Data for Self-Assessment and External Review

Individual Member

February 14, 2020

The University of Tokyo
Department of Earth and Planetary Science
Graduate School of Science

Contents

Member List (as of January 1st, 2020)

Atmospheric and Oceanic Science Group

SATO, Kaoru	P	Atmospheric Dynamics, Middle Atmosphere Sciences
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MASUMOTO, Yukio	P	Climate Dynamics, Physical Oceanography
KOIKE, Makoto	AP	Atmospheric Environmental Science/Atmospheric Chemistry
Tozuka, Tomoki	AP	Physical oceanography, Climate dynamics
MIURA, Hiroaki	AP	Atmospheric physics, Climate modeling
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TANAKA, Yuki	RA	Dynamical Oceanography, Physics in Marginal Seas, Mixing Processes in Straits

Space and Planetary Science Group

HOSHINO, Masahiro	P	Space and Astroplasma Physics
SEKI, Kanako	P	Space Physics
SUGITA, Seiji	P	Planetary Science, Astrobiology, Planetary exploration
TACHIBANA, Shogo	P	Cosmochemistry
AMANO, Takanobu	AP	Space Physics, Plasma Astrophysics
HIYAGON, Hajime	AP	Planetary science, isotope cosmochemistry, meteoritics
KASAHARA, Satoshi	AP	Planetary science; Space-borne instrumentation
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YOKOYAMA, Takaaki	AP	Solar and Astrophysical Plasma Physics
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OHIRA, Yutaka	RA	Astrophysics, Cosmic ray physics, Plasma physics

Earth and Planetary System Science Group

KAYANNE, Hajime	P	Earth System Science (coral reef, coast, carbon cycle, global change, paleoenvironment)
TAJIKA, Eiichi	P	Earth and planetary system science, Comparative planetology
IKOMA, Masahiro	AP	Theoretical planetology, Exoplanetology
KAWAHARA, Hajime	RA	Exoplanets (characterization, analysis, and instruments)
MOTEKI, Nobuhiro	RA	Atmospheric Chemistry and Physics, Environmental Physics
TAKAHASHI, Satoshi	RA	Paleontology, Geochemistry, Geology

Solid Earth Science Group

HIROSE, Kei	P	High-pressure geoscience, Study of deep Earth materials
IDE, Satoshi	P	Earthquake Source Physics
OZAWA, Kazuhito	P	Petrology
WALLIS, Simon	P	Structural petrology, tectonics
ANDO, Ryosuke	AP	Earthquake source physics, Seismotectonics
IIZUKA, Tsuyoshi	AP	Geochemistry and cosmochemistry
KAWAI, Kenji	AP	Global seismology, Study of Earth's deep interior
TANAKA, Yoshiyuki	AP	Geodesy

Geosphere and Biosphere Science Group

ENDO, Kazuyoshi	P	Molecular palaeontology, skeletogenesis

Atmospheric and Oceanic Science Group

Kaoru Sato

I. CV

Name: Kaoru Sato

Age: 58

Present Position: Professor, Graduate School of Science, The University of Tokyo

Education

Ochanomizu University Senior High School, Tokyo, March, 1980 (graduation)

B. Sc. (Geophysics), The University of Tokyo, March, 1984

M. Sc. (Geophysics), The University of Tokyo, March, 1986

Ph. D. Department of Geophysics, Kyoto University, March, 1991

Professional Experience

April, 1986-June, 1987, Opto-Electronics Research Laboratories, NEC Corporation

April, 1991-March, 1993, JSPS Research Fellow (PD), Graduate School of Science, Kyoto University

July 1993-March, 1995, Research Associate, Center for Climate System Research, The University of Tokyo

April, 1995-November, 1999, Assistant Professor, Graduate School of Science, Kyoto University

December, 1999-September, 2005, Associate Professor, National Institute of Polar Research

October, 2005-, Professor, Graduate School of Science, The University of Tokyo

July, 1995-August, 2001, Visiting Scientist, NorthWest Research Associates, U.S. A.

September, 2002-March, 2004, Wintering Member, The 44th Japanese Antarctic Research Expedition

October, 2005-March, 2006; April, 2010-, Visiting Professor, National Institute of Polar Research

September, 2018-March, 2019, Summer Party Member, The 60th Japanese Antarctic Research Expedition

II. Scientific Research Activity

2. Major Achievements

I had led the construction and continuous operation of the first Antarctic Mesosphere-Stratosphere-Troposphere (MST) radar (the PANSY radar). We had performed studies using PANSY radar observation data, using high-resolution general circulation models, and using satellite and reanalysis data as well as theoretical studies, and had deepened the understanding of middle atmospheric dynamics including the interplay of Rossby waves and gravity waves and its role in the general circulation.

<u>1. Research using the PANSY radar in the Antarctic</u>
MST radars can observe vertical profiles of wind vectors in the troposphere, stratosphere and mesosphere with high time and vertical resolution. In particular, since vertical winds can be estimated directly, high-precision estimation of momentum flux associated with gravity waves is possible. She led the construction and steady operation of the PANSY radar at Syowa Station (69°S, 40°E) and conducted many observational studies. Despite of a major hindrance to the transportation of cargos due to the abandonment of the icebreaker berthing at the station owing to an extremely bad sea ice

condition in two summer seasons, continuous observation had started with a subgroup of the radar system at the end of April 2012, and the first successful observation with the full radar system was performed in March 2015. Since October 2015, a full system of the PANSY radar have been performed continuously. In 2014, we published the first paper describing the radar system and the concept of scientific research by presenting preliminary observation results. Studies were performed on the characteristics of topographic gravity waves and hydraulic jumps in the lower troposphere, large-amplitude gravity waves near the tropopause, diurnal changes in the polar mesosphere winter echoes modulated by high-energy particles based on the initial subgroup radar observation data. Since the start of the full system observations, we performed a) a study of the entire frequency range of gravity wave spectra using data from continuous mesospheric observation over a few months that is possible for the sake of the midnight sun, b) studies showing the prominence of near-inertial gravity waves in the stratosphere and mesosphere through all seasons, c) a study showing highly accurate estimation of turbulent energy dissipation rate as a function of season by collaborating with scientists in the field of informatics. In these studies, we had also conducted simulations of gravity-wave permitting non-hydrostatic general circulation model (GCM). Since 2016, I had led the international joint observation campaign called ICSOM (Interhemispheric Coupling Study by Observations and Modeling) four times, which examines the mechanism of global modulation of the middle atmosphere triggered by the Arctic sudden stratospheric warming. In particular, in the campaign of Dec. 2018 to Jan. 2019, I had made observation at Syowa Station by myself as a summer party member of Japanese Antarctic Research Expedition (JARE). The PANSY radar is positioned as a core instrument of a primary research observation plan for JARE VIII (2012-2015) and IX (2016-2011) including many other complementary observation instruments. I have been working as a research representative for the JARE IX primary research observation group.

2. Research on the hierarchical structure of the middle atmosphere general circulation

2-a. Interplay of gravity waves and Rossby waves

As gravity waves and Rossby waves have much different temporal and spatial scales, they do not usually interact with each other. However, we theoretically showed that spontaneous emission of gravity waves occurs from the balance flow by resonance due to significant Doppler effect of the flow. In addition, it was shown by the analysis of simulation data from a high-resolution GCM and a whole atmosphere GCM that in the middle atmosphere, especially in the mesosphere, wave forcings caused by breaking and/or dissipation of gravity waves and Rossby waves disrupt the balance of large-scale fields. Meanwhile, Rossby waves and gravity waves are generated respectively due to barotropic/baroclinic instability and shear instability, which cannot be ignored in the momentum budget in the middle atmosphere. In particular, the phenomenon that gravity waves generate Rossby waves had not been well-known so far. Theoretical analysis of the unsteady response of Lagrangian flow to the wave forcing was also made.

2-b. Formulation of 3D Lagrangian flow applicable to both gravity waves and Rossby waves

A theoretical formulation for investigating the three-dimensional (3D) structure of the general circulation in the middle atmosphere was performed. While the zonal mean (i.e., 2D) Lagrangian flow is described only by ageostrophic winds, the 3D flow includes geostrophic winds. Also, as described in 2-a, for the importance of the interplay of gravity waves and Rossby waves in the middle atmosphere, the formulation to describe the Lagrangian flow and wave activity flux that can analyze both waves are necessary. We had derived the formulae that meet these necessities. In the course of this research, the unified dispersion relation of gravity wave and Rossby wave was also derived.

2-c. Climatology and propagation of gravity waves

We had also performed studies of the global gravity wave distribution, three-dimensional gravity wave characteristics, and the gravity wave parameterization that is indispensable for the climate prediction model and greatly affects the prediction accuracy. These include studies based on a gravity-wave permitting GCM simulation regarding a) horizontal distribution, seasonal variation, and intermittency of gravity waves in the southern hemisphere, b) relative roles of Rossby waves, gravity waves, and radiation in the Arctic stratospheric sudden warming event associated with the elevated stratopause, and c) non-migrating tides generated continental-scale diabatic heating associated with convective activity in the tropical region. The mechanism of horizontal propagation of orographic gravity waves was clarified and gravity wave parameterization including this mechanism was developed. Studies on the synchronization of the gravity wave characteristics observed by a satellite (AIRS) with the Madden Julian oscillation and the Southern Oscillation, and on close relation in the interannual variation of Antarctic gravity waves observed by an MF radar with subtropical convection.

2-d. Other studies on atmospheric dynamics

Many of the above studies were conducted as graduate students' master thesis or PhD thesis. There are other important studies on atmospheric dynamics with students: these include two studies using cloud data in the upper troposphere and lower stratosphere from satellite (CALIPSO) regarding the simultaneous occurrence mechanism of the polar-stratospheric clouds and the upper-tropospheric clouds, and regarding the modulation of static stability and clouds in the upper troposphere by the sudden stratospheric warming. It was also shown that the final warming date of the Antarctic stratosphere mainly determined by the integrated heat flux associated with planetary waves originating from the troposphere. I had also made international group research, review paper writing, and collaborative research by teaching young foreign researchers.

3. Five Important Papers (including three or more papers in this review period)

1. Sato K., A statistical study of the structure, saturation and sources of inertio-gravity waves in the lower stratosphere observed with the MU radar (1994), J. Atmos. Terr. Phys., 56, 755–774, doi:10.1016/0021-9169(94)90131-7. (Citation 156, GS/Sep. 18, 2019).

Statistical analysis was performed on the dynamical characteristics of inertia-gravity waves in the lower stratosphere, using data over three years (3600 hours in total) from an Mesosphere-Stratosphere-Troposphere (MST) radar called the MU radar in Shigaraki, Shiga, Japan (35°N, 136°E). The mean vertical wavelength and horizontal wavelength are 1.6 km and 300 km, respectively, with little seasonal dependence. In contrast, the propagation characteristics were highly dependent on the season: the gravity waves propagate southward from the north of the subtropical jet and upward (downward) in the stratosphere (troposphere) in winter, while they propagate from low latitudes to high latitudes in the lower stratosphere in summer.

2. Sato, K., S. Tateno, S. Watanabe, Y. Kawatani (2012), Gravity wave characteristics in the Southern Hemisphere revealed by a high-resolution middle-atmosphere general circulation model, J. Atmos. Sci., 69, 1378–1396, doi:10.1175/JAS-D-11-0101.1. (Citation 100, GS/Sep. 18, 2019).

Based on three-year simulation data using a gravity-wave resolving atmospheric general circulation model with seasonally-varying climatological sea surface temperature and stratospheric ozone, dynamical characteristics of gravity waves in the Southern Hemisphere were examined. The gravity wave energy is maximized in winter. The large wave energy in winter is distributed around the stratospheric polar vortex in the vicinity of the Southern Andes and leeward. The importance of horizontal propagation of orographic gravity waves was discussed theoretically. In addition, it was also shown that a partial reflection of gravity waves occurred where the static stability discontinuously changes in the vertical, causing significant downward energy flux in winter.

3. Sato, K., M. Tsutsumi, T. Sato, T. Nakamura, A. Saito, Y. Tomikawa, K. Nishimura, M. Kohma, H. Yamagishi and T. Yamanouchi (2014), Program of the Antarctic Syowa MST/IS Radar (PANSY), J. Atmos. Solar-Terr. Phys., 118, Part A, 2–15, doi:10.1016/j.jastp.2013.08.022. (Citation 48, GS/Sep. 18, 2019).

The PANSY radar is the first MST radar in the Antarctic installed at Syowa Station (69°S, 40°E) in early 2011. This paper reports the project's scientific objectives, technical descriptions, and the preliminary results of observations made to date. The construction and operation of this radar needed to overcome restrictions related to the severe environments of Antarctic research, such as very strong winds, limited power availability, short construction periods, and limited manpower availability. We had resolved these problems through the adoption of specially designed class-E amplifiers, light weight and tough antenna elements, and versatile antenna arrangements.

4. Sato, K., and M. Nomoto (2015), Gravity wave-induced anomalous potential vorticity gradient generating planetary waves in the winter mesosphere, J. Atmos. Sci., 72, 3609–3624. doi: 10.1175/JAS-D-15-0046.1 (Citation 14, GS/Sep. 18, 2019).

Using simulation data from a gravity-wave resolving general circulation model, it was shown that the baroclinic/barotropic instability frequently seen in the mesosphere is caused by the forcing of gravity waves originating from the troposphere. Rossby waves propagating eastward and westward are emitted so as to eliminate the potential vorticity maximum in middle latitudes which characterizes the instability. This fact suggests that the viewpoint of interplay of gravity waves and Rossby waves through the wave-mean flow interaction is necessary for understanding the momentum budget in the mesosphere.

5. Sato, K., M. Kohma, M. Tsutsumi, and T. Sato (2017), Frequency spectra and vertical profiles of wind fluctuations in the summer Antarctic mesosphere revealed by MST radar observations, J. Geophys. Res. Atmos., 122, 3–19, doi:10.1002/2016JD025834. (Citation 13, GS/Sep. 18, 2019).

Mesospheric observations by the MST radar are limited to the daytime when the atmosphere is ionized by solar radiation. Thus, the analysis of gravity wave characteristics in the mesosphere is usually restricted. However, in the polar summer region with the midnight sun, continuous observation data can be obtained over a few months. In this study, we showed the spectra of energy and momentum flux over the entire frequency range of the gravity waves in the mesosphere using continuous observation data from the PANSY radar in the Antarctic. It was clarified that dominant momentum fluxes are associated with long-period gravity waves, which is different from a theoretical expectation.

4. Awards and Honors

- Commendation for Science and Technology by the Minister of Education, Culture, Sports, Science and Technology, Japan, 2014
- Commendation of the Contributor of the Promotion of Building the Maritime Nation of Japan by the Prime Minister, Japan, 2015
- Fujiwara Award of The Meteorological Society of Japan, 2018
- AOGS Atmospheric Sciences Section Distinguished Lecturer, 2018

5. Future Research Plan

As already started in last seven years, our research target is expanded to the atmosphere from the ground to the turbopause (the top of the atmosphere located at ~100 km where the atmospheric mixing ratio is almost constant) (hereinafter referred to as the whole neutral atmosphere). We will clarify the hierarchical structure of the whole neutral atmosphere consisting of turbulence, various waves, various instabilities, and general circulation from a dynamical point of view. As reanalysis data created by the meteorological organizations covers the region only up to the lower mesosphere, we have been developing our own data assimilation system to create long-term analysis data for the entire neutral atmosphere. Quantitative and highly accurate discussions will be performed based on the data from the global middle atmosphere observation network including the PANSY radar and from high-resolution general circulation model experiments. We will also proceed with the theoretical research to model the obtained images of the hierarchical structure. As an activity of Japanese Antarctic Research Expedition, continuous PANSY radar observations started in October 2015 over 12 years, which covers one solar cycle, will be conducted in collaboration with the National Institute of Polar Research. Interdisciplinary and integrated research will be developed by collaborating with scientists in the fields of the upper atmosphere science and informatics. Highly versatile data such as long-term whole neutral atmosphere analysis data and observation data created or acquired in these studies will be released after the above-mentioned studies have been completed. Our studies are categorized as pure atmospheric physics. However, it is known that not a small percentage of the phenomena that have a large downward effect on the tropospheric climate, such as sudden stratospheric warming, start near the turbopause. Therefore, from the viewpoint of social returns, this research leads to improving the accuracy of the climate prediction model and extending the predictable period.

6. Funding Received

Principal Investigator

- MEXT KAKENHI (B), 22340134, FY2010-2012, 14,500,000 yen
- MEXT KAKENHI (A), 25247075, FY2013-2017, 26,700,000 yen
- MEXT KAKENHI (B), 18H01276, FY2018-2020, 12,200,000 yen
- JST CREST, JPMJCR1663, FY2016-2021, 180,913,000 yen
- The Sumitomo Foundation, FY2016-2017, 1,200,000yen

Host Researcher

- JSPS, Grand-in Aid for JSPS Fellows, 13F03734, FY2014-2015, 1,900,000 yen

Co-Investigator

- MEXT KAKENHI (B), 25287119, FY2013-2016, 1,000,000yen
- MEXT KAKENHI (B), 16H04048, FY2016-2020, 400,000 yen
- MEXT KAKENHI (B), 17H04578, FY2017-2019, 325,000yen

7. Publications and Patents

(1) Peer-reviewed Journal Articles

1. Tomikawa, Y., Sato, K., Watanabe, S., Kawatani, Y., Miyazaki, K., & Takahashi, M. (2012), Growth of planetary waves and the formation of an elevated stratopause after a major stratospheric sudden warming in a T213L256 GCM, *J. Geophys. Res.,* **117,** D16101. https://doi.org/10.1029/2011JD017243
2. Nishimura, K., Nakamura, T., Sato, T., & Sato, K. (2012), Adaptive Beamforming Technique for Accurate Vertical Wind Measurements with Multi-channel MST Radar, *J. Atmos. Oceanic Technol.,* **29,** 1769–1775. https://doi.org/10.1175/JTECH-D-11-00211.1
3. Kohma, M., & Sato, K. (2013), Simultaneous occurrence of polar stratospheric clouds and upper-tropospheric clouds caused by blocking anticyclones in the Southern Hemisphere, *Atmos. Chem. Phys.,* **13,** 3849-3864. https://doi.org/10.5194/acp-13-3849-2013
4. Yasuda, Y., and Sato, K. (2013), The effect of the horizontal component of the angular velocity of the Earth's rotation on inertia-gravity waves, *J. Meteor. Soc. Japan,* **91,** 23-41. https://doi.org/10.2151/jmsj.2013-102
5. Kohma, M., & Sato, K. (2013), Kelvin and Rossby waves trapped at boundaries under the full Coriolis force, *SOLA,* **9,** 9-14. https://doi.org/10.2151/sola.2013-003
6. Kinoshita, T., & Sato, K. (2013), A formulation of three-dimensional residual mean flow applicable both to inertia-gravity waves and to Rossby waves, *J. Atmos. Sci.,* **70,** 1577-1602. https://doi.org/10.1175/JAS-D-12-0137.1
7. Kinoshita, T., & Sato, K. (2013), A formulation of unified three-dimensional wave activity flux of inertia-gravity waves and Rossby waves, *J. Atmos. Sci.,* **70,** 1603-1615. https://doi.org/10.1175/JAS-D-12-0138.1

8. Geller, M. A., Alexander, M. J., Love, P. T., Bacmeister, J., Ern, M., Hertzog, A., Manzini, E., Preusse, P., Sato, K., Scaife, A. A., & Zhou, T. (2013), A Comparison Between Gravity Wave Momentum Fluxes in Observations and Climate Models, *J. Climate,* **26,** 6383-6405. https://doi.org/10.1175/JCLI-D-12-00545.1

9. Sato, K., Kinoshita, T., & Okamoto, K. (2013), A new method to estimate three-dimensional residual mean circulation in the middle atmosphere and its application to gravity-wave resolving general circulation model data, *J. Atmos. Sci.,* **70,** 3756–3779. doi: https://doi.org/10.1175/JAS-D-12-0352.1

10. Sato, K., Tsutsumi, M., Sato, T., Nakamura, T., Saito, A., Tomikawa, Y., Nishimura, K., Kohma, M., Yamagishi, H. & Yamanouchi, T. (2014) , Program of the Antarctic Syowa MST/IS Radar (PANSY), *J. Atmos. Solar-Terr. Phys.,* 118, PartA, 2-15.

    https://doi.org/10.1016/j.jastp.2013.08.022

11. Shibuya, R., Sato, K., & Nakanishi, M. (2014), Diurnal wind cycles forcing inertial oscillations: A latitude-dependent resonance phenomenon, *J. Atmos. Sci.,* 71, 767–781. https://doi.org/10.1175/JAS-D-13-0124.1

12. Kinoshita, T., & Sato, K. (2014), A formulation of three-dimensional residual mean flow and wave activity flux applicable to equatorial waves, *J. Atmos. Sci.,* 71, 3427-3438. https://doi.org/10.1175/JAS-D-13-0161.1

13. Kohma, M., & Sato, K. (2014), Variability of upper tropospheric clouds in the polar region during stratospheric sudden warmings, *J. Geophys. Res. Atmos.,* 119, 10,100-10,113. https://doi.org/10.1002/2014JD021746

14. Sakazaki, T., Sato, K., Kawatani, Y., & Watanabe S. (2015), Three-dimensional structures of tropical nonmigrating tides in a high-vertical-resolution general circulation model, *J. Geophys. Res. Atmos.,* **120,** 1759-1775. https://doi.org/10.1002/2014JD022464

15. Yasuda, Y., Sato, K., & Sugimoto, N. (2015), A Theoretical Study on the Spontaneous Radiation of Inertia-Gravity Waves Using the Renormalization Group Method. Part I: Derivation of the Renormalization Group Equations, *J. Atmos. Sci.,* 72, 957-983. https://doi.org/10.1175/JAS-D-13-0370.1

16. Yasuda, Y., Sato, K., & Sugimoto, N. (2015), A Theoretical Study on the Spontaneous Radiation of Inertia-Gravity Waves Using the Renormalization Group Method. Part II: Verification of the Theoretical Equations by Numerical Simulation, *J. Atmos. Sci.,* **72,** 984-1009. https://doi.org/10.1175/JAS-D-13-0371.1

17. Nishiyama, T., Sato, K., Nakamura, T., Tsutsumi, M., Sato, T., Kohma, M., Nishimura, K., Tomikawa, Y., Ejiri, M. K., & Tsuda, T.T. (2015), Height and time characteristics of seasonal and diurnal variations in PMWE based on 1 year observations by the PANSY radar (69.0°S, 39.6°E), *Geophys. Res. Lett.,* 42, 2100-2108. https://doi.org/10.1002/2015GL063349

18. Tomikawa, Y., Nomoto, M., Miura, H., Tsutsumi, M., Nishimura, K., Nakamura, T., Yamagishi, H., Yamanouchi, T. Sato, T. & Sato, K. (2015), Vertical Wind Disturbances during a Strong Wind Event Observed by the PANSY Radar at Syowa Station, Antarctica, *Mon. Wea. Rev.,* **143,** 1804-1821. https://doi.org/10.1175/MWR-D-14-00289.1

19. Shibuya, R., Sato, K., Tomikawa, Y., Tsutsumi, M. & Sato, T. (2015), A Study of Multiple Tropopause Structures Caused by Inertia-Gravity Waves in the Antarctic, *J. Atmos. Sci.,* **72,** 2109-2130. https://doi.org/10.1175/JAS-D-14-0228.1

20. Sato, K., & Nomoto, M. (2015), Gravity wave-induced anomalous potential vorticity gradient generating planetary waves in the winter mesosphere, *J. Atmos. Sci.,* **72,** 3609-3624. https://doi.org/10.1175/JAS-D-15-0046.1

21. Watanabe, S., Sato, K., Kawatani, Y. & Takahashi, M. (2015), Vertical resolution dependence of gravity wave momentum flux simulated by an atmospheric general circulation model, *Geosci. Model Dev.,* **8,** 1637-1644. https://doi.org/10.5194/gmd-8-1637-2015

22. Tomikawa, Y., Sato, K., Hirasawa, N., Tsutsumi, M., & Nakamura, T. (2015), Balloon-borne observations of lower stratospheric water vapor at Syowa Station, Antarctica in 2013, *Polar Sci.,* **9,** 345-353. https://doi.org/10.1016/j.polar.2015.08.003

23. Alexander, S. P., Sato, K., Watanabe, S., Kawatani, Y., & Murphy, D. J. (2016), Southern Hemisphere extra-tropical gravity wave sources and intermittency revealed by a middle atmosphere General Circulation Model, *J. Atmos. Sci.,* **73,** 1335-1349. https://doi.org/10.1175/JAS-D-15-0149.1

24. Yasui, R., Sato, K., & Tsutsumi, M. (2016), Seasonal and interannual variation of mesospheric gravity waves based on MF radar observations over 15 years at Syowa Station in the Antarctic, *SOLA,***12,** 46-50. http://doi.org/10.2151/sola.2016-010.

25. Mihalikova, M., Sato, K., Tsutsumi, M., & Sato, T. (2016), Properties of inertia-gravity waves in the lowermost stratosphere as observed by the PANSY radar over Syowa Station in the Antarctic, *Ann. Geophys.,* **34,** 543-555. https://doi.org/10.5194/angeo-34-543-2016

26. Amemiya, A., & Sato, K. (2016), A new gravity wave parameterization including three dimensional propagation, *J. Meteor. Soc. Japan,* **94,** 237-256. https://doi.org/10.2151/jmsj.2016-013

27. Minamihara, Y., Sato, K., Kohma, M. & Tsutsumi, M. (2016), Characteristics of vertical wind fluctuations in the lower troposphere at Syowa Station in the Antarctic revealed by the PANSY radar, *SOLA,* **12,** 116-120. http://doi.org/10.2151/sola.2016-026.

28. Sato, K., Tsuchiya, C., Alexander, M. J., & Hoffmann, L. (2016), Climatology and ENSO - related interannual variability of gravity waves in the southern hemisphere subtropical stratosphere revealed by high-resolution AIRS observations, *J. Geophys. Res. Atmos.,* **121,** 7622-7640. https://doi.org/10.1002/2015JD024462

29. Tsuchiya, C., Sato, K., Alexander, M. J., & Hoffmann, L. (2016), MJO-related intraseasonal variation of gravity waves in the southern hemisphere tropical stratosphere revealed by high-resolution AIRS observations, *J. Geophys. Res. Atmos.,* **121,** 7641-7651. https://doi.org/10.1002/2015JD024463

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31. Kinoshita, T., Sato, K., & Iwasaki, T. (2016), A formulation of three dimensional wave activity flux describing wave propagation on the mass-weighted isentropic time mean equation, *SOLA,* **12,** 198-202. https://doi.org/10.2151/sola.2016-040

32. Hirano, S., Kohma, M., & Sato, K. (2016), A three-dimensional analysis on the role of atmospheric waves in the climatology and interannual variability of stratospheric final warming in the Southern Hemisphere, *J. Geophys. Res. Atmos.,* **121,** 8429-8443. https://doi.org/10.1002/2015JD024481

33. Sato, K., Kohma, M., Tsutsumi, M. & Sato, T. (2017), Frequency spectra and vertical profiles of wind fluctuations in the summer Antarctic mesosphere revealed by MST radar observations, *J. Geophys. Res. Atmos.,* **122,** 3-19. https://doi.org/10.1002/2016JD025834

34. Hashimoto, T., Nishimura, K., Tsutsumi, M., Sato, K., & Sato, T. (2017), A user parameter-free diagonal-loading scheme for clutter rejection on radar wind profilers, *J. Atmos. Oceanic Technol.,* **34,** 1139-1153. https://doi.org/10.1175/JTECH-D-16-0058.1

35. Shibuya R., Sato, K., Tsutsumi, M., Sato, T., Tomikawa, Y., Nishimura, K. & Kohma, M. (2017), Quasi-12h inertia-gravity waves in the lower mesosphere observed by the PANSY radar at Syowa Station (39.6E, 69.0S), *Atmos. Chem. Phys.,* **17,** 6455-6476. https://doi.org/10.5194/acp-17-6455-2017

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49. Kinoshita, T., Sato, K., Ishijima, K., Takigawa, M., & Yamashita, Y. (2019), Formulation of three-dimensional quasi-residual mean flow balanced with diabatic heating rate and potential vorticity flux, *J. Atmos. Sci.,* **76,** 851–863. https://doi.org/10.1175/JAS-D-18-0085.1

(2) Non-peer-reviewed Articles

(3) Review Papers

1. Sato, K. (2019), The Program of the Antarctic Syowa MST/IS Radar (PANSY) and High-Resolution Middle Atmosphere Dynamics Study, TENKI, 66, 1-15, doi:10.24761/tenki66.1_5 (in Japanese)

(4) Books

(5) Other Publications

1. J. R. Fleming, Japanese translation by K. Sato (2017), Carl-Gustaf Rossby: Theorist, Institution Builder, von vivant, Parity, 32, 09, 14-22.

(6) Patents

8. Keynote, Invited, or Solicited Presentations

1. Sato, K., Kinoshita, T., & Okamoto, K., A new method to estimate three dimensional structure in the middle atmosphere circulation, WCRP Regional Workshop on Stratosphere-Troposphere Processes and their Role in Climate, Kyoto, Japan, 2013/4/2.
2. Sato, K., & Okamoto, K., Possible changes of atmospheric waves responding to changing earth's climate, International CAWSES II Symposium, Nagoya, Japan, 2013/11/20.
3. Sato, K., Tsutsumi, M., Sato, T., Nakamura, T., Saito, A., Tomikawa, Y., Nishimura, K., Kohma, M., Yamagishi, H., & Yamanouchi, T., Program of the Antarctic Syowa MST/IS Radar, Asia Oceania Geosciences Society (AOGS) 11th Annual Meeting, Sapporo, Japan, 2014/7/28.
4. Sato, K., Tsutsumi, M., Sato, T., Nakamura, T., Saito, A., Tomikawa, Y., Nishimura, K., Kohma, M., Yamagishi, H., & Yamanouchi T., Program of the Antarctic Syowa MST/IS Radar, The XXXI URSI General Assembly and Scientific Symposium (URSI GASS), Beijing, China, 2014/8/20.
5. Sato, K., & Masuda, A., A Study on the Structure of Barotropic/Baroclinic Instability in the Mesosphere Using a Gravity-wave Resolving General Circulation Model, AGU Fall Meeting, San Francisco, USA, 2014/12/17.
6. Sato, K., Nomoto, M., & Masuda, A., Gravity-wave induced anomalous potential vorticity gradient generating planetary waves in the winter mesosphere, 26th General Assembly of the International Union of Geodesy and Geophysics (IUGG), Prague, Czech Republic, 2015/6/29.
7. Sato, K., and Nomoto, M., Gravity-Wave Induced Anomalous Potential Vorticity Gradient Generating Planetary Waves in the Winter Mesosphere, 12th Annual Meeting Asia Oceania Geosciences Society (AOGS), Singapore, 2015/8/3.
8. Sato, K., On Interplay of Gravity Waves and Rossby Waves in the Middle Atmosphere.
Asian Conference on Meteorology (ACM), Kyoto, Japan, 2015/10/26.
9. Sato, K., Tsuchiya, C., Alexander, M. J., & Hoffmann, L., Interannual and intraseasonal variation

of gravity waves in the tropical stratosphere revealed by high-resolution AIRS observation, Second MS-GWaves Workshop, Schmitten, Germany, 2016/4/13.

10. Sato, K., Tsutsumi, M., Sato, T., Nakamura, T., Saito, A., Tomikawa, Y., Nishimura, K., Kohma, M., Nishiyama, T., Ejiri, M. K. ., Abo, M., Kawahara, T., Mizuno, A., Nagahama, T., & Suzuki, H., A study on earth climate change based on fine observations of the Antarctic atmosphere, Symposium on Gravity Waves, State College, USA, 2016/5/19.
11. Sato, K., Interhemispheric Coupling Study by Observations and Modelling (ICSOM), Japan Geoscience Union Meeting (JpGU) 2016, Makuhari, Japan, 2016/5/23.
12. Sato, K., Global change of the atmosphere associated with sudden Stratospheric warming in the Arctic, Japan-Norway Arctic Science & Innovation Week 2016, Tokyo, Japan, 2016/6/3.
13. Sato, K., The global atmosphere system explored by precise observations of the Antarctic atmosphere, The Seventh Symposium on Polar Science, Tokyo, Japan, 2016/12/1.
14. Sato, K., An interplay of Rossby waves and gravity waves in the general circulation of the middle atmosphere, MPI Klima Campus Kolloquium, Hamburg, Germany, 2017/5/11.
15. Sato, K., Kohma, M., Tsutsumi, M., & Sato T., Frequency spectra and vertical profiles of wind fluctuations in the summer Antarctic mesosphere revealed by MST radar observations, 15th International Workshop on Technical and Scientific Aspects of MST Radar, Tokyo, Japan, 2017/5/31.
16. Sato, K., Contribution of gravity waves to the mean meridional circulation and momentum budget in the middle atmosphere, Good Hope for Earth Science (IAPSO-IAMAS-IAGA Joint Assembly 2017), Cape Town, South Africa, 2017/8/30.
17. Sato, K., Mesospheric gravity waves revealed by a combination of radar observations and high resolution model simulation, Mats Science Meeting, Stockholm, Sweden, 2017/9/26.
18. Sato, K., Kohma, M., Nishimura, K., Tomikawa, Y., Tsutsumi, M., & Sato, T., Energy dissipation rate estimation based on observations by the PANSY radar in the Antarctic, Joint SPARC Dynamics & Observations Workshop (QBOi, FISAPS & SATIO-TCS), Kyoto, Japan, 2017/10/12.
19. Sato, K. & Hirano, S., Contribution of Gravity-Wave Forcing to the Brewer-Dobson Circulation. 10th Workshop on Long-term Changes and Trends in the Atmosphere, Hefei, China, 2018/5/14.
20. Sato, K. (Distinguished Lecture), Vertical and Interhemispheric Coupling in the Middle Atmosphere, 15th Annual Meeting Asia Oceania Geosciences Society, Honolulu, USA, 2018/6/6.
21. Sato, K., Yasui, R., & Miyoshi, Y., The momentum budget in the middle atmosphere based on a whole atmosphere model simulation over 11 years, COSPAR2018, Pasadena, USA, 2018/7/18.

5 Keynote and 4 invited presentations in Japanese conferences

III. Education Activity

9. Notable Achievements in Education

Advisees

- Master theses: 12 students

  Yoshikazu Kimoto, Masahiro Nomoto, Yuki Yasuda (Mar. 2013)

  Ryosuke Shibuya, Akihiro Masuda (Mar. 2014)

  Arata Amemiya, Soichiro Hirano (Mar. 2015)

  Yuki Hayashi, Ryosuke Yasui (Mar. 2016)

Yuichi Minamihara (Mar. 2017)

Dai Koshin, Shun Nakajima (Mar. 2018)

- Doctoral theses: 6 students

  Takenari Kinoshita (Sep. 2012)

  Masashi Kohma (Mar. 2013)

  Chikara Tsuchiya (Apr. 2013)

  Kota Okamoto (Sep. 2014)

  Ryosuke Shibuya (Oct. 2017)

  Arata Amemiya (Sep. 2018)

Lectures

- Undergraduate, Meteorology, FY2012-2018
- Undergraduate, Field observation for earth and planetary physics, FY2012-2018
- Undergraduate, Overview of earth and planetary physics, FY2013-2014
- Undergraduate/Graduate, Geophysical data analysis, FY2012-2016
- Graduate, Atmospheric Physics IV, FY2013, 2015, 2017

Student's awards

- The America Meteorological Society's 21th Symposium on Boundary Layers and Turbulence, the Best Student Oral Presentation award: [Ryosuke Shibuya]
- Incentive Award of the School of Science, the University of Tokyo: 3 students [Yuki Yasuda, Ryosuke Shibuya (twice)]
- Japan Geoscience Union, Student Presentation Award: 10 students [Kota Okamoto (twice), Ryosuke Shibuya (three times), Chikara Tsuchiya, Yuki Yasuda, Ryosuke Yasui, Shun Nakajima, Yuichi Minamihara]
- Society of Geomagnetism and Earth, Planetary and Space Sciences, Student Presentation Award (Aurora Medal): [Ryosuke Shibuya], Student Presentation Award: [Takenari Kinoshita, Yuki Hayashi]

IV. External Activities

10. Contribution to Academic Community

- Science Council of Japan, Member, FY2012-2018
- Science Council of Japan, Subcommittee on Future Plans for Earth Observation, Chair, FY2013-2018
- Science Council of Japan, Subcommittee on WCRP/SPARC, Chair, FY2014-2018
- Meteorological Society of Japan, Director, FY2012-2018
- Meteorological Society of Japan, Academic Committee Member, FY2012-2018
- Meteorological Society of Japan, Society Award Candidate Recommendation Committee, Member, FY2016-2017; Chair, FY2018.
- Meteorological Society of Japan, Human Resource Development and Gender Equality Committee, Chair, FY2012-2017

- Meteorological Society of Japan, Yamamoto Award Candidate Recommendation Committee, Chair， FY2013-2014, Member FY2015-2016
- Meteorological Society of Japan, Matsuno Award Candidate Recommendation Committee, Member FY2017-2018
- Japan Geoscience Union, Delegate, FY2012-2018
- Japan Geoscience Union, Director, FY2012-2013
- Japan Geoscience Union, Career Support Committee, Chair, FY2012-2013
- Japan Geoscience Union, Atmospheric and hydrospheric science section, Vice-President, FY2016-2018
- SPARC Gravity Wave Symposium, Co-convener, Pennsylvania State University, United States, 16-20 May, 2016.
- International Symposium on the Whole Atmosphere (ISWA), Co-convener, Tokyo, 14-16 September 2016.
- SPARC General Assembly 2018, LOC Co-chair, Kyoto, 1-5 October, 2018
- SPARC SSG meeting 2018, LOC chair, Kyoto, 6-8 October, 2018.

11. Outreach Activity

- Japan Meteorological Agency, Quality Evaluation Science Activity Committee, Member, FY2012
- Japan Meteorological Agency, Meteorological Research Institute, Board of Trustees, Member, FY2012-2018
- MEXT, Science, Technology and Academic Council, Expert Committee Member, FY2013-2014
- MEXT, Science, Technology and Academic Council, Temporary Committee Member, FY2015-2018
- MEXT, Earth Observation Promotion Subcommittee, Member, FY2015-2018
- MLIT, Transportation Policy Council, Member, FY2015-2018
- MLIT, Social Capital Development Council, Member, FY2015-2018
- SCOSTEP, CAWSES/CAWSES-II, Steering Group Member, FY2012-2013
- WCRP/WDAC member FY2013-2014
- WCRP/SPARC, SSG member, FY2013-2018
- WCRP/SPARC, Gravity wave activity, co-leader, FY2014-2018
- Lectures for general audience: 10 times (Apr. 2012, July 2012, Aug. 2013, Aug. 2013, Dec. 2013, Apr. 2013, Sep. 2015, Jan. 2016, Feb. 2016, Feb. 2017)
- Press Release: 5 times (June 2012, June 2013, Apr. 2015, Jan. 2017, Feb. 2019)

12. Internal Committee Membership

- The University of Tokyo, Planning and Coordination Subcommittee, Member, FY2012
- The University of Tokyo, Gap Term Working Group, Member, FY2012
- The University of Tokyo, Academic Planning Study Working Group, Member, FY2012
- The University of Tokyo, Gender Equality Room, Member, FY2012-2013

- School of Science, Adviser to the Dean, FY2012-2013
- School of Science, Gender Equality Room, Manager, FY2012-2013
- School of Science, Career Support Room, Manager, FY2012-2013
- School of Science, Career Support Office Steering Committee, Chair, FY2012-2013.
- School of Science, Gender Equality Committee, Chair, FY2012-2013; Member, FY2014-2016
- School of Science, Building Committee, Chair, FY2012-2013
- School of Science, Campus Planning Room Meeting, Member, FY2012-2013
- School of Science, Planning Room Meeting, Observer, FY2014
- School of Science, Education Committee, Member, FY2014-2016
- Department of Earth and Planetary Physics, Education Committee, Chair, FY2015-2016

V. International Exchange Activities

13. Hosting/Sending Foreign Students and Researchers

(1) Hosting

Foreign Students: 3

Foreign Researchers: 5

(2) Sending

Students: 22

Researchers: 1

(3) Visitors from Abroad: 61

Toshiyuki Hibiya

I. CV

Name: Toshiyuki Hibiya

Age: 62

Present Position: Professor

Education

Azabu High School, Tokyo, March 1975 (graduation)

B.S. Department of Geophysics, Faculty of Science, The University of Tokyo, March 1980

M.S. Department of Geophysics, Graduate School of Science, The University of Tokyo, March 1982

Ph.D. Department of Geophysics, Graduate School of Science, The University of Tokyo, September 1985

Professional Experience

Research Assistant: Department of Tsunami and Storm Surges, Earthquake Research Institute, The University of Tokyo, October 1985 – March 1987

Research Associate: Department of Tsunami and Storm Surges, Earthquake Research Institute, The University of Tokyo, April 1987 – February 1992

- Postdoctoral Research Associate: Department of Oceanography, University of British Columbia, B.C., Canada, May 1989 – April 1990
- Postdoctoral Research Associate: Geophysics Program, University of Washington, WA, U.S.A., May 1990 – April 1991

Associate Professor: Division of Earth and Planetary Sciences, Graduate School of Science, Hokkaido University, March 1992 – September 1995

Associate Professor: Center for International Cooperation, Ocean Research Institute, The University of Tokyo, October 1995 – October 1998

Associate Professor: Department of Earth and Planetary Physics, Graduate School of Science, The University of Tokyo, November 1998 – March 2000

Professor: Department of Earth and Planetary Science, Graduate School of Science, The University of Tokyo, April 2000 – Present

II. Scientific Research Activity

2. Major Achievements

The main objective of my research group is to make a significant breakthrough in modeling the general ocean circulation and/or ocean-atmosphere interactions by introducing updated subgrid-scale information such as turbulent mixing throughout the water column from the sea surface down to the seabed in the deep ocean. These updates are based on observational data including the ones in the Indonesian Archipelago and the Southern Ocean where microstructure observations have not been fully made. Major achievements during the last 7 years follow:

(1) Accurate modeling of the upper ocean response through improved parameterization of mixed layer dynamics

The fact that the Mellor-Yamada (MY) model underestimates the intensity of turbulent mixing in the atmospheric boundary layer lead to the construction of the Nakanishi-Niino (NN) model which modifies MY's formulation of the turbulent length scale. The assessment of NN model, however, was limited to the atmosphere and not yet fully examined in the ocean. We have, therefore, incorporated NN model into coupled ocean-atmosphere models to check its performance and found that, for example, the prediction of the growth and decay of the typhoon can be much improved.

(2) Improvement of fine-scale parameterizations of turbulent dissipation rates in the interior ocean

Based on the results of the simultaneous microscale and fine-scale observations in the interior ocean, we have checked the validity of the existing fine-scale parameterizations of turbulent dissipation rates, namely, Gregg's parameterization (shear-based parameterization), Wijesekera et al.'s parameterization (strain-based parameterization), and Gregg-Henyey-Polzin (GHP) parameterization (shear- and strain-based parameterization). We have found that, although GHP parameterization produces the most accurate estimates of turbulent dissipation rates in the interior ocean, there exists inconsistency in the derivation of their frequency-based correction. We have explored the possibility of further improvements of GHP parameterization to formulate the revised version termed Ijichi-Hibiya (IH) parameterization.

(3) A new parameterization of tidal mixing enhanced over rough seafloor topography for next-generation global circulation models

It is believed that tidal interaction with rough seafloor can create mixing hotspots extending higher up off the seafloor. Although there exist several parameterizations of tidal mixing enhanced over rough seafloor, they do not take into account the fact that the internal waves emanating from rough seafloor transform from internal tidal waves to quasi-steady internal lee waves as tide-topography interaction strengthens. Taking into account this fact, we have formulated a new parameterization of tidal mixing enhanced over rough seafloor in which the vertical decay scale of energy dissipation rates is estimated by multiplying the theoretically obtained vertical group velocity of quasi-steady internal lee waves by the time scale of their nonlinear interaction (induced diffusion) with the background Garrett-Munk internal wave field. The resulting equation has explicitly shown that the vertical decay scale of energy dissipation rates becomes independent of horizontal wavenumber of seafloor topography, but proportional to tidal flow amplitude squared, which is consistent with the result of eikonal experiments for quasi-steady internal lee waves emanating from rough seafloor.

(4) Microstructure observations in the Indonesian Seas (Feb.-Mar. 2019)

We carried out the first extensive microstructure measurements (120 casts of Vertical Microstructure Profilers) covering the whole Indonesian Seas where strong tidal mixing plays important roles in controlling the Indonesian Throughflow and air-sea interaction processes, both of which are strongly linked to the global climate. Through preliminary data analysis, we have found that vigorous turbulent mixing ($\varepsilon \sim 10^{-5}$ W/kg) occurs in the narrow straits (e.g. Lombok, Sape, Manipa, and Halmahera straits) that are major internal tide generation regions, whereas turbulent mixing is fairly weak, comparable to open-ocean mixing ($\varepsilon < 10^{-10}$ W/kg), away from these narrow straits. The observed temperature-salinity profiles have shown that significant water-mass transformations also occur quite locally in these narrow straits.

(5) Microstructure observations in the Southern Ocean (Jan.-Feb. 2016, Dec. 2017-Jan. 2018)

Simultaneous microscale and fine-scale observations were carried out in the south of Australia to assess the validity of the existing fine-scale parameterizations of deep ocean mixing in the Antarctic Circumpolar Current (ACC) region where mesoscale eddies coexist with the background internal wave field. We have found that the vertical wavenumber spectra of shear and strain in the ACC region have humps at low wavenumbers (vertical wavenumber $m \sim 0.01$ cpm), causing the existing fine-scale parameterizations to overestimate turbulent dissipation rates. It has been suggested that humps in shear spectra are created by downward-propagating near-inertial internal wave packets trapped by the mesoscale eddies, whereas humps in strain spectra are created by bottom-generated high-frequency internal lee wave packets.

(6) A new approach for large offshore tsunami detection using airborne radar altimetry

We have investigated the accuracy of sea surface height (SSH) data obtained by airborne radar observations to investigate the feasibility of using airborne radar in the early detection of large offshore tsunamis. The airborne measurements were carried out three times over the Pacific Ocean side of Japan. The concurrent use of GNSS and geoid and tide models enabled us to detect the Kuroshio Current along the flight track. Through a comparison with the satellite SSH data from Jason-2 or Jason-3, we have confirmed that our airborne radar measurements can capture the SSH with less than a 10 cm error. This level of error is sufficiently small to capture the signal of large offshore tsunamis. This is the first study to demonstrate the feasibility of such a real-time tsunami detection system using an airborne radar altimeter. For real-time tsunami forecasting, the use of commercial airplanes to undertake concurrent multiple measurements is recommended. Constructing the large-scale observation network by commercial airplanes is expected to improve the accuracy and reliability of real-time tsunami forecasting.

3. Five Important Papers (including three or more papers in this review period)

1. Hibiya, T., T. Ijichi, and R. Robertson: The impacts of ocean bottom roughness and tidal flow amplitude on abyssal mixing, *Journal of Geophysical Research Oceans*, **122**, 5645-5651, doi:10.1002/2016JC012564, 2017.

In the context in which diapycnal mixing enough to sustain the global overturning circulation is missing in the ocean interior, we have theoretically pointed out the possibility that, under certain conditions, internal lee waves emanate from the seafloor and create mixing hotspots extending higher up into the thermocline to make up for the shortage of diapycnal mixing in the ocean interior. (Citation 2, GS/Oct.10, 2019)

2. Nagai, T., and T. Hibiya: Internal tides and associated vertical mixing in the Indonesian Archipelago, *Journal of Geophysical Research Oceans*, **120**, 3373-3390, doi:10.1002/2014JC010592, 2015.

Using a high-resolution numerical model, we have calculated the generation, propagation, and dissipation of internal tide energy to predict the horizontal and vertical distribution of turbulent dissipation rates in the whole Indonesian Archipelago. The obtained results served as a useful guideline to make a plan of the first microstructure observation covering the whole Indonesian Archipelago carried out in 2019 to examine the important role of this region in controlling the global climate. (Citation 30, GS/Nov.6, 2019)

3. Hibiya, T., N. Furuichi, and R. Robertson: Assessment of fine-scale parameterizations of turbulent dissipation rates near mixing hotspots in the deep ocean, *Geophysical Research Letters*, **39**, L24601, doi:10.1029/2012GL054068, 2012.

On the basis of the results from simultaneous microscale and fine-scale observations in the various regions in the North Pacific, we have assessed the applicability of the existing fine-scale parameterizations of turbulent dissipation rates to the real ocean and confirmed that the Gregg-Henyey-Polzin parameterization most accurately estimates turbulent dissipation rates by compensating for deviations of internal wave spectra from Garrett-Munk in terms of the information of both fine-scale shear and strain. (Citation 19, GS/Oct.10, 2019)

4. Hibiya, T., and M. Nagasawa: Latitudinal dependence of diapycnal diffusivity in the thermocline estimated using a finescale parameterization, *Geophysical Research Letters*, **31**(1), L01301, doi:10.1029/2003GL017998, 2004.

This is the first observational study showing that the intensity of turbulent mixing in the ocean interior is strongly latitude-dependent as expected from the theoretical study by Hibiya et al. (2002) (see the item 5. below). This observational study lead to the publication of the first global mapping of diapycnal diffusivity averaged over a depth range of 500-1500 m (Hibiya et al., *Geophysical Research Letters*, **33**, L03611, doi:10.1029/2005GL025218, 2006). Note that this is part of the research awarded "The Society Prize of the Oceanographic Society of Japan" in 2008. (Citation 76, GS/Oct.10, 2019)

5. Hibiya, T., M. Nagasawa, and Y. Niwa: Nonlinear energy transfer within the oceanic internal wave spectrum at mid and high latitudes, *Journal of Geophysical Research*, **107**(C11), 3207, doi:10.1029/2001JC001210, 2002.

This is the first theoretical and numerical study showing that turbulent mixing in the ocean interior mainly results from the cascade of internal tide energy through the background Garrett-Munk spectrum to dissipation scales dominated by the mechanism of *parametric subharmonic instability*. Note that this is part of the research awarded "The Society Prize of the Oceanographic Society of Japan" in 2008. (Citation 101, GS/Oct.10, 2019)

4. Awards and Honors

- The Hidaka Outstanding-Publication Award of the Oceanographic Society of Japan (2013); "Estimation of internal tide energy available for deep ocean mixing based on three-dimensional global numerical simulations", *Journal of Oceanography*, **67**, 493-502, doi:10.1007/s10872-011-0052-1, 2011 (Niwa, Y., and T. Hibiya)
- The Hidaka Outstanding-Publication Award of the Oceanographic Society of Japan (2014); "Numerical study of tide-induced mixing over tough bathymetry in the abyssal ocean", *Journal of Oceanography*, **68**, 195-203, doi:10.1007/s10872-001-0088-2, 2012 (Iwamae, N., and T. Hibiya)

5. Future Research Plan

(1) Mapping of diapycnal diffusivity in the world's oceans to be incorporated into global circulation models.

Although we have succeeded in re-formulating the fine-scale parameterizations of turbulent dissipation rates in the surface mixed layer, in the interior ocean, and over rough seafloor topography, respectively, their validations are still limited. We therefore plan to deploy a free-fall microstructure profiler called VMP-X that can profile turbulent dissipation rates from the sea surface down to the seabed at ~5000 m depth. Once validated, these parameterizations, incorporated with fine-scale parameters for each domain in the global oceans, would supplement the global distribution of diapycnal diffusivities needed to improve the model's capability and skill to predict future climate changes.

(2) Quantification of tidal mixing intensity in the Indonesian Archipelago for accurate modeling of global climate system

Through the continuing analysis of the microstructure data obtained in 2019, we will quantify turbulent mixing in the whole Indonesian Seas, which is then incorporated into coupled ocean-atmosphere models to evaluate the important role of the Indonesian Seas in controlling the global climate.

(3) *In-situ* observations to assess the theoretically-predicted important role of Koshu-Seamount in the dynamics of the Kuroshio meander

We showed numerically and theoretically that Koshu-Seamout located off Kii Peninsula plays an important role in the transition to the large meander path of the Kuroshio. In order to check the validity of this theoretical prediction, we would like to carry out in-situ observations near Koshu-Seamount.

6. Funding Received

(1) JSPS Grants

- Grant-in-Aid for Scientific Research (A), Grant Number JP18H03731: "Quantification of tidal mixing intensity in the Indonesian Archipelago for accurate modeling of global climate system", (Principal Investigator, 2018-2020, 44,070,000 JPY)
- Grant-in-Aid for Challenging Research (Exploratory), Grant Number JP18K18781: "Construction of the fast and accurate tsunami prediction system using commercial airplanes", (Principal Investigator, 2018-2020, 6,370,000 JPY)
- Grant-in-Aid for Scientific Research (A), Grant Number JP17H01663: "Study of the physical, chemical and biological characteristics of the upwelling area in the east Indian Ocean", (Co-Investigator, 2017-2020, 2,900,000 JPY)
- Grant-in-Aid for Scientific Research on Innovative Areas (Research in a Proposed Research Area) (Planning research), Grant Number JP15H05824: "Dynamical analysis of diapycnal mixing processes in the ocean toward the formulation of their accurate parameterizations", (Principal Investigator, 2015–2019, 107,900,000 JPY)
- Grant-in-Aid for Scientific Research on Innovative Areas (Research in a Proposed Research Area) (Administration), Grant Number JP15H05817: "Ocean Mixing processes: Impact on Biogeochemistry, Climate and Ecosystem", (Co-Investigator, 2015-2019, 19,200,000 JPY)
- Grant-in-Aid for Scientific Research (A), Grant Number JP15H02131: "Quantification of mixing hotspots in the Southern Ocean for accurate modeling of the global overturning circulation", (Principal Investigator, 2015-2017, 42,250,000 JPY)
- Grant-in-Aid for Scientific Research (A), Grant Number JP26257208: "Quantification of tidal mixing in the Indonesian Archipelago and its impact on the global climate", (Principal Investigator, 2014–2016, 40,690,000 JPY)
- Grant-in-Aid for Scientific Research (A), Grant Number JP25247074: "Ocean bottom pressure gauge array for studying phenomena involving the ocean and solid Earth as a system", (Co-Investigator, 2013-2016, 1,300,000 JPY)
- Grant-in-Aid for Scientific Research (B), Grant Number JP24340109: "Accurate parameterization of turbulent mixing processes in the abyssal ocean for embedding in next-generation global overturning circulation models", (2012-2014, 18,720,000 JPY)
- Grant-in-Aid for Scientific Research (B) (2010–2012, 4,030,000 JPY) "Clarification of deep water circulation in the Japan Sea on the basis of the results of direct measurements of abyssal turbulent mixing and chemical tracer experiments", (Co-Investigator, 2010-2012, (1,820,000 JPY for 2012))
- Grant-in-Aid for Challenging Exploratory Research, Grant Number JP23654165: "Improvement of ocean mixed layer model toward the accurate prediction of global warming", (Principal Investigator, 2011-2012, (780,000 JPY for 2012))

(2) Cooperative Research

- Joint Research Program on Earth Environment Dynamics in the Research Institute for Applied Mechanics of Kyushu University, Japan, "*Observational and modeling studies of ocean turbulence*", (Principal Investigator, 2010–2012, 726,000 JPY)

7. Publications and Patents

(1) Peer-reviewed Journal Articles

1. Onuki Y., and T. Hibiya: Parametric subharmonic instability in a narrow-band wave spectrum, *Journal of Fluid Mechanics*, **865**, 247-280, doi:10.1017/jfm.2019.44, 2019.
2. Takahashi A., and T. Hibiya: Assessment of finescale parameterizations of deep ocean mixing in the presence of geostrophic current shear: Results of microstructure measurements in the Antarctic Circumpolar Current Region, *Journal of Geophysical Research*, **124**, doi:10.1029/2018JC014030, 2019.
3. Yang, W., T. Hibiya, Y. Tanaka, L. Zhao, and H. Wei: Modification of parametric subharmonic instability in the presence of background geostrophic currents, *Geophysical Research Letters*, **45**, 12957-12962, doi:10.1029/2018GL080183, 2018.
4. Onuki, Y., and T. Hibiya: Decay rates of internal tides estimated by an improved wave-wave interaction analysis, *Journal of Physical Oceanography*, **48**, 2689-2701, doi:10.1175/JPO-D-17-0278.1, 2018.
5. Inazu, D., T. Ikeya, T. Waseda, T. Hibiya, and Y. Shigihara: Measuring offshore tsunami currents using ship navigation records, *Progress in Earth and Planetary Science*, **5:38**, https://doi.org/10.1186/s40645-018-0194-5, 2018.
6. Ijichi, T., and T. Hibiya: Observed variations in turbulent mixing efficiency in the deep ocean, *Journal of Physical Oceanography*, **48**, 1815-1830, doi:10.1175/JPO-D-17-0275.1, 2018.
7. Endoh, T., D. Inazu, T. Waseda, and T. Hibiya: A parameter quantifying radiation damping of bay oscillations excited by incident tsunamis, *Continental Shelf Research*, **157**, 10-19, doi:10.1016/j.csr.2018.02.007, 2018.
8. Watanabe, M., and T. Hibiya: A near-inertial current event in the homogeneous deep layer of the northern Sea of Japan during winter, *Journal of Oceanography*, **74**, 209-218, doi:10.1007/s10872-017-0451-z, 2018.
9. Nagai, T., T. Hibiya, and P. Bouruet-Aubertot: Non-hydrostatic simulations of tide-induced mixing in the Halmahera Sea: A possible role in the transformation of the Indonesian Throughflow waters, *Journal of Geophysical Research*, **122**, 8933-8943, doi:10.1002/2017JC013381, 2017.
10. Tanaka, Y. and T. Hibiya: Effects of Koshu Seamount on the development of baroclinic instability leading to the Kuroshio large meander, *Journal of Physical Oceanography*, **47**, 2563-2576, doi:10.1175/JPO-D-17-0050.1, 2017.
11. Hibiya, T., T. Ijichi, and R. Robertson: The impacts of ocean bottom roughness and tidal flow amplitude on abyssal mixing, *Journal of Geophysical Research*, **122**, 5645-5651, doi:10.1002/2016JC012564, 2017.
12. Ijichi, T., and T. Hibiya: Eikonal calculations for energy transfer in the deep-ocean internal wave field near mixing hotspots, *Journal of Physical Oceanography*, **47**, 199-210, doi:10.1175/JPO-D-16-0093.1, 2017.
13. Inazu, D., T. Waseda, T. Hibiya, and Y. Ohta: Assessment of GNSS-based height of multiple ships for measuring and forecasting great tsunamis, *Geoscience Letters*, **3:25**, doi:10.1186/s40562-016-0059-y, 2016.
14. Nishina, A., H. Nakamura, J.-H. Park, D. Hasegawa, Y. Tanaka, S. Seo, and T. Hibiya: Deep ventilation in the Okinawa Trough induced by Kerama Gap overflow, *Journal of Geophysical Research*, **121**, 6092-6102, doi:10.1002/2016JC011822, 2016.
15. Tanaka, Y., T. Hibiya, and H. Sasaki: Downward lee wave radiation from tropical instability

waves in the central equatorial Pacific Ocean: A possible energy pathway to turbulent mixing, *Journal of Geophysical Research*, **120**, 7137-7149, doi:10.1002/2015JC011017, 2015.

16. Ijichi, T., and T. Hibiya: Frequency-based correction of finescale parameterization of turbulent dissipation in the deep ocean, *Journal of Atmospheric and Oceanic Technology*, **32**, 1526-1535, doi:10.1175/JTECH-D-15-0031.1, 2015.
17. Matsuno, T., T. Endoh, T. Hibiya, T. Senjyu, and M. Watanabe: Formation of the well mixed homogeneous layer in the bottom water of the Japan Sea, *Journal of Oceanography*, **71**, 441-447, doi:10.1007/s10872-015-0303-7, 2015.
18. Nagai, T., and T. Hibiya: Internal tides and associated vertical mixing in the Indonesian Archipelago, *Journal of Geophysical Research*, **120**, 3373-3390, doi:10.1002/ 2014JC010592, 2015.
19. Furuichi, N., and T. Hibiya: Assessment of the upper-ocean mixed layer parameterizations using a large eddy simulation model, *Journal of Geophysical Research*, **120**, 2350–2369, doi:10.1002/ 2014JC010665, 2015.
20. Onuki, Y., and T. Hibiya: Excitation mechanism of near-inertial waves in baroclinic tidal flow caused by parametric subharmonic instability, *Ocean Dynamics*, **65**, 107-113, doi:10.1007/s10236-014-0789-3, 2015.
21. Falahat, S., J. Nycander, F. Roquet, A.M. Thurnherr, and T. Hibiya: Comparison of calculated energy flux of internal tides with microstructure measurements, *Tellus A*, **66**, 23240, http://dx.doi.org/10.3402/tellusa. v66.23240, 2014.
22. Niwa, Y., and T. Hibiya: Generation of baroclinic tide energy in a global three-dimensional numerical model with different spatial grid resolutions, *Ocean Modelling*, **80**, 59-73, doi:10.1016/j.ocemod.2014.05.003, 2014.
23. Nagai, T., and T. Hibiya: Effects of tidally induced eddies on sporadic Kuroshio-water intrusion (kyucho), *Journal of Oceanography*, **69**, 369-377, doi:10.1007/ s10872-013- 0179-3, 2013 (**Received "The Young Author Award" from the Oceanographic Society of Japan**)
24. Watanabe, M., and T. Hibiya: Assessment of mixed layer models embedded in an ocean general circulation model, *Journal of Oceanography*, **69**, 329-338, doi:10.1007/ s10872- 013-0176-6, 2013.
25. Hibiya, T., N. Furuichi, and R. Robertson: Assessment of fine-scale parameterizations of turbulent dissipation rates near mixing hotspots in the deep ocean, *Geophysical Research Letters*, **39**, L24601, doi:10.1029/2012GL054068, 2012.
26. Nagai, T., and T. Hibiya: Numerical simulation of tidally induced eddies in the Bungo Channel: A possible role for sporadic Kuroshio-water intrusion (kyucho), *Journal of Oceanography,* **68**, 797-806, doi:10.1007/ s10872-012- 0141-9, 2012.
27. Furuichi, N., T. Hibiya, and Y. Niwa: Assessment of turbulence closure models for resonant inertial response in the oceanic mixed layer using a large eddy simulation model, *Journal of Oceanography,* **68**, 285-294, doi.10.1007/s10872-011-0095-3, 2012.
28. Iwamae, N., and T. Hibiya: Numerical study of tide-induced mixing over tough bathymetry in the abyssal ocean, *Journal of Oceanography*, **68**, 195-203, doi:10.1007/ s10872-001- 0088-2, 2012 (**Received "The Hidaka Outstanding-Publication Award" from the Oceanographic Society of Japan**)

(2) Non-peer-reviewed Articles

1. Hirobe, T., Y. Niwa, T. Endoh, I. E. Mulia, H. Tatehata, D. Inazu, A. Nadai, T. Yoshida, T. Waseda, and T. Hibiya, Observations of sea surface heights using an airborne radar altimeter for great

tsunamis detection in offshore (in Japanese), *Proceedings of The Japan Society of Naval Architects and Ocean Engineers*, **24**, 2017S-GS15-2, 621-624, 2017.

2. Inazu, D, T. Waseda, T. Hibiya, and Y. Ohta, GNSS-based height positioning of multiple ships derived from AIS data for measuring and forecasting great tsunamis (in Japanese), *Proceedings of The Japan Society of Naval Architects and Ocean Engineers*, **22**, 2016S-GS4-9, 365-368, 2016.

(3) Review Papers

1. Oka, E., A. Isobe, K. Ichikawa, Y. Masumoto, T. Suga, K. Kawai, K. I. Ohshima, K. Shimada, H. Hasumi, S. Minobe, T. Waseda, N. Iwasaka, M. Kawamiya, S. Itoh, M. Kubota, T. Nakano, T. Hibiya, and H. Yoritaka, Decadal vision in Oceanography (I) – Discussions in the physical oceanography subgroup of the future planning committee, The Oceanographic Society of Japan – (in Japanese with English Abstract), *Oceanography in Japan*, **22** (6), 191-218, 2013.
2. Hibiya, T., Y. Tanaka, T. Nagai, T. Ijichi, T. Takagi, Challenging study of turbulenct mixing in the deep ocean using the first Multi-Scale Profiler in Japan (in Japanese), *Kaiyo Monthly*, **45** (1), 57-63, 2013.

(4) Books

1. Hibiya, T., Internal waves and density currents in the coastal ocean (in Japanese), in, *Details of Coastal Oceanography*, Chapter 4 (pp.61-80), The 50th Anniversary Special Issue edited by Coastal Oceanography Research Committee, The Oceanographic Society of Japan, *Koseisha-Koseikaku*, 261 pp., 2014

(5) Other Publications

None

(6) Patents

None

8. Keynote, Invited, or Solicited Presentations

(1) Invited Talk at International Conferences

1. Hibiya, T., Global mapping of abyssal turbulence intensity using Deep Argo floats, The Sixth Argo Science Workshop (ASW-6) "The Argo Program in 2020 and beyond: Challenges and opportunities", Tokyo, Japan, October 24, 2018.
2. Hibiya, T., What we have learned about deep ocean mixing in the past 20 years, Munk Centennial May Symposium, La Jolla, USA, May 17, 2017.
3. Inazu, D., T. Waseda, and T. Hibiya: Measuring great tsunamis using GNSS-based ship height positioning and its use for early warning, 9th ACES International Workshop, Chengdu, China, August 13, 2015.

(2) Invited Talk at Domestic Conferences

1. Hibiya, T., “Global deployment of Deep Argo floats toward accurate prediction of future climate and ecosystem changes” (in Japanese), Hearings on 2020 Japanese Master Plan of Large Research Projects in Earth and Planetary Science, Science Council of Japan, Tokyo, Dec. 28, 2018.
2. Hibiya, T., “Global overturning circulation driven by the moon – Challenge to the mystery in the deep ocean” (in Japanese), Special Colloquium at Marine Ecology Research Institute, Chiba, Dec. 17, 2018.

3. Hibiya, T. and T. Nagai, "Study of internal gravity waves causing tidal mixing over floor topography" (in Japanese), Symposium at the Oceanographic Society of Japan Fall Meeting, Sep. 25, 2018
4. Hibiya, T., "Elucidation of tidal mixing processes over rough seafloor topography - Toward accurate modeling of global overturning circulation" (in Japanese), Japan Meteorological Agency, May 28, 2018.
5. Inazu, D., T. Ikeya, T. Waseda, T. Hibiya, and Y. Shigihara, "Measuring offshore tsunami currents using ship navigation records" (in Japanese), 2018 Japan Geoscience Union Annual Meeting, Makuhari, Chiba, May 24, 2018.
6. Hibiya, T., "Global deployment of Deep Argo floats toward accurate prediction of future climate and ecosystem changes" (in Japanese), The Japan Argo Promotion Committee, Tokyo, Japan Meteorological Agency, Tokyo, Jul. 24, 2017.
7. Hibiya, T., "Theoretical and observational studies of turbulent mixing in the deep ocean" (in Japanese), Commemorative Symposium for the Launch of the Center for East Asian Ocean-Atmosphere Research of the Research Institute for Applied Mechanics of Kyushu University, Jul. 14, 2017.
8. Hibiya, T., "Interest and perspective of the Oceanographic Society of Japan" (in Japanese), Symposium at the 2017 Japanese Society of Fisheries Oceanography, Mar. 22, 2017.
9. Hibiya, T., "Global deployment of Deep Argo floats toward accurate prediction of future climate and ecosystem changes" (in Japanese), 2016 Japan Geoscience Union Annual Meeting, Makuhari, Chiba, May 24, 2016.
10. Hibiya, T., "Theoretical and Observational studies of turbulent mixing in the deep ocean" (in Japanese), 2015 Geophysical Fluid Dynamics Seminar, Lake Shikotsu Seminar House, Hokkaido, Aug. 17-20, 2015.

(3) Keynote Speech

1. Hibiya, T., "What we have learned about deep ocean mixing in the last decade" (in Japanese), The 3rd OMIX YMR Summer School, Kanpo-no-Yado, Atami, Shizuoka, Oct. 8, 2018.

III. Education Activity

9. Notable Achievements in Education

(1) Advisees

I have supervised so far 36 M.Sc. students and 12 Ph.D. students; 11 graduates out of them are now engaged in scientific pursuit at universities and government/private research institutions including Dr. T. Endoh (Associate Professor, Research Institute for Applied Mechanics, Kyushu University: 2017~), Dr. Y. Niwa (Project Associate Professor, Marine Education Center, Graduate School of Education, The University of Tokyo: 2019~), Dr. Y. Tanaka (Assistant Professor, Department of Earth and Planetary Science, The University of Tokyo: 2012~), and Dr. Y. Onuki (Assistant Professor, Research Institute for Applied Mechanics of Kyushu University: 2017~).

(2) Lectures

I have given lectures shown below during 2012-2018. In particular, my undergraduate course lecture "Physical Oceanography" was constantly highly rated (more than 4.5 out of 5) by attending students. In addition, I have given 12 delivery lectures in total at various Junior and Senior High Schools nationwide during the last 7 years. Furthermore, I visited the Department of Oceanography, Udayana University, Indonesia in 2016 to give a lecture entitled "How is the Global Overturning Circulation driven?”

- Graduate, Physical Oceanography I, FY2012, FY2014, FY2016, FY2018
- Graduate, Seminar in Marine Affairs I, FY2013-2018
- Graduate, Basic Ocean Sciences, FY2012-2018
- Graduate, Field Work in Marine Science I, FY2013-2018
- Undergraduate, Physical Oceanography, FY2012-2018
- Undergraduate, Introduction to Earth and Planetary Physics, FY2014-2015
- Undergraduate, Observation Exercises in Earth and Planetary Physics, FY2012-2018
- Undergraduate, Academic Frontier Lecture Series, "Introduction to Earth and Planetary Science", FY2012-2014
- Undergraduate, Academic Frontier Lecture Series, "The Frontier of Marine Research”, FY2012-2014, FY2016-2018

(3) Student’s awards

Several graduate students in my laboratory were awarded during the last 7 years (see below). All of these graduate students successfully got postdoc positions in the USA (Woods Hole Oceanographic Institution, Applied Physics Laboratory of the University of Washington) and Europe (Ecole Normale Superieure de Lyon).

- The School of Science Encouragement Award of the University of Tokyo:
  Y. Onuki (2013 M.Sc.), T. Ijichi (2015 Ph.D.), Y. Onuki (2016 Ph.D.)
- The Outstanding Student Presentation Award of the Japan Geoscience Union:
  A. Takahashi (2016, 2018)
- The Outstanding Student Presentation Award, The Oceanographic Society of Japan:
  Y. Onuki (2015, 2016)
- Sasagawa Young Scientist Award:
  T. Ijichi (2015)

I also supervised one Chinese Ph.D. student during Dec. 2015 - Dec. 2017 and am now supervising one Chinese M.Sc. student and one Korean research student. I continued to supervise the Chinese student’s Ph.D. thesis via Skype even after he went back to China. His Ph.D. thesis was highly evaluated in China, and he successfully got a Research Assistant position at Tianjin University after he was awarded Ph.D. in 2018.

IV. External Activities

10. Contribution to Academic Community

(1) Journals editorships, etc.

- Editorial Board, *Frontiers in Marine Science*, Nov. 2018-Present
- Editorial Board, *Progress in Earth and Planetary Science*, Jun. 2013-Mar. 2018
- Editorial Board, *Geoscience Letters*, Aug. 2012-Aug. 2016
- Editor-in-Chief, *Journal of Oceanography*, Apr. 2011- Mar. 2015

(2) Academic Societies (International)

- Executive Committee Member, the International Association for the Physical Sciences of the Oceans (IAPSO), Jun. 2011–Jul. 2019
- President, Ocean Sciences Section of the Asia Oceania Geosciences Society (AOGS), Aug. 2012–Aug. 2014
- Vice-President, Ocean Sciences Section of the Asia Oceania Geosciences Society (AOGS), Aug. 2011–Aug. 2012, Aug. 2014.-Aug. 2015

(3) Academic Societies (Domestic)

- President, The Oceanographic Society of Japan, Apr. 2015-Mar.2019
- Councilor, The Oceanographic Society of Japan, Apr. 1997-Mar. 2015
- Officer, The Oceanographic Society of Japan, Apr. 1997-Mar.2001, Apr. 2003-Mar.2007, Apr. 2011-Mar. 2015
- Member, Awards Committee, The Oceanographic Society of Japan, Apr. 2008-Mar. 2010, Apr. 2012-Mar. 2014
- Member, Coastal Oceanography Research Committee, The Oceanographic Society of Japan, Apr. 1991-Present
- Delegate for General Affairs, Japan Geoscience Union (JpGU), May 2018-Present
- Director for International Affairs, Japan Geoscience Union (JpGU), May 2014-Present
- Member, Global Strategy Committee, Japan Geoscience Union (JpGU), Jun. 2014-May 2018
- Executive Committee Chairman, Japan Geoscience Union (JpGU) 2016 Annual Meeting, Jul. 2015-May 2016
- President, Academic Society Presidents Meeting of the Japan Geoscience Union (JpGU), Jul. 2015-May 2016
- Science Board Member, Japan Geoscience Union (JpGU), Jun. 2012–May 2013
- Member, General Affairs Committee, Japan Society of Ocean Policy, Apr. 2013-Present
- Director, Japan Society of Ocean Policy, Dec. 2014-Dec. 2018

(4) Conveners of Conferences

- Co-Convener, “Ocean Mixing Processes: Impact on Biogeochemistry, Climate, and Ecosystem”, *The 2018 Fall Meeting of the Oceanographic Society of Japan*, Tokyo University of Marine Science and Technology, Sep. 29, 2018
- Co-Convener, “Turbulence, Internal Waves, and Mixing on All Scales”, *The IAPSO-IAMAS-IAGA Joint Assembly*, The Cape Town International Convention Center, Cape Town, South Africa. Aug. 28-29, 2018
- Co-Convener, “The Oceanic Energy Cascade: From Mesoscale, Sub-mesoscale to Small-scale Turbulence”, *The 15th Annual Meeting of the Asia Oceania Geosciences Society (AOGS)*, Hawaii Convention Center, Honolulu, U.S.A., Jun. 6, 2018
- Lead Convener, “What We Have Learned about Ocean Mixing in the Last Decade”, *The 2018 Japan Geoscience Union (JpGU) Meeting*, Makuhari Messe, Chiba, Japan, May 21, 2018
- Lead Convener, “Ocean Mixing Matters”, *The 2017 Japan Geoscience Union (JpGU) Meeting*, Makuhari Messe, Chiba, Japan, May 21, 2017
- Co-Convener, “The Ocean’s Energy Cascade and Mixing”, *The 3rd Xiamen Symposium on Marine Environmental Sciences (XMAS)*, Xiamen University, Xiamen, China, Jan. 10-11, 2017
- Lead Convener, “Ocean Mixing Frontiers”, *The 2016 Japan Geoscience Union (JpGU) Meeting*,

Makuhari Messe, Chiba, Japan, May 22, 2016

- Co-Convener, “Ocean Mixing: the Roles of Wind, Tides, Lee Waves, Topography, and Biota”, *The 12th Annual Meeting of the Asia Oceania Geosciences Society (AOGS 2015) together with the 7th Asia Pacific Association of Hydrology and Water Resources Conference (APHW 2015)*, Suntec Singapore, Singapore, Aug. 5, 2015
- Lead Convener, P03 "Ocean Mixing", *The XXVI General Assembly of the International Union of Geodesy and Geophysics (IUGG 2015)*, Prague Congress Center, Czech Republic, Jun. 30–Jul. 1, 2015
- Lead Convener, “Ocean Mixing Frontiers”, *The 11th Annual Meeting of the Asia Oceania Geosciences Society (AOGS 2014)*, Royton Sapporo Hotel, Sapporo, Japan, Jul. 28–Aug. 1, 2014
- Lead Convener, P03 "Ocean Mixing", *The International Association of Hydrological Sciences (IAHS) - The International Association for the Physical Sciences of the Oceans (IAPSO) – The International Association of Seismology and Physics of the Earth's Interior (IASPEI) Joint Assembly*, Convention Center, Gothenburg, Sweden, Jul. 24–26, 2013
- Lead Convener, OS21 “Ocean Mixing: Where, Why, How Much, …”, *The 10th Annual Meeting of the Asia Oceania Geoscience Meeting (AOGS 2013)*, Brisbane Convention and Exhibition Center, Brisbane, Australia, Jun. 26, 2013
- Lead Convener, OS18 “Ocean Mixing Matters”, *Asia Oceania Geoscience Society – American Geophysical Union (Western Pacific Geophysics Meeting) Joint Assembly (AOGS-AGU (WPGM) Joint Assembly)*, Resorts World Convention Center, Singapore, Aug. 16, 2012

11. Outreach Activity

(1) Public Organization

- Member, National Committee for International Association for the Physical Sciences of the Oceans (IAPSO) in the Subcommittee for IUGG at the Japan Science Council’s Earth and Planetary Science Committee, Feb. 2012–Present
- Cooperation Member, Subcommittee for SCOR at the Japan Science Council’s Earth and Planetary Science Committee, Oct. 2016–Present
- Japan Coast Guard, Policy Advisor, Dec. 2017–Present
- Member, Management Council for the Shared Use of T/V Shinyo-Maru of the Tokyo University of Marine Science and Technology, May 2012-Present
- Member, MEXT Scientific Research on Innovative Areas Expert Committee, Dec. 2017-Mar. 2018
- Expert Investigator, MEXT Science and Technology Experts Network, Sep. 2012–May 2013
- Advisor, Japan Agency for Marine-Earth Science and Technology, Jun. 27, 2016-Jul. 1, 2016
- Member, Marine Science and Technology Project Team (PT) in the Councilors' Meeting of the Headquarters for Ocean Policy at the Cabinet Office of Japan, Jul. 2015-Mar. 2016
- Member, Committee of Validation and Examination for Degrees in the National Institution for Academic Degrees and University Evaluation, Apr. 2012-Mar. 2014
- Member, External Evaluation Committee for the Division of Earth Environmental Dynamics and the Center for East Asian Ocean-Atmosphere Research of the Research Institute for Applied Mechanics of Kyushu University, Apr. 2016–Mar. 2017
- Member, Science Advisory Committee for the International Pacific Research Center (IPRC) of the University of Hawaii, Honolulu, U.S.A., Apr. 2007–Mar. 2014

(2) Private Organization

- Director, Japan Marine Science Foundation, Jun 2014-Present
- Member, General Committee for Research and Development, Japan Marine Science Foundation, May 2015-Sep. 2017

(3) Seminars

- Hibiya, T., "The Global Overturning Circulation driven by the Moon – Challenge to the mystery in the Deep Ocean", Academic Frontier Lecture Series, The University of Tokyo Liberal Arts Program, Jun. 30, 2018.
- Hibiya, T., "How is the Global Overturning Circulation driven?", Udayana University, Bali, Indonesia, Mar. 6, 2017

(4) Public Lectures

- Hibiya, T., "Bringing up Human Resources to support Maritime Nation (Panel Discussion)" (in Japanese), The 9th Annual Meeting of Japan Society of Ocean Policy – Expectations for the 3rd Basic Plan on Ocean Policy, Koshiba Hall, The University of Tokyo, Dec. 2, 2017.
- Hibiya, T., "Possible impacts of the global warming on the human society", The first screening of "Exit" by Duller Scofidio and Renfro in Japan (organized by Institut des Hautes Études Scientifique (IHES), Tokyo, Oct. 3, 2016.
- Hibiya, T., "Global Overturning Circulation" (in Japanese), Greater UTokyo Seminar, The University of Tokyo, Dec.10, 2013.
- Hibiya, T., "Global Overturning Circulation driven by the Moon – Challenge to the Mystery in the Deep Ocean" (in Japanese), Spring-break Lecture for High School Students, Faculty of Science of the University of Tokyo, Apr. 2, 2013.
- Hibiya, T., "Global Overturning Circulation driven by the Moon – Challenge to the mystery in the Deep Ocean" (in Japanese), Music Concert and Lecture presented by Miyuzu Meson Inc., Yumeria Hall, Tokyo, Mar. 1, 2013.

(5) Delivery Lectures

- Hibiya, T., "Silent Tsunamis hitting the Western Coast of Kyushu Island" (in Japanese), Delivery Lecture for Tokyo Metropolitan Tachikawa International Secondary Education School, Dec. 18, 2018.
- Hibiya, T., "Silent Tsunamis hitting the Western Coast of Kyushu Island" (in Japanese), Delivery Lecture by the Ocean Alliance of the University of Tokyo, Zushi Kaisei Junior High School, Kanagawa, Jul. 5, 2018.
- Hibiya, T., "Global Overturning Circulation driven by the Moon: Challenge to the Mystery of Deep Ocean Circulation Around the Earth" (in Japanese), Delivery Lecture of the Ocean Alliance of the University of Tokyo, Miyazaki Prefectural Miyakonojo-Izumigaoka Junior High School, Tokyo, May 16, 2018.
- Hibiya, T., "Global Overturning Circulation driven by the Moon: Challenge to the Mystery of Deep Ocean Circulation Around the Earth" (in Japanese), Delivery Lecture by the Ocean Alliance of the University of Tokyo, Yamate Gakuin Senior High School, Kanagawa, Nov. 20, 2017.
- Hibiya, T., "Global Overturning Circulation driven by the Moon: Challenge to the mystery in the Deep Ocean " (in Japanese), Delivery Lecture by the Ocean Alliance of the University of Tokyo, Zushi Kaisei Junior High School, Kanagawa, Jun. 29, 2017.
- Hibiya, T., "The Discussion about the Tank Experiment of Global Overturning Circulation with students of Zushi Kaisei Junior and Senior High School" (in Japanese), The University of Tokyo,

Oct. 1, 2016.

- Hibiya, T., "Global Overturning Circulation driven by the Moon: Challenge to the mystery in the Deep Ocean" (in Japanese), Delivery Lecture by the Ocean Alliance of the University of Tokyo, Zushi Kaisei Junior High School, Kanagawa, Jun. 26, 2016.
- Hibiya, T., "Global Overturning Circulation driven by the Moon: Challenge to the Mystery of Deep Ocean Circulation Around the Earth" (in Japanese), Delivery Lecture of the Ocean Alliance of the University of Tokyo, Kichijo Girl's Junior High School, Jun. 25, 2016.
- Hibiya, T., "Global Obvertuning Circulation driven by the Moon: Challenge to the mystery in the Deep Ocean " (in Japanese), Delivery Lecture of the Ocean Alliance of the University of Tokyo, Zushi Kaisei Junior High School, Kanagawa, Jun. 18, 2015.
- Hibiya, T., "Deep Ocean Turbulent Mixing and Global Overturning Circulation: Challenge to the mystery in the Deep Ocean " (in Japanese), Delivery Lecture by the Ocean Alliance of the University of Tokyo, Tokyo Metropolitan Oshima Senior High School, Tokyo, Nov. 28, 2014.
- Hibiya, T., "Global Overturning Circulation driven by the Moon: Challenge to the Mystery of Deep Ocean Circulation around the Earth" (in Japanese), Delivery Lecture by the Ocean Alliance of the University of Tokyo, Gunma Prefectural Maebashi Girl's Senior High School, Gunma, Oct. 17, 2014.
- Hibiya, T., "Observations of Deep Ocean Mixing" (in Japanese), Delivery Lecture by the Ocean Alliance of the University of Tokyo, Ogasawara Village Junior High School, Tokyo, May 20, 2014.

(6) Others

- Hibiya, T., Opening Remarks for the Symposium "Marine Biology 2019" (in Japanese), Tokyo University of Marine Science and Technology, Mar. 23, 2019
- Hibiya, T., Opening Remarks for the Results Report Meeting "Studies toward improvement of disaster prevention for protecting lives from mega-tsunamis" (in Japanese), The University of Tokyo Ocean Alliance Comprehensive Ocean Infrastructure Program (The Nippon Foundation), The University of Tokyo, Mar. 23, 2019
- Hirobe, T., and T. Hibiya, "Airborne observations with a radar altimeter for early detection of mega-tsunamis" (in Japanese), The University of Tokyo Ocean Alliance Comprehensive Ocean Infrastructure Program (The Nippon Foundation), Symposium "Studies toward improvement of disaster prevention for protecting lives from mega-tsunamis", The University of Tokyo, Mar. 23, 2019
- Niwa, Y., and T. Hibiya, "Inversion analysis of tsunami waveforms using airborne radar on commercial airplanes" (in Japanese), The University of Tokyo Ocean Alliance Comprehensive Ocean Infrastructure Program (The Nippon Foundation) Symposium "Studies toward improvement of disaster prevention for protecting lives from mega-tsunamis", The University of Tokyo, Mar. 23, 2019
- Hibiya, T., "The role of research vessels in marine observations: Results and outlook" (Panel Discussions), Science Council of Japan Open Symposium, Tokyo, Dec. 25, 2018.
- Hibiya, T., Opening Remarks for the 13th Ocean Research Joint Symposium of the University of Tokyo Ocean Alliance and the Nippon Foundation "Recent Research Results by Young Scientists" (in Japanese), The University of Tokyo, Nov. 2, 2018
- Hibiya, T., "Global deployment of Deep Argo floats toward accurate prediction of future climate and ecosystem changes, Hearings on 2020 Japanese Master Plan of Large Research Projects in Earth and Planetary Science, Tokyo, Mar. 28, 2018
- Hibiya, T., Opening Remarks for the Symposium "Marine Biology 2018" (in Japanese), Tokyo

University of Marine Science and Technology, Mar. 24, 2018

- Hibiya, T., Opening Remarks for the Results Report Meeting "Studies toward improvement of disaster prevention for protecting lives from mega-tsunamis" (in Japanese), The University of Tokyo Ocean Alliance Comprehensive Ocean Infrastructure Program (The Nippon Foundation), The University of Tokyo, Mar. 3, 2018
- Hibiya, T., Revealing meteo-tsunamis ("Abiki") attacking the western coast of Kyushu, The University of Tokyo Ocean Alliance Comprehensive Ocean Infrastructure Program (The Nippon Foundation), Symposium "Studies toward improvement of disaster prevention for protecting lives from mega-tsunamis", The University of Tokyo, Mar. 3, 2018
- Hibiya, T., Opening Remarks for The University of Tokyo Ocean Alliance Workshop "Issues of Marine Spatial Planning in Japan", The University of Tokyo, Feb. 16, 2018
- Hibiya, T., Opening Remarks for the University of Tokyo Ocean Alliance (The Nippon Foundation) International workshop "Science behind decision making process for conservation and sustainable use of the ocean", The University of Tokyo, Feb. 15, 2018
- Hibiya, T., Opening Remarks for the 5th Japan Marine Education Summit "Learnings about marine affairs", The University of Tokyo Ocean Alliance (The Nippon Foundation) Research Center for Marine Education the 5th Japan Marine Education Summit, The University of Tokyo, Feb. 4, 2018
- Hibiya, T., Opening Remarks for the meeting to report results of Wind Challenger Project 2017, The meeting to report results of Wind Challenger Project 2017, The University of Tokyo, Sep. 30, 2017
- Hibiya, T., Introduction of recent studies in the Atmosphere and Ocean Science Group in the Department of Earth and Planetary Science of the Graduate School of Science of the University of Tokyo, The 1st EPS Department Seminar, The University of Tokyo, Aug. 9, 2017
- Hibiya, T., Opening Remarks for the 12th Ocean Research Joint Symposium of The University of Tokyo Ocean Alliance and The Nippon Foundation "Suggestion to the society", The 12th Ocean Research Joint Symposium of The University of Tokyo Ocean Alliance and The Nippon Foundation, The University of Tokyo, Jul. 18, 2017
- Hibiya, T., Hibiya's Laboratory Tour Guide for the 2016 Advisory Committee for the School of Science of the University of Tokyo, Mar. 3, 2017
- Hibiya, T., Opening remarks for the 4th Japan Marine Education Summit "A new trend in marine education" (in Japanese), The University of Tokyo Ocean Alliance (The Nippon Foundation) Research Center for Marine Education the 4th Japan Marine Education Summit, The University of Tokyo, Feb. 5, 2017
- Hibiya, T., Opening Remarks of the Forum "Let's Hear the Stories about the Ocean" for Junior and Senior High School Students", Joint Symposium of the University of Tokyo Ocean Alliance and the Nippon Foundation, The University of Tokyo, Nov. 20, 2016
- Hibiya, T., Opening remarks for the 11th Ocean Research Joint Symposium of the University of Tokyo Ocean Alliance and the Nippon Foundation "The Frontier of Ocean Research from the University of Tokyo Ocean Alliance" (in Japanese), The University of Tokyo, Jul. 19, 2016
- Hibiya, T., Opening remarks for the 10th Ocean Research Joint Symposium of The University of Tokyo Ocean Alliance and The Nippon Foundation "New Method and Perspectives Overturn Common Sense in Marine Science" (in Japanese), The 10th Ocean Research Joint Symposium of The University of Tokyo Ocean Alliance and The Nippon Foundation, The University of Tokyo, Jul. 23, 2015
- Hibiya, T., Opening remarks for international symposium "Islands and Oceans Net 1st General Meeting", Joint Symposium of Islands and Oceans Net and The University of Tokyo Ocean

Alliance, The University of Tokyo, May 25, 2015

- Hibiya, T., Opening remarks for the 9th Ocean Research Joint Symposium of The University of Tokyo Ocean Alliance and The Nippon Foundation "Links between Marine Research and Society" (in Japanese), The 9th Ocean Research Joint Symposium of The University of Tokyo Ocean Alliance and The Nippon Foundation, The University of Tokyo, Jul. 21, 2014
- Hibiya, T., Opening remarks for the 2nd seminar of The University of Tokyo Ocean Alliance "We will Introduce the Charm of the Sea! – From Women Working at Sea to Junior and Senior High School Girls", The 2nd Seminar for Junior and Senior High School Girls by the University of Tokyo Ocean Alliance, The University of Tokyo, Jan. 26, 2014
- Hibiya, T., Opening remarks for the 1st seminar of The University of Tokyo Ocean Alliance "We will Introduce the Charm of the Sea! – From Women Working at Sea to Junior and Senior High School Girls", The 1st Seminar for Junior and Senior High School Girls by the University of Tokyo Ocean Alliance, Tokyo Sea Life Park, Dec. 15, 2013.
- Hibiya, T., Opening remarks for the 8th Ocean Research Joint Symposium of The University of Tokyo Ocean Alliance and The Nippon Foundation "Age of Disturbance", The 8th Ocean Research Joint Symposium of The University of Tokyo Ocean Alliance and The Nippon Foundation, The University of Tokyo, Jul. 31, 2013.
- Hibiya, T., Opening remarks for the Joint Symposium of The University of Tokyo Ocean Alliance and The Nippon Foundation "Japan Sea: Great Benefits from a Small Sea", The Joint Symposium of The University of Tokyo Ocean Alliance and The Nippon Foundation, Mitsukoshi Theater, Tokyo, Jul. 15, 2013.
- Hibiya, T., Opening remarks for the 7th Ocean Research Joint Symposium of The University of Tokyo Ocean Alliance and The Nippon Foundation "Relationship between People and the Sea in the Future", The 7th Ocean Research Joint Symposium of The University of Tokyo Ocean Alliance and The Nippon Foundation, The University of Tokyo, Jul. 24, 2012.

(7) Media

- "Why does Water Flooding occur in Nagasaki even under no Typhoons and Storms?" (in Japanese), Tokyo Shimbun (Morning Newspaper), Mar. 23, 2019
- "Let's Solve the Mystery of "Global Overturning Circulation – Zushi Kaisei High School Students' Challenge" (in Japanese), YOMIURI ONLINE (Net News), Sep. 10, 2018
- "Is the Global Overturning Circulation driven by the Moon ? – Exploring the role of tide-induced turbulent mixing" (in Japanese), Academist Journal (Web Journal), Jul. 24, 2018
- "Huge Ocean Current – Kuroshio" (in Japanese), Commentary on the Kuroshio in Science Zero (NHK Educational TV Program), Jan. 21, 2018
- "The First Large Meander of Kuroshio in last 12 years" (in Japanese), Nihon Keizai Shimbun (Morning Newspaper), Dec. 3, 2017
- "Observations of tsunamis within an error of 5 cm will be possible using commercial airplanes: A new low-cost technology developed by the University of Tokyo" (in Japanese), Nihon Keizai Shimbun (Evening Newspaper), Aug. 19, 2017
- "How the oceanographic research should be: Deeper cooperation with private companies is needed" (in Japanese), Nihon Sangyo Shimbun (Morning Newspaper), Aug. 14, 2017
- "Is the generation of Abiki (meteo-tsunami) along the west coast of Kyushu related to weather conditions in the southern part of China?" (in Japanese), Minami Nippon Shimbun (Morning newspaper), Sep. 24, 2016.
- "The Oceanographic Society of Japan requests MEXT to incorporate a new educational unit "Important Roles of the Ocean" into the upcoming curriculum" (in Japanese), The Education

Newspaper, Apr. 4, 2016

- “What is the Global Overturning Circulation?” (in Japanese), Commentary on the Global Overturning Circulation on the CBC radio program, Mar. 3, 2015.
- “Does the water in the deep ocean move?” (in Japanese), DO Science with “Nono- chan”, Asahi Shimbun (Morning Newspaper), Dec. 6, 2014.

12. Internal Committee Membership

- President, the University of Tokyo Ocean Alliance, Apr. 2013–Mar. 2019
- Member, Promotion Committee of the University of Tokyo Ocean Alliance, Apr. 2009–Mar. 2019
- Member, Steering Committee of the University of Tokyo Ocean Alliance, Apr. 2011–Mar. 2019
- Member, Review Committee for the PEAK (Programs in English at Komaba) at the University of Tokyo, Apr. 2015–Present
- Member, Special Committee for the Interview for the Admission Office Entrance Examination for the PEAK (Programs in English at Komaba) at the University of Tokyo, Apr. 2012–Mar. 2014
- Member, Steering Committee of the Atmosphere and Ocean Research Institute of the University of Tokyo, Apr. 2009–Present
- Member, Steering Committee of the Earthquake Research Institute of the University of Tokyo, Apr. 2009–Mar. 2013
- Member, Steering Committee of the Global COE Program at the Department of Earth and Planetary Science of the Graduate School of Science of the University of Tokyo, Apr. 2009–Mar. 2014
- Member, Evaluation Committee of the School of Science of the University of Tokyo, Apr. 2017 – Present
- Member, Working Group to Reduce the Possible Number of Faculty Employment in the Graduate School of Science of the University of Tokyo, Apr. 2016–Mar. 2017
- Member, Academic Steering Committee of the Graduate School of Science of the University of Tokyo, Apr. 2012–Mar. 2014
- Member, Academic Affairs Committee in the Department of Earth and Planetary Science of the Graduate School of Science of the University of Tokyo, Apr. 2016–Present
- Chairman, Research Associate Activation Project in the Department of Earth and Planetary Science of the Graduate School of Science of the University of Tokyo, Apr. 2016–Present
- Secretary, Board of Education in the Department of Earth and Planetary Science of the Graduate School of Science of the University of Tokyo, Apr. 2014-Mar. 2015, Apr. 2016-Mar.2017, Apr. 2018-Mar. 2019
- Representative, Atmospheric and Oceanic Science Group in the Department of Earth and Planetary Science of the Graduate School of Science of the University of Tokyo, Apr. 2013-Mar. 2014, Apr. 2015-Mar.2016, Apr. 2017-Mar. 2018
- Member, Room Assignment Committee in the Department of Earth and Planetary Science of the Graduate School of Science of the University of Tokyo, Apr. 2008–Mar. 2016

V. International Exchange Activities

13. Hosting/Sending Foreign Students and Researchers

(1) Hosting

Foreign Students: 1 [M.Sc.: 1 (China: 1), Ph.D.: 0]

Foreign Researchers: 1 [China: 1]

(2) Sending

Students: 7 [M.Sc.: 2, Ph.D.: 5]

Researchers: 8

(3) Visitors from Abroad: 22 [U.S.A.: 17, Germany: 1, Netherland: 2, Australia: 1, Indonesia: 1]

Yukio Masumoto

I. CV

Name: Yukio Masumoto

Age: 56

Present Position: Professor

Education

Komaba High School, Tokyo, March, 1982 (graduation)

B. Sc. Department of Ocean Civil Development Engineering, Kagoshima University, March, 1987

M. Sc. Graduate School of Engineering, Kyushu University, March, 1989

Ph. D. Graduate School of Engineering, Kyushu University, December, 1991

Professional Experience

Jan. 1992-Nov. 2001, Research Associate, Department of Earth and Planetary Physics, The University of Tokyo

Dec. 1995-Nov. 1996, Visiting Scientist, Division of Oceanography, CSIRO, Australia

Nov. 2001-Mar. 2010, Associate Professor, Department of Earth and Planetary Science, The University of Tokyo

Jul. 2004-Apr. 2009, Group Leader, Frontier Research Center for Global Change, Japan Agency for Marine-Earth Science and Technology (concurrent post)

Jul. 2004-Apr. 2009, Sub Leader, Institute of Observational Research for Global Change, Japan Agency for Marine-Earth Science and Technology (concurrent post)

Apr. 2009-May 2013, Program Director, Research Institute for Global Change, Japan Agency for Marine-Earth Science and Technology

Jun. 2013-, Professor, Department of Earth and Planetary Science, The University of Tokyo

II. Scientific Research Activity

2. Major Achievements

My research interests are mechanisms of upper-layer circulations in the Indo-Pacific Ocean and their variability, and dynamical processes responsible for generation and evolution of large-scale climate variations that include air-sea interactions as key characteristics. In particular, climate variations, ocean circulations, and their mutual relations/interactions within the Indian Ocean are recent major research topics. Our previous researches reveal that forced Rossby wave propagation in the southern tropical Indian Ocean determines upper-ocean circulations and temperature variations and that a decadal variation in the Pacific Ocean can influence on ocean conditions in the southeastern Indian Ocean via the Indonesian throughflow. In addition, I have been leading a mooring observation project in the Indian Ocean, known as data sparse region among the tropics, and shown that large amplitude intraseasonal variations dominate variability in upper-layer currents in the eastern equatorial region. It has also been demonstrated that vertical energy propagation associated with such intraseasonal variability can generate deeper layer upwelling along the equator as a rectified mean signal. These research activities provide strong basis for my leading role under the international research projects, such as CLIVAR and IIOE-2.

3. Five Important Papers (including three or more papers in this review period)

1. Ogata, T., M. Nagura, and Y. Masumoto (2017), Mean subsurface upwelling induced by intraseasonal variability over the equatorial Indian Ocean, *J. Phys. Oceanogr.*, 47 (6), 1347-1365, doi: 10.1175/JPO-D-16-0257.1.

Despite downwelling favorable mean westerly winds over the equatorial Indian Ocean, many ocean circulation models indicate rather strong upwelling signals along the equator. This paper investigated a possible generation mechanism of this upwelling and showed that it is generated by a rectification process due to vertical propagation of intraseasonal mixed Rossby-gravity waves excited by the surface meridional wind stress. This result adds a new perspective in the meridional overturning circulation in the Indian Ocean.

2. Cai, W., A. Santoso, G. Wang, E. Weller, L. Wu, K. Ashok, Y. Masumoto, and T. Yamagata (2014), Increased frequency of extreme Indian Ocean Dipole events due to greenhouse warming, *Nature*, **510**, 254-258, doi: 10.1038/nature13327.

The Indian Ocean dipole mode (IOD), one of the significant interannual variability in the Indian Ocean, affects climate over surrounding regions by modifying temperature and precipitation, hence the socio-economic activities there. However, changes in its characteristics and behavior under global warming stresses have not been investigated in details. This paper analyzed outputs from recent prediction models with climate change scenarios and revealed that occurrence frequency of the IOD increased three times, together with flattened mean thermocline, under global warming condition. (Citation 88, WoS/Sep. 20, 2019)

3. Luo, J.-J., W. Sasaki, and Y. Masumoto (2012), Indian Ocean warming modulates Pacific climate change, *PNAS*, **109**, 18701-18706, doi: 10.1073/pnas.1210239109.

Relations and mutual interactions between climate variations over the Pacific Ocean and those in the Indian Ocean are among key issues in climate researches. This paper suggests possible influences of the rapid increase in the sea surface temperature (SST) in the eastern Indian Ocean on variability in the equatorial Pacific Ocean. Enhanced SST gradient between the two basins strengthened the Walker circulation over the Pacific Ocean, which leads a stronger zonal temperature gradient, and hence affects ENSO characteristics. This result has been referred to many times as a possible mechanism explaining stronger Trades under the global warming stresses. (Citation 166, WoS/Sep. 20, 2019)

4. Masumoto, Y., Y. Miyazawa, D. Tsumune, T. Tsubono, T. Kobayashi, H. Kawamura, C. Estournel, P. Marsaleix, L. Lanerolle, A. Mehra, and Z. D. Garraffo (2012), Oceanic dispersion simulations of Cesium 137 from Fukushima Daiichi Nuclear Power Plant, ELEMENTS, 8, 207-212, doi: 10.2113/gselements.8.3.207.

Detailed distribution and its time evolution of radionuclides discharged into the ocean associated with the Fukushima accident in 2011 have not been cleared yet, due to sparseness of in situ observation data. This paper compares outputs from five numerical models for dispersion of Cs137 in the continental shelf and slope regions off Fukushima. It turned out that distribution of Cs137 is largely determined by combination of large-scale ocean circulations, such as Kuroshio, meso-scale eddy features, and coastal currents associated with coastally trapped waves and tides. A part of results from the comparisons are utilized for press release from MEXT and played important role in dissemination of information on the radionuclides dispersion. (Citation 61, WoS/Sep. 20, 2019)

5. Y. Masumoto, H. Hase, Y. Kuroda, H. Matsuura, and K. Takeuchi (2005), Intraseasonal variability in the upper layer currents observed in the eastern equatorial Indian Ocean, *Geophys. Res. Letter,* 32, L02607, doi:10.1029/2004GL021896.

This paper shows, for the first time, long-term upper-ocean horizontal current variability observed in situ by an ADCP mooring system located in the eastern equatorial Indian Ocean. Zonal currents vary strongly with intraseasonal time-scale, as well as a semi-annual signal known as Wyrtki jets. Meridional current variability is dominated by intraseasonal variations associated with mixed Rossby-gravity waves with a typical time-scale of about 15 days, which are forced by wind variability over the eastern equatorial Indian Ocean. The results are cited by many articles on the variability in the Indian Ocean. (Citation 85, WoS/Sep. 20, 2019)

4. Awards and Honors

5. Future Research Plan

Studies on upper-ocean circulations and air-sea interactions will be continued, because of their important roles in monsoonal climate systems in Asia, Africa, and Oceania. In particular, my focusses will be put on the shallow meridional overturning circulations and their variability. In order to proceed this avenue, further studies on large-scale atmosphere-ocean interactions and upwelling systems, together with better understanding of upper-ocean circulation variability, would be required. For the study of upwelling, as a key connector between surface and sub-surface ocean variability, multi-scale variability within the upwelling systems and their relations/interactions with large-scale climate modes will be my main focus for the next few years. Generation and evolution mechanisms of interannual to decadal climate variability in the Indian Ocean will be another key research topic. I will try to tackle these issues using various approaches, including numerical modeling, in situ observation, and data analyses, on the basis of my previous research activities and international collaborations. Also, interdisciplinary approaches, as well as researches based on physical oceanography and climate dynamics, will be facilitated through collaboration with scientists within and outside of the department.

6. Funding Received

- JSPS KAKENHI, 17H01663, Principal Investigator, FY2017-2020, 40,800,000 yen
- Environment Research and Technology Development Fund, Physical processes responsible for large-scale dispersion and movement of ocean micro-plastic, Principal Investigator, FY2018-2020, 18,992,000 yen
- The Canon Foundation "Pursuit of Ideals", Four-dimensional ocean mapping: New frontier of modeling and visualization, Principal Investigator, FY2014-2016, 30,000,000 yen
- The Sumitomo Foundation Grant for Environmental Research Projects, Development of an ocean prediction system for accidental radionuclide dispersion, Principal Investigator, FY2013, 1,500,000 yen

7. Publications and Patents

(1) Peer-reviewed Journal Articles

1. Ratnam, J. V., S. K. Behera, Y. Masumoto, K. Takahashi, and T. Yamagata (2012), A simple regional coupled model experiment for summer-time climate simulation over southern Africa, *Climate Dynamics.* 36, DOI: 10.1007/s00382-011-1190-2
2. Sasaki, H., S.-P. Xie, B. Taguchi, M. Nonaka, S. Hosoda, and Y. Masumoto (2012), Interannual variations of the Hawaiian Lee Countercurrent induced by potential vorticity variability in the subsurface, J. Oceanogr., 68, 93-111, doi: 10.1007/s10872-011-0074-8.
3. Honda, M., T. Aono, M. Aoyama, Y. Hamajima, H. Kawakami, M. Kitamura, Y. Masumoto, Y. Miyazawa, M. Takigawa, and T. Saino (2012), Dispersion of artificial caesium-134 and -137 in the western North Pacific one month after the Fukushima accident, *Geochemical Journal*, **46**, e1-

e9.

4. Masumoto, Y., Y. Miyazawa, D. Tsumune, T. Tsubono, T. Kobayashi, H. Kawamura, C. Estournel, P. Marsaleix, L. Lanerolle, A. Mehra, and Z. D. Garraffo (2012), Oceanic dispersion simulations of Cesium 137 from Fukushima Daiichi Nuclear Power Plant, ELEMENTS, 8, 207-212, doi: 10.2113/gselements.8.3.207.

5. Prasanna Kumar, S., T. D. David, P. Byju, J. Narvekar, K. Yoneyama, N. Nakatani, A. Ishida, T. Horii, Y. Masumato, and K. Mizuno (2012), Bio-physical coupling and ocean dynamics in the central equatorial Indian Ocean during 2006 Indian Ocean Dipole, *Geophys. Res. Lett.*, **39**, L14601, doi:10.1029/2012GL052609.

6. Ratnam, J. V., S. K. Behera, Y. Masumoto, and T. Yamagata (2012), Role of Rossby waves in the remote effects of the north Indian Ocean tropical disturbances, *Mon. Wea. Rev.,* **140**, 3620-3633, doi:10.1175/MWR-D-12-00027.1.

7. Luo, J.-J., W. Sasaki, and Y. Masumoto (2012), Indian Ocean warming modulates Pacific climate change, *PNAS*, **109**, 18701-18706, doi: 10.1073/pnas.1210239109

8. Miyazawa, Y, Y. Masumoto, S. M. Varlamov, and T. Miyama (2012), Transport simulation of the radionuclide from the shelf to open ocean around Fukushima, *Continental Shelf Res.*, *Volumes 50–51*, *15 December 2012*, *Pages 16-29*.

9. Richter, I., S.K. Behera, Y. Masumoto, B. Taguchi, H. Sasaki, and T. Yamagata (2013), Multiple causes of interannual sea surface temperature variability in the equatorial Atlantic Ocean, *Nature Geoscience* **6** (1), 43-47 doi:10.1038/ngeo1660.

10. Miyazawa, Y., Y. Masumoto, S. M. Varlamov, T. Miyama, M. Takigawa, M. Honda, and T. Saino (2013), Inverse estimation of source parameters of oceanic radioactivity dispersion models associated with the Fukushima accident, *Biogeosciences*, **10**, 2349-2363, doi:10.5194/bg-10-2349-2013.

11. Liu, P., T. Li, B. Wang, M. Zhang, J.-J. Luo, Y. Masumoto, X.-C. Wang, and E. Roeckner (2013), MJO change with A1B global warming estimated by the 40-km ECHAM5, *Climate Dynamics*, **41** (3-4), 1009-1023, doi: 10.1007/s00382-012-1532-8.

12. Morioka, Y., J. V. Ratnam, W. Sasaki, and Y. Masumoto (2013), Generation mechanism of the South Pacific subtropical dipole, *J. Climate,* **26** (16), 6033-6045, doi:10.1175/JCLI-D-12-00648.1.

13. Behera, S. K., J. V. Ratnam, Y. Masumoto, and T. Yamagata (2013), Origin of Extreme Summers in Europe: The Indo-Pacific Connection, *Climate Dynamics*, 41 (3-4), 663-676, doi: 10.1007/s00382-012-1524-8.

14. Ratnam, J. V., S. K. Behera, S. B. Ratna, C. J. de W. Rautenbach, C. Lennard, J.-J. Luo, Y. Masumoto, K. Takahashi, and T. Yamagata (2013), Dynamical Downscaling of Austral Summer Climate Forecasts over Southern Africa Using a Regional Coupled Model, *J.Climate*, **26** (16), 6015-6032, doi: http://dx.doi.org/10.1175/JCLI-D-12-00645.1.

15. Sasaki, H., B. Taguchi, N. Komori, and Y. Masumoto (2014), Influence of Local Dynamical Air–Sea Feedback Process on the Hawaiian Lee Countercurrent, *J. Climate*, **26** (18), 7267-7279, , doi: http://dx.doi.org/10.1175/JCLI-D-12-00586.1.

16. Richter, I., S.-P. Xie, S.K. Behera, T. Doi, and Y. Masumoto (2014), Equatorial Atlantic variability and its relation to mean state biases in CMIP5, *Climate Dynamics*, **42** (1-2), 171-188, doi: 10.1007/s00382-012-1624-5

17. Nagura, M., Y. Masumoto, and T. Horii (2014), Meridional heat advection due to mixed Rossby gravity waves in the equatorial Indian Ocean, J. Phys. Oceanogr., Volume 44, Issue 1 (January 2014) pp. 343-358, doi: http://dx.doi.org/10.1175/JPO-D-13-0141.1.

18. Iskandar, I., Y. Masumoto, K. Mizuno, H. Sasaki, A. Affandi , D. Setiabudidaya , and F. Syamsudin (2014), Coherent intraseasonal oceanic variations in the eastern equatorial Indian Ocean and in the Lombok and Ombai Straits from observations and a high-resolution OGCM, *J. Geophys. Res.,* Volume 119, Issue 2, February 2014, Pages: 615–630, doi:10.1002/2013JC009592.
19. Ratnam, J. V., S. K. Behera, Y. Masumoto, and T. Yamagata (2014), Remote effects of El Niño and Modoki events on the Austral Summer Precipitation of Southern Africa, *J. Climate,* Volume 27, Issue 10 (May 2014) pp. 3802-3815, doi: http://dx.doi.org/10.1175/JCLI-D-13-00431.1.
20. Morioka, Y., S. Masson, P. Terray, C. Prodhomme, S. K. Behera, and Y. Masumoto (2014), Role of tropical SST variability on the formation of subtropical dipoles, J. Climate Volume 27, Issue 12 (June 2014) pp. 4486-4507, doi:10.1175/JCLI-D-13-00506.1.
21. Cai, W., A. Santoso, G. Wang, E. Weller, L. Wu, K. Ashok, Y. Masumoto, and T. Yamagata (2014), Increased frequency of extreme Indian Ocean Dipole events due to greenhouse warming, *Nature*, **510**, 254-258, doi: 10.1038/nature13327.
22. Han, W., J. Vialard, M. J. McPhaden, T. Lee, Y. Masumoto, M. Feng, and W. P. M. de Ruijter (2014), Indian Ocean Decadal Variability: A Review, *Bulletin of the American Meteorological Society*, Volume 95, Number 11, 1679-1703, doi: 10.1175/BAMS-D-13-00028.1.
23. Richter, I., S. K. Behera, T. Doi, B. Taguchi, Y. Masumoto, and S.-P. Xie (2014), What controls equatorial Atlantic winds in boreal spring?, *Climate Dynamics,* **43** (11), 3091-3104, doi: 10.1007/s00382-014-2170-0.
24. Sasaki, W., T. Doi, K. J. Richards, and Y. Masumoto (2014), Impact of the equatorial Atlantic sea surface temperature on the tropical Pacific in a CGCM, *Climate Dynamics,* 43 (9-10), 2539-2552, doi: 10.1007/s00382-014-2072-1.
25. Sasaki, W., T. Doi, K. J. Richards, and Y. Masumoto (2015), The influence of ENSO on the equatorial Atlantic precipitation through the Walker circulation in a CGCM, *Climate Dynamics*, **44**, 191-202, doi: 10.1007/s00382-014-2133-5.
26. Morioka, Y., K. Takaya, S. K. Behera, and Y. Masumoto (2015), Local SST impacts on the summertime Mascarene High variability, *J. Climate*, **28**, 678-694, doi:10.1175/JCLI-D-14-00133.1
27. Nagura, M., and Y. Masumoto (2015), A wake due to the Maldives in the eastward Wyrtki jet, *J. Phys. Oceanogr.,* **45** (7), 1858-1876, doi: 10.1175/JPO-D-14-0191.1.
28. Luo, J.-J., C. Yuan, W. Sasaki, S. K. Behera, Y. Masumoto, T. Yamagata, J.-Y. Lee, and S. Masson (2016), Current status of intraseasonal-seasonal-to-interannual prediction of the Indo-Pacific climate, In "Indo-Pacific Climate Variability and Predictability", Eds. S. K. Behera and T. Yamagata, World Scientific Series on Asia-Pacific Weather and Climate: Volume 7, pp. 63-107, World Scientific, ISBN: 978-981-4696-61-6, doi: 10.1142/9789814696623_0003.
29. Masumoto, Y., M. Nagura, T. Miyama, S.-P. Xie, Z. Yu, J. P. McCreary, P. N. Vinayachandran, R. Hood, and H. Gildor (2016), Ocean processes relevant to climate variations in the Indian Ocean sector, In "Indo-Pacific Climate Variability and Predictability", Eds. S. K. Behera and T. Yamagata, World Scientific Series on Asia-Pacific Weather and Climate: Volume 7, pp. 25-61, World Scientific, ISBN: 978-981-4696-61-6.
30. Rao, R. R., T. Horii, Y. Masumoto, and K. Mizuno (2016), Observed variability in the upper layers at the Equator, 90°E in the India Ocean during 2001-2008, 2: meridional currents, *Climate Dyn.,* doi: 10.1007/s00382-016-2979-9.
31. Rao, R. R., T. Horii, Y. Masumoto, and K. Mizuno (2016), Observed variability in the upper layers at the Equator, 90°E in the Indian Ocean during 2001-2008, 1: Zonal currents, *Climate*

Dyn., doi: 10.1007/s00382-016-3234-0.

32. Ando, K., Y. Kuroda, Y. Fujii, T. Fukuda, T. Hasegawa, T. Horii, Y. Ishihara, Y. Kashino, Y. Masumoto, K. Mizuno, M. Nagura, and I. Ueki (2017), Fifteen years progress of the TRITON array in the western Pacific and eastern Indian Oceans, *J. Oceanogr.*, 73, 403-426, doi:10.1007/s10872-017-0414-4.

33. Ogata, T., M. Nagura, and Y. Masumoto (2017), Mean subsurface upwelling induced by intraseasonal variability over the equatorial Indian Ocean, *J. Phys. Oceanogr.*, 47 (6), 1347-1365, doi: 10.1175/JPO-D-16-0257.1.

34. Sasaki, H., S. Kida, R. Furue, M. Nonaka, and Y. Masumoto (2018), An increase of the Indonesian Throughflow by internal tidal mixing in a high-resolution quasi-global ocean simulation, *Geophysical Research Letters*, 45, 8416–8424, doi:10.1029/2018GL078040.

35. Kumamoto, Y., M. Yamada, M. Aoyama, Y. Hamajima, H. Kaeriyama, H. Nagai, T. Yamagata, A. Murata, and Y. Masumoto (2019), Radiocesium in North Pacific coastal and offshore areas of Japan within several months after the Fukushima accident, Journal of Environmental Radioactivity, 198, 79-88. doi:10.1016/j.jenvrad.2018.12.015.

(2) Non-peer-reviewed Articles

(3) Review Papers

(4) Books

(5) Other Publications

1. Hood, R., W. Yu, Y. Masumoto, J. Wiggert, W. Naqvi, J. McCreary, Z. Yu, and L. Beckley, 2012, SIBER and IOP: Joint activities and science results, CLIVAR Exchanges, No.58, Vol.17, No.1, 17-20.

2. Meyers, G., and Y. Masumoto, 2012, Indian Ocean Observing System (IndOOS), Ship & Ocean Newsletter, 284, 2-3.

3. A Framework for Ocean Observing. By the Task Team for an Integrated Framework for Sustained Ocean Observing, UNESCO 2012, IOC/INF-1284 rev., doi: 10.5270/OceanObs09-FOO

4. Williamson, P., Smythe-Wright, D., and Burkill, P., Eds. (2016) Future of the Ocean and its Seas: a non-governmental scientific perspective on seven marine research issues of G7 interest. ICSU-IAPSO-IUGG-SCOR, Paris. (Participate in as an author/working group member for this document)

(6) Patents

8. Keynote, Invited, or Solicited Presentations

1. Y. Masumoto, Y. Miyazawa, S. Varlamov, R. Zhang, T. Doi, and OSJ Simulation SWG, Ocean Models: How far/fast does Fukushima contamination travel? Fukushima Ocean Impacts Symposium, Sanjo Kaikan, University of Tokyo, Tokyo, 2012/11/13.

2. Y. Masumoto, Possible interactions between Indian Ocean Dipole and intraseasonal variability in the tropical Indian Ocean, JpGU 2013 Meeting, Makuhari Messe, Chiba, 2013/5/24.

3. Y. Masumoto, K. Matsubara, T. Ogata, Interactions between intraseasonal variability and Indian Ocean Dipole in the tropical eastern Indian Ocean, International Symposia on Recent Progresses in Climate Variability Study: Scale-Interactions in Climate Variability, Miyoshi Hall, JAMSTEC, Yokohama, 2013/11/1.

4. Y. Masumoto, EIOURI and IIOE-2: Two international research activities of Indian Ocean oceanography, 5th ISAJ Symposium "Advances in Natural Sciences & Technologies", Embassy of

India, Tokyo, 2014/12/1.

5. Y. Masumoto, T. Ogata, and T. Nagura, Influences of intraseasonal variability in the tropical Indian Ocean on longer time-scale phenomena and the equatorial upwelling, Asia Oceania Geoscience Society 2016, Beijing, China, 2016/8/1.
6. Y. Masumoto, Scale-interactions in the tropical Indian Ocean, Indo-Pacific Ocean Variability and Air-Sea Interaction (IPOVAI) Workshop, 10th IOC WESTPAC International Scientific Conference, Qingdao, China, 2017/4/19.
7. Y. Masumoto, Education of atmosphere and ocean sciences at Faculty of Science, the University of Tokyo, Symposium on Challenges of Contemporary Meteorological Education, Nanjing, China, 2019/5/8.

III. Education Activity

9. Notable Achievements in Education

Lectures

- Undergraduate/Graduate, Introduction to Ocean-Atmosphere Circulation, FY2012-2018
- Undergraduate/Graduate, Numeral Analysis in Geophysics, FY2012-2018
- Graduate, FY2012-2018, FY2012, 2014, 2016, 2018
- Undergraduate, Field observation for earth and planetary physics, FY2018
- Undergraduate, Earth and Planetary Science II, FY2012-2018
- Undergraduate/Graduate, Research Ethics, FY2017-2018

IV. External Activities

10. Contribution to Academic Community

- Science Council of Japan, Specially-Appointed Member, FY2018
- Science Council of Japan, IIOE-2 Sub-Committee Member, FY2018
- Science Council of Japan, CLIVAR Sub-Committee Member, FY2012-2018
- The Oceanographic Society of Japan, Councilor, FY2012-2018
- The Oceanographic Society of Japan, Member for Japan Academic Network for Disaster Reduction, FY2015-2018
- Japan Meteorological Agency, Extreme Weather Review Committee Member, FY2012-2018
- Japan Agency for Marine-Earth Science and Technology, IOC Cooperation and Promotion Committee Member, FY2017-2018
- IOC/SCOR/GOOS IIOE-2, Science Theme 2 Co-chair, FY2016-2018
- IOC/SCOR/GOOS IIOE-2, Working Group 1 Member, FY2016-2018
- TPOS2020, SC member, FY2014-2017
- TPOS2020, Modelling and Data Assimilation Task Team Member, FY2014-2017
- Guest editor of “Ocean Dynamics” for a special issue on IWMO, FY2013
- CLIVAR/IOGOOS Indian Ocean Panel, Member, FY2012-2013

11. Outreach Activity

- KAKENHI Reviewer, FY2014-2017
- Lectures for general audience: 10 times (Apr. 2012, Nov. 2012, Nov. 2012, Dec. 2012, Jan. 2013, Oct. 2013, Mar. 2014, Apr. 2014, Nov. 2014, Jun. 2015)

12. Internal Committee Membership

- Department of Earth and Planetary Science, Department Chair, FY2014-2016
- Department of Earth and Planetary Physics, Department Chair, FY2014-2016
- Department of Earth and Planetary Science, Room and Space Committee, Chair, FY2017-2018

V. International Exchange Activities

13. Hosting/Sending Foreign Students and Researchers

(1) Hosting

Foreign Students: 2

Foreign Researchers: 2

(2) Sending

Students: 1

Researchers: 1

(3) Visitors from Abroad: 5

Makoto Koike

I. CV

Name: Makoto Koike

Age: 57

Present Position：Associate Professor, University of Tokyo, Graduate School of Science

Education

Waseda University Senior High School, Tokyo, March, 1981 (graduation)

B. Sc., Physics, March, 1985

M. Sc., Geophysics, March, 1987

Ph. D., Geophysics, March, 1990

Professional Experience

April, 1990-March, 1998, Research Associate, Atmospheric Environment Division, Solar-Terrestrial Environment Laboratory, Nagoya University

April, 1998-September, 2000, Associate Professor, Atmospheric Environment Division, Solar-Terrestrial Environment Laboratory, Nagoya University

October, 2000-, Associate Professor, Department of Earth and Planetary Science, Graduate School of Science, University of Tokyo

II. Scientific Research Activity

2. Major Achievements

Atmospheric aerosols (suspended particles) affect global radiation budget and climate by scattering and absorbing solar radiation (direct effect) and affecting clouds (indirect effect). I have been studying aerosol impacts on clouds in the East Asia and Arctic by making ground-based and aircraft measurements as well as numerical modeling. In the East Asia we have carried out a series of aircraft experiments and have successfully captured clear evidences for the first time that anthropogenic aerosols indeed affect cloud microphysical parameters. We further found that the strength of aerosol impacts is influenced by the warm Kuroshio ocean current because the warm sea surface temperature (SST) destabilized atmosphere. This is the first study, which designates SST impacts on aerosol – cloud interaction that is potentially important for climate study.

In the Arctic, we have carried out the first continuous in situ measurements of cloud microphysical properties in Spitsbergen Island. We have revealed their seasonal variation and evaluated aerosol impacts. A simple air parcel model can reproduce the observed droplet concentrations from observed aerosols and this result provide a constraint for aerosol impacts on clouds. We also found that small size aerosols, which could be formed by new particle formation, can affect clouds. From these studies, we have provided basic features of microphysical properties of Arctic clouds for the first time.

I have been also studying black carbon (BC) aerosols and anthropogenic iron oxides (FeOx) with colleagues in our group and other collaborators by making ground-based and aircraft measurements as well as numerical modeling. By making a network BC measurement in the Arctic, we have showed that previous observations overestimated BC mass concentrations. This study is considered to be an important contribution to the assessment of the Arctic Council. We have also showed that there is a considerable amount of anthropogenic FeOx in the atmosphere and they likely play important roles for the radiation budget and deposition flux of soluble iron to the ocean.

3. Five Important Papers (including three or more papers in this review period)

1. Koike, M., N. Takegawa, N. Moteki, Y. Kondo, H. Nakamura, K. Kita, H. Matsui, N. Oshima, M. Kajino, and T. Y. Nakajima, Measurements of Regional-Scale Aerosol Impacts on Cloud Microphysics over the East China Sea: Possible Influences of Warm Sea Surface Temperature over the Kuroshio Ocean Current *J. Geophys. Res.*, doi:10.1029/2011JD017324, 2012.

In this paper, we have provided the first clear evidence of anthropogenic aerosol impacts on warm clouds in the East Asia through a systematic aircraft measurement. We further showed that this aerosol impacts were enhanced over the warm Kuroshio ocean current because of enhanced updraft velocity. Temperature contrast between the atmosphere and ocean was found to affect both the macro (cloud thickness) and micro (aerosol impact) features of clouds. This is the first study, which suggests SST impacts on aerosol indirect effect that is potentially important for climate study.

2. Koike, M., N. Asano, H. Nakamura, S. Sakai, T. M. Nagao, and T. Y. Nakajima, Modulations of aerosol impacts on cloud microphysics induced by the warm Kuroshio Current under the East Asian winter monsoon, *J. Geophys. Res. Atmos.*, *121*, doi:10.1002/2016JD025375, 2016.

In this paper, we explore the spatial and temporal extent to which the warm SST influence on aerosol-cloud interaction is operative using MODIS satellite measurements. We found that cold air outbreaks in winter and early spring bring anthropogenic aerosols from the Asian continent to the western Pacific. This cold air outflow also destabilized the atmospheric boundary layer over the Kuroshio ocean current (warm SST), which leads to further enhancement of cloud particle number concentrations. These results suggest that SST impacts on aerosol-cloud interaction is operative over other high SST areas.

3. Koike, M., N. Moteki, P. Khatri, T. Takamura, N. Takegawa, Y. Kondo, H. Hashioka, H. Matsui, A. Shimizu, and N. Sugimoto, Case study of absorption aerosol optical depth closure of black carbon over the East China Sea, *J. Geophys. Res. Atmos., 118*, doi:10.1002/2013JD020163, 2014.

Absorption aerosol optical depth (AAOD) measurements made by sun-sky photometers are currently the only constraint available for estimates of the global radiative forcing of black carbon (BC), the third most important positive radiative forcer following CO_2 and CH_4. However, their validation studies are limited. In this paper, we report the first attempt to compare AAODs derived from ground-based sun-sky photometer measurements and vertical profiles of detailed aerosol properties measured from aircraft above the ground station. Although the calculated aerosol optical depth (AOD) agreed well between the two estimates, AAODs obtained from sky radiometer measurements were only half of the in situ estimates. These results indicate that there are considerable uncertainties to use photometer measurements to constrain BC radiative forcing.

4. Koike, M., J. Ukita, J. Ström, P. Tunved, M. Shiobara, V. Vitale, A. Lupi, D. Baumgardner, C. Ritter, O. Hermansen, K. Yamada, and C. Pedersen (2019), Year□round in situ measurements of Arctic low□level clouds: Microphysical properties and their relationships with aerosols, *J. Geophys. Res. Atmos.*, *124*. https://doi. org/10.1029/2018JD029802.

In this paper, we reported seasonal variations of microphysical properties of Arctic low-level clouds based on the first continuous in situ cloud particle measurements in the Arctic (Spitsbergen Island). We showed that water cloud droplets persistently appear at the site and their concentrations are well correlated with cloud condensation nuclei (CCN). In fact a simple air parcel model can reproduced observed droplet concentrations from observed aerosols. This result provide a constraint for aerosol impacts on clouds. We also found that small size aerosols, which could be formed by new particle formation, can affect clouds. We provided basic features of microphysical properties of Arctic clouds for the first time.

4. Matsui, H., N. M. Mahowald, N. Moteki, D. S. Hamilton, S. Ohata, A. Yoshida3, M. Koike, R. A. Scanza, M. G. Flanner, Anthropogenic combustion iron as a complex climate forcer, *Nature Communications*, DOI: 10.1038/s41467-018-03997-0, 2018.

Recently, we have developed a technique to measure mass of individual iron oxide (magnetite and hematite) particles in the atmosphere. In this paper, we showed that the atmospheric burden of anthropogenic combustion iron is 8 times greater than previous estimates by incorporating our recent measurements of anthropogenic magnetite into a global aerosol model. We provided a first estimate of global radiative forcing of anthropogenic magnetite and showed that it is comparable with that of brown carbon. We further show that anthropogenic irons likely contribute significantly to the deposition flux of soluble iron to the ocean, especially in southern oceans.

4. Awards and Honors

- Most influential author in Japan in publication of American Geophysical Union (2009-2015) from American Geophysical Union, 2016.

5. Future Research Plan

The atmospheric science is coming to the new stage. The atmospheric science was advanced by introducing climate research (ocean-atmosphere interactions) to the traditional meteorology. Now, the atmospheric chemistry (material science) is being introduced as the third component of the atmospheric science and becoming a driver to create new areas. The center of this comprehensive study is aerosol-cloud-radiation system. In the future study, I would like to promote the new atmospheric science by combining atmospheric chemistry with traditional meteorology and climate research.

First, the global warming and environmental changes in the atmosphere clearly show that research on atmospheric compounds, such as green-house gases and aerosols, is critical for the atmospheric science. Second, this situation indicates that clouds and radiations, the fundamental elements of the meteorology, should be investigated within the new atmospheric science framework, in which roles of aerosols are taken into account. Third atmospheric compounds control air quality on which human beings depend and play a central role as a linkage between human dimension, terrestrial eco-system, ocean, and other Earth sub-systems.

To promote this new atmospheric science, I will conduct both observational and modeling studies on aerosol-cloud-radiation system especially in Asia and Arctic. First, I will extend and strengthen network measurements of atmospheric black carbon (BC) particles in the Arctic. IPCC and Arctic Council (AC) have started a discussion for emission control of BC as a short-lived climate forcer (SLCF). We have developed instruments to accurately measure BC and have been conducting measurements in the Arctic atmosphere, precipitation, and snowpack. We have been contributing to an AC assessment report through these activities. To explore these studies, I will investigate other anthropogenic aerosols, such as iron oxide, and various natural aerosols, such as dust and organic aerosols through various collaborations. In the Arctic, I would like to contribute to make Ny-Alesund a super-site of aerosol-cloud-radiation measurements. I will also carry out numerical modeling studies by collaborating with investigators, who once were Ph.D students of our group, in meteorological research institute and Nagoya University. We plan to introduce detailed treatments to key microphysical processes for aerosols and clouds, as we have done in previous studies. We then evaluate impacts of various anthropogenic and natural aerosols on Arctic climate, such as impacts of increases in marine aerosols due to reductions of sea ice and increases in dust particles due to reductions of snow/ice cover over land. We have been also collaborating with ice-core group in National Institute of Polar Research (NIPR) by introducing our aerosol detection methods to their system. By also combining numerical models, we will investigate long-term changes in aerosols and their impacts.

Second, I will extend and strengthen aerosol-cloud interaction studies in the Arctic and Asia. In the Arctic, I have been making a continuous in situ measurements of cloud microphysics. They are the unique datasets available in the Arctic. I will introduce a new instrument to discriminate ice particles from water droplets and would like to analyze these data by combining cloud radar and lidar data obtained by German groups. In our previous studies, we successfully showed a quantitative relationship between aerosols, which act as cloud condensation nuclei (CCN), and cloud droplet concentrations. For a next step, we will evaluate a relationship between ice particles and ice nucleating particles (INP), which are being measured by NIPR group, or solid particles, which we will measure. This activity will also be made under the super-site framework in Ny-Alesund. Furthermore, we would like to validate vertical profile measurements of clouds using radar and lidar by in situ measurements, and validate measurements of EarthCARE satellite to be launched in 2021 by radar and lidar. These series of validation will allow us to study cloud microphysics over the entire Arctic using satellite-derived products. We have also started using a new cloud microphysics model developed at Kochi University of Technology that can treat ice microphysics (such as ice habit) in detail. By using and improving this model, we would like to interpret our ground-based and aircraft observations of Arctic clouds and quantify key processes controlling cloud properties. Most of previous numerical models of cloud microphysics have been developed using measurements at mid-latitudes and sub-tropics. I would like to improve the model by also using Arctic cloud measurements. In the western North Pacific low-level clouds also persistently appear and result in significant cloud radiative forcing. Clouds over the western Pacific are considered to be affected by high-amount anthropogenic aerosols. In previous studies, we found warm sea surface temperature (SST) over the Kuroshio ocean current modulate aerosol-cloud interactions. I would like to conduct further aircraft experiments to investigate how anthropogenic and marine aerosols affect precipitation and macro structure of low-level clouds under the western Pacific environment. By also using numerical models, I would like to quantify aerosol impacts on cloud amount, optical properties, and radiation budget.

