
U01-01

Room:419

Time:May 1 09:00-09:15

International Activities of Science Council of Japan (TBD)

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¹Science Council of Japan

International activities of Science Council of Japan will be reviewed and discussed, including Future Earth, ICSU-WDS, and CODATA etc. (TBD)

Keywords: Future Earth, ICSU-WDS, GEOSS

Global Data Framework and Japanese Contribution

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Open data is not only the subject discussed in the last G8 meeting 2013, but also can be a wide-spread argument and can become substantially important factor in conducting science. Of course we cannot make all the research data publicly open immediately after its creation. But also data and paper are important in the modern science scheme, for validating results of a scientific research, e.g., its reproduction or statistical significance particularly in fields such as physics, earth science, or so. Recently there are found scientific results in certain percentage of original papers which are not necessarily reproducible in life science fields. Today's society has increasingly big concern with climate change and huge earthquake etc., where scientific research may directly affect real worlds like political and people's decision making. Validation of scientific papers is important since it may affect mutual trust between science and society. Here electronic data which can be linked to scientific papers in data citation scheme, are part of evidence of our scientific truth. In comparison to the history for a couple of hundred year of the printing culture in scholarly communications, the modern technology like Internet, hard disk drives, etc., have only the tens-of-years history. Human beings are now challenging this new system of electronic way to conduct science with society, seeking the right strategy for management of scholarly information. International data management activity like ICSU-WDS from the academic side, and RDA related to governmental arrangement are part of such big challenges of the international community. Furthermore Future Earth, the international 10-year transdisciplinary research programme are promoted by ICSU, UN bodies, Belmont Forum, etc. for future of the planetary earth and human beings, where ICSU-WDS and CODATA are required to support Future Earth's international scientific data management. We need careful discussions to promote those activities, but with a bright hope for the human society who has the indispensable intellectual infrastructure called "science".

Keywords: Scientific data, World Data System, open data, data management, data science, geophysics

U01-03

Room:419

Time:May 1 09:30-09:45

The ICSU World Data System: Trusted Data Services for Global Science

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¹ICSU-World Data System International Programme Office

This presentation will give a brief overview of the current activities of the International Council for Science – World Data System (ICSU-WDS). In particular, it will focus on ICSU-WDS' close involvement in the new Future Earth initiative and the Belmont Forum e-Infrastructure Steering Committee. It will also highlight joint projects between ICSU-WDS and the Research Data Alliance.

Keywords: ICSU-WDS, trusted data, long-term preservation, interoperability

U01-04

Room:419

Time:May 1 09:45-10:05

Issues and Agenda toward Data Era

IWATA, Shuichi^{1*}

¹MPD

Issues and agenda toward "Data Era" will be discussed.

Keywords: Science Council of Japan, data, CODATA

Importance of Future Earth in Asia

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Future Earth (FE) has been launched as an international initiative to promote research for global sustainability by the international science and technology alliance with partnership of the International Council for Science (ICSU), the International Social Science Council (ISSC), the Belmont Forum of funding agencies, the United Nations Educational, Scientific, and Cultural Organization (UNESCO), the United Nations Environment Programme (UNEP), the United Nations University (UNU), and the World Meteorological Organization (WMO) as an observer (Future Earth, 2013). Future Earth will provide a single overarching structure for researchers, funders, service providers, and users, and integrates the existing Global Environmental Change (GEC) programmes. The GEC programmes have provided foci for several extensive international and multi-disciplinary networks of researchers investigating key human-environmental dynamics. Future Earth would develop a new generation network building on these. Future Earth proposes national and regional level committees, in addition to the regional nodes. The most essential issue for the overall FE activity towards global sustainability will be how to integrate efforts and activity of solving environmental problems and achieving sustainability for local to regional scales.

This paper introduces a strategic science plan for FE in Asia, which should be a guideline for implementing the overall FE activity in the whole of Asia, including a comprehensive archive of data in natural science as well humanity and social science fields.

Keywords: Global Environmental Change, Asia, Future Earth

Integrated Data System on Climate, Water and Disaster Risk Reduction

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Increased water cycle variability impacts primarily through water, biological processes and human dimensions with implications for land use and societal development. It is critically important to recognize the fundamental linkages among water; land use, including deforestation; carbon cycle and ecosystem services; and food-, energy- and health- securities. By sharing coordinated, comprehensive and sustained water cycle and related Earth observations and information for sound decision making, we are now in developing effective interdisciplinary collaborations for working together based on coordinated and integrated efforts and subsequently to both mitigation and adaptation benefits at a river basin scale. Reducing disaster risk and building resilience to the climate change and variability is essential for establishment toward the final goal, the sustainable development of Earth societies and ecosystems.

Keywords: Earth Observation, Water Cycle, Climate Change, Disaster Risk Reduction, Data Integration

Synergetic approach of bottom-up/top-down studies on CO₂ and CH₄ emissions from biomass burning and rice paddy in East A

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There has been still a large discrepancy in estimations between bottom-up and top-down approaches for both CO₂ emissions from biomass burning and CH₄ from rice paddy in East Asia. The purpose of this study is to update the emission inventory databases as to be more consistent between these two approaches through a synergetic usage of satellite data, ground-based remote sensing measurements, and in situ data. The most important parameter to estimate total CO₂ emissions from biomass burning is the biomass amount of the forests. In this study the amount is estimated based on the normalized vegetation index (NDVI) observed by satellites and, CO₂ emissions from burning area are estimated by multiplying the fire strength evaluated from hot spot data with some auxiliary data such as soil moisture and groundwater level. As for the top-down approach, CO₂ concentration data observed from space are useful for constraining the inverse analysis of CO₂ emission strength. The greenhouse gas observing satellite (GOSAT) dedicated to observe atmospheric CO₂ and CH₄ concentrations was launched in 2009 and has been operated for more than five years. The main band of its sensor can measure the columnar CO₂ concentration, however, it cannot be directly converted into the concentration near the surface. One of our attempts is to develop a retrieval method to estimate CO₂ concentration in the lower troposphere, particularly in the boundary layer, from a synergy of spectrum data in a wide spectral range covering from short wavelength infrared to the thermal infrared. In order to validate this method we have carried out CO₂ sonde observations around Tokyo city where GOSAT has been operated in a specific observation mode (targeting mode) to obtain sufficient number of data over this area. Based on the validated results, this method will be applied to analyze the data observed in biomass burning areas. One of our important targets is Kalimantan (Indonesia) where peat fire is the main CO₂ emission source. We started the ground-based measurement of columnar CO₂ concentration using an optical spectrum analyzer (OSA), and expect that these temporally continuous data would be effective for achieving the consistency between bottom-up and top-down approaches. Also started are observations of columnar CH₄ concentration using the same type of spectrometer in Sichuan basin (China) and Karnal (India) where are identified as the extremely high CH₄ concentration area based on the almost decadal record of observations by SCIAMACHY and GOSAT. It is expected that the synergetic analysis of data from satellite and ground-based measurements could contribute to make clear the cause of high concentration of CH₄ in these areas.

Keywords: carbon dioxide, methane, GOSAT, top down approach, bottom up approach, ground-based remote sensing

Estimation of Ecological Function based on Biodiversity and Ecosystem Information

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In the Green Network of Excellence (GRENE) - environmental information project, we are working on collecting biodiversity and ecosystem information, and developing methods to use them for evaluation. In the past three years, more than 500,000 plant distribution information and information of more than 10,000 localities of vegetation had been databaed, and now they become available for users. Based on those information, together with several kinds of environmental information and land use data, it is possible to estimate distribution probability of each plant species, and to estimate some ecosystem functions of the forests with higher accuracy by considering composition of tree species. Here, I will present some examples of estimation of ecological function in Japanese forests, such as forest biomass, CO₂ FLUX, and amount of pollination services for crops by insects. I also discuss a way from those ecosystem function to estimating Ecosystem Services, which is a total benefits for us provided by biodiversity and ecosystems function.

Keywords: Biodiversity Informatics, Eco Informatics, Ecosystem Function, Ecosytem Services, IPBES

Environmental Monitoring of Soil contaminated by Radiocaesium in Iitate Village using FMS developed in GRENE project

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Most of radiocaesium released from Fukushima Daiichi nuclear power plant has been accumulated in the topsoil within 5 cm. For decontamination of the top soil, Japanese government (Ministry of Agriculture, Forestry and Fisheries) has authorized three methods: topsoil stripping method, puddling method, and plowing method to replace surface soil with subsoil. Among three methods, the topsoil stripping method is being carried out and a lot of flexible container bags containing contaminated topsoil are piled up in the paddy field. We have not yet found the final disposal site of the contaminated soil. For agricultural regeneration and early return village, it is urgent and important to find a feasible decontamination method that farmers can conduct by themselves. Therefore, we are challenging a field test that buried the contaminated soil in the ground by a combination of the topsoil stripping method and the plowing method in Iitate Village in Fukushima Prefecture. We named this method "Madei-method" that means we treat contaminated soil carefully. Currently, we are monitoring the radiation level from the buried contaminated soil by using a soil radiation sensor combined to the Field Monitoring System (FMS) that we developed for agricultural use in GRENE project. At the moment, leakage of radiocaesium has not been confirmed from the buried contaminated soil despite rapid changes in ground water due to rainfall and irrigation to the paddy. In the presentation, I explain outline of the FMS we developed in GRENE project and would like to propose to build a useful soil radiation database in Fukushima as one of important global data.

Keywords: decontamination, radiation, soil, monitoring, database, GRENE project

Framework of Applications of Environmental Information for Realizing Resilient and Sustainable National Land Design

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¹Graduate School of Environmental Studies, Nagoya University, ²Institute of Industrial Science, The University of Tokyo, ³Graduate School of Engineering, The University of Tokyo, ⁴Center for Spatial Information Science, The University of Tokyo, ⁵Faculty of Engineering, Kyushu University, ⁶Earth Observation Data Integration and Fusion Research Initiative, The University of Tokyo

1. Introduction

This research project, GRENE-City, aims to construct a methodology to design and realize "resilient and sustainable national land" with mitigation and adaptation measures against vulnerabilities of national land and society. This "resilient" concept is derived from an understanding of "natural providence". The proposed system takes advantage of a broad range of information includes disaster risk caused by meteorological phenomena and others from DIAS (Data Integration and Analysis System) by the Earth Observation Data Integration and Fusion Research Initiative (EDITORIA), the University of Tokyo. As such the system will be developed as a "Progressive Integrated Database" based on various environmental information infrastructures provided by DIAS. In addition, this project aims to cultivate experts who can construct and utilize this database in actual policy making fields.

To achieve this goal, a re-design of national land and society for a reduplicative system in both normal and emergency situations is necessary. Both a "safety and security" concept, which takes account of damage reduction, and a "sustainability" concept which tackles low carbon, energy saving, and prevention of climate change, are needed in order to keep pace with the threats of predicted huge earthquakes and climate change.

2. Contents

Natural hazards caused by climate change, earthquakes and other disasters may be increasing, and could strike in the near future our vulnerable society which is characterized by with declining birth rate and a growing proportion of elderly people, population decline, urban sprawl and etc. Based on the common recognition on these problems, this research project sets out to construct a methodology to lead to safer peaceful mind and sustainable national land and society by using DIAS.

The system needs to use data on natural and social situations. The data on natural situations includes earthquakes, climate change and disasters. The data on social situations include population structure, economic conditions, infrastructure, and land use. Additionally, not only the present data, but also historical data, such as land use and infrastructure change, record of disasters, population structures, and other information, are collected. Therefore "four-dimensional GIS" will be constructed to allow quantitative prediction and to evaluate policies considering historical faces, past place names, and other qualitative information.

In consequence, the system will analyze the vulnerability of national land and society caused by social, geographical, and other conditions, and natural variations and disaster risks. This system supports the examination of various policies, especially, the effectiveness of "Smart shrink" which could stop urban sprawl.

3. Results and future works

1) Information archives

This project collected historical data on earthquakes, tsunamis, and other natural disasters from old documents and other resources. In particular, records of tsunami damages of the Great East Japan Earthquake are stored. A prototype Web-GIS is developed to show these photos and tsunami height with map information.

2) Analysis and design

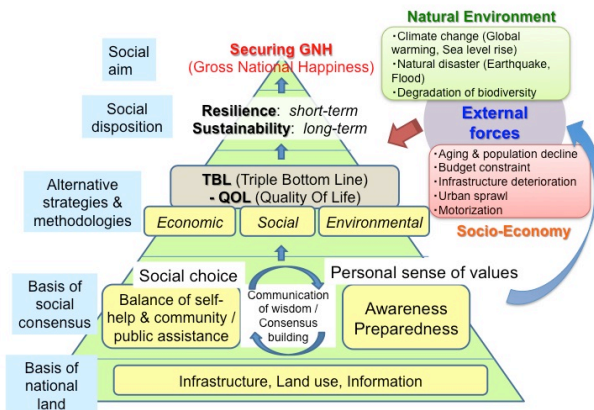
This project offers the evaluation of national land and cities with a view to safety, security, and sustainability. The system introduces QOL (Quality of Life) indicators. Data about accessibility, amenity, and disaster vulnerability to calculate QOL indicators are collected and added to the system. This will be utilized to illustrate conditions of residential amenity and disaster vulnerability in each area of the national land.

3) Utilization and deployment

This evaluation system will be applied to case study cities and regions. The problems and demands of the system will also

be clarified. As a result, the system and database will be developed to accommodate requests from policy planning of city and national land.

Keywords: resilient national land, sustainability, natural disaster, triple bottom line



Population health and global data sciences in Grene Ecohealth project

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Age of global and big data has come. The amount of data explosively increase and the expectations of exploring such data and effective utilization of data analysis results go wide of the mark. We enjoyed somehow the benefits from the big data analysis in daily life and some of the field in sciences; however, how can it be delivered to the health field, especially in areas or regions where the data collection is difficult due to the lack of data collection system? In developed countries, we can have data related to health and it has been already used for improvement public health service system. Furthermore, it has been linked to environmental data to know the results from climate and environmental changes. But this is only limited to developing countries and data or information from developing countries or regions, where the most vulnerable people from climate changes live and no information exists even on population, is still lack in identifying and monitoring the real situation. To sort out such information lack situation, the GRENEcoH project, a GRENE-Ecohealth project that is running under the GRENE-environmental information program, has started data collection of population health in areas in the Lao People's Democratic Republic using up-to-date technology to collect and link individual data. The system called in general as Health and Demographic Surveillance System (HDSS), which collect information about residents in the certain given areas for research. The HDSS programs are run in different areas and by different organization in African and Asian countries, however, in Japan; the HDSS is not paid enough attention. In this presentation, the introduction and the scientific and social values of HDSS and our technology will be presented.

Keywords: developing countries, marginal areas, population health, infectious disease

Development of DIAS Metadata System

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We are developing a metadata system in the Data Integration and Analysis System (DIAS) project sponsored by Japan Ministry of Education, Culture, Sports, Science and Technology. A major goal of the DIAS metadata system is to collect all metadata of earth observation data produced under the projects sponsored by Japanese government. The DIAS metadata system is comprised of metadata registration system, metadata retrieval system, and download system.

Cooperation with other data centers is also an important goal of the DIAS metadata system. We have imported metadata from JAMSTEC (Japan Agency for Marine-Earth Science and Technology) data catalog and JaLTER (Japan Long Term Ecological Research Network) database, and supported integrated metadata search through the DIAS retrieval system. On the other hand, by exporting DIAS metadata, DIAS is now listed in the Earth Observation Catalogs of GEOSS Portal. We are developing a metadata coordination system to make it possible more comprehensive exchange of metadata among data centers.

Keywords: earth observation data, metadata

Design and proposal of operational DIAS

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¹Japan Agency for Marine-Earth Science and Technology, ²Department of Civil Engineering, School of Engineering, The University of Tokyo, ³Earth Observation Research Center, Japan Aerospace Exploration Agency, ⁴National Institute for Environmental Studies

Data Integration and Analysis System (DIAS) is intended to create new scientific knowledge and public benefits through integration of various data under collaboration with stakeholders, in order to become a social infrastructure to make new innovations and social growth. DIAS will provide information toward resilient society and mitigation on social problems related to global environment, including resource management, bio-diversity, and natural hazards, by utilizing data on earth observation, climate-variability prediction, socio-economy, and so on.

Data Integration and Analysis Program (DIAS-P) started in 2011 as the second phase, aiming at (a) designing and proposing an operational scheme (operational DIAS) to realize public benefits through its operational application for global-scale solutions with sustainable scientific cutting-edge advancement, as well as (b) prototyping the operational regime with intelligent infrastructure to create new value, and (c) enabling stakeholders in various fields to together leverage the fusion of super-large-scale various data sets and information.

Japan Agency for Marine-Earth Science and Technology (JAMSTEC) is collaborating with the University of Tokyo EDITORIA, Japan Aerospace Exploration Agency (JAXA), and National Institute for Environmental Studies (NIES) to design the operational DIAS and present a tentative reference model including its roles. The infrastructure and schemes shown in the reference model will be the first practice if realized. This reference model has been designed in consideration with relevant progresses in relating research programs, and will be annually amended.

To achieve the above-mentioned objectives, DIAS comprehensively manages and publishes metadata as an integrated portal to provide and distribute the following data; (1) observation data listed in "Japan Earth Observation Implementation Plan," (2) observation data collected in each state to contribute toward nine social benefit areas of "Global Earth Observation System of Systems" (GEOSS), (3) observation data available in partner states under bilateral or multilateral collaboration, (4) data obtained through Application Workbenches, which are intelligent infrastructure to support projects toward application to each field, and (5) data provided by Function-Improvement Partners, which are inter-organization partnership to sustainably improve functions of DIAS. Their targeted fields include socio-economy, agriculture and fishery, land use and land cover, transportation network on roads and ports, landscape, and hazards. It is to be discussed how to create an environment where archives are acknowledged as research results.

The core infrastructure of DIAS will consist of large-scale storages to archive the data, and of analysis space and tools to analyze large-scale data.

The operational DIAS expects decision-makers (in domestic and developing countries) on resource management, disaster-protection, etc. to be the major users. The major users of integrated data and analysis function of DIAS will be not only researchers (science communities) who provide decision-makers with evidence but also stakeholders who collaborate on Application Workbenches. Moreover, end-users, social movements, and civilian services are also expected to use DIAS through access to the DIAS portal site.

For the above-mentioned purposes, we developed a remote collaboration system (ubiDIAS) utilizing open sources, and studied various policies and United Nations' Sustainable Development Goals.

Keywords: DIAS, operation, design

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Activities of the Union Commission for Data and Information of the International Union of Geodesy and Geophysics

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¹Rensselaer Polytechnic Institute, ²Australian National University

The data and information activities of IUGG, International Union of Geodesy and Geophysics, will be introduced, from a viewpoint of IUGG's Union Commission for Data and Information.

Keywords: IUGG, Data and Information, eGY

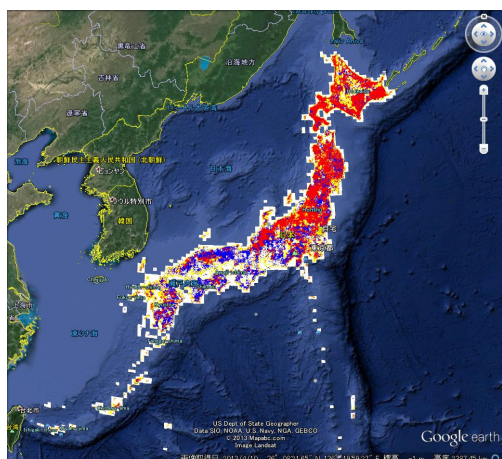
The Land Use Information System (LUIS) Database which has been developed under the GRENE-ei biodiversity area

NAKAJIMA, Hideaki^{1*} ; HIMIYAMA, Yukio² ; SAIGUSA, Nobuko¹ ; NOJIRI, Yukihiro¹

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We, the Office for Global Environmental Database, at the Center for Global Environmental Research (CGER), in National Institute for Environmental Studies (NIES), has been developing a new database called the Land User Information System (LUIS). LUIS is a database which was provided from NIES as one of the databases of GRID-Tsukuba before. LUIS is a database to visualize the land use in Japan which was extracted from the topographical maps of the Geospatial Information Authority of Japan in three different eras, i.e., Meiji-to-Taisyo era (around 1900s), early Syowa era (around 1950s), and late Syowa era (around 1985). The land use information was extracted in each 2x2 km mesh of 1:50,000 topographical map for the upper left corner, the maximum land use, and existing land use. We have developed a program to plot the land use, on a simple Japanese map and on Google Earth view screen. The figure shows the distribution of broadleaf trees in 1900s and 1985. Red area represents the existence in both era, blue represents the extinction, and yellow represents the appearance. We are thinking of distributing the map from the CGER's Database Web server in future. Current status and future plan of the LUIS database will be presented.

Keywords: database, land use, LUIS, topographical map, GRID-Tsukuba



Arctic Data archive System(ADS)

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Of all the regions on the planet, the Arctic currently shows the biggest rise in average temperature due to global warming, and is one of the regions expected to become most affected by climate change on the Earth in the future. The change in the Arctic area brings a profound impact to the global climate system through changes in interactions between the atmosphere, ocean circulation, and the cryosphere. These climate changes not only impact upon human activities, but also the Arctic flora and fauna ecosystem.

Large parts of the observations and mechanisms of the environmental change, including the climate of the Arctic region, are still not well understood. In order to further our understanding of these complex systems, an integrated study carried out with continuous observations in the Arctic is proposed. In the Arctic Environmental Observation Center in the National Institute of Polar Research, operations began on the Arctic Data archive System (ADS) in March 2012, in order to promote the mutual use of scientific data.

The purpose of the Arctic Data archive System is to archive and distribute multiple observational (atmosphere, ocean, terrestrial, and ecology) and model simulation datasets, and promote utilization of these datasets. ADS is the central repository of archived data on Arctic research in Japan.

Keywords: Arctic, Environment, Global Warming, ADS

JAXA's contributions for Earth and Planetary research using earth observation data

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JAXA's earth observation satellites play an important role in providing essential information for Earth science and applications regarding global warming, climate change, water cycle change, agriculture, public health and disaster management.

JAXA have been operating Greenhouse gas Observing SATellite (GOSAT), and Global Change Observation Mission-Water 1 (GCOM-W1) successfully. These satellites are collecting geophysical data of the earth's surfaces and atmosphere those are important for the earth and planetary researches.

In addition to those ongoing earth observation satellite missions, new satellites will be added to the line.

One is GPM (Global Precipitation Measurement), the successor of TRMM focusing to measure precipitation. Another one is ALOS-2 (Advanced Land Observing Satellite) carrying an L-band synthetic aperture radar. Those new generation satellites will contribute to observe disaster, earth resources, climate change, water cycle, etc.

JAXA will make continuous efforts to create and provide satellite-based information for not only scientists but also decision makers and stakeholders in order to contribute to solving global and regional issues. In order to make such information useful, close collaboration with various players in various sectors is essential.

Keywords: GCOM, ALOS, GPM, TRMM, GOSAT

IUGONET project and its products for multidisciplinary study on upper atmospheric physics

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¹International Center for Space Weather Science and Education, Kyushu Univ., ²Solar Terrestrial Environment Laboratory, Nagoya Univ., ³Data Analysis Center for Geomagnetism and Space Magnetism Graduate School of Science, Kyoto Univ., ⁴National Institute of Polar Research, ⁵Research Institute for Sustainable Humanosphere, Kyoto Univ., ⁶Kwasan & Hida Observatories, School of Science, Kyoto Univ., ⁷Planetary Plasma and Atmospheric Research Center, Graduate School of Science, Tohoku Univ.

In order to investigate the mechanism of long-term variations in the upper atmosphere, it is crucially important to make cross-cutting studies with various kinds of data observed between Sun and Earth region. Thus, it is needed to combine databases which maintained by each institute and to accelerate to make data-sharing network in the STP community. The IUGONET (Inter-university Upper atmosphere Global Observation NETwork) project was established in 2009 as a six-year research project supported from the Ministry of Education, Culture, Sports, Science and Technology (MEXT), Japan. It consists of the five Japanese universities and institutes (NIPR, Tohoku University, Nagoya University, Kyoto University, and Kyushu University, that have been leading ground-based observations of the upper atmosphere for decades), and collaborates with many domestic (for example, the National Institute of Information and Communications Technology (NICT), the National Astronomical Observatory of Japan (NAOJ), and the Kakioka magnetometer observatory, Japan Meteorological Agency) and overseas institutes/projects (for example, ESPAS in EU). One of our products in the IUGONET data management framework is developing systems for searching metadata of these observational data, and the metadata database (MDB). In the STP community, there are various kinds of archived data observed by many instruments, for example radars, magnetometers, photometers, radio telescopes, helioscopes, and so on. The IUGONET MDB is based on DSpace as a metadata registering system, which is mainly used in literature management. It also adopts an extension of the SPASE data model as a metadata format, which is widely used in the upper atmospheric community in USA. As a result, this system can deal with all kind of data belonging to IUGONET institutes, including cosmic ray, meteorological information observed by automatic weather station, etc. The system can also get flexibility to other type of data including the satellites and the numerical simulation which are used in the STP community. It is one of our challenges to apply the IUGONET system to many kinds of data in other communities. This MDB system is in operation since 2011 with over 10 million metadata. Other challenge of the IUGONET is developing software which can use for scientific research and publication. The iUgonet Data Analysis Software (UDAS) is a plug-in software of Themis Data Analysis Software (TDAS), which is upgraded to Space Physics Environment Data Analysis System (SPEDAS). The UDAS provides many routines for loading the ground-based observational data from various types of instruments, and performing scientific data analysis. This platform made it easier for STP community to analyze a various kind of data in a unified way. The IUGONET project will be closed at the end of fiscal year 2014. In this presentation, we will introduce the achievements and problems of our six-year project and discuss futures for global data sharing and research.

Keywords: Solar-Terrestrial Physics, metadata database, data analysis software, IUGONET

Introduction of NICT ionospheric data archive system

ISHII, Mamoru^{1*} ; MARUYAMA, Takashi¹ ; TSUGAWA, Takuya¹

¹NICT

NICT has a long history of operational ionospheric observation with ionosondes since IGY 1957. On the beginning, we had four domestic observatories, Wakkanai, Akita, Kokubunji and Yamagawa. After that Akita was closed and Okinawa joined and we operate these four observatories continuously. In addition, Syowa station in Antarctica has been observing ionosphere by NICT since IGY, too. In addition as the World Data Center for ionosphere, we have a lot of number of ionospheric data obtained by foreign institutes.

The present ionosonde system named 10C provides digital image of ionogram. However, all other previous systems provide analog image and recorded on films. Now it becomes a serious problem to lose data by corrupted of films. The only solution of this issue is to digitize the film image but usually the cost is very high. We search the way to keep low cost and comfortable quality for future analysis and find a method named ribbon scanning. In this method we keep whole of one film data in one file, which makes cost low and avoid losing data by frame skipping. We had trial of resolution of digital image and confirm the quality is same level of original image.

We already had some fruitful results using these data archive. Maruyama et al. [2012] shows the statistic results of ionospheric variation after large earthquakes. Other than these kinds of study we expect the archive is useful for discussion of long-term variation of ionosphere with climate change. For improving the use of these dataset we need to solve another issue. Film-digitized images are suitable to manual scaling with naked-eye but we cannot use these data automatically because the axes vary in each image. To solve the issue we need to try image analysis to detect the axes automatically.

Reference

Maruyama, T., T. Tsugawa, H. Kato, M. Ishii, and M. Nishioka, Rayleigh wave signature in ionograms induced by strong earthquakes, *J. Geophys. Res.*, DOI: 10.1029/2012JA017952.

Keywords: WDS, WDC, ionosphere, space weather

The Current and the Future of AIST GEO Grid Technologies- A Case Study of Fukushima Radiation Monitoring Application

KOJIMA, Isao^{1*} ; NAKAMURA, Ryosuke¹ ; OGAWA, Hiroataka¹ ; TANAKA, Yoshio¹ ; MATONO, Akiyoshi¹

¹National Institute of Advanced Industrial Science and Technology

The Current status and future perspective will be discussed of "GEO Grid" Technologies which have been studied and developed at AIST (National Institute of Advanced Industrial Science and Technology). Also a case study of Fukushima Radiation Monitoring Application will be reviewed.

Keywords: GRID computing, geoscience data, database technology, information technology, RDA, ICSU-WDS

Making Dynamic Data Citable: Approaches to Data Citation within the Context of the RDA Working Group

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Being able to reliably and efficiently identify entire or subsets of data in large and dynamically growing or changing datasets constitutes a significant challenge for a range of research domains. In order to repeat an earlier study, to apply data from an earlier study to a new model, we need to be able to precisely identify the very subset of data used. While verbal descriptions of how the subset was created (e.g. by providing selected attribute ranges and time intervals) are hardly precise enough and do not support automated handling, keeping redundant copies of the data in question does not scale up to the big data settings encountered in many disciplines today. Furthermore, we need to be able to handle situations where new data gets added or existing data gets corrected or otherwise modified over time. Conventional approaches, such as assigning persistent identifiers to entire data sets or individual subsets or data items, are thus not sufficient.

In this talk we will review the challenges identified above and discuss solutions that are currently elaborated within the context of the working group of the Research Data Alliance (RDA) on Data Citation: Making Dynamic Data Citable. These approaches are based on versioned and time-stamped data sources, with persistent identifiers being assigned to the time-stamped queries/expressions that are used for creating the subset of data. We will further review examples of how these can be implemented for different types of data and see how this fits into the larger context of activities on Data Citation.

Keywords: Research Data Alliance, data citation, dynamic data, information technology, interoperability

Recent activity of DOI-minting to database by WDCs in Japan

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Recent electronic journals are published with DOI (digital object identifier) such as doi:10.1029/2012SW000785. DOI is a persistent name that is resolved into URL, where readers can obtain digital objects of the journal articles; for example, abstract, figures, and pdf files. The DOI system was launched around 2000 and becomes popular these days so that DOI is ordinarily indicated in references and citations.

The next development of the DOI system is to extend it to database. It makes possible for researchers to cite the data used in a scientific publication, which is called "data citation". Data citation provides the following benefits:

- Readers can more easily locate the data used in the paper, obtain necessary information of the data (i.e., metadata), and validate the findings of the paper.
- Readers can also easily discover datasets which are relevant to their interests but has not been noticed.
- Data contributors can gain professional recognition and rewards for their published data in the same way as for traditional publications.
- Data centers can measure the impact of individual datasets and receive proper credit of their work.

Recognizing the importance of data citation, World Data Centers (WDCs) in Japan including WDC for Aurora (National Institute of Polar Research), WDC for Geomagnetism (Kyoto University), WDC for Ionosphere and Space Weather (National Institute of Information and Communications Technology), and WDC for Space Science Satellites (Japan Aerospace Exploration Agency) started discussion to mint DOI to their own database in August 2013. The discussion finds that Japan Link Center (JaLC) is a proper agency to register DOI-URL mapping, because JaLC aims at public information services to promote science and technology in Japan and it handles scientific and academic metadata and content from holders nationwide, including national institutes, universities. Two representatives of the above 4 WDCs are working closely with JaLC to define a registration scheme to implement the DOI-URL mapping. We are also developing a web-based system to register metadata with JaLC and create landing pages for database. We expect to start a pilot program to mint DOI to the database from the middle of 2014.

Keywords: DOI, Database, Data Citation, Data Publication

U01-23

Room:419

Time:May 1 17:20-17:45

Interlinking Articles And Data? The Past, Present, And Future

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Activities of linking scholarly articles and scientific data will be introduced.

Keywords: data publication, scholarly article, data citation

Open Science Data Discovery Platform

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Technology and use case studies of "Open Science Data Discovery Platform" will be introduced. So far we have harvested approximately 0.6 million metadata of data citation (DOIs and related metadata given to datasets) from publicly open databases of ICSU-WDS, PANGAEA, ICPSR, etc., and have been developing new technology to leverage those data-citation link information and scholarly article archives. This technology, including linguistic, time-space, and ontological analysis techniques, is expected to have potential to enable new knowledge finding from various relations between datasets and articles, as well as analysis of higher-class clustering and grouping structures of relationships and links between science-technology information sources and even various communities which are related to science and technology data and articles. Through this process, perhaps to be like easy user-interface in future (like Web of Science), even international perspectives will be easily captured of more general science and technology research information pieces, links, and inter-relations to each other. For example, regarding climate change prediction and related decision making we may be able to find easily by an online search system how different earth observation datasets are used in political papers and meteorological papers.

Keywords: Scientific data, ICSU-WDS, database technology, data search, data citation

Construction of spatio-temporal data mining system for time-series satellite imagery using Hadoop

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A large number of spatio-temporal data have been stored in various fields of science, such as remote sensing, numerical simulation, and astronomical observation, in which data often appears as time-series images. To extract spatio-temporal knowledge from spatio-temporal data including time-series images, spatio-temporal cross section relevant to a target task has to be extracted from a mass of data. Since these data are stored as a large number of files, utilization of distributed processing framework such as Hadoop or Gfarm is promising.

We constructed distributed data mining system for time-series satellite images using 53 nodes (3 masters and 50 slaves at maximum) of iMac and Hadoop which enables distributed file system and distributed processing using MapReduce. We evaluated the scalability and performance of the system for the task extracting time-series data from a large number of images carefully and found that partitioning the images into optimum numbers and reducing the data between map phase and reduce phase is essential.

The system was then applied to two different tasks focusing on time-series data analysis extracted from satellite imagery: statistical modeling of seasonal changes in vegetation index and spatio-temporal correlation analysis of weather satellite images. The tasks were successfully implemented on the system and the computational time was decreased in inverse proportion to the number of slave nodes, thus usefulness of the distributed system to spatio-temporal data mining for time-series images.

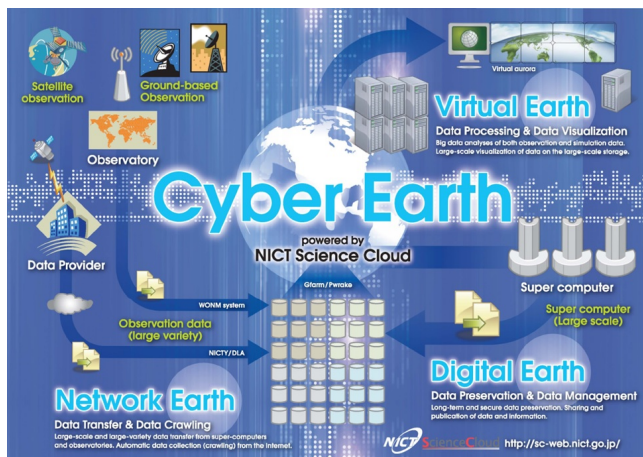
Keywords: distributed processing, Hadoop, MapReduce, data mining, spatio-temporal, satellite imagery

Basic Technologies, Integrated Systems and Applications of the NICT Science Cloud

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This paper is to propose a cloud system for science, which has been developed at NICT (National Institute of Information and Communications Technology), Japan. The NICT science cloud is an open cloud system for scientists who are going to carry out their informatics studies for their own science. The NICT science cloud is not for simple uses. Many functions are expected to the science cloud; such as data standardization, data collection and crawling, large and distributed data storage system, security and reliability, database and meta-database, data stewardship, long-term data preservation, data rescue and preservation, data mining, parallel processing, data publication and provision, semantic web, 3D and 4D visualization, out-reach and in-reach, and capacity buildings.



Global spectral crustal model

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We compile the harmonic coefficients, which describe the Earth crustal density structure with a spectral resolution complete to degree/order 180. These coefficients can be used in gravimetric studies of the Earth lithosphere structure, isostasy, crustal loading, sedimentary basins and related topics. The global spectral crustal model is separated into 9 specific layers of the topography, bathymetry, polar ice sheets, sediments (3-layers) and consolidated crust (3-layers). The harmonic coefficients describe uniformly the geometry and density (or density contrast) distribution within each crustal component. The topographic and bathymetric coefficients are generated from the topographic/bathymetric model ETOPO1 and the global geoid model GOCO03s. A uniform density model is adopted for the topography. The ocean density distribution is approximated by the depth-dependent seawater density model. The ETOPO1 topographic and the DTM2006.0 ice thickness data are used to generate the ice coefficients, while assuming a uniform density of the glacial ice. The geometry and density distribution within sediments is described by the 3 stratigraphic layers of a laterally varying density model, and the same structure is used to describe the density distribution within the consolidated crust down to the Moho interface. The sediment and consolidated crust coefficients are generated from the global crustal model CRUST1.0. The density contrasts of the ocean, ice, sediments and remaining crustal structures are taken relative to the reference crustal density.

Keywords: crust, density, gravimetric forward modeling, harmonic analysis

Muographic observations in Satsuma Iwojima, Japan

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Satsuma-Iwojima volcano continuously discharges large amounts of volcanic gasses without significant magma discharge. One of the proposed mechanisms of this continuous gas discharge is conduit magma convection. In this hypothesis, a magma conduit is connected to a deep magma chamber and a "degassing" phenomenon drives convection. Once the volatile component is released (by degassing) at the top of the magma conduit, the degassed magma sinks through the non-degassed magma occupying the pathway. A continuous supply of non-degassed magma from the magma chamber ensures that there is compensation for the degassed magma and the cycle continues. In 2008, a muography detector was placed at the foot of Satsuma-Iwojima volcano, and it captured an image of a large, shallow depth, low-density region existing beneath the crater floor. Degassing magma, with its high proportion of bubbles, has been interpreted as being the low-density region, and its dimension (location and size) was compared to the results from other field measurements, laboratory and theoretical studies. In 2013, an improved muography detector was developed and placed at the same location as the 2008 observation to exploit advanced muographic images in Satsuma-Iwojima. The recent progress in muographic observations will be reported.

Keywords: Muography, Muon, Volcanic Conduit, Imaging

Conduit magma convection: Constraints from Muography

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Muographic imaging is a powerful tool to radiographically reveal density structure of a shallow volcanic edifice with high energy muons and was applied to the rhyolitic dome of Iwodake, Satsuma-Iwojima in order to understand the conduit magma convection in this volcano. In this paper, we will discuss the constraints obtained by the muographic measurements performed in 2008 and their implication to the conduit magma convection model.

Conduit magma convection is a model to explain persistent degassing, that is continuous emission of large amount of volcanic gases without eruption and is driven by the density contrast between the ascending non-degassed magma and the descending degassed magma that is created by outgassing at the top of a magma column (Kazahaya et al., 1994). This model is commonly applied to less viscous basaltic magma systems but the application to andesitic or rhyolitic magma system is a matter of debate, because the large viscosity of these magmas can slow down the magma flows in the conduit. Although theoretical evaluation indicated that a larger diameter of a conduit can compensate the larger magma viscosity and can cause the rapid magma flows in the conduit, it is difficult to prove its occurrence under the ground, as the conduit magma convection is a steady state process with few seismic signals nor deformation. In contrast, the conduit magma convection suggests that intensive degassing occurs at top of a magma column, which is likely detectable as a low density zone in a shallow magma conduit system. Therefore the density structure survey the muon-radiography is an ideal method to reveal the size, shape and magnitude of density anomaly at the shallow volcanic edifice.

Quantitative re-evaluation of the muon radiography data at the Iwodake rhyolitic cone obtained by Tanaka et al. (2009) confirms the existence of a low-density body of 300 m in diameter and with $0.9-1.0 \text{ g cm}^{-3}$ at depths of 135-190 m from the summit crater floor. The low-density material is interpreted as rhyolitic magma with 60% vesicularity on average, and existence of this unstable highly vesiculated magma at shallow depth without any recent eruptive or intrusive activity is considered evidence of conduit magma convection. The structure of the convecting magma column top was modeled based on density calculations of vesiculated ascending and outgassed descending magmas, compared with the observed density anomaly. The existence of the low-density anomaly was confirmed by comparison with published gravity measurements, and the predicted degassing at the shallow magma conduit top agrees with observed heat discharge anomaly distribution localized at the summit area. This study confirms that high viscosity of silicic magmas can be compensated by a large size conduit to cause the conduit magma convection phenomena. The rare occurrence of conduit magma convection in a rhyolitic magma system at Iwodake is suggested to be due to its specific magma features of low H_2O content and high temperature.

Keywords: Conduit magma convection, muon-radiography, shallow volcanic edifice, density structure

Development of coupled Stokes–DEM simulation scheme for geodynamical magmatic studies

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For geodynamical magmatic studies such as crystal settling at the melting roof of a magma chamber, we develop a robust and efficient simulation scheme for solving high-viscosity fluid and particle dynamics in a coupled computational fluid dynamics and discrete element method (CFD–DEM) framework. The high-viscosity fluid is treated by the Stokes-flow approximation, where the fluid interacts with particles via the drag force in a cell-averaged manner. The particles are tracked with contact forces by DEM. To efficiently solve such Stokes–DEM coupled equations, we propose two key techniques. One is formulation of particle motion without the inertial term, allowing a larger time step at higher viscosities. The other is a semi-implicit treatment of the cell-averaged particle velocity in the fluid equation to stabilize the calculation. We will explain some details of our model developments in the presentation. A series of numerical experiments shows that our proposed scheme can handle sinking particles in a high-viscosity fluid; such problems are difficult for the conventional CFD–DEM method. Then we will discuss our targeting geodynamical problems tackled with this simulation method.

Keywords: Magma, Particle-Laden flow, Stokes flow, Discrete element method, Melt roof, Numerical simulation

Recent updates on the DIAPHANE project of muon tomography

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Density radiography with atmospheric muons aims at determining the density variations or the absolute densities of geological or large volume bodies. The density is measured through the screening effect on the incident muons flux induced by the presence of matter, like for the X rays in a standard medical radiography. We will present recent updates on the DIAPHANE project which studies volcanoes with this technique since many years and is now deployed in the Lesser Antilles (Guadeloupe, Montserrat), Italy (Etna), the Philippines (Mayon) and in underground sites (France and Switzerland). Time-of-flight techniques have been developed to improve the data analysis and provide significant results.

Keywords: Volcanology, Muon tomography, Particles detector, Inverse problem

Muon radiography by nuclear emulsions - Report on activity in Italy

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The nuclear emulsions technology has entered the field of muon radiography of volcanic edifices and faults in the last decade, and progressively attracted the interest of nuclear emulsion laboratories and experts from various countries. The historical first muographic image of a volcano was indeed generated by using this nuclear emulsion technology. In earlier times, large-scale application was limited by the readout time and manpower needs as the emulsion films had to be scanned by eye; modern fast automatic microscopes solved both issues with limited cost, and the readout and analysis speed increased by several orders of magnitude, opening the door to access muography that requires large statistics. The Italian nuclear emulsion groups of the Universities of Salerno, Napoli and Padova and the Laboratori Nazionali del Gran Sasso (INFN) have built an Italian network of scientists working on muography, establishing tight collaboration links with the Tokyo University Earthquake Research Institute; more Italian groups could join in the near future. The network performs many activities, from the preparation of emulsion film exposure, on-site data taking campaigns, to readout and data analysis.

Nuclear emulsions are usually cast in the shape of thin films (thickness in the range of 20-100 micrometers) coating transparent plastic bases. Even a single film can provide 3D tracks marking the passage path of ionizing particles, when observed by a dedicated microscope. Normally emulsions films are exposed in stacks, piling several sheets, so that a single particle, after development, leaves several aligned tracks, one in each film.

Automatic emulsion readout systems allow track detection and measuring on several m² of surface in few weeks, collecting large statistics, which is needed to investigate regions of high cosmic muon absorption. Angular resolution of the order of a few milliradians is commonly achieved, which gives the ability to discriminate relatively small details, depending on the distance between the detector and the observed volume. Currently, one line of research aims at developing faster and cheap film readout systems, based on commercial hardware, to increase the current data-taking speed by a factor 10 or better.

Emulsions are continuously sensitive, since the time of their production: while this is an advantage because they need no power supply, the lack of time discrimination makes data analysis for such detectors a delicate task. The high combinatorial background of 3D tracks, due to many months' pile-up, can be greatly reduced by exploiting the micrometric alignment precision of emulsion tracks. Application of nuclear emulsion data to muon radiography requires also particle identification. Multi-film stacks with interleaved slabs of dense scatterers (such as iron or lead), allow distinguishing soft particles, typically electrons/positrons from electromagnetic showers, from hard muons with 1 GeV/c momentum or higher. Dedicated simulation of the passage of hard muons through rock and in the emulsion-instrumented volume allows optimizing selection criteria and estimating purity and efficiency of the selection. Systematic errors on the predicted integrated flux, which is compared to the measured integrated flux, should be kept as small as possible; in turn, this requires proper modelling of the expected cosmic-ray muon flux, which demands specific efforts in some regions of the angular and energy spectrum, where the statistics is intrinsically lower. Simulation and modelling activities require specific software and sizeable computing resources and are shared among the collaborating groups.

Accounts are given of the status of muon radiography campaigns in which the Italian groups are mostly involved. The cases covered are Stromboli, Teide and the La Palma fault. For each case, the present situation, possible developments and future plans are also envisaged.

Keywords: nuclear, emulsion, muography, Italy, volcano, fault

Development of Nuclear Emulsion Detector for Cosmic-ray Muon Radiography and Its Applications

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¹Nagoya University

We are developing nuclear emulsion and its automatic analysis system for cosmic-ray muon radiography (muography). Nuclear emulsion is very high-sensitive photographic film for detecting 3-dimensional trajectories of charged particles like muon in its volume with the very high position resolution (sub-micron), which gives us the very high angular resolution (a few mrad). In addition, nuclear emulsion does not require electronic power, the size is very compact and the weight is very light. And also, it is easy to perform the tomographic analysis using multiple detectors placed around the target. These features have advantages in the field observation for the measurement of geoscience object, archeological object, or in the disaster area like Fukushima Dai-ichi nuclear power plant.

In the case of Fukushima Dai-ichi nuclear power plant, high radioactivity shielding and lack of electronic power supplies should be taken into account. Nuclear emulsion is the powerful candidate used in such area. We have conducted the basic study of muon radiography of reactor core at fast reactor Joyo, which belongs to Japan Atomic Energy Agency (JAEA), in order to demonstrate the imaging of the reactor core. The result validates the observation of the reactor core with high resolution.

We will present technical developments of nuclear emulsion, latest scientific results including other observed objects and future prospects.

Keywords: cosmic-ray muon radiography, nuclear emulsion, non-destructive observation, Fukushima Dai-ichi nuclear power plant

Muon radiography Monitoring for Structural Survey of the Prambanan World Heritage Temple

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¹Mie University, ²University of Tokyo

Muon cosmic-ray can penetrate rocks and soils and give us projection of the path' density, therefore, muography technology has been successfully developed in the geological field for disaster prevention of volcano explosion 1). Furthermore, it was utilized to survey the inner condition of a blast furnace in a steel mill during its operation time. On the other hand, non-destructive tests are required, in general, to conduct structural survey of heritage structures with cultural and historical values. In particular, when World Heritage Monuments are surveyed, we have to follow this principle strictly. There are a number of World Cultural Heritages of masonry in seismic regions in the World. When their seismic safety is assessed, seismic structural survey is conducted by employing non-destructive tests. Considering that muography technology can be useful for structural survey of massive masonry structures as a non-destructive test, we installed the muon detecting system at the Prambanan Temples, World Cultural Heritage in Indonesia and monitored the muon cosmic-ray for 5 months. Here, the Prambanan Temples of stone masonry structures were severely damaged by Central Java Earthquake of 2006. We have been successfully involved in architectural and structural survey project conducted by an international and interdisciplinary team. The damaged masonry monuments have been restored after the earthquake, however, restoration work of Candi Siva, the oldest and highest monument of the Prambanan Temples, was not started yet, as its inner structural condition was unknown. If the inner structural conditions are revealed, 3-D finite element model is available for seismic structural diagnosis of such massive masonry structures. The scope of the present paper is to describe this challenge of non-destructive test utilizing muography technology for the Prambanan restoration project and to demonstrate applicability of this advanced technology to structural survey of World Cultural Heritages of masonry. The muon data obtained at the site indicated that the monument must have inner chambers that had been unknown. The data also indicated their sizes and locations. This information will be useful to provide analysis model for seismic evaluation.

