection measure, a large seawall was built. Later, on the land side of the Sea wall was reclaimed by the mountain soil. However, the impact of them on the coastal dune ecosystem is unclear. This study clarifies the ecological impact on coastal sand dune vegetation of the Sea wall and mountain soil. And if there is a negative effect, how can we reduce that effect? This study records it as a reference for future solutions.

Three sites at the Yuriage district were selected as survey targets(figure 1.). From the north to the south: the Yuriage area 1(Y1), the Yuriage area 2(Y2), and the Yuriage area 3(Y3). In Y1, the Sea wall was built about 2 years ago and the coastal ecology recovered in nature. In August 2017, plants (*Ixeris repens*) were planted on both sides of the Sea wall in Y2. In Y3, the Sea wall was built about 5 years ago, and the coastal ecology recovered naturally. Additionally, the land sides of the three survey areas were reclaimed with mountain soil.

[Methods]

A belt was set up from the coastal forest to the shoreline. Then, the terrain was recorded with Unmanned aerial vehicle(UAV). Vegetation surveys were conducted at 5m intervals and Plant species / Coverage(%) / Grass height(cm) were investigated. Furthermore, samples of sand were collected at intervals of 10m, and the particle diameter composition(mm) as well as Electrical Conductivity(mS / m)(EC) of each sample were measured. After that, the average plant volume(mm^3) was calculated. Based on the above data, the current status of the plants on both sides of the Sea wall and the physical environment were analyzed.

[Results&Discussion]

About the result of vegetation, there are three plant species on both sides of the Sea wall: *Imperata cylindrica, Digitaria ciliaris* and *Artemisia capillaris*. On the land side, *Artemisia capillaris,* and *Setaria*

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viridis are the dominant species. On the sea side, *Carex kobomugi, Glehnia littoralis, Calystegia soldanella* and *Ixeris repens* are the dominant species. It is obvious that the plant species on land side and sea side are different because of the separation by the sea wall. It can be seen that the distribution of plants on the land side is significantly affected by the mountain soils, resulting in an increase in the number of inland plants, such as *Setaria viridis* and *Trifolium repens.* From the EC value, it is evident that the trend from the shoreline to the sea wall is gradually decreasing, and the trend from the sea wall to the inland is increasing. The phenomenon that the EC value increases inland can be considered as the impact of artificial coverage of mountain soil. About the result of particle diameter composition, it is obvious that the medium sand has a decreasing trend from the shoreline to the inland side. Closer to the shoreline, the proportion of the very fine sand is increasing. The closer to the inland, the greater the proportion of the very coarse sand and the coarse sand.

In general, the composition of particle diameter on both sides of the sea and land of the sea wall is of difference, and this phenomenon may be caused by the barrier effect of the sea wall. This phenomenon may become larger as time goes by.

キーワード：海岸植生、エコトーン、グリーンインフラ、防潮堤
Keywords: coastal plants, ecotone, green infrastructure, the sea wall



figure 1. Survey area

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Greening on the seawall: challenge to conversion from gray to green infrastructure.

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After the Tsunami disaster in March 11th, 2011 at east Japan area, especially on the pacific side of Tohoku region, our government built huge seawalls along the coastline about 400 km long to protect inland area from Tsunami disaster. We aimed to regenerate the ecotone of coastal ecosystem using the dune plants by greening the seawall. We were planting the seven species of dune plants on the seawall in 2017. On this presentation we report the survival rate for a year of planted dune plants on the seawall.
As a result, most dune plants were survived around 80% or more on the seaside seawall. But the survival rates were decreased around 70% on the landside seawall because of dried out by soil loss. Comparison between natural recovered seaside seawall and planted seaside seawall, the dominant species *Ischaemum anthephoroides* were similar. But *Ixeris repens* were less survived on the planted seaside seawall, in spite of one of the dominant species on the natural recovered seaside seawall. On the other hand, species of landside seawall were completely different with natural recovered landside seawall. This results shows that the greening on the seawall, especially on the landside seawall, were important for regeneration of coastal dune ecotone.

キーワード：グリーンインフラストラクチャー、エコトーン、海岸砂丘系、砂丘植物、防潮堤
Keywords: Green infrastructure, Ecotone, Coastal dune system, Dune plants, Seawall

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Fig.1 Planting of dune plants on the seawall with citizens

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Distribution Characteristics of Informal Green Space and Its Extension of perspective into Green Infrastructure

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1. introduction

The issues of Green Infrastructure (GI) and urban natural disasters are being addressed around the world, not only in North America and Europe, where the discussion first began, but throughout Asia. GI is a planned network strategically between natural and semi-natural areas, along with environmental factors designed for overall ecosystem services. A well-connected network provides positive benefits for quality of life and biodiversity and can receive ecosystem services such as reduction of disaster risk, water purification, air quality, recreational space, and climate change mitigation and adaptation. GI is a widely applicable element that can effectively respond to the various damage caused by climate change. Examples include efficient use of water resources, water restoration, protection of plant species susceptible to disasters, implementation of water conservation measures, reduction of heat island phenomena. In the case of the U.S. and Europe, a network of natural or semi-natural spaces with multidisciplinary functions is defined with the aim of restoring the functions of the ecosystem, and the policy is to utilize the combined spatial plan of domestic or countries. However, in recent years, the decline of cities has increased and limitations have been considered to create new urban green space as GI. Accordingly, the interest in informal green space such as vacant lots, street verges, water verges, and brownfields is increasing as an open space that is abandoned or overlooked in interstices in a city. In particular, interest is growing in strategies to enhance the urban environment and the vitality of residents by converting the value of vacant properties in urban areas to GI. Therefore, this study aims to examine the potential of informal green space as GI, and to suggests a connection with natural disaster prevention.

2. method

Since informal green spaces do not have an officially documented database, fieldwork on the site should be involved to derive the implications of this study. Therefore, in this study, Ichikawa City was analyzed as a study site, and informal green space and urban structures were analyzed using the spatial information collected from the field and the official open data sources. The sampling strategy used in this study was to set a square sample site of 50 meters at the intersection of a grid 500m and collect site information in focusing on the sample site. The total number of sample sites set up is 229 and the total area is about 1% of the entire city area.

3. results

Informal green space was found on 106 sample sites out of 229 sample sites in this study area. The total area of collected informal green space is 26,458 m^2 and consists of 229 patches. The total area of the informal green space found accounts for about 4.62% of the entire sample sites area, with an average area of about 115 m^2. Informal green space was distributed 123 patches and 67.6 m^2 mean size in residential areas, 15 patches and 48 m^2 mean size in commercial area, 16 patches and 230 m^2 mean size in industrial area, and 75 patches and 183 m^2 mean size in the urbanization control area. In the residential and commercial area, where are population density, informal green spaces are frequently distributed with a small scale. On the other hand, the informal green space of the urbanization control area with low population density and high elderly density is relatively large scale compared to residential and commercial area.

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4. discussion and conclusion

Informal green space is a secondary green space created by human activities. Therefore, the distribution characteristics of informal green space differ according to the land use patterns that are related to human activities. Given the accessibility according to the distribution characteristics of informal green space and the linkage with the surrounding natural environment, a supplementary system of urban green infrastructure can be proposed.

Keywords: vacant land, urban green space, green infrastructure policy , Asia

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DISASTER ANALYSIS OF LIGHTNING STRIKE DENSITY BASED ON LANDFORM FOR REDUCING VICTIMS IN WONOSOBO, INDONESIA

*Astry Zulky Permatasari[1], Gagad Nur Ridho[1], Yan Abdi Rahmanu[1], Emilya Nurjani[1]

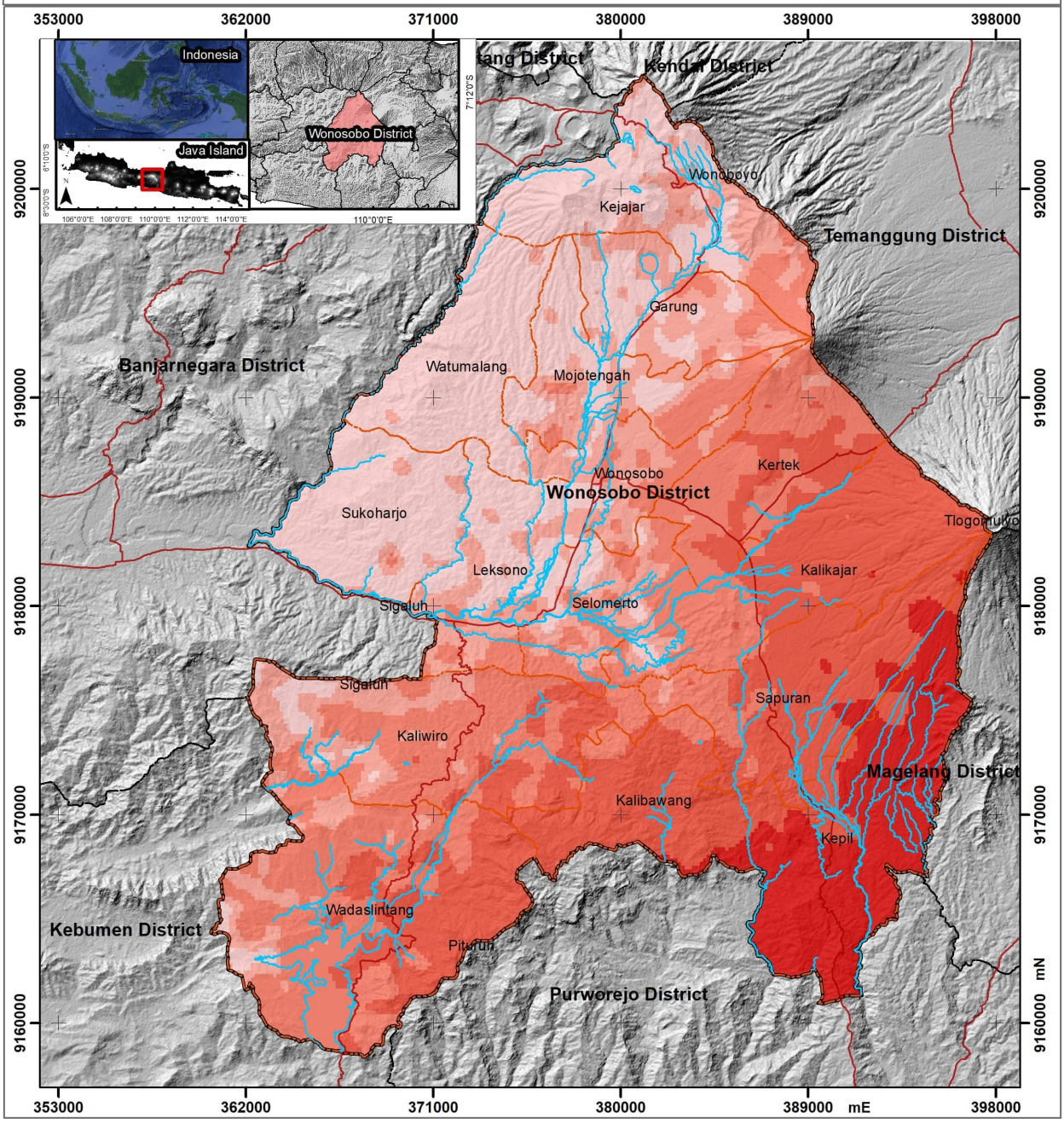
1. Gadjah Mada University

Wonosobo regency is a region with diverse configuration landforms. The morphological and material aspects of the landform different responses to the lightning strike density. The incident of lightning strikes in Wonosobo Regency has negative impacts on people, buildings, and environment. Therefore, a lightning strike density analysis is important to minimize the negative impact of lightning strikes. This study aims to determine the condition of landform, analyze the relationship of lightning strike density and the landform, to know the risk of a lightning strike and give a recommendation of mitigation to reduce the negative impacts caused lightning strike. The research was conducted in Wonosobo Regency, Central Java Province. The data used are lightning strike type Cloud to Ground (CG) on 2015 - 2017 obtained from BMKG Yogyakarta station. Data is processed using ArcGIS 10.3 software with Kernel Density modeling and analyzed quantitatively-qualitative. Lightning strike density in Wonosobo shows a lower pattern from the southeast to the northwest. Wonosobo's landforms are volcanic and structural. Structural landform in Wonosobo Regency is anticlinal mountains with a strong or moderate incision that has the highest lightning strike density. The condition of the lithology of Wonosobo Regency dominated by Breccia, Lava and Tuff rocks that effect on the number of lightning strikes, because it has a low resistivity value (conductor). Kepil District and Wonosobo District are areas that have the highest risk of lightning strikes. Some mitigation activities that can be applied to reduce the risk of losses and death are installing a lightning rod, unplug the cable of electronic device inside the house during a lightning strike and immediately ending the outdoor activities when Cumulonimbus clouds begin to appear, and protect yourself by going into permanent buildings.

Keywords: Landform, Cloud to Ground, Wonosobo Regency, Risk, Lightning Strikes

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LIGHTNING STRIKE DENSITY MAP IN WONOSOBO DISTRICT 2017



Legend

- Road
- River
- Subdistrict Border
- District Border

N

0 2 4 Km

Scale 1: 250.000

Density Class (in hectar)

Very Low	< 4.020
Low	4.021 - 5.303
Medium	5.306 - 8.330
High	8.331 - 15.435
Very High	15.436 - 32.138

Projection System : Transvers Mercator
Coordinate System : UTM
Datum : WGS 1984 Zone 49S
Source : 1.Lightning Strike Data's in Wonosobo District 2017 (Yogyakarta BMKG Station)
Made By : PKM-PE UGM Sambaran Petir's Team 2018

Faculty of Geography
Gadjah Mada University
Yogyakarta
2018

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Development of Cost Competitive Unmanned Aerial Vehicle for Search and Rescue

*Aditya Keshav Natoo

UAV Technology is progressing at a rapid pace around the world. Some organizations have tried to develop Enterprise class UAVs which aim to cater to large section of users.
A dedicated cost competitive UAV to be used during and after disaster and for search and rescue missions is currently not available.

An effort is made to develop quad/hexa copter based UAVs with thermal and/or regular video cameras alongwith a servo controlled arm for transporting objects during search and rescue mission.

The thermal camera can transmit video images to the UAV operator to check for presence of victims during floods, earthquakes, forest fires, landslides, avalanches, tsunamis and cyclones.
During the search and rescue operations, items like inflatable lifejackets, harness, food and water supply etc can be dropped to the victims as well as rescue teams.

Keywords: Cost Competitive, Unmanned Aerial Vehicle, Search and Rescue

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[E] 口頭発表 | セッション記号 H (地球人間圏科学)：H-DS 防災地球科学

2019年5月29日(水) 13:45 ~ 15:15 | 301B 3F

[H-DS10] Natural hazards impacts on human society, economics and technological systems

コンビーナ:PETROVA ELENA(Lomonosov Moscow State University, Faculty of Geography)、松島 肇(北海道大学大学院農学研究院)、座長:Hajime Matsushima、Elena Petrova

The last decade set a record for the number and scale of natural disasters and demonstrates high vulnerability of human society and technosphere to their impacts. The most serious consequences have the so-called natural-technological disasters in which natural hazards trigger accidents at technology and infrastructure such as nuclear power and chemical plants, oil refineries and pipelines, power supply systems, buildings, and roads. A distinctive feature of natural-technological events, such as of the 2011 Tohoku earthquake, is their multi-hazard and synergistic nature, which creates cascading impacts, resulting in simultaneous occurrences of myriad catastrophes. The main goal of this multidisciplinary session is to summarize case studies of relationships between natural hazards and technological disasters, their social and economic consequences; and to encourage a discussion about tools and methods to prevent disasters and to minimize their consequences, disaster reconstruction, and tourism for reconstruction, Eco-DRR, and green infrastructure.

13:45 ~ 14:00

[HDS10-07] **Seasonal variations of atmospheric hazard impacts on infrastructure**

★Invited Papers

*ELENA PETROVA[1] (1.Lomonosov Moscow State University, Faculty of Geography)

14:00 ~ 14:15

[HDS10-08] 大地震によって引き起こされる化学物質流出事故後の浄水場機能に対する影響と対策オプション評価

*伊藤 理彩[1]、中久保 豊彦[2]、小島 直也[1]、東海 明宏[1] (1.大阪大学 大学院工学研究科、2.お茶の水女子大学 基幹研究院)

14:15 ~ 14:30

[HDS10-09] Development of disaster risk management plan of a thermal power plant: Spearheading the paradigm shift from disaster management to disaster risk management of NATECH in India

*Repaul Kanji[1]、Madan Mohan Rout[2]、Ankur Srivastava[3] (1.Gujarat Institute of Disaster Management, Gandhinagar, Gujarat, India、2.Institute of Seismological Research, Gandhinagar, India、3.Indian Institute of Technology Delhi, India)

14:30 ~ 14:45

[HDS10-10] **Applying Transfer Learning to Improve Machine Learning Impact Model at Extremes**

*Peter Lawrence Watson[1]、Manos Anagnostou[1]、David Wanik[1] (1.University of Connecticut)

14:45 ~ 15:00

[HDS10-11] rescEU, the European Union Civil Protection System UCPM and the future role of Geosciences in natural disaster reduction

*Andreas Nikolaus Kueppers[1] (1.GFZ - Deutsches Geoforschungszentrum - Helmholtz Zentrum Potsdam)

15:00 ~ 15:15

[HDS10-12] The Probability of Satellite Anomalies by a Disastrous Solar Flare

*関 大吉[1,2,3] (1.京都大学大学院総合生存学館、2.ケンブリッジ大学極端リスク研究センター、3.京都大学大学院理学研究科附属天文台)

Seasonal variations of atmospheric hazard impacts on infrastructure

*ELENA PETROVA[1]

1. Lomonosov Moscow State University, Faculty of Geography

Infrastructure facilities consist of power, heat and water supply systems, communication lines, transport infrastructure including roads and bridges, railways, airports, oil and gas pipelines, etc. Above-ground and ground infrastructure facilities are most affected by impacts of various natural hazards, especially those of atmospheric origin. More than 90% of all natural-technological accidents in infrastructure facilities of Russia are triggered by atmospheric hazards such as strong winds, heavy snowfalls and rainfalls, snowdrifts, torrents, thunderstorms and lightning, hailstorms, hard frost, icing, etc. Natural factors cause about 70 percent of “blackouts”, more than 10 percent of accidents at heat and water supply systems as well as water accidents; about four percent of air crashes, automobile and railway accidents, and about two percent of pipeline ruptures. Various atmospheric hazards can also cause long delays in automobile, railway and air transportation of passengers and goods. The majorities of these events are triggered by windstorms and hurricanes (37 percent), snowfalls and snowstorms (27 percent), rainfalls (16 percent), hard frost and icing (12 percent), thunderstorms and lightning (nearly 4 percent). All of these weather conditions are subject to seasonal variations. During the cold season, there are much more weather events influencing the growth in the number of accidents than in the warm season. The author created a database of natural-technological accidents occurring in Russia, including those in infrastructure facilities. More than 18.5 thousands events are registered in the database between 1991 and 2018. The collected information allows analyzing the main causes and triggers of accidents, their distribution within area of Russia, temporal variations, and revealing “weak spots” to cope with. The risk of natural-technological accidents in infrastructure facilities was assessed for Russian federal regions. The Far Eastern, South and North-Western parts of Russia are at the most risk of atmospheric hazard impacts. The risk of natural-technological accidents is highest in Sakhalin region, Krasnodarsky and Primorsky territories.

Keywords: infrastructure facilities , atmospheric hazards , risk assessment, seasonal variations

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大地震によって引き起こされる化学物質流出事故後の浄水場機能に対する影響と対策オプション評価

Assessment of water supply function and measures for chemical release accidents triggered by major earthquakes

*伊藤 理彩[1]、中久保 豊彦[2]、小島 直也[1]、東海 明宏[1]
*Lisa Ito[1], Toyohiko Nakakubo[2], Naoya Kojima[1], Akihiro Tokai[1]

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近年、ヨーロッパを中心にNatech(Natural hazard triggered technological accident)と呼ばれる自然災害によるリスクが危惧されているが、日本でも阪神淡路大震災、東日本大震災では高濃度のフッ化水素酸や六価クロム等の有害な化学物質の流出および津波・火災による拡散が認められ、社会問題となっている。このように化学物質が流出した場合、大気・水圏への甚大な環境汚染リスクが懸念されるが、非定常状況下で化学物質が流出した後の環境中での挙動や、浄水施設といった産業基盤に与える影響については不明な点が多い。そこで本研究では、化学物質の水圏流出事故に着目し、大地震の揺れや液状化の影響によって有害化学物質が環境中へ流出した場合の影響を浄水場の給水機能停止をエンドポイントとして評価を行い、さらに対策オプションを導入によってみられる効果を明らかにすることを目的とした。

本研究の対象として、大阪府淀川水系を選択した。淀川は、琵琶湖を水源としており、灌漑・舟運・飲料水に広く利用され、関西の水資源・産業基盤を支える重要な河川である。また周囲には、淀川へ注ぐ排水路をもつ化学物質取扱事業所も数多く立地しているため、大地震が起こった際には大きな被害が予想される。

解析対象物質は、人の健康や生態系に悪影響を及ぼすおそれのある化学物質のうち、PRTR(Pollutant Release and Transfer Register)により排出実態が把握可能で、人に対する毒性値が特に高く(LD_{50} ≦300 mg/kg) (UN, 2015)、浄水施設でも除去が困難 (水溶解度≧10,000 mg/Lかつオクタノール/水分配係数(Log Kow)≦ 1.5) (伊藤ら, 2014)であるアクリロニトリルをはじめとする38物質に加え、使用量の多いトルエン、キシレンを評価対象とした。

地震による化学物質の流出事故予測件数は、世界の地震による流出事故の統計結果 (Santella et al., 2011)をもとに、日本の震度5強～7に相当する地震動で大規模流出事故が起きる件数の期待値(Y)を算出した。その後、ポアソン分布計算により、実際に花折断層を由来とする直下型地震が発生した場合を想定して、淀川流域に立地する大阪府の事業所で流出事故が発生する確率(P_n)を期待値ごとに算出し、対象地点の選択を行った。次に化学物質流出後の河川水中の濃度推計を行うため、産総研-水系暴露解析モデル(AIST-SHANEL ver.3)を用い、事故後の取水点での化学物質の最大到達濃度を求めた。想定事故日は、年間を通して河川流量が比較的少ない冬期を対象とし、淀川流域で対象化学物質の保有量が最大の事業所から流出が起きた事象を想定した。また、事故への対策オプションとしては、緊急遮断弁を採用した。水道事業体による給水停止の判断基準となる水質管理濃度は、長期的に該当物質を摂取し続けた場合の慢性毒性値を指標としているが、本基準は事故時の条件とは必ずしも合致しない。そこで本研究では、短期的に基準値を上回った場合でも摂取制限を伴う給水を継続できる判定基準として導入が検討されている亜急性毒性(厚生省、2016)を判定基準($JC_i^{subacute}$)として評価を行った。

モデル計算の結果、アクリロニトリルの全流出が起こった場合の浄水濃度は最大2.19×10^{-1} mg/Lと算出された。この場合、ラットの中・長期毒性試験から得られた無毒性量(NOAEL)(環境省、2003)をもとに算出した$JC_i^{subacute}$(=6.25×10^{-2} mg/L)を超過するため、給水機能の停止が予測される。さらに取水点において、水生生物の急性毒性値による予測無影響濃度(PNEC) である7.6×10^{-3} mg/L(環境省、2003)を超過しているため、取水停止となる可能性も高い。一方、緊急遮断弁が正常に機能した場合、大阪府(2013)の報告書に記載された緊急遮断弁の外側の配管の長さと管径をもとに計算すると、流出はタンク全体の2%以下にとどまると見積もられた。流出量が2%以下に抑えられた場合は、河川水中濃度は$JC_i^{subacute}$・PNEC以下となり、給水・取水停止とな

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る可能性が極めて低いことが分かった。これにより、緊急遮断弁という対策オプションは、地震などの災害時に非常に有効な手段であることが明らかとなった。また、アクリロニトリルのように毒性が高いにもかかわらず、水道水質基準値のない物質は、本研究の手法を適用し、亜急性毒性に基づく危機時管理を実施することで、迅速な対応が可能となることが見込まれる。本発表では、他の化学物質の事例についても議論する。

キーワード：化学事故、浄水場機能、大地震、モデリング、Natech
Keywords: Chemical accidents, Water supply function, Major earthquake, Modeling, Natech

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Development of disaster risk management plan of a thermal power plant: Spearheading the paradigm shift from disaster management to disaster risk management of NATECH in India

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With global phenomenon like climate change looming large on the horizon, occurrences of extreme events are expected to rise eventually. Rapid urbanisation and the powerful want of globalisation does little to control the exposure of our ‘assets’ to such events, thereby increasing the disaster risks. The quantum of risk rises exponentially if the exposed asset is a critical infrastructure like a nuclear power plant or a thermal power plant which might lead to ‘natural hazard triggered technological disasters’ like that of Fukushima. The damage and loss in such cases is borne not only by the infrastructure in question but also by the community in its immediate surrounding. Management of disasters, which has long been the usual trend, has a very little effectiveness in such tragic scenarios, thus rather than managing disasters, one should manage the disaster risks. Even the Sendai Framework for Disaster Risk Reduction (SFDRR) talks about reduction of the acceptable risks and management of the residual risks. However, for all this to be implemented, one needs to understand and anticipate risks, which is way more than the current practice of risk identification.

The researchers, when provided with the opportunity to develop a disaster management plan for a thermal power plant in India, took cognisance of the priorities of SFDRR embarked on a strategy of disaster risk management and disaster risk reduction rather than mere disaster management. This study elaborates on the strategy adopted during the development of the plan. The first step was to conduct field survey and collect primary geo-technical and meteorological data. Content analysis of hazard maps were done to identify the possible hazards which can affect the critical infrastructure. Earthquake, cyclone and technological hazards were identified as the main probable hazards. The methodology developed by Cornell (1968) for Probabilistic Seismic Hazard Assessment (PSHA) was applied for the estimation of seismic hazard for 10% and 2% probability of exceedence in 50 years. In this method, seismogenic zones were delineated and then seismicity parameters were estimated using the decluttered earthquake catalog and finally the ground motion was estimated using different ground motion prediction equations (GMPE). In addition to this, probable intensities of earthquakes were evaluated according to the seismic zonation and the corresponding grade of damage was estimated, taking into account the typology of building construction. To elucidate assessment of cyclonic winds and rainfall over the critical infrastructure an experiment was designed in which 9 major cyclonic systems occurring in the region in last ten years were considered. These cyclonic events were numerically simulated around the geographical location of the infrastructure. Weather Research Forecasting (WRF) model was used to carry out the simulations. As a result, the maximum windspeed and the maximum rainfall was obtained. In addition to these natural hazards, content analysis was done to enumerate all the possible technological hazards and Maximum Credible Accident Analysis (MCAA) was performed. These steps were integral in assessing the hazards and the outputs of these simulations were fed as inputs of the Quick Risk Estimation (QRE) tool developed by UNISDR. Based on the outputs of the QRE tool, the disaster risk management plan was developed.

This particular study tries to identify and assess the hazards, vulnerabilities and capacities and estimates

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the risks which is then used to develop risk management plans. Offcourse, management of extreme events through institutionalisation of Incident Response System (IRS) is a part of the plan but it forms only a part of it. Thus, in a way, this plan marks the first step taken towards disaster risk management of critical infrastructures in India; a step towards the management of risks of technological disasters due to natural hazards.

Keywords: Disaster risk management, Disaster risk reduction, Weather Research Forecasting, Ground Motion Prediction Equation, Quick Risk Estimation Tool

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Applying Transfer Learning to Improve Machine Learning Impact Model at Extremes

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Machine learning can be useful for modeling the impacts of natural hazards on infrastructural systems. By relying on empirical observations, these methods lack the prohibitive complexity of large-scale physical models, but can also operate in high-dimensional spaces: where a large number factors contribute to the observed damages to the system. However, modeling extreme events can be challenging with machine learning. Unlike parametric models, the dynamic range of these models is constrained to the training data, and the training data from extreme events is as rare as the events themselves. However, transfer learning, where a model trained on data from one system is retrained for another system, may enable the use of additional training data to improve the prediction of extreme events. This would allow for more examples of extreme events from more places to be included in the training data, and should improve the performance of machine learning based impact models at the extremes. In this study, we apply transfer learning methods to the University of Connecticut's Outage Prediction Model (OPM), a machine-learning based electrical power outage model. The OPM has a large domain that spans three states in the US: Connecticut, Massachusetts, and New Hampshire, and there is much more training data available for Connecticut than the other states. We investigate the effects of applying this additional data on the accuracy and dynamic range of models for the other states using transfer learning methods, in an effort to better predict the impacts of the most extreme weather events.

Keywords: Machine Learning, Impact Model, Transfer Learning, Extreme Events, Power Outage, Infrastructure

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rescEU, the European Union Civil Protection System UCPM and the future role of Geosciences in natural disaster reduction

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On February 12, 2019, the European Parliament in Strassbourg adopted the decision* for a substantial enhancement of the Union Civil Protection Mechanism which includes the 28 EU Member States plus a major number of affiliated nations. The actual legislational move had been directly instigated by the very serious impact of large wildfires in Europe with many fatalities in Portugal, Greece, Spain, Sweden, among others. It became clear in a dramatic way that sufficient technical resources for fire fighting, in particular aircraft, were neither available on a national nor an international base. The new and financially strengthened Mechanism embraces a large number of disaster types where geology based disasters like earthquakes, tsunami, volcanic eruptions including volcanic ash clouds and gravitational movements are among the most prominent. Expressis verbis, the decision calls for substantial foresight for the early discovery of future disasters which even may be not known to us today. While this without doubt means a great chance for broad geosciences to actively contribute from the start, the integration of more nations into the system and a possible globalisation constitute next stage challenges.

*Official text is expected to be published by the European Commission in due time.