6. Funding Received

- JSPS Grants, Scientific Research (S)23221001, “Integrated studies of aerosol-cloud-precipitation system in Asia based on measurement and model calculations”, Co- Investigator, FY2011-2014, 215,150,000 yen
- Environment Research and Technology Development Fund, 2-1403,“Comprehensive estimates of black carbon radiative forcing leading to global warming”, Principal Investigator, FY2014-2016, 169,509,000yen
- JSPS Grants, Scientific Research(A)26241003, “Indirect effects of anthropogenic aerosols in East Asia”, Principal Investigator, FY2014-2017, 39,130,000 yen
- JSPS Grants, Scientific Research(A)16H01770, “Study on black carbon aerosols in the Arctic and their climate impacts”, Co-Investigator, FY2016-2019, 41,600,000 yen
- Environment Research and Technology Development Fund, 2-1703,“Black Carbon and Dust Particles in the Arctic: Behavior, Radiative Forcing, and Linkage with Global Warming”, Principal Investigator, FY2017-2019, 139,868,625yen
- MEXT Arctic Challenge for Sustainability Project, “Atmospheric climate forcers in the Arctic” Principal Investigator of one of research themes, FY2016-2019, 504,630,000 yen

7. Publications and Patents

(1) Peer-reviewed Journal Articles

1. Koike, M., J. Ukita, J. Ström, et al. (2019). Year‐round in situ measurements of Arctic low‐level clouds: Microphysical properties and their relationships with aerosols. J. Geophys. Res. Atmos., 124. https://doi. org/10.1029/2018JD029802.
2. Tobo, Y., K. Adachi, P. J. DeMott, T. C. J. Hill, D. S. Hamilton, N. M. Mahowald, N. Nagatsuka, S. Ohata, J. Uetake, Y. Kondo, and M. Koike, (2019). Glacially sourced dust as a potentially significant source of ice nucleating particles. Nature Geoscience, 12,253 – 12,258.
3. Ohata, S., Y. Kondo, N. Moteki, T. Mori, A. Yoshida, P. R. Sinha, and M. Koike, (2019). Accuracy of black carbon measurements by a filter-based absorption photometer with a heated inlet. Aerosol Sci. Technol., 53,1079- 1091, https://doi.org/10.1080/02786826.2019.1627283.
4. Matsui, H., N. Moteki, M. Koike, et al. (2018). Anthropogenic combustion iron as a complex

climate forcer. Nature Communications, 9, 1593, doi:10.1038/s41467-018-03997-0.

5. Yoshida, A., N. Moteki, M. Koike, et al. (2018). Abundance and emission flux of the anthropogenic iron oxide aerosols from the East Asian continental outflow. J. Geophys. Res. Atmos., 123, https://doi.org/10.1029/2018JD028665.
6. Ohata. S., N. Moteki, M. Koike, (2018). Abundance of light-absorbing anthropogenic iron oxide aerosols in the urban atmosphere and their emission sources. J. Geophys. Res. Atmos., 123, 8115–8134. https://doi.org/10.1029/2018JD028363.
7. Sinha, P. R., Y. Kondo, K. Goto-Azuma, Y. Tsukagawa, K. Fukuda, M. Koike, C. A. Pedersen, (2018). Seasonal progression of the deposition of black carbon by snowfall at Ny-Ålesund, Spitsbergen. J. Geophys. Res. Atmos., 122, https://doi. org/10.1002/2017JD028027.
8. Sinha, P. R., Y. Kondo, M. Koike, J. A. Ogren, A. Jefferson, T.E. Barrett, R. J. Sheesley, S. Ohata, N. Moteki, H. Coe, D. Liu, M. Irwin, P. Tunved, P. K. Quinn, and Y. Zhao, (2017). Evaluation of ground-based black carbon measurements by filter-based photometers at two Arctic sites. J. Geophys. Res. Atmos., 122, 3544–3572, doi:10.1002/2016JD025843.
9. Moteki, N., K. Adachi, S. Ohata, A. Yoshida, T. Harigaya, M. Koike, Y. Kondo, (2017). Anthropogenic iron oxide aerosols enhance atmospheric heating. Nature Communications, 8:15329, DOI: 10.1038/ncomms15329.
10. Koike, M., N. Asano, H. Nakamura, S. Sakai, T. M. Nagao, and T. Y. Nakajima, (2016). Modulations of aerosol impacts on cloud microphysics induced by the warm Kuroshio Current under the East Asian winter monsoon. J. Geophys. Res. Atmos., 121, doi:10.1002/2016JD025375.
11. Matsui, H., and M. Koike, (2016). Enhancement of aerosol responses to changes in emissions over East Asia by gas-oxidant-aerosol coupling and detailed aerosol processes. J. Geophys. Res. Atmos., 121, 7161–7171, doi:10.1002/2015JD024671.
12. Ohata, S., N. Moteki, T. Mori, M. Koike, Y. Kondo, (2016). A key process controlling the wet removal of aerosols: new observational evidence. Scientific Reports, 6, Article number: 34113, doi:10.1038/srep34113.
13. Kondo, Y., N. Moteki, N. Oshima, S. Ohata, M. Koike, Y. Shibano, N. Takegawa, and K. Kita, (2016). Effects of Wet deposition on the abundance and size distribution of black carbon in East Asia. J. Geophys. Res. Atmos., 4691–4712, doi:10.1002/2015JD024479.
14. Miyakawa, T, Y. Kanaya1 2, Y. Komazaki1, T. Miyoshi, H. Nara, A. Takami, N. Moteki, M. Koike, and Y. Kondo, (2016). Emission Regulations altered the concentrations, origin, and formation of carbonaceous aerosols in the Tokyo Metropolitan Area. Aerosol and Air Quality Research, 16, 1603 – 1614.
15. Mori, T., N. Moteki, S. Ohata, M. Koike, K. Goto-Azuma, Y. Miyazaki, and Y. Kondo, (2016). Improved Technique for Measuring the Size Distribution of Black Carbon Particles in Liquid Water. Aerosol Sci. Technol., 50, NO. 3, 242 – 254.
16. Ohata, S., J. P. Schwarz, N. Moteki, M. Koike, A. Takami, and Y. Kondo, (2016). Hygroscopicity of Materials Internally mixed with Black Carbon Measured in Tokyo. J. Geophys. Res. Atmos., 121, doi:10.1002/2015JD024153.
17. Takegawa, N., N. Moteki, N. Oshima, M. Koike, K. Kita, A. Shimizu, N. Sugimoto, and Y. Kondo, (2014). Variability of aerosol particle number concentrations observed over the western Pacific in the spring of 2009. J. Geophys. Res. Atmos., 119, doi:10.1002/2014JD0022014.
18. Samset, B. H., G. Myhre, A. Herber, Y. Kondo, S.-M. Li, N. Moteki, M. Koike, N. Oshima, J. P. Schwarz, Y. Balkanski, S. E. Bauer, N. Bellouin, T. K. Berntsen, H. Bian, M. Chin, T. Diehl, R. C. Easter, S. J. Ghan, T. Iversen, A. Kirkevåg, J.-F. Lamarque, G. Lin, X. Liu, J. E. Penner, M. Schulz, Ø. Seland, R. B. Skeie, P. Stier, T. Takemura, K. Tsigaridis, and K. Zhang, (2014).

Modeled black carbon radiative forcing and atmospheric lifetime in AeroCom Phase II constrained by aircraft observations. Atmos. Chem. Phys., 14, 12465-12477.

19. Matsui, H., M. Koike, Y. Kondo, J. D. Fast, and M. Takigawa, (2014). Development of an aerosol microphysical module: Aerosol Two-dimensional bin module for foRmation and Aging Simulation (ATRAS). Atmos. Chem. Phys., 14, 10315-10331.
20. Matsui, H., M. Koike, Y. Kondo, A. Takami, J. D. Fast, Y. Kanaya, and M. Takigawa, (2014). Volatility basis-set approach simulation of organic aerosol formation in East Asia: implications for anthropogenic–biogenic interaction and controllable amounts. Atmos. Chem. Phys., 14, 1-21.
21. Koike, M., N. Moteki, P. Khatri, T. Takamura, N. Takegawa, Y. Kondo, H. Hashioka, H. Matsui, A. Shimizu, and N. Sugimoto, (2014). Case study of absorption aerosol optical depth closure of black carbon over the East China Sea. J. Geophys. Res. Atmos., 118, doi:10.1002/2013JD020163.
22. Oshima, N., M. Koike, Y. Kondo, H. Nakamura, N. Moteki, H. Matsui, N. Takegawa, and K. Kita, (2013). Vertical transport mechanisms of black carbon over East Asia in spring during the A-FORCE aircraft campaign. J. Geophys. Res. Atmos., 118, 13,175–13,198, doi:10.1002/2013JD020262.
23. Takegawa, N., N. Moteki, M. Koike, N. Oshima, and Y. Kondo, (2013). Condensation particle counters combined with a low-pressure impactor for fast measurement of mode-segregated aerosol number concentration. Aerosol Sci. Technol., 47, 1059-1065.
24. Liu, X., Y. Kondo, K. Ram, H. Matsui, K. Nakagomi, T. Ikeda, N. Oshima, R. L. Verma, N. Takegawa, M. Koike, and M. Kajino, (2013). Seasonal variations of black carbon observed at the remote mountain site Happo in Japan. J. Geophys. Res., 118, 3709-3722, doi:10.1002/jgrd.50317.
25. Oshima, N. and M. Koike, (2013). Development of a parameterization of black carbon aging for use in general circulation models. Geosci. Model Dev., 6179 – 6206.
26. Matsui, H., M. Koike, N. Takegawa, Y. Kondo, A. Takami, T. Takamura, S. Yoon, S.-W. Kim, H.-C. Lim, and J. D. Fast, (2013). Spatial and temporal variations of new particle formation in EastAsia using an NPF-explicit WRF-chem model: North-south contrast in new particle formation frequency. J. Geophys. Res. Atmos., 118, 11,647–11,663, doi:10.1002/jgrd.50821.
27. Matsui, H., M. Koike, Y. Kondo, N. Oshima, N. Moteki, Y. Kanaya, A. Takami, and M. Irwin, (2013). Seasonal variations of Asian black carbon outflow to the Pacific: Contribution from anthropogenic sources in China and biomass burning sources in Siberia and Southeast Asia. J. Geophys. Res., 118, 9948–9967, doi:10.1002/jgrd.50702.
28. Matsui, H., M. Koike, Y. Kondo, N. Moteki, J. D. Fast, and R. A. Zaveri, (2013). Development and validation of a black carbon mixing state resolved three-dimensional model: Aging processes and radiative impact. J. Geophys. Res., doi:10.1029/2012JD018446.
29. Koike, M., N. Takegawa, N. Moteki, Y. Kondo, H. Nakamura, K. Kita, H. Matsui, N. Oshima, M. Kajino, and T. Y. Nakajima, (2012). Measurements of Regional-Scale Aerosol Impacts on Cloud Microphysics over the East China Sea: Possible Influences of Warm Sea Surface Temperature over the Kuroshio Ocean Current. J. Geophys. Res., 117, D17205, doi:10.1029/2011JD017324.
30. Moteki, N., Y. Kondo, N. Oshima, N. Takegawa, M. Koike, K. Kita, H. Matsui, and M. Kajino, (2012). Size dependence of wet removal of black carbon aerosols during transport from the boundary layer to the free troposphere. Geophys. Res. Lett., 39, L13802, doi:10.1029/2012GL052034.
31. Oshima, N., Y. Kondo, N. Moteki, N. Takegawa, M. Koike, K. Kita, H. Matsui, M. Kajino, H. Nakamura, J. S. Jung, and Y. J. Kim, (2012). Wet removal of black carbon in Asian outflow:

Aerosol Radiative Forcing in East Asia (A-FORCE) aircraft campaign. J. Geophys. Res., doi:10.1029/2011JD016552. (2) Non-peer-reviewed Articles.

(3) Review Papers

1. Chapter 7: Clouds and aerosols, in IPCC (2013). *Climate change 2013: The physical science basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge, UK: Cambridge University Press. (contributing author)

(4) Books

(5) Other Publications

(6) Patents

8. Keynote, Invited, or Solicited Presentations

1. Koike, M., Aircraft experiments on interactions between low-level clouds and aerosols, Meteorological Society of Japan, 40th assembly of Association for meso-scale weather, Tohoku University, Miyagi, 2013/11/18.
2. Koike, M., N. Moteki, Y. Kondo, N. Takekawa, H. Nakamura, Y. Kawai, and Y. Tanimoto, Regional-scale aerosol impacts on cloud microphysics over the East China Sea and possible influences of warm sea surface temperature over the Kuroshio ocean current, The oceanography society of Japan, Hokkaido University, Hokkaido, 2013/9/19.
3. Koike, M., M. Shiobara, and J. Ukita, Cloud microphysics measurements in Ny-alesund and relationship with aerosols, Japan-AWI workshop, university of Tokyo, Japan, 2016/11/16.
4. Koike, M., S. Morimoto, M. Takigawa, and ARCS ACFA SCIENCS TEAM, Research activities on atmospheric climate forcers in the Arctic, The 7th symposium on polar science, National Institute of Polar Research, Tokyo, Japan, 2016/12/2.
5. Koike, M., Y. Kondo, K. Goto-Azuma, Y. Ogawa-Tsukagawa, P. R. Sinha, S. Ohata, N. Moteki, N. Oshima, and H. Matsui, Black carbon in the Arctic: Observation and numerical model calculation, AC3 workshop, Bremerhaven, Germany, 2017/11/29-30.

III. Education Activity

9. Notable Achievements in Education

Advisees

・ Master theses: 9 students

Rei Takatani, Yu Goto, (Mar. 2013)

Naruhiko Asano, Yuki Shibano, (Mar. 2014)

Tomoo Hirigaya, (Mar. 2015)

Atushi Yoshida, (Mar. 2016)

Kosuke Katumoto, Kouichi Sugiyama,(Mar. 2017)

Rina Konishi, (Mar. 2018)

・ Doctral theses: 1 student

Yuya Ozawa, (Mar. 2018)

Lectures

- Undergraduate/Graduate, Material science in the atmosphere and ocean I, FY2012-2018 (every two years)
- Undergraduate, Material science in the atmosphere and ocean I, FY2012-2018
- Undergraduate, Laboratory experiments for earth and planetary physics/chemistry, FY2012-2018
- Undergraduate, Field observation for earth and planetary physics, FY2012-2018

IV. External Activities

10. Contribution to Academic Community

- Contributing author for Chapter 7: Clouds and aerosols, in IPCC (2013). *Climate change 2013: The physical science basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge, UK: Cambridge University Press.
- Arctic Council, Arctic Monitoring and Assessment Programme (AMAP), Short-lived Climate force (SLCF) task force committee member, FY2017-2018
- Science Council of Japan, Committee of Environment and Earth and Planetary Sciences, IGBP・WCRP joint-committee, IGAC (International Global Atmospheric Chemistry) committee member, FY2012-2014
- Science Council of Japan, Committee of Environment and Earth and Planetary Sciences, IGBP・WCRP joint-committee, iLEAPS (Integrated Land Ecosystem-Atmosphere Processes Study) committee member, FY2012-present
- The Meteorological Society of Japan, Editor of SOLA (Scientific Online Letters on the Atmosphere), FY2012-2016
- Japan Society of Atmospheric Chemistry, Executive Board Member, FY2012-2013
- JAXA Earth Clouds, Aerosols and Radiation Explorer (EarthCARE) mission committee member, FY2002-present
- JAXA Global Change Observation Mission (GCOM) committee member, FT2012-present
- The Meteorological Society of Japan, member of committee of academic affairs, FY2014-present
- The Meteorological Society of Japan, chair of committee for aircraft experiment, FY2014-present
- The Meteorological Society of Japan, Executive Board Member,, 2018-present

11. Outreach Activity

12. Internal Committee Membership

V. International Exchange Activities

13. Hosting/Sending Foreign Students and Researchers

(1) Hosting

Foreign Students: none

Foreign Researchers: 1

(2) Sending

Students: 3

Researchers: 3

(3) Visitors from Abroad: 5

Tomoki Tozuka

I. CV

Name: Tomoki Tozuka

Age: 43

Present Position: Associate Professor

Education

Ardsley High School, New York, U.S.A, June, 1994 (graduation)

B. Sc. Department of Geophysics, The University of Tokyo, March, 1999

M. Sc. Department of Earth and Planetary Science, The University of Tokyo, March, 2001

Ph. D. Department of Earth and Planetary Science, The University of Tokyo, March, 2004

Professional Experience

Apr. 2004-Mar. 2006, Project Postdoctoral Fellow, Department of Earth and Planetary Physics, Graduate School of Science, The University of Tokyo

Apr. 2006-Mar. 2007: Project Research Associate, Department of Earth and Planetary Physics, Graduate School of Science, The University of Tokyo

Apr. 2007-Mar. 2008: Project Assistant Professor, Department of Earth and Planetary Physics, Graduate School of Science, The University of Tokyo

Apr. 2008-Nov. 2011: Assistant Professor, Department of Earth and Planetary Physics, Graduate School of Science, The University of Tokyo

Nov. 2011-, Associate Professor, Department of Earth and Planetary Physics, Graduate School of Science, The University of Tokyo

II. Scientific Research Activity

2. Major Achievements

I have been working on atmosphere-ocean interactions in mid- and low-latitudes from a thermodynamic perspective. First, I have investigated mechanisms of interannual variations in four oceanic upwelling domes in the world oceans based on heat budget analyses using high-resolution ocean general circulation models (OGCMs). While investigating the Mindanao Dome in the western tropical Pacific, I have identified the existence of “annual El Niño-Southern Oscillation”. Second, based on sensitivity experiments using an OGCM, I have shown for the first time that the South China Sea throughflow, which flows from the Luzon Strait to the Indonesian Seas, has a strong influence on the heat transport by the Indonesian Throughflow that governs the global climate. Regarding climate variation phenomena, I have clarified the generation mechanisms and associated air-sea interaction of the Ningaloo Niño off the west coast of Australia. Also, I have contributed to the understanding of decadal variations and diversity of the Indian Ocean Dipole. More recently, I made important contributions in the air-sea interaction study of the mid-latitude oceanic frontal regions. In particular, I have pointed out the importance of horizontal variations in mixed layer depth for the first time.

3. Five Important Papers (including three or more papers in this review period)

1. Kagimoto, T., Masumoto, Y., & Yamagata, T. (2002). Simulated multiscale variations in the western tropical Pacific: The Mindanao Dome revisited. Journal of Physical Oceanography, 32, 1338–1359. https://doi.org/10.1175/1520-0485(2002)032<1338:SMVITW>2.0.CO;2

The Mindanao Dome is a large-scale upwelling dome located in the western tropical Pacific, which plays an important role in global-scale climate variations through active air-sea interaction. This paper is the first to discuss interannual variations of this phenomenon. (Citation 80, GS/Sep. 10, 2019)

2. Qu, T., Kim, Y. Y., Yaremchuk, M., Tozuka, T., Ishida, A., & Yamagata, T. (2004). Can Luzon Strait transport play a role in conveying the impact of ENSO to the South China Sea? Journal of Climate, 17, 3644–3657. https://doi.org/10.1175/1520-0442(2004)017<3644:CLSTPA>2.0.CO;2

Although the El Niño/Southern Oscillation (ENSO) was considered to influence the South China Sea via the atmosphere, this paper showed the ENSO influence through the Luzon Strait for the first time. This paper is one of the most cited papers on the interannual variations of the South China Sea. (Citation 288, GS/Sep. 10, 2019)

3. Kataoka, T., Tozuka, T., Behera, S. K., & Yamagata, T. (2014). On the Ningaloo Niño/Niña. Climate Dynamics, 43, 1463–1482. https://doi.org/10.1007/s00382-013-1961-z

Ningaloo Niño that develop off the west coast of Australia is considered to be induced by the El Niño/Southern Oscillation, but this study showed for the first time that it may develop through local air-sea interaction. This is a highly cited paper among papers on this phenomenon. (Citation 63, GS/Sep. 10, 2019)

4. Tozuka, T., Cronin, M. F., & Tomita, H. (2017). Surface frontogenesis by surface heat fluxes in the upstream Kuroshio Extension region. Scientific Reports, 7, 10258. https://doi.org/10.1038/s41598-017-1

Based on a mixed layer heat budget analysis, surface frontogenesis by surface heat fluxes in the upstream Kuroshio Extension region is examined. While one might assume that larger surface heat losses on the equatorward side would tend to damp the sea surface temperature front, we have presented observational evidence that the surface heat losses actually strengthens the front. This counterintuitive but fascinating result may be explained by the fact that the effective heat capacity of the surface water depends on mixed layer thickness, which was overlooked in past studies. (Citation 4, GS/Sep. 10, 2019)

5. Tozuka, T., Ohishi, S., & Cronin, M. F. (2018). A metric for surface heat flux effect on horizontal sea surface temperature gradients. Climate Dynamics, 51, 547–561. https://doi.org/10.1007/s00382-017-3940-2

The contribution of surface heat fluxes to surface frontogenesis/frontolysis depends not just on their gradients, but also on the distribution of mixed layer depth. In this study, a new metric that quantifies the relative importance of horizontal variations in surface heat fluxes and mixed layer depth is proposed. Because of its vast implications, this paper has been cited 10 times in the first year after publication. (Citation 10, GS/Sep. 10, 2019)

4. Awards and Honors

- Tozuka, T., Journal of Geophysical Research-Oceans: 2013 Editor's Citation for Excellence in Refereeing, Apr. 2014

5. Future Research Plan

Climate variation phenomena such as the El Niño-Southern Oscillation are known to induce abnormal weather over the globe, and ocean-atmosphere interactions are known to play an important role in the development of climate variation phenomena. Since climate variations longer than few months are predominantly controlled by the ocean, I would like to improve our understanding of various climate variation phenomena in mid- and low-latitudes and ocean-atmosphere interactions involved in the development of those phenomena mainly from a physical oceanographic viewpoint. Also, since we may mitigate impacts of abnormal weather if we can accurately predict occurrence of climate variation phenomena, I will conduct predictability studies. Furthermore, in collaboration with researchers from other fields, I plan to investigate how climate variation phenomena influence marine and terrestrial ecosystems under changing climate.

6. Funding Received

- JSPS Grant-in-Aid for Challenging Exploratory Research, 24654150, Prediction of Atlantic Niño, Principal Investigator, FY2012-2014, 3,510,000 yen
- MEXT Grant-in-Aid for Scientific Research on Innovative Areas, 25106704, Role of mixed layer depth variability in generation of the oceanic front and sea surface temperature variability in the Kuroshio Extension region, Principal Investigator, FY2003-2014, 2,600,000 yen
- MEXT Grant-in-Aid for Scientific Research on Innovative Areas, 16H01589, Role of mixed layer depth variations in the Pacific Decadal Oscillation, Principal Investigator, FY2016-2017, 4,160,000 yen
- JSPS Grant-in-Aid for Scientific Research (B), 16H04047, Mechanisms and predictability of coastal niños, Principal Investigator, FY2016-2018, 17,940,000 yen
- MEXT Grant-in-Aid for Scientific Research on Innovative Areas, 18H04913, A study on the surface mixed layer based on the frontal Ekman theory, Principal Investigator, FY2018-2019, 5,200,000 yen

7. Publications and Patents

(1) Peer-reviewed Journal Articles

1. Kataoka, T., Tozuka, T., Masumoto, Y., & Yamagata, T. (2012). The Indian Ocean subtropical dipole mode simulated in the CMIP3 models. Climate Dynamics, 39, 1385–1399. https://doi.org/10.1007/s00382-011-1271-2
2. Yuan, C., Tozuka, T., & Yamagata, T. (2012). IOD influence on the early winter Tibetan Plateau snow cover: Diagnostic analyses and an AGCM simulation. Climate Dynamics, 39, 1643–1660. https://doi.org/10.1007/s00382-011-1204-0
3. Morioka, Y., Tozuka, T., Masson, S., Terray, P., Luo, J.-J., & Yamagata, T. (2012). Subtropical dipole modes simulated in a coupled general circulation model. Journal of Climate, 25, 4029–4047. https://doi.org/10.1175/JCLI-D-11-00396.1
4. Pourasghar, F., Tozuka, T., Jahanbakhsh, S., Sari Sarraf, B., Ghaemi, H., & Yamagata, T. (2012). The interannual precipitation variability in the southern part of Iran as linked to large-scale climate modes. Climate Dynamics, 39, 2329–2341. https://doi.org/10.1007/s00382-012-1357-5
5. Morioka, Y., Tozuka, T., & Yamagata, T. (2013). How is the Indian Ocean subtropical dipole excited? Climate Dynamics, 41, 1955–1968. https://doi.org/10.1007/s00382-012-1584-9
6. Nagura, M., Sasaki, W., Tozuka, T., Luo, J.-J., Behera, S., & Yamagata, T. (2013). Longitudinal biases in the Seychelles Dome simulated by 35 ocean-atmosphere coupled general circulation

models. Journal of Geophysical Research: Oceans, 118, 831–846. https://doi.org/10.1029/2012JC008352

7. Cronin, M. F., Tozuka, T., Biastoch, A., Durgadoo, J., & Beal, L. (2013). Prevalence of strong bottom currents in the greater Agulhas system. Geophysical Research Letters, 40, 1772–1776. https://doi.org/10.1002/grl.50400
8. Prodhomme, C., Terray, P., Masson, S., Izumo, T., Tozuka, T., & Yamagata, T. (2014). Impacts of Indian Ocean SST biases on the Indian Monsoon: as simulated in a global coupled model. Climate Dynamics, 42, 271–290. https://doi.org/10.1007/s00382-013-1671-6
9. Tozuka, T., Abiodun, B. J., & Engelbrecht, F. A. (2014). Impacts of convection schemes on simulating tropical-temperate troughs over southern Africa. Climate Dynamics, 42, 433–451. https://doi.org/10.1007/s00382-013-1738-4
10. Yuan, C., Tozuka, T., Luo, J.-J., & Yamagata, T. (2014). Predictability of the subtropical dipole modes in a coupled ocean-atmosphere model. Climate Dynamics, 42, 1291–1308. https://doi.org/10.1007/s00382-013-1704-1
11. Tozuka, T., Nagura, M., & Yamagata, T. (2014). Influence of the reflected Rossby waves on the western Arabian Sea upwelling region. Journal of Physical Oceanography, 44, 1424–1438. https://doi.org/10.1175/JPO-D-13-0127.1
12. Tozuka, T., & Cronin, M. F. (2014). Role of mixed layer depth in surface frontogenesis: the Agulhas Return Current front. Geophysical Research Letters, 41, 2447–2453. https://doi.org/10.1002/2014GL059624
13. Yuan, C., Tozuka, T., Landman, W. A., & Yamagata, T. (2014). Dynamical seasonal prediction of southern African summer precipitation. Climate Dynamics, 42, 3357–3374. https://doi.org/10.1007/s00382-013-1923-5
14. Kataoka, T., Tozuka, T., Behera, S. K., & Yamagata, T. (2014). On the Ningaloo Niño/Niña. Climate Dynamics, 43, 1463–1482. https://doi.org/10.1007/s00382-013-1961-z
15. Oettli, P., Tozuka, T., Izumo, T., Engelbrecht, F., & Yamagata, T. (2014). The self-organizing map, a new approach to apprehend the Madden-Julian Oscillation influence on the intraseasonal variability of rainfall in the southern-African region. Climate Dynamics, 43, 1557–1573. https://doi.org/10.1007/s00382-013-1985-4
16. Tozuka, T., Kataoka, T., & Yamagata, T. (2014). Locally and remotely forced atmospheric circulation anomalies of Ningaloo Niño/Niña. Climate Dynamics, 43, 2197–2205. https://doi.org/10.1007/s00382-013-2044-x
17. Tozuka, T., Qu, T., & Yamagata, T. (2015). Impacts of South China Sea Throughflow on the mean state and El Niño/Southern Oscillation as revealed by a coupled GCM. Journal of Oceanography, 71, 105–114. https://doi.org/10.1007/s10872-014-0265-1
18. Yamagami, Y., & Tozuka, T. (2015). Interdecadal changes of the Indian Ocean subtropical dipole mode. Climate Dynamics, 44, 3057–3066. https://doi.org/10.1007/s00382-014-2202-9
19. Pourasghar, F., Tozuka, T., Ghaemi, H., Oettli, P., Jahanbakhsh, S., & Yamagata, T. (2015). Influences of the MJO on intraseasonal rainfall variability over southern Iran. Atmospheric Science Letters, 16, 110–118. https://doi.org/10.1002/asl2.531
20. Yamagami, Y., & Tozuka, T. (2015). Interannual variability of South Equatorial Current bifurcation and western boundary currents along the Madagascar coast. Journal of Geophysical Research: Oceans, 120, 8551–8570. https://doi.org/10.1002/2015JC011069
21. Kohyama, T., & Tozuka, T. (2016). Seasonal variability of the relationship between SST and OLR in the Indian Ocean and its implications for initialization in a CGCM with SST-nudging. Journal of Oceanography, 72, 327–337. https://doi.org/10.1007/s10872-015-0329-x

22. Endo, S., & Tozuka, T. (2016). Two flavors of the Indian Ocean Dipole. Climate Dynamics, 46, 3371–3385. https://doi.org/10.1007/s00382-015-2773-0

23. Tozuka, T., Endo, S., & Yamagata, T. (2016). Anomalous Walker Circulations associated with two flavors of the Indian Ocean Dipole. Geophysical Research Letters, 43, 5378–5384. https://doi.org/10.1002/2016GL068639

24. Cronin, M. F., & Tozuka, T. (2016). Steady state ocean response to wind forcing in extratropical frontal regions. Scientific Reports, 6, 28842. https://doi.org/10.1038/srep28842

25. Kido, S., Kataoka, T., & Tozuka, T. (2016). Ningaloo Niño simulated in the CMIP5 models. Climate Dynamics, 47, 1469–1484. https://doi.org/10.1007/s00382-015-2913-6

26. Ohishi, S., Tozuka, T., & Komori, N. (2016). Frontolysis by surface heat flux in the Agulhas Return Current region with a focus on mixed layer processes: Observation and a high-resolution CGCM. Climate Dynamics, 47, 3993–4007. https://doi.org/10.1007/s00382-016-3056-0

27. Tanizaki, C., Tozuka, T., Doi, T., & Yamagata, T. (2017). Relative importance of the processes contributing to the development of SST anomalies in the eastern pole of the Indian Ocean Dipole and its implication for predictability. Climate Dynamics, 49, 1289–1304. https://doi.org/10.1007/s00382-016-3382-2

28. Kido, S., & Tozuka, T. (2017). Salinity variability associated with the positive Indian Ocean Dipole and its impact on the upper ocean temperature. Journal of Climate, 30, 7885–7907. https://doi.org/10.1175/JCLI-D-17-0133.1

29. Tozuka, T., Cronin, M. F., & Tomita, H. (2017). Surface frontogenesis by surface heat fluxes in the upstream Kuroshio Extension region. Scientific Reports, 7, 10258. https://doi.org/10.1038/s41598-017-1

30. Ohishi, S., Tozuka, T., & Cronin, M. F. (2017). Frontogenesis in the Agulhas Return Current region simulated by a high-resolution CGCM. Journal of Physical Oceanography, 47, 2691–2710. https://doi.org/10.1175/JPO-D-17-0038.1

31. Kataoka, T., Tozuka, T., & Yamagata, T. (2017). Generation and decay mechanisms of Ningaloo Niño/Niña. Journal of Geophysical Research: Oceans, 122, 8913–8932. https://doi.org/10.1002/2017JC012966

32. Tozuka, T., Ohishi, S., & Cronin, M. F. (2018). A metric for surface heat flux effect on horizontal sea surface temperature gradients. Climate Dynamics, 51, 547–561. https://doi.org/10.1007/s00382-017-3940-2

33. Kataoka, T., Masson, S., Izumo, T., Tozuka, T., & Yamagata, T. (2018). Can Ningaloo Niño/Niña develop without El Niño/Southern Oscillation? Geophysical Research Letters, 45, 7040–7048. https://doi.org/10.1029/2018GL078188

34. Tozuka, T., & Oettli, P. (2018). Asymmetric cloud–shortwave radiation–sea surface temperature feedback of Ningaloo Niño/Niña. Geophysical Research Letters, 45, 9870–9879. https://doi.org/10.1029/2018GL079869

35. Seow, M. X. C., & Tozuka, T. (2019). Ocean thermodynamics behind the asymmetry of interannual variation of South China Sea winter cold tongue strength. Climate Dynamics, 52, 3241–5253. https://doi.org/10.1007/s00382-018-4320-2

(2) Non-peer-reviewed Articles

(3) Review Papers

1. Tozuka, T. (2012). Climate variation. Encyclopedia of Simulation, Japan Society for Simulation Technology.

2. Yamagata, T., Tozuka, T., & Behera, S. K. (2013). New El Niño. Kishou Kenkyuu Note, 228, 89–95.
3. Kida, S., Mitsudera, H., Aoki, S., Guo, X., Ito, S., Kobashi, F., Komori, N., Kubokawa, A., Miyama, T., Morie, R., Nakamura, H., Nakamura, T., Nakano, H., Nishigaki, H., Nonaka, M., Sasaki, H., Sasaki, Y. N., Suga, T., Sugimoto, S., Taguchi, B., Takaya, K., Tozuka, T., Tsujino, H., & Usui, N. (2015). Oceanic Fronts and Jets around Japan - a review. Journal of Oceanography, 71, 469–497. https://doi.org/10.1007/s10872-015-0283-7

(4) Books

1. Richter, I., Chang, P., Xu, Z., Doi, T., Kataoka, T., Nagura, M., Oettli, P., de Szoeke, S., & Tozuka, T. (2016). An overview of coupled GCM biases in the tropics. In "The Indo-Pacific Climate Variability and Predictability", World Scientific Publisher on Asia-Pacific Weather and Climate, 213–263.
2. Qu, T., Tozuka, T., Kida, S., Guo, X., Miyazawa, Y., & Liu, Q. (2016). Western Pacific and marginal sea processes. In "The Indo-Pacific Climate Variability and Predictability", World Scientific Publisher on Asia-Pacific Weather and Climate, 151–186.

(5) Other Publications

(6) Patents

8. Keynote, Invited, or Solicited Presentations

1. Tozuka, T., Yokoi, T., & Yamagata, T., Interannual variations of the Seychelles Dome, 10th International Conference on Southern Hemisphere Meteorology and Oceanography, Noumea, New Caledonia, 2012/4/26.
2. Tozuka, T., Yokoi, T., & Yamagata, T., Variability of the Seychelles Dome and its possible connection to the Madden-Julian Oscillation. AGU Fall Meeting 2012, San Francisco, USA, 2012/12/3.
3. Tozuka, T., Endo, S., & Tanizaki, C., Diversity in the Indian Ocean Dipole, Otsuchi Symposium, Iwate, Japan, 2015/9/10.
4. Tozuka, T., Oettli, P., Doi, T., Morioka, Y., Ratna, S. B., Behera, S. K., & Yamagata, T., Application of network approach to upper ocean heat content and sea surface temperature anomalies in the Indian and Pacific Oceans, The Oceanographic Society of Japan 2016 Spring Meeting, Tokyo, Japan, 2016/3/16.
5. Tozuka, T., C. Tanizaki, and T. Doi, Is predictability of Indian Ocean Dipole events dependent on the developing mechanism? Asia Oceania Geosciences Society 16th Annual Meeting, Beijing, China, 2016/8/3.
6. Tozuka, T., Kataoka, T., Kido, S., Doi, T., Racault, M.-F., Behera, S. K., & Yamagata, T., Ningaloo Nino/Nina: Mechanism, predictability and impact, European Geosciences Union General Assembly 2018, Vienna, Austria, 2018/4/13.

III. Education Activity

9. Notable Achievements in Education

Advisees

・ Master theses: 7 students

Yoko Yamagami (Mar. 2015)

Satoru Endo, Chiho Tanizaki (Mar. 2016)

Shoichiro Kido (Sep. 2017)

Marvin Seow Xiang Ce (Sep. 2018)

Ryo Kobayashi, Kazumichi Murata (Mar. 2019)

・ Doctral theses: 3 students

Takahito Kataoka (Mar. 2015)

Shun Ohishi (Mar. 2017)

Yoko Yamagami (Mar. 2018)

Lectures

・ Undergraduate, Atmosphere-ocean system physics, FY2012-2018
・ Undergraduate, Exercises in earth and planetary physics, FY2012-2018
・ Undergraduate, Senior project in earth and planetary physics, FY2012, 2015-2018
・ Undergraduate, Senior research in earth and planetary physics, FY2012-2016, 2018
・ Graduate, Climate dynamics I, FY2012-2016
・ Graduate, Mathematical research on real world problems, FY2016-2018
・ Undergraduate, Earth science, FY2012-2018
・ Undergraduate, First year seminar for natural sciences students, FY2015-2016
・ Undergraduate, Overview of earth and planetary physics, FY2018

Student's awards

・ General Meeting of "Hot Spots" in the Climate System, Student Best Poster Award: 1 student [Shun Ohishi]
・ International symposium on the Indian Ocean, Best Poster Award: 1 student [Yoko Yamagami]
・ Japan Geoscience Union, Student Presentation Award: 2 students [Shoichiro Kido, Yoko Yamagami]

IV. External Activities

10. Contribution to Academic Community

・ Oceanographic Society of Japan, Officer, FY2015-2018
・ Oceanographic Society of Japan, Journal of Oceanography, Editor, FY2011-Present
・ Oceanographic Society of Japan, Councilor, FY2017- Present
・ Oceanographic Society of Japan, Paper Award Committee, Member, FY2018-Present
・ Oceanographic Society of Japan, Spring Meeting 2016, Local organizing committee, FY2016
・ Japan Geoscience Union, Representative, FY2016- Present
・ Japan Geoscience Union, Program Committee, Member, FY2016-2018
・ American Meteorological Society, Journal of Climate, Associate Editor, FY2016- Present
・ Frontiers in Atmospheric Science, Review Editor, FY2013-Present

- CLIVAR Indian Ocean Regional Panel, Member, FY2014-2018
- Science Council of Japan, National Committee for CLIVAR, FY2014- Present
- Science Council of Japan, National Committee for IIOE-2, FY2018- Present

11. Outreach Activity

- Lectures for general audience: 7 times (Aug. 2014, Aug. 2014, Aug. 2015, Aug. 2015, Jun. 2016, Aug. 2016, Aug. 2017)

12. Internal Committee Membership

- Department of Earth and Planetary Science, Education Committee, Member, FY2012-2018
- Department of Earth and Planetary Science, Public Relations Committee, Chair, FY2013-2015
- Department of Earth and Planetary Science, Public Relations Committee, Member, FY2012, 2016-2017

V. International Exchange Activities

13. Hosting/Sending Foreign Students and Researchers

(1) Hosting

Foreign Students: 6

Foreign Researchers: 1

(2) Sending

Students: 5

Researchers: 0

(3) Visitors from Abroad: 13

Hiroaki Miura

I. CV

Name: Hiroaki Miura

Age: 43

Present Position: Associate Professor

Education

Sendai Daiichi High School, Miyagi, March, 1994 (graduation)

B. Sc. Department of Science, Kyoto University, March, 1999

M. Sc. Department of Earth and Planetary Science, The University of Tokyo, March, 2001

Ph. D. Department of Earth and Planetary Science, The University of Tokyo, March, 2004

Professional Experience

Apr. 2004-Jan. 2008, Postdoctoral Researcher, Frontier Research Center for Global Change, Japan Agency for Marine-Earth Science and Technology, Japan

Feb. 2008-Sep. 2009, Visiting Scientist, Department of Atmospheric Science, Colorado State University, USA

Oct. 2009-Mar. 2012, Project Assistant Professor, Center for Climate System Research, The University of Tokyo, Japan

Apr. 2012-, Associate Professor, Department of Earth and Planetary Science, Graduate School of Science, The University of Tokyo, Japan

II. Scientific Research Activity

2. Major Achievements

By taking advantages of the Earth Simulator and the K-Computer, which were some of the most powerful computers in the world, I have conducted researches to validate the potentials of global cloud-system-resolving models (GCRMs) to reduce the uncertainties in climate predictions in the future. More specifically, I have shown that GCRMs have the potential to estimate smaller climate sensitivity than the global climate models, and that GCRMs have the potential to reproduce the Madden-Julian Oscillation realistically. Moreover, I have contributed significantly to the researche that improved reproducibility of aerosol transports to the Arctic region and also to the research that demonstrated a near one-month predictability of the Madden-Julian Oscillation. On the other hand, I am also carrying out researches to improve the accuracy of fluid dynamics solver of a GCRM by advancing the numerical schemes on the icosahedral hexagonal/pentagonal mesh. Other achievements include researches in collaboration with students that revealed background environments that enhance the realization of the Madden-Julian Oscillation, that provided a hypothesis about the self-organization of convective clouds, and that accomplished a direct numerical simulation of a falling rain droplet with deformation. I am also collaborating with observation groups, sending students to tropical observation campaigns.

3. Five Important Papers (including three or more papers in this review period)

1. Miura, H., Satoh, M., Nasuno, T., Noda, A., & Oouchi, K. (2007), A Madden-Julian oscillation

event realistically simulated by a global cloud-resolving model. *Science*, **318**, 1763-1765, doi: 10.1126/science.1148443

Simulations of the Madden-Julian Oscillation (MJO), which is characterized by a packet of large-scale organized cloud systems, had been thought insufficient in both weather prediction and climate models. This work demonstrated that a global cloud-system-resolving model (GCRM) had a potential to reproduce an MJO event realistically. (Citation 307, GS/Oct. 7, 2019)

2. Miura, H., Tomita, H., Nasuno, T., Iga, S., Satoh, M., & Matsuno, T. (2005), A climate sensitivity test using a global cloud resolving model under an aqua planet condition. *Geophys. Res. Lett.*, **32**, L19717, doi:10.1029/2005GL023672

There still remains uncertainties in estimating a sensitivity of our climate system to a climate change. This is partly because global climate models cannot simulate clouds directly. This work demonstrated that the climate sensitivity of a GCRM was smaller than a standard global climate model under an aquaplanet condition. (Citation 84, GS/Oct. 7, 2019)

3. Satoh, M., Tomita, H., Yashiro, H., Miura, H., Kodama, C., Seiki, T., Noda, A. T., Yamada, Y., Goto, D., Sawada, M., Miyoshi, T., Niwa, Y., Hara, M., Ohno, T., Iga, S., Arakawa, T., Inoue, T., Kubokawa, H., 2014: The Non-hydrostatic Icosahedral Atmospheric Model: Description and Development. Progress in Earth and Planetary Science, 1, 18. doi:10.1186/s40645-014-0018-1

The development of the nonhydrostatic icosahedral atmosphere model (NICAM) had been begun around 2000, targeting the Earth Simulator. NICAM had been updated, targeting the next flagship machine, the K-Computer. This work summarized those developments and described the future update plan. (Citation 174, GS/Oct. 7, 2019)

4. Miyakawa, T., Satoh, M., Miura, H., Tomita, H., Yashiro, H., Noda, A. T., Yamada, Y., Kodama, C., Kimoto, M., & Yoneyama, K. (2014), Madden-Julian Oscillation prediction skill of a new-generation global model demonstrated using a supercomputer. *Nature Communications*, **5**, 3769. 10.1038/ncomms4769

The work of Miura et al. (2007) only evaluated the reproducibility of a single MJO event. In this work, the predictability of the MJO of NICAM was evaluated by performing an ensemble prediction of multiple MJO events. The predictability longer than 25 days was demonstrated. (Citation 73, GS/Oct. 7, 2019)

5. Suematsu, T., & Miura, H. (2018), Zonal SST Difference as a Potential Environmental Factor Supporting the Longevity of the Madden–Julian Oscillation. *J. Climate,* **31**, 7549–7564. https://doi.org/10.1175/JCLI-D-17-0822.1

This work showed that not intraseasonal (20-60 days) component but low frequency component (>90 days) of sea surface temperature (SST) constitutes an important background for the realization of the Madden-Julian Oscillation. This work is a part of the Ph.D. dissertation of a former student, Dr. Suematsu. The MJO detection method proposed in this work forms an important foundation of the very recent research about the duration of MJO under the climate change (Roxy et al., Nature accepted). Dr. Suematsu will be the fourth author of that paper. (Citation 1, GS/Oct. 7, 2019)

4. Awards and Honors

- Miura, H., SOLA Paper Award (Miura, 2017), Jan. 2018
- Miura, H., PEPS Most Accessed Paper Award (Satoh et al. 2014), May 2017
- Miura, H., PEPS Most Cited Paper Award (Satoh et al. 2014), May 2018

5. Future Research Plan

I will continue to develop global cloud-system-resolving models (GCRMs). I will especially focus on advancing horizontal discretization method, which have been a weakness of the nonhydrostatic icosahedral atmosphere model (NICAM). Furthermore, by updating the advection schemes, I will improve the overall representation of atmospheric phenomena in which thermodynamics and moist processes play essential roles. To realize climate simulation by GCRMs in the future, I will not only make advances in the numerical schemes but also make progresses in improving and validating physical parameterizations. Building on to those improvements, I will make super-high-resolution atmosphere-ocean coupled models, which couples a GCRM with a high-resolution ocean model, available for practical use. With the global/regional CRMs, I will investigate the mechanisms of cloud organization and elucidate the role of moisture in extreme events such as the West Japan Heavy Rain Disaster. I will also investigate the role of the air-sea interactions in east Asia, which may be behind the formation of background environment for hazardous intense rainfall, and begin research for cloud development/dissipation processes that are necessary for more accurate predictions of heavy rainfall. On the other hand, I will work together with observation groups to solve mechanisms of the Madden-Julian Oscillation, often referred to as the holy grail of the tropical troposphere.

6. Funding Received

- JSPS Grant-in-Aid for Scientific Research (B) 16H04048, PI, FY2016-2020, 17,290,000 yen
- JSPS Grant-in-Aid for Scientific Research (B) 25287119, PI, FY2013-2016, 17,810,000 yen
- JSPS Grant-in-Aid for Young Scientists (B) 22750310, PI, FY2010-2013, 4,160,000 yen

7. Publications and Patents

(1) Peer-reviewed Journal Articles

1. Miura, H. (2017), Coupling the hexagonal B1-grid and B2-grid to avoid a computational mode problem of the hexagonal ZM-grid. *Sci. Online Lett. Atmos.*, **13**, 69-73, doi:10.2151/sola.2017-013
2. Miura, H., Suematsu, T., & Nasuno, T. (2015), An ensemble hindcast of the Madden-Julian Oscillation during the CINDY2011/DYNAMO field campaign and influence of seasonal variation of sea surface temperature. *J. Meteor. Soc. Japan*, **93A**, 115-137, https://doi.org/10.2151/jmsj.2015-055
3. Miura, H. (2013): An upwind-biased conservative transport scheme for multi-stage temporal integrations on spherical icosahedral grids. *Mon. Wea. Rev.*, **141**, 4049-4068, https://doi.org/10.1175/MWR-D-13-00083.1
4. Miura, H., & Skamarock, W. C. (2013), An upwind-biased transport scheme using a quadratic reconstruction on spherical icosahedral grids. *Mon. Wea. Rev.*, **141**, 832-847, https://doi.org/10.1175/MWR-D-11-00355.1
5. Miura, H., Maeda, T., & Kimoto, M. (2012), A comparison of the Madden-Julian Oscillation simulated by different versions of the MIROC climate model. *Sci. Online Lett. Atmos.*, **8**, 165-169. doi:10.2151/sola.2012-040
6. Ong, C. R., & Miura, H. (2018), Iterative Local Bézier Reconstruction Algorithm of Smooth Droplet Surface for the Immersed Boundary Method. *Sci. Online Lett. Atmos.*, **14**, 170-173, doi: 10.2151/sola.2018-030
7. Suematsu, T., & Miura, H. (2018), Zonal SST Difference as a Potential Environmental Factor Supporting the Longevity of the Madden–Julian Oscillation. *J. Climate,* **31**, 7549–

7564. https://doi.org/10.1175/JCLI-D-17-0822.1

8. Takasuka, D., Satoh, M., Miyakawa, T., & Miura, H. (2018), Initiation process of the tropical intraseasonal variability simulated in an aqua-planet experiment, What is the intrinsic mechanism for MJO onset? *Journal of Advances in Modeling Earth Systems*, **10**, 1047–1073. https://doi.org/10.1002/2017MS001243

9. Ullrich, P. A., et al. (Miura, H., 31 人中 26 番目) (2017), DCMIP2016: a review of non-hydrostatic dynamical core design and intercomparison of participating models, Geosci. Model Dev., 10, 4477-4509, https://doi.org/10.5194/gmd-10-4477-2017

10. Kikuchi, K., Kodama, C., Nasuno, T., Nakano, M., Miura, M., Satoh, M., Noda, A. T., & Yamada, Y. (2017), Tropical intraseasonal oscillation simulated in an AMIP-type experiment by NICAM. Climate Dyn., 48, 2507-2528; doi: 10.1007/s00382-016-3219-z

11. Sato, Y., Miura, H., et al. (2016), Unrealistically pristine air in the Arctic produced by current global scale models. Sci. Rep. 6, 26561; doi: 10.1038/srep26561

12. Shibuya, R., Miura, H., & Sato, K. (2016), A grid transformation method for a quasi-uniform, circular fine region using the spring dynamics. J. Meteor. Soc. Japan, 94; doi: 10.2151/jmsj.2016-022

13. Takasuka, D., Miyakawa, T., Satoh, M., & Miura, H. (2015), Topographical effects on internally produced MJO-like disturbances in an aqua-planet version of NICAM. Sci. Online Lett. Atmos., 11, 170-176

14. Tomikawa, Y., Nomoto, M., Miura, H., Tsutsumi, M., Nishimura, K., Nakamura, T., Yamagishi, H., Yamanouchi, T., Sato, T., & Sato, K. (2015), Vertical wind disturbances during a strong wind event observed by the PANSY radar at Syowa station, antarctica. *Mon. Wea. Rev.*, **143**, 1804–1821, https://doi.org/10.1175/MWR-D-14-00289.1

15. Satoh, M. Tomita, H., Yashiro, H., Miura, H., et al. (2014), The Non-hydrostatic Icosahedral Atmospheric Model: Description and Development. Progress in Earth and Planetary Science, 1, 18, doi:10.1186/s40645-014-0018-1

16. Miyakawa, T., Satoh, M., Miura, H., Tomita, H., Yashiro, H., Noda, A. T., Yamada, Y., Kodama, C., Kimoto, M., & Yoneyama, K. (2014), Madden-Julian Oscillation prediction skill of a new-generation global model demonstrated using a supercomputer. *Nature Communications*, **5**, 3769. 10.1038/ncomms4769

17. Yasunaga, K., Nasuno, T., Miura, H., Takayabu, Y. N., & Yoshizaki, M. (2013), Afternoon precipitation peak simulated in an aqua-planet global non-hydrostatic model (aqua-planet-NICAM). *J. Meteor. Soc. Japan*, 91A, 217-229, https://doi.org/10.2151/jmsj.2013-A07

18. Kubokawa, H., Fujiwara, M., Nasuno, T., Miura, H., Yamamoto, M. K., & Satoh, M. (2012), Analysis of the tropical tropopause layer using the Nonhydrostatic Icosahedral Atmospheric Model (NICAM): 2. An experiment under the atmospheric conditions of December 2006 to January 2007. *J. Geophys. Res.*, 117, D17114,doi:10.1029/2012JD017737

19. Miyakawa, T., Takayabu, Y. N., Nasuno, T., Miura, H., Satoh, M., & Moncrieff, M. W. (2012), Convective momentum transport by rainbands within a Madden-Julian oscillation in a global nonhydrostatic model with explicit deep convective processes. Part I: Methodology and general results. *J. Atmos. Sci.*, **69**, 1317-1338, https://doi.org/10.1175/JAS-D-11-024.1

(2) Non-peer-reviewed Articles

(3) Review Papers

(4) Books

(5) Other Publications

1. Miura, H., Chawan-no-yu (Hot water in a bawl) and atmospheric science, Gendai-Kagaku, Nov. 2017, Tokyo Kagaku Dojin

(6) Patents

8. Keynote, Invited, or Solicited Presentations

1. Miura, H., A global cloud-system-resolving model and its uncertainty due to the subgrid-scale moisture transport, 2018 American Geophysical Union Fall Meeting, Washington D. C., USA, 2018/12/11
2. Miura, H., A shallow-water model using the B-grid staggering on the spherical icosahedral grid, CASTS 2018 Fall Special Program in Applied Mathematics and Applied Mechanics, Taipei, Taiwan, 2018/11/28
3. Miura, H., A B-grid shallow-water model on the spherical icosahedral grid, Workshop on Moving and Adaptive Meshes for Global Atmospheric Modelling, Reading, UK, 2018/9/4
4. Miura, H., Rapid seasonal migration of the heavy precipitation region in the Southeast Asia and its relation to the Madden-Julian Oscillation, JpGU-AGU Joint Meeting 2017, Chiba, Japan, 2017/5/20
5. Miura, H., A global cloud-system-resolving model for studies of tropical meteorology and climate, International Workshop on Parameterization of Physical Processes (INTROSPECT 2017), Pune, India, 2017/2/13
6. Miura, H., et al., NICAM: A global cloud-system-resolving model, The 2016 Dynamical Core Model Intercomparison Project, Boulder, Colorado, 2016/6/7
7. Miura, H, Recent studies using a global cloud-system-resolving model NICAM, 3rd CCliCS Workshop on Climate System Modeling, Academia Sinica, Taipei, Taiwan, 2014/11/11
8. Miura, H., T. Miyakawa, and M. Satoh, Extended Madden-Julian Oscillation simulations by NICAM for CYNDY/DYNAMO period, Workshop on Tropical Dynamics and the MJO, Hawaii, USA, 2014/1/16

+4 invited talks in Japanese (May 2013, Dec. 2014, May 2015, Sep. 2015)

III. Education Activity

9. Notable Achievements in Education

Advisees

- Master theses: 5 students

    Tamaki Suematsu (Mar. 2015)

    Chia Rui Ong (Sep. 2016)

    Takuma Nakano (Mar. 2016)

    Shuhei Matsugishi (Mar. 2017)

Takuya Jinno (Mar. 2019)

- Doctral dissertations: 2 students

Tamaki Suematsu (Sep. 2018)

Chia Rui Ong (Mar. 2019)

Lectures

- Undergraduate/Graduate, Excercises in earth and planetary physics, FY2013-2018
- Undergraduate/Graduate, Atmosphere-ocean system physics, FY2012-2018
- Graduate, Atmospheric physics II, FY2013, 2015, 2017
- Graduate, Atmosphere-ocean aerosol science I, FY2016, 2018
- Undergraduate, Introduction to earth and planetary physics, FY2016-2018
- Undergraduate, Overview of earth and planetary physics, FY2016-2017
- Undergraduate, Introduction to earth and planetary physics: What are interesting now?, FY2012-2014

Student's awards

- American Geophysical Union, Student Travel Grant: 1 student [Tamaki Suematsu]
- Japan Geoscience Union, Student Presentation Award: 1 student [Tamaki Suematsu]

IV. External Activities

10. Contribution to Academic Community

- Meteorological Society of Japan, Journal of the Meteorological Society of Japan, Editor, FY2014-2018
- Meteorological Society of Japan, Human resource development and gender equality committee, Member, FY2013-2018
- Meteorological Society of Japan, Yamamoto prize selection committee, Member, FY2013-2018
- Japan Geoscience Union, Progress in Earth and Planetary Science, Editor, FY2016-2018
- Japan Geoscience Union, Representative, FY2018
- American Meteorological Society, Monthly Weather Review, Assistant Editor, FY2016-2018

11. Outreach Activity

- Press Release: 2 times (May 2014, May 2016)
- Lectures for general audience: 4 times (Nov. 2013, Jul. 2014, Nov. 2016, Aug. 2017)

12. Internal Committee Membership

- Department of Earth and Planetary Science, Accounting Committee, Member, FY2013-2017
- Department of Earth and Planetary Science, Network Committee, Member, FY2012-2016
- Department of Earth and Planetary Science, Network Committee, Chair, FY2017-2018
- School of Science, Network Committee, Member, FY2017-2018

V. International Exchange Activities

13. Hosting/Sending Foreign Students and Researchers

(1) Hosting

Foreign Students: 3

Foreign Researchers: 0

(2) Sending

Students: 5

Researchers: 0

(3) Visitors from Abroad: 13

Masashi Kohma

I. CV

Name: Masashi Kohma

Age: 33

Present Position: Assistant professor

Education

Odawara High School, Kanagawa, March, 2005 (graduation)

B. Sc. Department of Science, Kyoto University, March, 2009

M. Sc. Department of Earth and Planetary Science, The University of Tokyo, March, 2011

Ph. D. Department of Earth and Planetary Science, The University of Tokyo, March, 2014

Professional Experience

Apr. 2014-, Assistant professor, Department of Earth and Planetary Science, The University of Tokyo

Dec. 2015-Mar. 2017, Wintering member, The 57th Japanese Antarctic Research Expedition

II. Scientific Research Activity

2. Major Achievements

Combining a large amount of satellite observation data with reanalysis data and conducting careful dynamical/statistical analysis, I have shown the relationship between stratospheric and tropospheric clouds and dynamical phenomena in the polar region. For example, the simultaneous occurrence of stratospheric clouds and those around the tropopause in the Antarctic is caused by tropospheric blocking, and the amount of upper tropospheric clouds decreases when the Arctic stratospheric sudden warming occurs, which is caused by the enhancement of the stratospheric Brewer-Dobson circulation. Recently, a study collaborated with informatics researchers has been carried out on the accurate estimation of turbulence parameters using the atmospheric radar in the Antarctic (PANSY radar), and the dependence of the energy dissipation rate in the Antarctic troposphere and lower stratosphere on seasonal variation and altitude has been successfully demonstrated for the first time in the world. I am also conducting dynamics-oriented studies, such as the derivation of a theoretical equation for tendency of tropopause height, which is applicable to almost all latitude ranges.

3. Five Important Papers (including three or more papers in this review period)

1. Kohma, M. & Sato, K. (2011), The effects of atmospheric waves on the amounts of polar stratospheric clouds. Atmos. Chem. Phys., 11, 11535-11552. doi:10.5194/acp-11-11535-2011.

Polar stratospheric clouds (PSCs) are the clouds that appear in the lower stratosphere in polar regions and play a primary role in the catalytic destruction of polar stratospheric ozone. For a better understanding of stratospheric ozone destruction in association with PSCs, we examine the effects of planetary waves, synoptic-scale waves and gravity waves on PSC areal extent using three kinds of observational data: PSC data from CALIPSO, H2O and HNO3 mixing ratios from a satellite microwave limb sounder, and high-resolution dry temperature data from GPS radio occultation observations. It is shown that nearly 100% of PSCs in the both hemispheres at altitudes of 16–24 km are formed by temperature modulation, which is influenced by planetary waves. Around an altitude of

12 km more than 60% of the total PSC areal extent is formed by synoptic-scale waves. The effects of gravity waves on PSC areal extent are not large in the latitude range of 55S–70S.

2. Kohma, M. & Sato, K. (2013), Kelvin and Rossby waves trapped at boundaries under the full Coriolis force, SOLA, 9, 9-14, doi:10.2151/sola.2013-003

It is shown that there are two types of wave solutions trapped at the boundaries which are attributable to the Coriolis force proportional to the meridional component of the earth's rotation vector under the nontraditional approximation (non-TA). One is a type of Kelvin waves (non-TA Kelvin waves) trapped on the eastern and western boundaries. Unlike traditional Kelvin waves (TA Kelvin waves), non-TA Kelvin waves trapped on the western (eastern) boundary can have northward (southward) phase and group velocities in the Northern Hemisphere. The other is a type of Rossby waves trapped on the ground. The external Rossby waves can have wave structure in the vertical and amplitudes decaying with height.

3. Kohma, M. & Sato, K. (2013), Simultaneous occurrence of polar stratospheric clouds and upper-tropospheric clouds caused by blocking anticyclones in the Southern Hemisphere, Atmos. Chem. Phys., 13, 3849-3864, doi:10.5194/acp-13-3849-2013

This study statistically examines the simultaneous appearance of PSCs and upper tropospheric clouds using the CALIPSO. The analyses based on tropopause-relative altitude suggest that the occurrence frequency of clouds at altitudes higher than 6 km above the local tropopause (i.e., PSCs) is significantly correlated with that of clouds around and slightly above the tropopause. It is also shown that the simultaneous occurrence of PSCs and upper tropospheric clouds is frequently associated with blocking highs. This research results won the Yamamoto Prize of the Meteorological Society of Japan.

4. Kohma, M. & Sato, K. (2014), Variability of upper tropospheric clouds in the polar region during stratospheric sudden warmings, J. Geophys. Res., 119(17), 10,100-10113, doi:10.1002/2014JD021746

The variability of upper tropospheric clouds during stratospheric sudden warmings (SSWs) in 2009, 2010, and 2012 in the Northern Hemisphere is examined using satellite observations and reanalysis data. It is shown that the zonal mean cloud frequency decreases in the altitude range of 8–12 km, and the mean cloud top height descends soon after an SSW. Following a sudden decrease in upper tropospheric cloud frequency, an increase in temperature and static stability around the tropopause and a downward shift of the tropopause height are simultaneously observed. Another interesting feature is that the low cloud frequency in the upper troposphere that starts after an SSW continues for more than 1 month. These findings indicate that SSWs can affect the tropospheric radiative budget through the modification of cloud frequency and cloud top heights. This research results won the Yamamoto Prize of the Meteorological Society of Japan.

5. Kohma, M., Sato, K., Tomikawa, T., Nishimura, K., & Sato, T. (2019), Estimate of turbulent energy dissipation rate from the VHF radar and radiosonde observations in the Antarctic, J. Geophys. Res. Atmos., 124, doi:10.1029/2018JD029521

This study estimated the turbulent kinetic energy dissipation rates (TKEDRs) from 1-year observations of the Program of the Antarctic Syowa Mesosphere-Stratosphere-Troposphere/Incoherent Scatter radar (PANSY radar) from October 2015 to September 2016 and compared the results with estimates from radiosonde measurements based on Thorpe's method, which is conventionally used in estimating oceanic TKEDRs. The radar-based estimates showed that the TKEDR at Syowa Station was on the order of 10^{-5}–10^{-3} m^2/s^3 in the altitude range of 1.5–19 km. Taking the proportional constant for Thorpe's method (the ratio of the Thorpe scale to Ozmidov scale) as unity, the radiosonde-based measurements show values of TKEDR larger than radar-based estimates by a factor of 2–5. It is found that the difference in the TKEDR between radiosonde-and radar-based estimates is larger in the middle and upper troposphere than in the stratosphere. The seasonal variation was also examined. An analysis using the distance from the local tropopause level showed that the local maximum in the TKEDR around the tropopause is particularly clear in austral summer. This is likely connected to the seasonality in the gravity wave activity in the Antarctic stratosphere.

4. Awards and Honors

- Kohma, M., Best Poster Prize, SPARC General Assembly 2014, Jan. 2014
- Kohma, M., Yamamoto-Prize, Meteorological Society of Japan, Aug. 2016

5. Future Research Plan

It was confirmed that the Antarctic ozone hole tended to recover in the late 2000 s, while it was pointed out that the amount of ozone in the lower stratosphere at mid- and low latitudes has been decreasing in recent years. However, the present chemical climate model does not reproduce the decreasing trend, and it is considered that one of the causes is the lack of knowledge of turbulent mixing process in the height region. The objective of this study is to clarify the role of turbulent mixing and transport in the vertical distribution of atmospheric trace elements and the heat balance in the upper troposphere and lower stratosphere by integrating the observation data of the large atmospheric radar and the radiosonde at Syowa Station, Antarctica. In addition, turbulence parameter estimation by radiosonde is improved based on a large amount of simultaneous radar and radiosonde observations. By applying this method to a radiosonde observation network, we aim to obtain a global map of free atmospheric turbulence parameters.

6. Funding Received

- JSPS Fellow, 23-9377, FY 2011-2013, 2,000,000 yen
- JSPS KAKENHI, 16K17801, Principal Investigator, FY2016-2018, 4,290,000 yen
- JSPS KAKENHI, 25247075, Co-Investigator, FY2018-2020, 43,030,000 yen
- JSPS KAKENHI, 17H04578, Co-Investigator, FY2016-2018, 17,290,000 yen

7. Publications and Patents

(1) Peer-reviewed Journal Articles

1. Kohma, M. & Sato, K. (2013), Kelvin and Rossby waves trapped at boundaries under the full Coriolis force, SOLA, 9, 9-14, doi:10.2151/sola.2013-003
2. Kohma, M. & Sato, K. (2013), Simultaneous occurrence of polar stratospheric clouds and upper-tropospheric clouds caused by blocking anticyclones in the Southern Hemisphere, Atmos. Chem. Phys., 13, 3849-3864, doi:10.5194/acp-13-3849-2013
3. Sato, K., Tsutsumi, M., Sato, T., Nakamura, T., Saito, A., Tomikawa, Y., Nishimura, K., Kohma, M., Yamagishi, H., & Yamanouchi T. (2013), Program of the Antarctic Syowa MST/IS radar (PANSY), J. Atmos. Sol.-Terr. Phys., doi:10.1016/j.jastp.2013.08.022
4. Kohma, M. & Sato, K. (2014), Variability of upper tropospheric clouds in the polar region during stratospheric sudden warmings, J. Geophys. Res., 119(17), 10,100-10113, doi:10.1002/2014JD021746
5. Nishiyama, T., Sato, K., Nakamura, T., Tsutsumi, M., Sato. T., Kohma. M., Nishimura, K., Tomikawa, Y., Ejiri, M. K., & Tsuda, T. T. (2015), Height and time characteristics of seasonal and diurnal variations in PMWE based on 1 year observations by the PANSY radar (69.0°S, 39.6°E), Geophys. Res. Lett., doi:10.1002/2015GL063349
6. Minamihara, Y., Sato, K., Kohma, M., & Tsutsumi, M. (2016), Characteristics of Vertical Wind

Fluctuations in the Lower Troposphere at Syowa Station in the Antarctic Revealed by the PANSY Radar, SOLA, 12, 116-120, doi:10.2151/sola.2016-026

7. Hirano, S., Kohma, M., & Sato, K. (2016), A three-dimensional analysis on the role of atmospheric waves in the climatology and interannual variability of stratospheric final warming in the Southern Hemisphere, J. Geophys. Res., 121(14), 8429-8443, doi:10.1002/2015JD024481
8. Tsutsumi, M., Sato, K., Sato, T., Kohma, M., Nakamura, T., Nishimura, K., Tomikawa, Y. (2017), Characteristics of mesosphere echoes over Antarctica obtained using PANSY and MF radars, SOLA, 13, 19-23, doi:10.2151/sola.13A-004
9. Sato, K., Kohma, M., Tsutsumi, M., & Sato, T. (2017), Frequency spectra and vertical profiles of wind fluctuations in the summer Antarctic mesosphere revealed by MST radar observations, J. Geophys. Res. Atmos., 122, 3-19, doi:10.1002/2016JD025834
10. Shibuya, R., Sato, K., Tsutsumi, M., Sato, T., Tomikawa, Y., Nishimura, K., & Kohma, M. (2017), Quasi-12h inertia-gravity waves in the lower mesosphere observed by the PANSY radar at Syowa Station (39.6°E, 69.0°S), Atmos. Chem. Phys., 17(10), 6455-6476, doi:10.5194/acp-2016-813
11. Thurairajah, B., Sato, K., Yue, J., Nakamura, T., Kohma, M., Bailey, S. M., & Russell III, J. M. (2017), Simultaneous observation of gravity waves at PMC altitude from AIM/CIPS experiment and PANSY radar over Syowa (69°S, 39°E), J. Atmos. Sol.-Terr. Phys., 164, 324-331, doi:10.1016/j.jastp.2017.10.006
12. Nishiyama, T., Sato, K., Nakamura. T., Tsutsumi. M., Sato, T., Tanaka, Y.-M., Nishimura, K., Tomikawa, Y., & Kohma, M. (2018), Simultaneous observations of polar mesosphere winter echoes and cosmic noise absorptions in a common volume by the PANSY radar (69.0°S, 39.6°E), J. Geophys. Res. Space Phys., 123. doi:10.1029/2017JA024717
13. Kohma, M., Sato, K., Tomikawa, T., Nishimura, K., & Sato, T. (2019), Estimate of turbulent energy dissipation rate from the VHF radar and radiosonde observations in the Antarctic, J. Geophys. Res. Atmos., 124, doi:10.1029/2018JD029521

(2) Non-peer-reviewed Articles

(3) Review Papers

(4) Books

1. Kohma, M. & Sato, K. (2017). Antarctic clouds in the troposphere and stratosphere, in Kisho Kenkyu Note, Vol. 233.

(5) Other Publications

(6) Patents

8. Keynote, Invited, or Solicited Presentations

1. Kohma, M. Statistical analyses of PMSE and wind velocity around the mesopause using the PANSY radar, MTI research symposium, NICT, Japan, 2015/09/01
2. Kohma, M., Sato, K., Nishimura, K., Tomikawa, Y. & Sato, T., Turbulent kinetic energy dissipation rate derived from multi-year observations by radar and radiosonde in the Antarctic. SPARC FISPAS Workshop, Leibniz-Institut für Atmosphärenphysik, Kuehlungsborn, Germany, 2018/11/06

III. Education Activity

9. Notable Achievements in Education

Lectures

- Undergraduate, Exercises in Earth and Planetary Physics, FY2014-2015
- Undergraduate, Field Observation for Earth and Planetary Physics, FY2014-2015, FY2017-2018
- Undergraduate, Exercise in Basic Earth and Planetary Physics III, FY2017-2018

IV. External Activities

10. Contribution to Academic Community

- International Symposium on the Whole Atmosphere (ISWA), LOC member、2016/09
- SPARC General Assembly 2018, LOC member, 2018/10

11. Outreach Activity

- Lectures for general audience: 2 times (August. 2015, July. 2017)

12. Internal Committee Membership

- Department of Earth and Planetary Science, Library Committee, FY2014-2015, FY2017
- Department of Earth and Planetary Physics, Public Information Committee, FY2018

V. International Exchange Activities

13. Hosting/Sending Foreign Students and Researchers

(1) Hosting

Foreign Students: 0

Foreign Researchers: 0

(2) Sending

Students: 0

Researchers: 0

(3) Visitors from Abroad: 0

Yuki Tanaka

I. CV

Name: Yuki Tanaka

Age: 38

Present Position: Assistant Professor

Education

Musashi High School, Tokyo, March, 2000 (graduation)

B. Sc. Department of Earth and Planetary Physics, The University of Tokyo, March, 2005

M. Sc. Department of Earth and Planetary Science, The University of Tokyo, March, 2007

Ph. D. Department of Earth and Planetary Science, The University of Tokyo, March, 2010

Professional Experience

Apr., 2008–Mar., 2010, Research Fellow of the Japan Society for the Promotion of Science (DC2), Department of Earth and Planetary Science, Graduate School of Science, The University of Tokyo, Japan.

Apr., 2010–Mar., 2012, Postdoctoral Fellow, Atmosphere and Ocean Research Institute, The University of Tokyo, Japan.

Apr., 2012–, Assistant Professor, Department of Earth and Planetary Science, Graduate School of Science, The University of Tokyo, Japan

II. Scientific Research Activity

2. Major Achievements

I have been studying the generation, propagation, and dissipation processes of meso-scale and small-scale features in the ocean by combining theoretical, numerical, and observational approaches, with a special focus on the effects of bottom topography. Specific topics are as follows.

(1) <u>Evaluation of tidal mixing in the Kuril Strait and its impacts on the large-scale ocean circulation</u>

Tidal mixing in the Kuril Strait has been hypothesized to play an important role in the formation of the North Pacific Intermediate Water and to influence bidecadal climate variability in the North Pacific, although its intensity has long been unclarified. By combining satellite altimeter data, high-resolution numerical experiments, and field observations with a microstructure profiler, we have examined the characteristic features of diurnal internal tides in the Kuril Straits and obtained the detailed spatial distribution of turbulent mixing. Furthermore, the effects on the formation of the North Pacific Intermediate Water and bidecadal climate variability in the North Pacific have been quantitatively assessed by numerical experiments using general circulation models.

(2) <u>Generation mechanism of meso-scale and small-scale features in the zonal currents in the equatorial Pacific</u>

We have shown that tropical instability waves (TIWs), prominent meso-scale features in the equatorial Pacific, can be interpreted as resulting from a coupling of two counter-propagating Rossby waves: one trapped in the negative potential vorticity (PV) gradient just north of the equator and the other trapped in the positive PV gradient further north. We have also found that small-scale internal waves are radiated downward from the fronts of TIWs, significantly contributing to the turbulent mixing in the equatorial thermocline.

(3) Effects of Koshu Seamount on the development of baroclinic instability leading to the Kuroshio large meander

Baroclinic instability over Koshu Seamount, located to south of Japan, has been thought to play an important role in the transition from the nonlarge meander path to the large meander path of the Kuroshio. We have shown that baroclinic instability over the seamount is enhanced due to the coupling between the upper-layer Rossby wave and the lower-layer seamount-trapped wave.

3. Five Important Papers (including three or more papers in this review period)

1. Tanaka, Y., T. Hibiya, Y. Niwa, and N. Iwamae, 2010: Numerical study of K_1 internal tides in the Kuril straits, *Journal of Geophysical Research-Oceans*, **115**, C09016, doi:10.1029/2009JC005903.

Tidal mixing in the Kuril Straits, whose intensity was completely unknown although its importance to a large-scale ocean circulation had been pointed out, was quantitatively evaluated for the first time using a high-resolution three-dimensional numerical model. (Citation 40, GS/Sept. 20, 2019)

2. Tanaka, Y., I. Yasuda, H. Hasumi, H. Tatebe, and S. Osafune, 2012: Effects of the 18.6-year modulation of tidal mixing on the North Pacific bidecadal climate variability in a coupled climate model, *Journal of Climate*, **25**, 7625–7642.

Tidal mixing is modulated by the 18.6-yr period oscillation of the lunar orbital inclination. Numerical experiments using a coupled climate model have shown that the 18.6-yr oscillation of tidal mixing in the Kuril Straits can induce climate variability similar to the Pacific decadal oscillation. This suggests the potential for improving climate predictability by taking into account the 18.6-yr modulation of tidal mixing. (Citation 29, GS/Sept. 20, 2019)

3. Tanaka, Y., I. Yasuda, S. Osafune, T. Tanaka, J. Nishioka, and Y. N. Volkov, 2014: Internal tides and turbulent mixing observed in the Bussol Strait, *Progress in Oceanography*, **126**, 98–108.

The existence of bottom-trapped diurnal internal tides propagating clockwise around a seamount in the Kuril Straits was demonstrated observationally for the first time. In addition, it was shown that the turbulent mixing in the strait is strongly bottom-confined because of the bottom-intensified vertical shear associated with the trapped waves. (Citation 6, GS/Sept. 20, 2019)

4. Tanaka, Y., T. Hibiya, and H. Sasaki, 2015: Downward lee wave radiation from tropical instability waves in the central equatorial Pacific Ocean: A possible energy pathway to turbulent mixing, *Journal of Geophysical Research-Oceans*, **120**, 7137–7149, doi:10.1002/2015JC011017.

We have found that TIWs can radiate small-scale internal waves downward, which may have significant impacts on the sea surface temperature in the equatorial Pacific and hence the global climate by enhancing turbulent mixing in the equatorial thermocline. (Citation 6, GS/Sept. 20, 2019)

5. Tanaka, Y., and T. Hibiya, 2017: Effects of Koshu Seamount on the development of baroclinic instability leading to the Kuroshio large meander, *Journal of Physical Oceanography*, **47**, 2563–2576, doi:10.1175/JPO-D-17-0050.1.

The dynamical role of Koshu Seamount in enhancing baroclinic instability leading to the Kuroshio large meander was clarified for the first time. The method and results presented in this study are applicable to various areas to investigate the interaction between the mean-flow and bottom topography. (Citation 2, GS/Sept. 20, 2019)

4. Awards and Honors

5. Future Research Plan

I have been focusing on mesoscale (~300–1000 km) features and clarified their generation mechanism based on theoretical and numerical approaches. Recent advances in satellite observations and numerical simulations, on the other hand, emphasize the importance of submesoscale (~1–30 km) features in cascading energy to smaller-scales and in affecting large-scale ocean circulation through horizontal and vertical transfer of heat and momentum. I plan to examine the generation, propagation, and dissipation processes of submesoscale features as well as their role in large-scale phenomena by performing stability analyses and high-resolution numerical experiments.

Symmetric instability and ageostrophic baroclinic instability are thought to be the major energy sources for submesoscale features in the ocean. Clear evidence, however, has not yet been obtained which demonstrates that submesoscale features found in in-situ observations or realistic high-resolution numerical simulations are actually arising from these instabilities. This is because our understanding of these instability processes is still inadequate so that the theoretical prediction of the dispersion and polarization relations of submesoscale features in the real ocean is not yet complete.

I will first perform linear stability analyses for a background field with various levels of complexity and clarify the mechanism of these instabilities, especially from the viewpoint of wave–wave interactions. Next, nonlinear development of submesoscale features arising from these instabilities will be examined in detail by idealized high-resolution numerical experiments. Finally, I will perform a realistic numerical simulation for the Kuroshio region where active submesoscale features are observed, and the amount of energy dissipated from the Kuroshio current by these submesoscale features will be quantitatively assessed.

In the existing Kuroshio studies, mesoscale and submesoscale features have been examined independently. I will compare the above submesoscale instability processes with the mesoscale instability processes which I have been studying on so far. My final goal in this study is to reach a seamless understanding of mesoscale and submesoscale features widely found in the Kuroshio and other western boundary current regions.

6. Funding Received

- JSPS Grant-in-Aid for Young Scientists (B), 25800260, Oceanic mesoscale eddies as an energy source for deep ocean mixing needed to sustain the global overturning circulation, Principal Investigator, FY2013–2015, 3,770,000 yen
- JSPS Grant-in-Aid for Scientific Research (A), 15H02131, Quantitative evaluation of turbulent mixing hot spots in the Southern Ocean and its incorporation into an ocean general circulation model, Co-Investigator, FY2015–2017, 300,000 yen
- MEXT Grant-in-Aid for Scientific Research on Innovative Areas, 15H05824, Elucidation and parameterization of turbulent mixing processes in the ocean, Co-Investigator, FY2015–2019, 500,000 yen
- JSPS Grant-in-Aid for Young Scientists (B), 17K14389, Internal waves radiated from tropical instability waves in the equatorial Pacific Ocean and the associated turbulent mixing, Principal Investigator, FY2017–2019, 4,160,000 yen
- Research Institute for Applied Mechanics, Kyushu University, General Joint Research, Nonlinear development of baroclinic instability over Koshu Seamount leading to the Kuroshio large meander, Principal Investigator, FY2018, 100,000 yen

7. Publications and Patents

(1) Peer-reviewed Journal Articles

1. Tanaka, Y., I. Yasuda, H. Hasumi, H. Tatebe, and S. Osafune, 2012: Effects of the 18.6-year modulation of tidal mixing on the North Pacific bidecadal climate variability in a coupled climate model, *Journal of Climate*, **25**, 7625–7642.
2. Tanaka, T., I. Yasuda, Y. Tanaka, and G. S. Carter, 2013: Numerical study on tidal mixing along the shelf break in the Green Belt in the southeastern Bering Sea, *Journal of Geophysical Research-Oceans*, **118**, 6525–6542.
3. Tanaka, Y., I. Yasuda, S. Osafune, T. Tanaka, J. Nishioka, and Y. N. Volkov, 2014: Internal tides and turbulent mixing observed in the Bussol Strait, *Progress in Oceanography*, **126**, 98–108.
4. Itoh, S., Y. Tanaka, S. Osafune, I. Yasuda, M. Yagi, H. Kaneko, S. Konda, J. Nishioka, and Y. N. Volkov, 2014: Direct breaking of large-amplitude internal waves in the Urup Strait, *Progress in Oceanography*, **126**, 109–120.
5. Yagi, M., I. Yasuda, T. Tanaka, Y. Tanaka, K. Ono, K. I. Ohshima, and K. Katsumata, 2014: Re-evaluation of turbulent mixing vertical structure in the Bussol' Strait and its impact on water-masses in the Okhotsk Sea and the North Pacific, *Progress in Oceanography*, **126**, 121–134.
6. Tanaka, Y., T. Hibiya, and H. Sasaki, 2015: Downward lee wave radiation from tropical instability waves in the central equatorial Pacific Ocean: A possible energy pathway to turbulent mixing, *Journal of Geophysical Research-Oceans*, **120**, 7137–7149, doi:10.1002/2015JC011017.
7. Nishina, A., H. Nakamura, J.-H. Park, D. Hasegawa, Y. Tanaka, S. Seo, and T. Hibiya, 2016: Deep ventilation in the Okinawa Trough induced by Kerama Gap overflow, *Journal of Geophysical Research-Oceans*, **121**, 6092–6102, doi:10.1002/2016JC011822.
8. Tanaka, Y., and T. Hibiya, 2017: Effects of Koshu Seamount on the development of baroclinic instability leading to the Kuroshio large meander, *Journal of Physical Oceanography*, **47**, 2563–2576, doi:10.1175/JPO-D-17-0050.1.
9. Tatebe, H., Y. Tanaka, Y. Komuro, and H. Hasumi, 2018: Impact of deep ocean mixing on the climatic mean state in the Southern Ocean, *Scientific Reports*, **8**:14479, doi:10.1038/s41598-018-32768-6.
10. Yang, W., T. Hibiya, Y. Tanaka, L. Zhao, and H. Wei, 2018: Modification of parametric subharmonic instability in the presence of background geostrophic currents, *Geophysical Research Letters*, **45**, 12957–12962, doi:10.1029/2018GL080183.

(2) Non-peer-reviewed Articles

(3) Review Papers

1. Osafune, S., M. Yagi, S. Itoh, Y. Tanaka, H. Kaneko, S. Konda, I. Yasuda, and Y. N. Volkov, 2012: Observations of water-mass and current around the northeastern Kuril Straits, *Ocean Monthly*, **44**(7), 392–402 (in Japanese).
2. Itoh, S., I. Yasuda, M. Yagi, S. Osafune, H. Kaneko, J. Nishioka, T. Nakatsuka, Y. N. Volkov, Y. Tanaka, S. Konda, 2012: Turbulence in the Urup Strait and its influence on water mass formation, *Ocean Monthly*, **44**(8), 432–440 (in Japanese).
3. Tanaka, Y., I. Yasuda, H. Hasumi, H. Tatebe, S. Osafune, 2012: Effects of the 18.6-year modulation of tidal mixing on the North Pacific bidecadal climate variability in a coupled climate model, *Ocean Monthly*, **44**(8), 452–459 (in Japanese).
4. Hibiya, T., Y. Tanaka, T. Nagai, T. Ijichi, and T. Takagi, 2013: Challenging study of turbulent

mixing in the deep ocean using the first Multi-Scale Profiler in Japan, *Ocean Monthly*, **45**(1), 57–63 (in Japanese).

5. Osafune, S. and Y. Tanaka, 2018: Bidecadal variability in ocean related to the 18.6-year modulation of tide-induced vertical mixing, *Oceanography in Japan*, **27**(1), 19–30 (in Japanese).

(4) Books

(5) Other Publications

(6) Patents

8. Keynote, Invited, or Solicited Presentations

III. Education Activity

9. Notable Achievements in Education

Lectures

- Undergraduate, Exercise in basic earth and planetary physics II, FY2012–2018
- Undergraduate, Field observation for earth and planetary physics, FY2012–2018
- Undergraduate, Exercise in earth and planetary physics, FY2016
- Undergraduate, Introduction to earth and planetary science, FY2016, 2018
- Undergraduate, Frontiers of marine research, FY2018
- Undergraduate in Tokyo University of Marine Science and Technology, Physics, FY2017

IV. External Activities

10. Contribution to Academic Community

- Asia Oceania Geoscience Society, Ocean Science Section, Section Secretary, 2013–2014
- The Oceanographic Society of Japan 2016 Fall Meeting, Session "Ocean dynamics", Main Convener
- The Oceanographic Society of Japan 2017 Fall Meeting, Session "Turbulent mixing processes in the ocean", Co-Convener
- The Oceanographic Society of Japan 2018 Fall Meeting, Session "Dynamics of meso- and small-scale processes in the Kuroshio", Main Convener
- Japan Geoscience Union 2017 General Assembly, Session "Physical oceanography", Co-Convener
- Japan Geoscience Union 2018 General Assembly, Session "Ocean dynamics", Co-Convener

11. Outreach Activity

- Press Release "Impact of deep ocean tidal mixing on the climate of the Southern Ocean", 2018/10/12
- Tanaka, Y., The Kuroshio large meander: Mysteries of a huge ocean current, The University of Tokyo Open Campus, 2018/08/02

- Tanaka, Y., and T. Hibiya, The Kuroshio large meander: Its mechanism and impacts, The 13th Ocean Research Symposium of the University of Tokyo Ocean Alliance, 2018/10/30

12. Internal Committee Membership

- Department of Earth and Planetary Science, Library Committee, Committee Member, FY2012–2013, FY2016
- Department of Earth and Planetary Science, Advertisement Committee, Committee Member, FY2014–2018
- School of Science, Open Campus Executive Committee, Committee Member, FY2015–2017

V. International Exchange Activities

13. Hosting/Sending Foreign Students and Researchers

(1) Hosting

Foreign Students: 0

Foreign Researchers: 0

(2) Sending

Students: 0

Researchers: 2

(3) Visitors from Abroad: 0

Space and Planetary Science Group

Seiji Sugita

I. CV

Name: Seiji Sugita

Age: 52

Present Position: Professor

Education

Hamamatsu-kita High School, Shizuoka, March, 1986 (graduation)

B. Sc. Department of Geophysics, The University of Tokyo, March, 1990

M. Sc. Department of Earth and Planetary Physics, The University of Tokyo, March, 1992

Ph. D. Department of Geological Sciences, Brown University, May, 1999 (Defended, Sep., 1998)

Professional Experience

Oct. 1998 - Jan. 1999, Postdoctoral Research Fellow, Dept. of Geological Sciences, Brown Univ.

Feb. 1999 - Dec. 2003, Research Assistant, Dept. of Earth and Planetary Science, Univ. of Tokyo

Apr. 1999 - Jun. 2000, National Research Council, Research Fellow, NASA Ames Research Center

Jan. 2004 - Jun. 2009, Associate Professor, Dept. of Complexity Sci. and Engin., Univ. of Tokyo

Jun. 2009 - Sep. 2014, Professor, Dept.of Complexity Science and Engineering, Univ. of Tokyo

Oct. 2014 -, Professor, Dept.of Earth and Planetary Science, Univ. of Tokyo

II. Scientific Research Activity

2. Major Achievements

I have been studying solid planetary bodies including Earth using both laboratory experiments and space missions.

In laboratory, I have conducted many hyper-velocity impact experiments and obtained several important results on physical and chemical processes on inter-planetary collisions. First is about chemical reaction within impact vapor plumes generated by the large impact on Yukatan peninsula, Mexico at the end of Mesozoic era. Experiments using extremely clean impacts achieved with a “laser gun” and mass spectrometers revealed that hypervelocity impacts on anhydrites ($CaSO_4$) would generate a large amount of SO_3 gas, leading to rapid sulfuric acid formation. This would further lead to a transient and very strong acidification of surface ocean layer. This can account for the famous paleontological evidence that higher extinction ratios are found for marine species with more susceptibility to strong acid. Similarly, using laser-gun experiments, we found that ammonia ice can break down to N_2 gas at typical impact velocities (~ 4 km/s) to Saturn’s satellite, Titan. This finding was important because it would resolve the contradicting observations made by NASA’s Cassini mission: ^{36}Ar-rich Titan atmosphere and undifferentiated interior of Titan.

Among many planetary missions I was involved with, the most important mission to me is JAXA’s Hayabusa2. Since I because the science principal investigator (PI) of its optical navigation cameras (ONC) in 2011, I have shifted my research focus from laboratory work to mission work almost completely. Upon Hayabusa2’s arrival at asteroid Ryugu in 2018, we started global observations, high-resolution observations at low altitudes, and touchdown observations, obtaining image data needed for both Hayabusa2 touchdowns and science analysis for Ryugu. The initial science results were published in a special issue in Science journal early 2019. Among the most important science results from Hayabusa2 is the characterization of Ryugu's parent body and the proposition of the general evolution pathway from the parent body to the current Ryugu. Small (~1 km in diameter) asteroids, such as Ryugu and Bennu, which is the mission target of NASA's OSIRIS-REx, are estimated to be born recently (several 10^8 years) via catastrophic impact disruption of much larger (perhaps ~100 km in diameter) parent bodies, which would have been born ~4.5 billion years ago and hold key information of the early Solar System. Our mission results indicate that Ryugu's original parent body is likely either Polana or Eulalia, which are several ten km in diameter and located in the inner asteroid belt. Furthermore, Ryugu's spectral and albedo properties are consistent with thermally metamorphosed carbonaceous chondrites although the possibility for meteoritic materials not found on Earth cannot be ruled out yet. These results suggest that Ryugu's parent body may have lost water through internal heating during its early history. Because Polana and Eulalia families deliver the greatest number of C-type fragments, which would contain hydrated minerals and organics, to the Earth, the results obtained by Hayabusa2 observations suggest that the amount of water and organics delivered to Earth from the asteroid belt may be controlled by the dehydration processes within parent bodies, such as Polana and Eulalia.

3. Five Important Papers (including three or more papers in this review period)

1. S. Sugita, R. Honda, T. Morota, S. Kameda, H. Sawada, E. Tatsumi, M. Yamada, C. Honda, Y. Yokota, T. Kouyama, N. Sakatani, K. Ogawa, H. Suzuki, T. Okada, N. Namiki, S. Tanaka, Y. Iijima, K. Yoshioka, M. Hayakawa, Y. Cho, M. Matsuoka, N. Hirata, N. Hirata, H. Miyamoto, D. Domingue, M. Hirabayashi, T. Nakamura, T. Hiroi, T. Michikami, P. Michel, R. Ballouz, O. S. Barnouin, C. M. Ernst, S. E. Schröder, H. Kikuchi, R. Hemmi, G. Komatsu, T. Fukuhara, M. Taguchi, T. Arai, H. Senshu, H. Demura, Y. Ogawa, Y. Shimaki, T. Sekiguchi, T. G. Müller, A. Hagermann, T. Mizuno, H. Noda, K. Matsumoto, R. Yamada, Y. Ishihara, H. Ikeda, H. Araki, K. Yamamoto, S. Abe, F. Yoshida, A. Higuchi, S. Sasaki, S. Oshigami, S. Tsuruta, K. Asari, S. Tazawa, M. Shizugami, J. Kimura, T. Otsubo, H. Yabuta, S. Hasegawa, M. Ishiguro, S. Tachibana, E. Palmer, R. Gaskell, L. Le Corre, R. Jaumann, K. Otto, N. Schmitz, P. A. Abell, M. A. Barucci, M. E. Zolensky, F. Vilas, F. Thuillet, C. Sugimoto, N. Takaki, Y. Suzuki, H. Kamiyoshihara, M. Okada, K. Nagata, M. Fujimoto, M. Yoshikawa, Y. Yamamoto, K. Shirai, R. Noguchi, N. Ogawa, F. Terui, S. Kikuchi, T. Yamaguchi, Y. Ohki, Y. Takao, H. Takeuchi, G. Ono, Y. Mimasu, K. Yoshikawa, T. Takahashi, Y. Takei, A. Fujii, C. Hirose, S. Nakazawa, S. Hosoda, O. Mori, T. Shimada, S. Soldini, T. Iwata, M. Abe, H. Yano, R. Tsukizaki, M. Ozaki, K. Nishiyama, T. Saiki, S. Watanabe, Y. Tsuda (2019), The geomorphology, color, and thermal properties of Ryugu: Implications for parent-body processes, *Science*, *364*, eaaw0422 1-11. doi: 10.1126/science.aaw0422. (2019/3/21) Citation: 27 (GS/Oct. 1, 2019)

Our mission results indicate that Ryugu's original parent body is likely either Polana or Eulalia, which are several ten km in diameter and located in the inner asteroid belt. Furthermore, Ryugu's spectral and albedo properties are consistent with thermally metamorphosed carbonaceous chondrites although the possibility for meteoritic materials unsampled on Earth cannot be ruled out yet. These results suggest that Ryugu's parent body may have lost water through internal heating during its early history. Because Polana and Eulalia families are the families that deliver the greatest number of C-type fragments, which would contain hydrated minerals and organics, to the Earth. Thus, the results obtained by our Hayabusa2 observations suggest that the amount of water and organics delivered to Earth from the asteroid belt may be controlled by the dehydration processes driven by internal heating. (Citation: 27, GS/Oct. 1, 2019)

2. Tatsumi, E. and S. Sugita (2018), Cratering efficiency on coarse-grain targets: implications for the dynamical evolution of asteroid 25143 Itokawa, *Icarus*, *300*, 227-248, doi: 10.1016/j.icarus.2017.09.004.

Since Apollo era, Crater formation process has been studied under the condition that target particles, such as boulders and sand grains, are much smaller than impactor. This is a valid assumption for cratering on large planetary bodies, such as Earth's moon and Mars. This assumption, however, does not hold for small bodies, which are important for understanding the early evolution of the Solar System. The diameters of craters on small asteroids, such as Itokawa, are on the same order of magnitude as the average boulder size. Thus, we conducted a series of impact experiments to study the crater scaling rule under the condition where the ratio is near unity in preparation for Hayabusa2 observations of asteroid Ryugu. We obtained a successful crater scaling rule under such condition by adding to the standard scaling rule a term containing the ratio of impact energy to the catastrophic disruption energy for surface grains. (Citation: 9, GS/Oct. 1, 2019)

3. Ohno, S. T. Kadono, K. Kurosawa, T. Hamura, T. Sakaiya, K. Shigemori, Y. Hironaka, T. Sano, T. Watari, K. Otani, T. Matsui and S. Sugita (2014), Production of sulphate-rich vapour during the Chicxulub impact and implications for ocean acidification, *Nature Geoscience, 7*, 279–282, doi:10.1038/ngeo2095

We studied chemical reaction processes within impact vapor plumes generated large impact on Yukatan peninsula, Mexico at the end of Mesozoic era. Experiments using extremely clean impact experiments achieved by laser-gun and mass spectrometers revealed that hyper-velocity impacts on anhydrites would generate a large amount of SO_3 gas, leading to rapid sulfuric acid formation. This would further lead to a transient but very strong acidification of surface ocean water. This can account for the paleontological evidence that the higher extinction ratios are found for marine species with more susceptibility to strong acid. (Citation: 33, GS/Oct. 1, 2019)

4. Sugita, S., and P. H. Schultz, Efficient cyanide formation due to impacts of carbonaceous bodies on a planet with a nitrogen-rich atmosphere, *Geophys. Res. Lett., 36*, L20204, doi:10.1029/2009GL040252, 2009. Editor Highlights

We conducted hypervelocity impact experiments using the vertical gun range at NASA Ames Research Center using plastic projectiles and targets free from nitrogen within model atmospheres with a variety of N_2 partial pressures. In this series of experiments, we launched projectiles at 5 – 6 km/s to penetrate through thin sheets of resin, resulting in a large number of high-speed projectile fragments flying downrange at extremely high velocities (4 – 5 km/s). Experimental results indicate that the high-speed C-rich fragments interact intensively with an N-rich atmosphere to form CN. Because CN radicals may lead to hydrogen cyanide, which are widely considered as an important ingredient for organic synthesis on abiotic Earth. (Citation 13, GS/Oct. 1, 2019)

5. Sugita, S., T. Ootsubo, T. Kadono, M. Honda, S. Sako, T. Miyata, Sakon, T. Yamashita, H. Kawakita, H. Fujiwara, T. Fujiyoshi, N. Takato, T. Fuse, J. Watanabe, R. Furusho, S. Hasegawa, T. Kasuga, T. Sekiguchi, D. Kinoshita, K. J. Meech, D. H. Wooden, W. H. Ip, M. F. A'Hearn (2005), Subaru Telescope Observations of Deep Impact, *Science, 310*, 274-278. (Also published in *Science Express*)

We conducted imaging and spectroscopic observations of the collision between NASA's Deep Impact spacecraft and comet Temple 1 using the mid-infrared detector COMICS of the Subaru telescope of the National Observatory of Japan. The observation results indicate that dust ejected from the artificial impact is dominated by crystalline minerals and the high crystallinity is not resulted from heating due to the artificial impact. This finding suggests that subsurface dust on this Jupiter family comet, estimated to be from the scattered disk of Kuiper belt, has experienced high temperatures before the accretion of this comet, supporting large-scale material circulation in the solar nebula. This finding was confirmed in the sample analysis of NASA's Stardust mission samples. These established the picture that the solar nebula had vigorous circulation. (Citation 87, GS/Oct. 1, 2019)

4. Awards and Honors

5. Future Research Plan

I will continue to study the formation and evolution of planets as well as supply mechanisms of life's ingredients (i.e., water and organics) to Earth and other planetary bodies. In particular, I will focus on two topics: 1) material transports in the Solar System from the nebula evolution stage to the large planetary formation stage and 2) physical and chemical processing of volatile materials on planetary bodies. In coming years, I am planning to conduct data analyses of planetary missions including Hayabusa2 and development/operation of new onboard science instruments for space missions.

Currently, planetary formation theory is going through a major transition from the conventional static picture established in mid-20th century to a modern dynamic picture allowing great variety of planetary migration, triggered from recent findings of exoplanets and new observations of small bodies. Although it is an extremely attractive situation that new planetary formation theories are proposed constantly, it is a very confusion situation that there is no long-lasting standard theory. In order to contribute to establishing a next standard theory, I will attempt to obtain key observations on the material transport in the Solar System by conducting small-body missions in collaboration with space agencies of Japan and other countries as well as other university researchers. In these planetary mission activities, I will also investigate physical and chemical processing of water-baring materials and organics on planetary bodies.

6. Funding Received

- JSPS KAKENHI, 23340168, Principal Investigator, FY2011-2013, 15,800,000 yen
- MEXT KAKENHI, 251200006, Co-Investigator, FY2012-2017, 6,000,000 yen
- JSPS KAKENHI, 26247092, Principal Investigator, FY2014-2016, 32,100,000 yen
- JSPS KAKENHI, 17H01175, Principal Investigator, FY2017-2019, 34,500,000 yen
- JSPS Core-to-core program "International Network for Planetary Science" Principal Investigator, FY2016-2020, 86,500,000 yen
- JAXA/ISAS Corporation for open-use center of ultra-small spacecraft development, FY2015-2018, 80,110,000 yen.

7. Publications and Patents

(1) Peer-reviewed Journal Articles

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properties of Ryugu: Implications for parent-body processes, *Science*, *364*, eaaw0422 1-11. doi: 10.1126/science.aaw0422.

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(2) Non-peer-reviewed Articles

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8. Keynote, Invited, or Solicited Presentations

1. S. Sugita, R. Honda, T. Morota, S. Kameda, H. Sawada, E. Tatsumi, C. Honda, Y. Yokota, M. Yamada, T. Kouyama, N. Sakatani, H. Suzuki, K. Yoshioka, M. Hayakawa, Y. Cho, M. Matsuoka, N. Hirata, N. Hirata, D. Domingue, H. Miyamoto, H. Kikukch, R. Hemmi, T. Michikami, O. S. Barnouin, C. M. Ernst, E. Palmer, R. Gaskell, P. Michel, M. Hirabayashi, R. Jaumann, K. Otto, N. Schmitz, S. Schroeder, T. Hiroi, T. Nakamura, G. Komatsu, Y. Tsuda, M. Yoshikawa, S. Tanaka, K. Shirai, S. Watanabe (2018), The first detailed visible multi-band imaging observations of asteroid Ryugu, American Astronomical Society, *DPS meeting #50*, id.501.02, Oct. 21-26, Knoxville, TN, USA.
2. S. Sugita, R. Honda, T. Morota, S. Kameda, H. Sawada, E. Tatsumi, C. Honda, Y. Yokota, M. Yamada, T. Kouyama, N. Sakatani, H. Suzuki, K. Yoshioka, M. Hayakawa, Y. Cho, M. Matsuoka, N. Hirata, N. Hirata, D. Domingue, H. Miyamoto, H. Kikukch, R. Hemmi, T. Michikami, O. S. Barnouin, C. M. Ernst, E. Palmer, R. Gaskell, P. Michel, M. Hirabayashi, R. Jaumann, K. Otto, N. Schmitz, S. Schroeder, T. Hiroi, T. Nakamura, G. Komatsu, Y. Tsuda, M. Yoshikawa, S. Tanaka, K. Shirai, S. Watanabe (2018), The geologic properties of asteroid Ryugu revealed by Hayabusa2 visible multi-band imaging observations at multi-scales, *Geological Soc. Amer., Ann. Mtg*., Nov. 4-7, Indianapolis, IN, USA.
3. Sugita, S., R. Honda, T. Morota, S. Kameda, H. Sawada, E. Tatsumi, C. Honda, Y. Yokota, M. Yamada, T. Kouyama, N. Sakatani, H. Suzuki, K. Yoshioka, M. Hayakawa, Y. Cho, M. Matsuoka, Naru Hirata, Naoyuki Hirata, D. Domingue, H. Miyamoto, K. Kikuchi, R. Hemmi, T. Michikami, O. S. Barnouin, C. Ernst, E. Palmer, R. Gaskell, P. Michel, M. Hirabayash[3], R. Jaumann, C. Otto, N. Schmitz, S. Schröder, T. Hiroi, T. Nakamura, S. Sasaki, Kanamaru, G. Kokatsu, L. Le Corre, Y. Tsuda, M. Yoshikawa, S. Tanaka, K. Shirai, S. Watanabe (2018), The first detailed visible multi-band imaging observations of asteroid Ryugu, *Hayabusa Symposium 2018*, Dec. 4 – 7, Sagamihara, Japan.
4. S. Sugita, E. Tatsumi, S. Hasegawa, S. Yudai, H. Kamiyoshihara, R. Honda, S. Kameda, T. Morota, C. Honda, T. Kouyama, M. Yamada, M. Hayakawa, Y. Yasuhiro, N. Sakatani, H. Suzuki, K. Ogawa, H. Sawada (2018) Comparison of visible spectra between Ryugu and low-albedo asteroid families in the inner main belt, *Japan Geosci. Union,* Chiba, Makuhari Messe, May 24.
5. Sugita, S. (2014) The Early Atmospheres of Terrestrial Planets inferred from Impact experiments and Asteroid missions, *ELSI 3rd International Symposium "Life in the Universe"*, January 13-15.

III. Education Activity

9. Notable Achievements in Education

Advisees

・ Master theses: 4 students

Sumire Koga (Mar. 2015)

Hikari Furukawa (Mar. 2017)

Mamoru Okuno (Mar. 2018)

Naoya Tanabe, Yoshihisa Okitsu (Mar. 2019)

- Doctral theses: 2 students

  Hideharu Kuwahara (Sep. 2015)

  Eri Tatsumi (Mar. 2016)

Lectures

- Graduate, Comparative Planetology I, FY2016. 2018
- Graduate, Planetary Exploration I, FY2014
- Undergraduate/Graduate, Elementary Comparative Planetology, FY2012-2018
- Undergraduate, Evolution of Space and Planetary Materials, FY2012-2016
- Undergraduate, Experiments in Earth and Planetary Physics, FY2012-2018
- Undergraduate, Academic frontier seminar, FY2012-2018
- Undergraduate, First-Year Seminar for Natural Sciences Students, FY2015-2017

Student's awards

- Incentive Award of the School of Science, the University of Tokyo: 2 students [Yudai Suzuki and Koki Yumoto]
- Japan Society for Planetary Science , Student Presentation Award: 5 students [Yuichiro Cho]

IV. External Activities

10. Contribution to Academic Community

- Japan Geoscience Union, Program Committee Member, FY2017

11. Outreach Activity

- JAXA/ISAS Advisory Council for Research and Management member: 2017 – present
- NAOJ Advisory Committee for Research and Management member: 2015 – 2018
- JAXA/ISAS Science Steering Committee member: 2009-2012, 2019 – present
- Japan Geoscience Union, Program Committee Member, FY2017
- KAKENHI Review, FY2013-2014, 2017-2018
- NASA Proposal Review， FY 2016, 2017
- NHK Special Hayabusa2Live studio appearance 2019.9.8
- NHK World News, Live studio appearances, 2018.6.27 and 2019.2.11
- NHK Close-up Gendai Live studio appearance 2019.7.11
- Canadian Broadcasting Station, Radio interviews 2019.3.21, 2019.7.19

12. Internal Committee Membership

- Department of Earth and Planetary Science, Education Committee, Chair, FY2016-2017
- Graduate School of Science, Steering committee for the Center of Astronomy Education and Research, Member, FY2016-

V. International Exchange Activities

13. Hosting/Sending Foreign Students and Researchers

(1) Hosting

Foreign Students: 3

Foreign Researchers: 1

(2) Sending

Students: 3

Researchers: 2

(3) Visitors from Abroad: 10

Kanako Seki

I. CV

Name: Kanako Seki

Age: 47

Present Position: Professor

Education

Matsumoto-Fukashi High School, Nagano, March, 1991 (graduation)

B. Sc. Department of Geophysics, The University of Tokyo, March, 1995

M. Sc. Department of Earth and Planetary Physics, The University of Tokyo, March, 1997

Ph. D. Department of Earth and Planetary Physics, The University of Tokyo, March, 2000

Professional Experience

Apr. 1997-Mar. 2000, JSPS (Japan Society for the Promotion of Science) Research Fellow (DC1) at the University of Tokyo

Mar.-Oct. 1999, Graduate Research Assistant, Los Alamos National Laboratory

Apr. 2000-Feb. 2002, JSPS Research Fellow (PD) at the University of Tokyo (2000-2002)

Mar. 2002-Sep. 2015, Associate Professor, Solar-Terrestrial Environment Laboratory, Nagoya University

Oct. 2015-, Professor, Graduate School of Science, University of Tokyo

II. Scientific Research Activity

2. Major Achievements

Focusing on the role of the terrestrial plasma in variations of the space environment around the earth, we clarified the supply mechanism of the terrestrial cold ion beams discovered in the far tail of the Earth's magnetosphere (AGU's Scarf Award). We further applied the knowledge to study planetary space environment and atmospheric outflows. It was revealed that the oxygen outflow rate from the Earth can be decreased by about an order of magnitude due to the existence of the intrinsic magnetic field (Young Scientist Award from the Minister of MEXT). The study was further developed to interdisciplinary researches such as possible records of the ancient magnetic field in lunar soils. Recently, K.S. has lead of the theory/modeling team of the geospace exploration project ERG, which combines ground observations, satellite observations, and numerical experiments. She also serves as a member of the International Mercury Environment WG of the Japan-Europe joint Mercury exploration mission BepiColombo, and Participating Scientist of the NASA's Mars mission MAVEN. She is also conducting research project to investigate role of planetary magnetic field on the atmospheric escape and surface environment including its habitability.

3. Five Important Papers (including three or more papers in this review period)

1. <u>Seki, K.</u>, Keika, K., Kasahara, S.,Yokota, S., Hori, T., Asamura, K., N. Higashio, M. Takada, Y. Ogawa, A. Matsuoka, M. Teramoto, Y. Miyoshi, and I. Shinohara, Statistical properties of molecular ions in the ring current observed by the Arase (ERG) satellite, ***Geophys. Res. Lett.***, 46,

https://doi.org/10.1029/2019GL084163, 2019.

Molecular ions usually exist only in the low-altitude (< 300 km) deep ionosphere and cannot escape to space without a fast ion outflow to overcome a rapid loss due to dissociative recombination. Thus, molecular ion escape from the terrestrial atmosphere to space can be used as a tracer of effective ion loss from the deep ionosphere. Here we report new observations by Arase satellite which enables definitive identification of molecular ions by frequent TOF mode observations. The statistical analysis shows that molecular ions exist in near-Earth space during most magnetic storms, while they are not detected during geomagnetically quiet periods. The existence of molecular ions even during small magnetic storms suggests that the magnetic storm is an effective driver of the ion loss from the deep terrestrial ionosphere. The paper was selected as the Editor's Highlights of GRL and was introduced in the American Geophysical Union (AGU) academic news Eos. （just published）

2. Yamakawa, T., Seki, K., Amano, T., Takahashi, N., & Miyoshi, Y., Excitation of storm time Pc5 ULF waves by ring current ions based on the drift-kinetic simulation. ***Geophys. Res. Lett.***, 46, https://doi.org/ 10.1029/2018GL081573, 2019.

The excitation mechanism and global distribution of the Pc5 waves in geospace is a key to understand dynamic variation of the radiation belts. These waves can be excited through the wave‐particle interaction with the drifting and bouncing motions of ring current ions (drift‐bounce resonance). Using our global drift-kinetic model for ring current particles, we succeeded to self-consistently simulate the excitation mechanism of Pc5 waves in the Earth's inner magnetosphere for the first time. Pc5 waves are excited through the resonance with the drifting ions with energies of 80‐120 keV. Comparison of the wave properties and theory indicates that positive phase space density gradient in energy formed by the drifting injected ions is responsible for the excitation of the Pc5 waves.The results open up a new method to explore the internal excitation mechanisms of ULF waves in geospace. This study will be a part of Master thesis of the current master's course student and has attracted some international attention, such as invitation to the GEM workshop in US.　(Citation 0)

3. Seki, K., Y. Miyoshi, Y. Ebihara, Y. Katoh, T. Amano, S. Saito, M. Shoji, A. Nakamizo, K. Keika, T. Hori, S. Nakano, S. Watanabe, K. Kamiya, N. Takahashi, Y. Omura, M. Nose, M.-C. Fok, T. Tanaka, A. Ieda, and A. Yoshikawa, Theory, modeling, and integrated studies in the Arase (ERG) project, ***Earth Planets Space***, 70:17, doi:10.1186/s40623-018-0785-9, 2018.

The Geospace Exploration Project ERG is a research project aimed at elucidating the dynamic variation of the geospace with a focus on the acceleration and loss mechanisms of relativistic electrons consisting of the radiation belts. The project consists of three parts: satellite observations, ground-based observations, and theory/numerical modeling. For the purpose, the theory/numerical modeling team has developed various numerical methods and models over the years before the launch of the ERG (Arase) sattellite. This paper summarizes the models related to the ERG projects. The models have been applied to various geospace studies through comparison with satellite and ground-based observations.　(Citation 6)

4. Sakai, S., Seki, K., Terada, N., Shinagawa, H., Tanaka, T., and Ebihara, Y., Effects of a weak intrinsic magnetic field on atmospheric escape from Mars, ***Geophys. Res. Lett.***, 45, 9336–9343, doi:10.1029/2018GL079972, 2018.

Present Mars has a thin atmosphere and little water on the surface. Space missions have provided some evidence for the existence of liquid water and a thick atmosphere on ancient Mars. This evidence suggests Mars has experienced significant atmospheric loss from the past through the present. Ion outflow is one of the important atmospheric loss mechanisms. In the present day, Mars does not have a global magnetic field such as that of Earth, and thus, ions escape by the direct interaction with the solar wind. In contrast, it is inferred that ancient Mars had a global magnetic field. The global magnetic field forms the magnetosphere around the planet, changing the ion escape mechanism. In this study, the ion escape mechanism is investigated when Mars possesses a weak global magnetic field. The weak global magnetic field yields four escape routes associated with open magnetic field lines and magnetic reconnection. In contrast of previous expectation that the intrinsic magnetic field acts as a barrier, the study revealed that the oxygen escape rate with a weak magnetic field increases by ~25% compared to the unmagnetized case. (Citation 6)

5. B. Jakosky, 他93名, (アルファベット順79番目: K. Seki), MAVEN Observations of the Response of Mars to an Interplanetary Coronal Mass Ejection, ***Science***, Vol. 350, Issue 6261, DOI: 10.1126/science.aad0210, 2015.

Coupling between the lower and upper atmosphere, combined with loss of gas from the upper atmosphere to space, likely contributed to the thin, cold, dry atmosphere of modern Mars. To help understand ongoing ion loss to space, the Mars Atmosphere and Volatile Evolution (MAVEN) spacecraft made comprehensive measurements of the Mars upper atmosphere, ionosphere, and interactions with the Sun and solar wind during an interplanetary coronal mass ejection impact in March 2015. Responses include changes in the bow shock and magnetosheath, formation of widespread diffuse aurora, and enhancement of pick-up ions. Observations and models both show an enhancement in escape rate of ions to space during the event. Ion loss during solar events early in Mars history may have been a major contributor to the long-term evolution of the Mars atmosphere. The results were press-released by NASA and introduced by mass media and science magazines for general public. (Citation 106)

4. Awards and Honors

- Seki, K., Excellent Reviewer Award for JSPS Research Fellowship for Young Scientists 2014
- Seki, K., NASA Group Achievement Award (MAVEN), 2016; 2018

5. Future Research Plan

What kind of the world is the outer space, which is one of the frontiers of humans? What is the relationship between aurora and geospace environment? With expansion of our exploration to planets, what kind of new insights we can obtain about universality and diversity of solar-planetary environment and its habitability? Our laboratory pursues understanding of these problems, we promote combination of in-situ plasma observations by spacecraft and numerical simulations. Our primary focus lies on understanding of universal space plasma processes, space weather phenomena such as aurora and radiation belt variation, and atmospheric escape mechanisms as well as its effects on habitable environment of terrestrial planets. For this purpose, we have participated in various space missions that include geospace exploration ERG of JAXA, Mercury exploration BepiColombo of JAXA and ESA, Mars exploration MAVEN of NASA, and space plasma mission MMS of NASA.

6. Funding Received

- JSPS KAKENHI, 18KK0093, Principal Investigator, FY2018-2022, 8,100,000 yen (expected)
- JSPS KAKENHI, 16H02229, Principal Investigator, FY2016-2019, 29,400,000 yen
- MEXT KAKENHI, JP16H06286, Co-Investigator, FY2016-2020, 55,000,000 yen
- JSPS KAKENHI, 18KK0095, Co-Investigator, FY2015-2017, 3,700,000 yen
- JSPS KAKENHI, 16H02229, Principal Investigator, FY2016-2019, 8,900,000 yen

7. Publications and Patents

(1) Peer-reviewed Journal Articles

1. Seki, K., Keika, K., Kasahara, S.,Yokota, S., Hori, T., Asamura, K., N. Higashio, M. Takada, Y. Ogawa, A. Matsuoka, M. Teramoto, Y. Miyoshi, and I. Shinohara, Statistical properties of

molecular ions in the ring current observed by the Arase (ERG) satellite, ***Geophys. Res. Lett.***, 46, https://doi.org/10.1029/2019GL084163, 2019.

2. Inui, S., K. Seki, S. Sakai, D. A. Brain, T. Hara, J. P. McFadden, J. S. Halekas, D. L. Mitchell, G. A. DiBraccio, and B. M. Jakosky, Statistical study of heavy ion outflows from Mars observed in the Martian induced magnetotail by MAVEN, ***J. Geophys. Res.***, 124, accepted, 2019.

3. Ogawa, Y., K. Seki, K. Keika, and Y. Ebihara, Characteristics of CME- and CIR-driven ion upflows in the polar ionosphere, ***J. Geophys. Res.***, 124, accepted, 2019.

4. Mitani, K., K. Seki, K. Keika, M. Gkioulidou, L. J. Lanzerotti, D. G. Mitchell, C. A. Kletzing, A. Yoshikawa, and Y. Obana, Statistical study of selective oxygen increase in high-energy ring current ions during magnetic storms, ***J. Geophys. Res.***, 124. https://doi.org/10.1029/2018JA026168, 2019.

5. Yamakawa, T., Seki, K., Amano, T., Takahashi, N., & Miyoshi, Y., Excitation of storm time Pc5 ULF waves by ring current ions based on the drift-kinetic simulation. ***Geophys. Res. Lett.***, 46, https://doi.org/ 10.1029/2018GL081573, 2019.

6. Naoko Takahashi, Kanako Seki, Mariko Teramoto, Mei-Ching Fok, Yihua Zheng, Ayako Matsuoka, Nana Higashio, Kazuo Shiokawa, Dmitry Baishev, Akimasa Yoshikawa, and Tsutomu Nagatsuma, Global distribution of ULF waves during magnetic storms: Comparison of Arase, ground observations and BATSRUS+CRCM simulation, ***Geophys. Res. Lett.***, 45, 9390–9397, doi:10.1029/2018GL078857, 2018.

7. Sakai, S., Seki, K., Terada, N., Shinagawa, H., Tanaka, T., and Ebihara, Y., Effects of a weak intrinsic magnetic field on atmospheric escape from Mars, ***Geophys. Res. Lett.***, 45, 9336–9343, doi:10.1029/2018GL079972, 2018.

8. Keika, K., Kasahara, S., Yokota, S., Hoshino, M., Seki, K., Nosé, M., Amano, T., Miyoshi, Y., and Shinohara, I., Ion energies dominating energy density in the inner magnetosphere: Spatial distributions and composition, observed by Arase/MEP-i. ***Geophys. Res. Lett.***, 45, doi:10.1029/2018GL080047, 2018.

9. Hori, T., N. Nishitani, S. G. Shepherd, J. M. Ruohoniemi, M. Connors, M. Teramoto, S. Nakano, K. Seki, N. Takahashi, S. Kasahara, S. Yokota, T. Mitani, T. Takashima, N. Higashio, A. Matsuoka, K. Asamura, Y. Kazama, S.-Y. Wang, S. W. Y. Tam, T.-F. Chang, B.-J. Wang, Y. Miyoshi, and I. Shinohara, Substorm-associated ionospheric flow fluctuations during the 27 March 2017 magnetic storm: SuperDARN-Arase conjunction, ***Geophys. Res. Lett.***, 45, doi: 10.1029/2018GL079777, 2018.

10. Hara, T., J. G. Luhmann, F. François, S. Curry, J. Halekas, K. Seki, D. Brain, Y. Harada, J. P. McFadden, G. A. Dibraccio, Y. Soobiah, D. Mitchell, S. Xu, C. Mazelle, and B. M. Jakosky, Evidence for crustal magnetic field control of ions precipitating into the upper atmosphere of Mars, ***Geophys. Res. Lett.***, 45, https://doi.org/10.1029/2017JA024798, 2018.

11. Walia, N. K., K. Seki, M. Hoshino, T. Amano, N. Kitamura, Y. Saito, S. Yokota, C. J. Pollock, B. L. Giles, T. E. Moore, R. B. Torbert, C. T. Russell, and J. L. Burch, A statistical study of slow-mode shocks observed by MMS in the dayside magnetopause, ***Geophys. Res. Lett.***, 45, doi:10.1029/2018GL077580, 2018.

12. Jakosky, B.M., D. Brain, M. ChafÞn, S. Curry, J. Deighan, J. Grebowsky, J. Halekas, F. Leblanc, R. Lillis, J.G. Luhmann, L. Andersson, N. Andre, D. Andrews, D. Baird, D. Baker, J. Bell, M. Benna, D. Bhattacharyya, S. Bougher, C. Bowers, P. Chamberlin, J.-Y. Chaufray, J. Clarke, G. Collinson, M. Combi, J. Connerney, K. Connour, J. Correira, K. Crabb, F. Crary, T. Cravens, M. Crismani, G. Delory, R. Dewey, G. DiBraccio, C. Dong, Y. Dong, P. Dunn, H. Egan, M. Elrod, S. England, F. Eparvier, R. Ergun, A. Eriksson, T. Esman, J. Espley, S. Evans, K. Fallows, X. Fang, M. Fillingim, C. Flynn, A. Fogle, C. Fowler, J. Fox, M. Fujimoto, P. Garnier, Z. Girazian, H. Groeller, J. Gruesbeck, O. Hamil, K.G. Hanley, T. Hara, Y. Harada, J. Hermann, M. Holmberg, G. Holsclaw, S. Houston, S. Inui, S. Jain, R. Jolitz, A. Kotova, T.

Kuroda, D. Larson, Y. Lee, C. Lee, F. Lefevre, C. Lentz, D. Lo, R. Lugo, Y.-J. Ma, P. Mahaffy, M.L. Marquette, Y. Matsumoto, M. Mayyasi, C. Mazelle, W. McClintock, J. McFadden, A. Medvedev, M. Mendillo, K. Meziane, Z. Milby, D. Mitchell, R. Modolo, F. Montmessin, A. Nagy, H. Nakagawa, C. Narvaez, K. Olsen, D. Pawlowski, W. Peterson, A. Rahmati, K. Roeten, N. Romanelli, S. Ruhunusiri, C. Russell, S. Sakai, N. Schneider, K. Seki, R. Sharrar, S. Shaver, D.E. Siskind, M. Slipski, Y. Soobiah, M. Steckiewicz, M.H. Stevens, I. Stewart, A. Stiepen, S. Stone, V. Tenishev, N. Terada, K. Terada, E. Thiemann, R. Tolson, G. Toth, J. Trovato, M. Vogt, T. Weber, P. Withers, S. Xu, R. Yelle, E. Yi ù git, R. Zurek, Loss of the Martian atmosphere to space: Present-day loss rates determined from MAVEN observations and integrated loss through time, ***Icarus***, 315, 146-157, doi: 10.1016/j.icarus.2018.05.030, 2018.

13. Inui, S., K. Seki, T. Namekawa, S. Sakai, D. A. Brain, T. Hara, J. P. McFadden, J. S. Halekas, D. L. Mitchell, G. A. DiBraccio, and B. M. Jakosky**,** Cold dense ion outflow observed in the Martian induced magnetotail by MAVEN, ***Geophys. Res. Lett.***, 45, 10.1029/2018GL077584, 2018.

14. Mitani, K., K. Seki, K. Keika, M. Gkioulidou, L. J. Lanzerotti, D. G. Mitchell, and C. A. Kletzing, Radial transport of higher-energy oxygen ions into the deep inner magnetosphere observed by Van Allen Probes, ***Geophys. Res. Lett.***, 45, doi: 10.1029/2018GL077500, 2018.

15. Miyoshi, Y., I. Shinohara, T. Takashima, K. Asamura, N. Higashio, T. Mitani, S. Kasahara, S. Yokota, Y. Kazama, S.-Y. Wang, S. Tam, P. Ho, Y. Kasahara, Y. Kasaba, S. Yagitani, A. Matsuoka, H. Kojima, Y. Katoh, K. Shiokawa, and K. Seki, Geospace Exploration Project ERG, ***Earth, Planets Space***, 70:101, doi:10.1186/s40623-018-0862-0, 2018.

16. Seki, K., Y. Miyoshi, Y. Ebihara, Y. Katoh, T. Amano, S. Saito, M. Shoji, A. Nakamizo, K. Keika, T. Hori, S. Nakano, S. Watanabe, K. Kamiya, N. Takahashi, Y. Omura, M. Nose, M.-C. Fok, T. Tanaka, A. Ieda, and A. Yoshikawa, Theory, modeling, and integrated studies in the Arase (ERG) project, ***Earth Planets Space***, 70:17, doi:10.1186/s40623-018-0785-9, 2018.

17. Kasahara, S., Y. Miyoshi, S. Yokota, T. Mitani, Y. Kasahara, S. Matsuda, A. Kumamoto, A. Matsuoka, Y. Kazama, H. U. Frey, V. Angelopoulos, S. Kurita, K. Keika, K. Seki, and I. Shinohara, Pulsating aurora from electron scattering by chorus waves, ***Nature***, 554/7692, 337-340, doi:10.1038/nature25505, 2018.

18. Kamiya, K., K. Seki, S. Saito, T. Amano, and Y. Miyoshi, Formation of butterfly pitch angle distributions of relativistic electrons in the outer radiation belt with a monochromatic Pc5 wave, ***J. Geophys. Res.***, 123, doi:10.1002/2017JA024764, 2018.

19. Keika,K. K. Seki, M. Nosé, Y. Miyoshi, L. Lanzerotti, D. Mitchell, M. Gkioulidou, and J. Manweiler, Three-step buildup of the 17 March 2015 storm ring current: Implication for the cause of the unexpected storm intensification, ***J. Geophys. Res.***, 123, 414–428. doi:10.1002/2017JA024462, 2018.

20. Keika, K., Y. Miyoshi, S. Machida, A. Ieda, K. Seki, T. Hori, Y. Miyashita, M. Shoji, I. Shinohara, V. Angelopoulos, J. W. Lewis, and A. Flores, A visualization tool for three-dimensional plasma velocity distributions (ISEE_3D) as a plug-in tool for SPEDAS, ***Earth Planets Space***, 69:170, doi:10.1186/s40623-017-0761-9, 2017.

21. Shiokawa, K., Y. Kato, Y. Hamaguchi, Y. Yamamoto, T. Adachi, M. Ozaki, S.-I. Oyama, M. Nosé, T. Nagatsuma, Y. Tanaka, Y. Otsuka, Y. Miyoshi, R. Kataoka, Y. Takagi, Y. Takeshita, A. Shinbori, S. Kurita, T. Hori, N. Nishitani, I. Shinohara, F. Tuchiya, Y. Obana, S. Suzuki, N. Takahashi, K. Seki, A. Kadokura, K. Hosokawa, Y. Ogawa, M. Connors, J. M. Ruohoniemi, M. Engebretson, E. Turunen, T. Ulich, J. Manninen, T. Raita, A. Kero, A. Oksanen, M. Back, K. Kauristie, J. Mattanen, D. Baishev, V. Kurkin, A. Oinats, A. Pashinin, R. Vasilyev, R. Rakhmatulin, W. Bristow, and M. Karjala, Ground-based instruments of the PWING project to investigate dynamics of the inner magnetosphere at subauroral latitudes as a part of the ERG-ground coordinated observation network, Earth, Planets and Space, 69:160, doi: 10.1186/s40623-017-0745-9, 2017.

22. K. Matsunaga, K. Seki, D. Brain, T. Hara, K. Masunaga, J. P. McFadden, J. Halekas, D. Mitchell, C. Mazelle, J. Esplay, J. Gruesbeck, and B. M. Jakosky, Statistical Study of Relations Between the Induced Magnetosphere, Ion Composition, and Pressure Balance Boundaries around Mars Based on MAVEN Observations, ***J. Geophys. Res.***, 122, 9723–9737, DOI:10.1002/2017JA024217, 2017.

23. M. Yagi, K. Seki, Y. Matsumoto, D. C. Delcourt, and F. Leblanc, Global structure and sodium ion dynamics in Mercury's magnetosphere with the offset dipole, ***J. Geophys. Res.***, 122, 10990–11002, DOI: 10.1002/2017JA024082, 2017.

24. T. Hara, Y. Harada, D. L. Mitchell, G. A. Dibraccio, J. Espley, D. A. Brain, J. S. Halekas, K. Seki, J. G. Luhmann, J. P. McFadden, C. Mazelle, B. M. Jakosky, On the origins of magnetic flux ropes in near-Mars magnetotail current sheets, ***Geophys. Res. Lett.***, 44, 7653–7662, doi:10.1002/2017GL073754, 2017.

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(2) Non-peer-reviewed Articles

(3) Review Papers

(4) Books

1. Space Sciences Series of ISSI “Plasma sources for Solar System Magnetospheres”, Edss by A. F. Nagy, M. Blanc, C. R. Chappell, N. Krupp, ***Springer***, 2015（responsible for Chapter 2）.

(5) Other Publications

(6) Patents

8. Keynote, Invited, or Solicited Presentations

1. Kanako Seki, et al., Effects of the intrinsic magnetic field on the atmospheric escape from terrestrial planets, JpGU 2019 Meeting, May 2019, (Makuhari, Japan).
2. Kanako Seki, et al., Arase(*ERG*) mission and involvement of space simulations, 13th International Symposium for Space Simulations, September 2018, (UCLA, Los Angeles, USA).
3. Kanako Seki, Current understanding of water and atmospheric escape from Mars based on MAVEN observations, Symposium on Planetary Science 2018, February 2018 (Sendai, Japan).
4. Kanako Seki, Exploration into underlying physics in space weather phenomena around Earth and beyond, The 2nd UK-Japan FoS, Keynote Speaker, November 2016 (Chicheley, UK).
5. Kanako Seki, Takanobu Amano, Shinji Saito, Kei Kamiya, Yoshizumi Miyoshi, Yosuke Matsumoto, Takayuki Umeda, Kunihiro Keika, and Yukinaga Miyashita, A study on characteristics of radial transport of relativistic electrons by ULF Pc5 waves in the inner magnetosphere based on the GEMSIS-RC and RB models, 18th International Congress on Plasma Physics (ICPP 2016), June 2016 (Kaohsiung, Taiwan).
6. K. Seki, T. Amano, K. Kamiya, S. Saito, Y. Miyoshi, Y. Matsumoto, T. Umeda, K. Keika, K. Mitani, and Y. Miyashita, Self-consistent modeling of ring current ion dynamics with magnetic and electric fields based on the GEMSIS-RC models and related issues, ISSI (International Space Science Institute) team meeting on Ring Current Modeling: Uncommon Assumptions and Common Misconceptions, March 2016 (Bern, Switzerland).

7. K. Seki, N. Terada, H. Nakagawa, and MAVEN PS team, A review of MAVEN initial results: Dynamic variation of Martian upper atmosphere and new aurora, Symposium on Planetary Science 2016, February 2016 (Sendai, Japan).
8. Kanako Seki, A personal future perspective of international collaborations in space physics, 2015 Japan Geoscience Union (JpGU) Meeting 2015, May 2015 (Makuhari, Japan).
9. K. Seki, T. Amano, S. Saito, Y. Miyoshi, K. Keika, Y. Miyashita, Y. Matsumoto, T. Umeda, and Y. Ebihara, "Coupling between the ULF waves and high energy particles in the inner magnetosphere based on the GEMSIS-RC model", AOGS (Asia Oceania Geosciences Society) 2014 Annual Meeting, July 2014 (Sapporo, Japan).
10. K. Seki, N. Terada, M. Yagi, D.C. Delcourt, F. Leblanc, and T. Ogino, "Mercury's plasma dynamics and effects on surface conductivity", 5th SERENA-HEWG meeting, June 2014 (Killarney, Ireland).
11. K. Seki, "A comparison of planetary ion dynamics in the magnetospheres of Mercury and Earth", ISSI (International Space Science Institute) workshop on Plasma Sources of Solar System Magnetospheres, September 2013 (Bern, Switzerland).
12. K. Seki, N. Terada, M. Yagi, D.C. Delcourt, F. Leblanc, and T. Ogino, "Effects of the surface conductivity and the IMF strength on the dynamics of planetary ions in Mercury's magnetosphere", IAPS International Symposium on Planetary Sciences, July 2013 (Shanghai, China).
13. K. Seki, A. Matsuoka, N. Terada, T. Abe, A. Yamazaki, S. Yokota, H. Hayakawa, and Martian Atmospheric Escape Mission Working Group, "Science objectives of Japanese atmospheric escape mission to Mars (heir of NOZOMI): Role of atmospheric escape in evolution of Martian environment", IAPS International Symposium on Planetary Sciences, July 2013 (Shanghai, China).
14. K. Seki, T. Amano, S. Saito, Y. Miyoshi, Y. Matsumoto, T. Umeda, Y. Miyashita, and Y. Ebihara, "Coupling between the ULF waves and the ring current in the inner magnetosphere based on the GEMSIS-RC model", AOGS (Asia Oceania Geosciences Society) 2013 Annual Meeting, June 2013 (Brisbane, Australia).
15. K. Seki, Y. Matsumoto, B. Lavraud, Y. Saito, and R. Henri, "On roles of the K-H instability and double lobe reconnection in formation of CDPS in the geomagnetosphere: PSD observations and PIC simulation", AOGS-AGU(WPGM) Joint Assembly, August 2012 (Singapore).
16. K. Seki, T. Amano, S. Saito, Y. Miyoshi, Y. Matsumoto, T. Umeda, Y. Miyashita, and Y. Ebihara, Effects of the ring current and plasmasphere on ULF waves in the inner magnetosphere based on the GEMSIS-RC and RB models, International Conference on Radiation Belts and Space Weather: New Horizon from RBSP Mission, May 2012, (DaeJEon, South Korea).