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Keywords: muon, structural survey, masonry, World Heritage, seismic safety

An Application of Muography to Exploring Gigantic Masonry Architectures: Evolution in Pyramid Construction Technique

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Since the technique of Muography was used for the pyramid of Khafre (second pyramid of Giza) by L. W. Alvarez in 1970, academic researches using non-destructive testing methods have been applied to some huge stone structures (ex. the Pyramid of the Sun in Teotihuacan, Mexico, by A. Menchaca-Rocha). Although Alvarez and his team attempted to find a new chamber in the pyramid, they couldn't find any hidden chambers. However, now it is thought that the result was unreliable because their muon detector was an old type. After Alvarez the muon detector was developed and contributed to the elucidation of mechanism of a volcanic eruption in recent years (e.g. Asama volcano and Satsuma-Iwojima Volcano by H. Tanaka et al). Applying this technique, the internal structures of the Shiva temple in the Prambanan temple compounds (Indonesia) and the Parthenon (Greece) is explorable. On the basis of those results, we are going to go back to the roots of Muography by Alvarez by revisiting the pyramid.

It is assumed that if it is possible to use Muography for the pyramids in Egypt (the oldest huge stone building in the world), in terms of the usage and volume of differing density of the stone (limestone and granite), it would make clear the developmental sequence and construction way of pyramids which has been impossible to know until now. Therefore, we can confirm the human ingenuity of earthquake-proof structures by ancient Egyptians. Most of the pyramids were made of limestone. Harder granite was sometimes used to encase the pyramids. If it can be made clear where two different kinds of stones were used and how much stone were used for the pyramids, we can take possession of previously-unattainable new information in the study of earthquake-proof structures of pyramids.

The developmental sequence of burial of ancient Egyptian kings and the transition of the outer shape are as follows: 1. Simple graves, 2. Mastabas, 3. Step Pyramids, 4. Bent Pyramid, 5. Red Pyramid (true pyramid), 6. Pyramid of Khufu (true pyramid), 7. Pyramid of Khafre (true pyramid), 8. Pyramid of Menkaure (true pyramid).

Judging from the above-mentioned process, it is assumed that there were further stages in the development of pyramids. However, it is still not clear. If we have the opportunity to use muography to the above pyramids (from the step pyramid of Netjerykhet to three true pyramids in Giza), we can put an end to speculation as to the evolution theory of the pyramid from the viewpoint of earthquake-proof structures and advancement of civilization.

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Keywords: muography, pyramid, civilization, earthquake-proof structures

Overview of Neutrino Geoscience

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Radiogenic heating is a key component of the energy balance and thermal evolution of the Earth. Geo-neutrino observations from Japan and Italy are now measuring the radiogenic power of our planet. Although the error on the present measurement is too large to significantly constrain geological models, the potential of geo-neutrino observations is clearly demonstrated. This contribution traces the development of neutrino geosciences and discusses the prospects for geo-neutrino observations to inform geology.

Keywords: neutrino geoscience, radiogenic heat

KamLAND: geo-neutrino result

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Geo-neutrinos are anti-neutrinos (elementary particles) produced in radioactive decays within the Earth. Those anti-neutrinos can be detected in a terrestrial experiment using interaction via weak force, however, due to extremely low reaction probabilities, there were no feasible experiments for a long time. Owing to the development of large-size anti-neutrino detectors, the observation of geo-neutrinos has been finally made, and then composition models of the Earth are constrained from the radiogenic heat estimate. In this talk, a precise measurement of geo-neutrino flux from the Kamioka Liquid-scintillator Anti-Neutrino Detector (KamLAND) in Japan will be presented. In addition, the recent situation of KamLAND anti-neutrino data will be reviewed. Following the Fukushima nuclear accident in 2011, the most of Japanese nuclear reactors has been subjected to a protracted shutdown, resulting in the low reactor anti-neutrino background. It provides a unique opportunity to measure the geo-neutrinos with an improved sensitivity. Based on this low background data, prospects of geo-neutrino sensitivity with KamLAND data in the near future will be shown, and discuss the ability of discriminating between Earth models.

Keywords: geo-neutrino

Borexino: geo-neutrino results

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¹Yury Suvorov

Geo-neutrinos are the electron anti-neutrinos produced by long-lived radioactive isotopes (such as U, Th and K) in the earth crust and mantle. Geo-neutrinos can be detected in kiloton scale organic liquid scintillator detectors located in underground laboratories. The detection reaction is the inverse-beta decay, which has a particular signature given by two correlated in space and time prompt and delayed signals.

In spite of the strong signature geo-neutrino can only be detected in massive low background set-ups designed for low energy (1 MeV) neutrinos.

Borexino at the GranSasso underground laboratory in Italy has been in operation since 2007 to search for sub-MeV solar neutrinos.

At present experimental studies of geo-neutrinos are carried out with Kamland at the Kamioka mine in Japan and with Borexino at GranSasso. The first attempt of a geo-neutrino measurement was done in Kamland in 2005. Only in 2010 and 2011 both Borexino and Kamland observed at more the 4sigma C.L. a signal from geo-neutrinos. The search of geo-neutrinos likewise the one of solar neutrinos for the sun provides a unique tool to probe the interior of the earth. Uranium and thorium from the crust and the mantle make the geo-neutrino flux on surface. The energy spectrum of the detected geo-neutrinos depends on the abundance of uranium and thorium and on the different beta decays in the two radioactive chains. A spectroscopy determination of the geo-neutrino signal can be done. This has been recently shown by Borexino. By means of this analysis the ultimate goal of the geo-neutrino search will be the determination of the uranium and thorium content in the mantle. For this purpose a combined analysis of more than one experiment results will be necessary. In this talk we will review the present status of geo-neutrino research. We elaborate on the recent results from Borexino and Kamland. The experimental difficulties and background sources will be discussed.

Keywords: neutrinos, geo neutrinos, Earth, crust, mantle

A reference Earth model for geoneutrinos

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Geoneutrino data from the KamLAND and Borexino experiments provide insights into Earth's energetics and global radiogenic heat production. In 2014, SNO+ will begin to collect data; the era of the exploration of our planet through geoneutrinos is definitely open.

Detection of geoneutrinos provides quantitative information about the total amounts of U and Th in the Earth and their distribution within the different reservoirs (crust, mantle and possibly core). One of the greatest potentials of geoneutrino is to discriminate among the different models for the bulk composition of the Earth, which are based on cosmochemical arguments and geochemical and geophysical observations. In order to determine the U and Th concentration of the deep Earth from the geoneutrino signal, the regional and crustal contribution to the geoneutrino flux needs to be determined from detailed geological studies.

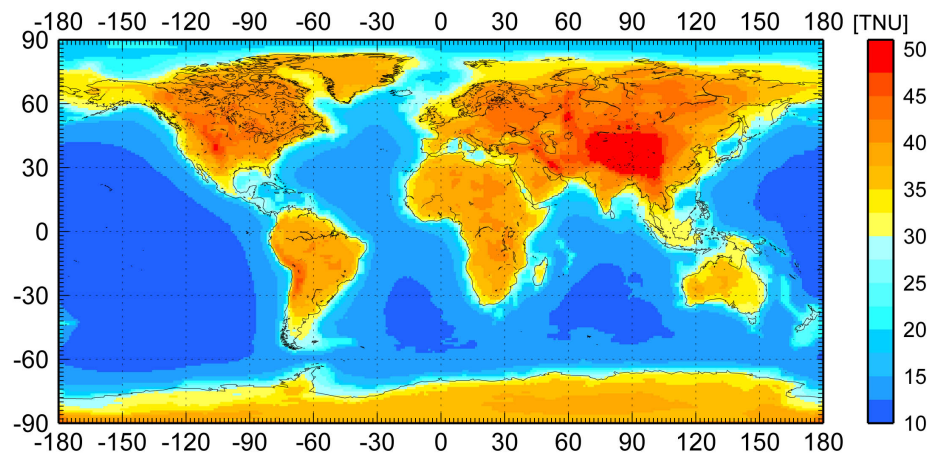
We developed a geophysically based, three-dimensional global reference model for the abundances and distributions of U and Th in a Bulk Silicate Earth (BSE) model. The structure and composition of the outermost portion of the Earth, the crust and underlying lithospheric mantle, are detailed in the reference model; this portion of the Earth has the greatest influence on the geoneutrino fluxes. The structure of the crust is based on $1^\circ \times 1^\circ$ surface map of the Earth discriminating layers of sediments, upper, middle and lower crust. For the first time three geophysical global crustal models based on reflection and refraction seismic body wave (CRUST 2.0), surface wave dispersion (CUB 2.0), and gravimetric anomalies (GEMMA) are studied with the aim to estimate the contribution of geophysical uncertainties to the reference crustal model.

On the base of new compilations of geochemical data for sediments, oceanic and continental crust, we estimate the expected geoneutrino signal and its uncertainties for the crust of the Earth. Evaluating the U and Th abundances and their uncertainties in middle and lower crust are a focus of this model, along with using seismic velocity data to determine the lithological nature of these layers. The fraction of felsic and mafic rocks in the deep portions of the continental crust has been estimated by comparing the velocities of longitudinal and transverse seismic waves reported in the crustal model with the laboratory values obtained for ultrasonic velocities of different rock types.

An updated xenolithic peridotite database is used to represent the average composition of continental lithospheric mantle. The geoneutrino signal from this reservoir is calculated for the first time and it exceeds that from the oceanic crust at all three existing detectors.

Geoneutrino signal at Earth's surface is calculated in TNU (Terrestrial Neutrino Unit) (see figure) and Monte Carlo simulation is used to track the asymmetrical uncertainties of different crustal inputs. The combination of the global crust model, detailed local crust models, and the measured signal for each detector provides the critical inputs needed to assess the global mantle signal and its uncertainty. Thus, the mantle signal at each detector and its uncertainty can be independently combined to place limits on acceptable models for the mantle's radiogenic power.

Keywords: geoneutrino flux, heat producing element, radiogenic heat power, reference crustal model, deep crust composition, bulk silicate Earth composition



Can noble gas reservoirs in Earth's mantle be identified from the geoneutrino distribution?

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Noble gas isotopes in mantle-derived samples are key tracers of chemical heterogeneity in the Earth's mantle and of the origin of the atmosphere. Samples of mid-ocean ridge basalt (MORB) and ocean island basalt (OIB) provide a comprehensive understanding of mantle noble gases. MORBs show relatively uniform $^3\text{He}/^4\text{He}$ ratios and in a $^{21}\text{Ne}/^{22}\text{Ne}$ - $^{20}\text{Ne}/^{22}\text{Ne}$ diagram form a mixing line between the atmospheric composition and the MORB-source endmember. The latter is formed by the addition of nucleogenic ^{21}Ne to the primordial Ne ("solar" or "Ne-B" composition, Ballentine et al., 2005; Honda et al., 1991; Tieloff et al., 2000; Mukhopadhyay, 2012). In contrast, OIB samples, which are derived from a deeper region of the mantle, can exhibit higher $^3\text{He}/^4\text{He}$ ratios and less nucleogenic Ne isotope compositions. The OIB characteristics provide evidence for a mantle source in which primordial He and Ne has been less diluted by addition of radiogenic ^4He and nucleogenic ^{21}Ne produced by the decay of U- and Th-series elements. Therefore, noble gas isotopic evolution in the mantle is directly related to the U and Th contents in their reservoirs. However, the reasons for the less-radiogenic/nucleogenic character of the plume source are under debate; it may be less degassed (e.g., Allegre et al. 1983; Kaneoka, 1983; Kurz et al. 1982; Porcelli and Ballentine, 2002; Porcelli and Elliott, 2008), re-gassed through volatile recycling (Holland and Ballentine 2006; Ballentine and Holland 2008), or depleted in U and Th by ancient melt extraction events (Parman, 2007; Albarede, 2008). Recent finding of different $^{129}\text{Xe}/^{130}\text{Xe}$ ratios (^{129}Xe is a product of extinct isotope ^{129}I , while ^{130}Xe is primordial) in the MORB and Icelandic plume source requires that a portion of the latter has been isolated from the MORB-source mantle over geological timescales (Mukhopadhyay, 2012). This finding is consistent with that the less degassed nature is essential for the high $^3\text{He}/^4\text{He}$ ratio of the plume source because high noble gas concentrations in the plume source is required to preserve Xe isotope heterogeneity against dilution by depleted or surface-recycled material with atmospheric or MORB-like $^{129}\text{Xe}/^{130}\text{Xe}$. If the plume source corresponds to the large low-shear-wave-velocity provinces (LLSVPs) or D'' layer at the base of the mantle, it may indeed have existed since the formation of the Earth and cannot exclusively be composed of subducted slabs (Mukhopadhyay, 2012). This is consistent with high $^3\text{He}/^4\text{He}$ (primordial) and low $^3\text{He}/^4\text{He}$ (recycled) components in Polynesian OIBs (Parai et al., 2009). The geoneutrino distribution will shed light on this issue; the less degassed (i.e., primordial) plume source is expected to contain 30-40% of the total mantle U and Th and if the LLSVPs is dominated by undiluted primordial material this feature will generate a significantly higher geoneutrino flux than a LLSVPs dominated by ancient subducted slabs with U and Th contents most likely lower than the convecting mantle.

Subcontinental lithospheric mantle (SCLM) exhibits slightly lower $^3\text{He}/^4\text{He}$ ratio and more nucleogenic Ne feature (Gautheron and Moreira, 2002; Buikin et al., 2005), indicating it is enriched in U and Th relative to noble gases. Although U and Th concentrations in SCLM is estimated as 10-30 times those in the convecting mantle, its small volume fraction (ca. 1.5%) results in insignificant contribution to global geoneutrino flux. However, it may be significant for existing detectors located in or close to continental region such as KamLAND (Japan) and Borexino (Italy). An ocean-based or transportable detector like Hanohano (Sramek et al., 2013) is therefore expected to have a great advantage to reveal geoneutrino flux from the deep mantle.

Keywords: Noble gas, Mantle, Uranium and Thorium, Geoneutrino, LLSVP, D'' layer

On the origin of large-scale heterogeneity in the deep mantle: Thermo-chemical mantle convection in a spherical geometry

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The origin of large-scale heterogeneous structure in the deep mantle, that is, large low shear velocity provinces (LLSVP) is still debated, which is between thermo-chemical [e.g. Nakagawa et al., 2012] and purely thermal [e.g. Davies et al., 2012]. If the large-scale heterogeneous anomalies in the deep mantle are generated by basaltic piles, the large-scale anomalies such as LLSVP may be enhanced for huge amount of heat source compared to the ambient mantle. Current efforts of geoneutrino observations attempt to detect the large-scale anomalous region of radioactive elements in the deep mantle [personal communication with H. Tanaka], which may have large-scale enhanced region of radioactive element in the deep mantle beneath the southern Pacific from test simulations of geoneutrino detectors. In addition, this approach could give an answer for the origin of large-scale heterogeneous structure in the deep mantle. Here we introduce our current numerical modeling of thermo-chemical mantle convection in a spherical geometry with self-consistently calculated mineralogy. The advantage of this approach is to include all phase transitions in the mantle without any linearization of physics of phase transition in mantle minerals and calculate seismic anomalies from thermo-chemical structure obtained from numerical modeling directly. In this presentation, we will show several important information on resolving this issue.

Keywords: thermo-chemical mantle convection, large-scale heterogeneity, mineral physics, radioactive heat source

Anti-Neutrino Directionality with KamLAND

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KamLAND holds its novelty in the observation of reactor anti-neutrino disappearance. After the great Tohoku earthquake in 2011, almost all nuclear power plants of Japan are closed for safety inspection. This Reactor-Off period offers a unique opportunity to study the directionality of anti-neutrinos from the earth and the remaining nuclear reactors with the liquid scintillator detector.

Keywords: neutrino

Tracking geo-neutrinos towards the future geo-neutrino graphy

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Directional sensitive neutrino detectors contributed to astronomy and particle physics. The solar neutrino problem was firmly believed by the directional measurement of solar neutrinos, and the atmospheric neutrino oscillation was confirmed by the zenith angle distribution for two types of neutrinos. Liquid scintillator detectors are marked by the ability to detect low energy neutrino signals, such as reactor, geo, and extraterrestrial neutrinos. On the other hand, liquid scintillator detectors do not have sensitivity of neutrino direction.

KamLAND (Kamioka, Japan) and Borexino (Gran Sasso, Italy) have showed the geo anti-neutrino detection realized by the event rate and energy spectra. We have begun to use neutrinos as “ probe ” to observe the Earth’s interior. Geo-neutrino measurement does not have the sensitivity of its direction, so we can not distinguish the crust and mantle contribution.

It is hoped the development of new measurement technology to measure neutrino direction. Lithium-loaded liquid scintillator has the potential to have the high sensitivity of coming anti-neutrino direction. Directional sensitive detectors will contribute to the better understanding of the earth interior using geo anti-neutrino flux information. Other motivations are the earlier determination of supernova direction and improvement of oscillation sensitivity for reactor anti-neutrinos.

Keywords: geo-neutrino

Geophysical Inversion of Geo-Neutrino Flux Data: Formulation for Revealing Chemical Structure in the Earth

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Observation of geo-neutrino flux enables us to constrain distribution of radiogenic heat sources in the Earth (e.g., Enomoto et al. 2007, EPSL). Although the data provides unique information, resolution was limited because the observed data has been just one scalar quantity (geo-neutrino flux at the observational site). However, recent challenge to directional measurements by the RCNS group will greatly improve the resolution, because the observed data becomes a vector quantity with large dimension (geo-neutrino flux as a function of incident angle and azimuth).

In this study, I will formulate geophysical inverse problem to effectively constrain where and how much we have radiogenic heat sources in the Earth. Following procedures by Enomoto et al. (2007), we first categorize reservoirs of radiogenic elements (e.g., crust, bulk mantle, slab and LLSVP) and develop a reference distribution model of radiogenic elements in the Earth. We then compute a synthetic geo-neutrino flux pattern (as a function of incident direction) for each reservoir category. We assume that the observed flux can be expressed by linear combination of synthetic patterns and define their coefficients as model parameters.

The optimal coefficients can be obtained by solving an inverse problem. If the reference model is perfect, every coefficients should be equal to one. If the optimal coefficient deviates from one, it suggests that the assumed concentration was not appropriate for that reservoir category. This formulation should be useful for geophysical interpretation. For example, if the coefficient for LLSVP is large, we can suggest that a large amount of crustal material is accumulated in the LLSVP.

At the time of presentation, besides the details of the above formulation, I plan to show expected resolution when we use data obtained by the ongoing KamLAND experiment.

Keywords: geo-neutrino, KamLAND, geophysical inversion

Hanohano: Future deep ocean geo-neutrino measurement

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Neutrinos from the decay chains of Uranium and Thorium from within the Earth's mantle constitute a vital signature of the origin of most of the heat thought to be driving all of geodynamics. The only means conceived as yet to study the magnitude and geographical distribution of the flux of mantle geo-neutrinos is from a large and mobile deep ocean detector. This study cannot be done from crustal locations due to the overwhelming flux of neutrinos from local rocks. We present a description of the Hanohano Project, aimed at opening this new discipline.

Keywords: neutrino, uranium, thorium, geoneutrino, tomography

Prospects of Earth Composition Measurements via Neutrino Tomography at Next-generation Neutrino Detectors

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The Earth matter density is well determined through seismological measurements, however the chemical composition of the Earth has not yet been measured and only been inferred from meteorite samples. The Earth interior composition could be determined using neutrino tomography. Neutrinos are naturally produced in the Earth atmosphere and can be detected at neutrino telescopes. Neutrinos are elementary particles that are extremely light and only rarely interact, so that they can traverse the entire Earth without being absorbed. For the measurement, one can utilize a unique property of neutrinos, which is known as matter induced neutrino oscillations. This effect changes the neutrino properties based on the electron density of the medium through which the neutrino travels.

The dependence on electron density is what allows us to get a handle on the composition of the Earth. While seismological measurements determine the matter density, so to speak the average mass of nuclei, the oscillation effects depend on the electron density. In combination we can determine the average Z/A , where Z is the proton number (number of protons per nucleus) and A is the atomic mass (number of protons and neutrons per nucleus). The talk will introduce the measurement and discuss prospects at next-generation neutrino detectors like PINGU and Hyper-K, that could perform it.

Keywords: Neutrino, Tomography, IceCube, PINGU, Hyper-K, Earth Composition

The Hyper-Kamiokande Project

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In this paper, we present the baseline design and expected performance of the Hyper-Kamiokande detector (Hyper-K)[1,2], a next generation underground water Cherenkov detector proposed in Japan. Hyper-Kamiokande is a successor of Super-Kamiokande (Super-K), which has been producing epoch-making results in particle physics and astrophysics, most notably the discovery of neutrino oscillation, since 1996. A water Cherenkov detector measures properties of elementary particles by detecting Cherenkov light, which is emitted when a charged particle travels faster than the velocity of light in water. Although neutrino itself does not emit Cherenkov light, it can be detected via particles produced in interaction with matter. Because the interaction probability is very small, a gigantic detector is necessary for the study of neutrinos. Water Cherenkov technique is the only solution to realize a Megaton scale detector with currently available technology. The design of Hyper-K is based on the highly successful Super-K, taking full advantage of a well-proven technology. The science goals of Hyper-K include not only the study of neutrino properties, but also broad topics in particle physics, astrophysics and geophysics.

Hyper-K consists of two cylindrical tanks lying side-by-side, the outer dimensions of each tank being 48 (W) 54 (H) 250 (L) m³. The total (fiducial) mass of the detector is 0.99 (0.56) million metric tons, which is about 20 (25) times larger than that of Super-K. The inner detector region is viewed by 99,000 20-inch PMTs, corresponding to the PMT density of 20% photo-cathode coverage (one half of that of Super-K). In order to enhance the performance of the detector and to reduce the construction cost, new types of photosensors are under development. The design of critical components such as excavation of large caverns, mechanical structure of the tank, and water purification system is established. Further R&D towards detailed technical design, together with study of science cases, is ongoing by an international working group consisting of more than hundred scientists from eleven countries over the world.

Hyper-K presents unprecedented potential for precision measurements of neutrino oscillation parameters and discovery reach for CP violation in the lepton sector. Hyper-K can extend the sensitivity to nucleon decays beyond what was achieved by Super-K by an order of magnitude or more. The scope of studies at Hyper-K also covers high precision measurements of solar neutrinos, observation of both supernova burst neutrinos and supernova relic neutrinos, and dark matter searches.

Although the main motivation of the Hyper-K project arises from particle physics and astrophysics, thanks to its large volume and excellent performance, Hyper-K will be also able to contribute to geophysics by detection of neutrinos coming through the inside of the earth as discussed in [1]. The prospects for geophysics using Hyper-K will be discussed.

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- [2] Hyper-Kamiokande Working Group, Hyper-Kamiokande Physics Opportunities, arXiv:1309.0184 [hep-ex].

Keywords: neutrino, radiography

Testing Geological Hypotheses Using Particle Physics

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Installations of muon and neutrino observatories are yielding an increasing spirit of collaboration between particle physicists and Earth scientists interested in leveraging their resources and techniques and to apply them to major outstanding scientific problems in both fields. This comes at a very good time, as experimental methods and seismological analysis has increasingly illuminated the frontier of Earth's deep geological structure, leading to new ideas and hypotheses regarding the evolution of Earth since its formation. Particle geophysics offers unique new tools to test hypotheses regarding the geological evolution of the entire Earth, some of which should help to break through non-uniqueness hurdles that arise using more traditional approaches. Here we discuss some of the frontier problems in Earth science, and describe some potentially novel approaches that may lead to breakthroughs in our understanding of our planet. One already well-known application involves detection of anti-neutrinos generated by naturally occurring radioactive decay processes in Earth's interior, the strength and distribution of which is sensitive to different hypotheses regarding Earth's origin and evolution. Other approaches, which will be made possible using the high energy detectors in Antarctica, is the determination of the electron density inside the Earth. This is especially useful, since the electron density is sensitive to the molar fraction of elements in solution inside bodies like the core, while seismology is only sensitive to the weight percent of those solutes. Here we show how combining this independent information will help to solve major questions such as the composition of the core.

Keywords: Thermal Evolution, Chemical Evolution, Composition of Earth, Earth Formation, Hadean Geology, Deep Earth

Review of the recent muon radiography observations by using nuclear emulsion detector

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Nuclear emulsion is one of three dimensional particle tracker which have micron position resolution and the feature that no electricity so we can put this detector everywhere easily and also this is suitable for non-fixed point observation.

Several observations for volcanoes were done and will be done from 2011 to 2014. The imaging the of Unzen lava dome, which was formed from 1991 to 1995, was done by Miyamoto et al and they found the detector got many back ground particles and the amount is more than several times than expected muon signal. this implies that we are on the stage of background particle study.

The emulsion cloud chamber (ECC) is a modular structure made of a sandwich of passive material plates such as lead interleaved with emulsion film layers. Nishiyama et al studied the source of background noise in cosmic-ray muon radiography using ECC. They found that the origin of background is expected to be electromagnetic components of air-showers or cosmic-ray muons scattered in topographic material whith momentums is less than 2GeV/c.

The shallow conduit shape of Stromboli will provide the important information for eruption dynamics modeling by Tioukov et al. Hernandez et al put the emulsion detector near the top of summit of Teide volcano to investigate the past eruption histroy of Teide. Teide volcano is located in Teferife, Canary Islands, Spain. They are also under observation of the fault appeared in La Palma, Canary Island, in 1949, which is the sign of huge land collapse or not. The width of the fault is expected to be 1 meter or less, so high position resolution of emulsion detector is suitable for this observation. They will measure the width, delth and the porosity of this fault.

Simultaneous inversion of muon radiography and gravity anomaly data for 3-D density structural analysis of lava domes

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Cosmic-ray muon radiography (muography) has been utilized for obtaining the density profiles of volcanoes (eg. Tanaka et al., 2007; Lesparre et al., 2010; Cârloganu et al., 2013). Since gravity measurement is also sensitive to the internal density of the Earth, a combination of muography and gravimetry is expected to provide density profiles with fine resolutions (Okubo and Tanaka, 2012). Nishiyama et al. (2014) has developed a simultaneous inversion method of both two data for determining the 3-D density structures of volcanoes and has presented the feasibility of the hybrid measurement through a case study of a small (500 m in diameter) lava dome, Showa-Shinzan, Hokkaido, Japan. This study revealed that a vent extends downward beneath the dome.

We are now planning another hybrid measurement at Tarumai Lava Dome on the Shikotsu caldera, Hokkaido, Japan, in order to perform a comparative study on the internal structures of lava domes. The Tarumai lava dome has formed at the top of Mt. Tarumai during the 1909 eruption. We conducted gravity measurements at 23 stations spanning 1.5 km (NS) x 1.5 km (EW). We are preparing the muography detector for the coming measurement. We report the possible detector sites and the result of the resolution test of this new hybrid measurement.

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Keywords: cosmic-ray muon radiography, gravity anomaly, density, lava dome

Introduction about test measurement of the muon detection system for monitoring a groundwater (With some observations)

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The technique to radiographically image the internal structure of gigantic objects by utilizing muon's significant penetration power (muography) enabled us to investigate the internal structure of volcanoes and the city foundation with higher spatial resolution than possible with the conventional techniques.

This observation technique is applicable to exploring a large-scale civil engineering structure, the internal state of a base rock, etc. However, feasibility of muographic application to monitoring inside the large-scale civil engineering structure has not confirmed yet. Therefore, we decided to carry out test measurements in order to explore the possibility of muography for monitoring groundwater levels.

We are currently investigating the response of the groundwater levels to major rainfall events in the landslide area. We selected this area as an observation area. The measurement was carried out from the inside of a scupper tunnel in the base rock. Our muon detection system consists of plastic scintillator, photomultipliers (PMTs), and a high voltage (HV) power supply.

The muography detector was installed to the observation site in August, 2012 and measurement was started on the same date.

The result will be compared with the independent measurement results of groundwater levels and soil resistivity in order to quantitatively assess the technological limit of muography.

So far, we obtained the preliminary result that showed variations in the penetrating muon intensity; hence the density as a response of major rain fall events by plotting a moving average of the 48-hour observation time at different time intervals of one hour, two hours, three hours, and six hours. It showed a clear rainfall effect when the time interval is 6 hours. The future prospect includes further case studies for different rainfall-underground water coupling scenarios.

Keywords: muography, muon detection system, groundwater, test measurement, landslide

A Historical View on the Degradation on Seismic Performance of The Parthenon, Greece and Muography as the Potential Eval

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To reinforce the Parthenon against earthquakes, the process of disassembling and reassembling Doric columns is obligatory. For this, the column strength and durability is required to withstand the reconstruction process. Wooden rods in the dowels of each drum provide the mechanical strength of each column, however some of these rods may have been damaged during the Venetian bombardment of the Acropolis on September 26, 1687. Due to the size of the Parthenon's Doric columns, muography is more appropriate to image the internal structure than conventional radiographic techniques. Muography may be utilized as a non-destructive technique targeting the inside composition of the Parthenon's Doric columns, potentially providing the following information: (1) the durability of the columns against future earthquakes, and (2) the magnitude of the internal damage sustained during the Venetian bombardment. The results of this muographic survey would aid conservator's efforts to protect the Parthenon along with the possibly of applying to other cultural properties. Secondly, the state of the wooden rod inside the column will provide evidence for the time and temperature around the column (based on the geometrical structure and thermal conductivity of the column) which would contribute further evidence to historical discussions particular to the Parthenon, such as estimates of the amount of gun powder stored in the Parthenon by the Ottoman Empire and information on the aforementioned siege. Muography may supplement efforts to preserve and protect the Parthenon as well as contributing to our understanding of the historical events that have occurred in this ancient structure.

Keywords: a Historical View, the Degradation on Seismic Performance, the Parthenon, Muography

Geo-neutrinos and reactor anti-neutrinos expected in Daya Bay II and in LENA

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Geo-neutrinos produced by beta decays occurring in ²³⁸U and ²³²Th decay chains are presently detected via inverse beta reaction in liquid scintillation detectors (KamLAND and Borexino). Geo-neutrinos are a unique direct probe of our planet's interior since they instantaneously bring to the Earth's surface information concerning the total amount and distribution of U and Th in the crust and in the mantle, which are thought to be the main reservoirs of these elements. The geo-neutrino spectrum allows to discriminate the different Th and U components. Measuring geo-neutrino fluxes and spectra can shed light on the radiogenic contribution to the terrestrial heat power and on the Earth's nowadays composition, providing a direct test of the Bulk Silicate Earth models and giving additional constraints on the Earth's evolution models.

A better discrimination among different Earth's global models can be reached combining the results from several sites: new measurements of geo-neutrino fluxes are highly awaited from experiments entering operation, such as SNO+, or proposed to the scientific community, as LENA or Daya Bay II. In particular, LENA and Daya Bay II would provide a substantial increase of the detection sensitivity and of the event rate thanks to their large target masses (50 kton and 20 kton, respectively) compared to the 1 kton mass of KamLAND and SNO+ and to the 0.3 kton of Borexino.

The main background in geo-neutrino measurements is due to the electron anti-neutrinos produced by nuclear power plants, which are the strongest man-made anti-neutrino sources. Many fission products decay through beta processes with the consequent emission of electron anti-neutrinos, the so called reactor anti-neutrinos. The reactor anti-neutrino spectrum covers an energy range extending up to about 8 MeV, which results in a significant overlap between geo-neutrino and reactor anti-neutrino signals in the geo-neutrino energy window (1.8 – 3.3 MeV). The events of reactor anti-neutrinos are strongly dependent on the distance of the closeby commercial nuclear power plants. Therefore, a careful analysis of the expected reactor anti-neutrino event rate at a given experimental site is mandatory.

In this framework, we estimate the expected reactor anti-neutrino signals at ongoing geo-neutrino experiments sites, in particular at Pyhasalmi and JUNO (Jiangmen Underground Neutrino Observatory), which are the candidate sites for hosting the LENA and Daya Bay II experiments, respectively. The inputs required to evaluate the reactor anti-neutrino flux come from neutrino properties, nuclear physics in the reactors and features of nuclear power plants. In our calculation we take into account the three neutrino oscillation mechanisms in vacuum, the most updated reactor anti-neutrino spectra and standard fuel compositions. According to the International Atomic Energy Agency (IAEA) database, we use detailed information on the locations and on the monthly time profiles of the thermal power for each nuclear core.

In Table 1 we report the expected geo-neutrino and reactor anti-neutrino signals for different locations, expressed in TNU (Terrestrial Neutrino Units). Nuclear power plants data refer to IAEA database reporting information of year 2012, when all of the Japanese nuclear power plants were still switched off. The ratio between the expected reactor anti-neutrino signal in the geo-neutrino energy window (R_G) and the expected geo-neutrino signal (G) is calculated all over the world in order to produce a R_G/G map. The values of R_G/G for future sites (Pyhasalmi and JUNO) are almost comparable to the operating ones (LNGS and Kamioka), with a slight preference for the Finnish location. The total uncertainty on the reactor signal predictions is on the order of 5%: among all the accounted sources of uncertainties, the ones giving the main contributions originate from the θ_{12} mixing angle, the anti-neutrino spectrum, the fuel composition and the thermal power.

Keywords: geo-neutrino, anti-neutrino from reactor, neutrino detector

U02-P05

Room:Poster

Time:April 28 18:15-19:30

Sites	R [TNU]	R_G [TNU]	G [TNU]	R_G/G
LNGS	85.8 ± 4.6	22.8 ± 1.1	$40.3^{+7.3}_{-5.8}$	0.6
KAMIOKA	70.1 ± 3.7	18.7 ± 1.1	$31.5^{+4.9}_{-4.1}$	0.6
SUDBURY	174.6 ± 9.0	43.1 ± 2.1	$45.4^{+7.5}_{-6.3}$	0.9
PHYASALMI	69.2 ± 3.7	17.5 ± 0.8	$45.3^{+7.0}_{-5.9}$	0.4
FREJUS	587.9 ± 31.0	134.0 ± 7.1	$42.4^{+7.6}_{-6.2}$	3.2
HOMESTAKE	27.7 ± 1.5	7.3 ± 0.3	$48.7^{+8.4}_{-6.9}$	0.1
HAWAII	3.4 ± 0.2	0.9 ± 0.04	$12.0^{+0.7}_{-0.6}$	0.1
CURACAO	9.5 ± 0.5	2.5 ± 0.1	$29.3^{+4.2}_{-3.3}$	0.1
JUNO	99.0 ± 5.1	27.4 ± 1.4	$39.7^{+6.5}_{-5.1}$	0.7

Table 1: Comparison between expected reactor (R) and geo (G) antineutrino signal. R_G indicates the reactor signal expected in the geo neutrino energy window ($E_{\bar{\nu}} < 3.26$ MeV). 1 TNU = 1event/year/ 10^{32} protons.

Towards a refined regional geological model for predicting geoneutrinos flux at Sudbury Neutrino Observatory (SNO+)

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¹University of Ferrara, ²University of Maryland, ³Carnegie Institution of Washington

The SNO+ detector is the redeployment of the illustrious Sudbury Neutrino Observatory (SNO) at SNOLAB in Ontario (Canada). After the substitution of heavy water (D₂O) with liquid scintillator (CH₂) inside the inner vessel, in 2014 the 1 kton detector will come on-line and together with KamLAND in Japan and Borexino in Italy will accumulate geoneutrino events. Geoneutrinos are electron antineutrinos originating from beta decays of natural radioactive nuclides in the Earth interior. A fraction of them, generated from ²¹⁴Bi and ²³⁴Pa of ²³⁸U decay chain and from ²²⁸Ac and ²¹²Bi of ²³²Th decay chain, are above the threshold for inverse beta reaction on free protons and can be detected by SNO+. Geoneutrinos are a real time probe of Earth interior, because the flux at the terrestrial surface depends on the amount and distributions of U and Th in the Earth's reservoirs. To extract global information such as terrestrial radiogenic heat power or to test compositional models of the Bulk Silicate Earth (BSE), the regional contribution to the geoneutrino signal has to be controlled by study of regional geology.

We present the 3-D refined geological model of the main reservoirs of U and Th in the regional crust extended for approximately 2×10^5 km² around SNOLAB, including estimates of the volumes and masses of Upper, Middle and Lower crust, together with their uncertainties. According to the existing global reference model (Huang et al., 2013), this portion of the crust contributes for 43% of the total expected signal at SNO+. The remaining contributions come from the far field crust (34%), from continental lithospheric mantle (5%) and from the mantle (18%). Since SNO+ will accumulate statistically significant amounts of geoneutrino data in the coming years, the calculated signal that is predicted to be derived from the lithosphere can be subtracted from the experimentally determined total geoneutrino signal to estimate the mantle contribution.

The main crustal reservoirs are modeled by identifying three main surfaces: the Moho discontinuity, the top of the Lower Crust and the top of the Middle Crust. About 400 depth-controlling data points obtained from deep crustal refraction surveys and from teleseismic receivers are the inputs for the spatial interpolation performed with the Ordinary Kriging estimator. This method takes into account the spatial continuity of the depths and it provides the uncertainties of the crustal volumes. The Upper Crust is further modeled in detail combining information from vertical crustal cross sections and Geological Map of North America at 1:5,000,000 scale. Seven sub-reservoirs with distinctive characteristics lithologies, metamorphism, tectonic events and chemical composition are identified. The density and the abundances of U and Th in the seven sub-reservoirs are evaluated from the published litho-geochemical databases, including analyses of representative outcrop samples. The Middle and Lower Crust densities and radioactivity contents are evaluated from seismic constraints.

The numerical 3D model consists of about 9×10^8 cells of 1 km \times 1 km \times 0.1 km dimensions. For each of them geophysical information, such as latitude, longitude, depth and reservoir type, are combined with estimates of the U and Th abundances to predict the geoneutrino signal at SNO+ originated from the regional crust. The total geoneutrino signal at SNO+ is about 12% less than that calculated using the global reference model (Huang et al., 2013).

Keywords: geoneutrinos, SNO+, uranium, thorium, geological modeling

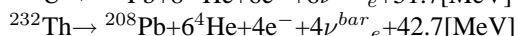
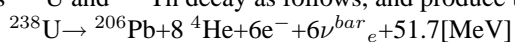
Upgrade plan of the KamLAND detector for improvement of sensitivity to geo-neutrino

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Neutrino, which is a kind of elementary particles, interacts with other particles only via weak interaction. RCNS, Tohoku University, researches the neutrino science with the large neutrino detector, KamLAND. Measuring the geo-neutrinos that are produced in beta decays within the Earth's interior, is only way to estimate the Earth's radiogenic heats production and constrain composition models of the Earth.

The KamLAND detector is marked by the ability to detect low energy electron-type anti-neutrinos. Radioactive isotopes, such as ²³⁸U and ²³²Th decay as follows, and produce the electron-type (anti-) neutrinos (geo-neutrino).



Geo-neutrino flux directly informs us the radiogenic heat generation. In fact, previously, the KamLAND experiment has given the result; the radiogenic heat production in the Earth's interior by ²³⁸U and ²³²Th is estimated to be $20.1_{-9.1}^{+9.1}$ TW through measuring the geo-neutrinos, and it is obviously smaller than the Earth's total heat flow (44 ± 1 TW).

In order to improve the sensitivity of the KamLAND detector, the upgrade plans (KamLAND2 experiment) are in progress. Large light intensity liquid scintillator, light collection mirror, high quantum efficiency photomultiplier, imaging device, scintillation film, etc...

In the KamLAND2 experiment, improving energy and vertex resolution are expected. Therefore it will be possible to observe geo-neutrinos with higher accuracy and statistics. This experimental improvement will have higher ability to discriminate between models and separate contributions from ²³⁸U and ²³²Th. The KamLAND2 will play a contribution to the geo physics in that way.

In this presentation, future prospects and R&D are discussed.

Keywords: geo-neutrino

The next-generation KamLAND electronics

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KamLAND was constructed to detect the low energy anti-neutrinos. And then, KamLAND detected reactor neutrinos and solved solar neutrino problem on 2003. And furthermore, KamLAND detected geo-neutrinos for the first time in the world on 2005. Currently, KamLAND has already been beginning to search several new physics. However, searching new physics in the detector of 10 years ago is difficult. So, it is necessary to update the detector. We are planning to update the KamLAND. As this updating, KamLAND electronics will be renewed using the latest technologies. The next-generation KamLAND electronics will certainly contribute to geoscience.

Keywords: Neutrino detector, Data taking, electronics

Imaging detector

MITSUI, Tadao^{1*}

¹RCNS, Tohoku University

Geo-neutrinos are emitted from radioactive elements, such as Uranium and Thorium, in the Earth's interior. Those elements contribute about one half of Earth's heat source. With high transmissivity of neutrinos, geo-neutrino may enable us to measure heat sources in the deep mantle. Since 1-kton liquid scintillator detector "KamLAND" detected geo-neutrinos in 2005, it has been expected as a new probe of Earth's interior. At present, an Italian detector "Borexino" is also observing geo-neutrinos, realizing a "stereo observation". However, observation points are still not enough. In addition, lack of the directional information of geo-neutrinos are serious disadvantage in making the data more precise. We are now developing a new detector for directional measurement of geo-neutrinos, aiming at installing it in KamLAND in the near future. Geo-neutrinos are electron antineutrinos being detected with an inverse beta decay channel with a free proton. Directional information of the neutron, emitted in the inverse beta decay channel, should be measured, in order to measure the direction of the incoming electron antineutrino. To this purpose, we are developing liquid scintillators doped with Lithium-6, which has large neutron capture cross section, and imaging detectors, which detect the vertex position of neutron capture precisely. In this poster, imaging detectors, that we are developing, are reviewed. To detect feeble light emission of the scintillator (actually one photon level), and determine the emission position precisely, optics with large acceptance and small aberration, together with a light detector with high quantum efficiency and positional sensitivity should be employed. In our current R&D, a hopeful design is that with a mirror of diameter 50 cm, and a 256-channel multi-anode photomultiplier tube. Highlighting that design, we will review the latest progress, plan of installing it, expected geophysical results.

Keywords: neutrino, geo-neutrino, radiogenic heat source

Li loaded liquid scintillator for directional measurement

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By the detection of the electron antineutrino using the current liquid scintillator, we can suppress the large background by the delayed coincidence of positron and neutron released by the inverse β -decay that proton and electron antineutrino cause. And we can observe electron antineutrino in the low energy scale.

On the other hand, we cannot know the coming direction of the electron antineutrino like the water Cerenkov method with the existing detector. But we can know the coming direction of the electron antineutrino by observing both reaction point of positron and capture point of neutron. If we could observe the coming direction of the electron antineutrino in the low energy scale, we would distinguish a neutrino every observation object and be able to expect observation with high precision.

There are three necessary conditions to detect the coming direction of the electron antineutrino by a liquid scintillator; (i) capture a neutron before losing directional information, (ii) cause luminous phenomenon at a neutron capture point, (iii) develop a new detection technology with the high position identification performance to detect the reaction points.

In current liquid scintillator, it takes about $200\mu\text{s}$ until a positron captures a thermal neutron released by inverse β -decay and this reaction emits 2.2MeV gamma ray. The released thermal neutron scatters about 10 cm, and so the neutron loses antineutrino's directional information. The neutron produces 2.2MeV capture gamma ray and it obscures the neutron capture point. To solve this problem, we developed ⁶Li loaded liquid scintillator. ⁶Li has large neutron capture cross section (940barn) and when ⁶Li captures neutron, it releases alpha ray that it cannot move a long distance in the liquid scintillator. We can expect to solve two problems by using this new liquid scintillator and also to detect the coming direction of the electron antineutrino using imaging detector that has high position resolution.

In presentation, I will talk about the lithium loaded liquid scintillator developed by an original method.

Keywords: geo-neutrino

Tomography of the earth with large-scale neutrino experiments

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Experimental techniques to study inside of the Earth have been developing remarkably in the past decades. For example, in-situ x-ray diffraction measurements under high-pressure and high-temperature opened new era for studying about possible chemical components and structures of deep Earth. In the next ten years, we will obtain yet another technique for direct measurements of the Earth's interior.

Probing inner structures of the Earth with neutrinos has been discussed for more than 30 years. Neutrinos are chargeless particles and have very small cross-sections. They normally penetrate the Earth without any interaction, and from the rare interactions that do occur we obtain information on the density profile of the Earth's interior. However, the elusive characteristic of neutrinos poses a challenge for detecting them at experimental sites. To compensate for the small interaction cross-section, one needs a large volume neutrino detector.

The IceCube[1] neutrino observatory, completed in 2011 and has 1 cubic kilo-meter volume of detector size, is a possible candidate for this study. Current status of a study for measuring the core density of the Earth with atmospheric neutrino will be presented.

Another characteristic of neutrino is that they change their flavor periodically (neutrino oscillation). These oscillation patterns are affected by the density profile of electrons along the path of the neutrino. Comparisons between the Earth's mass-density profile and the electron-density profile give us ratio profiles of atomic number vs mass number (A/Z), which contains information of chemical composition of the Earth.

It is crucial to use a specific energy range for source neutrinos in order to perform the neutrino oscillation tomography. For Earth's core, the energy range is $\sim 1\text{GeV}$ to 30GeV . To detect the GeV-range neutrinos with sufficient statistics, next-generation experiments Hyper Kamiokande[2] and PINGU[3] have been proposed. Possible discrimination powers of some chemical models of the Earth's core will be discussed.

Fig.1

Left: Exclusion of a pyrolite core model with respect to a pure iron core a time range of ten years. Right: The accuracy, measured in units of sigma, of the Z/A measurement for the assumption of an iron core. Calculated for PINGU[3].