Keywords: Earthquake, Tsunami, Volcanic Eruption, Landslide, European Civil Protection Mechanism, Globalisation

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The Probability of Satellite Anomalies by a Disastrous Solar Flare

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The Sun has a potential risk of various socioeconomic impacts on our human society. It often produces various eruptive phenomena such as a solar flare and a coronal mass ejection, which sometimes bring adverse effect to us like satellite anomalies, radiation exposure, and huge blackouts. For example, in 2003 October 28, X17-class flares (roughly once-in-10-year level severity) occurred and more than 60 % of NASA scientific satellites were affected.

Similar to other terrestrial disasters like an earthquake, the solar eruptive phenomena also follow the power-law distribution between frequency and severity, and low-frequency-high-impact solar disaster could also happen. Recently, it was revealed that a “super-flare”, a flare whose energy is 100 times larger than X10-class flare, can occur once in 1000 years from statistical and theoretical points of view [Maehara et al. 2012, Shibayama et al. 2013, Shibata et al. 2013].

However, though there are many assessment studies of “moderate” solar eruptive phenomena, the assessment of “disastrous” solar eruptive phenomena like a super-flare has been little conducted. For this reason, this research aims to evaluate the frequency (or probability) and the possible socioeconomic damage of a super-flare, especially focusing on satellite anomalies.

Using various data sets about satellites, their anomalies, flares, and plasma environment around the Earth*, 154 X-class flare events with 9 relating parameters (peak flux of X-ray (0.1–0.8 nm), integral fluxes of electron (> 2 MeV) and of proton (> 1, 5, 10, 30, 50, 60, 100 MeV)) were selected. To avoid multi-collinearity, Ridge regression model was used to compute the regression to the satellite anomaly rate (1/satellite/event). Also 10-fold cross validation was performed. After obtaining the model, the possible plasma parameters in case of X1000-class flare assumed by Takahashi et al. 2016 were input into the model.

As a result, we obtained the model with its coefficient of determination of 0.607 and its Pearson correlation coefficients of 0.691±0.212 (for 100 times randomly chosen dataset). Assuming that electron and proton follow the same scaling law, with applying scaling law by Takahashi et al. 2016, 0.573 satellite anomaly rate (57.3% per satellite per event) was obtained. It should be noted that the scaling law provided by Takahashi et al. 2016 is upper limit, so in the actual case, rate should be lower. The validity of assumption, the comparison between this research and others (Pilipenko et al. 2006; Iucci et al. 2005; Odenwald et al, 2006, 2007), and the possible socioeconomic loss will be also discussed.

* NOAA NGDC Spacecraft Anomaly Data, Satellite Catalogue (https://www.celestrak.com/satcat/search.php), NOAA GOES flare report (https://www.ngdc.noaa.gov/stp/space-weather/solar-data/solar-features/solar-flares/x-rays/goes/xrs/) , and OMNI 2 database

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キーワード：宇宙天気災害、人工衛星障害、スーパーフレア
Keywords: Space weather disaster, satellite anomaly, super-flare

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[E] 口頭発表 | セッション記号 H (地球人間圏科学)：H-DS 防災地球科学

2019年5月29日(水) 15:30 ~ 17:00 | 301B 3F

[H-DS10] Natural hazards impacts on human society, economics and technological systems

コンビーナ:PETROVA ELENA(Lomonosov Moscow State University, Faculty of Geography)、松島 肇(北海道大学大学院農学研究院)、座長:Elena Petrova、Hajime Matsushima

The last decade set a record for the number and scale of natural disasters and demonstrates high vulnerability of human society and technosphere to their impacts. The most serious consequences have the so-called natural-technological disasters in which natural hazards trigger accidents at technology and infrastructure such as nuclear power and chemical plants, oil refineries and pipelines, power supply systems, buildings, and roads. A distinctive feature of natural-technological events, such as of the 2011 Tohoku earthquake, is their multi-hazard and synergistic nature, which creates cascading impacts, resulting in simultaneous occurrences of myriad catastrophes. The main goal of this multidisciplinary session is to summarize case studies of relationships between natural hazards and technological disasters, their social and economic consequences; and to encourage a discussion about tools and methods to prevent disasters and to minimize their consequences, disaster reconstruction, and tourism for reconstruction, Eco-DRR, and green infrastructure.

15:30 ~ 15:50

[HDS10-13] 東京都における防災公園の維持管理について

★招待講演

*菊池 正芳[1] (1.公益財団法人東京都公園協会)

15:50 ~ 16:05

[HDS10-14] Rebuilding Tourism after the Great East Japan Earthquake and Examining Post-Disaster Tourism in Kamaishi City

*佐々木 啓[1]、山本 清龍[2]、佐々木 薫子[3] (1.岩手大学、2.東京大学、3.北海道大学)

16:05 ~ 16:20

[HDS10-15] Population Change in Ishinomaki City, Miyagi Prefecture, with a Focus on the Area around the Earthquake Ruins

*西坂 涼[1]、古谷 勝則[1] (1.千葉大学)

16:20 ~ 16:35

[HDS10-16] The Way of Seeing the Atomic Bomb Dome and the Relationship with Viewers' Attributes

*安原 有紗[1]、山本 清龍[1]、下村 彰男[1] (1.東京大学大学院農学生命科学研究科)

16:35 ~ 16:50

[HDS10-17] スリランカ国ラトゥナプラ市における洪水リスク分析

*土田 亮[1]、寶 馨[1] (1.京都大学大学院総合生存学館)

16:50 ~ 17:00

Discussion

東京都における防災公園の維持管理について
Management and Maintenance for Disaster prevention park in Tokyo Metropolitan Government

*菊池 正芳[1]
*Masayshi Kikuchi[1]

1. 公益財団法人東京都公園協会
1. Tokyo Metropolitan Park Association

東京は古くから何度もの地震により大きな被害を受け、壊滅と復興を繰り返してきた歴史がある。東京が地震災害を被るたびに、公園は新たな機能を求められるようになってきた。１つ目は避難場所としての役割であり、２つ目は、大規模救出救助活動拠点としての役割となっている。現在、都立公園は82個所あるが、主要な21箇所の公園は首都東京に大地震などの災害が発生した時、避難場所としての機能だけではなく、広域的な大規模救出救助活動拠点ともなる機能を有している。それらを防災公園と名付けて管理している。先ず、避難場所としての機能は、全ての公園が有している機能であり、災害発生時に多くの市民が安全な場所として逃げ込める場所を確保することである。そのために、特徴的な３つの公園施設がある。1つは、停電時となっても何処からでも場所を確認できるように「ソーラー式公園灯」である。2つ目は、多くの避難者が公園内に一時的に滞在しても利用できるために、排水管と直接接続された「マンホール型防災トイレ」である。3つ目は、平時は普通のベンチであるが、災害時には煮炊きのできる「かまど」として活用できる「かまどベンチ」である。次に、大規模救出救助活動拠点としての機能は、被災場所に救援部隊や医療部隊等の活動拠点としてヘリコプターの発着所や、大型緊急車両の集合拠点となる機能である。そのため、大規模な広場を有する公園が大規模救出強雨所活動拠点として指定されているが、特徴的な整備は、大型車両が通行できるように園路の拡幅と強化、ヘリコプター離着陸地点の確保等である。

これらの機能を十分に発揮するために必要なことは、日常的な防災訓練である。市民、警察、消防、企業等を含めて、公園では年に数回「マンホール型防災トイレ」や「かまどベンチ」の訓練を行い、ヘリコプターの離着陸訓練なども行っている。

キーワード：防災公園、避難場所、大規模救出救助活動拠点
Keywords: disaster prevention park, evacuation site , Base for Large-scald and Life-saving Operations

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Rebuilding Tourism after the Great East Japan Earthquake and Examining Post-Disaster Tourism in Kamaishi City

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1. Iwate University, 2. The University of Tokyo, 3. Hokkaido University

1. Introduction

Natural hazards can have a devastating effect on tourism. In the case of the Great East Japan Earthquake (GEJE) of 2011, the tsunami caused damage to not only human lives but also to critical infrastructures in coastal areas in the Tohoku region. Tourist attractions and facilities were also damaged by the tsunami, and people who lived in the metropolitan and Kinki regions understood that they should avoid traveling to the Tohoku region (Yamamoto, 2013). Thus, a decrease in the number of visitors to the tsunami-hit area was reported in the Tohoku region immediately following the disaster (Igarashi et al., 2017). Fortunately, after suffering a drop in the number of tourists, the disaster area is experiencing a trend in recovery these days. “Disaster tourism”—defined as the practice of visiting natural or man-made environmental disaster sites (Amujo et al., 2012)—has succeeded in bringing visitors to the disaster area. However, eight years have already passed since the disaster, and the time lapse should be taken into account for promoting post-disaster tourism (Sasaki et al., 2018). From this viewpoint, the purposes of this study were established as follows: 1) to clarify the current situation of tourism after the GEJE of 2011 and 2) to examine post-disaster tourism in the Tohoku region.

2. Methods

The case study area for this study was Kamaishi City, which is located in Iwate Prefecture in northeast Japan; it was hit by the tsunami in 2011 and more than 1,000 lives were lost to the disaster. Thanks to disaster prevention efforts, however, almost all of the nearly 3,000 elementary and junior high school students miraculously survived (i.e., the “Miracle of Kamaishi”). Accordingly, many people have been infused with hope. To grasp the awareness and behaviors of visitors to the city, two post-recall questionnaires were distributed to Japanese people over age 17 from July to September in 2018. One was disseminated to visitors who participated in the guided tours conducted by storytellers with the Kamaishi Volunteer Guide Association. The other was given to tourists at the JR Kamaishi Station, Kamaishi Sennin-toge roadside rest area, and Hashino Iron Mining and Smelting Site (listed as a UNESCO World Heritage Site). The survey focused on the following aspects: (1) visitor attributes (e.g., age, gender), (2) characteristics of visits (e.g., number of visits, group size, objectives of trips, places visited), (3) familiarity with guided tours (e.g., expectations, sources of information), (4) changes in awareness after a visit, (5) appreciation for disaster lore, and (6) the satisfaction and intention to revisit.

3. Results and Conclusion

In total, 478 people (guided: N = 155, non-guided: N = 323) participated in the survey, representing a response rate of 22%. As a result, the largest proportion of respondents included people over age 59 (47%); further, the total number was almost equally divided between the two genders (male: 51%, female: 47%). The most frequent group size of visitors was two or three people (43%); moreover, approximately 50% of visitors used private cars. The most common trip type was the day trip (46%), and the majority of visitors were not there for the first time (32%). The most commonly mentioned trip objectives were engaging in tourism (46%), visiting the disaster area (29%), and eating delicious food (25%). Additionally,

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the degree to which visitors intended to join a tour guided by a storyteller was high (77%), with the most common contents of interest being stories recounted from the time of the disaster (77%) and lessons from the disaster (68%). A few people acknowledged enjoying the storytelling tour locally (12%) and on the Web (6%). On the whole, the GEJE experience was regarded as worth handing down to future generations and sharing with the world (very valuable: 82%, somewhat valuable: 11%). Compared to non-guided visitors, guided visitors had a greater sense of being present during the disaster ($P < .01$, T-test) and were encouraged to change their attitudes toward disasters ($P < .01$, based on a single regression analysis). In conclusion, Kamaishi City still functions as a disaster tourism site but it is thought that efforts to increase the city’ s appeal in the future are necessary.

キーワード：ツーリズム、東日本大震災、語り部、アンケート調査
Keywords: tourism, Great East Japan Earthquake, storyteller, questionnaire



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Population Change in Ishinomaki City, Miyagi Prefecture, with a Focus on the Area around the Earthquake Ruins

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*Ryo Nishisaka[1], Katsunori Furuya[1]

1. 千葉大学
1. Chiba University

1. Introduction

Eight years have passed since the Great East Japan Earthquake of 2011. There is a movement to preserve buildings and structures affected by the earthquake and resulting tsunami as earthquake ruins and to utilize them for storytelling and disaster prevention. In the Tohoku region, where the birthrate is declining and the population is aging, sustainable management of the earthquake ruins will be an issue.

So far, the bereaved families and storytellers (called the kataribe) who live around the earthquake ruins of Ishinomaki are known to have been working on the management of flowers from visitors, cleaning up the earthquake ruins, and improving the flowerbeds. At the same time, residents around the earthquake ruins might be affected by the increase in the number of visitors when the earthquake ruins are opened to the public, so consideration of them is necessary. Therefore, this paper aims to clarify the population change around the former Kadonowaki Elementary School and the former Okawa Elementary School, which are the two earthquake ruins in Ishinomaki.

2. Methods

We investigated mesh population data of 500-meter mesh areas from “Population Census,” published by the Statistics Bureau, Ministry of Internal Affairs and Communications, Japan, and analyzed the population change of Ishinomaki between 2010, before the earthquake, and 2015, after the earthquake, using Geographic Information Systems (GIS). We extracted the two earthquake ruins and created buffers of 2,000 meters. We considered the population change within 2,000 meters of the two earthquake ruins as well as the situation regarding Ishinomaki’s recovery.

3. Results

As a general overview of the population change in the whole city of Ishinomaki, we can confirm a large population decline in coastal areas that were reached by the tsunami, such as Kadonowaki-*cho*. In addition, large-scale temporary housing was constructed and a population migration to the inland area was confirmed.

Although the overall population decline was significant within 2,000 meters of the former Kadonowaki Elementary School, a population increase was confirmed in a small area near the temporary housing in Hiyorigaoka.

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Even within 2,000 meters of the former Okawa Elementary School, the population was decreasing as a whole, but we could confirm an area where the population increased slightly. There were no large temporary housing structures around the former Okawa Elementary School, and the population did not accumulate.

4. Discussion

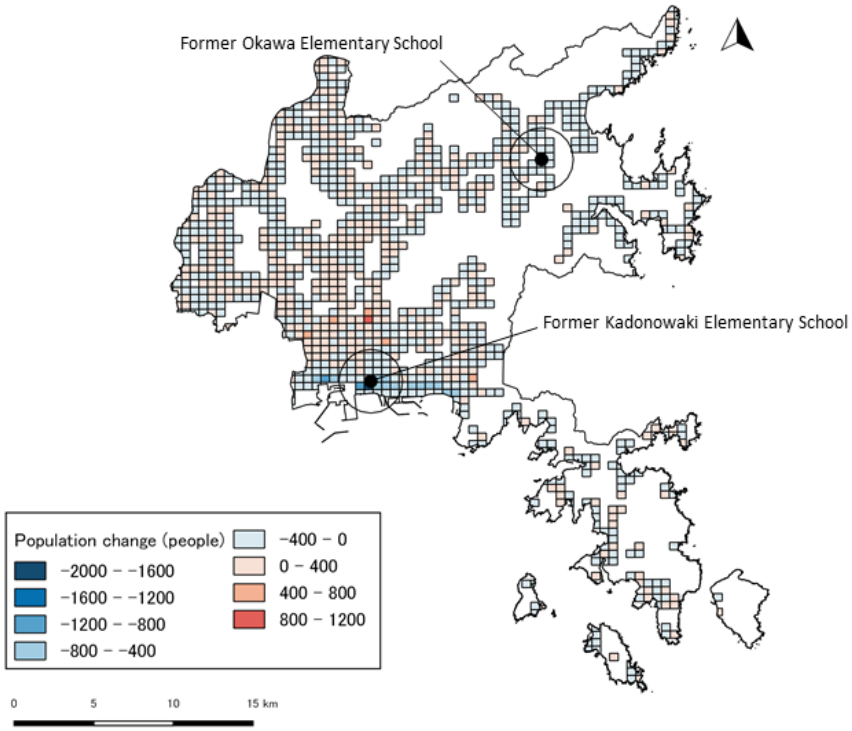
In Ishinomaki, after the Great East Japan Earthquake, the population of the coastal area drastically decreased, and population increase in the inland area was confirmed. Both the former Kadonowaki Elementary School and the former Okawa Elementary School had a drastic decrease in population within 2,000 meters. However, the existence of areas where the population was increasing even within 2,000 meters was confirmed. It seems that the presence of temporary housing greatly influenced the change in population.

The population changes around both earthquake ruins were large, so it is thought that there were many cases in which bereaved families and residents involved in the elementary schools had relocated. Particularly concerning the former Okawa Elementary School, there is a possibility that there was a large-scale relocation to the southwestern part of the city, where population increase advanced. In Ishinomaki, the situation with tenancy in temporary housing continues to change even after 2015, and now temporary housing is being demolished and residents are moving into public housing. In the future, it is necessary to track the population changes and consider how to support the activities in the earthquake ruins by residents who cannot easily get there.

キーワード：震災遺構、石巻市、GIS、人口変化
Keywords: Earthquake Ruins, Ishinomaki, GIS, Population Change

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Fig. Population change in Ishinomaki <2010-2015>



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The Way of Seeing the Atomic Bomb Dome and the Relationship with Viewers' Attributes

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1. Introduction

The Atomic Bomb Dome (ABD) is one of the major atomic bombing sites in Hiroshima. In 1996, it was registered as an UNESCO World Heritage Site under the name "Hiroshima Peace Memorial," and its lasting preservation was secured. However, like other world heritage sites, its maintenance and management were not easy. Hiroshima City, taking charge of the management, established "Preservation and maintenance policies of peace memorial museums (2006)," in which the role of the ABD was specified as "The witness of history who suffered heavy damage by an atomic bomb" and "The symbol of hope for nuclear weapon extinction and lasting peace." This policy considered the mindset of the people who wished for peace, tried to preserve the history, and achieve World heritage-registration. This description meant regarding the ABD as the memory of Hiroshima. In other words, it was aimed to include not only the Dome's visual image (the visual aspect) but also the history of Hiroshima and people who had an emotional connection with the town (the semantic aspect), and to preserve both. To embody the idea in a preservation plan, it is necessary to clarify the history of Hiroshima as the background of the ABD and the mindset of people. This study analyzes the "way of seeing" to reveal "how" and "by whom" the ABD has been seen until today, and to understand the memory of Hiroshima.
In light of the above issues and viewpoints, the objectives of this study are 1) to classify the way of seeing the dome and 2) to address the meaning of the relationship between the landscape types and viewers' attributes.

2. Methods

Photographs were collected to understand how ABD is seen by a variety of viewers. Approximately 561 photographs in which the ABD appeared were found in 52 books at the Hiroshima City Central Library. These were selected as materials for analysis, excluding those wherein who took the photograph and when it was taken could not be identified. Time, locations, and photographers were identified, and the constituent elements of each scene were counted to understand the characteristics of the photographs. The attributes of photographing through identification are as follows: (1) time: year of photographing; (2) locations: 6 areas of photographing; and (3) photographers: 4 categories extracted by combining "people who visited Hiroshima," "people who were born or lived in Hiroshima," "photographers," and "amateur photographers." After this process, the sceneries were divided into typical patterns by using quantification method of the third type and cluster analysis. Finally, the relationship between the landscape types and the photographers' attributes was analyzed.

3. Results and Conclusion

The ways of seeing were classified into 6 types, which were related to photographers' attributes. These were: I) landscape hit by atomic bomb, II) landscape with low buildings, III) landscape viewed through the Hiroshima Peace Memorial Monument, IV) landscape of the ABD, V) landscape with plants, and VI) landscape with high buildings. Moreover, it was revealed that landscape I) was photographed more by "people who visited Hiroshima." Likewise, II), III), and IV) were related to "photographers who were

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born or lived in Hiroshima,” “people who were born or lived in Hiroshima,” and “photographers who visited Hiroshima,” respectively. Additionally, the elements included in the photographs, the main period of photographing, and the viewpoint of photographing differ according to the landscape types. In conclusion, it was suggested that the meaning of Hiroshima’s memory as understood by the photographers was diverse and it was necessary to provide the visitors to ABD with various landscape experiences related to the ways of seeing the ABD.

キーワード：原爆ドーム、まなざし、風景、写真、世界遺産
Keywords: Atomic Bomb Dome, way of seeing, landscape, photograph, world heritage



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スリランカ国ラトゥナプラ市における洪水リスク分析
Flood Disaster Risk Analysis at Ratnapura in Sri Lanka

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本論文では2017年5月にスリランカで発生した洪水を対象に、洪水常襲地における災害リスクを明らかにする。まず、ケースとして山間部ラトゥナプラ市の125年間の年間最大降雨量をもとに、頻度解析を用いて2017年の洪水イベントの発生可能性を評価する。また、 人工衛星画像を用いた同地域における洪水災害前後の土地利用を解析する。そして、筆者は現地住民や地方行政に対して災害エスノグラフィを用いたインタビュー調査を行い、洪水被害の状況とどのように洪水に対処したのかを把握した。インタビューの結果から、現地住民は自らの経験や知識を使ったが、今回のような甚大な洪水が起きた際には上手く対応できず、多方面において悪影響を及ぼしたことが伺えた。加えて、国連機関や政府、非営利団体などの外部団体からの支援が十分でなく、住民のニーズや脆弱性をカバーできるものではなかった。また、政府による住宅と整形の被害調査に遅れが生じ、政府からの補償金や物資の調達が遅延したこともわかった。これらの結果はスリランカにおける洪水の減災や復旧プロセスの理解に役立つことが期待される。

キーワード：洪水災害、頻度解析、土地利用変化、復旧復興、スリランカ
Keywords: Flood Disaster, Frequent Analysis, Land Use Change, Recovery and Rehabilitation, Sri Lanka

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[E] 口頭発表 | セッション記号 H (地球人間圏科学)：H-TT 計測技術・研究手法

2019年5月29日(水) 15:30 ~ 17:00 | 101 1F

[H-TT21] 石造文化財に応用可能な非破壊分析

コンビーナ:小口 千明(埼玉大学大学院理工学研究科)、Celine Elise Thomachot-Schneider(Groupe d'etude des environnements naturels, anthropiques et archeologiques - Universite de Reims-Champagne-Ardenne (France))、宋 苑瑞(早稲田大学)、Miguel Gomez-Heras(Universidad Autonoma de Madrid)、座長:宋 苑瑞、小口 千明

非破壊的の分析・測定技術は、近年著しく発展してきており、これらの技術への関心はますます高まっている。本セッションでは、石や土材料で作られた文化遺産に適用されるこれらの新しい技術に関する研究発表を募集する。たとえば、1）文化遺産を調査対象とした新技術、装置の開発、非破壊測定技術、 2）屋内外の事例研究と室内実験に関する技術や手法、 3）風化機構、風化速度、および風化程度に関する調査方法と評価、4）風化・劣化・削剥など現象のモデリングとシミュレーション、保存修復方法などの提案など、多方面の分野からの研究発表を期待します。

15:30 ~ 15:45

[HTT21-01] Study on creation of 3D model by SfM photogrammetry: An example of Taya Cave

清水 きさら[1]、*小口 千明[1]、田村 裕彦[2]、早川 裕弌[3]、小倉 拓郎[4]、緒方 啓介[5] (1.埼玉大学大学院理工学研究科、2.田谷の洞窟保存実行委員会、3.北海道大学地球環境科学院、4.東京大学大学院新領域創成科学研究科社会文化環境学専攻、5.鶴見大学)

15:45 ~ 16:00

[HTT21-02] **人工洞窟における地上レーザ測量データと3Dプリントの地盤工学的および教育的活用**

*早川 裕弌[1,2]、小倉 拓郎[4,5]、田村 裕彦[2]、小口 千明[3]、清水 きさら[3] (1.北海道大学地球環境科学研究院、2.東京大学空間情報科学研究センター、3.埼玉大学、4.東京大学新領域創成科学研究科、5.北海道大学大学院環境科学院)

16:00 ~ 16:15

[HTT21-03] 沖縄県の世界遺産，園比屋武御嶽石門の保存修復ー モルタルによる穴埋めとシリコーン樹脂塗布から30年経過後の現状

*宋 苑瑞[1]、西浦 忠輝[2]、小口 千明[3] (1.早稲田大学、2.国士舘大学、3.埼玉大学)

16:15 ~ 16:30

[HTT21-04] 高知県沿岸部の海底石造物の起源推定のためのポータブルXRFの活用

★招待講演

*谷川 亘[1]、浦本 豪一郎[2]、村山 雅史[2]、濱田 洋平[1]、山本 裕二[2]、多田井 修[3] (1.国立研究開発法人海洋研究開発機構高知コア研究所、2.高知大学　海洋コア総合研究センター、3.マリン・ワーク・ジャパン)

16:30 ~ 16:45

[HTT21-05] pXRF analyses on Assyrain sculptures

★Invited Papers

*安間 了[1]、SHIN Ki-Cheol[2]、渡辺 千香子[3]、辻 彰洋[4] (1.徳島大学大学院社会産業理工学研究部、2.総合地球環境学研究所、3.大阪学院大学国際学部、4.国立科学博物館植物研究部)

16:45 ~ 17:00

[HTT21-06] Discussion

*小口 千明[1] (1.埼玉大学大学院理工学研究科)

Study on creation of 3D model by SfM photogrammetry: An example of Taya Cave

清水 きさら[1]、*小口 千明[1]、田村 裕彦[2]、早川 裕弌[3]、小倉 拓郎[4]、緒方 啓介[5]
Kisara Shimizu[1], *Chiaki T. Oguchi[1], Yasuhiko TAMURA[2], Yuichi S. Hayakawa[3], Takuro Ogura[4], OGATA KEISUKE[5]

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1. Institute for Environmental Science and Technology, Graduate School of Science and Engineering, Saitama University, 2. The Exective Committee for the Preservation of Taya Cavern, 3. Faculty of Environmental Earth Science, Hokkaido University, 4. Graduate School of Frontier Sciences, The University of Tokyo, 5. Tsurumi University

SfM (Structure-from-Motion) photogrammetry is one of the methods for creating 3D models of objects by extracting feature points in the images. Taya Cave, the investigation site of the present study, is a historical site of Yokohama City. It has about 200 base-reliefs on the surface of the cave tunnel walls, however, they are suffering from weathering and difficult to preserve from it in the future. The cave was excavated in Kamakura Era originally, and has a total length of 570 m with a three-layer structure. The present study tried to make a 3D model of this complicated, dark and narrow cave by SfM photogrammetry. The accuracy of the created 3D model were evaluated by comparing the values of distances between from the 3D model and from 2016 actual survey data.

キーワード：SfM、Taya Cave
Keywords: SfM, Taya Cave

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人工洞窟における地上レーザ測量データと3Dプリントの地盤工学的および教育的活用

TLS measurement data and 3D printing of an artificial cave for geotechnical and educational applications

*早川 裕弌[1,2]、小倉 拓郎[4,5]、田村 裕彦[2]、小口 千明[3]、清水 きさら[3]
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Conservation of an underground cultural heritage is often a controversial issue due partly to its invisibility and insufficient awareness in the local society. Also, the safety assessment is necessary to promote sustainable protection of an underground cultural heritage. The developments in high-definition topographic measurements enable to acquire detailed three-dimensional morphological data of a cave, which can be further utilized for the visualization and structural analyses. Regarding the measurements and visualization, we present a case study at the Taya Cave, a registered cultural heritage in Yokohama City, Kanagawa Prefecture in central Japan. The terrestrial laser scanning was performed from multiple scan positions throughout the cave, and the point clouds were registered using the feature-based iterated closest point algorithm. The registered point clouds were then converted into a mesh model, to which face error corrections and a solid filling were applied. After these processes, the mesh model can be printed out in three dimensions. The 3D print model of the cave is used for the class teaching in an elementary school in the local area, and such the visualization of the cave successfully enhanced the recognition by students regarding the underground cultural heritage. The 3D data can also be utilized for the structural assessment of the cave. Effective and sustainable protection of the cave will further be possible by integrating such geotechnical assessments and outreach activities in the local society.

キーワード：地上レーザ測量、点群、3Dプリント、アウトリーチ、地下文化財
Keywords: terrestrial laser scanning, point cloud, 3D printing, outreach, underground cultural heritage

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沖縄県の世界遺産，園比屋武御嶽石門の保存修復ー モルタルによる穴埋めとシリコーン樹脂塗布から30年経過後の現状

Conservation restoration of the world heritage of Okinawa Prefecture, Sonohyan-utaki Ishimon - Situation after 30 years since filling with mortar and applying silicone resin.

*宋 苑瑞[1]、西浦 忠輝[2]、小口 千明[3]
*Wonsuh Song[1], Tadateru Nishiura[2], Chiaki T. Oguchi[3]

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沖縄の首里城公園内にある園比屋武御嶽石門は「琉球王国のグスクおよび関連遺産群」の一カ所として2000年に世界遺産に登録された．石門とその奥の森を園比屋武御嶽といい，琉球王国の国王が外出するときに安全を祈願する礼拝所として使われてきた．1519年に琉球石灰岩で建てられ，1933年には旧国宝に指定されたが沖縄戦で大破され，1957年に復元された後に解体修理し1986年に完成し，1972年国指定建造物になった．解体修理時には古い屋根石を使用したが，この際にクリーニングや撥水性シリコーン樹脂の含浸や表面の穴埋めを行った．現在は図1でも確認できるように，石門全体の色は黒っぽくなり，屋根（右側が古屋根材を使用したところ）の部分の穴埋め箇所とオリジナル石材とは色の差も目立つようになっている．穴埋めとシリコーン樹脂塗布から30年後の状況を色彩計を用いて定量的に把握し，今後の修理処置に役立てられることを本研究の目的とする．

修復された屋根の表面の色や石門の全体的な色の把握するために，石門の表面の51か所で分光測色計（コニカミノルタ社製，CM-700d，測定径Φ8mm）を用いて定量的測定を行った．この測定器は，測定時間はわずか1秒程度で，簡便に携帯できる特徴があり，多様な分野で使用されている．石門の正面から見た際に黒色化した部分の割合をPhotoshopを用いて求めた．石門の表面温度を測定擦るため，FLIR社製の熱カメラを用いて，表面の温度分布を把握した．一年中の気温と湿度の変化を把握するために，那覇市市民文化部文化財課の許可を得て，ボタン型温湿度測定器（ハイグロクロン）を石門の南側の左上の方に設置し，観測を行った．

分光測色計による測定の結果，修復当時は石灰岩の色が明るく，屋根部分に修復材とほぼ同じ色だったが，30年後は変色速度や状況が異なり，修復材の方は灰色に，本来の石材はより黒色になっている箇所が多かったことが分かった．園比屋武御嶽石門の屋根の下で観測された年間平均気温は24℃，平均湿度は81.5%で，高温多湿な亜熱帯気候の特徴が見られた．冬季の平均気温も22.1℃で，湿度も80%に至り，最低気温も8.5℃だった．そのため，植生の成長がとても速く，建物の表面の色に影響を与えた可能性がある．

キーワード：石造文化財、保存修復、沖縄、石灰岩、測色計
Keywords: Stone cultural heritage, Restoration, Okinawa , Limestone, Colorimeter

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Fig. 1. After completing conservation restoration work of Sonohyan-utaki Ishimon (left) and situation of thirty years later (right).