III. Education Activity (@ UTokyo only)

9. Notable Achievements in Education

Advisees

- Master theses: 3 students

  Nehpreet Walia (Sep. 2018)

  Shogo Inui, Masayoshi Takada (Mar. 2019)

- Doctoral theses: 1 student
  Yoko Fukuda (May. 2017)

Lectures

- Undergraduate/Graduate, Planetary Aeronomy, FY2016-2019
- Graduate, Magnetospheric Physics I, FY2016, 2018
- Undergraduate, Overview of earth and planetary physics, FY2016-2017
- Undergraduate, Introduction to earth and planetary physics, FY2016 (omnibus)
- Undergraduate, Frontier Lecture, FY2017-2019 (omnibus)

Student's awards

- Aurora Medal from SGEPSS (Society of Geomagnetism and Earth, Planetary and Space Sciences): 1 student [Yoko Fukuda]

IV. External Activities

10. Contribution to Academic Community

- Member of Science Committee of ISSI (International Space Science Institute)
- Member of the Science Council of Japan (2017-present)
- Representatives of Japan Geoscience Union from the Space and Planetary Sciences Section (2014-present)
- Member of Selection Committee of Obayashi Award of SGEPSS (2015-present)

11. Outreach Activity

- Cabinet Office, Japan, Subcommittee for Space Science and Exploration of the National Space Policy Commitee, Member, FY2019-
- JSPS or MEXT Reviews, FY2012-
- ISAS/JAXA, Advisory Collaborative Research Committee for Space Science, Member, FY 2019-
- ISEE/Nagoya University, Collaborative Research Committee, Member, FY 2015-
- Press Release: 3 times (May 2017, Aug. 2019)
- Lectures for general audience: 8 times (Mar. 2013, Mar., Aug., Oct. 2014, Sep. 2016, Oct. 2017, Jul. 2018)

12. Internal Committee Membership

- Department of Earth and Planetary Science, Budget Committee, Chair, FY2018-2019
- School of Science, International Committee, Member, FY2017-2019
- School of Science, Gender-equality Committee, Member, FY2017-2019
- Department of Earth and Planetary Physics, Head, FY2016-2019

V. International Exchange Activities

13. Hosting/Sending Foreign Students and Researchers

(1) Hosting

Foreign Students: 1

Foreign Researchers: 3

(2) Sending

Students: 1

Researchers: 1

(3) Visitors from Abroad: 12

Shogo Tachibana

I. CV

Name: Shogo Tachibana

Age: 46

Present Position: Professor

Education

Kanazawa Izumigaoka High School, Kanazawa, March 1991

B. Sc. Department of Earth and Space Science, Osaka University, March 1995

M. Sc. Department of Physics, Osaka University, March 1997

Ph. D. Department of Earth and Space Science, Osaka University, March 2000

Professional Experience

April 2000-March 2003, Research Fellow of the Japan Society for the Promotion of Science (PD)

April 2003-March 2012, Research Associate, Department of Earth and Planetary Sciences, The University of Tokyo

April 2002-January 2013, Lecturer, Department of Natural History of Sciences, Hokkaido University

January 2013-September 2017, Associate Professor, Department of Natural History of Sciences, Hokkaido University

October 2017-, Professor, UTokyo Organization for Planetary and Space Science (UTOPS), The University of Tokyo

April 2019-, Specially Appointed Professor, Institute of Space and Aeronautical Science, JAXA

II. Scientific Research Activity

2. Major Achievements

I am interested in what was responsible for making diverse Solar System planets, including Earth. I have especially aimed at understanding the chemical evolution of the early Solar System by combining laboratory experiments, analysis of extraterrestrial materials, astronomical observation, modeling, and Solar System exploration. My research group has conducted laboratory experiments on (1) evaporation/condensation of mineral dust in circumstellar environments, (2) photochemistry of ice in molecular clouds, (3) crystallization and oxygen isotope exchange of amorphous silicate dust in protoplanetary disks, and (4) mineral-water-organics interaction in small bodies. I have put constraints on physicochemical conditions that early Solar System materials experienced during their evolution prior to planet formation. In order to obtain pristine materials with the geologic context, I have been involved in Hayabusa2 and OSIRIS-REx asteroidal sample return missions. I have worked to set the scientific goal of Hayabusa2 and to develop the sample acquisition system. I have also been involved in astronomical observations of metal-bearing gas molecules around an evolved star and a massive proto star candidate to understand the forming environments of presolar grains and refractory components found in chondrites. I believe that these studies open a new frontier in cosmochemistry.

3. Five Important Papers (including three or more papers in this review period)

1. Tachibana S., Kamizuka T., Hirota T., Sakai N., Oya Y., Takigawa A., & Yamamoto S. (2019). Spatial distribution of AlO in a high mass protostar candidate Orion Source I. *Astrophys. J. Letters* **875,** L29 (4 pp). doi.org/10.3847/2041-8213/ab1653

High-temperature molecular gas containing metallic elements is potentially a good probe to trace the kinematics/ dynamics of circumstellar disks, and its presence in circumstellar disks around young stellar objects (YSOs) may also give some insights into formation processes of high-temperature meteoritic components formed in the Sun's protoplanetary disk. The Orion Kleimann–Low (KL) region is the most famous and nearest massive star formation site, and has been extensively studied since the 1970s. The KL region harbors a candidate high-mass YSO, Source I, which has a hot circumstellar rotating gas disk emanating a magnetocentrifugal wind of SiO. In this study, we report spatially resolved distributions of aluminum monoxide (AlO) emission lines at 497 and 650 GHz in the rotating outflow of Orion Source I based on subarcsecond observations obtained by the Atacama Large Millimeter/ Submillimeter Array for the first time in star-forming regions. These AlO emissions are detected only at the base of the outflow as the high excitation line of H_2O in spite of their low excitation temperatures. The limited distribution of AlO to the launching point of the outflow indicates that AlO is not in the gas phase in the outer part of the outflow lobes away from the disk surface, which could be attributed to recondensation of AlO as dust due to its refractory nature.

2. Yamamoto D., Kuroda M., Tachibana S., Sakamoto N., & Yurimoto H. (2018). Oxygen isotopic exchange between amorphous silicate and water vapor and its implications to oxygen isotopic evolution in the early Solar System. *Astrophys. J.* **865,** 98 (14pp). doi.org/10.3847/1538-4357/aadcee

Meteoritic evidence suggests that oxygen isotopic exchange between ^{16}O-rich amorphous silicate dust and ^{16}O-poor water vapor occurred in the early Solar System. We experimentally investigated the kinetics of oxygen isotopic exchange between submicron-sized amorphous forsterite grains and water vapor at protoplanetary disk-like low pressures of water vapor. The isotopic exchange reaction rate is controlled either by diffusive isotopic exchange in the amorphous structure or by the supply of water molecules from the vapor phase. The diffusive oxygen isotopic exchange occurred with a rate constant D (m^2 s^{-1}) $= (1.5 \pm 1.0) \times 10^{-19} \exp[-(161.5 \pm 14.1 \text{ (kJ mol}^{-1}))R^{-1}(1/T-1/1200)]$ at temperatures below ~800–900 K, and the supply of water molecules from the vapor phase could determine the rate of oxygen isotopic exchange at higher temperatures in the protosolar disk. According to the kinetics for oxygen isotopic exchange in protoplanetary disks, original isotopic compositions of amorphous forsterite dust could be preserved only if the dust was kept at temperatures below 500–600 K in the early Solar System. The ^{16}O-poor signatures for the most pristine silicate dust observed in cometary materials implies that the cometary silicate dust experienced oxygen isotopic exchange with ^{16}O-poor water vapor through thermal annealing at temperatures higher than 500–600 K prior to their accretion into comets.

3. Takigawa A., Kamizuka T., Tachibana S., & Yamamura I. (2017). Dust formation and wind acceleration around the aluminum oxide-rich AGB star W Hydrae. *Science Advances* **3,** eaao2149. doi:10.1126/sciadv.aao2149

Dust grains, formed around asymptotic giant branch (AGB) stars, are accelerated by stellar radiation to drive stellar winds, which supply freshly synthesized nuclides to the Galaxy. Silicate is the dominant dust species in space, but ~40% of oxygen-rich AGB stars are thought to have comparable amounts of aluminum oxide dust. Dust formation and the wind-driving mechanism around these oxygen-rich stars, however, are poorly understood. We report on the spatial distributions of AlO and 29SiO molecules around an aluminum oxide–rich M-type AGB star, W Hydrae, based on observations obtained with the Atacama Large Millimeter/submillimeter Array. AlO molecules were only observed within three stellar radii, whereas ^{29}SiO was distributed in the accelerated wind beyond 5 stellar radii without significant depletion. This strongly suggests that condensed aluminum oxide dust plays a key role in accelerating the stellar wind and in preventing the efficient formation of silicate dust around W Hydrae.

4. Tachibana S., Kouchi A., Hama T., Oba Y., Piani L., Sugawara I., Endo Y., Hidaka H., Kimura Y., Murata K., Yurimoto H., & Watanabe N. (2017). Liquid-like behavior of UV-irradiated interstellar ice analog at low temperatures. *Science Advances* **3,** eaao2538. doi:10.1126/sciadv.aao2538

Interstellar ice is believed to be a cradle of complex organic compounds, commonly found within icy comets and interstellar clouds, in association with ultraviolet (UV) irradiation and subsequent warming. We found that UV-irradiated amorphous ices composed of H_2O, CH_3OH, and NH_3 and of pure H_2O behave like liquids over the temperature ranges of 65 to 150 K and 50 to 140 K, respectively, for the first time. The viscosity of the liquid-like amorphous H_2O-CH_3OH-NH_3 ice was estimated from in situ microscopic observations of bubble growth. The estimated viscosities at ~88 and ~112 K are ~4×10^2 to 7×10^2 Pa s, much lower than the viscosity at the glass transition temperature (10^{12} Pa s). The viscosity of the UV-irradiated amorphous water ice at 60 K was estimated to be 4 × 107 Pa s from the morphological change of the ice island. This viscosity is higher than that of UV-irradiated amorphous H_2O–CH_3OH–NH_3 ice but is still five orders of magnitude smaller than the viscosity at the glass transition temperature. This low-viscosity liquid-like ice may enhance the formation of organic compounds including prebiotic molecules and the accretion of icy dust to form icy planetesimals under certain interstellar conditions.

5. Tachibana S., Abe M., Arakawa M., Fujimoto M., Iijima Y., Ishiguro M., K. Kitazato, Kobayashi N., Namiki N., Okada T., Okazaki R., Sawada H., Sugita S., Takano Y., Tanaka S., Watanabe S., Yoshikawa M., Kuninaka H., & the Hayabusa2 Project Team (2014). Hayabusa2: Scientific importance of samples returned from C-type near-Earth asteroid (162173) 1999 JU_3. *Geochem. J.* **48,** 571-587. doi:10.2343/geochemj.2.0350

Hayabusa2 is an asteroid exploration mission to return surface samples of a near-Earth C-type asteroid (162173) 1999 JU_3 (later named as Ryugu) Because asteroids are the evolved remnants of planetesimals that were the building blocks of planets, detailed observation by a spacecraft and analysis of the returned samples will provide direct evidence regarding planet formation and the dynamic evolution of the solar system. Moreover, C-type asteroids are expected to preserve the most pristine materials in the solar system, a mixture of minerals, ice, and organic matter that interact with each other. Space missions are the only way to obtain such pristine materials with geologic context and without terrestrial contamination. Hayabusa2 will launch off in 2014, arrive at 1999 JU_3 in mid-2018, and fully investigate and sample the asteroid at three different locations during its 18-month stay. The concept and design of the Hayabusa2 sampler are basically the same as that on-board Hayabusa, and impact sampling with a 5-g Ta bullet will be made at three locations of the asteroid. The sample container has three separate chambers inside to store samples obtained at different locations separately. The spacecraft will return to Earth with samples in December 2020. Returned samples will be investigated by state-of- the-art analytical techniques in 2020 to understand the evolutionary history of the solar system from 4.56 Gyr ago to the present by combining results from laboratory examinations of the returned samples with remote-sensing datasets and comparing all results of observations of meteorites, interplanetary dust particles, and future returned samples.

4. Awards and Honors

- Tachibana, S., The Paul W. Gast Lectureship, Geochemical Society & European Association of Geochemistry, June 2016
- Tachibana, S., Acknowledgement for Excellent Reviewers of the Screening Committee for JSPS Research Fellowship for Young Researchers, September 2016

5. Future Research Plan

I aim at revealing the origin and evolution of Solar System through combining laboratory experiments, analysis of extraterrestrial materials, astronomical observations, and modeling. The analysis of extraterrestrial materials includes the sample from asteroid Ryugu that will be returned by Hayabusa2 at the end of 2020. I especially focus on (1) The Solar System forming environment: The chemical state of the Sun's parent molecular cloud and the formation/evolution of dust in the Galaxy prior to the delivery to the Solar System, (2) The Sun's protoplanetary disk: Material evolution in the disk, the physicochemical condition of the disk, the chemical diversity of terrestrial planets, (3) Small bodies: Chemical process(es) within planetesimals and its consequence for minerals, water, and organics, and (4) Comparison of the Solar System with other systems: Material evolution around evolved starts, inside molecular clouds, and in protoplanetary disks (observation by ALMA and the University of Tokyo Atacama Observatory).

6. Funding Received

- MEXT KAKENHI, 18H05186, Co-Investigator, FY2018, JPY 3,000 K
- JSPS KAKENHI, 16H06349, Co-Investigator, FY2016-2020, JPY 140,700 K
- JSPS KAKENHI, 16H04080, Principal Investigator, FY2016-2018, JPY 12,800 K
- MEXT KAKENHI, 15K21735, Co-Investigator, FY2015-2017, JPY 26,500 K
- JSPS Bilateral Programs: Joint Research Projects with FRANCE (MEAE-MESRI) "SAKURA Program", Principal Investigator, FY2014-2015, JPY 2,000 K
- MEXT KAKENHI, 25108002, Co-Investigator, FY2013-2017, JPY 111,100 K
- MEXT KAKENHI, 25108001, Co-Investigator, FY2013-2017, JPY 33,600 K
- JSPS KAKENHI, 25287140, Principal Investigator, FY2013-2015, JPY 11,700 K
- JSPS KAKENHI, 25610037, Principal Investigator, FY2013-2014, JPY 2,600 K
- Grants-in-Aid of AstroBiology Center Project, Principal Investigator, FY2013, JPY 1,000 K
- JSPS KAKENHI, 22224010, Co-Investigator, FY2010-2014, JPY 166,800 K
- The Sumitomo Foundation Grant for Basic Science Research Projects, Principal Investigator, FY2012, JPY 1,500 K
- Promotion for Young Research Talent and Network from Northern Advancement Center for Science & Technology, Principal Investigator, FY2012, JPY 400 K
- Hokkaido University President Research Grant for Young Researchers, Principal Investigator, FY2012, JPY 800 K
- Hokkaido University President Travel Grant for Young Researchers, Principal Investigator, FY2012, JPY 300 K
- JSPS KAKENHI, 23654183, Principal Investigator, FY2011-2012, JPY 2,600 K

7. Publications and Patents

(1) Peer-reviewed Journal Articles

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31. Takigawa A., Tachibana S., Nagahara H. and Ozawa K. (2015) Evaporation and condensation kinetics of corundum: The origin of the 13-μm feature of oxygen-rich AGB stars. *Astrophys. J. Suppl.* **218,** doi:10.1088/0067-0049/218/1/2

32. Hsu H. -W., Postberg F., Sekine Y., Shibuya T., Kempf S., Horányi M., Juhász A., Altobelli N., Suzuki K., Masaki Y., Kuwatani T., Tachibana S., Sirono S., Moragas-Klostermeyer G. and Srama R. (2015) Ongoing hydrothermal activities within Enceladus. *Nature* **519,** 207-210. doi:10.1038/nature14262

33. Connolly H. C., Jr., Lauretta D. S., Walsh K. J., Tachibana S. and Bottke W. F. Jr. (2015) Towards understanding the dynamical evolution of asteroid 25143 Itokawa: constraints from sample analysis. *Earth Planet. Sci.* **67,** doi:10.1186/s40623-015-0185-3

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37. Sakai R., Nagahara H., Ozawa K. and Tachibana S. (2014) Composition of the lunar magma ocean constrained by the conditions for the crust formation. *Icarus* **229,** 45-56. doi:10.1016/j.icarus.2013.10.031

38. Fujita K., Ozawa T., Okudaira K., Mikouchi T., Suzuki T., Takayanagi H., Tsuda Y., Ogawa N., Tachibana S. and Satoh T. (2014) Conceptual study and key technology development for Mars aeroflyby sample collection. *Acta Astronautica* **93,** 84-93. doi:10.1016/j.actaastro.2013.07.009

39. Takigawa A., Tachibana S., Huss G. R., Nagashima K., Makide K., Krot A. N. and Nagahara H. (2014) Morphology and crystal structures of solar and presolar Al_2O_3 in unequilibrated ordinary chondrites. *Geochim. Cosmochim. Acta* **124,** 309-327. doi:10.1016/j.gca.2013.09.013

40. Tachibana S., Tamada S., Kawasaki H., Ozawa K. and Nagahara H. (2013) Interdiffusion of Mg-Fe in olivine at 1,400-1,600°C and 1 atm total pressure. *Phys. Chem. Min.* **40,** 511-519. doi:10.1007/s00269-013-0588-2

41. Telus M., Huss G. R., Ogliore R. C., Nagashima K., & Tachibana S. (2012). Recalculation of data for short-lived radionuclide systems using less-biased ratio estimation. *Meteorit. Planet. Sci.* **47,** 2013-2030.

42. Takigawa A. & Tachibana S. (2012). Crystallographically anisotropic shape of forsterite: New probe for evaluating dust formation history from infrared spectroscopy. *Astrophys. J.* **750,** 149-164. doi:10.1088/0004-637X/750/2/149.

43. Kurosawa K., Kadono T., Sugita S., Shigemori K., Sakaiya T., Hironaka Y., Ozaki N., Shiroshita A., Cho Y., Tachibana S., Vinci T., Ohno S., Kodama R., & Matsui T. (2012). Shock-induced silicate vaporization: The role of electrons. *J. Geophys. Res. Planets,* **117,** E4. doi:10.1029/2011JE004031.

(2) Non-peer-reviewed Articles

1. Tachibana S. & Takigawa A. (2014). Experimental Studies on Dust Formation in Space. *Proceedings of "The Life Cycle of Dust in the Universe: Observations, Theory, and Laboratory Experiments "*PoS(LCDU2013)046

(3) Review Papers

1. Kouchi A., Tachibana S., Piani L., Orthous-Daunay, F.-R., & Naraoka, H. (2019). Preface: Evolution of molecules in space: From interstellar clouds to protoplanetary nebulae. *Geochem. J.* **53,** 1-3. doi:10.2343/geochemj.2.0555

2. Tachibana S., Busemann H., & Bonal L. (2014). Preface: Evolution of refractory grains, volatiles, and organic molecules from the interstellar medium to the early solar system. *Geochem. J.* **48,** 509-510. doi:10.2343/geochemj.2.0349

(4) Books

A cosmochemistry book for general public (2016); A chapter on origin of elements in a book for general public (2014); Two items in a dictionary for exoplanet research (2016)

(5) Other Publications

Three research essays and one book review in Japanese

(6) Patents

8. Keynote, Invited, or Solicited Presentations

1. Tachibana S. (2013) Scientific importance of return samples from near-earth C-type asteroid 1999 JU_3: sampling method/strategy and sample analyses. *HAYABUSA2013 - Symposium of the Solar System Materials* (Sagamihara, Japan), 2013.10.16-18.

2. Tachibana S. (2013) Experimental studies on dust formation in space. *The Life Cycle of Dust in the Universe* (Taipei, Taiwan), 2013.11.18-22.

3. Tachibana S. (2014) Hayabusa-2 - Sample Return from Near-Earth C-Type Asteroid 1999 JU_3: Sampling Method/Strategy and Sample Analyses. *OSIRIS-REx Science Team Meeting 6* (Tucson, USA), 2014.4.22-24.
4. Tachibana S. (2014) Hayabusa-2: Sample Return from a near-Earth C-Type Asteroid, 1999 JU_3. *Goldschmidt Conference 2014* (Sacramento, USA), 2014.6.8-13.
5. Tachibana S. (2016) Chemical evolution of the solar system: Laboratory experiments and small-body explorations. *Gast Lectureship, Goldschmidt Conference 2016* (Yokohama, Japan), 2016.6.26-7.1.
6. Tachibana S. (2017) Hayabusa2: Sample return from C-type near-Earth asteroid (162173) Ryugu. *Royal Astronomical Society Specialist Discussion meeting 'Science of Primitive Asteroid Sample Return Missions'* (London, UK), 2017.10.13.
7. Tachibana S. (2018) Key science drivers for new space missions: Solar System origin and formation scenarios. *ISSI-Beijing Forum 'Roads towards Sample Return from Comets and Asteroids'* (Beijing, China), 2018.1.17-18.
8. Tachibana S. (2018) Needed technologies: Sampling techniques for Hayabusa-2. *ISSI-Beijing Forum 'Roads towards Sample Return from Comets and Asteroids'* (Beijing, China), 2018.1.17-18.
9. Tachibana S. (2018) Asteroid sample return missions - Hayabusa-2 and OSIRIS-REx. *Europlanet & International Space Science Institute Workshop 'Role of Sample Return in Addressing Major Outstanding Questions in Planetary Sciences'* (Bern, Switzerland), 2018.2.5-9.
10. Tachibana S. (2018) Role of sample return missions from small bodies in Solar System science. *Winter school 'Volatile elements in the Solar System'* (Les Houches, France), 2018.3.11-16.
11. Tachibana S. (2018) Laboratory experiments on high- and low-temperature processes in the early Solar System. *Workshop: Experiment and Modeling in Investigation of Extraterrestrial Material, 81st Annual Meeting of the Meteoritical Society* (Moscow, Russia), 2018.7.23-27.
12. Tachibana S. (2018) Hayabusa2 at Ryugu. *Reading Terrestrial Planet Evolution in Isotopes and Element Measurements* (Bern, Switzerland), 2018.10.22-26.

Four invited talks at domestic meetings in Japanese.

III. Education Activity

9. Notable Achievements in Education

Advisees

- Master theses: 8 students (Hokkaido University)

  Minami Kuroda, Daiki Yamamoto (March 2016)

  Hikaru Iso (March 2017)

  Kodai Kobayashi, Yuki Isono, Ryo Matsumura (March 2018)

  Michiru Kamibayashi (March 2019)

- Doctral theses: 2 students (Hokkaido University)

  Minami Kuroda, Daiki Yamamoto (March 2019)

Lectures

- Graduate, Cosmic and Planetary Material Science I, 2018–
- Undergraduate, Practical: Microscopic Observation of Rock-forming Minerals, 2018–

- Undergraduate, Practical: Earth and Planetary Environmental Science, 2018–
- Undergraduate, Senior Project in Earth and Planetary Physics, 2018–
- Undergraduate, Experiments in Earth and Planetary Physics, 2018–
- Undergraduate, Academic Frontier Lecture Series, Frontier of Planetary Science, 2018—
- Undergraduate, Academic Frontier Lecture Series, Frontier of Earth and Planetary Science, 2018
- Graduate (Hokkaido University), Advanced Geochemistry, 2013, 2015, 2017
- Undergraduate (Hokkaido University), Teaching Method of School Subjects (Science II), 2015
- Undergraduate (Hokkaido University), Introduction to Modern Earth and Planetary Sciences, 2014, 2016
- Undergraduate (Hokkaido University), Laboratory Work in Earth and Planetary Sciences I, 2014-2018
- Undergraduate (Hokkaido University), Laboratory Work in Earth and Planetary Sciences III, 2013-2018
- Undergraduate (Hokkaido University), Exercises in Field Earth and Planetary Material Sciences, 2013-2018
- Undergraduate (Hokkaido University), Geochemistry, 2013-2018
- Undergraduate (Hokkaido University), Basic Earth and Planetary Science II, 2013-2018
- Intensive lectures on cosmochemistry at Kyoto University (2017), Yamagata University (2016), Kumamoto University (2015), Tsukuba University (2013), and Kobe University (2012)

Student's awards

- Hokkaido University Otsuka Prize [Minami Kuroda, 2019]
- Japan Geoscience Union, Student Presentation Award [Minami Kuroda, 2018]
- Hokkaido University Clark Award [Minami Kuroda, 2014]

IV. External Activities

10. Contribution to Academic Community

- Meteoritical Society, Nominating Committee, 2017–
- Meteoritical Society, 82nd Annual Meeting LOC, 2017–2019
- NASA, Laboratory Analysis of Returned Samples (LARS) Program Review Panel
- NASA, Research Opportunities in Space and Earth Sciences (ROSES) Review Panel
- NASA, Emerging World Review Panel
- Japan Geoscience Union, Representative, 2014–2017
- Japan Geoscience Union, Space and Planetary Sciences, Science Board, 2016–
- Japan Geoscience Union, Global Strategy Committee, 2014–
- Japan Geoscience Union, Publicity and Outreach Committee, Secretary, 2009–
- Japan Geoscience Union, Publicity and Outreach Committee, 2005–
- Japan Geoscience Union, JGL Editorial Committee, Secretary, 2015–
- Japan Geoscience Union, JGL Editorial Committee, 2005–

- The Geochemical Society of Japan, Councilor, 2016–2018
- The Geochemical Society of Japan, Secretary for general affairs, 2016–2018
- The Geochemical Society of Japan, Geochemical Journal Associate Editor, 2008-
- The Japanese Society for Planetary Sciences, Steering Committee, 2009–2016
- The Japanese Society for Planetary Sciences, External Cooperation Committee, 2009–
- The Japanese Society for Planetary Sciences, Future Planning Committee Chair, 2015–2016
- The Japanese Society for Planetary Sciences, Future Planning Committee, 2012–2016
- The Japanese Society for Planetary Sciences, Activity Committee, 2009–2016
- Japan Association of Mineralogical Sciences, Elements Editorial Committee, 2011–
- Science Organizing Committee, Hayabusa Symposium, 2017-
- Co-chair, Solar-System symposium in Sapporo, 2016-
- Co-organizer, Session on Experimental Cosmochemistry, Goldschmidt Conference 2017
- Co-chair, Theme on From Stars to Planets, Goldschmidt Conference 2016
- Co-organizer, Workshop on Experimental Cosmochemistry, Goldschmidt Conference 2016
- Co-convener, Session on Asteroids, Sample Return Missions and the Comet-Asteroid Continuum, Goldschmidt Conference 2015
- Co-convener, Session on Refractory Grains, Volatiles, and Organic Molecules Inherited from the Interstellar Medium, Goldschmidt Conference 2013
- Co-organizer, Workshop: Cosmochemical Perspective on the Early Evolution of the Solar System 2013
- Co-organizer, Workshop on Minerals-Water-Organics in the Early Solar System 2012

11. Outreach Activity

- JSPS Research Fellowship for Young Scientists Review, FY2014-2015
- KAKENHI Review, FY2017-2018
- 4 press releases (October 2017, November 2017, and April 2019)
- 24 public lectures in FY2012-2019

12. Internal Committee Membership

- UTokyo Organization for Planetary Space Science, Steering Committee, 2018-
- The University of Tokyo Atacama Observatory, Advisory Committee, 2018-

V. International Exchange Activities

13. Hosting/Sending Foreign Students and Researchers

(1) Hosting

Foreign Students: 2

Foreign Researchers: 4

(2) Sending

Students: 0

Researchers: 0

(3) Visitors from Abroad: 20

Masahiro Hoshino

I. CV

Name: Masahiro Hoshino

Age: 61

Present Position: Professor

Education

Kuwana High School, Mie, March, 1977 (graduation)

B. Sc. Department of Geophysics, The University of Tokyo, March, 1981

M. Sc. Department of Geophysics, The University of Tokyo, March, 1983

Ph. D. Department of Geophysics, The University of Tokyo, July, 1986

Professional Experience

July 1986-Sept. 1988, Resident Research Associate, NASA/GSFC, USA

Oct. 1988-May. 1991, Post-Doctoral Research Associate, Lawrence Livermore National Laboratory, USA

Apr. 1991-Sept. 1993, Special Researcher (Basic Science Program), Institute of Physical and Chemical Research (RIKEN)

Oct. 1993-Dec. 1998, Associate Professor, Institute of Space and Astronautical Science (ISAS)

Jan. 1999-present, Professor, Department of Earth and Planetary Science, The University of Tokyo

II. Scientific Research Activity

2. Major Achievements

My main interests are space and astroplasma physics, and I study various plasma processes such as magnetic reconnections in Earth's magnetosphere and in pulsar magnetospheres, interplanetary and supernova shocks with non-relativistic plasma flows, relativistic shocks seen in pulsar wind nebulae and AGN jets, and accretion disks around black holes. During the last seven years, I mainly studied four topics: (1) electron acceleration in a high-Mach number shock, (2) particle acceleration in a relativistic shock, (3) angular momentum transport in collisionless accretion disks, and (4) energy partition of ion and electron during magnetic reconnection.

The corresponding achievements are as follows: (1) synchrotron emission from supernova is widely explained by the diffusive shock acceleration (DSA) process, but many issues remain to be solved. One such unresolved issue is the pre-acceleration process, the so-called shock injection problem. We found that the electron shock injection problem may be overcome by the Buneman and Weibel instabilities [Ref. 6,12,18,30]. (2) most of relativistic shocks observed in astrophysical phenomena is categorized as a perpendicular shock where the DSA process is ineffective. We found a novel acceleration process in which the high-energy particles can be generated by the incoherent wakefield acceleration by an action of the precursor waves generated by synchrotron maser instability at the shock front [Ref 26,31]. (3) Magneto-rotational instability (MRI) is known to play the role on the angular momentum transport in the collisional MHD accretion disk, but our understanding of the collisionless MRI remained to be solved. We studied the collisionless MRI in PIC simulation and demonstrated that the angular momentum transport rate is enhanced compared with that of MHD regime [Ref. 10,17,25,27]. (4) In collisionless plasma, the energy equi-partition between ion and electron is not necessarily satisfied, and to determine the energy partition we need to understand micro-scale plasma process in detail. We investigated the energy partition during magnetic reconnection, and proposed a novel theoretical model to determine the temperature ratio of ion to electron [Ref. 34].

3. Five Important Papers (including three or more papers in this review period)

1. M. Hoshino, J. Arons, Y. Gallant, and A. B. Langdon, Relativistic Magnetosonic Shock Waves in Synchrotron Sources: Shock Structure and Nonthermal Acceleration of Positrons, Astrophys. J., 390, 2, 454-479 (1992).

This paper discussed the theoretical properties of relativistic, perpendicular collisionless shock waves in electron-positron-heavy ion plasmas of relevance to astrophysical sources of synchrotron radiation such as pulsar wind nebulae, by using ab initio, electromagnetic particle-in-cell (PIC) simulations. The synchrotron maser instability and its precursor waves are regarded as an important agent of relativistic shocks, and the mechanism of the preferential pair plasma acceleration was proposed. (Citation 375, GS)

2. M. Hoshino, T. Mukai, T. Terasawa, and I. Shinohara, Suprathermal electron acceleration in magnetic reconnection, J. Geophys. Res., 106, 25979-25998 (2001)

The suprathermal electrons whose energies exceed the thermal temperature of several keV have been often observed in the Earth's magnetotail, yet the mechanism of the electron acceleration was not understood. This paper discussed that those suprathermal electrons can be accelerated during magnetic reconnection by means of both Geotail observation and particle-in-cell (PIC) simulation. (Citation 269, GS)

3. Y. Matsumoto, T. Amano, T. Kato, and M. Hoshino, Stochastic electron acceleration during spontaneous turbulent reconnection in a strong shock wave, Science, 347, 6225, 974-978 DOI: 10.1126/science.1260168 (2015)

After the discovery of the electron surfing acceleration in a high-Mach number shock by using one-dimensional PIC simulation by Hoshion and Shimada (2002), it was highly desired to confirm the surfing acceleration in multi-dimensional system. This paper demonstrated not only the surfing acceleration but also magnetic reconnection generated by the ion Weibel instability plays an important role on electron acceleration by using two-dimensional PIC simulation.

4. M. Hoshino, Angular momentum transport and particle acceleration during magnetorotational instability in a kinetic accretion disk, Physical Review Letters, DOI:10.1103/PhysRevLett.114.061101 (2015)

Angular momentum transport and particle acceleration during the magneto-rotational instability (MRI) in a collisionless accretion disk were investigated by using three-dimensional PIC simulation. It was argued that the kinetic MRI can provide not only high-energy particle acceleration but also enhancement of angular momentum transport compared with collisional MHD MRI. This simulation study may explain the origin of high-energy particles observed around black holes.

5. M. Hoshino, Energy Partition between Ion and Electron of Collisionless Magnetic Reconnection, Astrophys. J. Letters, doi:10.3847/2041-8213/aaef3a (2018)

Energy partition between ion and electron in collisionless plasma is one of the most fundamental quests in plasma physics. This paper attacked the energy partition problem during magnetic reconnection. This paper proposed the ion and electron temperature ratio after reconnection can be approximated by a power of 1/4 of the ion to electron mass ratio. This theoretical prediction is consistent with the observation in the Earth's magnetotail.

4. Awards and Honors

- Hoshino, M., Group Achievement Award, NASA/Magnetospheric Multi-Scale Project, July 2016
- Hoshino, M., American Geophysical Union Fellow, Dec. 2016

5. Future Research Plan

My research area is not limited to space science in our Heliosphere, but includes the astroplasma physics in our universe. Owing to the universal validity of plasma physics, we can share many fundamental plasma problems in space and astroplasma physics to better and more clearly understand the plasma universe. I will keep continue this research and educational style, and will extend our knowledge of in-situ observations in the near-hand space plasma environment to our better understanding of astroplasma physics in general. Specifically, I will focus on the micro-scale/kinetic transport processes beyond MHD description, and will study particle acceleration, plasma heating, and nonlinear wave and turbulence in various plasma phenomena.

6. Funding Received

- MEXT KAKENHI, Grant-in-Aid for Scientific Research (B), Principal Investigator, FY2010-2012, 15,600,000 yen
- MEXT KAKENHI, Grant-in-Aid for Scientific Research (B), Principal Investigator, FY2013-2016, 19,240,000 yen
- MEXT KAKENHI, Bilateral Program, Principal Investigator, FY2017-2018, 4,850,000 yen
- MEXT KAKENHI, Grant-in-Aid for Challenging Research (Pioneering), Co-Investigator, FY2017-2021, 21,840,000 yen
- MEXT KAKENHI, Grant-in-Aid for Scientific Research (B), Co-Investigator, FY2017-2020, 18,980,000 yen
- MEXT KAKENHI, Grant-in-Aid for Challenging Research (Exploratory), Principal Investigator, FY2018-2019, 6,370,000 yen

7. Publications and Patents

(1) Peer-reviewed Journal Articles

1. M. Hoshino, Stochastic particle acceleration in multiple magnetic islands during reconnection, Phys. Rev. Lett., 108(13) DOI:10.1103/PhysRevLett.108.135003 (2012)
2. M. Hoshino and Y. Lyubarsky, Relativistic reconnection and particle acceleration, Space Sci. Rev., DOI: 10.1007/s11214-012-9931-z (2012)
3. K. Higashimori and M. Hoshino, The relation between ion temperature anisotropy and formation of slow shocks in collisionless magnetic reconnection, J. Geophys. Res., 117 (A1) DOI:10.1029/2011JA016817 (2012)
4. Y. Kuramitsu, Y. Sakawa, M. Hoshino, S.-H. Chen, and H. Takabe, On the universality of nonthermal electron acceleration due to quasi-turbulent wakefields, High Energy Density Physics, 8, 2068, DOI:10.1016/j.hedp.2012.03.016 (2012)
5. J. Birn, A.V. Artemyev, D.N. Baker, M. Echim, M. Hoshino and L. M. Zelenyi, Particle acceleration in the magnetotail and aurora, Space Sci. Rev., DOI:10.1007/s11214-012-9874-

4, (2012)

6. Y. Matsumoto, T. Amano and M. Hoshino, Electron acceleration at high Mach number shocks: two-dimensional Particle-in-Cell simulations in various parameter regions. Astrophys. J., 755 (2) 109, DOI:10.1088/0004-637X/755/2/109 (2012)
7. Y. Kuramitsu, Y. Sakawa, T. Morita, T. Ide, K. Nishio, H. Tanji, H. Aoki, S. Dono, C. D. Gregory, J. N. Waugh, N. Woolsey, A. Dizière, A. Pelka, A. Ravasio, B. Loupias, M. Koenig, S. A. Pikuz, Y. T. Li, Y. Zhang, X. Liu, J. Y. Zhong, J. Zhang, G. Gregori, N. Nakanii, K. Kondo, Y. Mori, E. Miura, R. Kodama, Y. Kitagawa, K. Mima, K. A. Tanaka, H. Azechi, T. Moritaka, Y. Matsumoto, T. Sano, A. Mizuta, N. Ohnishi, M. Hoshino and H. Takabe, Laboratory investigations on the origin of cosmic rays, Plasma Phys. and Control. Fusion, 54, 124049, doi:10.1088/0741-3335/54/12/124049 (2012)
8. A. V. Artemyev, M. Hoshino, V. N. Lutsenko, A. A. Petrukovich, S. Imada, and L. M. Zelenyi, Double power-law spectra of energetic electrons in the Earth magnetotail, Ann. Geophys., 31, 910106, doi:10.5194/angeo-31-91-2013 (2013)
9. K. Higashimori, N. Yokoi, and M. Hoshino, Explosive Turbulent Magnetic Reconnection, Physical Review Letters, DOI:10.1103/PhysRevLett.110.255001 (2013)
10. M. Hoshino, Particle acceleration during magnetorotational instability in a collisionless accretion disk, Astrophy. J., DOI: 10.1088/0004-637X/773/2/118 (2013)
11. T. Saito, M. Hoshino, and T. Amano, Stability of cosmic ray modified shocks: Two-fluid approach, Astrophy. J., DOI:10.1088/0004-637X/775/2/130 (2013)
12. Y. Matsumoto, T. Amano and M. Hoshino, Electron acceleration in a nonrelativistic very high Alfven Mach number shock, Physical Review Letters, DOI:10.1103/PhysRevLett.111.215003 (2013)
13. K. Hirabayashi and M. Hoshino, Magnetic reconnection under anisotropic MHD approximation, Physics of Plasmas, 20 (11), DOI:10.1063/1.4831754 (2013)
14. N. Yokoi, K. Higashimori, and M. Hoshino, Transport enhancement and suppression in turbulent magnetic reconnection: A self-consistent turbulent model, Physics of Plasmas, 20 (12), DOI:10.1063/1.4851976 (2013)
15. K. Shirakawa and M. Hoshino, Asymmetric evolution of magnetic reconnection in collisionless accretion disk, Physics of Plasmas, 21 (6), DOI:10.1063/1.4875739 (2014)
16. H. Itou, T. Amano and M. Hoshino, First-principles simulations of electrostatic interactions between dust grains, Physics of Plasmas, 21 (12), DOI:10.1063/1.4904373 (2014)
17. M. Hoshino, Angular momentum transport and particle acceleration during magnetorotational instability in a kinetic accretion disk, Physical Review Letters, DOI:10.1103/PhysRevLett.114.061101 (2015)
18. Y. Matsumoto, T. Amano, T. Kato, and M. Hoshino, Stochastic electron acceleration during spontaneous turbulent reconnection in a strong shock wave, Science, 347, 6225, 974-978 DOI: 10.1126/science.1260168 (2015)
19. K. Higashimori and M. Hoshino, Ion beta dependence on the development of Alfvenic fluctuations in reconnection jets, J. Geophys. Res., DOI:10.1002/2014JA020544 (2015)

20. M. Hoshino and K. Higashimori, Generation of Alfvenic waves and turbulence in reconnection jets, J. Geophys. Res., DOI:10.1002/2014JA020520 (2015)

21. S. Imada, M. Hirai, and M. Hoshino, Energetic ion acceleration during magnetic reconnection in the Earth's magnetotail, Earth, Planets and Space, 10.1186/s40623-015-0372-2 (2015)

22. K. Hirabayashi and M. Hoshino, Instability of non-uniform toroidal magnetic fields in accretion disk, Astrophy. J., DOI: 10.3847/0004-637X/822/2/87 (2016)

23. M. Hesse, N. Aunai, J. Birn, P. Cassak, R. E. Denton, J. F. Drake, T. Gombosi, M. Hoshino, W. Matthaeus, D. Sibeck, and S. Zenitani, Theory and modeling for Magnetospheric Multiscale Mission, Space Science Reviews, 199, 1-4, 577-630 (2016)

24. A. Vaivads, A. Retinò, J. Soucek, Yu. V. Khotyaintsev, F. Valentini, C. P. Escoubet, O. Alexandrova, M. André, S. D. Bale, M. Balikhin, D. Burgess, E. Camporeale, D. Caprioli, C. H. K. Chen, E. Clacey, C. M. Cully, J. De Keyser, J. P. Eastwood, A. N. Fazakerley, S. Eriksson, M. L. Goldstein, D. B. Graham, S. Haaland, M. Hoshino, H. Ji, H. Karimabadi, H. Kucharek, B. Lavraud, F. Marcucci, W. H. Matthaeus, T. E. Moore, R. Nakamura, Y. Narita, Z. Nemecek, C. Norgren, H. Opgenoorth, M. Palmroth, D. Perrone, J.-L. Pinçon, P. Rathsman, H. Rothkaehl, F. Sahraoui, S. Servidio, L. Sorriso-Valvo, R. Vainio, Z. Vörös, R. F. Wimmer-Schweingruber, Turbulence Heating ObserveR – satellite mission proposal, J. Plasma Phys., 82 (5) doi: 10.1017/S0022377816000775 (2016)

25. K. Hirabayashi, M. Hoshino, and T. Amano, A new framework for magnetohydrodynamic simulations with anisotropic pressure, J. Computational. Phys., 327, 851-872, http://doi.org/10.1016/j.jcp.2016.09.064 (2016)

26. M. Iwamoto, T. Amano, M. Hoshino and Y. Matsumoto, Persistence of precursor waves in two-dimensional relativistic shocks, Astrophys. J., https://doi.org/10.3847/1538-4357/aa6d6f (2017)

27. K. Hirabayashi and M. Hoshino, Stratified simulations of collisionless accretion disks, Astrophys. J., https://doi.org/10.3847/1538-4357/aa74b3 (2017)

28. Oka, M.; Wilson, L. B., III; Phan, T. D.; Hull, A. J.; Amano, T.; Hoshino, M.; Argall, M. R.; Le Contel, O.; Agapitov, O.; Gershman, D. J.; Khotyaintsev, Y. V.; Burch, J. L.; Torbert, R. B.; Pollock, C.; Dorelli, J. C.; Giles, B. L.; Moore, T. E.; Saito, Y.; Avanov, L. A.; Paterson, W.; Ergun, R. E.; Strangeway, R. J.; Russell, C. T.; Lindqvist, P. A., Electrons scattering by high-frequency whistler waves at Earth's bow shock, Astrophys. J., https://doi.org/10.3847/ 2041-8213/aa7759 (2017)

29. R. Blandford, Y. Yuan, M. Hoshino and L. Sironi, Magnetoluminescence, Space Sci. Reviews, 10.1007/s11214-017-0376-2 (2017)

30. Y. Matsumoto, T. Amano, T. N. Kato, and M. Hoshino, Electron surfing and drift accelerations in a Weibel-dominated high Mach-number shock, Physical Review Letters, DOI:10.1103/PhysRevLett.119.105101 (2017)

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32. N. K. Walia, K. Seki, M. Hoshino, T. Amano, N. Kitamura, Y. Saito, S. Yokota, C. J. Pollock, B. L. Giles, T. E. Moore, R. B. Torbert, C. T. Russell, J. L. Burch, A statistical study of slow-mode shocks observed by MMS in the dayside magnetopause. Geophysical Research Letters, 45, 4675–4684. https://doi.org/10.1029/2018GL077580 (2018)
33. Y. Kuramitsu, T. Moritaka, Y. Sakawa, T. Morita, T. Sano, M. Koenig, C. Gregory, N. Woolsey, K. Tomita, H. Takabe, Y.-L. Liu, S.-H. Chen, S. Matsukiyo, and M. Hoshino, Magnetic reconnection driven by electron dynamics, Nature Comm, doi:10.1038/s41467-018-07415-3 (2018)
34. M. Hoshino, Energy Partition between Ion and Electron of Collisionless Magnetic Reconnection, Astrophys. J. Letters, doi:10.3847/2041-8213/aaef3a (2018)
35. M Hesse, C Norgren, P Tenfjord, J Burch, Y-H Liu, L-J Chen, N Bessho, S Wang, R Nakamura, J Eastwood, M Hoshino, R Torbert, R Ergun, On the Role of Separatrix Instabilities in Heating the Reconnection Outflow Region, Phys. Plasmas, doi:10.1063/1.5054100 (2018)
36. K. Keika, S. Kasahara, S. Yokota, M. Hoshino, K. Seki, M. Nosé, T. Amano, Y. Miyoshi, I. Shinohara, Ion Energies Dominating Energy Density in the Inner Magnetosphere: Spatial Distributions and Composition, Observed by Arase/MEP-I, Geophys. Res. Letters, doi:10.1029/2018GL080047 (2018)

(2) Non-peer-reviewed Articles

(3) Review Papers

1. T. Amano and M. Hoshino, Recent progress in the theory of electron injection in collisionless shocks, Astrophy. Space Sci. Proc. 33, 143-152, DOI: 10.1007/978-3-642-30442-2_16 (2012)
2. M. Hoshino, Frontier in astrophysical plasma by using laser experiments, Progress in Photon Science, Springer Pub, 25-33 (2017)
3. Gurbax S Lakhina, Bruce T Tsurutani, George J Morales, Annick Pouquet, Masahiro Hoshino, Juan Alejandro Valdivia, Yasuhito Narita, Roger Grimshaw, Preface: Nonlinear waves and chaos, Nonlinear Processes in Geophysics 25 (2), 477-479 (2018)

(4) Books

(5) Other Publications

(6) Patents

8. Keynote, Invited, or Solicited Presentations

1. M. Hoshino, Magnetic reconnection and particle acceleration during magneto-rotational instability in an accretion disk, US-Japan magnetic reconnection workshop, Princeton University (May 23, 2012)
2. M. Hoshino, Magnetic reconnection and particle acceleration during magneto-rotational instability (MRI) in an accretion disk, COSPAR, Mysore, India (July 14, 2012)
3. M. Hoshino, L.N., Hau, K. Higashimori, Plasma dynamics and magnetic reconnection with anisotropic plasmas in magnetotail, COSPAR, Mysore, India (July 14, 2012)

4. M. Hoshino, Particle acceleration during magneto-rotational instability (MRI) in kinetic accretion disk, Asia-Pacific Center for Theoretical Physics (APCTP) workshop on Astrophysics: Magnetic Fields in Astrophysics, Pohang, Korea (November 19, 2012) (Keynote/Plenary)
5. M. Hoshino, Particle acceleration in plasma universe, 8th International Conference on Computational Physics (ICCP8) Hong Kong (January 7, 2013) (Plenary)
6. M. Hoshino, Particle acceleration during magnetorotational instability (MRI) in collisionless accretion disk, Nonlinear Wave and Chaos 9, La Jolla, USA (March 4, 2013)
7. M. Hoshino, Magnetic reconnection, turbulence, and particle acceleration in magnetotail, AGU Chapman Conference, Reykjavik, Iceland (March 10, 2013)
8. M. Hoshino, N. Yokoi, and K. Higashimori, Explosive turbulent magnetic reconnection: A new approach of MHD-turbulent simulation, EGU General Assembly, Vienna, Austria (April 7, 2013)
9. M. Hoshino, Particle Acceleration and Angular Momentum Transport during Magnetorotational Instability in Collisionless Accretion Disk, IPELS, Hakuba, Japan (July 1, 2013)
10. M. Hoshino, Particle Acceleration in Plasma Universe, East-Asian School and Workshop (EASW), Tokyo, Japan (July, 8, 2013)
11. M. Hoshino, Particle Acceleration and Magnetic Reconnection during Magnetorotational Instability in Collisionless Accretion Disk, Asia Pacific Physics Conference (APPC), Makuhari, Japan (July 14, 2013)
12. M. Hoshino, Angular Momentum Transport and Particle Acceleration in Accretion Disk, International School/Symposium for Space Simulation (ISSS), Taipei, Taiwan (July 21, 2013)
13. M. Hoshino, High Energy Particle Acceleration in Accretion Disc, Astronomy and Astrophysics from ALMA, Observatorio Cerro Calan, Universidad de Chili, Santiago, Chili (November 7, 2013)
14. M. Hoshino, Turbulent Magnetic Reconnection and Particle Acceleration, Japan-US Workshop on Laboratory Astrophysics, ILE Osaka University (February 24, 2014)
15. M. Hoshino, Generation of Alfvenic Waves and Turbulence in Reconnection Jets, MR2014, University of Tokyo, Tokyo (May 20, 2014)
16. M. Hoshino, Frontier in Astrophysical Plasma Theory and Laser Experiment, International Symposium on Status and Prospects of High Energy Density Science by Giant Laser, Gakushi Kaikan, Tokyo (June 3, 2014)
17. M. Hoshino, Turbulent Magnetic Reconnection and Particle Acceleration, 40th COSPAR Scientific Assembly, Moscow University, Moscow (August 1, 2014)
18. M. Hoshino, Stochastic Fermi Acceleration by Magnetic Reconnection in Various Plasma Environments, 40th COSPAR Scientific Assembly, Moscow University, Moscow (August 1, 2014)
19. M. Hoshino, Electron Acceleration and Reconnection at a High Mach Number Shock, 8th Korean Astrophysics Workshop on High-Beta Plasma in the Universe, Jeju Island, Korea (November 10, 2014)
20. M. Hoshino, Particle Acceleration and Angular Momentum Transport by Magneto-Rotational Instability in Kinetic Accretion Disks, 8th Korean Astrophysics Workshop on High-Beta Plasma in the Universe, Jeju Island, Korea (November 10, 2014)
21. M. Hoshino, Generation of Alfvenic Waves and Turbulence in Magnetic Reconnection Jets AGU Fall Meeting, San Francisco, USA (December 18, 2014)
22. M. Hoshino, Magnetic reconnection in turbulence, MMS Science Working Team Meeting, Cocoa Beach, Florida, USA (March 10, 2015)
23. M. Hoshino, Frontier in astrophysical plasma by using laser experiments, 1st STEPS Symposium on Photon Science, University of Tokyo, Tokyo, (March 21, 2015)

24. M. Hoshino, Multiscale phenomena of electron acceleration in high Mach number shocks, Princeton Center for Theoretical Science Workshop on Accelerating Cosmic Ray Comprehension, Princeton University, Princeton, USA (April 13, 2015)
25. M. Hoshino, Collisionless accretion disks: Role of reconnection in anisotropic plasmas, Workshop on Relativistic Jets: Creation, Dynamics and Internal Physics, Krakow, Poland (April 20, 2015)
26. M. Hoshino, Particle-in-cell simulation for Magnetorotational instability, International Space Simulation School/ISSS12, Prague, Czech Republic (July 3, 2015)
27. M. Hoshino, Kinetic aspects of Magnetorotational instability, Nordic Institute for Theoretical Physics/NORDITA workshop, Stockholm, Sweden (August 7, 2015)
28. M. Hoshino, Particle acceleration in turbulent magnetic reconnection, Nordic Institute for Theoretical Physics/NORDITA workshop, Stockholm, Sweden (August 10, 2015) (Plenary)
29. M. Hoshino, Particle acceleration in the plasma universe, 5th East-Asia School and Workshop on Laboratory, Space, Astrophysical Plasmas, Asia Pacific Center for Theoretical Physics, Pohan, Korea (August 17, 2015) (Plenary)
30. M. Hoshino, Magnetic reconnection in accretion disks with anisotropic plasma pressure, IPELS2015, Institute of Physics, Pitlochry, United Kingdom (August 23, 2015)
31. M. Hoshino, Particle acceleration in astrophysical plasma by using laser experiment, International Symposium on Status and Prospects of High Energy Density Science by Giant Lasers, Science Council of Japan, Lawrence Livermore Nat'l Lab, USA (September 28,2015)
32. M. Hoshino, Particle acceleration and energy dissipation of driven reconnection in plasma universe, US-Japan workshop on magnetic reconnection, Napa, California, USA (March 7, 2016) (tutorial talk)
33. M. Hoshino, Unresolved questions in magnetotail physics, International GEMSIS workshop: Future Perspectives of Researches in Space Physics, Nagoya University, Japan (March 22, 2016)
34. M. Hoshino, Particle acceleration in the plasma Universe, Spring meeting at Korean Physical Society, Daejeon Convention Center, Daejeon, Korea (April 20, 2016)
35. M. Hoshino, Magnetic energy dissipation of plasma sheet under coupling of magnetic reconnection and lower hybrid drift instability, Japan Geoscience Union Meeting 2016, Mkuhari Messe, Chiba (May 22-26, 2016)
36. M. Hoshino, Rapid Energy Dissipation during Magnetic Reconnection with Poynting Flux Injection, 18th International Congress of Plasma Physics (ICPP2016), Kaohsiung, Taiwan (June 27-July 1, 2016)
37. M. Hoshino, Turbulent dissipation and particle acceleration in high Mach number shocks, THOR workshop, Barcelona, Spain (September 27, 2016)
38. M. Hoshino, Particle Acceleration in Laboratory Plasma Astrophysics, International School and Workshop, Matter in Extreme Conditions from Material Science to Planetary Physics, Montgenevre, France (January 29, 2017)
39. M. Hoshino, M. Iwamoto, T. Amano and Y. Matsumoto, Large Amplitude Precursor Waves in Relativistic Magnetosonic Shock: Origin of Ultra-High-Energy Cosmic Ray, 10th International Workshop on Nonlinear Waves and Chaos, San Diego, USA (March 20, 2017)
40. M. Hoshino, Particle acceleration in non-relativistic and relativistic shocks, Seminar Talk, Institute of Nuclear Physics, Krakow, Poland (April 26, 2017)
41. M. Hoshino, Particle acceleration and reconnection in collisionless accretion disks, Seminar Talk, Obserwatorium Astronomiczne Uniwersytetu Jagiellońskiego, Krakow, Poland (April 28, 2017)
42. M.Hoshino, Ion and Electron Acceleration during Magnetic Reconnection, Space Science Institute Workshop, Advancing Plasma Physics from the Sun to the Earth, Breckenridge, Colorado, USA (May 21,2017)

43. M. Hoshino, Particle acceleration in plasma universe: magnetic reconnection, shock waves, and accretion disk, 44th Conference on Plasma Physics, European Physical Society, Belfast, Northen Ireland, England (June 26, 2017)
44. M. Hoshino, Wakefield acceleration in relativistic shocks: origin of ultra-high-energy cosmic rays, International Symposium: Tropical Problems of Nonlinear Wave Physics, Moscow-St. Petersburg, Russia (July 22, 2017) (plenary)
45. M. Hoshino, Ion and electron acceleration during driven magnetic reconnection, AOGS meeting, Singapore, (Aug 6, 2017)
46. M. Hoshino, Electron acceleration in high Mach number shocks, MACH 5 meeting, Institut de Planétologie et d'Astrophysique de Grenoble, Université Grenoble Alpes, Grenoble, France (Nov. 27, 2017)
47. Hoshino, M.; Matsumoto, Y.; Amano, T., Particle Acceleration by Magnetic Islands in a Strong Turbulent Shock, American Geophysical Union, Fall Meeting, New Orleans USA (December 11, 2017)
48. M. Hoshino、Nonlinear waves and particle acceleration in relativistic shocks, Workshop on Relativistic Plasma Astrophysics, Purdue University, USA (May 7, 2018)
49. M. Hoshino, Plasma heating and particle acceleration during magnetic reconnection (Lecture), 8the Ease-Asia School and Workshop on Laboratory, Space, and Astrophysical Plasmas, Chungnam National University, Daejeon, Korea (July 30, 2018)
50. M. Hoshino, Thermodynamics of magnetic reconnection, Max-Plank-Institute Symposium, Goettingen, Germany (June 18, 2018)
51. M. Hoshino, Energy partition between ion and electron during magnetic reconnection, International conference of turbulence, current sheets and reconnection in space and astrophysical plasmas, IKI, Moscow, Russia (October 1, 2018)
52. M. Hoshino, Particle acceleration in plasma universe, 2nd Asia-Pacific Conference on Plasma Physics, AAPPS-DPP, Kanazawa, JAPAN (November 12, 2018) (Plenary)
53. M. Hoshino, Ion and electron heating during magnetic reconnection, Max-Planck Princeton Center Workshop, Tokyo, JAPAN (February 28, 2019)

III. Education Activity

9. Notable Achievements in Education

Advisees

- Master theses: 7 students

  Kazuma Matsumoto (Mar. 2013)

  Tatsuhiko Nikai, Kouta Hirabayashi (Mar. 2014)

  H. Itoh, Ai Abe (Mar. 2015)

  Iwamoto (Mar. 2017)

  Ryota Asami (Mar. 2019)

- Doctral theses: 4 students

  Tasuhiko Saito, Keisuke Shirakawa, Katsuaki Higashimori (Mar. 2015)

  Kouta Hirabayashi (Mar. 2017)

Lectures

- Graduate, Space Plasma Physics II, FY2012, 2018

- Graduate, Space Plasma Physics I, FY2016
- Graduate, , Lecture on Advanced Photon Science V, FY2012-2018
- Undergraduate, Space Science I, FY2012-2013, 2015, 2017-2018
- Undergraduate, Space Science II, FY2012-2014
- Undergraduate, Material & Life General , FY2012

Student's awards

- SGEPSS Student Presentation Award (Aurora Medal) Katsuaki Higashimori, FY2012
- SGEPSS Student Presentation Award (Aurora Medal) Masanori Iwamoto, FY2018

IV. External Activities

10. Contribution to Academic Community

- European Physical Society, EPL (Europhysics Letters), Editor, FY2012-2017
- Division of Scientific Committee on Solar-Terrestrial Physics (SCOSTEP), Science Council of JAPAN, FY2012～2018
- East-Asia School and Workshop on Laboratory, Space, Astrophysical Plasmas, Science and Local Organizing Committees Chair, July 11-16, 2016
- International Space Science Institute, Switzerland, Science Committee FY2012～2014
- Space Research Institute, Austrian Academy of Sciences, Science Advisory Board Member FY2018
- Institute for Space-Earth Environmental Research, Nagoya University, Science Advisory Committee Member FY2012-2018
- Institute of Laser Engineering, Osaka University, Science Committee Member、FY2012-2018

11. Outreach Activity

- Research Organization for Information Science and Technology (RIST), Program Review Member, FY2012-2018
- KAKENHI Review, FY2014-2015
- INCITE Plasma Physics Panel (U.S. DoE), Panel Reviewer FY2017-2018
- Press Release: Nov. 2013, Feb. 2015, Feb 2015, Sept. 2017
- Public Lecture at Mie High School, Mar. 2018
- The University of Tokyo Co-op, Advisor FY2016-2018

12. Internal Committee Membership

- The University of Tokyo, Education and Research Council Member, FY2015-2016
- Faculty of Science, Vice-Dean, FY2012-2018
- Faculty of Science, UTokyo Organization for Planetary and Space Science (UTOPS), Director, FY2018
- Faculty of Science, Office of Research Strategy and Development (ORSD), General Manager,

FY2017-2018

- Faculty of Science, Student Support Office, Head of Office, FY2012-2016
- Faculty of Science, Information Technology Team, Head of Team, FY2014-2017
- Faculty of Science, International Liaison Office (ILO), Head of Office, FY2012-2013

V. International Exchange Activities

13. Hosting/Sending Foreign Students and Researchers

(1) Hosting

Foreign Students: 8

Foreign Researchers: 3

(2) Sending

Students: 8

Researchers: 4

(3) Visitors from Abroad: 31

Takanobu Amano

I. CV

Name: Takanobu Amano

Age: 38

Present Position: Associate Professor

Education

Tochigi High School, Tochigi, March, 1999 (graduation)

B. Sc. Department of Earth and Planetary Physics, The University of Tokyo, March, 2003

M. Sc. Department of Earth and Planetary Science, The University of Tokyo, March, 2005

Ph. D. Department of Earth and Planetary Science The University of Tokyo, March, 2008

Professional Experience

Apr. 2008-Mar. 2009, Postdoctoral Researcher, Solar-Terrestrial Environment Laboratory, Nagoya University

Apr. 2009-Mar. 2012, Designated Assistant Professor, Division of Particle and Astrophysical Science, Nagoya University

Mar. 2012-Jul. 2016, Assistant Professor, Department of Earth and Planetary Science, The University of Tokyo

Aug. 2016-, Associate Professor, Department of Earth and Planetary Science, The University of Tokyo

II. Scientific Research Activity

2. Major Achievements

I have been working on the dynamics of shock waves in collisionless space plasmas and associated high-energy particle acceleration mainly with theoretical and numerical approaches. Recent first-principles fully 3D numerical simulations found that a two-step particle acceleration mechanism through the successive occurrence of shock-surfing and shock-drift acceleration processes, which was proposed in our earlier studies based on 1D modeling, is indeed effective. Another recent surprising discovery is that efficient magnetic field amplification in the shock via Weibel instability leads to the spontaneous formation of current sheets, which ultimately dissipate via magnetic reconnection. In addition, motivated by these simulation results, we have constructed a theoretical model for a novel and efficient particle acceleration scheme, which was found to be consistent with recent in-situ spacecraft observations. This will provide a resolution to the electron injection problem, one of the most difficult problems in the shock acceleration theory of cosmic rays.

My research has also been extended to extreme relativistic plasmas often found around compact objects such as neutron stars and black holes. In particular, I found that magnetohydrodynamic waves may be mode-converted to electromagnetic waves when they interact with a strong shock standing in highly-magnetized relativistic outflows. The generated electromagnetic waves are subject to strong damping, which leads to electromagnetic-to-plasma energy conversion with substantially high efficiency. Intense electromagnetic waves may also be emitted from a relativistic shock via synchrotron maser instability even if the upstream plasma is homogeneous. The emission efficiency was quantified by using high-resolution multi-dimensional simulations, which was much higher than previously thought. The intense coherent radiation may provide a possible way to accelerate ultra-high-energy cosmic rays in gamma-ray bursts. It can also be considered as a possible scenario for explaining fast radio bursts.

In addition, I have been working on the development of new numerical techniques for better and efficient computational plasma modeling. I have proposed several algorithms for resolving numerical issues, in particular, to fill the gap between macroscopic magnetohydrodynamics and microscopic fully kinetic modeling.

3. Five Important Papers (including three or more papers in this review period)

1. Amano, T., and M. Hoshino (2007), Electron injection at high Mach number quasiperpendicular shocks: surfing and drift acceleration, Astrophys. J., 661(1), 190–202, https://doi.org/10.1086/53599.

With 1D particle-in-cell simulations, we found two different particle acceleration mechanism (known as shock-surfing and shock-drift) operate successively for the same particle. This was confirmed recently with much more computationally demanding fully 3D simulations. (Times Cited 63.)

2. Amano, T., and M. Hoshino (2009), Electron shock surfing acceleration in multidimensions: two-dimensional particle-in-cell simulation of collisionless perpendicular shock, Astrophys. J., 690(1), 244–251, https://doi.org/10.1088/0004-637X/690/1/244.

Shock-surfing acceleration mechanism, previously discussed under 1D assumption, was shown to be effective even in 2D. This was also confirmed by recent 3D simulations. (Times Cited 58.)

3. Amano, T., and J. G. Kirk (2013), The role of superluminal electromagnetic waves in pulsar wind termination shocks, Astrophys. J., 770(1), 18, https://doi.org/10.1088/0004-637X/770/1/18.

A strong shock standing in a relativistic outflow with a strong alternating magnetic field structure can be found around compact objects such as neutron stars. We demonstrated that the alternating magnetic field structure, when interacts with the shock, can be converted to electromagnetic waves and substantial electromagnetic-to-plasma energy conversion can take place. (Times Cited 33.)

4. Matsumoto, Y., T. Amano, T. N. Kato, and M. Hoshino (2015), Stochastic electron acceleration during spontaneous turbulent reconnection in a strong shock wave., Science, 347(6225), 974–978, https://doi.org/10.1126/science.1260168.

We found that the magnetic field in the shock internal structure amplified by Weibel instability forms current sheets and then dissipates spontaneously via magnetic reconnection. This results in substantial heating and acceleration of particles. (Times Cited 60.)

5. Katou, T., and T. Amano (2019), Theory of stochastic shock drift acceleration for electrons in the shock transition region., Astrophys. J. 874(2), 119. https://doi.org/10.3847/1538-4357/ab0d8a.

We developed a theory that takes into account scattering of particles while they are being accelerated by classical shock-drift acceleration mechanism. The theory is now being tested and confirmed by in-situ spacecraft measurements of plasmas in space. This model may apply also to astrophysical shocks, and possibly provides a universal picture for shock acceleration theory for cosmic rays. This paper is based on master thesis of the first author. (Times Cited 1.)

4. Awards and Honors

- Amano, T., Obayashi Early Career Scientist Award from Society of Geomagnetism and Earth, Planetary and Space Sciences, Nov. 2015
- Amano, T., Young Researcher Award (under 40 yrs. old) from Association of Asia Pacific Physical Societies, Division of Plasma Physics (AAPPS-DPP), Nov. 2018

5. Future Research Plan

Particle acceleration at shock waves is a topic that has been advanced substantially in recent years because of the increasing capability of large-scale numerical simulations as well as high time resolution in-situ spacecraft observations. Therefore, I will continue research on this topic by combining simulation, theory, and observations. Theoretical predictions will be tested by comparing with in-situ measurements, and detailed physical processes will be investigated by analyzing first-principles numerical simulations. This will provide a model that can predict the efficiency of both ion and electron acceleration as a function of macroscopic shock parameters, which can apply to remote sensing astrophysical observations.

There still remain elementary processes that are not very well understood in relativistic plasma dynamics around compact and highly-magnetized objects. In particular, the possibility and generality of mode conversion from magnetohydrodynamic waves to electromagnetic waves have not been understood. This potentially leads to efficient non-thermal particle production. I will investigate this issue theoretically mainly using numerical simulations for application to relativistic jets from compact objects, but also consider the possibility for laboratory experiments using high-power laser facilities.

6. Funding Received

- MEXT KAKENHI, 22740118, Principal Investigator, FY2010-2012, 3,100,000 yen
- MEXT KAKENHI, 24340118, Co-Investigator, FY2012-2015, 1,500,000 yen
- MEXT KAKENHI, 25800101, Principal Investigator, FY2013-2015, 3,300,000 yen
- MEXT KAKENHI, 16H01170, Principal Investigator, FY2016-2017, 2,600,000 yen
- MEXT KAKENHI, 17H02966, Principal Investigator, FY2017-2020, 9,200,000 yen
- MEXT KAKENHI, 17H06140, Co-Investigator, FY2017-2020, 37,1000,000 yen

7. Publications and Patents

(1) Peer-reviewed Journal Articles

1. Katou, T., Amano, T. (2019), Theory of stochastic shock drift acceleration for electrons in the shock transition region., Astrophys. J. 874(2), 119. https://doi.org/10.3847/1538-4357/ab0d8a.
2. Yamakawa, T., Seki, K., Amano, T., Takahashi, N., Miyoshi, Y. (2019), Excitation of storm-time Pc5 ULF waves by ring current ions based on the drift-kinetic simulation. Geophys. Res. Lett., 46(4), 1911-1918. https://doi.org/10.1029/2018GL081573.
3. Amano, T., Iwamoto, M., Matsumoto, Y., Hoshino, M. (2019). The efficiency of coherent radiation from relativistic shocks. Progress in Photon Science, 371-383. https://doi.org/10.1007/978-3-030-05974-3_19.
4. Keika, K., Kasahara, S., Yokota, S., Hoshino, M., Seki, K., Nose, M., Amano, T., Miyoshi, Y., Shinohara, I. (2018), Ion energies dominating energy density in the inner magnetosphere: spatial distributions and composition, observed by Arase/MEP-i. Geophys. Res. Lett., 45(22), 12153-12162. https://doi.org/10.1029/2018GL080047.
5. Kamiya, K., Seki, K., Saito, S., Amano, T., and Miyoshi, Y. (2018). Formation of butterfly pitch angle distributions of relativistic electrons in the outer radiation belt with a monochromatic Pc5 wave. J. Geophys. Res., 123(6) 4679-4691. https://doi.org/10.1002/2017JA024764.
6. Walia, N., K., Seki, K., Hoshino, M., Amano, T., Kitamura, N., Saito, Y., et al., (2018). A statistical study of slow-mode shocks observed by MMS in the dayside magnetopause. Geophys. Res. Lett., 45(10), 4675-4684. https://doi.org/10.1029/2018GL077580.

7. Iwamoto, M., Amano, T., Hoshino, M., and Matsumoto, Y. (2018). Precursor wave emission enhanced by Weibel instability in relativistic shocks. Astrophys. J., 858(2), 93. https://doi.org/10.3847/1538-4357/aaba7a.

8. Amano, T. (2018). A generalized quasi-neutral fluid-particle hybrid plasma model and its application to energetic-particle-magnetohydrodynamics hybrid simulation. J. Comput. Phys., 366, 366–385. https://doi.org/10.1016/j.jcp.2018.04.020.

9. Seki, K., Miyoshi, Y., Ebihara, Y., Katoh, Y., Amano, T., Saito, S., et al. (2018). Theory, modeling, and integrated studies in the Arase (ERG) project. Earth Planets Space, 70(1), 17. https://doi.org/10.1186/s40623-018-0785-9.

10. Matsumoto, Y., Amano, T., Kato, T. N., and Hoshino, M. (2017). Electron surfing and drift accelerations in a Weibel-dominated high-Mach-number shock. Phys. Rev. Lett., 119(10), 105101. https://doi.org/10.1103/PhysRevLett.119.105101.

11. Iwamoto, M., Amano, T., Hoshino, M., and Matsumoto, Y. (2017). Persistence of precursor waves in two-dimensional relativistic shocks. Astrophys. J., 840(1), 52. https://doi.org/10.3847/1538-4357/aa6d6f.

12. Oka, M., III, L. B. W., Phan, T. D., Hull, A. J., Amano, T., Hoshino, M., et al. (2017). Electron scattering by high-frequency whistler waves at Earth 's bow shock. Astrophys. J., 842(2), L11. https://doi.org/10.3847/2041-8213/aa7759.

13. Balsara, D. S., Amano, T., Garain, S., and Kim, J. (2016). A high-order relativistic twofluid electrodynamic scheme with consistent reconstruction of electromagnetic fields and a multidimensional Riemann solver for electromagnetism. J. Comput. Phys., 318, 169–200. https://doi.org/10.1016/j.jcp.2016.05.006.

14. Hirabayashi, K., Hoshino, M., and Amano, T. (2016). A new framework for magnetohydrodynamic simulations with anisotropic pressure. J. Comput. Phys., 327, 851–872. https://doi.org/10.1016/j.jcp.2016.09.064.

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17. Matsumoto, Y., T. Amano, T. N. Kato, and M. Hoshino (2015), Stochastic electron acceleration during spontaneous turbulent reconnection in a strong shock wave., Science, 347(6225), 974–978, https://doi.org/10.1126/science.1260168.

18. Minoshima, T., Y. Matsumoto, and T. Amano (2015), A finite volume formulation of the multi-moment advection scheme for Vlasov simulations of magnetized plasma, Comput. Phys. Commun., 187, 137–151, https://doi.org/10.1016/j.cpc.2014.10.023.

19. Amano, T., K. Higashimori, and K. Shirakawa (2014), A robust method for handling low density regions in hybrid simulations for collisionless plasmas, J. Comput. Phys., 275, 197–21, https://doi.org/10.1016/j.jcp.2014.06.048.

20. Itou, H., T. Amano, and M. Hoshino (2014), First-principles simulations of electrostatic interactions between dust grains, Phys. Plasmas, 21(12), 123707, https://doi.org/10.1063/1.4904373.

21. Amano, T., and J. G. Kirk (2013), The role of superluminal electromagnetic waves in pulsar wind termination shocks, Astrophys. J., 770(1), 18, https://doi.org/10.1088/0004-637X/770/1/18.

22. Matsumoto, Y., T. Amano, and M. Hoshino (2013), Electron acceleration in a nonrelativistic shock with very high Alfvén Mach number, Phys. Rev. Lett., 111(21), 215003,

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23. Minoshima, T., Y. Matsumoto, and T. Amano (2013), Multi-moment advection scheme in three dimension for Vlasov simulations of magnetized plasma, J. Comput. Phys., 236, 81–95, https://doi.org/1.1016/j.jcp.2012.11.024.
24. Saito, T., M. Hoshino, and T. Amano (2013), Stability of cosmic-ray modified shocks: two-fluid approach, Astrophys. J., 775(2), 130, https://doi.org/10.1088/0004-637X/775/2/130.
25. Amano, T., and M. Hoshino (2012), Recent progress in the theory of electron injection in collisionless shocks, Astrophysics and Space Science Proceedings, 33, 143-152, https://doi.org/10.1007/978-3-642-30442-2_16.
26. Minoshima, T., Matsumoto, Y., and Amano, T. (2012), Multi-moment advection scheme for Vlasov simulations, ASP Conference Series, 459, 277-280.
27. Hayakawa, T., K. Torii, R. Enokiya, T. Amano, and Y. Fukui (2012), Molecular and atomic gas toward HESS J1745-303 in the Galactic center: further support for the hadronic scenario, Publ. Astron. Soc. Japan, 64, 8. https://doi.org/10.1093/pasj/64.1.8.
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29. Umeda, T., S. Matsukiyo, T. Amano, and Y. Miyoshi (2012), A numerical electromagnetic linear dispersion relation for Maxwellian ring-beam velocity distributions, Phys. Plasmas, 19(7), 072107, https://doi.org/10.1063/1.4736848.

(2) Non-peer-reviewed Articles

(3) Review Papers

1. Amano, T. (2016). Inside a Plasma Shock. Physics, 9, 117. https://doi.org/10.1103/Physics.9.117.

(4) Books

(5) Other Publications

(6) Patents

8. Keynote, Invited, or Solicited Presentations

1. Three-dimensional Particle-In-Cell Simulations for High Mach Number Collisionless Shocks, The 2nd Asia-Pacific Conference on Plasma Physics, Kanazawa, Japan, Nov. 15, 2018.
2. Nonthermal Electron Acceleration at Earth’s Bow Shock: Theory, Simulation and Observation, The 13th International School/Symposium for Space Simulations (ISSS-13), Los Angeles, USA, Sep. 13, 2018.
3. Stochastic Shock Drift Acceleration for Electrons, 8th East-Asia Workshop on Laboratory, Space, Astrophysical Plasmas, Daejeon, Korea, Aug. 1, 2018.
4. Cosmic-Ray Acceleration via Astrophysical Coherent Radiation, 20th International Symposium on Very High Energy Cosmic Ray Interactions (ISVHECRI), Nagoya, Japan, May 24, 2018.
5. Particle Acceleration in Relativistic Plasmas, Dawn of a New Era for Black Hole Jets in Active Galaxies, Sendai, Japan, Jan. 26, 2018.
6. Nonthermal Electrons at Quasi-perpendicular Collisionless Shocks, 7th East-AsiaWorkshop on Laboratory, Space, Astrophysical Plasmas, Weihai, China, Jul. 25, 2017.

7. Coherent and Stochastic Acceleration in Quasi-perpendicular Collisionless Shocks,Workshop on Plasma Astrophysics from the Laboratory to the Non-thermal Universe, Oxford, UK, Jul. 4, 2017.
8. Kinetic Simulations of Particle Acceleration and Transport around Collisionless Shocks, AOGS 13th Annual Meeting, Beijing, China, Aug. 1, 2016.
9. Particle Acceleration and Transport at Collisionless Shocks, 6th East-Asia Workshop on Laboratory, Space, Astrophysical Plasmas, Tsukuba, Japan, Jul. 11, 2016.
10. Key Issues in Particle Acceleration Theory at Collisionless Shocks, 18th International Congress on Plasma Physics, Kaohsiung, Taiwan, Jun. 29, 2016.
11. Energetic Particle Hybrid Code and Its Application, 11th International Conference on Numerical Modeling of Space Plasma Flows (ASTRONUM2016), Monterey, USA, Jun. 9, 2016.
12. Superluminal Electromagnetic Waves in Highly Magnetized Relativistic Shocks, 5th East-Asia School and Workshop on Laboratory, Space, Astrophysical Plasmas, Pohang, Korea, Aug. 21, 2015.
13. Quasi-neutral Two-fluid Plasma Simulation Model, 10th International Conference on Numerical Modeling of Space Plasma Flows (ASTRONUM 2015), Avignon, France, Jun. 10, 2015.
14. Physics of Very High Mach Number Collisionless Shocks, The Many Facets of Supernova Remnants, Rikkyo University, Japan, Nov. 10, 2014.
15. Relativistic Electromagnetic Two-fluid Simulations of Pulsar Wind Termination Shocks, The 6th East-Asian Numerical Astrophysics Meeting (EANAM6), Suwon, Korea, Sep. 18, 2014.
16. Robust Handling of Low Density Regions in Hybrid Simulations, 9th International Conference on Numerical Modeling of Space Plasma Flows (ASTRONUM 2014), Long Beach, USA, Jun. 25, 2014.
17. Relativistic Pulsar Wind Termination Shocks Modified by Superluminal Electromagnetic Waves, 8th International Conference on Numerical Modeling of Space Plasma Flows (ASTRONUM 2013), Biarritz, France, Jul. 1, 2013.
18. Structure of Relativistic Shock Modified by Nonlinear Superluminal Waves, Nonlinear Waves and Chaos Workshop 9, La Jolla, USA, Mar. 7, 2013.

III. Education Activity

9. Notable Achievements in Education

Advisees

- Master theses: 2 students

  Takuma Katou, Makoto Suzuki (Mar. 2018)

Lectures

- Graduate, Space plasma physics I, FY2018
- Undergraduate/Graduate, Space Science II, FY2016-2018
- Undergraduate, Exercises in earth and planetary physics, FY2012-2016
- Undergraduate, Exercises in basic earth and planetary physics I, FY2012-2016

IV. External Activities

10. Contribution to Academic Community

- Society of Geomagnetism and Earth, Planetary and Space Sciences, Steering Committee, Member, FY2014-2018
- Japan National Committee of URSI, Commission H (Waves in Plasmas), Member, FY2018
- Inter-university research committee on KDK computer at RISH, Kyoto University, Member, FY2018

11. Outreach Activity

12. Internal Committee Membership

- School of Science, Publicity Committee, Member, FY2018

V. International Exchange Activities

13. Hosting/Sending Foreign Students and Researchers

(1) Hosting

Foreign Students: 2

Foreign Researchers: 0

(2) Sending

Students: 0

Researchers: 0

(3) Visitors from Abroad: 0

Satoshi Kasahara

I. CV

Name: Satoshi Kasahara

Age: 38

Present Position: Associate Professor

Education

Kawagoe High School, Saitama, March, 2000 (graduation)

B. Sc. Department of Earth and Planetary Physics, The University of Tokyo, March, 2004

M. Sc. Department of Earth and Planetary Science, The University of Tokyo, March, 2006

Ph. D. Department of Earth and Planetary Science, The University of Tokyo, March, 2009

Professional Experience

Apr. 2009-Mar. 2011, Project Researcher, ISAS/JAXA

Apr. 2011-Aug. 2016, Assistant Professor, ISAS/JAXA

Sept. 2016-, Associate Professor, Department of Earth and Planetary Science, The University of Tokyo

II. Scientific Research Activity

2. Major Achievements

I observationally study plasma dynamics in the earth and planetary magnetospheres. A recent example is the data analyses on the medium energy electron behavior in the radiation belt. The quasilinear plasma theory suggests that whistler waves scatter the electrons through cyclotron resonance, leading to the electron precipitation and associated aurora. However, there has no direct measurements to verify such a theory. The medium energy electron analyser, which I developed spending more than ten years, has sufficient angular resolution, high sensitivity, and low noise level for such analyses. Using the data from the instrument onboard ERG spacecraft, I demonstrated clearly that the electron scattering by whistler waves indeed takes place.

I also dedicate myself to instrumentation for future observations especially for composition measurements of planetary solid surface and neutral atmosphere.

3. Five Important Papers (including three or more papers in this review period)

1. Kasahara, S., Y. Miyoshi, S. Yokota, T. Mitani, Y. Kasahara, S. Matsuda, A. Kumamoto, A. Matsuoka, Y. Kazama, H. U. Frey, V. Angelopoulos, S. Kurita, K. Keika, K. Seki, I. Shinohara, "Pulsating aurora from electron scattering by chorus waves", Nature, doi:10.1038/nature25505, 2018.

The research revealed that the cause of pulsating aurora is the electron scattering by whistler chorus waves via cyclotron resonance. Highlighted as Editor's choice in 2018.

2. Kasahara, S., S. Yokota, T. Mitani, K. Asamura, M. Hirahara, Y. Shibano, T. Takashima, "Medium-Energy Particle experiments - electron analyzer (MEP-e) for the Exploration of energization and Radiation in Geospace (ERG) mission", Earth, Planets and Space, doi:10.1186/s40623-018-0847-z, 2018.

This paper describes the measurement principle, specification, and in-flight calibration of MEP-e instrument onboard the ERG spacecraft. The instrument enables the measurement of medium energy electrons, which has been technically difficult in previous space missions. Highlighted Papers of the EPS journal in 2018.

4. Awards and Honors

- Space science encouraging prize, Society for the Promotion of Space Science, 8 March, 2019.
- Obayashi encouraging prize (young scientist award), SGEPSS (Society of Geomagnetism and Earth, Planetary, and Space Sciences), 18 October, 2017.

5. Future Research Plan

I will develop a mass spectrometer onboard spacecraft for measuring compositions of surface material, neutral/ionized atmosphere in future planetary explorations. More specifically, ion source for neutral gas measurements as well as high-mass resolution optics are important items to be developed in the laboratory. One of concrete milestone is the Comet Interceptor mission, which will be launched in 2028. In this mission, in collaboration with European Space Agency, we will study the origin and evolution of comets by taking images and measuring compositions of a dynamically new comet. I will develop a mass spectrometer for this mission. In parallel, I will promote mission studies for future a Mars mission with the planetary community.

6. Funding Received

- Excellent researcher, The University of Tokyo, 6,000,000 yen.
- MEXT KAKENHI, 18H01264, FY2018-2020, 13,400,000 yen.
- MEXT KAKENHI, 26707026, FY2014-2017, 14,100,000 yen.

7. Publications and Patents

(1) Peer-reviewed Journal Articles

1. Kasahara, S., S. Yokota, T. Mitani, K. Asamura, M. Hirahara, Y. Shibano, T. Takashima, "Medium-Energy Particle experiments - electron analyzer (MEP-e) for the Exploration of energization and Radiation in Geospace (ERG) mission", Earth, Planets and Space, doi:10.1186/s40623-018-0847-z, 2018, [Highlighted Papers 2018].
2. Kasahara, S., Y. Miyoshi, S. Yokota, T. Mitani, Y. Kasahara, S. Matsuda, A. Kumamoto, A. Matsuoka, Y. Kazama, H. U. Frey, V. Angelopoulos, S. Kurita, K. Keika, K. Seki, I. Shinohara, "Pulsating aurora from electron scattering by chorus waves", Nature, doi:10.1038/nature25505, 2018, [Highlighted as Editor's choice in 2018].
3. Kasahara, S., Y. Ezoe, T. Kimura, Y. Miyoshi, "Radiation background and dose estimates for future X-ray observations in the Jovian magnetosphere", Planetary and Space Science, doi:10.1016/j.pss.2012.11.009, Volume 75, Pages 129-135, 2013.
4. Kasahara, S., E. A. Kronberg, T. Kimura, C. Tao, S. V. Badman, A. Masters, A. Retino, N. Krupp, M. Fujimoto, "Asymmetric distribution of reconnection jet fronts in the Jovian nightside magnetosphere", J. Geophys. Res., doi:10.1029/2012JA018130, VOL. 118, 375-384, 2013.
5. Smirnov, A. G., E. A. Kronberg, F. Latallerie, P. W. Daly, N. A. Aseev, Y. Y. Shprits, A. Kellerman, S. Kasahara, D. Turner, M. G. G. T. Taylor, "Electron intensity measurements by the Cluster/RAPID/IES instrument in Earth's radiation belts and ring current", Space weather, doi:10.1029/2018SW001989, 2019.

6. Keika, K., S. Kasahara, S. Yokota, M. Hoshino, K. Seki, M. Nose, T. Amano, Y. Miyoshi, I. Shinohara, "Ion Energies Dominating Energy Density in the Inner Magnetosphere: Spatial Distributions and Composition, Observed by Arase/MEP-i", Geophys. Res. Lett., doi:10.1029/2018GL080047, 2018.

7. Imajo, S., M. Nose, A. Matsuoka, S. Kasahara, S. Yokota, M. Teramoto, K. Keika, T. Motoba, B. Anderson, R. Nomura, A. Fujimoto, I. Shinohara, and Y. Miyoshi, "Magnetosphere-ionosphere connection of storm-time Region-2 field-aligned current and ring current: Arase and AMPERE observations", J. Geophys. Res., doi:10.1029/2018JA025865, 2018.

8. Ezoe, Y., Y. Miyoshi, S. Kasahara, T. Kimura, K. Ishikawa, M. Fujimoto, K. Mitsuda, H. Sahara, N. Isobe, H. Nakajima, T. Ohashi, H. Nagata, R. Funase, M. Ueno, G. Branduardi-Raymont, "Small satellites with MEMS x-ray telescopes for x-ray astronomy and solar system exploration", Proc. Space Telescopes and Instrumentation 2018: Ultraviolet to Gamma Ray, doi:10.1117/12.2311422, 2018.

9. Ezoe, Y., Y. Miyoshi, S. Kasahara, T. Kimura, K. Ishikawa, M. Fujimoto, K. Mitsuda, H. Sahara, N. Isobe, H. Nakajima, T. Ohashi, H. Nagata, R. Funase, M. Ueno, G. Branduardi-Raymont, "Ultra light-weight X-ray telescope missions: ORBIS and GEO-X", J. Astron. Telesc., Instrum. Systems,, doi:10.1117/1.JATIS.4.4.046001, 2018.

10. Hori, T., N. Nishitani, S. G. Shepherd, J. M. Ruohoniemi, M. Connors, M. Teramoto, S. Nakano, K. Seki, N. Takahashi, S. Kasahara, S. Yokota, T. Mitani, T. Takashima, N. Higashio, A. Matsuoka, K. Asamura, Y. Kazama, S.-Y. Wang, S. W. Y. Tam, T.-F. Chang, B.-J. Wang, Y. Miyoshi, and I. Shinohara, "Substorm-associated ionospheric flow fluctuations during the 27 March 2017 magnetic storm: SuperDARN-Arase conjunction", Geophys. Res. Lett., DOI:10.1029/2018GL079777, 2018.

11. Nose, M., A. Matsuoka, S. Kasahara, S. Yokota, M. Teramoto, K. Keika, K. Yamamoto, R. Nomura, A. Fujimoto, N. Higashio, H. Koshiishi, S. Imajo, S. Oimatsu, Y. -M. Tanaka, M. Shinohara, I. Shinohara, and Y. Miyoshi, "Magnetic field dipolarization and its associated ion flux variations in the dawn side deep inner magnetosphere: Arase observations", Geophys. Res. Lett., DOI:10.1029/2018GL078825, 2018.

12. Kurita, S., Y. Miyoshi, S. Kasahara, S. Yokota, Y. Kasahara, S. Matsuda, A. Kumamoto, A. Matsuoka, and I. Shinohara, "Deformation of electron pitch angle distributions caused by upper-band chorus observed by the Arase satellite", Geophys. Res. Lett., DOI:10.1029/2018GL079104, 2018.

13. Oimatsu, S., M. Nose, M. Teramoto, K. Yamamoto, A. Matsuoka, S. Kasahara, S. Yokota, K. Keika, G. Le, R. Nomura, A. Fujimoto, D. Sormakov, O. Troshichev, Y.-M. Tanaka, M. Shinohara, I. Shinohara, Y. Miyoshi, J. A. Slavin, R. E. Ergun, and P.-A. Lindqvist, "Drift-bounce resonance between Pc5 pulsations and ions at multiple energies in the nightside magnetosphere: Arase and MMS observations", Geophys. Res. Lett., DOI:10.1029/2018GL078961, 2018.

14. Yamamoto, K., M. Nose, S. Kasahara, S. Yokota, K. Keika, A. Matsuoka, M. Teramoto, K. Takahashi, S. Oimatsu, R. Nomura, M. Vellante, B. Heilig, A. Fujimoto, Y. Tanaka, M. Shinohara, I. Shinohara, Y. Miyoshi, "Giant Pulsations Excited by a Steep Earthward Gradient of Proton Phase Space Density: Arase Observation", Geophys. Res. Lett., DOI: 10.1029/2018GL078293, 2018.

15. Miyoshi, Y., T. Hori, M. Shoji, M. Teramoto, T-F. Chang, T. Segawa, N. Umemura, S. Matsuda, S. Kurita, K. Keika, Y. Miyashita, K. Seki, Y. Tanaka, N. Nishitani, S. Kasahara, S. Yokota, A. Matsuoka, Y. Kasahara, K. Asamura, T. Takashima, I. Shinohara, "The ERG Science Center", Earth, Planets and Space, DOI: 10.1186/s40623-018-0867-8, 2018.

16. Miyoshi, Y., I. Shinohara, T. Takashima, K. Asamura, N. Higashio, T. Mitani, S. Kasahara, S.

Yokota, Y. Kazama, S-Y., Wang, S. Tam, P.T.P., Ho, Y. Kasahara, Y. Kasaba, S. Yagitani, A. Matsuoka, H. Kojima, Y. Katoh, K. Shiokawa, K. Seki, "Geospace Exploration Project ERG", Earth, Planets and Space, doi:10.1186/s40623-018-0862-0, 2018.

17. Mitani, T., T. Takashima, S. Kasahara, W. Miyake and M. Hirahara, "High-energy electron experiments (HEP) aboard the ERG (Arase) satellite", Earth, Planets and Space, doi:10.1186/s40623-018-0853-1, 2018.

18. Hikishima, M., H. Kojima, Y. Katoh, Y. Kasahara, S. Kasahara, T. Mitani, N. Higashio, A. Matsuoka, Y. Miyoshi, K. Asamura, T. Takashima, S. Yokota, M. Kitahara and S. Matsuda, "Data Processing in the Software-type Wave-Particle Interaction Analyzer on board the Arase Satellite", Earth, Planets and Space, doi:10.1186/s40623-018-0856-y, 2018.

19. Asamura, K., Y. Kazama, S. Yokota, S. Kasahara, and Y. Miyoshi, "Low-energy particle experiments - ion mass analyzer (LEPi) onboard the ERG (Arase) satellite", Earth, Planets and Space, doi:10.1186/s40623-018-0846-0, 2018.

20. Katoh Y., H. Kojima, M. Hikishima, T. Takashima, K. Asamura, Y. Miyoshi, Y. Kasahara, S. Kasahara, T. Mitani, N. Higashio, A. Matsuoka, M. Ozaki, S. Yagitani, S. Yokota, S. Matsuda, M. Kitahara and I. Shinohara, "Software-type Wave-Particle Interaction Analyzer on board the Arase satellite", Earth, Planets and Space, 70:4, doi:10.1186/s40623-017-0771-7, 2018.

21. Yokota, S., S. Kasahara, T. Mitani, K. Asamura, M. Hirahara, T. Takashima, K. Yamamoto, Y. Shibano, "Medium-Energy Particle experiments - ion mass analyzer (MEP-i) onboard ERG (Arase)", Earth, Planets and Space, 69:172, doi:10.1186/s40623-017-0754-8, 2017.

22. Shoji, M., Y. Miyoshi, Y. Katoh, K. Keika, V. Angelopoulos, S. Kasahara, K. Asamura, S. Nakamura, and Y. Omura (2017), Ion hole formation and nonlinear generation of electromagnetic ion cyclotron waves: THEMIS observations, Geophys. Res. Lett., 44, 8730-8738, doi:10.1002/2017GL074254.

23. Miyoshi, Y., Y. Kasaba, I. Shinohara, T. Takashima, K. Asamura, H. Matsumoto, N. Higashio, T. Mitani, S. Kasahara, S. Yokota, S. Wang, Y. Kazama, Y. Kasahara, S. Yagitani, A. Matsuoka, H. Kojima, Y. Katoh, K. Shiokawa, K. Seki, M. Fujimoto, T. Ono, and ERG project group, "Geospace exploration project: Arase (ERG)", J. Phys.: Conf. Ser. 869 012095, 2017. Ono, and ERG project group, "Geospace exploration project: Arase (ERG)", J. Phys.: Conf. Ser. 869 012095, 2017.

24. Cho, Y., S. Kameda, Y. N. Miura, Y. Saito, S. Yokota, S. Kasahara, R. Okazaki, K. Yoshioka, K. Shibasaki, T. Oishi, and S. Sugita. "Conceptual Design of an In Situ K-Ar Isochron Dating Instrument for Future Mars Rover Missions". Transactions of the Japan Society for Aeronautical and Space Sciences, Aerospace Technology Japan. 2016. vol. 14, pp. Pk_89-Pk_94. doi:10.2322/tastj.14.Pk_89.

25. Badman, S. V., B. Bonfond, M. Fujimoto, R. L. Gray, Y. Kasaba, S. Kasahara, T. Kimura, H. Melin, J. D. Nichols, A. J. Steffl, F. Tsuchiya, C. Tao, A. Yamazaki, M. Yoneda, I. Yoshikawa, K. Yoshioka, "Weakening of Jupiter’s main auroral emission during January 2014", Geophys. Res. Lett., 43, 988-997, doi:10.1002/2015GL067366, 2016.

26. Tao. C., F. Sahraoui, D. Fontaine, J. de Patoul, T. Chust, S. Kasahara, A. Retino, "Properties of Jupiter's magnetospheric turbulence observed by the Galileo spacecraft", J. Geophys. Res. Space Physics, Volume 120, Issue 4, Pages 2477-2493, 2015.

27. Kimura. T., S. V. Badman, C. Tao, K. Yoshioka, G. Murakami, A. Yamazaki, F. Tsuchiya, B. Bonfond, A. J. Steffl, A. Masters, S. Kasahara, H. Hasegawa, I. Yoshikawa, M. Fujimoto, J. T. Clarke, "Transient internally driven aurora at Jupiter discovered by Hisaki and the Hubble Space Telescope", Geophys. Res. Lett., Volume 42, Issue 6, Pages 1662-1668, doi:10.1002/2015GL063272, 2015.

28. Louarn. P., N. Andre, C. M. Jackman, S. Kasahara, E. A. Kronberg, M. F. Vogt, "Magnetic Reconnection and Associated Transient Phenomena Within the Magnetospheres of Jupiter and Saturn", Space Sci Rev (187), 181-227, DOI 10.1007/s11214-014-0047-5, 2015.
29. Artemyev, A. V., I. Y. Vasko, S. Kasahara, "Thin current sheets in the Jovian magnetotail", Planetary and Space Science, Volume 96, p. 133-145, doi:10.1016/j.pss.2014.03.012, 2014.
30. Ezoe. Y., T. Kimura, S. Kasahara, A. Yamazaki, K. Mitsuda, M. Fujimoto, Y. Miyoshi, G. Branduardi-Raymont, K. Ishikawa, I. Mitsuishi, T. Ogawa, T. Kakiuchi, T. Ohashi, "JUXTA: A new probe of X-ray emission from the Jupiter system", Advances in Space Research, Volume 51, Issue 9, p. 1605-1621, 2013.
31. Kimura, T., L. Lamy, C. Tao, S. V. Badman, S. Kasahara, B. Cecconi, P. Zarka, A. Morioka, Y. Miyoshi, D. Maruno, Y. Kasaba, and M. Fujimoto, "Long-term modulations of Saturn's auroral radio emissions by the solar wind and seasonal variations controlled by the solar ultraviolet flux", J. Geophys. Res. Space Physics, 118, doi:10.1002/2013JA018833, 2013.
32. Artemyev, A.V., S. Kasahara, A.Y. Ukhorskiy, M. Fujimoto, "Acceleration of ions in the Jupiter magnetotail: Particle resonant interaction with dipolarization fronts", Planetary and Space Science, doi: 10.1016/j.pss.2013.04.013, Volumes 82-83, Pages 134-148, July 2013.
33. Katoh, Y., M. Kitahara, H. Kojima, Y. Omura, S. Kasahara , M. Hirahara, Y. Miyoshi, K. Seki, K. Asamura, T. Takashima, and T. Ono, "Significance of Wave-Particle Interaction Analyzer for direct measurements of nonlinear wave-particle interactions", Ann. Geophys., 31, 503-512, doi:10.5194/angeo-31-503-2013, 2013.
34. Badman, S. V., D. J. Andrews, S. W. H. Cowley, L. Lamy, G. Provan, C. Tao, S. Kasahara, T. Kimura, M. Fujimoto, H. Melin, T. Stallard, R. H. Brown, K. H. Baines, "Rotational modulation and local time dependence of Saturn's infrared H3+ auroral intensity", J. Geophys. Res., 117, A09228, doi:10.1029/2012JA017990, 2012.

(2) Non-peer-reviewed Articles

(3) Review Papers

1. Saito, S., H. Kojima, Y. Kasaba, T. Abe, S. Kasahara, A. Matsuoka, “Observational Technique of the Solar System Plasma”, J. Plasma Fusion Res. Vol.90, No.12 780-785, 2014.

(4) Books

(5) Other Publications

(6) Patents

8. Keynote, Invited, or Solicited Presentations

1. Kasahara, S., Y. Miyoshi, I. Shinohara, K. Asamura, N. Higashio, Y. Kasahara, Y. Kazama, H. Kojima, A. Matsuoka, T. Mitani, S.-Y., Wang, and S. Yokota, "In-situ observations of wave-particle interaction by ERG (Arase)", Magnetic Reconnection in Space, Solar, Astrophysical, and Laboratory Plasmas 2018, Oral (Invited), Princeton, 07 September 2018.
2. Kasahara, S., Y. Miyoshi, S. Yokota, T. Mitani, Y. Kasahara, S. Matsuda, A. Kumamoto, A. Matsuoka, Y. Kazama, H. U. Frey, V. Angelopoulos, S. Kurita, K. Keika, K. Seki, I. Shinohara, K. Asamura, M. Hirahara, T. Takashima, "Arase (ERG) Observation of Energetic Electrons in the Inner Magnetosphere and Roles of Waves", paper number: ST03-A025, AOGS, Oral (Invited), Hawaii, 4 June 2018.

3. Kasahara, S., Y. Miyoshi, S. Yokota, T. Mitani, Y. Kasahara, S. Matsuda, A. Kumamoto, A. Matsuoka, Y. Kazama, H. U. Frey, V. Angelopoulos, S. Kurita, K. Keika, K. Seki, I. Shinohara, "Arase (ERG) Observation of Electron Scattering by Chorus Waves near the Magnetospheric Equator", paper number:S-H02-07, AT-RASC (URSI Atlantic Radio Science meeting), Oral (Invited), Spain, 28 May 2018.
4. Kasahara, S., S. Yokota, T. Mitani, K. Asamura, M. Hirahara, Y. Shibano, K. Yamamoto, and T. Takashima, "Medium-Energy Particle experiments (MEPs) for the Exploration of energization and Radiation in Geospace (ERG) mission", (Final Paper Number: SM31E-03), AGU, Oral (Invited), New Orleans, Session Date: Thursday, 13 December 2017.
5. Kasahara S., K. Asamura, N. Higashio, M. Hirahara, Y. Kazama, H. Matsumoto, T. Mitani, W. Miyake, Y. Suto, T. Takashima, B.-J. Wang, S.-Y. Wang, K. Yamamoto, S. Yokota, "Charged particle measurements in the radiation belts by ERG", AOGS, Oral (Invited), Singapore, 09/August/2017.
6. Kasahara, S., E. A. Kronberg, T. Kimura, C. Tao, S. V. Badman, A. Masters, A. Retino, N. Krupp, and M. Fujimoto, "In-situ observations of magnetic reconnection in the Jovian nightside magnetosphere", (Final Paper Number: SM44B-05), AGU, Oral (Invited), Sanfrancisco, Session Date: Thursday, 18 December 2014.
7. Kasahara, S., E. A. Kronberg, T. Kimura, C. Tao, S. V. Badman, A. Masters, A. Retino, N. Krupp, M. Fujimoto, "Spatial distribution and local structure of reconnection jet fronts in the Jovian magnetosphere", AGU, (Invited) oral, Sanfrancisco, 07/12/2012.
8. Kasahara, S., E. A. Kronberg, T. Kimura, C. Tao, S. V. Badman, A. Masters, A. Retino, N. Krupp, M. Fujimoto, "Magnetic Reconnection in the Jovian tail: GLL observation", ISSI workshop, (Invited) oral, Bern, 26/11/2012.

III. Education Activity

9. Notable Achievements in Education

Lectures

- Undergraduate, First year seminar, FY2018
- Undergraduate, Earth and Planetary physics experiments, FY2016-2018
- Undergraduate, Earth and Planetary physics exercise, FY2017-2018
- Undergraduate, Earth and Planetary physics special exercise, FY2016-2018
- Undergraduate/Graduate, Basic Comparative Planetology, FY2017-2018
- Graduate, Planetary exploration I, FY2017
- Graduate, Planetary exploration II, FY2018

IV. External Activities

10. Contribution to Academic Community

- Japan Geoscience Union, Program Committee Member, FY2018
- Workshop of Nagoya university, FY2012-2018

11. Outreach Activity

- Asahi Culture Centre, lecture, 22 September, 2018, Kanagawa.
- Chiba city science museum, lecture, 9 September, 2018, Chiba.
- Sakata-Hayakawa lecture, short lecture, 2017, Aichi.
- Science Live Show, lecture, 2016, Tokyo.
- Instruction course for school teachers, lecture, 2014, Saitama.
- Science school, lecture, 2014, Saitama.
- Interdisciplinary academic café, lecture, 2012, Tokyo.

12. Internal Committee Membership

V. International Exchange Activities

13. Hosting/Sending Foreign Students and Researchers

(1) Hosting

Foreign Students: 0

Foreign Researchers: 0

(2) Sending

Students: 0

Researchers: 0

(3) Visitors from Abroad: 1

Hajime Hiyagon

I. CV

Name: Hajime Hiyagon

Age: 64

Present Position: Associate Professor

Education

Momoyama-Gakuin High School, Osaka, March, 1974 (graduation)

B. Sc. Department of Geophysics, The University of Tokyo, March, 1979

M. Sc. Department of Geophysics, The University of Tokyo, March, 1981

Dr. Sc. Department of Geophysics, The University of Tokyo, November, 1984

Professional Experience

Oct. 1984-Mar. 1985, Research Fellow, JSPS, Geophys. Institute, The University of Tokyo

Apr. 1985-Sept. 1986, Post Doc, Univ. California, Berkeley, USA.

Oct. 1986-Mar. 2000, Associate Professor, Geophysical Department, The University of Tokyo.

Apr. 2000-, Associate Professor, Department of Earth & Planetary Science, The University of Tokyo

II. Scientific Research Activity

2. Major Achievements

I have been conducted isotopic, chronological and mineralogical study on various components (e.g., refractory inclusions and chondrules) in primitive meteorites using mainly SIMS (secondary ion mass spectrometry) and ICP-MS (inductively-coupled-plazma mass spectrometry).to understand evolution of materials in the early solar system. (1) In the study of hibonite-bearing inclusions in CM chondrites, we found so-called FUN inclusions which show highly fractionated Mg and Si isotopes with unknown nuclear effects on Ca and Ti. (2) We found in a CR2 chondrite eclogitic clasts, which formed at high P-T conditions, and we discussed its origin based on REE abundances, O isotopes and diffusion profiles, and showed clearly that the high P-T conditions are not a shock pressure, but most likely achieved at a central part of Moon-sized planetary body. (3) We conducted Be-B isotope analyses on CAIs in CH/CB chondrites (which may be originated in the outer solar system) and found large excess boron-10, produced by in-situ decay from Be-10. Since Be-10 is a strong indication of solar cosmic ray irradiation, this suggests production of CAIs near the ancient sun and their effective transportation to the outer solar system. (5) We conducted high precision Mg isotope study of chondrules in an L chondrite using ICP-MS and discuss distribution of 26Al in the early solar system.

3. Five Important Papers (including three or more papers in this review period)

1. Hiyagon, H., Ozima, M., Marty, B., Zashu, S. & Sakai, H. (1992). Noble gases in submarine glasses from Mid Oceanic Ridges and Loihi Seamount: Constraints on early history of the Earth. *Geochim. Cosmochim. Acta* 56, 1301-1316.

We analyzed noble gas isotopes in mantle-derived submarine glasses from MORs and Loihi Seamount and discussed the origin of terrestrial atmospheres. Neon isotopes in the mantle show solar-like signature, i.e., higher 20Ne/22Ne ratios (>12) than that of the atmosphere (9.8), suggesting extensive loss of the terrestrial atmosphere resulting in fractionation of neon isotopes in the atmonspere. (Citation 150, Web of Science/Sep.20, 2019)

2. Hiyagon, H. & Hashimoto, A. (1999). ^{16}O excesses in olivine inclusions in Yamato-86009 and Murchison chondrites and their relation to CAIs. *Science* 283, 828-8316

We conducted in-situ SIMS analyses of oxygen isotopes in olivine-rich inclusions (AOAs) in primitive chondrites and found that the olivine-rich inclusions also show ^{16}O-rich signatures like CAIs. This paper first demonstrated that not only refractory minerals but also olivine, the most common mineral in chondrites, show such ^{16}O-rich signatures. This strongly suggests that the solar gas must be ^{16}O-rich in the formation regions of CAIs. (Cittion 58, Web of Science/Sep.20, 2019)

3. Fujiya, W., Sugiura, N., Sano, Y., & Hiyagon, H. (2013). Mn-Cr ages of dolomites in CI chondrites and the Tagish Lake ungrouped carbonaceous chondrite. *Earth Planet. Sci. Lett.* 362, 130-142.

We studied ^{53}Mn-^{53}Cr chronology of dolomite (carbonate) grains in CI and Tagish Lake carbonaceous chondrites and found their ages are identical within uncertainties with those of carbonate minerals in CM chondrites. Based on nearly identical ages of carbonate formations in different groups of carbonaceous chondrites, we estimated accretion ages of their parent bodies and the size of the CI parent body. (Citation 40, Web of Science/Sep.20, 2019)

4. Ushikubo, T., Tenner, T. J., Hiyagon, H. & Kita, N. T. (2017), A long duration of the ^{16}O-rich reservoir in the solar nebula, as recorded in fine-grained refractory inclusions from the least metamorphosed carbonaceous chondrites. *Geochim. Cosmochim. Acta* 201, 103-122. http://dx.doi.org/10.1016/j.gca.2016.08.032.

We analyzed oxygen isotopic compositions and ^{26}Al-^{26}Mg ages of fine-grained inclusions (probably direct condensation products from hot nebular gas) in least metamorphosed carbonaceous chondrites. It is shown that a ^{16}O-rich reservoir existed for a relatively long duration in the solar nebula. (Citation 14, Web of Science/Sep.20, 2019)

5. Fukuda, K., Fujiya, W., Hiyagon, H., Makino, Y., Sugiura, N., Takahata, N., Hirata, T., & Sano, Y. (2018) Beryllium-boron relative sensitivity factors for melilitic glasses measured with a NanoSIMS ion microprobe. *Geochem. J.* 52, 255-262. https://doi.org/10.2343/geochemj.2.0510

Beryllium-10, which decays to boron-10 with a half life of 1.4 My, is a good tracer of cosmic ray irradiation, because it can be produced by spallation reactions with energetic particles of Galactic or Solar Cosmic Rays. In the Be-B isotopic analysis using SIMS, relative sensitivity factors (RSFs) of Be and B must be determined using matrix-matched standards of known Be/B concentrations. We synthesized melilitic glass standards, suitable for the Be-B analysis of CAIs, and determined RSFs. This is a basic but very important study for the accurate SIMS analysis of Be and B isotopes. (Citation 2, Web of Science/Sep.20, 2019)

4. Awards and Honors

5. Future Research Plan

Recently, we discovered excess boron-10 (decay product of Be-10) not only in CAIs but also in chondrules in a carbonaceous chondrite. Since Be-10 is a strong indication of solar cosmic ray irradiation, this observation indicates that materials processed near the proto Sun under strong irradiation of solar cosmic rays might be transported and distributed widely in the early solar system and incorporated in chondrules. Distribution of Be-10 in the early solar system, esp., in chondrules, is not well known at present. I will further analyze Be-B isotopes in chondrules in different chondrite groups to better understand distribution and transportation of materials from near-proto Sun region to outer part of the solar system. I will also study distribution of Al-26 based on the data obtained by SIMS or ICP-MS.

6. Funding Received

- Grant-in-Aid for Scientific Research (C), 23540567, An ion microprobe study on fractionation of sideriphile elements in the early solar system, Principal Investigator, FY2011-2014, 4,940,000 yen
- Grant-in-Aid for Scientific Research (C), 23540565, Research on the genesis of rare metal deposits by SIMS analyses, Co-Investigator, FY2011-2014, 4,810,000 yen
- Grant-in-Aid for Scientific Research (C), 26400524, A study on isotopic homogenization processes in the early solar system, Principal Investigator, FY2014-2016, 4,810,000 yen
- Grant-in-Aid for Scientific Research (C), 15K05340, Research on the formation conditions of deep sea platinum metal deposits based on SIMS analyses, Co-Invesitigator, FY2015-2018, 4,550,000 yen
- Grant-in-Aid for Scientific Research (C), 18K03720, Reevaluation of Al-Mg chronology in the early solar system, Principal Investigator, FY2018-2020, 4,290,000 yen

7. Publications and Patents

(1) Peer-reviewed Journal Articles

1. Fujiya, W., Sugiura, N., Sano, Y., & Hiyagon, H. (2013). Mn-Cr ages of dolomites in CI chondrites and the Tagish Lake ungrouped carbonaceous chondrite. Earth Planet. Sci. Lett. 362, 130-142.
2. Fujiya, W., Sugiura, N., Marrocchi, T., Takahata, N., Hope, P., Shirai, K., Sano, Y. & Hiyagon, H. (2015). Comprehensive study of carbon and oxygen isotopic compositions, trace element abundances, and cathodoluminescence intensities in calcite in the Murchison CM2 chondrite. Geochim. Cosmochim. Acta, 161, 101-117.
3. Hiyagon, H., Sugiura, N., Kita, N. T., Kimura, M., Morishita, Y., &. Takehana, Y. (2016). Origin of the eclogitic clasts with graphite-bearing and graphite-free lithologies in the Northwest Africa 801 (CR2) chondrite: Possible origin from a Moon-sized planetary body inferred from chemistry, oxygen isotopes and REE abundances. Geochim. Cosmochim. Acta 186, 32–48.
4. Ushikubo, T., Tenner, T. J., Hiyagon, H. & Kita, N. T. (2017), A long duration of the 16O-rich reservoir in the solar nebula, as recorded in fine-grained refractory inclusions from the least metamorphosed carbonaceous chondrites. Geochim. Cosmochim. Acta 201, 103-122. http://dx.doi.org/10.1016/j.gca.2016.08.032.
5. Fukuda, K., Fujiya, W., Hiyagon, H., Makino, Y., Sugiura, N., Takahata, N., Hirata, T., & Sano, Y. (2018) Beryllium-boron relative sensitivity factors for melilitic glasses measured with a NanoSIMS ion microprobe. Geochem. J. 52, 255-262. https://doi.org/10.2343/geochemj.2.0510

(2) Non-peer-reviewed Articles

(3) Review Papers

1. Hiyagon, H. (2016) Principle of Secondary Ion Mass Spectrometry (in Japanese), A chapter of “Introduction to Precise Isotopic Analysis”, BUNSEKI, The Japan Society for Analytical Chemistry, pp.352-357.

(4) Books

(5) Other Publications

1. Hiyagon, H. (2013) "The formation and differentiation of Earth" (Translation to Japanese), "*PARITY*", Maruzen, Japan, vol.28, No.4, 14-23, (Original: Wood, B. (2011) *Physics Today*, 64, No.12, 40 (2011); doi: 10.1063/PT.3.1362.)

(6) Patents

8. Keynote, Invited, or Solicited Presentations

III. Education Activity

9. Notable Achievements in Education

Advisees

- Master theses: 2 students
  - Akinobu Hayakawa (Mar. 2015)
  - Yuuki Tanimura (Mar. 2018)
- Doctral theses: 1 student
  - Kohei Fukuda (Mar. 2017)

Lectures

- Undergraduate, Evolution of space and planetary materials,　FY2012, 2014, 2016～2018
- Undergraduate, Experiments in Earth and Planetary Physics,　FY2012～2018
- Graduate, Cosmic and Planetary Material Science II, FY2013, 2015, 2017
- Graduate, Introduction to Earth and Planetary Physics,　FY2014～2015

IV. External Activities

10. Contribution to Academic Community

11. Outreach Activity

12. Internal Committee Membership

- Department of Earth and Planetary Physics, Scientific Instruments Committee, FY2012-2018
- School of Science, Environment and Safety Management Office, Member, FY2013-2018
- Department of Earth and Planetary Physics, Safety Management Committee, FY2013-2018

V. International Exchange Activities

13. Hosting/Sending Foreign Students and Researchers

(1) Hosting

Foreign Students: 0

Foreign Researchers: 0

(2) Sending

Students: 0

Researchers: 0

(3) Visitors from Abroad: 0

Tomokatsu Morota

I. CV

Name: Tomokatsu Morota

Age: 44

Present Position: Professor

Education

Seiryo Senior High School, Kanazawa, March, 1994 (graduation)

B. Sc. Department of Earth Sciences, Kanazawa University, March, 1998

M. Sc. Department of Earth Sciences, Kanazawa University, March, 2000

Ph. D. Department of Earth Sciences, Kanazawa University, March, 2003

Professional Experienceå

Apr. 2003-Mar. 2005, Research student, Department of Earth Sciences, Kanazawa University

Apr. 2005-Mar. 2008, Project Researcher, Department of Planetary Sciences, Japan Aerospace Exploration Agency

Apr. 2008-Mar. 2011, Research Fellowship for Young Scientists, Department of Planetary Sciences, Japan Aerospace Exploration Agency

Apr. 2011-Aug. 2011, Researcher, RISE Project, National Astronomical Observatory of Japan

Sep. 2011-Dec. 2016, Assistant Professor, Department of Earth and Planetary Sciences, Nagoya University

Jan. 2017-Apr. 2019, Lecturer, Department of Earth and Planetary Sciences, Nagoya University

May 2019-, Associate Professor, Department of Earth and Planetary Science, The University of Tokyo

II. Scientific Research Activity

2. Major Achievements

I have studied on the surface and interior evolution of the Moon and small bodies based on geological and geophysical approaches using the images and geographical data obtained by lunar and planetary explorations. Also, I have prepared the observation plans and developed the data processing systems as a science member of Japanese Kaguya and Hayabusa2 missions. In particular, using Kaguya high-resolution image data we have investigated the impact history in the inner solar system and volcanic history on the Moon. We found that lunar mare volcanism was continued until about 2.0 billion years and that the lunar dichotomy of mare distribution is due to the difference in thermal condition between the nearside and farside. These findings are important to constrain the thermal evolution of the Moon. Also, we

3. Five Important Papers (including three or more papers in this review period)

1. Morota, T., and M. Furumoto (2003) Asymmetrical distribution of rayed craters on the Moon, Earth and Planetary Science Letters, 206, 315–323. doi:10.1016/S0012-821X(02)01111-1

The Moon is in a state of the synchronous rotation. The synchronous rotation of a planetary satellite should generate a spatial variation in the crater production rate on its surface. In this study, based on the spatial distribution of lunar rayed craters we found that the cratering production rate on the leading hemisphere is ~1.3 times higher than that on the trailing hemisphere for the first time. The lead/trail ratio is corresponds to an impactor velocity of about 15 km/s, suggesting that recent craters on the Moon are formed mainly by near-Earth asteroids rather than comets with higher encounter velocities. (Citation 50, GS/Oct. 1, 2019)

2. Morota, T., J. Haruyama, M. Ohtake, T. Matsunaga, C. Honda, Y. Yokota, J. Kimura, Y. Ogawa, N. Hirata, H. Demura, A. Iwasaki, T. Sugihara, K. Saiki, R. Nakamura, Y. Ishihara, H. Takeda, and H. Hiesinger (2011) Timing and characteristics of the latest mare eruption on the Moon, Earth and Planetary Science Letters, 302, 255–266. doi:10.1016/j.epsl.2010.12.028

Unraveling the timing and duration of mare volcanism on the Moon is essential for understanding its thermal evolution. The end of mare volcanism is poorly constrained, because mare basalts are incompletely sampled. In this study, employing SELENE (Kaguya) high-resolution images, we performed new crater size-frequency measurements for young mare units (<~3.0 Ga) in the Procellarum KREEP Terrane (PKT), in which the latest magma eruption of the Moon occurred. Mare volcanism in this region continued until ~1.5 Ga. The young mare units in the PKT tend to have spectral types corresponding to high titanium contents, while low titanium basalts occur mainly in the early stage. The titanium variation in mare basalts may reflect vertical heterogeneity in TiO_2 content in the upper mantle beneath the PKT. (Citation 77, GS/Oct. 1, 2019)

3. Ohtake, M., H. Takeda, T. Matsunaga, Y. Yokota, J. Haruyama, T. Morota, S. Yamamoto, Y. Ogawa, T. Hiroi, Y. Karouji, K. Saiki, and P.G. Lucey (2012) Asymmetric crustal growth on the Moon indicated by primitive farside highland materials, Nature Geoscience, 5, 384-388, doi:10.1038/ngeo1458

The Moon's nearside and farside differ in topography, crustal thickness, mare volcanic activity and elemental concentrations. The origin of this dichotomy is still unclear. It is also unknown whether the characteristics of the oldest crust, the anorthositic lunar highlands, reflect a different magmatic evolution of nearside and farside crust. Based on analyses of nearside highland rocks, it has been suggested that nearside crustal growth occurred from an evolved, ironrich magma ocean, but information from the farside highlands is lacking. Here we apply an empirical algorithm to lunar reflectance spectra from the Kaguya Spectral Profiler and report that magnesium contents relative to iron of primitive crustal highland rocks on the farside are higher than on the nearside. Our findings indicate that the farside crust consists of rocks that crystallized from less-evolved magma than the nearside crust. (Citation 37, GS/Oct. 1, 2019)

4. Morota, T., Y. Ishihara, S. Sasaki, S. Goossens, K. Matsumoto, H. Noda, H. Araki, H. Hanada, S. Tazawa, F. Kikuchi, T. Ishikawa, S. Tsuruta, S. Kamata, H. Otake, J. Haruyama, and M. Ohtake (2015) Lunar mare volcanism: Lateral heterogeneities in volcanic activity and relationship with crustal structure, in GSL Special Publications 401: Volcanism and Tectonism Across the Inner Solar System, edited by T. Platz, M. Massironi, P.K. Byrne, H. Hiesinger, pp. 127-138, doi:10.1144/SP401.11, Geological Society of London.

Although mare asymmetry has been attributed to thickness variations in the low-density anorthositic crust, the eruptive mechanism of lunar magma remains unknown. In this study, we investigate the relationship between mare distribution and crustal thickness using geological and geophysical data obtained by the SELENE (Kaguya) and the GRAIL spacecraft, and quantitatively re-evaluate the influence of the anorthositic crust on magma eruption. We identify a lateral heterogeneity in the upper limit of crustal thickness that allows magma extrusion to the surface. In the Procellarum KREEP Terrane, where the surface abundances of heat-producing elements are extremely high, magmas can erupt in regions of crustal thickness below about 30 km. In contrast, magma eruptions are limited to regions of crustal thickness below about 20 km in other nearside regions, around 10 km in the South Pole–Aitken Basin and approximately 5 km in the farside Felspathic Highland Terrane. Such heterogeneity may result from lateral variations in magma production in the lunar mantle and/or crustal density. (Citation 2, GS/Oct. 1, 2019)

5. Kato, S., T. Morota, S. Watanabe, Y. Yamaguchi, M. Ohtake, and H. Otake (2017) Magma source transition of lunar mare volcanism at 2.3 Ga, Meteoritics & Planetary Science, 52, 1899-1915, doi:10.1111/maps.12896.

The ages of mare basalts suggest a first peak of magma activity at 3.2–3.8 Ga and a second peak at ~2 Ga. In this study, we reassess the correlation between the titanium contents and the eruption ages of mare basalt units using the compositional and chronological data updated by SELENE (Kaguya). We found that the increase in the mean titanium content occurred within a relatively short period near approximately 2.3 Ga, suggesting that the magma source of the mare basalts changed at this particular age. Moreover, the high-titanium basaltic eruptions are correlated with a second peak in volcanic activity near ~2 Ga. The high-titanium basaltic eruptions occurring during the last volcanic activity period can be explained by a possible scenario that the ilmenite-bearing cumulate rich layer in the core-mantle boundary formed after the mantle overturn. (Citation 2, GS/Oct. 1, 2019)

4. Awards and Honors

- Morota, T., The Commendation for Science and Technology by the Minister of Education, Culture, Sports, Science and Technology, The Young Scientists' Prize, Apr. 2014

5. Future Research Plan

I will continue studies on evolutions of the surface and interior of the Moon and small bodies using data obtained by lunar and planetary explorations to constrain the surface processes and thermal evolution of planetary bodies. In particular, I will focus on the studies on the thermal evolution of planetary bodies, the impact history in the solar system based on the cratering records, and surface process of small bodies based on optical properties and morphology of surface.

6. Funding Received

- JSPS KAKENHI, 25870314, Principal Investigator, FY2013-2015, 3,200,000 yen
- JSPS KAKENHI, 26287107, Co-Investigator, FY2014-2017, 800,000 yen
- JSPS KAKENHI, 15H03707, Co-Investigator, FY2015-2018, 1,000,000 yen
- JSPS KAKENHI, 17K05633, Principal Investigator, FY2017-2019, 3,400,000 yen
- JSPS KAKENHI, 17H06459, Co-Investigator, FY2017-2021, 4,250,000 yen

7. Publications and Patents

(1) Peer-reviewed Journal Articles

1. Ohtake, M., H. Takeda, T. Matsunaga, Y. Yokota, J. Haruyama, T. Morota, S. Yamamoto, Y. Ogawa, T. Hiroi, Y. Karouji, K. Saiki, and P.G. Lucey (2012) Asymmetric crustal growth on the Moon indicated by primitive farside highland materials, Nature Geoscience, 5, 384-388, doi:10.1038/ngeo1458.
2. Cho, Y., T. Morota, M. Yasui, N. Hirata, J. Haruyama, and S. Sugita (2012) Young mare volcanism in the Orientale region contemporary with the Procellarum KREEP Terrane (PKT) volcanism peak period ~2 billion years ago, Geophysical Resarch Letters, 39, L11203, doi:10.1029/2012GL05183.
3. Kobayashi, S., Y. Karouji, T. Morota, H. Takeda, N. Hasebe, M. Hareyama, M. Kobayashi, E.

Shibamura, N. Yamashita, C. d'Uston, O. Gasnault, O. Forni, R.C. Reedy, K.L. Kim, and Y. Ishihara (2012) Lunar farside Th distribution measured by Kaguya gamma-ray spectrometer, Earth and Planetary Science Letters, 337-338, 10-16, doi:10.1016/j.epsl.2012.05.007

4. Yamamoto, S., R. Nakamura, T. Matsunaga, Y. Ogawa, Y. Ishihara, T. Morota, N. Hirata, M. Ohtake, T. Hiroi, Y. Yokota, and J. Haruyama (2012) Massive production of pure anorthosite on the Moon by the giant impact, Geophysical Resarch Letters, 39, L13201, doi:10.1029/2012GL052098

5. Nakamura, R., S. Yamamoto, T. Matsunaga, Y. Ishihara, T. Morota, T. Hiroi, H. Takeda, Y. Ogawa, Y. Yokota, N. Hirata, M. Ohtake, and K. Saiki (2012) Compositional evidence for an impact origin of the Moon's Procellarum basin, Nature Geoscience, 5, 775-778, doi:10.1038/ngeo1614

6. Kamata, S., S. Sugita, Y. Abe, Y. Ishihara, Y. Harada, T. Morota, N. Namiki, T. Iwata, H. Hanada, H. Araki, K. Matsumoto, and E. Tajika (2013) Viscoelastic deformation of lunar impact basins: Implications for heterogeneity in the deep crustal paleo-thermal state and radioactive element concentration, Journal of Geophysical Research (Planet), 118, 1–18, doi:10.1002/jgre.20056

7. Yamamoto, S., R. Nakamura, T. Matsunaga, Y. Ogawa, Y. Ishihara, T. Morota, N. Hirata, M. Ohtake, T. Hiroi, Y. Yokota, and J. Haruyama (2013) A new type of pyroclastic deposits on the Moon showing unique visible absorption bands: possible Fe-bearing spinel, Geophysical Resarch Letters, 39, L13201, doi:10.1029/2012GL052098

8. Ishihara. Y., Y. Saruwatari, A. Sawada, T. Morota, and Y. Hiramatsu (2014) Quantitative measurement method for impact basin characteristics based on localized spherical harmonics, Icarus, 228, 315–323, doi:10.1016/j.icarus.2013.10.018

9. Yokota, Y., K. Gwinner, J. Oberst, J. Haruyama, T. Matsunaga, T. Morota, H. Noda, H. Araki, M. Ohtake, S. Yamamoto, P. Gläser, Y. Ishihara, C. Honda, N. Hirata, and H. Demura, Variation of the lunar highland surface roughness at baseline 0.15-100 km and the relationship to relative age, Geophysical Resarch Letters, 41, 1444-1451, doi:10.1002/2013GL059091

10. Yamamoto, S., T. Matsunaga, Y. Ogawa, R. Nakamura, Y. Yokota, M. Ohtake, J. Haruyama, T. Morota, C. Honda, T. Hiroi, S. Kodama (2014) Calibration of NIR 2 of Spectral Profiler onboard Kaguya/SELENE, IEEE Trans. Geosci. Remote Sens., 52, 6882-6898, doi:10.1109/TGRS.2014.2304581

11. [49] Ohtake, M., K. Uemoto, Y. Yokota, T. Morota, S. Yamamoto, R. Nakamura, J. Haruyama, T. Iwata, T. Matsunaga, Y. Ishihara (2014) Distribution of ultramafic rock and location of impact melt pool within the South Pole-Aitken basin, Geophysical Resarch Letters, 41, doi:10.1002/2014GL059478

12. Morota, T., Y. Ishihara, S. Sasaki, S. Goossens, K. Matsumoto, H. Noda, H. Araki, H. Hanada, S. Tazawa, F. Kikuchi, T. Ishikawa, S. Tsuruta, S. Kamata, H. Otake, J. Haruyama, and M. Ohtake (2015) Lunar mare volcanism: Lateral heterogeneities in volcanic activity and relationship with crustal structure, in GSL Special Publications 401: Volcanism and Tectonism Across the Inner Solar System, edited by T. Platz, M. Massironi, P.K. Byrne, H. Hiesinger, pp. 127-138, doi:10.1144/SP401.11, Geological Society of London.

13. Kamata, S., S. Sugita, Y. Abe, Y. Ishihara, Y. Harada, T. Morota, N. Namiki, T. Iwata, H. Hanada, H. Araki, K. Matsumoto, E. Tajika, K. Kuramoto, and F. Nimmo (2015) The relative timing of Lunar Magma Ocean solidification and the Late Heavy Bombardment inferred from highly degraded impact basin structures, Icarus, 250, 492-503, doi:10.1016/j.icarus.2014.12.025

14. Cho, Y., S. Sugita, S. Kameda, Y.N. Miura, K. Ishibashi, S. Ohno, S. Kamata, T. Arai, T. Morota, N. Namiki, and T. Matsui (2015) Quantitative potassium measurements using laser-induced breakdown spectroscopy under high vacuum conditions for in situ K-Ar dating of planetary surfaces, Spectrochimica Acta Part B, 106, 28-35, doi:10.1016/j.sab.2015.02.002.

15. Yamamoto, S., R. Nakamura, T. Matsunaga, Y. Ogawa, Y. Ishihara, T. Morota, N. Hirata, M. Ohtake, T. Hiroi, Y. Yokota, and J. Haruyama (2015) Global occurrence trend of high-Ca pyroxene on lunar highlands and its implications, Journal of Geophysical Research (Planet), 120, doi:10.1002/2014JE004740
16. Yamamoto, S., R. Nakamura, T. Matsunaga, Y. Ogawa, Y. Ishihara, T. Morota, N. Hirata, M. Ohtake, T. Hiroi, Y. Yokota, and J. Haruyama (2015) Featureless spectra on the Moon as evidence of residual lunar primordial crust, Journal of Geophysical Research (Planet), 120, 2190-2205, DOI:10.1002/2015JE004935
17. Kameda, S., H. Suzuki, T. Takamatsu, Y. Cho, T. Yasuda, M. Yamada, H. Sawada, R. Honda, T. Morota, C. Honda, M. Sato, Y. Okumura, K. Shibasaki, S. Ikezawa, S. Sugita (2016) Preflight calibration test results for optical navigation camera telescope (ONC-T) onboard the Hayabusa2 spacecraft, Space Science Reviews, DOI:10.1007/s11214-015-0227-y.
18. Yamada, T., K. Ando, T. Morota, H. Katsuragi (2016) Timescale of asteroid resurfacing by regolith convection resulting from the impact-induced global seismic shaking, Icarus, 272, 165-177, doi:10.1016/j.icarus.2016.02.032.
19. Sawada, N., T. Morota, S. Kato, Y. Ishihara, and Y. Hiramatsu (2016) Constraints on timing and magnitude of early global expansion of the Moon from topographic features in linear gravity anomaly areas, Geophysical Resarch Letters, 43, 4865-4870, doi: 10.1002/2016GL068966.
20. Cho, Y., S. Sugita, Y.N. Miura, R. Okazaki, T. Morota, S. Kameda (2016) An in-situ K-Ar isochron dating method for planetary landers using a spot-by-spot laser-ablation technique, Planetary and Space Science, 128, 14–29, doi:10.1016/j.pss.2016.05.004.
21. Daket, Y., A. Yamaji, K. Sato, J. Haruyama, T. Morota, M. Ohtake, T. Matsunaga (2016) Tectonic evolution of northwestern Imbrium of the Moon that lasted in the Copernican period, Earth, Planets and Space, 68:157, doi: 10.1186/s40623-016-0531-0
22. Michikami, T., A. Hagermann, T. Morota, J. Haruyama, and S. Hasegawa (2017) Oblique impact cratering experiments in brittle targets: implications for elliptical craters on the Moon, Planetary and Space Science, 135, 27-36, doi.org/10.1016/j.pss.2016.11.004
23. Taguchi, M., T. Morota, and S. Kato (2017) Lateral heterogeneity of lunar volcanic activity according to volumes of mare basalts in the farside basins, Journal of Geophysical Research (Planet), 122, 1505-1521, doi:10.1002/2016JE005246
24. Kato, S., T. Morota, S. Watanabe, Y. Yamaguchi, M. Ohtake, and H. Otake (2017) Magma source transition of lunar mare volcanism at 2.3 Ga, Meteoritics & Planetary Science, 52, 1899-1915, doi:10.1111/maps.12896
25. Suzuki, H., M. Yamada, K. Kameda, T. Kouyama, E. Tatsumi, R. Honda, H. Sawada, N. Ogawa, T. Morota, C. Honda, N. Sakatani, M. Hayakawa, Y. Yokota, and S. Sugita (2018) Initial inflight calibration for Hayabusa2 optical navigation camera (ONC) for science observations of asteroid Ryugu, Icarus, 300, 341-359, doi:10.1016/j.icarus.2017.09.011
26. Hareyama, M., Y. Ishihara, H. Demura, N. Hirata, C. Honda, S. Kamata, Y. Karouji, J. Kimura, T. Morota, H. Nagaoka, R. Nakamura, S. Yamamoto, Y. Yokota, M. Ohtake (2018) Global classification of lunar reflectance spectra obtained by Kaguya (SELENE): Implication for hidden basaltic materials, Icarus, 321, 407-425, doi.org/10.1016/j.icarus.2018.11.016

(2) Non-peer-reviewed Articles

(3) Review Papers

1. Morota, T., Kuramoto, K, Takahashi, F., Chronological table of lunar geologic history, Planetary People 21, 57-63.

2. Morota, T., Sugita, S., Sawada, H., Honda, R., Kameda, S., Yamada, M., Honda, C., Suzuki, H., Ando, K., Hayabusa2 ONC team (2015). Phoenix "Hayabusa" : A tale of the future (8) - Morphological observation by ONC and dynamical and collisional evolution of NEAs-, Planetary People 24, 48-53.

(4) Books

(5) Other Publications

(6) Patents

8. Keynote, Invited, or Solicited Presentations

1. Morota, T., Lunar evolution and impact history revealed by the cratering records of the Moon, JpGU2018, Chiba, 2018/05/24.

III. Education Activity

9. Notable Achievements in Education

Advisees

- Master theses: 10 students
  - Shinsuke Kato, Mami Kato (Mar. 2014)
  - Kousuke Ando, Natsuki Sawada (Mar. 2015)
  - Masako Taguchi (Mar. 2016)
  - Seiya Morita (Mar. 2017)

Lectures

- Undergraduate, Numerical Analysis and Exercises, FY2012-2018
- Undergraduate, Earth and Planetary Physics, FY2012-2017
- Undergraduate, Solar System Physics, FY2018
- Undergraduate, Frontier of Earth and Planetary Sciences, FY2016-2018

Student's awards

- Japan Geoscience Union, Student Presentation Award [Shinsuke Kato]

IV. External Activities

10. Contribution to Academic Community

- Japanese Society for Planetary Sciences, Steering Committee Member, FY2015-2018
- Japanese Society for Planetary Sciences, General Affairs Committee Chair, FY2015-2018
- Japanese Society for Planetary Sciences, Editorial Board Secretary, FY2012-2014
- Japanese Society for Planetary Sciences, General Affairs Committee Member, FY2012-2018
- Japanese Society for Planetary Sciences, Editorial Board Member, FY2012-2018
- Japanese Society for Planetary Sciences, Future Planning Committee Member, FY2015-2018

- Japan Geoscience Union, Awards Committee Member, FY2014-2018
- Japan Geoscience Union, Student Presentation Award Committee Member, FY2014-2018

11. Outreach Activity

- Lectures for general audience: 15 times (Oct. 2013, Mar. 2014, Sep. 2014, Nov. 2014, Aug. 2015, Sep. 2015, Sep. 2015, Sep. 2017, Oct. 2017, Dec. 2017, Oct. 2018, Oct. 2018, Nov. 2018, Nov. 2018, Dec. 2018)

12. Internal Committee Membership

V. International Exchange Activities

13. Hosting/Sending Foreign Students and Researchers

(1) Hosting

Foreign Students: 0

Foreign Researchers: 0

(2) Sending

Students: 1

Researchers: 0

(3) Visitors from Abroad: 3

Takaaki Yokoyama

I. CV

Name: Takaaki Yokoyama

Age: 52

Present Position: Associate Professor

Education

March 1985 graduation Ibaraki High School

March 1990 B. Sc. Department of Aeronautical Engineering, Kyoto University

March 1992 M. Sc. Department of Aeronautical Engineering, Kyoto University

March 1997 Dr. of Sci. Department of Astronomy, The Graduate University for Advanced Studies (SOKENDAI)

Professional Experience

Apr. 1995, Post-doctoral research associate at National Astronomical Observatory of Japan (NAOJ)

Jan. 1996, PD Research fellow of the Japan Society for the Promotion of Science at NAOJ

Apr. 1998, Research associate at NAOJ

Apr. 2003, Associate Professor, Department of Earth and Planetary Science, The University of Tokyo

II. Scientific Research Activity

2. Major Achievements

We have been studying the solar and astrophysical plasma processes, mainly focusing on solar magnetic phenomena by using numerical simulations and observational data analysis. Our main achievements on solar activities are the reproduction of coronal jets, the reproduction of chromospheric evaporation in a flare, and the suggestion of a scaling-law on the temperature versus emission measure relation in solar, stellar and young star's flares. We have been also working on the basic physics of the MHD magnetic reconnection as a fundamental process behind these phenomena. We conducted numerical simulations of magnetic reconnection in the relativistic regime for the first time. We found an enhancement of reconnection rate under an influence of turbulent processes. As for the observation studies, we found an image data set of a reconnection inflow for the first time. Recent works are on the solar dynamo, in which we pointed out the importance of interactions between the local and global dynamos. The reproduction of tall spicules by proposing a noble mechanism to launch them by magnetic twist and the reproduction of chromospheric prominence's cool plasmas by proposing a noble reconnection-condensation model. Last year, we succeeded to update the turbulent acceleration model of solar wind by incorporating the effect of the parameter decay instability through which we are able to solve the missing reflection wave flux.