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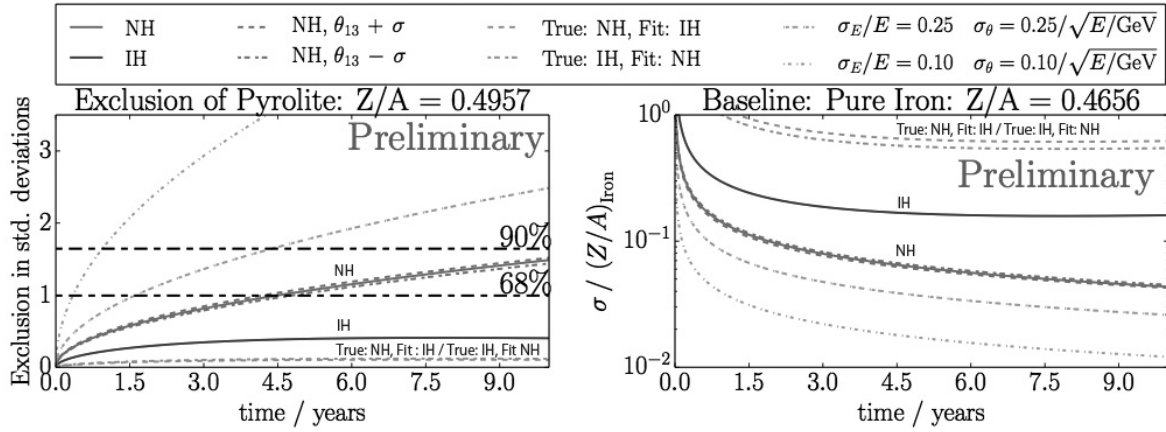
- 1.IceCube Collaboration, *Astroparticle Physics* 26, 155(2006)
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Keywords: neutrino tomography, neutrino radiography, IceCube

U02-P11

Room:Poster

Time:April 28 18:15-19:30



Muographic imaging of Usu volcano with a multilayer detector

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Usu volcano is one of the most active volcanoes in Japan and has erupted for four times in the recent 100 years (1910, 1943, 1977-1978 and 2000). In the 1977-1978 eruption, 18 craterlets and a U-shaped fault were formed in the summit crater. The eruption also caused the deformation in the summit crater area with a diameter of 1.8 km and formed an upheaval called Usu-Shinzan.

Preceding studies suggested that the cooling magma intrusion with a height of 600 m and a width of 300 m was located below the Usu-Shinzan by magnetotelluric soundings (e.g. Ogawa et al., 1998, Matsushima et al., 2001). And Yokoyama and Seino (2000) built a tilt model to interpret the formation of Usu-Shinzan. In this model, a block with a width of 800 m tilted approximately 11° on a pivot at a depth of 800 m. So, in the present work, we conducted the muographic imaging (radiography with cosmic-ray muon) of Usu volcano to confirm the existence of magma intrusion beneath Usu-Shinzan.

But there is the issue of background (BG) noise of muographic imaging for a large volcano (>1 km thick). Since the integrated intensity of traversing cosmic-ray muons steeply decays as a function of the thickness of the target, the signal-to-noise (S/N) ratio also decreases seriously as the size of target becomes larger, and thus the density distribution cannot be accurately measured at a large volcano. The background (BG) noise that reduces the S/N ratio mainly consists of the fake tracks that are generated by the accidental coincidence of the electromagnetic (EM) shower particles. The values of BG noise were $10^{-6} \text{ cm}^{-2} \text{ sr}^{-1} \text{ s}^{-1}$ (Lesparre et al., 2012) and $10^{-7} \text{ cm}^{-2} \text{ sr}^{-1} \text{ s}^{-1}$ (Carloganu et al., 2013). BG noise of $10^{-7} \text{ cm}^{-2} \text{ sr}^{-1} \text{ s}^{-1}$ corresponds to integrated cosmic-ray muon intensity after traversing 1 km of 2.65-g cm^{-3} rock.

In order to solve this problem, we developed a novel muon detection system that consists of multiple layers of position sensitive detectors (PSDs) in conjunction with a trajectory analysis method to effectively reduce the BG noise. In this method, the EM shower-originated fake tracks are rejected by requesting a linear trajectory for a muon event (linear cut method) since EM shower particles randomly hit each PSD layer and make a non-linear trajectory in the detection system. This detection system was applied to Usu volcano, Hokkaido, Japan to image its internal density structure (the spatial distribution of the density). In this measurement, we utilized a muon detection system that consisted of 7 layers of PSDs. One PSD consisted of x- and y- arrays of plastic scintillator strips with an active area of 1.21 m^2 and a segmented area of $10 \times 10 \text{ cm}^2$. The angular resolution was $\pm 3^\circ$. The measurement duration was 1977 hours (82 days).

In this measurement, we compared the integrated cosmic-ray muon intensity traversing 2500 m of 1.5-g cm^{-3} rock with observed data at an elevation angle of 55.6 mrad. Assuming that the residual between the calculated intensity and data is BG noise, we obtained the BG noises of $5.4 \times 10^{-5} \text{ cm}^{-2} \text{ sr}^{-1} \text{ s}^{-1}$ with two PSDs and $1.9 \times 10^{-6} \text{ cm}^{-2} \text{ sr}^{-1} \text{ s}^{-1}$ with seven PSDs. The multilayered muon detector was effective to reduce the BG noise. However, BG noise remains and they may be attributed to another source of BG noise such as upward-going particles (Jourde et al., 2013). This measurement yielded the following results: (A) by analyzing the region that has a thickness of more than 1000 m, we confirmed that our detection system is sensitive to a density variation of 10% in 1300-m rock; and (B) there are high- and low-density anomalies beneath between Oo-Usu and Usu-Shinzan peaks, which is consistent with the magma intrusion and the resultant fault generation suggested by Yokoyama and Seino (2000), Ogawa et al. (1998) and Matsushima et al. (2001).

For the future prospect, we will try to use the shield in order to distinguish the upward-going particles from muons arriving from a volcano side.

Keywords: muography, muon, radiography

U03-01

Room:Main Hall

Time:May 1 14:15-14:20

Expecting great development of PEPS

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JpGU is going launch "Progress in Earth and Planetary Science; PEPS" as a new open access E-journal, covering all scientific fields of JpGU.

Keywords: open access, e-journal, PEPS

Open Access Issues in Physics Journals

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¹Institute for Laser Science, University of Electro-Communications

I introduce some of Open Access activities in Physics journals.

1. arXiv, INSPIRE, SCOAP3

Open Access activities in Physics area have a long history and culture. The standard of judgement of physics papers is based on whether they give new knowledges or informations on human or not. We developed open access databases like arXiv and INSPIRE in 1991 at the beginning of WWW technology. High energy physics (HEP) has been a front runner of open data and open articles. SCOAP3 is a challenging program to serve OA services for top existing HEP journals not only to readers but also to the authors; most of the authors are poor theoretical physicists. Redirection of budget flow from subscription to SCOAP3 scheme is proposed. SCOAP3 started and challenge to establish a long term sustainable model.

2. Public Access activities

Physics communities have delivered charge-free access to the journal database of societies via public libraries and high school libraries since early 90's. All physics papers are open to the people in US when they visit these libraries. Researchers and teachers of developing countries have a charge-free-access to the physics papers through International Center of Theoretical Physics (ICTP). Most of physical societies and publishing companies join the ICTP OA library. ICTP developed a lot of research support and educational programs under a support of UNESCO.

3. Charge-free Reading vs Charge-free Publishing

There are intense discussions on Gold-OA, which means charge-free reading journal. In 1997, the first Gold-OA journals such as Optics Express (OSA) and New Journal of Physics (IOP) were published. In 2003, Optics Express reached breakeven point. Today OSA published more than 50% articles in Gold-OA journals with top IF in Optics. These Gold-OA journals demonstrated a sustainable model which satisfies high quality, article volume, and financial condition, altogether. Such a success was achieved by extraordinary efforts of editors group toward the new generation academic journals by online publishing techniques. APS developed Gold-OA Physical Review X for the real top journal under a different scope and vision. We understand Gold-OA is not a single issue, there are many variations in their scope and functions.

APS journals (Physical Review A-E, Physical Review Letters, etc) published more than 60% articles in Physics with high quality. The publication cost in APS journals is relatively low because authors send their manuscripts in REVTeX format. APS returned the benefit of electronic publication to the authors. The author-fee for Physical Review is zero when they send the manuscript in a manner of electronically acceptable format. The increase of subscriptions from Chinese institutions by WTO scheme contributed to their financial balance significantly.

How to share the scientific information with a reasonable cost, this is a main topics of OA movement today. However, we have to remind that the final target of information sharing is stimulation and activation of scientific activities. Physics communities have paid significant attention to the benefit of authors and readers in equal weight.

4. Try and Error, this is our principle.

Physics communities have made big efforts to improve the publication and access to the scientific informations last 20 years. Fortunately, Gold-OA journals in physics keep high quality by the effort of top societies like APS, IOP and OSA. The financial gain of Gold-OA is directly connected to the acceptance volume. This is an internal mechanism of Gold-OA. We need additional feedback mechanism to keep the scientific quality independently to the rejection rate. We have no rigid model for OA publishing and economical sustainability even now. It depends on the real situation of research and educational condition. Every academic community and every country have to develop their own model according to their requirement, scope and decision.

Keywords: Open Access Journals, IUPAP WG, Gold OA, Public Access, Subscription Model, Author fee

Open Access to Academic and Scholarly Information and Scientific Data

MURAYAMA, Yasuhiro^{1*}

¹National Institute of Information and Communicatoin Technology

Scholarly and scientific information is the infrastructure of science and humanity in a broad sense. The first successful academic journal, Philosophical Transactions, in 17 century have resulted in open and sharing of academic literature or information. In modern Science and Technology research, information which cannot be expressed in a written journal paper, including numerical data, 3-dimensional geospatial information, voice and sounds, and movies. are increasingly being recognized important in international community. Considering that Open Access (OA) of academic journals is to support further advancement of science and technology in coordination with transition from printing culture to electronic media, scientific research data which can be open should be subject to the scientific information infrastructure. International data management activity like ICSU-WDS from the academic side, and RDA related to governmental arrangement are part of such big challenges of the international community. Data citation, using DOI as a persistent identifier attached to a data set, is promoted by international organizations such as WDS, RDA, DataCite, ICSTI, Force11, etc., jointly with science publishers such as Thomson Reuter, Elsevier, Wiley, and so on.

Keywords: Open Data, Scientific Data, ICSU-WDS, RDA, G8

Toward the Founding of a Scholarly Publishing Consortium: UniBio Press Activities

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This is a report on UniBio Press activities toward the founding of a scholarly publishing consortium as suggested by the Science Council of Japan Special Committee on Scholarly Publishing in August of 2012.

UniBio Press has, in collaboration with 8 other academic societies, adopted Strengthening International Dissemination of Information (A), and has spent this last year actively pursuing the creation of arenas for information sharing among, not only the participant academic societies, but for the whole of academic societies across Japan.

Keywords: the Science Council of Japan, Scholarly Publishing, Consortium, UniBio Press

Renovation and future perspective of journal "Earth, Planets and Space"

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Earth, Planets and Space (EPS) is an academic journal published by the following five societies; The Society of Geomagnetism and Earth, Planetary and Space Sciences, The Seismological Society of Japan, The Volcanological Society of Japan, The Geodetic Society of Japan, and The Japanese Society for Planetary Sciences. The publication of EPS started in 1998 as continuations of the *Journal of Geomagnetism and Geoelectricity* and the *Journal of Physics of the Earth*. EPS is accepting scientific articles in the earth and planetary sciences covered by the five societies, in particular, geomagnetism, aeronomy, space science, seismology, volcanology, geodesy, and planetology. The 5-year publication project proposal on EPS to Grant-in-Aid for Publication of Scientific Research Results was accepted and open access publication has started from Jan. 2014. EPS is going to strengthen its international scholarly communication prioritizing letters, and will start publishing in cooperation with Japan Geosciences Union from Jan. 2016. Renovations of EPS including change of publishers and business model transition into open access carried out in FY2013 and the future perspectives will be presented.

Keywords: Earth, Planets and Space, open access, Grant-in-Aid for Publication of Scientific Research Results, business model transition, academic publisher, scholarly communication

Editorial policy and goal of Progress in Earth and Planetary Science

IRYU, Yasufumi^{1*}

¹General Chief Editor, Progress in Earth and Planetary Science

We at the Japan Geoscience Union (JpGU) launched a new open access e-journal called Progress in Earth and Planetary Science (PEPS) in October 2013. As its name suggests, the purpose of this journal is to publish papers that present new discoveries, ideas and unifying concepts in the various fields of earth and planetary sciences (space and planetary sciences, atmospheric and hydrospheric sciences, human geosciences, solid earth sciences, and biogeosciences). In addition to normal research papers and review articles we would also like to publish material based on the best presentations given at the JpGU Annual meetings, and we have asked and will ask session conveners from the meetings to recommend those presentations that they consider to be the most scientifically interesting.

Because PEPS is an open access journal, the following benefits can be provided to authors:

- All articles published by PEPS are made freely and permanently accessible online immediately upon publication, without subscription charges or registration barriers.
- Authors of articles published in PEPS are the copyright holders of their articles and have granted to any third party, in advance and in perpetuity, the right to use, reproduce or disseminate the article.

The authors will benefit from the e-journal as follows:

- No restrictions or limitations for pages, figures, tables, or additional files to enrich the content, including videos, animations, and large original data files.
- No cost for color figures/pictures.
- Fast publication?generally papers/articles can be published 3?4 months earlier in e-journals than in standard print publications.

By taking these advantages, we intend to make PEPS a top-level international journal, and therefore all submitted papers (including invited papers) will go through a full peer review process. In order to publish high level research papers and review articles, we have organized a strong editorial board composed exclusively of active scientists and asked them to ensure that the refereeing process is strict as well as fair.

The PEPS editorial team works and will work hard for PEPS. However success of this journal relies primarily on whether JpGU members submit many high quality manuscripts or not. We earnestly wait for your submission to PEPS.

Keywords: Progress in Earth and Planetary Science, Editorial policy, Open access, E-journal

Publication of Progress in Earth and Planetary Science by JpGU

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JpGU started Open Access e-journal of Progress in Earth and Planetary Science (PEPS). The purpose of this new journal is to strengthen international communication in the field of geo- and planetary-science, and in particular: 1) To establish a geoscience open access leading e-journal; 2) To publish the best presentations from the JpGU Annual Meeting and the high quality of articles from authors based anywhere in the world, both those concerning specific areas of research and general unifying concepts and 3) To work on this together with the JpGU member societies. Efforts for the Promotion of PEPS are 1) to receive the list of the best presentation recommended by the session conveners at the JpGU annual meeting for PEPS submission and 2) to provide travel support and submission fee to submit a review (overview)/high quality articles. We will have the JpGU Journal special international session as part of the JpGU Meeting 2014, the JpGU Journal special symposium (relevant to JpGU research activity), invitation of big scientists recommended by each Science Section in JpGU, and enhancement of communication of the latest information on current research activity (e.g., published) among JpGU members and others. We are developing new application software that will be used at JpGU annual meeting place and at home. Also special effort is required to make PEPS recognized as a leading international journal by many scientists abroad. We will put an advertisement in AGU, EGU, AOGS and others. Our policy for JpGU journal is to publish high quality of articles in order to contribute to geoscience community globally. We present the latest information about JpGU journal and discuss its future development in this session.

Keywords: JpGU, open access e-journal, PEPS, earth planetary science, Participating society, JSPS

Promotion of Scientific Research on Atmosphere and Climate System Using Aircrafts: Proposal of MSJ to SCJ

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Aircraft observation systems along with artificial satellite and ground-based measurement systems are one of the most important tools for earth observations. Rapidly on-going climate change is already influencing our social and economic activities and water and food resources, which are bases for the civilization. Therefore it is important to understand the current status of the earth system and make reliable predictions of its future to avoid serious risks caused by the climate change.

The Working Group for Earth Observation Promotion, Subdivision on Research Planning and Evaluation, the Council for Science and Technology of the MEXT has summarized critical scientific issues for understanding of the global change in its annual guidelines in 2013. These include circulation and budget of the greenhouse gases, cloud and precipitation processes, changes in tropospheric species, climate change in polar regions, and changes in water circulation. The necessity of establishing aircraft observation system for conducting well organized long-term research of the global change is also mentioned. In-situ measurements by the state-of-the-art instruments on board aircraft provide accurate data of key parameters with high spatial resolutions, which lead to improved understanding of the critical processes.

The needs for research aircrafts have long been discussed among the Japanese research communities of atmospheric science and earth science. The Meteorological Society of Japan recently proposed a research project entitled "Promotion of Scientific Research on Atmosphere and Climate System Using Aircraft" as a candidate for Master Plan of Large Research Project announced by the Japan Council of Science. This presentation gives a brief overview of the proposal. We plan to further polish up the research plans in the proposal and enrich the proposal by including possible subjects from other fields of earth science.

Keywords: Atmospheric Science, Climate System, Research Aircrafts, Meteorological Society of Japan, Science Council of Japan, Master Plan of Large Research Projects

Long-term Observation of Atmospheric Greenhouse Gases using Aircraft

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¹National Institute for Environmental Studies, ²Meteorological Research Institute, ³Graduate School of Science, Tohoku University

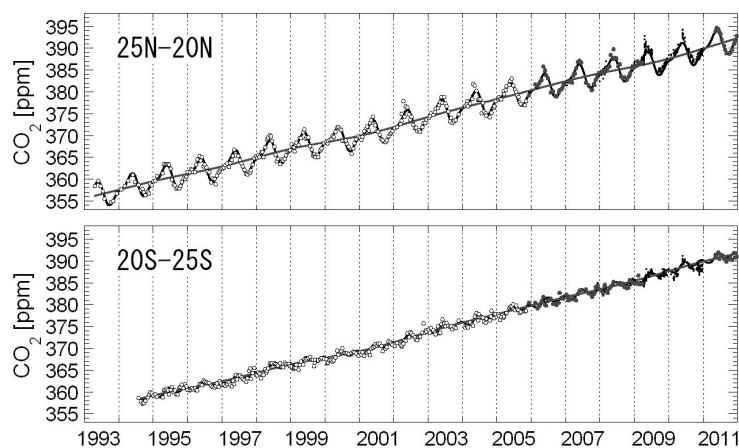
The more reliable prediction for future level of atmospheric greenhouse gases such as carbon dioxide (CO₂) requires the quantitative understanding of global cycles in these gases. Comprehensive observation in atmospheric mixing ratios of trace gases can reduce the uncertainties of emission and absorption of these gases at earth's surface. The atmospheric observations, however, are not enough in several areas in the world, especially observations in upper atmosphere are quite limited compared to surface measurements.

Aircraft is one of the most reliable tools to observe the atmospheric compositions in troposphere and lower stratosphere. Several activities have been conducted to understand the 3-dimensional distribution and temporal variation of atmospheric greenhouse gases.

Mixing ratios of atmospheric CO₂ have been measured from 200 to 10,000 m over Japan using chartered and commercial airliner since 1979 by Tohoku University (TU). Obtained data set is the longest record for CO₂ mixing ratio in upper air. Latitudinal distributions of CO₂ in upper troposphere are observed by commercial airliner operated by Japan Airlines (JAL) between Sydney, Australia and Narita, Japan, and Narita and Anchorage, USA from 1984 to 1985 by TU. The JAL observation in Australia-Japan route started again in 1993 using an Automatic Air Sampling Equipment (ASE) by Meteorological Research Institute (MRI). The new JAL observation named "Comprehensive Observation Network for Trace gases by AirLiner (CONTRAIL)" have been done using improved ASE and Continuous CO₂ Measuring Equipment (CME) since 2005 by National Institute for Environmental Studies (NIES) and MRI. Time series of CO₂ mixing ratio in upper troposphere observed by old ASE and improved ASE are shown in the Figure. CONTRAIL-CME provides a large amount of CO₂ data in upper air which contribute to solve global carbon cycle, atmospheric transport, model validation and satellite validation.

When dedicated aircraft is introduced in Japan, we propose to make a long-term observation for atmospheric greenhouse gases using above techniques and instruments.

Keywords: Greenhouse gases, Aircraft, CO₂, Long-term observation, Troposphere



Elucidation of atmospheric chemistry of reactive gases from airborne observations

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Knowledge on spatio-temporal variations in the concentrations of tropospheric NO_x, CO, and VOC is critical for closing the budget of OH radical, controlling oxidative capacity, and of O₃, as a pollutant and a warming substance. Although recent satellite observations of tropospheric NO₂, for example, have revealed regional/global distribution and seasonal features, they are based on column concentrations and thus limitation is present regarding information on vertical profiles and also on the spatial resolution.

In-situ airborne observations could provide complementary information with improved resolution in space, critical for validation of chemical transport model simulations. Validation of future satellite observations based on multi-spectral approach (e.g., O₃ and CO), which could provide a piece of vertical profile information, is also important. Successful retrieval of near-surface concentrations, having impact on health and ecosystems, should be targeted.

Remote sensing from aircraft could enhance spatial (horizontal and vertical) coverage and resolution. For example, an airborne multi-channel imaging spectrometer in a nadir view could detect detailed inhomogeneity of NO₂ and other gases present within cities at a 100-m resolution, contributing to studies on meso-scale atmospheric chemistry and physics. Limb observations in multiple angles could provide detailed vertical profile information.

In the presentation, observations of halogen and other unprecedented species, and observations to reveal air-sea or air-land interactions are also highlighted.

Keywords: vertical profile, nitrogen oxides, carbon monoxide, ozone, remote sensing from aircraft, spatial resolution

Aerosol measurements by aircraft and modeling studies

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Most aerosol components scatter solar radiation; however, black carbon (BC) aerosols efficiently absorb it and lead to heating of the atmosphere. Because of these effects, the role of BC particles in the climate system has been recognized to be particularly important. However, there remain large uncertainties in the calculations of the spatial distributions of BC and its light absorption in current global models. One of the main causes is considered to be large uncertainties in the vertical transport and wet removal processes of BC adopted in aerosol models. Understandings of the vertical transport and wet removal processes of BC are critically important because they directly controls spatial distribution of BC and its radiative effects. To improve our understanding of these processes, aircraft measurements covering the entire altitude range of the troposphere are needed; however, there have been no aircraft observations of BC measurements covering the entire altitude range of the troposphere over East Asia since the ACE Asia and TRACE-P campaigns in spring 2001.

The Aerosol Radiative Forcing in East Asia (A-FORCE) aircraft campaign was conducted over the Yellow Sea, the East China Sea, and the western Pacific Ocean in March-April 2009 (Oshima et al., 2012; Moteki et al., 2012; Koike et al., 2012; Takegawa et al., 2013). During the campaign, 120 vertical profiles of BC particles, carbon monoxide (CO) concentrations, aerosol number concentrations, and cloud microphysical properties were measured at 0-9 km in altitude. The A-FORCE measurements showed that concentrations of BC were greatly enhanced in the free troposphere (FT) over the Yellow Sea. In this study (Oshima et al., 2012), the transport efficiency of BC (namely the fraction of BC particles not removed during transport) for sampled air parcels was estimated from changes in observed BC-to-CO ratios, because CO can be used as an inert combustion tracer within a timescale of a few weeks. The transport efficiency of BC decreased primarily with the increase in the precipitation amount that air parcels experienced during transport, and its value was about 70-90% and 30-50% at 2-4 km and 4-9 km levels, respectively.

Vertical transport and removal processes of BC over East Asia in spring were examined through numerical simulations for the A-FORCE campaign using a modified version of the regional-scale three-dimensional chemical transport model WRF-CMAQ (Oshima et al., 2013). The simulations reproduced the vertical distributions of the transport efficiency of BC observed by the A-FORCE campaign reasonably well, indicating the validity of the treatment of the wet removal processes of aerosols in the model. We identified three major transport pathways for BC export from East Asia to the western Pacific in spring. One pathway was the planetary boundary layer (PBL) outflow through which BC was advected by the low-level westerlies without uplifting out of the PBL (weak BC removal). The second pathway was through uplifting from the PBL to the FT by migratory cyclones over northeastern China and the subsequent eastward transport in the lower FT (moderate BC removal). The third pathway was orographic uplifting and/or convective upward transport from the PBL to the FT over inland-southern China followed by westerly transport in the mid-FT (strong BC removal).

We will introduce our studies with a particular focus on the importance of the aerosol measurements by aircraft and its importance for modeling studies in this presentation.

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Keywords: Aircraft measurements, Aerosols, Black carbon, Aerosol model, Transport, Removal

Aircraft measurements of aerosol-cloud interactions

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1. Importance of aerosol ? cloud interactions

By serving as cloud condensation nuclei and ice nuclei, aerosols affect cloud droplet number concentrations and phase of cloud particles. These cloud microphysical changes cause cloud albedo changes and cloud adjustments (fast cloud response), such as changes in cloud liquid water path and/or cloud fraction. However, there are large uncertainties in estimations of these aerosol ? cloud interactions

2. Aircraft measurements

Satellite measurements can provide global view of the aerosol ? cloud interactions, however, quantities retrieved from satellite measurements are limited. Several artifacts are also known. Although aircraft measurements are limited in space and time, they can provide critical information to study aerosol ? cloud interactions, namely, aerosol and cloud droplet number size distributions. In fact, aircraft measurements have been intensively made over off the coast of California, Peru, and West Africa, tropical Pacific, Indian ocean, and Arctic ocean. Aircraft measurements act as a driving force to study aerosol ? cloud interactions.

3. Aircraft measurements in Asia

Aerosol concentrations in Asia are highest level in the world and they can potentially affect clouds forming over the Western Pacific. However, a number of aircraft measurements is limited. In this paper, results from aircraft measurements made over the Western Pacific during the A-FORCE-2009 and 2013S campaigns are shown. Future science of aerosol ? cloud interactions using aircraft is also discussed.

Keywords: aerosol, cloud, aircraft measurement, Asia

Evaluation of a result of a coupled atmosphere-ocean model around a tropical cyclone center using aircraft observations

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Aircraft observations enable us to understand the dynamical, thermodynamical, and microphysical structure of an inner region of TCs, such as their eye and eyewall. Numerical simulation is also a useful tool to clarify the structure of TCs, however, the reproducibility around the inner region of TCs could not be confirmed. This study shows an application of aircraft observations to evaluate the structure of a simulated TC using a coupled atmosphere-ocean non-hydrostatic model, Cloud Resolving Storm Simulator (CReSS) and Non-Hydrostatic Ocean model for Earth Simulator (NHOES), CReSS-NHOES.

The target typhoon is T1013 (Megi) developed over the tropical western Pacific Ocean in October 2010. During the Impact of Typhoons on the Ocean in the Pacific (ITOP), 200 dropsondes are dropped into and around T1013, including its eye and eyewall regions, from a height of about 2.5 km. Dropsondes can observe a vertical profile of pressure (height), temperature, humidity, wind direction, and wind speed. The profiles of these parameters are used to evaluate the simulation result using CReSS-NHOES. A simulation with horizontal grid resolution of 0.02 degree (approximately 2 km) is conducted for 7 days from 00 UTC on October 14, 2010, after one day of the formation of the T1013.

The simulation well reproduces its track and the tendency of the minimum central pressure. The reproduced minimum central pressure is 889 hPa and corresponds to the observed one (885 hPa). To conduct the direct comparison between dropsonde observations and the simulation result, the target time of the simulation to compare with the observed one is determined to consider the value of minimum central pressure and its tendency. At the observed target time when conducted the dropsonde observations, the observed TC center is determined by the linear interpolation of the best track data provided by Japan Meteorological Agency. The simulated TC center at the target time is defined by the application to the Braun's method to the CReSS-NHOES output data. The location of the simulated profiles are determined by that of the dropsonde observations relative to the center of the TC at the simulated target time.

The eyewall region in this study is defined as the region that relative humidity of all layers is greater than 95% and maximum wind speed exceeds 25 m s^{-1} below a height of 2 km. The eye and outer region are defined by the inner and outer ones of the eyewall. The simulated potential temperature, mixing ratio of water vapor, and wind speed in the outer region are in the range of 1-sigma (standard deviation), thus, the simulated thermodynamic parameters are well reproduced statistically. After the rapid intensification of T1013, weak and maximum wind speed regions are reproduced in the eye and lower level of the eyewall, respectively. High potential temperature in the low-level of the eye is also reproduced. Thus, qualitative properties of the TC are well reproduced in the simulation. However, the simulated potential temperature is 3 K greater than that in the observation. And the simulated wind speed is 25 m s^{-1} lesser than that in the observation. The quantitative differences are expected to be caused by the difference of the structure of the eye. The problem on the structure of the eye appears in comparison with the application of the aircraft observations for the first time.

Keywords: aircraft observation, tropical cyclone, cloud-resolving model, coupled atmosphere-ocean model, model evaluation

Aircraft observations over the Sea of Japan and the Sea of Okhotsk in winter

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It is well known that the Sea of Okhotsk is one of the southernmost seasonal sea ice zones in the Northern Hemisphere. The importance of the relationship between the Sea of Okhotsk ice cover and regional/global climate has long been recognized. Indeed, recent research work has tied the extreme maximum and minimum wintertime extents of sea ice cover to large scale changes in atmospheric circulation patterns. Recent studies suggest that a possible origin of the North Pacific Intermediate Water (NPIW) is produced in the Sea of Okhotsk. Thus, there are important climate issues that are associated with the Sea of Okhotsk. It is also known that Japan, especially along the coast of the Sea of Japan, is one of the heaviest snowfall regions in the world. Snowfall is brought by banded snow clouds formed when winter monsoon air from Siberia is supplied latent and sensible heat from the Sea of Japan. These banded snow clouds are also frequently formed in the lee side of the sea ice over the Sea of Okhotsk, and play an important role in the growth of the sea ice.

Despite of the scientific importance of these areas in regional/global climate system, in-situ observations there are extremely few, especially in winter. This is due to the fact that the wintertime environment is generally harsh and is not conducive to making high quality measurements. However, in recent years instrumentation and technology have improved to the point where it is now possible to make the requisite wintertime measurements. In this regard, we conducted aircraft observations over the Sea of Okhotsk and the Sea of Japan.

We had deployed an X-band Doppler radar at Monbetsu on November of 2005, and started observation on 16 January of 2006. The height of sea-ice is different from place to place. Air-born laser altimeter is only the tool that can make horizontal distribution of the height of sea-ice. However, this method is very expensive and severely affected by weather condition. We tried to make a three dimensional display of sea-ice and suggested that our radar system could be used to study the irregularity of the height of sea-ice. Therefore, we measured horizontal distribution of height of sea-ice by using aerial cameras and compared it with 3Dimages of our X-band radar.

Keywords: snow clouds, sea ice, marine boundary layer

Use of Aircraft for Coastal and Oceanographic Research and Observations

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Aircraft should be useful to observe coastal and ocean environments, including physical, chemical and biological properties, especially under the rapid, unexpected and dangerous conditions, such as typhoon or volcanic eruption, where ship operation is difficult. It is expected that there are two methods of observations from aircraft, other than seaplane, for oceanographic research; one is remote sensing and another is use of air-deployable sensors or platforms. Various remote sensing sensors are available using visible, infrared, microwave and sound waves. They have advantage to satellite-based remote sensors with high resolution and more flexible overflight, and they should be useful for coastal applications. Most of the remote sensing sensors can only obtain surface information; however LIDAR can detect vertical profiles of some parameters such as plankton distribution. Air-deployable sensors have been used for measurements of vertical profiles of temperature (AXBT; Airborne eXpendable BathyThermograph), salinity (AXCTD; Airborne eXpendable Conductivity Temperature and Depth probes), and current (AXCP; Airborne eXpendable Current Profilers). More recently, vertical profiling floats are developed and deployed for Argo project. There were attempts to deploy one of the vertical profiling floats, Electromagnetic Autonomous Profiling Explorer (EX-APEC), from airplane for typhoon observation and obtained profiles of temperature, density and currents. Autonomous profiling floats are now developing equipped with chemical, optical and biological parameters, and should be deployable from aircraft. Other various types of small autonomous underwater vehicles (AUV) are also underdevelopment and may be deployable from airplane in future. Combination studies of those physical, chemical, and biological parameters in coastal and ocean environments with atmospheric information, such as weather condition and chemical properties, are necessary to understand coupled atmospheric-ocean system.

Keywords: aircraft, coast, ocean, remote sensing, float, typhoon

U04-09

Room:211

Time:April 29 11:15-11:30

Earth Observation by using airborne SAR

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Pi-SAR2 and Pi-SAR are high resolution airborne SAR. We will present possibilities of these sensors for application to the earth science.

Keywords: Synthetic Aperture Radar, Polarimetry, Interferometry, Pi-SAR2

Applicability of airborne remote sensing to terrestrial ecosystem sciences

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Although the airborne remote sensing generally cannot be conducted repeatedly for a region during a multi-year long time period like satellite (space borne) remote sensing, the airborne remote sensing has many advantages in the observation of terrestrial ecosystem. One of them is, of course, the spatial resolution of the airborne remote sensing can be much higher than that of the satellite because the airborne platform flies at much lower altitude than satellite. Although WorldView-2 and GeoEye-1 provide high resolution images of land surfaces, it is practically hard to identify the individual tree in a forest, while the image of airborne remote sensing allows us to observe the tree crown structure and the forest floor condition. In 2000, an airborne remote sensing was conducted from spring to summer over forests around Yakutsk, eastern Siberia, and forest images were recorded by the onboard video camera from heights of 100 to 150m above the land surface. We examined the presences of green leaves in the crown of forest and the snow cover on the floor, and the spectral reflectance of the forest was investigated in relation to those conditions. The result suggested the reflectance from the forest floor significantly influenced the satellite-derived vegetation index (e.g. NDVI) in case of sparse boreal forests. The airborne remote sensing at a further lower height, several tens meters, enables us to indentify the individual leaf and insect, and subsequently, to study the biodiversity on individual basis. Recently, the remote sensing technique by airborne hyperspectral camera and LiDAR has explored a feasibility to identify species and retrieve the chemical trait and structure of vegetation. This methodology made a breakthrough for investigating the ecosystem function and biodiversity. Another advantage of airborne remote sensing is the capacity to select the observation geometry such as the incident angle of solar illumination and the view angle of the sensor. This capacity leads a robust development of radiative transfer model of vegetation based on the bidirectional reflectance distribution function (BRDF).

Keywords: forest ecosystem, LiDAR, ecosystem function, biodiversity

Ground Truth of Earth Observation Satellites using UAV

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Japan Aerospace Exploration Agency (JAXA) is going to launch new Earth observation satellite GCOM-C1 in near future. The core sensor of GCOM-C1, Second Generation Global Imager (SGLI) has a set of along track slant viewing Visible and Near Infrared Radiometer (VNR). These multi-angular views aim to detect the structural information from vegetation canopy, especially forest canopy, for estimating productivity of the vegetation. SGLI Land science team has been developing the algorithm for 10 standard products (above ground biomass, canopy roughness index, shadow index, etc).

In this paper, we introduce the ground observation method developed by using Unmanned Aerial Vehicle (UAV) in order to contribute the algorithm development and its validation. Mainly, multi-angular spectral observation method and simple BRF model have been developed for estimating slant view response of forest canopy. The BRF model developed by using multi-angular measurement has been able to obtain structural information from canopy. In addition, we have conducted some observation campaigns on typical forest in Japan in collaboration with other science team experienced with vegetation phenology and carbon flux measurement. Primary results of these observations are also be demonstrated.

Keywords: UAV, Second Generation Global Imager (SGLI), Multi-angular observation, Forest canopy, Vegetation productivity

New phase remote sensing stimulated by the use of airborne observation

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Center for Environmental Remote Sensing (CEReS), Chiba University, is processing, archiving, and disseminating satellite data and related ground observation data to wide communities in remote sensing and environment-related areas. In the field of atmospheric remote sensing, we have established a radiometer network (SKYNET), which contributes to satellite data validation through characterization of atmospheric aerosols and clouds in East Asia. Also, the radiometer data are valuable for studying air pollutants due to anthropogenic activities when coupled with data from lidar and high spectral resolution spectroradiometer observations. Quantitative analysis of global biomass can be implemented by means of vegetation remote sensing. Methodology for obtaining highly accurate vegetation reflectance has been sought using satellite- and ground-based observations, as well as directional observation using unmanned helicopters. This approach has been exploited for developing an algorithm to be used for GCOM-C1, JAXA's next-generation satellite. In the field of microwave remote sensing, sensors based on circularly polarized synthetic aperture radar (CP-SAR) technique have been developed for both small satellites and unmanned aircraft applications.

Currently a new cooperative study plan is being discussed among university research institutes/centers based on chartering a manned airplane for scientific observation purposes. Through this initiative, it is expected that atmospheric science and climate system studies (University of Tokyo), cloud and precipitation system studies (Nagoya University), as well as high-level scientific application of remote sensing data (Chiba University) will be promoted. The primary goal of CEReS activity will be to achieve highly accurate remote sensing of vegetation, snow and ice fields, and coastal areas through the realization of high-precision atmospheric correction of satellite data, which would have been impossible without resorting to aircraft observation.

As more and more high resolution satellite data are becoming available, needs are growing for high-precision retrieval of physical quantities such as land or ocean surface reflectance. The largest obstacle for this improvement is the spectral changes due to atmospheric scattering and absorption. The influence of air molecules (Rayleigh scattering) can be corrected relatively easily. In contrast, correcting the effects of clouds and aerosols (Mie scattering) tends to be much more difficult, due to their temporal and spatial variability. Conventionally, network observation using a number of sunphotometers and skyradiometers has been implemented for measuring the optical properties of atmospheric aerosols and clouds. Also helicopter and unmanned air vehicle (UAV) measurements have been undertaken covering altitude ranges lower than 150 m above ground. Still, it is difficult to carry out the validation of satellite remote sensing imagery over an extended region.

The aircraft project currently under discussion will enable the measurements of radiation quantities and surface reflectance from high altitudes. The radiometer and hyperspectral camera measurements from both unmanned (low altitude) and manned (high altitude) platforms will allow us to improve radiative transfer algorithms indispensable for high-precision atmospheric correction. This, in turn, will contribute to dramatically improving the accuracy of algorithm for estimating biomass amount based on reflectance measurements. In addition, all-weather and both day- and nighttime surface observation can be demonstrated by equipping the CP-SAR instrumentation.

Keywords: remote sensing, airborne observation, vegetation, atmosphere, microwave sensor

Aerosol particles collected using aircrafts from anthropogenic sources and biomass burning and electron microscopy

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Aerosol particles collected during four sampling campaigns using aircrafts were analyzed using transmission electron microscopes (TEM). The samples were collected from two A-Force campaigns in 2013 (winter and summer) conducted in Japan and Korea, BBOP campaign in 2013 in the USA, and MILAGRO campaign in 2006 in Mexico. These campaigns aim to characterize aerosol particles from regional transportation, biomass burning, and both. The samples collected using aircrafts are useful for characterization of particle agings, especially changes of their mixing states, from emissions as the aircrafts can chase plumes of different aging periods. An example of such aerosol-particle aging is tar ball formation in biomass burning smoke. Tar ball is spherical, organic aerosol particles commonly from combustion smoke of a wide range of biomass burning. At the early stage of the emission, tar balls are liquid but as they age in the smoke, they become solid and spherical. Sets of biomass burning aerosol samples with different aging stages collected using an aircraft revealed such processes in atmosphere. I will also discuss the samples collected over Japan during the A-Force campaigns.

Keywords: Electron microscope, East Asia, Northwest US, A-Force, BBOP, MILAGRO

Aerial observations for nitrogen compounds over the East China Sea

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In order to clarify long-range transport of air pollutants from the Asian continent, we have conducted aerial observation over the East China Sea and measured air pollutants centering on aerosols, as part of Grant-in-Aid for Scientific Research on Innovative Areas “ Impacts of Aerosols in East Asia on Plants and Human Health (ASEPH) ” . In this presentation, the results of nitrogen compounds such as nitrate are mainly described.

The aerial observations were conducted in October, 2009 (autumn), December, 2010 (winter) and March, 2012 (spring) over the East China Sea. The flights were performed between Fukue Island and the southern offing of Jeju Island and the flight altitudes were 500, 1000, 2000 and 3000 m. Onboard measurements of gaseous total odd nitrogen species, gaseous nitric acid ($\text{HNO}_3(\text{g})$), O_3 , SO_2 , CO and black carbon were made and particles were collected on filters for ionic and metal component analyses.

The concentration ratios of particulate nitrate ($\text{NO}_3^-(\text{p})$) to inorganic total nitrate ($\text{T.NO}_3 = \text{HNO}_3(\text{g}) + \text{NO}_3^-(\text{p})$) were less than 0.5 in most of the flights except under high concentrations of dust particles (Kosa) or transboundary air pollutants. Most of $\text{NO}_3^-(\text{p})$ would be NaNO_3 formed by the reaction of gaseous nitric acid ($\text{HNO}_3(\text{g})$) with sea salt aerosols during the observations in autumn and winter except on October 17 and December 11, when high concentrations of Kosa were transported. In the spring observation, the fraction of NaNO_3 in $\text{NO}_3^-(\text{p})$ was low and a large part of $\text{NO}_3^-(\text{p})$ would be originated from reactions of $\text{HNO}_3(\text{g})$ with gas phase ammonia and soil dust particles.

O_3 concentrations decreased with altitude in autumn and increased in winter. Positive and negative correlations between NO_y - T.NO_3 and O_3 concentrations were observed throughout the flights in autumn and winter, respectively. This indicates that the major components of NO_y - T.NO_3 were secondary photochemical nitrogen oxides such as PANs and NO_x , in autumn and winter, respectively. The differences of vertical distribution and NO_y components between autumn and winter may be caused by the variation of solar radiation intensity.

Keywords: aerial observation, nitrate, total odd nitrogen species, East Asia

Airborne lidar measurements of water-vapor profiles

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Measurements of water vapor profiles are very important in studies of the atmospheric dynamics, aerosol growth effect and the earth's radiation effects. Water vapor is the predominant greenhouse gas and its vertical distributions are important parameters in model simulation of the global climate system. Passive remote sensing techniques from space provide global coverage of water vapor distribution but do not provide good vertical resolution, while lidar remote sensing techniques can provide high resolution measurements of water vapor distributions.

For future spaceborne water vapor DIAL systems, we developed a high power diode-pumped Nd:YLF laser and Ti:sapphire laser for water vapor DIAL. A Ti:sapphire laser is pumped by the SHG of the Nd:YLF laser. Tuning of the Ti:sapphire laser to a strong absorption line (ON1), a weak absorption line (ON2) of water vapor and an off line (OFF) is made by an injection seeder which consists of two single longitudinal mode laser diode modules. Two on-line laser diodes are locked to water vapor absorption lines using an absorption cell or a photo-acoustic cell. These three laser lines (ON1, OFF and ON2) are transmitted into the atmosphere with a triple pulse technique for measurements of water vapor profiles from the ground up to 10 km. The laser spectral width of the on line was 0.045 pm with a stability of 0.06 pm. The output energy of each laser line is more than 45 mJ. We have demonstrated airborne measurements of water vapor profile using this laser system.

Keywords: water vapor, airborne, lidar

Bioavailable energy distributions in the hydrothermal systems on Enceladus and early Earth

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A recent research by Cassini spacecraft suggests that there are silica nanoparticles in Saturn's E-ring derived from the Enceladus plume (Hsu et al., submitted). The findings of silica nanoparticles imply active water-rock reactions. Furthermore, an experimental study simulating the reactions between chondritic material and alkaline seawater revealed that the formation of silica nanoparticles requires hydrothermal reactions at temperatures higher than 100 deg. C (Sekine et al., submitted). Considering a short residence time of nanoparticles in the ocean, these studies imply geologically-recent or on-going hydrothermal activity in the Enceladus' subsurface ocean. Therefore, we modeled possible hydrothermal fluid/rock reactions and bioavailable energy in the mixing zone between hydrothermal fluid and seawater on Enceladus. The thermodynamic calculations of reactions between CI chondrite and alkaline NaCl-NaHCO₃ seawater at 100 deg.C indicate that the pH of fluid increases up to about 10 and hydrogen concentration in the fluid is elevated up to 20 mmolal through the water/rock reaction. Based on the estimated fluid compositions, we calculated chemical property of the mixing zone between seawater and hydrogen-rich alkaline hydrothermal fluid, which revealed that a certain level of bioavailable energy is derived from redox reactions based on CO₂ and H₂ in the mixing zone whereas there are unlikely other electron acceptors such as sulfate and nitrate that are abundant in the terrestrial seawater. Thus, the CO₂-H₂ pair can be used for possible metabolic reaction, namely hydrogenotrophic methanogenesis and acetogenesis. In the low-temperature zone, the available energy of the Enceladus methanogenesis is higher than that of methanogenesis in the Rainbow field (Mid-Atlantic Ridge) where methanogens are certainly separated. It is therefore highly possible that H₂-based energy metabolisms have been generated in the Enceladus hydrothermal vent system. Considering that the most ancient metabolisms in the Hadean terrestrial hydrothermal vent system could be also H₂-based redox reactions, there is an energetic similarity between hydrothermal vent systems on Enceladus and Hadean Earth. The future exploration of Enceladus' plume would potentially provide clues to the origin of life on Earth.

Impact-induced D/L chiral changes of valine in early Earth's oceans

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It has widely known that proteins are composed of L-amino acid monomers and that nucleic acids contains exclusively D-sugars. Homochirality selection may be contributed to the consequence of life materials and their generation conditions. Regarding the enantiomeric excess in biomolecules, there are several proposals at present. Because the enantiomeric excess occurs in photoreactions by circularly polarized light, it has been believed that interstellar environments play an important role to the formation of chiral amino acids identified in chondrites and interstellar ices. However, it is also important to know whether the enantiomeric excess of amino acids occurs during oceanic impacts or not, because the enantiomeric enrichments are known under critical states of fluids due to density fluctuations.

We have investigated the shock-induced chiral changes of valine in aqueous solution coexisting with given solids. Powders of olivine, hematite, and calcite were selected to represent solids. Hypervelocity plane impact experiments were carried out using a propellant gun. Sample solution of each of L- and D-valine in sealed steel containers was subjected to impact at velocities of about 1 km/s. The calculated shock pressures are 5-6 GPa by the impedance match solution. The recovered solutions were analyzed with LC/MS (2695 separation module; Waters Corp. and Quattro micro API; Waters Corp) after the FDLA derivatization that makes a difference in hydrophobicity between D- and L-valine. The enantiomeric excess ($ee(\%)=100(L-D)/(L+D)$), the yield of the initial valine, and shock pressure are plotted to see their relationship. The results indicate a difference among the solid. Although there was no significant change from the racemic valine solution, the reaction from L-valine to D-valine was significantly faster than that from D-valine to L-valine in calcite. The adsorption of calcite powders was checked to display no difference between D- and L-valine. These results may suggest that oceanic impacts may change the chirality of amino acids in oceans. However the enrichment of L-amino acids on the Earth need another mechanism.

Keywords: Impact-induced D/L chiral changes, D/L valine, Calcite

The oldest remnant of life in 3.8 Ga old early Archaean rocks

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The suggestion that graphite in early Archaean rocks represents materials of biogenic origin has met with a degree of scepticism. Isotopic compositions of graphite in >3.7-billion-year-old rocks from the Isua Supracrustal Belt (ISB), western Greenland, which are believed to be of sedimentary origin, suggest that vast microbial ecosystems were present in early Archaean oceans. However, results of more recent studies suggest that most of graphite-bearing rocks were formed through interactions between crustal fluids and surrounding igneous rocks during later metasomatic events, thereby casting doubt on the existence of an extensive sedimentary sequence in the ISB and on the biogenic origin of constituents. In contrast, ¹³C-depleted graphite globules, which are considered to form from biogenic precursors, have been reported from the metamorphosed clastic sedimentary rocks in the ISB. However, these were found at a single locality. It therefore remains unclear whether traces of life at other localities in the ISB were lost during metamorphism or were originally absent. The presence of additional clastic sedimentary rocks containing graphite may provide evidence for the preservation of organic constituents in early Archaean rocks, thus supporting the notion that microbes were active in early Archaean oceans.