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高知県沿岸部の海底石造物の起源推定のためのポータブルXRFの活用
Application of portable XRF analysis for provenance of seabed worked stone in coastal are of Kochi Prefecture

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高知県土佐清水市爪白海岸海底には人為的に加工されたと考えられる長さ1mにもわたる巨大な石柱が存在する（2016年に28体確認）。この地域ではこれまでに南海地震による津波災害と台風による風水害が多発しているため、海底の石柱群は津波や土石流等による陸上からの運搬、もしくは海底沈降による可能性がある。そこで本研究では、爪白海底石柱群の起源を明らかにするために、石柱群および近隣に露出している岩石（堆積岩：三崎層群、来栖野層）、採石場の岩石、石造物を対象に化学分析と岩石物性測定を行った。化学分析はポータブルXRF（pXRF）を用いた全岩化学組成分析と粉末X線による鉱物構成比分析を行い、岩石物性測定は間隙率と密度の測定を実施した。

ポータブルXRFの結果、12種類の元素濃度（Mg、Si、S、K、Ca、Ti、Mn、Fe、Rb、Sr、Zr、Pd）に対して明確に判読できた。そこで12種類の元素濃度を用いて主成分分析を実施した。すべての種類の堆積岩（砂岩、シルト岩、頁岩）について主成分分析を実施した結果、第一主成分により砂岩と頁岩が明瞭に区分でき、Mg、Fe、Tiの分散が強く反映されていることがわかった。さらに、砂岩のみを抽出して主成分分析を実施した結果、個々の試料の特徴がより明確になった。海底の石柱は三崎層群竜串層（海岸に露出した試料・採石場の試料）、および爪白集落の建屋の基礎と同じ特徴を示した（Zrの寄与率が高い）。一方、間隙率、固体密度、および構成鉱物比についてもこの3種類の試料は類似性が認められた。
以上の結果から、海底の石柱群は三崎層群竜串層により制作された岩石で過去に爪白地区で基礎や石段として利用されたものと結論づけられる。

キーワード：主成分分析、起源、ポータブルXRF、堆積岩、南海地震
Keywords: Principle Component Analysis (PCA), Provenance, pXRF, sedimentary rock, Nankai earthquake

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pXRF analyses on Assyrain sculptures

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To evaluate a possibility of reconstruction and understanding the provenance of stone materials used in the ancient cities of Western Asia, some of which have been destroyed and/or dismantled, and are moved to different places of the world, we characterized the bulk geochemical composition of gypsum-carbonate rocks, on which the Assyrians carved sculptures to decollate their palaces, using an Olympus VANTA portable X-ray fluorescence spectroscopy (pXRF). To establish the methodology, we started with the Assyrian sculptures with known provenance: i.e. the collections of the British Museum, the Ashmolean Museum, Magdalen College (Oxford), the Okayama Orient Museum and the MIHO museum.
The pXRF analysis was performed using a Rh target at 40 kV and 100 μA. Beam time was 20 seconds for Beam 1 and 15 and 30 seconds, in later sessions, for Beam 2. The accuracy and precision of the analyses were assessed by analyzing several powdered reference samples of igneous rocks (JB-2 basalt, JA-1, JA-2 andesites, JR-2 rhyolite JG1, JG2 granites and JGb-1 gabbro) and sedimentary rocks (JLk-1 lake sediment, JSd-1 and JSd-2 river sediments, JLs-1 limestone and JDo-1 dolomite) distributed by the Geological Survey of Japan, and gypsum samples (alabaster, selenite and satin spar) distributed by Nichika Inc. We performed the measurement three-times for each spot to assess repeatability of the measurement and/or inhomogeneity of the samples.
Our results showed that ~ 99% of the measured Assyrian sculptures were made of gypsum-anhydrate rocks. Although their distribution fields largely overlap, the gypsum sculptures from Nineveh tend to have more impurities when compared with those from Nimrud and Khorsabad. Visually, the stone materials used in the sculptures in Nimrud often have homogeneously distributed large gypsum crystals, whereas those from Nineveh are rather inhomogeneous and finer in grain size, and often exhibit developed bedding planes. Together with the textural changes, we provisionally conclude that degraded stone materials became used over time.
The Til-Tuba sculpture from Room 33 of the Southwest Palace of Nineveh has higher Ca and lower S contents compared with others. Visually, it contains numerous foraminifera shells of *Alveolinidae Sp*. The different chemical composition could be attributed to the amount of the included foraminifera shells. Stones from Room 36 of Nineveh Southwest Palace have slightly higher Al and Fe contents than others. Although, few such examples have somewhat different compositions, the exact provenance would not be able to identify from a single chemical data. More information obtained through destructive analyses would be necessary for the reconstruction and understanding the provenance of stone materials, such as textural and mineralogical information through thin-section observation, crystallographic information through XRD analysis and analyses of micro-fossils.
Nevertheless, our observation from a material science point of view can provide evidence to what Sennacherib (705-681 BCE) described in his text. The king states that he used “Na_4.^{d}Še.tir” stone from Nipur (Judi Dagh in SE Turkey) that looks like cucumber seeds to construct the statues of Aladlammû and *Apsātu*. Based on this, Mitchel and Middleton (2002) speculated that this same stone was used for the reliefs in Room 33 of the Southwest Palace, Nineveh. If their speculation is correct, evaporites of the middle to late Miocene Fars formation should have comprised the quarry.

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キーワード：pXRF、アッシリア浮彫彫刻
Keywords: pXRF, Assyrian sculpture

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Discussion

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Discussion on non-destructive techniques for geoheritage.

キーワード：非破壊分析
Keywords: non-destructive techniques

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2019年5月29日(水) 13:45 ~ 15:15 | A09 東京ベイ幕張ホール

[S-IT26] New perspectives on the geodynamics of East Asia

コンビーナ:Timothy B Byrne(University of Connecticut)、山口 飛鳥(東京大学大気海洋研究所)、Jonny Wu(University of Houston)、沖野 郷子(東京大学大気海洋研究所)、座長:Jonny Wu、Okino Kyoko

The Pacific, Indo-Australia and Eurasian plates converge around the Philippine Sea plates in south and East Asia, resulting in one of the most tectonically active regions on earth. The area is also geologically and tectonically complex with numerous active tectonic environments, ranging from subduction to collision, and a long history of plate boundary interactions. The last decade has yielded a wide range of new observations, including detailed geologic data and high resolution crustal to mantle imaging. Here we seek oral and poster presentations that bear on the geologic history and geophysical character of modern and ancient plates in East Asia and their interactions since the Mesozoic. We also invite geodynamic models that integrate these diverse datasets into a more holistic view of this dynamic environment.

13:45 ~ 14:00

[SIT26-01] How to solve controversies in Cenozoic tectonics in western Pacific margin

*木村 学[1] (1.東京海洋大学・海洋資源環境学部)

14:00 ~ 14:15

[SIT26-02] Plio-Pleistocene plate interactions associated the Philippine Sea Plate

*Timothy B Byrne[1]、Gaku Kimura[3]、Jonny Wu[2] (1.University of Connecticut、2.University of Houston、3.Tokyo University of Science and Technology)

14:15 ~ 14:30

[SIT26-03] A regional mylonite zone between the Mesozoic metamorphic basement and the subducted Miocene covered schists in eastern Range of Taiwan: A possible Plio-Pleistocene transform fault between Eurasia and the Philippine Sea plate

*Gong-Ruei Ho[1]、Jian-Cheng Lee[1]、Timothy B Byrne[2]、En-Chao Yeh[3] (1.Institute of Earth Sciences, Academia Sinica、2.Department of Geography, University of Connecticut、3.Department of Earth Sciences, National Taiwan Normal University)

14:30 ~ 14:45

[SIT26-04] **Coeval exhumation or subduction channel extrusion of the high pressure Yuli belt? Insights from the Shoufeng fault in eastern Taiwan**

*Jian-Cheng Lee[1,5]、Gong-Ruei Ho[1,5]、Timothy B Byrne[2]、Yuan Hsi Lee[3,5]、En-Chao Yeh[4,5] (1.Academia Sinica、2.Univerity of Connecticut、3.National Chung Cheng University、4.National Taiwan Normal University、5.The Yuli Exhumation Study team (YES Team))

14:45 ~ 15:00

[SIT26-05] Metamorphic temperature variation across the Yuli belt: a clue about exhumation of high-pressure rocks?

*Chin-Ho Tsai[1]、Chih-Ying Yeh[1]、Yui Kouketsu[2]、Masaki Enami[3] (1.Department of Natural Resources & Environmental Studies, National Dong Hwa Univ.、2.Department of Earth & Planetary Sciences, Nagoya Univ.、3.Institute for Space-Earth Environmental Research, Nagoya Univ.)

15:00 ~ 15:15

[SIT26-06] **三次元モデリングによるマリアンナ沈み込み帯の温度構造、スラブ変成作用と境界面地震**

*季 顕鋒[1,2,3]、吉岡 祥一[3,4] (1.中国科学院チベット高原地球科学卓越創新センター、2.中国科学院チベット高原研究所、3.神戸大学都市安全研究センター、4.神戸大学大学院 理学研究科)

How to solve controversies in Cenozoic tectonics in western Pacific margin

*木村 学[1]
*Gaku Kimura[1]

1. 東京海洋大学・海洋資源環境学部
1. Tokyo University of Marine Science and Technology

Tectonics and their geodynamic backgrounds are difficult theme and keep controversial. Cenozoic tectonics in the western Pacific margin are of them. 1) Oceanic ridge subduction, 2) Back-arc spreading, 3) interaction between the Philippine Sea Plate and SW Japan, 4) collision and bending of the Japanese islands, 5) onset of present tectonic and dynamic frameworks, and 6) dynamic background of the earthquakes and volcanic eruption are key events but controversial.

To solve these controversies, a classic geological philosophy of “uniformitarianism” is significant. It means “the present is the key to the past”.

1. To solve the controversy of the Izanagi-Pacific Ridge subduction in early Cenozoic, a comparative study with modern examples of the ridge subduction at the Chile triple junction, Woodlrack Basin and Middle America trench with a new data set and simlation is a key.
2. To solve the back arc spreading controversy of Kuril and Japan Basins and Okinawa Trough, the promotion of International collaboration to acquire a new data set is necessary together with a comparative study among the modern backarc spreading. A classic controversy of double door opening vs pull-apart spreading will be progressed by comparison with progressed modern examples. A large scale perspective beyond the back-arc basins themselves is also necessary for geodynamic solution for the back-arc spreading.
3. To solve the controversy of the interaction between the Philippine Sea Plate and SW Japan; switch from the Pacific plate to Philippine Sea Plate at ~15Ma vs ~12Ma- 6Ma, detailed tomographic study with new perspectives and data sets from on-and geology and geophysics is necessary with simulation.
4. To solve the controversy of the collision and bending of the Japanese islands, not only the geological data set but more comprehensive data set of geophysics and geochemistry with simulation are necessary. Differentiation between the hypothesis and fact promotes a constructive controversy. In geology, data reliability and re-productablity is the most significance part of science.
5. To solve the controversy of onset of present tectonic and dynamic frameworks is the most essential part of “uniformitarianism”. The definition of “present” depends on the scientific field even in geoscience, Seismological “present” is a moment to minutes, days and month scale, That of geodesy is ~10s to 100 years. Geomorphology combined with geology is 100s to 10^4 scale. That of most geology is beyond 10^4 scale. Establishment of seamless “uniformitarianism” with seamless space perspective is a key to understand this controversy.
6. To solve dynamic background of the earthquakes and volcanic eruption, I like to emphasize the viewpoint of evolving effect of hysteresis. A final trigger of earthquakes and volcanic eruption is no doubt of physical consequence resulted from long and short term hysteresis.

キーワード：western Pacific、ridge subduction、back-arc spreading、collision、subduction、Japanese islands

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Keywords: western Pacific, ridge subduction, back-arc spreading, collision, subduction, Japanese islands

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Plio-Pleistocene plate interactions associated the Philippine Sea Plate

*Timothy B Byrne[1], Gaku Kimura[3], Jonny Wu[2]

1. University of Connecticut, 2. University of Houston, 3. Tokyo University of Science and Technology

Geologists have long recognized the possible significance of a change in motion of the Philippine Sea Plate (PSP) in the middle to late Cenozoic (Huchon, 1983; Seno and Maruyama, 1984), although the detailed timing and kinematics have remained elusive. The most recent reconstructions suggest a ~50° counterclockwise rotation of the plate motion vector relative to Eurasia possibly as recently as 2 Ma (Wu et al., 2015), which would have significant implications for the tectonics of east-central Asia. In southern Japan, for example, CCW rotation of the plate motion vector predicts a change from generally orthogonal plate convergence to the present NW-directed and oblique motion. In Taiwan, in contrast, plate convergence obliquity would decrease significantly. To better understand and possibly better constrain the geometry, kinematics and timing of this change in motion, we review the geologic histories of different geologic units and terranes along the boundary of the PSP, including: the Okinawa Trough, Kyushu and Shikoku Islands, Kumano Basin, Boso and Miura Peninsulas, the southern Marianas, the Philippines and Taiwan. Several areas in southern Japan also appear to provide critical constraints on the kinematics and timing of a possible change in motion. For example, geological and geophysical studies of the accretionary prism in SW Japan show a transition from shortening perpendicular to the plate boundary to extension perpendicular to the boundary <1.0 Ma (Gulick et al., 2010, and Sacks et al., 2013). Although these authors suggest that this change reflects changes in subduction zone dynamics, we propose that the change to extension relates to the decrease in the rate of convergence across the prism as the plate motion changed from nearly orthogonal to more oblique at ~1.0 Ma. Hayman et al. (2012) also documented a CCW rotation in the shortening direction deep in the Nankai accretionary prism just south of Shikoku Island, although the timing of this rotation was only constrained to be younger than ~5 Ma (the age of the youngest deformed sediments). In the eastern Nankai, Yamaji et al. (2003) interpreted a similar suite of faults to be related to a similar change in plate motion at ~1 Ma. Further landward, studies of the Median Tectonic Line on Shikoku Island document a change from thrusting to right-lateral strike-slip faulting at about ~0.8 Ma (Mizuno, 1999; Sato et al., 2015). This change in kinematics and timing is consistent with previous ideas on the age of formation of the Nankai forearc sliver (~0.8 Ma) based primarily on geologic and geomorphic data from Shikoku Island (Ohmori, 1978; Saito, 1999; Okamura, 1990). Finally, in Taiwan, Hsu et al. (2016) have proposed an acceleration in rock uplift at ~0.8 Ma based on low-temperature thermochronology data that may reflect an acceleration in plate convergence related to changing plate motions. Taken together, these observations suggest that a significant change in the plate motion vector (i.e., CCW rotation) occurred relatively recently and probably < 1 Ma.

Keywords: plate tectonics, philippine sea plate

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A regional mylonite zone between the Mesozoic metamorphic basement and the subducted Miocene covered schists in eastern Range of Taiwan: A possible Plio-Pleistocene transform fault between Eurasia and the Philippine Sea plate

*Gong-Ruei Ho[1], Jian-Cheng Lee[1], Timothy B Byrne[2], En-Chao Yeh[3]

1. Institute of Earth Sciences, Academia Sinica, 2. Department of Geography, University of Connecticut, 3. Department of Earth Sciences, National Taiwan Normal University

As one of the youngest orogenic belts, Taiwan offers insights into mountain building processes operating from the Earth’ s surface. In the eastern Central Range of the Taiwan mountain belt, the Tananao metamorphic belt, comprising the Tailuko Belt, high temperature/low pressure Mesozoic basement, was attached by the Yuli belt, a Miocene pelitic quartz-mica schist with high-pressure exotic mafic to ultra-mafic blocks (Yen, 1960; Tsai et al., 2013). Observations of meso- and microscopic structures show predominant asymmetric folds with top-to-east S2/S3 on the eastern Yuli belt and isoclinal folds with west dipping S2 on the western Tailuko belt. In the boundary between these two geological rock units, we observed a mylonite zone distributed about 2 kilometers wide, which has been called the Shoufeng Fault, which indicated sinistral sense of shear and shallow stretching lineation within the mylonite zone. The structural style of other area is relatively irregular and disordered (Stanley et al., 1981; Lu and Wang Lee, 1986; Pulver et al., 2002; Ho, 2007; Liao, 2011; Ji, 2011). This pattern was found from north to south in a distance of 100 km along the Yuli belt along the Mugua, Shoufeng, Wanliqiao, and Chinshui Rivers to the Southern Cross island highway and the Dawushan map (Usami, 1940). The above observations pointed out an apparently down-dip folding coupled with a dominant orogen-parallel lineation pattern around the Shoufeng mylonite zone between the Miocene Yuli belt and the Mesozoic Tananao complex. It provides structural constraints on the deformation associated with ductile metamorphism of the high-pressure Yuli belt terrane while attached against the much older continental crust of the Tananao complex as well as during the subsequent rapid exhumation processes.

Keywords: Tananao metamorphic belt, mylonite zone, left-lateral strike slip motion

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Coeval exhumation or subduction channel extrusion of the high pressure Yuli belt? Insights from the Shoufeng fault in eastern Taiwan

*Jian-Cheng Lee[1,5], Gong-Ruei Ho[1,5], Timothy B Byrne[2], Yuan Hsi Lee[3,5], En-Chao Yeh[4,5]

1. Academia Sinica, 2. Univerity of Connecticut, 3. National Chung Cheng University, 4. National Taiwan Normal University, 5. The Yuli Exhumation Study team (YES Team)

Based on field investigations, microscopic observations, and available geophysical, geochemical and geochronological data, this study intends to better understand the structural characteristics of the Eurasian continental margin (e.g., the eastern Central Range in Taiwan) during subduction and exhumation while the Philippine Sea plate has been approaching in the vicinity of Taiwan since the Miocene time. The eastern Central Range is composed of two major geological units: 1) the Tailuko belt, the Mesozoic metamorphic subduction complex, retro-metamorphosed in green schist facies and exhumed since late Miocene, and 2) the Yuli belt, continental margin rocks that contain high-pressure minerals (omphacite, glaucophane, garnet) with Miocene-Pliocene ages suggesting rapid exhumation from mantle depths of 40-50 km.

We conducted detailed field surveys around the Shoufeng fault which represents the boundary between the Tailuko belt and the Yuli belt. We found a mylonite zone of several kilometers wide in the boundary of these two belts. Based on the meso- and microscopic scale observations we define the boundary as ultra-mylonite, mylonite, and proto-mylonite zones. Within the ultra-mylonite and mylonite zones, rocks from two belts are intercalated each other in varied widths. The main dominant schistosity/cleavage in the mylonite zones (Sm/S3) remains the same orientation of striking in NE/NNE and dipping to the west. Also, the main composition layers, which we tentatively called S2 for the sake of field investigations, were more intensively deformed (i.e., crenulated, folded, etc.) from outside toward the core of the mylonite zones. As a result, the Sm/S3 becomes less persistent outside of the mylonite zones in the Yuli belt.
The mylonite zones exhibit left-lateral Sm/S3-related shearing without significant down-dip component. We also observed a general S2/S3-related top-to-west sense of shear across the two belts. As a consequence, we tend to interpret that the Yuli belt and the Tailuko belt have been mylonitically sheared (Sm/S3) in a left-lateral movement at the depth and that they exhumed coevally up to the surface level. The schistosity of the main composition layers S2 probably occurred before the mylonization during the transition from subduction to exhumation. The shallow dipping and less dominant S3 outside the mylonite zone might imply a upward and unroofing process during the rapid exhumation of the eastern Central Range of Taiwan.

Keywords: Mylonite, Exhumation, Shoufeng fault, Yuli belt, Taiwan

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Metamorphic temperature variation across the Yuli belt: a clue about exhumation of high-pressure rocks?

*Chin-Ho Tsai[1], Chih-Ying Yeh[1], Yui Kouketsu[2], Masaki Enami[3]

1. Department of Natural Resources & Environmental Studies, National Dong Hwa Univ., 2. Department of Earth & Planetary Sciences, Nagoya Univ., 3. Institute for Space-Earth Environmental Research, Nagoya Univ.

We applied Raman spectra of carbonaceous material (RSCM) geothermometer to estimate peak metamorphic temperatures of pelitic and psammitic schists across the Yuli belt, eastern Taiwan. The analyzed samples mainly consist of phengitic mica, quartz, chlorite, and albite, with accessory graphitic carbonaceous material, titanite, zircon, and tourmaline. In samples from the Juisui Schist and Chinshuichi Plantation units (both containing high-pressure allochthonous blocks), garnet, ilmenite, and paragonite may occur and albite tends to be porphyroblastic. Serpentinite and metabasite pods occur in these units, whereas the neighboring metasedimentary units lack such rocks and porphyroblastic phases. The yielded metamorphic temperatures reveal a systematic variation in spatial distribution across the Yuli belt. In the Wanjung and Juisui areas, peak temperatures of the four schist units are in the range of 430-510˚C, 410-470˚C, 560-620˚C and 420-450˚C, from west (structurally upper) to east (lower), respectively. In the Chinshuichi area, temperatures of the two units are in the range of 540-560˚C (structurally lower) and 400-450˚C (higher), whereas the temperatures of the low-grade Slate unit (Chulai Formation) bordering the Yuli belt in the east are 330-340˚C. The high-pressure Juisui Schist and Chinshuichi Plantation are apparently warmer than their neighboring units in each area, although boundaries of the units are poorly exposed or characterized. The spatial distribution of metamorphic temperatures requires a structural explanation. Possible interpretations include doming, extension, or extrusion, and the inferred structures and processes may shed new lights on the exhumation of high-pressure metamorphic rocks in the Yuli belt.

Keywords: metasedimentary rocks, thermobarometry, carbonaceous material, exhumation, high-pressure metamorphism

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三次元モデリングによるマリアンナ沈み込み帯の温度構造、スラブ変成作用と境界面地震

Thermal state, slab metamorphism and interface seismicity in Mariana based on 3-D modeling

*季 顕鋒[1,2,3]、吉岡 祥一[3,4]
*Yingfeng Ji[1,2,3], Shoichi Yoshioka[3,4]

1. 中国科学院チベット高原地球科学卓越創新センター、2. 中国科学院チベット高原研究所、3. 神戸大学都市安全研究センター、4. 神戸大学大学院 理学研究科
1. Center of Excellence in Tibetan Plateau Earth Science, Chinese Academy of Sciences, 2. Key laboratory of continental collision and plateau uplift, Institute of Tibetan Plateau, Chinese Academy of Sciences, 3. Research Center for Urban Safety and Security, Kobe University, 4. Graduate School of Science, Kobe University

The Marina arc system represents a typical mode of intra-oceanic convergent boundary characterizing circum-Pacific subduction zones, together with the Izu-Bonin, Kuril and Tonga-Kermadec margins well known for the tectonically formed deep trenches. Active back-arc extension driven by hydrothermal mantle upwell comprises one of the significant features of Mariana caused by steep subduction. Previous studies document that the narrow subduction constrains the seismicity in Mariana to be less than M7. However, the subduction thermal regime remains still unclear in detail. Based on the 3-D thermal model constructed for Mariana, we found that the highly curved Mariana arc presenting such a particular tectonic setting caused by trench retreat produces a cold thermal structure beneath the central and northern Mariana influenced by an oblique subduction. The deep earthquakes (>100 km) are therefore frequently detected compared with the southern Mariana. The subducted Pacific plate entraining the oceanic crust components is calculated to obtain their pressure-temperature conditions for different petrological faces undergoing multiple phase transition including the paths from amphibolite to eclogite or harzburgite at a high temperature of >500 degrees in Celsius which is conjectured to facilitate the deep earthquakes at Mariana. The dewatered oceanic plate is expected to releases ample fluids for the backarc volcanism and hydrous circulation at Mariana mantle wedge. The 3-D temperature structure of Mariana obtained in this study sheds lights on regional earthquake genesis and slab metamorphism in such an intro-oceanic subduction system featured by deep events.

キーワード：熱構造、スラブ変成作用、境界面地震、マリアンナ、三次元モデリング
Keywords: Thermal state, slab metamorphism , interface seismicity, Mariana, 3-D modeling

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2019年5月29日(水) 15:30 ~ 17:00 | A09 東京ベイ幕張ホール

[S-IT26] New perspectives on the geodynamics of East Asia

コンビーナ:Timothy B　Byrne(University of Connecticut)、山口 飛鳥(東京大学大気海洋研究所)、Jonny Wu(University of Houston)、沖野 郷子(東京大学大気海洋研究所)、座長:山口 飛鳥(東京大学大気海洋研究所)、Tim Byrne

The Pacific, Indo-Australia and Eurasian plates converge around the Philippine Sea plates in south and East Asia, resulting in one of the most tectonically active regions on earth. The area is also geologically and tectonically complex with numerous active tectonic environments, ranging from subduction to collision, and a long history of plate boundary interactions. The last decade has yielded a wide range of new observations, including detailed geologic data and high resolution crustal to mantle imaging. Here we seek oral and poster presentations that bear on the geologic history and geophysical character of modern and ancient plates in East Asia and their interactions since the Mesozoic. We also invite geodynamic models that integrate these diverse datasets into a more holistic view of this dynamic environment.

15:30 ~ 15:45

[SIT26-07] **A tomography-led plate reconstruction of NE Asia during the late Cretaceous**

*Jonny Wu[1]、Yi-An Lin[1]、Nicolas Flament[2]、Tsung-Jui Wu[1]、Yiduo Liu[1] (1.University of Houston、2.University of Wollongong)

15:45 ~ 16:00

[SIT26-08] Geodynamic models of late Mesozoic intraoceanic subduction offshore NE Asia caused by growing Izanagi plate

*Lorenzo Colli[1]、Jonny Wu[1]、Yi-An Lin[1] (1.University of Houston)

16:00 ~ 16:15

[SIT26-09] **Early Cretaceous to Paleocene magmatism in the Sikhote-Alin area and their implications for Paleo-Pacific plate subduction and continental evolution**

*Tsung-Jui Wu[1]、Jonny Wu[1]、Igor Alexandrov[2]、Thomas Lapen[1] (1.Department of Earth and Atmospheric sciences, University of Houston, Houston, U.S.、2.Far East Geological Institute, Russian Academy of Sciences, Vladivostok, Russia)

16:15 ~ 16:30

[SIT26-10] Processes of subduction initiation revealed by P-T paths of amphibolite and blueschist tectonic blocks in serpentinite mélange: An example from the Kamuikotan high-P/T metamorphic rocks in Hokkaido, northern Japan

*竹下 徹[1]、岡本 あゆみ、シン ウォンジ[1]、安藤 瑞帆[1] (1.北海道大学大学院理学院自然史科学専攻)

16:30 ~ 16:50

[SIT26-11] Metamorphism in the Sanbagawa belt of SW Japan as a record of subduction processes

★Invited Papers

*ウォリス サイモン[1] (1.東京大学)

16:50 ~ 17:00

[SIT26-12] Subduction and exhumation of the high pressure metamorphic rocks: What we know and what we need to know.

*Timothy B Byrne[1] (1.University of Connecticut)

A tomography-led plate reconstruction of NE Asia during the late Cretaceous

*Jonny Wu[1], Yi-An Lin[1], Nicolas Flament[2], Tsung-Jui Wu[1], Yiduo Liu[1]

1. University of Houston, 2. University of Wollongong

Contrasted plate tectonic reconstructions have been proposed for the northeast Asian margin during the late Cretaceous, including: an Andean-type subduction margin, the existence of marginal seas, the subduction of a spreading ridge, the subduction of remnant arcs, or continental block collision and continental subduction. Here we investigate which scenarios are consistent with tomography models by mapping and unsubducting the vanished western Pacific slabs along the Kurile-Kamchatka, Japan, and Izu-Bonin-Marianas trenches from global tomography models. We show that a mapped 4,000 km-long slab gap within the East Asian lower mantle is the tomographic signature of the subducted Izanagi-Pacific spreading ridge based on a comparison to global mantle flow models. We reconstruct the size of the lost Izanagi conjugate from the geometry of the unsubducted western Pacific slabs, the age of Pacific oceanic crust, and published synthetic seafloor isochrons.

Our tomography-based plate reconstruction implies that: (1) the Izanagi ocean basin crust (i.e. formed by Pacific MORB) first reached and subducted along Sikhote-Alin and northern Japan around ~100 Ma; (2) subduction of the Izanagi plate along northeast Asia during the late Cretaceous ~75 Ma was limited to north of southernmost Korea and Bohai Bay, China, and west of westernmost Alaska; and, (3) the Izanagi-Pacific ridge intersected with the northeast Asian margin at a low angle in the early Cenozoic. We discuss our plate model against proposed northeast Asian margin plate tectonics during the Cretaceous.

Keywords: NW Pacific Ocean, Izanagi plate, NE Asia

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Geodynamic models of late Mesozoic intraoceanic subduction offshore NE Asia caused by growing Izanagi plate

*Lorenzo Colli[1], Jonny Wu[1], Yi-An Lin[1]

1. University of Houston

The existence of the Izanagi plate is well established both from magnetic lineations and fracture zones in the western Pacific and from tomographic imaging of the deep mantle underneath East Asia. But its spatial extent, position and motion through time remain poorly known.

A common scenario envisages the Izanagi as a large and long-lived plate extending from central Panthalassa to the eastern margin of Eurasia. In this scenario the Izanagi plate is conjugate to the Farallon and Phoenix plates before the inception of the Pacific plate and it subducts continuously beneath East Asia during the Mesozoic (e.g. Müller et al., 2016).