3. Five Important Papers (including three or more papers in this review period)

1. Yokoyama, T. and Shibata, K. 1995, Magnetic reconnection as the origin of X-ray jets and H α surges on the Sun, Nature, 375, 42

Numerical simulations of solar coronal jets based on the magnetic reconnection model. Not only reproducing a hot coronal jet but also a cool jet association.

2. Yokoyama, T. and Shibata, K. 2001, `Magnetohydrodynamic Simulation of a Solar Flare with Chromospheric Evaporation Effect Based on Magnetic Reconnection Model', The Astrophys. J., 549, 1160-1174

Numerical simulation of the chromospheric evaporation in a solar flare. Multi-dimensional reproduction including both energy release and evaporation processes was conducted for the first time. Based on the results, a scaling-law was derived for the temperature versus magnetic field strength, which lead the authors to another scaling law explaining temperature versus emission measure relation in solar, stellar, and young star's flares.

3. Antolin, P. et al., 2015, Resonant Absorption of Transverse Oscillations and Associated Heating in a Solar Prominence. II. Numerical Aspects, The Astrophys. J., 809, 72
4. Okamoto, T. J. et al., 2015, Resonant Absorption of Transverse Oscillations and Associated Heating in a Solar Prominence. I. Observational Aspects, The Astrophys., J., 809, 71

A series of papers in which a discovery of evidence of heating by the resonant absorption process of Alfvenic waves in the corona. The 1st paper is for numerical simulations and the 2nd is for the observations.

5. Hotta, H., Rempel, M., Yokoyama, T., 2016, `Large-scale magnetic fields at high Reynolds numbers in magnetohydrodynamic simulations', Science, 351, 1427

   Large scale simulations of MHD flows in a rotating star were conducted for addressing the solar dynamo problem. A noble mechanism was proposed that reduce the destruction of global scale magnetic field by a suppression of turbulent fluctuations through the small-scale dynamo.

4. Awards and Honors

5. Future Research Plan

We have studied solar-astrophysical plasma physics by means of theoretical and observational approaches, and we would like to continue doing this in the future. Also, we would like to challenge new fields in astrophysical and planetary physics.

6. Funding Received

・ JSPS KAKENHI, 15H03640, Principal Investigator, FY2015-2019, 10,100,000 yen
・ JSPS KAKENHI, 16H03954, Co-Investigator, FY2016-2018, 1,200,000 yen

7. Publications and Patents

(1) Peer-reviewed Journal Articles

1. Estimation of turbulent diffusivity with direct numerical simulation of stellar convection. H. Hotta, Y. Iida, T. Yokoyama. The Astrophysical Journal 751, L9, 2012
2. Detection of flux emergence, splitting, merging, and cancellation of network field. I Splitting and Merging. Y. Iida, H. Hagenaar, T. Yokoyama. The Astrophysical Journal 752, 149, 2012
3. Detection of the Horizontal Divergent Flow prior to the Solar Flux Emergence. Toriumi, S., Hayashi, K., and Yokoyama, T. , The Astrophysical Journal 751, 154, 2012
4. Magnetic field intensification by three-dimensional explosion process. H. Hotta, M. Rempel, T. Yokoyama. The Astrophysical Journal 759, L25, 2012
5. Multi-wavelength Spectroscopic Observation of Extreme-ultraviolet Jet in AR 10960. Y. Matsui,

T. Yokoyama, N. Kitagawa and S. Imada. The Astrophysical Journal 759, 15, 2012

6. Generation of twist on magnetic flux tubes at the base of the solar convection zone. H. Hotta, T. Yokoyama. Astronomy and Astrophysics 548, A74, 2012
7. Temporal and Spatial Analyses of Spectral Indices of Nonthermal Emissions Derived from Hard X-Rays and Microwaves. Asai, Ayumi; Kiyohara, Junko; Takasaki, Hiroyuki; Narukage, Noriyuki; Yokoyama, Takaaki; Masuda, Satoshi; Shimojo, Masumi; Nakajima, Hiroshi. The Astrophysical Journal 763, 87, 2013
8. Three-dimensional magnetohydrodynamic simulation of the solar magnetic flux emergence. Parametric study on the horizontal divergent flow. Toriumi, S., Yokoyama, T., Astronomy and Astrophysics 553, A55, 2013
9. Probing the Shallow Convection Zone: Rising Motion of Subsurface Magnetic Fields in the Solar Active Region. Toriumi, Shin; Ilonidis, Stathis; Sekii, Takashi; Yokoyama, Takaaki. The Astrophysical Journal 770, L11, 2013
10. "High-resolution Calculations of the Solar Global Convection with the Reduced Speed of Sound Technique. I. The Structure of the Convection and the Magnetic Field without the Rotation". Hotta, H.; Rempel, M.; Yokoyama, T., The Astrophysical Journal 786, 24, 2014
11. Fine Strand-like Structure in the Solar Corona from Magnetohydrodynamic Transverse Oscillations. Antolin, P.; Yokoyama, T.; Van Doorsselaere, T., The Astrophysical Journal 787, L22, 2014
12. Statistical Analysis of the Horizontal Divergent Flow in Emerging Solar Active Regions. Toriumi, Shin; Hayashi, Keiji; Yokoyama, Takaaki. The Astrophysical Journal 794, 19, 2014
13. Simulation Study of Solar Plasma Eruptions Caused by Interactions between Emerging Flux and Coronal Arcade Fields. Kaneko, Takafumi; Yokoyama, Takaaki. The Astrophysical Journal 796, 44, 2014
14. "High-resolution Calculation of the Solar Global Convection with the Reduced Speed of Sound Technique. II. Near Surface Shear Layer with the Rotation". Hotta, H.; Rempel, M.; Yokoyama, T., The Astrophysical Journal 798, 51, 2015
15. Efficient Small-scale Dynamo in the Solar Convection Zone. Hotta, H.; Rempel, M.; Yokoyama, T., The Astrophysical Journal 803, 42, 2015
16. Electron Density of Active Region Outflows Measured by the EUV Imaging Spectrometer on board Hinode. Kitagawa, N.; Yokoyama, T., The Astrophysical Journal 805, 97, 2015
17. Numerical Study on In-Situ Prominence Formation by Radiative Condensation in the Solar Corona. Kaneko, T.; Yokoyama, T., The Astrophysical Journal 806, 115, 2015
18. Resonant Absorption of Transverse Oscillations and Associated Heating in a Solar Prominence. I. Observational Aspects". Okamoto, Takenori J.; Antolin, Patrick; De Pontieu, Bart; Uitenbroek, Han; Van Doorsselaere, Tom; Yokoyama, Takaaki. The Astrophysical Journal 809, 71, 2015
19. "Resonant Absorption of Transverse Oscillations and Associated Heating in a Solar Prominence. II. Numerical Aspects" . Antolin, P.; Okamoto, T. J.; De Pontieu, B.; Uitenbroek, H.; Van Doorsselaere, T.; Yokoyama, T., The Astrophysical Journal 809, 72, 2015
20. "Three-dimensional MHD Magnetic Reconnection Simulations with a Finite Guide Field: Proposal of the Shock-evoking Positive-feedback Model". Wang, Shuoyang; Yokoyama, Takaaki; Isobe, Hiroaki. The Astrophysical Journal 811, 31, 2015
21. "Apparent Cross-field Superslow Propagation of Magnetohydrodynamic Waves in Solar Plasmas". Kaneko, T.; Goossens, M.; Soler, R.; Terradas, J.; Van Doorsselaere, T.; Yokoyama, T.; Wright, A. N., The Astrophysical Journal 812, 121, 2015

22. "Effect of Coronal Temperature on the Scale of Solar Chromospheric Jets". Iijima, H.; Yokoyama, T., The Astrophysical Journal 812, L30, 2015
23. Detection of Flux Emergence, Splitting, Merging, and Cancellation of Network Fields. II. Apparent Unipolar Flux Change and Cancellation. Iida, Y.; Hagenaar, H. J.; Yokoyama, T., The Astrophysical Journal 814, 134, 2015
24. "Doppler shift of the quiet region measured by meridional scans with the EUV Imaging Spectrometer onboard Hinode". Kitagawa, N., Hara, H., Yokoyama, T., The Astrophysical Journal 816, 14, 2016
25. Large-scale magnetic fields at high Reynolds numbers in magnetohydrodynamic simulations. Hotta, H., Rempel, M., Yokoyama, T., Science 351, 1427, 2016
26. Nonlinear reflection process of linearly-polarized, boradband Alfvén waves in the fast solar wind. Shoda, M.; Yokoyama, T., The Astrophysical Journal 820, 123, 2016
27. Modeling Observed Decay-less Oscillations as Resonantly Enhanced Kelvin-Helmholtz Vortices from Transverse MHD Waves and Their Seismological Application. Antolin, P.; De Moortel, I.; Van Doorsselaere, T.; Yokoyama, T., The Astrophysical Journal 830, L22, 2016
28. Double-cell-type Solar Meridional Circulation Based on a Mean-field Hydrodynamic Model. Bekki, Y.; Yokoyama, T., The Astrophysical Journal 835, 9, 2017
29. Observational Signatures of Transverse Magnetohydrodynamic Waves and Associated Dynamic Instabilities in Coronal Flux Tubes. Antolin, P.; De Moortel, I.; Van Doorsselaere, T.; Yokoyama, T., The Astrophysical Journal 836, 219, 2017
30. Non-kinematic Flux-transport Dynamos Including the Effects of Diffusivity Quenching. Ichimura, C.; Yokoyama, T., The Astrophysical Journal 839, 18, 2017
31. Reconnection-Condensation Model for Solar Prominence Formation. Kaneko, T.; Yokoyama, T., The Astrophysical Journal 845, 12, 2017
32. A Three-dimensional Magnetohydrodynamic Simulation of the Formation of Solar Chromospheric Jets with Twisted Magnetic Field Lines. Iijima, H.; Yokoyama, T., The Astrophysical Journal 848, 38, 2017
33. Convective Velocity Suppression via the Enhancement of the Subadiabatic Layer: Role of the Effective Prandtl Number. Bekki, Y.; Hotta, H.; Yokoyama, T., The Astrophysical Journal 851, 74, 2017
34. A Self-consistent Model of the Coronal Heating and Solar Wind Acceleration Including Compressible and Incompressible Heating Processes. Shoda, M.; Yokoyama, T.; Suzuki, T., K., The Astrophysical Journal 853, 190, 2018
35. High-frequency Spicule Oscillations Generated via Mode Conversion. Shoda. M.; Yokoyama, T., The Astrophysical Journal 854, 9, 2018
36. Anisotropic magnetohydrodynamic turbulence driven by parametric decay instability: the onset of phase mixing and Alfvén wave turbulence. Shoda, M.; Yokoyama, T., The Astrophysical Journal Letters 859, L17, 2018
37. Frequency-dependent Alfvén-wave Propagation in the Solar Wind: Onset and Suppression of Parametric Decay Instability. Shoda, M.; Yokoyama, T.; Suzuki, T., K., The Astrophysical Journal 860, 17, 2018
38. ALMA Observations of the Solar Chromosphere on the Polar Limb. Yokoyama, T.; Shimojo, M.; Okamoto, T. J.; Iijima, H., The Astrophysical Journal 863, 96, 2018
39. Impact of Dynamic State on the Mass Condensation Rate of Solar Prominences. Kaneko, T.; Yokoyama, T., The Astrophysical Journal 869, 136, 2018

(2) Non-peer-reviewed Articles

(3) Review Papers

(4) Books

(5) Other Publications

(6) Patents

8. Keynote, Invited, or Solicited Presentations

1. Yokoyama, T., Convections and Dynamos in the Solar Interior; 3rd East-Asian School and Workshop on Laboratory, Space Astrophysical Plasmas; Yoyogi, Tokyo; 2013/7/10
2. Yokoyama, T., Convection and Magnetic Field in the Solar Interior; Symposium on Planetary Science; Tohoku Univ.; 2014/2/20
3. Yokoyama, T., Soalr Jets as a Manifestation of Magnetic Reconnection; AOGS annual meeting; Sapporo; 2014/7/28-8/1
4. Yokoyama, T., Hotta, H., Rempel, M., Numerical Simulations of Convection and Dynamo in the Solar Interior; AOGS annual meeting; Sapporo; 2014/7/28-8/1
5. Yokoyama, T., MHD aspects of ICM; Max's 4 questions in X-ray Astronomy to be addressed with Astro-H; UTokyo; 2015/7/:31
6. Yokoyama, T., Alfven Wave Generation by Magnetic Reconnection; ISSI-BJ meeting on MHD Seismology of the Solar Corona; Beijing, China; 2015/12/14-18
7. Yokoyama, T., Iijima, H., Radiative magnetohydrodynamic simulations of chromospheric spicules; The Dynamic Sun: I. MHD Waves and Confined Transients in the Magnetized Atmosphere; Varanasi, India; 2016/2/22-26
8. Yokoyama, T., Iijima, H., Numerical study of solar chromospheric jets; MR2016; Napa, USA; 2016/3/7-11
9. Yokoyama, T., Numerical studies of loop oscillations; Theoretical and observational approaches to the solar magnetic field; NAOJ; 2016/5/27
10. Yokoyama, T., Studies of the Sun with Hinode and Numerical Simulations; The 10th EAMA; Seoul National University; 2016/9/27-30
11. Iijima, H., Yokoyama, T., 3D MHD simulations of chromospheric jets launched by twisted magnetic field lines; ISSI-BJ meeting on MHD Seismology of the Solar Corona; Beijing, China; 2017/1/16
12. Yokoyama, T., Oi, Y., Kaneko, T., Wang, S., Magnetic reconnection as triggers of solar plasma eruptions and filament formations; MR2017; Matsuyama; 2017/3/19-22
13. Yokoyama, T., Iijima, H., Shimojo, M., Okamojo, T. J., Solar chromospheric dynamics by ALMA observations; JpGU meeting; Makuhari, Chiba; 2017/5/20-25
14. Yokoyama, T., Iijima, H., MHD waves and jets in the solar atmosphere; 1st Asia-Pacific Conference on Plasma Physics; Chengdu, China; 2017/9/18-23
15. Yokoyama, T., Wang, S., Development and enhancement of three-dimensional MHD turbulence reconnection by coupling among multiple tearing layers; MR2018; Princeton, USA; 2018/9/4-8
16. Yokoyama, T., Early results from ALMA observations of the Sun; East Asian ALMA Science Workshop 2018; Osaka-pref. Univ.; 2018/12/17-19

III. Education Activity

9. Notable Achievements in Education

Advisees

- Master theses: 10 students

  Mar. 2012 H. Iijima
  Mar. 2013 T. Kaneko
  Mar. 2014 S.-Y. Wang, T. Nasuda, S. Kono
  Mar. 2015 M. Shoda
  Mar. 2016 C. Ichimura, Y. Oi
  Mar. 2017 Y.-K. Wang, Y. Bekki

- Doctoral theses: 7 students

  Mar. 2013 N. Kitagawa, S. Toriumi, H. Hotta
  Mar. 2015 H. Iijima
  Mar. 2016 T. Kaneko
  Mar. 2017 S.-Y. Wang
  Mar. 2018 M. Shoda

Lectures

- Undergraduate/Graduate, Geophysical numerical analysis, FY2012-2018
- Graduate, Space plasma physics I, FY2012, 2014
- Graduate, Space plasma physics II, FY2015, 2017
- Undergraduate, Space physics I, FY2012, 2013, 2014, 2016
- Undergraduate, Space physics II, FY2012, 2013, 2015, 2017
- Undergraduate, Solar and stellar physics, FY2012-2018
- Undergraduate, Classical mechanics, FY2014-2015
- Undergraduate, Introduction to earth and planetary physics, FY2014-2018
- Undergraduate, Overview of earth and planetary physics, FY2018

Student's awards

- AY2013 Incentive Award of the School of Science, the University of Tokyo for doctor students: Hideyuki Hotta
- AY2014 JpGU outstanding presentation award for students: Takafumi Kaneko
- AY2015 JpGU outstanding presentation award for students: Haruhisa Iijima
- AY2017 Incentive Award of the School of Science, the University of Tokyo for master students: Yuto Bekki
- AY2018 SGEPSS aurora medal: Munehito Shoda
- AY2018 Rironkon symposium young researcher's outstanding presentation award: Munehito Shoda
- AY2018 Incentive Award of the School of Science, the University of Tokyo for doctor students: Munehito Shoda

IV. External Activities

10. Contribution to Academic Community

- Seismological Society of Japan, Executive Board Member, FY2012-2013
- Seismological Society of Japan, Representative, FY2012-2018
- Seismological Society of Japan, Overseas Travel Fund Committee Chair, FY2012-2013
- Japan Geoscience Union, Program Committee Member, FY2012-2015
- Japan Geoscience Union, Executive Board Member, FY2016-2018
- Japan Geoscience Union, Financial Committee Member, FY2016-2018
- American Geophysical Union, Journal of Geophysical Research: Solid Earth, Associate Editor, 2012-2019
- American Geophysical Union, Union Fellow Committee Member, 2018
- Seismological Society of America, Nominating Committee Member, 2017
- International Association of Seismology and Physics of the Earth's Interior, Commission on Earthquake Source Mechanics Chair, 2017-2018

11. Outreach Activity

12. Internal Committee Membership

- Department of Earth and Planetary Science, Network Committee, Chair, FY2013-2015
- Department of Earth and Planetary Science, Education Committee, FY2013-2018
- Department of Earth and Planetary Physics, Education Committee, FY2013-2016, Vice Chair, FY2017-2018
- School of Science, Network Committee, FY2013-2015
- School of Science, Public-Relation Committee, Rigakubu-News editorial board, Chair, 2013-2017

V. International Exchange Activities

13. Hosting/Sending Foreign Students and Researchers

(1) Hosting

Foreign Students: 7

Foreign Researchers: 1

(2) Sending

Students: 10

Researchers: 0

(3) Visitors from Abroad: 10

Yutaka Ohira

I. CV

Name: Yutaka Ohira

Age: 37

Present Position: Assistant professor

Education

Mishima High School, Osaka, March, 2001 (graduation)

B. Sc. Department of physics, Kwansei Gakuin University, March, 2005

M. Sc. Department of Earth and Space Science, Osaka University, March, 2007

Ph. D. Department of Earth and Space Science, Osaka University, March, 2010

Professional Experience

Apr. 2010-Mar. 2012, Postdoctoral Researcher, Institute of Particle and Nuclear Studies, KEK

Apr. 2012-Mar. 2014, Postdoctoral Researcher, Department of Physics and Mathematics, Aoyama Gakuin University

Apr. 2014-Dec. 2017, Assistant Professor, Department of Physics and Mathematics, Aoyama Gakuin University

Dec. 2018-, Assistant Professor, Department of Earth and Planetary Science, The University of Tokyo

II. Scientific Research Activity

2. Major Achievements

I have been studying on high energy astrophysics, mainly based on plasma physics. In particular, I'm interested in cosmic rays and generation of magnetic field in the universe. I study it by using various method such as large-scale simulations, analytical methods, phenomenological modeling, comparing observed data and theoretical expectations. In recent years, I extended my research areas to solar planetary physics, laser plasma physics and lightning. We showed that an energy spectrum of cosmic rays is modified by an escape process from an accelerator. In addition, we showed that the escape process is important for understanding the observed data of gamma rays from supernova remnants that are thought to be the accelerator of cosmic rays. Furthermore, we showed that neutral atoms have important roles on physics of cosmic-ray acceleration. I first performed a plasma particle simulation for collisionless shocks and showed that the charge exchange process of hydrogen atoms is important for injection of the cosmic ray acceleration.

3. Five Important Papers (including three or more papers in this review period)

1. Ohira, Y., Murase, K., & Yamazaki, R. (2011). Gamma-rays from molecular clouds illuminated by cosmic rays escaping from interacting supernova remnants. Monthly Notices of the Royal Astronomical Society, 2011, 410, 1577. https://doi.org/10.1111/j.1365-2966.2010.17539.x

Fermi gamma-ray space telescope showed that gamma-ray spectra from supernova remnants that are thought to be the accelerator of cosmic rays are extremely different from theoretical expectations. In this paper, we showed that the observed spectra can be naturally explained by considering the escape process of cosmic rays from supernova remnants. Our model became the standard model for gamma-ray spectra from middle-aged supernova remnants and the paper has been frequently cited. (Citation 133, ADS/Sept. 29, 2019)

2. Ohira, Y., Murase, K., & Yamazaki, R. (2010). Escape-limited model of cosmic-ray acceleration revisited. Astronomy and Astrophysics, 513, id.A17. https://doi.org/10.1051/0004-6361/200913495

The cosmic-ray spectrum observed at Earth was believed to be decided by acceleration and propagation in our galaxy of cosmic rays at that time. In this paper, we showed that the energy spectrum of cosmic rays is modified by the escape process from the accelerator of cosmic rays and the spectral change depends on the time evolution of the maximum energy of cosmic rays and time evolution of the number of cosmic rays in the accelerator. After this paper were published, detailed studies about the escape of cosmic rays have been studied actively. (Citation 78, ADS/Sept. 19, 2019)

3. Ohira, Y., & Ioka, K. (2011). Cosmic-ray helium hardening. The Astrophysical Journal Letters, 729, id. L13. https://doi.org/10.1088/2041-8205/729/1/L13

The standard model at that time predicted that cosmic-ray spectra of any heavy ions have a same spectrum. However, recent observation of cosmic rays showed that the spectrum of cosmic-ray protons is different from that of cosmic-ray helium. In this paper, we showed that the escape process of cosmic rays can explain the observed feature of cosmic-ray spectra. In addition, we proposed that the origin of galactic cosmic rays should be superbubbles generated by many supernova remnants to explain the observed data quantitatively. (Citation 67, ADS/Sept. 19, 2019)

4. Ohira, Y., Reville, B., Kirk, J. G., & Takahara, F. (2009). Two-dimensional particle-in-cell simulations of the nonresonant cosmic-ray-driven instability in supernova remnant shocks. The Astrophysical Journal, 698, 445. https://doi.org/10.1088/0004-637X/698/1/445

In this paper, we investigated by using large-scale plasma simulations the nonlinear evolution of the Bell instability that had been proposed to amplify magnetic fields around collisionless shocks of supernova remnants. Our simulation showed that all the behaviors are consistent with the linear analysis provided by Bell (MNRAS, 2004) at the linear phase and the magnetic fields are strongly amplified at the nonlinear phase. In addition, we showed that plasma is strongly heated during the magnetic field amplification. (Citation 43, ADS/Sept. 19, 2019)

5. Ohira, Y. (2013). Simulations of collisionless perpendicular shocks in partially ionized plasmas. Physical Review Letters, 111, 245002. https://doi.org/10.1103/PhysRevLett.111.245002

Galactic cosmic rays are believed to be accelerated by collsionless shocks of supernova remnants. Early studies about the collisionless shocks assmumed that the upstream gas is fully ionized. However, in reality, the collisionless shocks of supernova remnants propagate partially ionized plasmas. In this paper, we first performed a plasma particle simulation about the collisionless shock propagating to a partially ionized plasma. We showed that some downstream hot protons are leak to the upstream region by the charge exchange process and the leaking particles are preferentially accelerated by the shock wave. (Citation 13, ADS/Sept. 19, 2019)

4. Awards and Honors

- Ohira, Y., Young Scientist Award of the Physical Society of Japan, Oct. 2016

5. Future Research Plan

We will continue studies on cosmic rays in the current universe based on plasma physics. In particular, we are going to investigate the magnetic field amplification around collisionless shocks of supernova remnants, cosmic-ray acceleration in partially ionized plasmas, and escape of cosmic rays from accelerators. In addition, we will start to study high energy astrophysics in the early universe, which have not been studied based on plasma physics. We plan to study cosmic-ray accelerations and generations of magnetic fields in the early universe. Furthermore, we try to propose a new observation and a new plasma experiment to verify our studies.

6. Funding Received

- JSPS KAKENHI, 16K17702, Principal Investigator, FY2016-2018, 3,900,000 yen
- MEXT/JSPS Leading Initiative for Excellent Young Researchers, Principal Investigator, FY2018-2022, 24,000,000 yen

7. Publications and Patents

(1) Peer-reviewed Journal Articles

1. Kohri, K., Ohira, Y., & Ioka, K. (2012). Gamma-ray flare and absorption in the Crab nebula: lovely TeV-PeV astrophysics. Monthly Notices of the Royal Astronomical Society, 424, 2249-2254. https://doi.org/10.1111/j.1365-2966.2012.21388.x
2. Ohira, Y. (2012). Historical Effects of Leakage Neutral Particles on Shocks. The Astrophysical Journal, 758, article id. 97. https://doi.org/10.1088/0004-637X/758/2/97
3. Ohira, Y., Yamazaki, R., Kawanaka, N., & Ioka, K. (2012). Escape of cosmic-ray electrons from supernova remnants. Monthly Notices of the Royal Astronomical Society, 427, pp. 91-102. https://doi.org/10.1111/j.1365-2966.2012.21908.x
4. Fujita, Y., & Ohira, Y. (2013). Radio mini-halo emission from cosmic rays in galaxy clusters and heating of the cool cores. Monthly Notices of the Royal Astronomical Society, 428, p.599-608. https://doi.org/10.1093/mnras/sts050.
5. Fujita, Y., Ohira, Y., & Yamazaki, R. (2013). Entropy at the Outskirts of Galaxy Clusters as Implications for Cosmological Cosmic-Ray Acceleration. The Astrophysical Journal Letters, 767, article id. L4. https://doi.org/10.1088/2041-8205/767/1/L4.
6. Ohira, Y. (2013). Turbulent Shear Acceleration. The Astrophysical Journal Letters, 767, article id. L16. https://doi.org/10.1088/2041-8205/767/1/L16
7. Katsuda, S., Ohira, Y., et al.(Ohira, Y., 7 人中 2 番目). (2013). Dynamics of X-Ray-emitting Ejecta in the Oxygen-rich Supernova Remnant Puppis A Revealed by the XMM-Newton Reflection Grating Spectrometer. The Astrophysical Journal, 768, article id. 182. https://doi.org/10.1088/0004-637X/768/2/182.
8. Fujita, Y., Kimura, S., & Ohira, Y. (2013). Stability analysis for cosmic-ray heating of cool cores in galaxy clusters. Monthly Notices of the Royal Astronomical Society, 432, p.1434-1443. https://doi.org/10.1093/mnras/stt563/.
9. Inoue, T., Shimoda, J., Ohira, Y., & Yamazaki, R. (2013). The Origin of Radially Aligned Magnetic Fields in Young Supernova Remnants. The Astrophysical Journal Letters, 772, article id. L20. https://doi.org/10.1088/2041-8205/772/2/L20.
10. Fujita, Y., Ohira, Y., Yamazaki, R. (2013). The Fermi Bubbles as a Scaled-up Version of Supernova Remnants. The Astrophysical Journal Letters, 775, article id. L20. https://doi.org/10.1088/2041-8205/775/1/L20.
11. Ohira, Y. (2013). Simulations of Collisionless Perpendicular Shocks in Partially Ionized Plasmas. Physical Review Letters, 111, id. 245002. https://doi.org/10.1103/PhysRevLett.111.245002.
12. Yamazaki, R., Ohira, Y., Sawada, M., & Bamba, A. (2014). Research in Astronomy and Astrophysics, 14, article id. 165-178. https://doi.org/10.1088/1674-4527/14/2/005.

13. Shibata, T., Ohira, Y., Kazunori, K., & Yamazaki, R. (2014). Production cross sections of γ-rays, electrons, and positrons in p-p collisions. Astroparticle Physics, 55, p. 8-16. https://doi.org/10.1016/j.astropartphys.2014.01.001.
14. Ohira, Y. (2014). Acoustic instability in the neutral precursor region of collisionless shocks propagating into partially ionized plasmas. Monthly Notices of the Royal Astronomical Society, 440, p.514-518. https://doi.org/10.1093/mnras/stu248.
15. Fujita, Y., Ohira, Y., & Yamazaki, R. (2014). A Hadronic-leptonic Model for the Fermi Bubbles: Cosmic-Rays in the Galactic Halo and Radio Emission. The Astrophysical Journal, 789, article id. 67. https://doi.org/10.1088/0004-637X/789/1/67.
16. Yamazaki, R. et al. (Ohira, Y., 6 人中 5 番目). (2015). Electron acceleration with improved Stochastic Differential Equation method: Cutoff shape of electron distribution in test-particle limit. Journal of High Energy Astrophysics, 5, p. 1-8. https://doi.org/10.1016/j.jheap.2015.02.001.
17. Shimoda J., et al. (Ohira, Y., 6 人中 3 番目). (2015). On Cosmic-ray Production Efficiency at Supernova Remnant Shocks Propagating into Realistic Diffuse Interstellar Medium. The Astrophysical Journal, 803, article id. 98. https://doi.org/10.1088/0004-637X/803/2/98.
18. Katsuda, S., et al. (Ohira, Y., 18 人中 10 番目). (2015). Evidence for Thermal X-Ray Line Emission from the Synchrotron-dominated Supernova Remnant RX J1713.7-3946. The Astrophysical Journal, 814, article id. 29. https://doi.org/10.1088/0004-637X/814/1/29.
19. Ohira, Y. (2016). Magnetic Field Amplification by Collisionless Shocks in Partially Ionized Plasmas. The Astrophysical Journal, 817, article id. 137. https://doi.org/10.3847/0004-637X/817/2/137.
20. Katsuda, S., et al. (Ohira, Y., 12 人中 3 番目). (2016). Spatially Resolved Spectroscopy of a Balmer-dominated Shock in the Cygnus Loop: An Extremely Thin Cosmic-Ray Precursor?. The Astrophysical Journal Letters, 819, article id. L32. https://doi.org/10.3847/2041-8205/819/2/L32.
21. Ohira, Y., Kawanaka, N., & Ioka, K. (2016). Cosmic-ray hardenings in light of AMS-02 data. Physical Review D, 93, id.083001. https://doi.org/10.1103/PhysRevD.93.083001.
22. Yamazaki, R., Asano, K., & Ohira, Y. (2016). Electromagnetic afterglows associated with gamma-ray emission coincident with binary black hole merger event GW150914. Progress of Theoretical and Experimental Physics, 2016, id.051E017. https://doi.org/10.1093/ptep/ptw042.
23. Takeda, S., et al. (Ohira, Y., 9 人中 8 番目). (2016). Suzaku observations of the hard X-ray spectrum of Vela Jr. (SNR RX J0852.0-4622). Publications of the Astronomical Society of Japan, 68, id.S10. https://doi.org/10.1093/pasj/psw036.
24. Tomita, S., & Ohira, Y. (2016). Weibel Instability Driven by Spatially Anisotropic Density Structures. The Astrophysical Journal, 825, article id. 103. https://doi.org/10.3847/0004-637X/825/2/103.
25. Ohira, Y. (2016). Injection to Rapid Diffusive Shock Acceleration at Perpendicular Shocks in Partially Ionized Plasmas. The Astrophysical Journal, 827, article id. 36. https://doi.org/10.3847/0004-637X/827/1/36.
26. Sato, T., et al. (Ohira, Y., 13 人中 5 番目). (2017). Multi-year X-Ray Variations of Iron-K and Continuum Emissions in the Young Supernova Remnant Cassiopeia A. The Astrophysical Journal, 836, article id. 225. https://doi.org/10.3847/1538-4357/836/2/225.
27. Ohira, Y., & Yamazaki, R. (2017). Inverse Compton emission from a cosmic-ray precursor in RX J1713.7-3946. Journal of High Energy Astrophysics, 13, p. 17-21. https://doi.org/10.1016/j.jheap.2017.03.001.
28. Acero, F., et al., (Ohira, Y., 約 100 名中約 50 番目). (2017). Prospects for Cherenkov Telescope Array Observations of the Young Supernova Remnant RX J1713.7-3946. The Astrophysical

Journal, 840, article id. 74. https://doi.org/10.3847/1538-4357/aa6d67.

29. Shimoda, J., Ohira, Y., et al. (5 名中 2 番目). (2018). Polarized Balmer line emission from supernova remnant shock waves efficiently accelerating cosmic rays. Monthly Notices of the Royal Astronomical Society, 473, p.1394-1406. https://doi.org/10.1093/mnras/stx2339.
30. Bamba, A., Ohira, Y., (11 名中 2 番目). (2018). The Transition from Young to Middle-aged Supernova Remnants: Thermal and Nonthermal Aspects of SNR N132D. The Astrophysical Journal, 854, article id. 71. https://doi.org/10.3847/1538-4357/aaa5a0.
31. Ohira, Y., Kisaka, S., & Yamazaki, R. (2018). Pulsar Wind Nebulae inside Supernova Remnants as Cosmic-Ray PeVatrons. Monthly Notices of the Royal Astronomical Society, 478, p.926-931. https://doi.org/10.1093/mnras/sty1159.
32. Sezer, A., Ergin, T., Yamazaki, R., & Ohira, Y., Cesur, N. (2018). A Suzaku X-ray study of the mixed-morphology supernova remnant Kes 69 and searching for its gamma-ray counterpart. Monthly Notices of the Royal Astronomical Society, 481, p.1416-1425. https://doi.org/10.1093/mnras/sty2387.
33. Umeda, T., et al. (Ohira, Y., 15 人中 3 番目). (2019). Full particle-in-cell simulation of the interaction between two plasmas for laboratory experiments on the generation of magnetized collisionless shocks with high-power lasers. Physics of Plasmas, 26, id.032303. https://doi.org/10.1063/1.5079906.

(2) Non-peer-reviewed Articles

(3) Review Papers

1. Helder, E. A., Vink, J., Bykov, A. M., Ohira, Y., Raymond, J. C., & Terrier, R. (2012). Observational signatures of particle acceleration in supernova remnants. Space Science Review, 173, 369. https://doi.org/10.1007/s11214-012-9919-8

(4) Books

(5) Other Publications

(6) Patents

8. Keynote, Invited, or Solicited Presentations

1. Ohira, Y., Escape of cosmic-ray protons and electrons from SNRs, ALMA Workshop “Science with Mopra for the ALMA”, Tokyo Japan, 2012/06/08.
2. Ohira, Y., Simulation of collisionless perpendicular shocks in partially ionized plasmas, Workshop “Astrophysical Mechanisms of Particle Acceleration and Escape from the Accelerators, Aspen USA, 2013/09/01.
3. Ohira, Y., Supernova remnants as cosmic ray sources, LST General Meeting, Chiba Tokyo, 2014/01/14.
4. Ohira, Y., Cosmic Ray Acceleration Mechanism, The 7th International Workshop on Very High Energy Particles Astronomy, Chiba Japan, 2014/03/19.
5. Ohira, Y., Collisionless shocks, plasma instabilities, and particle accelerations in partially ionized plasmas, COSPAR2014, Moscow Russia, 2014/08/02.
6. Ohira, Y., Collisionless shocks, plasma instabilities, and particle accelerations in partially ionized plasmas, The ASTRO-H JP/NL Bilateral workshop 2015, Kanagawa Japan, 2015/05/16.

7. Ohira, Y., Collisionless shocks in partially ionized plasma, ISSI team meeting 2, Bern Switzerland, 2015/06/01.
8. Ohira, Y., Cosmic ray propagation, SNR Workshop 2015, Nagoya Japan, 2015/06/18.
9. Ohira, Y., Cosmic rays, supernova remnants and superbubbles, HEAP2015, Ibaraki Japan, 2015/10/06.
10. Ohira, Y., Particle acceleration, SNSNR2015, Kanagawa Japan, 2015/10/09.
11. Ohira, Y., Particle accelerations, plasma instabilities, and collisionless shocks in partially ionized plasma, AAPPS—DPP2018, Kanazawa Japan, 2018/11/12.
12. Ohira, Y., Collisionless shock driven by a high-power laser, 4th STEPS Symposium on Photon Science, Tokyo Japan, 2019/03/22.

III. Education Activity

9. Notable Achievements in Education

Advisees

- Master theses: no student
- Doctral theses: no student

Lectures

- Undergraduate, Exercise in Basic Earth and Planetary Physics Ⅳ, FY2018
- Undergraduate, Senior Project in Earth and Planetary Physics, FY2018
- Undergraduate, Senior Research in Earth and Planetary Physics, FY2018

IV. External Activities

10. Contribution to Academic Community

11. Outreach Activity

12. Internal Committee Membership

V. International Exchange Activities

13. Hosting/Sending Foreign Students and Researchers

(1) Hosting

Foreign Students: 0

Foreign Researchers: 0

(2) Sending

Students: 3

Researchers: 0

(3) Visitors from Abroad: 0

Kunihiro Keika

I. CV

Name: Kunihiro Keika

Age: 40

Present Position: Assistant Professor

Education

Hyuga Gakuin High School, Miyazaki, Mar. 1997 (graduation)

B. Sc. Department of Geophysics, Kyoto University, Mar. 2001

M. Sc. Department of Earth and Planetary Science, Kyoto University, Mar. 2003

Ph. D. Department of Earth and Planetary Science, Kyoto University, Mar. 2006

Professional Experience

Apr. 2006-Mar. 2009, Postdoctoral Fellow, Space Research Institute, Austrian Academy of Sciences.

Apr. 2009-Aug. 2011, Research Scientist, New Jersey Institute of Technology.

Sep. 2011-Jun. 2013, Assistant Research Professor, New Jersey Institute of Technology.

Jul. 2013-Oct. 2016, Designated Assistant Professor, Solar-Terrestrial Environment Laboratory (Institute for Space-Earth Environmental Research, as of Oct. 2015), Nagoya University.

Apr. 2015-Mar. 2017, Part-time Lecturer, School of International Liberal Studies, Chukyo University.

Nov. 2016-, Assistant Professor, Department of Earth and Planetary Science, The University of Tokyo.

II. Scientific Research Activity

2. Major Achievements

I have conducted observational research on the plasma dynamics in the Earth's magnetosphere, primarily using data from satellites and ground-based observatories. Particularly, my research has been focused on transport, acceleration, and loss of energetic particles (with energies of >keV), which dominates plasma pressure and in turn govern the global magnetospheric dynamics in response to explosive phenomena such as solar flares, magnetic storms, and substorms. One of my studies was successful in estimating the ion loss rate and its contribution to storm recovery, using a combination of remote-sensing and in-situ observations. Another study examined the occurrence probability of electromagnetic ion cyclotron waves, which are responsible for ion loss into the ionosphere, quantifying for the first time the spatial dependence on solar wind and geomagnetic activities (magnetic storm phases). Mass- and charge dependence of those acceleration and loss processes is one of my focused science topics; dominant ion species depend on plasma origins, namely the solar wind and the ionosphere. I have studied the behavior of ionospheric oxygen ions, which makes a significant contribution to magnetospheric dynamics under disturbed conditions. I published a review paper and have been leading observational studies based on recent multi-satellite missions. I have been involved in satellite missions such as Arase, Van Allen Probes, and THEMIS, for maximizing scientific outcomes and developing data analysis software. An ongoing study is extended toward plasma dynamics in the magnetospheres of other magnetized planets such as Saturn and Mercury.

3. Five Important Papers (including three or more papers in this review period)

1. K. Keika, L. M. Kistler, and P. C. Brandt (2013), Energization of O^+ Ions in the Earth's Inner Magnetosphere and the Effects on Ring Current Buildup: A Review of Previous Observations and Possible Mechanisms, *J. Geophys. Res.*, 118, 1–24, doi:10.1002/jgra.50371.

In situ observations and modeling work have confirmed that singly charged oxygen ions, O^+, which are of Earth's ionospheric origin, are heated/accelerated up to >100 keV in the magnetosphere. The energetic O^+ population makes a significant contribution to the plasma pressure in the Earth's inner magnetosphere during magnetic storms. However, it remains an open question what mechanism(s)/process(es) play the dominant role in stronger O^+ energization. This review paper summarizes important previous spacecraft observations, introduces the proposed mechanisms/processes that generate O^+-rich energetic plasma population, and outlines possible scenarios of O^+ pressure abundance in the Earth's inner magnetosphere. This paper makes a significant contribution to planning science objectives/topics to be achieved by new satellite missions such as Van Allen Probes and Arase. (Citation 48, GS/Sep. 20, 2019)

2. Keika, K. et al. (2018). Ion Energies Dominating Energy Density in the Inner Magnetosphere: Spatial Distributions and Composition, Observed by Arase/MEP-i, *Geophys. Res. Lett.*, doi:10.1029/2018GL080047.

This study investigates the spatial distributions and composition of *contributing energies*, which we term an energy range that makes the dominant contribution to energy density, in the inner magnetosphere during the main phase of magnetic storms. The results show that the inner part ($L \leq 5$) is dominated by relatively low-energy ions adiabatically transported from the plasma sheet by enhanced convection. The contributing energies are higher for O+ than for H+ at higher L shells ($L > 5$), particularly during the storms driven by coronal mass ejections. The results provide in situ evidence of the connection between a phenomenon on large spatial, long time scales and that on small spatial, short time scales, that is, the contribution from mass-dependent/selective acceleration processes associated with substorm activity to the buildup of the outer part the ring current. (Citation 1, GS/Sep. 20, 2019)

3. K. Keika, K. Seki, M. Nosé, Y. Miyoshi, L. J. Lanzerotti, D. G. Mitchell, M. Gkioulidou, and J. W. Manweiler (2018), Three-step buildup of the 17 March 2015 storm ring current: Implication for the cause of the unexpected storm intensification, *J. Geophys. Res. Space Physics*, 123, doi:10.1002/2017JA024462.

This study investigates the dynamics of energetic ions during an unexpectedly intense magnetic storm with the Dst minimum of -223 nT that occurred on 17 March 2015. The analysis results showed that the 17 March 2015 storm developed in three phases: penetration of cold plasma sheet population, further penetration of the population and oxygen energization (acceleration and/or transport), and deep penetration of hot plasma sheet population. We conclude that the third development magnifies the magnetic storm by about 50%. This is a pioneer work of the energy spectral evolution of energetic ions during magnetic storms, followed by new studies that focus on the relative contributions to the ring current dynamics from different energy ranges. (Citation 2, GS/Sep. 20, 2019)

4. K. Keika, K. Takahashi, A. Y. Ukhorskiy, and Y. Miyoshi (2013), Global characteristics of electromagnetic ion cyclotron waves: Occurrence rate and its storm dependence, *J. Geophys. Res.*, 118, 1–16, doi:10.1002/jgra.50385.

This study investigates the global characteristics and background plasma environments for electromagnetic ion cyclotron waves, which play an important role in acceleration and loss of geospace plasma. Using a large dataset (longer than 4 years) from satellite observations, the results showed that active regions of the waves depend on solar wind conditions, geomagnetic activity, and the dominant frequency of the waves. The results indicate at least two independent processes: solar wind compression and injections of new, highly energetic ion population from the plasma sheet. The derived spatial distributions and dominant frequency have been frequently used for the input of radiation belt models. (Citation 63, GS/Sep. 20, 2019)

5. K. Keika, M. Nosé, P. C. Brandt, S. Ohtani, E. C. Roelof, and D. G. Mitchell (2006), Contribution of charge exchange loss to the storm time ring current decay: IMAGE/HENA observations, *J. Geophys. Res.*, 111, A11S12, doi:10.1029/2006JA011789.

This study addresses the contribution of charge exchange loss of the ring current ions to the decay of the storm-time ring current, using the measurements of energetic neutral atoms (ENAs). This is a unique study based on the fact that total energy of measured ENAs is equal to the loss energy from the ring current region. This is also the first statistical estimate of the charge exchange contribution from both protons and oxygen ions. The modeling of the storm recovery based on the observations indicates that the rapid storm recovery cannot be reproduced by charge exchange loss alone. The results make a significant contribution to better understanding and modeling of magnetic storm development and recovery. (Citation 20, GS/Sep. 20, 2019)

4. Awards and Honors

- Obayashi Early Career Scientist Award: Society of Geomagnetism and Earth, Planetary and Space Sciences, Nov. 2015.
- Group Achievement Award to Van Allen Probes Project Team: National Aeronautics and Space Administration, Nov. 2013.

5. Future Research Plan

I will conduct research on the plasma dynamics of the Earth’s magnetosphere, particularly on one of the unresolved issues: the connection between phenomena on large spatial, long time scales (e.g., magnetic storms caused by inner magnetospheric pressure enhancements) and those on small spatial, short time scales (e.g., substorms caused by magnetic reconnection and dipolarization). Transport and heating/acceleration of solar wind plasma and ionospheric plasma are also an important science topic to be addressed by multi-spacecraft observations of plasma and fields as well as ground-based observations. The connection of global dynamics with micro-plasma physics such as wave-particle interactions also has to be taken into consideration. Utilizing in-situ ion measurements from multiple spacecraft that are capable of distinguishing between different ion species and have been available since 2010s’, I will also continue to study mass- and/or charge- dependent plasma energization in the magnetotail. The main purposes of these studies are to advance our understanding of the multi-species/fluid plasma dynamics in Earth’s magnetosphere and then provide clues for comprehensively understanding universal plasma dynamics in the magnetospheres of other magnetized planets. (e.g., plasma heating in the ionosphere-magnetosphere transition region, specie-dependent/selective ion acceleration in the magnetosphere)

6. Funding Received

- NASA Living with Star TR&T, The Role of Currents and Conductance in Controlling Plasmasphere Dynamics, FY2010-2013, ~$100,000.00.
- NASA Living with Star TR&T, Ring Current Control of the Outer Radiation Belt: Local Wave-Particle Interactions and Large-Scale Magnetopause Losses, FY2011-2013, ~$100,000.00.
- JSPS KAKENHI, 17K14400, Principal Investigator, FY2017-2019, 2,900,000 yen
- JSPS KAKENHI, 26800257, Principal Investigator, FY2014-2017, 3,000,000 yen
- JSPS KAKENHI, 16H02229, Co-Investigator, FY2016-2019, 1,500,000 yen

- JSPS KAKENHI, 19H01949, Co-Investigator, FY2019-2021, 2,000,000 yen (planned)
- JSPS KAKENHI, 16H04057, Co-Investigator, FY2016-2018, 1,050,000 yen
- JSPS KAKENHI, 25287127, Co-Investigator, FY2013-2015, 500,000 yen

7. Publications and Patents

(1) Peer-reviewed Journal Articles

1. K. Keika, S. Kasahara, S. Yokota, M. Hoshino, K. Seki, M. Nosé, T. Amano, Y. Miyoshi, and I. Shinohara (2018), Ion Energies Dominating Energy Density in the Inner Magnetosphere: Spatial Distributions and Composition, Observed by Arase/MEP-i, *Geophys. Res. Lett.*, doi:10.1029/2018GL080047.
2. K. Keika, K. Seki, M. Nosé, Y. Miyoshi, L. J. Lanzerotti, D. G. Mitchell, M. Gkioulidou, and J. W. Manweiler (2018), Three-step buildup of the 17 March 2015 storm ring current: Implication for the cause of the unexpected storm intensification, *J. Geophys. Res. Space Physics*, 123, doi:10.1002/2017JA024462.
3. K. Keika, Y. Miyoshi, S. Machida, A. Ieda, K. Seki, T. Hori, Y. Miyashita, M. Shoji, I. Shinohara, V. Angelopoulos, J. W. Lewis, A. Flores (2017), Visualization tool for three□dimensional plasma velocity distributions (ISEE_3D) as a plug□in tool for SPEDAS, *Earth, Planets and Space*, 69, 170, doi:10.1186/s40623□017□0761□9.
4. K. Keika, K. Seki, M. Nosé, S. Machida, Y. Miyoshi, L. J. Lanzerotti, D. G. Mitchell, M. Gkioulidou, D. Turner, H. Spence, and B. A. Larsen (2016), Storm time impulsive enhancements of energetic oxygen due to adiabatic acceleration of preexisting warm oxygen in the inner magnetosphere, *J. Geophys. Res. Space Physics*, 121, doi:10.1002/2016JA022384.
5. K. Keika, R. Kataoka, and Y. Ebihara (2015), What caused the rapid recovery of the Carrington storm?, Earth, Planets and Space, 67:65, doi:10.1186/s40623-015-0234-y
6. K. Keika, K. Takahashi, A. Y. Ukhorskiy, and Y. Miyoshi (2013), Global characteristics of electromagnetic ion cyclotron waves: Occurrence rate and its storm dependence, *J. Geophys. Res.*, 118, 1–16, doi:10.1002/jgra.50385.
7. Imajo, S., Nosé, M., Matsuoka, A., Kasahara, S., Yokota, S., Teramoto, M., et al. (2018). Magnetosphere-ionosphere connection of storm-time region-2 field-aligned current and ring current: Arase and AMPERE observations. *Journal of Geophysical Research: Space Physics*, *123*. https://doi.org/10.1029/2018JA025865
8. Yamamoto, K., Nosé, M., Kasahara, S., Yokota, S., Keika, K., Matsuoka, A., et al. (2018). Giant pulsations excited by a steep earthward gradient of proton phase space density: □Arase observation. *Geophysical Research Letters*, *45*, 6773–6781. https://doi.org/10.1029/2018GL078293
9. Oimatsu, S., Nosé, M., Teramoto, M., Yamamoto, K., Matsuoka, A., Kasahara, S., et al. (2018). Drift-bounce resonance between Pc5 pulsations and ions at multiple energies in the nightside magnetosphere: Arase and MMS observations. Geophysical Research Letters, 45, 7277–7286. https://doi.org/ 10.1029/2018GL078961
10. Nosé, M., Matsuoka, A., Kasahara, S., Yokota, S., Teramoto, M., Keika, K., et al. (2018). Magnetic field dipolarization and its associated ion flux variations in the dawnside deep inner magnetosphere: Arase observations. Geophysical Research Letters, 45, 7942–7950. https://doi.org/10.1029/ 2018GL078825
11. Miyoshi *et al. Earth, Planets and Space (2018) 70:96* https://doi.org/10.1186/s40623-018-0867-8.

12. Mitani, K., Seki, K., Keika, K., Gkioulidou, M., Lanzerotti, L. J., Mitchell, D. G., & Kletzing, C. A. (2018). Radial transport of higher-energy oxygen ions into the deep inner magnetosphere observed by Van Allen Probes. *Geophysical Research Letters*, *45*. https://doi.org/10.1029/2018GL077500

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16. M. Shoji, Y. Miyoshi, Y. Katoh, K. Keika, V. Angelopoulos, S. Kasahara, K. Asamura, S. Nakamura, and Y. Omura (2017), Ion hole formation and nonlinear generation of electromagnetic ion cyclotron waves: THEMIS observations, *Geophys. Res. Lett.*, 44, 8730–8738, doi:10.1002/2017GL074254.

17. T. Iwata, K. Y. Kawakatsu, G. Murakami, Y. Ezoe, S. Kameda, K. Keika, T. Arai, S. Matsuura, T. Saiki, T. Imamura, K. Ogohara, A. Oyama, T. Ikenaga (2016), Studies on Solar System Explorations using DESTINY: the Demonstration and Experiment of Space Technology for Interplanetary Voyage, Vol. 14, No. ists30, doi:10.2322/tastj.14.Pk_111.

18. N. Umemura, T. Segawa, Y. Miyashita, K. Keika, Y. Miyoshi, T. Hori, M. Shoji, Y. Tanaka, K. Seki, and I. Shinohara (2016), Development and Future Plans of the Web Based Data Analysis Tool ERGWAT, *J. Space Sci. Info. Jpn.*, vol. 4, JAXA-RR-16-007 (ISSN 1349-1113), 25-31, doi:10.20637/JAXA-RR-16-007/0003.

19. C. Martinez-Calderon, K. Shiokawa, Y. Miyoshi, K. Keika, M. Ozaki, I. Schofield, M. Connors, C. Kletzing, M. Hanzelka, O. Santolik, and W. S. Kurth (2016), ELF/VLF wave propagation at subauroral latitudes: Conjugate observation between the ground and Van Allen Probes A, *J. Geophys. Res. Space Physics*, *121*, doi:10.1002/2015JA022264.

20. M. Nosé, K. Keika, C. A. Kletzing, H. E. Spence, C. W. Smith, R. J. MacDowall, G. D. Reeves, B. A. Larsen, and D. G. Mitchell (2016), Van Allen Probes observations of magnetic field dipolarization and its associated O+ flux variations in the inner magnetosphere at L<6.6, *J. Geophys. Res. Space Physics*, *121*, doi:10.1002/2016JA022549.

21. D. Han, X.-C. Chen , J.-J. Liu, Q. Qiu, K. Keika, Z .-J. Hu, J.-M. Liu, H.-Q. Hu, and H. -G. Yang (2015), An extensive survey of dayside diffuse aurora based on optical observations at Yellow River Station, *J. Geophys. Res. Space Physics*, 120, doi:10.1002/2015JA021699.

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23. M. Nosé, S. Oimatsu, K. Keika, C. A. Kletzing, W. S. Kurth, S. DePascuale, C. W. Smith, R. J. MacDowall, S. Nakano, G. D. Reeves, H. E. Spence and B. A. Larsen (2015), Formation of the oxygen torus in the inner magnetosphere: Van Allen Probes observations, *J. Geophys. Res. Space Physics*, *120*, doi:10.1002/2014JA020593. .

24. I. Yoshikawa, K. Yoshioka, K. Keika, and Y. Ezoe (2014), Observational Technique of the Solar System Plasma: Remote Sensing of Planetary Plasma and Atmosphere, *Journal of Plasma and*

Fusion Research, *90* (12), 876-788.

25. T. Hori, Y. Miyashita, Y. Miyoshi, K. Seki, T. Segawa, Y.-M. Tanaka, K. Keika, M. Shoji, I. Shinohara, K. Shiokawa, Y. Otsuka, S. Abe, A. Yoshikawa, K. Yumoto, Y. Obana, N. Nishitani, A. S. Yukimatu, T. Nagatsuma, M. Kunitake, K. Hosokawa, Y. Ogawa, K. T. Murata, M. Nose, H. Kawano, and T. Sakanoi (2014), CDF data archive and integrated data analysis platform for ERG-related ground data developed by ERG Science Center (ERG-SC), J. Sp. Sci. Info. Jpn., 4, JAXA-RR-14-009, 75-89, ISSN 1349-1113.
26. A. Gerrard, L. J. Lanzerotti, M. Gkioulidou, D. G. Mitchell, J. Manweiler, J. Bortnik, and K. Keika (2014), Initial Measurements of O-ion and He-ion Decay Rates Observed from the Van Allen Probes RBSPICE Instrument, *J. Geophys. Res. Space Physics*, doi:10.1002/2014JA020374.
27. M. Nosé, K. Takahashi, K. Keika, L. M. Kistler, K. Koga, H. Koshiishi, H. Matsumoto, M. Shoji, Y. Miyashita, and R. Nomura (2014), Magnetic fluctuations embedded in dipolarization inside geosynchronous orbit and their associated selective acceleration of O^+ ions, *J. Geophys. Res. Space Physics*, doi:10.1002/2014JA019806
28. M. Mithaiwala, C. Crabtree, G. Ganguli, L. Rudakov and K. Keika (2013), Convective Amplification of Electromagnetic Ion Cyclotron Waves From Ring-distribution Protons in the Inner Magnetosphere, *J. Geophys. Res. Space Physics*, *118*, 7538-7544, doi:10.1002/2013JA019134.

(2) Non-peer-reviewed Articles

(3) Review Papers

1. K. Keika, L. M. Kistler, and P. C. Brandt (2013), Energization of O^+ Ions in the Earth's Inner Magnetosphere and the Effects on Ring Current Buildup: A Review of Previous Observations and Possible Mechanisms, *J. Geophys. Res.*, 118, 1–24, doi:10.1002/jgra.50371.

(4) Books

(5) Other Publications

(6) Patents

8. Keynote, Invited, or Solicited Presentations

1. K. Keika, Mass and Charge Dependent Characteristics of Earth's Magnetospheric Plasma, 2nd Asia-Pacific Conference on Plasma Physics, Kanazawa, Ishikawa, November 12, 2018.
2. K. Keika, S. Kasahara, S. Yokota, M. Hoshino, K. Seki, M. Nosé, Y. Miyoshi, T. Amano, I. Shinohara, Contribution from proton and oxygen ions to plasma pressure in the Earth's inner magnetosphere: Arase (ERG) observations, 2nd URSI AT-RASC meeting, Gran Canaria, Spain, May 28, 2018.
3. K. Keika, S. Kasahara, S. Yokota, M. Hoshino, K. Seki, M. Nosé, Y. Miyoshi, T. Amano, I. Shinohara, Spatial distribution of the contributions from electrons, protons, and oxygen ions to energy density in the inner magnetosphere, JpGU 2018 meeting, Makuhari Messe, Chiba, May 22, 2018.
4. K. Keika, Multi-spacecraft simultaneous observations of magnetospheric ion dynamics on storm and substorm time scales, Van Allen Probes - Arase Joint Meeting, Kyoto University, October 14, 2017.
5. K. Keika, Ring current spatio-temporal evolution affected by plasma sheet conditions and magnetosphere- ionosphere coupling, 2017 IAPSO-IAMAS-IAGA Joint Assembly, Cape Town

International Convention Center, Cape Town, South Africa, August 29, 2017.

6. K. Keika, On the effect of ionospheric ions on the magnetospheric dynamics, Institute for Space-Earth Environmental Research meeting, Rikkyo University, December 26, 2016.
7. K. Keika, Key unresolved issues to be addressed by in-situ ion measurements in the Earth's inner magnetosphere: ERG and Van Allen Probes collaborations, ISAS Symposium - Magnetospheric Plasmas 2015, Tokyo Institute of Technology, December 3, 2015.
8. K. Keika, L. M. Kistler, P. C. Brandt, K. Seki, M. Nosé, S. Machida, L. J. Lanzerotti, M. Gkioulidou, A. Ukhorskiy, and D. G. Mitchell, Ion composition and energization in the Earth's inner magnetosphere and the effects on the ring current buildup, 2014 AGU Fall Meeting, Moscone Center, San Francisco, CA., USA., December 16, 2014.
9. K. Keika, Y. Ebihara, R. Kataoka, Why did the Carrington storm recovery very rapidly? JpGU 2014 meeting, Yokohama, Japan, May 1, 2014.
10. K. Keika, Dynamics of heavy ions in the Earth's inner magnetosphere and its contribution to the global system, ISAS Symposium - Magnetospheric Plasmas 2013, Tokyo Institute of Technology, November 11, 2013
11. K. Keika, K. Takahashi, A. Y. Ukhorskiy, and Y. Miyoshi, Global Characteristics of Electromagnetic Ion Cyclotron Waves in the Earth's Magnetosphere, 2013 Asian-Pacific Science Conference, Howard International House, Taipei, Taiwan, September 5, 2013.
12. K. Keika, Global characteristics of plasma waves in the Earth's magnetosphere: Effects on radiation belt dynamics, Nagoya University Global COE Program QFPU Final International Forum, Gifu Miyako Hotel, Gifu, Japan, March 9, 2013.

III. Education Activity

9. Notable Achievements in Education

Lectures

- Undergraduate, Basic practice for earth and planetary physics I, FY2017-2018
- Undergraduate, Special practice for earth and planetary physics I, FY2017-2018
- Undergraduate, Special research for earth and planetary physics I, FY2017-2018
- Undergraduate, Academic frontier lecture, FY2018

IV. External Activities

10. Contribution to Academic Community

- Institute for Space-Earth Environmental Research meeting, Organizer, FY2014-2016
- Society of Geomagnetism and Earth, Planetary and Space Sciences, Student Award Committee Member, FY2017-2018
- American Geophysical Union Fall Meeting, Session Convener, FY2018
- Society of Geomagnetism and Earth, Planetary and Space Sciences, Session Convener, FY2017-2018
- Japan Geoscience Union Annual Meeting, Session Convener, FY2017

11. Outreach Activity

- NASA Proposal Review Board, Panel Member, FY2015

12. Internal Committee Membership

- Department of Earth and Planetary Science, Network Committee, Member, FY2017-2018

V. International Exchange Activities

13. Hosting/Sending Foreign Students and Researchers

(1) Hosting

Foreign Students: 0

Foreign Researchers: 0

(2) Sending

Students: 0

Researchers: 0

(3) Visitors from Abroad: 5

Yuichiro Cho

I. CV

Name: Yuichiro Cho

Age: 33

Present Position: Assistant Professor

Education

Tsuchiura First High School, Ibaraki, March, 2005 (graduation)

B. Sc. Department of Earth and Planetary Physics, The University of Tokyo, March, 2009

M. Sc. Department of Earth and Planetary Science, The University of Tokyo, March, 2011

Ph. D. Department of Earth and Planetary Science, The University of Tokyo, March, 2014

Professional Experience

Apr. 2014- Mar. 2016, Postdoctoral Fellow, Department of Physics, Rikkyo University

Apr. 2016- Sept. 2017, Visiting Post-doctoral Research Associate, NASA Marshall Space Flight Center/University of Alabama in Huntsville

Oct. 2017-Mar. 2018, Visiting Post-doctoral Research Associate, NASA Goddard Space Flight Center/University of Maryland Baltimore County

Apr. 2018-May. 2018, Assistant Research Scientist, NASA Goddard Space Flight Center/University of Maryland Baltimore County

Jun. 2018-, Assistant Professor, Department of Earth and Planetary Science, The University of Tokyo

II. Scientific Research Activity

2. Major Achievements

To understand the evolution of planetary surfaces through planetary explorations, I have been developing an instrument for measuring the age of rocks on the surface of a planetary body, as well as using image data obtained by spacecrafts. The geochronology instrument combines laser-induced breakdown spectroscopy (LIBS) and noble gas mass spectrometry to measure potassium and argon in the samples respectively, to derive the K-Ar age of the rocks. To achieve this, I first developed a method to measure potassium contents of geologic samples with LIBS. I made a number of calibration samples and constructed calibration curves to determine the limit of detection, accuracy, and precision of the K measurements. Then we applied the method to natural rocks, such as gneiss samples and basaltic rocks, and demonstrated that the K-Ar isochrons constructed with this approach yield accurate K-Ar ages. Based on these results, I designed a compact K-Ar geochronology instrument and tested it in the field. In addition, I used the image data obtained by the Japanese lunar orbiter “Kaguya” to determine the crater retention ages of mare basalt in the Orientale basin. Our observation revealed the presence of abnormally young mare unit on the ring of this large crater, suggesting that the Moon was actually active until 2 billion years ago without heat generating elements. More recently, I’m participating in the camera team of the Hayabusa-2 asteroid explorer and use the image data to reveal the geologic history of the C-type asteroid Ryugu.

3. Five Important Papers (including three or more papers in this review period)

1. Cho, Y., Sugita, S., Miura, Y.N., Okazaki, R., Morota, T., Kameda, S., 2016b. An in-situ K-Ar isochron dating method for planetary landers using laser-ablation technique. Planet. Space Sci. 128, 14-29.

We developed an in-situ geochronology technique based by combing laser-induced breakdown spectroscopy (LIBS) and noble gas mass spectrometry. In this paper we applied the method to a couple of gneiss samples and demonstrated that K-Ar isochron constructed with this approach yields accurate K-Ar ages.

2. Cho, Y. and Cohen, B.A. 2018. Dating igneous rocks using the Potassium-Argon Laser Experiment (KArLE) instrument: a case study for ~380 Ma basaltic rocks. Rap. Comm. Mass Spectrom. 2018, DOI: https://doi.org/10.1002/rcm.8214

This paper demonstrates that our in-situ K-Ar isochron approach yield accurate and precise ages for basaltic rocks, which have K concentrations much lower than the gneiss samples. We thereby demonstrated that our laser-based geochronology technique is applicable to most planetary rocks.

3. Cho, Y., Sugita, S., Kameda, S., Miura, Y.N., Ishibashi, K., Ohno, S., Kamata, S., Arai, T., Morota, T., Namiki, N., Matsui, T., 2015. High-precision potassium measurements using laser-induced breakdown spectroscopy under high vacuum conditions for in situ K–Ar dating of planetary surfaces. Spectrochim. Acta, Part B 106, 28-35.

We demonstrated that the K contents of geologic samples can be measured with LIBS when an internal standardization is applied. We constructed calibration curves and derived the limit of detection, accuracy and precision of the K measurements.

4. Cho, Y., Horiuchi, M., Shibasaki, K., Kameda, S., Sugita, S., 2017a. Quantitative potassium measurements with laser-induced breakdown spectroscopy using low-energy lasers: application to in situ K–Ar geochronology for planetary explorations. Appl. Spectrosc. 71, 1969-1981. DOI: https://doi.org/10.1177/0003702817701941.

This paper focuses on the capability of LIBS measurements with a compact, low-energy laser that would be on board actual spacecrafts. With an optimized optical setup and improved spectroscopic approach, we found that quantitative potassium measurements are possible with such a compact laser, which demonstrates the feasibility of our in situ K-Ar dating method. Selected as one of the Editor's Choice 2017 papers on *Applied Spectroscopy*.

5. Cho, Y., Morota, T., Haruyama, J., Yasui, M., Hirata, N., Sugita, S., 2012. Young mare volcanism in the Orientale region contemporary with the Procellarum KREEP Terrane (PKT) volcanism peak period ~2 billion years ago. Geophys. Res. Lett. 39, L11203.

We used image data taken by the Japanese lunar orbiter "Kaguya" to determine the crater retention ages of mare basalt in the Orientale basin. Our observation revealed the presence of abnormally young mare unit on the ring of this large crater, suggesting that the Moon was actually active until 2 billion years ago without heat generating elements.

4. Awards and Honors

- Cho, Y., NF Foundation 7th R&D Encouragement Award, Nov. 2018
- Cho, Y., Best Oral Presentation Award, Meeting of Isotope-ratio Mass Spectrometry, The Mass Spectrometry Society of Japan, Nov. 2012
- Cho, Y., Best Oral Presentation Award, The Japanese Society for Planetary Sciences Fall meeting 2012, Oct. 2012

5. Future Research Plan

I continue to develop instruments that conduct in situ geochemical analyses on planetary surfaces for future planetary lander missions. One of the major specific goals is to develop an analytical method that enables the measurement of potassium of 100 ppm. This is important for applying the in situ geochronology method to generally potassium-poor lunar or Martian rocks. Based on the laboratory analyses, I'm going to build a compact geochronology package by combining a small laser, optical spectrometer, and mass spectrometer. The package will be tested at the field to demonstrate its capability on the planetary surfaces. In parallel, I will participate in the lunar polar mission and Martian Moons exploration mission through international collaborations. I will continue to participate in the Hayabusa-2 mission within the camera team and study the geochronology of the C-type asteroid Ryugu.

6. Funding Received

- JSPS Overseas Research Fellowships, 28-170, Principal Investigator, FY2016-2017, 10,510,000 yen
- JSPS KAKENHI, 15K17796, Principal Investigator, FY2015, 4,290,000 yen
- JSPS KAKENHI, 26887040, Principal Investigator, FY2014, 1,300,000 yen

7. Publications and Patents

(1) Peer-reviewed Journal Articles

1. Cho, Y. and Cohen, B. A. (2018) Dating igneous rocks using the Potassium-Argon Laser Experiment (KArLE) instrument: a case study for ~380 Ma basaltic rocks. Rap. Comm. Mass Spectrom. 2018, DOI: https://doi.org/10.1002/rcm.8214
2. Cho, Y., Kameda, S., Okuno, M., Horiuchi, M., Shibasaki, K., Wagatsuma, R., Aida, Y., Miura, Y.N., Yoshioka, K., Okazaki, R., and Sugita, S. (2017b) Experimental characterization of elastomeric O-rings as reusable seals for mass spectrometric measurements: application to in situ K − Ar dating on Mars. Adv. Space Res. 60, 1453-1462. DOI: https://doi.org/10.1016/j.asr.2017.07.002
3. Cho, Y., Horiuchi, M., Shibasaki, K., Kameda, S., Sugita, S. (2017a) Quantitative potassium measurements with laser-induced breakdown spectroscopy using low-energy lasers: application to in situ K–Ar geochronology for planetary explorations. Appl. Spectrosc. 71, 1969-1981. DOI: https://doi.org/10.1177/0003702817701941. 2017 Editor's Choice
4. Cho, Y., Sugita, S., Miura, Y.N., Okazaki, R., Morota, T., Kameda, S. (2016b) An in-situ K-Ar isochron dating method for planetary landers using laser-ablation technique. Planet. Space Sci. 128, 14-29.
5. Cho, Y., Kameda, S., Miura, Y.N., Saito, Y., Yokota, S., Kasahara, S., Okazaki, R., Yoshioka, K., Shibasaki, K., Oishi, T., Sugita, S. (2016a) Conceptual Design of an In Situ K-Ar Isochron Dating Instrument for Future Mars Rover Missions. Transactions of the Japan Society for Aeronautical and Space Sciences, Aerospace Technology Japan 14, Pk_89-Pk_94.
6. Kameda, S., Suzuki, H., Takamatsu, T., Cho, Y., Yasuda, T., Yamada, M., Sawada, H., Honda, R., Morota, T., Honda, C., Sato, M., Okumura, Y., Shibasaki, K., Ikezawa, S., Sugita, S. (2016). Preflight Calibration Test Results for Optical Navigation Camera Telescope (ONC-T) Onboard the Hayabusa2 Spacecraft. Space Sci. Rev. doi: 10.1007/s11214-015-0227-y
7. Kameda, S., Suzuki, H., Cho, Y., Koga, S., Yamada, M., Nakamura, T., Hiroi, T., Sawada, H., Honda, R., Morota, T., Honda, C., Takei, A., Takamatsu, K., Okumura, Y., Sato, M., Yasuda, T.,

Shibasaki, K., Ikezawa, S., and Sugita, S. (2015) Detectability of hydrous minerals using ONC-T camera onboard the Hayabusa-2 spacecraft. Adv. Space Res. 56, 1519-1524.

8. Cho, Y., Sugita, S., Kameda, S., Miura, Y.N., Ishibashi, K., Ohno, S., Kamata, S., Arai, T., Morota, T., Namiki, N., Matsui, T. (2015). High-precision potassium measurements using laser-induced breakdown spectroscopy under high vacuum conditions for in situ K–Ar dating of planetary surfaces. Spectrochim. Acta, Part B 106, 28-35.
9. Cho, Y., Morota, T., Haruyama, J., Yasui, M., Hirata, N., Sugita, S., 2012. Young mare volcanism in the Orientale region contemporary with the Procellarum KREEP Terrane (PKT) volcanism peak period ~2 billion years ago. Geophys. Res. Lett. 39, L11203.

(2) Non-peer-reviewed Articles

(3) Review Papers

1. Cho, Y., Miura, Y. N., Kameda, S., Okazaki, R., Morota, T., Sugita, S. (2014) An outlook of *in-situ* geochronology techniques for planetary explorations, Chikyukagaku (Geochemistry), 48, 231-243.

(4) Books

(5) Other Publications

(6) Patents

8. Keynote, Invited, or Solicited Presentations

1. Y. Cho, T. Morota, J. Haruyama, M. Yasui, N. Hirata and S. Sugita, Formation history of Mare Orientale -Young volcanism contemporary with ~2 Ga PKT volcanic peak period, SELENE Symposium 2013, ISAS/JAXA, 2013/1/24

III. Education Activity

9. Notable Achievements in Education

Lectures

- Undergraduate, Earth and Planetary Physics Experiments, FY2018

IV. External Activities

10. Contribution to Academic Community

- The Japanese Society for Planetary Sciences, “Planetary People” Editorial Board Member, FY2018-

11. Outreach Activity

12. Internal Committee Membership

V. International Exchange Activities

13. Hosting/Sending Foreign Students and Researchers

(1) Hosting

Foreign Students: 0

Foreign Researchers: 0

(2) Sending

Students: 0

Researchers: 0

(3) Visitors from Abroad: 3

Earth and Planetary System Science Group

Hajime Kayanne

I. CV

Name: Hajime Kayanne

Age: 60

Present Position: Professor

Education

Musashi High School, Tokyo, March, 1978 (graduation)

B. Sc. Department of Geography, The University of Tokyo, March, 1982

M. Sc. Department of Geography, The University of Tokyo, March, 1984

Ph. D. Department of Geography, The University of Tokyo, March, 1989

Professional Experience

Apr. 1987-Mar. 1988, JSPS Research fellowship for young scientists (DC)

Apr. 1988-Oct. 1992, Scientist, Marine Geology, the Geological Survey of Japan

Oct. 1992-Mar. 1995, Chief Scientist, Marine Geology, the Geological Survey of Japan

Apr. 1995-Mar. 2000, Associate Professor, Department of Geography, the University of Tokyo

Apr. 2000-Nov. 2007, Associate Professor, Department of Earth and Planetary Science, the University of Tokyo

Nov. 2007-, Professor, Department of Earth and Planetary Science, the University of Tokyo

[Concurrent appointment]

Apr. 2013-Mar. 2019, Chairperson, Ocean Literacy Program, UTokyo Ocean Alliance, the University of Tokyo

Apr. 2019- , Deputy Head, Center for Ocean Literacy and Education, Graduate School of Education, the University of Tokyo

II. Scientific Research Activity

2. Major Achievements

Earth environment, ecosystem and human society are now confronting the global change regarded as the sixth mass extinction event during the new geologic era of **Anthropocene**. Earth scientists are responsible to tackle this issue by describing, projecting and alerting the early signs of the non-linear changes, based on which the tipping point and possible mitigation and adaptation measures should be addressed. **Coral reefs** are a model ecosystem directly related to and have already affected and responded to each factor of global environmental changes: suppression of calcification by **Ocean Acidification (OA)** via CO_2 increase, mass bleaching by **global warming**, and submergence of atoll islands by **sea level rise**. The world-wide **bleaching** event in 1998 was regarded as the first event of ecosystem-scale deterioration by global warming. Records of bleaching events and SST for the last 20 years in the northwest Pacific show that resilience has been reduced and coral fauna was replaced in the course of repeated bleaching events, and determined the threshold sea surface temperature as +2°C for the severe bleaching [Important paper (4)]. Reduction of ocean surface water pH to 7.8 would cause shift from hard coral to soft coral that does not have hard skeleton in coral reefs [Important paper

(2)]. A standardized protocol to evaluate **OA** by change in **alkalinity** was proposed [Important paper (5)], and autonomous analyzer to measure pH and alkalinity was developed for this protocol [Patent (5)]. Submergence of coral reefs by sea level rise of up to one meter results in a loss of their breakwater function and atoll islands submergence of national land, while deterioration of ecosystem reduced the resilience against sea level rise. +2°C (or RCP2.6) is the threshold to maintain coral reefs. Factors of global warming and responses of coral reefs are coupled to form feedback loops resulting in a phase shift at the tipping point, which will be applied to other ecosystems including human society.

3. Five Important Papers (including three or more papers in this review period)

1. Kayanne, H., Hongo, C., Okaji, K., Ide, Y., Hayashibara, T., Yamamoto, H., Mikami, N., Onodera, K., Ootsubo, T., Takano, H., Tonegawa, M., & Maruyama, S. (2012). Low species diversity of hermatypic corals on an isolated reef, Okinotorishima, in the northwestern Pacific. *Galaxea, Journal of Coral Reef Studies*, **14**, 73-95.

Ninety-three coral species have been identified at Okinotorishima Island, an isolated table reef located in the center of the Philippine Sea. The number is small in comparison with surrounding islands. The coral fauna at the island is characterized by a unique species independent of the Ryukyu Islands, mainland Japan, Palau, and the Mariana Islands. The relatively low species diversity at the island is explained by its small habitat diversity and isolation from other islands. Only coral larvae with a long competency period (>70 days) can settle at the island from surrounding islands. This unique species composition seems to have been maintained for at least the last 7600 years, since the last stage of sea level rise in the postglacial period. The paper provides basic information for maintenance of the reef island against sea level rise.

2. Inoue, S., Kayanne, H., Yamamoto, S., & Kurihara, H. (2013). Spatial community shift from hard to soft corals in acidified water. *Nature Climate Change*, **3**, 683-687.

Response of coral to Ocean Acidification has been examined by artificial CO_2 enrichment experiment, and long-term ecosystem-scale response remains unknown. This paper utilized natural CO_2 seep in Iwotorishima Island as a natural ecosystem-scale experiment. Hard corals are restricted to non-acidified low-pCO_2 zones (300-400 μatm) , while dense populations of soft coral dominate in medium-pCO_2 (800 μatm) zones, and both hard and soft corals are absent from the highest-pCO_2 (1,500 μatm) zone. These results suggest that reef communities may shift from reef-building hard corals to non-reef-building soft corals under pCO_2 levels of RCP8.6, and that higher pCO_2 levels would challenge the survival of some reef organisms.

3. Kayanne, H., Aoki, K., Suzuki, T., Hongo, C., Yamano, H., Ide, Y., Iwatsuka, Y., Takahashi, K., Katayama, H., Sekimoto, T., & Isobe, M. (2016). Eco-geomorphic processes that maintain a small coral reef island: Ballast Island in the Ryukyu Islands, Japan. *Geomorphology* **271**, 84-93.

Landform changes in Ballast Island, a small coral reef island in the Ryukyu Islands, were investigated by remote sensing analysis and a field survey. The area of the island almost doubled after a mass coral bleaching event in 1998. Coral branches generated by the mass mortality and broken by waves were delivered and stocked on a reef flat and accumulated to expand the area of the island. In 2012 high waves generated by typhoons also changed the island's topography. Overall, the island moved in the downdrift direction of the higher waves. Waves impacting both sides of the island piled up a large volume of coral gravels above the high-tide level. Eco–geomorphic processes, including a supply of calcareous materials from the corals on the same reef especially during stormy wave conditions, were key factors in maintaining the dynamic topographic features of this small coral reef island.

4. Kayanne, H. (2017). Validation of degree heating weeks as a coral bleaching index in the northwestern Pacific. *Coral Reefs*, **36**(1), 63-70.

Mass bleaching is the most significant threat to coral reefs. NOAA monitors world sea surface temperature and releases warnings for bleaching based on degree heating weeks (DHW), which is the accumulation of temperature anomalies exceeding the monthly maximum mean SST for a given region. This study validates the effectiveness of DHW as a mass bleaching index by on-site historical observation at eight sites in the northwestern Pacific Ocean. The mass bleaching events occurred during different years at different sites. The recorded years of the bleaching events matched well with DHW values of 8 degrees-weeks, and the logistically projected probability of bleaching against DHW showed a positive relationship. DHW provides a reasonable threshold for bleaching, and alerts that a thermal environment that could be easily attained even under projected +2°C global warming (RCP2.6).

5. Cyranok et al. (Kayanne, H.: the 15th in alphabetical order) (2018). Taking the metabolic pulse of the world's coral reefs. *PLos One*, 13(1), e0190872.

Coral reef metabolic performance (photosynthesis-respiration and calcification-dissolution) with its response to ocean acidification are varied among the reefs and have not been standardized. We compared them among 23 coral reefs across the globe, and standardized to show them on total alkalinity (TA) and total inorganic carbon (DIC) diagram, which clearly show the metabolic balance between net organic (photosynthetic) carbon production and net calcification. Reefs with lower net calcification potential could shift towards net dissolution sooner than reefs with a higher potential. The net organic production positively correlated with net calcification representing conjugated effect between photosynthesis and calcification. This work highlights the value of measuring carbonate chemistry when evaluating their susceptibility to ongoing global environmental change and offers a baseline from which to guide future conservation efforts aimed at preserving these valuable ecosystems.

4. Awards and Honors

・ Kayanne,H. et al., Distinguished Paper Award, Japanese Coral Reef Society, Nov. 2018

5. Future Research Plan

Under RCP8.5 scenario, coral reefs in the world is project to vanish by 2070. To tackle this issue, based on the early signatures of coral reef responses to warming, Ocean Acidification and sea level rise, not only monitoring and projection, but also **mitigation and adaptation** measures should be addressed. 1) A series of technologies for mass coral culture by sexual reproduction and outplanting the juveniles have been established, on which population- and ecosystem-scale coral reef **restoration** technology will be developed. Interventions for natural or artificial selection of corals resistant to heat stress and OA will be conducted and tested in fields to restore coral reefs. 2) To evaluate OA, a compact pH-alkalinity measurement system is now being developed [Patent (5)], which can be deployed to buoys and floats to **determine carbonate chemistry** in the ocean, so far only pH has been measured. To **mitigate OA** at least locally, a conjugated effect of coral culture and seaweed farming will be examined [Important Paper (5)] in Okinawa, with evaluation of economic values as organic production is removed as harvest. 3) To protect **low atoll islands** against sea level rise, natural processes of sand and gravel production, transportation and sedimentation will be rehabilitated accompanying with improvement of coastal environment. Also, the enhancement of coral gravel accumulation by permeable seawall [Patent (2), (4)], and their lithification [Patent (3)] will be field-tested. All these interventions based on science should be applied under a socio-economic perspective. Mitigation and adaptation measures with their application to sustain coral reefs will provide a model case to save other ecosystems during the **Anthropocene** to avoid the sixth mass extinction by **transdisciplinary** research by uniting not only earth and environmental science, and life sciences, but also social, political and economic sciences.

6. Funding Received

- JST-JICA Science and Technology Research Partnership for Sustainable Development (SATREPS), Eco-technological management of Tuvalu against sea level rise, Principal Investigator, FY2009-2013, 309,963,973 yen (including fund to Tuvalu through Univ. Tokyo) [total 369,373,773 yen including co-investigators].
- MEXT Grant-in-Aid for Scientific Research on Innovative Areas, Coral Reef Science-Strategy for Ecosystem Symbiosis and Coexistence with Humans under Multiple Stresses, Principal Investigator, FY2008-FY2013, 88,450,000 yen [total 686,840,000 yen].
- Ministry of Land, Infrastructure, Transport and Tourism, Research and Development of Construction Technology, Formation Model of Coral Reef Islands, Principal Investigator, FY2011-2013, 34,710,000 yen.
- Ministry of Land, Infrastructure, Transport and Tourism, Research and Development of Sand Erosion Control Technology (Coast), Protection model of coral reef coast, Principal Investigator, FY2015-2016, 29,679,000 yen.
- JST CREST, Continuous flow-through analyzer of small-sized seawater carbonate system to evaluate response of marine ecosystem against ocean acidification, Principal Investigator, FY2014-2018, 155,368,000 yen [total 207,766,000 yen].
- The Sumitomo Foundation, Preservation and Restoration of Cultural Properties, Preservation and Restoration of Ino maps (medium scale) of Japan, Principal Investigator, FY2015-2018, 22,920,000 yen.
- MEXT Grant-in-Aid for Scientific Research (A), Community shift from hard to soft corals in a natural CO_2 seep, FY2016-2019, Principal Investigator, 24,240,000 yen [total 30,000,000 yen].
- MEXT Development of Ocean Resources Utilization Technology, Development of Ocean Data Acquisition Technology. Development of autonomous pH-alkalinity analyzer deployable to BGC-Argo float, Principal Investigator, FY2018-2022, 82,987,000 yen [total 154,877,000 yen].

7. Publications and Patents

(1) Peer-reviewed Journal Articles

1. Dadhich, A. P., Nadaoka, K., Yamamoto, T., & Kayanne, H. (2012). Detecting coral bleaching using high-resolution satellite data analysis and 2-dimensional thermal model simulation in the Ishigaki fringing reef, Japan. *Coral Reefs*, **31**, 425-439.
2. Yamamoto, S., Kayanne, H., Terai, M., Watanabe, A., Kato, K., Negishi, A., & Nozaki, K.: (2012). Threshold of carbonate saturation state determined by CO_2 control experiment. *Biogeoscience*, **9**, 1441-1450.
3. Hosono, T., Fujita, K., & Kayanne, H. (2012). Estimating photophysiological condition of endosymbiont-bearing *Baculogypsina sphaerulata* based on the holobiont color represented in CIE *L*a*b** color space. *Marine Biology*, **159**, 2663-2673.
4. Kayanne, H., Hongo, C., Okaji, K., Ide, Y., Hayashibara, T., Yamamoto, H., Mikami, N., Onodera, K., Ootsubo, T., Takano, H., Tonegawa, M., & Maruyama, S. (2012). Low species diversity of hermatypic corals on an isolated reef, Okinotorishima, in the northwestern Pacific. *Galaxea, Journal of Coral Reef Studies*, **14**, 73-95.
5. Inoue, S., Kayanne, H., Yamamoto, S., & Kurihara, H. (2013). Spatial community shift from hard to soft corals in acidified water. *Nature Climate Change*, **3**, 683-687.
6. Fujita, M., Suzuki, J., Sato, D., Kuwahara, Y., Yokoki, H., & Kayanne, H. (2013). Anthropogenic impacts on water quality of the lagoonal coast of Fongafale Islet, Funafuti

Atoll, Tuvalu. *Sustainability Science*, **8**, 381-390.

7. Hosono, T., Lopati, P., & Kayanne, H. (2013). Estimation of the growth pattern of *Baculogypsina sphaerulata* (Foraminifera) in a tropical environment using a floating chamber method. *Journal of Experimental Marine Biology and Ecology*, **448**, 156-161.
8. Takahashi, K., Katayama, H., Iwatsuka, Y., Sekimoto, T., Suzuki, T., Kayanne, H., & Isobe, M. (2014). The topographic change mechanism of coral cays. *Proceedings of 34th Conference on Coastal Engineering*, **34**, sediment.86.
9. Fujita, M., Ide, Y., Sato, D., Kench, P. S., Kuwahara, Y., Yokoki, H., & Kayanne, H. (2014). Heavy metal contamination of coastal lagoon sediments: Fongafale Islet, Funafuti Atoll, Tuvalu. *Chemosphere*, **95**, 628-634.
10. Hosono, T., Lopati, P., Makolo, F., & Kayanne, H. (2014). Mass culturing of living sands (*Baculogypsina sphaerulata*) to protect island coasts against sea-level rise. *Jour. Sea Res.*, **90**, 121-126.
11. Tokoro, T., Hosokawa, S., Miyoshi, E., Tada, K., Watanabe, K., Montani, S., Kayanne, H., & Kuwae, T. (2014). Net uptake of atmospheric CO_2 by coastal submerged aquatic vegetation. *Global Change Biology* **20**, 1873–1884.
12. Yasukochi, T., Kayanne, H., Yamaguchi, T., & Yamano, H. (2014). Sedimentary facies and Holocene depositional processes of Laura Isaland, Majuro Atoll. *Geomorphplogy*, **222**, 59-67.
13. Harii, S., Hongo, C., Ishihara, M., Ide, Y., & Kayanne, H. (2014). Impacts of multiple disturbances on coral communities at Ishigaki Island, Okinawa, Japan, during a 15 year survey. *Marine Ecology Progress Series*, **509**, 171-180.
14. Fujita, K., Nagamine, S., Ide, Y., Umezawa, Y., Hosono, T., Kayanne, H., & Yamano, H. (2014). Distribution of large benthic foraminifers around a populated reef island: Fongafale Island, Funafuti Atoll, Tuvalu. *Marine Micropaleontology*, **113**, 1-9.
15. Yamano, H., Hata, H., Miyajima, T., Nozaki, K., Kato, K., Negishi, A., Tamura, M., & Kayanne, H. (2014). Water circulation in a fringing reef and implications for coral distribution and resilience. In: Nakano, S., Yahara, T., & Nakashizuka, T. (eds.) "The Biodiversity Observation Network in the Asia-Pacific Region: Integrative Observations and Assessments of Asian Biodiversity", *Ecological Research Monographs*, **4**, 275-293.
16. Yamamoto, S., Kayanne, H., Tokoro, T., Kuwae, T., & Watanabe, A. (2015). Total alkalinity flux in coral reefs estimated from eddy covariance and sediment pore-water profiles. *Limnol. Oceanogr.*, **60**, 229-241.
17. Fujita, K., Otomaru, M., Lopati, P., Hosono, T., & Kayanne, H. (2016). Shell productivity of the large benthic foraminifer *Baculogypsina sphaerulata*, based on the population dynamics in a tropical reef environment. *Coral Reefs*, **35,** 317-326.
18. Kayanne, H., Aoki, K., Suzuki, T., Hongo, C., Yamano, H., Ide, Y., Iwatsuka, Y., Takahashi, K., Katayama, H., Sekimoto, T., & Isobe, M. (2016). Eco-geomorphic processes that maintain a small coral reef island: Ballast Island in the Ryukyu Islands, Japan. *Geomorphology* **271**, 84-93.
19. Kayanne, H. (2016). Response of coral reefs to global warming. In Kayanne, H. ed., "Coral Reef Science: Strategy for Ecosystem Symbiosis and Coexistence with Humans under Multiple Stresses", *Coral Reefs of the World*, **5**, 81-94.
20. Kayanne, H. (2017). Validation of degree heating weeks as a coral bleaching index in the northwestern Pacific. *Coral Reefs*, **36**(1), 63-70.
21. Yamano, H., Kayanne, H., Yamaguchi, T., Inoue, T., Mochida, Y., & Baba, S. (2017).

Revisiting late Holocene sea-level change from the Gilbert Islands, Kiribati, west-central Pacific Ocean. *Quaternary Res.* **88**, 400-408.

22. Kayanne, H., Suzuki, R., & Liu, G. (2017). Bleaching in the Ryukyu Islands in 2016 and associated Degree Heating Week threshold. *Galaxea, Jour. Coral Reef Studies*, **19**, 17-18.
23. Cyronak, T., Andersson, A.J., Langdon, C., Albright, R. Bates, N.R., Caldeira, K., Carlton, R., Corredor, J.E., Dunbar, R.B., Enochs, I., Erez, J., Eyre, B.D., Gattuso, J.-P., Gledhill, D., Kayanne, H., Kline, D.I., Koweek, D.A., Lantz, C., Lazar, B., Manzello, D., McMahon, A., Meléndez, M., Page, H.N., Santos, I.R., Schulz, K.G., Shaw, E., Silverman, J., Suzuki, A., Teneva, L., Watanabe, A., & Yamamoto, S. (2018). Taking the metabolic pulse of the world's coral reefs. *PLos One*, 13(1), e0190872.
24. Tanaya, T., Watanabe, K., Yamamoto, S., Hongo, C., Kayanne, H., & Kuwae, T. (2018). Contributions of the direct supply of belowground seagrass detritus and trapping of suspended organic matter to the sedimentary organic carbon stock in seagrass meadows. *Biogeosciences*, **15**, 4033-4045.

[Peer-reviewed proceedings (in Japanese)]

25. Iwatsuka, Y., Katayama, H., Sekimoto, T., Aoki, K., Kayanne, H., & Isobe, M. (2012). Study on formation mechanism of coral cays on a steep slope reef. Proceedings of Japan Society of Civil Engineers B2 (Coastal Engineering), **68**(2), I_476-I_480.
26. Suzuki, T., Kayanne, H., Iwatsuka, Y., Katayama, H., Sekimoto, T., & Isobe, M. (2013). Studies on the topographic change mechanism of coral cays. Proceedings of Japan Society of Civil Engineers B2 (Coastal Engineering), **69**(2), I_838-I_843.
27. Katayama, H., Takahashi, K., Sekimoto, T., Kayanne, H., & Isobe, M. (2014). Study on formation mechanism and maintenance process of coral cays on a steep slope reef. Proceedings of Japan Society of Civil Engineers B2 (Coastal Engineering), **70**(2), I_726-I_730.
28. Takemori, R., Tajima, Y., Fujikawa, H., & Kayanne, H. (2015). Investigation on characteristics of local accumulation of coral gravels on an isolated reef. Proceedings of Japan Society of Civil Engineers B2 (Coastal Engineering), **71**(2), I_721-I_726.
29. Iwatsuka, Y., Kotoura, T., Katayama, H., Tajima, Y., & Kayanne, H. (2015). Fundamental study on topography of coral cays. Proceedings of Japan Society of Civil Engineers B2 (Coastal Engineering), **71**(2), I_517-I_522.
30. Maeda, Y., Kotoura, T., Sanuki, H., Tajima, Y., & Kayanne, H. (2016). Research about offshore structure for advancing formation of coral cays. Proceedings of Japan Society of Civil Engineers B2 (Coastal Engineering), **72**(2), I_823-I_828.
31. Yamaki, K., Kayanne, H., Ohba, H., Ko, N., Yamamoto, S., Tanaka, M., Lim, B.-K., & Ueno, Y. (2016). Studies on the beachrock formation mechanism by field surveys and laboratory experiment. Proceedings of Japan Society of Civil Engineers B2 (Ocean Development), 72(2), I_916-I_921.

(2) Non-peer-reviewed Articles

Three articles in Japanese

(3) Review Papers

1. Kayanne, H. (2017). Pacific region, Analysis and Proposal of Foreign Policies Regarding the Impact of Climate Change on Fragility in the Asia-Pacific Region With focus on natural disasters in the Region -, Ministry of Foreign Affairs, pp26-30, 39-40, Japan, 49p.

(and 9 review papers in Japanese)

(4) Books

1. Kayanne, H. (2015). Ocean education in social studied (Geogpraphy). In Center for Ocean Literacy and Education ed. "Curriculum Development of Ocean Education-Research and Practice", 17-30, Japan Education Press. (in Japanese)
2. Kayanne, H. ed. (2016). Coral Reef Science: Strategy for Ecosystem Symbiosis and Coexistence with Humans under Multiple Stresses. *Coral Reefs of the World*, **5**, Springer 101p.
3. Kayanne, H. (2019). Truth of submerging atolls: landform constructed by coral and star sand. In Yamaguchi, T. ed. "Island Landscape Histories: Bridging a Gap between Historical Ecology and Historical Anthropology", 333-348, Fukyosha Publishing Ltd. (in Japanese)

(and 9 books and book chapters in Japanese)

(5) Other Publications

1. Kayanne, H. (2015). Toward ocean education suitable to a maritime nation of Japan. Center for Ocean Literacy and Education Policy Brief, No. 3, 4p. (in Japanese)
2. Kayanne, H. (2018). How do other countries educate their territorial seas and exclusive economic zone? Center for Ocean Literacy and Education Policy Brief, No. 4, 4p. (in Japanese)
3. Kayanne, H., Oikawa, Y., & Tanaka, S. (2019). Three pillars of ocean education. Center for Ocean Literacy and Education Policy Brief, No. 6, 4p. (in Japanese)

(and 2 publications in Japanese)

(6) Patents

1. Hosono, T., Kayanne, H., & Ide, Y. (2013). Facility and method for breeding foraminifera, Patent application 2013-49062 (21 March 2013)
2. Kotoura, T., Katayama, H., Iwatsuka, Y., Kayanne, H., & Tajima, Y. (2015). Method for beach formation by accumulation of coral gravel, and permeable seawall for this method. Patent application 2015-195733 (1 October 2015)
3. Kayanne, H., Yamaki, K., Lim, & B.-K. (2016). Method to solidify sand and gravel, and beach protection method, Patent application 2016-076920 (7 April 2016)
4. Maeda, Y., Kotoura, T., Sanuki, H., Kayanne, H., & Tajima, Y. (2016). Method for beach formation by accumulation of coral gravel, and permeable seawall for this method. Patent application 2016-105989 (27 May 2016)
5. Kayanne, H., Yamamoto, S., Sato, Y., Nozaki, K., & Hemmi, A., (2016). Method of accurate measurement of seawater carbonate parameters and an analyzer for this method, Patent application 2017-558197 (21 December 2016)

8. Keynote, Invited, or Solicited Presentations

1. Kayanne, H., Eco-technological management of Tuvalu against sea level rise. American Geophysical Union Fall Meeting, San Francisco, USA, 2012/12/4.
2. Kayanne, H., S. Yamamoto, S. Inoue, & H. Kurihara, Assessing ocean acidification in the field of coral reefs, Japan-Australia Marine Science Workshop, Tokyo, Japan, 2013/7/11.
3. Kayanne, H., Geo-ecological maintenance of atoll islands with past and future global environmental change, International 'Polylogue' of Oceania studies, Keio Univ., Tokyo, 2014/1/12.

4. Kayanne, H., Eco-technological management of Tuvalu against sea level rise, The 2nd International Seminar of Islands and Oceans, Ocean Policy Research Institute, Tokyo, 2014/6/18.
5. Kayanne, H., Yamano, H., Fujita, M., K. Molu, T. T. Tima, Environmental issues in Tuvalu and eco-technological management against sea level rise, Expert Conference on Development of Island's Sustainable Society, The Ministry of the Environment and Okinawa Prefecture, OIST, Nago, Okinawa, 2014/6/24.
6. Kayanne, H., Ecosystem-based coastal protection in small island countries, Small Island States Resilience Initiative Workshop, Understanding Risk Forum, World Bank, Venice, Italy, 2016/5/17
7. Kayanne, H., Ecosystem-based coastal protection of atoll island countries against sea level rise, Islands and Oceans Net 2nd General Meeting, Univ. Tokyo, Tokyo, Japan, 2016/12/6
8. Kayanne, H., Local and global threats to coral reefs and their restoration technology, 3rd Meeting of the Council for Security Cooperation in the Asia Pacific, Tokyo, Japan, 2017/2/7
9. Kayanne, H., Continuous pH-alkalinity analyzer for a small amount of seawater, International Symposium Promotion of global network studies on seagrass ecosystem based on innovative new technology, TWIns, Waseda Univ., Tokyo, 2018/2/19
10. Kayanne, H., Atoll islands and people, the Japan Society of Tropical Ecology, Kyoto Univ.. 2015/6/19 (in Japanese)
11. Kayanne, H., Submergence of atoll island countries and their eco-technological management, Japan Society for Pacific Island Studies, Tokyo, 2017/7/18 (in Japanese)

III. Education Activity

9. Notable Achievements in Education

Advisees

- Master theses: 3 students
  - Takuya Suzuki (Mar. 2013)
  - Toko Tanaya (Mar. 2015)
  - Nobuhiro Ko (Mar. 2016)
- Doctoral theses: 1 student
  - Shoji Yamamoto (Sept. 2013)

Lectures

[as a main lecturer]

- Introductory Earth Environment (undergraduate), FY2012-2018
- Lecture and Practical: Geo-ecology (undergraduate), FY 2012-2018
- Field Exercise: Earth and Planetary Environmental Science II (undergraduate), FY2013, 2016, 2018
- Field Excursion: Earth and Planetary Environmental Science II (undergraduate), FY2013
- Environmental Ecology (graduate), FY2013, 2017
- Field Work in Marine Science II (graduate), FY2012-2017
- Field Work in Coral Reef Science (undergraduate), FY 2012-2017

[as a sub-lecturer]

- Physical Geography (undergraduate), FY2014-2018
- Frontier for Earth and Planetary Environmental Research, FY2017-2018
- Lecture: Human and Environment System (undergraduate), FY2014-2018
- Practical: Earth and Planetary Environmental Science (undergraduate), FY2013, 2016
- Practical: Geomorphology and Geology (undergraduate), FY2017-2018
- Lecture: Science Cluster Lecture I (undergraduate and graduate), FY2016
- Laboratory Experiments for Instrumental Analysis I (graduate), FY2012-2018
- Basic Ocean Science (graduate), FY2013-2018

IV. External Activities

10. Contribution to Academic Community

- Japanese Coral Reef Society, Council member and Executive Secretariat, FY2012-2017
- Japanese Coral Reef Society, Director, FY2018
- Japan Society for Pacific Island Studies, Director, FY2017-2018

11. Outreach Activity

- Ministry of Land, Infrastructure, Transport and Tourism, Committee for Protection of Coral Reef Coast, member, FY2015-2018
- Ministry of Defense, Committee for Environmental Impact Monitoring of Alternative Facility Construction for Futenma Air Station, member, FY2012-2018
- KAKENHI reviewer, FY2012-2014, FY2017-2018
- Japan Institute of Country-ology and Engineering, Research Committee for Protection of Okinotorishima (consigned by Ministry of Land, Infrastructure, Transport and Tourism), member, FY2012-2016
- Waterfront Vitalization and Environmental Research Foundation, Analysis and Evaluation Commission for Coral Transplantation regarding Port Facilities Construction at a Specified Remote Island (consigned by Ministry of Land, Infrastructure, Transport and Tourism), member, FY2012-2018
- Fisheries Infrastructure Development Center, Review Committee for Preservation and Restoration Technologies of Coral Reefs under Severe Conditions (consigned by Fisheries Agency), member, FY2012-2017, chair, FY2018
- Ocean Policy and Research Institute, Investigation Committee for Sustainable Development of Island and Ocean, member, FY2012-2017
- Media release: more than 40 news reports and commentaries for mass bleaching, Ocean Acidification, Okinotorishima, submergence of Tuvalu, and coral mass breeding.
- Lectures for general audience: 46 times.

12. Internal Committee Membership

- Department of Earth and Planetary Science (graduate), Education Committee, Chair, FY2012
- Department of Earth and Planetary Environmental Science (undergraduate), Head, FY2013

- Departments of Earth and Planetary Science, and Earth and Planetary Environmental Science (undergraduate), Education Committee, Chair, FY2018
- Graduate School of Science, Public-relations committee, Rigakubu-News Editorial board, FY2017-2018
- The University Museum, Univ. Tokyo, Council member and head of Geography Unit, FY2012-2018
- Center of Spatial Information Science, Univ. Tokyo, Council member, FY2012-2018

V. International Exchange Activities

13. Hosting/Sending Foreign Students and Researchers

(1) Hosting

Foreign Students: 1

Foreign Researchers: 3

(2) Sending

Researchers: 2

(3) Visitors from Abroad: 10

Eiichi Tajika

I. CV

Name: Eiichi Tajika

Age: 56

Present Position: Professor

Education

Tokyo Metropolitan Nishi High School, Tokyo, March 1982 (graduation)

B. Sc. Department of Geophysics, Faculty of Science, The University of Tokyo, March 1987

M. Sc. Department of Geophysics, Graduate School of Science, The University of Tokyo, March 1989

Ph. D. Department of Earth and Planetary Physics, Graduate School of Science, The University of Tokyo, March 1992

Professional Experience

April 1992-March 1993, Research Fellowship for Young Scientists of Japan Society for the Promotion of Science (JSPS), Center for Climate System Research (CCSR), The University of Tokyo

April 1993-June 2002, Research Associate, Department of Geology, Graduate School of Science, The University of Tokyo

July 2002-July 2010, Associate Professor, Department of Earth and Planetary Science, Graduate School of Science, The University of Tokyo

August 2010-April 2016, Professor, Department of Complexity Science and Engineering, Graduate School of Frontier Sciences, The University of Tokyo

May 2016-, Professor, Department of Earth and Planetary Science, Graduate School of Science, The University of Tokyo

II. Scientific Research Activity

2. Major Achievements

I have been studying on stability, variability, and evolution of Earth and planetary environments, from the perspective of Earth and planetary system science, mainly based on geochemical cycles and energy balance modeling.

We revealed influences of luminosity evolution of the Sun, crustal growth, thermal evolution of the Earth's interiors, evolution of seafloor spreading rate, and carbon and water cycles on the long-term evolution of the surface environment of the Earth (Tajika and Matsui, 1990, 1992, 1993). Then we developed an ocean biogeochemical carbon cycle model coupled with ocean general circulation model (Yamanaka and Tajika, 1996, 1997), which has been used widely as a standard for investigating ocean carbon cycle. We also developed a novel model of ocean biogeochemical cycle which includes various biogeochemical reactions under vary wide ranges of redox conditions and succeeded to reveal quantitative conditions to trigger ocean anoxia and euxinia (Ozaki et al., 2011; Ozaki and Tajika, 1993). Marine productivity and methane flux in the Archean and Proterozoic are reconstructed by using a marine microbial ecosystem model coupled with atmospheric photochemistry and carbon cycle models (Ozaki et al., 2017, 2018). We also revealed a causal mechanism for the rise of oxygen in the atmosphere with an overshoot in response to a climatic transition at the termination of the

Paleoproterozoic snowball glaciation (Harada et al., 2015; Tajika and Harada, 2017, 2019).

We have also investigated climatic evolution of Earth-like planets in habitable zone (HZ) around other stars. We found that there are conditions for the planets to be habitable, that is, degassing rate of CO_2 from planetary interiors should be above some critical level, otherwise climate should be in the snowball or limit cycle mode, even orbiting within the HZ (Tajika, 1999, 2003, 2007; Kadoya and Tajika, 2014). We also found that there is a lifetime for the Earth-like planet to be habitable because the CO_2 degassing rate should decrease with time owing to thermal evolution of the planet (Kadoya and Tajika, 2015, 2016). We predict that statistically there will be large number of snowball planets with internal oceans in the exoplanetary systems, which may be a new category of habitable planets with very wider conditions than those for a traditional Earth-like habitable planet with surface oceans (Tajika, 2008).

3. Five Important Papers (including three or more papers in this review period)

1. Tajika, E. (2008). Snowball planets as a possible type of water-rich terrestrial planets in the extrasolar planetary system. *The Astrophysical Journal*, **680**, L53-L56. https://doi.org/10.1086/589831

In this paper, I showed that global glaciations, occurred in the Earth history (known as snowball Earth events), could be a universal phenomenon for Earth-like water planets in exoplanetary systems. I also showed that internal oceans under ice shell should be formed and maintained by geothermal heat flux from planetary interiors under very wide conditions with very long lifetime. I suggested that large number of snowball planets within and beyond habitable zone in exoplanetary systems would be observed in the future, which would further expand a concept of habitability.

2. Ozaki, K., Tajima, S., & Tajika, E. (2011). Conditions required for oceanic anoxia/euxinia: Constraints from a one-dimensional ocean biogeochemical cycle model. *Earth and Planetary Science Letters*, **304**, 270-279. https://doi.org/10.1016/j.epsl.2011.02.011

It is known that ocean anoxic events (OAEs) occurred repeatedly during the Phanerozoic. The cause for OAEs has been discussed for many years, but most of them remain only qualitative. This paper developed a novel model for marine biogeochemical cycle, which includes major metabolic reactions of marine microorganisms under very wide range of redox conditions, in addition to primary productivity, decomposition of organic matters, sedimentation and diagenesis. We showed the diagram for ocean redox conditions with very wide ranges of parameters' space. We succeeded to reveal the condition for causing ocean anoxia and ocean euxinia quantitatively for the first time. This model is very useful for investigating ocean biogeochemical evolution and variation throughout the history of the Earth.

3. Kadoya, S. & Tajika, E. (2014). Conditions for oceans on Earth-like planets orbiting within habitable zone: Importance of volcanic CO2 degassing, *The Astrophysical Journal*, **790**, 107-113. https://doi.org/10.1088/0004-637X/790/2/107

There may be Earth-like planets with surface oceans in the habitable zone (HZ) around stars. In this paper, we showed that climate of the planet is not determined solely by the planetary orbit and/or luminosity of the central star, and that degassing rate of CO_2 via volcanism on the planets is another important factor for the planetary climate in addition to the insolation from the central star. We constructed the climate diagram for the Earth-like planets, and showed that, even the planet is orbiting within the HZ, it should be in the snowball or limit cycle mode for low degassing rate of CO_2. We further discussed in the subsequent papers (Kadoya and Tajika, 2015, 2016, 2017) that evolution of the planet and central star determine the evolution of the planetary climate. We therefore proposed that the age of the exoplanetary system should be considered as an important factor in the future astronomical observation.

4. Harada, M., Tajika, E., & Sekine, Y. (2015). Transition to an oxygen-rich atmosphere with an

extensive overshoot triggered by the Paleoproterozoic snowball Earth, *Earth and Planetary Science Letters*, **419,** 178-186. https://doi.org/10.1016/j.epsl.2015.03.005

Rise of oxygen just after the Paleoproterozoic snowball Earth event at 2.2 billion years ago has been indicated from the Transvaal Supergroup, South Africa. In this paper, we proposed a mechanism for the rise of oxygen caused by rise of nutrient concentration in the ocean by ten times the present concentration owing to intense chemical weathering on land under super-greenhouse condition (~60 ^oC) just after the snowball Earth event. We showed that a transition from low to high stable levels of oxygen should have inevitably occurred aftermath of the snowball Earth event, otherwise it never happens because an increase in the oxygen flux of one order of magnitude larger than that of today cannot be caused by any other conditions. The atmosphere of the Earth today containing high concentration of oxygen may have been formed owing to snowball Earth events. This study was master thesis of my graduate student (Mariko Harada), and she received an Incentive Award of the School of Science, the University of Tokyo (she also became a candidate for the UTokyo President's Award for Students). We published a press release, and many media reported the results as a science news.

5. Ozaki, K., Tajika, E., Hong, P.K., Nakagawa, Y., & Reinhard, C.T. (2017). Effects of primitive photosynthesis on Earth's early climate system, *Nature Geoscience*, **11**, 55-59. https://doi.org/10.1038/s41561-017-0031-2

Climate of the early Earth may have been warm although the Sun was dimmer than today. In this paper, we used a global redox balance model to explore the biogeochemical and climatological effects of different forms of primitive photosynthesis. We found that a hybrid ecosystem of H_2-based and Fe^{2+}-based anoxygenic photoautotrophs gives rise to a strong nonlinear amplification of Earth's methane (CH_4) cycle and would thus have represented a critical component of Earth's early climate system before the advent of oxygenic photosynthesis. We also found that a hybrid photosynthetic biosphere widens the range of geochemical conditions that allow for warm climate states well beyond either of these metabolic processes acting in isolation. We published a press release both in Japan and US, hence this work was reported by many media in both countries.

4. Awards and Honors

5. Future Research Plan

We will continue to study on stability, variability, and evolution of Earth and planetary environments from the perspective of Earth and planetary system science. In particular, we will focus on the evolution and variations of atmospheric composition such as O_2, CO_2, and CH_4, and resulting climate evolution through the history of the Earth. Understanding a detailed relationship between the snowball Earth events and the rise of oxygen in the atmosphere will be one of the most intriguing and important issues. Reconstruction of microbial ecosystem, and cycles of electron donors and other essential elements for life, and behaviors of redox sensitive elements would be important to understand coevolution of the Earth's surface environment and life. On the other hand, studies on physical and chemical conditions and diversity of habitable planets around main sequence stars will be also continued. Influence of surface ocean mass, and mantle dynamics on the surface environment and its evolution will be investigated to understand quantitative conditions for habitability of Earth-like planets, and also snowball planets in the exoplanetary systems.

6. Funding Received

- MEXT KAKENHI, 70251410, Study of climate modes and their physical conditions of Earth-like water planets in exoplanetary systems, Principal Investigator, FY2010-2012, 3,300,000 yen
- MEXT KAKENHI, 16K05618, Study of marine environmental change during Proterozoic by developing a new marine biogeochemical cycle model with considering microbial metabolic

processes, Principal Investigator, FY2016-2018, 3,400,000 yen

- NINS Astrobiology Center Research Funds, Investigation to habitability around gas giants: formation, evolution, and chemical diversity of internal oceans of icy satellites, Co-Investigator in 2016-2017 and Principal Investigator in 2018, FY2016-2018, Total 15,000,000Yen
- MEXT KAKENHI, 18KK0092, Evaluation of the crater, energy, and mode of asteroid impact occurred in Southeast Asia 800 thousand years ago, Co-Investigator, FY2018-2021, Total 13,800,000

7. Publications and Patents

(1) Peer-reviewed Journal Articles

1. Sakuma, H., Tada, R., Ikeda, M., Kashiyama, Y., Ohkouchi, N., Ogawa, N. O., Watanabe, S., Tajika, E., & Yamamoto, S. (2012). High-resolution lithostratigraphy and organic carbon isotope stratigraphy of the Lower Triassic pelagic sequence in central Japan, *The Island Arc*, **21**, 79-100. https://doi.org/10.1111/j.1440-1738.2012.00809.x
2. Kamata, S., Sugita, S., Abe, Y., Ishihara, Y., Harada, Y., Morota, T., Namiki, N., Iwata, T., Hanada, H., Araki, H., Matsumoto, K., & Tajika, E. (2013). Viscoelastic deformation of lunar impact basins: Implications for heterogeneity in the deep crustal paleo-thermal state and radioactive element concentration, *Journal of Geophysical Research*, **118**, 398-415. https://doi.org/10.1002/jgre.20056
3. Ozaki, K. & Tajika, E. (2013). Biogeochemical effects of atmospheric oxygen concentration and sea-level stand on oceanic redox chemistry, *Earth and Planetary Science Letters*, **373**, 129-139. https://doi.org/10.1016/j.epsl.2013.04.029
4. Goto, G. T., Sekine Y., Suzuki, K., Tajika E., Senda, R., Nozaki, T., Tada, R., Goto, K. Yamamoto, S., Maruoka, T., Ohkouchi, N., & Ogawa, N.O. (2013). Redox conditions in the atmosphere and shallow marine environments during the first Huronian deglaciation: insights from Os isotopes and redox-sensitive elements, *Earth and Planetary Science Letters*, **376**, 145-154. https://doi.org/10.1016/j.epsl.2013.06.018
5. Kadoya, S. & Tajika, E. (2014). Conditions for oceans on Earth-like planets orbiting within habitable zone: Importance of volcanic CO2 degassing, *The Astrophysical Journal*, **790**, 107-113. https://doi.org/10.1088/0004-637X/790/2/107
6. Kamata, S., Sugita, S., Abe, Y., Ishihara, Y., Harada, Y., Morota, T., Namiki, N., Iwata, T., Hanada, H., Araki, H., Matsumoto, K., Tajika, E., Kuramoto, K., & Nimmo F. (2015). The relative timing of Lunar Magma Ocean solidi cation and the Late Heavy Bombardment inferred from highly degraded impact basin structures, *Icarus*, **250**, 492-503. https://doi.org/10.1016/j.icarus.2014.12.025
7. Harada, M., Tajika, E., & Sekine, Y. (2015). Transition to an oxygen-rich atmosphere with an extensive overshoot triggered by the Paleoproterozoic snowball Earth, *Earth and Planetary Science Letters*, **419**, 178-186. https://doi.org/10.1016/j.epsl.2015.03.005
8. Kadoya, S., & Tajika, E. (2015). Evolutionary climate tracks of Earth-like planets, *The Astrophysical Journal Letters*, **815**:L7. https://doi.org/10.1088/2041-8205/815/1/L7
9. Kadoya, S., & Tajika, E. (2016). Evolutionary tracks of the climate of Earth-like planets around different mass stars, *The Astrophysical Journal Letters*, **825**:L21. https://doi.org/10.3847/2041-8205/825/2/L21
10. Ozaki, K., Tajika, E., Hong, P.K., Nakagawa, Y., & Reinhard, C.T. (2017). Effects of primitive photosynthesis on Earth's early climate system, *Nature Geoscience*, **11**, 55-59. https://doi.org/10.1038/ s41561-017-0031-2

11. Tajika, E. & Harada, M. (2017). A possible relationship between the Great Oxidation event and the Paleoproterozoic snowball Earth event, *Viva Origino*, **45**, No.5(pp.1-5).

12. Chang, Y., Goto, K., Sekine, Y., & Tajika, E. (2018). Depositional processes of impactites from the YAX-1 drill core in the Chicxulub impact structure inferred from vertical profiles of PDF orientations and grain size distributions of shocked quartz, *Meteoritics & Planetary Science*, **53**, Nr 7, 1323-1340. https://doi.org/10.1111/maps.13082

13. Ozaki, K., Reinhard, C.T., & Tajika, E. (2018). A sluggish mid-Proterozoic biosphere and its effect on Earth's redox balance, *Geobiology*, **17**, 3-11. https://doi.org/10.1111/gbi.12317

14. Tajika, E. & Harada, M. (2019). Great Oxidation Event and Snowball Earth, in Astrobiology - From the Origins of Life to the Search for Extraterrestrial Intelligence (eds. Yamagish, A., Kakegawa, T. and Usui, T.), Springer Nature. https://doi.org/10.1007/978-981-13-3639-3_17

15. Kadoya, S. & Tajika, E. (2019). Outer limits of the habitable zone in terms of climate mode and climate evolution of Earth-like planets. *The Astrophysical Journal*, **875**:7(11pp). https://doi.org/10.3847/1538-4357/ab0aef

(2) Non-peer-reviewed Articles

1. Kadoya, S., Tajika, E., & Watanabe, Y. (2014). Climate of Eccentric Terrestrial Planets with Carbonate-Silicate Geochemical Cycle. *Proceedings of the International Astronomical Union*, **8**, 319-322. https://doi.org/10.1017/S1743921313013070

2. Watanabe, Y., Tajika, E., & Kadoya, S. (2014). Climate of Extraterrestrial Planets with Oceans and Carbonate-Silicate Geochemical Cycle under Various Obliquities. *Proceedings of the International Astronomical Union*, **8**, 333-335. https://doi.rorg/10.1017/S1743921313013112

(3) Review Papers

1. Kadoya, S., Watanabe, Y., Sekine, Y., & Tajika, E. (2012). Evolution of Earth and planetary environments (1), *Journal of Japanese Society of Planetary Sciences*, **21**(3), 294-306 (in Japanese).

2. Kadoya, S. Watanabe, Y., Sekine, Y., & Tajika, E. (2013). Evolution of Earth and planetary environments (2), *Journal of Japanese Society of Planetary Sciences*, **22**(4), 234-241 (in Japanese).

3. Tajika, E. (2014). Radioactive heat source and evolution of planets, *ISOTOPE NEWS*, **727**, 35-38 (in Japanese).

4. Tajika, E., & Harada, M. (2017). Snowball Earth and great oxidation event -How did the Earth's atmosphere oxygenated? *Science of Life -Iden* (*Genetics*), **71**(2), 114-120 (in Japanese).

5. Tajika, E. (2018). Habitable planet Earth -Carbon cycle and evolution of environment, *Journal of Japan Society of Refrigerating and Air Conditioning Engineers*, **93**, 50-60 (in Japanese).

(4) Books

1. Nakajima, T., & Tajika, E. (2012). Mechanism of the Climate Change -Return to the Origin of the Controversy, Gijutsu-Hyohron Co., Ltd. (in Japanese).

2. Tajika, E. (2012). Dictionary of Chemistry of Earth and Universe (ed. The Geochemical Society of Japan), Asakura Publishing Co., Ltd. (in Japanese).

3. Tajika, E. (2012). Dictionary of Evolutionary Studies (ed. Society of Evolutionary Studies, Japan). Asakura Publishing Co.,Ltd. (in Japanese).

4. Tajika, E. (2012). The Tangled Bank: An Introduction to Evolution (Zimmer, C., editorial supervisor: Hasegawa, M. for Japanese Version). Iwanami Shoten, Publishers (in Japanese).

5. Tajika, E. (2012) Evolution of Earth and Life, Shinsei Publishing Co. Ltd. (in Japanese).
6. Tajika. E. (2013). Astrobiology -Search for Origins of Life in the Universe (ed. Yamagishi, A.), Kagaku-Dojin Publishing Company, INC (in Japanese).
7. Tajika, E. (2015) Astrobiology (Eds. Kaifu, N., et al.), University of Tokyo Press.
8. Tajika, E. (2016) Dictionary of Exoplanetology (eds. Uda, S. et al.), Asakura Publishing Co., Ltd. (in Japanese).
9. Tajika, E. (2018). Encyclopedia of Zoology (ed. Zoological Society of Japan), Maruzen Junkudo Bookstores Co., Ltd. (in Japanese).
10. Tajika, E. (2019) 4.6-billion-year Earth History, Mikasa Shobo Co. Ltd. (in Japanese).

Other 10 co-authored and supervised books (Total 20 books)

(5) Other Publications

1. Tajika, E. (2013). Preface, Journal of Japanese Society of Planetary Sciences, 22(1), 3. (in Japanese)
2. Tajika, E. (2015) Evolution of Earth and planets and radioactive elements 1, NL Letters, 452, 2. (in Japanese)
3. Tajika, E. (2016) Evolution of Earth and planets and radioactive elements 4, NL Letters, 459, 2. (in Japanese)
4. Tajika, E. (2018) Did primitive microbial ecosystem maintain the Earth warm? The Rigakubu News, School of Science, The University of Tokyo, 50(6) 13. (in Japanese)
5. Kawahata, H., & Tajika, E. (2019). Academic Society Today 8. Activity of Japan Geoscience Union, Academic Trends, 24(5), 88-89. (in Japanese)

Other 14 articles (Total 19 articles)

(6) Patents

8. Keynote, Invited, or Solicited Presentations

1. Tajika, E., Habitability in the Extrasolar Planetary Systems, The 8th Workshop on Exoplanets, Shizuoka, Japan, 2012/04/20.
2. Tajika, E., Co-evolution of Earth and Life: Did the snowball Earth event promote the evolution of life? The15th National Institutes of Natural Sciences (NINS) Symposium on Astrobiology, Tokyo, 2013/10/14.
3. Tajika, E., Harada, M., Ozaki, K., & Sekine, Y., Biogeochemical cycle change due to large-scale climate change: Snowball glaciation and formation of manganese ore deposit, The 121st Annual Meeting of the Geological Society of Japan, Kagoshima, Japan, 2014/09/13.
4. Tajika E., Evolution of the atmosphere, climate, and life on Earth, International Symposium on Multidisciplinary Sciences on the Earth, Tokyo, Japan, 2014/12/19.
5. Tajika, E., Co-evolution of Earth's environment and life -Oxygen and life, Natural Institutes of Natural Sciences (NINS)/Inter-University Research Institute Corporations (IURC) Colloquium 2015, Shizuoka, 2015/12/01.
6. Ozaki, K., & Tajika, E., Climatic, tectonic, and biological factors affecting the oxidation state of the atmosphere and oceans: Implications for Phanerozoic O2 evolution, AGU Fall Meeting 2015, San Francisco, USA, 2015/12/14.
7. Ozaki, K., & Tajika, E., Stability and dynamics of Proterozoic oceanic euxinia, Goldschmidt 2016,

Yokohama, Japan, 2016/6/26.

8. Tajika, E., Lifespan of habitable planets around main sequence stars, Astrobiology Center, Natural Institutes of Natural Sciences (NINS) International Workshop 2017, Hiroshima, Japan, 2017/3/21.
9. Tajika, E., Snowball Earth event and great oxidation event, The 42th Annual Meeting of the Society for the Study of the Origin and Evolution of Life Japan, Fukuoka, Japan, 2017/3/30.
10. Harada, M., Tajika, E., & Yamagishi, A., Evolutional response of metabolism under environmental stresses inferred from ancestral genetic sequence reconstruction. IGCP 630 annual meeting 2017, Sendai, Japan, 2017/06/14.
11. Tajika, E., Archean marine microbial ecosystem and faint young Sun paradox, The 64th Annual Meeting of the Geochemical Society of Japan 2017, Tokyo, Japan, 2017/09/14.
12. Tajika, E., Ozaki, K., Hong, P.K., Nakagawa, Y., & Reinhard, C.T., Primitive microbial ecosystem and faint young Sun paradox, Japan Geoscience Union (JpGU) Meeting 2018, Chiba, Japan, 2018/5/21.
13. Tajika, E., Why is the Earth habitable – Carbon cycle and environmental evolution of the Earth, 2018 Japan Society of Refrigerating and Air-Conditioning Engineers (JSRAE) Annual Conference, Tokyo, Japan, 2018/5/25.

III. Education Activity

9. Notable Achievements in Education

Advisees

- Master theses: 15 students

  Shintaro Kadoya, Yu Chang, Mariko Harada (March 2013)

  Satoshi Fukushima, Umi Nakamura, Toshiyuki Morimi (March 2014)

  Takeshi Kobayashi, Koichi Hagura (March 2015)

  Yusuke Nakagawa, Kana Oide (March 2016)

  Takahiro Kobayashi (March 2017)

  Ayumi Akiyama, Toshihiro Tada, Takuma Munehiro (March 2018)

  Yasuto Watanabe (March 2019)

- Doctral theses: 3 students

  Mariko Harada (March 2016)

  Shintaro Kadoya (March 2017)

  Takanori Kodama (March 2017)

Lectures

- Undergraduate, Theory of Earth and Planetary Environmental Evolution, FY2012, 2014, 2016, 2018
- Undergraduate/Graduate, Science Cluster Lecture I, FY2016
- Undergraduate/Graduate, Earth History, FY2012-2018
- Undergraduate, Global Geochemical Cycle, FY2012-2018
- Undergraduate, Basic Exercise on Earth and Planetary Environment I, FY2012-2018

- Undergraduate, Basic Exercise on Earth and Planetary Environment II, FY2012-2018
- Undergraduate, Introductory Earth System Evolution, FY2012-2018
- Undergraduate, Introduction to Earth and planetary Environmental Science, FY2012-2017
- Undergraduate, Frontier for Earth and Planetary Science, FY2017
- Undergraduate, Frontier for Planetary Science, FY2018
- Undergraduate, Frontier for Earth and Planetary Environmental Research, FY2018
- Undergraduate, The Asahi Lectures "Adventures of the Mind," the University of Tokyo, FY2018

Student's awards

- Incentive Award of the School of Science, the University of Tokyo: 1 student [Mariko Harada]
- Japan Geoscience Union, Student Presentation Award: 2 students [Mariko Harada (twice)]
- Paleosciences Society, Student Presentation Award: 1 student [Yasuto Watanabe]
- JSPS Research Fellowships for Young Scientists (Doctoral Course Studens) : 3 students [Mariko Harada, Shintaro Kadoya, Toshihiro Tada]
- JSPS Research Fellowships for Young Scientists (Postdocs): 1 student [Mariko Harada]

IV. External Activities

10. Contribution to Academic Community

- Japan Geoscience Union, Vice President, FY2016-2018
- Japan Geoscience Union, Executive Board Member, FY2012-2014, 2016-2018
- Japan Geoscience Union, Representative, FY2012-2014, 2016-2018
- Japan Geoscience Union, Union Science Board Member, FY2012-2018
- Japan Geoscience Union, Space and Planetary Sciences Section, Board Member, FY2012-2018
- Japan Geoscience Union, Congress of the Presidents of Earth and Planetary Science Societies, Chair, FY2014
- Japan Geoscience Union, Management Planning Committee Member, FY2012-FY2013
- Japan Geoscience Union, Publicity and Outreach Committee, Chair, FY2012-2018
- Japan Geoscience Union, Editor-in-Chief of JGL, FY2012-2018
- Japan Geoscience Union, Academic Publication Committee Member, FY2012-2013
- Japan Geoscience Union, Journal Management Planning Committee Member, FY2012-2018
- Japan Geoscience Union, Public Session Subcommittee Member, FY2018
- Japan Geoscience Union, Diversity Committee Member, FY2015-2016
- Japan Geoscience Union, Career Support Committee Member, FY2012-2015
- Japan Geoscience Union, Global Strategy Committee Member, FY2017-2018
- Japan Geoscience Union, Fellow System Preparatory Committee Member, FY2012-2013
- Japan Geoscience Union, Fellow Review Committee Member, FY2015-2016
- Japan Geoscience Union, Risk Management Committee Member, FY2018
- Japan Geoscience Union, The 25th Anniversary Commemorative Preparatory Committee Member,

FY2012-2013

- Japan Geoscience Union, The 25th Anniversary Commemorative Project Committee Member, FY2014-2015
- The Japanese Society for Planetary Sciences, President, 2013-2014
- The Japanese Society for Planetary Sciences, Vice President, 2012, 2015-2016
- The Japanese Society for Planetary Sciences, Executive Board Member, 2012-2018
- The Japanese Society for Planetary Sciences, External Coordinate Advisory Committee, Chair, 2017-2018
- The Society for the Study of the Origin and Evolution of Life Japan, Executive Board Member, FY2017-2018
- Science Council of Japan, Section III (Physical Sciences and Engineering), Council Member, FY2017-2018
- Science Council of Japan, Earth and Planetary Science Committee, Vice Chair, FY2017-2018
- Science Council of Japan, Earth and Planetary Science Committee, Planning Subcommittee, Vice Chair, FY2017-2018
- Science Council of Japan, Earth and Planetary Science Committee, Earth, Planetary and Space Science Subcommittee, Chair, FY2018-2018
- Science Council of Japan, Earth and Planetary Science Committee, Vice Chair, FY2017-2018
- Science Council of Japan, Earth and Planetary Science Committee, Social Contributions Subcommittee, Executive Secretary, FY2017-2018
- Science Council of Japan, Earth and Planetary Science Committee, Human Resources Development Subcommittee Member, FY2017-2018
- Science Council of Japan, Earth and Planetary Science Committee, International Cooperation Committee Member, FY2017-2018
- Science Council of Japan, Section III, Subcommittee for Academic Societies Activities and Academic Information, Executive Secretary, FY2018
- International Symposium on Multidisciplinary Sciences on the Earth (ISMS) in Tokyo, Organizing Committee Member, 2014
- Japan Geoscience Union 2015 Meeting Chair, FY2014-2015
- Japan Geoscience Union, Organizing Committee for JpGU Meeting 2019, FY2018

11. Outreach Activity

11.1. Ministries and Agencies

- Cabinet Office, Space Policy Committee, Temporary Member, FY2013-2014
- Ministry of Education, Culture, Sports, Science and Technology, Working Group on Post-K Computer Priority Issues Promotion, Sub-working Group on Post-K Computer Exploratory Challenge, Member, FY2016-2018
- Japan Society for the Promotion of Science, Grants-in-Aid for Scientific Research Review Committee, Expert Committee Member, FY2012-2013, 2016-2017, 2017-2018, 2018
- The Open University of Japan, Visiting Professor, FY2012-2016
- National Institutes of Natural Science (NINS), Visiting Professor, FY2013-2015

- National Institutes of Natural Sciences (NINS), Astrobiology Center (ABC), Executive Committee Member, FY2016-2018
- Japan Aerospace Exploration Agency (JAXA), Board of Councilors, FY2017-2018
- National Institution for Academic Degrees and Quality Enhancement of Higher Education, National University Corporation Education and Research Evaluation Committee Member, FY2016
- Kyushu University, Graduate School of Science, External Review Committee, Expert Committee Member, FY2016
- Kobe University, Center for Planetary Science External Review Committee Member, FY2014
- Grant-in-Aid for Scientific Research on Innovative Areas "Evolution of molecules in space: from interstellar clouds to proto-planetary nebulae", External Review Committee Member, FY2015-2018
- Japan Earth Science Olympiad Committee, Committee Member, FY2012-2018
- University of Tokyo Press, Planning Committee Member, FY2012-2018
- Iwanami Shoten, Kagaku Planning Committee Member, FY2012-2015
- Tokyo Shoseki Co,. LTD, Editorial Board Member of Geoscience Textbook for Senior High School, FY2014-2016
- Tokyo Shoseki Co,. LTD, Advisory Board Member of Geoscience Textbook for Senior High School, FY2017-2018

11.2. Outreach Activities for Public

a) Public Lectures

- Tajika, E., Introduction to Earth and Planetary Science, Asahi Culture Center, Tokyo, Japan, 2012/10/06
- Tajika, E., Co-evolution of Earth and life, 15th NINS Symposium on Astrobiology, Tokyo, 2013/10/14
- Tajika, E., Evolution of Earth and Life, Public Lecture of Hydrospheric Atmospheric Research Center, Nagoya University, 2013/12/21
- Tajika, E., Evolution of Earth's surface environment and Life, Chunichi Culture Center, Nagoya, Japan, 2015/03/08
- Tajika, E., Evolution and habitability of Earth and Earth-like exoplenets, Workshop of National Astronomical Observatory of Japan, Tokyo, Japan, 2015/11/15
- Tajika, E., Earth and habitable planets, Lecture at Tokyo Gakugei University High School, Tokyo, Japan, 2015/11/21
- Tajika, E., Frozen Earth, Open Campus of The University of Tokyo, Tokyo, Japan, 2016/08/04
- Tajika, E., Conditions for the Earth-like planets, Summer Course for High School Students at School of Science, The University of Tokyo, Tokyo, Japan, 2016/08/16
- Tajika, E., Snowball Earth and evolution of life, JAMSTEC Science Media Meeting, Tokyo, 2017/02/24
- Tajika, E., Evolution of Planet Earth and life, 100th Lecture on Astronomy, Katsushika City Museum, Tokyo, Japan, 2018/12/15

  Other 14 lectures (Total: 24 lectures)

b) Commentary

- Tajika, E. (2012). Snowball Earth and eolution of life, Science Magazine for Adults (Editorial Advisor), Gakken Educational.
- Tajika, E. (2014). Graphic Science Magazine Newton Book “Science of Miracle Planet Earth” (Editorial Advisor), Newton Press.
- Tajika, E. (2014). The 4.6 Billion Year Journey of Earth 03 Formation of Ocean (Editorial Advisor), Asahi Shimbun Publications Inc.
- Tajika, E. (2015). Miracle Planet Earth, MOKU Monthly, 278, 16-27.
- Tajika, E., & Kitano, T. (2015). Expert Talk “Earth was a white Planet!”, Shincho 45, 34(5), 278-289.
- Tajika, E. (2017) Graphic Science Magazine Newton Book “Water” (Editorial Advisor), Newton Press.
- Tajika, E. (2017) “Global Glaciations” (Editorial Advisor), Graphic Science Magazine Newton, 37(6), 38-53, Newton Press.

c) News and Report by the Media

- Tajika, E., “Climate Change due to formation of super continent”, The Tokyo Shimbun, 2012/11/24
- Tajika, E., “Life of the Sun”, Yomiuri Shimbun, 2013/03/16
- Tajika, E., What on Earth Happened?... in Brief: The Planet, Life and People from the Big Bang to the Present Day #41 Earth was globally frozen, TV Tokyo, 2014/02/01
- Tajika, E., Lost World of Deep Ocean “Enigmatic Ancient fish”, NHK BS Premium, 2015/03/21
- Tajika, E., “Icy satellites, why does internal oceans exist?”, The Nikkei Shimbun (Japan Economics Newspaper), 2014/05/04
- Tajika, E., Old planets always get too hot or cold for life in the end, New Scientist Magazine, 2016/07
- Tajika, E., Ancient Earth was warmed by Methane produced by multiple species of photosynthetic bacteria, The Nikkei Shimbun (Japan Economics Newspaper), 2017/12
- Tajika, E., News & Views: Methane multiplication (by Laakso, T.A.), Nature Geoscience, 11, 6-7. 2018
- Tajika, E., A new theory for the faint young Sun paradox, Nikkei Science (Japanese version of Scientific American), 2018/03
- Tajika, E., Questions by children in Nonstop, Fuji Television Network, 2018/08/02

  Other 13 news (Total: 23 news)

d) Others

- Tajika, E., Planetarium program “Habitable Earth” (Supervision), Suginami City Science Museum. FY2012
- Tajika, E., Special Exhibition “Minerals -Finding new natural resources” (Cooperation), Ibaraki Nature Museum, FY2012
- Tajika, E., Special Exhibition “Great move of animals in the ice age” (Cooperation), Ibaraki Nature Museum, FY2014
- Tajika, E., Karuta for origins of life (Cooperation), FY2014
- Tajika, E., Permanent Exhibition “Facing the risk of living on the Earth” (Supervision), The National Museum of Emerging Science and Innovation (Miraikan), FY2015

- Tajika, E., Permanent Exhibition “Earth system and hazard” (Supervision), The National Museum of Emerging Science and Innovation (Miraikan), FY2015
- Tajika, E., Visit of Senior High School Students (Miyagi 2nd Senior High School), 2017/08/08
- Tajika, e., Visit of Junior High School Students (Hokkaido University of Education Hakodate Junior High School), 2019/02/19

12. Internal Committee Membership

- The University of Tokyo, The University Museum Council Member, FY2013-2015
- The University of Tokyo, Center for High Energy Geophysics Research, Earthquake Research Institute, Committee Member, FY2016-2017
- The University of Tokyo, Budget Committee, Planning and Coordination Subcommittee Member, FY2016
- The University of Tokyo, Education Steering Committee, Undergraduate Course Subcommittee Member, FY2017-2018
- The University of Tokyo, Education Steering Committee, Advancement Selection Adjustment Subcommittee Member, FY2017-2018
- The University of Tokyo, General Course Steering Committee Member, FY2017-2018
- The University of Tokyo, First-Year Seminar Science Course Steering Committee Member, FY2017-2018
- Graduate School of Science, Assistant Dean, FY2017-2018
- Graduate School of Science, Academic Affairs Committee, Chair, FY2017-2018
- Graduate School of Science, Planning Office Committee Member, FY2017-2018
- Graduate School of Science, Academic Management and Educational Promotion Committee Member, FY2017-2018
- Graduate School of Science, Science and Engineering Executive Meeting Member, FY2017-2018
- Graduate School of Science, Advancement Selection Committee Member, FY2016
- Graduate School of Science, President’s Award Selection Committee, Chair, FY2017-2018.
- Graduate School of Science, Carrier Support Office Steering Committee Member, FY2017-2018.
- Graduate School of Science, Student Support Office Steering Committee Member, FY2017-2018
- Graduate School of Science, Science Promotion Office Steering Committee Member, FY2017-2018
- Graduate School of Science, New Lecture Room Specification Development Committee, Chair, FY2017
- Graduate School of Science, Appointment for Over Aged Professors WG Member, FY2017
- Graduate School of Science, Appointment for Young Researchers WG Member, FY2017-2018
- Department of Earth and Planetary Science, Academic Affair Committee, Vice Chair, FY2016
- Department of Earth and Planetary Science, Academic Affair Board Committee Member, FY2016-2018
- Department of Earth and Planetary Science, Chair of the Earth and Planetary System Science Group, FY2016-2018
- Department of Earth and Planetary Science, Budget Committee Member, FY2016-2018

- Department of Earth and Planetary Science, Academic Affair Committee Member, FY2018
- Department of Earth and Planetary Science, Leading Graduate Course for Frontiers of Mathematical Sciences and Physics, Instructor, FY2017-2018
- Department of Earth and Planetary Environmental Science, Academic Affair Committee Member, FY2013-2017
- Department of Earth and Planetary Science, Research Center for the Early Universe, RESCEU Research Affiliate (Concurrency), FY2017-2018
- Department of Earth and Planetary Science, UTokyo Organization for Planetary Space Science, Professor (Concurrency), FY2016-2018

V. International Exchange Activities

13. Hosting/Sending Foreign Students and Researchers

(1) Hosting

Foreign Students: 0

Foreign Researchers: 0

(2) Sending

Students: 2

Researchers: 0

(3) Visitors from Abroad: 5

Masahiro Ikoma

I. CV

Name: Masahiro Ikoma

Age: 47

Present Position: Associate Professor

Education

Kozu High School, Osaka, March, 1991 (graduation)

B. Sc. Department of Earth and Planetary Sciences, Tokyo Institute of Technology, March, 1996

M. Sc. Department of Earth and Planetary Sciences, Tokyo Institute of Technology, March, 1998

Ph. D. Department of Earth and Planetary Sciences, Tokyo Institute of Technology, March, 2001

Professional Experience

Apr. 2001-Oct. 2004, JSPS Research Fellow, Tokyo Institute of Technology

Nov. 2004-Feb. 2007, Specially Appointed Assistant Professor, Tokyo Institute of Technology

Mar. 2007-Jan. 2012, , Assistant Professor, Tokyo Institute of Technology

Jun. 2008-Mar. 2009, , Visiting Researcher, Observatory of Cote d'Azur, France

Feb. 2012-, Associate Professor, The University of Tokyo

II. Scientific Research Activity

2. Major Achievements

Large survey projects for exoplanets such as the Kepler Space Telescope have confirmed that planetary systems are obviously ubiquitous. Also, discoveries of many planetary systems utterly different from the Solar System have revealed the diversity of planets and planetary systems. In response to these observational discoveries, the solar system formation theory built in the 1980s and 1990s continued to undergo significant revisions such as the addition of new physical processes, including planetary migration and massive dissipation. I have been studying the origin of the so-called super-Earths, which accounts for the vast majority of exoplanets detected so far. In particular, we successfully showed the formation process of super-Earths with thick hydrogen-dominated atmospheres theoretically for the first time in the world. Besides, to verify the formation theory, we modeled various atmospheric features of exoplanets orbiting close to their central stars theoretically, launched an observation project using a ground-based telescope such as Subaru and Okayama 188cm, and partially succeeded in the verification. Furthermore, we succeeded in quantifying the observability with the next-generation space telescope. Such research activities of ours have been highly evaluated and I have been recently invited to join the ESA infra-red observation mission for exoplanet, ARIEL, and also the Russian ultraviolet space telescope mission (WSO-UV) as an international participating scientist.