We conducted a geological survey along the northwestern area of the ISB. Banded iron formations contain interbedded black to grey schist layers, typically 40-80 cm thick. Rare earth element patterns in samples lie close to that in Post Archaean Australian Shale, suggesting that the protoliths of the schist was clastic marine sediments. The black-grey schist samples contain abundant reduced carbon (0.1-8.8 wt%), identified as graphite by X-ray diffraction analysis. The range of $\delta^{13}\text{C}$ values was -23.8 to -12.5 per mil (average, -17.9 per mil), which is within the range of values reported in previous studies. Scanning transmission electron microscope and high-resolution electron microscope observations present different nanoscale morphologies between the graphite of metasediment and secondary vein samples. Examined metasediment included graphitic polygonal grains and nanotubes. Sheeted flakes were a dominant morphology of secondary graphite, whereas polygonal grains and nanotubes were absent from them, suggesting a different origin from the secondarily derived graphite.

We modelled the theoretical $\delta^{13}\text{C}$ values of fluid-precipitated graphites. The lowest $\delta^{13}\text{C}$ values exceed -16.4 per mil when Rayleigh-type isotope fractionation operates in the fluids. Therefore, ¹³C-depleted biogenic organic matter in Isua clastic sediments is postulated as an initial carbon source to explain the lightest carbon isotope compositions (e.g., -23.8 per mil) in the present study. Distorted structures are common in pyrolysed and pressurized organic compounds. Such precursors commonly contain non-planar carbon ring compounds associated with abundant pores. Biogenic organic matter, which contains various molecules and functional groups, is suggested as the precursors of the graphite observed in metasediment.

In summary, the graphite in metasediment from the northwest ISB is distinct from the graphite in secondary vein samples. The combined information on geological occurrences, graphite morphologies, nanoscale structures, and isotopic compositions of the graphite in the metasediment suggests a biogenic origin of the graphite. High concentrations of ¹³C-depleted graphite in these rocks would require widespread biological activity to support the high rate of production and sedimentary delivery of organic matter to the >3.7-billion-year-old ocean floor.

Keywords: origin of life, Greenland, Isua Supracrustal Belt, graphite, remnants of life

Mineralogical and geochemical study of clastic sedimentary rocks in Barberton greenstone belt, South Africa

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Cyanobacteria became active and oxidize surface ocean water in Archean. However, chronological constraint is still uncertain as to when ocean water became oxic. Some redox sensitive minerals in clastic sediments are often used to indicate the absence or presence of oxidative weathering, oxic sea water and diagenesis. Clastic sedimentary rocks in Barberton Greenstone Belt are studied by many previous investigators. However, detailed examination of redox sensitive minerals and elements are rare. Therefore, we set objectives of the present study (1) to investigate mineralogical and geochemical characteristics of clastic sedimentary rocks deposited in shallow water environments in ca.3.2Ga Moodies Group, (2) to discuss the origin of redox sensitive minerals in clastic sediments and (3) to decipher the redox conditions of the surface environments at the time of Moodies sedimentation.

We examined clastic sedimentary rocks (mainly sandstone) of the Joes Luck Formation in the Moodies Group. Samples were collected from drilled core collections of Sheba mine. All samples are belonging to Eureka Syncline blocks. Those samples are not affected by modern weathering.

The examined sandstones contained rounded quartz, K-feldspar, albite, minor zircon, and rutile. These minerals were detrital origins mainly from felsic crustal materials. Rounded chromite also occurs and we interpret that such chromite is a weathering product from mafic to ultramafic rocks. Rounded chromite is always surrounded by forming aggregates Cr-rich micas, and chromite never occurs without micas. We interpret that chromite was protected by micas, and survived from dissolution during weathering, transportation and diagenesis. Detrital pyrite and uraninite were not seen in these samples. Those mineral features indirectly indicate that presence of oxidative weathering, transportation and/or diagenesis at the sedimentation of Moodies Group. Geochemical analyses of the bulk samples indicate that most elements (e.g., Ti, Zr and V) are correlated to Al. Therefore, chemistry of examined samples are controlled by detrital components. On the other hand, Cu, Pb, Mn, and Mo are not correlated to Al, and apparently enriched in clastic sediments. Cu and Pb were mobilized in sediments during early to late diagenesis associated with late sulfide formations. Enrichment of Mn and Mo in the examined samples more reflected precipitation process from ocean water and diagenesis. In particular, enrichment of Mo is found in some samples with moderate amount of organic carbon. This suggests that Mo was dissolved in Moodies ocean water as oxidized species, and then reduced by microbial activities followed by sedimentation with organic matter. Overall results of this study suggested that oxygenic phototrophs already flourished in the photic zone of the 3.2 Ga ocean, making surface ocean water oxic.

Keywords: Cyanobacteria, Chromite, Barberton, RSE

Cerium stable isotopic fractionation as a potential paleo-redox proxy

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Cerium (Ce) anomaly that appears in rare earth element (REE) pattern is a tool to estimate paleoredox condition and has been used for many studies. Discussion in previous studies, however, has been limited to qualitative one based on the REE pattern. This study, therefore, aims to provide more quantitative information on the redox condition in paleoenvironment by Ce stable isotope ratio related to the redox-sensitive property of Ce. If fractionations of Ce stable isotope responds differently to various geochemical processes such as (i) oxidative scavenging on Mn oxide, (ii) precipitation as Ce(OH)₄, and (iii) adsorption of Ce³⁺ without oxidation, it is possible that Ce stable isotope ratio can give more information on redox condition in paleoenvironment.

Cerium(III) chloride solution was added to manganese oxide and iron hydroxide, respectively, with the concentration of Ce systematically changed. In both systems, pH was adjusted to 5.00, 6.80, 8.20, and 11.0 (±0.05) and shaken for 6 hours before the filtration using 0.2 μm membrane filter. In addition, precipitation of Ce was obtained by bubbling of O₂ gas in the same CeCl₃ solution. Stable isotope ratios of Ce in both liquid and solid phases were determined using MC-ICP-MS at Kochi Institute for Core Sample Research. The CeCl₃ solution used in the adsorption experiment was employed as standard solutions and the isotope ratio of each element was expressed in delta notation relative to the average standards, which is shown in the equation as follows: $\delta^{142}\text{Ce} = [(142\text{Ce}/140\text{Ce})_{\text{sample}} / (142\text{Ce}/140\text{Ce})_{\text{CeCl}_3} - 1] \times 10^3$.

Assuming equilibrium isotopic fractionation, the mean isotopic fractionation factor between the liquid and solid phases $\alpha_{Lq?So}$ of Ce adsorbed on ferrihydrite was within the analytical uncertainty for all the pH conditions. Meanwhile, the $\alpha_{Lq?So}$ of Ce adsorbed on δ-MnO₂ was gradually decreased with increasing pH. Most surprisingly, the $\alpha_{Lq?So}$ of spontaneous precipitation of Ce showed that, with increasing pH, the direction of the isotopic fractionation was in contrast to those in the adsorbed systems. These results suggest that the degree of mass-dependent fractionation of Ce can be used to clearly distinguish spontaneous precipitation from oxidative adsorption on δ-MnO₂, that occurs under more oxic conditions than the Ce(III)/Ce(IV) boundary. Our results suggest that the combination of the degrees of mass-dependent fractionation and chemical state of Ce can be used to classify the redox condition into the three stages based on Ce geochemistry, thereby offering a powerful tool for exploring redox conditions in paleo-ocean environments.

Keywords: cerium, stable isotope, redox

Decoding the Evolution of Early Atmosphere: Experimental Reconstruction of the D36S/D33S Chemostratigraphy

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Sulfur Mass-Independent Fractionation (S-MIF) has potential to monitor chemistry of the Earth's early atmosphere (Farquhar et al., 2000). Nonetheless, detailed mechanism of the S-MIF occurred in the Archean atmosphere is still poorly understood. Previous laboratory experiments indicate the anomalous isotopic fractionation depends largely on (1) wavelength or spectrum of the incident light source and (2) partial pressure of SO₂, though none of these experiments have not yet succeeded to fully reproduce the S-MIF recorded in the Archean sedimentary rocks (e.g., Danielache et al., 2008; Masterson et al., 2011; Whitehill & Ono, 2012). We have developed a new photochemical chamber for determining isotopic effect of the SO₂ photolysis under optically thin condition. Also, a new direct fluorination technique of carbonyl sulfide allowed us precise isotopic analysis down to 50 nmolS of photolysis product. The results indicate that the basic character of the S-MIF observed in the Archean record can be reproduced when SO₂ column density is reasonably low (i.e. 10 to 50 times higher than preindustrial atmosphere). The results with a numerical modeling of the atmospheric reaction network suggest that the observed change in D36S/D33S ratio can be adequately explained by the two factors: (1) SO₂ partial pressure and (2) amount of reducing gas (H₂, CH₄ and CO). In light of the new perspective, we have re-evaluated the geological record of the D36S/D33S ratio with additional analyses of Archean sedimentary sulfides from South Africa and India. Based on the magnitude of the S-MIF and the D36S/D33S ratio, the Archean period can be subdivided into four stages (i.e. > 3.0 Ga, 3.0-2.7 Ga, 2.7-2.5 Ga and 2.5-2.4 Ga). These changes probably reflect both intensity of volcanic SO₂ emission and concentration of reducing gasses under the O₂-free atmosphere. Particularly, the maximum scatter of D33S values observed in the stage 3 (2.7-2.5 Ga) requires high volcanic emission as well as very reducing atmospheric condition in the atmosphere at that time.

Keywords: Archean, atmospheric chemistry, mass independent fractionation

Archean Atmospheres Modeled with the KROME Chemistry Package

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Sulfur isotopic fractionation has been used as a tool to understand the composition of reducing atmospheres. Our previous work (Danielache et al., 2008 and 2012) have shown that UV-light triggers a large Sulfur Mass-Independent Fractionation (S-MIF) on the SO₂ photodissociation products. However photodissociation of unshielded UV-light alone cannot reproduce the S-MIF signals reported for the Archean and Early Proterozoic (>2300 Ma) nor its large variability mainly at 2600 Ma (D33S = +11 ‰) (Johnston, 2011). In order to study a planetary-like chemical network capable of accounting for a sulfur cycle in reducing conditions we have introduced a high-order solver (DLSODES) administrated by the KROME (Grassi et al.,) chemistry package. The package automatically generates a set of FORTRAN subroutines with build-in rate equations and solves them with accuracy and efficiency for sparse networks. This technique allows us to couple a detailed 4 sulfur isotopes chemistry to a 1D transport model capable of calculating the opacities influencing photochemistry and the temperature structure of an Archean atmosphere. We present preliminary results showing the ability of the code to deal with small isotopic fractionations and compare with already existing model studies of the Archean atmosphere.

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Keywords: Archean Atmosphere, Sulphur, Stable Isotopes

Effects of atmospheric composition on apparent activation energy of silicate weathering

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Silicate weathering is a major sink of atmospheric CO₂. Because CO₂ is an important greenhouse gas, silicate weathering regulates not only the partial pressure of atmospheric CO₂ (P_{CO_2}) but also the surface temperature (T). The apparent activation energy of silicate weathering represents the temperature dependence of silicate weathering and thus interrelates the intensity of silicate weathering, P_{CO_2} and surface temperature. It has been reported that solution composition can affect the apparent activation energy of dissolution/precipitation of silicates (e.g., Casey and Sposito, 1992; Lasaga, 1995; Cama et al., 1999). However, the relationship between the solution composition and the apparent activation energy of silicate reaction is not yet fully understood.

To investigate the apparent activation energy of silicate weathering in a natural weathering system, we formulated the apparent activation energy of silicate weathering in three different scales, namely, (i) dissolution/precipitation of each mineral, (ii) elemental loss as the net reactions of the minerals and (iii) weathering flux from a weathering profile, based on the rate expressions in the three scales. It was found that, due to the effects of solution composition on the apparent activation energy, the temperature dependence of atmospheric CO₂ ($\Delta H^*_{CO_2}$) affects the apparent activation energy of silicate weathering. Based on the formulated apparent activation energy, we estimated the apparent activation energy of silicate-weathering flux as a function of $\Delta H^*_{CO_2}$. Then, the compensation law between the pre-exponential factor and the apparent activation energy of silicate-weathering flux was introduced from the literature, leading to the establishment of the relationship between silicate-weathering flux (F_{CO_2}), T and $\Delta H^*_{CO_2}$.

Based on the F_{CO_2} - T - $\Delta H^*_{CO_2}$ relationship and the greenhouse effects of atmospheric CO₂ in the literature, we calculated the ratio of change in F_{CO_2} to that in P_{CO_2} as an indicator of silicate-weathering feedback in the Precambrian. The calculation revealed that when $P_{CO_2} > \sim 10^{-0.5}$ atm, the feedback is negative and independent of P_{CO_2} and surface temperature. On the other hand, when $P_{CO_2} < \sim 10^{-0.5}$ atm, the feedback is independent of P_{CO_2} but dependent on surface temperature; at low ($< \sim 30$ °C) and high ($> \sim 30$ °C) temperatures, the feedback is negative and positive, respectively. Due to the positive feedback, the conditions of $P_{CO_2} < \sim 10^{-0.5}$ atm and $T > \sim 30$ °C are unstable, and immediately change, with a slight change in P_{CO_2} , to either the conditions of $P_{CO_2} > \sim 10^{-0.5}$ atm or those of $P_{CO_2} < \sim 10^{-0.5}$ atm and $T < \sim 30$ °C. When $P_{CO_2} < \sim 10^{-0.5}$ atm and $< \sim 30$ °C, the feedback is not only negative, but also becomes more negative as temperature decreases, suggesting that global glaciations are harder to bring about than previously thought.

Keywords: silicate weathering, carbon dioxide, feedback, Precambrian

Kinetics and Mechanisms of Zeolite Crystallization at Hyperalkaline Conditions

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The predicted precipitation of zeolites in geologic barrier systems for radioactive wastes due to the alkaline alteration of bentonite may result in the modification or loss of favorable physicochemical properties of the bentonite as a suitable barrier material. Zeolites formation is typically preceded by an amorphous precursor, the transformation of which is seen as the rate-controlling step. However, the structure of the precursor phase and the rates and mechanisms by which it transforms into crystalline zeolites are poorly understood. In this study, we investigated the rates and mechanisms of zeolite crystallization from solutions.

Batch synthesis experiments were carried out over a range of solution compositions ($\text{Si}/\text{Al} = 0.1$ to 8.0), pH (9.5 to 13.5) and temperature (25C to 90C) conditions in order to clarify the effects of these parameters on zeolite crystallization. Solid products were characterized using XRD, SEM-EDX, FTIR spectroscopy, Raman spectroscopy and MAS NMR spectroscopy.

Zeolite crystallization proceeds by the rapid formation of an amorphous precursor phase, followed by the slower transformation of this precursor into crystalline zeolite. Depending on the Si/Al ratio of the parent solution, the species of zeolite may vary. At $\text{Si}/\text{Al} > 1$, Faujasite forms slowly, whereas for $\text{Si}/\text{Al} < 1$, Zeolite A forms more rapidly. Higher pH and temperatures favor transformation.

Morphological information from SEM shows intimate physical relationship between crystalline zeolites and the amorphous precursor phase. Spectroscopic results from FTIR, Raman and MAS NMR indicate that ring structures are present in both amorphous and crystalline phases, indicating structural similarity between the two phases. These data may suggest that amorphous phases transform directly into crystalline zeolites. The activation energy of crystallization suggests that solid-state processes occur alongside dissolution of the amorphous phase in order for the transformation of the amorphous phase into crystalline zeolite to proceed.

Keywords: zeolite, mechanisms, transformation, spectroscopy

Effects on Phosphate Ion for the Phase Changes of Amorphous Calcium Carbonate

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Under the biometric simulated environment, amorphous calcium carbonate (ACC) appears as initiation phase by reaction of calcium and carbonate ions. There is a strong relationship between the ACC phase and the forming crystalline polymorphs. We have shown a significant inhibit effect on the vaterite formation and calcite crystallized instead, and also stabilize ACC under higher PO₄ concentration conditions. We hypothesized that PO₄ ions incorporated in the ACC in that suspect that the adjusting the transfer mechanism of the amorphous phase. The structure and stability of ACC under various PO₄ concentrations were examined using in situ ultra violet/visible spectroscopy (UV/Vis). Further, in order to observe in detail the coupling state, the ex situ measurement of ACC by Raman spectroscopy and by using a Ca ion electrode were performed to evaluation of the presence time of the ACC phase. The bicarbonate buffer was mixed with supersaturated solution of calcium chloride and sodium bicarbonate solution to precipitate the ACC, under conditions of pH ~8.6. By mixing the potassium hydrogen phosphate at a concentration of any carbonate solution side during mixing, PO₄ ions was adjusted between 0-50 μM concentrations. The ACC contains no PO₄ ions shows a spectrum similar to calcite. However the concentration of PO₄ ions increase, UV / Vis absorption spectrum was carried out changed to spectrum like vaterite gradually. The similar behavior showed in the spectrum observed by Raman spectroscopy. By results of measurements of the molecular weight and particle size of the ACC by scattered light spectroscopy, the increasing both density and particle size of ACC was observed. Ion electrode measurements showed that the residence time of the ACC increased exponentially as increasing PO₄ concentration.

In the presence of PO₄ ion, ACC showed a structure similar to vaterite and its stability was increased. Moreover, the type of forming polymorphs greatly changes in variation of PO₄ ions in μM scale, and stability amorphous structure is also highly variable. The results suggest a need to consider the effects of coexisting PO₄ ions on ACC, when calcium carbonate tissue is formed in the organism.

Keywords: Amorphous, Calcium carbonate, Phosphate, Phase transformation, Biomineralization

Re-evaluation of mineral particles in geothermal fluid: Focus on polysilicic acid and adsorbed particles

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In geothermal system, the solubility of monosilicic acid concentration in geothermal fluid is controlled by physicochemical conditions. Once the supersaturated condition with respect to amorphous silica attained, the polymerization of silicic acid begins followed by the formation of the particles of polysilicic acid. In addition, the particles adsorbed on the solid surface can be a trigger for the further siliceous deposit. Therefore, in order to investigate the formation mechanism of siliceous deposit, the polysilicic acid particles formed by polymerization of silicic acid and the particles adsorbed on the solid surface in geothermal fluid are focused in terms of those size and chemical composition.

In this study, the polymerization mechanism of silicic acid is discussed based on the size variation of polysilicic acid in geothermal fluid as a function of time measured by dynamic light scattering (DLS) in addition to TEM observation of fractionated polysilicic acid. The filtered particles with different pore size and the adsorbed particles on the copper pipe are analyzed by SEM-EDX to characterize the particle size and chemical composition of the particles.

We expect that these results can be basic information for the prevention technology of siliceous deposit formation on the surface of heat exchanger during geothermal binary power generation.

Keywords: polysilicic acid, geothermal fluid, binary power generation, polymerization of silicic acid, mineral particles

Geomicrobiology of Uranium - Challenges for the Deep Geological Environment

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Our understanding of uranium mobility in the environment has been rapidly expanding in the past decades, especially due to problems associated with environmental remediation of uranium-contaminated sites and geological disposal of spent fuels composed mostly of UO_2 . Although neither of these environmental problems was relevant in Japan, Fukushima Daiichi nuclear disaster has dramatically changed our situation. Despite the significant advancement, it is still difficult to predict the form, distribution and fate of uranium in the deep subsurface, as exemplified by studies of a Swedish geological disposal site where high concentrations of uranium was unexpectedly found in the granitic aquifer. In this presentation, the state of the art investigations of microbially mediated redox reactions and uranium mobility in the deep granitic aquifer at Mizunami Underground Research Laboratory (URL) will be presented to discuss factors controlling long-term uranium migration, as well as the relevance to the formation processes of Tono uranium deposit nearby the URL.

Keywords: uranium, microorganisms, redox transformation, underground research laboratory

Haloarcula strains regulate transcription of two types of 16S rRNA genes by growth temperatures

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Translation is the process in which ribosome creates protein. The ribosome consists of two major components, the small and large subunits. In prokaryotes, small subunit of ribosome is composed of 16S rRNA and some ribosomal proteins. Many microbiologist use the 16S rRNA gene sequence for phylogenetic analysis and identification of prokaryotes. Previous studies have reported that the 16S rRNA gene sequence is naturally inscribed with the temperature adaptations of the prokaryotic host. This observation was based on the high correlation between the growth temperatures of prokaryotes and the guanine-plus-cytosine (G+C) contents of the 16S rRNA sequences. Thermophilic and hyperthermophilic prokaryotes generally have high G+C contents of 16S rRNA genes (56-69%). In contrast, mesophilic and psychrophilic prokaryotes have relatively low G+C contents of 16S rRNA genes (51-59%).

Haloarcula strains, belonging to a diverse group of salt-loving organisms in the archaeal phylum Euryarchaeota, have two types of 16S rRNA genes on the genome. These 16S rRNA genes indicate different sequences and G+C contents. Here, we proposed a hypothesis that *Haloarcula* strains preferentially expresses the high G+C contents of 16S rRNA gene (58%), having the stability to heat, during growth in high temperature, whereas they express low G+C contents of 16S rRNA gene (56%) during growth in low temperature. In order to verify this hypothesis, we surveyed transcriptional responses of *Haloarcula* strains in a wide range of temperature conditions by using RT-qPCR method. As the result, high G+C contents of 16S rRNA gene showed significant upregulation in high temperature conditions (40 to 55°C). In contrast, low G+C contents of the 16S rRNA gene expressed at significantly higher levels in low temperature conditions (25 to 35°C). The results suggest that *Haloarcula* strains regulate the transcription of two types of 16S rRNA genes by growth temperatures.

Keywords: halophilic archaea, 16S rRNA, G+C contents, translation, environmental temperature

The effect of methane concentration on methanotrophic bathymodiolid mussels in the Okinawa Trough hydrothermal fields

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As methane (CH₄) is a greenhouse effect gas, the emergence and activity of CH₄-oxidizing organisms is suggested to have triggered global glaciation. Although the threshold concentrations of CH₄ for the growth of CH₄-oxidizing microorganisms under laboratory conditions are well known, CH₄-oxidizing organisms in the field is poorly constrained for the threshold concentration of CH₄ for growth. This information is critical to reconstruct atmospheric and oceanic CH₄ levels when the activities of methanotrophic organisms are indicated from geologic records with ¹²C-enriched organic matter. We investigated sediment-hosted deep-sea hydrothermal fields in the Okinawa Trough where abundantly emitted CH₄ is known to support methanotrophic ecosystem represented by Bathymodiolid mussels. The distribution of Bathymodiolid mussels and the CH₄ concentrations of their habitats were determined in five hydrothermal fields throughout the Okinawa Trough, and it is suggested that approximately 10 μM is a threshold CH₄ concentration for the methanotrophic organism in the deep-sea ecosystem.

Keywords: hydrothermal vent, Bathymodiolus sp., Neoverruca sp., methanotroph, Okinawa Trough

Biogeochemical cycles of iron and carbon in biogenic iron-rich sediment

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Biogenic iron oxides are the mixture of iron oxyhydroxides and organic materials which are produced by the metabolic activities of bacteria. These biogenic iron oxides work not only as adsorbent for various trace elements, but also as a source of iron and carbon for microorganisms. However, there is only little information about the degradation process of biogenic iron oxides and the effect to microbial activities after their sedimentation. Thus, the purpose of our study is to identify the spatial changes of iron species and microbial communities in biogenic iron-rich sediment (10 cm long).

We observed the existence sharp shifts for iron mineral species and microbial communities in the sediment. The dominance of ferrihydrite at the surface sediment (0-2 cm) subsequently turned into goethite and siderite at sediment depth 2-5 cm, corresponding to the iron reduction. However, iron reduction was depleted at depth deeper than 5 cm, as opposed to the remarkable increase of methane concentration. The microbial clone libraries were dominated by iron-oxidizing chemolithoautotrophic bacteria in the sediment 0-2 cm. In contrast, phylotypes represented by iron reducing and fermenting bacteria at 4 cm, and uncultured delta-proteobacteria and methanogenic archaea were recovered at 10 cm depth. These changes of iron mineral species, carbon metabolisms, and microbial communities only within a few centimeter intervals will also couple to the drastic change in cycles of trace element around the biogenic iron-rich sediment.

Keywords: iron oxides, iron-oxidizing bacteria, Ferrihydrite, Siderite, iron-reducing bacteria, methane

Interaction of nanoparticles with microorganisms

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Nano-mineralization by microorganisms is a key process that can constrain the migration of actinides and REEs. This study demonstrates the REEs accumulation experiments to understand the effect of pH, coexistent REEs and the functional group of cells surfaces on the crystal chemistry of biogenic nanoparticle formation. During the experiment at 25 oC, all REEs were removed from the solution by 24 h at pH 4 and 5, while 50 % of the initial amount remained in the solution at pH 3 after 24 h. The nano-particles at pH 3 had monazite structure, while the particles forming at pH 4 and 5 were amorphous. The REE pattern at 24 h indicated the preferential uptake of LREEs. In case transuranic elements coexist, those elements should be preferentially incorporated into the particles compared to REEs. No cytotoxicity of CeNPs was detected; however, CeNPs induced an excess expression of two proteins: Eno2p and Rps24bp. The released organic substances enhanced anion adsorption and changed surface property of CeNPs. This leads to high colloid stability in solutions. This process is of great importance in the migration of radionuclides in the subsurface environment.

Keywords: Nanoparticles, Microorganisms, Rare earth elements

Microbial methanogenesis in coal seams and diatomaceous formations: Topics and application prospects

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1. Introduction

Microbial methanogenesis occurs in diverse subsurface environments. For example, biogenic methane has been detected from all representative ecosystems of the world and has been reviewed¹⁾. However, the process of methanogenesis in those subsurface environments has yet to be revealed. Understanding the methanogenesis process is necessary for discerning the global-scale carbon-cycle and for a more effective utilization of biological methane as an energy resource from subsurface environments.

2. Methanogenic archaea from coal-beds and diatomaceous rock

Research topics on biogenic methanogenesis in the Ishikari (bituminous coal)²⁾ and Tenpoku (brown coal) basin and the diatomaceous formations^{3,4,5)} of northernmost Japan will be introduced in this presentation. We were successful in isolating and culturing methanogens from these habitats. In particular, the dominant methanogens isolated from diatomaceous shale formation^{4,5)} will help in understanding some of the processes of methanogenesis in subsurface environments.

3. Biological methanogenic potential of coal-beds and diatomaceous rock formations as geobioreactors

The bottleneck of methanogenesis in subsurface environments is the production of suitable substrates for methanogens from persistent geomacromolecules. One of our approaches for eliminating the bottleneck is a geobioreactor for methanogenesis using hydrogen peroxide. Oxidation of low-rank coal using hydrogen peroxide produces a high yield of small-molecule substrates for methanogenic microorganisms (e.g., methanol, acetate, formate)⁶⁾. Substrate production from diatomaceous rock is considerably less than that from low-rank coal. However, the stratum thickness of diatomaceous rock (1 km or more) is much more than that of coal seams (several meters). Therefore, although the methanogenic potential of diatomaceous rock is low, by quantity, it constitutes an abundant resource. Furthermore, we have had success in microbial methanogenesis from small molecules produced from brown coal using hydrogen peroxide.

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Keywords: Methane, Coal, diatomaceous rock, subsurface microorganisms, methanogenesis, Geo-bioreactor

Transportation process of As in surface and shallow ground waters

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Natural As contaminated groundwater has been a serious problem in the world. Instead of numerous studies, sources and pollution mechanism are still in debate. Most accepted source of As is Fe-oxyhydroxides that adsorb the As, and reduction-dissolution of the Fe-oxyhydroxides is believed to release the As into groundwater. Biotite and pyrite would be candidate sources of As, however, few studies assured the presence of As in those minerals. Here, transportation process of the As in surface water and As release mechanism in shallow sediments.

Arsenic is transported as dissolved components and suspended matters. Total As concentration of Red River water is ~10 ppb, and dissolved As and As with suspended particles are 6:4. Although the Red River water contained gibbsite and goethite as suspended matters, those do not but clay minerals host the As as adsorbent. Concentrations of As of the riverbed sediments of Ganges-Bramaptra and Red Rivers are a few to 15 ppm, most of which are in insoluble detrital phases such as silicates and sulfides. Chlorite was the host phase of As in As contaminated groundwater aquifer in our study areas of Bangladesh and Pakistan, although different detrital minerals can host As in each rivers, of which tributaries As contaminated groundwater occurs. These results suggest that the transportation of As with detrital minerals is more important than that as dissolved components and adsorbed phases onto clay minerals and goethite.

In the shallow sediments, As concentration changes with redox potential and pH. Geochemical condition would be controlled by microbial activity in the aquifer. Dissolution of As occurs at the depths where detrital As host minerals are decomposed via oxidation. Newly formed Fe-oxyhydroxides would adsorb parts of the As but not all. Thus, the dissolution of As host minerals are the main reaction to cause As contaminated groundwater.

Keywords: arsenic contaminated groundwater, microbial geochemical reactio, chlorite, goethite, gibbsite

Adsorption behavior of organoarsenic compounds in soils

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The arsenic pollution is a world problem. Natural originated inorganic arsenic compounds are predominant cause of the water-related disease. In addition, anthropogenic originated organoarsenic compounds such as phenylarsonic acid (PAA) and diphenylarsinic acid (DPAA) are also pollution source. For example, DPAA polluted well water caused serious health problems in Kamisu, Japan [1]. These phenyl arsenic compounds are considered as a decomposition product of chemical warfare agents produced during World Wars I and II, and even now such compounds still remain in the ground [2]. Recently, adsorption and mobility of these aromatic arsenic compounds in agricultural soils have been investigated [3]. However, their adsorption mechanisms on soil are still unknown. In general, the adsorption property of chemical compounds influences its migration process in natural environments such as soil-water system. Thus, it is important to understand the adsorption mechanism of the arsenic compounds to predict future fate of them in environment. Recently, we reported adsorption structures of PAA and DPAA on ferrihydrite obtained by X-ray absorption fine structure (XAFS) analysis and quantum chemical calculations [4]. In this study, we conducted As K-edge XAFS measurements for organoarsenic compounds adsorbed on soil, as well as a sequential extraction, to understand their adsorption behavior in the soil. EXAFS analysis suggests that all arsenic compounds in this study adsorbed on Fe or Al (oxyhydr)oxide in the soil mainly regardless of the organic functional groups. This fact indicates that the Fe/Al (oxyhydr)oxide can control the mobility of organoarsenic compounds in the ground.

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Keywords: soil, adsorption, XAFS, organoarsenic

Impact-induced products from glycine polymers in early Earth's oceans

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Early oceans may have contained appreciable amounts of prebiotic organic molecules, since previous studies have indicated that simple organic molecules are capable to be formed through oceanic impact processes by meteorites. Geologic evidence suggests that the root for the origin of life materials occurred just after or during the heavy bombardment period. At that time the impact energy is considered to have been important for molecules present in oceans to react. Shock reactions of organic molecules in aqueous solutions have been subject to few studies.

Here we investigate the reactions for glycine polymers (dimer G2, trimer G3, and tetramer G4) and alanilglycine (AG) in aqueous solutions in order to know their stability and reaction products during impacts. The starting G2 (>99.0% Tokyo Chemical Industry Co. Ltd), G3 (>98.0%, Tokyo Chemical Industry Co. Ltd), G4 (>95%, Tokyo Chemical Industry Co. Ltd), and AG (>98.0%, Tokyo Chemical Industry Co. Ltd) were used in the present study. Hypervelocity plane impact experiments were carried out using a propellant gun. Sample solutions of glycine polymers in sealed steel containers were subjected to impact at velocities of about 1 km/s. The calculated shock pressures are 5-6 GPa by the impedance match solution. The recovered solutions were analyzed with a hybrid Fourier transform mass spectrometer (Thermo Fisher Scientific LTQ Orbitrap XL) at Hiroshima University.

The analytical results for the recovered samples were compared with those for the initial sample. Limited numbers of amino acids of Glycine, alanine, and their polymers, amines from propylamine to octylamine, and carboxylic acids from acetic acid to decanoic acid were selected due to a measured range of their m/z values. The identification of a molecule was done by the presence of a peak with the calculated m/z value (± 0.002). The results are discussed.

Keywords: Glycine polymers in early Earth's oceans, Impact-induced products

Effect of mineral species on the glycine polymerization

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Protein is a major constituent of life on the earth, and is produced by polymerization due to dehydration condensation of amino acids. Polymerization of amino acids is an important process for the origin of life. The understanding of amino acid polymerization process in the earth surface environment is important for the origin of life. It is well known that polymerization of amino acids under the ambient condition is thermodynamically difficult. Therefore, how the amino acids polymerization in the early earth environment proceeded is still under debates.

Many model experiments for amino acid polymerization had been designed so far. Among them, one of the promising method is mixing the mineral powder with glycine solution with heating (e.g., Bujdak and Rode, 1997a). Bujdak and Rode, (1997b) was confirmed that alumina could promote alanine polymerization than Quartz. They suggested that the effect of mineral type is important on the polymerization of amino acids. However, it is not known which functions of the mineral affect the amino acid polymerization. After Bujdak and Rode, (1997b), amino acid polymerization experiments by using various type of mineral species has been widely examined. However, the experiment condition has not been unified among the studies. We cannot compare the effect of amino acid polymerization on each mineral. In present study, we conducted the experiments of amino acid polymerization using t various types of minerals (Rutile, Anatase, Amorphous silica, Quartz, gamma-Al₂O₃, Corundum, Hematite, Magnetite, Forsterite) under the unified experimental conditions. The purpose of the study is to clarify the factors for promoting the amino acid polymerization in mineral species.

Keywords: amino acid, polymerization, mineral

Role of minerals for hydrogen generation in the interaction between ultramafic rocks and water

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Hydrogen generation by high temperature serpentinization is understood as hydration of mafic and ultramafic rocks, owing to the oxidation of reduced iron present in the olivine or pyroxene. On the other hand, in the Oman Ophiolite and Lost City Hydrothermal Field (LCHF) in the Mid-Atlantic Ridge, hydrogen is generated via low temperature serpentinization. Moreover, previous experimental study shown generating hydrogen at low temperatures (<100 degrees C). However, since even the rate of hydrogen generation by high temperature serpentinization is slow, the mechanism of hydrogen generation by low temperature in short period is yet to be explained. Therefore, the objective of this study is to clarify the mechanism of hydrogen generation via low temperature serpentinization for a short period. Batch experiments were conducted at 30 degrees C, 60 degrees C and 90 degrees C using minerals which constitute ultramafic rocks (olivine, Magnetite, Fe-Ni alloy), and serpentinite. Samples were taken after various reaction times (3h, 6h, 12h, 24h, and 1week). Liquid samples were analyzed by ICP-AES, ion chromatography, UV-Vis, pH, and ORP. Mineral phase changes in the solid samples were characterized by TG-DTA, SEM-EDX and XRD. The concentration of hydrogen gas was determined by GC-RGD.

Hydrogen generation was observed in all samples. Highest concentration of hydrogen gas was observed in the experiment using Fe-Ni alloy. In the experiment using Fe-Ni alloy, apparent surface change was not observed at the surface of Fe-Ni alloy. Therefore, hydrogen gas was generated by catalysis of Fe-Ni. The generation of hydrogen gas by this catalysis would be higher than that of generated hydrogen accomplished by the dissolution of olivine, which is the dominant mineral in the ultramafic rocks.

In this study, the hydrogen generation was confirmed at a temperature of less than 90 degrees C. The hydrogen generation process is catalyzed by Fe-Ni alloys or magnetite present in secondary minerals by serpentinization.

Spatial distribution of chromium enrichment in 3.2 Ga Moodies BIF, Barberton Greenstone Belt, South Africa

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Geochemical data for ferruginous chemical sedimentary rocks (e.g., Banded Iron Formation: BIF) have been used to understand surface environments on early Earth. For example, enrichment of Cr relative to Ti in BIFs that occurred ~2.48 billion years ago has been considered as a result of the chemical mobilization of Cr in acidic aqueous environments due to sulfide oxidation after the oxygenation of atmosphere. While the Archean sedimentary environments studied in most previous works are limited to deeper settings, the 3.2 Ga Moodies BIF in the Barberton Greenstone Belt, South Africa also indicated that Cr was enriched in the BIF and was therefore chemically mobile in a shallow marine environments. This finding could be significant because it may indicate the oxidation of, at least, some parts of the ocean and therefore, imply the emergence of oxygenic photosynthesis. However, spatial distribution of Cr enrichment in the BIF has not been well understood because the data were obtained from an outcrop and an underground mine. Therefore, the objective of this study is to investigate sedimentary environments and Cr enrichment of the Moodies BIF at another locality.

We conducted a geological survey of another outcrop of the Moodies BIF in the Eureka syncline located ~10 km northeast of Barberton. The section of the BIF exposed in the outcrop was underlain by a conglomeratic quartzite, which is stratigraphically correlated with the BIF at Moodies Hills block in the previous study. Whereas the BIF at Moodies Hills block are 22m in the thickness and overlain by 122m thick silty sandstone and sandstone, the BIF in this study has a thickness of 36m and is overlain by a 103m thick layer of greywacke and silty sandstone. Petrographic observation of the BIF samples shows that the reddish layers are composed of microcrystalline quartz and fine grains of hematite (~15 μ m), and that the black layers are composed of large grains of magnetite (~50 μ m). These observations indicate that they are typical oxide-type BIF and therefore were originally formed as precipitates from seawater. Although chromite, which is a host mineral for Cr, was found in both BIF and clastic sedimentary rock (e.g., silty sandstone) samples, chromite in the BIF was always overgrown by magnetite. This observation is also consistent with results from previous studies. The chemical compositions of the chromite determined by FE-EPMA were low Mg# (0.001~0.01) and high Cr# (0.76~0.89). No significant difference in chemistry was observed in chromite between BIF and clastic sedimentary rock samples. Bulk chemical compositions of the samples were also analyzed by XRF. The results show that the Cr/Ti ratio was not significantly different between BIF and clastic sedimentary rock samples. Therefore, Cr enrichment was not observed in the BIF in this study. The apparent contradiction to the previous study at Moodies Hills block can be explained by the difference in (1) analytical method used or (2) the sedimentary environment. The Ti contents of BIF at Moodies Hills block were determined by ICP-MS after acid decomposition, by which the detection limit is one order of magnitude lower than XRF used in this study. Therefore, the high detection limit in this study may lose the sensitivity for Cr enrichment in samples in which Ti content was low. Alternatively, the BIF in this study could have been deposited in a deeper setting than that at the Moodies Hills block. Therefore, the results may suggest that oxygenated seawater was only localized in very shallow parts.

Keywords: Banded Iron Formation, chromium, chromite, Barberton Greenstone Belt, surface environments on early Earth

Change by a diagenesis of first minerals in 1.9 Ga sedimentary rocks of the Gunflint Formation

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Some microfossils in the 1.9 Ga Gunflint Formation show clear morphology of aerobic microorganisms. However, carbon isotope compositions of microfossils and other geochemical characteristics suggest the activity of anaerobic microorganisms in the same rock sample. This leads to the skepticism if the 1.9 Ga surface ocean environments were essentially anoxic and oxic environments were very limited.

In order to examine if oxic world were more common or anoxic world were more common, shallow water sedimentary rocks were collected from Kakabeka (the bottom of the Gunflint) and Telly Fox (the top of the Gunflint) areas. The following features were found in the present study. (1) Chemistry of carbonate change into either Fe-rich or Mg-rich from calcite during diagenesis. Fe-rich feature is only found at the bottom of the Gunflint Formation, suggesting wide injection of reduced fluids in sediments. (2) Carbon isotope compositions were similar to cyanobacteria value, and feature of anaerobic bacteria were not detected. This suggests that previous report of carbon isotope compositions of anaerobic bacteria was limited in a few places and not widespread in the Gunflint Formation. Therefore, aerobic microorganism was the major life forms. (3) Sulfur isotope compositions of pyrite range from -2 to +15 per mil, suggesting closed system sulfate reduction. The closed system was most likely isolated oxic seawater from anoxic sediments, probably high sedimentation of SiO₂ and CaCO₃. In addition, isolated sediments were anaerobic bacterial world, where organic matter from the oxic world was largely consumed.

Keywords: diagenesis, oxic, anoxic, closed system

Origin of phosphate stromatolite formed after the snowball Earth

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The sedimentary rocks formed after Neoproterozoic snowball Earth distribute near Irece, Bahia, Brazil. Salitre Formation is one of them, and contains unique phosphate (apatite) stromatolites. They show dense columnar shape, and are surrounded by laminated dolomite. The relationship between stromatolite and dolomite is mostly sharply bounded, although some parts appear transitional. Stromatolite contains various shape of microfossils. Filamentous microfossil (5-10 μm diameter, about 300 μm long) is most abundant and resembles to filamentous cyanobacteria, and thus, photosynthetic microorganisms such as cyanobacteria are considered to be involved in the formation of stromatolite.

In order to understand the influence of microbial photosynthesis on apatite precipitation, saturation state of apatite after removing 200 μM of CO_2 from seawater was calculated by Phreeqc. The result indicated that photosynthesis can significantly increase saturation state of apatite, when the concentration of dissolved phosphate is at least 1 μM . Although the saturation state of CaCO_3 is also increased by photosynthesis, its degree is much smaller than that of apatite. As a result, apatite is more likely to precipitate than carbonate, and phosphate stromatolite is formed.

The concentration of dissolved phosphate is extremely low at the surface ocean due to the uptake by phytoplankton, and its concentration is as high as several μM even at the deep ocean. At the time of post-snowball Earth, similar situation is expected for the surface ocean, while the concentration of phosphate in the deep ocean is considered to be much higher than today. If occasional upwelling transported such water mass to the shallow sedimentary basin where cyanobacterial mat is developed, phosphate stromatolite will be formed even if dissolved phosphate concentration is several μM .

Large Fe isotope fractionations in ferruginous sedimentary rocks above Kuroko deposits in the Hokuroku district

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The Hokuroku district in Akita Prefecture, Japan, hosts many large volcanogenic massive sulfide (VMS) deposits called Kuroko deposits formed around 15.3 million years ago by ancient submarine hydrothermal activity. VMS deposits were formed by the precipitation of metals from hydrothermal fluids and could have contacted with seawater in geological timescales. Because they are composed of sulfide minerals that are stable in a reducing environment, such as pyrite and chalcopyrite, an anoxic environment in the Hokuroku basin may play an important role in the preservation of the sulfide ores containing valuable metals in Kuroko deposits. However, geochemical evidence of such an environment occurring in Hokuroku district is currently lacking. Therefore, objective of this study is to investigate the distribution of REEs and the variation of Fe isotope compositions in the Fe-Mn-rich sedimentary rocks associated with VMS deposits in the Hokuroku district to understand the depositional environments and ancient sea-floor hydrothermal systems in the Hokuroku basin. Sedimentary rock samples obtained from both outcrops and mines in the Hokuroku district include ferruginous cherts occurring directly on or above a Kuroko deposit, manganese-rich siliceous mudstone, and amber in mudstone or tuff. Samples were analyzed by XRD, petrography, and SEM-EDS for mineralogy, by XRF and LA-ICPMS for chemical composition and MC-ICPMS for iron isotope composition ($\delta^{56}\text{Fe}$ (‰) = $1000 * [(^{56}\text{Fe}/^{54}\text{Fe})_{\text{sample}} / (^{56}\text{Fe}/^{54}\text{Fe})_{\text{IRMM-14}} - 1]$).

The results of these analyses show the $\delta^{56}\text{Fe}$ values of mine samples occurring directly on and above Kuroko deposits were -1.5 to 0.5 ‰. These values are largely fractionated from $\delta^{56}\text{Fe}$ value that is similar with igneous rock's $\delta^{56}\text{Fe}$. Iron isotopic fractionation occurs when ferrioxide precipitate part of the bivalent iron present in the reservoir. These values are largely fractionated from the $\delta^{56}\text{Fe}$ value of the standard (i.e., 0 ‰), which is similar to that of igneous rocks. The samples that have a large negative value also bears negative Ce anomaly. These signatures indicate that partial oxidation of dissolved ferrous iron occurred by mixing ferrous iron-bearing anoxic water with oxygen-bearing seawater, and therefore that the sea-floor of the Hokuroku Basin was anoxic. On the other hand, $\delta^{56}\text{Fe}$ values of chemical sedimentary rocks formed during 2 -3 Ma after Kuroko deposits formed ranges from -0.8 to -0.3 ‰. These values are similar to that of dissolved ferrous ion in a modern sea-floor hydrothermal fluid. Therefore, the $\delta^{56}\text{Fe}$ values of the samples indicate near complete oxidation of dissolved ferrous iron in an oxic environment. Therefore, the results of this Fe isotope study suggest that the depositional environment in the Hokuroku basin shifted from anoxic to oxic after the formation of Kuroko deposit.

Keywords: iron isotope, rare earth pattern, anoxic environment, Volcanogenic massive sulfide, hydrothermal system

SEM and TEM observations of carbonate, Fe-oxide and silica minerals in Okuoku-hachikuro hot spring, Akita Prefecture

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Recent studies of biomineralization mainly treated biominerals produced by evolved life. It is uncertain if primordial microbes are capable to precipitate biominerals. If biomineralization by early life is well documented, it will help to understand the Precambrian environments more in details.

Abundant carbonates are precipitating at Okuoku-hachikuro hot spring, located in Kosaka, Akita Prefecture, Japan. We collected sinters, soft to solidified sediments and microbial mats. Then, those constituents were observed using field emission-scanning electron microscopy (FE-SEM). Minerals around microbial sheath were also observed by transmitted electron microscopy (TEM). Analyses of X-ray diffraction, pH, DO, dissolved amino acids, carbon isotope compositions and chlorophyll compositions were also performed.

Hot spring water does not contain appreciable amounts of dissolved oxygen, but Fe-oxides immediately precipitated after discharge. Chlorophyll analyses indicate no presence of anoxygenic photosynthesizing bacteria. These results suggest that Fe were precipitated by Fe-oxidizing bacteria dominantly, supported by SEM observation of characteristic morphology of the sheath. Cyanobacteria become more dominant in the distance.

Most samples contain radial aggregates of needle-shape aragonite. Such morphology was found in bubble in the "first" discharging fluid. Each needle in radial aggregates seems to be bigger depending on a distance from the discharging point. Aggregates of coarser and random orientated needles of aragonite are found in lower stream zone, where evaporation and cooling of hot spring water are more visible. Because of no systematic correlation to biological activities (microbial mat, amino acid, organic carbon, etc.) to those morphological changes, all aragonites are formed inorganically. On the other hand, Fe-oxide covering sheath are found locally. Using dilute hydrochloric acid etching, Fe-oxide is observed clearly, especially in zone 1. It has 3 morphological types: sheath-like, agglomerated and needle in radial aggregates. It is noteworthy that Fe-oxides never grow in large crystals. This can possibly because microbial activities or organic molecules may prohibit the growth of Fe-oxides. Furthermore Si was detected in Fe-oxide. This result suggests that Fe-oxide probably adsorbs amorphous silica selectively. Such unique morphology may help to interpret the origin of hematite in Precambrian banded iron formations.

Keywords: aragonite, Fe-oxide, Fe-oxidizing bacteria, SEM, TEM

Microbial processes forming lamination in hot spring stromatolites by sulfur oxidizing bacteria and cyanobacteria.