A conservative choice for the spatial and temporal extent of the Izanagi plate, limiting it to what can be extrapolated using the conjugate Pacific plate, leads to a very different scenario: in this case the Izanagi plate is born together with the Pacific plate around 190 Ma and grows triangular in shape. It overrides preexisting oceanic lithosphere causing extended intraoceanic subduction in western Panthalassa characterized by fast trench retreat towards the Eurasian margin. The tip of the Izanagi plate reaches the Eurasian continental margin near Japan and Sikhote-Alin around 100 Ma.

Here we assimilate these two scenarios in geodynamic models of global mantle convection in the form of time-dependent velocity boundary condition at the Earth’ s surface. Their implications for the evolution of mantle structure in East Asia during Mesozoic time up to present-day are presented and discussed.

Keywords: Izanagi plate, intraoceanic subduction, Panthalassa, East Asia, Mesozoic, Numerical model

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Early Cretaceous to Paleocene magmatism in the Sikhote-Alin area and their implications for Paleo-Pacific plate subduction and continental evolution

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The Sikhote-Alin area in southern Russian Far East is one of the few places in the East Asian margin that has extensively exposed Mesozoic geological units. In particular, Cretaceous to Cenozoic igneous rocks are abundant and formed in response to periodic subduction of Paleo-Pacific plates. Previous geochemical studies of igneous rocks, mainly from southern Sikhote-Alin, resulted in significant insights into the continental evolution of East Aisan margin and subduction history of Paleo-Pacific plates (Kruk et al., 2014; Jahn et al., 2015; Grebennikov et al., 2016). In this study, we present new zircon U-Pb chronology and geochemical data from ~50 samples in across the entire Sikhote-Alin area. We combine our new results with published data to discuss the history of arc magmatic evolution in the region.

In general, the data show a cycle of arc magmatism that started from the early Cretaceous to Paleocene in Sikhote-Alin. Zircon U-Pb geochronology of igneous rocks indicate a major population of granitoids that had ages of 135-57 Ma; a small population of volcaniclastic rocks were dated at 55-53 Ma. Three magmatic episodes with distinct geochemical characteristics were recognized: 135-120 Ma, 110-100 Ma and 100-57 Ma. The 135-120 Ma granitoids are dominated by S-type granites; zircons with inherited cores were frequently observed in this episode. The 110-100 Ma episode has mostly I-type granites, whereas the 100-57 Ma magmatism had I-type granites that show greater degrees at fractional crystallization than the other groups. Some magmatic rocks with 67-57 Ma and ~100 Ma were A2 type granites, suggesting that two periods of intraplate magmatism could had occurred within this subduction setting. The La/Yb ratio and Nd isotopic ratios of the granitoids remained relatively similar during the Cretaceous and even showed a La/Yb ratio decrease in the late Cretaceous, implying that the Andean subduction margin crustal thickening model (Haschke et al., 2002) may not applicable to the Sikhote-Alin area.

Keywords: continental arc, paleo-pacific plate subduction, Northeast Aisa, Sikhote-Alin, continental evolution

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Processes of subduction initiation revealed by P-T paths of amphibolite and blueschist tectonic blocks in serpentinite mélange: An example from the Kamuikotan high-P/T metamorphic rocks in Hokkaido, northern Japan

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It has been recently noted that serpentinite mélange which contains tectonic blocks of high-*P/T* type metamorphic rocks such as blueschist and eclogite and their counterclockwise P-T paths could indicate the subduction initiation (e.g. Willner et al., 2004; Escuder-Viruete et al., 2011; Agard et al., 2016; Bhowmik and Ao, 2016; Hunziker et al., 2017). We investigated tectonics in amphibolite and blueschist tectonic blocks in mélange, which are distributed at the highest structural level of the high-*P/T* type Kamuikotan metamorphic rocks in Hokkaido, northern Japan. We reconstructed their individual pressure-temperature (*P-T*) paths based on petrography, mineral chemistry and phase equilibria modeling. As a result, tectonic blocks in this study area are divided into six rock types: garnet-epidote amphibolite, epidote amphibolite, amphibolite, plagioclase-poor amphibolite, blueschist and quartz-rich blueschist. From the reconstruction of *P-T* paths, it is found that most of the tectonic blocks experienced blueschist facies metamorphism probably at the maximum depth, while the initial paths vary from a counterclockwise *P-T* path shown by different kinds of amphibolite to a prograde *P-T* path shown by blueschist and quartz-rich blueschist. We have concluded that these *P-T* paths, on the whole, could have reflected the cooling history of subduction channel from the beginning to steady state of subduction. The geothermal gradient could have been changed from ~25 ˚C/km to ~10 ˚C/km within *c.* 25 myr estimated by previously reported radiometric ages. These tectonic blocks could have started to subduct at a different timing to show the different *P-T* paths, and juxtaposed against each other at a certain depth in the subduction channel. Since these tectonic blocks show little deformation structures formed during exhumation stage, they might have behaved as a rigid body in serpentinite (i.e. mélange matrix) after they were incorporated in it during subduction stage.

キーワード：神居古潭高圧型変成岩、蛇紋岩メランジュ中の角閃岩および青色片岩構造岩塊、反時計回り圧力温度履歴、沈み込みの開始
Keywords: Kamuikotan high-P/T type metamorrphic rocks, amphibolite and blueschist tectonic blocks in serpentinite mélange, counterclockwise P-T paths, subduction initiation

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Metamorphism in the Sanbagawa belt of SW Japan as a record of subduction processes

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The Sanbagawa belt of SW Japan records Cretaceous suduction processes off the eastern Asian margin. The Sanbagawa belt can be traced for around 800 km throughout SW Japan, but the main exposure is found in Shikoku. The main constituent rock types are pelitic, quartz and mafic schists which were derived from the subducted oceanic slab. These are associated with widespread blocks and lenses of serpentinite and related rocks types derived from the mantle wedge.

A long running dispute about the age of peak metamorphism has recently been resolved. Evidence for an early stage of subduction associated at around 115 Ma is locally preserved with anticlockwise P-T paths. This is followed at around 90 Ma by the main been long disputed with estimates of the peak

キーワード：テクトニクス、三波川帯、沈み込み
Keywords: Tectonics, Sanbagawa belt, subduction

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Subduction and exhumation of the high pressure metamorphic rocks: What we know and what we need to know.

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1. University of Connecticut

Although great strides have been made in understanding the subduction and, to a lesser extent the exhumation, of high pressure rocks, the links between these two processes is much less clear. As a result, many of the regional-scale models of these processes are poorly constrained and weakly supported by data. In this discussion session, we would like to better understand the data and observations that provide evidence for exhumation of high pressure rocks and, in areas were data gaps remain, what data are necessary to advance our understanding.

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[E] 口頭発表 | セッション記号 S (固体地球科学)：S-GC 固体地球化学

2019年5月29日(水) 13:45 ~ 15:15 | A10 東京ベイ幕張ホール

[S-GC40] Volatile Cycles in the Deep Earth - from Subduction Zone to Hot Spot

コンビーナ:角野 浩史(東京大学大学院総合文化研究科広域科学専攻相関基礎科学系)、羽生 毅(海洋研究開発機構 地球内部物質循環研究分野)、佐野 有司(東京大学大気海洋研究所海洋地球システム研究系)、Gray E Bebout(Lehigh University)、座長:羽生 毅、Gray Bebout(Lehigh University)、佐野 有司、角野 浩史

Volatiles play an important role in the geodynamics and chemical differentiation in the mantle and crust by drastically changing mineral stability and rheological behavior. Fractionation-processes such as partial melting, hydration, and dehydration are all controlled by volatiles in the rocks. A significant portion of the volatiles in the Earth has been thought to be present in the atmosphere and oceans as a consequence of extensive degassing during accretion and subsequent mantle degassing. On the other hand, it has been recently recognized that substantial amounts of volatiles are recycled back into the mantle at subduction zones, where intensive devolatilization of descended materials during arc magma generation was once thought to act as an effective "subduction barrier". However, fundamental questions still remain, such as: how are volatiles species distributed throughout the early and present Earth? What are the mechanisms for, and rate at which, volatiles are fluxed between the atmosphere, crust, and mantle? And what role have volatiles played in driving the evolution of the Earth? The possible role of the core in storing primordial volatiles is also poorly constrained. We therefore welcome contributions from experimental, observational, and modeling studies that help shed light on the deep cycles of volatiles, such as hydrogen, carbon, nitrogen, noble gases, halogens and sulfur. We particularly encourage studies linking the behavior of multiple volatile elements and their isotopic compositions. Studies investigating the linkage between volatile and solid geochemical tracers, the phase equilibria of volatile-bearing mantle assemblages, and the effect of volatiles on the physical properties of the mantle are also welcome.

13:45 ~ 14:15

[SGC40-01] Continental growth, crustal recycling, and global water cycle

★Invited Papers

*是永 淳[1] (1.イェール大学地球科学科)

14:15 ~ 14:30

[SGC40-02] マントルプルーム内部でマグマ形成に果たす揮発成分の役割

*高橋 栄一[1]、王 錦団[1]、李 立[1] (1.中国科学院広州地球化学研究所)

14:30 ~ 14:45

[SGC40-03] DH partitioning experiment among high-pressure polymorph of olivine

*佐野 亜沙美[1]、伊藤 正一[2]、井上 徹[3]、野田 昌道[3] (1.日本原子力研究開発機構 J-PARCセンター、2.京都大学、3.広島大学)

14:45 ~ 15:00

[SGC40-04] **Formation of Fe-rich volatile-bearing phases in the deep lower mantle and the implications for deep Earth volatile cycles**

*Li Zhang[1]、Hongsheng Yuan[1]、Eiji Ohtani[2]、Lianjie Man[1]、Duck Young Kim[1]、Dmitry Popov[3]、Yue Meng[3]、Eran Greenberg[4]、Vitali Prakapenka[4] (1.Center for High Pressure Science and Technology Advanced Research (HPSTAR)、2.Department of Earth Science, Graduate School of Science, Tohoku University、3.HPCAT, X-ray Science Division, Argonne National Laboratory、4.GeoSoilEnviroCARS, University of Chicago)

15:00 ~ 15:15

[SGC40-05] Estimation of the origin of Pitcairn Island OIB by Independent Component Analysis

*小澤 恭弘[1]、岩森 光[1,2,3]、羽生 毅[2]、浜田 盛久[2]、清水 健二[4]、牛久保 孝之[4]、木村 純一[2]、常 青[2]、中村 仁美[5]、伊藤 元雄[4] (1.東京工業大学、2.海洋研究開発機構　地球内部物質循環研究分野、3.東京大学　地震研究所、4.海洋研究開発機構　高知コア研究所、5.国立研究開発法人産業技術総合研究所・地質調査総合センター)

Continental growth, crustal recycling, and global water cycle

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The evolution of continental crust provides first-order control on Earth’ s surface environment, but relevant studies on this important issue have long been in a confused state since 1990s. There are mainly two reasons for this situation. First, the volume of the global database of detrital zircons has been continuously growing in the last three decades, and as a result, the most of new crustal growth models have been built solely on such a zircon database. Zircons that have survived to the present day, however, do not constrain the amount of crust that has been lost to the mantle by subduction, so there is no way to reconstruct net crustal growth from zircon data. Second, this situation further deteriorated by two influential papers, Belousova et al. (2010) and Dhuime et al. (2012), with the former introducing an illogical method of using zircon age data to construct a growth model, and the latter claiming falsely that this method can actually reconstruct net crustal growth. The situation has recently been rescued by the development of a sensible method of utilizing zircon age data as well as a new geochemical box modeling of Nd isotope data. These new studies point to the possibility of rapid crustal growth and efficient crustal recycling in early Earth, and such crustal evolution is consistent with the operation of plate tectonics throughout Earth history. In particular, the secular evolution of crustal recycling, when considered jointly with the constancy of continental freeboard, indicates a novel connection between global water cycle and the stability of continental crust, which can naturally explain both the Hadean/Archean and Archean/Proterozoic transitions.

キーワード：プレートテクトニクス、大陸地殻、地質累代の起源
Keywords: Plate tectonics, Continental crust, Origin of geologic eons

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マントルプルーム内部でマグマ形成に果たす揮発成分の役割
Role of volatiles in magma genesis of ascending mantle plume

*高橋 栄一[1]、王 錦団[1]、李 立[1]
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It is now widely accepted that recycled former oceanic crust component (eclogite) plays a great role in magma genesis of OIBs and flood basalts (Hauri, 1996; Takahashi et al, 1998; Sobolev et al, 2005). In this study we investigated the effect of H_2O and K_2O in magma genesis of heterogeneous mantle plume that contains large amount of recycled eclogite component. K_2O was studied as a group of volatile component, because it is incompatible to most mantle minerals at P<7 GPa (Tsuruta and Takahashi, 1998) and it drops the solidus of both peridotite and eclogite dramatically (Wang and Takahashi, 1999, 2000).

High-pressure melting experiments were carried out using a piston-cylinder and a 2500 ton cubic-type multi-anvil that have been moved from Tokyo Institute of Technology to Guangzhou Institute of Geochemistry in 2017. In order to understand the melting reaction between recycled eclogite and surrounding peridotite, we investigated melting of layered eclogite/peridotite starting materials both under dry and wet conditions. Spinel lherzolite KLB-1 (Takahashi 1986) was employed as peridotite component in this study. Two basalt components were used as recycled crust component: 1) Columbia River basalt (CRB72-180, Takahashi et al., 1998) which is relatively enriched in K, Ti and LREE (K_2O=1wt%, TiO_2=3.2wt%), N-type MORB (NAM-7, Yasuda et al., 1994). The 2.9GPa experiments (corresponding to about 80km depth which is the top most horizon of the Hawaiian plume head) were carried out with Boyd-England type piston-cylinder apparatus at (1460~1540˚C for dry experiments; 1400~1500˚C for hydrous experiments), The 5GPa and 8 GPa experiments (corresponding to about 150km and 200km depth on the plume axis) were conducted cubic-type multi-anvil apparatus (1550~1650˚C for dry experiments; 1350~1550˚C for hydrous experiments).

Melts formed by reactive melting of dry eclogite and peridotite changes dramatically in the temperature range across the solidus of peridotite KLB-1 from basalt (below dry solidus) to picrite (20-40˚C above dry solidus). Basaltic melts are not saturated with olivine both at 2.9 and 5 GPa and therefore they are separated by peridotite matrix by Opx film. Chemical reaction between the basalt melt and the peridotite matrix proceeds only slowly by solid-diffusion across the Opx film. In hydrous experiments, solidus of peridotite decreases significantly, Opx film was not formed, therefore, the reaction between hydrous melt and the partially molten peridotite matrix proceeds significantly even at temperatures much below peridotite dry solidus.

Melt composition produced by reactive melting of dry basalt and peridotite are similar to basaltic andesite (below peridotite solidus), Hawaiian tholeiite (slightly below peridotite solidus) to picrite (above peridotite dry solidus). On the other hand, melt compositions formed by reactive melting between hydrous basalt and peridotite show a great diversity depending on the amount of H_2O and K_2O. At H_2O-rich conditions (3 to 5 wt.% in bulk), melting took place both in peridotite and eclogite layers and composition of partial melts are similar to silica-deficient basanite and nephelinite at temperatures 1300-1400˚C both at 3 and 5 GPa. At low H_2O conditions (1 wt.% in bulk) partial melts formed in the MORB layer at 1300˚C are similar to silica-rich dacite both at 3 and 5 GPa. On the other hand, partial melts formed in the

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CRB72-180 layer with 1 wt.% H_2O at 3 and 5 GPa are similar to K-rich alkali acidic magma (phonolite, tracyte, hawaiite).

Post shield stage phonolite and hawaiite magmas in Hawaii were considered to be fractionation product of alkali basalts under crustal magma chambers (e.g., Frey et al, 1990). However, our experimental results demonstrated an alternative scenario that phonolite and hawaiite magma were derived from partial melting of alkali basaltic blocks at deeper part (150-200km) of the plume. On the other hand, basanite and nephelinite which appears in rejuvenated stage in Oahu and Kawai may represent partial melts of peridotite portion of the plume beneath Pacific plate. Volatiles control the solidus and the depth of melting as well as enhancing chemical interaction between the peridotite and entrained eclogite component in the ascending plume. In this presentation, we discuss the role of volatile and K_2O in magma genesis in ascending plume based on our melting experiments and field occurrence of diverse magma types both geographically and in growth history of given shield volcanoes in Hawaii.

キーワード：マグマ生成、揮発成分の影響、マントルプルーム、ハワイホットスポット
Keywords: magma genesis, effect of volatile, mantle plume, Hawaii hot spot

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DH partitioning experiment among high-pressure polymorph of olivine

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Mantle is known to have homogeneous hydrogen isotope composition with δD = -80 ~ -60 ‰based on the analysis of MORB and OIB [1, 2]. The reason of the depletion of deuterium compared to the present ocean has been explained by the existence of isolated primordial reservoir in the mantle [1], evolution by the subduction of deuterium-poor hydrous mineral through the geological timescale [3], and addition of cometary water after the formation of ocean [4]. Hydrogen isotope partitioning factor among minerals is a key in these discussions, but little is known under high pressure and high temperature of mantle conditions. In this study we focused on DH partitioning between olivine and wadsleyite, which is a main constituent of upper mantle and mantle transition zone (MTZ). High pressure experiments suggest that wadsleyite and its high pressure polymorph of ringwoodite can contain significant amount of water up to 3.3 wt.% thus MTZ has an ability to keep water up to several times of ocean [5]. Finding of Ringwoodite with 1.4 wt.% H_2O in a diamond inclusion also reveals hydrated MTZ at least locally [6].

The partitioning experiment was conducted using Kawai-type multianvil press at GRC, Ehime University. Powder of $Mg(OH)_2$ and $Mg(OD)_2$ was mixed with synthetic olivine so that the starting composition is equivalent to $Mg_{1.8}Fe_{0.2}SiO_4$ + 1.0 wt.% HDO. The sample was sealed in the Au75Pd25 capsule and kept at 1300 ˚C and around 13 GPa, which is the condition of olivine and wadsleyite coexist. The recovered sample was polished and analyzed by micro-focused X-ray diffractometer, Raman spectroscopy and EPMA. Hydrogen isotope composition was determined using SIMS at Kyoto University.

To test for equilibrium, partitioning experiments are made with changing duration times from 1 h to 72 h. The fractionation factor decreases with increasing of duration time. After keeping for 30 h, $1000\ln\alpha_{\text{Olivine-Wadsleyite}}$ seems to reach almost equilibrium around -60 ‰. Assuming that the δD of olivine of upper mantle to -80, the δD of wadsleyite at MTZ become -20 to 0, which is more comparable to the composition of the ocean. The present result shows that the depletion of deuterium of upper mantle can be explained as a result of DH fractionation between upper mantle and MTZ.

[1] Kyser and O’ Neil, 1984, *Geochim Cosmochim. Acta.* [2] Clog et al., 2013, *Earth Planet. Sci. Lett.* [3] Kurokawa et al., 2018, *Earth Planet. Sci. Lett.* [4] Kokubu et al., 1961, *Geochim. Cosmochim. Acta* [5] Smyth et al., 1987, *Am. Mineral.* [6] Pearson et al., 2014, *Nature.*

キーワード：マントル遷移層、オリビン、ワズレアイト、水素同位体
Keywords: mantle transition zone, olivine, wadsleyite, hydrogen isotope

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Formation of Fe-rich volatile-bearing phases in the deep lower mantle and the implications for deep Earth volatile cycles

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Inclusions in deep diamonds provide a window to the actual deep mantle processes. The observation of hydrous ringwoodite with ~1 wt.% H_2O as a diamond inclusion indicates the transition zone is, at least locally, very wet [1]. Furthermore, the recent discovery of Ice-VII and halite inclusions at pressures as high as 24 GPa in diamonds provides direct evidence for the existence of saline fluid at least down to the shallow lower mantle [2]. To understand the interaction of water and Cl with the Fe-bearing lower mantle, we performed experiments to simulate the behavior of volatile-bearing systems in laser-heated diamond anvil cells (DACs) under high pressure-temperature (*P-T*) conditions corresponding to the deep lower mantle. The phase assemblages were determined by a combination of *in-situ* synchrotron-based X-ray diffraction (XRD) and *ex situ* transmission electron microscope (TEM) analysis. In the system MgO-Al_2O_3-Fe_2O_3-SiO_2-H_2O containing ~7 wt.% water, the hydrous Fe-bearing δ-phase coexists with both bridgmanite (Bdg) and post-perovskite (pPv) in a broad *P-T* range of 104-126 GPa and 1900-2500 K, whereas the pyrite-type (py) FeOOH phase was observed coexisting with the pPv phase. *In situ* XRD data further revealed that saline fluid reacts with Fe-bearing pPv to form a previously unknown cubic phase of $FeCl_2$ that adopts the identical space group of *Pa3* with the py-phase FeOOH. The TEM chemical analysis revealed that the composition of the pPv phase contains 3.5 wt.% Na_2O and 16.5 wt.% FeO after the reaction with the oversaturated saline fluid. Formation of the very dense Fe-rich volatile-bearing phases in the lowermost mantle provides clues for the deep storage of water and Cl and may contribute to the chemical heterogeneities in this region.

[1] D. G. Pearson *et al.*, Nature **507** (2014).
[2] O. Tschauner *et al.*, Science **359** (2018).

Keywords: deep lower mantle, volatile cycle, post-perovskite, synchrotron X-ray diffraction

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Estimation of the origin of Pitcairn Island OIB by Independent Component Analysis

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*Takahiro Ozawa[1], Hikaru Iwamori[1,2,3], Takeshi Hanyu[2], Morihisa Hamada[2], Kenji Shimizu[4], Ushikubo Takayuki[4], Jun-Ichi Kimura[2], Q. Chang[2], Hitomi Nakamura[5], Motoo Ito[4]

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Ocean island basalts (OIB) are thought to bring information concerning geochemistry and material cycling of the deep mantle. For this reason, OIB have been studied extensively, among which Pitcairn Island in the South Pacific is regarded as a unique and important location as a hotspot volcano. Previous studies reported that the lavas in Pitcairn involve multiple components from DM (depleted mantle) to EM1 (enriched mantle) (Woodhead & McCulloch, 1989), of which EM1 component has been argued to originate from recycling oceanic plate, delaminated lower crust, continental marine sediment and others (Eisele et al., 2002; Garapic et al., 2015). The mechanism to produce the specific isotopic composition of EM1 is still under extensive debate.

We analyzed concentrations of major elements, volatile elements (CO_2, H_2O, F, S, and Cl), and trace elements, as well as lead isotopic ratios, by using SIMS, EPMA and LA - ICP - MS for melt inclusions contained in olivine from basalt and pyroclastic rock in Pitcairn Island. Melt inclusions are thought to retain the volatile elements without losing them upon eruption, which is suitable for discussing the origin of the EM1 component. In this study, four lavas (PC-2, PC-16, PC-38, and PC-40) and a pyroclastic rock collected from the Tedside formation of Pitcairn Island were analyzed. The whole-rock composition of these lavas show EM1 signatures. Melt inclusions in olivine are crystallized, but those of pyroclastic rock are all glassy and homogeneous as they are. The crystalized melt inclusion samples from the four lavas were homogenized at the individual liquidus temperatures (1150 degrees and 1175 degrees). A small amount of H2O loss was found for 10 min heating for homogenization, by comparing the analyses of both melt inclusion with/without reheating of the pyroclastic rock samples. On the other hand, virtually no effect was seen for F and Cl.

Multivariate statistical analysis is useful to extract the geochemical features from these data set. McKenzie et al. (2004) identified the coherence between the trace element concentrations and the isotopic ratios, and argued that such coherence must indicate multiple sources of different origin. Instead of Principal Component Analysis (PCA) as used by McKenzie et al. (2004), we utilize Independent Component Analysis (ICA) to extract geochemically independent features. At the same time, we also performed k-means cluster analysis on the whitened data set (Iwamori et al., 2017) to clarify the multiple sources hidden in the lavas from a small area within the Pitcairn Island. In this paper, we will present the results of the geochemical analyses and statistical analyses to identify and discuss the nature of the sources involved in the Pitcairn volcanism.

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[E] 口頭発表 | セッション記号 S (固体地球科学)：S-GC 固体地球化学

2019年5月29日(水) 15:30 ~ 17:00 | A10 東京ベイ幕張ホール

[S-GC40] Volatile Cycles in the Deep Earth - from Subduction Zone to Hot Spot

コンビーナ:角野 浩史(東京大学大学院総合文化研究科広域科学専攻相関基礎科学系)、羽生 毅(海洋研究開発機構 地球内部物質循環研究分野)、佐野 有司(東京大学大気海洋研究所海洋地球システム研究系)、Gray E Bebout(Lehigh University)、座長:羽生 毅、Gray Bebout(Lehigh University)、佐野 有司、角野 浩史

Volatiles play an important role in the geodynamics and chemical differentiation in the mantle and crust by drastically changing mineral stability and rheological behavior. Fractionation-processes such as partial melting, hydration, and dehydration are all controlled by volatiles in the rocks. A significant portion of the volatiles in the Earth has been thought to be present in the atmosphere and oceans as a consequence of extensive degassing during accretion and subsequent mantle degassing. On the other hand, it has been recently recognized that substantial amounts of volatiles are recycled back into the mantle at subduction zones, where intensive devolatilization of descended materials during arc magma generation was once thought to act as an effective "subduction barrier". However, fundamental questions still remain, such as: how are volatiles species distributed throughout the early and present Earth? What are the mechanisms for, and rate at which, volatiles are fluxed between the atmosphere, crust, and mantle? And what role have volatiles played in driving the evolution of the Earth? The possible role of the core in storing primordial volatiles is also poorly constrained. We therefore welcome contributions from experimental, observational, and modeling studies that help shed light on the deep cycles of volatiles, such as hydrogen, carbon, nitrogen, noble gases, halogens and sulfur. We particularly encourage studies linking the behavior of multiple volatile elements and their isotopic compositions. Studies investigating the linkage between volatile and solid geochemical tracers, the phase equilibria of volatile-bearing mantle assemblages, and the effect of volatiles on the physical properties of the mantle are also welcome.

15:30 ~ 16:00

[SGC40-06] Tracing recycled volatiles in MORB with halogens

★Invited Papers

*Ray Burgess[1]、Lorraine Ruzie-Hamilton[1]、Patricia Clay[1]、Bastian Joachim[2]、Christopher Ballentine[3] (1.School of Earth and Environmental Sciences, University of Manchester, Manchester, M13 9PL UK、2.Institute for Mineralogy and Petrography, University of Innsbruck, Innrain, 52A-6020, Innsbruck, Austria、3.Department of Earth Sciences, University of Oxford, South Parks Road, Oxford, OX1 3AN UK)

16:00 ~ 16:15

[SGC40-07] Volatile composition in ocean island basalts

*羽生 毅[1] (1.海洋研究開発機構 地球内部物質循環研究分野)

16:15 ~ 16:30

[SGC40-08] Halogen heterogeneity in the subcontinental lithospheric mantle

*角野 浩史[1]、小林 真大[2]、Ray Burgess[3]、Chris Ballentine[4] (1.東京大学大学院総合文化研究科広域科学専攻、2.東京都立産業技術研究センター、3.マンチェスター大学地球環境学教室、4.オックスフォード大学地球科学科)

16:30 ~ 16:45

[SGC40-09] Efficiency of Deep Carbon Subduction: Input, Metamorphic Records, and Bearing on Estimated Sources of Arc Volcanic Gases

*Gray E Bebout[1,2]、Gabe S Epstein[2]、Brian M House[3] (1.Institute for Planetary Materials, Okayama University、2.Lehigh University、3.University of California, San Diego)

16:45 ~ 17:00

[SGC40-10] Helium isotope variations in subduction-type volcanic hydrothermal systems

*佐野 有司[1]、鹿児島 渉悟[1]、高畑 直人[1]、尾上 哲治[2]、柴田 智郎[3]、Tobias Fischer[4] (1.東京大学大気海洋研究所海洋地球システム研究系、2.熊本大学先端科学研究部基礎科学部門地球環境科学講座、3.京都大学地球熱学研

究施設、4.ニューメキシコ大学地球惑星科学教室)

Tracing recycled volatiles in MORB with halogens

*Ray Burgess[1], Lorraine Ruzie-Hamilton[1], Patricia Clay[1], Bastian Joachim[2], Christopher Ballentine[3]

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Interactions between the Earth’ s mantle and the surface have controlled the evolution of the crust, the oceans, and the atmosphere. The mantle is by many orders of magnitude the largest silicate reservoir for volatiles, and volcanic release of these species has played a major role throughout Earth history in global chemical cycles. Understanding the distribution and geochemical evolution of volatiles in the terrestrial mantle is therefore central to understanding the unique planetary history of Earth. The input and output of volatiles at plate boundaries provides major controls on the cycles of many important elements and exerts long-term controls on habitibale conditions at the surface.

Noble gases have provided key insight into the processes controlling the mantle system. Primordial heavy noble gases in the MORB-source mantle are accompanied by atmosphere noble gases with an elemental composition consistent with subduction of an ocean/pore-fluid signature into the mantle (1). Pore fluid subduction represents an important opportunity to use halogens, in particualr iodine which is highly enriched in marine pore fluids, in conjunction with noble gases as sensitive tracers of water and volatile enrichment processes in the mantle.

To assess the control of subduction zones on the mantle halogen budget we have investigated basaltic glass samples from the Manus Back-Arc Basin as some of the volatiles may survive forearc to subarc devolatilization to depths beyond arcs/back-arcs and contribute to the long term volatile budget of the mantle. We also investigated two sets of samples: one from the Central Indian Ridge (2) containing D(epleted)-MORB, N(ormal)-MORB and E(nriched)-MORB and one from the Siqueiros Transform Fault (STF) known for sampling the depleted upper mantle (3). In contrast to axial MORB, lavas from STF are tapping smaller mantle melt without mixing in large magmatic chambers. These melts provide better estimates of the volatile contents of the potential mantle sources.

Based on new halogen determinations, we show that the volatile budget in the mantle sampled by the mid oceanic ridge basalts is a mixture between the depleted upper mantle and a fluid-modified mantle enriched during its residency in subduction zone. This enables us to revisit the global halogen budget and assess how subduction of halogens has affected the habitability of our planet.