3. Five Important Papers (including three or more papers in this review period)

1. Valencia, D., Ikoma, M., Guillot, T., & Nettelmann, N. (2010). Composition and fate of short-period super-Earths. The case of CoRoT-7b. Astronomy & Astrophysics, 516, id. A20, 11p. DOI: 10.1051/0004-6361/200912839

While nearly 2000 super-Earths have been identified outside the solar system until today, CoRoT-7b is the first one whose radius and mass were measured. In this study, we explored the internal structure of CoRoT-7b and showed possible pathways of its formation and evolution. This paper gives guidance for subsequent researches regarding super-Earths and is cited in many papers. (Citation 143, NASA-ADS/Sep. 20, 2019)

2. Ikoma, M. & Hori, Y. (2012). In-situ accretion of hydrogen-rich atmospheres on short-period super-Earths: Implication for the Kepler-11 planets. The Astrophysical Journal, 753, id. 66, 6 pp. DOI: 10.1088/0004-637X/753/1/66

Many super-Earths orbiting close to their central stars are known to have a thick atmosphere (called low-density super-Earths). No such planets exist in the Solar System. In this paper, we showed the atmosphere formation process of low-density super-Earths for the first time and applied to the super-Earths detected around the host star Kepler-11, which was the first low-density super-Earths. (Citation 84, NASA-ADS/Sep. 20, 2019)

3. Narita, N., Fukui, A., Ikoma, M. et al. (他 19 人) (2013). Multi-color transit photometry of GJ 1214b through BJHKs bands and a long-term monitoring of the stellar variability GJ 1214. The Astrophysical Journal, 773, id. 144, 10 pp. DOI: 10.1088/0004-637X/773/2/144

It is crucial to understand the properties of their atmospheres to investigate the origin of super-Earths. In this study, we conducted a spectroscopic observation of the stellar light transmitted through the atmosphere of the transiting super-Earth GJ1214b, which was discovered following CoRoT-7b, using the Subaru Telescope. Then we showed that the atmosphere contains water vapor or is covered with clouds. (Citation 32, NASA-ADS/Sep. 20, 2019)

4. Ito, Y., Ikoma, M., Kawahara, H., Nagahara, H., Kawashima, Y., & Nakamoto, T. (2015). Theoretical emission spectra of atmospheres of hot rocky super-Earths. The Astrophysical Journal, 801, id. 144, 15 pp. DOI: 10.1088/0004-637X/801/2/144

Since rocky super-Earths orbiting very close to their central star receive intense stellar irradiation, it may be covered with magma ocean and have an atmosphere formed as a result of vaporization of the magma. In this study, we theoretically modeled the atmospheric composition and temperature structure and showed that it is possible to detect SiO in the mid-infrared wavelength region via transit observation using next-generation space telescopes such as JWST. (Citation 21, NASA-ADS/Sep. 20, 2019)

5. Kawashima, Y. & Ikoma, M. (2018). Theoretical transmission spectra of exoplanet atmospheres with hydrocarbon haze: effect of creation, growth, and settling of haze particles. I. Model description and first results. The Astrophysical Journal, 853, id. 7, 26 pp. DOI: 10.3847/1538-4357/aaa0c5

The reducing atmosphere of super-Earths is likely to be covered with organic clouds under intense UV irradiation from the central star. In this study, we modeled the photochemical reaction and cloud particle growth/precipitation process in the super-Earth atmosphere. Then, we demonstrated that cloudy and molecular features are detectable by transit observation. This study is regarded as one of the vital science cases for the next-generation space telescopes such as ARIEL and JWST. This study was part of the master's thesis, and the student received the Encouragement Award of the Graduate School of Science Encouragement. (Citation 15, NASA-ADS/Sep. 20, 2019)

4. Awards and Honors

- Ikoma, M., The Commendation for Science and Technology by the Minister of Education, Culture, Sports, Science and Technology, The Young Scientist's Prize, Apr. 2012
- Ikoma, M., Japan Geoscience Union, Nishida Prize, May 2017

5. Future Research Plan

In the field of exoplanet science, we will promote understanding of the diversity and origin of planets and planetary systems. The field has entered the so-called era of characterization from the era when new planets are discovered one after another. We will be able to investigate the characteristics of known exoplanets in detail. In the next 10 years, several space telescopes are scheduled for launch from Europe, the United States, Russia, and Japan. Atmospheric properties for many exoplanets are expected to be constrained by the spectroscopic observations. I will actively commit to such space telescope projects and verify and improve the formation theory that we have developed so far. On the other hand, while we have been focusing on relatively large planets such as gas giants and super-Earths until recently, we will investigate the formation and evolution processes of relatively small exoplanets such as Earth-sized and Mars-sized planets to be ready in the coming 30m-telescope era in which life-hosting exoplanets will be explored.

6. Funding Received

- JSPS Grant-in-Aid for Scientific Research (C), Principal Investigator, FY2013-2015, 2,700,000 yen
- JSPS Grant-in-Aid for Scientific Research (A), Co-Investigator, FY2013-2016, 3,000,000 yen
- Astrobiology Center Project, Principal Investigator, FY2017, 1,300,000 yen
- Astrobiology Center Project, Principal Investigator, FY2018, 1,800,000 yen
- JSPS Grant-in-Aid for Scientific Research (A), Principal Investigator, FY2017-2020, 43,200,000 yen
- JSPS Grant-in-Aid for Scientific Research on Innovative Areas, Principal Investigator, FY2018-2022, 104,700,000yen
- JSPS Grant-in-Aid for Scientific Research (B), Co-Investigator, FY2018-2020, 9,000,000 yen

7. Publications and Patents

(1) Peer-reviewed Journal Articles

1. Ikoma, M. & Hori, Y. (2012). In-situ accretion of hydrogen-rich atmospheres on short-period super-Earths: Implication for the Kepler-11 planets. The Astrophysical Journal, 753, id. 66, 6 pp. DOI: 10.1088/0004-637X/753/1/66
2. Narita, N., Nagayama, T., Suenaga, T., Fukui, A., Ikoma, M., Nakajima, Y., Nishiyama, S., & Tamura, M. (2013). IRSF SIRIUM JHKs simultaneous transit photometry of GJ 1214b. Publications of the Astronomical Society of Japan, 65, id.27. DOI:10.1093/pasj/65.2.27
3. Fukui, A., Narita, N., Kurosaki, K., Ikoma, M. et al. (plus 14 co-authors) (2013). Optical-to-near-infrared simultaneous observations for the hot Uranus GJ 3470b: A hint of a cloud-free atmosphere. The Astrophysical Journal, 770, id. 95, 13 pp. DOI: 10.1088/0004-637X/770/2/95
4. Narita, N., Fukui, A., Ikoma, M. et al. (plus 19 co-authors) (2013). Multi-color transit photometry of GJ 1214b through BJHKs bands and a long-term monitoring of the stellar variability GJ 1214. The Astrophysical Journal, 773, id. 144, 10 pp. DOI: 10.1088/0004-637X/773/2/144
5. Kawahara, H., Hirano, T., Kurosaki, K., Ito, Y., & Ikoma, M. (2013). Starspots-transit depth relation of the evaporating planet candidate KIC 12557548b, The Astrophysical Journal Letters, 776, id. L6, 6 pp. DOI: 10.1088/2041-8205/776/1/L6
6. Maruyama, S., Ikoma, M., Genda, H., Hirose, K., Yokoyama, T., & Santosh, M. (2013). The naked planet Earth: Most essential pre-requisite for the origin and evolution of life. Geoscience

Frontier, 4, 141-165. http://dx.doi.org/10.1016/j.gsf.2012.11.001

7. Kurosaki, K., Ikoma, M., & Hori, Y. (2014). Impact of photo-evaporative mass loss on masses and radii of water-rich sub/super-Earths. Astronomy & Astrophysics, 562, id. A80, 14 pp. DOI: 10.1051/0004-6361/201322258

8. Maruyama, S., Sawaki, Y., Ebisuzaki, T., Ikoma, M., Omori, S. & Komabayashi, T. (2014). Initiation of leaking Earth: An ultimate trigger of the Cambrian explosion. Gondwana Research, 25, 910-944. DOI: 10.1016/j.gr.2013.03.012

9. Fukui, A., Kawashima, Y., Ikoma, M. (plus 22 co-authors) (2014). Multi-band, multi-epoch observations of the transiting warm Jupiter WASP-80b. The Astrophysical Journal, 790, id. 108, 12 pp. DOI: 10.1088/0004-637X/790/2/108

10. Ito, Y., Ikoma, M., Kawahara, H., Nagahara, H., Kawashima, Y., & Nakamoto, T. (2015). Theoretical emission spectra of atmospheres of hot rocky super-Earths. The Astrophysical Journal, 801, id. 144, 15 pp. DOI: 10.1088/0004-637X/801/2/144

11. Venturini, J., Alibert, Y., Benz, W., & Ikoma, M. (2015). Critical core mass for enriched envelopes: the role of H_2O condensation. Astronomy & Astrophysics 576, id. A114, 16 pp. DOI: 10.1051/0004-6361/201424008

12. Fukui, A., Narita, N., Kawashima, Y., Kusakabe, N., Onitsuka, M., Ryu, T., Ikoma, M., Yanagisawa, K. & Izumiura, H. (2016). Demonstrating high-precision, multiband transit photometry with MuSCAT: a case for HAT-P-14b, The Astrophysical Journal, 819, id. 27, 11 pp. DOI: 10.3847/0004-637X/819/1/27

13. Massol, H., Hamano, K., Tian, F., Ikoma, M. (plus 12 co-authors) (2016). Formation and evolution of proto-atmospheres. Space Science Reviews, 205, 153-211. DOI: 10.1007/s11214-016-0280-1

14. Kurosaki, K. & Ikoma, M. (2017). Acceleration of cooling of ice giants by condensation in early atmospheres. The Astronomical Journal, 153, id. 260, 9 pp. DOI: 10.3847/1538-3881/aa6faf

15. Genda, H., Iizuka, T., Sasaki, T., Ueno, Y. & Ikoma, M. (2017). Ejection of iron-bearing giant-impact fragments and the dynamical and geochemical influence of the fragment re-accretion. Icarus, 470, 87-95. DOI: 10.1016/j.epsl.2017.04.035

16. Kawashima, Y. & Ikoma, M. (2018). Theoretical transmission spectra of exoplanet atmospheres with hydrocarbon haze: effect of creation, growth, and settling of haze particles. I. Model description and first results. The Astrophysical Journal, 853, id. 7, 26 pp. DOI: 10.3847/1538-4357/aaa0c5

17. Ikoma, M., Elkins-Tanton, L., Hamano, K., & Suckale, J. (2018). Water partitioning in planetary embryos and protoplanets with magma oceans. Space Science Reviews, 214, id. 76, 28 pp. DOI: 10.1007/s11214-018-0508-3

18. Hasegawa, Y., Bryden, G., Ikoma, M., Vasisht, G., & Swain, M. (2018). The origin of the heavy-element content trend in giant planets via core accretion. The Astrophysical Journal, 865, id. 32, 16. pp. DOI: 10.3847/1538-4357/aad912

19. Aoyama, Y., Ikoma, M., & Tanigawa, T. (2018). Theoretical model of hydrogen line emission from accreting gas giants. The Astrophysical Journal, 866, id. 84, 16 pp. DOI: 10.3847/1538-4357/aadc11

20. Tavrov, A., Kameda, S., Yudaev, A. et al. (Ikoma, M., 13th among 14 co-authors) (2018). Stellar imaging coronagraph and exoplanet coronal spectrometer: two additional instruments for exoplanet exploration onboard the WSO-UV 1.7 meter orbital telescope. Journal of Astronomical Telescopes, Instruments, and Systems, 4, 044001.

21. Tinetti, G., Drossart, P., Eccleston, P. et al. (Ikoma, M., 154th among 245 co-authors) (2018). A

chemical survey of exoplanets with ARIEL. Experimental Astronomy, 46, 135-209. DOI: 10.1007/s10686-018-9598-x

22. Gonçalves, I., Schmider, F. X., Gaulme, P. et al. (Ikoma, M., 12th among 15 co-authors) (2019). First measurements of Jupiter's zonal winds with visible imaging spectroscopy. Icarus, 319, 795-811. DOI: 10.1016/j.icarus.2018.10.019

(2) Non-peer-reviewed Articles

(3) Review Papers

1. Maruyama, S. & Ikoma, M. (2012). What happened at the Precambrian Era-Phanerozoic boundary? Iden, 66, 494-501.
2. Ikoma, M. (2012). Recent progress in exoplanet research: Super-Earths. Parity, 28, 55-56.

(4) Books

1. Ida, S., Tamura, M., Ikoma, M., & Sekine, Y. (2016). Encyclopedia of Exoplanets, Asakura

(5) Other Publications

(6) Patents

8. Keynote, Invited, or Solicited Presentations

1. Ikoma, M. & Hor, Y., Origin of hydrogen-rich atmospheres of low-density super-Earths: the case of Kepler-11 super-Earths, 8th Exoplanet Conference, Kanagawa, Japan, 2012/04/18.
2. Ikoma, M., On the impact of protoplanetary disk properties on the accretion of super-Earths's atmospheres, "Revealing Evolution of Protoplanetary Disks in the ALMA Era" Workshop, Kyoto, Japan, 2012/03/09.
3. Ikoma, M., Compositions and origins of exoplanets, Nagoya GCOE program final international forum, Gifu, Japan, 2013/03/09.
4. Ikoma, M., Current understanding of the interior and formation of giant planets in and outside the Solar System, SEDI Japan Pre-symposium, Kanagawa, Japan, 2013/9/29
5. Ikoma, M., Composition and origin of short-period low-mass planets: The importance of observation of their atmospheres, Subaru International Conference, Hawaii, USA, 2013/12/11
6. Ikoma, M., Formation of the Nebular-Captured Protoatmosphere, Workshop on the Disk in Relation to the Formation of Planets and Their Protoatmospheres. Beijing, China. 2014/08/27.
7. Ikoma, M., Theoretical perspective on super-Earths and mini-Neptunes with a focus on the origins and compositions of short-period exoplanets, 31st int'l colloquium of the Institut D'Astrophysique de Paris From super-Earths to brown dwarfs: who's who? Paris, France, 2015/06/30.
8. Ikoma, M., What can we learn from atmospheres of transiting low-mass exoplanets as a stepping stone towards habitable planets? Pathways 2015: Pathways towards habitable planets. Bern, Switzerland, 2015/07/15.
9. Ikoma, M., Exoplanet atmospheres, 138th SGEPSS Fall Meeting, Tokyo, Japan, 2015/11/02.
10. Ikoma, M., Role of magma ocean and primitive atmospheres for the hydration of planetary embryos, ISSI Workshop on The Delivery of Water to Protoplanets, Planets, and Satellites. Bern, Switzerland, 2016/01/13.
11. Ikoma, M., Formation and evolution of giant planets with snowy envelopes, Planet2 Symposium

2017: Origin and diversity of planetary systems from the microscope to the telescope, Villefranche-sur-Mer, France, 2017/02/21.

12. Ikoma, M. Sato, B., Sekii, T., Hanayama, H., & Ida, S., Probing the interior of Jupiter toward unveiling its formation: A new attempt with Jovian seismology. IAG-IASPEI, Kobe International Conf. Center, Kobe, Japan, 2017/07/31.
13. Ikoma, M., Unresolved issues regarding giant planet formation. Workshop on Jovian Trojan exploration, Osaka, Japan, 2017/09/30.
14. Ikoma, M., Late-stage Accretion and Subsequent Evolution of Giant Planets. CHARIS International Workshop, NAOJ, Tokyo, Japan, 2017/12/15.
15. Ikoma, M., Late-stage Capture of Solids by Proto-gas Giants. Workshop on Giant Planet Formation, Evolution and Interior, University of Zurich, Zurich, Switzerland. 2018/03/10.
16. Ikoma, M., Overview of exoplanet atmospheric science, Japanese Geoscience Union (JpGU) meeting 2018, Chiba, Japan, 2018/05/20.
17. Ikoma, M., Theoretical prediction for atmospheric spectra of highly irradiated low-mass exoplanets, ExoMol Conference on Spectroscopy of Exoplanets, London, UK, 2018/07/10.
18. Ikoma, M., Formation of planetary envelopes and atmospheres: Role of vaporized icy material, COSPAR 2018, Pasadena, CA, USA, 2018/07/19.
19. Ikoma, M., Theoretical and observational studies on exoplanet atmospheres: Current understanding and future perspective, The 20th Symposium on Planetary Sciences, Sendai, Japan, 2019/02/20.

III. Education Activity

9. Notable Achievements in Education

Advisees

- Master theses: 7 students
  - Yui Kawashima (Mar. 2015)
  - Yuhiko Aoyama, Yusuke Shirai (Mar. 2016)
  - Norifumi Hasegawa, Mankichi Mitsumoto (Mar. 2017)
  - Mayuko Ozawa, Sho Shibata (Mar. 2018)
- Doctral theses: 4 students
  - Kenji Kurosaki (Mar. 2016)
  - Yuichi Ito (Mar. 2018)
  - Yui Kawashima (Mar. 2018)
  - Yuhiko Aoyama (Mar. 2019)

Lectures

- Graduate, Planetary system formation, FY2012, 2014, 2016, 2018
- Graduate, GCOE Special lecture (Internal structure of giant planets), FY2012
- Undergraduate/Graduate, Exoplanet, FY2013-2018
- Undergraduate/Graduate, Earth and planetary system sciences, FY2013, 2015-2018
- Undergraduate, Earth and planetary physics exercise (Thermodynamics and statistical physics),

FY2016-2018

- Undergraduate, Overview of earth and planetary physics, FY2012-2018
- Undergraduate, Introduction to earth and planetary physics, FY2014-2016, 2018
- Undergraduate, Planetary and earth science exercise FY2014-2015

Student's awards

- Incentive Award of the School of Science, the University of Tokyo: 1 student [Yui Kawashima]

IV. External Activities

10. Contribution to Academic Community

- The Japanese Society for Planetary Sciences, General Purpose Committee Member, FY2012-2014
- The Japanese Society for Planetary Sciences, Editorial Committee Member, FY2012-2018
- The Japanese Society for Planetary Sciences, Executive Board Member, FY2015-2018
- The Japanese Society for Planetary Sciences, International Journal Committee Chair, FY2015-2018
- Earth, Planets, Space, Management Committee Member, FY2015-2018
- Subaru Telescope Scientific Advisory Committee Member, FY2018

11. Outreach Activity

- Ikoma, M., What exoplanets tell us. The University of Tokyo Open Campus 2012, Tokyo, Japan, 2012/8/7
- Ikoma, M., Frontier of exoplanet science: Is our planetary system unique?, Katsushika City Museum, Tokyo, Japan, 2012/11/24
- Ikoma, M., Lecture for high school students: A variety of planets beyond the solar system. Tokyo, Japan, 2014/4/2
- Ikoma, M., Special lecture at Katashimo-minami elementary school: The origin and history of the moon. Osaka, Japan, 2014/9/19
- Ikoma, M., How the Earth formed. Asahi Culture School, Tokyo, Japan, 2015/1/31
- Ikoma, M., Frontier of planetary science: New picture of the solar system. Kawasaki Citizen Academy Course, Kanagawa, Japan, 2015/6/23
- Ikoma, M., Mysteries of the solar system that exoplanets tell us. The University of Tokyo Open Campus 2015, 2015/8/5, 6
- Ikoma, M., Exoplanet research: beginning of a new era. JpGU 2016 Top seminar, Chiba, Japan, 2016/5/22
- Ikoma, M., Exoplanets: Worlds around other stars. Special lecture at Yashiro High School, Nagano, Japan, 2017/5/9
- Ikoma, M., Exoplanets: Worlds around other stars. Special lecture for students from Ueno High School, Tokyo, Japan, 2017/7/13
- Ikoma, M., Find a second Earth! Miraikan, Tokyo, Japan, 2018/1/13
- Ikoma, M., Diversity of gas giant planets in the solar system and beyond, JpGU Meeting 2018,

Chiba, Japan, 2018/05/23

- Ikoma, M., Exoplanets: New worlds around other stars. Special lecture for students from Kozu High School, Tokyo, Japan, 2018/7/31
- Ikoma, M., Want to know more about exoplanets. The University of Tokyo Open Campus 2018, Tokyo, Japan, 2018/8/1
- Ikoma, M., Jupiter: the planet that brought water to the Earth. The southern island festival 2018, Okianwa, Japan, 2018/08/19
- Ikoma, M., Exoplanets: New worlds around other stars. Special lecture for students from Tokyo Nogakudai Daiichi High School, Tokyo, Japan, 2018/10/4

12. Internal Committee Membership

V. International Exchange Activities

13. Hosting/Sending Foreign Students and Researchers

(1) Hosting

Foreign Students: 2

Foreign Researchers: 0

(2) Sending

Students: 6

Researchers: 4

(3) Visitors from Abroad: 6

Hajime Kawahara

I. CV

Name: Hajime Kawahara

Age: 38

Present Position: Assistant Professor

Education

Tokyo Gakugeidai huzoku high school, March, 2000 (graduation)

B. Sc. Department of Physics, The University of Tokyo, March, 2004

M. Sc. Department of Physics, The University of Tokyo, March, 2006

Ph. D. Department of Physics, The University of Tokyo, March, 2009

Professional Experience

Apr. 2009-March. 2010, JSPS PD, The University of Tokyo

Apr. 2010-Oct. 2012, JSPS PD, Tokyo Metropolitan University

Nov. 2012- , Assistant Professor, Department of Earth and Planetary Science, The University of Tokyo

II. Scientific Research Activity

2. Major Achievements

In the near future, direct imaging missions will search for Earth-like planets around nearby stars. One of the problems was how to characterize the planet surface, including the presence of ocean or land. To address this question, I have developed a surface map reconstruction method using a one-dimensional light curve of a direct-imaged planet (spin-orbit tomography, or “SOT”). The orbital motion and spin rotation of a planet convey information about the spherical surface to the time-series of the light curve. The SOT disentangles the information from the amplitude modulation of the light curve and reconstructs a 2D surface map using techniques of the inverse problem in information science. We showed that a 2D distribution of continents and oceans can be well retrieved from a reflected light curve through direct imaging. Recently, I extended the technique to the time-frequency domain and showed that the planet spin axial tilt can be inferred from the frequency modulation of the light curve. In the future, this theoretical work will be tested in the era of space direct imaging of exoplanets.

Since 2012, I have been working on a methodology for the detection of molecules and the dynamics of exoplanets. I showed that direct imaging using a 30 m class, ground-based telescope can detect oxygen for use as a biosignature in Earth-like planets around a nearby M-type star. I have also pursued a new technique to detect molecules in exoplanets using high-resolution spectroscopy (HRS). I proposed that the axial tilt of exoplanets can be inferred from the planet radial velocity anomaly. In real observation, we detected Titanium Oxide, known as an agent of thermal inversion layers, in a hot Jupiter (WASP 33b) for the first time using High Dispersion Spectrograph on s Subaru telescope.

In 2014, I proposed a new instrumental concept for the HRS, which included the connection of the high-contrast instrument (AO+coronagraph) and the high-resolution spectrograph to efficiently detect atmospheric molecules in directly-imaged exoplanets. We are now developing the light injection module, which connects SCExAO (AO+coronagraph) with IRD (IR spectrograph) on a Subaru telescope in international collaboration with the SCExAO team. I am involved with the international collaboration of the PSI (Planet System Imager) for TMT because the instrument for the HRS+direct imaging is expected to play an essential role in characterizing small planets including Earth-like planets in the TMT era.

While astronomers have confirmed 4,000 exoplanets so far, it is still difficult to directly compare exoplanets with solar planets because most of the transiting exoplanets discovered so far have an orbital period shorter than one year. Using graphic processing unit (GPU) computing and techniques in machine learning, we surveyed 200,000 stars observed by the Kepler spacecraft for signals of transiting planets whose orbital period is larger than two years. Most of these signals were overlooked because only one or two transits occurred in four-year light curves, and they were difficult to identify through standard periodic analysis of the detection pipelines. We identified dozens of long-period transiting exoplanets and finally published the catalog of these planets including Jupiter-like gas giants. Also, we found that Neptunian-sized planets around the snow line (at a few au) are common around FGK stars. It is difficult to explain this population using the current formation theory.

3. Five Important Papers (including three or more papers in this review period)

1. Kawahara and Fujii (2010), **Global Mapping of Earth-like Exoplanets From Scattered Light Curves,** The Astrophysical Journal, Volume 720, Issue 2, pp. 1333-1350 (2010)

This paper shows that the 2D surface map can be inferred from the light curve of directly imaged Earth-like planets for the first time. This work was selected for Martin Block award from Aspen Physics Center (58 citations(GS/Jul. 29, 2019))

2. Akamatsu and Kawahara (2013). **Systematic X-Ray Analysis of Radio Relic Clusters with Suzaku,** Publications of the Astronomical Society of Japan, Vol.65, No.1, article id.16, 10 pp.

The Japanese X-ray satellite Suzaku had the advantage of low background noise. We explored the physics of cluster merger using the Suzaku data. In particular, we showed that a radio relic (arc-like structure in radio) is a shock front by finding a clear temperature jump measured by the X-ray spectrum. The paper was selected for the ASJ excellent paper award (101 citations (ADS/Jul. 29, 2019))

3. Kawahara, Murakami, Matsuo, and Kotani (2014), **Spectroscopic Coronagraphy for Planetary Radial Velocimetry of Exoplanets,** The Astrophysical Journal Supplement, Volume 212, Issue 2, article id. 27, 10 pp. (2014).

This paper proposed a new instrumental concept for the HRS, which included the connection of the high-contrast instrument (AO+coronagraph) and the high-resolution spectrograph to efficiently detect atmospheric molecules in directly-imaged exoplanets. We are now developing the light injection module, which connects SCExAO (AO+coronagraph) with IRD (IR spectrograph) on a Subaru telescope in international collaboration with the SCExAO team. (13 citations (ADS/Jul. 29, 2019))

4. Nugroho, Kawahara, Masuda, Hirano, Kotani, and Tajitsu (2017), **High-resolution Spectroscopic Detection of TiO and a Stratosphere in the Day-side of WASP-33b**, The Astronomical Journal, Volume 154, Issue 6, article id. 221, 16 pp. (2017).

In this paper, we detected Titanium Oxide, known as an agent of thermal inversion layers, in a hot Jupiter (WASP 33b) for the first time using High Dispersion Spectrograph on s Subaru telescope. The first author got Ph.D. by this work. (35 citations (ADS/Jul. 29, 2019))

5. Kawahara, Masuda, MacLeod, Latham, Bieryla, and Benomar (2018)、**Discovery of Three Self-lensing Binaries from Kepler,** The Astronomical Journal, Volume 155, Issue 3, article id. 144, 16 pp. (2018).

A self-lensing binary (SLB) is the periodic magnification of a star due to gravitational lensing by a compact star companion, which was predicted by Kip Thorne in 1969. After the serendipitous detection of the first SLB, we performed a systematic survey of SLBs in the Kepler data in international collaboration with Harvard-Smithsonian Center for Astrophysics et al. Using GPU computing, we found four of the five known SLBs. We discovered that these SLBs, which are a white dwarf and a normal star binary, have features similar to field blue stragglers (FBS), and they are likely to have experienced the stable mass transfer due to the Roche lobe overflow (8 citations (ADS/Jul. 29, 2019))

4. Awards and Honors

- The PASJ Excellent Paper Award 2017, Astronomical Society of Japan (for Akamatsu and Kawahara, PASJ 65, 13, 2013, on the shock structure of radio relic clusters)

5. Future Research Plan

As the scope of astronomy expands, it should address humans and life in the universe as one of its central themes. Researching exoplanets is directly related to this theme because it helps to understand the universality of our solar system, Earth, and life. I intend to devote my effort to expanding our understanding of the exoplanet worlds by leading projects about exoplanets in collaboration with other researchers and facilities. My plan consists of three strategies: (1) the connection of space science and the ground-based facilities; (2) borderless collaboration between theory and observations for the modern astronomical data, and (3) education for the forthcoming era of astronomy. These strategies are further explained below.

(1) After the launch of the Kepler spacecraft, cooperation between space and ground-based observations is becoming essential in the field of exoplanets. The survey from space provides large datasets (light curve) with incredible precision, while follow-up observations from the ground enable us to understand the target from a variety of perspectives including the characterization of exoplanet atmosphere by high-dispersion spectroscopy. The space-ground connection is already critical to studying habitable planets and solar system analogs. Also, I believe that this connection encourages more fruitful results in other fields of astronomy as well as exoplanets in general. (2) As high precision observations become available in the field of exoplanets, analysis and interpretation of the observational data will require sophisticated theoretical computation from models. During my past research, I have worked on astronomy both from theoretical and observational aspects. So, I would promote the borderless collaboration of theory and observations. (3) In my experience at the University of Tokyo, I recognize the importance of education, especially for exoplanet research, because this is a relatively new field, and it is difficult to provide information for students and early-career researchers.

6. Funding Received

1. **Mext, New approach for the gravitational wave using time frequency analysis** 2018 – 2019 ￥2,000,000
2. **Mext for young research B, Cool worlds explored by GPU,** 2017 – 2020、￥4,030,000
3. **Mext for young researcher B, Remote sensing of Earth-like planets,** 2013 – 2016 ￥4,030,000

Funding from Astrobiology Center

4. 2017 ￥2,700,000
5. 2016 ￥1,500,000
6. **NINS** 2014 ¥600,000

7. Publications and Patents

(1) Peer-reviewed Journal Articles

1. **Self-lensing Discovery of a 0.2 $M_{\odot}$ White Dwarf in an Unusually Wide Orbit around a Sun-like Star**

   Masuda, Kawahara, Latham, Bieryla, Kunitomo, MacLeod, Aoki

   The Astronomical Journal Letters, Volume 881, Issue 1, article id. L3, 27 pp. (2019).

2. **Transiting Planets Near the Snow Line from Kepler. I. Catalog**

   Kawahara and Masuda (2019)

   The Astronomical Journal, Volume 157, Issue 6, article id. 218, 27 pp. (2019).

3. **Back to "Normal" for the Disintegrating Planet Candidate KIC 12557548 b**

   Schlawin, Hirano, Kawahara et al. (2018)

   The Astronomical Journal, Volume 156, Issue 6, article id. 281, 15 pp. (2018).

4. **A Linear and Quadratic Time-Frequency Analysis of Gravitational Waves from Core-collapse Supernovae**

   Kawahara, Kuroda, Takiwaki, Hayama, and Kotake (2018)

   The Astrophysical Journal, Volume 867, Issue 2, article id. 126, 13 pp. (2018).

5. **X-ray study of the double radio relic Abell 3376 with Suzaku**

   Urdampilleta, Akamatsu, Mernier, Kaastra, de Plaa, Ohashi, Ishisaki, and Kawahara (2018)

   Astronomy & Astrophysics, Volume 618, id.A74

6. **Systematic Search for Rings around Kepler Planet Candidates: Constraints on Ring Size and Occurrence Rate**

   Aizawa, Masuda, Kawahara, and Suto (2018)

   The Astronomical Journal, Volume 155, Issue 5, article id. 206, 18 pp. (2018).

7. **Discovery of Three Self-lensing Binaries from Kepler**

   Kawahara, Masuda, MacLeod, Latham, Bieryla, and Benomar (2018)

   The Astronomical Journal, Volume 155, Issue 3, article id. 144, 16 pp. (2018).

8. **Suzaku and Chandra observations of the galaxy cluster RXC J1053.7+5453 with a radio relic**

   Itahana et al. [5/13] (2017)

   Publications of the Astronomical Society of Japan, Volume 69, Issue 6, id.88

9. **High-resolution Spectroscopic Detection of TiO and a Stratosphere in the Day-side of WASP-33b**

   Nugroho, Kawahara, Masuda, Hirano, Kotani, and Tajitsu (2017)

   The Astronomical Journal, Volume 154, Issue 6, article id. 221, 16 pp. (2017).

10. **Toward Detection of Exoplanetary Rings via Transit Photometry: Methodology and a Possible Candidate**

    Aizawa, Uehara, Masuda, Kawahara, and Suto (2017)

    The Astronomical Journal, Volume 153, Issue 4, article id. 193, 23 pp. (2017)

11. **Suzaku observations of the merging galaxy cluster Abell 2255: The northeast radio relic**

Akamatsu et al. [6/15] (2017)

Astronomy & Astrophysics, Volume 600, id.A100, 12 pp.

12. **Frequency Modulation of Directly Imaged Exoplanets: Geometric Effect as a Probe of Planetary Obliquity**

    Kawahara (2016)

    The Astrophysical Journal, Volume 822, Issue 2, article id. 112, 11 pp. (2016).

13. **Transiting Planet Candidates Beyond the Snow Line Detected by Visual Inspection of 7557 Kepler Objects of Interest**

    Uehara, Kawahara, Masuda, Yamada, and Aizawa (2016)

    The Astrophysical Journal, Volume 822, Issue 1, article id. 2, 11 pp. (2016).

14. **Suzaku observations of the galaxy cluster 1RXS J0603.3+4214: Implications of particle acceleration processes in the ”Toothbrush” radio relic**

    Itahana, Takizawa, Akamatsu, Ohashi, Ishisaki, Kawahara, and van Weeren (2015)

    Publications of the Astronomical Society of Japan, Volume 67, Issue 6, id.11314 pp.

15. **Suzaku X-ray study of the double radio relic galaxy cluster CIZA J2242.8+5301**

    Akamatsu et al. [4/10] (2015)

    Astronomy & Astrophysics, Volume 582, id.A87, 12 pp.

16. **Absolute Dimensions of a Flat Hierarchical Triple System KIC 6543674 from the Kepler Photometry**

    Masuda, Uehara, and Kawahara (2015)

    The Astrophysical Journal Letters, Volume 806, Issue 2, article id. L37, 7 pp. (2015).

17. **Lifetime and Spectral Evolution of a Magma Ocean with a Steam Atmosphere: Its Detectability by Future Direct Imaging**

    Hamano, Kawahara, Abe, Onishi, and Hashimoto (2015)

    The Astrophysical Journal, Volume 806, Issue 2, article id. 216, 17 pp. (2015).

18. **Theoretical Emission Spectra of Atmospheres of Hot Rocky Super-Earths**

    Ito, Ikoma, Kawahara, Nagahara, Kawashima, and Nakamoto (2015)

    The Astrophysical Journal, Volume 801, Issue 2, article id. 144, 15 pp. (2015).

19. **Spectroscopic Coronagraphy for Planetary Radial Velocimetry of Exoplanets**

    Kawahara, Murakami, Matsuo, and Kotani (2014)

    The Astrophysical Journal Supplement, Volume 212, Issue 2, article id. 27, 10 pp. (2014).

20. **Exploring Hot Gas at Junctions of Galaxy Filaments with Suzaku**

    Mitsuishi, Kawahara, Sekiya, Sasaki, Sousbie, and Yamasaki (2014)

    The Astrophysical Journal, Volume 783, Issue 2, article id. 137, 12 pp. (2014).

21. **Starspots-Transit Depth Relation of the Evaporating Planet Candidate KIC 12557548b**

    Kawahara, Hirano, Kurosaki, Ito, and Ikoma (2013)

    The Astrophysical Journal Letters, Volume 776, Issue 1, article id. L6, 6 pp. (2013).

22. **Probing the extreme planetary atmosphere of WASP-12b**

    Swain et al. [7/10] (2013)

Icarus, Volume 225, Issue 1, p. 432-445.

23. **Validity of Hydrostatic Equilibrium in Galaxy Clusters from Cosmological Hydrodynamical Simulations**

    Suto, Kawahara, Kitayama, Sasaki, Suto, and Cen (2013)

    The Astrophysical Journal, Volume 767, Issue 1, article id. 79, 11 pp. (2013).

24. **Systematic X-Ray Analysis of Radio Relic Clusters with Suzaku**

    Akamatsu and Kawahara (2013)

    Publications of the Astronomical Society of Japan, Vol.65, No.1, article id.16, 10 pp.

25. **The Spin Effect on Planetary Radial Velocimetry of Exoplanets**

    Kawahara (2012)

    The Astrophysical Journal Letters, Volume 760, Issue 1, article id. L13, 6 pp. (2012).

(2) Non-peer-reviewed Articles

1. **SCExAO, an instrument with a dual purpose: perform cutting-edge science and develop new technologies**

   Lozi et al. [15/34] (2018)

   Proceedings of the SPIE, Volume 10703, id. 1070359 12 pp. (2018).

2. **The infrared Doppler (IRD) instrument for the Subaru telescope: instrument description and commissioning results**

   Kotani et al. [44/57] (2018)

   Proceedings of the SPIE, Volume 10702, id. 1070211 11 pp. (2018).

3. **Radial Velocity Follow-up of the Disintegrating Planet KIC 12557548b**

   Masuda, Hirano, Kawahara, and Sato

   Research Notes of the American Astronomical Society, Volume 2, Issue 1, article id. 50, (2018).

4. **Development of speckle nulling technique for the Savart-plate lateral-shearing interferometric nuller for exoplanets (SPLINE)**

   Yoneta, Murakami, Kotani, Kawahara, Matsuo, Baba, and Tamura (2016)

   Proceedings of the SPIE, Volume 9912, id. 99126I 8 pp. (2016).

5. **The SCExAO high contrast imager: transitioning from commissioning to science**

   Jovanovic et al. [18/37] (2016)

   Proceedings of the SPIE, Volume 9909, id. 99090W 10 pp. (2016).

6. **Laboratory demonstration of the Savart-plate lateral-shearing interferometric nuller for exoplanets (SPLINE)**

   Kitou, Murakami, Kida, Baba, Matsuo, Kotani, Kawahara, and Tamura (2014)

   Proceedings of the SPIE, Volume 9151, id. 91515N 7 pp. (2014).

7. **High-contrast planet imager for Kyoto 4m segmented telescope**

   Matsuo et al. [4/23] (2014)

   Proceedings of the SPIE, Volume 9147, id. 91471V 20 pp. (2014).

8. **Infrared Doppler instrument (IRD) for the Subaru telescope to search for Earth-like**

planets around nearby M-dwarfs

Kotani et al. [53/54] (2014)

Proceedings of the SPIE, Volume 9147, id. 914714 12 pp. (2014).

9. **Development of the Savart-plate lateral-shearing interferometric nuller for exoplanet (SPLINE)**

   Murakami, Kida, Baba, Matsuo, Kotani, Kawahara, Fujii, and Tamura (2012)

   Ground-based and Airborne Instrumentation for Astronomy IV. Proceedings of the SPIE, Volume 8446, article id. 84468H, 8 pp. (2012).

10. **Second-Earth imager for TMT (SEIT): concept and its numerical simulation**

    Matsuo et al. [4/14] (2012)

    Ground-based and Airborne Instrumentation for Astronomy IV. Proceedings of the SPIE, Volume 8446, article id. 84461K, 8 pp. (2012).

11. **SUZAKU observation of filamentary junctions in the SDSS galaxies**

    Kawahara

    SUZAKU 2011: Exploring the X-ray Universe: Suzaku and Beyond. AIP Conference Proceedings, Volume 1427, pp. 340-341 (2012).

(3) Review Papers

(4) Books

1. Hajime Kawahara (2018), Exoplanet Exploration toward Exolife, Textbook written in Japanese, University of Tokyo Press, 273 pages, ISBN 978-4-13-062727-6 (5) Other Publications

(6) Patents

8. Keynote, Invited, or Solicited Presentations

1. **Kawahara, JpGU 2018, B-A001 Astrobiology session,**

   Title How to find an Earth analog and a solar-system analog in the world of exoplanets, Hajime Kawahara, May 22th, (2018)

2. **Kawahara, Towards Gravitational-Wave Astronomy of core-collapse SuperNovae (GWASNe2018),**

   Title Time-Frequency Analysis of Multimodal Gravitational Wave, Hajime Kawahara, Jan 31th (2018), NAOJ, Mitaka

3. **Kawahara, Planet formation around snowline,**

   Title Finding transiting objects around snowline, Hajime Kawahara, Nov 30th (2017), The University of Tokyo

4. **Kawahara, Origin and Diversity of Planetary Systems from the Microscope to the Telescope, Planet2 Symposium**

   Title Transiting Planets near and beyond the snow line, Hajime Kawahara Feb. 20th (2017), Nice, France

5. **Kawahara, German-Japanese Exoplanet Conference**

   Title Characterization of Exoplanets with High-Contrast and High-Dispersion Instruments on

Extremely Large Telescopes, Hajime Kawahara, Nov 6th (2014)

Heiderberg, Germany,

6. **Kawahara, JpGU Meeting 2014**

   Title Characterization of Exoplanets with High Contrast Instruments, Hajime Kawahara, Apr 28 (2014)

   Yokohama, Japan

III. Education Activity

9. Notable Achievements in Education

Advisees

- Master theses: 1 students

  Sho Uehara (Mar. 2016, from TMU)

- Doctral theses: 1 students

  Stevanus Nugroho (Mar. 2017 from Tohoku U)

Lectures

- Undergraduate, Earth and Planetary physics enshu I　FY2013-2018
- Undergraduate Remote sensing and GIS, FY2013-2018

10. Contribution to Academic Community

- Subaru/TMT Science book, writer, 2018
- International Association of Seismology and Physics of the Earth's Interior, Commission on Earthquake Source Mechanics Chair, 2017-2018

11. Outreach Activity

12. Internal Committee Membership

V. International Exchange Activities

13. Hosting/Sending Foreign Students and Researchers

(1) Hosting

Foreign Students: 0

Foreign Researchers: 0

(2) Sending

Students: 0

Researchers: 0

(3) Visitors from Abroad: 0

Satoshi Takahashi

I. CV

Name: Satoshi Takahashi

Age: 36

Present Position: Assistant Professor

Education

Morioka-Daiichi High School, Iwate, March 2002 (graduation)

B. Sc., Geology and Paleontology, Science, Tohoku University, March 2006

M. Sc., Geology and Paleontology, Science, Tohoku University, March 2008

Ph. D., Geology and Paleontology, Science, Tohoku University, March 2011

Professional Experience

April 2009-March 2011, Research Fellow of Japan Society for the Promotion of Science (DC1), Tohoku University Japan.

April 2011-present, Assistant Professor of Department of Earth and Planetary Science, University of Tokyo, Japan.

II. Scientific Research Activity

2. Major Achievements

Geology of North Kitakami Belt, North Japan

We carried out a detailed study of the geology of the boundary area between the two sub-belts in the west Akka area in North Japan. Distributions of microfossil dates (mainly conodonts) support the previously proposed criterion for the Iwaizumi Tectonic Line. But, the feldspar and alkali-feldspar compositions of sandstones change gradually across the boundary, indicating that they are not consistent with the proposed idea of the tectonic line. (Takahashi et al., 2006, 2016; Awarded by Geological Society Japan)

Study on deep-sea sedimentary rocks ranging Paleozoic and Mesozoic

We also carried out the paleoenvironmental conditions Paleozoic-Mesozoic transition associated with significant mass extinction events. Our research materials are deep-sea sedimentary rocks in the accretionary complexes of Japan and New Zealand. Usually, such deep-sea sedimentary sequences are rarely preserved, making our studies unique. So far, we have established continuous Permian-Triassic boundary sections in Japan and New Zealand using microfossil dating and stable carbon isotope stratigraphy (Takahashi et al., 2009a, 2010, 2013; Hori et al., 2011). Some well-preserved sections of Early Triassic and Middle Triassic have also been established (Takahashi et al., 2009b; Muto et al., 2018, 2019). Discovered age-diagnosis microfossil include complete conodont natural assemblage, which provides rare information on the pelagic ecosystem (Takahashi et al., 2019a). Currently, we have obtained geochemical data of the interval between the end-Permian mass extinction and recovery stage of the Early Triassic. These data indicate that anoxic and partly sulphidic water mass were frequently developed in the pelagic ocean, coinciding with decreases in silicic microfossil occurrences as well as a reduction of their diversity (Takahashi et al., 2009b, 2013, 2014, 2015). Further, we mentioned burial flux of redox-sensitive elements into the deep-sea basin, and firstly show the evidence of decreases in reactive iron and bio-essential trace element from the seawater after the mass extinction event (Takahashi et al., 2014, 2019b).

3. Five Important Papers (including three or more papers in this review period)

1. Satoshi Takahashi, Satoshi Yamakita, Noritoshi Suzuki, Kunio Kaiho, Masayuki Ehiro (2009). High organic carbon content and a decrease in radiolarians at the end of the Permian in a newly discovered continuous pelagic section: a coincidence ?, Palaeogeography, Palaeoclimatology, Palaeoecology, Elsevier, 271, 1-12.

This paper reports one of the most well continuously preserved Permian-Triassic boundary section which deposited in the low-latitude deep-sea. (Citation 45, Research Gate)

2. Satoshi Takahashi, Shin-ichi Yamasaki, Yasumasa Ogawa, Kazuhiko Kimura, Kunio Kaiho, Takeyoshi Yoshida, Noriyoshi Tsuchiya, (2014). Bioessential element-depleted ocean following the euxinic maximum of the end-Permian mass extinction, Earth and Planetary Science Letters 33, 94-104. (Citation 34, Research Gate)

This paper indicates geochemical evidences on anoxic-sulfidic water in the end-Permian pelagic oceanic region. Furthermore, it mentioned on redox-sensitive trace elements drawdown in the seawater after the mass extinction event.

3. Satoshi Takahashi, Shin-ich Yamasaki, Kazuhiro Ogawa, Kunio Kaiho, Noriyoshi Tsuchiya, (2015). Redox conditions in the end-Early Triassic Panthalassa. Palaeogeography, Palaeoclimatology, Palaeoecology 432, 15–28.

This paper suggests that weakly anoxic environment (suboxic condition) occurred the low-latitude pelagic ocean at the late Early Triassic based on geochemical analysis and stratigraphic observations. (Citation 14, ResearchGate)

4. Takahashi, S., Ehiro, M., Suzuki, N., Yamakita, S., (2016). Subdivisional scheme of the North Kitakami Belt, Northeast Japan and its tectonostratigraphic correlation to the Oshima and South Chichibu belts: J. Geol. Soc. Japan 122, 1–22. (in Japanese with English abstract)

This paper shows detailed geologic map of the western Akka district, Iwate, North Japan. It also reports results of microfossil data and sandstone compositions and discuss the boundary criteria of the North Kitakami Belt which is divided by the Iwaizumi Tectonic Line (Citation 2, ResearchGate)

5. *Satoshi Takahashi, Satoshi Yamakita, and Noritoshi Suzuki* (2019). Natural assemblages of the conodont Clarkina in lowermost Triassic deep-sea black claystone from northeastern Japan, with probable soft-tissue impressions. Palaeogeography, Palaeoclimatology, Palaeoecology,524, 212-229.

This reports a rare and important finding on conodont natural assemblages from the earliest Triassic black shale which deposited in the pelagic deep-sea. All of totally five specimen include possible imprints of soft-tissue parts (“eye” -like sensory organs)　(Citation 0, ResearchGate)

4. Awards and Honors

- Takahashi, S., The Japanese Association of Organic geochemists research encouragement award (Taguchi award), 2012/8/22
- Takahashi, S.,　Paleoscience Society research encouragement award, 2014/04/28
- Takahashi, S.,　Geological Society of Japan research encouragement award, 2018/09/05

5. Future Research Plan

Long-term objective:

Reconstruct environmental history in the past recorded in the sedimentary rocks. Especially, I focus on the significant environmental changes in the Earth history, its spatio-temporal extensity, contemporaneous responses of life, using paleontological and geochemical methods.

Specific objectives:

1. Process of sedimentary records relate to paleo oceanic environment

To understand modern sedimentary process corresponding to oceanic environmental changes, we are focusing on the Quarternary sedimentary materials which record oxic-anoxic transitions. We obtained the continuous sedimentary core from the Japan Sea cites ranging last 150 kilo years associated with glacial-interglacial alternations and oxic-anoxic oxygen-poor seawater conditions. Based on these study materials, we will conduct geochemical approaches such as quantitative redox-sensitive elements analyses (e.g. organic carbon, sulphur, molybdenum, uranium etc.) and that of their isotopes. Therefore, these results will be compared with other datasets of bio-assemblages, primary productivity, terrigenous nutrient influx and seawater exchange rates. Then, it will provide empirical data indicating sedimentary compositions reflecting redox seawater conditions and biotic activity.

2. Mechanism of pelagic water anoxia in the geologic past:

I want to mention the main driver of the marine anoxia-euxinia in the pelagic oceanic region, which occurred in the geologic past, such as the end-Permian mass extinction event. For this aim, we will attempt to split the samples equally and show the geochemical proxies data for each time unit (e.g., per a thousand years) to easily compare the modern marine environmental system. Furthermore, we will add additional data of osmium isotope (187/188Os) and fossilized chlorophyll organic molecules and nutrient elemental flux to the previous results on the end-Permian anoxic ocean event. And we will reveal the timing and developing process starting possibly from a volcanic eruption, high nutrient-driven primal productivity and oxygen consumption in the oceanic regions. Based on those results, the causality of each phenomenon and possible threshold which cause future widely extended anoxic ocean and mass extinction event.

6. Funding Received

- Fukada Geological Institute Research Fund, Principal Investigator, FY2013, 500,000 yen
- JSPS KAKENHI, 16H01765, Co-Investigator, FY2016–2019, 41,340,000 yen
- JSPS KAKENHI, 26610166, Co-Investigator, FY2014-2015, 3,770,000 yen
- Tokyo Geographical Society, Principal Investigator, FY2016, 500,000 yen
- JSPS KAKENHI, 17K05689, Principal Investigator, FY2017–2019, 3,100,000 yen
- UTokyo Global Activity Support Program for Young Researchers (For visiting University of Leeds), FY2018-2019, 2500,000 yen
- JSPS KAKENHI, 19H02007, Co-Investigator, FY2019-2022, 17,680,000 yen

7. Publications and Patents

(1) Peer-reviewed Journal Articles

1. Satoshi Takahashi, Kunio Kaiho, Rie S. Hori, Paul Gorjan, Takahiro Watanabe, Satoshi Yamakita, Yoshiaki Aita, Atsushi Takemura, K Bernhard Spörli, Takeshi Kakegawa, Masahiro Oba, (2013). Sulfur isotope profiles in the pelagic Panthalassic deep sea during the Permian–Triassic transition, Global and Planetary Change 105, 68-78.
2. Ryosuke Saito, Kunio Kaiho, Masahiro Oba, Satoshi Takahashi, Zhong-Qiang Chen, Jinnan Tong, (2012). A terrestrial vegetation turnover in the middle of the Early Triassic. Global and Planetary Change 105, 152–159.

3. Satoshi Takahashi, (2013). Palaeontological and geochemical studies on Permian-Triassic pelagic deep-sea sedimentary rocks, Research Organic geochemistry 29, 1-16. (in Japanese with English abstract)

4. Ryoichi Nakada, Kazuhiro Ogawa, Noritoshi Suzuki, Satoshi Takahashi, Yoshio Takahashi, (2014). Late Triassic compositional changes of aeolian dusts in the pelagic Panthalassa: Response to the continental climatic change. Palaeogeography, Palaeoclimatology, Palaeoecology 393, 61-75.

5. Satoshi Takahashi, Shin-ichi Yamasaki, Yasumasa Ogawa, Kazuhiko Kimura, Kunio Kaiho, Takeyoshi Yoshida, Noriyoshi Tsuchiya, (2014). Bioessential element-depleted ocean following the euxinic maximum of the end-Permian mass extinction, Earth and Planetary Science Letters 33, 94-104.

6. Ryoichi Nakada, Taka'aki Shirai, Satoshi Takahashi, Noritoshi Suzuki, Kazuhiro Ogawa, Yoshio Takahashi, (2014). A geochemical constraint on the formation process of a manganese carbonate nodule in the siliceous mudstone of the Jurassic accretionary complex in the Mino Belt, Japan. Journal of Asian Earth Sciences 96, 59–68.

7. Ryosuke Saito, Masahiro Oba, Kunio Kaiho, Philippe Schaeffer, Pierre Adam, Satoshi Takahashi, Fumiko Watanabe Nara, Zhong-Qiang Chen, Jinnan Tong, Noriyoshi Tsuchiya, (2014). Extreme euxinia just prior to the Middle Triassic biotic recovery from the latest Permian mass extinction. Organic Geochemistry 73, 113—122.

8. Yuichiro Nishikane, Kunio Kaiho, Charles M. Henderson, Satoshi Takahashi, Noritoshi Suzuki, (2014). Guadalupian–Lopingian conodont and carbon isotope stratigraphies of a deep chert sequence in Japan. Palaeogeography, Palaeoclimatology, Palaeoecology 403, 16-29.

9. Jack Grant Mackie, Satoshi Yamakita, T. Matsumoto, Rie Hori, Atsushi Takemura, Yoshiaki Aita, Satoshi Takahashi, Hamish Campbell, (2014). A probable shark dorsal fin spine fragment from the Early Triassic of the Arrow Rocks sequence, Whangaroa, northern New Zealand. New Zeal. J. Geol. Geophys., 1–5.

10. Satoshi Takahashi, Shin-ich Yamasaki, Kazuhiro Ogawa, Kunio Kaiho, Noriyoshi Tsuchiya, (2015). Redox conditions in the end-Early Triassic Panthalassa. Palaeogeography, Palaeoclimatology, Palaeoecology 432, 15–28.

11. Takahashi, S., Ehiro, M., Suzuki, N., Yamakita, S., (2016). Subdivisional scheme of the North Kitakami Belt, Northeast Japan and its tectonostratigraphic correlation to the Oshima and South Chichibu belts: J. Geol. Soc. Japan 122, 1–22. (in Japanese with English abstract)

12. Ryosuke Saito, Kunio Kaiho, Masahiro Oba, Jinnan Tong, Zhong-Qiang Chen, Satoshi Takahashi, Jing Chen, Li Tian, Raman Kumar Biswas, (2016). Secular changes in environmental stresses and eukaryotes during the Early Triassic to the early Middle Triassic. Palaeogeography Palaeoclimatology Palaeoecology 451, 35-45.

13. Kunio Kaiho, Ryosuke Saito, Kosuke Ito, Takashi Miyaji, Raman Biswas, Li Tian, Hiroyoshi Sano, Zhiqiang Shi, Satoshi Takahashi, Jinnan Tong, Lei Liang, Masahiro Oba, Fumiko W. Nara, Noriyoshi Tsuchiya, (2016). Effects of soil erosion and anoxic–euxinic ocean in the Permian–Triassic marine crisis. *Heliyon*, *2* (8), e00137.

14. Ryosuke Saito, Kunio Kaiho, Masahiro Oba, Jinnan Tong, Zheng Q. Chen, Li Tian, Satoshi Takahashi, Meguru Fujibayashi, (2017). Tentative identification of diagenetic products of cyclic biphytanes in sedimentary rocks from the uppermost Permian and Lower Triassic. Organic Geochemistry 111, 144–153.

15. Shun Muto, Satoshi Takahashi, Satoshi Yamakita, Noritoshi Suzuki, Nozomi Suzuki, Yoshiaki Aita, Y., (2018). High sediment input and possible oceanic anoxia in the pelagic Panthalassa during the latest Olenekian and early Anisian: Insights from a new deep-sea section in Ogama, Tochigi, Japan. Palaeogeography, Palaeoclimatology, Palaeoecology. 490, 687–707.

16. Shun Muto, Satoshi Takahashi, Satoshi Yamakita, Katsuhito Soda and Tetsuji Onoue, (2019). Conodont-based age calibration of the Middle Triassic Anisian radiolarian biozones in pelagic deep-sea bedded chert, bulletin of geological survey of Japan, 70, 40-89.
17. Satoshi Takahashi, Ryoichi Nakada, Yusuke Watanabe, Yoshio Takahashi, (2019). Iron-depleted pelagic water at the end-Permian mass extinction inferred from chemical species of iron and molybdenum in deep-sea sedimentary rocks. Palaeogeography, Palaeoclimatology, Palaeoecology, 516,384-399.
18. *Satoshi Takahashi, Satoshi Yamakita, and Noritoshi Suzuki,* (2019). Natural assemblages of the conodont Clarkina in lowermost Triassic deep-sea black claystone from northeastern Japan, with probable soft-tissue impressions. Palaeogeography, Palaeoclimatology, Palaeoecology,524, 212-229

(2) Non-peer-reviewed Articles

(3) Review Papers

(4) Books

(5) Other Publications

1. Takahashi, S. (2014). Interactive comment on " Amelioration of marine environments at the Smithian – Spathian boundary, Early Triassic " by L . Zhang et al ., 7416–7419.
2. Takahashi, S., Yoshizawa, K., Nakajima, Y., Muto, S., Tashiro, T., Tsuihiji, T., Misaki, A., (2017). Oceanic environment and biotic revolution of late Early Triassic oceanic region around the South Kitakami Block, (2017). Journal of Geography ("Chigaku Nyusu") N95. (in Japanese)

(6) Patents

8. Keynote, Invited, or Solicited Presentations

1. Satoshi Takahashi, Shin-ichi Yamasaki, Yasumasa Ogawa, Kazuhiko Kimura, Kunio Kaiho, Takeyoshi Yoshida, Noriyoshi Tsuchiya: Bioessential element-depleted ocean following the euxinic maximum of the end-Permian mass extinction. SE44-A006, Asia Oceania Geoscience, Sapporo, Japan, 2014/6/30.
2. S. Takahashi, S. Yamasaki, Y. Ogawa, K. Kimura, T. Yoshida, N. Tsuchiya, R. Nakada, K. Kaiho, and Y. Takahashi, Trace elemental behavior at the pelagic deep sea during the Permian-Triassic mass extinction, 2E02, annual meeting of geochemical scocitety of Japan, Yokohama national University, Yokohama, Japan, 2015/9/17. (in Japanese)
3. Satoshi Takahashi, Kunio Kaiho, Satoshi Yamakita, Masahiro Oba, Shin-ichi Yamasaki, Noriyoshi Tsuchiya, Takeshi Kakegawa, Takeyoshi Yoshida, Noritoshi Suzuki,Masayuki Ehiro,Ryoichi Nakada,Yusuke Watanabe,Yoshio Takahashi, Yasumasa Ogawa, Kazuhiko Kimura, The end-Permian mass extinction event in the pelagic Panthalassa, annual meeting of palaeontological society of Japan, Tohoku University Japan, Miyagi, 2018/6/22

III. Education Activity

9. Notable Achievements in Education

Advisees

・ Graduation thesis: 4 students

Shun Muto (Mar. 2013)

Koya Uchida (Mar. 2014)
Kazuko Yoshizawa (Mar. 2015)
Hironao Matsumoto (Mar. 2016)

- Master theses: 3 students (co-supervised with Prof. R Tada)
  Akane Mizutani (Mar. 2014)
  Shun Muto (Mar. 2015)
  Koya Uchida (Mar. 2016)
- Doctral theses: 1 student (co-supervised with Prof. R Tada)
  Shun Muto (Mar. 2018)

Lectures

- Undergraduate, Textures of sedimentary rocks, FY2012-2018
- Undergraduate, Fieldwork skill on Geology and Geography, FY2012-2018
- Undergraduate, Student training on geologic field works 1, FY2012-2018
- Undergraduate, Drill on Earth and Planetary Science, FY2016-2018
- Undergraduate, Practical works on Earth and Planetary Science, FY2017-2017

Student's awards

- Japan Geoscience Union, Student Presentation Award: 1 student [Shun Muto]
- InterRad 2017 Best Presentation Award: 1student [Shun Muto]

IV. External Activities

10. Contribution to Academic Community

- Geological Society of Japan, Voting monitor, FY2011, FY2013, FY2015
- Paleosciences Society, Councillor, FY2012-2018
- The Japanese Association of Organic geochemists, Editor of annual News Letter, FY2012-2018
- Journal of Geological Society of Japan Guest Editor, FY2017-2018
- Japan Geoscience Union, Event organizer (Geofut), FY2016-2017

11. Outreach Activity

- Newspaper articles: 3 times (Nov. 2013, Feb. 2016, Dec. 2017)
- Lectures for general audience: 7 times (Jul. 2013, Feb. 2015, Jul. 2016, Nov. 2017, Dec. 2017, Dec. 2017, Sep. 2016, May 2017, Aug. 2017, Aug. 2018, Feb. 2019)

12. Internal Committee Membership

- Department of Earth and Planetary Science, Public information Committee，FY2013-2018
- Department of Earth and Planetary Environmental Science, Education Committee, FY2013～2018
- Department of Earth and Planetary Science, Rock warehouse management，FY2015-2016

- Department of Earth and Planetary Science, Thin section room management FY 2015-2018

V. International Exchange Activities

13. Hosting/Sending Foreign Students and Researchers

(1) Hosting

Foreign Students: 0

Foreign Researchers: 0

(2) Sending

Students: 0

Researchers: 0

(3) Visitors from Abroad: 1

Nobuhiro Moteki

I. CV

Name: Nobuhiro Moteki

Age: 38

Present Position: Assistant Professor

Education

B. Sc. Department of Chemistry, Tokyo Institute of Technology, March, 2003

M. Sc. Department of Earth and Planetary Physics, The University of Tokyo, March, 2005

Ph. D. Department of Earth and Planetary Physics, The University of Tokyo, March, 2008

Professional Experience

Apr. 2008-Mar. 2011, Assistant Professor, Research Center for Advanced Science and Technology, The University of Tokyo

Apr. 2011-Jul. 2014, Project Assistant Professor, Department of Earth and Planetary Science, The University of Tokyo

Aug. 2014-, Assistant Professor, Department of Earth and Planetary Science, The University of Tokyo

II. Scientific Research Activity

2. Major Achievements

I have been working on observational research related to “aerosol and its effect on clouds”, which is a sub-theme that needs to improve understanding of elementary processes controlling the earth’s climate. The dark-colored light absorbing aerosols (AA) ubiquitous in the Earth’s atmosphere such as black carbon (BC), brown carbon (BrC), and iron-containing mineral dust (Dust), absorb the shortwave radiation and directly heat the atmosphere and snowpack. The BC is the strongest light absorber globally among the known AA species and could be the second-most important contributor to the positive climate forcing after the carbon dioxide. The atmospheric heating by AA perturbs the surface-atmosphere energy exchange and weaken hydrologic cycle in regional-to-global scales. The light-absorption cross section per unit mass, as well as the effectiveness as a cloud condensation nucleus of each AA particle, are strongly dependent on the particle size and the state of internal mixing with other non-absorbing aerosols. For these reasons, observational understandings on the abundance and microphysical properties of each AA species and reflecting these observational findings to the atmospheric models are crucial for quantitative analysis, prediction, and planning the mitigation strategy of global changes. During the evaluation period (2012-2018), I have contributed to the key research issues on the AA in the atmosphere: (1) the experimental method to identify and quantify the AA unambiguously, (2) observational understandings on the mass concentration, size distribution, and mixing state of AA and their controlling factors in the troposphere, (3) the theoretical method to predict the optical properties of each AA from its microphysical properties. The detailed description of each of the three contributions is explained below.

【Experimental method and instrument developments】

I contributed to establishing the method to quantify the BC mass content of each BC-containing particles in the atmosphere using the single particle soot photometer (SP2), an aerosol measuring instrument based on the laser-induced incandescence (LII). Particularly, the applicant experimentally quantifies the effects of coating materials on the BC core to the incandescence signal of BC particles, and provide a theoretical interpretation to the relationships between the microphysical properties (including particle's shape and mixing state) of BC-containing particles and the observed LII signals. These series of fundamental investigations provide a physical basis of quantifications of the mass concentration and the size distribution of BC in the current research community. Also, I proposed a method to measure time-dependent scattering cross-section of the evaporating AA particle in a laser beam from the signal waveform of the particle's light-scattering. This method enables to quantify the mixing state of BC with other non-absorbing aerosols from the light-scattering signal acquired by an LII-instrument without a complicated position-sensitive scattering detector

【Observational investigations】

I observationally constrained for the first time the timescale of evolution of BC mixing state (BC aging timescale) in urban plumes during their boundary layer transport, a very influential factor to the BC rainout efficiency during the moist convections and thus to the BC lifetime and burden in the global atmosphere. These results are used in regional-to-global scale aerosol models for testing their BC aging scheme. Also, I observationally found from aircraft observations that the strong particle-size dependence of the efficiency of BC vertical transport from the boundary layer to the free troposphere. The applicant showed from the simultaneous measurements of BC-containing particles in rainwater and boundary layer air that the size-dependent filtering of BC-containing particles (and other aerosols as well) during the moist convection is explained by the dominance of the nucleation-scavenging among the potential physical process contributing the aerosol wet deposition. These findings suggest the importance of further sophistication in the models and observations on the initial conditions and evolution of BC core size, thickness and hygroscopicity of coating materials on BC, and of unbiased assumptions on the water-vapor supersaturation in precipitating clouds. The applicants showed from the aircraft measurement in East Asian outflow and ground observation at an arctic site that the anthropogenic iron-oxide (aggregate of magnetite-like particles) is ubiquitous in the troposphere and showed from global simulation that its positive radiative forcing could be comparable to the BrC.

【Theoretical methods】

An accurate prediction using the electromagnetic theory of the optical properties of solid-state AA (BC, anthropogenic and natural iron oxide containing particles) with acceptable computational costs is a non-trivial task, considering the enormously complex and variable shape and state of mixing with other non-absorbing compounds. The applicant developed a general-purpose light scattering solver (block-DDA) originally implementing the following features to improve the accuracy and efficiency: the electric-and-magnetic dipoles, hybrid discretization of clusters of monomers and coating materials, FFT-based far-field computation, and block-Krylov iterative method for averaging over many orientations at a single-execution.

3. Five Important Papers (including three or more papers in this review period)

1. Moteki, N., Mori, T., Matsui, H., Ohata, S. (2019), Observational constraint of in-cloud supersaturation for simulations of aerosol rainout in atmospheric models, npj Climate and Atmospheric Science, 2, 6, doi: 10.1038/s41612-019-0063-y. (Citation 1, GS/Sep. 4, 2019).

Quantitative simulation of an aerosol's lifecycle by regional-scale and global-scale atmospheric models is mandatory for unbiased analysis and prediction of aerosol radiative forcing and climate change. Globally, aerosol deposition is dominated by the rainout process, which is mostly triggered by activation of aerosols to liquid droplets in supersaturated domains of precipitating clouds. However, the actual environmental supersaturation value that aerosols experience in precipitating clouds is difficult for models to predict, and it has never been constrained by observations; as a result, there is large uncertainty in atmospheric aerosol simulations. Here, by a particle-tracer analysis of 37 rainfall events in East Asia, near the largest source region of anthropogenic aerosols in the northern hemisphere, we observed that the environmental supersaturation actually experienced by the removed aerosols in precipitating clouds averaged 0.08 ± 0.03% and ranged from 0.03 to 0.2%. Simulations by a mixing-state-resolved global aerosol model showed that the simulated long-range transport efficiency and global atmospheric burden of black carbon aerosols can be changed by a factor of two or three as a result of a change in the environmental supersaturation in precipitating clouds within just 0.08 ± 0.03%. This result is attributable to the fact that the sensitivity of an aerosol's rainout efficiency to environmental supersaturation is higher for the less-aged black carbon concentrated near source regions. Our results suggest that observational constraints of environmental supersaturation in precipitating clouds, particularly near source regions, are of fundamental importance for accurate simulation of the atmospheric burden of black carbon and other aerosols.

2. Matsui, H., Mahowald, N. M., **Moteki, N.**, Hamilton, D. S., Ohata, S., Yoshida, A., Koike, M., Scanza, R. A., Flanner, M. G. (2018), Anthropogenic combustion iron as a complex climate forcer, *Nature communications*, 9, 1, 1593. (Citation 14, GS/Sep. 4, 2019).

Atmospheric iron affects the global carbon cycle by modulating ocean biogeochemistry through the deposition of soluble iron to the ocean. Iron emitted by anthropogenic (fossil fuel) combustion is a source of soluble iron that is currently considered less important than other soluble iron sources, such as mineral dust and biomass burning. Here we show that the atmospheric burden of anthropogenic combustion iron is 8 times greater than previous estimates by incorporating recent measurements of anthropogenic magnetite into a global aerosol model. This new estimation increases the total deposition flux of soluble iron to southern oceans (30–90 °S) by 52%, with a larger contribution of anthropogenic combustion iron than dust and biomass burning sources. The direct radiative forcing of anthropogenic magnetite is estimated to be 0.021 W m−2 globally and 0.22 W m−2 over East Asia. Our results demonstrate that anthropogenic combustion iron is a larger and more complex climate forcer than previously thought, and therefore plays a key role in the Earth system.

3. **Moteki, N.**, Adachi, K., Ohata, S., Yoshida, A., Harigaya, T., Koike, M., Kondo, Y. (2017). Anthropogenic iron oxide aerosols enhance atmospheric heating, *Nature communications*, 8, 15329. (Citation 37, GS/Sep. 4, 2019).

Combustion-induced carbonaceous aerosols, particularly black carbon (BC) and brown carbon (BrC), have been largely considered as the only significant anthropogenic contributors to shortwave atmospheric heating. Natural iron oxide (FeOx) has been recognized as an important contributor, but the potential contribution of anthropogenic FeOx is unknown. In this study, we quantify the abundance of FeOx over East Asia through aircraft measurements using a modified single-particle soot photometer. The majority of airborne FeOx particles in the continental outflows are of anthropogenic origin in the form of aggregated magnetite nanoparticles. The shortwave absorbing powers (Pabs) attributable to FeOx and to BC are calculated on the basis of their size-resolved mass concentrations and the mean Pabs(FeOx)/Pabs(BC) ratio in the continental outflows is estimated to be at least 4–7%. We demonstrate that in addition to carbonaceous aerosols the aggregate of magnetite nanoparticles is a significant anthropogenic contributor to shortwave atmospheric heating.

4. Yoshida, A., **Moteki, N.** (Corresponding author), Ohata, S., Mori, T., Tada, R., Dagsson-Waldhauserova, P., Kondo, Y. (2016). Detection of light-absorbing iron oxide particles using a modified single-particle soot photometer, *Aerosol Science and Technology*, 50, 3, 1-4. (Citation 12, GS/Sep. 4, 2019).

We propose a method for real-time single-particle measurement of iron oxide aerosols using the laser-induced incandescence (LII) technique. We demonstrate from laboratory experiments and theoretical calculations that we can identify and quantify particulate light-absorbing iron oxides simultaneously with black carbon based on careful analyses of LII and light scattering signals, if wavelength bands for LII detection were adequately chosen.

5. **Moteki, N.**, Kondo, Y., Oshima, N., Takegawa, N., Koike, M., Kita, K., Matsui, H., Kajino, M. (2012). Size dependence of wet removal of black carbon aerosols during transport from the

boundary layer to the free troposphere, Geophysical Research Letters, 39, 13, L13802. (Citation 55, GS/Sep. 4, 2019)

We found that size distributions of black carbon (BC) measured by aircraft over East Asia were highly correlated with BC transport efficiency in air parcels uplifted from the planetary boundary layer to the free troposphere. The average single-particle BC mass decreased with decreasing transport efficiency, which suggests that aerosols containing larger BC mass were removed more efficiently. This is the first successful observation of the size-dependent wet removal of aerosols, qualitatively consistent with the Köhler theory. The size distribution of BC uplifted to the free troposphere with high efficiency was similar to the size distribution of BC in the planetary boundary layer. Conversely, the size distribution of BC uplifted with low efficiency was similar to that of background air in the free troposphere. We conclude that wet removal during upward transport is important in controlling the size distribution of BC in the free troposphere.

4. Awards and Honors

5. Future Research Plan

I will continue studies on earthquake science, to enhance our knowledge on seismogenesis, which includes long-term loading by plate tectonics, preparation of rupture by slow deformation, dynamic rupture propagation and arrest, and following slow relaxation. In addition to such an earthquake cycle for each event, we need to know about the mechanism of interaction among many earthquakes, including slow earthquakes. Analyzing large volume of high-quality seismic and geodetic data in Japan and collaborating with researchers in different field in the Slow Earthquake Project, we improve our knowledge for the basic mechanisms of slow deformation processes. Moreover, we will strengthen our international collaboration network for comparative studies on earthquakes and slow earthquakes worldwide. For fast dynamic rupture process, key concepts for future earthquake seismology would be broadband hierarchical heterogeneity and inherent unpredictability of whole earthquake process. Empirically and theoretically, we develop methods to quantify hierarchical fast rupture with slow processes and assess the predictability of earthquakes.

6. Funding Received

- JSPS KAKENHI, 19H04236, Principal Investigator, FY2019-2021, 17,290,000 yen
- JSPS KAKENHI, 19H04259, Co-Investigator, FY2019-2022, 17,290,000 yen
- JSPS KAKENHI, 19H05699, Co-Investigator, FY2019-2023, 191,100,000 yen
- JSPS KAKENHI, 16H01770, Co-Investigator, FY2016-2019, 41,600,000 yen
- JSPS KAKENHI, 15H05465, Principal Investigator, FY2015-2017, 21,580,000 yen

7. Publications and Patents

(1) Peer-reviewed Journal Articles

1. Ohata, S., Kondo, Y., **Moteki, N.**, Mori, T., Yoshida, A., Sinha, P. R., Koike, M., Accuracy of black carbon measurements by a filter-based absorption photometer with a heated inlet, *Aerosol Science and Technology*, Accepted, doi: 10.1080/02786826.2019.1627283, 2019.
2. **Moteki, N.**, Mori, T., Matsui, H., Ohata, S., Observational constraint of in-cloud supersaturation for simulations of aerosol rainout in atmospheric models, *npj Climate and Atmospheric Science*, 2, 6, doi: 10.1038/s41612-019-0063-y, 2019.
3. Matsui, H., Mahowald, N. M., **Moteki, N.**, Hamilton, D. S., Ohata, S., Yoshida, A., Koike, M., Scanza, R. A., Flanner, M. G., Anthropogenic combustion iron as a complex climate forcer,

Nature communications, 9, 1, 1593, 2018.

4. Sinha, P. R., Kondo, Y., Goto□Azuma, K., Tsukagawa, Y., Fukuda, K., Koike, M., Ohata, S., **Moteki, N.**, Mori, T., Oshima, N., Seasonal Progression of the Deposition of Black Carbon by Snowfall at Ny□Alesund, Spitsbergen, *Journal of Geophysical Research: Atmospheres*, 123, 2, 997-1016, 2018.
5. Ohata, S., Yoshida, A., **Moteki, N.**, Adachi, K., Takahashi, Y., Kurisu, M., Koike, M., Abundance of light□absorbing anthropogenic iron oxide aerosols in the urban atmosphere and their emission sources, *Journal of Geophysical Research: Atmospheres*, 123, 15, 8115-8134, 2018.
6. Yoshida, A., Ohata, S., **Moteki, N.** (Corresponding author), Adachi, K., Mori, T., Koike, M., Takami, A., Abundance and emission flux of the anthropogenic iron oxide aerosols from the East Asian continental outflow, *Journal of Geophysical Research: Atmospheres*, 123, 19, 11,194-11,209, 2018.
7. Lamb, K., Perring, A., Samset, B., Peterson, D., Davis, S., Anderson, B., Beyersdorf, A., Blake, D., Campuzano-Jost, P., Corr, C., Diskin, G., Kondo, Y., **Moteki, N.**, Nault, B., Oh, J., Park, M., Pusede, S., Simpson, I., Thornhill, K., Wisthaler, A., Schwarz, J., Estimating Source Region Influences on Black Carbon Abundance, Microphysics, and Radiative Effect Observed over South Korea, *Journal of Geophysical Research: Atmospheres*, 123, 23, 13,527-13,548, 2018.
8. **Moteki, N.**, Adachi, K., Ohata, S., Yoshida, A., Harigaya, T., Koike, M., Kondo, Y., Anthropogenic iron oxide aerosols enhance atmospheric heating, *Nature communications*, 8, 15329, 2017.
9. Sinha, P. R., Kondo, Y., Koike, M., Ogren, J. A., Jefferson, A., Barrett, T. E., Sheesley, R. J., Ohata, S., **Moteki, N.**, Coe, H., Evaluation of ground□based black carbon measurements by filter□based photometers at two Arctic sites, *Journal of Geophysical Research: Atmospheres*, 122, 6, 3544-3572, 2017.
10. Ohata, S., **Moteki, N.** (Corresponding author), Mori, T., Koike, M., Kondo, Y., A key process controlling the wet removal of aerosols: new observational evidence, *Scientific reports*, 6, 34113, 2016.
11. **Moteki, N.**, Discrete dipole approximation for black carbon-containing aerosols in arbitrary mixing state: A hybrid discretization scheme, *Journal of Quantitative Spectroscopy and Radiative Transfer*, 178, 306-314, 2016.
12. Kondo, Y., **Moteki, N.**, Oshima, N., Ohata, S., Koike, M., Shibano, Y., Takegawa, N., Kita, K., Effects of wet deposition on the abundance and size distribution of black carbon in East Asia, *Journal of Geophysical Research: Atmospheres*, 121, 9, 4691-4712, 2016.
13. Adachi, K., **Moteki, N.**, Kondo, Y., Igarashi, Y., Mixing states of light□absorbing particles measured using a transmission electron microscope and a single□particle soot photometer in Tokyo, Japan, *Journal of Geophysical Research: Atmospheres*, 121, 15, 9153-9164, 2016.
14. Ohata, S., Schwarz, J. P., **Moteki, N.**, Koike, M., Takami, A., Kondo, Y., Hygroscopicity of materials internally mixed with black carbon measured in Tokyo, *Journal of Geophysical Research: Atmospheres*, 121, 1, 362-381, 2016.
15. Yoshida, A., **Moteki, N.** (Corresponding author), Ohata, S., Mori, T., Tada, R., Dagsson-Waldhauserova, P., Kondo, Y., Detection of light-absorbing iron oxide particles using a modified single-particle soot photometer, *Aerosol Science and Technology*, 50, 3, 2016.
16. Mori, T., **Moteki, N.**, Ohata, S., Koike, M., Goto-Azuma, K., Miyazaki, Y., Kondo, Y., Improved technique for measuring the size distribution of black carbon particles in liquid water, *Aerosol Science and Technology*, 50, 3, 242-254, 2016.
17. Miyakawa, T., Kanaya, Y., Komazaki, Y., Miyoshi, T., Nara, H., Takami, A., **Moteki, N.**, Koike, M., Kondo, Y., Emission Regulations altered the concentrations, origin, and formation of carbonaceous aerosols in the Tokyo Metropolitan Area, *Aerosol and Air Quality Research*, 16, 7, 1603-1614, 2016.

18. Irwin, M., Kondo, Y., **Moteki, N.**, An empirical correction factor for filter-based photo-absorption black carbon measurements, *Journal of Aerosol Science*, 80, 86-97, 2015.
19. Taketani, F., Kanaya, Y., Nakamura, T., Takeda, N., Koizumi, K., Hirayama, N., Miyakawa, T., Pan, X., **Moteki, N.**, Takegawa, N., Analysis of the mixing state of airborne particles using a tandem combination of laser-induced fluorescence and incandescence techniques, *Journal of Aerosol Science*, 87, 102-110, 2015.
20. **Moteki, N.**, Mori, T., Theoretical analysis of a method to measure size distributions of solid particles in water by aerosolization, *Journal of Aerosol Science*, 83, 25-31, 2015.
21. Takegawa, N., **Moteki, N.**, Oshima, N., Koike, M., Kita, K., Shimizu, A., Sugimoto, N., Kondo, Y., Variability of aerosol particle number concentrations observed over the western Pacific in the spring of 2009, *Journal of Geophysical Research: Atmospheres*, 119, 23, 13,474-13,488, 2014.
22. Mori, T., Kondo, Y., Ohata, S., **Moteki, N.**, Matsui, H., Oshima, N., Iwasaki, A., Wet deposition of black carbon at a remote site in the East China Sea, *Journal of Geophysical Research: Atmospheres*, 119, 17, 10485-10498, 2014.
23. Samset, B., Myhre, G., Herber, A., Kondo, Y., Li, S.-M., **Moteki, N.**, Koike, M., Oshima, N., Schwarz, J., Balkanski, Y., Modelled black carbon radiative forcing and atmospheric lifetime in AeroCom Phase II constrained by aircraft observations, *Atmospheric Chemistry and Physics*, 14, 22, 12465-12477, 2014.
24. Koike, M., **Moteki, N.**, Khatri, P., Takamura, T., Takegawa, N., Kondo, Y., Hashioka, H., Matsui, H., Shimizu, A., Sugimoto, N., Case study of absorption aerosol optical depth closure of black carbon over the East China Sea, *Journal of Geophysical Research: Atmospheres*, 119, 1, 122-136, 2014.
25. **Moteki, N.**, Kondo, Y., Adachi, K., Identification by single□particle soot photometer of black carbon particles attached to other particles: Laboratory experiments and ground observations in Tokyo, *Journal of Geophysical Research: Atmospheres*, 119, 2, 1031-1043, 2014.
26. Wang, Q., Jacob, D., Spackman, R., Perring, A., Schwarz, J., **Moteki, N.**, Marais, Eloase A., Ge, C., Wang, J., Barrett, Steven R. ,Global budget and radiative forcing of black carbon aerosol: Constraints from pole□to□pole (HIPPO) observations across the Pacific, *Journal of Geophysical Research: Atmospheres*, 119, 1, 195-206, 2014.
27. **Moteki, N.**, Kondo, Y., A new theoretical method for calculating temperature and water vapor saturation ratio in an expansion cloud chamber, *Journal of Geophysical Research: Atmospheres*, 118, 12, 6633-6642, 2013.
28. Matsui, H., Koike, M., Kondo, Y., Oshima, N., **Moteki, N.**, Kanaya, Y., Takami, A., Irwin, M., Seasonal variations of Asian black carbon outflow to the Pacific: Contribution from anthropogenic sources in China and biomass burning sources in Siberia and Southeast Asia, *Journal of Geophysical Research: Atmospheres*, 118, 17, 9948-9967, 2013.
29. Matsui, H., Koike, M., Kondo, Y., **Moteki, N.**, Fast, J., Zaveri, R., Development and validation of a black carbon mixing state resolved three□dimensional model: Aging processes and radiative impact, *Journal of Geophysical Research: Atmospheres*, 118, 5, 2304-2326, 2013.
30. Oshima, N., Koike, M., Kondo, Y., Nakamura, H., **Moteki, N.**, Matsui, H., Takegawa, N., Kita, K., Vertical transport mechanisms of black carbon over East Asia in spring during the A□FORCE aircraft campaign, *Journal of Geophysical Research: Atmospheres*, 118, 23, 13,175-13,198, 2013.
31. Taketani, F., Kanaya, Y., Nakamura, T., Koizumi, K., **Moteki, N.**, Takegawa, N., Measurement of fluorescence spectra from atmospheric single submicron particle using laser-induced fluorescence technique, *Journal of Aerosol Science*, 58, 2013.
32. Ohata, S., **Moteki, N.**, Schwarz, J., Fahey, D., Kondo, Y., Evaluation of a method to measure black carbon particles suspended in rainwater and snow samples, *Aerosol Science and Technology*, 47, 10, 1073-1082, 2013.
33. Takegawa, N., **Moteki, N.**, Koike, M., Oshima, N., Kondo, Y., Condensation particle counters

combined with a low-pressure impactor for fast measurement of mode-segregated aerosol number concentration, *Aerosol Science and Technology*, 47, 10,1059-1065, 2013.

34. Irwin, M., Kondo, Y., **Moteki, N.**, Miyakawa, T., Evaluation of a Heated-Inlet for Calibration of the SP2, *Aerosol Science and Technology*, 47, 8, 895-905, 2013.
35. Aoki, H., **Moteki, N.**, Kondo, Y., Corona-Imaging Colorimetric Method for Accurate Measurement of the Size of Water Droplets in an Expansion Chamber, *Aerosol Science and Technology*, 47, 10, 1134-1143, 2013.
36. Koike, M., Takegawa, N., **Moteki, N.**, Kondo, Y., Nakamura, H., Kita, K., Matsui, H., Oshima, N., Kajino, M., Nakajima, T. Y., Measurements of regional□scale aerosol impacts on cloud microphysics over the East China Sea: Possible influences of warm sea surface temperature over the Kuroshio ocean current, *Journal of Geophysical Research: Atmospheres*, 117, D17, 2012.
37. Oshima, N., Kondo, Y., **Moteki, N.**, Takegawa, N., Koike, M., Kita, K., Matsui, H., Kajino, M., Nakamura, H., Jung, J. S., Wet removal of black carbon in Asian outflow: Aerosol Radiative Forcing in East Asia (A□FORCE) aircraft campaign, *Journal of Geophysical Research: Atmospheres*, 117, D3, 2012.
38. Sahu, L. K., Kondo, Y., **Moteki, N.**, Takegawa, N., Zhao, Y., Cubison, M. J., Jimenez, J. L., Vay, S., Diskin, G. S., Wisthaler, A., Emission characteristics of black carbon in anthropogenic and biomass burning plumes over California during ARCTAS□CARB 2008, *Journal of Geophysical Research: Atmospheres*, 117, D16, 2012.
39. **Moteki, N.**, Kondo, Y., Oshima, N., Takegawa, N., Koike, M., Kita, K., Matsui, H., Kajino, M., Size dependence of wet removal of black carbon aerosols during transport from the boundary layer to the free troposphere, *Geophysical Research Letters*, 39, 13, 2012.

(2) Non-peer-reviewed Articles

(3) Review Papers

(4) Books

(5) Other Publications

(6) Patents

1. Nobuhiro Moteki, ”Particle measurement devise”, PTZTA204, 2018-184083, International Patent Classification: G01B 11/00, Application Date: September 28, 2018.

8. Keynote, Invited, or Solicited Presentations

1. Moteki, N., Particle Size-dependence of Wet Removal of Aerosols Demonstrated by the Observations of Black Carbon-containing Particles, MSJ Spring Meeting, Tokyo, Japan, 2013/05/15.
2. Moteki, N., Keynote lecture of Yamamoto-Syono Award for outstanding paper, MSJ Fall Meeting, Sendai, Japan, 2013/11/20.

III. Education Activity

9. Notable Achievements in Education

Advisees

・ Master theses: 7 students

Hidehiro Fujiwara (Mar. 2014)
Hideaki Hashioka, Tatsuhiro Mori (Mar. 2015)
Hiroka Aoki (Mar. 2016)
Tomoo Harigaya (Mar. 2017)
Atsushi Yoshida (Mar. 2018)
Hirokazu Sugiyama (Mar. 2019)

- Doctral theses: 2 students

Sho Ohata (Mar. 2016)
Tatsuhiro Mori (Mar. 2018)

Lectures

- Undergraduate, Numerical Data Analysis (Practical course), FY2013-2018
- Undergraduate, Experimental Environmental Chemistry (Practical course), FY2012-2018
- Undergraduate, Field observation for earth and planetary physics (Practical course), FY2012-2018

Student's awards

- Incentive Award of the School of Science, the University of Tokyo: 1 student [Sho Ohata]
- Japan Geoscience Union, Student Presentation Award: 2 students [Sho Ohata, Tatsuhiro Mori]
- Japan Society of Atmospheric Chemistry, Student Presentation Award: 1 student [Atsushi Yoshida]

IV. External Activities

10. Contribution to Academic Community

- Meteorological Society of Japan, Election Manager, FY2016

11. Outreach Activity

- Press Release: 3 times (May 2017, Apr. 2018, Feb. 2019)
- Laboratory Tour in the open campus event: 3 times (2015, 2017, 2018)

12. Internal Committee Membership

- Department of Earth and Planetary Science, Safety Committee, FY2014-2018
- Department of Earth and Planetary Science, Public Relations Committee, FY2014-2018
- School of Science, Education Commettee, FY2015-2018

V. International Exchange Activities

13. Hosting/Sending Foreign Students and Researchers

(1) Hosting

Foreign Students: 0

Foreign Researchers: 0

(2) Sending

Students: 0

Researchers: 0

(3) Visitors from Abroad: 8

Akihiko Fukui

I. CV

Name: Akihiko Fukui

Age: 36

Present Position: Project Assistant Professor

Education

Ayabe High School, Kyoto, March, 2002 (graduation)

B. Sc. Department of Physics, Kobe University, March, 2006

M. Sc. Department of Physics, Nagoya University, March, 2008

Ph. D. Department of Physics, Nagoya University, March, 2011

Professional Experience

Aug. 2011-Sep. 2011, Project Researcher, Solar-Terrestrial Environment Laboratory, Nagoya University

Oct. 2011-Mar. 2015, Project Researcher, Okayama Astrophysical Observatory, National Astronomical Observatory of Japan

Apr. 2015-Sep. 2018, Specially Appointed Senior Specialist, Okayama Astrophysical Observatory (renamed to Okayama Branch Office of Subaru Telescope in Apr. 2018), National Astronomical Observatory of Japan

Oct. 2018-, Project Assistant Professor, Department of Earth and Planetary Science, The University of Tokyo

II. Scientific Research Activity

2. Major Achievements

I have been studying on the variety, origin, and atmospheric nature of exoplanets by means of the following two observational techniques. One is the microlensing technique, which relies on the gravitational lensing effect on a background star caused by a planetary system. I have contributed to discover dozens of exoplanets located beyond the snow line, where gas giants are thought to be born, as a member of the MOA collaboration which has been conducted microlensing survey using a dedicated telescope in New Zealand. The other is the transit method, which uses periodic stellar dimming caused by a planet passing in front of the star. I have played a main role to develop two optical multi-band imagers MuSCAT and MuSCAT2 to study transiting exoplanets. Using various instruments such as these, I have worked on validating transiting planetary candidates discovered by wide-field surveys such as KELT, K2, and TESS, and studying atmospheres of exoplanets. The main results of my past researches include the observation of a hint of clear atmosphere in the Neptune-sized planet GJ3470b (2013), the first ground-based observation of a transit of the earth-sized planet in the habitable zone K2-3d (2016), and the discovery of the hottest-ever planet KELT-9b (2017).

3. Five Important Papers (including three or more papers in this review period)

1. Fukui, A., Narita, N., Kurosaki, K., et al., (2013), Optical-to-near-infrared Simultaneous Observations for the Hot Uranus GJ3470b: A Hint of a Cloud-free Atmosphere, The

Astrophysical Journal, 770, 95, https://doi.org/10.1088/0004-637X/770/2/95

This paper studied the atmosphere of the Neptune-sized transiting planet GJ3470b using the 188-cm and 50-cm telescopes at the Okayama Astrophysical Observatory, NAOJ, and reported the detection of a hint of clear (no-thick-cloud) atmosphere. Following this paper, a number of additional observations of this planet have been conducted, confirming the effect of Rayleigh scattering by molecules in the planetary atmosphere, a hint of which was first observed in this paper. (citation: 30 (ADS/2019.9))

2. Fukui, A., Kawashima, Y., Ikoma, M., et al., (2014), Multi-band, Multi-epoch Observations of the Transiting Warm Jupiter WASP-80b, The Astrophysical Journal, 790, 108, https://doi.org/10.1088/0004-637X/790/2/108

This paper studied the atmosphere of WASP-80b, a giant planet with a relatively low-surface temperature (equilibrium temperature of ~800 K), by using the 188cm and 50cm telescopes at Okayama Astrophysical Observatory, NAOJ, and 1.4m IRSF telescope in South Africa. The observed transit spectrum was consistent with a hazy atmosphere, which is theoretically predicted for a low-temperature atmosphere. (citation: 18 (ADS/2019.9))

3. Fukui, A., Livingston, J., Narita, N., et al., (2016), Ground-based Transit Observation of the Habitable-zone Super-Earth K2-3d, The Astronomical Journal, 152, 171, https://doi.org/10.3847/0004-6256/152/6/171

This paper reported the first ground-based detection of a transit of the Earth-sized planet in the habitable zone K2-3d. A shallow transit with the depth of only 0.06% was observed with the Okayama 188cm telescope and multi-band imager MuSCAT. From this observation, the orbital period of this planet was determined with the uncertainty of 18 sec, which significantly improved the precision of transit timing forecast in the near future. (citation: 6 (ADS/2019.9))

4. Fukui, A., Gould, A., Sumi, T., et al., (2015), OGLE-2012-BLG-0563Lb: A Saturn-mass Planet around an M Dwarf with the Mass Constrained by Subaru AO Imaging, The Astrophysical Journal, 809, 74, https://doi.org/10.1088/0004-637X/809/1/74

This paper reported the discovery of a Saturn-mass exoplanet beyond the snow line by the gravitational microlensing technique. This was the result of international collaboration in which our microlensing survey using the MOA-II telescope in New Zealand played a main role. We also used the Subaru telescope in Hawaii to constrain the mass of the host star by measuring the brightness of the host star. This paper also discussed about the possible paucity of Jovian planets around low-mass stars. (citation: 32 (ADS/2019.9))

5. Gaudi, B. S., Stassun, K. G., Collins, K. A., et al., (2017), A giant planet undergoing extreme-ultraviolet irradiation by its hot massive-star host, Nature, 546, 514-518, https://doi.org/10.1038/nature22392

This paper reported the discovery of the hottest-ever exoplanet KELT-9b, which has the day-side temperature of about 4600K. This planet was discovered by the ground-based wide-field transit survey KELT led by US team, and we contributed to the discovery by confirming the discovery by observing this planet with the Okayama 188-cm telescope and multi-band imager MuSCAT. There were huge public reactions after we did a public release in Japan. (citation: 62 (ADS/2019.9))

4. Awards and Honors

5. Future Research Plan

I have been involved in the development of MuSCAT3, the 3rd version of a series of multi-band imagers MuSCATs, for a 2m telescope at Mt. Haleakala in Hawaii in order to establish a global network of multi-band follow-up observations in the northern hemisphere. In coordination with the ongoing MuSCAT (Okayama, Japan) and MuSCAT2 (Tenerife, Spain), we plan to intensively follow-up transiting planets discovered by the all-sky survey satellite TESS, which was launched in 2018, to validate planetary candidates and to study their atmospheres. In addition, I plan to go forward a project to find and monitor gravitational microlensing events in nearby fields by using the big data gathered by the 1.05m Schmidt telescope and wide-field camera named Tomo-e Gozen at the Kiso observatory of University of Tokyo.

6. Funding Received

- Astrobiology Project of the Center for Novel Science Initiatives, National Institutes of Natural Sciences, AB261005, Principal Investigator, FY2014, 1,000,000 yen
- The Astrobiology Center Project, National Institutes of Natural Sciences, Principal Investigator, FY2015, 1,100,000 yen
- The Astrobiology Center Project, National Institutes of Natural Sciences, Principal Investigator, FY2016, 1,500,000 yen
- JSPS KAKENHI, 17H04574, Principle Investigator, FY2017-2020, 12,500,000 yen (estimate)
- JSPS KAKENHI, 17H02871, Principle Investigator, FY2017-2020, 8,100,000 yen (estimate)

7. Publications and Patents

(1) Peer-reviewed Journal Articles

1. Narita, N., Fukui, A., Kusakabe, N., et al., (2019), MuSCAT2: four-color simultaneous camera for the 1.52-m Telescopio Carlos Sánchez, Journal of Astronomical Telescopes, Instruments, and Systems, 5, 015001, https://doi.org/10.1117/1.JATIS.5.1.015001
2. Onitsuka, M., Fukui, A., Narita, N., et al., (2017), Multi-color simultaneous photometry of the T-Tauri star with planetary candidate, CVSO 30, Publications of the Astronomical Society of Japan, 69, L2, https://doi.org/10.1093/pasj/psx004
3. Narita, N., Hirano, T., Fukui, A., et al., (2017), The K2-ESPRINT project. VI. K2-105 b, a hot Neptune around a metal-rich G-dwarf, Publications of the Astronomical Society of Japan, 69, 29, https://doi.org/10.1093/pasj/psx002
4. Fukui, A., Livingston, J., Narita, N., et al., (2016), Ground-based Transit Observation of the Habitable-zone Super-Earth K2-3d, The Astronomical Journal, 152, 171, https://doi.org/10.3847/0004-6256/152/6/171
5. Hirano, T., Fukui, A., Mann, A. W., et al., (2016), The K2-ESPRINT Project III: A Close-in Super-Earth around a Metal-rich Mid-M Dwarf, The Astrophysical Journal, 820, 41, https://doi.org/10.3847/0004-637X/820/1/41
6. Fukui, A., Narita, N., Kawashima, Y., et al., (2016), Demonstrating High-precision, Multiband Transit Photometry with MuSCAT: A Case for HAT-P-14b, The Astrophysical Journal, 819, 27, https://doi.org/10.3847/0004-637X/819/1/27
7. Narita, N., Hirano, T., Fukui, A., et al., (2015), Characterization of the K2-19 Multiple-transiting Planetary System via High-dispersion Spectroscopy, AO Imaging, and Transit Timing Variations, The Astrophysical Journal, 815, 47, https://doi.org/10.1088/0004-637X/815/1/47
8. Narita, N., Fukui, A., Kusakabe, N., et al., (2015), MuSCAT: a multicolor simultaneous camera for studying atmospheres of transiting exoplanets, Journal of Astronomical Telescopes, Instruments, and Systems, 1, 045001, https://doi.org/10.1117/1.JATIS.1.4.045001

9. Fukui, A., Gould, A., Sumi, T., et al., (2015), OGLE-2012-BLG-0563Lb: A Saturn-mass Planet around an M Dwarf with the Mass Constrained by Subaru AO Imaging, The Astrophysical Journal, 809, 74, https://doi.org/10.1088/0004-637X/809/1/74
10. Fukui, A., Kawashima, Y., Ikoma, M., et al., (2014), Multi-band, Multi-epoch Observations of the Transiting Warm Jupiter WASP-80b, The Astrophysical Journal, 790, 108, https://doi.org/10.1088/0004-637X/790/2/108

(2) Non-peer-reviewed Articles

(3) Review Papers

(4) Books

(5) Other Publications

(6) Patents

8. Keynote, Invited, or Solicited Presentations

1. Fukui, A., Atmospheric Study of Exoplanets by Transmission Spectroscopy, The Origins of Planetary Systems: from the Current View to New Horizons, NAOJ (Mitaka), 2015/06/05
2. Fukui, A., TESS and MuSCATs Observations of Exoplanets, Symposium on Planetary Sciences 2019, Tohoku University, 2019/02/20

III. Education Activity

9. Notable Achievements in Education

Advisees

・ Master theses: 1 student

Yuka Terada (Mar. 2019)

Lectures

・ Undergraduate, Exercise of earth and planetary physics IV, FY2019

Student’s awards

IV. External Activities

10. Contribution to Academic Community

・ The Astronomical Society of Japan, Editor of The Astronomical Herald, FY2018-2021

11. Outreach Activity

・ Coordinating Committee of Earthquake and Volcanic Eruption Prediction Researches, Member, FY2012-2018

・ Cabinet Office, Japan, Investigation Committee for Large Earthquake along the Nankai Trough, Member, FY2012-2013, 2016-2017

・ KAKENHI Review, FY2013-2014, 2017-2018

- Press Release: 3 times (Aug. 2013, Nov. 2014, Jun. 2017)
- Lectures for general audience: 10 times (Sep. 2012, Oct. 2013, Aug. 2014, Oct. 2014, Aug. 2015, Sep. 2016, May 2017, Aug. 2017, Aug. 2018, Feb. 2019)

12. Internal Committee Membership

V. International Exchange Activities

13. Hosting/Sending Foreign Students and Researchers

(1) Hosting

Foreign Students: 0

Foreign Researchers: 0

(2) Sending

Students: 0

Researchers: 0

(3) Visitors from Abroad: 0

Solid Earth Science Group

Satoshi Ide

I. CV

Name: Satoshi Ide

Age: 50

Present Position: Professor

Education

Chiba High School, Chiba, March, 1988 (graduation)

B. Sc. Department of Geophysics, The University of Tokyo, March, 1992

M. Sc. Department of Earth and Planetary Physics, The University of Tokyo, March, 1994

Ph. D. Department of Earth and Planetary Physics, The University of Tokyo, March, 1997

Professional Experience

Apr. 1997-Apr. 2002, Research Assistant, Earthquake Research Institute, The University of Tokyo

Dec. 2000-Nov. 2001, Visiting Scholar, Stanford University

Apr. 2002-Dec. 2008, Lecturer, Department of Earth and Planetary Science, The University of Tokyo

Dec. 2008-Apr. 2013, Associate Professor, Department of Earth and Planetary Science, The University of Tokyo

Apr. 2013-, Professor, Department of Earth and Planetary Science, The University of Tokyo

II. Scientific Research Activity

2. Major Achievements

I have been studying on various aspects of earthquake rupture processes, mainly based on seismic data analysis. The targets include large to giant earthquakes like the 1995 Kobe and 2011 Tohoku-Oki earthquakes, small to medium natural earthquakes, and rock bursts in mines. For Kobe earthquake, we determined the constitutive relation of earthquake fault from seismic wave analysis, which was the first attempt in earthquake seismology. Our rapid report on the complex source process of the Tohoku-Oki earthquake had significant influences both in science and society. From studies on earthquakes of a wide variety of sizes, we derived an image of self-similar seismic rupture, which is supported by the almost constant ratio between seismic energy and seismic moment. This image was conceptually represented by a hierarchical patchy source model. Other important achievements are in the study on slow earthquakes, which include low frequency earthquakes, tectonic tremors, and slow slip events. Although these events were first considered as different phenomena, our studies revealed that are likely to be a unique physical process observed seismologically and geodetically in a very wide frequency range. The scaling relation presented in 2007 is a key to understand these apparently different phenomena, and has been cited may times. In recent years, we extended research areas to worldwide through collaborations with various countries, such as USA, Taiwan, Mexico, and Chile, to quantify the diversity of slow earthquakes.

3. Five Important Papers (including three or more papers in this review period)

1. Ide, S., Beroza, G. C., Shelly, D. R., & Uchide, T. (2007). A scaling law for slow earthquakes.

Nature, 447(7140), 76. https://doi.org/10.1038/nature05780

Since the discovery around 2000, slow earthquakes were recognized differently, as low frequency earthquakes, non-volcanic tremors, very low-frequency earthquakes, and slow slip events. This paper provided a common scaling law for these phenomena, which is totally different from the scaling law of ordinary earthquakes. The lack of events between these two scaling laws suggests that these are two regimes of earthquake-like phenomena, governed by different physical mechanisms. After the publication, the arguments on this hypothesis are continuing and the paper has been frequently cited. (Citation 449, GS/Jul. 29, 2019)

2. Ide, S., Baltay, A., & Beroza, G. C. (2011). Shallow dynamic overshoot and energetic deep rupture in the 2011 Mw 9.0 Tohoku-Oki earthquake. Science, 332(6036), 1426-1429. https://doi.org/10.1126/science.1207020

This is a rapid report on the source process of the 2011 Tohoku-Oki M9 earthquake, published only three months after the devastating event. By seismic data analysis, we showed that the rupture process was complex and lasted for more than two minutes, with the largest slip at the shallow subduction interface near the trench axis, which was the direct cause of large tsunamis, while the high-frequency waves were radiated from the deep part. This result was broadcasted by many newspaper and TV news, and influenced the following researches on this earthquake. (Citation 499, GS/Jul. 29, 2019)

3. Nishikawa, T., & Ide, S. (2014). Earthquake size distribution in subduction zones linked to slab buoyancy. Nature Geoscience, 7, 904-908. https://doi.org/10.1038/ngeo2279

The size-frequency statistics of earthquakes are not common for subduction zones worldwide. By objectively quantifying the statistics in many regions, this paper demonstrated that the relative number of large earthquakes are large along a young plate boundary, where warm and light oceanic plate is subducting, and the opposite for the old plate boundary. The difference can be explained by the stress level on the plate boundary, which is dependent on the buoyancy of the slab. This paper was a master thesis of a student, who won the Incentive Award of the School of Science, the University of Tokyo. (Citation 44, GS/Jul. 29, 2019)

4. Ide, S., Yabe, S., & Tanaka, Y. (2016). Earthquake potential revealed by tidal influence on earthquake size-frequency statistics. Nature Geoscience., 9, 834-837. https://doi.org/10.1038/ngeo2796

The relation between earthquakes and tidal stress is a long standing problem discussed for more than a century in seismology. This study focused on the amplitude of tidal shear stress and tried to find some correlation between tide and size-frequency statistics of earthquakes. The correlation is too weak to be identified by using only the timing of very large earthquakes, but visible when we compare the relative number between large and small earthquakes. This weak correlation suggests that some slow deformation changed the growth probability of earthquakes. This study was covered widely by international journalisms. (Citation 35, GS/Jul. 29, 2019)

5. Araki, E., Saffer, D.M., Kopf, A.J., Wallace, L.M., Kimura, T., Machida, Y., Ide S., & E. Davis (2017). Recurring and triggered slow-slip events near the trench at the Nankai Trough subduction megathrust. Science, 356(6343), 1157-1160. https://doi.org/10.1126/science.aan3120

A large slow slip events (SSE) and many tectonic tremors were observed after a M6 earthquake in the Nankai subduction zone on April, 2016. In this paper, we analyzed seismograms and pressure gauge records of DONET, an ocean-bottom seismometer network, to constrain the space-time behavior of these phenomena. We also identified many similar SSEs and tremors in the past, and inferred that similar phenomena are frequency occurring in this region. This was the first discovery of the simultaneous activity of tremors and SSE, and cited many times. (Citation 74, GS/Jul. 29, 2019)

4. Awards and Honors

- Ide, S., Japan Society for the Promotion of Science (JSPS) Prize, Feb. 2014
- Ide, S., Japan Academy Medal, Feb. 2014
- Ide, S., American Geophysical Union Fellow, Dec. 2016
- Ide, S., Yomiuri Techno Forum Gold Medal, Apr. 2017

5. Future Research Plan

I will continue studies on earthquake science, to enhance our knowledge on seismogenesis, which includes long-term loading by plate tectonics, preparation of rupture by slow deformation, dynamic rupture propagation and arrest, and following slow relaxation. In addition to such an earthquake cycle for each event, we need to know about the mechanism of interaction among many earthquakes, including slow earthquakes. Analyzing large volume of high-quality seismic and geodetic data in Japan and collaborating with researchers in different field in the Slow Earthquake Project, we improve our knowledge for the basic mechanisms of slow deformation processes. Moreover, we will strengthen our international collaboration network for comparative studies on earthquakes and slow earthquakes worldwide. For fast dynamic rupture process, key concepts for future earthquake seismology would be broadband hierarchical heterogeneity and inherent unpredictability of whole earthquake process. Empirically and theoretically, we develop methods to quantify hierarchical fast rupture with slow processes and assess the predictability of earthquakes.

6. Funding Received

- MEXT KAKENHI, 21107007, Principal Investigator, FY2009-2013, 126,750,000 yen
- MEXT KAKENHI, 21107001, Co-Investigator, FY2009-2014, 2,500,000 yen
- J-RAPID, DYNATOHOKU, Principal Investigator, FY2011-2012, 5,000,000 yen
- JSPS KAKENHI, 23244090, Principal Investigator, FY2011-2015, 47,970,000 yen
- MEXT KAKENHI, 16H06477, Principal Investigator, FY2016-2020, 132,340,000 yen
- MEXT KAKENHI, 16H06472, Co-Investigator, FY2016-2020, 500,000 yen
- MEXT KAKENHI, 16K21728, Co-Investigator, FY2016-2020, 500,000 yen
- JSPS KAKENHI, 16H02219, Principal Investigator, FY2016-2020, 45,760,000 yen
- SATREPS, Hazard Assessment of Large Earthquakes and Tsunamis in the Mexican Pacific Coast for Disaster Mitigation, Co-Investigator, FY2016-2020, 13,500,000 yen
- JSPS KAKENHI, 18KK0095, Co-Investigator, FY2018-2020, 300,000 yen

7. Publications and Patents

(1) Peer-reviewed Journal Articles

1. Ide, S. (2013). The proportionality between relative plate velocity and seismicity in subduction zones. Nature Geoscience, 6, 780-784. https://doi.org/10.1038/ngeo1901
2. Ide, S., & Aochi, H. (2013). Historical seismicity and dynamic rupture process of the 2011 Tohoku-Oki earthquake. Tectonophysics, 600, 27-40. https://doi.org/10.1016/j.tecto.2012.10.018
3. Aso, N., Ohta, K., & Ide, S. (2013). Tectonic, volcanic, and semi-volcanic deep low-frequency earthquakes in western Japan. Tectonophysics, 600, 1-13. https://doi.org/10.1016/j.tecto.2012.12.015

4. Yabe, S., & Ide, S. (2013). Repeating deep tremors on the plate interface beneath Kyushu, southwest Japan. Earth, Planets and Space, 65(1), 17-23. https://doi.org/10.5047/eps.2012.06.001
5. Aso, N., & Ide, S. (2014). Focal mechanisms of deep low-frequency earthquakes in eastern Shimane in western Japan. Journal of Geophysical Research: Solid Earth, 119(1), 364-377. https://doi.org/10.1002/2013JB010681
6. Namiki, A., Yamaguchi, T., Sumita, I., Suzuki, T., & Ide, S. (2014). Earthquake model experiments in a viscoelastic fluid: A scaling of decreasing magnitudes of earthquakes with depth. Journal of Geophysical Research: Solid Earth, 119(4), 3169-3181. https://doi.org/10.1002/2014JB011135
7. Ide, S., & Yabe, S. (2014). Universality of slow earthquakes in the very low frequency band. Geophysical Research Letters, 41(8), 2786-2793. https://doi.org/10.1002/2014GL059712
8. Nishikawa, T., & Ide, S. (2014). Earthquake size distribution in subduction zones linked to slab buoyancy. Nature Geoscience, 7, 904-908. https://doi.org/10.1038/ngeo2279
9. Yabe, S., Ide, S., & Yoshioka, S. (2014). Along-strike variations in temperature and tectonic tremor activity along the Hikurangi subduction zone, New Zealand. Earth, Planets and Space, 66(1), 142. https://doi.org/10.1186/s40623-014-0142-6
10. Yabe, S., & Ide, S. (2014). Spatial distribution of seismic energy rate of tectonic tremors in subduction zones. Journal of Geophysical Research: Solid Earth, 119(11), 8171-8185. https://doi.org/10.1002/2014JB011383
11. Idehara, K., Yabe, S., & Ide, S. (2014). Regional and global variations in the temporal clustering of tectonic tremor activity. Earth, Planets and Space, 66(1), 66. https://doi.org/10.1186/1880-5981-66-66
12. Yabe, S., Baltay, A. S., Ide, S., & Beroza, G. C. (2014). Seismic wave attenuation determined from tectonic tremor in multiple subduction zones. Bulletin of the Seismological Society of America, 104(4), 2043-2059. https://doi.org/10.1785/0120140032
13. Ide, S., & Tanaka, Y. (2014). Controls on plate motion by oscillating tidal stress: Evidence from deep tremors in western Japan. Geophysical Research Letters, 41(11), 3842-3850. https://doi.org/10.1002/2014GL060035
14. Aochi, H., & Ide, S. (2014). Ground motions characterized by a multi-scale heterogeneous earthquake model. Earth, Planets and Space, 66(1), 42. https://doi.org/10.1186/1880-5981-66-42
15. Baltay, A. S., Beroza, G. C., & Ide, S. (2014). Radiated energy of great earthquakes from teleseismic empirical Green's function deconvolution. Pure and Applied Geophysics, 171(10), 2841-2862. https://doi.org/10.1007/s00024-014-0804-0
16. Ide, S., & Aochi, H. (2014). Modeling earthquakes using fractal circular patch models with lessons from the 2011 Tohoku-Oki earthquake. Journal of Disaster Research, 9(3), 264-271. https://doi.org/10.20965/jdr.2014.p0264
17. Ide, S., Yabe, S., Tai, H.-J., & Chen, K. H. (2015). Thrust type-focal mechanisms of tectonic tremors in Taiwan: Evidence of subduction. Geophysical Research Letters, 42(9), 3248-3256. https://doi.org/10.1002/2015GL063794
18. Tanaka, Y., Yabe, S., & Ide, S. (2015). An estimate of tidal and non-tidal modulations of plate subduction speed in the transition zone in the Tokai district. Earth, Planets and Space, 67(1), 1-11. https://doi.org/10.1186/s40623-015-0311-2
19. Yoshioka, S., Matsuoka, Y., & Ide, S. (2015). Spatiotemporal slip distributions of three long-term slow slip events beneath the Bungo Channel, southwest Japan, inferred from inversion analyses of GPS data. Geophysical Journal International, 201(3), 1437-1455. https://doi.org/10.1093/gji/ggv022
20. Nishikawa, T., & Ide, S. (2015). Background seismicity rate at subduction zones linked to slab-

bending-related hydration, Geophysical Research Letters, 42(17), 7081-7089. https://doi.org/10.1002/2015GL064578

21. Yabe, S., Ide, S., Tanaka, Y., & Houston, H. (2015). Tidal sensitivity of tectonic tremors in Nankai and Cascadia subduction zones. Journal of Geophysical Research: Solid Earth, 120(11), 7587-7605. https://doi.org/10.1002/2015JB012250
22. Aso, N., Ohta, K., & Ide, S. (2016). Mathematical review on source-type diagrams. Earth, Planets and Space, 68(1), 1-21. https://doi.org/10.1186/s40623-016-0421-5
23. Ide, S., Yabe, S., & Tanaka, Y. (2016). Earthquake potential revealed by tidal influence on earthquake size-frequency statistics. Nature Geoscience., 9, 834-837. https://doi.org/10.1038/ngeo2796
24. Maury, J., Ide, S., Cruz-Atienza, V. M., Kostoglodov, V., González-Molina, G., & Pérez-Campos, X. (2016). Comparative study of tectonic tremor locations: Characterization of slow earthquakes in Guerrero, Mexico. Journal of Geophysical Research: Solid Earth, 121(7), 5136-5151. https://doi.org/10.1002/2016JB013027
25. Ide, S. (2016). Characteristics of slow earthquakes in the very low frequency band: Application to the Cascadia subduction zone. Journal of Geophysical Research: Solid Earth, 121(8). 5942-5952. https://doi.org/10.1002/2016JB013085
26. Yabe, S., & Ide S. (2017). Slip-behavior transitions of a heterogeneous linear fault. Journal of Geophysical Research: Solid Earth, 122(1), 387-410. https://doi.org/10.1002/2016JB013132
27. Nishikawa, T., & Ide, S. (2017). Detection of earthquake swarms at subduction zones globally: Insights into tectonic controls on swarm activity. Journal of Geophysical Research: Solid Earth, 122(7), 5325-5343. https://doi.org/10.1002/2017JB014188
28. Ohta, K., & Ide S. (2017). Resolving the Detailed Spatiotemporal Slip Evolution of Deep Tremor in Western Japan. Journal of Geophysical Research: Solid Earth, 122(12), 10,009-10,036. https://doi.org/10.1002/2017JB014494
29. Aochi, H., & Ide S. (2017). Role of multiscale heterogeneity in fault slip from quasi-static numerical simulations. Earth, Planets and Space, 69(1), 94. https://doi.org/10.1186/s40623-017-0676-5
30. Araki, E., Saffer, D.M., Kopf, A.J., Wallace, L.M., Kimura, T., Machida, Y., Ide S., & E. Davis (2017). Recurring and triggered slow-slip events near the trench at the Nankai Trough subduction megathrust. Science, 356(6343), 1157-1160. https://doi.org/10.1126/science.aan3120
31. Kaneko, L., Ide, S., & Nakano, M. (2018). Slow earthquakes in the microseism frequency band (0.1−1.0 Hz) off Kii Peninsula, Japan. Geophysical Research Letters, 45(6), 2618-2624. https://doi.org/10.1002/2017GL076773
32. Ide, S., & Maury, J. (2018). Seismic moment, seismic energy, and source duration of slow earthquakes: Application of Brownian slow earthquake model to three major subduction zones. Geophysical Research Letters, 45(7), 3059-3067. https://doi.org/10.1002/2018GL077461
33. Maury, J., Ide, S., Cruz□Atienza V. M., & Kostoglodov, V. (2018). Spatiotemporal variations in slow earthquakes along the Mexican subduction zone. Journal of Geophysical Research: Solid Earth, 123(2), 1559-1575. https://doi.org/10.1002/2017JB014690
34. Nakano, M., Hori, T., Araki, E., Kodaira, S., & Ide, S. (2018). Shallow very-low-frequency earthquakes accompany slow slip events in the Nankai subduction zone. Nature Communications, 9(1), 984. https://doi.org/10.1038/s41467-018-03431-5
35. Yabe, S., & Ide, S. (2018). Why do aftershocks occur within the rupture area of a large earthquake? Geophysical Research Letters, 45(10), 4780-4787. https://doi.org/10.1029/2018GL077843
36. Ide, S., & Maury, J. (2018). Seismic moment, seismic energy, and source duration of slow earthquakes: Application of Brownian slow earthquake model to three major subduction zones.

Geophysical Research Letters, 45(7), 3059-3067. https://doi.org/10.1002/2018GL077461

37. Cruz-Atienza, V. M., Ito, Y., Kostoglodov, V., Hjörleifsdóttir, V., Iglesias, A., et al. (Ide, S., the tenth out of fifteen authors). (2018). A seismogeodetic amphibious network in the Guerrero Seismic Gap, Mexico. Seismological Research Letters, 89(4), 1435-1449. https://doi.org/10.1785/0220170173
38. Kano, M., Aso, N. Matsuzawa, T., S. Ide, et al. (and more 25 authors) (2018). Development of a slow earthquake database, Seismological Research Letters, 89(4), 1566-1575. https://doi.org/10.1785/0220180021
39. Chen, K. H., Tai, H.-J., Ide, S., Byrne, T. B., & Johnson, C. W. (2018). Tidal modulation and tectonic implications of tremors in Taiwan. Journal of Geophysical Research: Solid Earth, 123(7), 5945-5964. https://doi.org/10.1029/2018JB015663
40. Nishikawa, T., & Ide, S. (2018). Recurring slow slip events and earthquake nucleation in the source region of the M 7 Ibaraki□Oki earthquakes revealed by earthquake swarm and foreshock activity. Journal of Geophysical Research: Solid Earth, 123(9), 7950-7968. https://doi.org/10.1029/2018JB015642
41. Okuda, T., & Ide, S. (2018). Hierarchical rupture growth evidenced by the initial seismic waveforms. Nature Communications, 9(1), 3714. https://doi.org/10.1038/s41467-018-06168-3.
42. Okuda, T., & Ide, S. (2018). Streak and hierarchical structures of the Tohoku-Hokkaido subduction zone plate boundary. Earth, Planets and Space, 70(1), 132. https://doi.org/10.1186/s40623-018-0903-8
43. Yabe, S., & Ide, S. (2018). Variations in precursory slip behavior resulting from frictional heterogeneity. Progress in Earth and Planetary Science, 5(1), 43. https://doi.org/10.1186/s40645-018-0201-x
44. Ide, S., & Yabe, S. (2019). Two-dimensional probabilistic cell automaton model for broadband slow earthquakes. Pure and Applied Geophysics, 176(3), 1021-1036. https://doi.org/10.1007/s00024-018-1976-9
45. Mizuno, N., & Ide, S. (2019). Development of a modified envelope correlation method based on maximum-likelihood method and application to detecting and locating deep tectonic tremors in western Japan. Earth, Planets and Space, 71(1), 40. https://doi.org/10.1186/s40623-019-1022-x

(2) Non-peer-reviewed Articles

(3) Review Papers

1. Ide, S. (2014). Modeling fast and slow earthquakes at various scales. Proceedings of the Japan Academy, Series B, 90(8), 259-277. https://doi.org/10.2183/pjab.90.259

(4) Books

1. Ide, S. (2015). Slip inversion, in Treatise on Geophysics 2nd ed., 4. Elsevier B. V.

(5) Other Publications

(6) Patents

8. Keynote, Invited, or Solicited Presentations

1. Ide, S., Rupture dynamics of the 2011 Tohoku earthquake, International Scientific Meeting "Frontiers of Source Studies for the 2011 Tohoku Earthquake", Tokyo, Japan, 2012/04/05.
2. Ide, S., Global perspective on controls on megathrust slip behaviour, GeoPRISM Workshop,

Wellington, New Zealand, 2013/04/15.

3. Ide, S., Modeling scale-independent heterogeneities of earthquake dynamic rupture, IAHS-IAPSO-IASPEI 2013, Gothenburg, Sweden, 2013/07/25.
4. Ide, S., Modeling scale-independent heterogeneities of earthquake dynamic rupture, ISSE, Hakone, Japan, 2013/09/24.
5. Ide, S., Broadband earthquake science, JpGU Meeting 2015, Chiba, Japan, 2015/05/26.
6. Ide, S. and Y. Tanaka, Controls on plate motion by oscillating tidal stress: Evidence from deep tremors in western Japan, AGU Fall Meeting, San Francisco CA, USA, 2014/12/15.
7. Ide, S., Deformation mechanism and rheology for slow earthquakes, 26th IUGG General Assembly, Prague, Czech Republic, 2015/06/30.
8. Ide, S., Multiscale heterogeneities in earthquake source processes, Best Practices in Physics-based Fault Rupture Models for Seismic Hazard Assessment of Nuclear Installations, Vienna, Austria, 2015/11/19.
9. Ide, S., Universality of slow earthquakes in the very low frequency band (Summary of regional studies), Seismological Society of America, Reno, Nevada, USA, 2016/04/20.
10. Ide, S., Diversity and universality of slow earthquakes, Cargese Summer School EARTHQUAKES: nucleation, triggering, rupture, and relationships to aseismic processes, Cargese, France, 2017/10/04.
11. Ide, S., Scaling relations of fast and slow earthquakes, Workshop: Frontiers in Studies of Earthquakes and Faults, Shenzhen, China, 2017/11/29.
12. Ide, S., Multiscale heterogeneities in earthquake source process, International Symposium on Earthquake Forecast, Chiba, Japan, 2018/05/25.
13. Yabe, S., & Ide, S., Foreshocks and aftershocks on the frictionally heterogeneous fault, AGU Fall Meeting 2018, Washington DC, USA, 2018/12/14.

III. Education Activity

9. Notable Achievements in Education

Advisees

- Master theses: 10 students

    Suguru Yabe (Mar. 2014)

    Tomoaki Nishikawa, Masamichi Ara (Mar. 2015)

    Junji Kikuchi, Naoto Mizuno (Mar. 2017)

    Takashi Okuda (Mar. 2018)

    Ta-Wei Chang (Sep. 2018)

    Miki Aso, Lisa Kaneko, Kansuke Uemura (Mar. 2019)

- Doctral theses: 4 students

    Kazuaki Ohta (Mar. 2014)

    Naofumi Aso (Mar. 2015)

    Suguru Yabe (Mar. 2017)

    Tomoaki Nishikawa (Mar. 2018)

Lectures

- Undergraduate/Graduate, Earthquake physics, FY2012-2018
- Undergraduate/Graduate, Geophysical data analysis, FY2012-2018
- Undergraduate/Graduate, Solid geoscience, FY2012-2016
- Undergraduate, Field observation for earth and planetary physics, FY2012-2018
- Undergraduate, Introduction to earth and planetary physics, FY2016-2018
- Undergraduate, Overview of earth and planetary physics, FY2017-2018

Student's awards

- Incentive Award of the School of Science, the University of Tokyo: 3 students [Suguru Yabe (twice), Tomoaki Nishikawa]
- American Geophysical Union, Outstanding Student Presentation Award: 2 students [Naofumi Aso, Lisa Kaneko]
- Japan Geoscience Union, Student Presentation Award: 5 students [Suguru Yabe (twice), Tomoaki Nishikawa, Takashi Okuda, Lisa Kaneko]
- Seismological Society of Japan, Student Presentation Award: 5 students [Naofumi Aso, Tomoaki Nishikawa, Masamichi Ara, Suguru Yabe, Takashi Okuda]

IV. External Activities

10. Contribution to Academic Community

- Seismological Society of Japan, Executive Board Member, FY2012-2013
- Seismological Society of Japan, Representative, FY2012-2018
- Seismological Society of Japan, Overseas Travel Fund Committee Chair, FY2012-2013
- Seismological Society of Japan, Award Committee Chair, FY2014-2015
- Seismological Society of Japan, IASPEI Committee Member, FY2018
- Japan Geoscience Union, Program Committee Member, FY2012-2015
- Japan Geoscience Union, Executive Board Member, FY2016-2018
- Japan Geoscience Union, Financial Committee Member, FY2016-2018
- American Geophysical Union, Journal of Geophysical Research: Solid Earth, Associate Editor, 2012-2019
- American Geophysical Union, Union Fellow Committee Member, 2018
- Seismological Society of America, Nominating Committee Member, 2017
- International Association of Seismology and Physics of the Earth's Interior, Commission on Earthquake Source Mechanics Chair, 2017-2018

11. Outreach Activity

- Coordinating Committee of Earthquake and Volcanic Eruption Prediction Researches, Member, FY2012-2018
- Cabinet Office, Japan, Investigation Committee for Large Earthquake along the Nankai Trough, Member, FY2012-2013, 2016-2017

- KAKENHI Review, FY2013-2014, 2017-2018
- Press Release: 3 times (Aug. 2013, Nov. 2014, Jun. 2017)
- Lectures for general audience: 10 times (Sep. 2012, Oct. 2013, Aug. 2014, Oct. 2014, Aug. 2015, Sep. 2016, May 2017, Aug. 2017, Aug. 2018, Feb. 2019)

12. Internal Committee Membership

- Department of Earth and Planetary Science, Education Committee, Chair, FY2013-2014
- Department of Earth and Planetary Physics, Education Committee, Vice Chair, FY2015-2016
- School of Science, Advisor to the Dean, FY2015-2016
- School of Science, Library Committee, Chair, FY2015-2016
- School of Science, Committee for International Communication, Chair, FY2015-2016
- Department of Earth and Planetary Physics, Head, FY2017-2018
- Advisor to the President of the University of Tokyo, FY2018

V. International Exchange Activities

13. Hosting/Sending Foreign Students and Researchers

(1) Hosting

Foreign Students: 17

Foreign Researchers: 3

(2) Sending

Students: 9

Researchers: 4

(3) Visitors from Abroad: 30

Simon Wallis

I. CV

Name: Simon Wallis

Age: 57

Present Position: Professor

Education

Millfield School, Street, Somerset, UK, March, 1980 (graduation)

B. A., Department of Earth Sciences, Oxford University, UK, July, 1983

Doctorate (D. Phil.), Department of Earth Sciences, Oxford University, UK, March, 1988

Professional Experience

Oct. 1988– Dec. 1992, Post-doctoral fellow, Department of Geology and Mineralogy, Kyoto University

Jan. 1993–June 1994, Financial derivatives trader, Credit Commercial de France, Tokyo

July 1994–Dec. 2000, Assistant Professor, Department of Geology and Mineralogy, Kyoto University

Jan 2001–May 2011, Associate Professor, Department of Earth and Planetary Sciences, Nagoya University

June 2011–Sept 2017, Professor, Department of Earth and Planetary Sciences, Nagoya University

Oct 2017–present, Professor, Department of Earth and Planetary Science, The University of Tokyo

II. Scientific Research Activity

2. Major Achievements

I work on the natural rock record of tectonic movements and metamorphic processes using observations from the micro to macro scales. I am particularly interested in the study of metamorphic rocks originally formed deep in subduction and continental collision zones to develop a better understanding of these otherwise inaccessible regions. I have developed the Sanbagawa belt as a type example of a warm subduction zone analogous to modern day SW Japan. A significant recent advance was showing the ultramafic units distributed in the high-grade part of the Sanbagawa belt were derived from the mantle wedge above the former subduction zone solving a long-standing dispute about the origin of these rocks. This means the paleo subduction boundary is exposed on land and has led to several impactful studies including identifying the type of crystallographic preferred orientation patterns related to subduction and how these may be reflected in seismic anisotropy observed in modern subduction zones, and identifying brucite as an important mineral in the mantle wedge with implications for the strength and hydrology of these regions. My work on Raman spectral studies of carbonaceous material and its use in estimating peak metamorphic temperatures has led to several influential studies. In particular, this work has improved existing protocols and led to the development a new analytical technique that greatly expands the lower temperature range that can be studied. These results have been widely cited. I have also studied the Tibetan plateau as the largest active region of continental convergence. The origin of normal faulting in the central high altitude part of the plateau is a major topic for research. The studies of my group have shown two sets of differently-oriented normal faults are tectonically linked—not temporally independent as generally thought—and best explained as the result of south-directed radial spreading of the Himalayas. Radiometric dating and deformation features of Himalayan metamorphic and igneous rocks suggest the trigger for normal faulting was magma formation and reduction in stresses supporting the plateau.