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Travertines are carbonate precipitates from hot-spring water containing a sufficient amount of calcium and carbon dioxide. Most of travertines show sub-mm order laminations that were resemble to ancient stromatolites. Recently, daily microbial processes were identified in some travertines precipitated from some sulfide-poor and moderate temperature (<55 degree C) springs. In the process, daily growth of biofilms consisting cyanobacteria or heterotrophic bacteria, which inhibited inorganic mineral precipitation (1,2). While, lamination is less common in the travertines at higher temperature (>60 degree C) and sulfide-rich springs (3) likely because such daily microbe-mineral interaction might not be occurred. In order to understand the geomicrobiological system in high temperature and sulfide-rich spring, this study investigates a travertine in Sipoholon, Northern Sumatra, Indonesia.

Sipoholon hot spring forms the hugest travertine mound among the hot springs in Tarutung area located about 30 km south from the Lake Toba. The travertine mound spread in total area of 50,000 km². The actively precipitated region was separated 3 areas; A is natural mound without artificial effect, B is the mounds in a quarry, C is exposes the rim pools behind spa facilities. In all area, sulfur-rich yellow sediments were formed near the vents, while white laminated sediment was formed from midstream to downstream. The surface color of the laminated travertine was changed with water temperature; pale pink around 55 degree C and green below 50 degree C. Lamination in the green travertine consisted of light colored crystalline layer and dark colored biofilm-rich porous layer in the interval of 0.5-1.0 mm. While, some lamination in the pink travertine was not clear.

12 sequences of water and travertine samples were collected at a green travertine and a pink travertine in Area C every 4 hours during 48 hours. Samples of both types of the travertine showed that the dark layer was formed during daytime and light colored layer was formed during nighttime without variation in pH, water temperature, Ca ion concentration, alkalinity, and flow. Only dissolved oxygen concentration showed the daily variation in the water chemistry, which was higher during the daytime and lower during the nighttime. Phylogenetic analysis on 16S rRNA gene showed that the pink and green travertines have a microbial composition dominated by obligatory chemolithoautotrophic sulfur-oxidizing bacteria. Phototrophs, cyanobacteria and chloroflexus were more diverse in the green travertine than in the pink one. Epifluorescence microscopy showed that phototrophs were concentrated in the diurnal dark layer in the green travertine, while sparsely distributed near the surface in the pink travertine.

These results suggest that formation of phototroph biofilm in daily cycle was responsible for lamina formation in the green travertine same as previous study. On the other hand, formation of sulfur-oxidizer biofilm stimulated daytime increment of oxygen concentration was likely responsible for lamina formation in the pink travertine. The obscure lamination in the pink travertine possibly due to growth of chemolithoautotrophs stimulated by extrinsic factor that is daily supplement of oxygen, in contrast to intrinsic daily growth of phototrophs. This novel microbial process could be occurred in ancient stromatolites formed under the anoxic sulfide-rich ancient ocean.

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Keywords: travertine, lamination, stromatolite, cyanobacteria, sulfur-oxidizing bacteria

Influences of silica and embedding on thermal alteration of aliphatic hydrocarbons in cyanobacteria as evaluated by FTIR

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To study influences of the presence of silica and embedding on thermal changes of aliphatic hydrocarbons in prokaryotic cells, cyanobacteria *Synechocystis* sp. PCC6803 were isothermally heated at 250-400 °C and the changes in IR signals were monitored by micro-Fourier transform infrared (FTIR) spectroscopy. The absorbance of aliphatic C-H decreased with heating time, indicating the degradation of aliphatic hydrocarbons. Both the presence of silica and embedding delayed the degradation of the aliphatic C-H. The absorbance ratios of 2960 cm⁻¹ band (aliphatic CH₃) to 2925 cm⁻¹ band (aliphatic CH₂) (R_{3/2} values) increased or changed little by the heating. Raman spectral features showed that some experimental products had a structural ordering similar to the Proterozoic microfossils, indicating that they were carbonized to a degree similar to the microfossils. These results reveal that the presence of silica and embedding affect the thermal degradation rate of aliphatic C-H in cyanobacteria but do not lead to the decrease in R_{3/2} values. The low R_{3/2} values of Proterozoic prokaryotic fossils from Bitter Springs and Gunflint Formations are not considered to be due to thermal degradation upon fossilization during diagenesis. Although other possibility cannot be ruled out, the results suggest that precursor lipids, having low R_{3/2} values, were selectively preserved in microfossils.

Keywords: micro-FTIR, cyanobacteria, silica, thermal alteration, aliphatic hydrocarbon

Role(s) of extracellular polymeric substance in microbial mineralization

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Microbialites are defined as organosedimentary deposits that have accreted as a result of benthic microbial community binding detrital sediment or forming the locus of mineral precipitation. Most of microbialites are consisted of carbonate minerals, and considered to be formed by microorganism, such as cyanobacteria and sulfate reducing bacteria. Microbialite records the history of interaction between life and Earth environment, and therefore, it is important to understand their formation. Microbialites are formed mainly by three processes, including grain-trapping, mineral precipitation by metabolism and mineral nucleation by extracellular polymeric substances (EPS). Grain-trapping is locally important, but key processes are precipitation and nucleation. The knowledge of precipitation process by bacterial metabolism has increased, while that of EPS is still limited. Therefore, this study aims to investigate the influences of EPS on microbialite formation. We examined carbonate deposit developed at Kibedani hot spring, Shimane Prefecture. Calcite was despite of undersaturation in bulk water. Microelectrode measurement revealed that this deposit is formed as a result of photosynthesis-induced CaCO_3 precipitation. The result of EPS staining observation by Confocal Laser Scanning Microscope revealed that this deposit contains abundant acidic EPS, which is generally considered to have important roles in mineral nucleation. This deposit composed of two layers: the upper layer is consisted of empty EPS sheaths and the lower layer is of cyanobacteria with EPS sheaths. Both layers contain acidic EPS, while only lower layer was mineralized. This observation implies that acidic EPS cannot solely cause nucleation, and requires high mineral saturation state induced e.g. by photosynthesis.

Controlling factors of microbialite textures inferred by a tufa deposit

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Microbialite is organosedimentary deposits that are formed by the interaction between life, water and mineral. It has accreted as a result of a benthic microbial community trapping and binding detrital sediment and/or forming the locus of mineral precipitation. Typical examples of microbialite are laminated stromatolite, and clotted thrombolite. In the Earth history, stromatolite appeared from about 3500 Ma, followed by its peak at 1300 Ma. At about 500 Ma, stromatolite rapidly declined, and thrombolite appeared. Although this transition is considered to reflect evolution of life and Earth environment, its detail is still not well understood. To understand the basic mechanisms forming microbialites, the geomicrobiological studies of recent samples are essential. While microbialite in modern marine environment is scarce, it is relatively common at freshwater environment as a tufa. The present study focuses on tufa for investigating the relationship between depositional structure and microbial composition. Tufa deposit usually has laminated structure resembling stromatolite. However, tufa deposit developed in Takahashi city (Okayama prefecture) exhibits both stromatolitic and thrombolitic structures by reflecting the difference of hydrodynamic condition. The chemical compositions of creek water at the sites where stromatolitic and thrombolitic tufa are depositing are almost the same, and similar to that of common tufa-depositing creek. Extracellular polymeric substances (EPS) staining observation applied for deposits surface by Conforcal Laser Scanning Microscope (CLSM) showed that the distribution patterns of phototrophs and EPS were different between stromatolitic and thrombolitic tufa. At the surface of thrombolitic tufa, coccoid cyanobacteria densely colonized to form small mounds (500 μm in diameter) and EPS located inner and marginal part of the mounds. On the other hand, at the surface of stromatolitic tufa, filamentous cyanobacteria distributed sparsely with EPS, and calcite was widely exposed. Vertical thin section observation revealed that there were large calcite crystals (500 μm in diameter) at the surface of thrombolitic tufa, and filamentous one colonized around them. Stromatolitic tufa, on the other hand, was consisted of fine grained calcite (10 μm in diameter) with filamentous cyanobacteria colonized perpendicular to the lamination. Microbial composition of both deposits was examined by 16S rRNA gene analysis. The result indicated that cyanobacteria were abundant and some strains were common between thrombolitic and stromatolitic tufa. However, the diversity of microbial population microbial population was higher in thrombolitic tufa than stromatolitic ones.

From the results above, it is inferred that the transition from stromatolite to thrombolite in \sim 500 Ma was caused by microbial diversification and resultant EPS composition change.

Keywords: microbialite, stromatolite, thrombolite, tufa, carbonate rock

Soil micromorphology and the effect of biotic activity

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Soil is formed on a boundary between geosphere and biosphere in relation with hydrosphere and atmosphere. The major component is quite very fine-grained particles which are not still unknown in detail. A great variety of microbes are associated in soil (e.g., Hattori, 1987). Hattori (2006) suggests that there is a possibility some bacteria produce very fine-grained mineral particles, silica-nano particle as a part of soil material. Micromorphology is observed under petrological microscope. The technique for preparation to make thin section from unconsolidated soil is followed by method in FitzPatrick (1993). Soil fragments are examined by scanning electron microscope. Samples are collected from recent cultivated soil (Okayama University Farm), fluvial soil (Sendai City), rice field soil (150 to 2000 years old fluvial soil from Okayama University), paleosol (about 3000 years old organic rich fluvial soil from Dhaka City, Bangladesh).

The formation of microaggregates: The structure of soil macroaggregate (1~2mm) which is composed of microaggregates (0.05~0.3mm) and sand grains of mineral and rock fragments is observed in the recent cultivated soil from Okayama University Farm. Similar microaggregates (0.1~0.5mm), structure with heterogeneous granular domains is observed in rice field soil from Okayama University. A paleosol from Dhaka, which is not considered to have artificial effects, also consists of microaggregate. The aggregates do not have distinctive boundary but are distinguished by different compositions (content of organic materials, deposited ferri-hydrate and manganese dioxide, particles of mineral and rock fragment). Root pipes and cracks are associated in the soil. The compound structure is interpreted to be formed under effects of microorganisms, root and physical process as demonstrated by previous soil research (e.g., FitzPatrick, 1993).

The formation of silica-nano particle: Under scanning electron microscope, surface of mineral grain has structures caused by weathering, for example embayment, fracture and etch pit. Crystallized nano-sized minerals are formed on weathered surface of a mineral. A bacterial cell surrounded by radiate fibrous mineral is found. The feature indicates a possibility that some bacteria promote to form minerals. And also there is a possibility that a part of inorganic soil materials might be formed relation with organism.

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Keywords: soil, microaggregate, silica-nano particle, bacteria

A novel remediation method for nickel-bearing wastewater at neutral conditions

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Advances in technology such as the electronics and metal plating industries have increased the demand of Ni year by year. On the other hand, the resources are unevenly distributed in a few countries and the supply is highly dependent on strategic policies. Moreover, since Ni is not produced in Japan and it is dependent on imports from foreign countries, the supply structures of Ni are vulnerable. Because of this, the necessity of recovering Ni from wastewaters and other waste forms has been increasing. Some industrial wastewaters contain large amounts of Ni. Generally, the removal of Ni from contaminated wastewater by adding antalkaline and flocculants to increase the pH to 10 or above would result in the generation of Ni-hydroxides after treatment. After that, it is necessary to adjust the pH below the effluent standard (pH 5.8~8.6). However, this method suffers from some disadvantages, such as the high cost for chemical reagents, problems in the disposal of alkali sludge and inefficient treatment system. Therefore, a more sustainable remediation method must be developed to achieve sustainable wastewater treatment operations. This study focused on natural attenuation processes which are safer, cost-effective and more environmentally friendly than traditional methods. For example, at Dougamaru abandoned mine in Japan, high concentrations of Cu and Zn in wastewater are naturally incorporated in the structure of layered double hydroxides (LDH), which forms in the presence of Al ions, hence, natural attenuation of Cu and Zn occurs (Okamoto et al., 2010). Because LDH has the hydroxide structure, six-coordinated heavy metals such as Cu, Ni and Co can be incorporated into the structure during the formation process. Therefore the objective of this study is to develop a remediation method for Ni-bearing wastewaters at neutral conditions, and to clarify the behavior of Ni in the neutralization and precipitation process.

In this context, to check the applicability of LDH in the treatment of Ni-bearing wastewaters, synthesis experiments were carried out by co-precipitation of Ni-bearing LDHs containing SO_4^{2-} as the interlayer anion with different concentrations of dissolved Al ions. Analysis of water chemistry before and after the co-precipitation show that the removal efficiencies of Ni from the synthetic wastewaters increased with increasing dissolved Al concentration. The results further show that the presence of Al in the formation of LDH removed Ni at pH values lower than previous methods which precipitated Ni-hydroxides. It is expected that treatment costs will be reduced in actual wastewater treatment systems because Al addition leads to the reduction of antalkaline use and the neutralization process.

Ni adsorption experiments and extraction experiments were conducted to investigate the sorption behavior of Ni. Only a small amount of Ni was adsorbed to LDH and basaluminite (major minerals in coprecipitation experiments) as inner- and outer-sphere complexes. From the result of XAFS analysis, Ni was incorporated into the structure by being able to precipitate LDH selectively. This shows Ni is fixed securely in the structure of LDH and that the mobility of Ni will be governed by the solubility of LDH. Thermodynamic modeling suggests that the precipitation of LDHs with the optimum Al/Ni molar ratio (0.25~0.50) is determined by the initial conditions (e.g. pH, Al, Ni concentrations). Furthermore, modeling results reproduce the experimental results such as removal efficiency and mineral species well, opening the possibility of its application in actual wastewater treatment operations.

Keywords: Remediation, Layered double hydroxide, Nickel

Changes in water properties and microbial facies along a flow path of a travertine developed in northern Sumatra Island,

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Sumatra Island has many hot springs related with volcanoes belonged to the Ring of fire. Geothermal studies for these hot springs have been performed actively, but hot spring sediments including travertines have rarely been reported. Travertine is a useful modern analog for the Precambrian stromatolites (Takashima and Kano, 2008; Okumura et al., 2013).

We studied travertines at Sipoholon hot spring located about 30 km south from the Lake Toba which is the largest caldera lake in the world. The travertines spread in total area of 50,000 km², in which active deposition occurs mainly in three separated sites; Area A, B and C from north to south, respectively. This study focused on Area A that lacks artificial effect.

In this study, we measured chemical components and stable isotopes of water and observed textures and bacteria of the travertine. Based on these results, we cleared that relationship between water properties, travertine textures and distribution of bacteria.

The travertine deposit occurs along ~35-m-long flow path. The water from the vent first flows 15 m on a narrow (50 cm) and gentle passage and then widely on a steep slope on the travertine dome. Below the dome, the water passes on terrace-like rim pools and finally flows into a pool about 5 m in diameter.

The water with sulfurous smell emits from a vent at a rate of 286 L/min. This water is high temperature (61.4 degree Celsius), neutral pH (6.48) and microaerobic (DO of 0.6 mg/L). The water is rich in Ca²⁺ and SO₄²⁻, and poor in Mg²⁺ and Cl⁻. To the downstream, the water temperature decreases, pH increase, and conversely alkalinity and Ca²⁺ concentration decrease. These and increased carbon isotope of dissolved inorganic carbon indicate that CO₂ degassing increased supersaturation and induced deposition of calcium.

The travertine in Sipoholon hot spring is mainly composed of aragonite, but in one place, calcite coexists. It tends to become softer from the upstream to the downstream. This may reflect difference in crystal shape and texture. The harder travertines consist of tightly packed spherical aggregates of aragonite needles, while softer travertines have loose textures containing dumbbell-shape crystals.

Microbial facies on the travertine surface changes obviously from the upstream to the downstream. A white sulfur-turf in upper stream is composed of sulfur oxidizing bacteria with sulfur particles (Maki et al., 2004). It is known that the sulfur-turf prefers in high temperature, neutral pH and rich in hydrogen sulfide, which corresponds the conditions of the upstream. On high flow parts of the travertine dome, the travertine colored in pale pink likely due to the occurrence of purple sulfur bacteria. Green microbial mat covers the travertine deposited in in lower part with low flow rate. The mat is composed of filamentous bacteria with photosynthesis pigment identified in fluorescence observation. These are cyanobacteria. Water temperatures on the mat are all below 45 degree Celsius. Thus, color change of travertine surface reflect that of microbial composition responded to water properties, such as water temperature, flow rate, flow volume, nutrient.

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Keywords: travertine, aragonite, sulfur oxidizing bacteria, cyanobacteria

A study of irregular shaped tests formation of planktonic foraminifera

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Planktonic foraminifera are protist forming carbonate tests. They are used as useful index fossils, and moreover, the oxygen isotopic and trace element compositions in their calcite tests are recognized as a promised archive representing paleo-ocean environments. Foraminifera generally consist of multipul chambers, and each chamber forms spirally for the center of the first chamber. Culturing observations have contributed for understanding relationships between trace elements and isotopic indices, and environmental factors. However, the transfer of elements and trigger of test formation are poorly understood. Cultured specimens sometimes show irregular-shaped tests, which are unlikely formed under natural condition in the ocean.

In this study, we focused the test formation of planktonic foraminifera, and cultured two species (*Globigerina bulloides*, *Globigerinoides ruber*) collected at Sagami bay. Culturing temperature was controlled at 19, 21, 23 and 25 °C. Calcium isotopic reagents were added to the culturing seawater to mark the timing of test formation. Moreover, we also investigated the other specimens cultured with seawater, whose calcium concentration was raised for 10% respective to the original concentration. In those cases, the pH of calcium reagents were adjusted to appropriate pH, and therefore, the seawater pH was kept at constant during the observation.

As a result, three of ten specimens of *G. ruber* have newly formed a regular test at 19, 21 and 23 °C. On the other hand, 5 of 7 specimens of *G. bulloides* have formed new tests, three of which have formed irregular shaped tests. These three specimens are ones survived more than a couple of weeks after sampling. The water temperature of irregular test formation was 21 or 25 °C, suggesting that the temperature was not a direct controlling factor of irregular test formation. Potential factors are concentrations of dissolved oxygen or dissolved organic matters. Foraminifera first forms organic layer called POM at the beginning of test formation. Anomalously high organic concentration in crystallization liquid may impede the regular formation of POM, consequently resulting in the formation of irregular-shaped tests.

For the specimens with increasing calcium concentration of seawater, the spines fell out within 12 hours. Because calcium is an essential element not only for test formation but also various biological reactions, rapid increase of calcium concentration might disturb the biofunction of planktonic foraminifera.

Keywords: planktonic foraminifera, laboratory culture

Anion adsorption and post-adsorption behavior of metastable iron hydroxides

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Pollution by dissolved anions has been a pertinent environmental concern in many areas around the world. For example, acid mine drainage from abandoned mines and contaminated waters resulting from the Fukushima nuclear power plant accident emphasize the importance of predicting the behavior of the dissolved trace elements on Earth's surface environments. Iron minerals may play a potentially important role in the control of dissolved trace elements in the environment. In particular, poorly crystalline iron minerals exhibit excellent adsorption capacities for toxic anions due to their high specific surface areas and reactivity. In order to evaluate the potential of poorly crystalline iron minerals as stable sinks of dissolved hazardous ions, it is necessary to investigate the adsorption mechanism on these minerals and their post-adsorption behaviors.

Adsorption experiments using arsenate, phosphate, chromate, sulfate, selenate, fluoride, and chloride were performed to investigate the selectivity of Schwertmannite and Ferrihydrite for various anions. Adsorption selectivity decreases in the following order: $\text{H}_2\text{AsO}_4^- > \text{H}_2\text{PO}_4^- > \text{HCrO}_4^- > \text{SeO}_4^{2-} \approx \text{SO}_4^{2-} \gg \text{F}^- \approx \text{Cl}^-$. Schwertmannite and Ferrihydrite didn't have an ability to adsorb F^- and Cl^- . The adsorption mechanism of these anions was investigated using zeta potential measurements. The results indicated that H_2AsO_4^- , H_2PO_4^- and HCrO_4^- formed inner-sphere complexes while SeO_4^{2-} and SO_4^{2-} formed outer-sphere complexes. The adsorption mechanism of these anions to both Schwertmannite and Ferrihydrite is generally similar, except in the case of HCrO_4^- .

Accelerated alteration experiments were performed to observe post-adsorption behaviors of Schwertmannite and Ferrihydrite. Oriented specimens loaded with varying amounts of adsorbed anions were aged under saturated water vapor pressure conditions at 50 °C for 30 days and analyzed by XRD. Results show that larger amounts of adsorbed anions delay the transformation of Schwertmannite and Ferrihydrite into more stable phases, indicating that adsorption of anions, particularly as inner-sphere complexes, stabilizes poorly crystalline iron minerals.

These results show that poorly crystalline iron minerals are capable of taking up a range of toxic anions from contaminated waters and that the stability of these minerals will be affected by the amount of anions sorbed on the surface. These suggest that poorly crystalline iron minerals may serve as stable, long-term sinks for toxic anions.

Anion adsorption and post-adsorption behavior of metastable calcium carbonate polymorph

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In Japanese transuranic (TRU) waste disposal facilities, I-129 is the most important radionuclide that must be considered in long-term safety assessments of the repository. However, the degradation of cement materials used in the repositories can produce high pH pore fluids that can affect to anion transport behavior. Therefore, it is necessary to understand the behavior of anions such as I⁻ in hyperalkaline conditions. Examples of I⁻ behavior in natural hyperalkaline environments, such as in Oman, show that I⁻ is taken up by aragonite, opening up the possibility of calcium carbonates as inhibitors of I⁻ migration. This concept is currently being applied in the development of the Advanced Liquid Processing System (ALPS), which employs carbonate coprecipitation to treat contaminated waters resulting from the Fukushima Daiichi nuclear power plant accident. However, the stability of the carbonate phases precipitated in this system as well as the anion uptake capacities of these phases are poorly understood. In a previous study, (Kasahara, 2012), it was found that monohydrocalcite (MHC), a precursor of aragonite, affects the iodine capacity of aragonite, making it a possibly important material that can control the behavior of anions. The objective of this study therefore, is to investigate the sorption capacity of MHC for anions and its stability. MHC ($Mg^{2+}/Ca^{2+}=6$; $Ca^{2+}/CO_3^{2-}=1$) was synthesized and used for sorption experiments involving F⁻, Br⁻, I⁻, IO₃⁻, SO₄²⁺, CrO₄²⁻, HAsO₄²⁻, and phase transformation experiments. Results show that Kd values of HAsO₄²⁻ and F⁻ on MHC are high, while IO₃⁻, SO₄²⁻ are relatively low. On the other hand, Br⁻, I⁻, NO₃⁻, CrO₄²⁻ were not taken up. It is because MHC has high chemical reactivity and high specific surface (4 times large of aragonite, 15 times large of calcite), in addition MHC is most low density of calcium carbonate, so MHC can take up relatively large amount of anions than other calcium carbonate. And other thing, MHC involves Mg²⁺ abundantly. This study indicates that Mg²⁺ form fluoride adsorption site. Results of the transformation experiments show that MHC with no adsorbed anions easily transforms into a stable phase, whereas MHC loaded with increasing amounts of anions transform after longer durations. It is because the driving force for the transformation decreases with the anions content in the solution. In conclusion, MHC can take up fluoride and oxyanions that ionic radii is similar to carbonate but larger than that. In addition, MHC is stabilized as a function of uptake amount of anions.

On activities in the interdisciplinary science of Hayabusa-2

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Hayabusa-2 is an asteroid sample return mission of which target asteroid is 1999JU3, a near Earth asteroid of type C, and it is scheduled to be launched late in this year. As on-board scientific instruments, Hayabusa-2 has a near infrared spectrometer (NIRS3), thermal IR imager (TIR), optical navigation camera (ONC-T) used as a multi-band imager with seven band-pass filters, laser altimeter (LIDAR), sampler (SMP), small carry-on impactor (SCI), separation digital camera (DCAM-D), and small lander (MASCOT). Using these instruments, we try to characterize the surface properties and materials of 1999JU3 and select three sampling points from which material samples will be obtained to reveal physical and chemical processes on the asteroid and its history from the formation to the present. Thus scientific success of Hayabusa-2 strongly depends on a strategy for characterizing the surface and selecting sampling sites, which can be achieved making the best use of data from the above all sensors. We, for this purpose, organize a working team called as the Interdisciplinary Science Team (IDST) of Hayabusa-2. In this presentation, we introduce the activity of the IDST.

The IDST was established in the first meeting held on Dec. 2012. Its purposes are to obtain the general picture of a scientific scenario of Hayabusa-2, define interdisciplinary science themes and contribution of individual instruments to the themes, define scientific constraints and validations on the mission scenario, and promote planetary sciences and think out planetary sciences from a standpoint of the asteroid mission. The discussion in the IDST is open to the project members. So far, we have discussed deeply a strategy in return sample analyses, heterogeneity detection by the remote sensing sensors, surface temperature detection, crater chronology, morphology produced by meteoroid impacts, reflectance spectra of C-type asteroids, space weathering, and so on. As a result of these discussion, we produce a logical flow chart to characterize the surface material and property. In the chart, mutual relations between basic observation quantities, quantities inferred by multiple sensors, their indexes, identified characters and general inferences on primitiveness are described. Contributions from each sensor are clarified in the chart. In addition, we also depicted an operational picture of SCI which is a grand experiment for an impact process in the low gravity space and exposes material in a depth that can be less suffered by space weathering, but SCI is wasteful of the satellite resources. It is necessary to polish up the operation plan of SCI from the view point of the system resources.

The logical flow chart is a guiding principle in the science of the Hayabusa-2 mission. We continue to refine the chart and complete the logic. For this purpose, we make several working groups to reinforce the logic flows. As closing the development phase of on-board instruments, we now rush up to make the IDST of Hayabusa-2 more active. We think that the activity in the IDST is a key point to succeed in the science mission and promote planetary sciences and explorations in Japan.

Keywords: Hayabusa-2, asteroid, exploration, surface material, interdisciplinary science, sample return

Detectability of 0.7 um absorption band of hydrous minerals using the Hayabusa2 ONC-T Flight Model

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Hayabusa2 has three cameras for optical navigation to the asteroid 1999JU3. ONC-T is one of them and it can be used also for reflectance spectroscopy. The results of the ground-based observation suggested that hydrous materials might remain on the 1999JU3 but on the small part of the surface. To bring them to the Earth, we should perform reflectance spectroscopic observation near the asteroid using ONC-T to locate the point where hydrous mineral is rich.

In this presentation, we will report the result of final calibration test of ONC-T and discuss the detectability of hydrous minerals on 1999JU3.

Development and tests of Hayabusa-2 LIDAR

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The Japanese first asteroid mission, Hayabusa, visited at the small asteroid 25143 Itokawa in September, 2005. Images taken by Hayabusa are combined with other remote sensing observations and revealed that the asteroid as small as 500 m in the longest axis is the first rubble-pile body identified in our solar system. Despite of several serious failures of the spacecraft occurred during and after rendezvous, Hayabusa successfully retrieved samples from the surface of 25143 Itokawa to the Earth in 2010 to disclose unpredicted nature of a very small asteroid.

JAXA and collaborating scientists are now developing the second asteroid mission named "Hayabusa-2". Hayabusa-2 is based on a heritage of the first Hayabusa. At the same time, Hayabusa-2 is intended to improve engineering and scientific achievements of the first Hayabusa, and also to challenge new technologies. Furthermore, target asteroid is different from that of the first Hayabusa. The asteroid 25143 Itokawa is a silicate-rich S-type. On the other hand, Hayabusa-2 is visiting a C-type asteroid, (162173) 1999 JU3. Needless to say, C-type is more primitive than S-type, therefore is expected to be a key to understand chemical evolution of the early solar system.

LIDAR measures altitudes of the spacecraft from the surface of the asteroid by taking a time of flight of laser pulse. As a part of Attitude and Orbit Control System (AOCS), the LIDAR data are used for navigation of the spacecraft. The data are particularly important during touchdown operation. Besides, the LIDAR data are served for scientific analysis of the shape, mass, and surface properties of the asteroid in order to elucidate physical evolution of minor bodies such as impact fragmentation and coagulation. We also wish to expand outcomes of Itokawa exploration by examining uniformity and variation of porosity within rubble-pile body and detecting dusts levitating above the surface of asteroid. The remote sensing observations of Hayabusa-2 will be carried out from Home Position (HP), middle altitude, and low altitude whose distances from the asteroid surface are nominally 20 km, 5 km, and 1 km, respectively. We report recent progress of LIDAR development anticipating the launch in December 2014.

Keywords: Hayabusa, asteroid, exploration, LIDAR

A strategy to estimate thermal properties using Thermal Infrared Imager on board Hayabusa-2.

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Thermal InfraRed imager (TIR) on board Hayabusa-2, an upcoming japanese mission to C-type asteroid 1999JU3, is non-cooled bolometer which image mid-infrared thermal emission from the asteroidal surface. The field-of-view (FOV) of TIR is 16x12 degrees and its effective pixels are 320x240. So the spacial resolution, which depends on distance from the surface, is about 18m from an altitude of 20km (Home position) and less than 1m from an altitude of 1km.

By comparing the temperature distribution obtained by TIR and thermal evolution model, we can get thermophysical properties such as thermal inertia and emissivity. These parameters are diagnostic for the characteristic size of surface grain.

In this presentation we will present our strategy to estimate the thermophysical properties from TIR observation.

Keywords: hayabusa-2, thermal infrared imager, surface temperature, thermal properties, thermal inertia, emissivity

Relationship on Surface Morphology of Small Asteroids and Geopotential

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We compared the distribution of smooth terrains with the geopotential map of the asteroid Itokawa, and demonstrate that the distribution of smooth terrains on Itokawa is strongly controlled by the geopotential distribution. Because the geopotential distribution of an asteroid can be estimated from its shape, rotation state and density, we can predict the distribution of smooth terrains on the asteroid from these observations.

Keywords: Asteroid, geopotential, smooth terrain, Itokawa, 1999JU3

Spectral evolution of s-type asteroids suggested by principal component analysis of multi-band images of Itokawa

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Objective

Itokawa is covered with materials from the same initial material with different degree of space weathering[1,2]. However, it has not been verified sufficiently if there is other factors that change the spectra. Our analyses of principal component analysis (PCA) using multi-band images taken by Hayabusa's AMICA (Asteroid Multi-band Imaging CAmera) so far have provided the results that a component of spectral reddening, a typical trend of space weathering effect, is the first principal component (PC1) with comparison to laser-irradiated meteorites spectra. The comparison with main-belt asteroids suggests how the spectra of the asteroids develop in their PC space with weathering (by micrometeorites bombardment[3])[4]. However, further analysis had been impeded by electromagnetic noise. In this study, we remove the noise and examine spectral change trends caused by processes other than space weathering.

Methods

We used 2 sets of images of six visible bands (Central wavelengths of 381, 429, 553, 700, 861, 960 nm) taken by AMICA. Periodic electromagnetic noise is imposed on most of the images. We removed it by subtracting superposition of sine waves. The images were calibrated following [4] and coresistrated. Normalized ratio images were obtained by dividing the images by those of 553 nm.

We performed PCA on the normalized reflectance spectra. We used a set of images of a Itokawa semisphere and another set including a dark rock (Black Boulder). Shock darkening is indicated as a possible origin of it [5].

We also performed PCA on spectra of main-belt asteroids obtained in ECAS [6] and each Itokawa spectrum superimposed. Because AMICA and ECAS filter wavelengths are approximately same, we can compare the Itokawa surface in the PC space defined by ECAS data set.

Results

The PC1 of spectra of only Itokawa had a shape rising to the right with a steep rise in 430-700nm. The PC1 score spatial distribution was consistent with the distribution of space weathering degree obtained by [7]. PC2 had positive coefficients at the wavelengths except 553nm, and the spectrum shape was upward to both sides. The PC2 is different from silicate spectra, therefore interpretation in a context of material science is difficult. We found a feature that PC1 score is low and PC2 score high in boulder-rich regions, but the maximum area of PC2 score lay around a boulder where PC1 score were minimum. Proportion of variance of PC1 and PC2 was 60-75% and 20-30%.

In the ECAS-defined PC space, the spectra of Black Boulder were distributed apart from the cluster of the other parts.

Discussion

The proportions of variance of PC1 and PC2 would suggest that the heterogeneity in Itokawa surface spectrum is dominated by two processes. The PC1 and PC2 score distribution might suggest that the process which changes PC2 score occurs where space weathering has moderately developed. We have observed only a part of the surface, and features observed in a global analysis will be reported in our presentation.

The fact Black Boulder spectral trend is different from that of the other parts suggests that another process than space weathering (shock darkening is a candidate) is the origin of its peculiar spectrum.

In this analysis, another trend than the general space weathering was captured. Consideration of an evolution caused by larger impacts together as well as the space weathering caused by micrometeorites bombardment may enable us to constrain the spectral evolution processes of asteroids and derive relationships among asteroids of different spectral classes.

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Small carry-on impactor of Hayabusa2

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Small Carry-on Impactor of Hayabusa2

A Japanese spacecraft, Hayabusa2, the successor of Hayabusa, which came back from the Asteroid Itokawa with sample materials after its 7-year-interplanetary journeys, is a current mission of Japan Aerospace Exploration Agency (JAXA) and scheduled to be launched in 2014. Hayabusa2 is a similar sample return mission to Hayabusa, however the type of the target asteroid is different from that of Hayabusa. Asteroid Itokawa, explored by Hayabusa is a rock-rich S-type one. Hayabusa2 will go to a C-type asteroid. Both C-type and S-type asteroids consist of rocks, but C-type asteroids are considered to have organic and water materials. Hayabusa2 has two objectives to discover: organic matters and water in the solar system and relationship between life and ocean water. C-type asteroids are the most common variety and many of them are in the outer part of the asteroid belt beyond 2.7 AU. An asteroid, called 1999 JU3, is chosen as the target of Hayabusa2 mission because it is considerably easy to reach. It has a similar orbit as that of Itokawa and it is in the orbit that occasionally comes close to the earth orbit.

The design of Hayabusa2 basically follows Hayabusa. Its configuration, size and weight are almost same as Hayabusa and the touch-down operation will be performed in much the same way. However, it is planned to be equipped with some new components. Small Carry-on Impactor (SCI) is one of the new challenges. The observations by Hayabusa discovered that Itokawa was rubble-pile body with the macro-porosity. No direct observational data as for their internal structures and sub-surface materials were available, however. One of the most important scientific objectives of Hayabusa2 is to investigate chemical and physical properties of the internal materials and structures in order to understand the history of formation of small bodies such as small, un-differentiated asteroids. In order to achieve this objective, the SCI is required to remove the surface regolith and create an artificial crater on the surface of the asteroid. Different from other impact missions, Hayabusa2 can make a detailed observation of the resultant crater after the impact. Observing the size of the crater is very important to investigate the physical properties of the asteroid. Additionally, Hayabusa2 will try to touchdown near the crater to get the fresh material of the asteroid.

It is very difficult to create a meaningful crater on the asteroid. High kinetic energy (i.e. about 2km/s impact speed and 2kg impact mass) is required to make a crater, but the high speed is difficult to realize. The famous impact mission, Deep Impact was the direct impact mission, which used the interplanetary velocity for the impact speed. Consequently, the impact energy became very high. On the other hand, SCI of Hayabusa2 is a carry-on type impactor and it should accelerate itself after the separation from the mother spacecraft. Therefore, how to accelerate the impact body is a big challenge of SCI. The traditional acceleration devices such as rocket motors and thrusters are difficult to hit the asteroid without a guidance system because the acceleration distance is large. To overcome this difficulty, the powerful explosive is use in SCI. The special type of shaped charge makes it possible to accelerate the impact head in a very short amount of time (less than 1 millisecond) and it becomes possible to crash into the asteroid.

The development of SCI is now almost finished. A lot of tests were conducted during the development period. The overview of the small carry-on impactor system and the results of the development tests will be presented in the conference.

Keywords: Hayabusa2, Impactor, Artificial Crater

Small Carry-on Impactor Elucidates the Nature of Craters and the Evolution of our solar system

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Hayabusa-2, the Japanese next asteroid exploration mission, equips Small Carry-on Impactor (SCI) to launch a decimeter scale projectile on an asteroid surface. This is a novel apparatus to excavate the asteroid surface, and hopefully it will enable us to observe a fresh surface without space weathering and thermal alteration. Furthermore, we will be able to recover the asteroid sample excavated from several 10 cm depth at the deposit of the impact ejecta. The SCI impact on the asteroid is very good chance to examine the projectile scale on the crater scaling law in addition to the study on the gravity effect on the crater formation process. In this presentation, I will introduce the scientific goals of Hayabusa-2 mission using SCI and the scientific problems to be solved in the near future to maximize the scientific outputs of the SCI impact.

Keywords: Hayabusa-2, SCI, impact, asteroid

The final impact tests of Small Carry-on Impactor(SCI) equipped on HAYABUSA-2

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HAYABUSA-2(the next Japanese Asteroid Sample Return Explorer) is now at the final integrated test. Before this test, all sub-systems experienced final test individually. The Small Carry-on Impactor:SCI has been adopted the new sub-system of HAYABUSA-2, it is one of the self forging fragment which will be able to eject the 2kg projectile by 2km/sec velocity by detonation.

In this paper we show the outline and results of the final performance test of the SCI explosive part on Oct. 2013. The test bodies have been made by the same rot of flight model, and experienced environmental stress tests. The projectiles formed explosion impacted on the sand target and made craters.

A point of view of understanding of impact phenomena, these tests are larger scale impact experiments than those made in laboratory, between space scale and laboratory scale. Therefore we observed and measured the crater formation processes by two high-speed video cameras, an infrared video camera, accelerometers, geophones, and digital handy video cameras. We succeeded to obtain five cratering processes.

Keywords: HAYABUSA-2, Small Carry-on Impactor, impact experiment, crater, explosion



Optical performance verification of DCAM3-D/Hayabusa 2

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Small Carry-on Impactor (SCI) is one of the instruments carried on Hayabusa-2 space craft. It will be used for an active exploration on the surface of asteroid 1999JU3. The SCI consists of a disk impactor made of copper. This disk will be accelerated to a velocity of ~2km/s for the collision onto the asteroid surface, creating an artificial crater on 1999JU3. Then, samples in the crater and/or around the crater will be recovered by the Hayabusa-2 mother ship. Observation of the crater is expected to reveal the surface structure of 1999JU3. This SCI impact also has an aspect of an "impact experiment" on an asteroid that elucidates the impact phenomena on small bodies.

A miniaturized optical camera unit (DCAM3) is being developed for observations of the SCI impact. DCAM3 will be detached from Hayabusa-2 mother ship and obtain a close-up image of the SCI impact. The detached part of DCAM3 has two cameras; one is an analog camera (DCAM3-A) and the other is a digital camera (DCAM3-D). The purposes of DCAM3-D are (1) the detection of SCI explosion and impact on the asteroid and (2) the observation of ejecta created by the SCI impact.

DCAM3-D optical system has to satisfy strict required specifications to fulfill these purposes: it requires a large view angle (74 deg) to detect both the SCI and the asteroid, high imaging capability for whole sensor area, a bright optical system ($F > 1.7$) to detect dark SCI and ejecta, resistance to radiation, and limited size and weight. Moreover, these conditions have to be accomplished without active temperature control.

In this presentation we report the results of the optical performance verification of a flight model of DCAM3-D. The optical performance verification tests consist of electrical test, collimator test, and integration sphere test. The electrical test evaluated the performance of the CMOS sensor. In the collimator test, lens-sensor distance and lens-sensor angle were adjusted. Then, imaging capability (i.e., ensquared energy), spatial resolution, and distortion were evaluated under vacuum condition (< 1 torr) with various temperatures, wavelength regions, and angles of view. In the integration sphere test, sensitivity, limb darkening, and stray light were evaluated. We confirmed that the results of these evaluations were favorable and that the strict required specifications of the optical system are almost satisfied.

Keywords: asteroid, planetary exploration, Hayabusa-2, scientific payload

The effect of substrate structure of rubble-pile bodies on cratering process

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Introduction: Hayabusa obtained many high-resolution images and revealed that this asteroid has many unique morphological features which are not seen on other small planetary bodies. One of the most symbolic configurations are quasi-circular depressions (QCD) on boulder-rich surfaces, which are inferred as impact craters (Hirata et al., 2009). If the QCDs are impact craters, then the surface crater retention age of Itokawa can be estimated based on crater chronology approach. However, age estimates has great uncertainty: 75Myr-1Gyr (Michel et al., 2009). The uncertainty in age results mostly from the uncertainty in crater scaling formed on the boulder-rich surface observed on rubble-pile bodies. The impact energy required for forming a crater on a small body is much smaller than that on a large body because of the limitation of catastrophic disruption energy (Benz and Asphaug, 1999). Impact cratering with such small energy on rubble-pile bodies are expected to follow a scaling low between the strength-regime rates and the gravity-regime cratering. The impactor destroys a surface boulder and dissipates its energy, then leading to a smaller crater: an armoring effect.

Moreover, impact induced mass loss is a critical value for estimating the life time of small bodies. The escape velocity of small bodies is very small. For example, Itokawa has an escape velocity of 10-20cm/sec. Thus, small bodies can easily lose their mass upon impact cratering.

As mentioned above, crater size and ejecta mass are important parameters for calculating the life-time of small bodies. However, these values for the rubble-pile bodies are not constrained well. Cratering process may be influenced greatly by the substrate structure of small bodies. In this study, the effect of the substrate structure of the rubble-pile bodies on the impact process is examined experimentally.

Experiment: Sintered glass beads blocks crashed into 8-15 mm chips and 200 micro meter glass beads are used as boulder simulants and regolith simulant in our experiments, respectively. We employ two types of targets: one consists of all boulders simulants (target 1) and the other consists of a surface layer of boulders simulants and regolith substrate (target 2). Polycarbonate projectiles 10mm diameter were launched at 160-180 m/sec of velocities. The impact cratering process was observed by a high-speed camera. We also measured the size of final crater and the ejecta mass.

Result: Crater size of target 1 is smaller by ~20% than target 2, and ejecta mass of target 1 is smaller than by a factor of five than target 2. High-speed camera observations revealed that the surface boulders are destroyed by the impactor more heavily in the target 1. This difference occurs because the shock impedance of boulder simulants are larger than that of regolith simulant by a factor of ten and much stronger reflected stress waves comes back to the surface boulders for target 1, but the stress wave transmits efficiently from surface boulders to regolith layer in target 2.

These results suggest that the substrate structure of small bodies changes the impact process greatly. Crater size varies by ~20% depending on substrate layers: boulders or regolith. Crater forming on bodies consisting of only boulder is smaller than bodies with regolith substrate but still much larger than crater on monolith (i.e., the scaling in strength-regime scaling). Consequently, the surface age of Itokawa could be on the younger side of the previous estimates as 75Myr-1Gyr with the strength-regime crater scaling. Furthermore, the substrate structures of the rubble pile bodies change the ejecta mass by 5 times. Rubble-pile bodies consisted of boulders possibly live longer.

Keywords: rubble-pile bodies, impact cratering, mass loss, fragmentation

Computer Vision in Space: Optical Navigation Technology Development for Hayabusa-2

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Computer vision (CV) is a research field aiming to establish technologies by which information of objects is extracted from their images. Using CV technologies, our research group are developing methods to construct shape model of an asteroid for Hayabusa-2 navigation. We report this activity in this article. In addition, applying CV technologies to space environment has a potential to drive CV itself to a new research direction. We also touch on this observation.

For Hayabusa-2 navigation, we need to know shape of the destination asteroid, but the long distance between the asteroid and the earth prevent us from measuring it from the earth. Therefore we have to measure it after the arrival to the asteroid. Because active measurement methods need too much power, we are developing methods using images taken from the spacecraft.

Our project is mainly run by Dr. Seiji Sugita at Univ. of Tokyo and Dr. Naru Hirata at Aizu Univ., who are researchers in planetary science. However, because shape reconstruction techniques using images have intensively been studied in CV and CG (computer graphics) areas, the project is contributed by Dr. Hiroshi Ishikawa at Waseda Univ. and the author from CV area, and Dr. Shigeo Takahashi at Univ. of Tokyo from CG area.

We have applied a structure from motion technique developed in CV without modifications to the shape reconstruction of asteroids. We have had a minimum result required for Hayabusa-2 navigation, but more precise model is needed to make the navigation more certain and flexible. Therefore, we are combining photometric stereo to it.

Photometric stereo is a shape reconstruction method utilizing reflectance information of objects. However, we cannot directly apply such techniques developed in CV to the asteroid, because the conditions assumed in CV are fairly different from our case. The CV techniques assume that a number of images are taken from the same position, but the spacecraft cannot be controlled in such a way because it requires too much fuel. In addition, the reflectance models are different; Lambertian and Phong, for example, are used in CV, but we need algorithms based upon models such as Hapke and Minnaert, which describe reflectance of planet materials. Therefore, we are developing new algorithms that match the space environment for Hayabusa-2 navigation.

Looking at the origin of CV, it was regraded as a part of artificial intelligence research and has been motivated by artificially realizing functions of visual systems of human beings, or creatures in general. It seems that, from this reason, methods developed in CV tend to be general-purpose, and also that environments on the earth are implicitly assumed. Therefore, algorithms in CV are sometimes not applicable to problems in space science. However, viewing the situation from a different point, it may inspire CV itself to a new research direction by giving clear purposes.

When assuming usage in space, the following peculiarities are observed. The light source is usually only the sun, so it often suffice to consider only parallel light as the illumination. We can develop algorithms fully taking advantage of this simplicity. As mentioned above, reflectance models special to planet are used. If the process is executed in spacecrafts, the amount of computation is very limited, so the view point to develop a minimum algorithm to fulfill the objective becomes important. On the other hand, if images are transferred to the earth, the number of images is limited, but usually no limitation exists in amount of the computation. In such a case, CG-CV loop where a CG model is iteratively modified so that the generated images match to the observed images becomes to have reality. In addition to stated above, computing other information needed for space science than shape, estimating error information (variance), and so on, are important tasks for space science. We believe developing these techniques is an important direction of CV research.

Keywords: image measurement, shape reconstruction, optical navigation, Hayabusa-2

Analytical chemistry of organic compounds in the Solar System: An attempt to link with planetary science

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Analytical chemistry of organic compounds in the Solar System small bodies is a microscopic approach for understanding of the origin and evolution of building blocks of the Solar System and life, which has a complementary relationship with macroscopic approaches such as observational and theoretical astronomy. This approach would provide a significance of considering organic compounds in the planetary formation theory, which has been constructed only by silicate and ice dusts. Indeed, significant roles of organic compounds in the early Solar System are explained by (1) high abundances of C, H, O, N in the Solar System, (2) major components of dusts in interstellar clouds, (3) high reactivity to heat, light, shock, water, and minerals (chemical indicator recording the processes in the Solar System), (4) possible contribution to accretion of dusts, due to their stickiness (Kouchi et al. 2002), and (5) possible contribution to redox imbalance in solar nebula (that determined the chemical compositions of chondrules) (Yurimoto and Kuramoto, 1998). Despite these significant roles, however, organic cosmochemistry was not a very popular field in planetary science until several years ago. One of the reasons may be because of difficulty in visualization of organic compounds, i.e., drawing of a big picture. In this point, I attempt to show a simple example. When starch-syrup is heated, how is it changed. One would tell that the color is changed from colorless to brown, the originally sticky syrup becomes less sticky candy, and water-soluble syrup becomes an insoluble solid. These descriptions are based on visibility and are easy to understand. On the other hand, if these phenomena are translated to organic analytical chemistry, the description becomes quite different from the former; hydroxyl groups of glucose changes to carbonyl groups via dehydration as well as aromaticity increases with heating. However, it should be noted that two ways of descriptions explain exactly the same phenomenon. That demonstrates that physical properties (color, stickiness, and solubility) are determined by molecular chemical structures. Likewise, analytical chemistry of organic compounds in the Solar System has a potential to reveal the molecular science that determines physics of macroscopic planetary formation, such as the color of asteroids (albedo). This will become possible by improvements of the in-situ organic analyses such as spectromicroscopy (e.g., STXM), electron microscopy (TEM), and ion probe mass spectrometry (e.g., nanoSIMS), through visualization of the distributions of organics and minerals in the Solar System materials which record the chemical evolution from dusts to planetesimals.