1. Holland & Ballentine, Nature 441, 186-191, 2006.

2. Nauret et al. Earth Planet. Sci Lett. 245, 137-152, 2006.

3. Saal et al., Nature 419, 451-455, 2002.

Keywords: Halogens, Recycling, Mantle, Volatiles

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Volatile composition in ocean island basalts

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1. Japan Agency for Marine-Earth Science and Technology, Department of Solid Earth Geochemistry

Volatile reservoirs and transport mechanisms in the mantle are one of fundamental questions in mantle geochemistry. The atmosphere and hydrosphere are major volatile reservoirs in the Earth. Portions of volatiles in the surface layers can be incorporated into oceanic crust and sediment by fluidal reaction and organic and inorganic sedimentation, and then they are delivered to the mantle via slab subduction. However, the efficiency of volatile transport against subduction barrier is poorly constrained. Studies of volatiles in ocean island basalts (OIBs) should document the origin and distribution of volatiles in the deep mantle. This presentation provides an overview of previous studies of volatiles on OIBs using submarine quenched glasses and olivine-hosted melt inclusions.

Whether the mantle source of OIBs is enriched in H_2O is measured by taking H_2O/Ce ratio, where Ce is a lithophile element that has similar incompatibility to H_2O during partial melting. While many OIBs exhibit H_2O/Ce that overlap with the MORB range, OIBs with robust EM1, EM2, and HIMU signatures have significantly lower H_2O/Ce. The fact that H_2O/Ce decreases proportionately with increasing $^{87}Sr/^{86}Sr$ for Pitcairn, Kerguelen (EM1), and Society (EM2), and with decreasing $^{207}Pb/^{206}Pb$ for Tuvalu (HIMU) documents that the mantle components with robust EM1, EM2, and HIMU signatures are commonly depleted in H_2O relative to Ce [1-3]. If their precursor was any type of subducted material, fluid or hydrous melt extraction from the subducted slab reasonably explains the low H_2O/Ce. However, an alternative explanation is a contribution from pyroxenite components in the magma sources, where Ce is more efficiently partitioned into pyroxene than H [4].

Enrichment in F (i.e., F/Nd) in the EM1 and EM2 OIBs from Pitcairn and Samoa is equivocal [2,5]. In contrast, melt inclusions from Mangaia HIMU basalts have high F/Nd (~30) as a group relative to the average MORB value (~21) [1,6], which is best explained by the efficient transfer of F to the mantle by F-bearing minerals such as amphibole, serpentinite, mica, and clinohumite in subducted slabs [7]. Detecting Cl enrichment is not always straightforward because shallow-level magma assimilation with seawater, brines, and altered oceanic crust easily alter the Cl composition [8]. Submarine glasses from Pitcairn and Society exhibit decreasing Cl/K with increasing $^{87}Sr/^{86}Sr$ [2]. Such covariation precludes assimilation as the principal cause of Cl/K variation, and therefore low Cl/K is the source feature of EM1 and EM2. Chlorine loss from subducted components due to fluid release or hydrous melt extraction accounts for low Cl/K. In contrast, HIMU OIBs show increase of Cl/K and Cl/Nb along with decreasing $^{207}Pb/^{206}Pb$ (more robust HIMU signature from ancient altered oceanic crust) as observed in olivine-hosted melt inclusions in Raivavae basalts from Austral Islands [9]. Because such correlation is not ascribed to shallow-level assimilation, this fact requires a mechanism to return Cl from the hydrosphere to the HIMU mantle source via altered oceanic crust against subduction dehydration. Although Cl-hosting minerals beyond the sub-arc depth have not been thus far identified, the lattice defects in major minerals or mineral grain boundaries may be a carrier of small amounts of Cl in subducted oceanic crust. Subduction of altered oceanic crust would transfer Cl from seawater to the deep mantle, forming Cl-rich HIMU mantle reservoir in the deep mantle.

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[6] Cabral et al., Geochem. Geophys. Geosyst. 15, 4445-4467 (2014).

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[8] Stroncik & Haase, Geology 32, 945-948 (2004).

[9] Hanyu et al., Nat. Commun. 10, 60 (2019).

キーワード：揮発性成分、物質循環、マントル
Keywords: volatile, recycle, mantle

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Halogen heterogeneity in the subcontinental lithospheric mantle
Halogen heterogeneity in the subcontinental lithospheric mantle

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Volatile recycling back to the Earth’ s mantle at subduction zones has a significant, yet poorly constrained impact to the volatile budget in the mantle. Halogen and noble gas systematics are powerful tracers of volatile recycling. The presence of noble gases and halogens with seawater and sedimentary pore-fluid signatures in exhumed mantle wedge peridotites from the Sanbagawa-metamorphic belt, southwest Japan [1], and in forearc serpentinites [2] along with seawater-like heavy noble gases (Ar, Kr, and Xe) in the convecting mantle [3] strongly suggest the subduction of sedimentary-pore-fluid-like noble gases and halogens. In order to better constrain how such subduction fluids may modify the halogen composition of subcontinental lithospheric mantle, we have analyzed halogens in mantle-derived xenoliths from volcanic front and back-arc regions of subduction zones, and intraplate continental settings.

In addition to a MORB-like halogen component observed in most of the samples, three other distinct components were identified: (A) a marine-pore-fluid-like component with high Br/Cl and I/Cl ratios similar to mantle wedge peridotites [1], (B) a Cl-enriched component relative to MORB, similar to bulk altered oceanic crust [4]; and (C) a component enriched in Br and moderately in I compared to MORB, which resembles to fluid components in altered oceanic crust and diamonds [4,5].

The component (A) is typically observed in the volcanic front samples containing abundant H_2O-rich fluid inclusions. This suggests that marine pore fluids in deep-sea sediments are carried by serpentine and supplied to the mantle wedge, preserving their original halogen and noble gas compositions. However, the measured Cl/H_2O and $^{36}Ar/H_2O$ in the peridotites are higher than those in sedimentary pore fluids and serpentine in oceanic plates [2]. The halogen/noble gas/H_2O systematics are interpreted within a model where water is incorporated into serpentine in a closed system formed along fracture zones developed at the outer rise, where oceanic plates bend prior to entering subduction zones, preserving Cl/H_2O and $^{36}Ar/H_2O$ values of sedimentary pore fluids. Dehydration-hydration process within the oceanic lithospheric mantle maintains the closed system until the final stage of serpentine dehydration. The sedimentary pore fluid-like halogen and noble gas signatures in fluids released at the final stage of serpentine dehydration are preserved due to highly channelized flow [6].

The samples involving the component (B) have higher Cl concentration and trace elements ratios, whereas the samples involving the component (C) have relatively low Cl concentration and low ratios of highly incompatible elements relative to heavy rare earth elements. Considering that these two components are observed in some back-arc samples having radiogenic/nucleogenic noble gases [7], they could be remnants of metasomatic agents derived from subducted altered oceanic crust, or could result from secondary processes of volatile loss during partial melting and secondary phase formation during

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interaction with melts [8].

The common primary MORB-like halogen ratios in mantle xenoliths from different parts of the globe indicate that the mantle itself must have a relatively uniform composition over a wide scale. The mantle has maintained its halogen composition over billion year timescales without being affected by I-rich halogens being transported into the mantle. Mass balance calculations suggest that, in order to maintain the I/Cl ratio of the convecting mantle over 2 Gyr, the I/Cl ratio of the subducted halogens must be no more than several times higher than the present-day mantle value [8].

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キーワード：ハロゲン、大陸下マントル、希ガス、沈み込み、揮発性物質循環
Keywords: halogen , subcontinental mantle, noble gas, subduction, volatile recycling

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Efficiency of Deep Carbon Subduction: Input, Metamorphic Records, and Bearing on Estimated Sources of Arc Volcanic Gases

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Circum-Pacific and Italian Alps high- and ultrahigh-pressure metasedimentary rocks record the subduction of organic (reduced) and carbonate (oxidized) C through forearcs (10-70 km) to depths approaching those beneath volcanic fronts. Still uncertain are the efficiency of delivery of such sections to subarc depths, as related to varying degrees of accretion and underplating, the mobilization of C during prograde metamorphism and fluid-rock interactions, and the fractions of C recycled in arcs, stored in forearc reservoirs (e.g., the mantle wedge), or added to the deeper mantle.

Franciscan Complex (FC) blueschist-facies rocks, and lower-grade units (lawsonite-albite and lawsonite-blueschist) of the carbonate-poor Catalina Schist (CS), preserve reduced C (RC) concentrations and $\delta^{13}C$, and C:N, similar to those of sediment protoliths, as does the lowest-grade unit of the Schistes Lustres (SL) exposed in the Alps (regardless of carbonate content). In CS units that experienced warmer prograde *P-T* paths (epidote-blueschist grade and higher), RC is shifted in $\delta^{13}C_{VPDB}$ from -25 per mil to as high as -19 per mil, seemingly related to minor loss of C as CH_4 during prograde devolatilization. The higher-grade units of the SL extend, to depths of ~70km, the extremely low-*P/T* trajectory represented by the FC and low-grade CS. Across this range of grade, RC shows little evidence of loss but considerable increase in $\delta^{13}C$ toward mantle values (-5 to -6 per mil) related to isotopic exchange with coexisting carbonate. In SL metashales, RC preserves protolith $\delta^{13}C$ of -24 to -21 per mil independent of grade and degrees of devolatilization. Reduced C occurs as amorphous carbonaceous matter at low grades, and its transformation to graphite at higher grades presumably enhances isotopic exchange with carbonate. This work implies that much of the RC reservoir is retained to depths beneath volcanic fronts and could be available for transfer into the sub-arc mantle wedge, likely via partial melting (K. Kraft, Lehigh Univ. M.S. thesis, 2018).

The blueschist to eclogite facies SL contains carbonate-rich flysch formed prior to and during Eocene subduction of the Piemonte-Liguria Ocean and underplated at 40-70 km depths. We analyzed $\delta^{13}C$ and $\delta^{18}O$ of carbonate in this unit, over a regional scale, and made field and petrographic observations bearing on mechanisms of C mobilization. A study of decarbonation history by Cook-Kollars et al. (2014) for the same suite demonstrated that, depending on extents of open-system infiltration by H_2O-rich fluid, large fractions of initially subducted carbonate could be retained in such rocks to at least 70 km depths. Assessing the magnitude of removal of carbonate via dissolution, at the whole-unit scale, has proven difficult. Isotopic exchange between the reduced and oxidized C reservoirs, and any fractionation during sub-arc mobilization and delivery into the mantle wedge, would have implications for the approach of Sano and Marty (1995) used to estimate proportions of gas from mantle and disparate sediment sources.

Study of along-margin C input flux at the Sunda margin (House et al., 2016; Fall AGU) emphasizes the role of sediment composition, source, and degree of accretion on the nature and size of the deeply subducted C reservoir. Ongoing NSF-funded work on the Hikurangi margin, New Zealand (collaborative with Bruce Christenson-GNS-NZ, Hirochika Sumino-Univ. Tokyo, and Ikuko Wada-Univ. Minnesota), is aimed at resolving C inputs vs. outputs in arc volcanoes and associated hydrothermal systems, in part considering the makeup of the incoming sediment section (based on drilling by IODP Exp. 375), extents of accretion,

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along-margin thermal structure, and calculated extents of devolatilization. Studies of the Schistes Lustrés and other HP and UHP suites provide insight regarding the structural and geochemical evolution of sediments similar in composition to those subducting at modern margins (e.g., Sunda).

Keywords: carbon, subduction, arc volcanism, metamorphism

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Helium isotope variations in subduction-type volcanic hydrothermal systems

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Large variations of $^{3}He/^{4}He$ ratios of gas and fluid samples were observed in subduction-type modern hydrothermal systems (0.3Ra −8Ra where Ra is the atmospheric ratio of $1.38x10^{-6}$) compared with those of mid-ocean ridge basalt (MORB) glasses (7.5Ra −9.5Ra). These variations are principally attributable to binary mixing of two components: mantle He (8Ra) and crustal helium (0.1Ra). Major source of the latter component could be due to radiogenic helium in the subsurface crustal material. Thus, shallow assimilation would result in helium isotope variations around an isolated volcano. Early case study on the Ontake volcanic hydrothermal system showed that high-Ra was located in hot spring close to the central cone and decreased with distance from the volcano. Subsequent studies around Mt Nevado del Ruiz and Mt Kusatsu-Shirane confirmed the negative correlation between the $^{3}He/^{4}He$ ratio and the distance. There may be three necessary conditions to produce such a tendency. First, the volcano is independent strato-type and there is no other volcano close to the subject. Second, the magma chamber is located just beneath the volcano so that the conduit is not inclined significantly. Third, the hydrothermal system is well developed and the emission of mantle helium is stable for a long time. In order to apply these hypothetical conditions to a caldera volcano, we have carried out helium isotope survey around Aso volcano in Southwest Japan. Mt Aso is the largest active volcano in Japan with a caldera 25 km north-south and 18 km east-west. Post caldera activity is currently observed in central cone at Mt Nakadake. We have collected hot spring gas and fluid samples within the Aso caldera together with the outside and measured $^{3}He/^{4}He$ and $^{4}He/^{20}Ne$ ratios by a noble gas mass spectrometer. The helium isotopes, after correction of air contribution, decrease with the distance from the central cone in the region. The tendency is consistent with those of strato-volcanoes reported in literatures.

キーワード：volcano、subduction
Keywords: helium, isotopes

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[E] 口頭発表 | セッション記号 S (固体地球科学)：S-CG 固体地球科学複合領域・一般

2019年5月29日(水) 9:00 ~ 10:30 | 国際会議室 2F

[S-CG48] Science of slow earthquakes: Toward unified understandings of whole earthquake process

コンビーナ:井出 哲(東京大学大学院理学系研究科地球惑星科学専攻)、廣瀬 仁(神戸大学都市安全研究センター)、氏家 恒太郎(筑波大学生命環境系)、波多野 恭弘(東京大学地震研究所)、座長:廣瀬 仁、田中 愛幸

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 loadings. 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 ~ 9:30

[SCG48-01] Variability of the space-time evolution of slow slip events off the Boso Peninsula, central Japan, from 1996 to 2018

★Invited Papers

*福田 淳一[1] (1.東京大学地震研究所)

9:30 ~ 9:45

[SCG48-02] Cumulative slip distribution of short-term slow slip events in the western Shikoku area, southwest Japan based on tilt change measurements

*廣瀬 仁[1,2]、田村 和華子[2]、木村 武志[3] (1.神戸大学都市安全研究センター、2.神戸大学大学院理学研究科惑星学専攻、3.防災科学技術研究所)

9:45 ~ 10:00

[SCG48-03] Shallow undersea SSEs off the western Japan monitored by the GNSS-A

*横田 裕輔[1]、石川 直史[2] (1.東京大学生産技術研究所、2.海上保安庁海洋情報部)

10:00 ~ 10:15

[SCG48-04] Co- and Post-seismic deformation due to the 2016 moderate earthquake sequence at the Chaman fault

*松本 史子[1]、古屋 正人[1] (1.北海道大学)

10:15 ~ 10:30

[SCG48-05] GNSSと重力データを用いたスロースリップ中における流体移動の定量化の試み　第一報

*梅宮 悠輔[1]、田中 愛幸[1] (1.東京大学理学部)

Variability of the space-time evolution of slow slip events off the Boso Peninsula, central Japan, from 1996 to 2018

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Continuous geodetic measurements over the past two decades have identified numerous recurrent slow slip events (SSEs) in subduction zones and other tectonic settings. Many previous studies revealed static source characteristics of SSEs, including the magnitudes, durations, recurrence intervals, and spatial slip distributions. However, our current knowledge of the time-dependent evolution of SSEs and their variability is much more limited.

In this study, we focus on a series of SSEs that occurred off the Boso Peninsula, central Japan. Since the installation of a dense GNSS network in Japan in the early 1990s, six Mw 6.6-6.7 SSEs, accompanied by swarms of regular earthquakes, have been identified on the subducting Philippine Sea Plate interface offshore of the Boso Peninsula in 1996, 2002, 2007, 2011, 2013-2014, and 2018. We invert GNSS time series to estimate the space-time evolution of the six SSEs using a modified version of the Network Inversion Filter (NIF) [Fukuda et al., 2008]. Our analyses reveal the similarities and differences in the time-dependent evolution of the six SSEs. We find that the nucleation style and space-time evolution of slip vary among the SSEs. The 2002, 2007, and 2011 SSEs nucleated more rapidly, with slip accelerations significantly higher than those of the 1996 and 2013-2014 SSEs. Furthermore, the 2002, 2007, and 2011 SSEs exhibited more rapid temporal variations in their slip and slip rates, and showed larger seismic moments and higher maximum slip rates than the 1996 and 2013-2014 SSEs. The along-strike expansion/propagation of slip is identified for the SSEs, revealing that the expansion/propagation patterns vary from event to event. Our results also show that the swarm seismicity accompanying the SSEs is highly correlated in space and time with slip rate, and seismicity only occurred after the slip rate exceeded ~4 m/yr, suggesting that the evolution of seismicity is controlled by the instantaneous stressing rate determined by slip rate.

Finally, we show that the space-time evolution of slow slip obtained here can potentially be used to study mechanisms governing the SSEs. We model the spatiotemporal evolution of shear stress on the plate interface due to slow slip obtained in the NIF analysis using the rate-and-state friction law. The rate-and-state friction parameters and initial state variable are adjusted to reproduce the stress histories. Results show that the rate-and-state friction law well reproduces the spatiotemporal evolution of stress on the plate interface during the SSEs. The critical fault size calculated from the estimated friction parameters is similar to the size of the SSE region, suggesting that the evolution of slow slip is governed by frictional properties near the stability boundary between stable and unstable slip.

キーワード：slow slip event、GNSS、crustal deformation
Keywords: slow slip event, GNSS, crustal deformation

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Cumulative slip distribution of short-term slow slip events in the western Shikoku area, southwest Japan based on tilt change measurements

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In the western Shikoku area, southwest Japan, so-called short-term slow slip events (SSE) accompanying tremor activities repeatedly occur with an average recurrence interval of about six months (e.g., Obara et al., 2004; Sekine et al., 2010). This activity has been detected by high-sensitivity accelerometers (tiltmeters) equipped at NIED Hi-net stations (Obara et al., 2005). Using the observed tilt records, Sekine et al. (2010) estimated a history of released seismic moment by short-term SSEs and reported that about 65\% of the accumulated moment by the relative plate convergence is released as short-term SSEs in the western Shikoku area. Because this estimation is based on a fault model such that slip is uniform on a plane rectangular fault and a location of the fault, especially a depth of the fault, is an unknown (nonlinear) parameter in their inversion, it is possible that an estimated seismic moment of an SSE could be biased.

In this study, we apply an inversion method that can express a spatial fault slip distribution assuming the slip is on the plate interface to the same tilt change data set that were detected in Sekine et al. (2010). They measured a tilt change caused by a short-term SSE as a difference between two averages of tilt values in one-day-long time interval (this can vary on a case-by-case basis) just before and after the SSE episode. We estimated each slip distribution of 18 short-term SSEs in western Shikoku between January 2001 and March 2008 although a reliable slip distribution is not estimated in a couple of episodes because of the limited number of available stations.

A cumulative slip distribution of the 18 SSEs shows that (1) slip area is localized within a narrow zone with its width of about 30-40~km in dip direction and about 70~km in strike direction of the subducting plate; (2) accumulated moment by the plate subduction is considered as fully released by SSEs at an area with larger cumulative slip; (3) the width of the slip zone is wider in the western part and narrower in the eastern part. The last characteristics is in agreement with the tremor epicenter distribution in this area (e.g., Obara et al., 2010). This suggests that there is a segment boundary that separates the western and eastern part of the SSE area in the western Shikoku region, and these segments likely have different frictional property and/or different pore fluid distribution.

Acknowledgments: This work was supported by JSPS KAKENHI Grant Number JP16H06474.

キーワード：沈み込み帯、スロー地震、傾斜変化、地震サイクル
Keywords: subduction zone, slow earthquakes, tilt changes, earthquake cycle

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Shallow undersea SSEs off the western Japan monitored by the GNSS-A

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In the last two decades, many kinds of SEQs including non-seismic SSE have been detected using the onshore high-precision seismometer and GNSS networks. Along the Nankai Trough having dense seismic and geodetic monitoring network, their relationships were discussed and compared in detail [e.g., Hirose et al., 2010, Science; Obara and Kato, 2016, Science]. Observation of deep and shallow SEQ analogies and differences has multidisciplinary value for the physical properties of the plate boundary, submarine geology and earthquake disaster research. However, comparison between deep underground SEQs and shallow undersea SEQs cannot easily be performed due to the undersea observation technical constraint.

In these several years that the technology has been upgraded, shallow SEQs (tremor, LFE, VLF and short-term SSE) have been detected along the pan-Pacific subduction zones in high-precision onshore seismometers, seafloor seismometers, ocean bottom pressure gauges and submarine borehole strainmeters [e.g., Wallace et al., 2016, Science; Araki et al., 2017, Science]. However, there was no geodetic monitoring technology for detecting undersea longer sequence of SSE than week-scale. Longer-term SSE than week-scale cannot be monitored except for the GNSS-A technique.

Recently, we improved the GNSS-A technology and upgraded observation frequency and precision [Yokota et al., 2017, Rep. Hydro. Ocean. Res; Yokota et al., 2018, MGR]. With the present observation capability, yearly time change of the amount of undersea crustal deformation was newly unclosed. Then, the GNSS-A monitoring uncloses the occurrence situation of undersea SSE which could not be observed by the onshore geodetic network.

We detected SSE signals in the GNSS-A data using c-AIC detection process based on the method of Nishimura et al. [2013, JGR]. Then, SSE rectangle models were estimated by the grid search process using the GNSS-A signals and the onshore GEONET data. The detected models are located off the Kii channel and the Bungo channel at shallow side around the Nankai Trough historical seismogenic zone and strong coupling regions estimated by Yokota et al. [2016, Nature] and Nishimura et al. [2018, Geosphere]. We detected about M_w 6.0 and 6.5 events off the Kii channel and a migration of about M_w 6.1 ~ 6.2 events off the Bungo channel.

Shallow VLF events [NIED and Asano et al., 2008, EPS] were also activated simultaneously with these undersea SSEs. Off the Kii channel, VLF activity in 2009 was a little closer to the western side than 2018. Off the Bungo channel, VLF activity after 2015 was synchronized with the undersea SSEs. These suggest the temporal synchronization and the spatial relationship between SSE and VLF in these regions.

キーワード：SSE、GNSS-A、南海トラフ
Keywords: SSE, GNSS-A, Nankai Trough

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Co- and Post-seismic deformation due to the 2016 moderate earthquake sequence at the Chaman fault

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1. Hokkaido University

Chaman fault system, located in Pakistan and Afghanistan, forms a transform boundary between Indian and Eurasian plates. Previous geological survey found the relative velocity of the Indian plate to the Eurasian at ~36mm/yr. Chaman fault is the major sinistral strike-slip fault which has ~900km long in the system. However, no large earthquakes (M>7) have been documented on the Chaman fault. Low seismicity results from either a long recurrence interval or aseismic creeping. Recent studies indicate a heterogeneous distribution of locked and creeping segments along the fault. In previous work, Furuya and Satyabala(2008) revealed a long lasted afterslip following a moderate earthquake (M5) in 2005 on the Chaman fault. We examine other earthquakes on the Chaman fault and their behavior comparing with the results in Furuya and Satyabala(2008). We find two moderate events occurred on May 13 and July 10 in 2016, first events larger than M5 on the Chaman fault after the M5 earthquake in 2005. The first event on May 13 was the largest M5-class earthquake since the 2005 M5 event examined by Furuya and Satyabala (2008). According to USGS catalogue, this May 13 event has three earthquakes observed within a few kilometers every minute in a row. We use ascending Sentinel-1 SAR data from March 31, 2016 to January 13, 2017. We generate InSAR images that suggest that the co- and post-seismic deformation of left-lateral strike-slip. Especially the second July 10 event almost implies the same behavior with the results in Furuya and Satyabala(2008). We must pick up real deformation except atmospheric trend, so we stack five InSAR images using different master date for each events before estimation of fault source model.

キーワード：合成開口レーダー、スロースリップ、地殻変動
Keywords: InSAR, Slow slip, Crustal deformation

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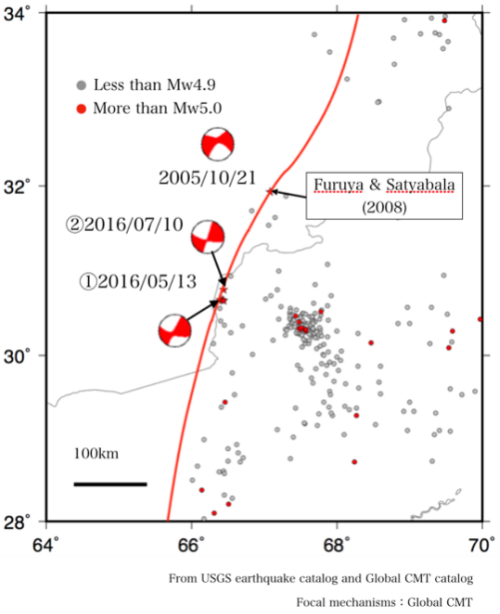


Figure1. Location map of Chaman fault and earthquakes after 2005/10/21. Gray dots show events less than Mw4.9 while red dots show more than Mw5.0. We pick up two events from more than Mw5.0 along the fault.

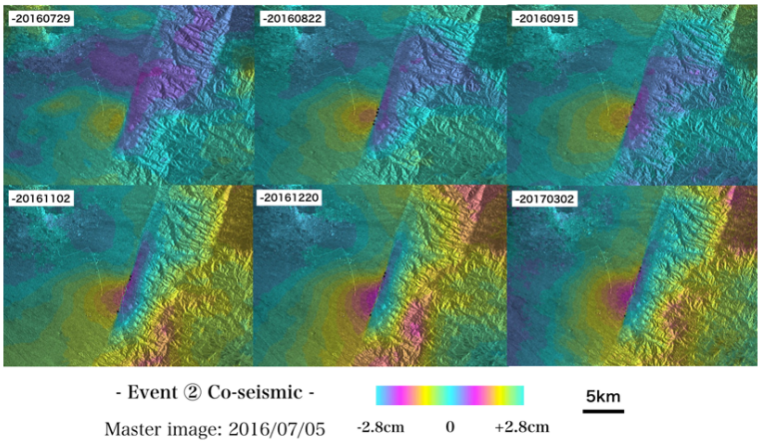


Figure2. Co-seismic deformation regarding the second event on 2016/07/10. There are six interferograms using same master image on 2016/07/05. These patterns are consistent with left lateral deformation. The phase and extent of deformation area gradually become larger.

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GNSSと重力データを用いたスロースリップ中における流体移動の定量化の試み　第一報

An attempt to quantify transient fluid flow during slow slip event using GNSS and gravity data-1st report

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スロースリップは地殻変動を引き起こす。観測された地殻変動は、通常、弾性転位論に基づくプレート境界の断層すべりで説明される。ところが、東海地方において、断層すべりによる地殻変動だけでは説明できない重力変化が観測され、スロースリップの発生期に断層破砕帯内部で流体の一時的な移動が起きている可能性が示唆された。ただし、彼らが構築した流体移動モデルは、観測された重力変化を再現することはできるが、断層破砕帯外では地殻変動は起きないという仮定を置いていた。このため、流体移動がどの程度地表の地殻変動を引き起こすかは見積もられていない。

本研究では、流体移動による重力変化に加え、断層破砕帯外の地殻変動も考慮したモデルを提案する。間隙弾性体理論の代わりに、通常の断層モデルに茂木モデルを組み合わせたモデルを考える。この運動学的なモデルには流体移動を駆動するメカニズムは組み込まれていないが、断層破砕帯に流入した流体の量を地殻変動と重力観測データから簡単に見積もることができる。予備的な計算結果から、流入した流体の量が断層破砕帯の体積の0.01%のオーダーのときに地殻変動と重力の両方の観測データが説明できることが分かった。

キーワード：スロースリップ、流体移動、GNSS、重力
Keywords: slow slip, fluid flow, GNSS, Gravity

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[E] 口頭発表 | セッション記号 S (固体地球科学)：S-CG 固体地球科学複合領域・一般

2019年5月29日(水) 13:45 ~ 15:15 | コンベンションホールA 2F

[S-CG48] Science of slow earthquakes: Toward unified understandings of whole earthquake process

コンビーナ:井出 哲(東京大学大学院理学系研究科地球惑星科学専攻)、廣瀬 仁(神戸大学都市安全研究センター)、氏家 恒太郎(筑波大学生命環境系)、波多野 恭弘(東京大学地震研究所)、座長:小原 一成(東京大学地震研究所)、加藤 愛太郎(東京大学地震研究所)

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 loadings. 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.