3. Five Important Papers (including three or more papers in this review period)

1. **Wallis, S. R.**, Tsuboi, M., Suzuki, K., Fanning, M., Jiang, L. & Tanaka, T. (2005). Role of partial melting in the evolution of the Sulu (eastern China) ultrahigh-pressure belt. *Geology* **33**, 129-132.

Metamorphic rocks that have risen from depths of more than about 90 km that commonly contain coesite are known as ultrahigh-pressure or UHP rocks. These rocks are important for the information they hold concerning deep inaccessible parts of continental collision zones. One of the puzzling aspects has been that evidence for UHP metamorphism is general restricted to blocks of mafic rocks within felsic gneisses that lack this evidence. This paper shows that the felsic rocks in a UHP belt of China underwent partial melting close to peak metamorphism. Melting reduces the strength of rocks allowing the felsic gneisses to return towards the earth's surface by buoyancy. The UHP blocks were carried along in this flow. Melting increases the reactivity of minerals and can explain the absence of UHP indicators in much of the gneiss. This paper has made major contributions to our understanding of the formation, exhumation and preservation of UHP belts. (Citation 164, GS/Sept. 14, 2019)

2. Mitsuishi, M., **Wallis**, **S. R.**, Aoya, M., Lee, J. and Wang, Y. (2012, April). E-W extension at 19 Ma in the Kung Co area, S. Tibet: Evidence for contemporaneous E-W and N-S extension in the Himalayan orogeny. *Earth and Planetary Science Letters* **325-326,** 10-20.

Tibet is the largest currently active region of continental collision. It is particularly attractive to researchers such as myself interested in how the rock record reflects tectonics because both brittle and ductile deformation regimes are exposed in the area and the kinematic boundary conditions in the form of plate motion are well known. A key point of discussion has been why normal faulting, particularly strong in the south of the plateau, should develop in a region of active convergence. There are two distinct orientations of normal faults: E-W and N-S. This paper presents evidence the two sets began to form at the same time and suggests a model of south-directed gravity-driven radial spreading to account for the relationships. These results differ greatly from many proposed models that invoke two separate geodynamic processes to account for the two sets of normal faulting and have significant implications for lithospheric-scale deformation processes. (Citation 50, GS/ Sept. 14, 2019)

3. Aoya, M., Endo, S., Mizukami, T. and **Wallis, S. R**. (2013, April). Paleo-mantle wedge preserved in the Sambagawa high-pressure metamorphic belt and the thickness of forearc continental crust. *Geology* **41,** 451-454.

One of the results of my research has been to establish the Sanbagawa belt as a type example of warm subduction analogous to modern day SW Japan. The belt mainly consists of meta sediments and meta mafic rocks derived from the subducting slab. There is also a volumetrically smaller but distinct set of ultramafic rocks, which are derived from the mantle. There has been a long-running dispute about the origin of these rocks with both subducted ocean floor and wedge mantle proposed. In this study with several students, I showed that the ultramafic units in the Sanbagawa belt are restricted to the high-grade regions demonstrating that slab units had to be subducted to a depth of around 35km before they came into contact with the mantle rocks. This implies a wedge mantle origin for these rocks. An important implication is that the paleo subduction boundary is exposed on land and studies of this contact can be used to investigate otherwise inaccessible parts of the subduction system. (Citation 23, GS/Sept. 14, 2019)

4. Kouketsu, Y., Mizukami, T., Mori, H., Endo, S., Aoya, M., Hara, H., Nakamura, D. and **Wallis, S**. (2014, Mar). A new approach to develop the Raman carbonaceous material geothermometer for low-grade metamorphism using peak width. *Island Arc* **23** 33-50.

This work developed from a master's thesis (Shimizu) and was completed with other members of my research group. Geological processes are strongly influenced by temperature and determining the thermal structure of the earth's interior recorded rocks has been an important part of metamorphic petrology over the past 40 years. However, estimating metamorphic temperatures in relatively low grade (<350°C) rocks has been difficult requiring special samples and time-consuming techniques. This paper establishes a new technique based on Raman spectroscopy of carbonaceous material that easy to use and gives reproducible results independent of the laboratory where the analyses are made. This new geothermometer has been applied to a wide variety of geological problems and the study has been widely cited. (Citation 113, GS/Sept. 14, 2019)

5. The Geology of Japan, (2016, March) edited by Moreno, T., **Wallis, S. R.**, Kojima, T. & Gibbons, W. Geological Society, London, pp. 522.

This book is the first English language summary of the geology of Japan for more than 25 years with a broader scope than any attempted before. I was instrumental in the planning and execution of this large project involving more than 70 authors, was closely involved in the editing and was the main author for two chapters. Involving the Geological Society of London ensured good publicity for the book. It has received good reviews and sold well. This book serves as an introduction to anyone interested in finding out about the geology of Japan and should be of particular interest to those working on convergent plate margins. The inclusion of a field excursion and extensive list of Japanese and English place names and geology-related names adds to the appeal of the book.

Underline represents students and post-docs

4. Awards and Honors

- Wiley, Island Arc Award, Sept. 2013 (co-author)
- Mineralogical Society of Japan, Best Paper Award, Sept., 2014 (co-author)
- Geological Society of Japan, Best Paper Award, Sept. 2015 (co-author)
- Annual Bennet Lecturer, Leicester University, UK, March 2017
- Wiley, Island Arc Award, Sept 2017 (co-author)
- Geological Society of Japan Prize, Sept. 2017

5. Future Research Plan

In my future work I will continue to explore how quantitative information on tectonic processes can be estimated from petrological and structural geological studies of natural systems. In particular I am interested in developing methods to estimate stresses acting along major tectonic boundaries such as subduction zones and the amount of fluid flow in these regions. Both are important but poorly constrained controls on the dynamics of plate boundaries. The approaches will be a combination of microstructural analysis, petrological studies and thermal modeling. In addition, I will work with other members of the department to strengthen research links between seismology, structural geology and petrology based on studies of rock properties determined through observation of both modern and ancient domains of deformation. In particular, I am interested in the use of seismic anisotropy to interpret the structure and rock distribution (including hydrous phases) in convergent margins. I will continue to develop international collaboration with researchers working in China on the processes of continental collision and with groups in UK and Switzerland working on magmatic systems including how observations of natural systems can be used to test models of melt extraction and magma flow.

6. Funding Received

- JSPS Kakenhi Project, the geology of slow earthquakes and elucidation of the frictional and hydrological characteristics. Co-Investigator, 2016–2020, 14,300,000 JPY.

- Industry-University Collaborative Research Funds (Billiton–Bristol University, UK), new perspectives on porphyry copper deposits, Co-Investigator, 2016–2018, ~3,000,000 JPY
- JSPS Kakenhi Project, lake shoreline deformation and crustal magmatic flow in the Andes. Principal Investigator, 2015–2018, 12,480,000 JPY
- Leverhulme International Network Funds, UK, assembling the Early Palaeozoic terranes of Japan, Co-Investigator, 2015–2017, ~1,000,000 JPY
- JSPS Kakenhi Project, structural petrological studies along the subduction boundary: the example of the Sanbagawa belt, SW Japan, Principal Investigator, 2012–2016, 43,030,000 JPY
- JSPS Kakenhi Project, Raman spectroscopy petrology: deciphering the plume action preserved in diamond-bearing xenoliths, Co-Investigator, 2009-2012, 900,000JPY

7. Publications and Patents

(1) Peer-reviewed Journal Articles

1. Shigematsu, N., Fujimoto, K., Tanaka, N., Furuya, N., Mori, H. and **Wallis, S. R.** (2012, Apr). Internal Structure of the Median Tectonic Line fault zone, SW Japan, revealed by borehole analysis. *Tectonophysics* **532-535**, 103-118.
2. Endo, S., **Wallis, S. R.**, Tsuboi, M., Aoya, M. and Uehara, S. (2012, Aug). Slow subduction and buoyant exhumation of the Sanbagawa eclogite. *Lithos* **146** 183-201.
3. Mitsuishi, M., **Wallis**, **S. R.**, Aoya, M., Lee, J. and Wang, Y. (2012, April). E-W extension at 19 Ma in the Kung Co area, S. Tibet: Evidence for contemporaneous E-W and N-S extension in the Himalayan orogeny. *Earth and Planetary Science Letters* **325-326,** 10-20.
4. Aoya, M., Endo, S., Mizukami, T. and **Wallis, S. R**. (2013, April). Paleo-mantle wedge preserved in the Sambagawa high-pressure metamorphic belt and the thickness of forearc continental crust. *Geology* **41,** 451-454.
5. Endo, S., Nowak, I. and **Wallis, S. R**. (2013, May). High-pressure garnet amphibolite from the Funaokayama unit, western Kii Peninsula and the extent of eclogite facies metamorphism in the Sanbagawa belt. *Journal of Mineralogical and Petrological Science* **108**, 189-200.
6. Nagaya T., **Wallis S. R.**, Kobayashi H., Michibayashi K., Mizukami T., Seto Y., Miyake, A. and Matsumoto M. (2014, Feb) Dehydration breakdown of antigorite and the formation of B-type olivine CPO, *Earth and Planetary Science Letters* **387**, 67–76. doi: 10.1016/j.epsl.2013.11.025
7. Kouketsu, Y., Mizukami, T., Mori, H., Endo, S., Aoya, M., Hara, H., Nakamura, D. and **Wallis, S**. (2014, Mar). A new approach to develop the Raman carbonaceous material geothermometer for low-grade metamorphism using peak width. *Island Arc* **23** 33-50.
8. Williams, M., **Wallis, S.**, Oji, T. and Lane, P. D. (2014, Jun). Ambiguous biogeographical patterns mask a more complete understanding of the Ordovician to Devonian evolution of Japan. *Island Arc* **23**, 76-101.
9. Mizukami, T., Yokoyama, H., Hiramatsu, Y., Arai, S., Kawahara, H., Nagaya, T. and **Wallis**, **S.** (2014, Sept). Two types of antigorite serpentinite controlling heterogeneous slow-slip behaviours of slab-mantle interface. *Earth and Planetary Science Letters* **401**, 148-158.
10. Nagaya, T., **Wallis S. R.**, Kobayashi H., Michibayashi K., Mizukami T., Seto Y., Miyake A. and Matsumoto M. (2014, Dec). Reply to comment by Nozaka on "Dehydration breakdown of antigorite and the formation of B-type olivine CPO". *Earth and Planetary Science Letters* **408**, 406-407. 10.1016/j.epsl.2014.10.026
11. Kim, D., Katayama, I., **Wallis, S.**, Michibayashi, K., Miyake, A., Seto, Y. and Azuma, S. (2015, Feb). Deformation microstructures of glaucophane and lawsonite in experimentally deformed

blueschists: implications for intermediate-depth intraplate earthquakes. *Journal of Geophysical Research: Solid Earth* **120**, 1229-1242.

12. Mori, N., **Wallis, S.** & Mori, H. (2015, Jun). Graphitization of carbonaceous material in sedimentary rocks on short geologic time-scales: An example from the Kinsho-zan area, central Japan. *Island Arc* **24**, 119–130.
13. Endo, S., Mizukami, T., **Wallis, S. R.**, Tamura, A. & Arai, S. (2015, Jun). Orthopyroxene-rich Rocks from the Sanbagawa Belt (SW Japan) Fluid Rock Interaction in the Forearc Slab Mantle Wedge Interface. *Journal of Petrology* **56**, 1113–1137.
14. Weller, O. M., **Wallis, S. R.**, Aoya, M. & Nagaya, T. (2015, Aug). Phase equilibria modelling of blueschist and eclogite from the Sanbagawa metamorphic belt of southwest Japan reveals along-strike consistency in tectonothermal architecture. *Journal of Metamorphic Geology* **33**, 579–596.
15. Furuichi, H., Ujiie, K., Kouketsu, Y., Saito, T., Tsutsumi, A. & **Wallis, S.** (2015, Aug). Vitrinite reflectance and Raman spectra of carbonaceous material as indicators of frictional heating on faults: Constraints from friction experiments. *Earth and Planetary Science Letters* **424**, 191–200.
16. Sugitani, K., Mimura, K., Takeuchi, M., Yamaguchi, T., Suzuki, K., Senda, R., Asahara, Y., **Wallis, S.** & Van Kranendonk, M. J. (2015, Nov). A Paleoarchean coastal hydrothermal field inhabited by diverse microbial communities: the Strelley Pool Formation, Pilbara Craton, Western Australia. *Geobiology* **13**, 522–545.
17. Mori, H., **Wallis, S.**, Fujimoto, K. and Shigematsu, N. (2015, Dec). Recognition of shear heating on a long-lived major fault using Raman carbonaceous material thermometry: implications for strength and displacement history of the MTL, SW Japan. *Island Arc* **24**, 425–446.
18. Williams, M., **Wallis, S.**, Komatsu, T., Tanaka, G., Oji, T. and Clark, N. (2016, Jan-Feb). Dragons, brimstone and the geology of a volcanic arc on the island of the last Samurai, Kyushu, Japan. *Geology Today* **32**, 21-26.
19. Williams, M., Komatsu, T., Tanaka, G., Nguyen, H. H., Zalasiewicz, J., Vandenbroucke, T. R. A., **Wallis, S**. & Perrier, V. (2016, Feb). Upper Llandovery (Telychian) graptolites of the *Oktavites spiralis* Biozone from the Long Dai Formation, at Lam Thuy villiage, Quang Binh Province, central Vietnam. *Canadian Journal of Earth Sciences* **53**, 1–6.
20. Ishizawa, T., Watanabe, M., Goto, K., Ikehara, K., **Wallis, S.** & Iryu, Y. (2016, March). Traces of paleotsunamis in the Shetland Islands. *Journal of the Geological Society of Japan*, **122** I-II.
21. **Wallis, S. R.** & Okudaira, T. (2016, Mar). Paired metamorphic belts of SW Japan: the geology of the Sanbagawa and Ryoke metamorphic belts and the Median Tectonic Line. In: *The Geology of Japan*, edited by Moreno, T., Wallis, S. R., Kojima, T. & Gibbons, W. Geological Society, London, pp. 101–124.
22. Taira, A., Ohara, Y., **Wallis, S. R.**, Ishiwatari, A. & Iryu, Y. (2016, Mar). Geological evolution of Japan: an overview. In: *The Geology of Japan*, edited by Moreno, T., Wallis, S. R., Kojima, T. & Gibbons, W. Geological Society, London, 1-24.
23. Kim, D. **Wallis, S.**, Endo, S. & Ree, J.-H. (2016, May). Seismic properties of lawsonite eclogites from the southern Motagua fault zone, Guatemala. *Tectonophysics* **677–678**, 88-98.
24. Kawahara, H., Endo, S., **Wallis, S. R**., Nagaya, T., Mori, H. & Asahara, Y. (2016, Jun). Brucite as an important phase of the shallow mantle wedge: Evidence from the Shiraga unit of the Sanbagawa subduction zone, SW Japan. *Lithos* **254-255**, 53–66.
25. Nagaya, T., Walker, A. M., Wookey, J., **Wallis, S. R.**, Ishii, K. and Kendall, J.-M. (2016, Jul). Seismic evidence for flow in the hydrated mantle wedge of the Ryukyu subduction zone. *Scientific Reports* **6**, 29981.
26. Mori, H., Mori, N., **Wallis, S. R.**, Westaway, R. and Annen, C. (2017, Feb). The importance of

heat duration for Raman CM thermometry: evidence from contact metamorphism. *Journal of Metamorphic Geology* **35**, 165–180.

27. Nagaya, T., **Wallis, S. R.**, Seto, Y., Miyake, A., Soda, Y., Uehara, S. & Matsumoto, M. (2017, Feb). Minimizing and quantifying mis-indexing in electron backscatter diffraction (EBSD) determinations of antigorite crystal directions. *Journal of Structural Geology* **95**, 127-141.
28. Hartung, E., Caricchi, L., Floess, D., **Wallis, S.**, Harayama, S., Kouzmanov, K. & Chiaradia, M. (2017, Apr). Evidence for Residual Melt Extraction in the Takidani Pluton, Central Japan. *Journal of Petrology* **58**, 763–788.
29. Clark, N. & **Wallis, S.** (2017, May/June). Flamingos, salt lakes and volcanoes: hunting for evidence of past climate change on the high Altiplano of Bolivia. *Geology Today* **33**, 101–107.
30. Endo, S. and **Wallis, S. R**. (2017, Aug). Structural architecture and low-grade metamorphism of the Mikabu-Northern Chichibu accretionary wedge, SW Japan. *Journal of Metamorphic Geology* **35,** 695-716.
31. Stocker, C., Komatsu, T., Tanaka, G., Williams, M., Siveter, D., Bennett, C., **Wallis, S. R.**, Oji, T., Maekawa, T. and Okura, M. (2018, Jan). Carboniferous Ostracods from Central Honshu, Japan. *Geological Magazine* **155**, 98–108.
32. **Wallis, S. R.**, Fujiwara, O. & Goto, K. (2018, Jan). Geological studies in tsunami research since the 2011 Tohoku earthquake. *Geological Society, London, Special Publications* **456**, 39-53.
33. Stocker, C., Tanaka, G., Siveter, David. J., Lane, P., Tsutsumi, Y., Komatsu, T., **Wallis, S.**, Oji, T., Siveter, Derek J., Williams, M. (2018, Jan). Biogeographical and Biostratigraphical Significance of a New Middle Devonian Phacopid Trilobite from the Naidaijin Formation, Kurosegawa Terrane, Kyushu, Southwest Japan. *Paleontological Research* **22**, 75-90.
34. Tsang, D. P. W., **Wallis, S. R.**, Yamamoto, K., Takeuchi, M., Hidaka, H., Horie, K. & Tattitch, B. C. (2018, Feb). Zircon U–Pb geochronology and geochemistry of the Cerro Colorado porphyry copper deposit, northern Chile. *Ore Geology Reviews* **93**, 114-140.
35. Stocker, C. P., Siveter, D. J., Lane, P. D., Williams, M., Oji, T., **Wallis, S. R.**, Tanaka, G., Komatsu, T., Siveter, D. J. & Vandenbroucke, T. R. A. (2019, March). The paleobiogeographical significance of the Silurian and Devonian trilobites of Japan. *Island Arc* **28**, https://doi.org/10.1111/iar.12287
36. Vandenbroucke, T. R. A., Hints, O., Williams, M., **Wallis, S.,** Velleman, J., Kurihara, T., Tanaka, G., Komatsu, T., Männik, P., Siveter, D. J., de Backer, T. (2019, March). Palynomorphs (chitinozoans and scolecodonts) from the Silurian and Devonian of Japan. *Island Arc* **28**, 1–15 https://doi.org/10.1111/iar.12287

(2) Non-peer-reviewed Articles

1. Shigematsu, N., Fujimoto, K., Okudaira, T., Tanaka, N., Mori, H. and **Wallis, S.** (2014, March). Median Tectonic Line fault zone revealed by borehole analysis. Earth Monthly **36**, 120–129. (in Japanese)
2. *100 Selected Structural Geology Sites in Japan,* Edited by Takagi, H. (2012, May) Asakura Publishers (part contribution) (in Japanese).
3. Extending the ocean rights of Japan with science 2013, 理 Philosophia (outreach magazine for Nagoya University Faculty of Science), **24** 16–17 (in Japanese)

(3) Review Papers

(4) Books

1. *The Geology of Japan*, (2016, March) edited by Moreno, T., **Wallis, S. R.**, Kojima, T. & Gibbons,

W. Geological Society, London, pp. 522.

2. *Tsunami Hazards and Risks: Using the Geological Record*, (2018, Jan) edited by Scourse, E., Chapman, N., Tappin, D. and **Wallis, S. R.** Geological Society Special Publication, London. pp. 244.
3. *An Illustrated Dictionary of Earth Science*, (2018, April). Edited by Toriumi, M., Irifune, T., Iwamori, H., **Wallis, S.**, Kodaira, H., Komiya, T., Sakaguchi, H., Sagiya, T., Sueji, D., Nakagawa, T. and Miyamoto, H. Asakura Publishers, (in Japanese), pp. 236.

(5) Other Publications

1. *The Palaeozoic evolution of the Korean Peninsula and Japan* (2019, Feb.). Special Issue Edited by **Wallis, S.**, Oji, T., Williams, M. & Cho, M. *Island Arc **28***.

(6) Patents

8. Keynote, Invited, or Solicited Presentations

1. Wallis, S. R., Geological Society of Korea, invited talk, Oct. 2013.
2. Wallis, S. R., Taiwan Geoscience Assembly, invited talk, May 2016
3. Wallis, S. R., Oxford Instruments, Yokohama, invited lecture, July 2017

III. Education Activity

9. Notable Achievements in Education

Advisees

- Master theses: 10 students
- Doctoral theses: 4 students

Lectures

- Undergraduate/Graduate, Structural Geology, 2017-
- Undergraduate, Basic Stratigraphy and Geology 2017
- Undergraduate/Graduate, Practical: analyses of rock textures I
- Undergraduate, Practical: Earth and Planetary Environmental Science
- Undergraduate, Field exercise: Earth and Planetary Environmental Science II
- Undergraduate, Field exercise: Earth and Planetary Environmental Science III
- Graduate, Petrological Tectonics
- Graduate, Structural Petrology

Students’ awards

- Geological Society of Japan, Best Poster Presentation Award: 2 students, 3 awards
- Japan Geoscience Union, Student Presentation Award: 2 students
- Geological Society of Japan, Young Researcher Award: 1 student

IV. External Activities

10. Contribution to Academic Community

- American Geophysical Union, Committee for International Participation (2014–2018)
- Geological Society of Japan, Executive Director (2012–2016, 2018–)
- Geological Society of Japan, Vice President (2012–2014)
- Japan Geoscience Union, Director (2010–)
- Japan Geoscience Union, Vice President and Chair of Committee for Global Strategy (2018–)
- Japan Geoscience Union, Solid Earth Section Board Member (2009–)
- *Royal Society-Open Science,* Associate Editor (2014–)
- *Progress in Earth and Planetary Science*, Associate Editor (2014–)
- *Island Arc*, Editorial Advisory Board (2008–)

11. Outreach Activity

- Advisor to the Japanese Foreign Office for application to extend continental shelf around Japan (2007–2017)
- Member of Ministry of Education Review Panel of Japan Agency for Marine-Earth Science and Technology (JAMSTEC) (April 2016–present)
- JAMSTEC Review and advice committee member (Research Theme: Determining Conditions along the Plate boundary seismogenic zone) (2015–present)
- Grant reviewer for JSPS (Japan) 2014–15, NERC (UK), NSF (US) etc.
- Lectures for general audience (5 times)
  - (NHK lecture series「ひとの大学」, Sept. 2018
  - Global Science Campus for Tokai Region high school students, July 2018
  - Leicester University Annual Bennett Lecture, March 2017
  - Global Science Campus for Tokai Region high school students, June 2017
  - Science Café at Nagoya University, Nov. 2014
- Television: narrator for Asahi tv natural science program ‘the story of our miraculous earth: the science behind our near future’ for program entitled ‘Nagatoro of the Chichibu region: 300 million years since the formation of the Japanese islands’, broadcast 27 April 2014
- Presenter for TEDx NagoyaU 2014: ‘Finding your place outside of the comfort zone’
- Instructed two high school students from Okazaki Super Science High School 「研究室体験研修」July 30–August 3, 2018

12. Internal Committee Membership

- Department of Earth and Planetary Science, Education Committee, Member, 2018–
- Employment committee: member (6), Chair (1)

V. International Exchange Activities

13. Hosting/Sending Foreign Students and Researchers

(1) Hosting

Foreign Students: 11

Foreign Researchers: 6

(2) Sending

Students: 6

Researchers: 0

(3) Visitors from Abroad: 5

Kazuhito Ozawa

I. CV

Name: Kazuhito Ozawa

Age: 64

Present Position: Professor

Education

Matsumoto Fukashi High School, Nagano Prefecture, March, 1974 (graduation)

B. Sc., Geology, Geological Institute, Faulty of Science, The University of Tokyo, March, 1978

M. Sc., Petrology, Geological Institute, Faulty of Science, The University of Tokyo, March, 1980

Ph. D., Petrology, Geological Institute, Faulty of Science, The University of Tokyo, March, 1983

Professional Experience

May, 1983-May, 1993, Assistant Professor, Geological Institute, Faulty of Science, The University of Tokyo

May, 1991-December, 1991, Guest Scientist, Woods Hole Oceanographic Institute, USA

December, 1991-May, 1993, Visiting Scientist, Department of Geology and Geophysics, Yale University, USA

May, 1993-May, 1997, Associate Professor, Geological Institute, Faculty of Science, The University of Tokyo

May, 1997-April, 2000, Professor, Institute for Study of the Earth's Interior, Okayama University

April, 2000-, Professor, Department of Earth and Planetary Science, Graduate School of Science, The University of Tokyo

II. Scientific Research Activity

2. Major Achievements

My research achievement in the past seven years is better understanding (1) processes taking place in the lithosphere-asthenosphere boundary (LAB) zone based on geological, petrological, and geochemical studies of mantle materials either exposed as large peridotite massifs or peridotites xenoliths occurring in volcanic rocks and (2) kinetics of reactions between gas and condensed phases related to the evolution of the early solar nebula based on high-temperature vacuum experiments and theoretical study. They are summarized as follows.

(1) Quantitative information related to magma generation in the mantle has been extracted from mantle materials by utilizing the general mass balance equation developed by Ozawa (2001) that can deal with completely open reactions between solid and melt. The studies revealed: (a) involvement of carbonate-rich melt in the formation of magmas in subduction environment (Yoshikawa et al., 2012), (b) open-system melting of ascending mantle in the back-arc entraining fluid-contaminated shallow upper mantle (Sakuyama et al, 2014a, 2014b), (c) three-dimensional transportation of heat and melt accompanied by chemical reactions beneath a mid-oceanic ridge (Akizawa et al., 2016). Also, the evolution of the Hayachine-Miyamori ophiolite, formed and exhumed during the Cambrian-Ordovician ophiolite pulse, was reconstructed by compiling all the chronological and geological

information available from the Kitakami mountains in addition to the extensive geological, petrological, and geochemical data from the ophiolite (Ozawa et al., 2015). The origin of the ophiolite pulse is attributed to very hydrous upper mantle and frequent occurrence of slab breakoff during the early Phanerozoic periods. Further, the status quo and critical issues to be addressed concerning LAB zone were clarified through reviewing thermal history of the earth (Ozawa and Nagahara, 2015) and geobarometry of spinel peridotite xenolith derived from the shallow mantle. On the basis of these reviews, mantle xenoliths from the Ichinomegata maar were examined to reveal that the LAB beneath arc is attributable to partial melting of hydrous upper mantle (Sato and Ozawa, 2019).

(2) Kinetics of anisotropic evaporation of forsterite, the most abundant and important dust phase in the early solar nebula, was examined by high-temperature vacuum experiments and quantitative observation of surface microstructures to reveal temperature and face-dependent intrinsic free evaporation rate and evaporation mechanisms (Ozawa et al., 2012). A general model for kinetics of reactions between condensed phase and ambient gas in the early solar nebula was constructed to find the importance of exchange reactions in addition to net-transfer reactions accelerating isotopic exchange. The model was applied to understand diversity in oxygen isotopes commonly reported from chondrules.

3. Five Important Papers

1. Ozawa, K., and Shimizu, N. (1995), Open-system melting model in the upper mantle: constraints from the Hayachine-Miyamori ophiolite, northeastern Japan, *Journal of Geophysical Research*, **100**, 22315-22335.

There had been mass balance equation for melting in closed systems or systems open only for melt separation at that time, this paper proposes a model for melting systems open not only to melt output but also to melt input and presents the mass balance equation. This paper examined open-system melting process in the mantle for the first time. (Citation 85, WS/ Sept. 19, 2019).

2. Ozawa, K. (2001), Mass balance equations for open magmatic systems: Trace element behavior and its application to open system melting in the upper mantle. *Journal of Geophysical Research*, **106**, 13407-13434.

This paper developed the master mass balance equation for general open magmatic reaction systems, from which almost all the mass balance equations formulated so far can be derived as a specific case of the general equation. A spreadsheet calculator and a Java application for web calculation were made available, and have been used by many researchers. I have been receiving inquires about the applications, and I also held a seminar for how to use the spreadsheet. (Citation 35, WS/ Sept. 19, 2019).

3. Ozawa, K., Maekawa, H., Shibata, K., Asahara, Y., and Yoshikawa, M., (2015), Evolution processes of Ordovician-Devonian arc system in the South-Kitakami Massif and its relevance to the Ordovician ophiolite pulse. *Island Arc*, **24**, 78-118.

This paper proposed a model for the development of Hayachine-Miyamori ophiolite, an arc ophiolite formed during Cambrian-Ordovician ophiolite pulse, which is marked by high frequency of formation and exhumation of oceanic crust-mantle sections (ophiolites), through compilation of chronological and geological information of the Kitakami Mountains as well as extensive data on geology, petrology, and geochemistry of the ophiolite. The proposed model consisting of a series of tectonic processes: arc-continent collision, trench retreat, slab breakoff, and subduction inversion, have paved the way for researches on sub-slab mantle, which is the most inaccessible upper mantle. (Citation 3, WS/ Sept. 19, 2019)

4. Akizawa, N., Ozawa, K., Tamura, A., Michibayashi, K., and Arai, S., (2016), Three-dimensional evolution of melting, heat and melt transfer in ascending mantle beneath a fast-spreading ridge segment constrained by trace elements in clinopyroxene from concordant dunites and host

harzburgites of the Oman ophiolite. *Journal of Petrology*, **57**, 777-814, doi: 10.1093/petrology/egw020.

This paper revealed three-dimensional transportation of heat and melt accompanied by chemical reactions beneath an ancient oceanic ridge on the basis of geological, petrologic, and geochemical data obtained from dunite bodies frequently occurring in the mantle section of the Oman ophiolite. This paper extensively utilized the mass balance equations for open magma system developed by Ozawa (2001) to constrain variability in compositions, flux, and influx timing of melt flowing through the mantle along a segment of fast-spreading ridge (Citation 8, WS/ Sept. 19, 2019)

5. Sato, Y. and Ozawa, K. (2019), Reconstruction of the lithosphere-asthenosphere boundary zone beneath Ichinomegata maar, Northeast Japan, by geobarometry of spinel peridotite xenoliths. *American Mineralogist*, **104**, 1285-1306.

This paper made accurate estimation of derivation depths of spinel lherzolite xenoliths for the first time, in which nobody has succeeded because of the lack of reliable geobarometers for the mantle materials derived from the shallow upper mantle, and reconstructed the thermal, chemical, and rheological structures of lithosphere-asthenosphere boundary (LAB) zone beneath the northeast Japan arc. The reconstruction is consistent with various geophysical observations and has revealed the formation mechanism of LAB as partial melting of hydrous mantle, shallowing LAB from the back-arc to the forearc, and lithosphere thinning after the opening of Japan Sea. The paper was picked up as “Highlight and Breakthroughs” in the journal of American Mineralogist.

4. Awards and Honors

5. Future Research Plan

Extending the achievement thus far on processes in the evolution of the earth, I will focus my future research on examination of the roles of lithosphere-asthenosphere boundary zone played in the thermal histories of the earth based on information from natural earth materials. The target materials are ophiolites and orogenic peridotite exposed on the surface as a large-scale bodies, mantle xenoliths brought to the surface by kimberlite and alkali basalt magmas, volcanic and sub-volcanic complexes active for a long period of time in arc and continental environments. If melt compositions are available from these materials, melting depths, contribution of volatile elements, melting degrees, and mantle potential temperatures are estimated. If no melt compositions are available, pressure and temperature histories recorded in lithosphere driven by asthenosphere dynamics are extracted. The localities and materials on which the data have been acquired and are acquiring are peridotite from Horoman (northern Japan), Ronda (Spain), Pyrénées (France), and Lanzo (Italy), mantle xenoliths from Ichinomegata (northeast Japan), Middle Atlas (Morocco), Arabian shield, Colorado Plateau/Rio Grande Rift (USA), and Finland, and ring complexes from the Hidaka metamorphic belt (northern Japan) and Nubian-Arabian shield.

6. Funding Received

- JSPS KAKENHI, 17H02982, Principal Investigator, FY2017-2019, 11,500,000 yen
- JSPS KAKENHI, 16K13910, Co-Investigator, FY2016-2017, 600,000 yen
- JSPS KAKENHI, 16H06285, Co-Investigator, FY2018-2020, 1500,000 yen (expected)
- JSPS RONPAKU (DISSERTATION PhD) PROGRAM, R118042018, Hassan Eman Saad Abdelsalam, FY2018-2020, 3,550,000 yen (expected)

7. Publications and Patents

(1) Peer-reviewed Journal Articles

1. Ozawa, K., Nagahara, H., Morioka, M., Matsumoto, M., Hutcheon, I. D., Noguchi, T., and Kagi, H., (2012), Kinetics of evaporation of forsterite in vacuum. *American Mineralogist*, **97**, 80-99, doi.org/10.2138/ am.2012.3750.
2. Nagahara, H. and Ozawa, K. (2012), The role of exchange reactions in oxygen isotope fractionation during CAI and chondrule formation. *Meteoritics and Planetary Science*, **47**, 1209-1228.
3. Yoshikawa, M., Suzuki, K., Shibata, T. and Ozawa, K., (2012), Geochemical and Os isotopic characteristics of a fresh harzburgite in the Hayachine-Miyamori ophiolite: Evidence for melting under influx of carbonate-rich silicate melt in an infant arc environment, *Journal of Mineralogical and Petrological Sciences*, **134**, 107-122.
4. Obata, M., Ozawa, K., and Naemura, K., (2013), Isochemical breakdown of garnet in orogenic garnet peridotite and its implication to reaction kinetics. *Mineralogy and Petrology*, **107**, 881-895, DOI 10.1007/s00710-012-0260-4.
5. Tachibana, S., Tamada, S., Kawasaki, H., Ozawa, K., and Nagahara, H., (2013), Interdiffusion of Mg-Fe in olivine at 1,400-1,600 °C and 1 atm total pressure. *Physics and Chemistry of Minerals*, **40**, 511-519, DOI 10.1007/ s00269-013-0588-2.
6. Sakai, R., Nagahara, H., Ozawa, K., and Tachibana, S., (2014), Composition of the lunar magma ocean constrained by the conditions for the crust formation. *Icarus*, **229**, 45-56.
7. Sakuyama, T. Nagaoka, S., Miyazaki, T., Chang, Q., Takahashi, T., Hirahara, Y., Senda, R. Itaya, T. Kimura, J., and Ozawa, K., (2014), Melting of the upper most metasomatized asthenosphere triggered by fluid fluxing from ancient subducted sediment: Constraints from the Quaternary basalt lavas at Chugaryeong Volcano, Korea., *Journal of Petrology*, **55**, 499-528.
8. Sakuyama, T., Nakai, S., Yoshikawa, M., Shibata, T., and Ozawa, K., (2014), Progressive interaction between dry and wet mantle during high temperature diapiric upwelling: constraints from Cenozoic Kita-Matsuura intraplate basalt province, northwestern Kyushu, Japan. *Journal of Petrology*, **55**, 1083-1128.
9. Takigawa, A., Tachibana, S., Nagahara, H., and Ozawa, K., (2015), Evaporation and condensation kinetics of corundum: The origin of the 13μm feature of oxygen-rich AGB stars. T*he Astrophysical Journal Supplement Series*, **218.2** 16pp, doi: 10.1088/0067-0049/218/1/2.
10. Ozawa, K., Maekawa, H., Shibata, K., Asahara, Y., and Yoshikawa, M., (2015), Evolution processes of Ordovician-Devonian arc system in the South-Kitakami Massif and its relevance to the Ordovician ophiolite pulse. *Island Arc*, **24**, 78-118.
11. Akizawa, N., Ozawa, K., Tamura, A., Michibayashi, K., and Arai, S., (2016), Three-dimensional evolution of melting, heat and melt transfer in ascending mantle beneath a fast-spreading ridge segment constrained by trace elements in clinopyroxene from concordant dunites and host harzburgites of the Oman ophiolite. *Journal of Petrology*, **57**, 777-814, doi: 10.1093/petrology/egw020.
12. Hibiya, Y., G. J. Arche, R. Tanaka, M. E. Sanborn5, Y. Sato, T. Iizuka, K. Ozawa, R. J. Walker, A. Yamaguchi, Q.-Z. Yin, A. J. Irving, T. Nakamura (2019), The origin of the unique achondrite Northwest Africa 6704: Constraints from petrology, chemistry and Re–Os, O and Ti isotope systematics. *Geochimica et Cosmochimica Acta*, **254**, 597-627.
13. Sato, Y. and Ozawa, K. (2019), Reconstruction of the lithosphere-asthenosphere boundary zone beneath Ichinomegata maar, Northeast Japan, by geobarometry of spinel peridotite xenoliths.

American Mineralogist, **104**, 1285-1306.

(2) Non-peer-reviewed Articles

1. Hasegawa, T., Michibayashi, K., and Ozawa, K. (2017), Structural and petrological characteristics of ultramafic rocks in Hayachine-Miyamori Ophiolite. Geoscience Reports of Shizuoka University no. 44, 31-46. (in Japanese with English abstract)

(3) Review Papers

1. Ozawa, K. and Nagahara, H. (2013), Elucidating thermal history of the earth based on information of earth materials: retrospect and prospect. *Ganseki Kobutsu Kagaku*, **42**, 136-1552, doi: 10.2465/gkk. 121105. (in Japanese with English abstract)
2. Ozawa, K. Maekawa, H., and Ishiwatari, A. (2013), Reconstruction of the structure of Ordovician-Devonian arc system and its evolution processes: Hayachine-Miyamori ophiolite and Motai high-pressure metamorphic rocks in Iwate Prefecture. *Journal of Geological Society of Japan*, **119** Supplement, 134-153. Doi: 10.5575/geosoc.2013.0025. (in Japanese with English abstract)
3. Ozawa, K., Sato, Y., and Narita, S. (2018), Pressure estimation of spinel peridotite xenoliths, the status quo, problems, resolutions: Towards a better understanding of the lithosphere-asthenosphere boundary region. *Journal of Geological Society of Japan*, **124**, 575-592, doi: 10.5575/geosoc.2018.0008. (in Japanese with English abstract)

(4) Books

1. Ishiwatari, A., Ozawa, K., Arai, S., Ishimaru, S., Abe, N., and Takeuchi, M. (2016), Ophiolites and ultramafic rocks, In: *The Geology of Japan*, eds., Moreno, T., Wallis, S. R., Kojima, T. & Gibbons, W. Geological Society, London, p. 223-250.

(5) Other Publications

1. Ozawa (2012-2018), Chronological Scientific Tables 2012-2018, Geology and Minerals, edited by National Astronomical Observatory of Japan，Maruzen Publishing Co. Ltd., Tokyo, pp. 644-676.

(6) Patents

8. Keynote, Invited, or Solicited Presentations

1. Ozawa, K., Thermal history of the earth based on approaches from material information, 120th Annual Meeting of the Geological Society of Japan, Sendai, Japan, 2013/09/14.
2. Ozawa, K. and Maekawa, H. Field excursion for Hayachine-Miyamori Ophiolite and Motai Metamorphic Complex in Iwate Prefecture, 120th Annual Meeting of the Geological Society of Japan, Sendai, Japan, 2013/09/17-18.
3. Ozawa, K., Contrasting P-T histories recorded in exhumed mantle peridotites and its implication in lithosphere-asthenosphere interaction, 6th Orogenic Lherzolite Conference, Marrakech, Morocco, 2014.5/4-15.
4. Ozawa, K., Youbi, N., Boumehdi, M. A., and Nagahara, H., Thermobarometry for spinel lherzolite xenoliths in alkali basalts, EGU General Assembly, Vienna, Austria, 2016/4/19.
5. Ozawa, K., Youbi, N., Boumehdi, M. A., McKenzie, D., and Nagahara, H., Evaluation of thermobarometry for spinel lherzolite fragments in alkali basalts, EGU General Assembly, Vienna, Austria, 2017/4/27.

6. Ozawa, K., Sato, Y., Narita, S., Youbi, N., Boumehdi, M. A., and Nagahara, H., Decoding thermal events before and during mantle xenolith extraction. EGU General Assembly 2018, Vienna, Austria, 2018/4/9.
7. Ozawa, K., Garrido, C. J., Hidas, K., and Bodinier, J-L., Modes of asthenosphere-lithosphere interaction revealed from evolution of the internal thermal structure of orogenic peridotite complexes, 3rd European Mantle Workshop, Pavia, Italy, 2016/6/28.

III. Education Activity

9. Notable Achievements in Education

Advisees

- Master theses: 9 students

  Satoshi Ogino, Hiroko Suzuki (Mar. 2014)
  Fumiya Morisato, Yumi Hisaoka (Mar. 2015)
  Ryugen Sakata (Mar. 2017)
  Takafumi Kimura (Mar. 2018)
  Saeri Narita (Mar. 2019)
  Soh Tanoue, Tomo Aoki (Mar. 2020 expected)

- Doctoral theses: 2 students

  Yuto Sato, Takafumi Kimura (Mar. 2020 expected)

Lectures

- Graduate, Lecture in magma science, FY2014, 2017
- Graduate, Laboratory experiments for instrumental analysis II, FY2012-2018
- Undergraduate/Graduate, Lecture in Solid earth science, FY2012-2017
- Undergraduate, Lecture in Earth and planetary physical chemistry, FY2012-2018
- Undergraduate, Exercise in Physical chemistry in earth and planetary science, FY2012-2018
- Undergraduate, Field Exercise in earth and planetary environmental science III, FY2012-2018
- Undergraduate, Practical in earth and planetary environmental science, FY2012-2018
- Undergraduate, Practical in microscopic observation rock forming minerals, FY2012-2017
- Undergraduate, Field excursion in earth and planetary environmental science I, FY2016
- Undergraduate, Experiments in earth and planetary physics, FY2012-2018
- Undergraduate, Field excursion in earth and planetary environmental science I, FY2016
- Undergraduate, Basic earth and planetary material science, FY2018
- Undergraduate, Seminar for junior/sophomore students in earth and planetary science, FY2016
- Graduate/Undergraduate at Tohoku University, Special lecture in arc magmatism I/Special lecture in volcanology and geofluids III (I), FY2013

Student's awards

- Japan Geoscience Union, Student Presentation Award: 2 students [Takafumi Kimura, 2016; Fumiya Morisato, 2017]
- Japan Association of Mineralogical Science, Annual Meeting, Excellent Presentation Award: 2 students [Takafumi Kimura, 2016, 2018]

IV. External Activities

10. Contribution to Academic Community

- Japanese Association of Mineralogical Sciences, Council member, FY2012-2014
- Manjiro Watanabe Award of Japanese Association of Mineralogical Sciences, Chair of the selection committee, FY2012
- Award of Japanese Association of Mineralogical Sciences, Selection committee member, FY2013
- 6th Orogenic lherzolite conference 2014 Morocco: Organization Committee, FY2014
- Japanese Association of Mineralogical Sciences Annual Meeting at Tokyo, Organization Committee, FY2015
- Workshop on earth's mantle at Tokyo, Organizer, FY2018
- International Association of Seismology and Physics of the Earth's Interior, Commission on Earthquake Source Mechanics Chair, 2017-2018

11. Outreach Activity

- Council and organization committee of Institute for Study of the Earth's Interior, Member, FY2012-2013
- Council and organization committee of Institute for Study of the Earth's Interior, Chair, FY2014
- Review board for tenure track at Chiba University, External member, FY2017
- Research grant review, FY2014-2018
- Lectures for general high school students: 3 times (2014/07/24, 2012/11/10, 2013/11/17)

12. Internal Committee Membership

- Department of Earth and Planetary Science, Head, FY2012-2013
- Department of Earth and Planetary Physics, Budget Committee, Chair, FY2014-2017
- School of Science, Committee for Education, Member, FY2014-2015
- University of Tokyo, Committee for Education, Member, FY2015
- School of Science, Committee for Education and Steering, Member, FY2015-2016

V. International Exchange Activities

13. Hosting/Sending Foreign Students and Researchers

(1) Hosting

Foreign Students: 0

Foreign Researchers: 2

(2) Sending

Students: 1

Researchers: 0

(3) Visitors from Abroad: 11

Kei Hirose

I. CV

Name: Kei Hirose

Age: 51

Present Position: Professor

Education

Kaisei High School, Tokyo, March 1986 (graduation)

B. Sc. Geological Institute, The University of Tokyo, March 1990

M. Sc. Geological Institute, The University of Tokyo, March 1992

Ph. D. Geological Institute, The University of Tokyo, March 1994

Professional Experience

Oct. 1994-Nov. 1999, Research Assistant, Department of Earth and Planetary Sciences, Tokyo Institute of Technology

Nov. 1996-Mar. 1998, Visiting Scholar, Geophysical Lab., Carnegie Institution of Washington

Dec. 1999-Dec. 2005, Associate Professor, Department of Earth and Planetary Sciences, Tokyo Institute of Technology

Jan. 2006-Dec. 2012, Professor, Department of Earth and Planetary Sciences, Tokyo Institute of Technology

Dec. 2012-, Director & Professor, Earth-Life Science Institute (ELSI), Tokyo Institute of Technology

Apr. 2017-, Professor, Department of Earth and Planetary Science, The University of Tokyo

II. Scientific Research Activity

2. Major Achievements

I have been studying the phase transition and physical/chemical properties of deep Earth materials based on high-pressure experiments using a diamond-anvil cell, in order to understand the structure, dynamics, and evolution of the lower mantle and the core. Our group has discovered several important phase transitions including the post-perovskite phase transition that occurs around 2600-km depth in the lowermost mantle, which greatly contributes to understanding the D" layer that had been recognized the most enigmatic layer in the Earth's interior. We have also succeeded in generating the ultrahigh-pressure and -temperature conditions that exceed the one at the center of the Earth, for the first time by a static compression experiment, and obtained the phase diagram of Fe under the Earth's inner core conditions using such techniques. More recently our experiments demonstrated that the thermal conductivity of the Earth's core is three times as high as previously thought, suggesting the difficulty of thermally-driven core convection (this problem is called "new core paradox"). Alternatively we have proposed that core convection and geodynamo have been driven and sustained by crystallization of SiO_2 in the liquid core. In addition, $FeSiO_3$ crystal with the perovskite-type structure (the Fe analogue of $MgSiO_3$ bridgmanite, the most abundant mineral inside the Earth) has been officially named "hiroseite".

3. Five Important Papers (including three or more papers in this review period)

1. Murakami, M., Hirose, K., Kawamura, K., Sata, N., Ohishi, Y., Post-perovskite phase transition in $MgSiO_3$, ***Science***, 304, 855–858, 2004.

We discovered the phase transition from $MgSiO_3$ perovskite to post-perovskite above 120 GPa, corresponding to conditions at the lowermost mantle. The lowermost mantle, called the D” layer, had been considered the most hidden layer inside the Earth, because its seismic properties cannot be explained by known mantle minerals. This discovery greatly contributed to the understanding this mysterious layer, the bottom 300-km of the mantle.

2. Tateno, S., Hirose, K., Ohishi, Y., Tatsumi, Y., The structure of iron in Earth’s inner core, ***Science***, 330, 359–361 (2010).

We succeeded in generating 377 GPa and 5700 K, which exceeds the condition at the center of the Earth, for the first time by a static compression experiment. Using this technique, we explored the phase diagram of Fe and found that the hcp phase is stable under inner core conditions.

3. Nomura, R., Hirose, K., Uesugi, K., Ohishi, Y., Tsuchiyama, A., Miyake, A., Low core-mantle boundary temperature inferred from the solidus of pyrolite, ***Science***, 343, 522–525, DOI: 10.1126/science.1248186, 2014.

We determined the solidus temperature of a representative mantle composition (pyrolite) over the entire lower mantle pressure range. The results show that it is about 3600 K at the bottom of the mantle, 500 K lower than previous estimates based on in-situ XRD observations based on the disappearance of one of constituent minerals. It gives the upper bound for the core temperature at the CMB because the lowermost mantle is not globaly molten. The low core temperature suggests it includes a substantial amount of hydrogen, which depresses the melting temperature of iron to a large extent.

4. Ohta, K., Kuwayama, Y., Hirose, K., Shimizu, K., Ohishi, Y., Experimental determination of the electrical resistivity of iron at Earth's core conditions, ***Nature***, 534, 95–98, doi:10.1038/nature17957, 2016.

We measured the electrical resistivity of iron to core high-pressure and -temperature conditions and found it is much lower than previous estimates. This is because the electrical resistivity does not increase linearly with increasing temperature as predicted by the Bloch-Grüneisen law but saturates at a value changes with interatomic distance. The thermal conductivity of the Earth’s core calculated from the electrical resistivity is three times as high as previously thought, suggesting that the core has cooled rapidly or its convection has been driven compositionally rather than thermally.

5. Hirose, K., Morard, G., Sinmyo, R., Umemoto, K., Hernlund, J., Helffrich, G., Labrosse, S., Crystallization of silicon dioxide and compositional evolution of the Earth's core, ***Nature***, 543, 99–102, doi:10.1038/nature21367, 2017.

It is well known that the simultaneous solubility of Si and O in molten Fe is limited at 1 bar. We determined it under core conditions and found that the Si and O contents in the initial core exceed the Si+O solubility under the present-day core condition. It indicates that the Earth’s liquid core has crystallized SiO_2, which can drive core convection and geodynamo since the early history of the Earth.

4. Awards and Honors

- Fellow of Japan Geoscience Union (JpGU), 2017
- Fujihara Award, 2016

・ Geochemical Fellow (European Association of Geochemistry and Geochemical Society), 2014

5. Future Research Plan

I will continue high-pressure experiments on deep Earth (lower mantle, core) materials. It is important to understand the "starting point" of the solid Earth, in order to better understand its present state. We will therefore need to explore the Earth accretion and the early evolution of our planet. For the former, we will have a new project in collaboration with the planet formation theory group at Earth-Life Science institute (ELSI), Tokyo Institute of Technology. For the latter, we will examine the fractionation of major and trace elements and the formation of chemical stratification that may have occurred upon the crystallization of a magma ocean. In addition, we will try to identify the core chemical composition by determining the metal-silicate partitioning of volatile elements, density and sound velocity of liquid iron and alloys, liquidus phase relations of Fe alloy systems, interactions between possible light elements in the core, etc. We will constrain the Earth formation process, in particular the transport of volatile elements (H, C, and N) to the Earth, from the core light elements.

6. Funding Received

・ WPI Program, Center director, Earth-Life Science Institute (ELSI), Tokyo Institute of Technology, FY2012-2021

・ JSPS KAKENHI, Especially Promoted Research, Study of Earth's core materials and evolution, PI, FY2012-2015, total 354,000,000 yen

・ JSPS KAKENHI, Especially Promoted Research, Study of high-pressure liquid and early Earth evolution, PI, FY2016-2020, 401,800,000 yen

7. Publications and Patents

(1) Peer-reviewed Journal Articles

1. Yamanaka, T., Hirose, K., Mao, W. L., Meng, Y., Ganesh, P., Shulenburger, L., Shen, G., Hemley, R. J., Crystal structures of $(Mg_{1-x},Fe_x)SiO_3$ post-perovskite at high pressures, ***Proceedings of the National Academy of Sciences of USA***, 109, 1035–1040, doi:10.1073/pnas.1118076108, 2012.

2. Ohta, K., Cohen, R. E., Hirose, K., Haule, K., Shimizu, K., Ohishi, Y., Experimental and theoretical evidence for pressure-induced metallization in FeO with rocksalt-type structure, ***Physical Review Letters***, 108, 026403, 2012.

3. Komabayashi, T., Hirose, K., Ohishi, Y., In-situ X-ray diffraction measurements of the fcc-hcp phase transition boundary of an Fe-Ni alloy in an internally-heated diamond anvil cell, ***Physics and Chemistry of Minerals***, 39, 329–338, doi: 10.1007/s00269-012-0490-3, 2012.

4. Murakami, M., Ohishi, Y., Hirao, N., Hirose, K., A perovskititic lower mantle inferred from high pressure and temperature sound velocity data, ***Nature***, 485, 90–94, doi:10.1038/nature11004, 2012.

5. Imada, S., Hirose, K., Komabayashi, T., Suzuki, T., Ohishi, Y., Compression of $Na_{0.4}Mg_{0.6}Al_{1.6}Si_{0.4}O_4$ the NAL and Ca-ferrite type phases, ***Physics and Chemistry of Minerals***, 39, 525–530, DOI 10.1007/s00269-012-0508-x, 2012.

6. Tateno, S., Hirose, K., Komabayashi, T., Ozawa, H., Ohishi, Y., The structure of Fe-Ni alloy in Earth's inner core, ***Geophysical Research Letters***, 39, L12305, doi:10.1029/2012GL052103, 2012.

7. Ohta, K., Yagi, T., Taketoshi, N., Hirose, K., Komabayashi, T., Baba, T., Ohishi, Y., Hernlund, J., Lattice thermal conductivity of $MgSiO_3$ perovskite and post-perovskite at the core-mantle

boundary, ***Earth and Planetary Science Letters***, 349/350, 109–115, http://dx.doi.org/10.1016/j.epsl.2012.06.043, 2012.

8. Kudo, Y., Hirose, K., Murakami, M., Asahara, Y., Ozawa, H., Ohishi, Y., Hirao, N., Sound velocity measurements of $CaSiO_3$ perovskite to 133 GPa and implications for lowermost mantle seismic anomalies, ***Earth and Planetary Science Letters***, 349/350, 1–7, http://dx.doi.org/10.1016/j.epsl.2012.06.040, 2012.

9. Sugimura, E., Komabayashi, T., Ohta, K., Hirose, K., Ohishi, Y., Dubrovinsky, L., Experimental evidence for superionic conduction in H_2O ice, ***Journal of Chemical Physics***, 137, 194505, org/10.1063/1.4766816, 2012.

10. Kato, J., Hirose, K., Ohishi, Y., High-pressure experiments on phase transition boundaries between corundum, Rh_2O_3(II) and $CaIrO_3$-type structures in Al_2O_3, ***American Mineralogist***, 98, 335–339, 10.2138/am.2013.4133, 2013.

11. Sinmyo, R., Hirose, K., Iron partitioning in pyrolitic lower mantle, ***Physics and Chemistry of Minerals***, 40, 107–113, DOI 10.1007/s00269-012-0551-7, 2013.

12. Noguchi, M., Komabayashi, T., Hirose, K., Ohishi, Y., High-temperature compression experiments of $CaSiO_3$ perovskite to lowermost mantle conditions and its thermal equation of state, ***Physics and Chemistry of Minerals***, 40, 81–91, DOI 10.1007/s00269-012-0549-1, 2013.

13. Hirose, K., High-Pressure, High-Temperature X-ray Diffraction Measurements and the Discovery of Post-Perovskite Phase Transition, ***Journal of the Physical Society of Japan***, 82, 021010, doi: 10.7566/JPSJ.82.021010, 2013.

14. Dai, L., Kudo, Y., Hirose, K., Murakami, M., Asahara, Y., Ozawa, H., Ohishi, Y., Hirao, N., Sound velocities of $Na_{0.4}Mg_{0.6}Al_{1.6}Si_{0.4}O_4$ NAL and CF phases to 73 GPa determined by Brillouin scattering method, ***Physics and Chemistry of Minerals***, 40, 195–201, DOI 10.1007/s00269-012-0558-0, 2013.

15. Hirose, K., Labrosse, S., Hernlund, J., Composition and state of the core, ***Annual Review of Earth and Planetary Sciences***, 41:657–691, DOI: 10.1146/annurev-earth-050212-124007, 2013.

16. Asahara, Y., Hirose, K., Ohishi, Y., Hirao, N., Ozawa, H., Murakami, M., Acoustic velocity measurement for stishovite across the post-stishovite phase transition under deviatoric stress: implication to the seismic feature of subducting slabs in the mid-mantle, ***American Mineralogist***, 98, 2053–2062, DOI: 10.2138/am.2013.4145, 2013.

17. Gomi, H., Ohta, K., Hirose, K., Labrosse, S., Hernlund, J., The high conductivity of iron and thermal evolution of Earth's core, ***Physics of the Earth and Planetary Interiors***, 224, 88–103, doi:10.1016/j.pepi.2013.07.010, 2013.

18. Ohta, K., Yagi, T., Hirose, K., Thermal diffusivities of $MgSiO_3$ and Al-bearing $MgSiO_3$ perovskites, ***American Mineralogist***, 99, 94–97, doi:10.2138/am.2014.4598, 2014.

19. Ozawa, H., Hirose, K., Suzuki, T., Ohishi, Y., Hirao, N., Decomposition of Fe_3S above 250 GPa, ***Geophysical Research Letters***, 40, 1–5, doi:10.1002/grl.50946, 2013.

20. Kato, C., Hirose, K., Komabayashi, T., Ozawa, H., Ohishi, Y., NAL phase in K-rich portion of the lower mantle, ***Geophysical Research Letters***, 40, 5085–5088, doi:10.1002/grl.50966, 2013.

21. Tatsumi, Y., Suzuki, T., Ozawa, H., Hirose, K., Hanyu, T., Ohishi, Y., Accumulation of 'anti-continent' at the base of the mantle and its recycling in mantle plumes, ***Geochimica Cosmochimica Acta***, 143, 23–33 DOI:10.1016/j.gca.2013.11.019, 2014.

22. Nomura, R., Hirose, K., Uesugi, K., Ohishi, Y., Tsuchiyama, A., Miyake, A., Low core-mantle boundary temperature inferred from the solidus of pyrolite, ***Science***, 343, 522–525, DOI: 10.1126/science.1248186, 2014.

23. Caracas, R., Ozawa, H., Hirose, K., Ishii, H., Hiraoka, N., Ohishi, Y., Hirao, N., Identifying the spin transition in Fe^{2+}–rich $MgSiO_3$ perovskite from X-ray diffraction and vibrational spectroscopy, ***American Mineralogist***, 99, 1270–1276, 2014.

24. Hirose, K., Deep Earth mineralogy revealed by ultrahigh-pressure experiments, ***Mineralogical Magazine***, 78, 437–446, 2014.

25. Tateno, S., Hirose, K., Ohishi, Y., Melting experiments on peridotite to lowermost mantle conditions, ***Journal of Geophysical Research***, Solid Earth, 119, 4684–4694, doi:10.1002/2013JB010616, 2014.

26. Imada, S., Ohta, K., Yagi, T., Hirose, K., Yoshida, H., Nagahara, H., Measurements of lattice thermal conductivity of MgO measured to core-mantle boundary pressures, ***Geophysical Research Letters***, 41, 4542–4547, doi:10.1002/2014GL060423, 2014.

27. Umemoto, K., Hirose, K., Imada, S., Nakajima, Y., Komabayashi, T., Tsutsui, S., Baron, A. Q. R., Liquid iron-sulfur alloys at outer core conditions by first-principles calculations, ***Geophysical Research Letters***, 41, doi:10.1002/2014GL061233, 2014.

28. Tateno, S., Kuwayama, Y., Hirose, K., Ohishi, Y., Crystal structure of Fe-Si alloy in the Earth's inner core, ***Earth and Planetary Science Letters***, 418, 11–19, 2015.

29. Labrosse, S., Hernlund, J., Hirose, K., Fractional melting and freezing in the deep mantle and implications for the formation of a basal magma ocean, in *"Early Earth: Accretion and Differentiation"*, ***AGU monograph***, 212, 111–130, 2015.

30. Gomi, H., Hirose, K., Electrical resistivity and thermal conductivity of hcp Fe-Ni alloys under high pressure: Implications for thermal convection in the Earth's core, ***Physics of the Earth and Planetary Interiors***, doi:10.1016/j.pepi.2015.04.003, 2015.

31. Minobe, S., Nakajima, Y., Hirose, K., Ohishi, Y., Stability and compressibility of a new iron-nitride β-Fe_7N_3 to core pressures, ***Geophysical Research Letters***, 42, doi:10.1002/2015GL064496, 2015.

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33. Umemoto, K., Sugimura, E., de Gironcoli, S., Nakajima, Y., Hirose, K., Ohishi, Y., Wentzcovitch, R. M., Nature of the volume isotope effect in ice, ***Physical Review Letters***, 115, 173005, 2015.

34. Umemoto, K., Hirose, K., Liquid iron-hydrogen alloys at outer core conditions by first-principles calculations, ***Geophysical Research Letters***, 42, 7513–7520, doi:10.1002/2015GL065899, 2015.

35. Nakajima, Y., Imada, S., Hirose, K., Komabayashi, T., Ozawa, H., Tateno, S., Tsutsui, S., Kuwayama, Y., Baron, A. Q. R., Carbon depleted outer core revealed by sound velocity measurements of liquid Fe-C alloy, ***Nature Communications***, 6:8942 doi: 10.1038/ncomms9942, 2015.

36. Hirose, K., Phase transition and melting in the deep lower mantle, ***AGU monograph*** "*Deep Earth: Physics and Chemistry of the Lower Mantle and Core*", p. 209–224, 2016.

37. Kato, C., Hirose, K., Nomura, R., Miyake, A., Ohishi, Y., Melting in the FeO-SiO_2 system to deep lower mantle pressures: implications for subducted Banded Iron Formations, ***Earth and Planetary Science Letters***, 440, 56–61, 2016.

38. Ohta, K., Kuwayama, Y., Hirose, K., Shimizu, K., Ohishi, Y., Experimental determination of the electrical resistivity of iron at Earth's core conditions, ***Nature***, 534, 95–98, doi:10.1038/nature17957, 2016.

39. Umemoto, K., Kawamura, K., Hirose, K., Wentzcovitch, R. M., Post–stishovite transition in hydrous aluminous SiO_2, ***Physics of the Earth and Planetary Interiors***, 255, 18–26, 2016.

40. Tagawa, S., Ohta, K., Hirose, K., Kato, C., Ohishi, Y., Compression of Fe–Si–H alloys to core pressures, ***Geophysical Research Letters***, 43, doi:10.1002/ 2016GL068848, 2016.

41. Gomi, H., Hirose, K., Akai, H., Fei, Y., Electrical resistivity of substitutionally disordered hcp Fe-Si and Fe-Ni alloys: chemically induced resistivity saturation in the Earth's core, ***Earth and Planetary Science Letters***, 451, 51–61, 2016.

42. Ozawa, H., Hirose, K., Yonemitsu, K., Ohishi, Y., High-pressure melting experiments on Fe–Si alloys and implications for silicon as a light element in the core, ***Earth and Planetary Science Letters***, 456, 47–54, 2016.

43. Hirose, K., Morard, G., Sinmyo, R., Umemoto, K., Hernlund, J., Helffrich, G., Labrosse, S., Crystallization of silicon dioxide and compositional evolution of the Earth's core, ***Nature***, 543, 99–102, doi:10.1038/nature21367, 2017.

44. Ballmer, M., Houser, C., Hernlund, J., Wentzcovitch, R., Hirose, K., Persistence of strong silica-enriched domains in the Earth's lower mantle, ***Nature Geoscience***, 10, 236–240, doi:10.1038/ngeo2898, 2017.

45. Mori, Y., Ozawa, H., Hirose, K., Sinmyo, R., Tateno, S., Morard, G., Ohishi, Y., Melting experiments on Fe–Fe_3S system to 254 GPa, ***Earth and Planetary Science Letters***, 464, 135–141, 2017.

46. Ohta, K., Yagi, T., Hirose, K., Ohishi, Y., Thermal conductivity of ferropericlase in the Earth's lower mantle, ***Earth and Planetary Science Letters***, 465, 29–37, 2017.

47. Kawaguchi, S., Nakajima, Y., Hirose, K., Komabayashi, T., Ozawa, H., Tateno, S., Kuwayama, Y., Tsutsui, S., Baron, A. Q. R., Sound velocity of liquid Fe–Ni–S at high pressure, ***Journal of Geophysical Research***, *Solid Earth*, 122, 3624–3634, doi:10.1002/2016JB013609, 2017.

48. Ishii, T., Sinmyo, R., Komabayashi, T., Ballaran, T., Kawazoe, T., Miyajima, N., Hirose, K., Katsura, T., Synthesis and crystal structure of $LiNbO_3$-type $Mg_3Al_2Si_3O_{12}$: A possible indicator of shock conditions of meteorites, ***American Mineralogist***, 102, 1947–1952, 2017.

49. Okuda, Y., Ohta, K., Yagi, T., Sinmyo, R., Wakamatsu, T., Hirose, K., Ohishi, Y., The effect of iron and aluminum incorporation on lattice thermal conductivity of bridgmanite at the Earth's lower mantle, ***Earth and Planetary Science Letters***, 474, 25–31, 2017.

50. Ballmer, M.D., Lourenço, D.L., Hirose, K., Caracas, R., Nomura, R., Reconciling magma-ocean crystallization models with the present-day structure of the Earth's mantle, ***Geochemistry, Geophysics, Geosystems***, 18, 2785–2806, doi:10.1002/ 2017GC006917.

51. Kidokoro, Y., Umemoto, K., Hirose, K., Ohishi, Y., Phase transition in SiC from zinc-blende to rock-salt structure and implications for carbon-rich extrasolar planets, ***American Mineralogist***, 102, 2230–2234, 2017.

52. Suehiro, S., Ohta, K., Hirose, K., Morard, G., Ohishi, Y., The influence of sulfur on the electrical resistivity of hcp iron: implications for the core conductivity of Mars and Earth, ***Geophysical Research Letters***, 44, 8254–8259, doi:10.1002/ 2017GL074021, 2017.

53. Hirose, K., Sinmyo, R., Hernlund, J., Perovskite in Earth's deep interior, ***Science***, 358, 734–738, 2017.

54. Wakamatsu, T., Ohta, K., Yagi, T., Hirose, K., Ohishi, Y., Measurements of sound velocity in iron–nickel alloys by femtosecond laser pulses in a diamond anvil cell, ***Physics and Chemistry of Minerals***, https://doi.org/10.1007/s00269-018-0944-3, 2018.

55. Helffrich, G., Ballmer, M., Hirose, K., Core-exsolved SiO_2 dispersal in the Earth's mantle, ***Journal of Geophysical Research Solid Earth***, 123, 176–188, https://doi.org/10.1002/2017JB014865, 2018.

56. Sakai, T., Yagi, T., Irifune, T., Kadobayashi, H., Hirao, N., Kunimoto, T., Ohfuji, H., Kawaguchi, S., Ohishi, Y., Tateno, S., Hirose, K., High pressure generation using double-stage diamond anvil

technique: problems and equations of state of rhenium, ***High Pressure Research***, DOI: 10.1080/08957959.2018.1448082, 2018.

57. Tateno, S., Hirose, K., Sinmyo, R., Morard, G., Hirao, N., Ohishi, Y., Melting of Fe–Si–S alloys to core pressures: silicon in the core?, ***American Mineralogist***, 103, 742–748, 2018.
58. Helffrich, G., Shahar, A., Hirose, K., Isotopic signature of core-derived SiO_2, ***American Mineralogist***, 103, 1161–1164, 2018.
59. Tateno, S., Hirose, K., Sakata, S., Yonemitsu, K., Ozawa, H., Hirata, T., Hirao, N., Ohishi, Y. Melting phase relations and element partitioning in MORB to lowermost mantle conditions, ***Journal of Geophysical Research, Solid Earth***, 123, https://doi.org/10.1029/2018JB015790, 2018.
60. Ozawa, K., Anzai, M., Hirose, K., Sinmyo, R., Tateno, S., Experimental determination of eutectic liquid compositions in the MgO–SiO_2 system to the lowermost mantle pressures, ***Geophysical Research Letters***, 45, https:// doi.org/10.1029/2018GL079313, 2018.
61. Ohta, K., Nishihara, Y., Satoh, Y., Hirose, K., Yagi, T., Kawaguchi, S. I., Hirao, N., Ohishi, Y., An experimental examination of thermal conductivity anisotropy in *hcp* iron, ***Frontiers in Earth Science***, 6, 176, doi:10.3389/feart.2018.00176, 2018.
62. Badro, J., Aubert, J., Hirose, K., Nomura, R., Blanchard, I., Borensztajn, S., Siebert, J., Magnesium partitioning between Earth's mantle and core and its potential to drive an early exsolution geodynamo, ***Geophysical Research Letters***, 45, https://doi.org/10.1029/2018GL080405, 2018.
63. Ohta, K., Suehiro, S., Hirose, K., Ohishi, Y., Electrical resistivity of fcc phase iron hydrides at high pressures and temperatures, ***Comptes Rendus Geoscience***, 351, 147–153, https://doi.org/10.1016/j.crte.2018.05.004, 2019.
64. Hasegawa, A., Ohta, K., Yagi, T., Hirose, K., Okuda, Y., Kondo, T., Composition and pressure dependence of lattice thermal conductivity of (Mg,Fe)O solid solutions, ***Comptes Rendus Geoscience***, 351, 229–235, https://doi.org/10.1016/j.crte.2018.10.005, 2019.
65. Tateno, S., Komabayashi, T., Hirose, K., Hirao, N., Ohishi, Y., Static compression of B2 KCl to 230 GPa and its *P-V-T* equation of state, ***American Mineralogist***, DOI: https://doi.org/10.2138/am-2019-6779, 2019.
66. Sinmyo, R., Hirose, K., Ohishi, Y., Melting of iron to 290 gigapascals determined in a resistance-heated diamond-anvil cell, ***Earth and Planetary Science Letters***, 510, 45–52, 2019.
67. Kusakabe, M., Hirose, K., Sinmyo, R., Kuwayama, Y., Ohishi, Y., Helffrich, G., Melting curve and equation of state of β-Fe_7N_3: Nitrogen in the core?, ***Journal of Geophysical Research, Solid Earth***, 124, https://doi.org/10.1029/2018JB015823, 2019.
68. Mashino, I., Miozzi, F., Hirose, K., Morard, G., Sinmyo, R., Melting experiments on the Fe–C binary system up to 255 GPa: Constraints on the carbon content in the Earth's core, ***Earth and Planetary Science Letters***, 515, 135-144, https://doi.org/10.1016/j.epsl.2019.03.020, 2019.

(2) Non-peer-reviewed Articles

(3) Review Papers

(4) Books

1. Hirose, K., Wentzcovitch, R., Yuen, D., Lay, T., Mineralogy of the deep mantle – the post-perovskite phase and its geophysical significance, In: Gerald Schubert (editor- in-chief) ***Treatise on Geophysics***, 2nd edition, Vol 2. Oxford: Elsevier; p. 85-115, 2015.

(5) Other Publications

(6) Patents

8. Keynote, Invited, or Solicited Presentations

1. Hirose, K., Exsolution of SiO_2 crystals and silicate melt from the liquid core: Implications for the origins of mid-lower mantle scatters and the ultra-low velocity zone above the CMB, AGU Fall Meeting, Washington, D.C., 2018.
2. Hirose, K., Core composition?-Constraints from melting phase relations in binary and ternary iron alloy systems (keynote), The 16th Symposium of SEDI, Edmonton, Canada, 2018.
3. Hirose, K., Chemical Evolution and the Present-Day Composition of the Liquid Outer Core, Gordon Research Conference 2017, South Hadley, USA, 2017.
4. Hirose, K. et al., Hydrogen in the core?, AGU 2016 Fall meeting, San Francisco, 2016.
5. Hirose, K., Morard,G., Sinmyo, R., Hernlund, J., Crystallization of SiO_2 in the core and the mechanism of early dynamo, CIDER 2016 Community Workshop, California, USA, 2016.
6. Hirose, K., Earth, Planetary and Mineral Science, Gordon Research Conference 2016, Holderness, USA, 2016.
7. Hirose, K., Crystallization of SiO2 in Earth's core after high-temperature core formation, The Earth's Mantle and Core: Structure, Composition, Evolution, Matsuyama, Japan, 2015.
8. Hirose, K., Overview of the dynamo evolution problem and the heat paradox, Geophysical & Geochemical Constraints on Early Planetary Dynamos, Kawaguchiko, Japan, 2015.
9. Hirose, K., Crystallization in Earth's core after high-temperature core formation, AGU Fall meeting 2015, San Francisco, 2015.
10. Hirose, K., Melting experiments in a diamond-anvil cell combined with ex-situ textual and chemical characterizations by FIB/SEM/TEM, New Frontier in Studying Chemistry under Extreme Conditions, Shanghai, China, 2015.
11. Hirose, K., Iron-rich eutectic liquid composition in Fe-Si system at core pressures: Ex-situ textural and chemical characterization of DAC samples, AGU Fall meeting 2014, San Francisco, 2014.
12. Hirose, K., The discovery of post-perovskite and its unique physical property, ppv@10: a meeting for the 10th anniversary of the discovery of post-perovskite, Bristol, UK, 2014.
13. Hirose, K., Measurements of core properties at high pressure., Workshop on the Elastic Properties of Iron in Extreme Conditions, Takarazuka, Japan, 2013.
14. Hirose, K., Measurements of transport properties in DAC, 2013 Workshop on Transport Properties in the Earth's Core, Kawaguchiko, Japan, 2013.
15. Hirose, K., Crystal structure in Earth's inner core, Goldschmidt 2013, Florence, Italy, 2013.
16. Hirose, K., Spin crossover and iron-rich dense partial melt in pyrolitic lower mantle, AGU Fall meeting 2012, San Francisco, 2012.

III. Education Activity

9. Notable Achievements in Education

Advisees

- Master theses: 1 student
  Mayu Kusakabe (Mar. 2019)

Lectures

- Undergraduate/Graduate, Solid Earth science, FY2017-2018
- Undergraduate/Graduate, Deep Earth and planetary materials, FY2017-2018
- Undergraduate, Evolving Earth systems, FY2017-2018
- Undergraduate, Geophysics laboratory training, FY2018

Student's awards

- American Geophysical Union, Outstanding Student Presentation Award 2018 [Shoh Tagawa]

IV. External Activities

10. Contribution to Academic Community

- *Science*, Member of the Board of Reviewing Editors, 2009-2015
- *Physics of the Earth and Planetary Interiors*, Editor, 2010-
- European Association of Geochemistry/Geochemical Society, Geochemical Fellow Committee, 2012-2013

11. Outreach Activity

- JSPS KAKENHI Review, FY2018
- Press Release: 2 times (Jan. 2014, Feb. 2017)
- Lectures for general audience: 15 times in FY2012-2018

V. International Exchange Activities

13. Hosting/Sending Foreign Students and Researchers

(1) Hosting

Foreign Students: 0

Foreign Researchers: 0

(2) Sending

Students: 1

(3) Visitors from Abroad: 4

Ryosuke Ando

I. CV

Name: Ryosuke Ando

Age: 43

Present Position: Associate Professor

Education

Yamada High School, Aichi, March, 1994 (graduation)

B. Sc. Department of Mathematics and Physics, Ritsumeikan University, March, 2000

M. Sc. Department of Earth and Planetary Science, The University of Tokyo, March, 2002

Ph. D. Department of Earth and Planetary Science, The University of Tokyo, March, 2005

Professional Experience

Apr. 2005-March. 2006, Postdoctoral Fellow, Japan Society for Promotion of Science

Aug. 2005-Dec. 2005, Visiting Scholar, California University, Santa Barbara

Dec. 2005-Mar. 2006, Visiting Scholar, Columbia University

Apr. 2006-Mar. 2007, Researcher, National Institute for Disaster Prevention and Earth Science

Apr. 2007-Feb. 2013, Tenure-track Researcher, National Institute of Advanced Industrial Science and Technology

Mar. 2013-Apr. 2013, Principal Researcher, National Institute of Advanced Industrial Science and Technology

Apr. 2013-Mar. 2014, Principal Planning Officer, National Institute of Advanced Industrial Science and Technology

Mar. 2014-Aug. 2014, Principal Researcher, National Institute of Advanced Industrial Science and Technology

Aug. 2014-present, Associate Professor, Department of Earth and Planetary Science, The University of Tokyo

II. Scientific Research Activity

2. Major Achievements

I have been studying the generation process of earthquakes and tectonic deformation by integrating physics modeling and observations including those of geology and geomorphology. To analyze dynamic rupture processes, I have developed a new efficient algorism based on the boundary integral method and implemented on high-performance computer such as the K computer. By applying this method, the rupture processes of the recent worldwide large earthquakes, including the Kumamoto earthquake and the Kaikoura (New Zealand) earthquakes, were simulated and the models were validated systematically under international and domestic collaborations. The physics-based model is also developed and the importance of the heterogeneous structures are pointed out for the first time in the world. I have showen that the rheological characteristics of fault zones are inferred from the migration patterns of slow earthquakes. This finding leads to the study of fault zone materials. I also explored the triggering mechanisms of earthquakes including the foreshock activity of the 2011

Tohoku-oki earthquake. The proposed model for the slow earthquakes are now considered as one of the standard models. On the other hand, the numerical data analysis method and physics-based model are introduced to the geological and geomorphological study of paleo-seismicity, and histories of previous large earthquakes are reconstructed to improve the long term focus method of large earthquakes.

3. Five Important Papers (including three or more papers in this review period)

1. Ando, R. and Y. Kaneko, Dynamic rupture simulation reproduces spontaneous multi-fault rupture and arrest during the 2016 Mw 7.9 Kaikoura earthquake, Geophys. Res. Lett., 10.1029/2018GL080550, 2018.

This is a report of the numerical simulation to reproduce the dynamic rupture process of the Kaikoura (New Zealand) earthquake, which is one of the most complicated fault processes ever observed. The initial condition of the physics model is constrained with the preseismic observations including the regional stress field, and we show that the overall characteristics of the observed rupture process were successfully reproduced without fine parameter tunings. The fault geometry and the regional stress are observable parameters to some extent, this result will lead to improving the predictability of the earthquake sizes.（引用回数 4 回(GS/Sep. 16, 2019)）

2. Komori, J., M., Shishikura, R. Ando, Y. Yokoyama and Y. Miyairi，History of the great Kanto earthquakes inferred from the ages of Holocene marine terraces revealed by a comprehensive drilling survey, Earth and Planetary Science Letters, 47,174-84, 2017.

This study clarified a few thousand years of the history of the Sagami trough subduction zone earthquakes, including the disastrous Kanto earthquake. While the previous limited geological data indicated the mean recurrence intervals of two thousand years, this study shows the minimum interval becomes five hundred years with large fluctuation based on the comprehensive drilling surveys and dating targeting marine terraces there. This study consists of an undergraduate project and a master's thesis, and it is covered by a variety of mass media.（引用回数 5 回(GS/Sep. 16, 2019)）

3. Ando, R., Fast Domain Partitioning Method for dynamic boundary integral equations applicable to non-planar faults dipping in 3-D elastic half-space, Journal of Geophysical International, 207, 833-847, doi: 10.1093/gji/ggw299, 2016.

I have developed a new efficient and highly accurate numerical method based on the boundary integral equation method (BIEM), capable of the dynamic rupture simulation considering the realistic and complicated fault geometry. The original BIEM presents the numerical cost of $O(N^3)$, and this method reduced it to $O(N^2)$ for the time step N by considering the mathematical nature of Green's function. This algorithm was implemented to high-performance computing environments and hereafter the systematic modeling of the actual earthquakes has been made possible.（引用回数 6 回(GS/Sep. 16, 2019)）

4. Ando, R., K. Imanishi, Possibility of Mw 9.0 mainshock triggered by diffusional propagation of after-slip from Mw 7.3 foreshock, Earth, Planets, Space, doi.org/10.5047/eps.2011.05.016 , 2011.

This is a report of clarifying the fact that the M7 earthquake triggered the 2011 M9 Tohoku-oki earthquake two days later, by analyzing the observed seismicity. The found seismicity exhibited the migrating aftershocks of the M7 earthquake approached toward the hypocenter of the M9 earthquake. This observation can be evidence indicating that the afterslip of the M7 earthquake perturbed the stress field and triggered the mainshock. This study triggered the various intensive studies of the foreshocks and seismicity migration afterward.（引用回数 62 回(GS/Sep. 16, 2019)）

5. Ando, R., R. Nakata and T. Hori, A slip pulse model with fault heterogeneity for low-frequency earthquakes and tremor along plate interfaces, Geophys. Res. Lett., doi.org/10.1029/2010GL043056, 2010.

This is the first paper clearly demonstrated the importance of the brittle-ductile heterogeneity on faults to explain the generation mechanism of slow earthquakes based on the physics modeling and observational evidence. This paper presents the physical mechanism that is very different from the previous interpretation of slow earthquakes, invoking the finely-tuned energy balance realized by the homogeneous rheological characteristics on the faults. This study further influenced the geological studies and the fault zone materials were intensively analyzed, showing the heterogeneous nature of the fault zone rheology has been excavated ubiquitously in exhumed rock samples.（引用回数 76 回 (GS/Sep. 16, 2019)）

4. Awards and Honors

5. Future Research Plan

I will continue studies on earthquake generation and underlying tectonics in various spatiotemporal scales by integrating the earthquake science and tectonophysics. I will particularly focus on the integration of the physics models with geological and geomorphological observations together with geophysical observations, and the continuously make effort to test and develop the physics models by targeting the actual earthquake events and fault activities world-wide under international collaborations. To this end, I will first closely collaborate with computer scientists to enhance our capability to treat realistic models and to develop efficient algorithms in the high-performance computing environment. Secondly, the quantitative analysis method including machine learnings will be developed to extract the amounts of tectonic deformations from field data by closely collaborating with geomorphologists and geologists. To improve the physics models, it is important not only to reduce the modeling errors by considering observational data as far as possible but also to understand the physical characteristics that are not direct observables including scale dependences. I will develop multi-scale and multi-physics models to understand the relationship between the processes of microscopic laboratory or outcrop scales and the processes of macroscopic scales such as natural earthquakes.

6. Funding Received

- JSPS KAKENHI, 25800253, Principal Investigator, FY2013-2017, yen 2,800,000
- MEXT KAKENHI, 26109007, Co-Investigator, FY2014-2018, yen 5,000,000
- JSPS KAKENHI, 16H02219, Co-Investigator, FY2016-2020, yen 3,000,000 (planned)
- Joint Usage/Research Center for Interdisciplinary Large-scale Information Infrastructures and High Performance Computing Infrastructure in Japan, jh170017-NAH, Principal Investigator, FY2017-2019, 180,000 Machine time
- JSPS KAKENHI, 18K03810, Co-Investigator, FY2018-2020, yen 2,000,000 (planned)
- JSPS KAKENHI, 18KK0095, Principal Investigator, FY2018-2020, yen6,100,000 (planned)
- MEXT KAKENHI, 19H04622, Principal Investigator, FY2019-2020, yen 1,800,000 (planned)
- JSPS KAKENHI, 19K04031, Principal Investigator, FY2019-2024, yen 3,300,000 (planned)

7. Publications and Patents

(1) Peer-reviewed Journal Articles

1. Ando, R. and Y. Kaneko, Dynamic rupture simulation reproduces spontaneous multi-fault rupture and arrest during the 2016 Mw 7.9 Kaikoura earthquake, Geophys. Res. Lett., 10.1029/2018GL080550, 2018.

2. Kano, M., A. Kato, R. Ando and K. Obara, Strength of tremor patches along deep transition zone of a megathrust, Scientific Reports, 8, Article number: 3655, doi:10.1038/s41598-018- 22048-8, 2018.
3. Ando, R., K. Imanishi, Y. Panayotopoulos, T. Kobayashi, Dynamic rupture propagation on geometrically complex fault with along-strike variation of fault maturity: insights from the 2014 Northern Nagano earthquake, Earth Planets Space, Springer, 69: 130., https://doi.org/10.1186/s40623-017-0715-2, 2017.
4. Ando, R., On Applications of Fast Domain Partitioning Method to Earthquake Simulations with Spatio-temporal Boundary Integral Equation Method, .Mathematical Analysis of Contimuum Mechanics and Industrial Applications II - Proceedings of the International Conference CoMFoS16, Springer,30, 87-99, https://doi.org/10.1007/978-981-10-6283-4_8, 2017.
5. Komori, J., M., Shishikura, R. Ando, Y. Yokoyama and Y. Miyairi, History of the great Kanto earthquakes inferred from the ages of Holocene marine terraces revealed by a comprehensive drilling survey, Earth and Planetary Science Letters, 47,174-84, 2017.
6. Ando, R., Fast Domain Partitioning Method for dynamic boundary integral equations applicable to non-planar faults dipping in 3-D elastic half-space, Journal of Geophysical International, 207, 833-847, doi: 10.1093/gji/ggw299, 2016.
7. Uchide, T., H. Horikawa, M. Nakai, R. Matsushita, N. Shigematsu, R. Ando, K. Imanishi, The 2016 Kumamoto-Oita earthquake sequence: Aftershock seismicity gap and dynamic triggering in volcanic areas, Earth Planets Space, in press, 2016.
8. Otsubo M., N. Shigematsu, K. Imanishi, R. Ando, M. Takahashi, T. Azuma,
9. Temporal slip change based on curved slickenlines on fault scarps along Itozawa fault caused by 2011 Iwaki earthquake, northeast Japan
10. Tectonophys., 608, 970-979, 2013.
11. Kuwano, O., R. Ando and T. Hatano, Crossover from negative to positive shear rate dependence in granular friction, Geophys. Res. Lett., 40, 1295-1299, 2013.
12. Ando, R., N. Takeda and T. Yamashita, Propagation Dynamics of Seismic and Aseismic Slip Governed by Fault Heterogeneity and Newtonian Rheology, J. Geophys. Res., 117, B11308, 2012

(2) Non-peer-reviewed Articles

(3) Review Papers

1. Ide, S. (2014). Modeling fast and slow earthquakes at various scales. Proceedings of the Japan Academy, Series B, 90(8), 259-277. https://doi.org/10.2183/pjab.90.259

(4) Books

(5) Other Publications

1. J. E. Vidale, H. Houston, Trans. R. Ando, A new kind of earthquake, slow slip, Parity, Maruzen publishing, 2013

(6) Patents

8. Keynote, Invited, or Solicited Presentations

1. Ando, R., T. Uchide and Y. Ohta, Foreshock, After-slip: 2011 Tohoku-oki case, AGU Chapman conference, Am. Geoph. Union, Ixtapa (Mexico), 2/22, 2016.

2. Ando, R., Application of dynamic earthquake rupture simulation to the 2016 Kumamoto earthquake, International Conference of Continuous Mechanics Focusing on Singularity, Jpn. Soc. Indst. App. Math., Fukuoka, 10/23, 2016.

III. Education Activity

9. Notable Achievements in Education

Advisees

・ Master theses: 2 students

Junki Komori (Mar. 2017)

Kyohei Suzuki (Mar. 2018)

・ Doctral theses: 1 students

Daisuke Sato (Mar. 2018)

Lectures

・ Undergraduate/Graduate, Elasto mechanics, FY2015-2018
・ Undergraduate/Graduate, Plate tectonics, FY2015-2016
・ Undergraduate/Graduate, Solid geoscience, FY2016-2018
・ Undergraduate, Introduction to earth and planetary physics, FY2015
・ Undergraduate, First year seminar, FY2017-2018

IV. External Activities

10. Contribution to Academic Community

・ Seismological Society of Japan, Representative, FY2012-2018
・ Seismological Society of Japan, Meeting planning Committee, FY2015-2016
・ Earth, Planets and Space, Associate Editor, 2017-2018

11. Outreach Activity

・ KAKENHI Review, FY2016-2017
・ Press Release: (Mar. 2017)
・ Lectures for general audience: 2 times (Aug. 2016, Feb. 2017)

12. Internal Committee Membership

・ Department of Earth and Planetary Science, Education Committee, FY2015-2016
・ Department of Earth and Planetary Physics, Education Committee, FY2017-2018
・ Department of Earth and Planetary Physics, Library Committee, FY2017-2018
・ School of Science, Gender equality Committee, FY2017-2018

V. International Exchange Activities

13. Hosting/Sending Foreign Students and Researchers

(1) Hosting

Foreign Students: 2, Foreign researcher: 1

(2) Sending

Students: 1

(3) Visitors from Abroad: 5

Tsuyoshi Iizuka

I. CV

Name: Tsuyoshi Iizuka

Age: 40

Present Position: Associate Professor

Education

Musashi High School, Tokyo, March, 1997 (graduation)

B. Sc. Department of Earth and Planetary Sciences, Tokyo Institute of Technology, March, 2001

M. Sc. Department of Earth and Planetary Sciences, Tokyo Institute of Technology, March, 2003

Ph. D. Department of Earth and Planetary Sciences, Tokyo Institute of Technology, March, 2006

Professional Experience

4/2017-present: Current position

4/2011-3/2017: Lecturer at the Department of Earth & Planetary Science of the University of Tokyo

2/2010-3/2011: Postdoctoral Fellow at the Research School of Earth Sciences (RSES) of the Australian National University (ANU), funded by Australian Research Council Postdoctoral Fellowship

4/2009-1/2010: Postdoctoral Fellow at RSES of ANU, funded by Japan Society of the Promotion of Science (JSPS)

8/2007-3/2009: Visiting Fellow at RSES of ANU

4/2006-3/2009: Postdoctoral Fellow at the Earthquake Research Institute of the University of Tokyo, funded by JSPS Research Fellowship (SPD)

II. Scientific Research Activity

2. Major Achievements

I have been studying on the evolution of terrestrial planets over the solar system history by trace element and isotope geochemistry of rock and mineral samples. To determine the timing of planetesimal and planetary formation and major magmatic events in the Earth's history, I have developed radiometric dating methods and applied them to various terrestrial and extraterrestrial samples. One of major outcomes is the determination of the timing of the earliest silicate differentiation and, by implication, of the magma ocean solidification on the Earth using Hf isotopes in meteorite zircon. In addition, I was responsible for the installation of laser ablation inductively coupled plasma mass spectrometry in 2003 and have been operated the instrument since then, which has contributed the advancement of isotope geochemistry in our department. Through collaborative research using the instrument, I have extended the application of isotope geochemistry to biological and fossil samples.

3. Five Important Papers (including three or more papers in this review period)

1. Iizuka, T., Yamaguchi, T., Itano, K., Hibiya, Y., & Suzuki, K. (2017). What Hf isotopes in zircon tell us about crust–mantle evolution. Lithos, 274-275, 304-327. http://dx.doi.org/10.1016/j.lithos.2017.01.006

This is an invited review article which discuss crust–mantle evolution inferred from Hf isotopes in zircon. Emphasis is placed on emphasis on the Lu–Hf isotope composition of the bulk silicate Earth (BSE), early differentiation of the silicate Earth, and the evolution of the continental crust over geologic history. (Citation 27, GS/ Sep. 16, 2019)

2. Iizuka, T., Lai, Y.-J., Akram, W., Amelin, Y., & Schönbächler, M. (2016). The initial abundance and distribution of ^{92}Nb in the Solar System. Earth and Planetary Science Letters, 439, 172-181. https://dx.doi.org/10.1016/j.epsl.2016.02.005

Niobium-92 is an extinct proton-rich nuclide, which decays to ^{92}Zr with a half-life of 36 Ma. This study presents internal Nb–Zr isochrons for three basaltic achondrites with known U-Pb ages. The results allow us to establish the initial abundance and distribution of ^{92}Nb in the Solar System. On the basis of our newly established initial solar ^{92}Nb abundance, the potential of the Nb–Zr decay system for early Solar System chronology and the origin of *p*-nuclei are discussed. (Citation 8, GS/ Sep. 16, 2019)

3. Iizuka, T., Yamaguchi, T., Hibiya, Y., & Amelin, Y. (2015). Meteorite zircon constraints on the bulk Lu–Hf isotope composition and early differentiation of the Earth. Proceedings of National Academy of Sciences of the United States of America, 112(17), 5331-5336. https://www.pnas.org/cgi/doi/10.1073/pnas.1501658112

The ^{176}Lu-^{176}Hf radioactive decay system has been used to trace Earth's crust-mantle differentiation. Yet the data interpretation requires a well-defined Hf isotope composition of the bulk silicate Earth, which is difficult to estimate from bulk composition of variably metamorphosed chondrites. This study solves the bulk silicate Earth composition conundrum through the first Lu-Hf analysis of meteorite zircon. The results directly define the initial ^{176}Hf abundance of the Solar System and further reveal pristine chondrites that accurately represent the bulk silicate Earth composition. The results further provide evidence for differentiation of the silicate Earth by 4.5 billion years ago. (Citation 40 GS/ Sep. 16, 2019)

4. Iizuka, T., Horie, K., Komiya, T., Maruyama, S., Hirata, T., Hidaka, H., & Windley, B.F. (2006). 4.2 Ga zircon xenocryst in an Acasta gneiss from northwestern Canada: Evidence for early continental crust. Geology, 34(4), 245-248. https://doi.org/10.1130/G22124.1

A major issue in the study of early Earth's evolution is whether significant continental crust existed in the first few hundred million years of Earth's history (Hadean). So far, direct evidence for the presence of continental crust older than 4.1 Ga has been obtained only from zircons in the Narryer Gneiss Complex of Western Australia. In this study, it was shown that a 3.9 Ga tonalitic Acasta gneiss from northwestern Canada, one of the oldest known rocks, contains a 4.2 Ga zircon xenocry. The finding suggests that significant continental crust was formed in the late Hadean, and was reworked into early Archean continental crust. (Citation 163, GS/ Sep. 16, 2019)

5. Iizuka, T., & Hirata, T. (2005). Improvements of precision and accuracy in in situ Hf isotope microanalysis of zircon using the laser ablation-MC-ICPMS technique. Chemical Geology, 220, 121-137. https://doi.org/10/1016/j.chemgeol.2005.03.010

This study present a new analytical technique for precise and accurate *in-situ* Hf isotope ratio measurements for zircons by means of laser ablation-multiple collector-inductively coupled plasma mass spectrometry (LA-MC-ICPMS). The developed technique has been widely used in zircon Hf isotopic study. This paper is one of the most cited Chemical Geology papers published between 2005–2010. (Citation 374, GS/Sep. 16, 2019)

4. Awards and Honors

- *Island Arc* Paper Award 2016 for Yamamoto et al. (2013)

5. Future Research Plan

I will continue studies on the evolution and formation of terrestrial planets using cosmochemistry and geochemistry. Emphasis will be placed on magmatism that has occurred at various places, magnitudes and timescales over the solar system history. Research subjects in the next five years include on-going volcanic activity, formation and differentiation of the Earth's continental crust, and magma ocean formation and solidification on planets. Currently, there is considerable debate as to when and how the Earth's and lunar magma oceans had solidified. To address this issue, I will analyze lunar and ancient terrestrial samples for high-precision chronology, trace element abundances, and isotope compositions. In addition, I will improve the precision and accuracy of the analytical methods. Besides, I will evaluate the validity of a long-standing paradigm in geochemistry—the Earth and chondritic meteorites have identical relative abundances of refractory elements—by combining Earth and neutrino sciences. These studies will be conducted under collaboration with various institutions such as JAMSTEC, Research Centre of Neutrino Science at the Tohoku University, Curtin University, and Washington University.

6. Funding Received

- **JSPS Grant-in-Aid for Scientific Research-B** (#18H01301)

  Period: FY2018–2020
  Title: Deciphering the evolution of continental crust using monazite
  Budget: 17,290,000 JPY (Primary Investigator)

- **JSPS Grant-in-Aid for Challenging Exploratory Research** (#16K13910)

  Period: FY2016–2017
  Title: U–Pb dating of ultramafic rocks
  Budget: 2,545,000 JPY (Primary Investigator)

- **JSPS Grant-in-Aid for Young Scientists-A** (#25707042)

  Period: FY2013–2016
  Title: Deciphering water contents in planetesimals
  Budget: 25,610,000 JPY (Primary Investigator)

- **JSPS Grant-in-Aid for Challenging Exploratory Research** (#25610149)

  Period: FY2013–2014
  Title: Development of a new method to decipher water contents in ancient magmas using apatite
  Budget: 2,630,000 JPY (Primary Investigator)

- **JSPS Grant-in-Aid for Research Activity Start-up** (#23840013)

  Period: FY2011–2012
  Title: Deciphering the solar system chronology & planetary chemistry using meteorite zircon
  Budget: 3,250,000 JPY (Primary Investigator)

- **JSPS Grant-in-Aid for Scientific Research-B** (#17H02982; PI–Kazuhito Ozawa)

  Period: FY2017–2019
  Title: Development of high-precision geobarometry for spinel lherzolite xenoliths: Applications to resolving mechanism of the lithosphere thinning
  Budget: 2,100,000 JPY (Cooperative Investigator)

- **JSPS Grant-in-Aid for Scientific Research on Innovative Areas—Research in a Proposed Research Area** (#15H05833; PI–Hiroyuki Tanaka)

  Period: FY2015–2019
  Title: Chemical compositions of the core & mantle constrained from geoneutrino observation
  Budget: 8,600,000 JPY (Cooperative Investigator)

- **JSPS Grant-in-Aid for Scientific Research-S** (#26220713; PI–Tsuyoshi Komiya)

  Period: FY2014–2018
  Title: Decoding of the early Earth's evolution
  Budget: 5,000,000 JPY (Cooperative Investigator)

- **JSPS Grant-in-Aid for Scientific Research-A** (#15H02149; PI–Yoshio Takahashi)

  Period: FY2015–2017
  Title: Speciation of trace elements for the prediction of isotope fractionation
  Budget: 1,600,000 JPY (Cooperative Investigator)

7. Publications and Patents

(1) Peer-reviewed Journal Articles

1. Naemura K., Hirajima T., Svojtka M., Shimizu I. & **Iizuka T.** (2018) Fossilized melts in mantle wedge peridotites. ***Scientific Reports*** 8, 10116
2. Itano K., **Iizuka T.** & Hoshino M. (2018) REE-Th-U and Nd isotope systematics of monazites from magnetite- and ilmenite-series granitic rocks of the Japan arc: Implications for its use as a tracer of magma evolution and detrital provenance. ***Chemical Geology*** 484, 69–80.
3. **Iizuka T.,** Yamaguchi T., Itano K., Hibiya Y. & Suzuki K. (2017) What Hf isotopes in zircon tell us about crust–mantle evolution. ***Lithos*** 274–275, 304–327.
4. Itano K. & **Iizuka T.** (2017) Unraveling the mechanism and impact of oxide production in LA-ICP-MS by comprehensive analysis of REE-Th-U phosphates. ***Journal of Analytical Atomic Spectrometry*** 32, 2003–2010.
5. Liu F.L., Liu C.H., Itano K., Iizuka T., Cai J. and Wang F. (2017) Geochemistry, U-Pb dating, and Lu-Hf isotopes of zircon and monazite of porphyritic granites within the Jiao-Liao-Ji orogenic belt: Implications for petrogenesis and tectonic setting. ***Precambrian Research*** 300, 78–106.
6. Genda H., **Iizuka T.,** Sasaki T., Ueno Y. & Ikoma M. (2017) Ejection of iron-bearing giant-impact fragments and the dynamical and geochemical influence of the fragment re-accretion. ***Earth and Planetary Science Letters*** 470, 87–95.
7. Kashiwabara T., Kubo S., Tanaka M., Senda R., **Iizuka T.,** Tanimizu M. & Takahashi Y. (2017) Stable isotope fractionation of tungsten during adsorption on Fe and Mn (oxyhydr)oixides. ***Geochimica et Cosmochimica Acta*** 204, 52–67.
8. **Iizuka T.,** Lai Y.-J., Akram W., Amelin Y. & Schönbächler M. (2016) The initial abundance and distribution of ^{92}Nb in the Solar System. ***Earth and Planetary Science Letters*** 439, 172–181.
9. Kurisu M., Takahashi Y., **Iizuka T.** & Uematsu M. (2016) Very low isotope ratio of iron in anthropogenic aerosols related to its contribution to the surface ocean. ***Journal of Geophysical Research*** 121, 11119–11136.
10. Itano K., **Iizuka T.,** Qing C., Kimura J.-I. & Maruyama S. (2016) U–Pb chronology and geochemistry of detrital monazites from major African rivers: Constraints on the timing and nature of the Pan-African Orogeny. ***Precambrian Research*** 282, 139–156.
11. Kurisu M., Sakata K., Takaku Y., **Iizuka T.** & Takahashi Y. (2016) Variation of iron isotopes in

airborne materials emitted through combustion processes. ***Chemistry Letters*** 45, 970–972.

12. Koefoed P., Amelin Y., Yin Q.-Z., Wimpenny J., Sanborn M., **Iizuka T.** & Irving A.J. (2016) U–Pb and Al–Mg systematics of the ungrouped achondrite Northwest Africa 7325. ***Geochimica et Cosmochimica Acta*** 183, 31–45.
13. **Iizuka T.,** Yamaguchi T., Hibiya Y. & Amelin Y. (2015) Meteorite zircon constraints on the bulk Lu-Hf isotope composition and early differentiation of the Earth. ***Proceedings of the National Academy of Sciences*** 112, 5331–5336.
14. **Iizuka T.,** Yamaguchi A., Haba M.K., Amelin Y., Holden P., Zink S., Huyskens M.H. & Ireland T.R. (2015) Timing of global crustal metamorphism on Vesta as revealed by high-precision U-Pb dating and trace element chemistry of eucrite zircon. ***Earth and Planetary Science Letters*** 409, 182–192.
15. Cheong C.-S., Kim N., Yi K., Jo H.J., Jeong Y.-J., Kim Y., Koh S.M. & **Iizuka T.** (2015) Recurrent rare earth element mineralization in the northwestern Okcheon Metamorphic Belt, Korea: SHRIMP U-Th-Pb geochronology, Nd isotope geochemistry, and tectonic implications. ***Ore Geology Reviews*** 71, 99–115.
16. Kimura J.-I., Qing C., †Itano K., **Iizuka T.,** Vaglarov B.S. & Tani K. (2015) An improved U-Pb age dating method for zircon and monazite using 200/266 nm femtosecond laser ablation and enhanced sensitivity multiple-Faraday collector inductively coupled-plasma mass spectrometry. ***Journal of Analytical Atomic Spectrometry*** 30, 494–505.
17. **Iizuka T.,** Amelin Y., Kaltenbach A. Kofoed P. & Stirling C.H. (2014) U-Pb systematics of the unique achondrite Ibitira: Precise age determination and petrogenetic implications. ***Geochimica et Cosmochimica Acta*** 132, 259–273.
18. Rumble D., Bowring S., **Iizuka T.,** Komiya T., Lepland A., Rosing M.T. & Ueno Y. (2013) The oxygen isotope composition of Earth's oldest rocks and evidence of a terrestrial magma ocean. ***Geochemistry, Geophysics, Geosystems*** 14, 1929–1939.
19. **Iizuka T.,** Campbell I.H., Allen C.M., Gill J.B., Maruyama S. & Makoka F. (2013) Evolution of the African continental crust as recorded by U-Pb, Lu-Hf and O isotopes in detrital zircons from modern rivers. ***Geochimica et Cosmochimica Acta*** 107, 96–120.
20. Yamamoto S., Komiya T., Yamamoto H., Kaneko Y., Terabayashi M., Katayama I., **Iizuka T.,** Maruyama S., Yang J., Kon Y. & Hirata T. (2013) Recycled crustal zircons from podiform chromitites in the Luobusa ophiolite, southern Tibet. ***Island Arc*** 22, 89–103.
21. Huyskens M., **Iizuka T.** & Amelin Y. (2012) Evaluation of colloidal silicagels for lead isotopic measurements using thermal ionisation mass spectrometry. ***Journal of Analytical Atomic Spectrometry*** 27, 1439–1446.

(2) Non-peer-reviewed Articles

(3) Review Papers

1. **Iizuka T.** (2016) Formation of oceans and continents on the Earth. ***Chikyu kagaku (Geochemistry)*** 50, 121–133 (in Japanese with English abstract).
2. **Iizuka T.** (2014) Deciphering early crustal evolution using hafnium and tungsten isotopes. ***Chikyu kagaku (Geochemistry)*** 48, 13–30 (in Japanese with English abstract).

(4) Books

(5) Other Publications

1. Takeuchi N., Ueki K., Iizuka T. & Enomoto S. (2018) Improvement of geoneutrino observation

by statistical modeling of three-dimensional chemical composition distribution in the crust. ***Chikyu Monthly*** 40, 332–338 (in Japanese).

2. Harada C., Iizuka T., Hamada M., Yasuda A. & Yoshimoto M. (2018) Chemical evolution of magma at Fuji volcano revealed from trace element and isotope geochemistry. ***Chikyu Monthly*** 40, 234–241 (in Japanese).
3. Hirata T., Sakata S., Iwano H., Orihashi Y., Okabayashi S., Yokoyama T., Maki K., Kon Y., Hattori K., Komiya T., Iizuka T., Danhara T., Maruyama S. (2013) New generation laser ablation-ICP-mass spectrum (LA-ICPMS) for further precise and accurate U-Pb chronology. ***Gogai Chikyu*** 62, 100–110 (in Japanese).

(6) Patents

8. Keynote, Invited, or Solicited Presentations

1. Iizuka, T., Evolution of the continental crust as recorded in accessory minerals. 7th Asia-Pacific Workshop on Laser Ablation & Microanalysis, October 18, 2018
2. Iizuka, T., Evolution of the continental crust as recorded by detrital zircon. 5th International Conference on Analytical Science & Technology, October 23, 2017
3. Iizuka, T., Radiogenic Isotope Systematics Developed by LA-ICP-MS. Lecture at Japanese Discussion Group for Plasma Mass Spectrochemistry, July 6, 2017
4. Iizuka, T., Lai, Y.J., Akram, W., Amelin, Y. & Schönbächler, M., The initial abundance and distribution of niobium-92 in the solar system. Japanese Geoscience Union Annual Meeting, May 24, 2016
5. Iizuka, T., Early Earth differentiation inferred from short-lived isotope systematics. Japanese Geoscience Union Annual Meeting, April 29, 2014
6. Iizuka, T., Towards comprehensive understanding of the early solar system chronology. Japanese Geochemical Society Annual Meeting, September 13, 2013
7. Iizuka, T., Evolution of the continental crust as recorded by U-Pb and Hf isotopes in detrital zircon. European Geoscience Union General Assembly 2013, April 12, 2013

III. Education Activity

9. Notable Achievements in Education

Advisees

- Master theses: 8 students

  Takao Yamaguchi (Mar. 2014)

  Keita Itano, Yuki Hibiya (Mar. 2016)

  Yoshitaka Homma, Jun Nagao (Mar. 2017)

  Kengo Ito (Mar. 2018)

  Hatsuki Enomoto, Chiyo Harada (Mar. 2019)

- Doctoral theses: 2 students

  Keita Itano, Yuki Hibiya (Mar. 2019)

Lectures

- Undergraduate/Graduate, Volcanology and magma science, FY2012-2018
- Undergraduate/Graduate, Stratigraphic Age, FY2012-2016
- Undergraduate/Graduate, Cosmochemistry and geochemistry, FY2017-2018
- Undergraduate/Graduate, Practical: Analyses of Rock Textures I, FY2017-2018
- Undergraduate, Field Exercise: Earth and Planetary Environmental Science III, FY2012-2018
- Undergraduate, Practical: Earth and Planetary Environmental Science, FY2012-2018
- Graduate, Laboratory Experiments for Instrumental Analysis, FY2016-2018
- Graduate, Magma science, FY2012, 2015, 2018
- Graduate, GCOE Special Lecture 4, FY2013
- Undergraduate General Education, PEAK Earth sciences, FY2016-2017
- Undergraduate General Education, Fresh-Year Education Seminar, FY2015-2016

Student's awards

- Japan Geoscience Union, Student Presentation Award: Yuki Hibiya
- Korea-Japan Joint Meeting on Isotope-Ratio Mass Spectrometry, Student Presentation Award: Yuki Hibiya
- Japan Geochemical Society Meeting, Student Presentation Award: Yuki Hibiya

IV. External Activities

10. Contribution to Academic Community

- *Chikyu Kagaku* (Japanese Journal by *the Geochemical Society of Japan*), Editorial Board, FY2014–2018
- Member of Election Board for *the Japan Geoscience Union*, FY 2015–2018

11. Outreach Activity

- Seminar on "**Formation of the Earth & Moon**" to the public, *Kawasaki City Program* at Kawasaki, Japan on October 26, 2016
- Seminar on "**The First Billion Years: Formation of a Habitable Planet**" to the public (mainly primary and junior high school students), *the Japanese Geochemical Society Program*, at Yokohama, Japan on July 2, 2016
- Seminar on "**The First Billion Years: Formation of a Habitable Planet**" to the members of *the Young Geoscientist Association* at Tokyo, Japan on October 25, 2015
- Lecture on "Learning the Earth" to the public (primary school students), *Showyoudo Co. Ltd. Program* at Nagareyama, Japan on August 24, 2014
- Seminar on "**Early Earth: Continents-Oceans-Life**" to the public (mainly high school students), *the University of Tokyo Program* at Tokyo, Japan on January 20, 2012

12. Internal Committee Membership

- Director for Scientific Equipment Committee at the Department of Earth & Planetary Science of the University of Tokyo, FY 2015–2018

- Member of Gender Equality Committee at the School of Science of the University of Tokyo, FY 2011–2014

V. International Exchange Activities

13. Hosting/Sending Foreign Students and Researchers

(1) Hosting

Foreign Students: 0

Foreign Researchers: 6

(2) Sending

Students: 1

Researchers: 0

(3) Visitors from Abroad: 20

Kenji Kawai

I. CV

Name: Kenji Kawai

Age: 42

Present Position: Associate Professor

Education

Shonan High School, Kanagawa, March, 1996

B.Sc., Earth and Planetary Physics, The University of Tokyo, March, 2001

M.Sc., Earth and Planetary Science, The University of Tokyo, March, 2003

Ph.D., Earth and Planetary Science, The University of Tokyo, March, 2006

Doctor of Science, The University of Tokyo, March, 2006

Professional Experience

Apr. 2003-Mar. 2006, JSPS Research Fellow (DC1), Department of Earth and Planetary Science, The University of Tokyo

Apr. 2006-Mar. 2009, Instructor, Department of Earth and Planetary Sciences, Tokyo Institute of Technology

Apr. 2009-Mar. 2012, JSPS Research Fellow (PD), Department of Earth and Planetary Sciences, Tokyo Institute of Technology

May 2009-Oct. 2010, Visiting Researcher, Institut de Physique du Globe de Paris, France

Apr. 2012-Mar. 2013, Assistant Project Scientist, Department of Earth Science, University of California, Santa Barbara, U.S.A.

Apr. 2012-Mar. 2014, Project Assistant Professor (GCOE), Department of Earth and Planetary Sciences, Tokyo Institute of Technology

Apr. 2014-Mar. 2016, Assistant Professor, Department of Earth Science and Astronomy, Graduate School of Arts and Sciences, The University of Tokyo

Apr. 2016-, Associate Professor, Department of Earth and Planetary Science, The University of Tokyo

II. Scientific Research Activity

2. Major Achievements

My main research interest has been directly inverting seismic waveform data for earth structure and understanding the earth's thermal and chemical evolution. During the period before 2009 we developed the accurate and efficient formulation and software for computing the synthetic seismograms (Kawai et al. GJI 2006) and their partial derivatives (Kawai et al. GRL 2007; Kawai & Geller JGR 2010).

In the period from 2009-2013, we applied our methods to inversion of actual data to determine the 1-D profile of S-wave velocity variation with depth in the lowermost mantle. We published results for several regions (beneath Central America, the Arctic, the western Pacific, etc: Kawai et al. GJI 2007ab; Konishi et al. EPSL 2009; GJI 2012). Then, we interpreted them via seismological and mineral physics joint modeling and inferred the temperature profile in the lowermost mantle with a CMB temperature of 3800 K, explaining the large-scale lateral variation in seismic velocity structure without the need to invoke chemical heterogeneity (Kawai & Tsuchiya PNAS 2009).

In the period from 2014-2018 we made major progress in our work on waveform inversion. We extended our methods to infer the 3-D S-wave velocity structure and confirmed their feasibility (Kawai et al. GJI 2014; Konishi et al. GJI 2014). We applied our methods to inversion of USArray data deployed recently and successfully imaged the subducted slab in the lowermost mantle beneath the northern Pacific (Suzuki et al. EPS 2016) and Central America (Borgeaud et al. Sci. Adv. 2017), showing that the subducted slabs reach the core-mantle boundary from the earth's surface over ~2 Gyr, induce the passive plume of hot material immediately above the core-mantle boundary, and cool the outer core directly. This suggests that the plate tectonics at the earth's surface control the dynamics at the lowermost mantle and outer core via subduction of oceanic plates through geological time.

3. Five Important Papers (including three or more papers in this review period)

1. Borgeaud, A.F.E., K. Kawai, K. Konishi, & R.J. Geller (2017). Imaging paleoslabs in the D″ layer beneath Central America and the Caribbean using seismic waveform inversion. Science Advances, 3, e1602700, doi:10.1126/sciadv.1602700

We inferred the 3-D S-wave velocity structure in the lowermost mantle beneath Central America and imaged the Farallon slab subducted 1.8 Ga immediately above the core-mantle boundary, inducing the passive plume of hot material in the thermal boundary layer.

2. Kawai, K., & T. Tsuchiya (2015). Small shear modulus of cubic $CaSiO_3$ perovskite. Geophysical Research Letters, 42, 2718-2726

We investigated the elasticity of cubic $CaSiO_3$ perovskite using the density functional first principles molecular dynamics method and obtained smaller shear modulus than examined by previous studies, suggesting that CaPv-rich materials can produce a seismologically low-velocity anomaly.

3. Kawai, K., K. Konishi, R.J. Geller and N. Fuji (2014). Methods for inversion of body-wave waveforms for localized three-dimensional seismic structure and an application to D″ beneath Central America, Geophysical Journal International, 197, 495-524

We formulated the inverse problem of waveform inversion for localized 3-D seismic structure, applied it to inversion of actual data to determine the 3D structure in the lowermost mantle, and showed feasibility of our method and robustness of the inferred model via various tests.

4. Kawai, K., & T. Tsuchiya (2009). Temperature profile in the lowermost mantle from seismological and mineral physics joint modeling, Proceedings of the National Academy of Sciences of the United States of America, 106, 22,119-22,123

We performed the seismological and mineral physics joint modeling and determined the temperature profile in the lowermost mantle to show that the seismic velocities in D" could be explained as the thermal boundary layer with a CMB temperature of 3800 K without the need to invoke a double crossing phase boundary between MgPv and MgPPv.

5. Kawai, K., N. Takeuchi, & R.J. Geller (2006). Complete synthetic seismograms up to 2 Hz for transversely isotropic spherically symmetric media Geophysical Journal International, 164, 411-424

We developed a new version of our algorithm for computing synthetic seismograms for transversely isotropic spherically symmetric media for the shallow earthquakes as well as the deep ones, and made free downloadable software available on the web.

4. Awards and Honors

- Kawai, K., Young Scientist Award of the Seismological Society of Japan Mar. 2012
- Kawai, K., Excellent Young Researcher, The University of Tokyo 2016

5. Future Research Plan

As summarized above, in the years leading up to 2014 we developed methods for waveform inversion for earth structure, and applied these methods to analyze observed waveform data to determine the localized 3-D structure in the lowermost mantle.

We are now working on applying these methods to waveform inversion for localized 3-D structure of the mantle transition zone and the 3-D anisotropic structure in the lowermost mantle. Promising results have been obtained and served as the basis for A.F.E Borgeaud's Ph.D thesis and will serve as the basis for Y. Suzuki's Ph.D thesis. We plan to follow up aggressively and conduct large scale work on waveform inversion for 3-D earth structure. We hope to use these results to obtain important new information for understanding geodynamic processes together with recent progress in mineral physics.

We plan to develop the new techniques for accurate and stable computation of synthetic seismograms in the cracked and saturated elastic media, which rigorously satisfies the energy conservation and reciprocity. In the near future we plan to begin work on waveform inversion for strongly heterogenous media including pore and fluid in the earth's crust and around the solid-liquid boundary such as core-mantle boundary and inner core boundary.

The clay minerals found at the subduction plate interface by JFAST drilling project have small friction coefficients. It is, therefore, important to investigate the origin of molecular friction and relation between macroscopic friction and molecular friction of the clay minerals in order to understand faulting processes and earthquakes at the subduction plate interface. We plan to conduct density functional theory calculations and frictional experiments and investigate the frictional properties of clay minerals.

6. Funding Received

- JSPS KAKENHI, 23224012, Co-Investigator, FY2012-2015, 166,530,000 yen
- JSPS KAKENHI, 24840020, Principal Investigator, FY2012-2013, 2,990,000yen
- JSPS KAKENHI, 26257212, Co-Investigator, FY2014-2017, 39,780,000 yen
- JSPS KAKENHI, 26287105, Co-Investigator, FY2014-2017, 17,030,000 yen
- JSPS KAKENHI, 15H05832, Co-Investigator, FY2015-2019, 178,750,000yen
- JSPS KAKENHI, 15H02147, Co-Investigator, FY2015-2018, 38,090,000 yen
- JSPS KAKENHI, 15K17744, Principal Investigator, FY2015-2017, 4,160,000yen
- JSPS KAKENHI, 16K05531, Co-Investigator, FY2016-2018, 4,680,000yen
- JSPS KAKENHI, 18F18312, Co-Investigator, FY2018-2019, 1,500,000 yen
- JSPS KAKENHI, 18K03797, Principal Investigator, FY2018-2020, 4,550,000yen

7. Publications and Patents

(1) Peer-reviewed Journal Articles

1. Fuji, N., S. Chevrot, L. Zhao, R.J. Geller, K. Kawai (2012), Partial derivatives of high-frequency

compressional body waves for 3-D Earth structure, Geophysical Journal International, 190, 522-540, https://doi.org/10.1111/j/1365-246X.2012.05495.x

2. Konishi, K., K. Kawai, R.J. Geller, N. Fuji (2012), Waveform inversion of broad-band body-wave data for the S-velocity structure in the lowermost mantle beneath the Indian subcontinent and Tibetan Plateau, Geophysical Journal International, 191, 305-316, https://doi.org/10.1111/j.1365-246X.2012.05614.x
3. Kawai, K., T. Tsuchiya (2013), First principles study on the high-pressure phase transition and elasticity of $KAlSi_3O_8$ K-hollandite, American Mineralogist, 98, 207-218, https://doi.org/10.2138/am.2013.4077
4. Kawai, K., S. Yamamoto, T. Tsuchiya, S. Maruyama (2013), The second continent: Existence of granitic continental materials around the bottom of the mantle transition zone, Geoscience Frontiers, 4, 1-6, https://doi.org/10.1016/j.gsf.2012.08.003
5. Tsuchiya, T., K. Kawai, S. Maruyama (2013), Expanding-contracting Earth, Geoscience Frontiers, 4, 341-347, https://doi.org/10.1016/j.gsf.2012.11.008
6. Ichikawa, H., K. Kawai, S. Yamamoto, M. Kameyama (2013), Supply rate of continental materials to the deep mantle through subduction channels, Tectonophysics, 592, 46-52, https://doi.org/10.1016/j.tecto.2013.02.001
7. Ichikawa, H., M. Kameyama, K. Kawai (2013), Mantle convection with continental drift and heat source around the mantle transition zone, Gondwana Research, 24, 1080-1090, https://doi.org/10.1016/j.gr.2013.02.001
8. Kawai, K., K. Konishi, R.J. Geller and N. Fuji (2014), Methods for inversion of body-wave waveforms for localized three-dimensional seismic structure and an application to D" beneath Central America, Geophysical Journal International, 197, 495-524, https://doi.org/10.1093/gii/ggt520
9. Kawai, K., T. Tsuchiya (2014), *P-V-T* equation of state of cubic $CaSiO_3$ perovskite from first principles computation, Journal of Geophysical Research: Solid Earth, 119, 2801-2809, https://doi.org/10.1002/2013JB010905
10. Konishi, K., K. Kawai, R.J. Geller, and N. Fuji (2014), Waveform inversion for localized 3-D seismic velocity structure in the lowermost mantle beneath the Western Pacific, Geophysical Journal International, 199, 1245-1267,

    https://doi.org/10.1093/gji/ggu288
11. Ichikawa, H., M. Kameyama, H. Senshu, K. Kawai, S. Maruyama (2014),
    Influence of majorite on hot plumes, Geophysical Research Letters, 41, 7501-7505, https://doi.org/10.1002/2014GL061477
12. Kawai, K., T. Tsuchiya (2015), Elasticity and phase stability of pyrope garnet from ab initio computation, Physics of the Earth and Planetary Interiors, 240, 125-131, https://doi.org/10.1016/j.pepi.2014.10.005
13. Kawai, K., T. Tsuchiya (2015), Small shear modulus of cubic $CaSiO_3$ perovskite, Geophysical Research Letters, 42, 2718-2726, https://doi.org/10.1002/2015GL063446
14. Kawai, K., H. Sakuma, I. Katayama, K. Tamura (2015), Frictional characteristics of single and polycrystalline muscovite and influence of fluid chemistry, Journal of Geophysical Research: Solid Earth, 120, 6209-6218, https://doi.org/10.1002/2015JB012286
15. Katayama, I., T. Kubo, H. Sakuma, K. Kawai (2015), Can clay minerals account for the non-asperity on the subducting plate interface, Progress in Earth and Planetary Science, 2, 30(8pp), https;//doi.org/10.1186/s40645-015-0063-4

16. Suzuki, Y., K. Kawai, K. Konishi, A.F.E. Borgeaud, R.J. Geller (2016). Waveform inversion for 3–D shear velocity structure of D” beneath the Northern Pacific: Possible evidence for a remnant slab and a ‘passive plume’. Earth, Planets and Space, 68, 198 (8pp) https://doi.org/10.1186/s40623-016-0576-0

17. Ishikawa, A., K. Kawai (2015), Ultrapotassic magma from the deep mantle, Leucite Hills Lamproite, Wyoming USA, Journal of Geography, 124, 515-523, https://doi:10.5026/jgeography.124.515

18. Borgeaud, A.F.E. *, K. Konishi, K. Kawai, R.J. Geller (2016). Finite frequency effects on apparent S-wave splitting in the D” layer: comparison between ray theory and full-wave synthetics. *Geophysical Journal International,* **207,** 12-28, https://doi.org/10.1093/gji/ggw254

19. Ichikawa, H., S. Yamamoto, K. Kawai, M. Kameyama (2016). Estimate of subduction rate of island arcs to the deep mantle. Journal of Geophysical Research: Solid Earth, 121, 5447-6460, https://doi.org/10.1002/2016JB013119

20. Borgeaud, A.F.E., K. Kawai, K. Konishi, R.J. Geller (2017). Imaging paleoslabs in the D″ layer beneath Central America and the Caribbean using seismic waveform inversion. *Science Advances*, 3, e1602700, https://doi.org/10.1126/sciadv.1602700

21. Gréaux, S., M. Nishi, S. Tateno, Y. Kuwayama, N. Hirao, K. Kawai, T. Irifune, S. Maruyama (2018). High-pressure phase relation of KREEP basalts: a clue for finding the lost Hadean crust?. *Physics of the Earth and Planetary Interiors,* 274, 184-194, https://doi.org/10/1016/j.pepi.2017.12.004

22. Yamaya, L., A.F.E. Borgeaud, K. Kawai, R.J. Geller, K. Konishi (2018). Effects of redetermination of source time functions on the 3-D velocity structure inferred by waveform inversion. *Physics of the Earth and Planetary Interiors,* 282, 117-143, https://doi.org/10.1016/j.pepi.2018.04.012

23. Nishi, M., S. Gréaux, S. Tateno, Y. Kuwayama, K. Kawai, T. Irifune, S. Maruyama (2018). High-pressure phase transitions of lunar highland anorthosite in the deep Earth’s mantle. *Geoscience Frontiers,* **9,** 1859-1870,

https://doi.org/10.1016/j.gsf.2017.10.002

24. Sakuma, H., K. Kawai, I. Katayama, S. Suehara (2018). What is the origin of macroscopic friction?. *Science Advances,* 4, eaav2268, https://doi.org/10.1126/sciadv.aav2268

25. Komatsu, G., R. Ishimaru, N. Miyake, K. Kawai, M. Kobayashi, H. Sakuma, and T. Matsui (2019). The Goshogake mud volcano field, Tohoku, northern Japan: An acidic, high-temperature system related to magmatic volcanism. Geomorphology, 329, 32-45, https://doi.org/10.1016/j.geomorph.2018.12.035

26. Kenji, K., T. Uchide (2019). Teaching materials for determination of epicenters using P wave lateral polarity data for small earthquakes in the Hida, Japan, region before and after the 2011 off the Pacific coast of Tohoku Earthquake. Journal of Geography (Chigaku Zasshi), 128,465-475, https://doi.org/10.5026/jgeography.128.465

(2) Non-peer-reviewed Articles

(3) Review Papers

(4) Books

(5) Other Publications

(6) Patents

1. Kawai, K., S. Shoji, Y. Kobayashi (2016). Source information visualization system and source information visualization method. 2016-187518, 9/26/2016

8. Keynote, Invited, or Solicited Presentations

1. Kenji Kawai, Waveform inversion for shear wave velocity structure in the lowermost mantle, MISASA VI Misasa International Symposium 2016
2. Kenji Kawai, Full waveform inversion for 3D S-velocity structure in the D" region, 138th SGEPSS, University of Tokyo, Tokyo, 2015
3. Kenji Kawai, Temperature profile and chemical heterogeneity in the lowermost mantle from seismological and mineral physics joint modeling, 12th Japanese-German Frontiers of Science Symposium (JGFoS), Kyoto Brighton Hotel, Kyoto, 2015
4. Kenji Kawai, Supercontinent cycle and 2nd continents, Geodynamics Seminar, Seoul National University, Seoul, South Korea, 2013
5. Kenji Kawai, Kensuke Konishi, Robert J. Geller, Nobuaki Fuji, Methods for inversion of body-wave waveforms for localized three-dimensional seismic structure and an application to D", Workshop "Wave Propagation through the Earth's Interior", Wuhan, Hubei, China, 2013
6. Kenji Kawai, Toward inversion of body-wave waveforms for localized three-dimensional seismic structure, Geodynamics Seminar, Institute of Geophysics and Planetary Physics, UC San Diego, San Diego, CA, USA, 2012
7. Kenji Kawai, Shinji Yamamoto, Hiroki Ichikawa, Taku Tsuchiya, Shigenori Maruyama, Subducted continental materials around the bottom of the mantle transition zone, Workshop "Geophysics of Slab Dynamics" Jeju Island, South Korea, 2012

III. Education Activity

9. Notable Achievements in Education

Advisees

- Master theses: 1 student
  Lina Yamaya (Mar. 2019)
- Doctoral theses: 1 student
  Anselme F.E. Boargeaud (Mar. 2019)

Lectures

- Undergraduate, Exercises in Earth and Planetary Physics III, FY2017-2018
- Undergraduate, Theory of elastic waves, FY2017-2018
- Graduate, Scientific English, FY2017-2018

Student's awards

- Incentive Award of the School of Science, The University of Tokyo: 2 students
  [Lina Yamaya, Anselme F.E. Borgeaud]
- Japan Geoscience Union, Student Presentation Award: 2 students
  [Hanaya Okuda, Anselme F.E. Borgeaud]
- Interaction and Coevolution of the Core- Mantle 1st Winter School, Poster Award: 1 student
  [Yuki Suzuki]

IV. External Activities

10. Contribution to Academic Community

- Member, Editorial Board of the Newsletter of the Seismological Society of Japan, FY2015-2018
- Editor, Editorial Board of the Newsletter of the Seismological Society of Japan, 2016-2017
- The Board of Directors, Seismological Society of Japan, FY2016-2017

11. Outreach Activity

- Kenji Kawai, What happens in the Earth?, Kawasaki public lectures, 2017/6/13
- Press Release "Imaging paleoslabs in the D" layer", 2017/11
- Press Release "Identifying the origin of macroscopic friction between clay mineral surfaces", 2019/1

12. Internal Committee Membership

- Department of Earth and Planetary Science, Education Committee, Member, FY2016-2018

V. International Exchange Activities

13. Hosting/Sending Foreign Students and Researchers

(1) Hosting

Foreign Students: 1 (1 Switzerland)

Foreign Researchers: 1 (1 India)

(2) Sending

Students: 2

Researchers: 0

(3) Visitors from Abroad: 20

Yoshiyuki Tanaka

I. CV

Name: Yoshiyuki Tanaka

Age: 43

Present Position: Associate Professor

Education

La Salle High School, Kagoshima, March, 1995 (graduation)

B. Sc. Department of Geophysics, The University of Tokyo, March, 1999

M. Sc. Department of Earth and Planetary Science, The University of Tokyo, March, 2001

Dr. Sc. Department of Earth and Planetary Science, The University of Tokyo, March, 2006

Professional Experience

Apr. 2002-Mar. 2008, Ministry of Land, Infrastructure, Transport and Tourism, Geospatial Information Authority of Japan

Nov. 2006-Oct. 2007, Visiting Scientist, GFZ German Research Centre for Geosciences

Apr. 2008-Oct. 2017, Research Assistant, Earthquake Research Institute, The University of Tokyo

Nov. 2017-Mar. 2018, Associate Professor, Earthquake Research Institute, The University of Tokyo

Apr. 2018-, Associate Professor, Department of Earth and Planetary Science, The University of Tokyo

II. Scientific Research Activity

2. Major Achievements

I have studied on tectonic phenomena having time scales up to 100 thousand years which occur mainly in plate subduction zones, including tides, slow slips, co-, post- and inter-seismic deformations and viscoelastic relaxation, based on geodetic data with both theoretical and observational approaches.

I have developed theoretical computational methods based on self-gravitating, viscoelastic spherical earth model. A numerical difficulty arising from considering a compressible material, which had not been solved since 1980s, was resolved by the method that I developed in my PhD work, which was awarded the 2012 Tsuboi award from the geodetic society in Japan. This theory was further expanded to deal with 3D heterogeneities for accurate interpretations of observation data. A series of these developments was awarded the International Association of Geodesy Bomford Prize in 2015, which is given every four year to a person for outstanding theoretical work.

Other theoretical work which I have been tackling with in recent years is associated with triggering of slow earthquakes. I proposed a mechanism by which decadal, non-tidal ocean variations, when combined with short-term tides, could fluctuate plate subduction speed in the transition zone for the first time.

For more than 10 years, I have engaged in absolute and relative gravity measurements across Japan. The anomalous gravity changes associated with long-term slow slip events were detected and a possibility of deep fluid flow was quantitatively shown in 2018 for the first time.