Keywords: Organic compounds, Solar System, Analytical chemistry, small bodies, planetary formation, visualization

Formation Process of Complex Organic Molecules in Protoplanetary Disks

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It is believed that chemical reactions in protoplanetary disks will lead the origin of materials in our Solar System. Recently, many complex organic molecules (COMs) have been found in molecular clouds by radio observations of molecular transition lines. Meanwhile, amino-acids are found in a comet and meteorites in our Solar System. In this work we investigate the synthesis of complex organic molecules in protoplanetary disks using a large gas-grain chemical network together with a 2D steady-state physical model of a disk irradiated by UV and X-rays from the central star. We find COMs are efficiently formed on cold and warm grains in the disk midplane via grain-surface reactions through efficient migration of icy species on grain surface. Radiation processing on ice forms reactive radicals and helps build further complexity. We find the grain-surface abundances predicted by our calculations are consistent with those derived from cometary comae observations. We also predict line spectra of COMs, which are partly photodesorbed into gas from grain surface, will be observable in nearby protoplanetary disks with ALMA. In this talk I would like to discuss further on formation process of COMs on grains in the asteroid belt region, too.

Keywords: protoplanetary disks, formation of organic molecules

Status report of curation of Hayabusa-returned samples

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Hayabusa spacecraft returned samples from S-type Near-Earth Asteroid (NEA) Itokawa in June 2010. After the return, Extraterrestrial Sample Curation Team (ESCuTe) of JAXA have recovered particles from a sample catcher of Hayabusa, and more than 400 particles initially described have been presented in public (Yada et al., 2014a). In this presentation, we review the recovery and initial description of Hayabusa-returned samples and mention their future schedule.

A sample container had been extracted from the reentry capsule of Hayabusa and cleaned in cleanrooms of the Extraterrestrial Sample Curation Center (ESCuC) of JAXA. It was introduced into a clean chamber No.1 and opened in vacuo, and then a sample catcher, which enclosed samples captured on the surface of asteroid Itokawa, was extracted to be transferred to a clean chamber No.2 which is designed to handle Hayabusa-returned samples in highly purified nitrogen condition. The sample catcher is mainly composed of a rotational cylinder through which captured samples had been transferred, a room A in which samples obtained by the second touchdown on Itokawa and a room B in which captured those of the first one. At first, we had prepared quartz glass disks of the same size with covers of the room A and B, on which particles inside each room were fallen by tapping. The particles on the quartz disks have been picked up one by one with a specially designed electrostatically-controlled micromanipulator to be placed onto a SEM holder which can seal the samples in nitrogen condition and initially described by SEM-EDS. Then they sent back to the clean chamber No.2 to be placed onto gridded quartz glass slides to be given their ID and preserved. In fiscal year of 2013, we started to describe particles on a cover of the room B with SEM-EDS directly, utilizing a SEM holder specially designed for the cover of the catcher (Yada T. et al., 2014b).

The initial description method using the quartz glass disks has disadvantages in inefficiency and risk of particles transportation one by one with the micromanipulator. In order to resolve these disadvantages, we have developed metal disks which particles can be fallen on by tapping and can be set to the SEM holder designed for the covered of the catcher in fiscal year of 2013. We are planning to start sample recovery by the metal disks in fiscal year of 2014, and going to confirm vast majority of particles inside the catcher for more than two years (Yada T. et al., 2014a).

The ESCuTe of JAXA started the international AO for Hayabusa-returned samples in the beginning of 2012. In the international AO, worldwide researchers can apply their proposals and the committee composed mainly of top scientists outside JAXA reviews the proposals to determine which proposal the precious samples should be distributed. The AO have been published approximately annually, and the third AO will be published in the beginning of fiscal year 2014. The research results of the AOs are presented in the international symposium held by JAXA, named as "Hayabusa 2013: Symposium of Solar System Materials", and its proceedings will be published in the international journal.

Particles having rare features have not been provided to the international AOs, but to consortium studies led by ESCuTe of JAXA until 2013. So far, four consortia, including the maximum-sized particle, a NaCl-bearing one, an iron sulfide one, and ones containing phosphates Uesugi et al., 2013; Yada et al., 2013; Karouji et al., 2013). Particles having other rare features will be provided to consortium studies in future.

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Keywords: Hayabusa, asteroid, curation, sample return

Examination of the origin of carbonaceous particles in Hayabusa-returned samples

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Extraterrestrial Sample Curation Team (ESCuTe) recovered more than 50 carbonaceous particles from the sample catcher of the Hayabusa spacecraft. Those carbonaceous materials, named as category 3, were found in the form of particles with similar size range of the silicate particles those confirmed as Itokawa regolith particles. Initial description by the SEM-EDS analysis shows variable textures and chemical compositions of them, suggesting the multiple origins of the carbonaceous materials.

Preliminary examinations of category 3 particles were carefully processed in parallel with those of silicate materials. However, we could not obtain the information for the origin of category 3 particles before the opening of international announcement of opportunity (A/O). The ESCuTe and preliminary examination team of category 3 particles have continued the investigations. In this paper, we report the several recent results obtained from the sequential analyses.

Samples allocated for the preliminary examinations of category 3 are RA-QD02-0008, RA-QD02-0120, RA-QD02-0180, RB-QD04-0001, RB-QD04-0037-01 and RB-QD04-0047-02. RA-QD02-0008 was lost during the manipulation at first preliminary examination. Three samples, RA-QD02-0120, RB-QD04-0001, and RB-QD04-0047-02, were pressed on the Au plate and fixed without any adhesive materials. We analyzed H, C and N isotopic composition by nano-SIMS in the beginning of the sequential study, in order to investigate the isotopic anomaly which is a direct evidence of extraterrestrial origin of organic materials [8]. FT-IR and micro-Raman spectroscopy were also applied for the pressed samples [9]. After ToF-SIMS analysis of those particles, the samples were sliced by FIB in order to investigate the fine structure of the samples by XANES and TEM/STEM [10].

We performed those analyses with determining the effect on the subsequent analyses, such as sample damages and contaminations. The rest two particles, RA-QD02-0180 and RB-QD04-0037-01 were pressed on indium plates, because significant disturbance by Au on the ToF-SIMS analyses was found. We will also report the construction of the sequential analysis flow of tiny carbonaceous particles.

In parallel with the Hayabusa-returned particles, we processed observation and analysis of insoluble organic matter (IOM) of A881458 (CM2) and several possible materials of the origin of the category 3 particles, such as viton, silicon rubber, vectran and particles collected from the Hayabusa2 clean room.

We did not obtain any signature of extraterrestrial origin from category 3 particles so far. We are planning to continue the preliminary examination of category 3 by the end of March 2014. We are also planning to open the category 3 particles to the future International A/O, with the data of preliminary examinations before the end of 2014.

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H, C and N isotopic compositions of HAYABUSA Category 3 organic samples

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Hayabusa spacecraft had brought back asteroid Itokawa particles to the Earth on June 2010. More than 1,500 mineral particles were identified on the Qz glass after the compulsive free fall, and most of them were very small ranging from 10 to 300 μm but are mostly smaller than 50 μm (Nakamura et al., 2011). In addition several amount of carbonaceous materials were found that is called Category 3. Based on FE-SEM and EDS observations at JAXA Extraterrestrial Sample Curation Team, those samples mainly composed of C, N, O and some of them contain NaCl and KCl (JAXA Hayabusa sample catalogue).

H, C and N isotopic compositions of extraterrestrial organic materials in Stardust cometary samples (McKeegan et al., 2006), IDPs (Messenger, 2000), IOM (Busemann et al. 2006) and nanoglobules in primitive chondrite (Nakamura-Messenger et al., 2006) provide a clue for understanding of origin and nature of the Solar System. Large D and ¹⁵N isotopic enrichments were observed, and C isotope is slightly enriched in ¹³C in extraterrestrial organic materials (Pizzarello, 2005). Those data suggest that extraterrestrial organics are probably interstellar material that was survived through formation processes (planetesimals) of the Solar System (Sanford et al., 2001), and may also have material that formed in the cold molecular cloud region of the proto-planetary disk (Aikawa et al., 2002).

Here we report H, C and N isotopic measurement of organic materials from Hayabusa Category 3 samples, RB-QD04-0047-02, RA-QD02-0120 and RB-QD04-0001, by an ion imaging with the JAMSTEC NanoSIMS ion microprobe. The purposes of this study are to evaluate terrestrial contaminations in the Hayabusa spacecraft and in the JAXA curation facility, and to find extraterrestrial organic materials on the basis of H, C and N isotope measurements.

Each Hayabusa organic sample was pressed on Au plate together with terrestrial organic standards of 1-hydroxybenzotriazole hydrate and BBOT with known H, C and N isotopic compositions. Following the SEM study to check the sample condition, texture and morphology, the samples were analyzed for H, C and N isotopic compositions by an isotopic imaging with the JAMSTEC NanoSIMS 50L at Kochi Institute for Core Sample Research.

We studied three Hayabusa organic samples, RB-QD04-0047-02, RA-QD02-0120 and RB-QD04-0001. All of the samples have been initially investigated by a FE-SEM and EDX observation at JAXA Hayabusa curation facility, and the EDX spectra of the samples contain C, N and O; the dominant elements are C, and N (Hayabusa sample catalogue).

Based on NanoSIMS isotopic images of H, C and N in RB-QD04-0047-02, RA-QD02-0120 and RB-QD04-0001, all three samples show homogeneous and terrestrial H, C and N isotopic compositions within an error ($\delta\text{D} = 60 \pm 13$ permil, $\delta^{13}\text{C} = 3 \pm 3$ permil and $\delta^{15}\text{N} = -4 \pm 2$ permil for RB-QD04-0047-02; $\delta\text{D} = 81 \pm 54$ permil, $\delta^{13}\text{C} = -20 \pm 8$ permil and $\delta^{15}\text{N} = 2 \pm 2$ permil for RA-QD02-0120; $\delta\text{D} = 135 \pm 32$ permil, $\delta^{13}\text{C} = -20 \pm 9$ permil and $\delta^{15}\text{N} = 16 \pm 12$ permil for RB-QD04-0001).

The IOMs in CI and CM chondrites show heterogeneous distributions of delta-D at the molecular (Remusat et al. 2009) and micron scale level (Busemann et al., 2006). The IOMs of CR, CM and CI have D and ¹⁵N isotopic enrichments in micron-sized regions (hot spots). The IOMs in ordinary chondrites are heterogeneous, however, they do not show many micron-scale anomalies as IOMs in carbonaceous chondrite (Remusat et al., 2013). It is obvious that H, C and N isotope signatures of Hayabusa organic samples are different from those of IOMs in carbonaceous and ordinary chondrites: i.e., No hot spots, terrestrial values for H, C and N isotopes.

We have not found strong evidence of extraterrestrial origin because isotope compositions of H, C and N in Hayabusa organic samples show terrestrial values, and homogeneous distributions of H, C and N in the samples, which are unlike to IOM in various types of chondrites.

Albedo properties of main belt asteroids based on the infrared all-sky surveyors

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Presently, the number of asteroids is known to be more than 620,000, and more than 90% of asteroids are classified as the main-belt asteroids (MBAs). The spatial distribution of compositions among MBAs is of particular interest, because the main belt is the largest reservoir of asteroids in the solar system. Asteroids are thought to be the remnants of planetesimals formed in the early solar system, and have a clue to study the formation and evolution of asteroids, origin of meteoroids and the near-Earth asteroids, as well as the formation of the solar system. Size and albedo are one of the most basic physical quantities of asteroid. Knowledge of size and albedo is essential in many fields of asteroid research, such as chemical composition and mineralogy, the size-frequency distribution of dynamical families and populations of asteroids, and the relationship between asteroids in the outer solar system and comets.

Several techniques have been developed to determine the size of asteroids. One of the most effective methods for measuring asteroidal size and albedo indirectly is through the use of radiometry, where a combination of the thermal infrared flux and the absolute magnitude as the reflected sunlight. Using radiometric measurements, a large number of objects can be observed in a short period of time, providing coherent data for large populations of asteroids within the asteroid belt. Infrared observations can be made still better under ideal circumstances, from space. The first space-borne infrared telescope is the Infrared Astronomical Satellite (IRAS; Neugebauer et al. 1984), launched in 1983 and performed a survey of the entire sky. To date, there are two other infrared astronomical satellites dedicated to all-sky survey: the Japanese infrared satellite AKARI (Murakami et al. 2007), and the Wide-field Infrared Survey Explorer (WISE; Wright et al. 2010). Based on the all-sky survey data obtained by IRAS, AKARI, and WISE, the largest asteroid catalogs containing size and albedo data were constructed (e.g., Tedesco et al. 2002; Usui et al. 2011; Mainzer et al. 2011). The total number of asteroids detected with size and albedo information with these three surveyors is 138,285, which is 22% of currently known asteroids with orbits.

In addition, several outstanding works have provided the taxonomic classification of asteroids (e.g., Tholen 1989; Bus & Binzel 2002; Lazzaro et al. 2004; Carvano et al. 2010), based on ground-based spectroscopic observations within optical and near-infrared wavelengths. Along with these taxonomic classifications, size and albedo data also contribute to our understanding of asteroid compositions. In general, the albedo of C-types is considered as low and that of S-types is high (e.g., Zellner & Gradie 1976). The relationship between taxonomic types and albedo is, however, complex and type determinations cannot be made on the basis of albedo values alone. Recently albedos of C- and S-type asteroids are found to vary widely, especially for sizes smaller than several tens km (Usui et al. 2013). Furthermore, in spite of the albedo transition process like space weathering, the heliocentric distribution of the mean albedo of asteroids in each taxonomic type is found to be nearly flat. In the total distribution, on the other hand, the mean albedo value gradually decreases with increasing the semimajor axis, presumably due to the compositional mixing ratios of taxonomic types.

In this talk, we present the details of data compiling of size, albedo, and taxonomy of MBAs, and discuss the compositional distribution in the main belt regions.

Keywords: asteroids, main belt, infrared surveys, size and albedo, taxonomic classifications

Lightcurve Survey of Vestoids in the Inner Asteroid Belt

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We have made the lightcurve observation of 13 vestoids ((1933) Tinchin, (2011) Veteraniya, (2508) Alupka, (3657) Ermolova, (3900) Knezevic, (4005) Dyagilev, (4383) Suruga, (4434) Nikulin, (4796) Lewis, (6331) 1992 FZ₁, (8645) 1998 TN, (10285) Renemichelsen, and (10320) Reiland).

Lightcurves in the R-band of rotation periods were found for (1933) Tinchin, (2011) Veteraniya, (2508) Alupka, (3657) Ermolova, (3900) Knezevic, (4005) Dyagilev, (4383) Suruga, (4796) Lewis, (6331) 1992 FZ₁, (8645) 1998 TN, and (10320) Reiland.

The distribution of rotational rates of 59 vestoids in the inner main belt, including 29 members of the Vesta family that are regarded as ejecta from the asteroid (4) Vesta, is inconsistent with the best-fit Maxwellian distribution.

This inconsistency may be due to the effect of thermal radiation Yarkovsky- O'Keefe-Radzievskii-Paddack (YORP) torques, and implies that the collision event that formed vestoids is sub-billion to several billion years in age.

Keywords: asteroid, vesta

Near-infrared spectral measurements of zodiacal light by CIBER rocket experiments

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We have observed the cosmic near-infrared background light as the integrated light along the line of sight, which is the near-infrared diffuse radiation in wide range of the cosmic structure from the solar system to extragalactic universe, with the CIBER (Cosmic Infrared Background ExpeRiment) rocket experiments. One of scientific objectives of CIBER is to measure the zodiacal light in the near-infrared, which is the scattered sun light by interplanetary dusts. From the results of CIBER, we first observed the zodiacal light spectrum and its polarization in the near-infrared range from 0.8 to 2 microns. In this paper, we present the observation results.

CIBER is an international collaboration study among Japan, US and Korea, and a sounding rocket program by NASA. In a term from 2009 to 2013, we have carried out four times of launch and obtained high quality data at the altitudes above 200 km with no contamination by the earth atmosphere. In order to measure the extragalactic background light, we selected the observation field to have solar elongation over 90 degrees with relatively low brightness. We extracted the zodiacal light component from the total sky brightness by using the ecliptic latitude dependence. As the result, we could obtain information of spectrum, polarization and seasonal variation of the zodiacal light.

The observed infrared spectrum shows neither ecliptic latitude dependence nor time variation, and reddened color compared with the solar spectrum at wavelengths below 1.5 microns. From this result, size of interplanetary dust is larger than the order of micron, and there may be absorption of dust minerals at shorter wavelengths. We found the polarization of 20-25% at the maximum at the north ecliptic pole, which is higher than that previously observed in the visible wavelength range. The polarization result also suggest that the majority of the dust size is much larger than the observation wavelength.

In this paper, we report the observation result, and we discuss the optical properties of interplanetary dust by comparing our result with the spectral reflectance of meteorites and cometary dust.

Keywords: zodiacal light, interplanetary dust, infrared, observation

Reflectance Spectra of Jovian Small Satellites and Implication of their Origin

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Abstract

Jupiter has many small satellites other than the four giant Galilean satellites. Four of them revolve inside Io's orbit and others revolve outside Calisto's orbit. Based on the similarities of their photometric and orbital properties, these small satellites are thought to be captured asteroids. However, it is still unknown where and when these satellites were captured by Jupiter. We can reveal the dynamic history of our solar system evolution by investigating these questions.

Here, we have made optical spectroscopies of 11 small satellites which were not yet taxonomically classified by spectroscopy so far. We compared the number ratio of C- and X-type to D-type of the 11 satellites, and the Hilda and Trojan groups observed recently by Grav et al. (2012) as a function of diameter. We found that the diameter-(C,X)/D relation of the Jovian irregular satellites is similar to that of Hilda's, not Trojan's. This result suggests that the Jovian irregulars and the Hilda members originate from the same source of asteroids.

We also observed the 3.05 μm narrow-band photometry of the inner small satellite Thebe and found that there is absorption. This can be attributed to hydrated minerals.

Keywords: satellites, Jupiter, spectrum, Hilda group, Trojan

Weathering effect of solar wind proton on hydrated silicate minerals

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NIRS3 is an on-board near infrared spectrometer of Hayabusa-2 project which is aimed at returning samples from C-type asteroid 1999 JU3. In this project, it is important to characterize mineralogical and heterogeneities on the asteroid surface for the sampling site selection. Observing wavelength of NIRS3 is including the 3 μm band which is charactering C-type asteroid (Rivkin *et al.* LPSC 2002, Milliken *et al.* 2007). The NIRS3 will measure reflectance spectra of asteroid surface in the wavelength range of 1.8 - 3.2 μm . This wavelength region includes features mainly related to OH and H₂O.

The spectral properties of the surface, however, would have different trend to the subsurface, because the surface of asteroids would be exposed to solar wind and micrometeorite. As for the reflectance spectrum of the moon, the absorption feature from 2.8 μm to 3.0 μm was reported in M³ data (Pieters *et al.* 2009). It is thought that the implantation of solar wind proton is one of the causes (McCord *et al.* 2011). The solar wind protons will affect the spectral shape of 3 μm region of air less bodies. Thus we study effect of irradiation of solar wind protons on near-infrared reflectance spectra by laboratory experiment.

We executed the simulation of irradiation of solar wind protons using ion implantation device at the Wakasa Wan Energy Research Center (WERC), Fukui. This device can irradiate H₂⁺ beam with 10 keV in a vacuum (under 1×10^{-5} Pa). The total amount of H₂⁺ was about 10^{18} ion/cm². Three samples were prepared; olivine (San Carlos, Arizona), antigorite (Sangenchaya, Kyoto), saponite (synthetic: Kunimine Industries Co., Ltd.). Antigorite and saponite were sieved between 50 μm and 75 μm and olivine served between 75 μm and 105 μm , and then they were heated for 24 hours at 423 K. They were packed into Cu cups and formed pellets. After irradiated the spectra were measured using FTIR, which resolution was 2.0 cm⁻¹ in wavenumber. We adopted the analysis method of Ichimura *et al.* (2012), which is to compare the reflectance spectra of altered sample, R, with unaltered sample, R₀, to determine the alteration ratio of spectra, R/R₀, without absorption water.

The alteration ratios of irradiated samples were different between minerals. The alteration ratio of olivine showed increasing of broad absorption feature from 2.8 μm to 3.8 μm due to OH/H₂O production. In antigorite and saponite, the alteration ratio, additionally, showed characteristic change related to coupling state of -OH. In the alteration ratio of antigorite, stretching of -OH bonded water molecule (-OH \cdots ^HOH) at 2.77 μm and stretching of -OH \cdots ^HOSi at 2.85 μm was increased conspicuously. On the other hands, the alteration ratio of saponite was changed conspicuously at 2.77 μm .

We think that the difference of the bands which showed conspicuously change is related with structure of minerals. Antigorite have -OH into the crystal. Therefore the irradiated protons broke bonds of Si-O and produced newer hydrogen bonds which are -OH \cdots ^HOH or -OH \cdots ^HOSi. Saponite has H₂O as interlayer water. It would be similarly broken bands of Si-O and produced newer hydrogen bonds which are -OH \cdots ^HOH. These spectral changes can explain same process. These features support that the irradiated protons react with bonds of Si-O in the crystal.

In this study, we showed that the alteration of feature related with OH/H₂O is different from each mineral. Next step, we will examine the other minerals against determination minerals and the amount of water from reflectance spectra.

Keywords: Hayabusa-2, space weathering, solar wind, OH/H₂O, C-type Asteroid, proton implantation

The effect of coexisting iron sulfide on space weathering by nanosecond pulse laser irradiation

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High-velocity impacts of micrometeorites and solar-wind particles change the surface optical properties of airless silicate bodies such as asteroids and the Moon. This process is called "space weathering". Experiments using nanosecond pulse laser confirmed the prediction that the formation of nanometer-size metallic iron particles should cause darkening, reddening and attenuation of absorption bands in visible and near infrared reflectance. The space weathering may explain the spectral mismatch between S-type asteroids and ordinary chondrites.

Previously sulfur depletion from asteroid surface was advocated on the basis of low sulfur abundance on Eros.

Recently on the surface of dust particles from Itokawa's surface returned by Hayabusa, a thin layer containing nano particles of FeS over amorphous zone containing nano iron particles. A 10 micron size FeS crystal is also found in one Itokawa-derived grain.

To examine the effect of FeS on the space weathering, we conducted simulation experiments of the space weathering of silicate-FeS mixture using nanosecond pulse laser irradiation.

Then S is rich in volatility, so we guessed if sulfur has a certain influence on space weathering at the astronomical surface, and the experiments on chondrites with S by using nanosecond pulse laser.

We prepared pellet samples of powdered olivine and pyroxene (45-75 micrometer) mixed with iron sulfide particles (of 10, 20wt%) with same (and smaller) size range. We also prepared olivine pellet samples containing metallic iron particles of 10 to 20 wt%.

We found that the addition of Fe should enhance reddening and also darken near infrared reflectance (about 20% in the case of 10-20wt % FeS), as compared with the case of the addition of Fe.

Although it was space weathering which has so far attracted attention from reddening, such as reddening by weathering in case Fe is contained, in the case where FeS is added, darkening was also seen and it has checked that space weathering became strong. Although existence of nano iron particulates can be considered about reddening, about overall darkening, it is under examination.

The samples were irradiated by nano-second pulse laser.

Keywords: space weathering, iron sulfide, experiments using pulse laser, asteroids, Itokawa



Photometric Properties of (162173) 1999 JU3 in Preparation for JAXA Hayabusa 2 Sample Return Mission

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A near-Earth asteroid, (162173) 1999 JU3 (hereafter 1999 JU3), is a primary target asteroid for Hayabusa 2 sample return mission. We conducted a worldwide campaign to make photometric observations of the asteroid to determine the physical properties. 1999 JU3 is classified into C-type asteroid having a nearly spherical shape and the synodic rotational period of 7.6312 ± 0.0010 hr.

In this presentation, we will report further information about 1999 JU3 determined since last JpGU meeting in 2013. We investigated the magnitude-phase angle relation. We obtained the parameters for IAU H-G formalism, $H = 19.20 \pm 0.12$ and $G = 0.077 \pm 0.011$ (V-band, 550nm), respectively. In combination of our result with infrared photometry, the geometric albedo is updated to be 0.05 (Mueller et al. in preparation), which is typical to but slightly smaller than the average of C-type asteroids in main-belt. We found that the magnitude-phase angle relation has a linear behavior in a wide range of the phase angles (5-80 degree) and show a possible non-linear opposition brightening within the phase angle of < 5 degree. The phase slope is consistent to those of tens-km C-type asteroids, that is, $0.04 \text{ mag degree}^{-1}$. The opposition effect amplitude, $\approx 10\%$ or less, is slightly weaker than that of a precursor C-type mission target body, (253) Mathilde, but the difference seems to reflect the diversity of C-type asteroids. Recently, Shevchenko & Belskaya (2010) reported that $\sim 20\%$ of all studied low albedo asteroids did not show detectable opposition effect. We explore the significance of 1999 JU3 data with remote-sensing devices in terms of the opposition effect.

Keywords: Hayabusa 2, 1999 JU3, Ground-based observations

Observation of geometric albedo of the C-type asteroid by the laser altimeter on Hayabusa-2 spacecraft

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The Japanese asteroid explorer 'Hayabusa2' will be launched at end of 2014, and it will probe the near-Earth C-type asteroid '1999JU3'. In this mission, we have a plan to utilize the laser altimeter (LIDAR) to investigate the distribution of geometric albedo of 1999JU3 at laser wavelength (1064 nm). The LIDAR on-board Hayabusa2 has functions to measure the intensities of sending laser pulse and receiving laser pulse reflected from the asteroid surface in addition to measurement of distance between the spacecraft and the asteroid. We can evaluate the geometric albedo of the 1999JU3 using the measured intensities of sending and receiving pulses.

In this presentation, we will indicate results of the performance tests of the LIDAR and expected accuracy of the albedo evaluated from the results of the tests. We will also describe not only effect of characteristic of the LIDAR but also effects of inclination and roughness of the asteroid surface on estimation of the albedo.

In our study, three types of scientific topics using information of the albedo on asteroid surface estimated from the LIDAR data with other equipment data are considered; they are (1) rock and mineral category of 1999JU3, (2) degree of water content on asteroid surface and (3) variation of asteroid surface caused from space weathering and/or exterior material. We will report prospects to obtain information about these science topics applying the LIDAR which has our evaluated performance.

Keywords: Albedo of Asteroid, C-type asteroid, 1999JU3, Hayabusa-2, Laser Altimeter

Performances of Flight Model of NIRS3: the Near Infrared Spectrometer on Hayabusa-2

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NIRS3: the Near Infrared Spectrometer is one of the candidate scientific instruments which will be equipped on Hayabusa-2 mission. It aims to observe near infrared spectroscopy at the wave length band of 1.8-3.2 micrometer to detect specific molecular absorption lines, including the absorption by hydrated minerals at 3 micrometer, on the target C-type asteroid. The major purpose of NIRS3 is to observe the absorption bands of hydrated minerals in the 3 micrometer band on the candidate target C-type asteroid 1999JU3. C-type asteroids are thought to be mother celestial bodies of carbonaceous chondrites (C-chondrites). C-chondrites have been classified into sub-groups by their composition, organization, and isotope ratio of oxygen. The spectra of C-type asteroids have also been classified into sub-types by their inclination and the existence of absorption bands detected in ground observations. However, the relationship between the sub-groups of C-chondrites and the sub-types of C-type asteroids has not been clarified due to the effects of solar radiation and space weathering. Therefore, we will directly observe the surface of a C-type asteroid without the terrestrial atmospheric absorption in the 3 micrometer band using NIRS3. Detecting younger terrain by global mapping of the asteroid and the ejecta of new crater by the Small Carry-on Impactor (SCI) will also provide the spectra of surface less affected by space weathering. To estimate the quantities of the hydrated minerals with accuracies of 1 to 2 wt%, we designed the NIRS3 system to have a signal-to-noise ratio (SNR) exceeding 50 at 2.6 micrometer for global mapping.

The ground tests for NIRS3 flight model started in 2013. Results of the flight model tests implied that the dark current at the InAs sensor is much lower than that of the engineering model which improves SNR. The projected on-board SNR was confirmed to be sufficient during the one-year observation period of 1999JU3 assuming the asteroid surface temperature estimated from the heliocentric range and solar phase angle. The SNR exceeds 300 after 2.5 ms integration and 1024-stacking at the home position observations. The data obtained after the vibration tests and thermal-vacuum tests indicate that NIRS3 is sufficiently durable for the launching and on-orbit environments. The observed spectra for samples of serpentine, olivine, and C-chondrites (Murchison, Murray, and Jbilet Winselwan) demonstrated that the derived reflectances are almost the same as those obtained by Fourier-transform infra-red (FTIR) spectroscopy. These design results show that NIRS3 has sufficient performance for scientific objectives.

Keywords: Hayabusa-2, asteroid, 1999JU3, NIRS3, near infrared, spectrometer

Thermal Infrared Imager TIR on Hayabusa2: Instrumentation and Ground Calibration

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Thermal Infrared Imager TIR onboard Hayabusa2 is to map thermo-physical properties of Near-Earth C-class asteroid (162173) 1999JU3 through thermal imaging. Scientific significance must be placed on physical properties of asteroids as well that imply the planetesimal formation in solar nebula and its mechanical evolution to current small bodies, although planetary material science is often more focused in small body missions.

In the typical solar system evolution scenario, very fluffy porous bodies are formed in solar nebula and then become denser due to high-speed collision and thermal metamorphism. Some C-class asteroids are less dense, implying a highly porous assembly of densely compacted rocks or a loosely bound rubble-pile of porous rocks and soils. Those features will be identified by thermo-physical properties derived with TIR. Some C-class asteroids must have experienced dehydrated process whose clues might be found as veins or grooves on the asteroid. Those features are expected to be investigated by TIR. Granular flows which were found on asteroid Itokawa and ejecta sediments around impact craters will be measured by TIR as different thermal inertia zones because they have smaller particle size or higher porosity. Floating boulders (or moons), surrounding dust or vapor clouds ejected from asteroid surface could be detected by TIR if they exist sufficiently. Furthermore, on-site TIR observation will contribute to more confident and accurate determination of asteroid thermo-physical properties by ground observation.

TIR is a thermal infrared imager using two-dimensional micro-bolometer array, which has 328 x 248 effective pixels, 16 x 12 degrees field of view, and 0.05 degree per pixel, so that pixel resolution is 20m when observed from 20km altitude Home Position (HP), and less than 1m from 1km altitude covering 280m x 210m. The imaging feature is suitable for obtaining asteroid global feature from HP and investigating local geological context before and after sample collection. Hayabusa2 will observe asteroid 1999JU3 at the heliocentric distance from 0.96 to 1.42 AU and the dayside surface temperature is estimated -40 to 150 °C assuming the albedo is 0.05 and emissivity is 0.90 to 0.95. Detection range of TIR is 8 to 12 μm, which is best for observing thermal radiation from asteroid.

We have calibrated TIR performance for the target temperature ranging from -40 to 150 °C. Goal is to construct the calibration curves for each pixel by 3 °C absolute temperature as well as 0.3 °C NETD. The apparatus for TIR calibration are the vacuum chamber for cold target and the clean-booth for hot target, with adjusting the optics and mounted panel temperatures. It is ideal that a single OFPN (Onboard Flat Pattern Noise) data is applicable for all the temperature range. Now efforts have been taken to improve its performance by interrelation between cold and hot calibration cases, adjusting bias levels due to different thermal energy input to detector, as well as geometric calibration. Instrumentation and results of calibration for TIR will be reported in detail.

Keywords: asteroid, Hayabusa2, thermo-physical property, Thermal Infrared, bolometer, planetary exploration

Relationship between Regolith Particle Size and Porosity on Small Bodies

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Planetary small bodies are covered by a particulate layer called regolith. The particle size and porosity of the regolith surface of small bodies are important physical properties. The responses of the surface to solar irradiation are dependent on the particle size and porosity. The particle size and porosity have influences on the dynamic responses of the surface, such as cratering efficiency. By Apollo missions, the particle size was directly measured and estimated the mean porosity of the regolith 51% (Mitchell et al., 1974). The near-surface bulk porosity of asteroid was estimated using ground-based radar data to have a mean of $51 \pm 14\%$ (Magri et al., 2001). The angular width of opposition surge in optical reflectance was interpreted in terms of porosity and particle size distribution : surface porosities of S-class asteroids were ranging from 40 to 80 % (Hapke, 1986; Domingue et al., 2002).

An empirical relationship between porosity and the ratio of the magnitudes of the interparticle force that was estimated as the capillary force and gravity which act on a particle was presented by Yu et al. (2003). The porosity was measured for the particles in the loose packing state and different porosities were interpreted as due to the difference of particle size. In this study we assume that the van der Waals force is predominant in the interparticle forces. A model formula of the van der Waals force in which the effect of adsorbate molecules is taken into account by a parameter is defined as

$$F_v = AS^2 r / 48 \Omega^{-2} \quad (1)$$

where A is Hamaker constant, r is particle radius, Ω is diameter of an O^{-2} ion, S is cleanliness ratio which shows the smallness of a number of the adsorbate molecules (Perko et al., 2001). It was shown that cleanliness ratio, S, is approximately 0.1 on the Earth, and is almost unity in the interplanetary space. In addition to the data of the several past studies, our own measurement result of micron-size fly ash particles in atmospheric condition.

We calculate F_v of all data using Eq.2, and obtain a revised relationship between porosity and the ratio RF of the magnitudes of the van der Waals force and gravity F_g , $R_F = F_v / F_g$. An empirical formula used in the previous study (Yu et al., 2003),

$$p = p_0 + (1 - p_0) \exp(-m R_F^{-2}) \quad (2)$$

is applied to fit the data, where p_0 , m and n are constants. Substituting Eq.1 to Eq.2 yields,

$$p = p_0 + (1 - p_0) \exp\{-m(AS^2 / 64\pi \Omega^{-2} \rho g r^2)^{-n}\} \quad (3)$$

where ρ is particle density and g is gravitational acceleration.

We apply Eq. 3 to the conditions of small bodies' surfaces to derive the relationship between particle radius and porosity. For example, we obtained the relationship for asteroid 25143 Itokawa surface. The particle size of Itokawa is ranging from millimeter to centimeter in the area of fine particles, smooth terrain of the Muses Sea (Yano et al., 2006). The result shows the range of porosity would be 0.55-0.8. Similarly, we can calculate the above relationships for other small bodies.

Gundlach and Blum (2013) estimated the particle size of small bodies by using the thermal inertia data and a heat conductivity model for regolith. By combining the relationship described for Eq.3 with those of Gundlach and Blum (2013), we can estimate the particle size and the porosity of regolith for the small bodies simultaneously.

Keywords: asteroid, regolith, porosity

How to detect a small crater produced by Small Carry-on Impactor (SCI) using Thermal InfraRed Camera (TIR)

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In Hayabusa-2 mission, a crater will be formed on the surface of a C-type asteroid 1999JU3 using Small Carry-on Impactor (SCI) and the crater should be quickly detected from the mother ship. The detection, however, will become difficult when the crater is very small with a diameter of only 30 cm, near to the resolution limit of on-board cameras. On the other hand, Thermal InfraRed Camera (TIR) mounted on Hayabusa-2 has a possibility to detect such a small crater even if the crater size is sub-pixel of TIR resolution, because the temperature on the surface of a small crater is expected to be different from that around the crater. We, therefore, have started examination about the possibility and method to detect a SCI-formed small crater using TIR. In this presentation, we introduce the basic idea and the preliminary results of our modeling.

Keywords: Hayabusa-2, Impact, SCI, TIR, crater thermal model, asteroid

Hayabusa 2/SCI: calibration impact experiments

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SCI (Small Carryon Impactor" boarded on "Hayabusa 2" is a hollow Cu sphere with a mass of 15 kg, a diameter of 15 cm, which will impact a surface of asteroid 1999JU3. To estimate the conditions of the surface of the asteroid, such as composition and structure, we should investigate the results of the impact experiments with similar projectiles and various targets. We carried out impact experiments with gypsum and basalt targets and small hollow projectiles accelerated by a two-state light-gas gun at ISAS/JAXA, and sand targets and real scale projectiles at Kamioka. We report a summary of the results of these experiments.

Keywords: Hayabusa 2, Small Carryon Impactor, Impact experiments

Impact crater formation on quartz sand: the effect of projectile density on ejecta velocity distributions

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Introduction : Regolith formation and surface evolution on asteroid are caused by high velocity impacts of small bodies. The ejecta velocity distribution is one of the most important physical properties related to the crater formation and it is necessary to reconstruct the planetary accretion process among planetesimals. The surface of small bodies in the solar system has a various property on the porosity, strength and density. Therefore, the impact experiment on the target with the various properties is necessary to clarify the crater formation process applicable to the small bodies in the solar system. However, there have not enough studies on the effect of projectile density on the ejecta velocity distribution. Therefore, we would try to determine the effect of projectile density on the ejecta velocity distribution using 8 projectiles with different density by means of the observation of the each ejecta grain.

Experimental method: The cratering experiment was made by using a vertical type one-stage light gas gun (V-LGG) set at Kobe Univ. We used 3 types of targets: that is, they are the 100micron-glass beads target (porosity 37.6%), the 500 micron-glass beads target (porosity 37.6%), and 500-micron quartz sand (porosity 44.7%). These granular materials were put into the stainless steel container with the diameter of 30cm and the depth of 11cm. The target container was set in a large chamber with the air pressure less than 10^3 Pa or 10^5 Pa. The material of the projectile that we used was a lead, a copper, an iron, a titanium, a zirconia, an alumina, a glass, and a nylon (1.1 - 11.3 g/cm³), and it had a diameter of 3mm and was launched at the impact velocity (v_i) of 24 to 217m/s.

We made an impact experiment using 8 types of projectiles on the 500-micron quartz sand target and observed each ejecta grain by using a high speed digital video camera taken at 2000-10000 FPS. Then, we measured the ejection velocity and the initial position of each grain. We successfully obtained the relationship between the initial position and the initial ejection velocity or ejection angle for the quartz sand grains.

Result: In (Eq.1), μ is proportional to density of projectile in the range less than 6 g/cm³. (Eq.2)

$$v_e/v_i = a(x/R)^{(-1/\mu)} \quad (1)$$

, where v_e is an ejection velocity of grain, x is the initial position of ejecting quartz sand grains and R is the crater radius.

$$\mu = 0.05\rho + 0.38 \quad (2)$$

Moreover, we obtain the relation between crater size and projectile density.(Eq.3)

$$[R * (\rho t/m)^{(1/3)}] = 11 * [\rho t / \rho p]^{0.096} \quad \text{Eq(3)}$$

The ejection angle of quartz sand grains is also obtained. For all projectiles, the grain that ejects from near impact point have high ejection angle and the more distant that grain ejects from, the lower the ejection angle is. There are no effect of projectile density.

The obtained empirical equation between the ejection velocity and the initial position is as follows Eq(4),

$$v_e/v_i = 1.5 * 10^{-3} (x/R)^{-1.8} \quad (0.3 < x/R < 0.9) \quad (4)$$

Impact cratering experiments on granular slopes

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Impact cratering is an important process for the evolution of planetary surfaces. Many experiments of impact cratering into granular media have been conducted to understand its basic physics (e.g., Walsh et al., 2003, de Vet and Bruyn, 2007). These studies have shown that as impact energy becomes larger, simple craters transform into complex craters. In addition when gravity is more important than the target strength, the crater diameter increases in proportion to the 1/4 power of the impact energy. Peculiar craters on asteroids have been discovered in recent planetary missions. Some craters on asteroids are likely to be in the transitional regime between the gravity and strength dominated regimes. In order to better understand how such craters may have formed, we have recently conducted experiments around the transitional regime (Takita and Sumita, 2013). In addition, because asteroids have large topography relative to its size, some craters seem to have formed by impact on slopes (Jaumann et al., 2012). However, since most previous experiments were performed on horizontal targets, impact cratering on slopes is still poorly understood. In this study, we report the results of experiments to understand the effects of slope angle on crater formation.

The experiments in this study were performed by dropping spherical projectiles into an inclined granular target. Projectiles are made of stainless steel (density: 7.70g/cm³) and their diameters are 11.0mm and 22.2mm. We use sand (mean diameter of 0.204mm, density of 2.66g/cm³, angle of repose of 37.2°, volumetric packing fraction of 0.56) for the granular target. The slope angle ϑ was 0°, 11°, 16°, 22°, 34°. Impact energy E was 0.055, 0.073 and 0.58 J. Crater formation process was recorded by a high speed camera. The 3-D topographies of the granular target before and after the impact were measured by a laser displacement meter which we move by a stepping motor. Resolution of the laser displacement meter is about 0.024mm for vertical direction, and about 0.1mm for horizontal direction. The stepping motor moves at 0.2mm intervals. We obtained the vertical displacement of the granular target caused by the impact by subtracting the topography of the target before and after the impact. We defined the maximum vertical displacement as the crater depth, the length of the crater in the dip direction projected to the horizontal plane as the crater length, and the width in the strike direction as crater width.

We find that the part of the crater rim disappears when ϑ is larger than about 20°. From studying the images recorded by high speed camera, we find that when ϑ becomes large, the slope above the impact point collapses and this causes the partial disappearance of the rim.

Comparing with the Vestan craters (Jaumann et al., 2012), we find that both laboratory and Vestan craters have common asymmetric shape with ejecta spreading down slope and the location of the maximum depth also shifted towards downslope. We find that the crater depth decreases with ϑ . On the other hand, crater length and crater width remains unchanged from 0° to 22° and increased when ϑ was larger than 22°. As a result, the depth / length ratio decreased from 0.25 to 0.05 with the increase of ϑ .

We also analyzed the impact energy dependence of the crater scales and fit them by a power law relation $AE \propto \alpha$. We find that with the increase of ϑ , both the prefactor A, and the exponent α changes. This shows that the scaling law obtained for the horizontal granular target cannot be directly applied to impacts on slopes.

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Keywords: impact cratering, granular matter

Size Dependence of Impact Disruption Threshold of Iron Meteorites

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Iron meteorites and some M-class asteroids are generally understood to be fragments that were originally part of cores of differentiated planetesimals or part of local melt pools of primitive bodies. On these primitive bodies and planetesimals, a wide range of collisional events at different mass scales, temperatures, and impact velocities would have occurred between the time when the iron was segregated and the impact that eventually exposed the iron meteorites to interplanetary space.

In this study, we performed impact disruption experiments of iron meteorite specimens as projectiles or targets at room temperature to increase our understanding of the disruption process of iron bodies. Our iron specimens (as projectiles or targets) were almost all smaller in size than their counterparts (as targets or projectiles, respectively), with one exceptional shot. Experiments of impacts of steel specimens were also conducted for comparison.

The fragment size distribution of iron material is different from that of rocks because in iron fragmentation, a higher percentage of the mass is concentrated in larger fragments, probably due to its ductility. The largest fragment mass fraction is dependent not only on the energy density but also on the size of the specimen. We show the largest fragment mass fraction has a power-law dependence to initial peak pressure normalized by a dynamic strength, which is defined to be dependent on the size of the iron material.

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Keywords: Small Bodies, Iron Meteorite, Impact Process

Cratering chronology models for the near-Earth asteroid 1999 JU3

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The Japanese asteroid explorer Hayabusa-2, that is scheduled for launch in 2014, will observe a near Earth C-type asteroid 1999 JU3 and will return to Earth with its samples. In this study, we model cratering and crater erasure processes on 1999 JU3 to provide an age estimate for 1999 JU3 based on high-resolution images that will be obtained by Hayabusa-2. The impact rate on 1999 JU3 is calculated from population models of main-belt asteroids (MBAs) and near-Earth asteroids (NEAs) and the average collision probabilities for the main belt and for NEAs. By converting the impactor size to the size of consequent crater based on crater scaling law and the average collision velocities for the main belt and for NEAs, the cratering rate on 1999 JU3 is calculated. For comparison, we use two population models of asteroids, two crater scaling laws and five conditions of surface of 1999JU3. In addition, two crater erasure processes, seismic shaking and saturation of craters, are considered in our model. As a result, our models indicate that age estimate of 1999 JU3 primarily depends on crater scaling laws used and assumptions of surface conditions of 1999 JU3 rather than population models of asteroids.

Scaling analysis of cavity morphology and disruption threshold for highly porous targets

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The morphology of the cavity formed by an impact can be dependent on parameters such as porosity, bulk density and strength of target bodies and size, bulk density, strength and impact velocity of impactors. Laboratory impact experiments have been conducted and cavity diameter and depth have been studied in previous studies in which highly porous targets up to 60% in porosity were used (e.g. gypsum, sintered glass and snow). Based on recent spacecraft missions and ground-based observation, it is shown that small bodies have even higher bulk porosities up to 86% (Consolmagno et al., 2008). Experiments using further highly porous targets are necessary for understanding collisional evolution of such bodies in the formation period. We study cavity morphology of highly porous targets and compile the result with previous studies. We also study disruption threshold of targets and compile the results.

We prepared porous targets with three different porosities, which have porosity of 94%, 87% and 80% (Okamoto et al., 2013). Various projectiles with different density and strength were used; titanium, aluminum, stainless steel and nylon spheres of 1 and 3.2 mm in diameter, and basalt cylinder of 3.2 mm in diameter and 2.0 mm in height. The impact velocity was ranged from 1.7 to 7.2 km/s.

The track was long and thin, in carrot-shape, when the projectile was intact, while it was short and thick, in bulb-shape, when the projectile was fragmented. We report the results of bulb-shape cavity in this presentation.

We apply crater scaling law in strength regime for maximum diameter and entrance hole diameter of the cavity. We compile data of previous studies and ours to obtain empirical relationships. A correlation is shown between the distance from entrance hole to maximum diameter and characteristic depth where initial kinetic energy of projectile becomes $1/e$. Characteristic length is a function of drag coefficient. Since the drag coefficient depends on the fragmentation degree of projectile, it is shown that disruption of projectile affects the distance from the entrance hole to the maximum diameter.

Volume, maximum diameter and depth of cavity during its growth were measured on flash X-ray images. Normalized cavity volume and time (Schmidt and Housen., 1987) are applied for the analyses of the results. They have a power law relationship. The power law index for shots with larger density ratio (target density / projectile density) is slightly larger than those with smaller density ratio. Similarly power law relationships between normalized depth of cavity, maximum diameter and normalized time were obtained, respectively. The power indices are consistent of the power index determined for the normalized volume and time. Thus the growth of cavity volume can be explained by growth of maximum diameter and depth.

The threshold energy density for disruption Q^* is defined by energy density leading to a largest remnant having half the mass of the target. Q^* increases slightly with porosity of the targets. Q^* for the targets with equal diameter-height ratio is slightly larger than those with longer shape (diameter / height = 0.5). In this presentation, we will discuss scaling of Q^* with various previous study.