13:45 ~ 14:00

[SCG48-06] Interplay between long-term SSE and ETS facilitated by different underground environment

*小原 一成[1] (1.東京大学地震研究所)

14:00 ~ 14:15

[SCG48-07] **Determination of sVLFE epicenters around the subducted Kyushu-Palau Ridge from coda interferometry**

*利根川 貴志[1]、山下 裕亮[2]、伊藤 亜妃[1]、篠原 雅尚[3]、末次 大輔[1]、高橋 努[1]、石原 靖[1]、小平 秀一[1]、金田 義行[4] (1.海洋研究開発機構、2.京都大学防災研究所、3.東京大学地震研究所、4.香川大学)

14:15 ~ 14:30

[SCG48-08] Detection of slow earthquakes in the microseism frequency band (0.05–1.0 Hz) by large-scale waveform stacking

*増田 滉己[1]、井出 哲[1]、太田 和晃[2] (1.東京大学大学院理学系研究科地球惑星科学専攻、2.京都大学防災研究所)

14:30 ~ 14:45

[SCG48-09] Source characteristics of low-frequency earthquakes in Nankai subduction zone inferred from analysis of large event dataset

*Natalia Poiata[1]、Mariano Supino[1,2]、Gaetano Festa[2]、Jean-Pierre Vilotte[1]、Kazushige Obara[3] (1.Institut de Physique du Globe de Paris、2.Università degli Studi di Napoli “ Federico II ”, Napoli, Italy、3.Earthquake Research Institute, University of Tokyo, Japan)

14:45 ~ 15:00

[SCG48-10] **High-frequency radiation prior to semi-volcanic low-frequency earthquake in Eastern Shimane, SW Japan, illuminated by “0.1 manten” Hyper Dense Seismic Observation**

*加藤 愛太郎[1]、酒井 慎一[1]、松本 聡[2]、飯尾 能久[3] (1.東京大学地震研究所、2.九州大学、3.京都大学防災研究所)

15:00 ~ 15:15

[SCG48-11] Variation of Focal Mechanisms of Low Frequency Earthquakes in Parkfield

*麻生 未季[1,3]、麻生 尚文[2]、井出 哲[1] (1.東京大学大学院理学系研究科、2.東京工業大学理学院、3.応用アール・エム・エス株式会社)

Interplay between long-term SSE and ETS facilitated by different underground environment

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Slow earthquakes consist of fault slip phenomena with various characteristic times. Geodetically detected slow earthquakes are mainly classified into two types; short-term and long-term slow slip events (SSEs) with duration from days to weeks and from months to years, respectively. In southwest Japan, at the deeper part from the seismogenic zone along the subducting plate interface, long-term and short-term SSEs are adjacently distributed and they indicate interaction. Because the short-term SSE usually occurs as an Episodic Tremor and Slip (ETS) associated with low-frequency tremor and very-low-frequency earthquake, the interaction is usually observed clearly in ETS tremor seismicity.
In Bungo channel, the long-term SSE is well known to occur at interval of 6-7 years. After the deployment of dense high-sensitivity seismograph network, major long-term SSEs in 2003 and 2010 were accompanied by activation of tremor seismicity. The activated tremor region is limited within a narrow width of 10 km from the updip edge of ETS zone and the tremor activity of the rest downdip part is constant irrespective to the occurrence of the long-term SSE.
In this region, two small long-term SSEs were detected by GNSS in 2014 and 2016; however, the interaction to ETS tremor were different from cases in 2003 and 2010. In 2014, activated tremor was smaller than that in 2010 according to the difference in the magnitude of SSE. On the other hand, there was no tremor activity associated with 2016 SSE. This is because the slip region of SSE was located southward apart from the tremor zone. By the way, a long-term SSE from the end of 2018 continues associated with activation of tremor lasting for several months. This SSE might be expected as a major SSE since 2010.
The main difference between long-term and short-term SSEs is slip rate. The difference in the slip rate may affect to the tremor rate. During the long-term SSE in 2003 and 2010, the temporal change in cumulative number of tremor increased smoothly similar to the GNSS displacement. However, the gradual increase of tremor number was actually composed of superposition of small bursts corresponding to the faster speed slip compared to the long-term SSE. This suggests that the ETS region has a characteristic slip and frictional property different from the long-term SSE region.
A recent receiver function study conducted along a linear seismic array installed at the west of Shikoku besides from Bungo channel has revealed a low velocity oceanic crust and a continental Moho discontinuity just above ETS activity. This indicates that the ETS occur at the boundary between the subducting oceanic plate and the overlying mantle wedge, whereas that long-term SSE occurs at the boundary between oceanic plate and the continental lower crust. The difference of slow earthquake behavior controlled by the structure in the hanging wall is very similar to the Tokai region (Kato et al., 2010). Therefore, the different environment at the plate interface facilitates these SSEs with different characteristic times.

キーワード：スロー地震、深部低周波微動、スロースリップイベント、沈み込み帯
Keywords: slow earthquake, low frequency tremor, slow slip event, subduction zone

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Determination of sVLFE epicenters around the subducted Kyushu-Palau Ridge from coda interferometry

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*Takashi Tonegawa[1], Yusuke Yamashita[2], Aki Ito[1], Masanao Shinohara[3], Daisuke Suetsugu[1], Tsutomu Takahashi[1], Yasushi Ishihara[1], Shuichi Kodaira[1], Yoshiyuki Kaneda[4]

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Shallow very low frequency earthquakes (sVLFEs) occur at the shallow portion of the plate boundary. The Rayleigh waves at a frequency of 0.03–0.2 Hz radiated from their sources are observed in land and seafloor seismic records. Although sVLFE locations have been estimated from land records, there is a possibility to determine them more precisely if seafloor records near the epicenters are available. In the Hyuga-nada region and off Nansei Islands, ocean bottom seismometer (OBS) arrays were deployed 4 times during 4 years, each of which contained 5–13 OBSs and could observe at least one episode of sVLFE activity. In this study, we estimated the group velocity of the Rayleigh wave in the OBS arrays from coda interferometry, and applied it to the envelope correlation method (ECM) using seafloor seismic records for determining sVLFE epicenters.

As a result, the locations of sVLFE during 2014 and 2016 were determined at the northern edge of the Kyushu-Palau Ridge (KPR) (Yamamoto et al. 2013), while those on 2017 and 2018 were estimated to be the southern edge of the KPR. In particular, the sVLFEs on 2015 firstly occurred at the northern edge of the KPR, but occurred near the trough afterwards. Also, comparing the area of slow slip event (SSE) in the Hyuga-nada region (Ozawa 2017), sVLFE region at the northern part of KPR directly connects to the SSE region, indicating that slow earthquakes potentially occur from deep to shallow plate interface around the KPR.

Acknowledgement
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キーワード：浅部超低周波地震、日向灘、九州パラオ海嶺
Keywords: shallow very low frequency earthquake, Hyuga-nada region, Kyushu-Palau Ridge

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Detection of slow earthquakes in the microseism frequency band (0.05–1.0 Hz) by large-scale waveform stacking

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Slow earthquakes have been intensively studied because of the proximity of their source area to that of megathrust earthquakes and their high sensitivity to regional stress change. They have been classified according to their characteristic time scale into tremors and low frequency earthquake (LFE; >1 Hz), very low frequency earthquake (VLFE; 20-100 sec), and slow slip event (SSE; > 1 day). Microseism noise is dominant in the frequency band between LFE and VLFE, which we call the microseism frequency band, and it is difficult to detect signals of slow earthquakes in this band. As a rare exception, signals in this band accompanied with LFEs and VLFEs were detected on the shallow subduction interface by near-field ocean bottom broadband seismometers with fortuitously low microseism noise (Kaneko et al., 2018). The characteristics of signals in this band are totally unknown for deep slow earthquakes.

In this study, we first report the observation of slow earthquake signals in the microseism frequency band in the western Shikoku region of the Nankai subduction zone, Japan, by stacking a lot of seismograms relative to the timing of high-frequency signals. First, we made synthetic template waveforms and conducted a matched filter analysis using these template waveforms (Ohta & Ide, 2017). Utilizing GPU, we detected about 700,000 events in continuous records at 9 Hi-net stations, operated by National Research Institute for Earth Science and Disaster Resilience, from 2005 to 2015. Their temporal distribution suggests that LFEs are episodic phenomena and their spatial distribution indicates the sources are concentrated in several patches, as reported by previous researches (e.g., Ohta & Ide, 2017). Then we stacked seismograms at the timing of these detected events, after band-pass filtering in different frequency bands (4-8 Hz, 2-4 Hz, 1-2 Hz, 0.5-1 Hz, 0.25-0.5 Hz, and 0.125-0.25 Hz). In-phase waveforms are confirmed in all frequency bands, despite low sensitivity of Hi-net seismometers in lower frequencies than 1 Hz. This result suggests that slow earthquakes radiate broadband signals without characteristic frequencies from 0.125 to 8 Hz.

キーワード：スロー地震、低周波地震、脈動、マッチドフィルター、南海沈み込み帯
Keywords: slow earthquakes, LFE, microseism, matched filter, Nankai subduction zone

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Source characteristics of low-frequency earthquakes in Nankai subduction zone inferred from analysis of large event dataset

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Application of advanced detection and location methods to the analysis of low-frequency earthquakes (LFE) allows building large event catalogues rich in information that can provide a better understanding of their source characteristics. Up to now, LFE characterization in terms of size, stress drop and rupture propagation still remains uncertain, the main difficulty owing to the low signal-to noise ratio of corresponding records.

We present a catalog of LFE in western part of Nankai subduction zone derived by applying a full waveform-based detection and location scheme of Poiata et. al. (2016) to the continuous records form Hi-net seismic stations covering a 3-year period from 2013-2016. The applied method is based on the frequency-selective coherence of signals’ statistical features recorded across the stations of seismic network, not requiring a prior assumption about the event source (i.e., template event). The derived catalog (~ 40000 events) allows to look into the details of LFE space-time activity (i.e., clustering and migration patterns) during the energetic tectonic tremor sequences as well as inter-sequence periods as well as characterize source properties of these events.

We derive source parameters of LFEs extracted from this 3-year catalog by applying the probabilistic approach of Supino et al. (2019) based on the conjunction of states of information between data and model and estimating the joint probability density function of the parameters. The events S-wave displacement amplitude spectrum is described by a circular source model, characterized by a plateau at low frequencies and a coherent decay at high frequencies; the frequency of transition between these two regimes is the corner frequency. Processing of this large LFE data set is performed using accurate quality criteria, allowing to automatically reject noisy data and unconstrained solutions.

The resulted moment magnitudes, estimated from low-frequency plateau, range between Mw 0.9 and 2.2, while corner frequencies vary between 0.8 and 12 Hz, being lower than expected for ordinary earthquakes, as already observed for LFEs. We found that LFE sources exhibit a power-law scaling between corner frequency and seismic moment, with an exponent of -3.5, very similar to the scaling observed for classical earthquakes.

Keywords: low-frequency earthquakes, source characteriziation, continuous data analysis, event detection and location

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High-frequency radiation prior to semi-volcanic low-frequency earthquake in Eastern Shimane, SW Japan, illuminated by “0.1 manten” Hyper Dense Seismic Observation

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Semi-volcanic deep low-frequency earthquake (LFE) that occurs distant from active volcanoes has been investigated by previous several studies [Ohmi and Obara, 2002; Aso et al., 2013]. In eastern Shimane of SW Japan, there is a spot hosting frequent semi-volcanic LFE activity for over 20 years. Above this source area, we installed a thousand of seismic stations from March 2017 to March 2018, which covers an entire aftershock zone of the 2000 Western-Tottori earthquake (Mw 6.7). The spatial interval of each seismic station ranges from 1 to 2 km.

We found out clear arrivals of high-frequency waveforms prior to arrivals of low-frequency signals by a hundred of the dense seismic stations. The differential arrival times between the high- and low-frequency waveforms are approximately 1.5 s. The high-frequency radiation has the strongest amplitude at 28 Hz and 16 Hz and is characterized by stronger P-wave amplitude than faint S-wave. In contrast, the low-frequency component is predominant from 1 to 6 Hz and shows variation of the ratio of P-wave to S-wave with epicentral distance. This observation clarifies that different excitation mechanisms are needed to explain bimodal radiations at the high- and low-frequency bands.

We relocated the high- and low-radiation sources by both visually picked arrival times and Source Scanning Algorithm. Then, each radiation source is located within a cloud of LEFs determined by the JMA. The depth of the high- and low-frequency sources are imaged around the depth of 30 km, namely around Moho discontinuity. But, the high-frequency radiation is slightly deeper than that of the low-frequency with a few km horizontal offset. The origin time of the high-frequency radiation is by 1.5 ~ 2 seconds earlier than that of the low-frequency. This slight spatial gap indicates that the two sources appear to be not collocated, while the spatial separation between the two sources is not so large in terms of the hypocenter accuracy. The present study first shows that the high- and low-frequency radiation sources are close to each other around Moho discontinuity.

Combined with these observations, we interpret that the early high-frequency radiation is derived from brittle breakage of low-permeability seal may arise from hydrothermal cementation. Infiltration of high-pressurized fluids into the bottom of lower crust may trigger slow shear slip or resonance of crustal fluids along a pre-existing fracture.

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Variation of Focal Mechanisms of Low Frequency Earthquakes in Parkfield

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*Miki Aso[1,3], Naofumi Aso[2], Satoshi Ide[1]

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Tectonic low frequency earthquakes (LFEs) occur at plate boundaries around the world, and considered as local slow deformation. LFEs in subduction zones are found to have low-angle thrust fault mechanisms in southwest Japan [Ide et al., 2007], Mexico [Frank et al., 2013], and Cascadia [Royer and Bostock, 2014]. LFEs along Alpine fault, a transform fault in New Zealand, are known to have right-lateral strike slip mechanism [Baratin et al., 2018]. However, the focal mechanisms of LFEs at Parkfield along the San Andreas Fault zone have not been revealed yet, regardless of the frequent activities. The San Andreas Fault is one of the most matured active faults in the world, especially at Parkfield, and large damaging earthquakes also repeatedly occurred in history. Therefore, many seismologists and geologists have been challenging to reveal the cause of earthquakes and LFEs.
In this study, we estimate the focal mechanisms of 88 LFE families in the catalog of Shelly [2017]. We first stack seismograms of over one million events in the catalog to improve the signal-to-noise (S/N) ratio. P-wave polarities of the stacked waveforms suggest the existence of variations in focal mechanisms of the LFE families.
Then, we evaluate the absolute amplitudes of original seismograms using the stacked waveforms. The SH wave amplitudes are inverted to the focal mechanisms for each LFE family. Specifically, the contributions from source radiation, path attenuation, and site amplification are represented by independent terms based on the assumption of simple ray theory, and estimated by solving a two-step inversion problem. The source terms are utilized to determine focal mechanisms. While most of the focal mechanisms are strike-slip consistent with the San Andreas Fault motion, those for families near the central Parkfield and the family off the surface trace contain large dip-slip (Figure 1 and 2). These variations are consistent with tidal sensitivities of LFEs in Parkfield [Thomas et al., 2012]. Our study reveals regional dip-slip focal mechanisms at first glance to be strike-slip along matured San Andreas Fault.

キーワード：サンアンドレアス断層、パークフィールド、震源メカニズムインバージョン、波形スタック、低周波地震、振幅評価
Keywords: San Andreas Fault, Parkfield, focal mechanism inversion, waveform stacking, low frequency earthquake, amplitude evaluation

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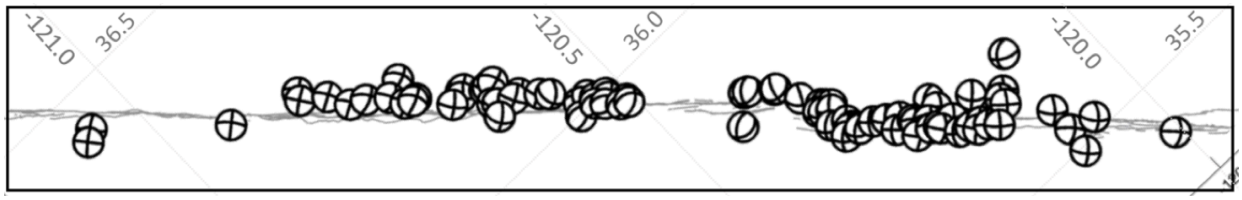


Figure 1. The focal mechanisms of LFE families

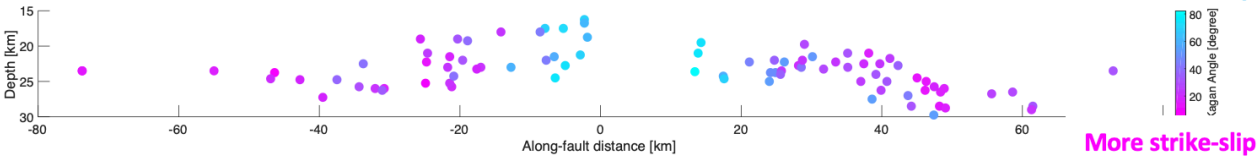


Figure 2. The difference from strike-slip focal mechanism of ordinary earthquake

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[E] 口頭発表 | セッション記号 S (固体地球科学)：S-CG 固体地球科学複合領域・一般

2019年5月29日(水) 15:30 ~ 17:00 | コンベンションホールA 2F

[S-CG48] Science of slow earthquakes: Toward unified understandings of whole earthquake process

コンビーナ:井出 哲(東京大学大学院理学系研究科地球惑星科学専攻)、廣瀬 仁(神戸大学都市安全研究センター)、氏家 恒太郎(筑波大学生命環境系)、波多野 恭弘(東京大学地震研究所)、座長:井出 哲(東京大学大学院理学系研究科)、太田 和晃

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 loadings. 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.

15:30 ~ 16:00

[SCG48-12] Mapping seismic data to slow slip using machine learning

★Invited Papers

*Bertrand Rouet-Leduc[1]、Claudia Hulbert[2]、Ian McBrearty[1]、Paul Johnson[1] (1.Los Alamos National Laboratory, USA、2.Ecole Normale Superieure, France)

16:00 ~ 16:15

[SCG48-13] Revealing the slow earthquake activity in the Japan Trench and its relation to the 2011 Tohoku-Oki earthquake

*西川 友章[1]、松澤 孝紀[2]、太田 和晃[1]、内田 直希[3]、西村 卓也[1]、井出 哲[4] (1.京都大学防災研究所、2.防災科学技術研究所、3.東北大学大学院理学研究科、4.東京大学大学院理学系研究科)

16:15 ~ 16:30

[SCG48-14] Tremor and slow slip associated with afterslip of the 2011 Tohoku earthquake

*太田 和晃[1]、伊藤 喜宏[1]、日野 亮太[2]、大柳 修慧[1]、松澤 孝紀[3]、篠原 雅尚[4]、塩原 肇[4] (1.京都大学防災研究所、2.東北大学大学院理学研究科、3.防災科学技術研究所、4.東京大学地震研究所)

16:30 ~ 16:45

[SCG48-15] High definition imaging of the Japan Trench by OBS Array of Arrays: Does shallow tectonic tremor occur in the plate interface?

*大柳 修慧[1]、太田 和晃[2]、伊藤 喜宏[2]、日野 亮太[3]、太田 雄策[3]、東 龍介[3]、篠原 雅尚[4]、望月 公廣[4]、佐藤 利典[5]、村井 芳夫[6] (1.京都大学理学研究科、2.京都大学防災研究所、3.東北大学、4.東京大学地震研究所、5.千葉大学、6.北海道大学)

16:45 ~ 17:00

[SCG48-16] 東北地方太平洋沖地震後の繰り返し地震活動：海陸地震観測網による検討

*内田 直希[1]、高木 涼太[1]、平原 聡[1]、中山 貴史[1]、松澤 暢[1]、田中 佐千子[2]、浅野 陽一[2] (1.東北大学大学院理学研究科附属地震・噴火予知研究観測センター、2.防災科学技術研究所)

Mapping seismic data to slow slip using machine learning

*Bertrand Rouet-Leduc[1], Claudia Hulbert[2], Ian McBrearty[1], Paul Johnson[1]

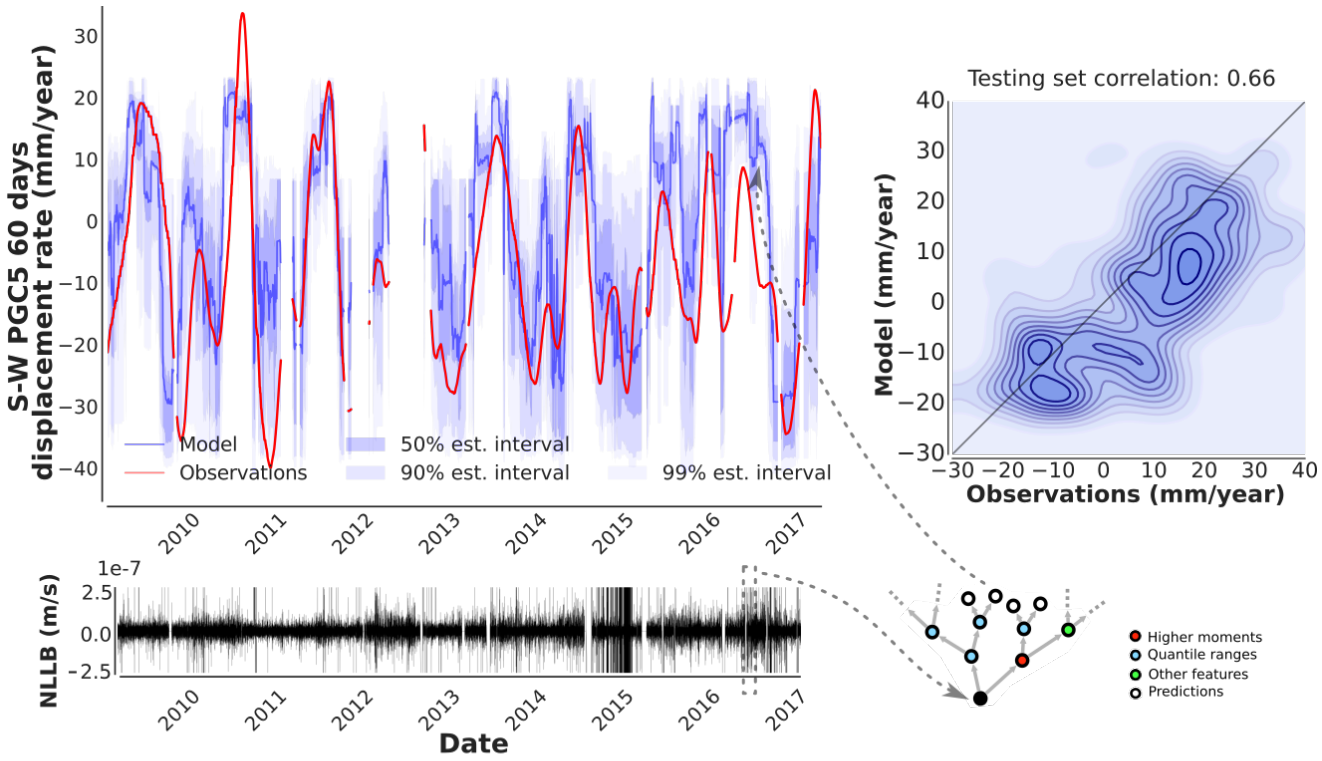
1. Los Alamos National Laboratory, USA, 2. Ecole Normale Superieure, France

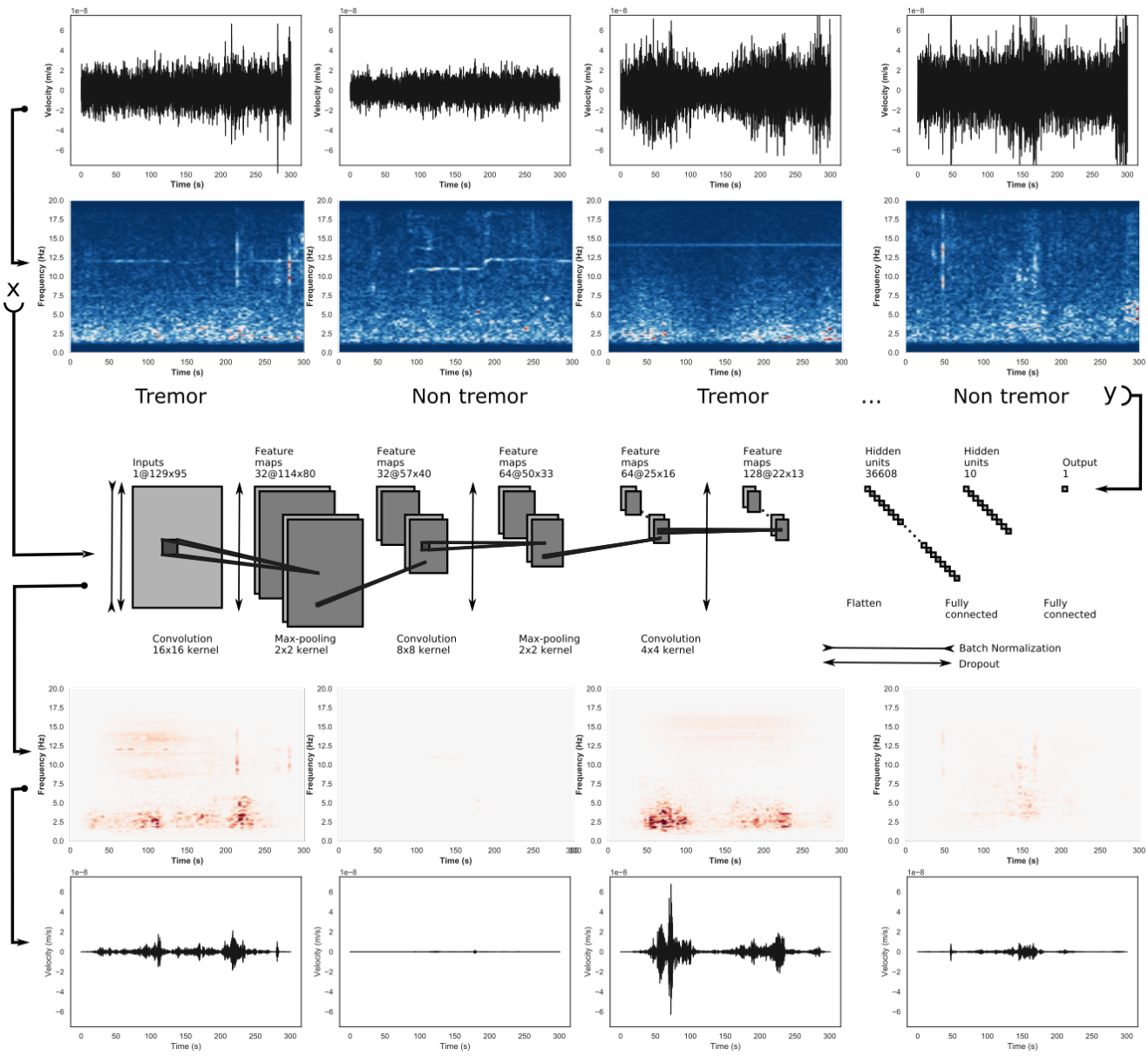
We show that the Cascadia subduction zone is apparently continuously broadcasting a low-amplitude, tremor-like signal that precisely informs of the fault displacement rate throughout the slow slip cycle. Using a method based on machine learning previously developed in the laboratory, we analysed large amounts of raw seismic data from Vancouver Island to separate this signal from the background seismic noise. We posit that this provides indirect real-time access to fault physics on the down-dip portion of the megathrust, and thus may prove useful in determining if and how a slow slip may couple to or evolve into a major earthquake.

In a parallel approach, we show that tremor can be accurately detected on a single seismic station by a deep convolutional neural network. Seismic tremor is posited to provide information on the physical state of the slowly slipping portion of the megathrust, and a single station tremor detector gives a direct access to the tremor signal and its physical characteristics. A deep learning model trained to detect tremor in Cascadia recognizes catalogued tremor in other subduction zones, arguing for the universality of tremor and slow slip characteristics. The detection rate of a deep learning model trained to recognize tremor in Cascadia and applied on waveforms from Northern Chile shows strong correlation with surface displacement rate, arguing for episodic tremor and slip detection where slow earthquakes and associated tremor had not been seen so far, presumably taking place too deep to have been detected using conventional multi-station methods.

Keywords: Tremor, Slow earthquake, Machine learning, Deep learning

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Revealing the slow earthquake activity in the Japan Trench and its relation to the 2011 Tohoku-Oki earthquake

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*Tomoaki Nishikawa[1], Takanori Matsuzawa[2], Kazuaki Ohta[1], Naoki Uchida[3], Takuya NISHIMURA[1], Satoshi Ide[4]

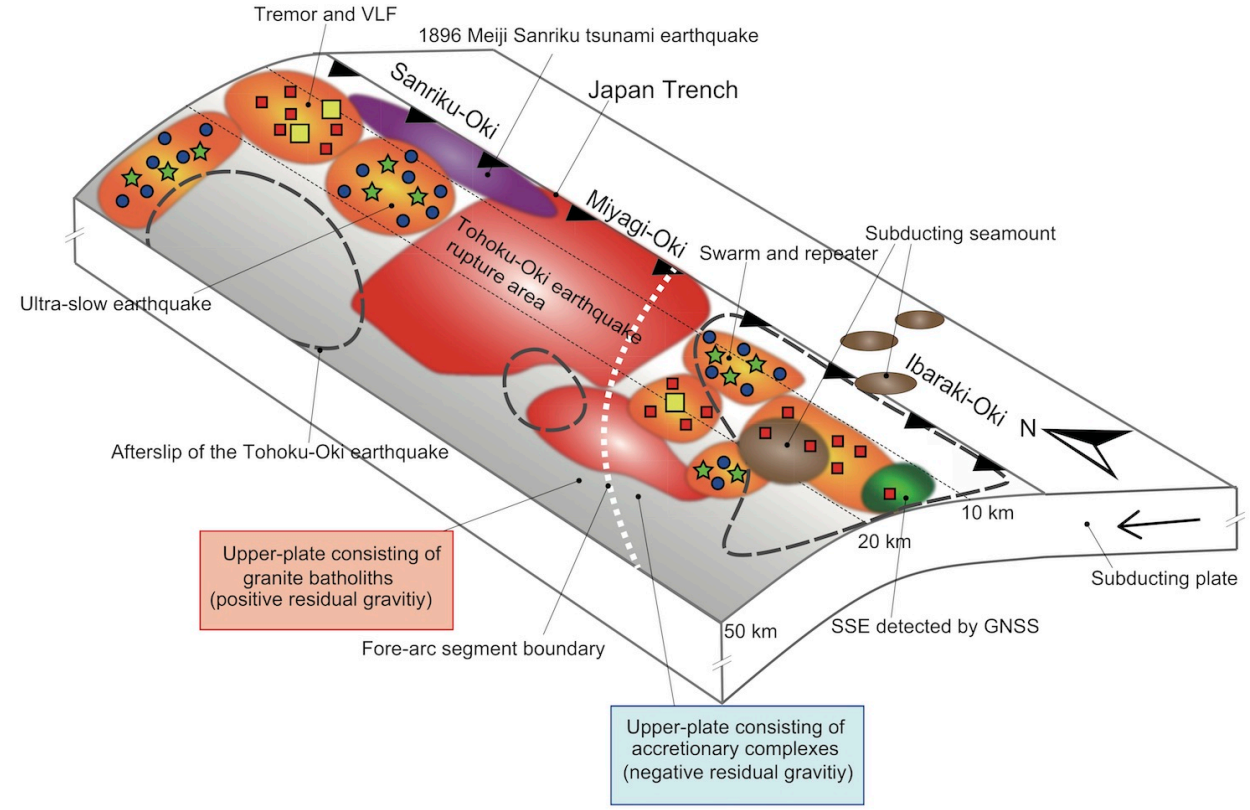
1. 京都大学防災研究所、2. 防災科学技術研究所、3. 東北大学大学院理学研究科、4. 東京大学大学院理学系研究科
1. Disaster Prevention Research Institute, Kyoto University, 2. National Research Institute for Earth Science and Disaster Resilience, 3. Graduate School of Science, Tohoku University, 4. Graduate School of Science, The University of Tokyo

Subduction zone megathrust earthquakes result from the interplay between fast dynamic rupture and slow deformation processes, which are directly observed as various slow earthquakes, including tectonic tremors, very low-frequency earthquake (VLFs) and slow slip events (SSEs), and indirectly suggested by a temporal change in the frequency of repeating earthquakes and the occurrence of episodic earthquake swarms. Some megathrust earthquakes have been preceded by slow earthquakes and terminated near the areas where slow earthquakes were frequently observed. While capturing the entire spectrum of slow earthquake activity is crucial for estimating the occurrence time and rupture extent of future megathrust earthquakes in a given subduction zone, such an observation is generally difficult, and slow earthquake activity is poorly understood in most subduction zones, including the Japan Trench, which hosted the 2011 M_w9.0 Tohoku-Oki earthquake. Here we reveal the slow earthquake activity in the Japan Trench in detail using tectonic tremors, which we detected in the seismograms of a new ocean-bottom seismograph network, VLFs, SSEs, repeating earthquakes, and earthquake swarms. We show that the slow earthquake distribution is complementary to the rupture area of the Tohoku-Oki earthquake and correlates with the structural heterogeneity along the Japan Trench. Concentrated slow earthquake activities were observed in the afterslip area of the Tohoku-Oki earthquake, which is located to the south of the fore-arc geological segment boundary. Our results suggest that the megathrust in the Japan Trench is divided into three segments that are characterised by different frictional properties, and that the rupture of the Tohoku-Oki earthquake, which nucleated in the central segment, was terminated by the two adjacent segments.