After I moved to the current department in April 2018, I have been studying triggering of slow earthquakes due to earth rotation and constructing a physical model for reproducing fluid flow during the long-term slow slip events, together with bachelor and master students.

3. Five Important Papers (including three or more papers in this review period)

1. Tanaka, Y. (2013) An approximately 9-yr-period variation in seismicity and crustal deformation near the Japan Trench and a consideration of its origin, Geophys. J. Int., 196, 760-787.

This paper reported that the occurrence of the past large earthquakes (M>7.5) associated with the Pacific Plate in the Utsu catalogue is correlated with the 8.85-year variation in the lunar perigee and presented a hypothetical physical model to quantitatively explain a cyclic stress disturbance.

2. Tanaka, Y., T. Hasegawa, H. Tsuruoka, V. Klemann and Z. Martinec (2014) Spectral-finite element approach to post-seismic relaxation in a spherical compressible Earth: application to gravity changes due to the 2004 Sumatra-Andaman earthquake, Geophys. J. Int. 200, 299-321, doi: 10.1093/gji/ggu391

This paper presents a theoretical method to calculate viscoelastic deformation of the solid earth with a spherical model. An ordinary finite-element method (FEM) can treat self-gravitation only approximately in most cases. The proposed method based on a spherical earth model with lateral heterogeneities incorporates analytical expressions of the energy variations into the FEM, which allows us to deal with self-gravitation, rigorously. By this method, we can make the most use of GNSS and satellite gravity for analyzing postseismic deformations. This method can be applied to surface loading due to atmosphere, ocean, ice sheets and continental water (Tanaka et al., 2011; 2019).

3. Tanaka Y., S. Yabe and S. Ide (2015) An estimate of fluctuating plate subduction velocities caused by tidal modulations and decadal variations in the ocean, Earth Planets and Space, 67, 141-151, DOI 10.1186/s40623-015-0311-2 (highlighted paper)

This paper presents a mechanism by which the effect of longer-term external stress disturbances are amplified in fault slip on the plate interface having a nonlinear frictional law. When tides are combined with decadal ocean bottom pressure changes, for example, the latter is more strongly reflected in the long-term slip behavior. It was confirmed that the large meandering of the Kuroshio Current changes background seismicity in the Tokai area in Japan, based on the mechanism. This work contributes to improve a mid-term estimation of earthquake risk.

4. Tanaka, Y., T. Suzuki, Y. Imanishi, S. Okubo, X. Zhang, M. Ando, A. Watanabe, M. Saka, C. Kato, S. Oomori, and Y. Hiraoka (2018) Temporal gravity anomalies observed in the Tokai area and a possible relationship with slow slips, Earth, Planets and Space, 70, 25, doi:10.1186/s40623-018-0797-5

This is the first report of an anomalous gravity change during long-term slow slip events in the world, which was found in the Tokai area in Japan, based on the past 20-year absolute gravity observation. The quantitative model constructed suggests that this anomaly can be interpreted as a result of fluid flow in the slow slip area, which contributes to elucidate the mechanism of slow slip as well as circulation processes of fluid in a subduction zone.

5. Tanaka, Y., Y. Kuroishi and H. Katori (2018). Potential applications of optical lattice clocks for earthquake and volcano studies, Earthquake Journal, 65, 36-44. (Japanese)

Optical lattice clocks are an atomic clock which can measure gravitational potential changes with a relative uncertainty of 10^{-18} level, based on general relativity. This low uncertainty has not yet been achieved except in Japan. This paper discusses a possibility that optical lattice clocks can detect gravitational field variations and crustal deformations associated with earthquake and volcano phenomena more accurately than existing geodetic methods including the GNSS.

4. Awards and Honors

- Tanaka, Y., The geodetic society of Japan, 20th Tsuboi Prize, May 2012
- Tanaka, Y., International Association of Geodesy, 2015 Guy Bomford Prize, June 2015

5. Future Research Plan

I will continue and expand my work to understand the dynamics in plate subduction zones using geodetic approaches in collaboration with seismological and geological study groups in our department, which deal with shorter and longer time scale phenomena than those of geodesy, respectively. In theoretical work, I will improve the deformation theory based on the spherical earth model for considering the dislocation problem in a more realistic earth structure and apply the model to earthquake cycles. Moreover, I would like to prove the generality of my findings on the fluctuating plate subduction speed and fluid flow in the slow slip area, by modeling and observation together with those groups.

It is also an important role to develop a new observation method in geodesy. The Japan Science and Technology Agency initiated a project called “the space-time information platform with a cloud of optical lattice clocks” in November 2018. In this project, I proposed the use of optical lattice clocks for crustal deformation monitoring based on so called gravitational red shift in general relativity and have become the leader of the sub group, “relativistic geodesy”. The dense GNSS network is a powerful tool in monitoring crustal deformation. However, it inevitably suffers from the atmospheric noise. The clocks put on the ground can avoid this problem and detect vertical deformations in shorter measurement time with higher accuracy than the GNSS. In the near future, by combining the GNSS and the clocks, we will try to show that performance to monitor slip distribution on the plate interface, for example, is largely improved.

6. Funding Received

- JSPS KAKENHI, 23340125, Principal Investigator, FY2011-2013, 7,200,000 yen
- JSPS KAKENHI, 23244092, Co-Investigator, FY2011-2015, 800,000 yen
- JSPS KAKENHI, 15K17746, Principal Investigator, FY2015-2018, 3,200,000 yen
- JSPS KAKENHI, 16H06474, Co-Investigator, FY2016-2020, 37,200,000 yen
- JSPS KAKENHI, 16H02219, Co-Investigator, FY2016-2020, 2,100,000 yen
- Japan Science and Technology Agency, JPMJMI18A1, Co-Investigator, FY2018-2028, 93,000,000 yen

7. Publications and Patents

(1) Peer-reviewed Journal Articles

1. Tanaka, Y., X. Zhang, G. Fu, T. Sugano, S. Matsumoto, M. Furuya, W. Sun and S. Okubo (2012) Results of Absolute Gravity Measurements in the Tokai Area from November 1996 to February 2012, Bull. Earthq. Res. Inst. Univ. Tokyo, 87, 1-6.
2. Tanaka, Y. (2013) An approximately 9-yr-period variation in seismicity and crustal deformation near the Japan Trench and a consideration of its origin, Geophys. J. Int., 196, 760-787.
3. Okubo, S., Y. Tanaka, S. Ueki, H. Oshima, T. and Y. Imanishi (2013) Gravity variation around Shinmoe-dake volcano from February 2011 through March 2012-Results of continuous absolute gravity observation and repeated hybrid gravity measurements, Earth Planets and Space, 65, 563-571.

4. Tanaka, Y. (2013) Theoretical computation of long-term postseismic relaxation due to a great earthquake using a spherically symmetric viscoelastic Earth model (in commemoration of the 20th Tsuboi Award), J. Geod. Soc. Jpn., 59, 1-10. (in Japanese with English abstract)
5. Okubo, S., T. Kazama, K. Yamamoto, M. Iguchi,Y. Tanaka, T. Sugano, Y. Imanishi, W. Sun, M. Saka, A. Watanabe and S. Matsumoto (2013) Absolute Gravity Variation at Sakurajima Volcano from April 2009 through January 2011 and its Relevance to the Eruptive Activity of Showa Crater, Bull. Volcanol. Soc. Jpn, 58, 153-162.
6. Tanaka, Y., T. Hasegawa, H. Tsuruoka, V. Klemann and Z. Martinec (2014) Spectral-finite element approach to post-seismic relaxation in a spherical compressible Earth: application to gravity changes due to the 2004 Sumatra-Andaman earthquake, Geophys. J. Int. 200, 299-321, doi: 10.1093/gji/ggu391.
7. Ide, S. and Y. Tanaka (2014) Controls on plate motion by oscillating tidal stress: Evidence from deep tremors in western Japan, Geophys. Res. Lett., 41, 3842-3850, doi:10.1002/2014GL060035.
8. Nishiyama, R., Y. Tanaka, S. Okubo, H. Oshima, H. K. M. Tanaka, and T. Maekawa (2014) Integrated processing of muon radiography and gravity anomaly data toward the realization of high-resolution 3-D density structural analysis of volcanoes: Case study of Showa-Shinzan lava dome, Usu, Japan, J. Geophys. Res., 119, 699-710, doi:10.1002/2013JB010234.
9. Yabe, S., Y. Tanaka, H. Houston, and S. Ide (2015) Tidal sensitivity of tectonic tremors in Nankai and Cascadia subduction zones, J. Geophys. Res. Solid Earth, 120, 7587-7605, doi:10.1002/2015JB012250
10. Tanaka Y., S. Yabe and S. Ide (2015) An estimate of fluctuating plate subduction velocities caused by tidal modulations and decadal variations in the ocean, Earth Planets and Space, 67, 141-151, DOI 10.1186/s40623-015-0311-2 (highlighted paper).
11. Kazama, T., S. Okubo, T. Sugano, S. Matsumoto, W. Sun, Y. Tanaka and E. Koyama (2015) Absolute gravity change associated with magma mass movement in the conduit of Asama Volcano (Central Japan), revealed by physical modeling of hydrological gravity disturbances, J. Geophys. Res., 120, doi:10.1002/2014JB011563
12. Tanaka, Y., T. Sato, Y. Ohta, S. Miura, J. T. Freymueller and V. Klemann (2015) The effects of compressibility on the GIA in southeast Alaska, J. Geodyn., 84, 55-61.
13. Ide, S., S. Yabe, and Y. Tanaka (2016), Earthquake potential revealed by tidal influence on earthquake size-frequency statistics, Nature Geosci., 9, 834–837, doi:10.1038/ngeo2796
14. Tanaka, Y. (2016) Geophysical applications of optical lattice clocks as a gravity potential difference meter, Optics, 45, 259-263. (in Japanese)
15. Tanaka Y. and S. Yabe (2017) Two long‐term slow slip events around Tokyo Bay found by GNSS observation during 1996–2011, Earth Planets and Space, 69, 43-52, doi 10.1186/s40623-017-0628-0
16. Tanaka, Y., T. Suzuki, Y. Imanishi, S. Okubo, X. Zhang, M. Ando, A. Watanabe, M. Saka, C. Kato, S. Oomori, and Y. Hiraoka (2018) Temporal gravity anomalies observed in the Tokai area and a possible relationship with slow slips, Earth, Planets and Space, 70, 25, doi:10.1186/s40623-018-0797-5
17. Tanaka, Y., V. Klemann, Z. Martinec (2019). Surface loading of a self-gravitating, laterally heterogeneous elastic sphere –preliminary result for the 2D case, International Association of Geodesy symposia, https://doi.org/10.1007/1345_2019_62

(2) Non-peer-reviewed Articles

1. Tanaka, Y., Y. Kuroishi and H. Katori (2018). Potential applications of optical lattice clocks for

earthquake and volcano studies, Earthquake Journal, 65, 36-44. (Japanese)

(3) Review Papers

(4) Books

1. Tanaka, Y. (2018). Tides (Chap. 5), in Encyclopedia of Geosciences, ed. By M. Toriumi et al., Asakura Publishing

(5) Other Publications

(6) Patents

8. Keynote, Invited, or Solicited Presentations

1. Tanaka, Y. (2013) Geodetic observation data and modeling of viscoelastic relaxation, Japan Geoscience Union Spring meeting, Chiba, May 24.
2. Tanaka, Y., S. Yabe, R. Kikuchi, S. Ide (2015), Estimating fluctuations of plate subduction speed due to tides and long-term ocean variations, Japan Geoscience Union Spring meeting, Chiba, May 27.
3. Tanaka, Y. (2015) Physical modeling of gravity field variations to explore mechanisms of great earthquakes, 26th IUGG General Assembly 2015, Prague, the Czech Republic, IAG Bomford Prize commemorative lecture, 6/25.
4. Tanaka, Y. (2015) Some Applications of Satellite Gravity Data to Seismological Problems in the Future, American Geophysical Union 2015 Fall Meeting, San Francisco (USA), Dec. 17.
5. Tanaka, Y. (2016) Relativistic geodesy in plate subduction zones -applications to crustal deformation monitoring, ERATO International workshop: Challenges in Precision Science, the University of Tokyo, Tokyo, Jan. 26.
6. Tanaka, Y., Mass transfer in plate subduction zones as seen from temporal gravity changes-theory and observation, “Geodynamics from interior to surface based on geodesy”, National Institute of Polar Research, Tokyo, Japan, 2019/03/11.

III. Education Activity

9. Notable Achievements in Education

Advisees

- Bachelor thesis: 1 student
  Yusuke Umemiya (Mar. 2019)

Lectures

- Undergraduate/Graduate, Solid Earth Mechanics, FY2018
- Undergraduate, Field observation for earth and planetary physics, FY2018
- Graduate, Methodology of Solid Earth Observation, FY2012-2018
- Graduate, Laboratory Experiments for Geophysical Observation, FY2012-2018

IV. External Activities

10. Contribution to Academic Community

- The Geodetic Society of Japan, Board Member, FY2014-2015, 2017-2018
- The Geodetic Society of Japan, General Affairs Committee Member, FY2016-2017
- The Geodetic Society of Japan, Financial Committee Chair, FY2018
- The Geodetic Society of Japan, Overseas Travel Fund Committee Member, FY2018
- The Geodetic Society of Japan, Earth, Planets and Space, Steering Committee Member, FY2014-2016
- The Geodetic Society of Japan, Earth, Planets and Space, Editor, FY2016-2018
- The Geodetic Society of Japan, Summer School, representative, FY2014
- The Seismological Society of Japan, Summer School, lecturer, 2018/09/05
- Japan Geoscience Union, Road Map for Geosciences Task Force Member, FY2017-2018
- Japan Geoscience Union, Board Member, FY2014-2015
- Japan Science and Technology Agency, SAKURA SCIENCE Exchange Program, host researcher, FY2017
- International Association of Geodesy, commission WG1.3.2 (4D deformation models for reference frame) member, 2012-2018
- International Association of Geodesy, Global Geodetic Observation System (GGOS) Science Panel Member,2017-present
- International Association of Geodesy, Inter-Commission Committee on Theory, JSG 0.21 “Geophysical modelling of time variations in deformation and gravity”, Chair, 2015-present
- IAG-IASPEI2017, Executive Committee, LOC， FY2017
- Science Council of Japan, Earth and Planetary Science Committee, IUGG Subcommittee Member, 2018

11. Outreach Activity

- College of Land, Infrastructure, Transport and Tourism, Lecture, Solid Earth Mechanics, FY2012-2018
- Disaster Prevention Research Institute, Kyoto University, Intensive Lecture, Lecturer, FY2016-2017
- 15th Founding Commemorative Symposium of The Institution of Professional Engineers, Applied Science Sectional Meeting, Lecturer, Kanagawa Kenmin Hall, Nov. 13, 2016

12. Internal Committee Membership

- Department of Earth and Planetary Science, Education Committee, Member, FY2018
- Department of Earth and Planetary Physics, Network Committee, Member, FY2018

V. International Exchange Activities

13. Hosting/Sending Foreign Students and Researchers

(1) Hosting

Foreign Students: 1

Foreign Researchers: 1

(2) Sending

Students: 0

Researchers: 1

(3) Visitors from Abroad: 3

Yasuhiro Kuwayama

I. CV

Name: Yasuhiro Kuwayama

Age: 40

Present Position: Project Assistant Professor

Education

Hakuyo High School, Kanagawa, March, 1997 (graduation)

B. Sc. Department of Earth and Planetary Sciences, Tokyo Institute of Technology, March, 2002

M. Sc. Department of Earth and Planetary Sciences, Tokyo Institute of Technology, March, 2004

Ph. D. Department of Earth and Planetary Sciences, Tokyo Institute of Technology, March, 2007

Professional Experience

Apr. 2004-Mar. 2007, JSPS Research Fellow (DC1)

Apr. 2007-Mar. 2009, JSPS Research Fellow (PD)

Apr. 2009-Dec. 2016, Assistant Professor, Geodynamics Research Center. Ehime University

Jun. 2017-, Project Assistant Professor, Graduate School of Science, University of Tokyo

II. Scientific Research Activity

2. Major Achievements

Determinations of the density and sound velocity of liquid iron at high pressures have long been a great challenge for static high-pressure experiments. I have recently succeeded in measuring the density of liquid iron at high pressures for the first time via static compression using a diamond-anvil cell. In-situ x-ray diffraction experiments on liquid iron were performed up to 116 GPa, close to the pressure range for the Earth's core. Conventional methods to estimate a density of liquid from diffuse scattering signals cause large uncertainty arising from experimental limitation that XRD data are collected in a limited Q (momentum transfer) range. In order to overcome such practical limitation, I have developed an innovative analytical method in which observed S(Q) (structure factor) is extended beyond the maximum Q in experimental data so that radial distribution function g(r) is 0 at the small r region (no atoms within a distance between the nearest neighboring atoms). I have also measured the compressional wave velocity of liquid iron to 45 GPa based on inelastic x-ray scattering (IXS) spectroscopy, much higher than the pressure range in previous measurements (<6 GPa). Combining these density (ρ) and velocity (V_P) data together with previous shock compression data collected only around 300 GPa (I did not employ their uncertain temperature estimates), I obtained the P–T–ρ–V_P relation for liquid iron over the Earth's entire outer core conditions, demonstrating that the outer core exhibits 7.5–7.6% density deficit and 3.7–4.4% velocity excess with respect to pure iron. It also shows a difference in density between solid and liquid Fe at the inner core boundary (ICB) conditions, indicating that the compositionally-derived ICB density jump is about half of the previous estimates. These findings give strong constraints on a possible compositional range of the Earth's liquid outer core, which has been a matter of debate since 1952. The present new analytical method to derive a liquid density from diffuse X-ray signals as well as experimental techniques under static high-pressure conditions described here is crucial for investigating properties of dense liquids under pressure.

3. Five Important Papers (including three or more papers in this review period)

1. Kuwayama, Y., Hirose, K., Sata, N. and Ohishi, Y., The pyrite-type high-pressure form of silica, *Science*, 309, 923-925, doi:10.1126/science.1114879 (2005)

New high-pressure phase of SiO_2 with a high silicon coordination number of 6+2 was discovered at extremely high pressure and high temperature condition (~270 GPa, ~1800 K) using a laser heated diamond anvil cell.

2. Kuwayama, Y., Hirose, K., Sata, N. and Ohishi, Y., Phase relations of iron and iron–nickel alloys up to 300 GPa: Implications for composition and structure of the Earth's inner core, *Earth and Planetary Science Letters*, 273, 379–385, doi:10.1016/j.epsl.2008.07.001 (2008)

Phase relations of iron and iron-nickel alloys were determined up to 300 GPa using a laser heated diamond anvil cell. The origin of the structure in the Earth's inner core was discussed.

3. Ohta, K., Kuwayama, Y., Hirose, K., Shimizu, K. and Ohishi, Y., Experimental determination of the electrical resistivity of iron at Earth's core conditions, *Nature*, 534, 95-98, doi:10.1038/nature17957 (2016)

Electrical conductivity of iron was determined up to ~157 GPa and ~3500 K, indicating the high thermal conductivity of Earth's core. The results suggest rapid core cooling and a young inner core less than 0.7 billion years old.

4. Tateno, S., Kuwayama, Y., Hirose, K. and Ohishi, Y., The structure of Fe–Si alloy in Earth's inner core, *Earth and Planetary Science Letters*, 418, 11-19, doi:10.1016/j.epsl.2015.02.008 (2015)

Phase relations of iron-silicon alloys were determined up to 407 GPa and 5960 K, higher than the pressure and temperature in the center of the Earth. Si amount in the inner core was discussed.

5. Nishi, M., Kuwayama, Y., Tsuchiya, J., and Tsuchiya, T., The pyrite-type high-pressure form of FeOOH, *Nature*, 547, 205–208, doi:10.1038/nature22823 (2017)

A new FeOOH phase, which is stable at the conditions of the base of the mantle, was discovered. The transportation of hydrogen into the depth of mantle was discussed.

4. Awards and Honors

5. Future Research Plan

Density (ρ) and longitudinal sound velocity (V_P) (equivalent to bulk sound velocity, V_Φ, in a liquid) are the primary observables of the Earth's liquid outer core. Recently, I have developed high pressure and temperature techniques using laser heated diamond anvil cells combined with in-situ x-ray diffraction and in-situ x-ray inelastic scattering spectroscopy, developed an analytical method to extract ρ from the diffuse XRD signal characteristic of a liquid, and succeeded in degerming density and sound velocity of liquid iron at high pressures. My near future research plan is determination of density and sound velocity of liquid iron alloys with various compositions at high pressures. Currently, H, C, O, Si, and S are considered as candidates of major impurities in the Earth's core. I will determine the effect of these light elements on density and sound velocity of liquid iron alloys at high pressures. Comparing with the differences between those of liquid pure iron and the seismologically observed values, the maximum amount of each elements in the core will be constrained. Density and sound velocity contrast between the inner ad the outer core might be another important constraint to estimate the composition of the core. I will determine the density and sound velocity change of iron alloys upon melting as a function of composition. Combined with melting phase relations of iron alloys, I will constrain the composition of the Earth's inner and outer core.

6. Funding Received

- KAKENHI, Grant-in-Aid for Scientific Research (B), 19H01994, Co-Investigator, FY2019-2022, 17,810,000 yen
- KAKENHI, Grant-in-Aid for Young Scientists (B), 26800274, Principal Investigator, FY2014-2017, 3,770,000 yen
- KAKENHI, Grant-in-Aid for Young Scientists (B), 24740356, Co-Investigator, FY2012-2015, 4,420,000 yen
- KAKENHI, Grant-in-Aid for Young Scientists (B), 23740396, Principal Investigator, FY2011-2013, 4,290,000 yen

7. Publications and Patents

(1) Peer-reviewed Journal Articles

1. Tange, Y., Kuwayama, Y., Irifune, T., Funakoshi, K. and Ohishi, Y., P-V-T equation of state of MgSiO3 perovskite based on the MgO pressure scale: A comprehensive reference for mineralogy of the lower mantle, Journal of Geophysical Research: Solid Earth, 117, B06201, doi:10.1029/2011JB008988 (2012)
2. Fujino, K., Nishio-Hamane, D., Kuwayama, Y., Sata, N., Murakami, S., Whittaker, M., Shinozaki, A., Ohfuji, H., Kojima, Y., Irifune, T., Hiraoka, N., Ishii, T. and Tsuei, K.-D., Spin transition and substitution of Fe3+ in Al-bearing post-Mg-perovskite, Physics of the Earth and Planetary Interiors, 217, 31-35, doi: doi.org/10.1016/j.pepi.2013.01.006 (2013)
3. Fujino, K., Nishio-Hamane, D., Nagai, T., Seto, Y., Kuwayama, Y., Whitaker, M., Ohfuji, H., Shinmei, T. and Irifune. T., Spin transition, substitution, and partitioning of iron in lower mantle minerals, Physics of the Earth and Planetary Interiors, 228, 186-191, doi:10.1016/j.epsl.2015.02.008 (2014)
4. Ohta, K., Fujino, K., Kuwayama, Y., Kondo, T., Shimizu, K. and Ohishi, Y., Highly conductive iron-rich (Mg,Fe)O magnesiowüstite and its stability in the Earth’s lower mantle, Journal of Geophysical Research: Solid Earth, 119, 4656-4665, doi:10.1002/2014JB010972 (2014)
5. Kimura, T., Kuwayama, Y. and Yagi, T., Melting temperatures of H2O up to 72 GPa measured in a diamond anvil cell using CO2 laser heating technique, The Journal of Chemical Physics, 140, 074501, doi:10.1063/1.4865252 (2014)
6. Tateno, S., Kuwayama, Y., Hirose, K. and Ohishi, Y., The structure of Fe–Si alloy in Earth's inner core, Earth and Planetary Science Letters, 418, 11-19, doi:10.1016/j.epsl.2015.02.008 (2015)
7. Nakajima, Y., Imada, S., Hirose, K., Komabayashi, T., Ozawa, H., Tateno, S., Tsutsui, S., Kuwayama, Y. and Baron, A., Carbon-depleted outer core revealed by sound velocity measurements of liquid iron–carbon alloy, Nature Communications, 6, 8942, doi:10.1038/ncomms9942 (2015)
8. Ohta, K., Kuwayama, Y., Hirose, K., Shimizu, K. and Ohishi, Y., Experimental determination of the electrical resistivity of iron at Earth’s core conditions, Nature, 534, 95-98, doi:10.1038/nature17957 (2016)
9. Ohnishi, S., Kuwayama, Y. and Inoue, T., Melting relations in the MgO-MgSiO3 system up to 70 GPa, Physics and Chemistry of Minerals, 44, 445-453, doi:10.1007/s00269-017-0871-8 (2017)
10. Kawaguchi, S. I., Nakajima, Y., Hirose, K., Komabayashi, T., Ozawa, H., Tateno, S., Kuwayama, Y., Tsutsui, S., and Baron, A. Q. R., Sound velocity of liquid Fe-Ni-S at high pressure, Journal of Geophysical Research: Solid Earth, 122, 3624–3634, doi:10.1002/2016JB013609 (2017)

11. Nishi, M., Kuwayama, Y., Tsuchiya, J., and Tsuchiya, T., The pyrite-type high-pressure form of FeOOH, Nature, 547, 205-208, doi:10.1038/nature22823 (2017)
12. Nishi, M., Greaux, S., Tateno, S., Kuwayama, Y., Kawai, K., Irifune, T., Maruyama, S., High-pressure phase transitions of anorthosite crust in the Earth's deep mantle, Geoscience Frontiers, doi:10.1016/j.gsf.2017.10.002 (2017)
13. Greaux, S., Nishi, M., Tateno, S., Kuwayama, Y., Hirao, N., Kawai, K., Maruyama, S., Irifune, T., High-pressure phase relation of KREEP basalts: A clue for finding the lost Hadean crust? Physics of the Earth and Planetary Interiors, 274, 184-194, doi:10.1016/j.pepi.2017.12.004 (2018)
14. Kusakabe, M., Hirose, K., Sinmyo, R., Kuwayama, Y., Ohishi, Y., Helffrich, G., Melting Curve and Equation of State of -Fe7N3: Nitrogen in the Core? Journal of Geophysical Research: Solid Earth, 124, 3448-3457, doi:10.1029/2018JB015823 (2019)
15. Hirose, K., Tagawa, S., Kuwayama, Y., Sinmyo, R., Morard, G., Ohishi, Y., Genda, H., Hydrogen Limits Carbon in Liquid Iron, Geophysical Research Letters, 46, 5190-5197, doi: 10.1029/2019GL082591 (2019)
16. Nishi, M., Tsuchiya, J., Kuwayama, Y., Arimoto, T., Tange, Y., Higo, Y., Hatakeyama, T., Irifune, T., Solid solution and compression behavior of hydroxides in the lower mantle, Journal of Geophysical Research: Solid Earth, in press (2019)
17. Oka, K., Hirose, K., Tagawa, S., Kidokoro., Y., Nakajima, Y., Kuwayama., Y., Morard, G., Coudurier, N., Fiquet, G., Melting in the Fe-FeO system to 204 GPa: Implications for oxygen in Earth's core, Journal of Geophysical Research: Solid Earth, in press (2019)

(2) Non-peer-reviewed Articles

(3) Review Papers

(4) Books

(5) Other Publications

1. Kuwayama, Y., Tsuchiya, T., Pressure-induced phase transition in Fe alloys, Dictionary of Minerals and Gems, edited by Japan Association of Mineralogical Sciences, 2019

(6) Patents

8. Keynote, Invited, or Solicited Presentations

1. Tsuchiya, J., Thompson, E. C., Tsuchiya, T., Nishi, M. and Kuwayama, Y., First principles investigation of the high-pressure behavior of the FeOOH-AlOOH-phase H ($MgSiO_4H_2$) system, IAG-IASPEI (Joint Scientific Assembly of the International Association of Geodesy and the International Association of Seismology and Physics of the Earth's Interior), Kobe International Conference Center, Kobe, August 2, 2017
2. Nishi, M., Kuwayama, Y., Tsuchiya, J., Tsuchiya, T. and Irifune, T., High-pressure phase transitions in AlOOH and FeOOH, High-Pressure Mineral Physics Seminar (HPMPS-9), Saint Malo, France, September 27, 2017
3. Tsuchiya, J., Thompson, E. C., Tsuchiya, T., Nishi, M. and Kuwayama, Y., First principles investigation of high pressure behavior of FeOOH-AlOOH-phase H (MgSiO4H2) system, AGU Fall Meeting 2017, New Orleans, USA, December 13, 2017
4. Nishi, M., Kuwayama, Y., Tsuchiya, J., Tsuchiya, T. and Irifune, T., The high-pressure phase

transitions of hydroxides, AGU Fall Meeting 2017, New Orleans, USA, December 11, 2017

III. Education Activity

9. Notable Achievements in Education

Research Supervison (2012-2019)

Postdoctral fellow: 1, PhD student: 1, Master course student: 1 (at Ehime University)

Lecture

・ Undergraduate, Experiments in Earth and Planetary Physics Earthquake physics, FY2018-2019

IV. External Activities

10. Contribution to Academic Community

11. Outreach Activity

12. Internal Committee Membership

V. International Exchange Activities

13. Hosting/Sending Foreign Students and Researchers

(1) Hosting

Foreign Students: 0

Foreign Researchers: 0

(2) Sending

Students: 0

Researchers: 0

(3) Visitors from Abroad: 0

Ataru Sakuraba

I. CV

Name: Ataru Sakuraba

Age: 47

Present Position: Assistant Professor

Education

Akita High School, Akita, March, 1991 (graduation)

B. Sc. Department of Earth and Planetary Physics, University of Tokyo, March, 1995

M. Sc. Department of Earth and Planetary Physics, University of Tokyo, March, 1997

Ph. D. Department of Earth and Planetary Physics, University of Tokyo, March, 2000

Professional Experience

Apr. 2000-Mar. 2002, Research Fellow (PD), Japan Society for Promotion of Science (University of Tokyo)

Apr. 2012-, Assistant Professor, Department of Earth and Planetary Science, University of Tokyo

II. Scientific Research Activity

2. Major Achievements

(1) I mainly studied convection of Earth's and planetary liquid metallic cores and generation processes of intrinsic magnetic fields. I carried out low-viscosity Earth-type dynamo simulations (with Prandtl number 0.2 and Ekman number $O(10^{-7})$) using Earth Simulator (JAMSTEC) and found a numerical solution possessing Earth-like properties such as a strong dipole and large-scale convection structures. I also made linear analysis of thermally driven magnetoconvection and of magnetic instability of a toroidal magnetic field using a zero-viscosity approximation to get an insight into flow and magnetic-field structures in the Earth's extreme condition.

(2) I joined an experimental research project co-organized with JAMSTEC and Hokkaido University, aiming to understand flow and magnetic-field structures in liquid-metal natural convection. Comparison was successfully made between experiment and numerical simulation, enabling better understanding of a newly found flow reversals and transition of flow structures in thermally driven magnetoconvection.

(3) I made an attempt to verify the hypothesis that self-oscillations caused by a magma flow through a conduit might be an origin of long-period volcanic tremor. A linear stability analysis suggested existence of a flexural mode that was destabilized with much slower flow speed than previously thought.

3. Five Important Papers (including three or more papers in this review period)

1. Vogt, T., Ishimi, W., Yanagisawa, T., Tasaka, Y., Sakuraba, A., & Eckert, S. (2018). Transition between quasi-two-dimensional and three-dimensional Rayleigh-Bénard convection in a horizontal magnetic field. Physical Review Fluids, 3, 013503. DOI: 10.1103/PhysRevFluids.3.013503

This paper showed that transition from two-dimensional rolls to three-dimensional turbulent flows observed in a laboratory experiment of Rayleigh-Bénard convection under a horizontal uniform magnetic field could be understood as a competition of two different viscous boundary layers that were constrained by magnetic field and roll's circulation. (Citation 6)

2. Yanagisawa, T., Hamano, Y., & Sakuraba, A. (2015). Flow reversals in low-Prandtl-number Rayleigh-Bénard convection controlled by horizontal circulations. Physical Review E, 92, 023018. DOI: 10.1103/PhysRevE.92.023018

A new phenomenon was observed in Rayleigh-Bénard magnetoconvection under a horizontal magnetic field, where convection rolls aligned along the magnetic field became unstable so that the adjacent rolls reconnected and such flow reversals occurred repeatedly. (Citation 3)

3. Sakuraba, A. & Yamauchi, H. (2014). Linear stability of plane Poiseuille flow in an infinite elastic medium and volcanic tremors. Earth Planets Space, 66:19. doi:10.1186/1880-5981-66-19

This paper showed that a viscous flow through a conduit like dikes could be destabilized with a much slower flow speed than previously thought, and pointed out that the waves emitted due to this instability might be an origin of long-period volcanic tremor. (Citation 2)

4. Sakuraba, A. & Roberts, P. H. (2009). Generation of a strong magnetic field using uniform heat flux at the surface of the core. Nature Geoscience, 2, 802-805. DOI: 10.1038/NGEO643

They found a dipolar strong-field solution of a low-viscosity Earth-type dynamo model using an Ekman number of $O(10^{-7})$ and showed importance of the boundary condition for the core-surface temperature that had been overlooked. (Citation 91)

5. Sakuraba, A., & Kono, M. (1999). Effect of the inner core on the numerical solution of the magnetohydrodynamic dynamo. Physics of the Earth and Planetary Interior, 111, 105-121. DOI: 10.1016/S0031-9201(98)00150-2

This study is recognized as the first successful attempt to obtain a nonlinear numerical Earth-type dynamo solution in the whole-sphere setting, which could be applied to ancient Earth that had no inner core. (Citation 82)

4. Awards and Honors

5. Future Research Plan

Computer simulation of the Earth's (and planetary) core convection is still difficult despite the power of modern computers. We cannot correctly answer the fundamental questions of how the Earth's magnetic field intensity and convection patterns are determined. In addition to traditional researches to approach the Earth's low-viscosity condition by decreasing viscosity parameters in numerical geodynamo simulations, I take another approach combining several basic methods. I plan to perform stability analysis of a toroidal magnetic field confined in a rotating fluid sphere and a kinematic dynamo under a given flow field, and attempt to find a scaling law between flow speed, magnetic field intensity, and convection wavelength. I also research a computational technique to make it possible to obtain nonlinear geodynamo solutions with a zero-viscosity (magnetostrophic) approximation.

Flow-induced vibration as a possible origin of volcanic tremor is an attractive topic, but the plausibility is not established. I am going to attempt nonlinear computer simulations and laboratory experiments to verify whether such vibrations could occur and what kind of waves propagate.

6. Funding Received

・ JSPS KAKENHI, Grant-in-Aid for Challenging Exploratory Research, Origin of volcanic tremor: A new hypothesis of flow-induced vibration, Principal Investigator, FY2014-2016, 1,600,000 yen

- JSPS KAKENHI, Grant-in-Aid for Scientific Research (A), New mechanism for geomagnetic polarity reversals induced by flow reversals, Co-Investigator, FY2012-2015, 3,500,000 yen
- JSPS KAKENHI, Grant-in-Aid for Young Scientist (B), Numerical simulations of geomagnetic short-timescale variations, Principal Investigator, FY2011-2012, 1,700,000 yen (in 2012)

7. Publications and Patents

(1) Peer-reviewed Journal Articles

1. Vogt, T., Ishimi, W., Yanagisawa, T., Tasaka, Y., Sakuraba, A., & Eckert, S. (2018). Transition between quasi-two-dimensional and three-dimensional Rayleigh-Bénard convection in a horizontal magnetic field. Physical Review Fluids, 3, 013503. DOI: 10.1103/PhysRevFluids.3.013503
2. Yanagisawa, T., Hamano, Y., & Sakuraba, A. (2015). Flow reversals in low-Prandtl-number Rayleigh-Bénard convection controlled by horizontal circulations. Physical Review E, 92, 023018. DOI: 10.1103/PhysRevE.92.023018
3. Sakuraba, A., & Yamauchi, H. (2014). Linear stability of plane Poiseuille flow in an infinite elastic medium and volcanic tremors. Earth Planets Space, 66:19. DOI: 10.1186/1880-5981-66-19.

(2) Non-peer-reviewed Articles

(3) Review Papers

(4) Books

(5) Other Publications

(6) Patents

8. Keynote, Invited, or Solicited Presentations

1. Sakuraba, A., Magnetic instability, slow-wave propagation, and dynamo saturation, The 16th Symposium of SEDI, Edmonton, Canada, 2018/07/09.
2. Sakuraba, A., & Yamauchi, H., A flow-induced volcanic tremor, AOGS Annual Meeting, Sapporo, Japan, 2014/07/31.
3. Sakuraba, A., Westward drift, torsional oscillations and jerks in a low-viscosity numerical geodynamo model, The 13th Symposium of SEDI, Leeds, UK, 2012/07/02.

III. Education Activity

9. Notable Achievements in Education

Lectures

- Undergraduate, Earth and planetary physics fundamental exercise III (electromagnetism), FY2012-2018
- Undergraduate, Overview of solid-earth science (core dynamics), FY2016-2018
- Undergraduate, Earth and planetary physics exercise (time evolution problem), FY2012

IV. External Activities

10. Contribution to Academic Community

- SGEPSS (Society of Geomagnetism and Earth, Planetary and Space Sciences), Future Plan Working Group, Member, FY2012

11. Outreach Activity

12. Internal Committee Membership

V. International Exchange Activities

13. Hosting/Sending Foreign Students and Researchers

(1) Hosting

Foreign Students: 0

Foreign Researchers: 0

(2) Sending

Students: 0

Researchers: 0

(3) Visitors from Abroad: 0

Masahiko Sato

I. CV

Name: Masahiko Sato

Age: 34

Present Position: Assistant Professor

Education

Toho Senior High School, Chiba, March, 2003 (graduation)

B. Sc. Department of Earth and Planetary Sciences, Tokyo Institute of Technology, March, 2007

M. Sc. Department of Earth and Planetary Sciences, Tokyo Institute of Technology, March, 2009

Ph. D. Department of Earth and Planetary Sciences, Tokyo Institute of Technology, September, 2012

Professional Experience

Oct. 2012-Dec. 2012, Postdoctoral Researcher, Graduate School of Science and Engineering, Tokyo Institute of Technology

Jan. 2013-Mar. 2015, Postdoctoral Researcher, Graduate School of Social and Cultural Studies Research, Kyushu University

Apr. 2015-Dec. 2017, Researcher, Geological Survey of Japan, National Institute of Advanced Industrial Science and Technology

Jan. 2018-, Assistant Professor, Department of Earth and Planetary Science, The University of Tokyo

II. Scientific Research Activity

2. Major Achievements

I have been studying on the magnetic field paleointensity of earth and rocky planets and the rock-magnetic properties of magnetic recording media. As the paleomagnetic studies, we developed the experimental method for measuring the magnetic properties of single silicate crystals and succeeded the paleointensity estimation using single zircon and single plagioclase crystals. We also investigated basic properties of the transition remanent magnetization and the oblique anhysteretic remanent magnetization and proposed the paleointensity method using these remanences. As the rock-magnetic studies, we developed the method for in-situ magnetic hysteresis measurement under high pressure and obtained the pressure dependences of magnetic hysteresis parameters of magnetites up to 1GPa. Using the obtained pressure dependences, we evaluated the relaxation time of remanence carried by various types of magnetite and gave new constrains on the source of Martian magnetic anomalies. As the other important achievements, we developed the rock-magnetic method to determine the constituent magnetic minerals of sediments and revealed the abrupt intensification of deep water circulation in the North Atlantic at around 2.68 Ma.

3. Five Important Papers (including three or more papers in this review period)

1. Sato, M., Yamamoto, Y., Nishioka, T., Kodama, K., Mochizuki, N., & Tsunakawa, H. (2014). Hydrostatic pressure effect on magnetic hysteresis parameters of multidomain magnetite: Implication for crustal magnetization, Physics of Earth and Planetary Interior, 223, 33-40. https://doi.org/10.1016/j.pepi.2014.06.001

This paper reported the new method for in-situ magnetic hysteresis measurement under high pressure up to 1GPa and the pressure dependences of magnetic hysteresis parameters of multidomain magnetite. The obtained pressure dependences enabled us to evaluate the source of magnetic anomalies in Earth and rocky planets. Result of this paper was valued in the Society of Geomagnetism and Earth, Planetary and Space Sciences and won the Obayashi Early Career Scientist Award. (Citation 4, GS/Sep. 20, 2019)

2. Sato, M., Seita, K., Miyagawa, T., Mochizuki, N., Kogiso, T., & Tsunakawa, H. (2015). Basic properties of transition remanent magnetizations of magnetite in relation to the ambient field using granite samples, Geophysical Journal International, 200, 25-34. https://doi.org/10.1093/gji/ggu371

This paper reported the basic properties of transition remanent magnetization, which was imparted during cooling and/or warming through the low-temperature transition of magnetite. The relationship between the transition remanent magnetization and the thermoremanent magnetization was recognized in this study, and the new method of paleointensity evaluation using the obtained relationship was proposed. Result of this paper was valued in the Japan Geoscience Union Meeting 2012 and won the Outstanding Student Presentation Award. (Citation 3, GS/Sep. 20, 2019)

3. Sato, M., Makio, M., Hayashi, T., & Ohno, M. (2015). Abrupt intensification of North Atlantic Deep Water formation at the Nordic Seas during the late Pliocene climate transition, Geophysical Research Letters, 42, 4949-4955. https://doi.org/10.1002/2015GL063307

This paper reported the new rock-magnetic method to determine the constituent magnetic minerals of sediments. The north Atlantic deep-sea sediments were measured using the new method and the abrupt intensification of deep water circulation in the North Atlantic at around 2.68 Ma was revealed in this study. Result of this paper was valued in the Society of Geomagnetism and Earth, Planetary and Space Sciences and won the Obayashi Early Career Scientist Award. (Citation 7, GS/Sep. 20, 2019)

4. Sato, M., Yamamoto, S., Yamamoto, Y., Okada, Y., Ohno, M., Tsunakawa, H., & Maruyama, S. (2015). Rock-magnetic properties of single zircon crystals sampled from the Tanzawa tonalitic pluton, central Japan, Earth, Planets and Space, 67, 150. https://doi.org/10.1186/s40623-015-0317-9

Using the zircon crystals collected in the Tanzawa tonalitic pluton, this paper reported the experimental method for measuring the magnetic properties of single zircon crystals and the evaluation criteria for selecting the zircon crystals that was suitable for paleointensity experiment. The rock-magnetic properties of single zircon crystals, which are essential for future work establishing the reliable paleointensity method using single zircon crystals, could be obtained using the measurement and analysis methods proposed in this study. Result of this paper was valued in the Society of Geomagnetism and Earth, Planetary and Space Sciences and won the Obayashi Early Career Scientist Award. (Citation 14, GS/Sep. 20, 2019)

5. Sato, M., Yamamoto, Y., Nishioka, T., Kodama, K., Mochizuki, N., Ushioda, M., Nakada, R., & Tsunakawa, H. (2018). Constraints on the source of the Martian magnetic anomalies inferred from relaxation time of remanent magnetization, Geophysical Research Letters, 45, 6417-6427. https://doi.org/10.1029/2018GL077498

This paper evaluated the relaxation time of remanence carried by various types of magnetite to understand the source of strong magnetic anomalies observed over Mars. The estimation results indicated that fine-grained and high-aspect-ratio magnetite in deep crust was needed to explain the observed anomalies. These results suggested that the formation mechanism of fine-grained and high-aspect-ratio magnetite in deep crust could constrain the intensity of paleo-martian magnetic field. (Citation 2, GS/Sep. 20, 2019)

4. Awards and Honors

- Sato, M., JpGU 2012 Outstanding Student Presentation Award, May 2012
- Sato, M., SGEPSS Obayashi Early Career Scientist Award, Nov. 2018

5. Future Research Plan

I will continue the paleomagnetism of rocky planets, to understand the interior dynamics generating the change in magnetic field and the magnetic field related changes in surface environment. In the case of magnetic mineral contained in silicate minerals, the grain-size and composition of magnetic minerals can be precisely characterized. It is expected that the origins of these minerals are ascertainable, and then the paleointensity method using single silicate crystals will provide the paleointensity value in high accuracy compared to the conventional paleomagnetic method using whole rock samples. We plan to study the paleointensity of single silicate crystals of rocky planets using the previously developed paleointensity method for single silicate crystals. In addition to the paleointensity measurements of single silicate crystals, we will conduct mineralogical and petrological measurements on these silicate crystals, to understand the origins of magnetic minerals in silicate crystals and to select the reliable paleointensity data. We will also conduct the fundamental study for shock remanent magnetization, to understand the magnetic anomalies data obtained from space explorations of rocky planets and to reveal the evolutions of magnetic field.

6. Funding Received

- JSPS KAKENHI, 26610142, Principal Investigator, FY2014-2016, 2,900,000 yen
- JSPS KAKENHI, 25247073, Co-Investigator, FY2016, 200,000 yen
- JSPS KAKENHI, 16K13876, Co-Investigator, FY2016-2017, 200,000 yen
- JSPS KAKENHI, 18H03358, Co-Investigator, FY2018-2020, 300,000 yen
- JSPS KAKENHI, 19K14777, Principal Investigator, FY2019-2020, 3,300,000 yen

7. Publications and Patents

(1) Peer-reviewed Journal Articles

1. Sato, M., Yamamoto, Y., Nishioka, T., Kodama, K., Mochizuki, N., & Tsunakawa, H. (2012). Pressure effect on low-temperature remanence of multidomain magnetite: Change in demagnetization temperature, Geophysical Research Letters, 39, L04305. https://doi.org/10.1029/2011GL050402
2. Kurokawa, H., Sato, M., Ushioda, M., Matsuyama, T., Moriwaki, R., Dohm, J.M., & Usui, T. (2014). Evolution of Water Reservoirs on Mars: Constraints from Hydrogen Isotopes in Martian Meteorites, Earth and Planetary Science Letters, 394, 179-185. https://doi.org/10.1016/j.epsl.2014.03.027
3. Sato, M., Yamamoto, Y., Nishioka, T., Kodama, K., Mochizuki, N., & Tsunakawa, H. (2014). Hydrostatic pressure effect on magnetic hysteresis parameters of multidomain magnetite: Implication for crustal magnetization, Physics of Earth and Planetary Interior, 223, 33-40. https://doi.org/10.1016/j.pepi.2014.06.001
4. Sato, M., Seita, K., Miyagawa, T., Mochizuki, N., Kogiso, T., & Tsunakawa, H. (2015). Basic properties of transition remanent magnetizations of magnetite in relation to the ambient field using granite samples, Geophysical Journal International, 200, 25-34. https://doi.org/10.1093/gji/ggu371

5. Sato, M., Yamamoto, Y., Nishioka, T., Kodama, K., Mochizuki, N., Usui, Y., & Tsunakawa, H. (2015). Pressure effect on magnetic hysteresis parameters of single-domain magnetite contained in natural plagioclase crystal. Geophysical Journal International, 202, 394-401, https://doi.org/10.1093/gji/ggv154
6. Sato, M., Makio, M., Hayashi, T., & Ohno, M. (2015). Abrupt intensification of North Atlantic Deep Water formation at the Nordic Seas during the late Pliocene climate transition, Geophysical Research Letters, 42, 4949-4955. https://doi.org/10.1002/2015GL063307
7. Sato, M., Yamamoto, S., Yamamoto, Y., Okada, Y., Ohno, M., Tsunakawa, H., & Maruyama, S. (2015). Rock-magnetic properties of single zircon crystals sampled from the Tanzawa tonalitic pluton, central Japan, Earth, Planets and Space, 67, 150. https://doi.org/10.1186/s40623-015-0317-9
8. Shibuya, T., Yoshizaki, M., Sato, M., Shimizu, K., Nakamura, K., Omori, S., Suzuki, K., Takai, K., Tsunakawa, H., & Maruyama, S. (2015). Hydrogen-rich hydrothermal environments in the Hadean ocean inferred from serpentinization of komatiites at 300 °C and 500 bar, Progress in Earth and Planetary Science, 2, 46. https://doi.org/10.1186/s40645-015-0076-z
9. Kurokawa, H., Usui, T., Sato, M. (2016). Interactive Evolution of Multiple Water-Ice Reservoirs on Mars: Insights from Hydrogen Isotope Compositions, Geochemical Journal, 50, 67-79. https://doi.org/10.2343/geochemj.2.0407
10. Kawai, J., Oda, H., Fujihira, J., Miyamoto, M., Miyagi, I., & Sato, M. (2016). SQUID Microscope with Hollow-Structured Cryostat for Magnetic Field Imaging of Room Temperature Samples, IEEE Transactions on Applied Superconductivity, 26, 1600905. https://doi.org/10.1109/TASC.2016.2536751
11. Ohno, M., Hayashi, T., Sato, M., Kuwahara, Y., Mizuta, A., Kita, I., Sato, T., & Kano, A. (2016). Millennial-scale interaction between ice sheets and ocean circulation during marine isotope stage 100, Frontiers in Earth Science, 4, 55. https://doi.org/10.3389/feart.2016.00055
12. Sato, M., Yamamoto, Y., Nishioka, T., Kodama, K., Mochizuki, N., & Tsunakawa, H. (2016). Hydrostatic pressure effect on magnetic hysteresis parameters of pseudo-single-domain magnetite, Geochemistry, Geophysics, Geosystems, 17, 2825-2834. https://doi.org/10.1002/2016GC006406
13. Oda, H., Kawai, J., Miyamoto, M., Miyagi, I., Sato, M., Noguchi, A., Yamamoto, Y., Fujihira, J., Natsuhara, N., Aramaki, Y., Masuda, T., & Xuan, C. (2016). Scanning SQUID microscope system for geological samples: system integration and initial evaluation, Earth, Planets and Space, 68, 179. https://doi.org/10.1186/s40623-016-0549-3
14. Sato, M., Mochizuki, N., Watanabe, M., & Tsunakawa, H. (2017). Composition law of oblique anhysteretic remanent magnetization and its relation to the magnetostatic interaction, Geochemistry, Geophysics, Geosystems, 18, 1043-1052. https://doi.org/10.1002/2016GC006671
15. Noguchi, A., Oda, H., Yamamoto, Y., Usui, A., Sato, M., & Kawai, J. (2017). Scanning SQUID microscopy of a ferromanganese crust from the northwestern Pacific: Submillimeter scale magnetostratigraphy as a new tool for age determination and mapping of environmental magnetic parameters, Geophysical Research Letters, 44, 5360-5367. https://doi.org/10.1002/2017GL073201
16. Kodama, K., Byrne, T., Lewis, J.C., Hibbard, J.P., Sato, M., & Koyano, T. (2018). Emplacement of a layered mafic intrusion in the Shimanto accretionary complex of southwest Japan: Evidence from paleomagnetic and magnetic fabric analysis, Geological Society of America Special Paper, 534, 129-140. https://doi.org/10.1130/2018.2534(08)
17. Sato, M., Yamamoto, Y., Nishioka, T., Kodama, K., Mochizuki, N., Ushioda, M., Nakada, R., & Tsunakawa, H. (2018). Constraints on the source of the Martian magnetic anomalies inferred

from relaxation time of remanent magnetization, Geophysical Research Letters, 45, 6417-6427. https://doi.org/10.1029/2018GL077498

18. Kato, C., Sato, M., Yamamoto, Y., Tsunakawa, H., & Kirschvink, J. (2018). Paleomagnetic studies on single crystals separated from the middle Cretaceous Iritono granite, Earth, Planets and Space, 70, 176. https://doi.org/10.1186/s40623-018-0945-y
19. Sato, M., Yamamoto, Y., Nishioka, T., Kodama, K., Mochizuki, N., Ushioda, M., Nakada, R., & Tsunakawa, H. (2018). Evaluation of source of the Martian magnetic anomalies based on relaxation time of remanent magnetization, Planetary People, 27, 173-179. https://doi.org/10.14909/yuseijin.27.3_173

(2) Non-peer-reviewed Articles

(3) Review Papers

(4) Books

(5) Other Publications

(6) Patents

8. Keynote, Invited, or Solicited Presentations

1. Sato, M., & Kurosawa, K., Research plan and expected result for shock remanence measurement using SQUID Microscope, Symposium on Laboratory Experiment for Space Science, Kanagawa, Japan, 2015/02/23.
2. Sato, M., Yamamoto, S., Yamamoto, Y., Ohno, M., Tsunakawa, H., & Maruyama, S., Rock-magnetic properties of single zircon crystals sampled from the Tanzawa tonalitic pluton, central Japan, ELSI Workshop on Geophysical & Geochemical Constraints on Early Planetary Dynamos, Yamanashi, Japan, 2015/9/17.
3. Sato, M., Ushioda, M., Nakada, R., Yamamoto, Y., Nishioka, T., Kodama, K., Tsunakawa, H., & Mochizuki, N., Rock-magnetic studies concerning source of the Martian magnetic anomaly, Japan Geoscience Union Meeting 2016, Chiba, Japan, 2016/05/24.

III. Education Activity

9. Notable Achievements in Education

Lectures

- Undergraduate, Experiments in Earth and Planetary Physics, FY2018
- Undergraduate, Practical: Earth and Planetary Environmental Science Detail, FY2018
- Undergraduate, Field Exercise: Earth and Planetary Environmental Science III, FY2018

IV. External Activities

10. Contribution to Academic Community

- Seismological Society of Japan, Student Presentation Award Board Member, FY2016

11. Outreach Activity

12. Internal Committee Membership

V. International Exchange Activities

13. Hosting/Sending Foreign Students and Researchers

(1) Hosting

Foreign Students: 0

Foreign Researchers: 0

(2) Sending

Students: 0

Researchers: 0

(3) Visitors from Abroad: 0

Takayoshi Nagaya

I. CV

Name: Takayoshi Nagaya

Age: 31

Present Position: Assistant Professor

Education

Tajimi Kita High School, Gifu, March, 2007 (graduation)

B. Sc. Department of Physical Science, Osaka Prefecture University, March, 2011

M. Sc. Department of Earth and Planetary Sciences, Nagoya University, March, 2013

Ph. D. Department of Earth and Planetary Sciences, Nagoya University, March, 2016

Professional Experience

Apr. 2013-Mar. 2016, JSPS Research Fellow (DC1), Department of Earth and Planetary Sciences, Nagoya University

Sep. 2014-Mar. 2015, Part-time lecturer, Center for General Education, Aichi Institute of Technology

Sep. 2015-Mar. 2016, Part-time lecturer, Center for General Education, Aichi Institute of Technology

Apr. 2016-Mar. 2019, JSPS Postdoctoral Research Fellow (PD), Department of Environmental Studies for Advanced Society, Tohoku University

Oct. 2017-Mar. 2019, Post-Doctoral Scholar–Visiting Fellow, Department of Earth Sciences, University of Southern California

Apr. 2019-Aug. 2019, JSPS Overseas Research Fellow, Department of Earth Sciences, University of Southern California

Sep. 2019-, Assistant Professor, Department of Earth and Planetary Science, The University of Tokyo

II. Scientific Research Activity

2. Major Achievements

I have been studying on the structure and its development processes of the upper mantle in subduction zones based on field geological surveys and microstructural observations and analyses of natural and experimental samples in laboratory. Serpentinization due to the hydration of the upper mantle is predicted to form strongly anisotropic domains associated with the deformation of hydrous sheet silicates. Therefore, we succeeded in improving EBSD measurement procedures to make it possible to obtain a reliable data set of crystal orientations of hydrous sheet silicates from rock samples. The internal structure was estimated combined the elastic anisotropy of serpentinite obtained by the EBSD procedure and seismic observations, and we clarified the quantitative hydrated distribution and degree of the forearc mantle in the Ryukyu subduction zone. we also proposed the flow direction and effective viscosity of the forearc mantle based on the alignment of antigorite in serpentinite. In addition, we studied regarding the formation mechanism of crystallographic preferred orientations of olivine, which is important in the anisotropy study of the upper mantle. We found that olivine grains with the crystallographic preferred orientation are formed and grown after the dehydration of aligned antigorite grains. The discovery of the new formation mechanism of the crystallographic preferred orientation of olivine that was not caused by deformation processes results in the need to reassess the proposed interpretations of olivine textures in natural samples and the flow directions of the upper mantle.

3. Five Important Papers (including three or more papers in this review period)

1. Nagaya, T., Wallis, S. R., Seto, Y., Miyake, A, Soda, Y., Uehara, S., & Matsumoto, M. (2017). Minimizing and quantifying mis-indexing in electron backscatter diffraction (EBSD) determinations of antigorite crystal directions. Journal of Structural Geology, 95, 127-141. https://doi.org/10.1016/j.jsg.2016.12.006

The measurements of mineral crystal orientations in rock samples by EBSD enable to easily quantify the natural rock texture, and directly compare it with the geophysical observations by using the mineral physical properties. Therefore, the EBSD has been actively used in the earth science fields since the 2000s. However, there has not been enough discussion on the accuracy of EBSD measurements. We used different analysis methods for the same measurement area, clarified that there were common mis-indexing patterns of antigorite crystallographic orientations in EBSD measurements, and quantitatively showed the influence on estimation of the elastic anisotropy of bulk rock. In addition, the improved EBSD procedure to measure reliable crystal orientations of hydrous sheet silicates is expected to be widely utilized in future EBSD studies.

2. Enami, M., Nagaya, T., & Maw Maw Win (2017). An integrated EPMA-EBSD study of metamorphic histories recorded in garnet. American Mineralogists, 102, 192-204. https://doi.org/10.2138/am-2017-5666

In addition to the analysis of the garnet chemical composition using EPMA, we tried to clarify the metamorphic/deformation histories of metamorphic rocks utilized crystal orientation information obtained by EBSD. In metapelitic rocks from the Besshi area, Shikoku, we found by EBSD that garnet with compositional zoning consists of multiple grains, which was generally interpreted as a single crystal from common methods based on polarized optical microscopy and compositional zoning characteristics by EPMA. We also proposed a formation-growth model of garnet that can explain EBSD and EPMA measurements in metapelitic rocks. In addition, from the EBSD and EPMA measurements of the pelitic gneiss from the Mogok area, Myanmar, we clarified that deformation associated with the change in intragranular crystal orientations of garnet didn't occur during the exhumation process from depths of ~9–12 km in the continental crust. These examples show the potential that the EBSD may significantly advance the study of metamorphic rocks.

3. Nagaya, T., Walker, A. M., Wookey, J., Wallis, S. R., Ishii, K., & Kendall, J.-M. (2016). Seismic evidence for flow in the hydrated mantle wedge of the Ryukyu subduction zone. Scientific Reports, 6, 29981. https://doi.org/10.1038/srep29981

We carried out 3D modeling of shear wave polarization anisotropy using the elastic anisotropy data of natural serpentinite derived from the wedge mantle in subduction zones, and suggested the comprehensive model of the content, distribution and orientation of antigorite, which can explain the seismic anisotropies observed in the Ryukyu forearc mantle. The modeling also showed that the model of antigorite serpentinite later to be distributed parallel to the subducting slab where the foliation is parallel to the slab cannot explain the seismic anisotropy observations, and the forearc mantle is widely hydrated. The change in the foliation of serpentinite in our model implies the existence of the forearc mantle convection. It is expected that the source code released in this study will be used for research using anisotropy properties of minerals and seismic observations.

4. Kawahara, H., Endo, S., Wallis, S. R., Nagaya, T., Mori, H., & Asahara, Y. (2016). Brucite as an important phase of the shallow mantle wedge: evidence from the Shiraga unit of the Sanbagawa subduction zone, SW Japan. Lithos, 254–255, 53-66. https://doi.org/10.1016/j.lithos.2016.02.022

A detailed field survey of the Shiraga ultramafic body, Shikoku in the Sanbagawa belt and its surrounding area, and microtextures and chemical composition analyses of the collected samples by the polarized optical microscopy and EPMA were conducted. As a result, olivine formed by the dehydration reaction of antigorite and brucite, and the existence of brucite derived from the wedge mantle in the subduction zone, which very few previous studies have reported, ware widely observed in the body. In addition, thermodynamic modeling showed the existence of brucite of ~10–15 vol.% before peak metamorphic conditions. However, brucite-free antigorite-serpentinite is distributed in a 100-m-thick marginal zone of the body. This implies that the metasomatic reaction of the shallow mantle wedge with SiO2 fluids is limited at the slab-mantle interface. This study is an example showing the importance of petrological studies based on field works and natural samples in subduction zone studies.

5. Nagaya, T., Wallis, S. R., Kobayashi, H., Michibayashi, K., Mizukami, T., Seto, Y., Miyake, A., & Matsumoto, M. (2014). Dehydration breakdown of antigorite and the formation of B-type olivine CPO. Earth and Planetary Science Letters, 387, 67-76. https://doi.org/10.1016/j.epsl.2013.11.025

We conducted mineral chemical composition analyses using EPMA, olivine inclusion analyses using microscopic Raman spectroscopy, crystallographic orientation measurements using EBSD and of dislocation density measurements of olivine using FIB-TEM for natural samples that formed due to partially and completely dehydration of antigorite schist by the contact metamorphism associated with the granite intrusion. As a result, we found that the crystallographic preferred orientation of olivine that is a characteristic pattern common in subduction zones, which is generally referred to as the B-type, was formed due to the topotactic growth from antigorite. This is the first report that shows non-deformed olivine can have the crystallographic preferred orientation, and the new B-type formation mechanism can explain formation conditions of the B-type observed in natural samples, which are difficult to explain by plastic deformation of olivine.

4. Awards and Honors

- Nagaya, T., JpGU 2015 Outstanding Student Presentation Award, May. 2015

5. Future Research Plan

I will continue to study the interior structure of the Earth from subducting slab to continental crust based on interdisciplinary research approach by collaborating with a wide range of research fields of seismology and geophysics including seismic anisotropy observations, and structural geology, mineralogy, and petrology including microstructural analyses of natural and experimental rock samples. In microstructural analyses, I will improve EBSD analysis procedures to clarify micro textures and crystal structures of minerals in rocks that have been considered to be difficult to obtain. Based on this, the development of bulk rock structures and physical properties, depending on mineral formation and deformation processes in subduction zones can be revealed, which results in the deeper understanding of physical and chemical phenomena at various time- and spatial-scales that occur in subduction zones. In the estimation of the interior structure of the Earth using seismic observations, I will use the elastic constants of the bulk rock calculated from the microstructural analysis of the rock by the EBSD to construct rock structures and clarify the fluid distribution and components in current subduction zones.

6. Funding Received

- JASSO Student Exchange Support Program, Nagoya University Program for Academic Exchange, FY2012, 240,000 yen
- JSPS Researcher Overseas Visit Fund, Institutional Program for Young Researcher Overseas Visits, FY2012, 140,000 yen

- JASSO Student Exchange Support Program, Nagoya University Program for Academic Exchange, FY2013, 240,000 yen
- JSPS KAKENHI, 13J00199, Principal Investigator, FY2013-2015, 3,000,000 yen
- JSPS KAKENHI, 16J01480, Principal Investigator, FY2016-2018, 3,400,000 yen
- JSPS KAKENHI, 17K14405, Principal Investigator, FY2017-2019, 3,200,000 yen

7. Publications and Patents

(1) Peer-reviewed Journal Articles

1. Enami, M., Kimura, J., Tsuboi, M., Kouketsu, Y., Nagaya, T., & Huang, S. (2019). Coexisting different types of zoned garnet in kyanite-quartz eclogites from the Sanbagawa metamorphic belt: evidence for material mixing during prograde metamorphism. Island Arc, 28, e12274. https://doi.org/10.1111/iar.12274
2. Nagaya, T., Wallis, S. R., Seto, Y., Miyake, A, Soda, Y., Uehara, S., & Matsumoto, M. (2017). Minimizing and quantifying mis-indexing in electron backscatter diffraction (EBSD) determinations of antigorite crystal directions. Journal of Structural Geology, 95, 127-141. https://doi.org/10.1016/j.jsg.2016.12.006
3. Enami, M., Nagaya, T., & Maw Maw Win (2016). An integrated EPMA-EBSD study of metamorphic histories recorded in garnet. American Mineralogists, 102, 192-204. http://doi.org/10.2138/am-2017-5666
4. Nagaya, T., Walker, A. M., Wookey, J., Wallis, S. R., Ishii, K., & Kendall, J. -M. (2016). Seismic evidence for flow in the hydrated mantle wedge of the Ryukyu subduction zone. Scientific Reports, 6, 29981. https://doi.org/10.1038/srep29981
5. Kawahara, H., Endo, S., Wallis, S.R., Nagaya, T., Mori, H., & Asahara, Y. (2016). Brucite as an important phase of the shallow mantle wedge: evidence from the Shiraga unit of the Sanbagawa subduction zone, SW Japan. Lithos, 254-255, 53-66. https://doi.org/10.1016/j.lithos.2016.02.022
6. Weller, O.M., Wallis, S.R., Aoya, M., & Nagaya, T. (2015). Phase equilibria modelling of blueschist and eclogite from the Sanbagawa metamorphic belt of south-west Japan reveals along-strike consistency in tectonothermal architecture. Journal of Metamorphic Geology, 33, 579-596. https://doi.org/10.1111/jmg.12134
7. Nagaya, T., Wallis, S.R., Kobayashi, H., Michibayashi, K., Mizukami, T., Seto, Y., Miyake, A., & Matsumoto, M. (2014). Reply to comment by Nozaka (2014) on "Dehydration breakdown of antigorite and the formation of B-type olivine CPO". Earth and Planetary Science Letters, 408, 406-407. https://doi.org/10.1016/j.epsl.2014.10.026
8. Mizukami, T., Yokoyama, H., Hiramatsu, Y., Arai, S., Kawahara, H., Nagaya, T., & Wallis, S.R. 2014. Two types of antigorite serpentinite controlling heterogeneous slow-slip behaviours of slab–mantle interface. Earth and Planetary Science Letters, 401, 148-158. https://doi.org/10.1016/j.epsl.2014.06.009
9. Nagaya, T., Wallis, S.R., Kobayashi, H., Michibayashi, K., Mizukami, T., Seto, Y., Miyake, A., & Matsumoto, M. (2014). Dehydration breakdown of antigorite and the formation of B-type olivine CPO. Earth and Planetary Science Letters, 387, 67-76. https://doi.org/10.1016/j.epsl.2013.11.025

(2) Non-peer-reviewed Articles

(3) Review Papers

(4) Books

(5) Other Publications

(6) Patents

8. Keynote, Invited, or Solicited Presentations

III. Education Activity

9. Notable Achievements in Education

Lectures

- Undergraduate, Physics (Mechanics), Faculty of Engineering, Aichi Institute of Technology, FY2014-2015

IV. External Activities

10. Contribution to Academic Community

- Symposium on metamorphism and metamoprhic rocks : further perspectives & 14th International Symposium on Water Dynamics, Organizing Member, FY2016

11. Outreach Activity

- Lecture for general audience: 1 times (Aug. 2014)

12. Internal Committee Membership

V. International Exchange Activities

13. Hosting/Sending Foreign Students and Researchers

(1) Hosting

Foreign Students: 0

Foreign Researchers: 0

(2) Sending

Students: 0

Researchers: 0

(3) Visitors from Abroad: 0

Akiko Toh

I. CV

Name: Akiko Toh

Age: 44

Present Position: Project assistant professor

Education

Meijigakuen High School, Fukuoka, March, 1994 (graduation)

B. Sc. Department of Earth and Planetary Sciences, School of Science, Kyushu University, March, 1998

M. Sc. Department of Earth and Planetary Physics, The University of Tokyo, March, 2000

Ph. D. Department of Earth and Planetary Sciences, University of California, Berkeley, December, 2006

Professional Experience

Jan. 2007-Mar. 2007, Postdoctral researcher, University of California, Berkeley

Apr. 2007-Jan. 2010, JSPS Postdoctral Fellow, IFREE, Japan Agency for Marine-Earth Science and Technology

Feb. 2010-Mar. 2010, JSPS Excellent Young Researcher Overseas Visit Program, Institut de Physique du Globe de Paris

Apr. 2010-May 2010, Postdoctral Researcher, Earthquake Research Institute, The University of Tokyo

Jun. 2010-Mar. 2014, Technical Scientist, IFREE/DONET, Japan Agency for Marine-Earth Science and Technology

Apr. 2014-Mar. 2017, Researcher, CEAT, Japan Agency for Marine-Earth Science and Technology

Apr. 2017-May 2017, Part-time research assistant, CEAT, Japan Agency for Marine-Earth Science and Technology

May 2017-May 2018, Ministry of Science and Technology visiting specialist, Institute of Earth Sciences, Academia Sinica

Jun. 2018-, Project assistant professor, Department of Earth and Planetary Science, The University of Tokyo

II. Scientific Research Activity

2. Major Achievements

I have been working toward understanding of seismic activities and Earth's interior structures by analyses of seismic waveforms.

I have been studying anomalous earthquakes that occur off-shore Japan, in shallow part of Nankai plate subduction zone, recorded by a cabled network (DONET1 since 2010) of ocean bottom seismometers (OBS) deployed just above their source regions. Using the near-field broadband seismic records, one of the achievements I made is a clear classification of local seismicity beneath DONET1. I found that the so called slow-earthquakes (such as tremors, very low frequency earthquakes (VLFE)) and ordinary earthquakes are best separated based on frequency ranges of the observed signals. This is in contrast to other studies where the “signal duration” is used as the criteria, which seems inappropriate for the OBS data. The robust classification of seismicity has become the basis for my further study on pursuing the cause of slow earthquakes. Another achievement was on estimating the spatial distribution of VLFEs recorded by DONET1. We found that it is influenced by a subducting-ridge that take place beneath DONET1. The distribution should be closely related to strain accumulation and release pattern; therefore, should be an important factor in assessing spatial patterns of tsunami generation in this region.

I worked at JAMSTEC until 2017 where I was engaged in data consolidation and database/website development for efficiently browsing data of a few different seismic networks. The experience of setting the system to detect local seismicity has led me to the current research topic. Also, I obtained a detailed structure at the core-mantle boundary region, considered as the root of Hawaiian hotspot, using full-waveform forward modelling method, which is the work continued from my Ph. D. thesis.

3. Five Important Papers (including three or more papers in this review period)

1. Toh, A., Obana, K., and Araki, E. (2018). Distribution of very low frequency earthquakes in the Nankai accretionary prism influenced by a subducting-ridge. Earth and Planetary Science Letters, 482: 342–356. https://doi.org/10.1016/j.epsl.2017.10.062

We investigated the distribution of very low frequency earthquakes (VLFE) that occurred in shallow accretionary prism of the eastern Nankai trough, using data from a cabled ocean bottom network (DONET1). The result suggested that the distribution is influenced by a ridge-subduction, or a localized topographic high on the subducting plate, that has been known to take place in this region. This was also one of the first work to apply cluster analyses to VLFE data, and showed its usefulness in assessing the source locations in details. (Citation 8, GS/Sep. 30, 2019)

2. To, A., Capdeville, Y., and Romanowicz, B. (2016). Anomalously low amplitude of S waves produced by the 3D structures in the lower mantle. Phys. Earth Planet. Inter., 256: 26–36. https://doi.org/10.1016/j.pepi.2016.04.001

It had been known that seismic waveform that sample the core-mantle boundary region in the central Pacific are distorted due to an ultra-low velocity zone located beneath Hawaii (To et al., 2011; Cottaar and Romanowicz, 2012), also considered as a root of the Hawaiian hotspot (French and Romanowicz, 2015). This paper further discusses the features of the distorted S-waves whose direct arrival phase disappear at some stations, and proposes a more detailed seismic structure, based on the observations, for the root of the plume. (Citation 4, GS/Sep. 30, 2019)

3. To, A., Obana K., Sugioka H., Araki E., Takahashi, N., and Fukao, Y. (2015). Small size very low frequency earthquakes in the Nankai accretionary prism, following the Tohoku-Oki earthquake. Phys. Earth Planet. Inter., 245: 40–51. https://doi.org/10.1016/j.pepi.2015.04.007

The first report on slow earthquakes (tremors and VLFEs) recorded by DONET1 that was deployed since 2010. They were triggered by 2011 Mw9.0 Tohoku-oki earthquake and occurred just beneath the DONET1 at very shallow depth. The paper also discussed about classification of local seismicity beneath DONET1. It concluded that VLFEs and tremors, the seismicity named differently due to the frequency ranges of observed signals, likely represent the same phenomenon of large and small magnitudes. (Citation 12, GS/Sep. 30, 2019)

4. To, A., Becker, J., Weber, B., Takaesu, M., Takahashi, N., Fukao, Y. and Tsuboi, S. (2014) Development of a SeisComP3 module for detecting micro earthquakes and its application to ocean bottom network data. JAMSTEC-R, 18: 1-16. https://doi.org/10.5918/jamstecr.18.1

We developed an automated system to monitor and archive seismic records from networks of different sizes, including DONET1, using an existing earthquake monitoring system SeisComP3. Since original target of SeisComP3 was on earthquakes in global or semi-global scales, the earthquake detections tended to fail for small sized local seismicity. To overcome the difficulty, we developed a new python module named "binder" that fits into the SeisComP3 messaging system. The development was successful and enabled the detection of earthquakes of magnitude down to 2 using DONET1 records.

5. To, A., Romanowicz, B., Capdeville, Y. and Takeuchi, N. (2005) 3D effects of sharp boundaries at the borders of the African and Pacific Superplumes: Observation and modeling. Earth and Planetary Science Letters, 233: 137-153. https://doi.org/10.1016/j.epsl.2005.01.037

It had been known that strong seismic anomalies exist near the core-mantle boundary, and quantitive estimation of the anomalies was crucial for revealing their causes (e.g. temperature anomaly or chemical anomaly). However most seismic analysis had been dependent on weak heterogeneity approximations. Here, we first showed observational evidence of a sharp lateral boundary structure at the southern edge of the Pacific superplume. Then, we conducted forward waveform modelling using the coupled mode/spectral element method, a method that can fully handle the strong lateral variations near the core-mantle boundary in 3D. The result showed that the velocity contrast across the sharp boundary becomes larger than in existing tomographic models, implying that the "superplume" features cannot be purely thermal. The study addressed the importance of rigorously including the 3D structural effects in the seismic waveform modelling. (Citation 112, GS/Sep. 30, 2019)

4. Awards and Honors

5. Future Research Plan

In the short term, I plan to reveal the detailed structures along the fault zone that host slow earthquakes, using new forward waveform modeling approach. The near-filed records of tremors infer that anomalous structures exist along the slow earthquake fault zone, which could also be a factor governing the slow earthquake occurrence process. Interestingly, it is a type of structure that would be poorly resolved with conventional structure-imaging methods based on inversion. Building on my experience on forward waveform modelling, we plan to quantify this anomalous structure together with some experts in numerical simulations of elastic wave propagation,

In the longer term, I plan to work on the following two subjects. The first subject is to further investigate the coupling effects between seismic source and the anomalous structures near the source, by not limiting the target to slow earthquakes. The second subject is a development of a system that allows semi-automatic and systematic examination of rapidly increasing seismic waveform data from ocean bottom and land. Currently, it is often considered that AI would take over the handling task of big data, which is probably partly true especially for handling "known" signals. However, identifications of unknown yet meaningful new signals seem to be still done by experienced researchers. My plan is to be involved in or develop a system that enables efficient browsing of seismic data.

6. Funding Received

- JSPS KAKENHI, 23740345, Principal Investigator, FY2011-2014, 4,030,000 yen
- JSPS KAKENHI, 15H06904, Principal Investigator, FY2015-2016, 2,600,000 yen
- JSPS KAKENHI, 19K04010, Principal Investigator, FY2019-2021, 4,420,000 yen

7. Publications and Patents

(1) Peer-reviewed Journal Articles

1. Tono, Y., Nishida, K., Fukao, Y., To, A. and Takahashi, N. (2014). Source characteristics of ocean

infragravity waves in the Philippine Sea: analysis of 3-year continuous network records of seafloor motion and pressure. Earth Planets Space, 66:99.

2. To, A., Becker, J., Weber, B., Takaesu, M., Takahashi, N., Fukao, Y. and Tsuboi, S. (2014). Development of a SeisComP3 module for detecting micro earthquakes and its application to ocean bottom network data. JAMSTEC-R, 18: 1-16.
3. To, A., Obana K., Sugioka H., Araki E., Takahashi, N., and Fukao, Y. (2015). Small size very low frequency earthquakes in the Nankai accretionary prism, following the Tohoku-Oki earthquake. Phys. Earth Planet. Inter., 245: 40–51.
4. To, A., Capdeville, Y., and Romanowicz, B.(2016). Anomalously low amplitude of S waves produced by the 3D structures in the lower mantle. Phys. Earth Planet. Inter., 256: 26–36.
5. Toh, A., Obana, K., and Araki, E. (2018). Distribution of very low frequency earthquakes in the Nankai accretionary prism influenced by a subducting-ridge. Earth and Planetary Science Letters, 482: 342–356.

(2) Non-peer-reviewed Articles

(3) Review Papers

(4) Books

(5) Other Publications

(6) Patents

8. Keynote, Invited, or Solicited Presentations

III. Education Activity

9. Notable Achievements in Education

Advisees

Lectures

- Undergraduate, Computation and programming exercise in earth and planetary science, FY2019
  Four teachers were in charge. I was in charge of scoring 20 points out of 100 points.

Student's awards

IV. External Activities

10. Contribution to Academic Community

- Marine Geophysical Research, Editorial Board, FY2016-2017

11. Outreach Activity

12. Internal Committee Membership

V. International Exchange Activities

13. Hosting/Sending Foreign Students and Researchers

(1) Hosting: 1

(2) Sending

Students: 0

Researchers: 0

(3) Visitors from Abroad: 1

Geosphere and Biosphere Science Group

Kazuyoshi Endo

I. CV

Name: Kazuyoshi Endo

Age: 56

Present Position: Professor

Education

Niigata High School, Niigata, Mar., 1981 (graduation)

B. Sc. Department of Geology, The University of Tokyo, Mar., 1985

M. Sc. Department of Geology, The University of Tokyo, Mar., 1987

Ph. D. Department of Geology, The University of Glasgow, Jul., 1992

Professional Experience

Apr. 1992-Mar. 1993, Postdoctoral Fellow, Japan Society for the Promotion of Science, The University of Tokyo

Apr. 1993-May 2002, Research Associate, Department of Geology, The University of Tokyo

Jun. 2002-Mar. 2010, Associate Professor, Graduate School of Life and Environmental Sciences, The University of Tsukuba

Apr. 2010-, Professor, Department of Earth and Planetary Science, The University of Tokyo

II. Scientific Research Activity

2. Major Achievements

I have been working on living brachiopods and molluscs so as to understand the origins and evolution of the skeletons in lophotrochozoans. Major achievements include: (1) Lophotrochozoan genomics – sequenced the pearl oyster (1,150 Mbp) and the *Lingula* (425 Mbp) genomes for the first time in molluscs and brachiopods, respectively, revealing their gene contents and gene structures, producing the bases for functional analyses of their genes, and showing that brachiopods are closer to molluscs than to annelids among lophotrochozoans. (2) Structures of animal mitochondrial (mt) genomes – characterized the complete primary structures of the mt-genome of the brachiopod *Lingula*, revealing that *Lingula* mt-genomes have gene arrangements and repetitive sequences, which are completely different from those of other animals, and indicative of frequent occurrence of recombination. (3) Structure, function, and evolution of shell matrix proteins (SMPs) – characterized the complete primary structures of super-acidic SMPs in molluscs for the first time, showing indirect evidence that they control the crystal polymorphism in carbonate shells. From combined mantle transcriptome and shell proteome analyses, brachiopod and mollusc SMPs have been comprehensively analyzed, revealing that they share a number of common domain structures, while they have evolved very quickly at the gene sequence levels. (4) Genetic basis of shell spiral growth – discovered that the signal transduction factor Dpp is responsible for the control of spiral growth in molluscan shells.

3. Five Important Papers (including three or more papers in this review period)

1. Tsukamoto, D., Sarashina, I., & Endo, K. (2004). Structure and expression of an unusually acidic matrix protein of pearl oyster shells. Biochemical and Biophysical Research Communications,

320(4), 1175-1180. https://doi.org/10.1016/j.bbrc.2004.06.072

Report on the primary structure and gene expression patterns in the mantle of the super-acidic shell matrix protein Aspein isolated from the pearl oyster *Pinctada fucata*. Aspartate residues occupy 60 % of the whole sequence of Aspein, making it the protein with the lowest theoretical isoelectric point among known proteins. The Aspein gene is expressed in the outer part of the mantle, corresponding to the calcitic prismatic shell layer, while it is not expressed in the inner part of the mantle, corresponding to the aragonitic nacreous shell layer, suggesting that Aspein could be involved in the formation of shell microstructures and/or carbonate crystal polymorphism. (Citation 200, GS/Sept. 20, 2019)

2. Endo, K., Noguchi, Y., Uechima, R., & Jacobs, H. T. (2005). Novel repetitive structures, deviant protein-encoding sequences and unidentified ORFs in the mitochondrial genome of the brachiopod *Lingula anatina*. Journal of Molecular Evolution, 61(1), 36-53. DOI: 10.1007/s00239-004-0214-5

Report on the complete sequence of the mt-genome of the brachiopod *Lingula anatina*, showing that the genome is much larger than those of other animals, that the gene orders are completely different from those of other animal mt-genomes, and that the genome contains complex repetitive structures, including those of nested ones, suggesting that the genome has experienced frequent recombination events, which are considered not to occur in animal mt-genomes. Since the sequence is so bizarre that even colleagues in this field only half believed the story, but a second mt-genome for a different sibling species was sequenced in 2015 in the genome project of *Lingula*, confirming that *Lingula* indeed has a bizarre mt-genome. (Citation 35, GS/Sept. 20, 2019)

3. Shimizu, K., Iijima, M., Setiamarga, D. H. E., Sarashina, I., Kudoh, T., Asami, T., Gittenberger, E., & Endo, K. (2013). Left-right asymmetric expression of dpp in the mantle of gastropods correlates to the asymmetric shell coiling. BMC EvoDevo, 4, 15. DOI:10.1186/2041-9139-4-15

This study demonstrated that the signal transduction factor Dpp is expressed asymmetrically in the shell gland, where the shell is first formed during development, and in the mantle, where the shell is formed later in development, in the pond snail *Lymnaea stagnalis*. Taken together with the observation that a straight cone shell, rather than the normally coiled shell, is formed when the embryos are treated with a chemical that inhibit the Dpp signal transduction pathway, Dpp is considered as an agent involved in the control of “curving” in the spiral growth of molluscan shells. (Citation 19, GS/Sept. 20, 2019)

4. Takeuchi, T., Kawashima, T., Koyanagi, R., Gyoja, F., Tanaka, M., Ikura, T., Shoguchi, E., Fujiwara, M., Shinzato, C., Hisata, K., Fujie, M., Usami, T., Nagai, K., Maekawa, K., Okamoto, K. Aoki, H., Ishikawa, T., Masaoka, T., Fujiwara, A. Endo, K., Endo, H., Nagasawa, H., Kinoshita, S., Asakawa, S., Watabe, S., & Satoh, N. (2014). Draft genome of the pearl oyster *Pinctada fucata*: a platform for understanding bivalve biology. DNA Research, 19(2), 117-130. https://doi.org/10.1093/dnares/dss005

Report on the genome sequence of the pearl oyster *Pinctada fucata*, revealing its gene content and gene structures, including the gene paralogs for all the shell matrix proteins characterized before. It represents the first genome to be completely sequenced among molluscs or lophotrochozoans. As such, it demonstrated, for the first time based on phylogenomic analysis, that lophotrochozoans are closer to the ecdysozoans than to deuterostomes. This study was carried out by the leadership of the researchers in Okinawa Institute of Science and Technology (OIST). As is also the case for the *Lingula* genome project described below, this genome project was started by the appeal of mine to the Principal Investigator Dr. Nori Satoh in OIST. The first author of this paper is a postdoc in Satoh’s lab, who took his PhD under my supervision. A version 2 of this genome sequence was published in 2016 by the same authors. (Citation 232, GS/Sept. 20, 2019)

5. Luo, Y.-J., Takeuchi, T., Koyanagi, R., Yamada, L., Kanda, M., Khalturina, M., Fujie, M., Yamasaki, S., Endo, K., & Satoh N. (2015). The *Lingula* genome provides insights into brachiopod evolution and the origin of phosphate biomineralization. Nature Communications, 6,

8301. DOI: 10.1038/ncomms9301

Report on the genome sequence, transcriptomes of different adult tissues and of different developmental stages, and shell proteome in the brachiopod *Lingula anatina*, revealing the gene set involved in its body plan formation, including biomineralization of the phosphatic shells. Phylogenetic analysis indicated that the collagens contained in the *Lingula* shells evolved independent from those contained in vertebrate bones. Phylogenomic analysis demonstrated that brachiopods are more closely related to molluscs than to annelids. (Citation 73, GS/Sept. 20, 2019)

4. Awards and Honors

5. Future Research Plan

I aim at establishing a new paleobiological field which may be called Paleo/Evo/Devo. It reconsiders the evolutionary histories of adult morphologies inferred based on fossils as histories of changes in developmental programs. Morphological evolution has been overwhelmed with interpretations based on either phylogeny or adaptation, or both. Under this view, developmental processes, which are essential to understand phylogeny, adaptation, and morphological evolution, have been overlooked as black box. Recent advancement in developmental genetics made it possible to make clear the genetic bases on which the morphologies manifested by fossils developed and evolved. A key aspect here is *in vivo* functional analyses of the genes that control the development of hard tissues that are often preserved as fossils. The recently developed techniques of genome editing, e.g., CRISPR/Cas9, are especially relevant. In the next few years, I try to elucidate the molecular mechanisms of skeletal formation in fossiliferous lophotrochozoans using those methodologies. Another important issue in the field of geobiology is the understanding of causal relationships between environmental changes and organismal evolution. I plan to address this issue by studying arguably among the largest environmental changes, i.e., the rise of atmospheric oxygen, through reconstructions of ancestral genome sequences of key evolutionary nodes, and functional analyses of their gene products. I also study genetic codes, which could have evolved in accordance with the rise of oxygen.

6. Funding Received

・ JSPS KAKENHI, 26610165, Principal Investigator, FY2014-2016, 3,640,000 yen
・ JSPS KAKENHI, 18H01323, Principal Investigator, FY2018-2022, 17,160,000 yen
・ JSPS KAKENHI, 17H01673, Co-Investigator, FY2012-2016, 40,820,000 yen
・ JSPS KAKENHI, 26400498, Co-Investigator, FY2014-2016, 4,860,000 yen
・ JSPS KAKENHI, 17H02977, Co-Investigator, FY2017-2020, 17,940,000 yen
・ JSPS KAKENHI, 17H01673, Co-Investigator, FY2017-2021, 38,610,000 yen
・ JSPS KAKENHI, 18H03962, Co-Investigator, FY2018-2021, 44,200,000 yen

7. Publications and Patents

(1) Peer-reviewed Journal Articles

1. Isowa, Y., Sarashina, I., Setiamarga, D. H. E., & Endo, K. (2012). A Comparative Study of the Shell Matrix Protein Aspein in Pterioid Bivalves. J. Mol. Evol., 75, 11-18. DOI: 10.1007/s00239-012-9514-3
2. Takeuchi, T., Kawashima, T., Koyanagi, R., Gyoja, F., Tanaka, M., Ikura, T., Shoguchi, E., Fujiwara, M., Shinzato, C., Hisata, K., Fujie, M., Usami, T., Nagai, K., Maekawa, K., Okamoto, K. Aoki, H., Ishikawa, T., Masaoka, T., Fujiwara, A. Endo, K., Endo, H., Nagasawa, H., Kinoshita,

S., Asakawa, S., Watabe, S., & Satoh, N. (2012). Draft genome of the pearl oyster *Pinctada fucata*: a platform for understanding bivalve biology. DNA Research, 19(2), 117-130. https://doi.org/10.1093/dnares/dss005

3. Miyamoto, H., Endo, H., Hashimoto, N., Iimura, K., Isowa, Y., Kinoshita, S., Kotaki, T., Masaoka, T., Miki, T., Nakayama, S., Nogawa, C., Notazawa, A., Ohmori, F., Sarashina, I., Suzuki, M., Takagi, R., Takahashi, J., Takeuchi, T., Yokoo, N., Satoh, N., Toyohara, H., Miyashita, T., Wada, H., Samata, T., Endo, K., Nagasawa, H., Asakawa, S., & Watabe, S. (2013). The diversity of shell matrix proteins: genome-wide investigation of the pearl oyster *Pinctada fucata*. Zoological Science, 30, 801-816. DOI: 10.2108/zsj.30.801
4. Kawashima, T., Takeuchi, T., Koyanagi, R., Kinoshita, S., Endo, H.& Endo, K. (2013). Initiating the mollusk genomics annotation community: Toward creating the complete curated gene-set of the Japanese pearl oyster, *Pinctada fucata*. Zoological Science, 30, 794-796. DOI: 10.2108/zsj.30.794
5. Setiamarga, D., Shimizu, K., Kuroda, J., Inamura, K., Sato, K., Isowa, Y., Ishikawa, M., Maeda, R., Nakano, T., Yamakawa, T., Hatori, R., Ishio, A., Kaneko, K., Matsumoto, K., Sarashina, I., Teruya, S., Ran Zhao, Satoh, N., Sasaki, T., Matsuno, K., & Endo, K. (2013). An in-silico genomic survey to annotate genes coding for early development-relevant signaling molecules in the pearl oyster Pinctada fucata. Zoological Science, 30, 877-888. DOI: 10.2108/zsj.30.877
6. Shimizu, K., Iijima, M., Setiamarga, D. H. E., Sarashina, I., Kudoh, T., Asami, T., Gittenberger, E., & Endo, K. (2013). Left-right asymmetric expression of dpp in the mantle of gastropods correlates to the asymmetric shell coiling. BMC EvoDevo, 4, 15. DOI:10.1186/2041-9139-4-15
7. Endo, K., & Takeuchi, T. (2013). Annotation of the pearl oyster genome. Zoological Science, 30, 779-780. DOI: 10.2108/zsj.30.779
8. Pérez-Huerta, A., Aldridge, A. E., Endo, K., & Jeffries, T. E. (2014). Brachiopod shell spiral deviations (SSD): Implications for trace element proxies. Chemical Geology, 374-375, 13-24. http://dx.doi.org/10.1016/j.chemgeo.2014.03.002
9. Isowa, Y., Sarashina, I., Oshima, K., Kito, K., Hattori, M., & Endo, K. (2015). Proteome analysis of shell matrix proteins in the brachiopod *Laqueus rubellus Proteome Science*, 13, 21. DOI:10.1186/s12953-015-0077-2
10. Luo, Y.-J., Takeuchi, T., Koyanagi, R., Yamada, L., Kanda, M., Khalturina, M., Fujie, M., Yamasaki, S., Endo, K., & Satoh, N. (2015). The *Lingula* genome provides insights into brachiopod evolution and the origin of phosphate biomineralization. Nature Communications, 6, 8301. DOI: 10.1038/ncomms9301
11. Luo, Y.-J., Satoh, N., & Endo, K. (2015). Mitochondrial gene order variation in the brachiopod *Lingula anatina* and its implications for mitochondrial evolution in lophotrochozoans. Marine Genomics, 24, 31-40. DOI: 10.1016/j.margen.2015.08.005
12. Shimizu, K., & Endo, K. (2015). *Evo-Devo* of spiral shell growth in gastropods. *Biological Shape Analysis,* World Scientific, 130-137.
13. Clark, J. V., Aldridge, A. E., Reolid., M., Endo, K., & Pérez-Huerta, A. (2015). Application of shell spiral deviation methodology to fossil brachiopods: Implications for obtaining specimen ontogenetic ages. Palaeontologia Electronica, 18.3.54A: 1-39.
14. Takeuchi, T., Koyanagi, R., Gyoja, F., Kanda, M., Hisata, K., Fujie, M., Goto, H., Yamasaki, S., Nagai, K., Morino, Y., Miyamoto, H., Endo, K., Endo, H., Nagasawa, H., Kinoshita, S., Asakawa, S., Watabe, S., Satoh, N., & Kawashima, T. (2016). Bivalve-specific gene expansion in the pearl oyster genome: Implications of adaptation to a sessile lifestyle. Zoological Letters, 2, 3. DOI: 10.1186/s40851-016-0039-2

15. Shimizu, K., Luo, Y.-J., Satoh, N., & Endo, K. (2017). Possible co-option of *engrailed* during brachiopod and mollusc shell development. Biology Letters, 13, 20170254.
16. Cusack, M., Chung, P., Zhu, W., & Endo, K. (2018). Tuning of calcite crystallographic orientation to support brachiopod lophophore. Advanced Engineering Materials, 20, 1800191. DOI:10.1002/adem.201800191.
17. Zhao, R., Takeuchi, T., Luo, Y.-J., Ishikawa, A., Kobayashi, T., Koyanagi, R., Villar-Briones, A., Yamada, L., Sawada, H., Iwanaga, S., Nagai, K., Satoh, N., & Endo, K. (2018). Dual gene repertoires for larval and adult shells reveal molecules essential for molluscan shell formation. Molecular Biology and Evolution, 35, 2751-2761. DOI:10.1093/molbev/msy172
18. Shimizu, K., Kimura, K., Isowa, Y., Oshima, K., Ishikawa, M., Kagi, H., Kito, K., Hattori, M., Chiba, S., & Endo, K. (2018). Insights into the evolution of shells and love darts of land snails revealed from their matrix proteins. Genome Biology and Evolution, 11, 380-397. doi.org/10.1093/gbe/evy242

(2) Non-peer-reviewed Articles

(3) Review Papers

1. Setiamarga, D. & Endo, K. (2015). Transcriptome and proteome analyses of the Nautilus' shell matrix proteins: Insights into their evolution in Mollusks. Book of Abstracts (Proceeding) of CIAC 2015, p. 42.

(4) Books

1. Endo, K., Kogure, T., & Nagasawa, H. (eds.) (2018). Biomineralization. From molecular and nano-structural analysis to environmental science. Springer Open.

(5) Other Publications

(6) Patents

8. Keynote, Invited, or Solicited Presentations

1. Endo, K. (2016) Genomic natural history of the brachiopod *Lingula*, International Symposium in Commemoration of the 130th Anniversary of MMBS, Koshiba Hall, University of Tokyo, 2016/11/21.

III. Education Activity

9. Notable Achievements in Education

Advisees

- Master theses: 6 students

  Akito Ishikawa (Mar. 2015)
  Ryo Sugano (Mar. 2016)
  Akane Shingu, Tatsushi Kobayashi (Mar. 2017)
  Tomohiro Sasaki (Mar. 2018)
  Nanami Suzuki (Mar. 2019)

- Doctoral theses: 4 students

  Keisuke Shimizu (Mar. 2014)
  Kentaro Izumi (Mar. 2015)

Yukinobu Isowa (Mar. 2016)
Zhao Ran (May 2019)

Lectures

- Undergraduate/Graduate, Evolutionary Biology, FY 2012-2018
- Undergraduate, Lecture and Practical: Biodiversity Science, FY 2012-2018
- Undergraduate, Paleontology, FY 2012-2018
- Undergraduate, Introductory Earth System Evolution, FY 2012-2018
- Undergraduate, Evolutionary Biology, 2012-2018
- Undergraduate, Field Excursion: Earth and Planetary Environmental Science I, FY 2012-2017
- Undergraduate/Graduate, Basic Stratigraphy and Geology, FY 2012-2016
- Graduate, Basic Ocean Sciences, FY2015-2018
- Graduate, Evolution of the Biosphere, FY 2013, 2015, 2017
- Graduate, Mechanisms of Biomineralization, FY 2013, 2015, 2017
- Graduate, Special Lectures on Macrobiology, FY 2015-2018
- Osaka City University, Graduate, Special Lectures, 2012/7/25-7/27
- Kanagawa University, Undergraduate, Special Lectures, 2015/8/3-8/5.
- Shizuoka University, Undergraduate, Special Lectures, 2018/9/24-9/25.
- University of the Sacred Heart, Undergraduate, Evolutionary Theory, FY 2014-2017

Student's awards

- Society of Evolutionary Studies, Japan, Best Poster Award: 1 student [Keisuke Shimizu]
- Society of Evolutionary Studies, Japan, Outstanding Young Scientist Presentation Award: 1 student [Keisuke Shimizu]
- Palaeontological Society of Japan, Best Poster Award: 2 students [Keisuke Shimizu, Kentaro Izumi]
- Sedimentological Society of Japan, Best Poster Award: 1 student [Kentaro Izumi]
- Japan Geoscience Union, Student Presentation Award: 2 students [Keisuke Shimizu, Kentaro Izumi]

IV. External Activities

10. Contribution to Academic Community

- Palaeontological Society of Japan, Councillor, FY2012-2018
- Palaeontological Society of Japan, Member of Standing Committee, FY2012-2018
- Palaeontological Society of Japan, Chair of the IPC5 Bid Committee, FY2013-2014
- Japan Geoscience Union, Representative Member, FY2012-2018
- Japan Geoscience Union, President of the Biogeosciences Section, FY2016-2018
- Society of Evolutionary Studies, Japan, Chair of the Organization Committee for the 17th Annual Meeting, FY2015
- Society of Evolutionary Studies, Japan, Councilor, FY2018
- Association for Propagation of the Knowledge of Genetics, Member of Journal Editorial Committee, FY2012-2018

- Science Council of Japan, Sub-committee for IPA, Member, FY2012-2018
- Organization Committee for the 14th International Symposium on Biomineralization, Member, FY2017
- International Paleontological Association, Delegate from PSJ, FY2012-2018

11. Outreach Activity

- Japan Wildlife Research Center (Ministry of the Environment), Assessment Committee for the Red List of threatened species of marine organisms, Member, FY2012-2018
- Nomination Committee for International Prize for Biology (Japan Society for the Promotion of Science), Member, FY2016
- Coordinating Committee for Commemorative Symposium for the 32nd International Prize for Biology(Japan Society for the Promotion of Science), Chair, FY2016
- Research Grant Reviewing Committee, Fujiwara Natural History Foundation, Member, FY2017
- KAKENHI Review, FY2013-2014, 2017-2018
- Asahi Culture Center, Lecturer, 2016/12/24, 2017/7/22, 2019/2/23
- Tokyo Metropolitan Tachikawa Kokusai Secondary Education School, Lecturer, Feb., 2017
- Expert advice for program production for NHK BS, May, 2014

12. Internal Committee Membership

- School of Science Committee for Department of Bioinformatics and Systems Biology, The University of Tokyo, Member, FY2012-2018
- School of Science, School Affairs Committee, Member, FY2015
- School of Science, Admission Committee, Member, FY2013-2014, 2016-2018
- School of Science, Admission Committee, Chair, FY2017
- University of Tokyo, Committee for Teacher-Training Course, Member, FY2012-2018
- University Museum, University of Tokyo, Department of Historical Geology and Palaeontology, Chair, FY2012-2018

V. International Exchange Activities

13. Hosting/Sending Foreign Students and Researchers

(1) Hosting

Foreign Students: 1

Foreign Researchers: 3

(2) Sending

Students: 5

Researchers: 3

(3) Visitors from Abroad: 3

Akihiro Kano

I. CV

Name: Akihiro Kano

Age: 59

Present Position: Professor

Education

Sendai Daiichi High School, Sendai, March, 1979 (graduation)

B. Sc. Department of Geology & Paleontology, Tohoku University, March, 1983

M. Sc. Department of Geology & Paleontology, Tohoku University, March, 1985

Ph. D. Department of Geology & Geochemistry, Stockholm University, August, 1990

Professional Experience

Oct. 1990-July. 2002, Research Assistant, Department of Earth & Planetary System Sciences, Hiroshima University

Aug. 2002-Mar. 2008, Associate Professor, Department of Earth & Planetary System Sciences, Hiroshima University

Apr. 2008-Nov. 2016, Professor, Department of Social and Cultural Study, Kyushu University

Dec. 2016-, Professor, Department of Earth and Planetary Science, The University of Tokyo

II. Scientific Research Activity

2. Major Achievements

I have been studying carbonate rocks to reconstruct the environmental conditions and the biological evolution in the Earth history. My several research topics that cover different ages and time-scales can be summarized into three. In studies on laminated freshwater deposits, continuous investigation by my research team identified that the laminations of tufas and the lamination of travertines are annual and daily, respectively. We also suggested that the isotopic and elemental signature in tufas could be used for paleoclimatic records. Important outcomes of the travertine research were recently compiled in a textbook. Knowledge from these studies was extended to paleoclimatic researches using stalagmites. Stable isotopic compositions of the Japanese stalagmites represent the changes in temperature and rainfall with time intervals from tens to thousands of years. In 2005, I lead the IODP project that drilled a deep-sea coral mound in Irish offshore. In this project I successfully developed the age-model of the coral mound cores revealing that the deep-sea coral mounds in NE Atlantic were developed with the modern oceanic structure when climatic cooling in the northern hemisphere started around 2.6 Ma. I am also studying drastic climatic changes and biological evolution during late Neoproterozoic. Based on the research results in China, Brazil, and Austlaria, I have proposed a novel hypothesis that explains crucial relationship between the climatic change and the biological evolution. In addition, I am working on carbonate clumped isotopes, a new technique to reconstruct temperature of the past.

3. Five Important Papers (including three or more papers in this review period)

1. Kano, A., Ferdelman, T. G., Williams, T., Henriet, J. P., Ishikawa, T., Kawagoe, N., Takashima, C., Kakizaki, Y., Abe, K., Sakai, S., Browning, E.L., Li, X. and Integrated Ocean Drilling

Program Expedition 307 Scientists (2007). Age constraints on the origin and growth history of a deep-water coral mound in the northeast Atlantic drilled during Integrated Ocean Drilling Program Expedition 307. *Geology*, *35*(11), 1051-1054. https://doi.org/10.1130/G23917A.1

The deep-sea coral mound drilled by IODP Expedition 307 in 2005 is a 150-m-thick sediment body developed at 800 m deep in Irish offshore. The sediment consists of fine-grained calcareous mud and fragments of coral skeletons. We first presented the age model based on strontium isotope, which reveals that the coral mound started growing around 2.6 Ma when the climatic cooling started in northern hemisphere. The principle requirement for the deep-sea coral mound is suspending particles organic matter that is currently concentrated at -800 m where a density gradient occurs in water column in the northeastern Atlantic. This study improved our understanding on the origin and history of the deep-sea coral mounds in Atlantic. （Citation 87, GS/Aug. 20, 2019）

2. Shen, C. C., Wu, C. C., Cheng, H., Edwards, R. L., Hsieh, Y. T., Gallet, S., Chang, C.-C., Li, T.-Y., La,. D. D., Kano, A., Hori, M. & Spötle (2012). High-precision and high-resolution carbonate ^{230}Th dating by MC-ICP-MS with SEM protocols. *Geochimica et Cosmochimica Acta*, *99*, 71-86. https://doi.org/10.1016/j.gca.2012.09.018

Dating based on uranium-thorium isotopic composition in carbonate minerals is the principle technique for the Quaternary paleoclimatology. This paper synthesized resent improvements of this dating technique and proposed the standard practical protocols. I contributed by providing data from a stalagmite collected in Hiroshima Prefecture, and by proposing the preferable procedures of sample preparation and isotopic analyses. (Citation 145, GS/Aug. 20, 2019)

3. Furuyama, S., Kano, A., Kunimitsu, Y., Ishikawa, T., & Wang, W. (2016). Diagenetic overprint to a negative carbon isotope anomaly associated with the Gaskiers glaciation of the Ediacaran Doushantuo Formation in South China. Precambrian Research, 276, 110-122. https://doi.org/10.1016/j.precamres.2016.01.004

Geochemistry of the Neoproterozoic sedimentary carbonate records the unusual climatic conditions and ocean circulation. In this study, we investigate the Ediacaran carbonate of the Doushantuo Formation in South China, and found that the diagenetic control to the negative carbon isotopic anomaly corresponding to the Gaskies glaciation. Methenogenesis in anoxic shallow subsurface generated calcite cements having very low carbon isotopic composition. (Citation 13, GS/Aug. 20, 2019)

4. Mori, T., Kashiwagi, K., Amekawa, S., Kato, H., Okumura, T., Takashima, C., Wu, C.-C., Shen, C.-C., Quade, J. & Kano, A. (2018). Temperature and seawater isotopic controls on two stalagmite records since 83 ka from maritime Japan. Quaternary Science Reviews, 192, 47-58. https://doi.org/10.1016/j.quascirev.2018.05.024

This study deals with climate changes since 83 ka, which were recorded in stable oxygen isotopes of two stalagmites collected from Mie and Gifu Prefectures. Considering with isotopic composition of rainwater collected near the caves, the stalagmite records refuted the previous interpretation that the stalagmite oxygen isotopes record the change in rainfall intensity. Our new interpretation associates the stalagmite oxygen isotopes with the change in temperature and the isotopic composition of sseawater. (Citation 1, GS/Jul. 29, 2019)

5. Kato, H., Amekawa, S., Kano, A., Mori, T., Kuwahara, Y., & Quade, J. (2019). Seasonal temperature changes obtained from carbonate clumped isotopes of annually laminated tufas from Japan: Discrepancy between natural and synthetic calcites. Geochimica et Cosmochimica Acta, 244, 548-564. https://doi.org/10.1016/j.gca.2018.10.016

Carbonate clumped isotopes provide a novel paleo-thermometer, however there are serious discrepancies in paleo-temperature estimates fro natural samples. In this study clumped isotopes were analyzed for two sample sets of synthetic calcites and tufas collected monthly from two sites in southwest Japan with known oxygen isotopes and temperatures of parent water. Our analytical results provided a new temperature calibration that can applyed to natural carbonate formed in freshwater environments. Our function is expected to be used the future research in carbonate clumped isotopic thermometry. (Citation 1, GS/Aug. 20, 2019)

4. Awards and Honors

5. Future Research Plan

I will continue studies on sedimentary carbonates on the basis of my research expertizes. I would concentrate the research project decoding paleoclimate information recorded in stalagmites and tufas. This research field connecting the future climate changes is expected to gather attention. Especially, the records of warmer interval of Holocene and Pleistocene may provide the images of terrestrial climate after the global warming, and also test the numeric climate models. I would also pay my effort to the catastrophic climatic changes in Neoproterozoic. I will start working on evaporate sediments that contains geochemical signatures of climate condition and seawater chemistry in the early Earth. This may provide key information to unsolved problem of the Earth history including the initiation of Snowball Earth, ocean circulation and biologic evolution during the Neoproterozoic interglacial. I would also expand my international relationship with USA, China, Brazil, Indonesia, and Australia, which improves the educational effect to our students.

6. Funding Received

- JSPS KAKENHI, 23403014, Principal Investigator, FY2010-2014, 17,030,000 yen
- JSPS KAKENHI, 24654163, Principal Investigator, FY2012-2013, 3,770,000 yen
- JSPS KAKENHI, 25287131, Principal Investigator, FY2013-2016, 13,130,000 yen
- JSPS KAKENHI, 16H02235, Principal Investigator, FY2016-2019, 42,510,000 yen
- JSPS KAKENHI, 18KK0094, Principal Investigator, FY2018-2021, 15,340,000 yen
- JSPS KAKENHI, 15K13580, Principal Investigator, FY2015-2016, 3,770,000 yen
- JSPS KAKENHI, 15H01729, Co-Investigator, FY2015-2018, 400,000 yen
- JSPS KAKENHI, 18H04142, Co-Investigator, FY2018-2021, 400,000 yen

7. Publications and Patents

(1) Peer-reviewed Journal Articles

1. Shen, C.-C., Wu, C.-C., Cheng, H., Edwards, R.L., Hsieh, Y.-T., Gallet, S., Chang, C.-C., Li, T.-Y., Lam, D.D., Kano, A., Hori, M., & Spotl, C. (2012). High-precision and high-resolution carbonate 230Th dating by MC-ICP-MS with SEM protocols. Geochimica et Cosmochimica Acta, 99, 71-86.
2. Hasegawa, T., Crampton, J., Shololer, P., Field, B., Fukushi, K., & Kakizaki, Y. (2012). Carbon isotope stratigraphy and depositional oxia through Cenomanian-Turonian boundary sequences (Upper Cretaceous) in New Zealand. Cretaceous Research, 40, 61-80.
3. Okumura, T., Takashima, C., Shiraishi, F., Akmaluddin, & Kano, A. (2012). Textural transition in an aragonite travertine formed under various flow conditions at Pancuran Pitu, Central Java, Indonesia. Sedimentary Geology, 265-266, 195-209.
4. Kakizaki, Y., Ishikawa, T., Nagaishi, K., Tanimizu, M., Hasegawa, T., & Kano, A. (2012). Strontium isotopic ages of the Torinosu-type limestones (latest Jurassic to earliest Cretaceous, Japan): implication for biocalcification event in northwestern Palaeo-Pacific. Journal of Asian

Earth Sciences, 46, 140-149.

5. Li, X.-H., Kano, A., Chen, Y.-H., Takashima, C., Xu, W.-L., Xu, B.-L., Wang, R.-J. & IODP Leg 307 Scientists (2012). Quaternary primary productivity in Porcupine Seabight, NE North Atlantic. Science China Earth Science, 55, 306-314.

6. Sone, T., Kano, A., Okumura, T., Kashiwagi, K., Hori, M., Jiang, X., & Shen, C.-C. (2013). Holocene stalagmite oxygen isotopic record from the Japan Sea side of the Japanese Islands, as a new proxy of the East Asian winter monsoon. Quaternary Science Reviews, 75, 150-160.

7. Okumura, T., Takashima, C., & Kano, A. (2013). Textures and processes of laminated travertines formed by unicellular cyanobacteria in Myoken hot spring, southwestern Japan. Island Arc, 22, 410-426

8. Kakizaki, Y., Weissert, H.J., Hasegawa, T., Ishikawa, T., Matsuoka, J., & Kano, A. (2013). Strontium and carbon isotope stratigraphy of the Late Jurassic shallow marine limestone in western Palaeo-Pacific, northwest Borneo. Journal of Asian Earth Sciences, 73, 57-67.

9. Okumura, T., Takashima, C., Shiraishi, F., Nishida, S., & Kano, A. (2013). Processes forming daily lamination in a microbe-rich travertine under low flow condition at the Nagano-yu Hot Spring, Southwestern Japan. Geomicrobiology Journal, 30, 910-927.

10. Hori, M., Ishikawa, T., Nagaishi, K., Lin, K., Wang, B.-S., You, C.-F., Shen, C.-C., & Kano, A. (2013). Prior calcite precipitation and source mixing process influence Sr/Ca, Ba/Ca and $^{87}Sr/^{86}Sr$ of a stalagmite developed in southwestern Japan during 18.0-4.5 ka. Chemical Geology, 347, 190-198.

11. Furuyama, S., Kano, A., Kuminitsu, Y. Osanai, Y., Adachi, T., Liu, X., & Wang, W. (2013). Ediacaran mineralized microfossils from the basinal facies of the Doushantuo Formation in northwestern Hunan Province, South China. Paleontological Research, 17, 241-250.

12. Liu, X., Wang, W., Shen, S., Gorgij, M.N., Ye, F., Zhang, Y., Furuyama, S., Kano, A., & Chen, X. (2013). Late Guadalupian to Lopingian (Permian) carbon and strontium isotopic chemostratigraphy in the Abadeh section, central Iran. Gondwana Research, 24, 222-232.

13. Kakizaki, Y., & Kano, A. (2014). Carbon isotope stratigraphy of the Torinosu-type limestone in western Paleo-Pacific and its implication to paleoceanography in the late Jurassic and earliest Cretaceous. Island Arc, 23, 16-32.

14. Hori, M., Ishikawa, T., Nagaishi, K., You, C.-F., Huang, K.-F., Shen, C.-C., & Kano, A. (2014). Rare earth elements in a stalagmite from southwestern Japan: a potential proxy for chemical weathering. Geochemical Journal, 48, 73-84.

15. Sone, T., Kano, A., Kashiwagi, K., Mori, T., Okumura, T., Shen, C.-C., & Hori, M. (2015). Two modes of climatic control in the Holocene stalagmite record from the Japan Sea side of the Japanese islands. Island Arc, 24, 342-358.

16. Furuyama, S., Kano, A., Kunimitsu, Y., Ishikawa, T., & Wang, W. (2016). Diagenetic overprint to a negative carbon isotope anomaly associated with the Gaskiers glaciation of the Ediacaran Doushantuo Formation in South China. Precambrian Research, 276, 110-122. https://doi.org/10.1016/j.precamres.2016.01.004

17. Fujita, M., Yamasaki, S., Katagiri, C., Oshiro, I., Sano, K., et al. (Kano, A., 19 人中 10 番目). (2016). Advanced maritime adaptation in the western Pacific coastal region extends back to 35,000-30,000 years before present. Proceedings of the National Academy of Science of USA, 113, 11184-11189. https://doi.org/10.1073/pnas.1607857113

18. Furuyama, S., Kano, A., Kunimitsu, Y., Ishikawa, T., Wang, W., & Liu, X. C. (2017). Chemostratigraphy of the Ediacaran basinal setting on the Yangtze platform, South China: Oceanographic and diagenetic aspects of the carbon isotopic depth gradient. Island Arc, 26(5),

e12196. https://doi.org/10.1111/iar.12196

19. Shiraishi, F., Hanzawa, Y., Okumura, T., Tomioka, N., Kodama, Y., Suga, H., Takahashi, Y., & Kano, A. (2017). Cyanobacterial exopolymer properties differentiate microbial carbonate fabrics. Scientific reports, 7(1), 11805. https://www.nature.com/articles/s41598-017-12303-9
20. Kalanat, B., Gharaie, M. H., Vahidinia, M., Vaziri-Moghaddam, H., & Kano, A. (2017). Nitrogen isotope variations and environmental perturbations during Cenomanian-Turonian transition in the NE Tethyan realm, Koppeh-Dagh basin. Geopersia, 7(1), 1-9. https://doi.org/10.1029/2018JB015642
21. Kano, A., Miyahara, R., Yanagawa, K., Mori, T., Owari, S., Tomaru, H., Kakizaki, Y., Glen, S., Shimono, T., Kakuwa, Y., & Matsumoto, R. (2017). Gas hydrate estimates in muddy sediments from the oxygen isotope of water fraction. Chemical Geology, 470, 107-115. https://doi.org/10.1016/j.chemgeo.2017.08.027
22. Shiraishi, F., Nakao, K., Takashima, C., Kano, A., & Itai, T. (2018). Fe (II) oxidation processes at the surface of bacterially colonized iron deposits. Chemical Geology, 476, 161-170. https://doi.org/10.1016/j.chemgeo.2017.11.014
23. Kalanat, B., Mahmudy-Gharaie, M. H., Vahidinia, M., Vaziri-Moghaddam, H., Kano, A., & Kumon, F. (2018). Paleoenvironmental perturbation across the Cenomanian/Turonian boundary of the Kopet-Dagh Basin (NE Iran), inferred from geochemical anomalies and benthic foraminiferal assemblages. Cretaceous Research, 86, 261-275. https://doi.org/10.1016/j.cretres.2017.09.019
24. Zhang, N., Yamada, K., Kano, A., Matsumoto, R., & Yoshida, N. (2018). Equilibrated clumped isotope signatures of land-snail shells observed from laboratory culturing experiments and its environmental implications. Chemical Geology, 488, 189-199. https://doi.org/10.1016/j.chemgeo.2018.05.001
25. Mori, T., Kashiwagi, K., Amekawa, S., Kato, H., Okumura, T., Takashima, C., Wu, C.-C., Shen, C.-C., Quade, J. & Kano, A. (2018). Temperature and seawater isotopic controls on two stalagmite records since 83 ka from maritime Japan. Quaternary Science Reviews, 192, 47-58. https://doi.org/10.1016/j.quascirev.2018.05.024
26. Kato, H., Amekawa, S., Kano, A., Mori, T., Kuwahara, Y., & Quade, J. (2019). Seasonal temperature changes obtained from carbonate clumped isotopes of annually laminated tufas from Japan: Discrepancy between natural and synthetic calcites. Geochimica et Cosmochimica Acta, 244, 548-564. https://doi.org/10.1016/j.gca.2018.10.016
27. Shiraishi, F., Ohnishi, S., Hayasaka, Y., Hanzawa, Y., Takashima, C., Okumura, T., & Kano, A. (2019). Potential photosynthetic impact on phosphate stromatolite formation after the Marinoan glaciation: Paleoceanographic implications. Sedimentary geology, 380, 65-82. https://doi.org/10.1016/j.sedgeo.2018.11.014

(2) Non-peer-reviewed Articles

(3) Review Papers

1. Kano, A. (2012). Evolutionary step and skeletalization of early animals. Iden: Science of Life, 66, 509-513.
2. Kano, A. (2012). Principles and perspectives of stalagmite paleoclimatology. Journal of Geological Society Japan, 118, 157-171. https://doi.org/10.5575/geosoc.2011.0025
3. Kano, A. (2013). Paleoclimatology and historical meteorology. Social and Cultural Study, Kyushu Univ., 19, 11-18.
4. Kano, A., Mori, T., & Yanagawa, K. (2014). Principles and procedures of carbonate clumped

isotope thermometry. Integrated Sciences of Earth Society, 21, 83-92.

5. Kano, A., & Furuyama, S. (2015). Ediacaran drast eincvironmental changes and animal evolution: achievement from integrated sciences for the Earth's history. Chikyu Kagaku, 69, 175-183.
6. Kano, A. (2014). Exp. 307: Unveiled mysteries of deep-sea coral mounds. Special Issue, Monthly Chikyu, 59-65.
7. Okumura, T., & Kano, A. (2014). Processes for annual and daily layering of terrestrial carbonate. Special Issue, Monthly Chikyu, 82-88.
8. Kawahata, H., Yokoyama, Y., Kuroda, J., Iryu, Y., & Kano, A. (2018). Topics on carbonate relevant topics by IODP. Journal of Geological Society of Japan, 124, 35-45. https://doi.org/10.5575/geosoc.2017.0081

(4) Books

1. Kano, A., Okumura, T., Takashima, C., & Shiraishi, F. (2019). Geobiochenimal Properties of Travertine with Focus on Japanese Sites. Springer Nature. 176 pp.

(5) Other Publications

(6) Patents

8. Keynote, Invited, or Solicited Presentations

1. Kano, A., Stalagmite paleoclimatology in Japan. Annual Meeting of Japanese Society of Applied Geology, Fukuoka, 2014/09/03.
2. Kano, A., & Mori, T., Temperature and seawater isotopic controls on stalagmite oxygen isotopic records since 83 ka from maritime Japan. International Conference on Holocene Climate Change, Taipei, Taiwan, 2018/02/07.
3. Kano, A., Dolomite problem and seawater chemistry of Proteozoic. Invited seminar of Japanese Association for Petroleum Technology, Tokyo, 2019/02/15.

III. Education Activity

9. Notable Achievements in Education

Advisees

- Master theses: 8 students
  - Iori Kurosaki (Mar. 2013)
  - Tomomi Sone (Mar. 2014)
  - Taiki Mori (Mar. 2015)
  - Chiya Sugihara (Mar. 2016)
  - Misa Hirano (Sep. 2016)
  - Reina Miyahara, Lan Tien (Mar. 2017)
  - Muhlash Hada Firman Syah (Mar. 2018)
- Doctral theses: 1 student
  - Seishiro Furuyama (Mar. 2014)

Lectures

- Undergraduate, Basic Stratigraphy and Geology, FY2017-2018
- Undergraduate, Sedimentology, FY2018
- Undergraduate, Practical Geomorphology and Geology, FY2017-2018
- Undergraduate, Field Exercise I, FY2017-2018
- Undergraduate, Practical Analyses of Rock Texture II, FY2018
- Undergraduate, Practical Earth and Planetary Environmental Science, FY2018
- Graduate, Evolution of Geosphere Environment, FY2017
- Graduate, Field Work in Earth Science, FY2018
- Graduate, Practical Instrumental Analyses, FY2017-2018

IV. External Activities

10. Contribution to Academic Community

- Geological Society of Japan, Executive Board Member, FY2016-2018
- Geological Society of Japan, Chair of Executive Board, FY2018
- Geological Society of Japan, Editorial Board Member of “Island Arc”, FY2016-2018
- Geological Society of Japan, Award Selection Committee Member, FY2017
- Sedimentological Society of Japan, Acting Committee Member, FY2016-2018
- Sedimentological Society of Japan, Award Selection Committee Member, FY2016-2018
- Japanese Association for Petroleum Technology, Executive Board Member, FY2018
- Japanese Association for Petroleum Technology, Mining Technology Committee, FY2018
- “Earth Science”, Editor, FY2016-2018
- “Sedimentary Geology”, Advisory Board Member, FY2018

11. Outreach Activity

- KAKENHI Review, FY2016
- Lectures for general audience (2018/12/26)

12. Internal Committee Membership

- Department of Earth and Planetary Science, Education Committee, Chair, FY2013-2014
- Department of Earth and Planetary Physics, Education Committee, Vice Chair, FY2015-2016
- School of Science, Advisor to the Dean, FY2015-2016
- School of Science, Library Committee, Chair, FY2015-2016
- Department of Earth and Planetary Physics, Head, FY2017-2018
- Advisor to the President of the University of Tokyo, FY2018

V. International Exchange Activities

13. Hosting/Sending Foreign Students and Researchers

(1) Hosting

Foreign Researchers: 5

(2) Sending

Students: 20

Researchers: 5

(3) Visitors from Abroad: 10

Toshihiro Kogure

I. CV

Name: Toshihiro Kogure

Age: 61

Present Position: Professor

Education

Hakuo Tokyo Metropolitan High School, Tokyo, March, 1976 (graduation)

B. Sc. Geology & Mineralogy Course, Faculty of Science, The University of Tokyo, March, 1981

M. Sc. Mineralogical Institute, Graduate School of Science, The University of Tokyo, March, 1983

Ph. D. of Science (Mineralogy), The University of Tokyo, October, 1996

Professional Experience

Apr. 1983, Researcher, Nippon Sheet Glass Co., Ltd.

Jul. 1987, Visiting Researcher, Massachusetts Institute of Technology

Nov. 1988, Senior Researcher, Nippon Sheet Glass Co., Ltd.

Jan. 1996, Research Associate, Mineralogical Institute, Graduate School of Science, The University of Tokyo

Nov. 1998, Associate Professor, Mineralogical Institute, Graduate School of Science, The University of Tokyo

Apr. 2000, Associate Professor, Department of Earth and Planetary Science, Graduate School of Science, The University of Tokyo

Sep. 2016-, Professor, Graduate School of Science, The University of Tokyo

II. Scientific Research Activity

2. Major Achievements

The accident in Fukushima Daiichi Nuclear Power Plant caused by the East Japan Earthquake in March 2011 has brought a long-term radioactive contamination around Kanto region due to radioactive cesium (Cs) scattered from the damaged nuclear reactors. Most of the radioactive Cs is thought to have been released to the environment in a gaseous form, fallen onto ground surfaces by rainfall, and strongly fixed to specific clay minerals in the soil. I have been investigating fine structures of clay minerals or phyllosilicates mainly by electron microscopy, and their origins and formation mechanisms for more than 15 years. After the accident, I started elucidation of the real state of the radioactive contamination in the environment from a mineralogical perspective, using the knowledge and experiences of mineralogy obtained so far.

Most of the surface of the eastern Fukushima Prefecture is thickly covered with weathered soil ("Masado") of Abukuma granite. By combining autoradiography using imaging plates (IP) with special processing and electron microscope technology, we could identify radioactive fine particles in the contaminated soil containing radioactive Cs. Most of the radioactive soil particles were biotite-vermiculite mixed-layer mineral (weathered biotite) that is common in weathered granite soil. The distribution of radioactive Cs in the weathered biotite particles was also investigated by micro-processing using a focused ion beam (FIB) apparatus. On the other hand, mineral-adsorption/desorption experiments were performed using radioactive Cs whose concentration is extremely low, as in the actual contamination soil. As a result, it was found that weathered biotite adsorbs Cs much more efficiently than other minerals in soils, and once adsorbed, Cs in the weathered biotite could not be removed almost at all by normal ion exchange process.

In addition to radioactive Cs released in a gaseous state and fixed in the soil as mentioned above, it was reported that the radioactive Cs was scattered in the environment as a constituent of fine particles with a diameter of several microns formed in damaged nuclear reactors. The particles containing radioactive Cs in high concentration are called CsMPs (Cesium-bearing microparticles) or "cesium balls", and elucidation of their structure and properties has become an urgent issue. We made thin film specimens from CsMPs with a FIB and analyzed it by electron microscopy. It was found that CsMPs were substantially silicate glass, and Fe, Zn, K, Rb, Sn, Cl, and Cs were dissolved in the glass. Furthermore, the distribution of these elements and the presence of various nanocrystallites in the particles were elucidated. We also reported the structural changes of CsMPs by heating and the dissolution characteristics in various solutions.

3. Five Important Papers (including three or more papers in this review period)

1. Kogure T., K. Morimoto, K. Tamura, H. Sato, and A. Yamagishi (2012), XRD and HRTEM evidence for Fixation f Cesium Ions in Vermiculite Clay, Chem. Lett., 41, 380-382, DOI: 10.1246/cl.2012.380.

The radioactive Cs scattered by the Fukushima nuclear accident was thought to be adsorbed in clay minerals in the soil. In this report, biotite-vermiculite mixed-layer minerals sorbing Cs in laboratory were observed using high-resolution transmission electron microscopy (HRTEM) and the distribution of Cs in the structure was elucidated. As a result, it was confirmed that the hydrated (or vermiculite) interlayers were selectively occupied by Cs with dehydration. (Cited 71 times (WoS / Sep. 06, 2019))

2. Mukai, H., T. Hatta, H. Kitazawa, H. Yamada, T. Yaita, and T. Kogure (2014), Speciation of radioactive soil particles in the Fukushima contaminated area by IP autoradiography and microanalyses, Environ. Sci. Technol., 48, 13053-13059, DOI: 10.1021/es502849e.

Soil particles collected from a highly radiation-contaminated area were dispersed on an imaging plate (IP) where minute grids were formed using laser processing. About one week later, the soil particles at the bright spot positions in the readout image from the IP were picked up with a vacuum tweezer on a micromanipulator and analyzed with a scanning electron microscope. It was shown that a significant proportion of the radioactive soil particles were biotite-vermiculite mixed-layer mineral (weathered biotite) common in weathered granite soil. In addition, by cutting these weathered biotites with FIB and examining the change of radioactivity, it was indicated that radioactive Cs was distributed around the whole particle, not around the edges of the platy mineral particle as previously suggested. (Cited 58 times (WoS / Sep. 06, 2019))

3. Mukai, H., A. Hirose, S. Motai, R. Kikuchi, K. Tanoi, T. M. Nakanishi, T. Yaita and T. Kogure (2016), Cesium adsorption/desorption behavior of clay minerals considering actual contamination conditions in Fukushima, Sci. Rep., 6, 21543, DOI: 10.1038/srep21543

Cesium adsorption/desorption experiments for various clay minerals, considering actual contamination conditions in Fukushima, were conducted using the ^{137}Cs radioisotope and an autoradiography using imaging plates (IPs). A 50 μl solution containing 0.185 ~ 1.85 Bq of ^{137}Cs (10^{-11} ~ 10^{-9} $molL^{-1}$ of ^{137}Cs) was dropped onto a substrate where various mineral particles were arranged. It was found that partially-vermiculitized biotite, which is termed "weathered biotite" (WB) in this study, from Fukushima sorbed ^{137}Cs far more than the other clay minerals (fresh biotite, illite, smectite, kaolinite, halloysite, allophane, imogolite) on the same substrate. When WB was absent on the substrate, the amount of ^{137}Cs sorbed to the other clay minerals was considerably increased, implying that selective sorption to WB caused depletion of radiocesium in the solution and less sorption to the coexisting minerals. Cs-sorption to WB continued for about one day, whereas that to ferruginous smectite was completed within one hour. The sorbed ^{137}Cs in WB was hardly leached with hydrochloric acid at pH 1, particularly in samples with a longer sorption time. The presence/absence of WB sorbing radiocesium is a key factor affecting the dynamics and fate of radiocesium in Fukushima. (Cited 56 times (WoS / Sep. 06, 2019))

4. Yamaguchi, N., M. Mitome, K. Akiyama-Hasegaea, M. Asano., K. Adachi and T. Kogure (2016), Internal structure of cesium-bearing radioactive microparticles released from Fukushima nuclear power plant, Sci. Rep., 6, 20548, DOI: 10.1038/srep20548

Microparticles containing substantial amounts of radiocesium collected from the ground in Fukushima were investigated mainly by transmission electron microscopy (TEM) and X-ray microanalysis with scanning TEM (STEM). Particles of around 2 μm in diameter are basically silicate glass containing Fe and Zn as transition metals, Cs, Rb and K as alkali ions, and Sn as substantial elements. These elements are homogeneously distributed in the glass except Cs which has a concentration gradient, increasing from center to surface. Nano-sized crystallites such as copper- zinc- and molybdenum sulfide, and silver telluride were found inside the microparticles, which probably resulted from the segregation of the silicate and sulfide (telluride) during molten-stage. An alkali-depleted layer of ca. 0.2 μm thick exists at the outer side of the particle collected from cedar leaves 8 months after the nuclear accident, suggesting gradual leaching of radiocesium from the microparticles in the natural environment. (Cited 35 times (WoS / Sep. 06, 2019))

5. Kogure, T., and A. Inoue: "Determination of defect structures in kaolin minerals by High-Resolution Transmission Electron Microscopy (HRTEM) ", Am. Mineral., 90 (2005) 85-89. DOI: 10.2138/am.2005.1603

Near-atomic resolution TEM imaging has been successfully applied to determine the stacking defect structures in kaolin minerals, especially in kaolinite. The specimen studied is at mid-stage of the depth-related kaolinite-to-dickite transformation in a sandstone reservoir. Although electron radiation damage is a serious obstacle, a number of high-quality images were recorded on films, in which the tetrahedral and octahedral positions in a kaolinite unit layer were clearly resolved. Electron diffraction and high-resolution imaging of dickite showed that few stacking defects exist in this polytype. On the other hand, kaolinite crystals contain high density of stacking defects. These defects or stacking disorder are formed by mixture of the two kinds of lateral interlayer shifts, $\boldsymbol{t}_1$ (approximately $-\boldsymbol{a}/3$) and $\boldsymbol{t}_2$ ($-\boldsymbol{a}/3 + \boldsymbol{b}/3$), between adjacent layers. Disorder by the coexistence of B layer and C layer, or dickite-like stacking sequence was never observed. These results provide not only an unambiguous settlement for the long controversy of the defect structures in kaolinite, but also a new clue to understand kaolinite-to-dickite transformation mechanism (Cited 40 times (WoS / Sep. 06, 2019))

4. Awards and Honors

- Kogure, T., The Mineralogical Society of America, Fellow (Oct., 2013)
- Kogure, T., The Mineralogical Society of Great Britain and Ireland, George Brown Lecture Award (July, 2019)

5. Future Research Plan

JSPS KAKENHI (Grant-in-Aid for Scientific Research (A)) titled “Development of quantification methods of radiocesium-bearing materials by their properties and application to contaminated s” has been adopted over 4 years from FY2019. So far, weathered biotite and CsMPs have been investigated as the carrier materials of radioactive Cs in the environment, and their compositions, structures and various characteristics have been clarified. However, the abundance ratio of these two materials in the environment and its regional dependence are still unclear. In particular, since CsMPs are very small, their identification using electron microscopy is still time-consuming, and their abundance density is almost impossible to estimate. Therefore, we have started a study to quantify their abundance ratio in samples using the difference between the two materials in the loss of radioactivity by heating, the reaction with additives, and/or the solution treatment. We intend to provide useful information for long-term prediction of radioactive contamination in Kanto area, volume reduction of decontamination wastes, and their storage methods. In addition, in order to estimate the long-term dynamics of CsMP in the environment more accurately, we are synthesizing silicate glass with the same composition and chemical state as CsMPs. For this purpose, it is necessary to accurately determine the valence of transition metal ions (Fe and Sn) in CsMPs. Furthermore, it should be clarified at which site the radioactive Cs is fixed in the structure of clay minerals, though it is very challenging because the actual concentration of radioactive Cs is extremely low.

6. Funding Received

- JSPS KAKENHI Grant-in-Aid for Scientific Research (S), “Elucidation of regulation mechanism of calcification in marine organisms toward preservation of global environment”, Co-Investigator, 22228006, FY2010-2012, 24,888,000 yen
- JSPS KAKENHI Grant-in-Aid for Scientific Research (B), “Development of high-resolution analytical techniques for heavy metal ions sorbed to terrestrial surface materials and elucidation of their sorption mechanism”, Principal investigator, 24340133, FY2012-2014, 12,600,000 yen
- Commissioned research (Japan Atomic Energy Agency) “Elucidation of adsorption and transport mechanism of radioactive cesium in soil particles”, Principal Investigator, FY2013-2016, 37,628,000 yen
- Commissioned research (Japan Atomic Energy Agency) “Identification of mineral phases and fine particles adsorbing radioactive cesium in the environment of Fukushima Prefecture and elucidation of cesium elution from them”, Principal Investigator, FY2017-2019, 21,072,000 yen

7. Publications and Patents

(1) Peer-reviewed Journal Articles

1. Inoue, S. and T. Kogure (2012), Electron backscatter diffraction (EBSD) analyses of phyllosilicates in petrographic thin sections, Am. Mineral., 97,755-758, DOI: 10.2138/am.2012.4061.
2. Kogure T., K. Morimoto, K. Tamura, H. Sato, and A. Yamagishi (2012), XRD and HRTEM evidence for Fixation f Cesium Ions in Vermiculite Clay, Chem. Lett., 41, 380-382, DOI: 10.1246/cl.2012.380.
3. Miyabe, K., H. Tokunaga, H. Endo, H. Inoue, M. Suzuki, N. Tsutsui, N. Yokoo, T. Kogure, and H. Nagasawa (2012), GSP-37, a novel goldfish scale matrix protein: identification, localization and functional analysis, Farad. Discuss., 159, 463-481, DOI: 10.1039/c2fd20051a.
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6. Morimoto K., T. Kogure, K. Tamura, S. Tomofuji, A. Yamagishi, and H. Sato (2012), Desorption of Cs+ Ions Intercalated in Vermiculite Clay through Cation-exchanging with Mg2+ Ions, Chem. Lett., 41, 1715-1717, DOI: 10.1246/cl.2012.1715.