Keywords: impact experiment, small body, crater, catastrophic disruption

A consortium study of the largest particle of Hayabusa-returned samples

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Hayabusa-returned samples retrieved by the Hayabusa spacecraft were already distributed and investigated in the preliminary examinations and international A/Os. Through the investigations, several insights have been obtained on the formation process of 25143 Itokawa and surface processes occurred on the asteroid, as well as the confirmation that the particles were certainly regolith particles from there [1-6].

There are several particles, however, which have not been distributed for those examinations because of their rare features appeared in the initial description done by extraterrestrial sample curation team (ESCuTe) of JAXA. Though those particles will provide us further information for Itokawa and evolution of the asteroid, the samples should be investigated as carefully as possible to reduce consumption and damage of the samples. RA-QD02-0136-01 is currently the largest sample of Hayabusa-returned samples recovered from the sample catcher. The major axis of the particle r_a is around 310 μm , and weight of the particles is estimated around 20 μg , assuming the volume $V = 4/3\pi r_a r_b r_c \sim 4/3\pi/(2\sqrt{2})r_a^3$ and density of the particle as 3.4 g/cm^3 , where r_a , r_b and r_c are major axis, semi-major axis and minor axis, respectively. The RA-QD02-0136-01 is mainly composed of Ca-rich pyroxene, and also contains minor amount of low-Ca pyroxene, olivine, plagioclase and troilite. In order to maximize scientific gain from the Hayabusa-returned samples, we decided to investigate this particle by constructing a specific consortium for the analysis.

6 teams were joined the consortium, and following analyses were proposed.

M. Uesugi and A. Tsuchiyama : CT observation of 3D texture and surface observation

J. Park and Rutger team : Ar age analysis to determine the shock ages

K. Nishiizumi and K. Nagao : Analysis of cosmogenic nuclides to estimate the erosion rate of Itokawa

N. Kita and D. Nakashima : O-isotope analysis of high-Ca pyroxenes and plagioclases by SIMS

F. Langenhorst : TEM observation of the dislocations for estimating shock effect by small impacts

L. Keller : TEM observation of the space weathering rims

Currently, we prepare the sample cutting method, and evaluate effect of the cutting and sample transfer on the subsequent analysis. We will report the sequential flow of the analyses and results of the rehearsals.

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Present status of a consortium study of a NaCl bearing Itokawa particle

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Hayabusa spacecraft returned samples from S-type Near-Earth Asteroid (NEA) Itokawa in June 2010. After the return, Extraterrestrial Sample Curation Team (ESCuTe) of JAXA have recovered particles from a sample catcher of Hayabusa, and more than 400 particles initially described have been presented in public (Yada et al., 2014). Among them, some types of particles having rare features are assigned to consortium studies, because they are supposed to be applied by multiple proposals so that they could not be distributed. Members of the ESCuTe would lead consortium studies to ask for research plans from worldwide researchers, discuss a research flow for the particles with the researchers to maximize their scientific gain, and push the plan forward.

One of the consortium studies is for a silicate particle bearing NaCl. The sample ID RA-QD02-0129 is 40 micron in size, mainly composed of silicate similar to plagioclase in chemical composition, and have euhedral NaCl particles of 3-5 micron in size on its surface. This is the only silicate particle bearing NaCl among those initially described so far.

In planetary material samples, NaCl is very rare and unique component. It has been discovered only in Monahan and Zag H chondrites among all ordinary chondrites so far. Trace of extinct ¹²⁹I was discovered in the NaCl in the meteorites, which means that it should have formed in their parent body(ies), H chondrite or other, in the early solar system and involved in the meteorites in some processes afterward (Zolensky et al., 1999; Whitby et al., 2000). The formation of NaCl should be linked with water in their parent bodies, so it could provide important information about the origin of its parent body. Additionally, water and salt should be closely linked with organic material revolution and might provide interesting suggestion for the origin of life.

One of the most important purposes of this consortium is to prove extraterrestrial origin of the particle (silicate) and NaCl. And next step is to clarify whether its parent body would be Itokawa and/or LL chondrite parent body or other ones. What can prove the extraterrestrial origin of the NaCl is (1) discovery of solar flare tracks in the NaCl, (2) detection of solar wind He on its surface, (3) presence of space weathering layer on its surface. Transmitted electron microscope (TEM) observation for ultrathin section of the NaCl made by focused ion beam (FIB) system will be necessary for (1) and (3), and a laser ionization mass spectrometer is necessary for (2). In the research plan so far, terrestrial NaCl with instrumentally implanted He and NaCl in Monahan meteorite will be prepared for the rehearsal analyses to establish analytical techniques and then we will try the real particle.

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Keywords: Itokawa, asteroid, NaCl, consortium

Three-dimensional structures of aggregate-type Itokawa particles

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Regolith particles, which should have been formed by fragmentation and abrasion due to impact and impact-induced vibration, exist on surfaces of minor bodies. Their formation processes and causes will tell us physical and chemical condition of the surfaces of the minor bodies and their parent bodies.

Hayabusa spacecraft returned samples from S-type Near-Earth Asteroid (NEA) Itokawa in June 2010 (Abe et al., 2011). Among the returned regolith particles, we focus on aggregate-type particles composed of tiny component grains to analyze their three-dimensional (3D) structure in order to clarify their formation processes and environments.

In this study, we chose five aggregate-type Itokawa particles, which are 55-128 micron in size, assigned for JAXA's research among more than 400 particles initially described. They were firstly analyzed by synchrotron X-ray computed tomography (CT). Because they might be fragile, they were placed inside tiny, upside-down pyramid-shaped sample holder made of SiN. They were irradiated in beam line (BL) 47XU of SPring-8 by photon light source of both 7keV and 8keV in energy and obtained their transmitted X-ray images. The obtained images were calibrated by computers, and their 3D structure could be reconstructed. Mineral species in the particles could be estimated by the different X-ray adsorption factors of different energy X-ray in each of the minerals.

The obtained data are under calibration so far. We will clarify their 3D structure and discuss about their formation processes. Additionally, we are planning to make their ultrathin sections by focused ion beam fabrication system (FIB) and confirm detailed structures between the tiny component grains with transmitted electron microscope (TEM).

References:

- Abe M. et al. (2011) LPS XLII, Abstract #1638.
- Tsuchiya et al. (2013) GCA 116, 5.

Keywords: Itokawa, asteroid, aggregate, three-dimensional structure, synchrotron CT

Consortium Study of Troilite and Phosphate-bearing HAYABUSA Returned Samples

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HAYABUSA returned samples have been shown as Itokawa origin by the preliminary examinations (e.g. Nakamura et al., 2011). Furthermore, international AO study has begun last year, and a formation process of asteroid Itokawa is becoming revealed.

HAYABUSA returned samples are described initially by JAXA Extraterrestrial Sample Curation Team (ESCuTe), and a sample catalogue is prepared based on the data of initial description (e.g. Yada et al., 2014). More than 400 returned samples were described so far. These described samples are classified into four categories. A number of samples of each category to be distributed for international AO are decided based on the sample catalogue. But it is difficult to distribute such samples with rare characteristics in composition, mineralogy, structure, or size, although those samples should maintain scientifically important information.

Therefore, in JAXA, ESCuTe started to organize the consortium studies in order to obtain the scientific information as many as possible from these samples (e.g. Yada et al., 2014; Uesugi et al., 2014). In this paper, we report the research plan for the particles mainly composed of FeS and which contain phosphate minerals.

RA-QD02-0245 composed mainly of FeS (40 micron) with smaller attached olivine and pyroxene grains. This particle was analyzed by X-ray CT at SPring-8 for 3D texture without atmosphere. Two ultra-thin section will be made from the edge of this particle by FIB. The ultra-thin sections will be examined by TEM in detail for space-weathering effect on FeS surface. The main mass of this particle will be analyzed for chemical composition. Especially, the siderophile element composition gives us information on the formation process of Itokawa parent body.

Some particles including phosphate mineral were found by the initial description. Because Ca-phosphate tends to be enriched in incompatible elements such as REEs, Th and U, we propose the investigation of U-Pb systematics using Nano-SIMS in order to study the history recorded in the phosphates. We will perform the U-Pb dating of the phosphates as many as possible and aim to understand the thermal history of Itokawa parent body such as crystallization age and the catastrophic collision if recorded.

Keywords: HAYABUSA, Itokawa, troilite, phosphate, siderophile element, U-Pb dating

Asteroid Shape Reconstruction by Structure-from-Motion Method with Bundler and PMVS2

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Here we report results on application of open source shape reconstruction tools to an asteroid image data set. We test two tools that cooperatively work to reconstruct an object shape from images. Bundler is an open source implementation of a stereo shape reconstruction method called Structure from Motion (SfM). PMVS2 gives a more dense shape model, since Bundler only estimates 3D locations of a limited number of feature points. A global image data set of the asteroid Itokawa taken by AMICA on board the Hayabusa spacecraft is employed to our test data set. An obtained model satisfies that most requirements from the Hayabusa-2 mission on the shape model that used during the mission phase. An important advantage of these new tools compared to previous ones is its short processing time. This advantage will be effective in quick evaluation of observation data and decision making during the mission operations. More precise and high definition models will be reconstructed by other method such as shape-from-shading or photometric stereo.

Keywords: Asteroid, shape reconstruction, bundler, PMVS2, Structure-from-Motion, Hayabusa-2

Feature matching in planetary images with multiple spatial resolutions by using SIFT algorithm

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This study uses feature matching in planetary images with multiple spatial resolution. To know where lower altitude images are taken in high altitude images is performed based on images without the position and attitude of spacecraft in this study. The lower altitude images of AMICA on-board the Hayabusa spacecraft, asteroid probe are found as a correspondence of image features (keypoint) in higher altitude images. We adopted the Scale Invariant Features Transform (SIFT) to represent a kind of key-point of image for image feature matching. In generally, the SIFT keypoint is robust to scale transition, change of lighting condition, parallel displacement, and rotation of image, so this keypoint is suitable to feature matching of planetary image which contains of scale and rotation between different images. As a result, for the improvement of accuracy of feature matching, it is important to have a preprocessing of image (e.g., equalizing).

Keywords: planetary image, SIFT, feature matching, AMICA

Grooves on Phobos: Spatial distributions and their implications to the formational mechanism

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Grooves are roughly-defined as trough-like depressions commonly found on asteroids and small satellites. Among the various features categorized as grooves, the most typical are considered as those found on the surface of Phobos. Grooves on Phobos are the most extensively-existing geological features on the satellite, and thus are documented and discussed for years. However, their formational processes remain controversial. Previously-proposed hypotheses are (1) grooves are some kind of intentional fractures and (2) they are results of impacts caused likely by linearly-aligned impactors ejected from Mars.

Former hypothesis has difficulty in explaining the geographical distribution of grooves (Murray 2011). In fact, because of this difficulty, Murray (2011) concluded that the latter (i.e., secondary impactors derived from Mars) could only be the reasonable explanation for the observed characteristics of grooves on Phobos, including their morphological features, distributions, and hemispheric coverage. Nevertheless, Ramsley and Head (2013) recently showed that, in order to form grooves well organized as those found on Phobos, each of fragments ejected from Mars should have no relative velocity, which is difficult to be achieved for ejecta from Mars. They also showed that most grooves on the northern hemisphere cannot be formed as secondary impacts from Mars because the impactors ejected from Mars do not impact in the directions normal to the equatorial plane of Phobos. Therefore, neither hypothesis remains satisfactory to explain the observational facts.

We carefully reevaluate previous hypothesis based on recently-acquired data, which are partly not available at the time of previous studies. We scrutinize all of the high-resolution images obtained so far to map them out on a numerical shape model. As a result, we identify 488 grooves, whose spatial distributions are precisely mapped three dimensionally. We newly find that each of grooves is always aligned on a certain plain even though it sometimes appears to be an undulating curved depression. We consider this strongly indicates that a groove is a result of a series of impacts of aligned fragments.

We statistically study the angle between the equatorial plane of Phobos and the plane, which contain each groove and find that the distributions of the angles have three peaks at 25, 90 and 155 degrees (hereafter we call A, B, and C type, respectively). Most of the B type grooves exist on the northern hemisphere.

To explain our mapping results, we propose a new hypothesis for the formation of Phobos as follows: (1) An asteroid of a collection of smaller fragments held together by self-gravity in the form of a rubble-pile is pulled apart and stretched straightly by tides during a close approach to Mars; (2) The asteroid (now separates into a train of fragments) is caught by the Mars gravity and revolves around Mars; (3) Every time it revolves around Mars, a part of the fragments hit Phobos and form a lineated depression, which is observed as a type A or C groove; (4) When the eccentricity of the impactor becomes low until the overlapping the trajectory of Phobos, type B grooves are formed.

Our hypothesis is along the idea that grooves are formed by aligned impactors as proposed by Murray (2011) but essentially different in the origin of the fragments, which can resolve the difficulty pointed out by Ramsley and Head (2013). Not only that, our hypothesis has advantage of completely satisfying both the morphological and geographical characteristics of grooves on Phobos. Furthermore, our hypothesis can also explain the deficiency of grooves on Deimos.

Reference

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- [2]Ramsley, K.R., James, W. H., 2013. *Planetary and Space Science*, 69-95

Keywords: Phobos, groove, Mars, tidal-disruption, impact

Visible wavelength spectroscopy of sub-km-sized Near-Earth Asteroids with low delta-v

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We present a unique data set of the taxonomic type of near-Earth asteroids (NEAs) accessible with available spacecraft.

The research on NEAs has entered a new phase thanks to sample-return space explorations together with state-of-the-art large ground-based telescopes. We made observations of twelve asteroids with Subaru, GEMINI-North, GEMINI-South and Okayama 188cm telescopes. They have low delta-v orbits with potential to be investigated by manned/unmanned spacecraft. Also, ten sub-km-sized bodies are included in them, and are one of remarkable characteristics in terms of an evolutionary scenario.

We find that eleven asteroids are classified as S-complex and one asteroid as V-type. Most S-complex asteroids (eight out of eleven, ~70%) have spectra similar to subgroups of Q or Sq-type, suggesting that these objects are less matured against space weathering.

In this presentation, we show their spectra and discuss dominance of S-complex asteroids based on the previous research.

Keywords: asteroid, visible spectroscopy, taxonomic classification

Development of a wide-band optical filter optimized for deep imaging of small solar-system bodies

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We developed a newly designed wide-band optical filter and evaluated its performance. It is optimized for deep imaging of small solar-system bodies. The new filter, which we denote as Wi , is designed to reduce contamination by light pollution from street lamps, especially strong mercury and sodium emission lines. For the reasons that (1) much of artificial light pollution concentrates in the V band, (2) the photon numbers peak at a wavelength of 6350 \AA in the spectrum of sunlight, and (3) many asteroids have their peak/plateau reflectance at around 7000 \AA in the optical range, the new filter's cut-on wavelength is set to 5880 \AA by using an OG590 Schott color glass filter. On the other hand, the cut-off wavelength, which is achieved by a short-pass interference coating, is set to 9380 \AA in consideration of worst of the OH night sky emission and the atmospheric water vapor absorption band at 9400 \AA .

Compared with the use of a commercially available long-wave cut wide-band filter (W filter, $4900\text{-}9100 \text{ \AA}$), the sky brightness is 10-20 % reduced by the Wi filter under bright-sky conditions by not only artificial light pollution but scattered moonlight. In the detection of asteroids, the detected total flux of an asteroid through the Wi filter has been 3% larger than that through the W filter, though the width of the Wi filter response function is 16% narrower than that of the W filter. By using the Wi filter, the S/N ratios in the detection of asteroids were improved by about 6%, on average, compared with the use of the W filter, and the improvements were slightly larger in a brighter sky. The use of the CCD with high sensitivity at longer wavelength, such as the back-illuminated, fully-depleted CCD, will show a larger improvement in the S/N ratio by using the Wi filter.

Reference:

Wide-Band Optical Filter Optimized for Deep Imaging of Small Solar-System Bodies,
Okumura *et al.* Publications of the Astronomical Society of Japan, **64**, 47 (2012)

Keywords: optical, small solar system body, light pollution, wide-band filter

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Prediction of Phoenicid in 2014

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Phoenicid appeared in 1956 is a meteors yielded by the comet 289P/Blanpain founded in 1819. We calculrated a prediction of Phoenicid in 2014.

Comet Blanpain has a mean motion resonance of 9:4 with Jupiter. Therefore Phoenicid has 95 year cycle. The next big apparition will be in 2051.

Keywords: Meteors

Solidified and mixed materials on Asteroid body

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The results of the present study are summarized as follows:

1) Study of the Asteroids provides characteristic formation processes of primordial terrestrial and extraterrestrial celestial bodies.

2) Identification of crystalline solids are almost similar between the Asteroids and Earth, though the Asteroid rocks might be formed by similar formation processes of terrestrial rocks based on the crystalline parts. However, extraterrestrial Asteroids show irregular mixtures of multiple states solidified amorphous solids.

3) Formation of non-spherical Asteroid body formed mainly by impact-related melting process is observed as heterogeneous and irregular distribution of impacted grains.

4) Local fluid-bearing depositions irregularly distributed on the surface and interior of the Asteroids might be based on storages on the interior formed by solidified mixtures of multiple states triggered by impact process on the Asteroids.

5) Different processes of solids between the Asteroids and Earth can be observed silica Si-O frameworks which can be obtained by the ion bombardment experiments. Crystalline rocks with hard silicate structures on Earth show higher ion-peaks of alkali ions (Na, K and Ca etc.), whereas solid-aggregates of the Asteroids show higher ion-peaks of Si and Al ions which are relatively destroyed by ion bombardments.

6) Ion-peaks by the sputtering of terrestrial impact-breccias are clearly higher than those of the Asteroid meteorites, which the main differences are not rock textures of breccias but atomic bonding of slow or rapid cooling process.

7) The air- and water-less Asteroids with solidified materials with multi-states are formed from nano-grains to macroscopic rocks by impact-related evolution process,

8) The primordial planet Earth with remained heterogeneous surface by impact-related process is considered to be cyclic system of three material states (air, liquid and solid) with macro-life activity which is formed by huge production from the interior triggered by huge collision process of the giant impact. On the other hand, the Asteroids without global cyclic changes of three materials states, microscopic quasi life-like materials might be locally found (mainly by high-resolution electron microscopy on in-situ or returned samples finally).

9) It should be avoided to collect artificial impacted samples, because irregular mixtures of solidified amorphous solids from vapor and liquid states are easily destroyed to be escaped to be exaggerated solids with less volatiles.

Keywords: Asteroids, solid aggregates, amorphous materials, fluid, ion bombardment run, micro quasi life-like materials

The Origin of The Moon and The Earth in Multi-Impact Hypothesis

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¹SEED SCIENCE Lab.

Origin of the moon and the earth in the multi-impact hypothesis

This new hypothesis to the origin of the Moon and Earth, This is the proposal of solutions that satisfy unified manner new hypothesis to the origin of the Earth and the Moon, all of the following questions.

- (1). Why, large biological extinction of five times or more were happened on the earth?
- (2). The meteorite falling on Earth, why stony-meteorites, stony-iron meteorite, iron-meteorite, such as differentiated and undifferentiated chondrites, what mixed in there?
- (3). The old theory, why cosmic dust or did not become a planet in the asteroid belt? I think Itokawa's aggregate piece of crust differentiated?
- (4). We have proposed a theory of the origin of the original description to solve the problems of the giant planet collision theory, all of the earth and the moon and deep sea bottom.
- (5). Why, protoplanetary Serra did they destruction? = The tragedy caused by tidal forces and deformation due to Jupiter orbit perturbation.
- (6). Increase in the aspect ratio of Serra orbital perturbation by Jupiter, destruction by tidal force of the approaching Jupiter.
- (7). Plate boundary formation of plate tectonics, I suggest the formation origin of the deep sea bottom crust by peeling.
- (8). The origin of deep-sea bottom update and continental drift and Mystery of the driving force was solved.
- (9). Why diamond pipe did formed in South Africa?
- (10). Why core eccentric (about ten percent) of what is happening? Radiation anomaly of Brazil over the Van Allen belt.
- (11). New hypothesis at the origin of Jupiter's Great Red Spot, I think about How and Why to that Mystery !
- (12). Why is whether the silicate star (asteroid now) Pluto of the outer planets?

Until now, Giant impact hypothesis is a theory only for making the moon. Protoplanet is the result of accidental collision with the Earth there Mars core size to the Earth, It only has to calculate the conditions formed by the mantle further moon.

It is the original collision hypothesis.

Protoplanetary Serra was born in Ceres position of Bode's law. The planet Serra that differentiated, elliptical orbit was flattened by the Jupiter perturbations.

Major axis is constant because of energy conservation law. Eccentricity of Serra increases, the orbit that focus of the solar get closer so as to extend to the point of near-side Jupiter.

Just before the collision with Jupiter, Serra was rupture in tidal forces of Jupiter. By the mantle debris collides with the Earth, the moon was formed.

Position Serra collides to the Earth becomes the Pacific Ocean, it becomes the origin of the plate boundary crack. In addition, deep-sea of multiple formed with Impact of Multi-attack which is the time difference.

Eccentricity of the moment of inertia is estimated to be the driving force of the seabed update theory and theory of continental drift.

Mantle debris energy is large becomes Pluto, heavy and high density Koaritchi debris became Mercury with scattered to the inner planet side.

I estimated that the debris of Serra collide to Jupiter, it became the origin of the Jupiter's Great Red Spot.

The fact that iron meteorites, stony-iron meteorites, stony meteorites are differentiated, and chondrite undifferentiated are mixed, Ceres is present in the asteroid belt, the origin of the meteorite is convinced straightforwardly with this hypothesis.

Multi-impact theory be the basis of large organism extermination repeated, it is also the reason sea accounts for 70%, it was possible to understand the origin of the plate boundary crack.

Multi-impact hypothesis can be explained in a unified manner present condition of the earth as well as make the moon in this manner.

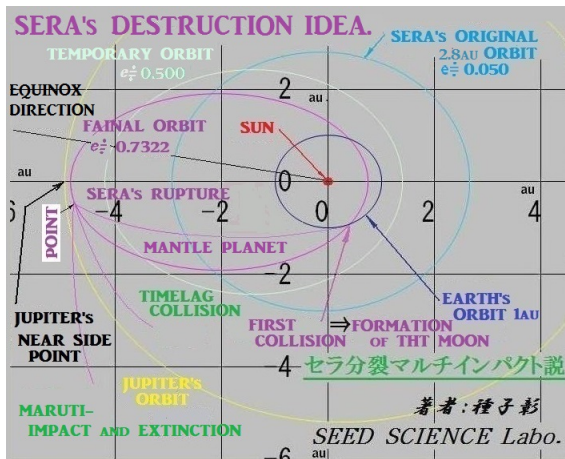
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It is believed that asteroid Itokawa could check a set? Like Serra crust, then it becomes even proof of this hypothesis.

Keywords: Serra tidal disruption, Perturbation of Jupiter, Orbit transition of Serra, Match of the planets revolving surface, Feedengue zone (integrated range), Origin of Deep Sea Bottom



Importance of Future Earth in Asia

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Future Earth (FE) has been launched as an international initiative to promote research for global sustainability by the international science and technology alliance with partnership of the International Council for Science (ICSU), the International Social Science Council (ISSC), the Belmont Forum of funding agencies, the United Nations Educational, Scientific, and Cultural Organization (UNESCO), the United Nations Environment Programme (UNEP), the United Nations University (UNU), and the World Meteorological Organization (WMO) as an observer (Future Earth, 2013). Future Earth will provide a single overarching structure for researchers, funders, service providers, and users, and integrates the existing Global Environmental Change (GEC) programmes. The GEC programmes have provided foci for several extensive international and multi-disciplinary networks of researchers investigating key human-environmental dynamics. Future Earth would develop a new generation network building on these. Future Earth proposes national and regional level committees, in addition to the regional nodes. The most essential issue for the overall FE activity towards global sustainability will be how to integrate efforts and activity of solving environmental problems and achieving sustainability for local to regional scales.

This paper introduces a strategic science plan for FE in Asia, which should be a guideline for implementing the overall FE activity in the whole of Asia, including part of the Pacific/Australasia and the Indian Ocean basin region.

Keywords: Future Earth, Asia

Trade-offs in climate risks and societal risk decision

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The need to take mitigation measures in order to hold the increase in global average temperature below 2 degree C above pre-industrial levels are recognized in international negotiations of the United Nations Framework Convention on Climate Change (UNFCCC). According to the fifth assessment report by the Working Group I of Intergovernmental Panel on Climate Change (IPCC) which was published last September, attaining the temperature goal with a probability of 50% will require cumulative CO₂ emissions from all anthropogenic sources to stay approximately 300 GtC from the present. If the current level of anthropogenic CO₂ emission, 10 GtC yr⁻¹, continues, the cumulative emissions will reach this upper limit in only 30 years. If we will seriously pursue the goal of temperature increase below 2 degree C, global CO₂ emission should be turned to decline as soon as possible, and to be reduced at nearly zero by around the end of this century.

A great deal of research on climate change impacts and mitigation measures exist; however, large uncertainties remain in their overall pictures. So far, nobody can grasp clearly risks for human society and ecosystem associated with global warming exceeding "2 degree C", and risks for socioeconomics due to severe emission reductions of greenhouse gases. Furthermore, the risks will be realized in different ways by country, region, generation, and social attribution, and therefore, either if no specific response measures are conducted or if strong measures are conducted, a part of people in the world will have benefits and another part of people will make a loss. Climate change impact is not just an issue on benefits and losses of each person; but it relates to issues how we feel distress on risks for ecosystem, developing countries, and future generations. It relates to different value judgment among people. Deliberate work will be necessary in order to lead a decision-making which have both scientifically high rationality and socially high consensus, by connecting expert knowledge with social value judgment.

Integrated MRV system using Monitoring-Sensing-Modeling in Tropical Peatland and Wet/lowland

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The Earth's remaining tropical forests are found mainly in the peatlands of the Amazon, Central Africa, and Southeast Asia, especially in regions of Kalimantan, Sumatra, and Papua New Guinea, where rich biodiversity can still be found and large amounts of carbon are stored in peat soils. Also, Wet/low-land where locate especially in South-East Asia is globally one of most important Bioproduction Ecosystem on food production, livelihood, mitigation and adaptation on climate change. This kind of Bioproduction Ecosystem have been supporting to feed large population, because of sustainability of soil fertility and nature friendly production system, calling as human-nature coexistence such as Satoyama in Japan. This human-nature coexistence Ecosystem (Satoyama Ecosystem) in wet/low-land is widely distributed in South-East Asia and South Asia, such as Cambodia, Thailand, Myanmar, Malaysia, Indonesia, Philippines and Bangladesh. Thus, peatland and wet/low-land Ecosystem has a role to stock large amount of Carbon, especially in peat and organic soils, and Mangrove soil. However, this human-nature coexistence Ecosystem (Satoyama Ecosystem) has been gradually or quality degrading and breaking down because of human-impact and climate change. Thus Sustainability of this human-nature coexistence Ecosystem (Satoyama Ecosystem) is one of key issue in not only regional, but also global. As SBSTA38 and Workshop of UNFCCC in 2013 have been focusing on "Ecosystem of High Carbon Reservoirs" such as peatland, costal ecosystem including Mangrove and Coral, and Permafrost, South-East Asia is key in this aspect.

Focusing on carbon emission estimation related with the REDD (Reducing Emissions from Deforestation and Forest Degradation in Developing Countries) Mechanism, at COP15 in Copenhagen, MRV (Measurement, Reporting and Verification) focused on establishing reference emission levels, national monitoring systems. At COP15 of Copenhagen, it was declared that an MRV system that should be coupled with two components ? satellite sensing and grand truth- is urgently required. Presently, our JST-JICA Project (SATREPS) on "Wild Fire and Carbon Management in Peat-Forest in Indonesia" is the only project in the world to propose all aspects of MRV in tropical peatlands, enabling it to contribute significantly to also in tropical wet/low-land. Actually, carbon stock mapping and carbon flux mapping in peatland were obtained. Therefore, this paper describes our MRV system as a sensing standard for REDD+, biodiversity, and LLULUCF in tropical peatland and Wet/low lands.

Keywords: Satoyama Ecosystem, MRV, REDD+, Tropical peatland, Wet/low lands, High Carbon Reservoir Ecosystem

Current state of international governance on conservation and sustainable use of marine ecosystem services

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Conservation and sustainable use of marine ecosystem services has been discussed internationally. For instance, discussions on EBSA (Ecologically or Biologically Significant Areas) are ongoing at meeting under the CBD (Convention on Biological Diversity). Likewise, the issues of VME (vulnerable marine ecosystem) are also discussed at FAO (Food and Agriculture Organization of the United Nations). In addition, General Assembly Ad Hoc Open-ended Informal Working Group to study issues relating to the conservation and sustainable use of marine biological diversity beyond areas of national jurisdiction has been held by the United Nations in order to discuss the need for creating an international instrument under UNCLOS to address the issue of the conservation and sustainable use of marine biological diversity of areas beyond national jurisdiction before the end of the 69th Session of the United Nations General Assembly (which is winter time in 2014).

The author has closely monitored the development of the discussions on the above meetings and found that their discussions were narrowly focused upon the control of fishing activities and they lacked considerations on the ecosystem services as a whole. This is most likely because stakeholder identifications, such as polluters and users of ecosystem services, are difficult and creating a legal framework is extremely hard. Under this situation, it can be argued that agreeing economical tools such as payment for ecosystem services would be more practical.

Keywords: Ecosystem services, UNCLOS, CBD, FAO, EBSA

Global and regional platforms for integrated environmental and sustainability studies

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Future Earth is a new 10 years initiative of international research program for global sustainability. The objectives of the Future Earth are to provide the knowledge required for societies in the world to face risks posed by global environmental change and to seize opportunities in a transition to global sustainability. Future earth was launched at 2013 by international academic, funding, organizations as alliances including ICSU, ISSC, IGFA, Belmont Forum, UNEP, UNESCO, and UNU. Future Earth focuses on co-design, co-production, and co-delivery, transdisciplinarity, vertical (global-regional-local) and horizontal (multi issue with different sectors and stakeholders) integrations, and the involvement of young scientists. There are three themes, 1) Dynamic Planet, 2) Global Development, and 3) Transformation towards Sustainability. Researches on global environment and sustainability are urgent in Asia, because more than 50 percent of the world population lives in Asia, and drastic changes (both increase and decrease) of population, urbanization, material consumptions, environmental deteriorations, natural and social disasters, occurs in Asia, i.e. Asia is a hot spot area in terms of human and nature drives. Therefore core research hubs of the global environment and sustainability study such as Future Earth are needed in Asia, where is the hot spot area for global sustainability. Structures of the global and regional hubs for the Future Earth, core projects, and others are now under discussion during the interim period. Japan is expected to be Asian regional hub and a part of global hubs because many experiences and good practices on global environmental researches with stakeholders. Methodology, data, and knowledge for interdisciplinary and transdisciplinary researches, should be established in a platform and networking as regional hub of the Future Earth in Asia Pacific and others. Capacity building and education for global sustainability are also very important in Future Earth. Beyond the existing one-way capacity building and environmental education, knowledge transfers between different stakeholders may be a key for the next step of capacity building and education for global sustainability.

Keywords: global environmental change studies, global sustainability, future earth, platform, capacity building

On Sustainability Initiative for Marginal Seas in East Asia

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The marginal seas of East Asia (MSEA hereafter) along the western Pacific, geologically as the interface between the Pacific Ocean and the Asian land mass, have islands spread from the Bering Sea down to the Indonesian seas consisting mainly of the Japanese, Philippine, and Indonesian Archipelagos. The MSEA is very important to international commerce and global security as linkage of heavily populated megacities with active societal, economical and industrial activities.

The MSEA is also the region of the highest marine biodiversity in the world, and its coral reefs and waters around atolls and small islands serve as the spawning ground and nursery of many marine species including tuna and other pelagic species that serve as very important food commodities in the Pacific islands, the Asia mainland and North America. To conserve the health of the MSEA under the pressure from the global change is of our urgent need. The region also lies along the path of destructive typhoons that originate in the western North Pacific and affect the Philippines, Vietnam, Hong Kong, China, Korea, and Japan. It is known that the western North Pacific is one of the most active basins where about 26 typhoons are generated annually, majority of which enter the Philippine area. The latest typhoon, Haiyan, the strongest storm recorded at landfall and the deadliest Philippine typhoon causing storm surges ever recorded, impinged heavily on human life, food security, energy supply, health, wellbeing, and transportation and communication systems in addition to extreme destruction of property, the economy and the ecosystem of Central Philippines. The outpouring of support from the international community to help the Philippines rise out of the disaster is well appreciated particularly by the victims of typhoon Haiyan and its storm surges. Many lessons now learned can be shared to minimize the impact, improve the resiliency of communities and to ensure protection of people against the anticipated increase in the number of future disasters due to global climate change. The cold phase of the Interdecadal Pacific Oscillation which brought the apparent hiatus of the global warming will eventually change and we expect a dramatic climate regime shift as observed in 1976.

In the spirit of the Future Earth initiative of ICSU, we are proposing a collaboration mechanism to share knowledge and expertise for better well-being among ICSU members around the MSEA to work for solutions of relevant problems in the region. While focusing on the maritime region, the researchers will aim to contribute to the attainment of the goals of Future Earth, namely: 1) to develop the knowledge for responding effectively to the risks and opportunities of global environmental change, and 2) to support transformation towards global sustainability in the coming decades. The main region of the proposed study will be the Exclusive Economic Zone beyond the territorial limit (generally 12 nautical miles from shore) in MSEA as well as international waters relevant to the sustainable use of common areas. The collaboration will involve joint researches and capacity building particularly of young scientist in developing countries. We had the brainstorming pre-scoping workshop for SIMSEA in February in Yokohama, of which purposes are:

1) To exchange information and knowledge on the existing discipline-oriented research programs on the marginal seas in Asia and the western Pacific for integrative sustainability research program involving natural, social, economic, engineering and technological sciences.

2) To discuss and co-design a collaborative interdisciplinary research program on the marginal seas of Asia and the western Pacific that meets the criteria of research toward global sustainability under the framework of Future Earth.

We will summarize the outcome of the pre-scoping meeting and envisage the future of SIMSEA in accord with Future Earth.

Keywords: Future Earth, Marginal Seas, East Asia, Interdecadal Pacific Oscillation, Global Change, Climate Variations

Digital Earth as a communication platform for Future Earth

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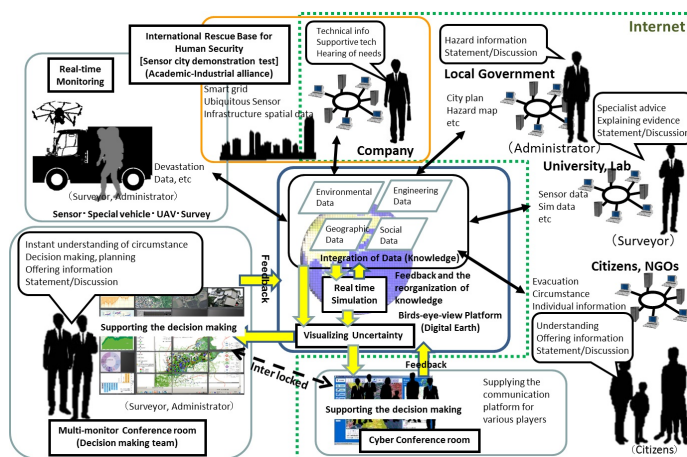
¹International Digital Earth Applied Science Research Center, Chubu Univ.

As we can see in problematique, such as environmental issues and disasters, the various risks we face at both local and global scale are all interrelated to each other, and also tend to suddenly emerge at very local level. Conventional science has only been able to deal with parts of these problems. The first step to build a sustainable and disaster resilient society is to monitor, identify, store the data of phenomena on the earth, then process and interpret the raw data, turn them into understandable information to display, publish and distribute. We must share a common recognition of the issues. Therefore we need the Digital Earth (DE) that is a virtual representation of our planet on the internet, and enables a person to explore and interact with the vast amounts of natural, socio-economic and cultural information gathered about the earth. These infrastructures are using for the ESD (Education for Sustainable Development) that focus on systems thinking, critical thinking and holistic views. The Digital Earth can also facilitate collaborative, data-intensive studies for problematiques of Future Earth Project in the 21st century

It was reviewed Digital Earth concept, applications, and some of projects for promoting disaster resilient and sustainable society with information and communication technology in this paper.

We propose Digital Earth platform as the public information base which has cloud-based geospatial information system and services in cooperation with multi stakeholder as shown in Fig. These information systems should be autonomous, distributed and coordinated, interoperable as well. They work for ESD especially for the multi-risks, both mitigation and preparedness in ordinary time and emergency to reduce the vulnerability of our society. It would be a comprehensive facility and social system dedicated to disaster and environment management for sustainable future, with the capacity to supply the necessary staff and equipment such as sensor web supporting by a wide range of associated organizations.

Keywords: Digital Earth, Geographic Information System, Citizen Sciences, Data Journalism, Education for Sustainable Development, Future Earth



Future Earth and Sustainable Development Goals

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One of the next major challenges for research and policy in the field of sustainable development is the agreement of the post-2015 development agenda. This challenge is a direct result from the 2012 United Nations Conference on Sustainable Development (Rio+20), as well as from the formal ending of the Millennium Development Goals (MDG) in 2015. Governments, supported by civil society, now need to agree on a series of new global sustainable development goals and on the related governance mechanisms. At the Rio+20 Conference, governments decided on a process to develop such novel Sustainable Development Goals (SDG), to be integrated into the post-2015 global development agenda. Differently from the MDGs that target developing countries, the new Sustainable Development Goals are meant to apply to both developing and developed countries.

The research community that works in this field is faced with essentially two research tasks:

- ? First, we need to analyze the goal setting and implementation processes (governance questions);
- ? Second, we need to analyze and identify the goals and indicators themselves.

The first task entails an inquiry into who will be involved in setting these goals (Agency, Accountability), by which decision making mechanisms (Architecture, Adaptiveness), what these goals will be (Allocation and Access), and how to arrive at the framework for formulating the goals as well as an inquiry into how these goals will be translated into outcomes. The second task includes the question on how to elaborate the global development goals to facilitate achieving human well-being for all within resource constraints and environmental boundaries set by the earth system. A related question is the conceptual framework for the goals, and what goals, targets and indicators need to be developed. This in turn poses questions on enabling institutions and governance processes. We have witnessed in the past years that the development model that underpinned the post-1945 decades appears to be unable to handle the crises that many societies and institutions are struggling with (financial, demographic, environmental, etc.).

Therefore, questions related to the Post-2015 development agenda are not solely about SDGs, but are rather fundamental questions on how to achieve sustainability in the 21st century. To do so requires knowledge innovation, and it is possible through transdisciplinary research, one of the purposes of Future Earth, including co-design, co-production and co-design. This is a theme that should be explored in the year to come.

Keywords: Future Earth, Sustainable Development, Sustainable Development Goals, Post 2015 Development Agenda, Governance

How will Humanity Survive and Flourish on Future Planet Earth?

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In the past half century the world has changed in an unprecedented way. For the first time ever humans observed their planet from outer space. Our species also has become a geologic factor while beginning to interfere with natural forces in the Earth to a scale which can no longer be ignored. These caused geographic modifications at the Earth's surface and geographic maps begin to show more and more distinct human imprints. Simultaneously, our knowledge about the Earth has increased to a level that the Earth crust's anatomy and composition is increasingly known and that we begin to understand how our planet works. Knowing the basic principles of the Earth processes paves the way to forward modelling and more and more accurately predicting the impacts of human interaction with planet Earth. That, in turn, provides tools to anticipate on both assets and threats for an increasingly large and complex human population. As long as we remain dependent on our home planet societies should benefit more from such rapidly increasing knowledge to balance development with the Earth's bearing capacity. Here, we describe recent progress in our knowledge of the Earth and some trends in human development. In combination, these may point to knowledge-based options on how human societies may cope with potentials and limitations posed by planet Earth in view with the ambitions expressed by the Future Earth science initiative.

Planet Earth by itself is not in danger and humans will never threaten its existence for another 5 billion years. But human activities will continue and possibly aggravate impacting the biosphere, the hydrosphere, and to a lesser degree, also the geosphere. Dimensions of such changes will be determined by physical factors in the first place but ability of human societies to cope with such changes also depends on cultural diversity.

Five global trends in human development are discussed: population, urbanisation, living standard, environmental awareness and science & technology. Together these trends point to a growing need for physical space to accommodate future human ambitions. Science and technology trends demonstrate accelerating potential abilities of human society to address such needs. As we proceed in the Anthropocene the need to integrate humanity issues and the geosciences will further increase while reconfirming the growing relevance of the discipline of the Human Geosciences.

So far, the Earth sciences play a modest role in the Future Earth initiative. That is in sharp contrast with global ambitions to arrive at a Green Economy, as expressed in Rio+20, to be developed in balance with the Earth's bearing capacities. Recent progress in geoscientific and technological research demonstrate the potential of such development. This has been widely exposed during the International Year of Planet Earth (IYPE, 2007-2009). This global initiative was proclaimed by the UN and was particularly successful in its outreach programme. In turn, the IYPE served as a model for developing the International Year of Global Understanding, spearheaded by the IGU, and for the UN Year of the Soil (2015).

Human ingenuity spurred discovery of larger natural resources than ever before to drive our economies to unprecedented heights. Future Earth might mobilize the brain powers accumulated in the heads of 400,000 Earth scientists around the world towards a sustainable economy.

Scientific Knowledge Creation Supported by Data Integration and Information Fusion

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What is scientific knowledge? We create some hypothesis based on theories, develop models, and implement experimental observation for validation of the hypothesis. This approach is called deductive inference. Based on the accumulation of factual knowledge, we can form the hypothesis. This approach is called inductive inference. Scientific knowledge is called formal knowledge which can be transferred and shared among wide scientific communities. By publishing paper and promoting communication, we exchange the factual knowledge. Such widely shared factual knowledge is defined as scientific knowledge. We are doing science in this way. During past one hundred years, this scientific knowledge has been increasing explosively. Differentiation and systematization have proceeded, and then a large number of disciplines have been established.

However, it is very difficult to reflect accumulated sub-system knowledge to holistic knowledge. Knowledge on a whole system can be rarely introduced to a targeted subsystem. In many cases, knowledge in one discipline is inapplicable to others. We are far from solution of issues across disciplines. It is critically important to establish inter-disciplinarity and create scientific knowledge crossing disciplines. To realize the benefits of scientific knowledge in society, we need to combine scientific knowledge in the natural world, the socio-economic world and the recognition world and to develop trans-disciplinarity as well as inter-disciplinarity.

How can we develop inter-disciplinarity and trans-disciplinarity? We need to share the data and information and develop inter-linkage of our knowledge by developing models and exchanging tools. Based on this kind of scientific activities, we can cooperate between science community and society by making effective use of opportunities.

Data Integration and Analysis System (DIAS) coordinates the cutting-edge information science and technology and the various research fields addressing the earth environment, constructs data infrastructure that can integrate earth observation data, numerical model outputs, and socio-economic data effectively, creates knowledge enabling us to solve the earth environment problems, and generates socio-economic benefits, aiming to create knowledge to be shared among different disciplines, to create knowledge to be shared throughout the world, and to disseminate data and information that brings awareness.

Keywords: Data Integration, inter-disciplinarity, trans-disciplinarity

Geospatial data and Future Earth: a case of digital elevation models

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Future Earth is related to the concept of Digital Earth, proposed by US Vice-President Al Gore in 1998. Digital Earth aimed to compile global geospatial data with various resolutions and make them open to public worldwide for efficient solution of environmental problems. Although some related projects were launched, such activities in the 21st century have been relatively limited, partly because Gore lost in the 2000 presidential election. However, some of the elements of Digital Earth have been realized in the form of Internet virtual globes such as Google Earth and Bing Maps. These services allow us to browse maps, satellite images and airphotos with various resolutions. Although Digital Earth planned to provide more varied geospatial data related to science and culture, compilation and broad distribution of such data have been more delayed. It is important to understand the current state of available geospatial data and utilize them for activities associated with Future Earth. This presentation deals with digital elevation models (DEMs), one of the most basic geospatial data. It introduces currently available DEMs and application examples related to Future Earth.

Keywords: Future Earth, geospatial data, digital elevation model, Digital Earth

Promoting Studies under Future Earth supported by Super-High Resolution Simulations on the Global Environment

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The new terminology "Anthropocene", the geological era when anthropogenic activities substantially altering global environmental systems in which human beings are also a part of it, has been a popular word, but how the Anthropocene evolved? Population growth, economic development, and urbanization are inducing the climate change, the depletion of non-renewable resources, and the degradation of ecosystem services through the enhancement of the waste of resources, the emission of greenhouse gases, and the land use-land cover changes. Consequently, economic equity and the stable accesses to food, water, and energy are threatened, the potential risks to natural disaster are increased, and the minimum standards of wholesome and cultured living are in danger. How socio-ecological systems are changing and interacting with global and local environment?

In order to answer to these questions, it is necessary to understand the inter-linkages among factors of the socio-ecological systems through earth observations, field studies, data archive of social statistics and historical information on local and global changes, and the synthesis of them with integrated analysis and mapping. The study should have a scope with multi-spatial scale including Japan, Asia, and the globe, and with the target period of drastic changes for human beings in 300 years from the 150 years from the industrial revolution till now, and the 150 years from now on.

A research project of "Super-High Resolution Simulations on the Global Environment" is proposed in order to promote various studies under Future Earth. Cycles and budgets of energy, water, and materials such as carbon, will be eventually simulated by 1km (30 arc second) over global continent for past 150 and future 150 years considering social and climatic changes. Past and projected changes will prevail the historic transition and future anticipations in sustainable energy, renewable resources such as food and water, impacts and transition of health and ecosystem services with super-high resolution.

Research components to enable the study are mostly ready to start feasibility studies. Motivated researchers are welcome to join.

Keywords: future earth, offline simulation, super-high resolution, anthropocene

Asian Economic Development and Global Environmental Sustainability

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During the last twenty years or so, growth economies of Asia collectively became the largest importer of resources (particularly of energy resources) in the world, as not only resource-poor countries like Japan but countries like Indonesia and China, which used to be resource exporters, turned to net importers. Meanwhile, East Asia historically pursued a path of economic development, different from that of capital- and resource-intensive industrialization developed in the West, by fostering relatively labour-intensive and resource-saving technology. The energy intensity (energy consumption per GDP) has been kept low in many Asian countries, and Japan's energy-saving technology still leads the world in a number of respects. Thus, growth economies of Asia (now including most of South and Southeast Asia) are major players in the global market of resources, influencing both demand and supply.

Needless to say, monsoon Asia creates the world's largest circulation of water and heat energy around the Himalayas (and the Tibetan Plateau), and about a half of world population live in this environment. It has formed a uniquely coherent civilization and economy, such as densely populated society based on rice farming, transcending the geospheric and biospheric boundaries between the tropics and temperate zones. Today, this region is going through comprehensive industrialization and urbanization, and the resource and energy use there is beginning to affect the health of the entire world economy.

In what ways has Asian economic development been affecting global environmental sustainability? If Asia has long fostered a path of economic development under the unique environmental outfit of monsoon Asia, how would it influence the region's ability to address global environmental issues? This presentation offers a review of recent history literature on these questions, with comments on its utility for the understanding of the future of global sustainability.