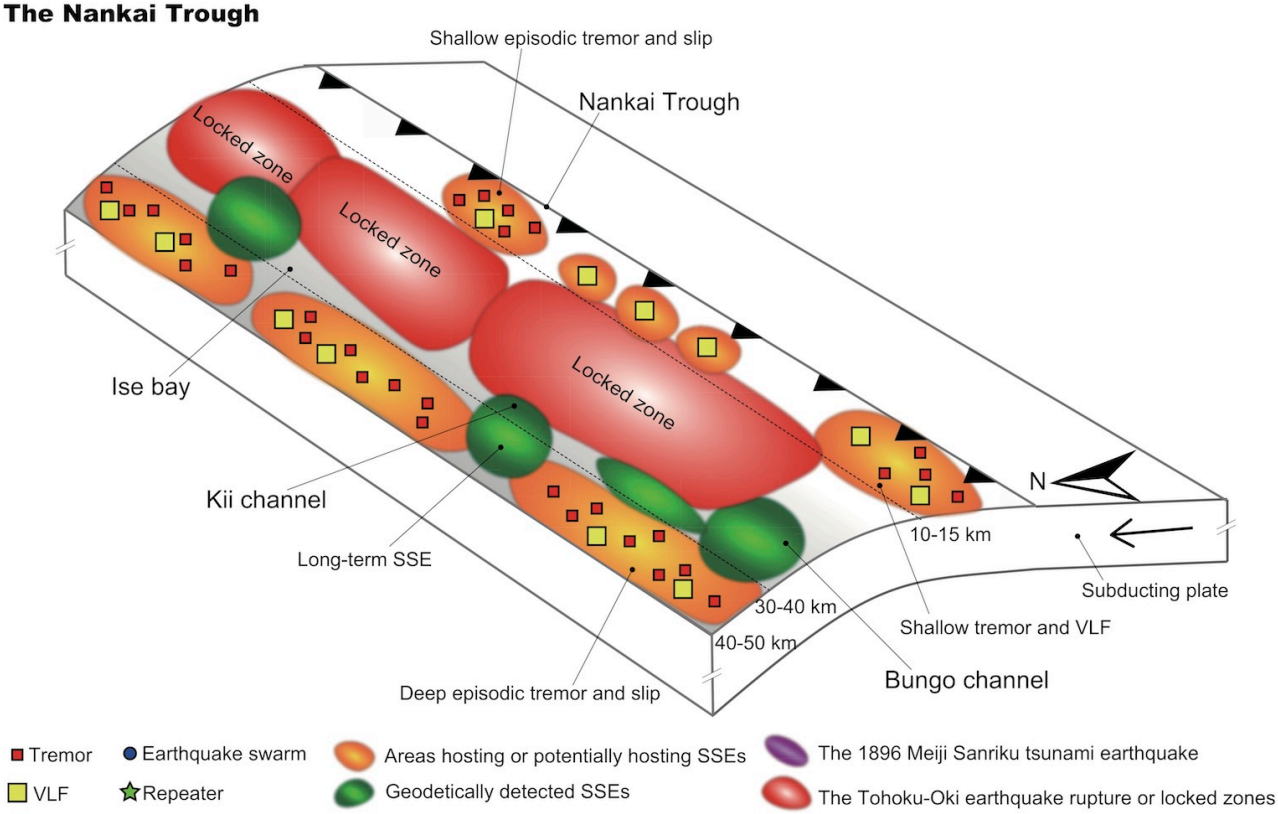
キーワード：スロー地震、巨大地震、沈み込み帯、東北地方太平洋沖地震
Keywords: Slow earthquake, Megathrust earthquake, Subduction zone, The 2011 Tohoku-Oki earthquake

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The Japan Trench



The Nankai Trough



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Tremor and slow slip associated with afterslip of the 2011 Tohoku earthquake

Tremor and slow slip associated with afterslip of the 2011 Tohoku earthquake

*太田 和晃[1]、伊藤 喜宏[1]、日野 亮太[2]、大柳 修慧[1]、松澤 孝紀[3]、篠原 雅尚[4]、塩原 肇[4]
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Characterizing shallow interplate slip is essential for modeling the potential generation of megathrust earthquakes and tsunamis. Large postseismic crustal deformation caused by the 2011 Tohoku-Oki earthquake suggests the occurrence of shallow afterslip, but it is unclear what kind of slip is dominant at the shallow plate interface. Here we report episodic tremor activity south of the primary rupture area based on ocean bottom seismometer observations.

We deployed 24 OBSs at 6 sites close to the trench axis in the Fukushima-Oki region. Three of these sites were small arrays, each consisting of 1 broad-band OBS and 6 short-period (1 Hz) OBSs. The 3 other sites each had 1 short-period OBS. Continuous observations were made from October 2016 to September 2017. For OBS records, we applied the envelope correlation method to detect and locate tremor activity. We also estimate the focal mechanisms of the detected tremor events using S-wave polarization particle motion.

We identified ~ 2000 tremor events in five burst episodes. The duration of each burst ranges from 6 to 18 days, with recurrence intervals of ~60 days. The tremor region largely coincides with the region of very low frequency earthquakes and lies between geodetically observed coseismic and afterslip region of the Tohoku earthquake. Tremor shows clear migration behavior with the speed of ~ 5 km/day and shear mechanisms consistent with plate subduction direction.

The characteristics of the tremor –episodicity, migration and shear mechanisms –strongly suggest that it is accompanied by slow slip events (SSEs). We further approximated the slip amount of SSEs based on the ground displacement of the tremor seismograms. The estimated slip of 1.5 cm/year corresponding to a seismic moment of ~7.4×10^{17} Nm is slightly smaller than but comparable to that of typical short-term SSEs, however, much smaller than that of afterslip. Thus, both SSEs and afterslip exist in the shallow part of the Japan trench. We propose that the tremor and SSE region illuminate the boundary between coseismic slip and stable aseismic slip that could limit the rupture extent of future megathrust earthquakes. Besides, the observed tremor and slow slip activities may also suggest that the interplate stress state has been recovered to the level of that before the Tohoku earthquake.

キーワード：tremor、slow slip、afterslip、Japan trench、Tohoku earthquake
Keywords: tremor, slow slip, afterslip, Japan trench, Tohoku earthquake

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High definition imaging of the Japan Trench by OBS Array of Arrays: Does shallow tectonic tremor occur in the plate interface?

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1. Kyoto University, Graduate School of Science, 2. Kyoto University, Disaster Prevention Research Institute, 3. Tohoku University, 4. Tokyo University, Earthquake Research Institute, 5. Chiba University, 6. Hokkaido University

The Japan Trench is the host to various scale and slip behavior of seismic activities, such as the M9 Tohoku-Oki megathrust earthquake, slow slip events, low frequency tremors and very-low frequency earthquakes (VLFEs). Since these events occur under the seafloor, observation capability of the onshore seismic network is limited due to far distance from their source regions. During 2016 and 2017, we have performed the dense OBS Array of Arrays observation in the offshore Fukushima prefecture near the trench axis to achieve high resolution imaging of the shallow portion of the Japan Trench.
Our network consists of three OBS arrays. Each array consists of one broad band OBS, and six 1Hz short period OBSs. These seven OBSs form a triangular array of 300m to 500m of interstation distance, which results in the array diameter of ~1km. High resolution imaging of complicated seismic phenomena (such as tectonic tremor) is enabled by installing the arrays in the vicinity of the target region.
Based on visual inspection of the observed data, we have identified two episodes of low frequency tremors, triggered dynamically by M7.8 event in offshore Solomon Islands on December 2016, and M7.7 event in offshore Kamchatka Peninsula on July 2017. In both cases, the tremors were accompanied by arrival of Rayleigh waves. The episode of December 2016 lasted 7 minutes, and ceased after passage of Rayleigh wave. On the other hand, the episode of July 2017 continues even after passage of Rayleigh wave, and lasted for more than 12 minutes.
To reveal the origin of these tremors, we apply a beamforming technique to estimate back azimuth and slowness of incoming wave observed by the arrays. Observed tremors are beamformed in horizontal components of OBSs after their absolute orientations are determined using particle-motion of T-phase. From the resulting beam, we have estimated epicenters of the tremors every 60 seconds using only azimuthal information at each array. In this presentation, we are going to discuss about depth of the tremor sources from observed slowness. The tremor activities probably indicate the potential for the occurrence of shallow slow slip events near the Japan Trench, in which VLFEs and after slip were activated after the 2011 Tohoku-Oki earthquake.

Acknowledgements: This study is supported by JSPS KAKENHI (26000002).

キーワード：低周波微動、海底地震計、アレイ解析、動的誘発、日本海溝、スロー地震
Keywords: Low frequency tremor, Ocean Bottom Seismometer, Array analysis, Dynamic triggering, Japan Trench, Slow earthquake

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東北地方太平洋沖地震後の繰り返し地震活動：海陸地震観測網による検討
The activity of small repeating earthquakes after the 2011 Tohoku-oki earthquake: an examination based on the S-net and land networks

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東北日本の海域下の繰り返し地震活動を防災科学技術研究所による日本海溝海底地震津波観測網（S-net）および陸域の定常観測点のデータを用いて調査した。気象庁の一元化震源に記載されている地震について，同一観測点で得られた速度波形の相似性を評価することにより繰り返し地震を抽出した。P波S波を含む40 秒間についてコヒーレンスを計算し，コーナー周波数の1/2から2倍の周波数で0.8以上のコヒーレンスを持つものを繰り返し地震として抽出した。解析は1993年から2018年の長期間のM2.5以上の地震，および2016年8月から2018年10月のS-netデータが利用できる短期間のM2.0以上の地震について行った．

長期の解析からは，2011年東北地方太平洋沖地震の地震時すべり域では繰り返し地震がほとんどない状態が2018年まで続いており，この領域にまだひずみがたまっていないことを示唆する．すべり域外のプレート境界浅部（深さ30km以浅）では，すべり域の北側では活動が消長を繰り返しながら減衰するのに対し，南側では単調に減衰していた．また，すべり域外のプレート境界深部（深さ30-60km）では，すべり域の深部延長で特に活動が活発で2018年も東北沖地震前と比べてかなり活発な状況が続いている．

短期の解析からは，同じ期間についてS-netおよび大学の陸域定常観測点のデータを用いて解析すると，S-net，陸域観測とも同等の数の繰り返し地震が抽出されることがわかった（S-net 520個, 陸域観測684個）．S-netにより繰り返し地震の抽出数が増えなかったのは陸域で震源決定されている地震は，もともと陸域で十分S/Nのよい波形が得られていたことが考えられる．なお，陸域の長期の解析では，2016年8月から2018年10月の短期解析を行った期間についてM2.5以上の大きい地震に限ってみても894個の繰り返し地震が抽出されており，短期の解析では，発生間隔が2.2年以上の繰り返し地震が抽出できないことによる，繰り返し地震の抽出数の減少も存在する．

謝辞：本研究では東北大学の定常観測点の他に，防災科学技術研究所のS-netおよび北海道大学の観測点の地震波形データを用いた．観測点の設置および維持にかかわって来られた皆様に感謝いたします．

キーワード：繰り返し地震、S-net、スロースリップ
Keywords: repeating earthquakes, S-net, slow slip

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[E] 口頭発表 | セッション記号 M (領域外・複数領域)：M-IS ジョイント

2019年5月29日(水) 15:30 ~ 17:00 | 201A 2F

[M-IS07] アストロバイオロジー

コンビーナ:薮田 ひかる(広島大学大学院理学研究科地球惑星システム学専攻)、杉田 精司(東京大学大学院理学系研究科地球惑星科学専攻)、深川 美里(国立天文台)、藤島 皓介(東京工業大学地球生命研究所)、座長:深川 美里(名古屋大学大学院 理学研究科)、藤島 皓介(ELSI 地球生命研究所)

様々な分野を横断し、宇宙における生命の起源と進化、生命存在可能性の解明を目的とするアストロバイオロジーが発祥して20年。太陽系物質進化、惑星系形成、初期地球の前生物的化学、地球と生命の共進化、極限環境生物、ハビタブルな惑星環境、といった個々のテーマが複数分野の知見や手法で研究されるようになり、「我々はどこから来たか」を或る幾つかの形では示すことができるようになってきた。しかし、最終的には成し遂げるべき、挑戦的な領域が残っている。それは、地球惑星環境で生じた非生物的な物質は、どのように生命機能を獲得したのか？　生命の起源に至る、または、生命存在可能な条件を満たす、有機化学と生化学の接点には未だに隔たりが大きい。そこで、これからのJpGUアストロバイオロジーセッションでは、これまで以上の取り組みが重要と考えられる「天文学、地球科学、生化学の融合」を模索し、この未知領域の開拓に臨む。例えば系外惑星と分子進化など、試験管の中の知見を超えた、”場”と対応づけた生化学的・分子生物学的な事象を議論し「生命とはなにか」の理解に近づけ、将来の宇宙生命探査に必要な非生命と生命の識別法の議論や開発に繋げる。

15:30 ~ 15:35

Introduction

15:35 ~ 15:50

[MIS07-01] METEOROID AND DEBRIS IMPACT FLUX IN LOW EARTH ORBIT WITNESSED BY THE TANPOPO CAPTURE PANELS ONBOARD THE ISS IN 2015-2017

*Hajime Yano[1]、K. Yamamoto[2]、E. Minakami[2]、M. Eitel[1,3]、S. Sasaki[4]、J. Imani[5]、K. Okudaira[6]、M. Higashide[7]、E. Imai[8]、Y. Kawaguchi[9]、Yoko Kebukawa[10]、H. Mita[11]、M. Nishi[12]、T. Noguchi[13]、Makoto Tabata[14]、A. Tsuchiyama[12]、Hikaru Yabuta[15]、K. Arai[8]、H. Hashimoto[1]、Kensei Kobayashi[10]、A. Yamagishi[16] (1.Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency、2.Hosei University、3.University of Stuttgart、4.Tokyo University of Technology、5.Yuki Seimitsu, Co. Ltd.、6.University of Aizu、7.JAXA/Aerospace Research and Development Directorate、8.Nagaoka University of Technology、9.Chiba Institute of Technology、10.Yokohama National University、11.Fukuoka Institute of Technology、12.Kyoto University、13.Kyushu University、14.Chiba University、15.Hiroshima University、16.Tokyo University of Pharmacy and Life Science)

15:50 ~ 16:10

[MIS07-02] Growth and transport of dust, ice, and organics in the inner part of protoplanetary disks

★Invited Papers

*奥住 聡[1] (1.東京工業大学地球惑星科学系)

16:10 ~ 16:25

[MIS07-03] Model Prediction of Complex Organic Molecules in Protoplanetary Disks

*野村 英子[1]、Catherine Walsh[2]、Tom Millar[3] (1.東京工業大学理学院地球惑星科学系、2.リーズ大学、3.クィーンズ大学ベルファスト)

16:25 ~ 16:40

[MIS07-04] Abiotic synthesis of organic matters in environments simulating asteroids and the catalytic effect of minerals on amino acid formation

*Walaa Elmasry[1]、Yoko Kebukawa[1]、Kensei Kobayashi[1] (1.Yokohama National University)

16:40 ~ 16:55

[MIS07-05] 模擬海底熱水系環境下でのアミノ酸前駆体からのペプチド生成

*小林 憲正[1]、内藤 敬介[1]、内藤 弘毅[1]、倉本 想士[1]、今井 栄一[2]、三田 肇[3]、癸生川 陽子[1] (1.横浜国立大学、2.長岡技術科学大学、3.福岡工業大学)

16:55 ~ 17:00

Discussion

METEOROID AND DEBRIS IMPACT FLUX IN LOW EARTH ORBIT WITNESSED BY THE TANPOPO CAPTURE PANELS ONBOARD THE ISS IN 2015-2017

*Hajime Yano[1], K. Yamamoto[2], E. Minakami[2], M. Eitel[1,3], S. Sasaki[4], J. Imani[5], K. Okudaira[6], M. Higashide[7], E. Imai[8], Y. Kawaguchi[9], Yoko Kebukawa[10], H. Mita[11], M. Nishi[12], T. Noguchi[13], Makoto Tabata[14], A. Tsuchiyama[12], Hikaru Yabuta[15], K. Arai[8], H. Hashimoto[1], Kensei Kobayashi[10], A. Yamagishi[16]

1. Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency, 2. Hosei University, 3. University of Stuttgart, 4. Tokyo University of Technology, 5. Yuki Seimitsu, Co. Ltd., 6. University of Aizu, 7. JAXA/Aerospace Research and Development Directorate, 8. Nagaoka University of Technology, 9. Chiba Institute of Technology, 10. Yokohama National University, 11. Fukuoka Institute of Technology, 12. Kyoto University, 13. Kyushu University, 14. Chiba University, 15. Hiroshima University, 16. Tokyo University of Pharmacy and Life Science

Twenty-three pairs of silica aerogels and aluminum covers consisted of the Tanpopo capture panels were optically investigated and over 200 hypervelocity impacts signatures were identified and documented for further detailed analyses.
Among them, a low Ca-pyroxene micrometeoroid was captured intact inside the 10mg/cc density silica aerogel. In particular, we compared these data from both space and ram pointing faces of the Tanpopo panels exposed on the International Space Station for deducing meteoroid impact flux by taking into account of effects of local shielding and secondary ejecta impacts. This direct measurement showed that the micrometeoroid impact flux in low Earth orbit in 2015-7 are generally consistent with the previous post-retrieval measurements of LDEF, EuReCa, and SFU in 1980’s to 1990’s.

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Growth and transport of dust, ice, and organics in the inner part of protoplanetary disks

*奥住 聡[1]
*Satoshi Okuzumi[1]

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1. Department of Earth and Planetary Sciences, Tokyo Institute of Technology

Dust grains in protoplanetary disks are the fundamental building blocks of planets. Although recent radio interferometric observations have provided us with detailed images of gas and dust in the outer part of protoplanetary disks, it is still poorly understood how solids evolve in the warmer inner regions of the disks. Understanding the physics of gas and dust evolution in the inner part of disks is thus essential to address the question of how Earth-like planets form.

In this talk, I will discuss two topics on the growth and transport of solids (silicates, ices, and organics) in inner protoplanetary disks. The first topic is related to the water content of planets in the habitable zones. Models of protoplanetary disks suggest that the snow line in the dusty disks migrates with time. In the particular case of the solar nebula, the snow line could have moved to the current orbit of Venus in a late stage of its evolution. This raises the question of why the Earth today is so "dry" with the bulk water content of much less than 1 wt%. I will present simulations of ice pebble accretion by terrestrial planetary embryos, showing that Mars-sized rocky embryos would have grown into Neptune-sized waterworlds unless either the solar nebula was compact or a gas giant's core formed early and blocked the inward flux of the ice pebbles. I will also present the results of our latest MHD simulations of protoplanetary disks that imply that the snow line can migrate much faster than expected from the classical accretion model. These results indicate that Earth-like, modestly "water-poor" planets with both oceans and continents do not necessarily form easily in habitable zones.

The second topic is related to the role of organics in the formation of rocky planetesimals. It is widely accepted that silicate grains are poorly sticky and their growth into planetesimal-sized bodies is severely hindered by collisional fragmentation. Here I propose a scenario in which the seeds of rocky planetesimals form through direct coagulation of silicates coated by an organic mantle, like those found in interplanetary dust particles. Our adhesion model for core-mantle particles show that organic-mantled grains are much stickier than bare silicate grains, in particular in warm environments, thanks to the low elasticity of organic matter. I present simulations of the collisional evolution of organic-mantled grains in the inner part of protoplanetary disks, demonstrating that aggregates of organic-mantled grains are able to overcome the fragmentation barrier and directly form km-sized bodies. These organic-rich planetesimals may further evolve into carbon-poor rocky planetesimals by accreting carbon-poor chondrules.

キーワード：protoplanetary disks、planet formation
Keywords: protoplanetary disks, planet formation

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Model Prediction of Complex Organic Molecules in Protoplanetary Disks

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Protoplanetary disks are the natal place of planets. Understanding chemical components of gas, dust and ice in the disks is essential to investigate the origins of materials in our Solar system and other planetary systems. We investigate the synthesis of complex organic molecules (COMs) in protoplanetary disks using a large gas-grain chemical network including COMs together with a 2D steady-state physical model of a disk irradiated by UV and X-rays from the central star. COMs are efficiently formed on cold and warm grains in the disk midplane via hydrogen adding as well as radical-radical reactions on grain surface. Radiation processing on ice forms reactive radicals and helps build further complexity. Part of the icy molecules are photodesorbed into gas and their transition lines become observable. Actually, ALMA observations have detected CH3CN and CH3OH from protoplanetary disks. The line emitting region of these molecules are the outer relatively cold disk, which suggests that the molecules are non-thermally desorbed from grains following the formation on dust garains. Based on our model calculations, we perform ray-tracing calculations to predict line spectra of complex organic molecules observable with SPICA. Also, we discuss possible connection of COMs in protoplanetary disks to those in the Solar system objects, such as comets.

キーワード：原始惑星系円盤、星間化学、輻射輸送
Keywords: protoplanetary disks, astrochemistry, radiative transfer

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Abiotic synthesis of organic matters in environments simulating asteroids and the catalytic effect of minerals on amino acid formation

*Walaa Elmasry[1], Yoko Kebukawa[1], Kensei Kobayashi[1]

1. Yokohama National University

Solar system materials, such as comets, meteorites, and interplanetary dust particles are known to contain extraterrestrial molecules, which might have a heritage from interstellar, nebular, and/or parent body processing. Delivery of these molecules including amino acids to the early Earth may have been important for the origin of life as they are the building blocks of proteins and enzymes. It is suggested that chondritic organic matter was produced through condensation of interstellar formaldehyde, which is an abundant component of the interstellar medium (ISM) organic inventory and, presumably, the solar nebula followed by condensation and carbonization probably during hydrothermal alteration on chondritic asteroids (Cody et al 2011). According to Kebukawa et al. (2013, 2015), the presence of ammonia significantly enhances the formation of organic solids similar to chondritic insoluble organic matter (IOM) from formaldehyde via the formose reaction at 150˚C and could produce amino acids. Carbonaceous chondrites contain abundant clay minerals. Clays may act as absorbents and catalysts for the polymerization of organic interstellar precursor molecules in the early solar system (Pearson et.al 2002).

In this research, we are studying amino acid formation from formaldehyde and ammonia at 150˚C and reveal the expected effect of minerals, namely, montmorillonite clay, olivine and serpentine to simulate the processes of amino acid productions in water-bearing planetesimals.

We synthesized organic compounds using a mixture of water, formaldehyde and ammonia (H_2O, H_2 CO, NH_3) in a ratio of 100:7:1 (mol) with adding minerals (6 mg/ 0.6 mL solution) by simulating primordial materials in comets and asteroids. Aqueous solutions were heated at 150˚C for 24 hours. The resulted products were divided into two parts, the first analyzed using a FT/IR and the other part was acid hydrolyzed, desalted, and subjected to amino acid analysis using a HPLC.

FT/IR spectra indicated that the differences in the spectral intensities are due to synthesis of more organic compounds. In HPLC analysis, various amino acids including glycine and alanine were detected. Presence of non-protein amino acids (β-Ala, γ-ABA) is considered as evidence against terrestrial contamination. Our preliminary results showed that the obtained amount of amino acids was elevated with the presence of minerals. These results suggested that the associated minerals act as catalysts to produce amino acid precursors during aqueous activities in the planetesimals.

References:

1. Cody, G. D. et al. PNAS 108, 19171–19176 (2011).

2. Kebukawa, Y., David Kilcoyne, A. L. & Cody, G. D. The Astrophysical Journal 771, 19 (2013).

3. Kebukawa, Y. & Cody, G. D. Icarus 248, 412–423 (2015).

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4. Pearson, V. K. Meteoritics & Planetary Science 37, 1829–1833 (2002).

Keywords: Meteorite, Formaldehyde, Olivine, Serpentine

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模擬海底熱水系環境下でのアミノ酸前駆体からのペプチド生成
Peptide Formation from amino acid precursors under simulated submarine hydrothermal environments

*小林 憲正[1]、内藤 敬介[1]、内藤 弘毅[1]、倉本 想士[1]、今井 栄一[2]、三田 肇[3]、癸生川 陽子[1]
*Kensei Kobayashi[1], Keisuke Naito[1], Koki Naito[1], Soushi Kuramoto[1], Ei-ichi Imai[2], MITA Hajime[3], Yoko Kebukawa[1]

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1. Yokohama National University, 2. Nagaoka University of Technology, 3. Fukuoka Institute of Technology

海底熱水噴出孔は、加熱と急冷のサイクル、還元的環境、触媒となりうる遷移金属元素の存在といった有機化合物の合成に有利な特長を持っているため、化学進化の場の一つとして注目されている。また模擬星間物質に陽子線を照射した際には、アミノ酸前駆体が含まれる混合有機物が得られることが判明している。これらのことから、星間にて生成したアミノ酸前駆体が隕石や彗星などにより原始地球の海底熱水噴出孔へ至り、反応するという段階が生命誕生までにあった可能性が考えられる。本研究では、海底熱水噴出孔の高温高圧と急冷を模擬したフローリアクター[1]を用いてグリシン(Gly)、その前駆体となるヒダントイン(Hyd)、アミノアセトニトリル(AAN)、模擬星間有機物(CAW)を反応させ、その生成物の分析を行った。

実験：Gly40 mM、Hyd 40 mM、AAN 40 mM、CAW（CO、NH_3、H_2Oの混合気体に陽子線を照射して得られた生成物）各0.25 mLをフローリアクター(FR)に注入し、反応させた。温度は室温または200~400℃、圧力は250 kg cm^{-2}、反応時間は2分とし、キャリア溶液には純水または1 mM塩酸を用いた。注入5分後から13分後までの流出液を回収しイオンペアクロマトグラフィーを用いた分析を行った。また、Gly, Hydそれぞれ をCAWと混合したサンプルについても同様の実験を行い、単独で反応させた場合と結果を比較した。

結果・考察：Gly、Hydを加熱したサンプルからはGlyの二量体であるグリシルグリシン(GlyGly)及びジケトピペラジン(DKP)が検出された。DKP, GlyGlyともにHydを反応させたサンプルについて収量は大きくなり、HydはGlyの重合物の生成においては遊離のGlyに比べ良い出発物質となることが分かった。また、この際の収量は、DKPについては200℃、250℃、GlyGlyについては200℃、どちらも純水中で反応させた場合に最大となった。

GlyとCAWを混合し反応させたサンプルについては、200℃で加熱した場合に純水中、酸中ともにGlyGly, DKPともに収量は増加した。一方、HydとCAWを混合し反応させたサンプルについては、200℃にて酸性中で反応させた場合のみGlyGlyの収量の増加が見られた。同条件でのDKPの収量に関しては、純水中酸性中ともに増加し、酸性中で反応させた場合に特に大きく増加した。

以上の結果より、遊離のGlyに比べ、アミノ酸前駆代であるHydが海底熱水噴出孔におけるペプチド生成に有利であるということ、また星間環境中で生成する複雑有機物が、ある条件においてはペプチド生成を触媒し得るということが示唆された。

[1] Md. N. Islam *et al. Bull. Chem. Soc. Jpn.*, **76**, 1171 (2003).

キーワード：海底熱水系、化学進化、アミノ酸前駆体、ペプチド、急熱急冷
Keywords: Submarine hydrothermal systems, Chemical Evolution, Amino acid precursors, Peptides, Flash and quench

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[E] 口頭発表 | セッション記号 M (領域外・複数領域)：M-GI 地球科学一般・情報地球科学

2019年5月29日(水) 13:45 ~ 15:15 | 104 1F

[M-GI30] Data assimilation: A fundamental approach in geosciences

コンビーナ:中野 慎也(情報・システム研究機構　統計数理研究所)、藤井 陽介(気象庁気象研究所)、宮崎 真一(京都大学理学研究科)、三好 建正(理化学研究所)、座長:三好 建正(理化学研究所計算科学研究機構)、中野 慎也(情報・システム研究機構 統計数理研究所)

Data assimilation is an inversion approach to estimate the evolution of a system by utilizing a constraint given by a dynamical simulation model. Data assimilation is now widely used not only in meteorology and oceanography but also other fields of geosciences such as hydrology, solid earth science, and space science. This session aims at providing an opportunity for discussion on data assimilation studies among researchers of various field of geosciences. We encourage contributions addressing novel methods and theoretical developments of data assimilation. Contributions dealing with useful applications of data assimilation are also welcome.