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(2) Non-peer-reviewed Articles

(3) Review Papers

1. Kogure (2013) Chirality in clay minerals, NendoKagaku (Clay Science), 51, 132-134.(Japanese)
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4. Kogure (2015) Geometry of Electron Diffraction and Its Calculation, Kenbikyo (Microscopy) 50, 1-5. (Japanese)
5. Kogure (2015) Clay minerals sorbing radiocesium in Fukushima: Investigation by IP autoradiography and electron microscopy, Nendokagaku (Clay Science), 54, 22-27. (Japanese)
6. Kogure (2015) Identification of Cs-sorbing minerals in Fukushima, Chikyukagaku (Geochemistry), 49, 195-201. (Japanese with English abstract)

(4) Books

1. Kogure, T. (2013), "Electron Microscopy", Handbook of Clay Science, Vol. 5, 2nd Edition (Developments in Clay Science), Elsevier, 275-317.
2. Kogure, T. (2016), "Characterization of Halloysite by Electron Microscopy", Nanosized Tubular Clay Minerals, Vol. 7, Halloysite and Imogolite (Developments in Clay Science), Elsevier, 92-114.
3. T, Kogure., H. Mukai, and R. Kikuchi (2019), "Weathered Biotite: A Key Material of Radioactive

Contamination in Fukushima". In: Nakanishi T, Tanoi K, O'Brien M (eds) Agricultural Implications of the Fukushima Nuclear Accident(Ⅲ), Springer, pp. 59-75.

(5) Other Publications

(6) Patents

8. Keynote, Invited, or Solicited Presentations

1. Kogure, T., Real Structures of Clay Minerals Revealed by HRTEM, 2nd International Conference - CMLM2013 (St. Petersburg, Russia, Sep. 11-15, 2013) (Oral p.) (Invited)
2. Kogure, T., Electron Microscopy for clay science, Argilla Studium 2013 - 2nd Russian school by clay minerals (St. Petersburg, Russia, Sep. 8-10, 2013) (Oral p.) (Invited)
3. Kogure, T., Finding and analyses of soil particles adsorbing radioactive cesium in Fukushima, Caesium Workshop: Fukushima recovery - understanding, modelling and managing radiocaesium decontamination (CORASSE, Fukushima, Sep. 30- Oct. 3, 2013) (Oral p.) (Invited)
4. Kogure, T., T. Okumura, M. Suzuki, Regulation of calcium carbonate crystals in shells, The 8th International Conference on the Science & Technology for Advanced Ceramics (STAC-8) (Mielparque-Yokohama, Kanagawa, June 26, 2014) (Oral p.) (Invited)
5. Kogure, T., T. Yaita, Fukushima nuclear disaster and clay, Euroclay 2015 (Edinburgh, UK, July 6, 2015) (Invited)
6. Kogure, T., Clay Structures Revealed by TEM, Goldschmidt 2016 (Pacifico Yokohama, Kanagawa, Yokohama, 2016.6.27). (Keynote)
7. Kogure, T., Various modes of stacking disorder in clay minerals: Comprehensive analyses by XRD and HREM, The 3rd Asian Clay Conference (Guangzhou, China, 2016.11.19). (Keynote)

III. Education Activity

9. Notable Achievements in Education

Advisees

- Master theses: 6 students
  - Sayako Inoue, Hyejin Kim (Mar. 2013)
  - Chisaki Kuramata (Mar. 2015)
  - Ryosuke Kikuchi, Masahiro Yoshimura (Mar. 2016)
  - Takahiro Ishii (Mar. 2019)
- Doctral theses: 4 students
  - Naoki Yokoo (Mar. 2013)
  - Taiga Okumura (Mar. 2014)
  - Sayako Inoue (Mar. 2016)
  - Ryosuke Kikuchi (Mar. 2019)

Lectures

- Graduate, Analysis of Biosphere Materials, FY2012-2018 (every other year)
- Graduate, Biomineralization, FY2012-2018 (every other year)

- Graduate, Laboratory Experiments for Instrumental Analysis I & II, FY2012-2018
- Undergraduate/Graduate, Diffraction Crystallography, FY2012-2018
- Undergraduate/Graduate, Instrumental Analyses of Solids, FY2017-2018
- Undergraduate, Analyses of Earth and Planetary Materials, FY2012-2016
- Undergraduate, Advanced Mineralogy, FY2016-2018
- Undergraduate, Laboratory Experiments for Crystallography, FY2012-2018

Student's awards

- The Clay Mineral Society 2013 Annual Meeting Best Student's Oral Presentation Award [Sayako Inoue]
- European Clay Conference (EuroClay) 2015 Best Student's Oral Presentation Award [Sayako Inoue]
- Japan Association of Mineralogical Sciences, FY2016 JMPS Best Student Paper Award [Ryosuke Kikuchi]
- Japan Association of Mineralogical Sciences, FY2016 Meeting Student Presentation Award [Ryosuke Kikuchi]

IV. External Activities

10. Contribution to Academic Community

- Japan Association of Mineralogical Sciences, Councilor, FY2012-2016
- Japan Association of Mineralogical Sciences, Director, FY2017-2018
- Japan Association of Mineralogical Sciences, GKK (Journal of the Society) Associate Editor, FY2012-2018
- Japan Association of Mineralogical Sciences, Executive Committee Chair of 2015 Annual Meeting
- The Clay Science Society of Japan, Councilor, FY2012-2016
- The Clay Science Society of Japan, Vice president, FY2017-2018
- The Clay Science Society of Japan, Clay Science (Journal of the Society) Associate Editor, FY2012-2018
- The Japanese Society of Microscopy, Delegate, FY2012-2018
- The Japanese Society of Microscopy, Executive Committee Chair of Denshikenbikyou Daigaku (Lecture Course for Electron Microscopy), FY2012-2014
- AIPEA (International Association for the Study of Clays) Japanese representative of Nomenclature Committee, 2012-2018

11. Outreach Activity

- Press Release: 5 times (Dec. 2014, Feb. 2016, Feb. 2016, Jun. 2018, Mar. 2019)
- Lectures for general audience: 10 times (Aug. 2014, Jun. 2015, Jul. 2016, Aug. 2016, Aug. 2015, Sep. 2016, May 2017, Aug. 2017, Aug. 2018, Feb. 2019)

12. Internal Committee Membership

- Department of Earth and Planetary Science, Scientific Instrument Committee, Chair, FY2012-2014
- Department of Earth and Planetary Science, Engineering Committee, Chair, FY2015-2017
- Department of Earth and Planetary Science, Undergraduate Education Committee, Chair, FY2017
- Department of Earth and Planetary Science, Education Committee, Chair, FY2018-2019

V. International Exchange Activities

13. Hosting/Sending Foreign Students and Researchers

(1) Hosting

Foreign Students: 2

Foreign Researchers: 0

(2) Sending

Students: 3

Researchers: 0

(3) Visitors from Abroad: 10

Kazuhisa Goto

I. CV

Name: Kazuhisa Goto

Age: 42

Present Position: Professor

Education

Kakegawa Nishi High School, Shizuoka, March, 1995 (graduation)

B. Sc. Department of Earth Science, Tohoku University, March, 1999

M. Sc. Department of Geology, The University of Tokyo, March, 2001

Ph. D. Department of Earth and Planetary Science, The University of Tokyo, March, 2004

Professional Experience

Apr. 2002-Mar. 2004, JSPS Research Fellowship for Young Scientists (DC2)

Apr. 2004-Jun. 2005, 21COE Designated Researcher, The University of Tokyo

Jul. 2005-Mar. 2010, Assistant Professor, Disaster Control Research Center, Tohoku University

Apr. 2010-Aug. 2012, Staff Scientist, Planetary Exploration Research Center, Chiba Institute of Technology

Sep. 2012-Mar. 2019, Associate Professor, International Research Institute of Disaster Science, Tohoku University

Apr. 2019-, Professor, Department of Earth and Planetary Science, The University of Tokyo

II. Scientific Research Activity

2. Major Achievements

Based on field geology and sedimentology, I have studied various phenomena in the Earth's history especially on tsunami hazards. Regarding to the study of asteroid impact at the Cretaceous/Paleogene (K/Pg) boundary, we clarified tsunami generation and consequent sedimentation based on the field survey in Cuba and analyses of sediment cores taken from inside the crater. Moreover, we reviewed the studies of K/Pg boundary mass extinction and asteroid impact and confirmed that the Chicxulub impact triggered the mass extinction. We also studied sedimentation by the recent tsunamis such as the 2004 Indian Ocean tsunami at Thailand and Sri Lanka and 2011 Tohoku-oki tsunami at the Pacific coast of Tohoku. Also, we investigated the paleotsunami history and size along the coasts of Japan and some countries in Indian Ocean and Pacific Ocean based on the field survey, laboratory experiments, and numerical modeling.

3. Five Important Papers (including three or more papers in this review period)

1. Yanagisawa, H., Goto, K., Sugawara, D., Kanamaru, K., Iwamoto, N., Takamori, Y., 2016, Tsunami earthquake can occur elsewhere along the Japan Trench -Historical and geological evidence for the 1677 earthquake and tsunami-. Journal of Geophysical Research-Solid Earth, 121, 3504-3516. (3 citations (Web of Science/September. 19, 2019))

We conducted paleotsunami survey at a pond in high elevation of Choshi City in Chiba Prefecture, Japan. We identified the 1677 Enpo Boso tsunami deposit. Then, we performed numerical modeling and revealed that tsunami earthquake, which is equivalent size to the 1896 Meiji-Sanriku earthquake, could have been generated on 1677. This result was important for tsunami risk assessment in Japan and was referred by the report of Headquarters for Earthquake Research Promotion in 2019.

2. Morgan, J., Gulick, S., Bralower, T., Chenot, E., Christeson, G., Claeys, P., Cockell, C., Collins, G. S., Coolen, M. J. L., Ferriere, L., Gebhardt, C., Goto, K., Jones, H., Kring, D. A., Le Ber, E., Lofi, J., Long, X., Lowery, C., Mellett, C., Ocampo-Torres, E., Osinski, G. R., Perez-Cruz, L., Pickersgill, A., Polchau, M., Rae, A., Rasmussen, C., Rebolledo-Vieyra, M., Riller, U., Sato, H., Schmitt, D. R., Smit, J., Tikoo, S., Tomioka, N., Urrutia-Fucugauchi, J., Whalen, M., Wittmann, A., Yamaguchi, K., Zylberman, W., 2016, The formation of peak rings in large impact craters. Science, 354, 878-882. (57 citations (Web of Science/September. 10, 2019))

We investigated the impactite and basement rock in the core that was recovered from the Chicxulub crater by the IODP exp. 364. We also performed numerical modeling for the crater formation and revealed formation process of peak ring. The research was highlighted by many media in the world.

3. Goto, K., Miyagi, K., Imamura, F., 2013, Localized tsunamigenic earthquakes inferred from preferential distribution of coastal boulders on Ryukyu Islands, Japan. Geology, 41, 1139-1142. (19 citations (Web of Science/September. 10, 2019))

We reported distribution of boulders deposited by tsunamis and storm waves along the Ryukyu Islands. We proposed identification criteria of tsunami boulders. Then, we revealed that tsunami boulders were preferentially distributed at southern Ryukyu Islands suggesting that tsunamigenic earthquakes might have only been occurred in this region while not at northern and central Ryukyu Islands.

4. Goto, K., Chague-Goff, C., Fujino, S., Goff, J., Jaffe, B., Nishimura, Y., Richmond, B., Sugawara, D., Szczucinski, W., Tappin, D. R., Witter, R., Yulianto, E., 2011, New insights of tsunami hazard from the 2011 Tohoku-oki event. Marine Geology, 290, 46-50. (167 citations (Web of Science/September. 10, 2019))

The 2011 Tohoku-oki tsunami deposits were studied by international research group at Sendai Plain. We revealed that maximum extent of sand was significantly shorter than the maximum limit of seawater inundation. While, geochemical signature was observed up to the inundation limit. This paper awarded the Most Cited Paper Award 2012-2013 and was highlighted in the news article of Science.

5. Schulte, P., Alegret, L., Arenillas, I., Arz, J. A., Barton, P. J., Bown, P. R., Bralower, T. J., Christeson, G. L., Claeys, P., Cockell, C. S., Collins, G. S., Deutsch, A., Goldin. T. J., Goto, K., Grajales-Nishimura, J. M., Grieve, R. A. F., Gulick, S. P. S., Johnson, K. R., Kiessling, W., Koeberl, C., Kring, D. A., MacLeod, K. G., Matsui, T., Melosh, J., Montanari, A., Morgan, J. V., Neal, C. R., Nichols, D. J., Norris. R. D., Pierazzo, E., Ravizza, G., Rebolledo-Vieyra, M., Reimold, W. U., Robin, E., Salge, T., Speijer, R. P., Sweet, A. R., Urrutia-Fucugauchi, J., Vajda, V., Whalen, M. T., Willumsen, P. S., 2010, The Chicxulub asteroid impact and mass extinction at the Cretaceous-Paleogene boundary. Science, 327, 1214-1218. (527 citations (Web of Science/September. 10, 2019))

We reviewed 30 years research history of K/Pg boundary mass extinction. We concluded that the extinction can be well explained by environmental disturbance due to the Chicxulub impact. While, volcanic eruption and other hypothesis failed to explain the geological evidence. The paper was highlighted by many media in the world. Also, it is recognized as a very high citation paper according to the Web of Science.

4. Awards and Honors

- (Japan Society for Natural Disaster Science) FY2012 Academic Award (co-author) (2012)
- (Marine Geology) Most Cited Paper Award 2009-2012 (2013)

- (Marine Geology) Most Cited Paper Award 2012-2013 (2014)
- (Coastal Engineering Journal) Citation Award of 2014 (co-author) (2015)

5. Future Research Plan

I will conduct interdisciplinary researches based on field survey, multi-proxy analyses, and numerical modeling. Among them, paleotsunami research is very important for contributing both academic researches and disaster prevention for governors and public people. In this point, paleotsunami research is very important research discipline in the earth sciences. By collaborating with other academic disciplines such as biology, I will perform paleotsunami research at the Pacific Ocean and Indian Ocean. The major research topics will be 1) tsunami sedimentation and impact on ecosystem, 2) evaluation of subduction-type large earthquake and tsunami by numerical modeling, 3) development of statistical methodology for radiocarbon dating, and 4) chemical and biological approach to estimate sedimentary environment and to identify tsunami deposit. Also, tsunami generation by the asteroid impact at the K/Pg boundary is critically important to understand the impact process together with the further improvement of numerical modeling. Therefore, we will continuously perform the research for K/Pg boundary including the IODP drilling program.

6. Funding Received

<Listed JSPS KAKENHI (Principal Investigator) only (total amount)>

- JSPS KAKENHI, 17H02971, Principal Investigator, FY2017-2020, 8,000,000 yen
- JSPS KAKENHI, 26302007, Principal Investigator, FY2014-2016, 10,250,000 yen
- JSPS KAKENHI, 23684041, Principal Investigator, FY2011-2013, 3,900,000 yen

Plus twelve JSPS KAKENHI as collaborative researcher.

7. Publications and Patents

(1) Peer-reviewed Journal Articles

1. Goto, K., Hongo, C., Watanabe, M., Miyazawa, K., Hisamatsu, A., 2019, Large tsunamis reset growth of massive corals. Progress in Earth and Planetary Science 6, 14.
2. Yokoyama, Y., Hirabayashi, S, Goto, K., Okuno, J., Sproson, A., Haraguchi, T., Ratnayake, N., Miyairi, Y., 2019, Holocene Indian Ocean Sea level, Antarctic melting history and Past Tsunami depositsinferred using sea level reconstructions from the Sri Lankan, SoutheasternIndian and Maldivian coasts. Quaternary Science Reviews, 206, 150-161.
3. Komatsu, G., Ormo, J., Bayaraa, T., Arai, T., Nagao, K., Hidaka, Y., Shirai, N., Ebihara, M., Alwmark, C., Gereltsetseg, L., Tserendug, S., Goto, K., Matsui, T., Demberel, S., 2019, Further evidence for an impact origin of the Tsenkher structure in the Gobi-Altai, Mongolia: geology of a 3.7 km crater with a well-preserved ejecta blanket. Geological Magazine, 156, 1-24.
4. Riller, U., Poelchau, M. H., Rae, A. P., Schulte, F. M., Collins, G. S., Melosh, H. J., Grieve, R. A., Morgan, J., Gulick, S., Lofi, J., Diaw, A., McCall, N., Kring, D., the IODP-ICDP Expedition 364 Science Party (including Goto, K.), 2018, Rock fluidization during peak-ring formation of large impact structures. Nature, 562, 511-518.
5. Goff, J., Goto, K., Chagué, C., Watanabe, M., Gadd, P. S., King, D. N., 2018, New Zealand's most easterly palaeotsunami deposit confirms evidence for major trans-Pacific event. Marine Geology, 404, 158-173.
6. Chang, Y., Goto, K., Sekine, Y., Tajika, E., 2018, Depositional processes of impactites from the YAX-1 drill core in the Chicxulub impact structure inferred from vertical profiles of PDF orientations and grain size distributions of shocked quartz. Meteoritics & Planetary Science,

53(7), 1323-1340.

7. Lowery, C. M., Bralower, T. J., Owens, J. D., Rodriguez-Tovar, F. J., Jones, H., Smit, J., Whalen, M. T., Claeys, P., Farley, K., Gulick, S. P. S., Morgan, J. V., Green, S., Chenot, E., Christeson, G. L., Cockell, C. S., Coolen, M. J. L., Ferriere, L., Gebhardt, C., Goto, K., Kring, D. A. Lofi, J., Ocampo-Torres, R., Perez-Cruz, L., Pickersgill, A. E., Poelchau, M., Rae, A. S. P., Rasmussen, C., Rebolledo-Vieyra, M., Riller, U., Sato, H., Tikoo, S. M., Tomioka, N., Urrutia-Fucugauchi, J., Vellekoop, J., Wittmann, A., Xiao, L., Yamaguchi, K. E., Zylberman, W., 2018, Rapid recovery of life at ground zero of the end Cretaceous mass extinction. Nature, 558, 288-291.

8. Christeson, G.L., Gulick, S.P.S., Morgan, J.V., Gebhardt, C., Kring, D.A., Le Ber, E., Lofi, J., Nixon, C., Poelchau, M., Rae, A.S.P., Rebolledo-Vieyra, M., Riller, U., Schmitt, D.R., Wittmann, A., Bralower, T.J., Chenot, E., Claeys, P., Cockell, C.S., Coolen, M.J.L., Ferriere, L., Green, S., Goto, K., Jones, H., Lowery, C.M., Mellett, C., Ocampo-Torres, R., Perez-Cruz, L., Pickersgill, A.E., Rasmussen, C., Sato, H., Smit, J., Tikoo, S.M., Tomioka, N., Urrutia-Fucugauchi, J., Whalen, M.T., Xiao, L., Yamaguchi, K.E., 2018, Extraordinary rocks from the peak ring of the Chicxulub impact crater: P-wave velocity, density, and porosity measurements from IODP/ICDP Expedition 364. Earth and Planetary Science Letters, 495, 1-11.

9. Takeda, H., Goto, K., Goff, J., Matsumoto, H., Sugawara, D., 2018, Could tsunami risk be underestimated using core-based reconstructions? Lessons from ground penetrating radar. Earth Surface Processes and Landforms, 43, 808-816.

10. Koiwa, N., Takahashi, M., Sugisawa, S., Ito, A., Matsumoto, H., Tanavud, C., Goto, K., 2018, Barrier spit recovery following the 2004 Indian Ocean tsunami at Pakarang Cape, southwestern Thailand. Geomorphology, 306, 314-324.

11. Watanabe, M., Goto, K., Bricker, J. D., Imamura, F., 2018, Are inundation limit and maximum extent of sand useful for differentiating tsunamis and storms? An example from sediment transport simulations on the Sendai Plain, Japan. Sedimentary Geology, 364, 204-216.

12. Chagué, C., Sugawara, D., Goto, K., Goff, J., Dudley, W., Gadd, P., 2018, Geological evidence and sediment transport modelling for the 1946 and 1960 tsunamis in Shinmachi, Hilo, Hawaii. Sedimentary Geology, 364, 319-333.

13. Ishizawa, T., Goto, K., Yokoyama, Y., Miyairi, Y., Sawada, C., Takada, K., 2018, Reducing the age range of tsunami deposits by ^{14}C dating of rip-up clasts. Sedimentary Geology, 364, 334-341.

14. Chagué-Goff, C., Goto, K., Sugawara, D., Nishimura, Y., Komai, T., 2018, Restoration measures after the 2011 Tohoku-oki tsunami and their impact on tsunami research. In: Santiago-Fandino, V., Sato, S., Maki, N., Iuchi, K. (eds.), The 2011 Japan Earthquake and Tsunami: Reconstruction and Restoration, 47, 229-247, Springer.

15. Lofi, J., Smith, D., Delahunty, C., Le Ber, E., Brun, L., Henry, G., Paris, J., Tikko, S., Zylberman, W., Pezard, P. A., Celerier, B., Schmitt, D. R., Nixon, C., and the Expedition 364 Scientists (including Goto, K.), 2018, Drilling□induced and logging□related features illustrated from IODP□ICDP Expedition 364 downhole logs and borehole imaging tools. Scientific Drilling, 24 1-13.

16. <in Japanese> Yoshikawa, S., Sugawara, D., Goto, K., Sato, A., Kanamatsu, T., Sakaguchi, H., 2018, Numerical simulation for understanding of the offshore-directed sediment transport by 2011 Tohoku-oki tsunami at southern part of the Sendai Bay. Journal of Japan Society of Civil Engineers, Ser. B2 (Coastal Engineering), 74, I_337─I_342.

17. Inoue, T., Goto, K., Nishimura, Y., Watanabe, M., Iijima, Y., Sugawara, D., 2017, Paleotsunami history along the northern Japan Trench: evidence from Noda Village, northern Sanriku coast, Japan. Progress in Earth and Planetary Science, 4, 42. DOI 10.1186/s40645-017-0158-1

18. Artemieva, N., Morgan, J. and Expedition 364 Science Party (including Goto, K.), 2017, Quantifying the release of climate-active gases by large meteorite impacts with a case study of Chicxulub. Geophysical Research Letters, 44, 10180-10188.

19. Yanagisawa, H., Goto, K., 2017, Source model of the 1703 Genroku Kanto earthquake tsunami

based on historical documents and numerical simulations: modeling of an offshore fault along the Sagami Trough. Earth, Planets and Space, 69, 136. Doi: 10.1186/s40623-017-0713-4

20. Ishizawa, T., Goto, K., Yokoyama, Y., Miyairi, Y., Sawada, C., Nishimura, Y., Sugawara, D., 2017. Sequential radiocarbon measurement of bulk peat for high-precision dating of tsunami deposits. Quaternary Geochronology, 41, 202-210.

21. Watanabe, M., Bricker, J. D., Goto, K., Imamura, F., 2017, Factors responsible for the limited inland extent of sand deposits on Leyte Island during 2013 Typhoon Haiyan. Journal of Geophysical Research -Oceans, 122, 2795-2812.

22. Kon, S., Nakamura, N., Nishimura, Y., Goto, K., Sugawara, D., 2017, Inverse magnetic fabric in unconsolidated sandy event deposits in Kiritappu Marsh, Hokkaido, Japan. Sedimentary Geology, 349, 112-119.

23. <in Japanese> Yoshikawa, S., Goto, K., Sugawara, D., Kanamatsu, T., Sakaguchi, H., 2017, Nearshore erosion and offshore-directed sediment transport by Tohoku-oki tsunami off southern part of Sendai Plain. Journal of Japan Society of Civil Engineers, Ser. B2 (Coastal Engineering), 73, I_823-I_828.

24. Morgan, J., Gulick, S., Bralower, T., Chenot, E., Christeson, G., Claeys, P., Cockell, C., Collins, G. S., Coolen, M. J. L., Ferriere, L., Gebhardt, C., Goto, K., Jones, H., Kring, D. A., Le Ber, E., Lofi, J., Long, X., Lowery, C., Mellett, C., Ocampo-Torres, E., Osinski, G. R., Perez-Cruz, L., Pickersgill, A., Polchau, M., Rae, A., Rasmussen, C., Rebolledo-Vieyra, M., Riller, U., Sato, H., Schmitt, D. R., Smit, J., Tikoo, S., Tomioka, N., Urrutia-Fucugauchi, J., Whalen, M., Wittmann, A., Yamaguchi, K., Zylberman, W., 2016, The formation of peak rings in large impact craters. Science, 354, 878-882.

25. Watanabe, M., Goto, K., Imamura, F., Hongo, C., 2016, Numerical identification of tsunami boulders and estimation of local tsunami size at Ibaruma reef of Ishigaki Island, Japan. Island Arc, 25, 316-332.

26. Goff, J., McFadgen, B., Chagué-Goff, C., Goto, K., Nichol, S., 2016, Putting a spin on palaeotsunami deposits. Earth Surface Processes and Landforms, 41, 1293-1296.

27. Yanagisawa, H., Goto, K., Sugawara, D., Kanamaru, K., Iwamoto, N., Takamori, Y., 2016, Tsunami earthquake can occur elsewhere along the Japan Trench -Historical and geological evidence for the 1677 earthquake and tsunami-. Journal of Geophysical Research-Solid Earth, 121, 3504-3516.

28. Suppasri, A., Goto, K., Muhari, A., Ranasinghe, P., Riyaz, M., Affan, M., Mas, E., Yasuda, M., Imamura, F., 2015, A decade after the 2004 Indian Ocean tsunami: The progress in disaster preparedness and future challenges in Indonesia, Sri Lanka, Thailand and the Maldives. Pure and Applied Geophysics, 172, 3313-3341.

29. Shinozaki, T., Goto, K., Fujino, S., Sugawara, D., Chiba, T., 2015, Erosion of a paleo-tsunami record by the 2011 Tohoku-oki tsunami along the southern Sendai Plain. Marine Geology, 369, 127-136.

30. Yoshikawa, S., Kanamatsu, T., Goto, K., Sakamoto, I., Yagi, M., Fujimaki, M., Imura, R., Nemoto, K., Sakaguchi, H., 2015, Evidence for erosion and deposition by the 2011 Tohoku-oki tsunami on the nearshore shelf of Sendai Bay, Japan. Geo-Marine Letters, 35, 315-328.

31. Hayakawa, Y. S., Oguchi, T., Saito, H., Kobayashi, A., Baker, V. R., Pelletier, J. D., McGuire, L. A., Komatsu, G., Goto, K., 2015, Geomorphic imprints of repeated tsunami waves in a coastal valley in northeastern Japan. Geomorphology, 242, 3-10.

32. Shinozaki, T., Fujino, S., Ikehara, M., Sawai, Y., Tamura, T., Goto, K., Sugawara, D., Abe, T., 2015, Marine biomarkers deposited on coastal land by the 2011 Tohoku-oki tsunami. Natural Hazards, 77, 445-460.

33. Kan, H., Urata, K., Nagao, M., Hori, N., Fujita, K., Yokoyama, Y., Nakashima, Y., Ohashi, T., Goto, K., Suzuki, A., 2015, Submerged karst landforms observed by multibeam bathymetric

survey in Nagura Bay, Ishigaki Island, southwestern Japan. Geomorphology, 229, 112-124.

34. <in Japanese> Hayakawa, Y., Oguchi, T., Saito, H., Kobayashi, A., Komatsu, G., Goto, K., 2015, Characteristics of erosional morphology formed by tsunami waves along the Sanriku coast, northeastern Japan: Analysis using terrestrial laser scanning. Journal of Geography (Chigaku Zasshi), 124, 241-258.

35. Hisamatsu, A., Goto, K., Imamura, F., 2014, Local paleo-tsunami size evaluation using numerical modeling for boulder transport at Ishigaki Island, Japan. Episodes, 37, 265-276

36. Nakamura, A., Yokoyama, Y., Sekine, Y., Goto, K., Komatsu, G., Kumar, S., Matsuzaki, H., Kaneoka, I., Matsui, T., 2014, Formation and geomorphologic history of the Lonar impact crater deduced from in situ cosmogenic ^{10}Be and ^{26}Al. Geochemistry, Geophysics, Geosystems, 15, 3190-3197.

37. Schneider, J. L., Chagué-Goff, C., Bouchez, J. L., Goff, J., Sugawara, D., Goto, K., Jaffe, B., Richmond, B., 2014, Using magnetic fabric to reconstruct the dynamics of tsunami deposition on the Sendai Plain, Japan - the 2011 Tohoku-oki tsunami. Marine Geology, 358, 89-106.

38. Yamada, M., Fujino, S., Goto, K., 2014, Deposition of sediments of diverse sizes by the 2011 Tohoku-oki tsunami at Miyako City, Japan. Marine Geology, 358, 67-78.

39. Goff, J., Terry, J. P., Chagué-Goff, C., Goto, K., 2014, What is a mega-tsunami? Marine Geology, 358, 12-17.

40. Goto, K., Hashimoto, K., Sugawara, D., Yanagisawa, H., Abe, T., 2014, Spatial thickness variability of the 2011 Tohoku-oki tsunami deposits along the coastline of Sendai Bay. Marine Geology, 358, 38-48.

41. Sato, T., Nakamura, N., Goto, K., Kumagai, Y., Nagahama, H., Minoura, K., 2014, Paleomagnetism reveals the emplacement age of tsunamigenic coral boulders on Ishigaki Island, Japan. Geology, 42, 603-606.

42. Iijima, Y., Goto, K., Minoura, K., Komatsu, G., Imamura, F., 2014, Hydrodynamics of impact-induced tsunami over the Martian ocean. Planetary and Space Science, 95, 33-44.

43. Komatsu, G., Kumar, P. S., Goto, K., Sekine, Y., Giri, C., Matsui, T., 2014, Drainage systems of Lonar Crater, India: Contributions to Lonar Lake hydrology and crater degradation. Planetary and Space Science, 95, 45-55.

44. Chagué-Goff, C., Wong, H.K.Y., Sugawara, D., Goff, J., Nishimura, Y., Beer, J., Szczuciński, W., Goto, K., 2014, Impact of tsunami inundation on soil salinisation: up to one year after the 2011 Tohoku-oki tsunami. In: Kontar, Y., Santiago-Fandino, V., Takahashi, T. (eds.), Tsunami Events and Lessons Learned: Environmental and Societal Significance, 35, 193-214, Springer.

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49. Ranasinghe, D. P., Goto, K., Takahashi, T., Takahashi, J., Wijetunge, J. J., Nishihata, T., Imamura, F., 2013, Numerical assessment of bathymetric changes caused by the 2004 Indian Ocean tsunami at Kirinda Fishery Harbor, Sri Lanka. Coastal Engineering, 81, 67-81.

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51. Haraguchi, T., Goto, K., Sato, M., Yoshinaga, Y., Yamaguchi, N., Takahashi, T., 2013, Large bedform generated by the 2011 Tohoku-oki tsunami at Kesennuma Bay, Japan. Marine Geology, 335, 200-205.

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53. <in Japanese> Goto, K., Iijima, Y., Wada, K., Imamura, F., Chang, Y., 2013, Tsunami risk assessment for the oceanic impact on Earth. Planetary People - The Japanese Society for Planetary Sciences, 22, 207-213.

54. Goto, K., Fujima, K., Sugawara, D., Fujino, S., Imai, K., Tsudaka, R., Abe, T., Haraguchi, T., 2012, Field measurements and numerical modeling for the run-up heights and inundation distances of the 2011 Tohoku-oki tsunami at Sendai Plain, Japan. Earth, Planets and Space, 64, 1247-1257.

55. Tappin, D.R., Evans, H. M., Jordan, C. J., Richmond B., Sugawara, D., Goto, K. 2012, Coastal changes in the Sendai area from the impact of the 2011 Tohoku-oki tsunami: Interpretations of time series satellite images, helicopter-borne video footage and field observations. Sedimentary Geology, 282, 151-174.

56. Jaffe, B., Goto, K., Sugawara, D., Richmond, B., Fujino, S., Nishimura, Y., 2012, Flow speed estimated by inverse modeling of sandy tsunami deposits: results from the 11 March 2011 tsunami on the coastal plain near the Sendai Airport, Honshu, Japan. Sedimentary Geology, 282, 90-109.

57. Richmond, B., Szczuciński, W., Chagué-Goff, C., Goto, K., Sugawara, D., Witter, R., Tappin, D.R., Jaffe, B., Fujino, S., Nishimura, Y., Goff, J., 2012, Erosion, deposition and landscape change on the Sendai coastal plain, Japan, resulting from the March 11, 2011 Tohoku-oki tsunami. Sedimentary Geology, 282, 27-39.

58. Sugawara, D., Goto, K., 2012, Numerical modelling of the 2011 Tohoku-oki tsunami in the offshore and onshore of Sendai Plain, Japan. Sedimentary Geology, 282, 110-123.

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60. Szczuciński, W., Kokociński, M., Rzeszewski, M., Chagué-Goff, C., Cachão, M., Goto, K., Sugawara, D., 2012, Sediment sources and sedimentation processes of 2011 Tohoku-oki tsunami deposits on the Sendai Plain, Japan - Insights from diatoms, nannoliths and grain size distribution. Sedimentary Geology, 282, 40-56.

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62. Goto, K., Sugawara, D., Ikema, S., Miyagi, T., 2012, Sedimentary processes associated with sand and boulder deposits formed by the 2011 Tohoku-oki tsunami at Sabusawa Island, Japan. Sedimentary Geology, 282, 188-198.

63. Goto, K., Takahashi, J., Fujino, S., 2012, Variations in the 2004 Indian Ocean tsunami deposits thickness and their preservation potential, southwestern Thailand. Earth, Planets and Space, 64, 923-930.

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source of the A.D. 2011 Tohoku-oki tsunami deposits at Sendai Plain, Japan. Geology, 40, 887-890.

65. Hongo, C., Kawamata, H., Goto, K., 2012, Catastrophic impact of typhoon waves on coral communities in the Ryukyu Islands under global warming. Journal of Geophysical Research-Biogeoscience, 117, G02029.

(2) Non-peer-reviewed Articles

Five publications in Japanese on Report of Tsunami Engineering in 2012 (3 papers), 2013, and 2017.

(3) Review Papers

1. Lowery, C., Morgan, J. V., Gulick, S. P. S., Bralower, T., Christeson, G. L., the Expedition 364 Scientists (including Goto, K.). 2019, Ocean drilling perspectives on meteorite impacts. Oceanography, 32, 120-134.
2. Wallis, S., Fujiwara, O., Goto, K., 2018, Geological studies in tsunami research since the 2011 Tohoku earthquake. In: Scourse, E. M., Chapman, N. A., Tappin, D. R., Wallis, S. R. (eds.), Tsunamis: Geology, Hazards and Risks, Geological Society, London, Special Publications, 456, 39-53.
3. Kring, A. D., Claeys, P., Gulick, S. P. S., Morgan, J. V., Collins, G. S., and the IODP-ICDP Expedition 364 Science Party (including Goto, K.). 2017, Chicxulub and the Exploration of Large Peak-Ring Impact Craters through Scientific Drilling. GSA Today, 27, 4-8.
4. Goto, K., 2017, Tsunamis. In: Bobrowsky P., Marker B. (eds.) Encyclopedia of Engineering Geology, Springer, doi.org/10.1007/978-3-319-12127-7_286-1
5. <in Japanese> Goto, K., 2017, Paleotsunami researches along the Ryukyu Trench. Journal of Geological Society of Japan, 123, 843-855.
6. Goff, J., Ebina, Y., Goto, K., Terry, J., 2016, Defining tsunamis: Yoda strikes back? Earth-Science Reviews, 159, 271-274.
7. Goto, K., Imamura, F., Koshimura, S., Yanagisawa, H., 2016, Observations and modeling of environmental and human damage caused by the 2004 Indian Ocean tsunami. In: Chavez, M., Ghil, M., Urrutia-Fucugauchi, J. (eds.), Extreme Events: Observations, Modeling, and Economics, Geophysical Monograph 214, 137-152.
8. Jaffe, B., Goto, K., Sugawara, D., Gelfenbaum, G., Selle, S.P., 2016, Uncertainty in tsunami sediment transport modeling. Journal of Disaster Science, 11, 647-661.
9. Sugawara, D., Goto, K., Jaffe, B., 2014, Numerical models of tsunami sediment transport - Current understanding and future directions. Marine Geology, 352, 295-320.
10. Goto, K., Ikehara, K., Goff, J., Chagué-Goff, C., Jaffe, B., 2014, The 2011 Tohoku-oki tsunami - 3 years on. Marine Geology, 358, 2-11.
11. Goto, K., Fujino, S., Sugawara, D., Nishimura, Y., 2014, The current situation of tsunami geology under new policies for disaster countermeasures in Japan. Episodes, 37, 258-264.
12. Goto, K., Chagué-Goff, C., Goff, J., Jaffe, B., 2012, The future of tsunami research following the 2011 Tohoku-oki event. Sedimentary Geology, 282, 1-13.
13. <in Japanese> Namiki, N., Komatsu, G., Usui, T., Sugita, S., Miyamoto, H., Kubota, T., Ishigami, G., Demura, H., Okada, T., Miura, Y., Cho, Y., Goto, K., Senshu, H., Wada, K., Ishibashi, K., Arai, T., Kobayashi, M., Ohno, S., Mars rover study group, 2012, A proposal for rover geological exploration on Mars. Journal of Geological Society of Japan, 118, 606-617.
14. <in Japanese> Goto, K., Komatsu, G., 2012, The comparative planetary geology of oceans, lakes and outflow channels on Mars. Journal of Geological Society of Japan, 118, 618-631.
15. <in Japanese> Goto, K., Minoura, K., 2012, Lessons learned from the 2011 Tohoku-oki tsunami and future perspective of the tsunami geology. Journal of the Sedimentological Society of Japan,

71, 105-117.

16. <in Japanese> Goto, K., 2012, Current progress and perspectives of the research on tsunami boulders. Journal of the Sedimentological Society of Japan, 71, 129-139.

(4) Books

Two Japanese books published from Nikkei Publishing Inc. (2014) and Iwanami Shoten (2012).

(5) Other Publications

1. Fujino, S., Goto, K., Tappin, D., Fujiwara, O., 2016, Geological records of storms, tsunamis and other extreme events. Island Arc, 25, 303-304. <Preface>
2. Goto, K., Chagué-Goff, C., Goff, J., Ikehara, K., Jaffe, B., 2014, Preface for Special Issue of Marine Geology: In the wake of the 2011 Tohoku-oki tsunami - Three years on. Marine Geology, 358, 1. <Preface>
3. Komatsu, G., Goto, K., Tanaka, K. L., 2014, Planetary Geology Field Symposium, Kitakyushu, Japan, 2011: planetary geology and terrestrial analogs. Planetary and Space Science, 95, 1-4. <Preface>
4. Goto, K., Tanioka, Y., Nishimura, Y., Imamura, F., Koshimura, S., Mastronuzzi, G., 2012, Preface. Earth Planets Space, 64, 785. <Preface>

Plus seventeen Japanese papers, articles, preface and other publications.

(6) Patents

8. Keynote, Invited, or Solicited Presentations

1. Goto, K., Whalen, M., Kring, D. A., Smit, J., Bralower, T. J., Ormö, J., Morgan, J. V., Gulick, S., Expedition 364 scientists, Resurge processes of the upper suevite in the IODP-ICDP Expedition 364 core from the Chicxulub impact crater. IGCP 630 meeting in Japan (2017 June, Sendai).
2. Goto, K., Tsunami damages to the nearshore and onshore environments at Tohoku area. International Symposium on Restoration after Great East Japan Earthquake –Our knowledge on the ecosystem and fisheries–. (2016 March, Tokyo)
3. Goto, K., Japanese tsunami countermeasure before and after the Tohoku tsunami and how geological evidence was incorporated into government policy. Arthur Holmes Meeting 2015, The Geological Society (2015, September, London).
4. Goto, K., The 2011 Tohoku-oki tsunami deposits: simple or complex? 4th International Tsunami Field Symposium (2015, March, Phuket).
5. Goto, K., Nakamura, N., Sato, T., Hisamatsu, A., Multiple paleotsunamis inferred from a single coral boulder. 2013 AGU Fall Meeting (2013 December, San Francisco).
6. Goto, K., The 2011 Tohoku-oki tsunami and paleotsunami deposits at the Pacific coast of Tohoku. 2nd G-EVER International Symposium and the 1st IUGS & SCJ International Workshop on Natural Hazards (2013 October, Sendai)
7. Goto, K., The paleotsunami histories along the Ryukyu Islands inferred from coastal boulders. Paleotsunami workshop in Taiwan (2013 July, Taipei).
8. Goto, K., Tsunami geology and the future tsunami risk assessment in Japan. Asia Oceania Geosciences Society (AOGS) (2013 June, Brisbane)
9. <in Japanese> Goto, K., Suda, Y., Imamura, F., Hongo, C., Yagi, Y., Revisiting the unusual uplift of the Kikai Island at northern Ryukyu Islands, Japan. JpGU meeting 2013 (2013 May, Chiba).
10. Goto, K., Geological features of the tsunami -lessons learned from the 2011 Tohoku-oki event-. JpGU meeting 2013 (2013 May, Chiba).

11. Goto, K., Tsunami geology: current understanding, future direction, and social relationship after the 2011 Tohoku-oki event. Western Pacific Sedimentology Meeting (2013 May, Yaoyuan, Taiwan).
12. Goto, K., Interdisciplinary approaches to better understand the past tsunamis - Case study of the 1771 Meiwa Tsunami, Japan-. 2012 AGU Fall Meeting (2012 December, San Francisco).
13. Goto, K., Geological and geomorphological features of the 2011 Tohoku-oki tsunami at Sendai Plain, Japan. International Symposium on Emerging Issues after the 2011 Tohoku Earthquake (2012 November, Tsukuba).

III. Education Activity

9. Notable Achievements in Education

Advisees

- FY2015 Master theses, 1 student (Tohoku Univ.)
- FY2016 Master theses, 1 student (Tohoku Univ.)
- FY2017 Master theses, 1 student (Tohoku Univ.)
- FY2018 Master theses, 2 students, Doctoral theses 1 student (Tohoku Univ.)

Lectures

- Undergraduate, Earth System Science (Faculty of Science), Tohoku Univ. FY2014-2018
- Undergraduate, Earth System Science (others), Tohoku Univ. FY2014-2018
- Undergraduate, Earth System Science (Faculty of Engineering), Tohoku Univ. FY2014-2018
- Undergraduate, Sedimentology, Tohoku Univ. FY2015-2018
- Undergraduate, Applied sedimentology, Tohoku Univ. FY2017-2018
- Graduate, Natural Disasters, Tohoku Univ. FY2013, 2015, 2017

IV. External Activities

10. Contribution to Academic Community

Committee member of academic society

- 2017-, AOGS Publication Committee
- 2017-, AOGS Regional Advisory Committee
- 2017, The 5th International Tsunami Field Symposium, Scientific Committee
- 2017-, Secretary General, IUGS Task Group on Geohazards
- 2016-2018, AOGS Interdisciplinary Geoscience section, President
- 2015-2016, 2018-, AOGS Interdisciplinary Geoscience section, Vice President

Nine Japanese committee members for academic societies

Journal editors

- 2018-, Earth-Science Reviews (Special issue), Lead Guest Editor
- 2016, Island Arc (Special issue), Guest Editor

- 2014, Marine Geology (Special issue), Lead Guest Editor
- 2014, Planetary and Space Science (special issue), Guest Editor
- 2012, Sedimentary Geology (Special issue), Guest Editor
- 2012, Earth, Planets and Space (Special issue), Lead Guest Editor
- 2012-, Editorial Board "Marine Geology", Elsevier

Four Japanese Journal guest editors of special issues.

11. Outreach Activity

Seven Japanese committee members organized by national and local governments and other associations.

12. Internal Committee Membership

V. International Exchange Activities

13. Hosting/Sending Foreign Students and Researchers

(1) Hosting

Foreign Students: 0

Foreign Researchers: 0

(2) Sending

Students: 0

Researchers: 0

(3) Visitors from Abroad: 0

Yoshio Takahashi

I. CV

Name: Yoshio Takahashi

Age: 51

Present Position: Professor

Education

Tsuchiura Daiichi High School, Ibaraki, March, 1987 (graduation)

B. Sc. Department of Chemistry, The University of Tokyo, March, 1992

M. Sc. Department of Chemistry, The University of Tokyo, March, 1994

Ph. D. Department of Chemistry, The University of Tokyo, March, 1997

Professional Experience

Apr. 1997-Mar. 1998, Postdoctoral Fellow of Japan Society for the Promotion of Science (host institute: The University of Tokyo)

Apr. 1998-Nov. 2000, Research Associate, Department of Earth and Planetary Systems Science, Hiroshima University

Dec. 2000-Mar. 2009, Associate Professor, Department of Earth and Planetary Systems Science, Hiroshima University

Apr. 2009-May. 2014, Professor, Department of Earth and Planetary Systems Science, Hiroshima University

June. 2014-, Professor, Department of Earth and Planetary Science, The University of Tokyo

II. Scientific Research Activity

2. Major Achievements

I have developed molecular geochemistry, which is to study various macro-scale phenomena in various systems in earth and planetary sciences based on molecular-scale information. Although geochemical data such as concentrations and isotopic compositions of various elements have been employed to deduce various macroscopic phenomena, chemical processes that control the concentrations and isotopic compositions are not always clear, which inhibits accurate interpretation of the data. However, to obtain chemical-state and speciation of a target element in natural samples is not straightforward due to interferences from other elements included in the sample. On the other hand, physico-chemical understanding of any elements from molecular scale that can be common in various systems is highly important. I have developed various types of X-ray spectroscopies such as X-ray absorption fine structure (XAFS) and X-ray fluorescence (XRF) spectroscopies using synchrotron radiation having high selectivity of element and high sensitivity, which has enabled us to develop the molecular geochemistry. The application field of the molecular geochemistry in our laboratory has been very wide such as ranging from (i) speciation of various elements in extraterrestrial materials, (ii) distribution of various elements between water and solid surface phases related to enrichment of elements in geological materials and its utilization by biota, (iii) development of new isotopic tool based on understanding of isotope fractionation by investigating chemical processes from molecular scale, to (iv) aerosol chemistry including evaporation and aqueous chemistry of elements in the atmosphere related to its effect on radiation balance and biological productivities in the ocean. Concrete examples of such studies are given in Section 3. The importance of my approach can be understood from high citations of our achievements (total number of refereed manuscripts: 264; total citations: 5951; h-index: 41 from Web of Science examined on Sep. 20, 2019).

3. Five Important Papers (including three or more papers in this review period)

1. Takahashi, Y., Minamikawa, R., Hattori, K. H., Kurishima, K., Kihou, N., & Yuita, K. (2004). Arsenic Behavior in Paddy Fields during the Cycle of Flooded and Non-flooded Periods. Environmental Science and Technology, 38(4), 1038–1044. https://doi.org/10.1021/es034383n

Speciation and solid-water distribution of arsenic was investigated in the experimental paddy field for two years including flooded and non-flooded periods that causes large oxic-anoxic cycle in the soil during the period. X-ray absorption fine structure (XAFS) spectroscopy analysis revealed that the reduction of arsenic and iron during flooded period increased arsenic concentration in the soil water. The paddy is the main land use in south-eastern Asia which includes Bangladesh and West Bengal suffering from serious contamination of arsenic in groundwater. As a result, this study stimulated various researches related to arsenic behavior in paddy fields and intake of arsenic to rice grains, main crop in the region, which may absorb relatively high concentration of arsenic due to its high concentration during the flooded period. This study initiated our various studies on the molecular geochemistry of various toxic elements in environment using XAFS spectroscopy including antimony, tellurium, and iodine. (Citation 295, Scopus/Sep. 20, 2019)

2. Takahashi, Y., Manceau, A., Geoffroy, N., Marcus, M. A., & Usui, A. (2007). Chemical and structural control of the partitioning of Co, Ce, and Pb in marine ferromanganese oxides. Geochimica et Cosmochimica Acta, 71, 984–1008. https://doi.org/10.1016/j.gca.2006.11.016

Enrichment of various elements to marine ferromanganese oxides (nodule and crust) has been studied based on the speciation using XAFS related to their potential as metal resources. This was followed by similar studies on other elements by other researchers for the marine ferromanganese oxides. In particular, this study was successful in revealing systematics of redox reactions for enrichment of various elements and distinguishing their host phases, either iron or manganese oxides, to understand the degree of enrichment of the elements. The approach to describe the chemical processes was extended to understand the systematics of enrichment of various elements and mechanisms of isotope fractionation during the adsorption-desorption reactions. The latter application is also important in terms of estimation of paleoenvironment using isotopic fractionation recorded in marine authigenic minerals. (Citation 155, Scopus/Sep. 20, 2019)

3. Yoshida, N., & Takahashi, Y. (2012). Land-surface contamination by radionuclides from the Fukushima Daiichi nuclear power plant accident. Elements, 8, 201–206. https://doi.org/10.2113/gselements.8.3.201

Various studies on the behavior of various radionuclides including radiocesium, radioiodine, and radiostrontium emitted by the Fukushima Dai-ichi Nuclear Power Plant accident triggered by huge tsunami caused by the Great East Japan Earthquake in 2011 were reviewed in this review article at the time of 2012, a year after the accident. Molecular-scale information by our studies, which was clearly linked to the macroscopic behavior, was also included in the review. In particular, the strong affinity of radiocesium for phyllosilicates was important to understand its behavior in Fukushima area. Results on their transport in the atmosphere using atmospheric model on the dispersion of the radionuclides during the early stage of the accident were also summarized to understand the initial deposition map of the radionuclides on the land. This is one of review articles published in the early stage after the accident (Citation 107, Scopus/Sep. 20, 2019)

4. Takahashi, Y., Furukawa, T., Kanai, Y., Uematsu, M., Zheng, G., & Marcus, M. A. (2013). Seasonal changes in Fe species and soluble Fe concentration in the atmosphere in the Northwest

Pacific region based on the analysis of aerosols collected in Tsukuba, Japan. Atmospheric Chemistry and Physics, 13, 7695–7710. https://doi.org/10.5194/acp-13-7695-2013.

In this study, the Fe species, chemical composition, and soluble Fe concentrations in aerosols collected in Tsukuba, Japan were investigated over a year to identify the factors affecting the amount of soluble Fe supplied into the ocean. The soluble Fe concentration in aerosols is correlated with those of sulfate and oxalate originated from anthropogenic sources, suggesting that the degree of Fe dissolution is influenced by the magnitude of anthropogenic activity, such as fossil fuel combustion. In particular, speciation using XAFS showed that the Fe(III) sulfate is the main soluble Fe in the aerosols. This study was extended to Fe isotope studies that allows us to determine anthropogenic fraction of Fe relative to total Fe in aerosols due to tis large fractionation during evaporation of Fe during combustion processes, which in turn revealed that anthropogenic Fe of combustion origin in aerosols can contribute to the increase of biological productivities in the North Pacific suggested in our recent publications Kurisu et al., 2016a, 2016b, 2019a, 2019b） on Fe stable isotopes in aerosols. (Citation 20, Scopus/Sep. 20, 2019)

5. Kashiwabara, T., Kubo, S., Tanaka, M., Senda, R., Iizuka, T., Tanimizu, M., & Takahashi, Y. (2017). Stable isotope fractionation of tungsten during adsorption on Fe and Mn (oxyhydr)oxides. Geochimica et Cosmochimica Acta, 204, 52–67. https://doi.org/10.1016/j.gca.2017.01.031

This study clarified isotopic fractionation of tungsten during its distribution between seawater and ferromanganese oxides in marine system coupled with speciation of tungsten within the ferromanganese oxides using XAFS spectroscopy. The speciation results showing the change of the symmetry of tungsten from tetrahedral (= dissolve tungstate) to octahedral for tungsten adsorbed both on iron and manganese oxides is contrastively different from that of molybdate which shows the similar change only found during its adsorption on manganese oxides. Consequently, tungsten isotope fractionation was found both for adsorption reactions on iron and manganese oxides, but only the latter causes isotope fractionation for molybdenum (Kashiwabara et al., 2011). Hence, the combination of tungsten and molybdenum isotopes can distinguish marine environment under (i) suboxic condition in the presence of only iron oxide and (ii) oxic condition that form both iron and manganese oxides, which contribute to the understanding of paleoredox environment. This study highlighted the importance of molecular geochemistry approach to establish new isotopic tools in geochemistry. (citation 15, Scopus/Sep. 20, 2019)

4. Awards and Honors

- Takahashi, Y., Geochemical Society of Japan Award, Sep. 2015
- Usui, A., Takahashi, Y. et al., Kochi Academic Publication Award, March 2016
- Takahashi, Y., Japan Society for Environmental Chemistry Award, June 2016
- Takahashi, Y. (Community reception), The Association of American Publishers PROSE Subject Category Award: the Encyclopedia of Geochemistry 2016

5. Future Research Plan

I will establish molecular geochemistry in various fields in earth and planetary sciences in terms of its methodology and its application. We are currently developing novel methods of X-ray spectroscopies such as scanning transmission X-ray microscopy (STXM) and fluorescence XAFS using transition edge sensor (TES) detector. The former is a powerful tool to obtain imaging of chemical species such as functional group of carbon, while the latter has ultra-high energy resolution to obtain XAFS of trace elements usually interfered by major elements. The state-of-the-art speciation methods coupled with isotope ratio determinations and quantum chemical calculations enable us to obtain chemical processes inherited in natural samples in any fields of earth and planetary sciences. The physico-chemical knowledge common in any chemical processes in earth and planetary systems extracted by the method will be useful to understand various geochemical data theoretically in terms of periodic table and quantum chemical information for various samples. Actual researches we plan are as follows. (1) Application of STXM to returned samples of Ryugu in Hayabusa2 project to estimate physico-chemical conditions and evolution of organic matters on the asteroid. (2) Establishment of relationship between volatility and isotopic fractionation of metal ions in aerosols, which enables us to use isotope ratios of various elements to know their emission processes and its application as a signature of human activities such as for iron, cadmium, and zinc. (3) Systematic understanding of solid-water distributions and isotopic fractionation based on chemical species, which enables us to establish various geochemical tracers for paleoenvironment research such as rubidium isotope fractionated by its formation of inner-sphere complex within interlayer of phyllosilicate. Throughout these studies, we try to focus on the extraction of systematics of various elements, and common theory to explain the systematics based on the periodic table and quantum chemical knowledge. The approach of the molecular geochemistry from molecular-scale to macroscopic phenomena will provide novel knowledge and open completely new field that cannot be achieved without molecular scale knowledge. Ideally speaking, if we know the abundances of elements in the solar system, such physico-chemical theories for any interactions of elements can reproduce the earth, which is an ultimate goal of geochemistry.

6. Funding Received

- MEXT KAKENHI, 20109005, Co-Investigator, FY2008-2012, 28,000,000 yen
- MEXT KAKENHI, 22224011, Principal Investigator, FY2010-2014, 57,000,000 yen
- MEXT KAKENHI, 23540535, Co-Investigator, FY2010-2014, 500,000 yen
- MEXT KAKENHI, 24110008, Co-Investigator, FY2013-2016, 12,000,000 yen
- MEXT KAKENHI, 25550013, Principal Investigator, FY2013-2015, 3,100,000 yen
- Kurita Water and Environmental Foundation, Principal Investigator, FY2014, 1,000,000 yen
- The Sumitomo Foundation, Principal Investigator, FY2014-2015, 1,400,000 yen
- MEXT KAKENHI, 26550020, Co-Investigator, FY2014-2015, 1,900,000 yen
- MEXT KAKENHI, 26257402, Co-Investigator, FY2014-2017, 1,000,000 yen
- Next-generation technology for ocean resources exploration, Cross-ministerial Strategic Innovation Promotion Program, Co-Investigator, FY2015-2018, 5,000,000 yen
- MEXT KAKENHI, 15H02149, Principal Investigator, FY2015-2017, 33,000,000 yen
- MEXT KAKENHI, 16K13911, Principal Investigator, FY2016-2018, 2,800,000 yen
- MEXT KAKENHI, 16K12627, Co-Investigator, FY2016-2018, 490,000 yen
- MEXT KAKENHI, 16K05581, Co-Investigator, FY2016-2018, 220,000 yen
- MEXT KAKENHI, 16K04073, Co-Investigator, FY2016-2018, 1,000,000 yen
- Reimei research, Japan Atomic Energy Research Agency, Principal Investigator, FY2017, 2,800,000 yen
- MEXT KAKENHI, 17F17084, Principal Investigator, FY2017-2019, 2,300,000 yen
- MEXT KAKENHI, 17F17383, Principal Investigator, FY2017-2019, 2,900,000 yen
- MEXT KAKENHI, 17F17332, Principal Investigator, FY2017-2019, 2,300,000 yen
- MEXT KAKENHI, 17H06458, Co-Investigator, FY2017-2021, 21,000,000 yen
- MEXT KAKENHI, 17H04582, Principal Investigator, FY2017-2019, 12,000,000 yen

- MEXT KAKENHI, 18KK0296, Co-Investigator, FY2018-2020, 1,000,000 yen
- MEXT KAKENHI, 18H04134, Principal Investigator, FY2018-2021, 34,700,000 yen

7. Publications and Patents

(1) Peer-reviewed Journal Articles

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(2) Non-peer-reviewed Articles

1. Qin, H.-B., Zhu, J.-M., Takahashi, Y., & Zheng, L.-R. (2014). Selenium speciation in soils from selenosis area: Comparison between a Sequential Extraction Procedure and XAFS. Selenium in the Environment and Human Health - Proceedings of the 3rd International Conference on Selenium in the Environment and Human Health.
2. Takeichi, Y., Ueno, T., Inami, N., Suga, H., Takahashi, Y., & Ono, K. (2016). Soft x-ray spectromicroscopy using compact scanning transmission x-ray microscope at the photon factory.

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3. Takeichi, Y., Inami, N., Suga, H., Takahashi, Y., & Ono, K. (2016). Compact scanning transmission X-ray microscope at the photon factory. AIP Conference Proceedings, 1696. https://doi.org/10.1063/1.4937514

(3) Review Papers

1. Tsuji, K., Nakano, K., Takahashi, Y., Hayashi, K., & Ro, C.-U. (2012). X-ray spectrometry. Analytical Chemistry, 84(2), 636–668. https://doi.org/10.1021/ac202871b
2. Yoshida, N., & Takahashi, Y. (2012). Land-surface contamination by radionuclides from the Fukushima Daiichi nuclear power plant accident. Elements, 8, 201–206. https://doi.org/10.2113/gselements.8.3.201

(4) Books

1. Ishibashi, J.-I., Miyoshi, Y., Tanaka, K., Omori, E., Takahashi, Y., Furuzawa, Y., Yamanaka, T., Kawagucci, S., Miyazaki, J., Konno, U., Watanabe, S., Yanagawa, K., Yoshizumi, R., & Urabe, T. (2015). Pore fluid chemistry beneath active hydrothermal fields in the mid-Okinawa Trough: Results of shallow drillings by BMS during taiga11 cruise. In Subseafloor Biosphere Linked to Hydrothermal Systems: TAIGA Concept. https://doi.org/10.1007/978-4-431-54865-2_42
2. Yokoyama, Y., Takahashi, Y., Miyoshi, Y., Ishibashi, J.-I., & Kawagucci, S. (2015). Sediment–pore water system associated with native sulfur formation at jade hydrothermal field in Okinawa Trough. In Subseafloor Biosphere Linked to Hydrothermal Systems: TAIGA Concept. https://doi.org/10.1007/978-4-431-54865-2_31
3. Takahashi, Y., Ariga, D., Fan, Q., & Kashiwabara, T. (2015). Systematics of distributions of various elements between ferromanganese oxides and seawater from natural observation, thermodynamics, and structures. In Subseafloor Biosphere Linked to Hydrothermal Systems: TAIGA Concept. https://doi.org/10.1007/978-4-431-54865-2_4
4. Takahashi, Y. (2018). Technetium, in Encyclopedia of Geochemistry, Springer, Switzerland, pp. 1421–1423.
5. Takahashi, Y. (2018). Tellurium. in Encyclopedia of Geochemistry, Springer, Switzerland, pp. 1423–1425.

(5) Other Publications

(6) Patents

8. Keynote, Invited, or Solicited Presentations

1. Takahashi, Y., Radionuclides migration emitted from the Fukushima Daiichi nuclear power plant: Heterogeneity in their distributions in aerosol, soil and particulate matters, Joint International Conference on "Pacific Basin Consortium for Environment and Health" and "Society for Environmental Geochemistry & Health", Kwangju, Korea, 2012/04/12.
2. Takahashi, Y., Speciation of elements in aerosols by XAFS related to the neutralization of acid rain, cooling effect, and iron supply to the Pacific Ocean, 27th International symposium on environmental analytical chemistry, Antwerp, Belgium, 2012/05/24.
3. Takahashi, Y., speciation of elements in aerosols by XAFS related to the neutralization of acid rain, cooling effect, and iron supply to the Pacific Ocean, The 15th International Conference on X-ray Absorption Fine Structure (XAFS15), Beijing, China, 2012/07/23.
4. Takahashi, Y., XAFS applications to environmental & resource studies, The 6th Asia-Oceania

Forum for Synchrotron Radiation Research (AOFSRR 2012), Bangkok, Thailand, 2012/08/08.

5. Takahashi, Y., Changes of Ca and Fe species in Asian dust during its transport to the Pacific Ocean related to neutralization of acid rain and Fe solubility, (AOGS-AGU (WPGM) Joint Assembly 2012, Sentosa, Singapore, 2012/08/17.
6. Takahashi, Y., Molecular environmental geochemistry: a bridge between atomic- and macro-scale phenomena, Invited Seminar at Institute of Geology and Geophysics, Lanzhou, China, 2013/02/28.
7. Takahashi, Y., Molecular environmental geochemistry: a bridge between atomic- and macro-scale phenomena, Invited Seminar at Lanzhou University, Lanzhou, China, 2013/03/01.
8. Takahashi, Y., Fan, Q., Sakaguchi, A., Togo, Y. S., & Tanaka, K., Migration of radiocesium and radioiodine in soil-water-river system related to Fukushima Dai-ichi Nuclear Power Plant Accident, Goldschmidt2013, Firenze, Italy, 2013/08/29.
9. Takahashi, Y., Fan, Q., Sakaguchi, A., Togo, Y. S., & Tanaka, K., Migration of radiocesium and radioiodine in soil-water-river system related to Fukushima Dai-ichi Nuclear Power Plant Accident , APSORC2013, Kanazawa, 2013/09/23.
10. Takahashi, Y., Influences of aerosols on environment based on the speciation analysis of elements by X-ray absorption fine structure (XAFS) spectroscopy, UNU & GIST Joint Programme Symposium 2013, Kota Kinabalu, Malaysia, 2013/10/24.
11. Takahashi, Y., & Yoshida, N. (2014) Migration of Radionuclides in Land-Surface in Fukushima: Mechanisms of Secondary Transport, Goldschmidt 2014, Sacrament, USA, 2014/06/10
12. Takahashi, Y., Speciation of Elements in Aerosols related to the Neutralization of Acid Rain, Global Cooling Effect, and Iron Supply to the Pacific Ocean, 2014 International Aerosol Conference, Busan, Korea, 2014/08/30.
13. Takahashi, Y., Molecular environmental geochemistry: a bridge between atomic- and macro-scale phenomena, The 74th Okazaki Conference " Frontier of X-ray Absorption Spectroscopy and Molecular Science", Okazaki, 2015/02/05.
14. Takahashi, Y., Speciation and water soluble fraction of iron in aerosols from various sources, American Geophysical Union Fall Meeting, San Francisco, USA, 2015/12/14.
15. Takahashi, Y., Incorporation of anions into calcite and barite., The 28th Reimei Workshop on Radioactive Waste Treatment and Remediation, Tokai, Ibaraki, 2016/02/26.
16. Takahashi, Y., Transfer of rare earth elements (REE) from manganese oxides to phosphates during early diagenesis in pelagic sediments, International Workshop on Marine Manganese Minerals, Kochi, 2016/03/17.
17. Takahashi, Y., Development of recovery and separation methods of rare earth elements by adsorption on bacteria and DNA-related materials: importance of identification of binding site using EXAFS Spectroscopy, Rare Earths 2016, Sapporo, 2016/06/08.
18. Takahashi, Y., Molecular geochemistry as a basis for systematic understanding of environmental behaviors of various elements, Goldschmidt 2016, Yokohama, 2016/06/30.
19. Takahashi, Y., Effect of humic substances on the migration of cesium and iodine related to Fukushima Daiichi Nuclear Power Plant (FDNPP) accident revealed by applications of X-ray spectroscopies, 8th International Conference of International Humic Substances Society, Kanazawa, Japan, 2016/09/12.
20. Takahashi, Y., Migration of radionuclides in land-surface in Fukushima: mechanisms of secondary transport, The 5th International Geo-hazards Research Symposium (IGRS 2016), Taipei, Taiwan, 2016/10/13.

21. Takahashi, Y., Importance of chemical process study for the precise prediction of environmental change, JpGU-AGU Joint meeting (Session: Future Earth - Implementing Integrated Research for Sustainable Future), Chiba, Japan, 2017/05/20.
22. Takahashi, Y., Overview of the radioactive particles emitted from the F1NPP, 3d Research Coordination Meeting, IAEA Coordinated Research Project 'Environmental Behaviour and Potential Biological Impact of Radioactive Particles', Vienna, 2017/06/08.
23. Takahashi, Y., Future application of X - ray microscopy (STXM etc.) to Hayabusa 2 asteroid samples, Joint meeting of Multi - scale asteroid science & Aqua planetology, Sagamihara, Japan 2017/12/03.
24. Takahashi, Y., Development of STXM at Photon Factory and its application to extraterrestrial materials, Mini-workshop "Towards Japanese exploration program of Mars", ISAS, Sagamihara, 2018/03/06.
25. Takahashi, Y., Migration of various elements in the presence of microbes and humic substances at earth surfaces using STXM for characterization of organic matters, AOGS 2018, Oahu, USA, 2018/06/07.
26. Takahashi, Y., Studying trace element speciation (molecular geochemistry) allows to better understand geochemical controls on their distributions and isotopic signatures in sediments, Goldschmidt 2018 (Session: Session honoring Prof. G. R. Helz: Understanding the Geochemistry of Redox-Sensitive Trace Elements), Boston, USA, 2018/08/15.

III. Education Activity

9. Notable Achievements in Education

Advisees

- Master theses: 15 students

  Rieko Ohmori, Masatomo Fujiwara (Mar. 2013)

  Kohei Tokunaga, Hiroko Yamada, Asami Miyaji, Daisuke Ariga (Mar. 2014)

  Horoki Suga, Aya Miyahara (Mar. 2015)

  Tasuku Honda, Yoshiaki Yamakawa (Mar. 2016)

  Soichiro Uesugi, Chihiro Miyamoto, Minako Kurisu (Mar. 2017)

  Hikaru Miura (Mar. 2018)

  Akiko Yamaguchi (Mar. 2019)

- Doctral theses: 7 students

  Yuka Yokoyama (Mar. 2013)

  Ryoichi Nakada (Sep. 2013)

  Sakiko Kikuchi (Mar. 2015)

  Kohei Tokunaga (Sep. 2017)

  Kohei Sakata, Yusuke Watanabe (Mar. 2018)

  Lisa Ito (May. 2018)

Lectures

- Undergraduate/Graduate, Earth's Environmental Chemistry, FY2015-2018

- Undergraduate/Graduate, Practical: Earth's Environmental Chemistry, FY2015-2018
- Undergraduate/Graduate, Instrumental Analyses of Solids, FY2015-2018
- Undergraduate/Graduate, Cosmo- and Geo- chemistry, FY2015-2018
- Undergraduate/Graduate, Resource Geology, FY2016-2018
- Undergraduate, Field Excursion: Earth and Planetary Environmental Science I, FY2015-2018
- Undergraduate, Introduction to Earth, Planetary, and Environmental Science, FY2015-2018
- Undergraduate, Environmental Science, FY2015-2016

Student's awards

- Incentive Award of the School of Science, the University of Tokyo: 3 students [Minako Kurisu, Hikaru Miura, Akiko Yamaguchi]
- Joint International Conference on "Pacific Basin Consortium for Enviornment and Health" and "Society for Environmental Geochemistry & Health", Student Presentation Award: 1 student [Hiroko Yamada]
- Japan Geoscience Union, Student Presentation Award: 2 students [Kohei Tokunaga, Akiko Yamaguchi]
- Geochemical Society of Japan, Student Presentation Award: 7 students [Yuka Yokoyama, Ryoichi Nakada (twice), Daisuke Ariga, Kohei Sakata, Minako Kurisu (twice)]
- Meeting of Japan Society for Environmental Chemical Society of Japan, Student Presentation Award: 4 students [Yuka Yokoyama, Hiroko Yamada, Minako Kurisu, Chihiro Miyamoto]

IV. External Activities

10. Contribution to Academic Community

- Japan Academy of Science, Member, FY2017
- Atomic Weight Committee, Chemical Society of Japan, Member, FY2018
- Japan Geoscience Union, Program Committee Member, FY2016-2018
- Japan Geoscience Union, Representative, FY2014-2017
- Japan Geoscience Union, Board Member, FY2016-2018
- JpGU-AGU Joint Meeting, Joint Program Committee, FY2017
- Japan Union of Chemical. Science and Technology, Board member, FY2018
- Chikyukagaku (Geochemistry), Executive Editor, FY 2012-2013
- Geochemical Society of Japan, Councilor, FY 2012, 2016-2017
- Geochemical Society of Japan, Board member, FY 2018
- Award Selection Committee, Geochemical Society of Japan, Chair, FY 2017
- The Japan Society of Nuclear and Radiochemical Science, Board member, FY 2012-2015
- The Japan Society of Nuclear and Radiochemical Science, Vice president, FY 2018
- Award Selection Committee, The Japan Society of Nuclear and Radiochemical Science, Chair, FY 2016, 2018
- IAEA Final Research Coordination Meeting, 2016
- Editor, Geosystem Engineering, FY2010-2018

- Guest Editor, Geochemical Journal Guest Editor (Special issue: Fukushima Review I, FY2012
- Guest Editor, Geochemical Journal Guest Editor (Special issue: Fukushima Review II, FY2018
- Goldschmidt conference, Program Committee, Goldschmidt 2015
- Goldschmidt conference, Vice president, Organization committee, Goldschmidt 2016

11. Outreach Activity

- Board of investigation on enrichment of metals in biota, Ministry of Economy, Trade and Industry, Member, FY2014
- KAKENHI Review, FY2012-2013, 2015-2018
- Press Release: 3 times (June. 2017, Sep. 2017, Feb. 2019)
- Lectures for general audience: 6 times (Aug. 2012, Sep. 2012, Aug. 2013, Dec. 2015, Aug. 2015, Aug. 2016)
- Lectures for high school students: 6 times (Oct. 2012, June. 2013, June 2014, June 2016, Sep. 2017, Nov. 2017)
- Experimental courses in National Museum of Nature and Science, Tokyo: 2 times (Aug. 2015, Feb. 2016)

12. Internal Committee Membership

- Department of Earth and Planetary Environmental Science, Education Committee, Vice Chair, FY2015
- Department of Earth and Planetary Environmental Science (undergraduate course), Head, FY2016-2018
- Department of Earth and Planetary Science (graduate course), Chair, FY2017-2018

V. International Exchange Activities

13. Hosting/Sending Foreign Students and Researchers

(1) Hosting

Foreign Students: 5

Foreign Researchers: 11

(2) Sending

Students: 3

Researchers: 1

(3) Visitors from Abroad: 10

Takaaki Itai

I. CV

Name: Takaaki Itai

Age: 39

Present Position: Associate Professor

Education

Heijo High School, Nara, March, 1999 (graduation)

B. Sc. Department of Earth Science, Osaka-city University, March, 2004

M. Sc. Graduate School of Natural Science and Technology, Okayama University, March, 2006

Ph. D. Department of Earth and Planetary Science, Hiroshima University, March, 2009

Professional Experience

Apr. 2009-Jun. 2012, Assistant Professor, Center for Marine Environmental Studies, Ehime University

Jun. 2012-Jun. 2016, Lecturer, Center for Marine Environmental Studies, Ehime University

Jun. 2014-May. 2016, Visiting Researcher, Centre de la National Rechercher Scientifique, Geoscience Environment Toulouse, France

Jul. 2016-Aug. 2017, Senior Researcher, Ministry of Environment, National Institute of Minamata Disease

Sep. 2017-, Associate Professor, Department of Earth and Planetary Science, The University of Tokyo

II. Scientific Research Activity

2. Major Achievements

I have been investigated trace element cycle in the Earth's surface environment by geochemical approaches. My particular target was As during 2000s when the mechanism of As contamination in groundwater was still debated in Asian countries. I applied X-ray absorption spectroscopy to measure chemical species of As which is key information to assess mobility and toxicity. Our research contributed to the quantative understanding for the solid-water portioning of As, and gave some new insight to control large variation of As level in groundwater in alluvial aquifer. After 2010, I opened my focus to applied science field. For example, (i) mobilization of toxic metal from lake sediment induced by decrease of oxygen level, (ii) development of new geochemical data analysis method to understand fate of trace element by industrial activity in developing country, (iii) mechanism of trace element accumulation to the marine predators, (iv) biogeochemical cycle of Hg using X-ray absorption spectroscopy and Hg stable isotope analysis. Throughout these researches, I have been clarified the link between basic geochemical research and various applied sciences from theoretical and educational aspects.

3. Five Important Papers (including three or more papers in this review period)

1. Itai, T., Takahashi, Y., Seddique, A. A., Maruoka, T., & Mitamura, M. (2010). Variations in the redox state of As and Fe measured by X-ray absorption spectroscopy in aquifers of Bangladesh and their effect on As adsorption. Applied Geochemistry, 1. 34-47.

This work aimed to clarify the geochemical mechanism of As release from alluvial sediment in Bangladesh. The novel approach is application of X-ray absorption fine structure to the solid phase speciation of As. This approach helped quantative understand of solid-water portioning of As. We used this information to develop adsorption equilibrium model to predict future change in As distribution of groundwater. (Citation 33, GS/Sep 17, 2019)

2. Itai, T., Hayase, D., Hyobu, Y., Hirata S., Kumagai, M., & Tanabe, S. (2012). Hypoxia-induced exposure of the isaza fish to manganese and arsenic in the bottom of Lake Biwa, Japan - Experimental and geochemical verification. Environmental Science & Technology, 46, 5789-5797.

This work investigated unknown environmental issue induced by metal mobilization due to hypoxia of lake bottom. In autum of 2007, mass mortality of the endemic fish of the Lake Biwa ("*isaza*") was observed when DO level near the bottom of lake being < 1 mg/L. At that event, exceptionally high level of As and Mn was detected from died fish. I tried to assess the possibility of exposure to these metals under low DO condition. The results and implication of this work has been used for the explanation to the local citizens living near the lake. (Citation 8, GS/ Sep 17, 2019)

3. Sakamoto, M., Itai, T., Yasutake, A., Iwasaki, T., Yasunaga, G., Fujise, Y., Nakamura, M., Murata, K., Chan, H.M., Domingo, J.L. & Marumoto, M. (2015). Mercury and selenium speciation in toothed-whale muscles. Environmental Research. 143, 55-61.

This work aimed to assess the mechanism of accumulation of Hg to the cetaceans. Although high correlation of Hg and Se in the muscle of cetaceans has been proposed, molecular mechanism of this accumulation has been unclear. Since some Japanese residence have the custom to eat whale meat, to clarify the chemical form of Hg is important to evaluate risk to human. Application of X-ray absorption fine structure revealed that majority of Hg forms Hg-Se complex and finally mineral in the muscle tissue. This result supported internal detoxification and lower toxicity to human. (Citation 17, GS/ Sep 17, 2019)

4. Fujimori, T., Itai, T., Goto, A., Otsuka, M., Asante, K.A., Takahahi, S., & Tanabe, S. (2016) Interplay of metals and bromine with dioxin-related compounds concentrated in E-Waste open burning soil from Agbogbloshie in Accra, Ghana. Environmental Pollution. 209, 155-163.

The open-burning of electric waste causes emission of anthropogenic aerosol to the environment. This low temperature combustion process causes formation of volatile metal species. We measured speciation of Cu, Zn and Pb of ash and residual soil using X-ray absorption fine structure to assess the volatility and toxicity of metal. Formation of Cu chloride was important since this form is highly bioavailable and facilitate formation of toxic organohalogen compounds such as dioxins. This information is well cited by news and used by local government. (Citation 29, GS/ Sep 17, 2019)

5. Sakamoto, M., Itai, T., Marumoto, K., Marumoto, M., Kodamatani, H., Tomiyasu, T., Nagasaka, H., Mori, K., Poulain, A.J., Domingo, J., Horvat, M., & Matsuyama, A. (2019). Mercury speciation in preserved historical sludge: Potential risk from sludge contained within reclaimed land of Minamata Bay, Japan. Environmental Research. In press.

This work aimed to assess possible release of Hg by highly contaminated sediment reclaimed in the Bay of Minamata. Although the contaminated sediment is isolated by surrounding sediment, some possible events such as earthquake can triggers exposure to environment. We assessed lability of Hg in these sediment by leaching experiment as well as spectroscopic method. Our results reveled formation of insoluble metacinnabar in contaminated sediment which strongly support that fate of Hg remobilization is quite low. This result is used by government to inform the situation to local residences. (Citation 1, GS/ Sep 17, 2019)

4. Awards and Honors

・ Itai T, Young researcher award, Geochemical Society of Japan. Sep. 2015

5. Future Research Plan

Recently, theoretical and experimental studies of low temperature geochemistry have been gained attention in the world, while this activity is less motivated in the Japanese academic society. In order to create center of this field in our department, I will try to develop the new field "molecular geochemistry" collaborating with Prof. Yoshio Takahashi. Prof. Takahashi has been developed various new geochemical theories of trace elements applying various molecular level analytical methods for mineral-water-aerosol system. In addition to this trend, I would like to expand my focus to the trace element cycle in the aquatic biosphere including not only primary producer, but also predator animals which gains attention by fisheries and ecological management societies. Development of novel analytical methods and new environmental signature of elemental/isotope ratios should contribute to the comprehensive understanding of element cycling in hydrosphere including ecosystem. Through this research activity, I would like to contribute for the design of sustainable society from mode 1 science.

6. Funding Received

- JSPS KAKENHI, 17H04712, Principal Investigator, FY2017-2020, 1,220,000 yen
- JSPS KAKENHI, 15K00533, Co-Investigator, FY2015-2018, 100,000 yen
- JSPS fellowship for foreign research, Principal Investigator, FY2014-2016, 5,256,000 yen
- Environmental Research by Nihonseimei-zaidan, Principal Investigator, FY2014-2015, 1,300,000 yen
- JSPS KAKENHI, 25281007, Principal Investigator, FY2013-2015, 13,780,000 yen
- JSPS KAKENHI, 22681001, Principal Investigator, FY2010-2012, 12,800,000 yen

7. Publications and Patents

(1) Peer-reviewed Journal Articles

1. Asante, K.A., Agusa, T., Biney, C.A., Agyekum, W.A., Bello, M., Otsuka, M., Itai, T., Takahashi, S., & Tanabe, S., (2012). Multi-trace element levels and arsenic speciation in urine of e-waste recycling workers from Agbogbloshie, Accra in Ghana. Science of the Total Environment, 424, 63-73.
2. Nishi, K., Kim, I.H., Itai, T., Sugahara, T., Takeyama, H., & Ohkawa, H. (2012). Immunochromatographic assay of cadmium levels in oysters. Talanta, 92, 266-262.
3. Itai, T., Hayase, D., Hyobu, Y., Hirata S., Kumagai, M., & Tanabe, S. (2012). Hypoxia-induced exposure of the isaza fish to manganese and arsenic in the bottom of Lake Biwa, Japan - Experimental and geochemical verification. Environmental Science & Technology, 46, 5789-5797.
4. Nakashima, E., Isobe, A., Kako, S., Itai, T., & Takahashi, S. (2012). Quantification of toxic metals leaching from plastic litter collected from Ookushi beach, Japan. Environmental Science & Technology. 46, 5789-5797.
5. Itai, T., Kumagai, M., Hyobu, Y., Hayase, D., Horai, S., Kuwae, M., & Tanabe, S. (2012). Apparent increase in Mn and As accumulation in the surface of lake sediment from 1977 to 2009 in Lake Biwa, Japan. Geochemical Journal. 46. e47-e52.
6. Hamamura, N., Fukushima, K., & Itai, T. (2013). Identification of arsenite- and antimonite-oxidizing bacteria associated with antimony mine tailings. Microbes and Environments. 2. 257-263.
7. Asante, K. A., Takahashi, S., Itai, T., Isobe, T., Devanathan, G., Muto, M., Agyakwah, S. K., Adu-

Kumi, S., Subramanian, A., & Tanabe, S. (2013). Occurrence of halogenated contaminants in inland and coastal fish from Ghana: Levels, dietary exposure assessment and human health implications. Ecotoxicology and Environmental Safety. 94. 123-130.

8. Itai, T., Maruoka, T., Kusakabe, M., Uesugi, K., & Mitamura, M. (2013). Use of soil color meter for aqueous iron and ammonium measurements. Soil Science and Plant Nutrition. 59, 450-454.
9. Sakai, S., Yoshida, H., Hiratsuka, J., Vandecasteele, C., Kohlmeyer, R., Passarini, F., Santini, A., Peeler, M., Li, J., Oh, G.J., Chi, N.K., Bastian, L., Moore, S., Kajiwara, N., Takigami, H., Itai, T., Takahashi, S., Tanabe, S., Tomoda, K., Hirai, Y., Asari, M., & Yano, J. (2013). An international comparative study of End-of-Life vehicles (ELVs) recycling systems. Journal of Material Cycles and Waste Management. doi: 10.1007/s10163-013-0173-2.
10. Noguchi, T., Itai, T., Tue, N.M., Agusa, T., Ha, N.N., Horai, S., Trang, P.T.K., Viet, P.H., Takahashi, S., & Tanabe, S. (2013). Exposure assessment of lead to workers and children in the battery recycling craft village, Dong Mai, Vietnam. Journal of Material Cycles and Waste Management. doi: 10.1007/s10163-013-0159-0.
11. Itai, T., Otsuka, M., Asante, K.A., Opoku-Ankomah, U., Ansa-Asare, O.D., Muto, M., & Tanabe, S. (2014). Variation and distribution of metals and metalloids in soil/ash mixtures from Agbogbroshie e-waste recycling site in Accra, Ghana. Science of the Total Environment. 470-471. 707-716.
12. Hamamura, N., Itai, T., Liu, Y., Reysenbach, A-N., Damdinsuren, N., & Inskeep, W.P. (2014). Identification of anaerobic arsenite-oxidizing and arsenate-reducing bacteria associated with an alkaline saline lake in Khovsgol, Mongolia. Applied Environmental Microbiology. DOI: 10.1111/1758-2229.12144.
13. Horai, S., Itai, T., Noguchi, T., Yasuda, Y., Adachi, H., Hyobu, Y., Riyadi, A.S., Lowers, R., Guillette Jr. L.J., & Tanabe, S. (2014). Contamination status of trace elements in American alligators (Alligator mississippiensis) from Florida, USA. Chemosphere. 108, 159–167.
14. Riyadi, A., Itai, T., Hayase, D., Isobe, T., Horai, S., Miller, T., Omori, K., Sudaryanto, A., Ilyas, M., Setiawan, I., & Tanabe, S. (2015). Comparison of trophic magnification slopes of mercury in temperate and tropical regions -Case studies in Oregon coast, USA, Sanriku coast, Japan and Jakarta Bay, Indonesia-. Chemistry Letters.44, 1470-1472.
15. Sakamoto, M., Itai, T., Yasutake, A., Iwasaki, T., Yasunaga, G., Fujise, Y., Nakamura, M., Murata, K., Chan, H.M., Domingo, J.L., & Marumoto, M. (2015). Mercury and selenium speciation in toothed-whale muscles. Environmental Research. 143, 55-61.
16. Tue, H.M., Goto, A., Takahashi, S., Itai, T., Asante, K.A., Kunisue, T., & Tanabe, S. (2016). Release of chlorinated, brominated and mixed halogenated dioxin-related compounds to soils from open burning of e-waste in Agbogbloshie (Accra, Ghana). Journal of Hazardous Materials. 302, 151-157.
17. Fujimori, T., *Itai, T., Goto, A., Otsuka, M., Asante, K.A., Takahahi, S., & Tanabe, S. (2016). Interplay of metals and bromine with dioxin-related compounds concentrated in E-Waste open burning soil from Agbogbloshie in Accra, Ghana. Environmental Pollution. 209, 155-163.
18. Nakashima, E., Isobe, A., Kako, S., Itai, T., Takahashi, S., & Guo, X. (2016). The potential of oceanic transport and onshore leaching of additive-derived lead by marine macro-plastic debris. Marine Pollution Bulletin 1. 333-339.
19. Coelho, S.D., Pastorinho, M.R., Itai, T., Isobe, T., Kunisue, T., Nogueira, A.J.A., Tanabe, S., & Sousa, A.C.A. (2016). Lead in duplicate diet samples from an academic community. Science of the Total Environment, 573, 603-607.
20. Tue, N. M., Goto, A., Takahashi, S., Itai, T., Asante, K. A., Nomiyama, K., Tanabe, S., & Kunisue,

T. (2017). Soil contamination by halogenated polycyclic aromatic hydrocarbons from open burning of e-waste in Agbogbloshie (Accra, Ghana). Journal of Material Cycles and Waste Management, 19, 1324-1332

21. Nishimura, C., Horii, Y., Tanaka, S., Asante, K. A., Ballesteros Jr, F., Viet, P. H., Itai, T., Takigami, H., Tanabe, S., & Fujimori, T. (2017). Occurrence, profiles, and toxic equivalents of chlorinated and brominated polycyclic aromatic hydrocarbons in E-waste open burning soils. Environmental Pollution. 225, 252-260.
22. Coelho, S.D., Maricoto, T., Pastorinho, M.R., Itai, T., Isobe, T., Kunisue, T., Tanabe, S., Sousa, A.C.A., & Nogueira, A.J.A. (2017). Cadmium intake in women from Aveiro University, Portugal – a duplicate diet study. Journal of Geochemical Exploration, 183, 187-190.
23. Shiraishi, F., Nakao, K., Takashima, C., Kano, A., & Itai, T. (2018). Fe(II) oxidation processes at the surface of bacterially colonized iron deposits. Chemical Geology, 476, 161-170.
24. Tue, N.M., Matsushita, T., Goto, A., Itai, T., Asante, K.A., Obiri, S., Mohammed, S., Tanabe, S., & Kunisue, T. (2019). Complex mixtures of brominated/chlorinated diphenyl ethers and dibenzofurans in soils from the Agbogbloshie e-waste site (Ghana): Occurrence, formation, and exposure implications. Environmental Science & Technology, 53. 3010-3017.
25. Qin, H.B., Uesugi, S., Yang, S., Tanaka, M., Kashiwabara, T., Itai, T., Usui, A., & Takahashi, Y. (2019). Enrichment mechanisms of antimony and arsenic in marine ferromanganese oxides: insights from the structural similarity. Geochimica Cosmochimica Acta, 257, 117-130.
26. Shiraishi, F., Matsumura Y., Chihara, R., Okumura, T., Itai, T., Kashiwabara, T., Kano, A., & Takahashi, Y. (2019). Depositional processes of microbially colonized manganese crusts, Sambe hot spring, Japan. Geochimica Cosmochimica Acta, 258, 1-18.
27. Sakamoto, M., Itai, T., Marumoto, K., Marumoto, M., Kodamatani, H., Tomiyasu, T., Nagasaka, H., Mori, K., Poulain, A.J., Domingo, J., Horvat, M., & Matsuyama, A. (2019). Mercury speciation in preserved historical sludge: Potential risk from sludge contained within reclaimed land of Minamata Bay, Japan. Environmental Pollution, In Press.

(2) Non-peer-reviewed Articles

(3) Review Papers

1. Itai T. (2016) The studies on environmental behavior of arsenic and other toxic elements: Including an insight into the relationship between “environmental geochemistry” and “environmental chemistry”, Chikyukagaku, 50, 251-262.
2. Itai T. (2017). Some chemical factors related to the mineral/water partitioning of As: Particular focus on the Fe oxyhydroxides. Chikyukankyo, 22, 25-33.
3. Seto M., & Itai T. (2017). Preface of special issue “biogeochemistry” Chikyukagaku, 51, 4, 157-158.
4. Sakamoto M., Itai T., & Murata K. (2017). Health effect by fetal exposure to methylmercury, Nihon-Eiseigakkaishi, 72, 140-148.

(4) Books

(5) Other Publications

1. Itai T. (2014). Oxygen and manganese in Lake Biwa. Kagaku-to-Kyoiku, 62, 6
2. Itai, T. (2015). Analytical methods of mercury stable isotope in seawater. Bunseki, 7, 309.
3. Itai T. (2018). Trends of environmental mercury analysis. Bunseki, 11, 492-496.

(6) Patents

8. Keynote, Invited, or Solicited Presentations

1. Itai, T., Sonke, J.E., Point, D., Kamei, T., & Tanabe, S. Geographical variation of total mercury level and its stable isotope composition in skipjack tuna (Katsuwonus pelamis) from western North Pacific Ocean. Goldschmidt Conference, Prague Czech Republic, 2015/8/17.
2. Itai, T., Kamei, T., & Tanabe. S. Comprehensive assessment for controlling factor of total Hg level in skipjack tuna from Western North Pacific Ocean. Society of Environmental Toxicology and Chemistry (SETAC) North America 32nd Annual Meeting, Mineapolis, Minesota, USA, 2017/11/13.
3. Itai T. & Tanabe S. The range of applicability of mercury stable isotope ratio to trace the origin and source of human exposure. 2016 annual meeting of Geochemical Society of Japan, Osaka-city University, 2016/9/14.
4. Itai T, New insight of mercury behavior in marine ecosystem using mercury stable isotope. Regular meeting of plasma spectrochemistry, Tsukuba, 2018/9/4.

III. Education Activity

9. Notable Achievements in Education

Lectures

- Undergraduate/Graduate, geochemistry and cosmochemistry, FY2017-2018
- Undergraduate/Graduate, practical training on environmental chemistry, FY2017-2018
- Undergraduate, Introduction to environmental science, FY2017-2018
- Undergraduate, Introduction to earth and planetary environmental science, FY2017-2018
- Undergraduate, freshman seminar, FY2018

Student's awards

- Student Award of the Geochemical Society of Japan, 1 students [Sachika Natori]

IV. External Activities

10. Contribution to Academic Community

- Geochemical Society of Japan, Executive Board Member, FY2017-2018
- Geochemical Society of Japan, Executive Board Member, FY2011-2012

11. Outreach Activity

- KAKENHI Review, FY2016, 2018
- High school special lecture, 2012/2/12
- Advisory board of Aomori prefecture, Promotion committee of illegal dumping site restoration policy near the border of prefecture. FY2018.
- Advisory board member of Environment Research and Technology Development Fund. FY2018.
- Science café, WE Cafe week 72. 2018/10/13

12. Internal Committee Membership

- Department of Earth and Planetary Science, Office allocation Committee, FY2018
- Department of Earth and Planetary Science, Education Committee, FY2018

V. International Exchange Activities

13. Hosting/Sending Foreign Students and Researchers

(1) Hosting

Foreign Students: 0

Foreign Researchers: 0

(2) Sending

Students: 0

Researchers: 0

(3) Visitors from Abroad: 0

Yohey Suzuki

I. CV

Name: Yohey Suzuki

Age: 46

Present Position: Associate Professor

Education

Waseda University High School, Tokyo, March, 1992 (graduation)

B. Sc. Department of Mineral Resource Engineering, Waseda University, March, 1996

M. Sc. Department of Mineralogy, The University of Tokyo, March, 1998

Ph. D. Department of Geology & Geophysics, The University of Wisconsin-Madison, August, 2002

Professional Experience

June 2002-Sep. 2005, Researcher, Frontier Research System for Extremophiles, Japan Marine Science and Technology Center (JAMSTEC)

Oct. 2005-Mar. 2007, Researcher, Research Center for Deep Geological Environments, National Institute of Advanced Industrial Science and Technology (AIST)

Apr. 2007-Mar. 2011, Researcher, Institute for Geo-Resource and Environment, National Institute of Advanced Industrial Science and Technology (AIST)

Apr. 2011-, Associate Professor, Department of Earth and Planetary Science, The University of Tokyo

II. Scientific Research Activity

2. Major Achievements

I have been conducting researches on the deep-sea and deep underground ecosystems that are considered to be the candidate places of life emergence. Focusing on life-water-mineral interactions, I am developing state-of-the-art solid analysis methods and microbial analysis methods. I have conducted technological development using underground facilities constructed in granite to investigate the subsurface ecosystems that depend on energy from the rock interior rather than photosynthetic organic matter. We have succeeded in elucidating subsurface microbial communities, quantifying metabolic activity using hydrogen and methane, and metagenomic analysis of subsurface methane-oxidizing archaea. Given that granite is known to have occurred 4 billion years ago, my results suggest that granite may play an important role in the early microbial ecosystem on Earth.

Focusing on uranium, which is an important element for dating and the internal heat source on Earth, I have been performing investigations to understand the origin and evolution of microbe-uranium interactions. Recently, it has been found that there is an isotope fractionation in uranium metabolism by microorganisms, and it is expected to become a trace of early life activities. My finding of microbial production of uranium nanoparticles and the associated analytical method become an important foundation in the research field. The method has been further developed to analyze calcium carbonate infilling granite fractures, by which uranium nanoparticles formed by microbial activity have been sequestered and concealed in calcium carbonate for one million years. Based on the finding, I have also applied a patent with a technology for fixing cesium in calcium carbonate, which is considered to be a serious contaminant after the Fukushima Daiichi accident.

3. Five Important Papers (including three or more papers in this review period)

1. Ino, K., Hernsdorf, A.W., Konno, U., Kouduka, M., Yanagawa, K., Kato,S., Sunamura, M., Hirota, A., Togo, Y.S., Ito, K., Fukuda, A., Iwatsuki, T., Mizuno,T., Komatsu, D.D., Tsunogai, U., Ishimura, T., Amano, Y., Thomas, B.C., Banfield,J.F., Suzuki, Y. (2018) Ecological and genomic profiling of anaerobic methane・oxidizing archaea in a deep granitic environment. ISME Journal, 12:31-47.

Metagenomic analysis and stable isotope labeling experiments revealed that the genome of methane-oxidizing archaea inhabiting deep granite was capable of anaerobic methane oxidation coupled sulfate reduction.

2. Suzuki, Y., Mukai, H., Ishimura, T., Yokoyama, T.D., Sakata, S., Hirata, T., Iwatsuki, T., Mizuno, T (2016) Formation and Geological Sequestration of Uranium Nanoparticles in Deep Granitic Aquifer. Scientific Reports, doi:10.1038/srep22701.

Uranium silicate nanoparticles were formed by microbial metabolism and trapped and fixed in fracture-infilling calcium carbonate for more than 1 million years.

3. Suzuki, Y., Konno, U., Fukuda, A., Komatsu, D. D., Hirota, A., Watanabe, K., Togo, Y., Morikawa, N., Hagiwara, H., Aosai, D., Iwatsuki, T., Tsunogai, U., Nagao, S., Ito, K., Mizuno, T (2014) Biogeochemical Signals from Deep Microbial Life in Terrestrial Crust. PLOS One, id. 0113063.

Biogeochemical characteristics of groundwater from 200- to 400-m deep boreholes in the granitic body of the Mizunami Underground Research Laboratory were investigated over 6 years. As a result, it was revealed that sulfate-reducing microorganisms thrive in deep groundwater lacking organic matter derived from photosynthesis by using rock-hosed energy sources.

4. Ino, K., Konno, U., Kouduka, M., Hirota, A., Togo, Y., Fukuda, A., Komatsu, D., Tsunogai, U., Tanaba, A.S., Yamamoto, S., Iwatsuki, T., Mizuno, T., Ito, K., Suzuki, Y. (2016) Deep microbial life in high-quality granitic groundwater from geochemically and geographically distinct underground boreholes. Environmental Microbiology Reports, doi: 10.1111/1758-2229.12379.

Microbiological characteristics of groundwater from a 300-m deep borehole in the granitic body of the Mizunami Underground Research Laboratory were investigated over 6 years. By stable-isotope labelling incubation coupled to NanoSIMS analysis revealed that microbial populations dominantly colonized in the borehole are chemoautotrophs using H_2 as an energy source.

5. Suzuki, Y., Kelly, S.D., Kemner, K.M., Banfield, J.F. (2002) Nanometer・size products of uranium bioreduction. Nature 419:134.

By coupling high-resolution transmission electron microscopy and synchrotron-based X-ray absorption fine structure analysis, the products of microbial uranium reduction were shown to be crystalline nanoparticles of UO_2 with a size range from 1 to 2 nm.

4. Awards and Honors

5. Future Research Plan

In the previous research, I have established research methods for subsurface ecosystems, solid analysis at the nanometer level, and metagenome analysis. To elucidate deep microbial life hosted in rocks rather than groundwater, I will develop metagenomic analysis, which is applicable to microbial biofilms in rock cracks, fractures, veins and grain boundaries, in combination with solid analysis sensitively detecting microbial cells in rock samples. In particular, I will study metal sulfides at deep-sea hydrothermal vents, deep-sea manganese crusts and nodules, basaltic lava in the oceanic crust, and granitic rocks in the continental crust. Regarding rock-hosed life, I will develop technologies aiming to achieve both scientific research and planetary protection for Mars sample return.

6. Funding Received

- JSPS KAKENHI, 26287133, Principal Investigator, FY2014-2017, 17,160,000 yen
- JSPS KAKENHI, 24651005, Principal Investigator, FY2012-2015, 4,030,000 yen
- JSPS KAKENHI, 17K05712, Co-Investigator, FY2017-2019, 600,000 yen
- JSPS KAKENHI, 16K13896, Co-Investigator, FY2016-2018, 1,000,000 yen
- JSPS KAKENHI, 16K12578, Co-Investigator, FY2016-2018, 1,500,000 yen
- JSPS KAKENHI, 16K05581, Co-Investigator, FY2016-2018, 500,000 yen
- JSPS KAKENHI, 24340132, Co-Investigator, FY2012-2015, 300,000 yen
- JSPS KAKENHI, 15K05338, Co-Investigator, FY2015-2017, 300,000 yen

7. Publications and Patents

(1) Peer-reviewed Journal Articles

1. Kouduka, M., Suko, T., Morono, Y., Inagaki, F., Ito, K., Suzuki, Y. (2012) A new DNA extraction method by controlled alkaline treatments from consolidated subsurface sediments. FEMS Microbiology Letter,326: 47-54 . https://doi.org/10.1111/j.1574-6968.2011.02437.x
2. Saito, T., Suzuki Y., Mizuno, T. (2012) Size and Elemental Analyses of Nano Colloids in Deep Granitic Groundwater: Implications for Transport of Trace Elements. Colloids and Surfaces A: Physicochemical and Engineering Aspects, Available online 29 November 2012. https://doi.org/10.1016/j.colsurfa.2012.11.031
3. Konno, U., Kouduka, M., Komatsu, D., Ishii, K., Fukuda, A., Tsunogai, U., Ito, K., Suzuki Y. (2013) Novel microbial populations in deep granitic groundwater from Grimsel Test Site, Switzerland. Microbial Ecology, 65: 626-637. https:// 10.1007/s00248-013-0184-5
4. Suko, T., Kouduka, M., Nanba, K., Takahashi, M., Ito, K., Suzuki, Y. (2013) Geomicrobiological properties of Tertiary sedimentary rocks from the deep terrestrial subsurface. Physics and Chemistry of the Earth, 58-60: 28-33. https://doi.org/10.1016/j.pce.2013.04.007
5. Machida, I., Suzuki, Y., Takeuchi, M. (2013) Carbon-14 age and chemical evolution of Ca(HCO3)2-type groundwater of age less than 8000 years in a confined sandy and muddy Pleistocence aquifer, Japan. Hydrogeology Journal, 21: 1289-1235. http:// 10.1007/s10040-013-0990-3
6. D'Hondt S., Inagaki, F., Alvarez, Zarikian, C.A., the Expedition 329 Scientists (2013) IODP Expedition 329: Life and Habitability Beneath the seafloor of the South Pacific Gyre. Scientific Drilling, 15: 4-10. https://doi.org/10.2204/iodp.sd.15.01.2013
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8. Yanagawa, K., Kouduka, M., Nakamura, Y., Hachikubo, A., Tomaru, H., Suzuki, Y. (2014) Distinct microbial communities thriving in gas hydrate-associated sediments from the eastern Japan Sea. Journal of Asian Earth Sciences, 90: 243-249. https://doi.org/10.1016/j.jseaes.2013.10.019
9. Suzuki, Y., Konno, U., Fukuda, A., Komatsu, D. D., Hirota, A., Watanabe, K., Togo, Y., Morikawa, N., Hagiwara, H., Aosai, D., Iwatsuki, T., Tsunogai, U., Nagao, S., Ito, K., Mizuno, T (2014)

Biogeochemical Signals from Deep Microbial Life in Terrestrial Crust. PLOS One, id. 0113063. https://doi.org/10.1371/journal.pone.0113063

10. D'Hondt, S., Inagaki, F., Zarikian, C., Abrams, K., Dubois, N., Engelhardt, T., Evans, H., Ferdelman, T., Gribsholt, B., Harris, R., Hoppie, B., Hyun, J.-H., Kallmeyer, J., Kim, J., Lynch, J., McKinley, C., Mitsunobu, S., Morono, Y., Murray, R., Pockalny, R., Sauvage, J., Shimono, T., Shiraishi, F., Smith, D., Smith-Duque, C., Spivack, A., Steinsbu, B., Suzuki, Y., Szpak, M., Toffin, L., Uramoto, G., Yamaguchi, Y., Zhang, G.-L., Zhang, X.-H. and Ziebis, W. (2015) Presence of oxygen and aerobic communities from seafloor to basement in deep-sea sediment. Nature Geoscience, 8: 299-304. http://doi:10.1038/ngeo2387

11. Ino, K., Konno, U., Kouduka, M., Hirota, A., Togo, Y., Fukuda, A., Komatsu, D., Tsunogai, U., Tanaba, A.S., Yamamoto, S., Iwatsuki, T., Mizuno, T., Ito, K., Suzuki, Y. (2016) Deep microbial life in high-quality granitic groundwater from geochemically and geographically distinct underground boreholes. Environmental Microbiology Reports, http://doi: 10.1111/1758-2229.12379

12. Suzuki, Y., Mukai, H., Ishimura, T., Yokoyama, T.D., Sakata, S., Hirata, T., Iwatsuki, T., Mizuno, T (2016) Formation and Geological Sequestration of Uranium Nanoparticles in Deep Granitic Aquifer. Scientific Reports, http://doi:10.1038/srep22701

13. Hug, L., Baker, B., Anantharaman, k., Brown, C., Probst, A., Castelle,C., Butterfield, C., Hernsdorf, A., Amano, Y., Ise, K., Suzuki, Y., Dudek, N., Relman, D., Ronald Amundson, F., Thomas, B., Banfield, J. (2016) A new view of The Tree and life's diversity. Nature Microbiology, http://doi:10.1038/nmicrobial16048

14. Togo, Y.S., Takahashi, Amano Y., Matsuzaki, H., Suzuki , Y., Terada, Y., Muramatsu, Y., Ito, K., Iwatsuki T. (2016) Age and speciation of iodine in groundwater and mudstones of the Horonobe area, Hokkaido, Japan: Implications for the origin and migration of iodine during basin evolution. Geochimica et Cosmochimica Acta, 191, 165-186. https://doi.org/10.1016/j.gca.2016.07.012

15. Yanagawa, K., Tani, A., Hachikubo, A., Kano, A., Suzuki, Y. (2016) Biogeochemical Cycle of Methanol in Anoxic Deep-Sea Sediments. Microbes and Environments, 31:190-193. https://doi.org/10.1264/jsme2.ME15204

16. Kouduka, M. Tanabe, A.S., Yamamoto, S., Yanagawa, K., Nakamura, Y., Akiba, F., Tomaru, H., Toju, H., Suzuki, Y. (2017) Eukaryotic diversity in late Pleistocene marine sediments around a shallow methane hydrate deposit in the Japan Sea. Geobiology, 15:715-727. https://doi.org/10.1111/gbi.12233

17. Hernsdorf, A.W., Amano, Y., Miyakawa, K., Ise, K., Suzuki, Y., Anantharaman, K., Probst, A., Burstein, D., Thomas, B.C., Banfield, J.F. (2017) Potential for microbial H2 and metal transformations associated with novel bacteria and archaea in deep terrestrial subsurface sediments. The ISME Journal, 11:1915-1929. http://doi:10.1038/ismej.2017.39

18. Ino, K., Hernsdorf,A.W., Konno, U., Kouduka, M., Yanagawa, K., Kato,S., Sunamura, M., Hirota, A., Togo, Y.S., Ito, K., Fukuda, A., Iwatsuki, T., Mizuno,T., Komatsu, D.D., Tsunogai, U., Ishimura, T., Amano, Y., Thomas, B.C., Banfield,J.F., Suzuki, Y. (2018) Ecological and genomic profiling of anaerobic methane-oxidizing archaea in a deep granitic environment. ISME Journal, 12:31-47. http://doi:10.1038/ismej.2017.140

19. Mitsunobu, S., Suzuki, Y., Watanabe, K., Yang, K., Kim, J.W. (2018) μXAFS and TEM studies of Fe(III) oxides precipitated on submarine basaltic glass from South Pacific Gyre. Chemical Geology, 501, 51-57. https://doi.org/10.1016/j.chemgeo.2018.10.005

(2) Non-peer-reviewed Articles

(3) Review Papers

1. Yanagawa, K., Matsumoto, R., Suzuki, Y. (2012) Subseafloor biosphere mediating global methane cycle. Journal of the Japanese Association for Petroleum Technology, 77: 374-383. https://doi.org/10.3720/japt.77.374
2. Nagao, S., Niibori, S., Tanaka, T., Sasaki, T., Saito, T., Kirishima, A., Yoshikawa, H., Iijima, K., Hama, K., Iwatsuki, T., Takahashi, Y., Adachi, Y., Suzuki, Y., Watanabe, Y. (2013) The Present situation and future prospects of groundwater colloids studies on the performance assessment of geological disposal of radioactive wastes in Japan. Journal of Nuclear Fuel Cycle and Environment 20(1) 3-14. https://doi.org/10.3327/jnuce.20.3

(4) Books

1. Suzuki, Y. (2012) Exploration and industrial application of subsurface microorganism. in Industrial Application of Extremophiles, CMC Publishing Co., Ltd, p.271-280
2. Suzuki, Y. (2014) Microbes respiring uranium. Encyclopedia of environmental microbiology. Asakura Publishing Co., Ltd (co-author).

(5) Other Publications

1. Suzuki, Y. (2017) Discovery of long-term fixation mechanism applicable to contamination purification by radioactive elements. Isotope News 749: 12-16
2. Suzuki, Y. (2017) What does rapid global warming bring to marine ecosystems? Japan Geoscience Letter 13 No.2

(6) Patents

Japanese Patent Application No. 2017-229152, Treatment of soil contaminated with radionuclides.

8. Keynote, Invited, or Solicited Presentations

1. Suzuki, Y., Geomicorbiology of Uranium – Challenges for the deep subsurface. Japan Geoscience Union, Yokohama, 2014/5/24.
2. Suzuki, Y. Exploring mineral-microbe interactions and microbial ecology in deep marine environments. Institute of Oceanology Seminar, Chinese Academy of Science, Qingdao, 2017/7/24
3. Suzuki, Y., Methane is a key reagent for preservation of aDNA in marine sediments. “A workshop for "Assessing the potential of acient DNA in marine sediments” 2017/9/14
4. Suzuki, Y. Deep microbial ecosystems within Cretaceous igneous rocks , JSME annual meeting & 10th ASME 2018, Ginowan, 2018/7/12
5. Suzuki, Y. Microbial communities and their metabolic activities in deep crustal environments. Gordon Research Conference 2018, Smithfield, Rhode Island, 2018/8/20

III. Education Activity

9. Notable Achievements in Education

Advisees

・ Master theses: 10 students

Hiromichi Kawasaki (Mar. 2013)
Hitoshi Furutani (Mar. 2014)
Yutaro Ao (Mar. 2015)
Kohei Ino, Tomoyasu Ktaoka (Mar. 2016)
Seiya Yamashita (Mar. 2018)

Lectures

- Undergraduate/Graduate, Earthquake physics, FY2012-2018
- Undergraduate/Graduate, Geophysical data analysis, FY2012-2018
- Undergraduate/Graduate, Solid geoscience, FY2012-2016
- Undergraduate, Field observation for earth and planetary physics, FY2012-2018
- Undergraduate, Introduction to earth and planetary physics, FY2016-2018
- Undergraduate, Overview of earth and planetary physics, FY2017-2018
- Undergraduate level: Environmental Geochemistry, Biogeoscience, Advanced Mineralogy
- Graduate level: Geomicrobiology
- Undergraduate/Graduate, Geomicoriobiogy, FY 2012-2018
- Undergraduate, Biogeoscience, FY 2012-2018
- Undergraduate, Biodiversity science and laboratory practce, FY 2012-018
- Undergraduate, Environmental geochemistry, FY 2012-2018
- Undergraduate, Advanced mineralogy, FY 2012-2018
- Undergraduate, Resource geology, FY 2015-2018
- Undergraduate, Introduction to Earth & Planetary Environmental Science, FY 2016-2018
- Undergraduate, First-year undergraduate seminar, FY 2017-2018

Student's awards

- Incentive Award of the School of Science, the University of Tokyo: 1 student [Kohei Ino (twice)]

IV. External Activities

10. Contribution to Academic Community

- Seismological Society of Japan, Executive Board Member, FY2012-2013
- Seismological Society of Japan, Representative, FY2012-2018
- Seismological Society of Japan, Overseas Travel Fund Committee Chair, FY2012-2013
- Japan Geoscience Union, Program Committee Member, FY2012-2015
- Japan Geoscience Union, Executive Board Member, FY2016-2018
- Japan Geoscience Union, Financial Committee Member, FY2016-2018
- American Geophysical Union, Journal of Geophysical Research: Solid Earth, Associate Editor, 2012-2019
- American Geophysical Union, Union Fellow Committee Member, 2018
- Seismological Society of America, Nominating Committee Member, 2017

- International Association of Seismology and Physics of the Earth's Interior, Commission on Earthquake Source Mechanics Chair, 2017-2018
- Japan Geoscience Union, Program Committee Member, FY2012-2014
- Japan Geoscience Union, Program Committee Vice Chairman, FY2013, 2015-2017
- Paleosciences Society, Councilo, FY2014-2016
- Japan Geoscience Union, Biogeosciences Section Board Member, FY2012-2018

11. Outreach Activity

- Japan Drilling Earth Science Consortium, IODP Section, Member, FY2012-2014
- Integrated Ocean Drilling Program (IODP) Proposal Evaluation Panel (PEP) committee member, FY2012 -2013
- Marine Mineral Resources Related Projects Public Selection Committee member, FY2013~2014
- Comprehensive Ocean Drilling Science Research and Development Task Evaluation and Advisory Committee member, FY2015
- COSPAR Sample Safety Assessment Protocol Working Group member, FY2018
- Japan Aerospace Exploration Agency, Planetary Protection Examination Subcommittee member, FY2018

12. Internal Committee Membership

- Department of Earth and Planetary Environment, Education Committee, Chair, FY2014
- Department of Earth and Planetary Environment, Education Committee, Vice Chair, FY2017-2018

V. International Exchange Activities

13. Hosting/Sending Foreign Students and Researchers

(1) Hosting

Foreign Students: 3

Foreign Researchers: 5

(2) Sending

Students: 1

Researchers: 1

(3) Visitors from Abroad: 8

Shigenori Ogihara

I. CV

Name: Shigenori Ogihara

Age: 59

Present Position: Research Assistant

Education

Takasaki High School, Gunma, March, 1979 (graduation)

B. Sc. Department of Geoscience, Tohoku University, March, 1984

M. Sc. Department of Geoscience, Tohoku University, March, 1986

Ph. D. Department of Geology, The University of Tokyo, March, 1989

Professional Experience

Apr. 1989-, Research Assistant, Department of Geology, The University of Tokyo.

II. Scientific Research Activity

2. Major Achievements

I have continued research on mineral chemistry of sedimentary minerals such as zeolites and phosphate minerals using classical methods such as field surveys and microscopic observation. (1) For the zeolite in sedimentary rocks, I studied in detail the temperature dependence of phase change during submerged diagenesis, the mechanism of the phase change and the change of chemical composition. A new mineral application is being prepared for the Na heulandite described in this study. (2) The role of bacteria in the formation of phosphate minerals (rocks) was clarified by biomarker (bacterial lipid) analysis. I described a freshwater phospholite that was unprecedented in the world and discussed its origin. Using organic geochemical techniques, (3) a method to identify microbial species in the present and geological period was developed, and the diffusion and evolution of microorganisms in the geological period were clarified. A identifying method for cold spring limestone was established. It was elucidated by membrane lipid analysis of methane-oxidizing archaea that cold seep limestone was formed by modest methane oxidation based on the activity of sulfate-reducing bacteria that coexist with methanogenic archaea. (4) Analyzes of lake sediment cores revealed the history of the diffusion of anthropogenic compounds released into the environment by mankind since the industrial revolution. (5) Organic earth analysis of surface sediments of the Sea of Japan was conducted to discuss changes in the marine environment in the Sea of Japan associated with methane discharge. (6) In cooperation with the "Mass Spectrum Database Creation" conducted by the Organic Geochemical Society of Japan, we published a lot of mass spectrum data for biomarkers as environmental indicators and maturity indicators.

3. Five Important Papers (including three or more papers in this review period)

1. S.Ogihara (1996) Diagenetic transformation of clinoptilolite to analci me in silicic tuffs of Hokkaido Japan. Minerallium Deposita, 30, 548-553.

It changes from clinoptilolite to analcime according to the temperature rise accompanying the increase in burial depth. The mechanism of the phase change that occurred at this time was clarified.

Na clinoptilolite is once converted into Ca clinoptilolite by cation exchange, and then dissolves, and analcime precipitates.

2. S.Ogihara and R. Ishiwatari (1998) Unusual distribution of hydrocarbon compounds from hydrothermally-altered phosphorite nodule from Kusu Basin, northern Kyushu, Japan.Org. Geochem. 29, 155-161.

A freshwater phosphate nodule was discovered from the Kusu basin, Ooita Prefecture, and its origin was revealed by inorganic-organic geochemical analysis. In this paper, it was clarified that the origin of phosphoric acid originated from diatom by biomarker analysis.

3. S. Ogihara (1999) Geochemical characteristics of phosphorite and carbonate nodules from the Miocene Funakawa Formation, western margin of the Yokote Basin, northeast Japan, Sedimentary Geology, 123, 255-268.

Differences between Japanese Oil Tertiary and the US West Coast Monterrey Formation are the presence of the phosphate phase in Monterrey, the absence in Japan, and the distribution of glauconite in the corresponding strata. In this paper, I discovered phosphate nodules from the Funakawa Formation and discussed their origin and the difference in the sedimentary environment in the east and west of the Pacific Ocean.

4. S, Ogihara. (2008) An organic geochemical investigation of cold seep carbonates from central Hokkaido, northern Japan. Geochemical Journal. 42, 421-427.

Cold seep carbonate, the first major discovery of 21st century geology, was described mainly from the Cretaceous strata of Hokkaido, and the species of methane-oxidizing archaea was identified by biomarker analysis. I could provide basic data on the evolution of methane oxidizing archaea in the Cretaceous. The relationship with the Cretaceous environmental change was discussed.

5. S, Ogihara. (2014) Is the lycopane/n-C31 ratio an effective proxy of palaeoxicity of bottom water for the Japan Sea? - Unusual distribution of lycopane in the shallow sediment from the Japan Sea collected by the MD179 Cruise -. Journal of Asian Earth Science, 58. 250-253.

Correlation was found between methane emission and lycopane / n-C31 ratio in Toyama Bay by analysis of surface sediments of the Japan Sea. The possibility that it can be used not only as an indicator of methane emission but also as an environmental indicator was shown.

4. Awards and Honors

5. Future Research Plan

As a culmination of zeolite research, we will clarify the genesis of zeolites that are presumed to be formed in high-salt environments formed by methane hardrate formation / melting. This is a new formation mechanism that is completely different from the generally known zeolite origin mechanism. From the late Pliocene Shirahama Formation distributed in the Boso Peninsula, we found a group of zeolites with a special occurrence. These zeolites have not been reported so far, and flake observation, diffraction X-ray analysis, EPMA analysis, and carbonate carbon oxygen isotope composition analysis were performed. Biomarker analysis of mudstone was conducted to elucidate the thermal history. The zeolites in this region are thought to originate from the alkaline environment related to methane hardrate formation / melting and methane seepage, and elucidating the mechanism of zeolite formation is the biggest research theme.

Furthermore, it is a study that was planned from my student days, "Study on the relationship between mineral fluorescence and the elements that originated from it."　The plan is to use LA-ICP-MS set up in the Department to analyze micro-regions that could not be analyzed before. The element that is the origin of fluorescence is known to some extent, but the ionization state has not been clarified. This is another major research theme. The fluorescence of minerals, especially quartz, is influenced not only by inorganic elements but also by organic compounds. In addition to foreign fluorescent crystals such as Pakistan / Afghanistan, Haikimer, etc., we will clarify the origins of petroleum-filled crystals from Sagawa Town, Kochi Prefecture.

6. Funding Received

- JSPS KAKENHI, Principal Investigator, 2013-2016, ¥4160000
- Fund from Shell Japan, 2012, ¥27,594,029

7. Publications and Patents

(1) Peer-reviewed Journal Articles

(written in English)

1. S, Ogihara. (2014) Is the lycopane/n-C31 ratio an effective proxy of palaeoxicity of bottom water for the Japan Sea?　- Unusual distribution of lycopane in the shallow sediment from the Japan Sea collected by the MD179 Cruise -. Journal of Asian Earth Science, 58. 250‐253.
2. Ogihara, S. (2018) GC/MS Analysis of long-chain aldehydes from recent coral. American Journal of Analytical Chemistry, 9,46-51.

(written in Japanese)

1. S, Ogihara, Tomaru J, Matsumoto R, (2012) Sulfur isotope composition in the MD179 core surface sediment of the eastern margin of the Sea of Japan, Journal of Japan Petroleum Technology Association, 77,365-369.

(2) Non-peer-reviewed Articles

(3) Review Papers

(4) Books

1. The latest pictorial creatures of Square (2013)　Daiichi Gakushusya, Co-authored.

(5) Other Publications

(6) Patents

III. Education Activity

9. Notable Achievements in Education

Lectures

- <u>Undergraduate</u>

  Earth and Planetary Environment Excursion I, 3rd year

  Environmental Chemistry Training, 3rd year

  Biodiversity Training, 3rd and 4th year

  Rock Histology Practice II Faculty, 4th year

Earth and Planetary Environment Seminar, 4th year

Earth and Planetary Environmental Exercises, 4th year

- Graduate

  Instrumental analysis training I (Carbonate isotope analysis)

  Instrumental analysis training II (X-ray fluorescence analysis)

IV. External Activities

10. Contribution to Academic Community

11. Outreach Activity

12. Internal Committee Membership

V. International Exchange Activities

13. Hosting/Sending Foreign Students and Researchers

(1) Hosting

Foreign Students: 0

Foreign Researchers: 0

(2) Sending

Students: 0

Researchers: 0

(3) Visitors from Abroad: 0

Michinari Sunamura

I. CV

Name: Michinari Sunamura

Age: 50

Present Position: Assistant Professor

Education

Toin gakuen High School, March, 1988 (graduation)

B. Ag. Department of Fisheries, The University of Tokyo, March, 1992

M. Ag. Department of Aquatic Bioscience, The University of Tokyo, March, 1994

Ph. D. Department of Aquatic Bioscience, The University of Tokyo, March, 1997

Professional Experience

May. 1997-Sep. 1997, Post doctor researcher, Graduated school of Agricultural and Life Sciences, The University of Tokyo

Sep. 1997-Sep. 2001, Post doctor researcher, Mitsubishi Kagaku Institute of Life Science

Sep. 2001-Apr. 2003, Researcher, National Institute of Advanced Industrial Science and Technology

Apr. 2003-, Research Associate, Department of Earth and Planetary Science, The University of Tokyo

Apr. 2005-, Assistant Professor, Department of Earth and Planetary Science, The University of Tokyo

II. Scientific Research Activity

2. Major Achievements

I have been studying microbial ecosystems in deep sea such as hydrothermal plumes, hydrothermal subsurfaces, and ultra-deep trenches based on field sampling and analysis of microbial community distribution. In this process, I developed microscopic techniques and molecular biological techniques for deep-sea microorganisms, which have low activity and are difficult to detect, and apply them to the environmental microorganisms. In the Suiyo seamount deep-sea hydrothermal plume, we revealed the predominance of sulfur-oxidizing-chemolithoautotrophic SUP05 (Suiyo Plume #5 clone) phylotype based on molecular biological techniques and cell observation as the first report of microbial community structure in hydrothermal plumes. The SUP05 phylotype is widely distributed in the anoxic region of the ocean that extends to the west side of the continent, and plays an extremely important role in ocean sulfur, carbon, and nitrogen cycles. In the submarine hydrothermal system, we identified the critical temperature range of earth life and elucidated the microbial ecosystem including viruses. We also determined the vertical structure of the microbial ecosystem in the ultra-deep-sea trench for the first time by molecular biology techniques, and found the unique microbial ecosystem in the trench, which was different from the general deep sea.

3. Five Important Papers (including three or more papers in this review period)

1. Sunamura, M., Y. Higashi, C. Miyako, J. Ishibashi, and A. Maruyama (2004) Two Bacteria phylotypes predominant the Suiyo Seamount hydrothermal plume. Applied and Environmental Microbiology, 70, 1190-1198.

Deep-sea hydrothermal fluids released into the deep-sea water forms a hydrothermal plume, where the microbial densities increase several times compared to general deep sea water. This report is the first study that determined the microbial community structures in the hydrothermal plume. We found the predominace of sulfur-oxidizing microbial phylotype, named SUP05 in Suiyo Seamount hydrothermal plume on Izu-Ogasawara Arc. After our finding, SUP05 is recognized to be important microbial group, which greatly affects the elemental circulation of the ocean by sulfur oxidation, denitrification (laughing gas release), and carbon fixation in ODZ (marine anoxic water mass) spreading on the west coast of the Pacific Ocean, Atlantic Ocean, Indian Ocean, etc. （Citation 147 (GS/Sep. 18, 2019)）

2. Nunoura T, M. Hirai, S. Shimamura, A. Makabe , O. Koide, T. Kikuchi, J.Miyazaki, K. Koba, N. Yoshida, M. Sunamura, Y. Takaki, and K. Takai (2015) Hadal biosphere: insight into the microbial ecosystem in the deepest ocean on Earth. Proc. Natl. Acad. Sci. USA. E1230-E1236, doi: 10.1073/pnas.1421816112.

This is the first paper to investigate the vertical profile of the microbial community from the surface to the deepest part at 10950 m at the deepest Mariana Trench Challenger Ridge. It has been clarified that heterotrophic bacteria predominate in the trenches deeper than 6000m, creating a characteristic ultra-deep trench life zone. In addition, we found that ammonia-oxidizing archaea prominent from deeper than 200m are segregated according to water depth. (Citation 104 (GS/Sep. 18, 2019)）

3. Yanagawa, K., A. Ijiri, A. Breuker, S. Sakai, Y. Miyoshi, S. Kawagucci, T. Noguchi, M. Hirai, A. Schippers, J. I. Ishibashi, Y. Takaki, M. Sunamura, T. Urabe, T. Nunoura, and K. Takai (2017), Defining boundaries for the distribution of microbial communities beneath the sediment-buried, hydrothermally active seafloor, ISME J, 11, 529-542.

As part of the measurement of the upper limit range of life, we excavated a submarine hydrothermal system with a large temperature gradient, and investigated for the first time the temperature range with microbes and activity. Beneath the seafloor of the hydrothermal area, the temperature fluctuates violently according to the flow path of high-temperature hydrothermal fluids, and it is thought that the extinction and proliferation of microbial cells are repeated. We have found that the limit of microbial habitat is limited to historical depths of up to 106-198 ° C in the past. We also determined the structure of the microbial ecosystem close to the high temperature limit of life. （Citation 13(GS/Sep. 18, 2019)）

4. Sunamura, M. and K. Yanagawa (2015) Microbial cell densities, community structures, and growth in the hydrothermal plumes of subduction hydrothermal systems. in Subseafloor Biosphere Linked to Global Hydrothermal Systems; TAIGA Concept. J. Ishibashi et al. ed., Springer, Tokyo

The distribution of marine sulfur-oxidizing autotrophic bacteria SUP05 was investigated in several submarine hydrothermal plumes in the western Pacific. The distribution and abundance ratio of SUP05 was found to be proportional to the thermodynamic energy obtained from the reduced sulfur component contained in the jetted hot water. It was also shown that the ratio of SUP05 was higher in the hydrothermal system in the subduction zone than in the hydrothermal plume at the ridge. （Citation 1(GS/Sep. 18, 2019)）

5. Hirai, M., S. Nishi, M. Tsuda, M. Sunamura, Y. Takaki, and T. Nunoura (2017), Library Construction from Subnanogram DNA for Pelagic Sea Water and Deep-Sea Sediments, Microbes Environ, 32(4), 336-343.

In a deep sea environment with a low density of microorganisms and a great deal of labor for collecting a large amount of samples, it is difficult to obtain sufficient DNA for direct analysis of microbial DNA in the environment, and it is necessary to use a DNA amplification kit. In this paper, we conducted shotgun metagenomic analysis using a number of commercially available DNA amplification kits on extremely small amounts of environmental DNA, examined the quality and quantification of the data obtained, and at least 10 ng of DNA to ensure quantification. Clarified that is necessary. （Citation 7(GS/Sep. 18, 2019)）

4. Awards and Honors

5. Future Research Plan

I will advance understanding of the interaction between the environment and the microbial ecosystem in the fields of biogeoscience, environmental microbiology, and microbial ecology. Currently, I am working on microbial ecosystems in a wide-area survey of deep-sea water in the Pacific, submarine resources such as hydrothermal deposits and manganese crusts, and acidified oceans in collaboration with domestic researchers (JAMSTEC, Atmosphere and Ocean Research Institute, Tokyo University of Marine Science and Technology, Kochi University). I will continue analysis based on the fluorescent microscopy and environmental genome analysis techniques. In addition, I would like to strengthen collaboration within the GBS group to make use of these methods in the field of geochemistry.

Recent advances in genetic analysis technology and bioinformatics have led to rapid elucidation of genetic and functional information on environmental microorganisms, but there are endless combinations of microbial diversity in the environment. To break the limit of the application to specific functions in microbial ecosystems, I will develop and apply statistical analysis such as multivariate analysis and evaluation of stochastic processes of control of microbial ecosystems, utilizing cooperation with the field of mathematical statistics through CRIIME (Collaborative Research Institute for Innovative Microbiology, TheUniversity of Tokyo). We will apply microscopic analysis to evaluate the environmental diversity of microregions and physiological diversity at the cellular level of microbial communities. Finally, I will examine the predictability of microbial ecosystems.

6. Funding Received

- MEXT KAKENHI, 20109003, Principal Investigator,FY2008-2012, 49,200,000 yen
- JSPS KAKENHI, 24654160, Co-Investigator, FY2012-2014, 1,50,000 yen
- CAO SIP Next-generationtechnology for ocean resources exploration, Co-Investigator, FY 2015-2018,4,700,000 yen

7. Publications and Patents

(1) Peer-reviewed Journal Articles

1. Ino, K., A. W. Hernsdorf, U. Konno, M. Kouduka, K. Yanagawa, S. Kato, M. Sunamura, A. Hirota, Y. S. Togo, K. Ito, et al. (2018), Ecological and genomic profiling of anaerobic methane-oxidizing archaea in a deep granitic environment, ISME J, 12(1), 31-47.
2. Hirai, M., S. Nishi, M. Tsuda, M. Sunamura, Y. Takaki, and T. Nunoura (2017), Library Construction from Subnanogram DNA for Pelagic Sea Water and Deep-Sea Sediments, Microbes Environ, 32(4), 336-343.
3. Yanagawa, K., A. Ijiri, A. Breuker, S. Sakai, Y. Miyoshi, S. Kawagucci, T. Noguchi, M. Hirai, A. Schippers, J. I. Ishibashi, Y. Takaki, M. Sunamura, T. Urabe, T. Nunoura, and K. Takai (2016), Defining boundaries for the distribution of microbial communities beneath the sediment-buried, hydrothermally active seafloor, ISME J, 11, 529-542.
4. Nunoura, T., M. Hirai, Y. Yoshida-Takashima, M. Nishizawa, S. Kawagucci, T. Yokokawa, J. Miyazaki, O. Koide, H. Makita, Y. Takaki, M. Sunamura, and K. Takai (2016), Distribution and Niche Separation of Planktonic Microbial Communities in the Water Columns from the Surface to the Hadal Waters of the Japan Trench under the Eutrophic Ocean, Front Microbiol, 7, 1261.
5. Matsu'ura F., M. Sunamura, Y. Ueno and T. Urabe (2016) Influence of cell's growth phase on the

sulfur isotopic fractionation during in vitro microbial sulfate reduction. Chemical Geology 431: 1-9

6. Nunoura T, M. Hirai, S. Shimamura, A. Makabe , O. Koide, T. Kikuchi, J. Miyazaki, K. Koba, N. Yoshida, M. Sunamura, Y. Takaki, and K. Takai (2015) Hadal biosphere: insight into the microbial ecosystem in the deepest ocean on Earth. Proc. Natl. Acad. Sci. USA. E1230-E1236, doi: 10.1073/pnas.1421816112.
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(2) Non-peer-reviewed Articles

(3) Review Papers

(4) Books

3 Chapters in different books (2013,2014,2015) in Japanese

(5) Other Publications

(6) Patents

8. Keynote, Invited, or Solicited Presentations

III. Education Activity

9. Notable Achievements in Education

Lectures

- Graduate/UTokyo Ocean Alliance, Marine basic science, FY2012～2018
- Undergraduate, Geochemistry lab course, FY2012-2018
- Undergraduate, Biodiversity lab course, FY2012-2018
- Undergraduate, Field work course II, FY 2013, 2015, 2017
- Undergraduate, Field trip course I, FY2018
- Undergraduate, Earth and Planetary environment exercises, FY 2014,2016,2018
- Undergraduate, Earth and Planetary environment lab course, FY2015

IV. External Activities

10. Contribution to Academic Community

- Japanese society of Microbial Ecology, Councilor, FY 2012, 2015-2018
- Japanese society of Microbial Ecology, Assistant Chairman (Outreach), FY2013-2017
- Japanese society of Microbial Ecology, annual meeting committee member, FY2014,2015
- Microbes and Environment, Managing editor, FY2017-2018
- Japan Geoscience Union, Election administration committee Chair, FY 2012

11. Outreach Activity

- Japan Agency for Marine-Earth science and technology, Ocean Research Promotion Committee Task Review Subcommittee Member, FY2014-2017
- InterRidge Steering Commitee member, FY2012-2014

12. Internal Committee Membership

- Department of Earth and Planetary Environmental Science, Education Committee, Member, FY2012-2018
- Department of Earth and Planetary Science, Outreach committee, Member, FY2012-2018

- Department of Earth and Planetary Science, Network committee, Member, FY2012-2018
- University of Tokyo, Full-time representative member, FY2017
- University of Tokyo, Health and safety committee member in Hongo campus, FY2018
- Department of Earth and Planetary Science, Education Committee, Chair, FY2013-2014
- Department of Earth and Planetary Physics, Education Committee, Vice Chair, FY2015-2016
- School of Science, Advisor to the Dean, FY2015-2016
- School of Science, Library Committee, Chair, FY2015-2016
- Department of Earth and Planetary Physics, Head, FY2017-2018
- Advisor to the President of the University of Tokyo, FY2018

V. International Exchange Activities

13. Hosting/Sending Foreign Students and Researchers

(1) Hosting

Foreign Students: 0

Foreign Researchers:0

(2) Sending

Students: 0

Researchers: 0

(3) Visitors from Abroad: 0