I am currently serving for the Future Earth Committee at the Science Council of Japan, to promote humanities and social science research for this global initiative. I hope to have an opportunity to exchange ideas with members of this Union, and to explore possibilities of interdisciplinary research, specifically designed for the activities of Future Earth.

Keywords: Asia, economic development, global environmental sustainability, path dependency

International Earth Science Olympiad from the viewpoint of Future Earth

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When considering the Future Earth-sustainable Earth, it is important to know the whole Earth and the international cooperation. As the study of the whole Earth is Earth Science, we consider International Earth Science Olympiad (IESO) which is the international competition for high school students from the viewpoint of Future Earth.

IESO was hold on 2007 (Korea), 2008(Philippine), 2009(Taiwan), 2010(Indonesia), 2011(Italia), 2012(Argentina) and 2013(India). In 2016, we will have IESO at Mie.

1) International Team Field Investigation (ITFI)

ITFI is the typical event which is not existed on other science Olympiads. This event is the presentation event after high school students from other countries investigated some subjects with international cooperation. At this event, communication language is English and sometimes subjects of this investigation include the regional social life. This experience will guide the consideration of Future earth to students in future.

2) Increase of participating countries

Participating countries were increased from about 6 (2007,2008) to over 20 (2011-). One of the reason might be due to the understanding the importance of Earth Science for Future Earth.

3) Examination questions at IESO

At present, questions are consisting from three disciplines; Geology and Solid Earth, Metrology and Oceanology, Astronomy. However, members of IESO want to include multidisciplinary questions which are important for considering Future Earth. At 2016 IESO at Mie, we want include these examination questions aggressively.

4) Japan Earth Science Olympiad (JESO)

The half of students for participating the JESO will enter the universities of art divisions and 30% of students are girls. This fact is good for consideration of Future Earth because many peoples, not scientist, have basic earth science knowledge. However, it is regret that more high school students study another science curriculum than earth science.

I think that it is very important for Future earth to learn Earth Science and to join the Earth Science Olympiad.

Keywords: Earth Science Olympiad

The education for sustainable earth - The International Geography Olympiad

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The International Geography Olympiad (iGeo) is a competition for the best 16 to 19 year old geography students from all over the world. Four students represent each country in a series of Geography tests in (generally) a four-five day program. An adult Team leader and International Board Member accompany each national team. The official language of the iGeo is English.(from iGeo home page)

There are three aims of iGeo. First is to stimulate active interest in geographical and environmental studies among young people, second to contribute positively to debate about the importance of geography as a senior secondary school subject by drawing attention to the quality of geographical knowledge, skills and interests among young people, third to facilitate social contacts between young people from different countries and in doing so, contribute to the understanding between nations.

The test questions in iGeo are presented from each country and are made. The international standard test is aimed by these questions. These questions are divided into three types that are multimedia, description, and fieldwork. The aim of each type test is to make students develop the ability to look the future society and earth on underlying knowledge, skills and view points of the geography. Particularly, in the fieldwork test, students can learn not only the present understanding but also the future by observing local natural phenomenon and the life of people, directly. Regarding geography education of our country, though present understandings more importance, a point of view to inquire the relation between nature and human in the future is not enough. In factually, the Japanese team in iGeo really tends that the point of the fieldwork test is low. As for this, the main factor would be that thinking the future is not educated in geography education in Japan. In addition, students have few chances to experience the fieldwork in geography class of our country.

In the geography education of Japan, it is necessary for the learning content including the consideration for the future based on geographical knowledge, skill and inquires.

Keywords: sustainable earth, future earth, geography education, international geography olympiad, fieldwork

Sustainable Future of Coastal and Marine Ecosystems in the Indo-Pacific Ocean

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The Indo-Pacific Ocean Region encompasses diverse coastal ecosystems, as represented by coral reefs, mangrove forests, sea-grass beds, and even deep basin over 4000 m deep. These diverse environments harbor the unique and extremely high biodiversity of the region, known as the major biodiversity hotspot in the world. However, the region is also under serious threat of environmental decline from various human impacts due, for example, to loads of pollutants from land and habitat destruction associated with resort development and fisheries. There are also concerns about negative impacts of global climate change associated with ocean acidification.

As one of Future Earth initiatives, we should establish future perspectives and needs for strengthening sustainable ocean environment and development. A project aims at further expanding the network of the scientific and socio-economic studies and education on the Indo-Pacific Ocean Region, through (1) research collaboration applying new approaches and methodologies such as satellite remote sensing, molecular genetic analyses, and high-precision analyses of biogeochemical parameters, (2) integrative, inter-disciplinary ecosystem researches, and (3) establishment of core of coastal marine science and socio-economy in each country and multilateral network. Through these activities the project aims at enhancing education of researchers who will play major roles not only in domestic but also in international activities on global issues.

As a practical matter that impeded harmonized implementation of the program, there will be a large gap among the member countries in their funding capabilities, resulting in the shortage of funding in some countries. This may be partly due to the differences in political priorities for basic environmental and/or socio-economic research among countries. There are also problems that the importance and practical application of basic research to urgent environmental issues have not effectively been reflected in the response of funding organizations, policy makers, and/or popular audience, despite our efforts to demonstrate and disseminate these issues in various occasions.

Keywords: Indo-Pacific Ocean region, marine ecosystem, coastal region, biodiversity, inter-disciplinary research, impacts of global climate change

Geoscientific Perspective for Sustainable Future Earth

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The world global environmental studies are being re-organized under the flag of Future Earth led by ICSU, ISSC etc. Geoscience, which specializes in the dynamic nature and phenomena of the earth's surface, including lithosphere, hydrosphere, atmosphere, biosphere and human-geosphere, assumes unique responsibility in contributing to Future Earth. It was highly relevant for JpGU to establish Human Geoscience Section as one of its five academic sections when it was born in 2005 in response to the restructuring of the Science Council of Japan. The paper discusses the roles and the roadmaps of the geoscience community in general and those of the human geoscience in particular in implementing Future Earth.

Keywords: geoscience, Future Earth, global environmental problem, human geoscience, sustainability

Actions to the Eastern Japan earthquake disaster by SSJ and to disaster and environmental issues in academic communities

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The Seismological Society of Japan (SSJ) has organized the Investigation Committee for disaster. The committee corrected preliminary research outputs and opened them as a link correction on the SSJ's web site at the 2011 eastern Japan great earthquake disaster.

One of the important tasks of the committee is the contact point for other related academic societies dealing with earthquake and tsunami. The SSJ participated in the Liaison Committee on the off the Pacific coast of Tohoku Earthquake established with the related societies, as well as in the Environmental Hazard Countermeasure Committee of the Japan Geoscience Union (JpGU). The Outreach Committee of SSJ performed enlightening actions for general public and mass media. The SSJ cooperated the action also by the Science Council of Japan.

What we learn from the 2011 eastern Japan great earthquake and tsunami disaster is global environmental issues and natural disaster are inseparable. Earth and planetary sciences should integrate such problems that we have considered completely different problems in the past. For this purpose, cooperative action among our community is a matter of course. In addition, cooperation with the community outside of us is indispensable to earth and planetary sciences, studies about basis of the prosperity of the human, contribute for building sustainable human society. The JpGU is expected to be a core for such cooperative actions. It is important to make careful preparations to be successful in the actions and cooperation between the societies during the emergence period. I propose a workshop such as " global environmental issues among natural disaster " for brainstorming.

Activities of the Geological Society of Japan in support of reconstruction after the 2011 Tohoku earthquake disaster

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¹Waseda University (JGS Director of Outreach and Geopark Affairs)

I introduce the activities of the Geological Society of Japan (JGS) in support of the reconstruction after the 2011 Tohoku earthquake disaster on behalf of the Social Contribution Committee of the JGS. The JGS asked its members to submit proposals in support of the disaster recovery, and six of nine research programs in 2011 and one of two in 2012 were adopted and supported by funds of the Society. The seven projects can be categorized into three research categories: 1. recovery of specimens from museums destroyed by the tsunami, 2. development of methods of decontamination to help deal with the radioactive material spread by the Fukushima Daiichi nuclear power plant accident, and 3. surveys to recognize and quantify liquefaction caused by the Tohoku earthquake. The results of these studies were reported in poster presentations given at the JGS annual meetings and in newsletter articles published in 2012 and 2013. This report also introduces briefly the geopark activity that has been promoted by the JGS and its importance for local education in earth science including disaster prevention and mitigation in the eastern Tohoku coastal area (Sanriku area).

Keywords: Geological Society of Japan, 2011 Tohoku earthquake disaster, tsunami, liquefaction, decontamination of radioactive materials, recovery of museum specimens

Reframing the academic responsibility of JSAF on the basis of its activities after the 2011 Tohoku earthquake

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The Japanese Society for Active Fault Studies (JSAF) is devoted to the study of not only inland active faults but also offshore active faults including subduction zone mega-thrusts. The members of JSAF have been conducted emergently survey for every earthquake disasters related to active fault since the establishment of 2007. One of the important purposes of the survey is to identify and to describe any geological and geomorphological phenomena associated with earthquake and tsunami such as trace, geometry and displacement of surface rupture, coastal change and tsunami deposit. These modern analogues are key to reveal the past phenomena. And clarifying the past is key to estimate the future. This philosophy of paleoseismology and active fault study has been socially recognized in its importance for measuring low frequent great disaster after the 2011 great Tohoku earthquake (M9.0). However, as the lessons from the 2011 event and its triggered 2011 Fukushima Prefecture Hamadori earthquake (M7.0), we also recognized a limit of the current investigation technique of geological and geomorphological methods. The JSAF has an important role as a community for discussing new technique.

Keywords: Japanese Society for Active Fault Studies, 2011 great Tohoku Earthquake, 2011 Fukushima Prefecture Hamadori Earthquake, Active Fault Study, Paleoseismological Study

Activity of the AJG to the Great East Japan Earthquake Disaster: Role of academic societies at a big disaster

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The activity of the Association of Japanese Geographers (AJG) responding to the Great East Japan Earthquake Disaster was as follows:

1) "The Headquarters for Disaster Response," the general manager of which was the chairperson of the executive committee of AJG, was set up just after the disaster occurrence. It performed correspondence to a various inquiries, liaison and information exchange with other associations, communication to geographers in the fields, uploading quick reports and proposals to the web site, etc.

2) Based on a geographical property to make much of air-photo interpretation and mapping, AJG organized a working group for clarifying the entire surface of the tsunami inundation and published the first report on March 28 (revised eight times until December).

3) AJG gave the geography teaching materials to damaged schools by the members' contribution.

4) Until March, 2014, ten symposia relating to the Great East Japan Earthquake Disaster were held. The theme were of physical geography (tsunami, liquefaction, slope disaster, disaster of land developed for housing, radioactive contamination, etc.) and of human geography (life of damaged inhabitants, the revival way, etc).

On the occasion of a big disaster, societies of geosciences should do not only the academic activity but also take a social role as follows:

1) dispatching the research results in a easily understandable way quickly and broadly

2) Supporting people and governments based on specialized intellect.

3) Supporting to school education.

It is important for JpGU to have an open window for the society for disaster outbreak as well as to support the researchers who act in the field.

Cartographic society's contributions to crisis resolution of environmental issues and disasters

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¹Japan Cartographers Association

Maps are important for crisis management in environmental issues and disasters, however it is not clear if the current situations of providing and using maps for crisis management are appropriate or not. We try to clarify contributions and problems on map provisions and uses for crisis management from the viewpoint of cartographic society in our talk. Particularly, we focus on the following points.

- (1) prompt action and quality
- (2) appropriateness of map provisions to suffered communities depending on their situation
- (3) designing action plans of map provisions for levels of situations
- (4) paper maps and digital maps
- (5) appropriateness of current hazard maps
- (6) weak map literacy in decision making, communication, and media
- (7) international contributions
- (8) volunteered geographic information, location-based SNS, and ubiquitous mappings
- (9) use of spatio-temporal big data

Keywords: maps, disaster maps, aerial photographs, geospatial information, hazard maps, Volunteered Geographic Information

Disaster Response Support Activity based on Geospatial Information

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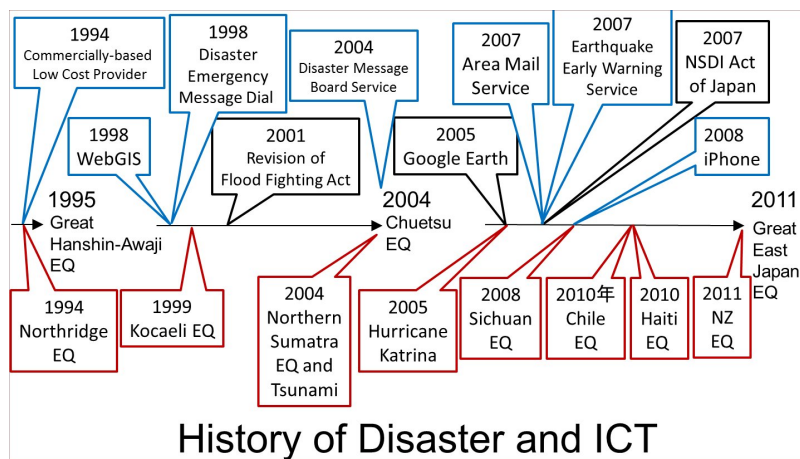
In this presentation, the history of major disasters and progress of information communication technology related to geospatial information after 1994.

In 1995 Great Hanshin-Awaji Earthquake, GIS and Remote Sensing got a lot of attention to manage disaster information.

In 2004 Chuetsu Earthquake, GSI and voluntary base research group tried to share damage and recovery process information through Web GIS.

After launch of Google Earth, ordinary person can share his/her geospatial information though internet. And in 2011 Great East Japan Earthquake, most layers of geospatial information were shared.

Keywords: Geospatial Information, GIS, Disaster Response Support Activity



Environmental pollution by the Fukushima Daiichi nuclear power plant accident and role of the atmospheric science

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There are several past and future issues to be discussed regarding the role of the atmospheric science in the accident of the Fukushima Daiichi nuclear power plant. SPEEDI model results were not effectively used in the evacuation plan by the government. It was found, on the other hand, that the performance of atmospheric chemistry transport models are comparable to or better than that of SPEEDI, for simulation of distribution of radioactive material over the wide area contaminated by the accident. In that situation, a bottom-up process were useful to gather results of simulation and in situ measurements by volunteer scientists to be utilized in the decision process of the government. The Science Council of Japan is now under discussion of establishing an emergency action manual for gathering data and knowledge by scientists to be shared by professionals to make useful outputs to government and public. As also indicated by the IPCC assessment process for climate change, it is important to present uncertainties included in the scientific knowledge to be released. In this regard, it is important for the atmospheric science to contribute to reducing the uncertainties through a further progress of the atmospheric dynamics, physics, and chemistry modeling system and through establishing more robust monitoring system of weather and other quantities. I like to discuss these issues for improving our ability to reduce damage caused by future disasters that may happen.

How JAHS will manage the Great East Japan Earthquake?

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JAHS (Japanese Association of Hydrological Sciences) is an academic society that treat hydrological cycle on the Earth. Water is one of the most important component that makes feature of earth's surface. Water also is indispensable resources for human's life and activity, so hydrological sciences involves the relationship between hydrological cycle and human activities. JAHS have deep concern to human dimensions of environmental changes. To realize "Hydrological Sciences in the society" becomes important subject to be accomplished after the great earth quick in March 11, 2011.

After the great disaster, we carried out the studies both on Tsunami and on nuclear disaster. At a lecture, we will focus on the nuclear disaster in Fukushima District, because we think our knowledge and experiences on hydrology will be useful to understand the actual situation and future perspectives of radioactive contamination, and also useful to propose measures to restore the region contaminated by radioactive fallout.

The research works on the behavior of radioactive nuclides in the environment are divided into mechanism study and distribution study. In the latter, the distribution map should be discussed with the scales, because often what looks important at one scale is less important at another.

The small scale dose rate maps published by the government was useful to determine the evacuation area at the initial stage of the nuclear disaster, however, large scale map is necessary at the restoration stage. In the mountain village, the life and livelihood are strongly dependent to water and material cycles in SATOYAMA watershed. We have to know the distribution of radioactive materials, water and material cycles in the watershed. The knowledge and experiences in hydrology have great effect to make measures to cope with radioactive materials based on the SATOYAMA watershed scale. We are now conducting hydrological research in the small watershed in one of evacuation area. The outcomes are shared with local people and make them the materials to discuss the future of the region.

At the Fukushima Dai-ichi nuclear power plant, control of polluted water flowing from nuclear reactor buildings becomes an urgent issue to be solved. The buildings are located on the independent plateau. At this situation, local groundwater flow system, recharged on the surface and discharge to surrounding lowland, is the main system of hydrologic cycle. Groundwater from Abukuma Mountains belongs regional groundwater system, and its flux should be very low and residence time should be extremely long. This is hydrological knowledge, however, why accumulated knowledge does not apply to the field in problem?

Science is in the society, and supported by the society. We, scientists, have to consider how to use scientific knowledge in the framework that have common purpose.

Keywords: Japanese Association of Hydrological Sciences, nuclear disaster, FUKUSHIMA, the roll of hydrological sciences, distribution map and its scale, groundwater flow system

Transfer of radionuclides to river by Fukushima Daiichi NPP

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A number of studies have been conducted to monitor and model the time series change of radiocesium transfer through aquatic systems after significant fallout, especially from the Chernobyl disaster. Our research team has been monitoring the environmental consequences of radioactive contamination just after the Fukushima Daiichi NPP accident in Yamakiya-district, Kawamata town, Fukushima prefecture. Research items are listed below.

1. Radiocesium wash-off from the runoff-erosion plot under different land use.
2. Measurement of radiocesium transfer in forest environment, in association with hydrological pathways such as throughfall and overlandflow on hillslope.
3. Monitoring on radiocesium concentration in soil water, ground water, and spring water.
4. Monitoring of dissolved and particulate radiocesium concentration in river water, and stream water from the forested catchment.
5. Measurement of radiocesium content in drain water and suspended sediment from paddy field.

Our monitoring result demonstrated that the Cs-137 concentration in eroded sediment from the runoff-erosion plot has been almost constant for the past 3 years, however the Cs-137 concentration of suspended sediment from the forested catchment showed slight decrease through time. On the other hand, the suspended sediment from paddy field and those in river water from large catchments exhibited rapid decrease in Cs-137 concentration with time. The decreasing trend of Cs-137 concentration were fitted by the two-component exponential model, differences in decreasing rate of the model were compared and discussed among various land uses and catchment scales. Such analysis can provide important insights into the future prediction of the radiocesium wash-off from catchments with different land uses.

Keywords: Cs-137, Fukushima Daiichi NPP, soil erosion, suspended sediment, river, flux

U08-10

Room:Main Hall

Time:May 2 11:30-11:45

Stock and Flow of Environmental radionuclides in Lake ecosystem

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Stock and Flow of Environmental radionuclides in Lake ecosystem

Keywords: Fukushima daiichi nuclear plant accident, environmental radioactivity, Lake ecosystem

Activities of JAGH relating to the earthquake disaster and disaster relief

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Followings are the activities of Japanese Association of Groundwater Hydrology (JAGH) relating to the 2011 off the Pacific coast of Tohoku Earthquake.

Program Committee (Chair: Makoto Nakashima) organized the symposium “ The way of groundwater use as the emergency water source at the time of the earthquake ” on May 26, 2012, at the Kashiwa Campus of the University of Tokyo. In the symposium, following presentations were given; “ Ensuring safety and security of the water supply system ” by Kenichi Yamamoto (Ministry of Land, Infrastructure, Transport and Tourism), “ The securing water in areas affected by the Great East Japan Earthquake Tsunami ” by Yoshiharu Ueno (Iwate prefecture), “ About the use of groundwater as a domestic water at the time of the disaster in Nagoya ” by Kazuhiro Takemoto (Nagoya City), “ Investigation of the effect of tsunami induced by the Great East Japan Earthquake on groundwater ” by Kei Nakagawa (Nagasaki University). Then, the panel discussion was coordinated by Makoto Taniguchi (Research Institute for Humanity and Nature). In this symposium, difference of water usage between emergency and non-emergency times, management method and registration system were discussed based on the presentations.

Editorial Committee (Chair: Tomochika Tokunaga) organized and published two special issues. In the special issue of “ The 2011 off the Pacific Coast of Tohoku Earthquake and groundwater ” (Vol.54, No.1, Feb, 2012), Technical Report of “ Change in groundwater environment caused by the 2011 off the Pacific Coast of Tohoku Earthquake in the southern part of Sendai Plain ” by Kazushi Mori et al. and Research-in-Progress of “ Impact of Tsunami caused by the 2011 off the Pacific coast of Tohoku Earthquake on groundwater usage and quality in Asahi-city, Chiba Prefecture Japan ” by Fumi Sugita are published. In the special issue of “ Earthquake Hazard and Groundwater ” (Vol.55, No.1, Feb, 2013), Review of “ Importance of groundwater as security ” by Makoto Taniguchi, Research-in-progress of “ Field study on the damages of a well due to the Great East Japan Earthquake ” by Kunio Ohtoshi et al., Data of “ Effect of Tsunami induced by the 2011 off the Pacific coast of Tohoku Earthquake on groundwater ” by Kei Nakagawa et al., Data of “ Treatment and effective utilization of debris and tsunami deposits generated by the Great East Japan Earthquake ” by Takeshi Katsumi et al., and Data of “ Symposium, The way of groundwater use as the emergency water source at the time of the earthquake ” by Makoto Taniguchi and Makoto Nakashima were published. All these papers have been published in the J-stage (<https://www.jstage.jst.go.jp/browse/jagh/-char/ja/>).

Prof. Ichirow Kaihotsu organized the joint investigation team of JAGH and JSHWR (Japan Society of Hydrology and Water Resources). They visited public water works offices and collected water samples at the wells of the city in Kamaishi city, Rikuzen Takata city, and Minami Sanriku town during June 16-19 and August 1-3, 2011. They also sampled water at the well for disaster in Wakaba-ku, Sendai City at that time. As a follow up of these investigations, the team of University of Tokyo and Nagasaki University sampled groundwater, river water and soil in Minami Sanriku town. In these investigations, we mainly focused on recovery from the salinization of groundwater due to tsunami induced by the earthquake.

Keywords: JAGH, The 2011 off the Pacific coast of Tohoku Earthquake, Symposium, Special issue, Joint investigation team, Salinization of groundwater

Oceanic dispersion model intercomparison for the Fukushima accident

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There are several attempts to simulate oceanic dispersion of radionuclides discharged into the ocean after the accident of Fukushima Daiichi Nuclear Power Plant on March 11, 2011. In order to understand a present status of model capability to simulate the dispersion of radionuclide and uncertainty in the model simulations, detailed comparisons of model results with observations and also among the model results are necessary. A model intercomparison project, launched by a working group established under the Oceanographic Society of Japan, and then under Japan Science Council, compared results from several downscaling dispersion models focusing on Cesium 137 dispersion for the Fukushima case. Eleven model results from ten groups are participating in the project. Although there are general similarities in basic flow fields and dispersion patterns, significant differences among the simulated results also exist, due to differences in model settings and uncertainty in the forcing fields. This presentation introduces the model intercomparison activity and discuss some preliminary results of the comparisons.

Keywords: Oceanic Dispersion Model, Radionuclides, Model Intercomparison

Development of Composite Materials with Zeolite and Magnetite for Radioactive Cs Decontamination in Soil

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1. Introduction

The decontamination of radioactive Cs from the accident at the Fukushima No.1 nuclear power plant is an urgent problem. Zeolites are the most promising material for the Cs decontamination in water such as ponds and rice fields. The movement of the Cs⁺ ions in the soil to the zeolite should be possible when the powdered zeolite mixes with the soil during the wet process using a K⁺ or NH₄⁺ ion-containing solution for ion exchange with the Cs⁺ ions in the soil. However, the collection of the zeolite after the decontamination of the radio Cs⁺ ions is impossible when the powder material mixes with the soil. Magnetic collection is one of the methods using a composite material composed of the zeolite and a magnetic material after the Cs⁺ ion adsorption.

An Na-P1 type artificial zeolite (Na₆Al₆Si₁₀O₃₂·12H₂O) having a high cation exchange capacity (CEC) is able to be synthesized at a low cost using alkali from the waste coal fly ash of thermal power stations. On the other hand, the synthesis method using alkali for the nano-sized magnetite (Fe₃O₄) is very similar to that for the Na-P1 type artificial zeolite. We considered that a new composite material using alkali from a suspension of both starting materials would be a promising material for the Cs decontamination.

In this study, we synthesized the composite material (magnetic zeolite) of the Na-P1 type zeolite and nano-sized magnetite by alkali processing from a mixed solution of the fly-ash and iron chlorides for the magnetic collection of the zeolite after Cs⁺ ion adsorption.

2. Experimentals

Fly ash (JIS II type) from thermal power stations (Shikoku Electric Power Co.) was used for the preparation of the Na-P1 type zeolite. For the preparation of the Na-P1 type zeolite, the fly ash and 2M NaOH were mixed and refluxed at 100 °C for 24 h. The powder was collected and washed several times by centrifugal separation, and then dried at 80 °C. For the preparation of the nano-sized magnetite, FeCl₂·4H₂O and FeCl₃·6H₂O (mole ratio=1:2) were dissolved in pure water. The mixed solution was placed in a water bath at 100 °C, and then a 2M NaOH solution was added with stirring and held at the same temperature for 30 min. For the preparation of the composite material (magnetic zeolite) of the Na-P1 type zeolite and magnetite, the synthesized magnetite in water and then fly ash was added to the mixed solution. A 2M NaOH solution was added to the mixed solution and refluxed at 100 °C for 24 h.

3. Results and discussion

For the material without magnetite, the main peaks for the XRD were the Na-P1 type zeolite with mullite (Al₆Si₂O₁₃) as the second phase. The peak intensity of the magnetite increased with an increase in the magnetite content. The peaks of the magnetite were very broad due to its small crystalline size. The particle size for the magnetic zeolite was 5~30 μm for a SEM observation. These particles of the magnetic zeolite were easily attracted by the neodymium magnet. For the TEM observation, the Na-P1 zeolite, the magnetite, and amorphous phases were confirmed using the electronic diffraction of the center of the particle. The nano-sized and aggregated magnetite particles were observed in the bright-field image. Due to the slow formation of the zeolite crystals after formation of the nano-sized magnetite, the magnetite particles existed at the grain boundary between the polycrystalline zeolites.

We tested that the magnetic zeolite (200 g) and the soil (2 kg) obtained from the rice fields in Fukushima were mixed using a shaking apparatus with NH₄⁺ ion containing solution. The magnetic zeolite with radioactive Cs collected using neodymium magnet (8000 gauss). We succeeded to decontaminate ca. 80 % radio active Cs from the soil using the magnetic zeolite.

Keywords: Radioactive Cs Decontamination, Na-P1 type zeolite, Magnetite, Composite Material

The Mission of Human Geoscience in the Study of Disasters and Global Environmental Problems

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The Human Geoscience Section of JpGU has been emphasizing the importance of studying increasing disasters and global environmental problems together in an integrative way, and has worked together with the Human Geoscience Committee of the Science Council of Japan to organize various meetings and issued proposals related with global environmental problems and hazards/disasters. The lecture reviews these activities and their achievements, the harsh reality of the still continuing Great East Japan Disaster, and the worsening global environmental problems and the efforts to combat them, and discusses the missions of human geoscience now and towards future.

Keywords: human geoscience, Great East Japan Disaster, global environmental problem, sustainability, disaster

A new research field after the 2011 Tohoku earthquake and tsunami

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The Tohoku region in Japan was hit by a gigantic earthquake of M=9.0 subsequently followed by a huge tsunami which occurred off the Pacific ocean. Both of them have caused huge damage on the eastern coast of Japan, having a huge inundation area more than 500km² with the attack of destructive wave forces. There are several issues why this tragedy occurred, and what unrecognized factors contributed to the high vulnerability of the area, and how the risk at each region in the future earthquake and tsunami.

The damage actual situation of the East Japan great earthquake disaster and the study base formation of practical disaster prevention studies based on the lesson are big problems and develop the situation of the damage, a future evaluation, prediction from elucidation of a giant earthquake and the outbreak mechanism of the tsunami and must record a then lesson to earthquake disaster archives. Furthermore, study such as the ways of the disaster prevention that stood on improvement of the trust of the risk evaluation, the construction of support studies, cooperation with the disaster medicine, the history culture will be necessary to prepare for domestic and foreign disasters.

In natural disaster scientific research, I arrest prior measures, the outbreak of the disaster, influence of the damage, urgent correspondence, restoration, revival, forehandedness with a series of disaster cycles and elucidate the phenomenon in each process, and it is necessary to make the lesson generalization, unification. Social incorporate result of the natural disaster scientific research that assumed knowledge and the world provided from the research in the East Japan great earthquake disaster, the action to reconstruction contracts a field and a human being, society is smart and copes for a disaster cycle to become complicated and systematizes study to build society system keeping a lesson alive through hardship as "practical disaster prevention studies", and a wound wants to form the scientific value.

Keywords: Disaster Science, 2011 Tohoku earthquake and tsunami

How volcanology will manage environment and hazard?

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In order to mitigate volcanic disaster, it is necessary to understand the timing and magnitude of eruption before eruption, and to evaluate the transit of eruption properly, indicating the development of volcanology is essential. Therefore, the roles of volcanology and volcanologist are important to mitigate the volcanic disaster.

Japanese volcanologists have contributed to mitigate the volcanic disaster in case of volcanic unrest or eruption. A few examples will be reviewed during the session.

However, these contributions have not been made by the volcanological society, but by volcanologists personally. It is not clear how the academic society such as volcanological society should contribute to mitigate the natural disaster. Academic society could be an organ to contribute in risk evaluation through the scientific discussion within the society, but may not be an organ to engage in risk management.

Keywords: Volcanology, volcanic hazard, volcanic disaster mitigation

Recent transformation of the snow and ice disaster and emerging issues

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Recently, the natural environment and social environment surrounding Japan, such as the increased global warming and the acceleration of demographic aging, have changed greatly. A few decades ago, there was a view that snowfall will decrease sharply with the progress of global warming and the resultant snow disaster will be drastically alleviated. However, since heavy snowfall appears frequently after the 21st century, it is being accepted widely that the impact of global warming on variations in snow cover is not a simple problem. The heavy snowfall events which appeared in three consecutive years from 2010/11 winter to 2012/13 winter are good examples, and consequently more than 100 people were killed each year. Moreover, it is noteworthy that the aspect of snow disaster has greatly differed from the time of Showa. In relation to earthquakes and heavy rainfalls which occurred frequently in the heavy-snow region of Japan, new issues of the compound disaster events, hardly taken note until now, began to gain prominent attention recently. In this study, I am going to discuss about the research perspective towards mitigation of the snow disaster.

Keywords: snow and ice disaster

Space disasters and space weather studies

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When the solar flare occurs, the high energy particles hit the satellite and cause serious troubles in the communication and broadcasting systems. The geomagnetic storm causes induced currents giving damages to the power transmission system. To avoid the damages due to the solar flare and geomagnetic storms, we are doing research to achieve the prediction model of the solar flare and magnetospheric and ionospheric storms. This talk will present examples of the satellite failures and power outage and also the simulation studies which will enable us to predict the space weather.

Keywords: Space weather, magnetic storm, geomagnetically induced current, radiation particles, satellite anomaly, power outage

Estimation of the paleotsunami size using tsunami deposits along the eastern Nankai Trough

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Repeated great earthquakes (M8 class) and accompanying tsunamis occurred along the Nankai Trough have severely damaged the coastal areas along the trough. In response to the 2011 Tohoku-oki earthquake and tsunami, Cabinet office, Government of Japan came up with a new policy to the damage assumptions for the great earthquake and tsunami generated from this plate boundary. That is, a doctrine that gives serious consideration to the greatest class of earthquake and tsunami, which take every possibility into account, was announced.

The announced "greatest class of earthquake and tsunami" along the Nankai Trough by the Central Disaster Management Council of the Cabinet Office (2011, 2012) has a rupture zone covering the almost entirety of the Nankai Trough (Mw 9.1) and is much larger than formerly estimated one. As this great earthquake and tsunami would hit the area with clustered population and industries, disaster prevention measure for these catastrophes increasingly attracts public attention.

Japanese historical documents cover the past 1300 year records of the great tsunami-inducing earthquakes generated from the Nankai Trough, so called Nankai and Tokai/Tonankai earthquakes. However, M9-class mega earthquake as mentioned above has never reported in this area. In considering whether out-sized earthquake and tsunami announced for the Nankai Trough will do occur or not, it is necessary to verify whether unknown out-sized earthquake has occurred in the geological time scale. Paleo-seismological studies including the tsunami deposit researches are also needed to expand the time range of the earthquake and tsunami records beyond the historical documents and to make the reliable and realistic size estimation for the plate boundary earthquakes and tsunamis based on their recurrence history.

In reconstructing the paleotsunami size, it is needed to consider the influence of coastal geomorphic developments in centennial to millennium time-scale. Seaward expansion of alluvial lowland (migration of coast line) and coastal uplift are primary factors for these topographic changes, which can function as "natural barrier" for the tsunami inundation. For this reason, the older tsunami deposits tend to distribute the deeper inland and higher altitude. If the effect of these natural barrier is not considered, there is a risk that will come into the over estimation for the size of paleotsunamis. In considering the effect of natural barrier, tsunami deposits suggesting the out-sized earthquake have not found from the sedimentary sequence formed along the Enshu-nada and Suruga Bay coast in the last 4000-5000 years.

Keywords: Nankai Trough, Tokai earthquake, Tsunami, Tsunami deposit

Tsunami Sediment along the Nankai Trough and Nuclear Power Plants

OKAMURA, Makoto^{1*}

¹Science Research Center

We know well interplate megathrust earthquakes have been occurred repeatedly through several decades to centuries. Based on this common knowledge, huge earthquakes and tsunamis must be occurred within a period of several thousand years. We research on tsunami sediment from lacustrine deposits along the Nankai Trough for prehistoric Nankai Trough Earthquake. As a result, large tsunami has been occurred 300 years interval through past 6,000 years. The Hoei Earthquake, AD1707 was the biggest tsunami through last millennium as mentioned after ancient manuscripts. Nevertheless, over the Hoei Earthquake tsunami sediments were found in several cores collected from lacustrine deposits.

However, we only have poor knowledge about these interplate earthquakes through millennium. Actually, the Fukushima Accident after the Kashiwazaki, we cannot evaluate even small-sized earthquake (Mw6.8), and 3.11 tsunami. We, seismologists and engineers, said "out of image" just after 3.11 off Tohoku District Earthquake. Never say "safe or safety" again about future earthquake and tsunami related nuclear power plants.

Keywords: mega-quake, Nankai Trough, tsunami sediment, nuclear power plant

Change of giant tsunami study and the risk evaluation of the NPP before and after the 2011 Tohoku earthquake

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When the 2011 Tohoku earthquake occurred, the study of the 869 Jogan earthquake by AIST has finished the first stage and the evaluation of the Jogan earthquake was almost concluded in the Headquarters for Earthquake Research Promotion, and also the back check of nuclear power plants seem to have been slowing down.

The study of Jogan earthquake by AIST started 2004 and was included in the project supported by MEXT from 2005 to 2009. The final report of the project submitted to MEXT in 2010, which concluded that a giant tsunami was generated during the AD869 Jogan earthquake which was larger than M 8.4 based on tsunami deposits survey in the Sendai and Ishinomaki plains, and that the recurrence interval of the giant tsunamis was 450 to 800 years. The AIST study team understands that the source area could extend to the north and south because the survey area of tsunami deposits was insufficient, and tsunami inundation was wider than the distribution of tsunami deposits. The survey of tsunami deposits of wider area had been started from 2010, but it was difficult to find coastal plains which preserve tsunami deposits.

The re-evaluation of all of the nuclear power plans started in 2007 based on new criteria of the safety assessment. The plants were evaluated by three sub-committees and the result was reported to the joint committee. Evaluation against strong motion by earthquake was preceded putting tsunami evaluation off later. In 2009, the middle reports of the Fukushima No.1 NPP was submitted to the joint committee which did not mentioned to the Jogan earthquake, and then only the minimum model of the Jogan earthquake was evaluated. The further discussion of its magnitude and tsunami has not been conducted before March 11, 2011.

The study of Jogan earthquake have been presented in meetings of earth science societies by AIST and medias reported several times since 2005, but the possibility of giant earthquake along the Japan trench was not discussed in the community of earthquake science. In addition, it is not easy to change the society that was not ready to giant earthquake. In these circumstances, nuclear power plants were working during the re-evaluatio, while many problems have been pointed out.

The situation has changed dramatically after the 2011 Tohoku earthquake. Society shares sense of crises against giant tsunami. The tsunami assessment has been made not based on known maximum earthquakes but unknown possible maximum. The safety of nuclear power plant were in doubt and the operation can be started after the safety of the plant was confirmed. Government dose not hesitated to assume maximum earthquake and tsunami, then possibility to point put unknown giant tsunami has been declined. But there is still unknown in earthquake, so it is necessary to continue study and to tell the society truce what we know and do not.

Keywords: tsunami deposits, giant tsunami, Jogan earthquake, Tsunami evaluation

Strong motion characteristics of Mega-Thrust earthquake and the seismic response of NPP as a massive, stiff structure

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The 2011 Tohoku earthquake generated a large number of strong motion records with high acceleration at many observation points, mainly in Miyagi and Ibaraki Prefectures. The distribution of seismic intensities observed or collected by JMA shows that intensity 7 was recorded only at K-NET Tsukidate (MYG004) in Kurihara City, but that intensity 6 upper were recorded at 40 points in four prefectures. When we compare the distribution of the peak ground acceleration (PGA) and velocity (PGV) of the strong motion records observed by K-NET and KiK-net of NIED with the empirical attenuation relation of Si and Midorikawa we can see that PGAs exceeded 500 Gals extensively along the coast from the Central Sanriku to Ibaraki Prefecture, but that PGVs in the area were lower than 80 cm/s. Because of the stochastic nature of the strong motion generation from the large-sized ruptured area there is no site with the coherent intermediate-period (around 1 s) velocity pulse with PGA larger than 800 Gals and PGV higher than 100 cm/s, which is the primary reason for not having severe seismic damage onto the ordinary low-rise buildings.

Prof. Sakai of Tukuba University investigated the structural damage around the site with JMA intensity 6 upper to find that there are no site with heavy damage. We also found that, by using the nonlinear response models which can reproduce the damage ratios caused by the 1995 Hyogo-ken Nanbu (Kobe) earthquake, the structural damage potentials of the observed strong motions were relatively minor for most of the sites. These facts suggest that the current ordinary buildings in Japan, which is basically designed by using the rigid-structure concept, are capable to survive to the strong shakings from the mega-thrust earthquakes.

On the other hand the structural damage prediction by the Cabinet Office of the Japanese Government is made from the empirical relations with respect to seismic intensities of the predicted strong motions. Since such empirical relationship are all based on the damage observed during the 1995 Kobe earthquake, the relationship is good for the inland earthquake but not appropriate to the strong motions pervasively observed during the mega-thrust earthquakes with high PGAs but not so high PGVs. To prove this we independently predict strong motions and using the nonlinear response models we estimated structural damages and found heavily damaged sites only close to the shore line with soft ground conditions.

The same kind of smaller responses were predicted for the nuclear power plant (NPP) structures by using the strong motions predicted by the Cabinet Office in 2003 (Seckin et al., 2008, WCEE). The response of the NPP for predicted strong motions were about twice larger than the elastic limit of the structure, in terms of the relative shear deformation ratios. This is because on one hand the rigid body design concept makes structures sufficiently strong to the high PGA input and on the other hand the elastic limit used for the design is quite low compared to the ordinary buildings. Thus from the structural point of view strong motions during future mega-thrust earthquakes would not be a primary risk for NPPs despite of the spectral amplitude higher than the design input.

Keywords: strong motion, Mega-thrust earthquake, Stiff structure, shear deformation

Safety regulations of nuclear power plant for tsunami after the 2011 great Tohoku-oki earthquake

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Due to large tsunamis caused by the 2011 great Tohoku-oki earthquake, at First Fukushima Nuclear Power plant, cores were melted and explosions were occurred. Many inhabitants are still evacuated now because of radioactive contamination on land. About four months after this accident, the Nuclear Safety Commission of Japan made the committee for earthquake and tsunami related regulation guidance. In the committee, the revision of the earthquake-resistant design examination guidance was discussed. Before the accident, tsunami was treated as "consideration for the earthquake accompanying phenomenon". In the new guidance, "the safe design policy for tsunami" became an item different from "the earthquake-resistant safe design policy". In March, 2012, a new examination guidance including the safe design policy for tsunami was made.

Then, in September, 2012, the Nuclear Regulation Authority was newly established in Japan. Under the Authority, "the study team on the regulatory requirement for light water nuclear power plants - earthquake and tsunami ?" was established. The study team discussed about "new safety design standard for earthquake and tsunami". That was finalized in June, 2013.

In this new safety design standard, concept of the multiplex defense is adopted. 1) Tsunami should not get into a site. 2) When a tsunami get into a site with any reasons, the tsunami should be protected from a house or constructions. 3) When a tsunami get into a house, the power should be supplied from higher place near a site to prevent a severe accident. For tsunami should assume the largest tsunami source from the largest expected event. It is important to understand the concept of the multiplex defense. Some people may think that it is OK to have small inundation from small holes because the houses are protected from water. If such a thought comes out for the multiplex defense, a risk may increase ironically. I wish that the concept of the multiplex defense should be applied closely.

Seismic Safety Regulations and Earthquake Science

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The first parts of seismic safety regulations for nuclear power plants consist of seismic and tsunami hazard evaluations as in the regulations for other structures. Although there are probabilistic and scenario assessments for the seismic hazard evaluation, the scenario assessment is mainly used and the probabilistic assessment is only in auxiliary use to evaluate remaining risk. Therefore, knowledge of earthquake science mostly contributes to making choices of scenario earthquakes in the scenario assessment.

This presentation mostly discusses the seismic hazard evaluation for nuclear power plants as the conveners requested, but also discusses the tsunami hazard evaluation as related to large subduction zone earthquakes. In addition, various phenomena occurring at nuclear power plants due to the 2011 Tohoku earthquake and their relation to these hazard evaluations and choices of scenario earthquakes are discussed.

We finally show from the above that the earthquake science cannot contribute to the real safety of a nuclear power plant unless unknown phenomena can be foreseen. We also discuss the danger of the idea that real safety can be reached if "decision is made without prejudice only from the scientific and technical point of view."

Collaboration beyond the difference between science and government

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Government and public take actions with decisions and judgments based on scientific knowledge. Science community widens and deepens human knowledge with continual research efforts. Therefore, any scientific conclusion, which is once regarded as true, can be denied by later researches. This is the origin of disagreement between science, which has essential uncertainties, and government and society, which require definite decisions. They need to acknowledge such differences that exist between science and government to improve the society.

In the volcano eruption prediction in Japan, the relationship between science community and government-public functions well. The reason is "reasonable distance" between them. Japan Meteorological Agency (JMA) is responsible for issuing volcano information for evacuations. The information is justified in the discussion of the Coordinating Committee for the Prediction of Volcanic Eruption (CCPVE), where both scientists, geologists to geophysicists, and government personnel participate. Scientists often devoted themselves to the disaster reduction plan in local society near volcanoes, also contributing establishment of reasonable-distance between scientists and local government-public.

The Headquarters of Earthquake Research Promotion (HERP) is responsible for making use of the scientific knowledge of earthquakes in disaster reduction. In contrast to the volcano eruption prediction, it is rather difficult to keep reasonable distance between scientists and government-public for the following reason. The community of earthquake science is much bigger than that of volcano eruption prediction. Government personnel are changed in two years. Most of earthquake scientists live in Mega cities, and many prefectures have no earthquake scientists to ask for advices.

Volcanic Alert Levels were established following the requirement by the public. The level is designed so that each level corresponds to a definite evaluation action of the residents. Although, this is more than that volcano science can provide, the level functions so far with a conservative operations. For example, in the 2011 eruption of Kirishima nobody was insured or killed in spite of no precursors are observed. The alert level was kept level 2 after the small eruption of the previous year.

HERP issues long-term probability of earthquake occurrence in Japan, which was a strong requirement of the public after the 1995 Kobe earthquake. Characteristic earthquake model is used for the evaluation, because this the only usable model for the calculation of long-term probability of earthquake. To meet the responsibility for the public the government have to evaluate earthquake probability for all of major active faults and plate boundaries in Japan territory, in spite of large uncertainty. In the evaluation the off-Tohoku area are divided into several regions, each of which was assigned its own characteristic earthquake. Interaction of asperities, which represents the region division, was not taken into account. The off the coast of Tohoku earthquake is really a result of such interaction. After the earthquake the "Off-the-coast-of-Tohoku-type" earthquake are introduced in the evaluation process, but still based on the characteristic earthquake hypothesis. The disaster reduction plan based on the long-term evaluation depends on the polity of the Cabinet Office or local governments.

The above examples are the results of interaction among social demands, governmental policy and state-of-the art of scientific knowledge. Though we have to admit that they are more than the present achievement of volcano and earthquake science, it is inevitable to issue some information for practical disaster reduction. We need to make continual efforts to improve the disaster reduction measure through effective communication between governmental personnel, public and scientists.

U10-02

Room:Main Hall

Time:May 1 09:45-10:15

Space Policy in Japan after new decision system

MATSUI, Takafumi^{1*}

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In 2012, decision system on space policy in Japan changed. Since then, new space policy has been decided under the supervision of national committee on space policy. In this talk I will introduce the structure of this new system and vision of space exploration of our country in the next decade.

U10-03

Room:Main Hall

Time:May 1 10:15-10:45

The relationship between Earth and Planetary Science and politics from the stand point of oceanography

KOIKE, Isao^{1*}

¹University of Ryukyus

Ocean political issue is one of the most critical issues in recent Japan including continental shelf, resources, fishing, conservation of living resources, and total environment of the Earth. Science has been required to give contribution to policy making, which means that to keep balance is important for us. I will discuss the situation of science in recent Japanese ocean politics and how we should go.

Transdisciplinary approach for global environment and Future Earth

YASUNARI, Tetsuzo^{1*}

¹Research Institute for Humanity and Nature

The global environmental studies are now required to make progress toward global sustainability and futurability of the earth system. RIHN is now stepping forward to transdisciplinary approach for tackling these issues. This approach involves strong collaboration with the international Future Earth initiative. We also emphasize the importance of Asia-Pacific region as a complex tectonic-environmental hot spot region on these issues.

U10-05

Room:Main Hall

Time:May 1 11:30-12:00

Relationship between scientists and government - public

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¹Department of Earth and Planetary Science

How scientists should be saying to the government and society? Based on the norms of scientists, I will discuss the social role of scientists.

Keywords: scientists, government, public

U10-06

Room:Main Hall

Time:May 1 12:00-12:30

Earth science, community, and government

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Earth and planetary science stands on a special position between natural science and the community and government, which in turn means an importance of our community from both sides. We have encountered various difficulties in March 2011, when our words gave a great influence on community and we had frustration how we presented scientific results that might have caused social confusion. We will discuss how Earth and planetary science keep good distances from social community and government and how we should play our role.

Keywords: earth and planetary science, community, government