13:45 ~ 14:00

[MGI30-01] Recent progresses and applications of geomagnetic data assimilation

★Invited Papers

*Julien Aubert[1]、Vincent Lesur[1]、Alexandre Fournier[1]、Gauthier Hulot[1] (1.Institut de Physique du Globe de Paris, France)

14:00 ~ 14:15

[MGI30-02] Accounting for non-locality of vertical error correlation within ETKF through eigen-spectral localization

★Invited Papers

*堀田 大介[1] (1.気象庁気象研究所)

14:15 ~ 14:30

[MGI30-03] Data assimilation experiments with MODIS LAI observations and the dynamic global vegetation model SEIB-DGVM over Siberia

★Invited Papers

*荒木田 葉月[1]、小槻 峻司[1]、大塚 成徳[1]、澤田 洋平[1,2]、三好 建正[1] (1.理化学研究所 計算科学研究センター、2.気象庁気象研究所)

14:30 ~ 14:45

[MGI30-04] アジョイント法による定常トレーサー分布から海洋鉛直拡散係数分布を推定する試み

★招待講演

*岡 顕[1] (1.東京大学大気海洋研究所)

14:45 ~ 15:00

[MGI30-05] Nonlinear data assimilation with 4DEnVar using iterative weather forecast model

*横田 祥[1]、小泉 耕[1]、國井 勝[2,1]、伊藤 耕介[3,1] (1.気象庁気象研究所、2.気象庁予報部数値予報課、3.琉球大学)

15:00 ~ 15:15

[MGI30-06] Development of Data Assimilation System for Atmospheric Density to Improve Satellite's Orbit Prediction Accuracy

*加藤 博司[1]、日南川 英明[1]、秋山 恭平[1]、秋山 祐貴[1]、中野 将弥[2]、大日向 大地[2]、中村 信一[1] (1.宇宙航空研究開発機構、2.富士通株式会社)

Recent progresses and applications of geomagnetic data assimilation

*Julien Aubert[1], Vincent Lesur[1], Alexandre Fournier[1], Gauthier Hulot[1]

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Over the past ten years, numerical simulations of Earth’ s core magnetohydrodynamics have advanced to a point where their output can be compared in detail to the geomagnetic field behaviour over time scales ranging from a few years to centuries. Motivated by this progress, geomagnetic data assimilation is an emerging discipline that aims at optimally combining the statistical output of such simulations with geomagnetic data. Among the many possible outcomes of this approach, the main goals are to infer the hidden dynamical properties of Earth’ s core from the surface observations, forecast the future evolution of the geomagnetic field in a dynamically consistent way and at horizons of a few years to a century, and improve the quality of source separation in analyses of the geomagnetic field. We will present a few examples to emphasize the value added by statistics extracted from Earth-like geodynamo simulations when attempting to tackle these underdetermined geophysical inverse problems. We will also put these works in context of forthcoming contributions to the 13th iteration of the International Reference Geomagnetic Field (IGRF 2020).

Keywords: Geomagnetism, Numerical Simulations, Earth's core, data assimilation

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Accounting for non-locality of vertical error correlation within ETKF through eigen-spectral localization

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Covariance localization is an indispensable component of any EnKF and it is most straightforwardly formulated as tapering of the sampled background error covariance matrix by means of Schur product (B-loc). However, within most (L)ETKF implementations, this operation is substituted by artificial inflation of R-matrix for observations distant from the analyzed grid-point (R-loc) due to the computational the difficulty of B-loc approach. Recently studies (Bocquet et al. 2016; Bishop et al. 2017) have derived an efficient way to implement B-loc within an ETKF, so that B-loc within ETKF is now a feasible option.

The author's recent work has focused on clarifying the differences between B-loc and R-loc, and showed with idealized 1D models that B-loc can increase the effective rank of the background covariance while R-loc cannot and that B-loc can more faithfully reproduce canonical KF analysis than R-loc does when the observation operator is non-local, suggesting that B-loc is particularly advantageous in cases where the desired amount of assimilated observations are much larger than the affordable ensemble size and/or the observation operator is highly non-local.

This work extends the B-loc approach to accommodate situations where the true background error covariance is not well localized (i.e., the correlation between two grid-points is not given in terms of the physical distance between them). In the proposed scheme, the state vector of each background ensemble is first linearly transformed into the space spanned by the (truncated) eigenbasis of the climatological background error covariance prior to performing data assimilation. The transformed ensemble is then used to form sample covariance to which we apply localization (i.e., control on sampling noises) by neglecting all the off-diagonal components. This method reposes on two assumptions: (1) the true covariance, when expressed in its eigen-space, is diagonal, so that, in this space, any off-diagonal component present in the sample covariance from ensemble is a sign of sampling error, and (2) the eigenstructure of the true covariance is close to its climatological expectation.

In this presentation, I will show several preliminary verifications of this approach using an idealized 1-dimensional system and discuss its

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promise and limitations.

キーワード：データ同化、共分散局所化、アンサンブル・カルマンフィルタ
Keywords: data assimilation, covariance localization, EnKF

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Data assimilation experiments with MODIS LAI observations and the dynamic global vegetation model SEIB-DGVM over Siberia

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In the previous study, Arakida et al. (2017) developed a data assimilation system with the SEIB-DGVM (Spatially Explicit Individual-Based Dynamic Global Vegetation Model, Sato et al. 2007) and assimilated satellite-observed Leaf Area Index (LAI) successfully at a flux measurement site in Siberia. In this study, we extend the experiment to a large domain in Siberia and estimate the vegetation functions and structures, and model parameters related to the phenology of the deciduous needle-leaved tree and the undergrowth. At the annual meeting in 2017, we presented the results of total LAI, tree LAI, above ground biomass, carbon flux, and the model parameters. This year, we present further comparisons with the previous studies: carbon flux (FLUXCOM: Tramontana et al., 2016, Jung et al., 2017) estimated by a machine learning method using in-situ flux measurements and various explanatory data, tree LAI (Delbart et al., 2005, Kobayashi et al., 2010) estimated by a radiative transfer model and satellite observations, and above ground biomass (Liu et al., 2015) estimated by satellite observations. The results showed high correlations between this study and the previous studies except for above ground biomass. This is probably because above ground biomass of Liu et al. [2015] is estimated from microwave-based observations, different from optical-based observations in this study, Kobayashi et al. [2010], and FLUXCOM. The results suggest that the type of the satellite sensor affect the estimation results. Most of the estimated variables by DA were highly correlated with the observed LAI and the previous studies, indicating that the DA system generally performed well over Siberia.

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キーワード：データ同化、植生モデル、衛星データ
Keywords: data assimilation, vegetation model, satellite data

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アジョイント法による定常トレーサー分布から海洋鉛直拡散係数分布を推定する試み

Inversion of the ocean vertical diffusivity from steady-state tracer distributions by using an adjoint method

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海洋中の鉛直拡散係数の値は、温度・塩分などのトレーサー分布や、海洋深層循環の強さをコントロールする重要な要素である。近年の研究から、その分布は空間的な非一様性が高いことが明らかになってきているが、分布の詳細や定量的な値についてはよく分かっていない。一方、温度・塩分をはじめとするトレーサー分布についての観測データは近年飛躍的に増加しており、全球をカバーした良質なデータセットが利用可能である。先行研究では、観測データから得られるトレーサー分布の情報から海洋の流速場を逆推定する試みもなされてきている（Wunsch,1996など）。流速場と合わせて、鉛直拡散係数分布についても逆推定した試みもあるが(Ganachaud and Wunsch, 2000)、その３次元分布について詳細に議論した研究は少ないと思われる。本発表では、温度、塩分、炭素同位体分布（Δ14C）の３つのトレーサー分布を用いて、鉛直拡散係数の３次元分布をどの程度逆推定することができるか、その可能性について議論するとともに現段階での試みを紹介する。

キーワード：海洋鉛直拡散係数、アジョイント法、海洋トレーサーモデル
Keywords: ocean vertical diffusivity, adjoint method, ocean tracer model

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Nonlinear data assimilation with 4DEnVar using iterative weather forecast model

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En4DVar and 4DEnVar are two popular ensemble-based variational data assimilation methods for the numerical weather prediction. Although the ensemble-based forecast error covariance can be reflected in the analyses of both methods, En4DVar calculates the gradient of the cost function with the adjoint of tangent linear forecast model, which requires large development and computational costs. Such costs are generally not required in 4DEnVar because 4DEnVar does not use the tangent linear forecast model. However, 4DEnVar analyses are generally worse than those of adjoint-based En4DVar probably because 4DEnVar does not iteratively calculate the nonlinear forecast model. In this study, therefore, we developed 4DEnVar with iterative nonlinear forecast model (hereafter, 4DEnVar-IF). In 4DEnVar-IF, the nonlinear forecast model is iteratively calculated to gain the non-quadratic cost function and its gradient in each iteration. The 4DEnVar-IF applied to the Lorenz63 model showed that the 4DEnVar-IF analysis can be better than those of En4DVar and general 4DEnVar when nonlinearity is strong and ensemble perturbations are appropriate. Moreover, we also applied 4DEnVar-IF to JMA nonhydrostatic model-based 4DVar data assimilation (JNoVA) system. The single-observation assimilation experiments with JNoVA showed that 4DEnVar-IF can make the cost function smaller than En4DVar when the assimilated observation has the strong nonlinearity as like potential temperature associated with cloud microphysics. In the assimilation experiment of multiple real observations with 4DEnVar-IF of the small localization scale, however, the minimization of the cost function was not sufficiently succeeded. As a next step, we will develop the localization and hybrid of forecast error covariance matrix.

キーワード：データ同化、アンサンブル予報、非線形、4次元アンサンブル変分法
Keywords: data assimilation, ensemble forecast, nonlinear, 4DEnVar

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Development of Data Assimilation System for Atmospheric Density to Improve Satellite's Orbit Prediction Accuracy

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*Hiroshi Kato[1], Hideaki Hinagawa[1], Kyohei Akiyama[1], Yuki Akiyama[1], Masaya Nakano[2], Daichi Obinata[2], Shinichi Nakamura[1]

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低軌道環境には、わずかに大気が存在する。そのため、低軌道衛星の軌道予測の高精度化には、大気から受ける抵抗（大気抵抗）を高精度に予測することが必要不可欠となっている。大気抵抗は、大気密度、各衛星の弾道係数（質量、断面積、抵抗係数）から計算できるが、大気密度の不確かさが、大気抵抗予測の不確かさの大部分を占めると言われている。

大気密度の予測モデルは、これまで、いくつか提案されている。それらは、低軌道環境の観測情報は、非常に乏しいが、わずかに存在する衛星観測情報に基づいている。しかし、大気密度を高精度の予測することは、困難であり、衛星運用者は、軌道決定値に基づき、なんらかの補正量を求めることで、軌道予測精度を高めている。

JAXAは、2018年度から、大気密度再解析システム（データ同化システム）の開発を開始している。本システムは、地上から推定できる衛星軌跡上の大気密度平均情報と、各大気密度モデルの計算情報から、大気密度の再解析を実現するものである。大気密度観測情報としては、米国NORADが提供している各衛星の軌道情報（Two Line Element）に基づき推定することができる。大気密度モデルは、軌道分野で使われているNRLMSIS-00モデルとJacchia Bowman 2008モデルを利用している。そして、データ同化手法としては、アンサンブルカルマンフィルター、アンサンブル変換カルマンフィルタを実装している。

本発表では、大気密度再解析システムの詳細を紹介するとともに、システム検証として進めている双子実験（数値実験）の結果について報告する。

キーワード：衛星軌道予測、大気密度、データ同化
Keywords: Satellite orbit prediction, Atmospheric density, Data assimilation

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[E] 口頭発表 | セッション記号 M (領域外・複数領域)：M-GI 地球科学一般・情報地球科学

2019年5月29日(水) 15:30 ~ 17:00 | 104 1F

[M-GI30] Data assimilation: A fundamental approach in geosciences

コンビーナ:中野 慎也(情報・システム研究機構　統計数理研究所)、藤井 陽介(気象庁気象研究所)、宮崎 真一(京都大学理学研究科)、三好 建正(理化学研究所)、座長:宮崎 真一(京都大学)、藤井 陽介

Data assimilation is an inversion approach to estimate the evolution of a system by utilizing a constraint given by a dynamical simulation model. Data assimilation is now widely used not only in meteorology and oceanography but also other fields of geosciences such as hydrology, solid earth science, and space science. This session aims at providing an opportunity for discussion on data assimilation studies among researchers of various field of geosciences. We encourage contributions addressing novel methods and theoretical developments of data assimilation. Contributions dealing with useful applications of data assimilation are also welcome.

15:30 ~ 15:45

[MGI30-07] An LETKF-based ocean reanalysis for the Asia-Oceania region using Himawari-8 SSTs and SMOS/SMAP SSS

★Invited Papers

*大石 俊[1]、日原 勉[2]、相木 秀則[1]、石坂 丞二[1]、宮澤 泰正[2]、可知 美佐子[3] (1.名古屋大学、2.JAMSTEC、3.JAXA)

15:45 ~ 16:00

[MGI30-08] Validation of JCOPE-T DA ocean assimilation product

*日原 勉[1]、Varlamov Sergey[1]、宮澤 泰正[1]、美山 透[1]、可知 美佐子[2]、村上 浩[2] (1.国立研究開発法人海洋研究開発機構、2.国立研究開発法人宇宙航空研究開発機構)

16:00 ~ 16:15

[MGI30-09] **Do surface lateral flows matter for land data assimilation?: Implication for hyper-resolution land modeling and observation**

*澤田 洋平[1] (1.気象庁気象研究所)

16:15 ~ 16:30

[MGI30-10] Geodynamo data assimilation for candidate models of IGRF13-SV from Japan team

*南 拓人[1]、中野 慎也[2]、高橋 太[3]、松島 政貴[4]、清水 久芳[1]、藤 浩明[5] (1.東京大学地震研究所海半球観測研究センター、2.統計数理研究所、3.九州大学大学院理学研究院、4.東京工業大学理学院地球惑星科学系、5.京都大学大学院理学研究科)

16:30 ~ 16:45

[MGI30-11] A pilot study of geomagnetic data assimilation into a geodynamo model

*中野 慎也[1]、南 拓人[2]、高橋 太[3]、松島 政貴[4]、藤 浩明[5]、清水 久芳[2] (1.情報・システム研究機構　統計数理研究所、2.東京大学地震研究所、3.九州大学大学院理学研究院、4.東京工業大学理学院、5.京都大学大学院理学研究科附属地磁気世界資料解析センター)

16:45 ~ 17:00

[MGI30-12] Bayesian parameter estimation of a physics-based model of postseismic crustal deformation

★Invited Papers

*福田 淳一[1]、Johnson Kaj[2] (1.東京大学地震研究所、2.Department of Earth and Atmospheric Sciences, Indiana University)

An LETKF-based ocean reanalysis for the Asia-Oceania region using Himawari-8 SSTs and SMOS/SMAP SSS

*大石 俊[1]、日原 勉[2]、相木 秀則[1]、石坂 丞二[1]、宮澤 泰正[2]、可知 美佐子[3]
*Shun Ohishi[1], Tsutomu Hihara[2], Hidenori AIKI[1], Joji Ishizaka[1], Yasumasa Miyazawa[2], Misako Kachi[3]

1. 名古屋大学、2. JAMSTEC、3. JAXA
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With the global spread of the Argo floats and development of high-resolution ocean models, global ocean reanalysis datasets have been released. Although regional high-resolution ocean reanalysis datasets also have been established around the North Pacific, most of their coverage area is limited to regions north of 10˚N. We suggest that reanalysis datasets for tropical-subtropical oceans are yet to be constructed for coastal environmental monitoring and typhoon researches around the Asia-Oceania region.
Since July 2015, a geostationary satellite “Himawari-8” has been measuring sea surface temperatures (SSTs) with a high spatial and temporal resolution of 2 km and 10 min. in the western Pacific region using an infrared sensor. Because of the high temporal resolution, daily composite map shows that coverage area of Himawari-8 exceeds that of an orbital satellite “GCOM-W” with a microwave sensor. The infrared sensor enables us to capture fine nearshore SST structure, such as localized cool SSTs induced by Ekman upwelling along the Vietnam coast during the southwesterly summer monsoon.
We have established a one-way nest high-resolution ocean data assimilation system based on LETKF (Hunt et al. 2007) with 20 ensemble members at 1-day interval. The southeast Asia coastal region [98˚–115˚E, 0˚–22˚N] has been modeled at a spatial resolution of 1/36˚ and 47 layers with an intent to be applied for fishery and marine environmental monitoring, while the large-scale western Pacific region [95˚E–165˚W, 50˚S–50˚N] has been constructed at a spatial resolution of 1/12˚ and 47 layers to make contributions to tropical cyclone studies. Himawari-8 SSTs and sea surface salinity (SSS) derived from SMOS and SMAP satellites as well as sea surface height, and temperature/salinity derived from GTSPP and AQC Argo dataset have been assimilated. To improve the salinity field, freshwater fluxes also have been incorporated. To avoid generation of spurious gravity waves, the Incremental analysis Update (IAU) filter (Bloom et al. 1996) have been implemented. We will introduce low salinity water transport from the Mekong river in the southeast Asia system and the SST cooling with the passage of tropical cyclones in the western Pacific system.

キーワード：東南アジア、西部太平洋、データ同化、LETKF、ひまわり８号、SMOS/SMAP
Keywords: southeast Asia, western Pacific, data assimilation, LETKF, Himawari-8, SMOS/SMAP

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Validation of JCOPE-T DA ocean assimilation product

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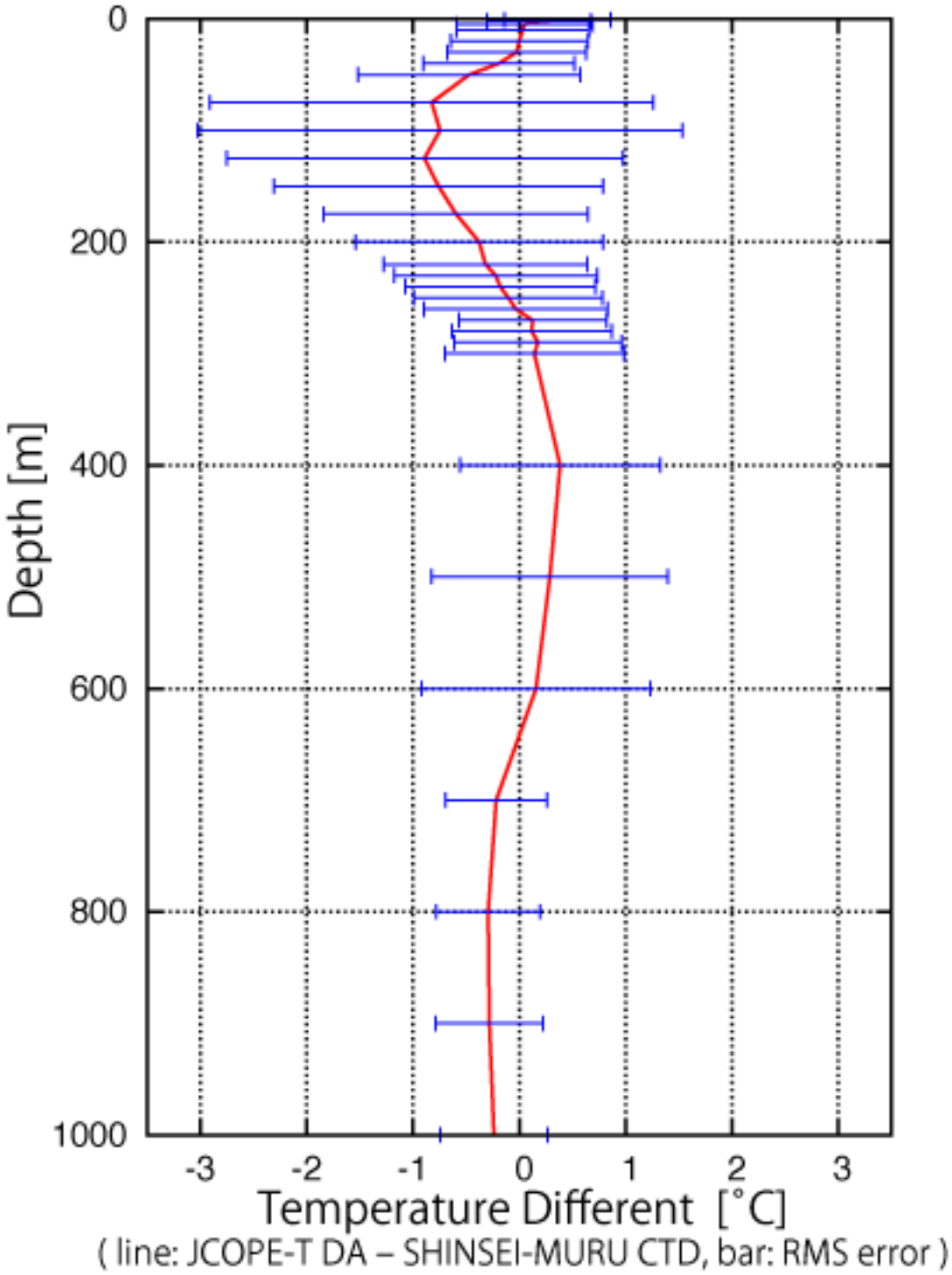
We constructed the high resolution (3km, 1hour) ocean data assimilation system named as JCOPE-T DA which targets around Japan. This system is running operationally and that’ s outputs have been provided by JAXA through the Himawari Monitor website and P-Tree System since November 2018. One of the aims in this system is to make the useful ocean analysis and forecast data by assimilating satellite SST data provided by JAXA directly. We assimilate the satellite SST data observed by Himawari/AHI, GCOM-W/AMSR2, GPM main satellite/GMI, and Coriolis/WindSAT. Multi-3DVAR (Miyazawa et al. 2017) and IAU are applied in this system.

We will show the results of validation of JCOPE-T DA using independent in situ data observed by buoys and ship in this presentation. The results of comparison with CTD data observed by SHINSEI-MARU off the Kii Channel show that JCOPE-T DA ocean temperature data are good estimate in upper layer (Figure 1). Biases and RMS error are lower than ±0.2 deg.C and 0.7 deg.C in 2 –40m depth respectively. On the other hand, there are negative bias and large RMS difference (over 1 deg.C) in thermocline (5 –200 m depth). These mean that mixed layer of JCOPE-T DA is deeper than that of observation.
JCOPE-T DA clearly show the internal tide because the ocean model of JCOPE-T DA considers the tide effects. Especially, we find that the channel between Taiwan and Philippines causes strong internal tide which is made change of several degree Celsius at 500m depth in a day.

In the future plan, we are going to construct the higher resolution (1km grid) ocean model with CaMa-Flood river flow data. And also, we are going to assimilate the GCOM-C/SGLI SST data which have 250m resolution. Furthermore, we will construct a nest model for coastal area.

キーワード：データ同化、衛星海面水温データ、領域海洋モデル
Keywords: Data assimilation, Satellite SST data, Regional ocean model

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Do surface lateral flows matter for land data assimilation?: Implication for hyper-resolution land modeling and observation

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Hyper-resolution land modeling is expected to innovate the simulation of terrestrial water, energy, and carbon cycles. One of the major advantages of existing hyper-resolution land models against conventional 1-demensional land surface models is that surface and subsurface lateral water flows can be explicitly simulated. Despite a lot of efforts on assimilating hydrological observations into the hyper-resolution integrated surface-groundwater land models, how and in what case topography-driven surface water flows matter for data assimilation of soil moisture observations has yet to be clarified. In this study, I perform a minimalist synthetic numerical experiment, in which shallow soil moisture observations are assimilated into an integrated surface-groundwater land model by an ensemble Kalman filter. Propagation of a background error due to surface lateral water flows is crucially important to adjust the unobserved model state and parameter variables by horizontally propagating the information of soil moisture observations. However, the non-Gaussianity of the background error induced by the nonlinear dynamics of topography-driven surface flows harms the performance of an ensemble Kalman filter and the efficiency of data assimilation strongly depends on soil characteristics. The new capability of data assimilation with the hyper-resolution land models found in this study may improve the monitoring and prediction of flash floods caused by local severe rainfalls.

Sawada, Y. (2018), Do surface lateral flows matter for data assimilation of soil moisture observations into hyperresolution land models?, *EarthArXiv,* https://doi.org/10.31223/osf.io/byguf

キーワード：陸域データ同化
Keywords: land data assimilation

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Geodynamo data assimilation for candidate models of IGRF13-SV from Japan team

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International Geomagnetic Reference Field (IGRF) is a series of standard global geomagnetic field models that consist of Gauss coefficients to represent spatial distribution. International Association of Geomagnetism and Aeronomy (IAGA) produces IGRF every five years, the last version of which, the 12th generation of IGRF (IGRF-12), was released in December 2014 (Thebault et al., 2015). Each generation of IGRF comprises not only the main field part but secular variation (SV) part (first time derivative of the main field) to forecast evolution of the geomagnetic field for the next five years to come. The next generation, IGRF-13, will be published around December 2019, comprising the spatial distribution of the field at epoch 2020.0 and its secular variation in the period from 2020.0 to 2025.0. We plan to submit a candidate SV model to contribute for determining IGRF13-SV.
We employ data assimilation with geodynamo calculations to generate a SV candidate model for the period from 2020.0 to 2025.0. Although the two standard approaches, (1) adoption of SV at the IGRF release time and (2) spline extrapolation of the main field in the future, are common for generating SV candidates, they are not “physics-based” forecasts, and, intrinsically, cannot alleviate the effect of sudden changes in the SV field called “geomagnetic jerks” (Mandea et al., 2010). In this context, data assimilation is one of novel approach to obtain an appropriate initial condition for geodynamo calculations at the time of IGRF release time. Since the parameters used in geodynamo calculations are apart by some orders of magnitude from those for the Earth's core, it is not appropriate to take geodynamo solutions as they are for the predictions. Nevertheless, it is possible to rescale the time-axis of geodynamo calculations using the ratio of the so-called “secular-variation time-scale” (Chlistensen and Tilgner, 2004) between the geomagnetic field and geodynamo calculations. In this presentation, we are going to show candidate models of secular variation obtained by geodynamo data assimilation with discussions on the time-scales, the method of assimilation, and data-set employed for the assimilation.

キーワード：IGRF、データ同化、ダイナモ
Keywords: IGRF, Data assimilation, dynamo

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A pilot study of geomagnetic data assimilation into a geodynamo model

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Geomagnetic secular variation is a long-term variation of the Earth's magnetic field. The magnetic field of the Earth is originated from a dynamo in the outer core. Modeling of geodynamo process is thus a straightforward approach for predicting geomagnetic secular variations. However, it is intrinsically difficult to resolve the current state of the geodynamo from observable magnetic field and to predict future evolution of geodynamo. We are developing a framework for estimating the current state of the geodynamo by using a data assimilation approach. As a preliminary study, we performed data assimilation experiments using synthetic geomagnetic data in order to evaluate if data assimilation methods are effective for estimating the state of the geodynamo. Some data assimilation schemes based on ensemble-based variational method were applied and compared. Preliminary results of the experiments will be demonstrated.

キーワード：ensemble-based data assimilation、geodynamo model、secular variation
Keywords: ensemble-based data assimilation, geodynamo model, secular variation

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Bayesian parameter estimation of a physics-based model of postseismic crustal deformation

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Recent development GPS and other geodetic networks makes it possible to capture transient crustal deformation at high resolution in both space and time. A primary example of geodetically observed transient deformation in plate boundary zones is postseismic deformation following large earthquakes. Two primary processes that are responsible for observed postseismic deformation are viscoelastic relaxation of in the asthenosphere and afterslip on the plate interface surrounding the coseismic rupture. Both of the processes are triggered by stress changes induced by an earthquake and the evolution of the two processes is governed by rheological properties of the asthenosphere and frictional properties of the plate interface as well as coseismic stress perturbations.

In this study, we develop a physics-based model of postseismic deformation following the 2011 Mw9.0 Tohoku-oki earthquake that incorporates stress-driven afterslip and viscoelastic relaxation. In this model, the evolution of afterslip is assumed to be governed by a velocity-strengthening friction law that is characterized with a friction parameter. Viscoelastic relaxation of the asthenosphere is modeled with a biviscous Burgers rheology that is characterized with steady-state and transient viscosities. The evolution of afterslip and viscoelastic relaxation is calculated using coseismic slip distribution as an initial condition. We treat the friction parameters, viscosity parameters, coseismic slip distribution, and a smoothing parameter for coseismic slip distribution as unknown parameters and estimate them using coseismic and postseismic GPS and seafloor geodetic data.

In order to quantify uncertainties of the model, we adopt a Bayesian approach and estimate the posterior probability density function (PDF) of the model parameters. In principle, the Markov chain Monte Carlo (MCMC) methods can be used for this purpose. However, the MCMC methods require many forward calculations and the forward model employed in this study is computationally intensive. Therefore, it is difficult to sample the posterior PDF within a realistic computation time. We thus combine a surrogate modeling approach with the MCMC methods to efficiently sample the posterior PDF. In this approach, we first obtain a function approximation to the posterior PDF by fitting a surrogate function to the posterior probability densities calculated for sample points in the model parameter space. Then a MCMC method is used to sample the surrogate posterior PDF. By using this approach, we obtain the posterior PDFs of the model parameters that successfully reproduce the observed coseismic and time-dependent postseismic displacement fields. Our results suggest that such approaches may be useful for parameter estimation and uncertainty quantification of computationally intensive forward models.

キーワード：Bayesian inference、parameter estimation、GPS、postseismic crustal deformation
Keywords: Bayesian inference, parameter estimation, GPS, postseismic crustal deformation

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