National Report for INTERNATIONAL UNION OF GEODESY AND GEOPHYSICS (IUGG)

Activity Reports on Geodesy and Geophysics in Japan for the Period from 2011 to 2014

JUNE 2015

JAPANESE NATIONAL COMMITTEE FOR IUGG

SCIENCE COUNCIL OF JAPAN

CONTENTS

Japanese National Committee for IUGG
Foreword

Setsuya NAKADA

Chair, Japanese National Committee for the International Union of Geodesy and Geophysics

Japan was one of the first nine member countries of the International Union of Geodesy and Geophysics (IUGG), founded in 1919. The Japanese National Committee for Geodesy and Geophysics was organized by the Science Council of Japan (SCJ) as the national adhering body of the IUGG. As reformulated in 2005, the SCJ has 30 disciplinary committees, including the Earth and Planetary Sciences (EPS) Committee, which covers all fields related to earth and planetary sciences. The present Japanese National Committee for Geodesy and Geophysics is one of the subcommittees of the EPS Committee.

Our National Committee maintains a close relationship with the Japan Geoscience Union (JpGU). The JpGU was established in May 2005 and became a Public Interest Incorporated Association in December 2011; it currently represents 50 academic societies and associations related to earth and planetary sciences. The organization aims to promote the earth and planetary sciences as a whole through research activities, information exchange, international partnerships, and transmission of research results to the public. The JpGU contains more than 7,000 registered individual members. Its annual meeting is held every spring in Chiba or Tokyo; in 2014, approximately 7,000 participants attended roughly 4,000 presentations. Academic societies corresponding to the eight associations of the IUGG actively function under the JpGU.

The Tohoku Earthquake, with a magnitude of 9.0, occurred on 11 March 2011. The casualties from the resultant tsunami, including missing persons, reached approximately 18,000. The earthquake and its induced tsunami also destroyed the cooling systems for the reactors of the Fukushima-Daiichi Nuclear Power Plant. As a result, the plant's nuclear fuels melted down, hydrogen explosions occurred, and the area near the site was exposed to radiation. These events tremendously impacted Japanese scientists related to geodesy and geophysics, offering not only subjects of scientific study but also causes to reconsider what scientists should be. Scientists' efforts in clarifying the mechanism of this earthquake led to new ideas and technological developments. The newly moved fault zone along the Japan Trench was promptly penetrated using the drilling research vessel "Chikyu." Ocean bottom observation systems with dense seismic and electromagnetic stations on the sea bottom were developed. The ionospheric disturbance induced by the tsunami, as well as the large stress variation and strong ground motion associated with the earthquake, were studied by the high-resolution GPS-TEC network in Japan. The drift and dispersion of marine debris in the tsunami were also studied from a physical and chemical oceanography perspective.

We held the following important international conferences and workshops during 2011–2014. The IAVCEI Scientific Assembly (IAVCEI 2013) was held in Kagoshima in July 2013 with 1,069 participants. The 18th International Workshop on Laser Ranging was held in Fujiyoshida of Yamanashi Prefecture in November 2013. The Geodesy for Earthquake and Natural Hazards workshop (GENAH2014) was conducted in Matsushima, Miyagi Prefecture in July 2014. The International Symposium on the Climate and Weather of the Sun-Earth System (CAWSES-II) of the ICSU's scientific committee, Solar-Terrestrial Physics (SCOSTEP), was held in Nagoya in November 2013 with 320 participants. A conference of the IUGG Commission of Study of the Earth's Deep Interior (SEDI 2014) was held in Hayama, Kanagawa Prefecture in August 2014.

This report summarizes the activities that the Japanese science communities conducted during 2011–2014 in relation to the eight associations of the IUGG.

Membership of Japan National Committee for the International Union of Geodesy and Geophysics, Science Council of Japan

The 23rd Term of the Science Council of Japan (2014–2017)

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	Takuji NAKAMURA	National Institute of Polar Research
	Kouichi NISHIMURA	Nagoya University (IACS)
	Kenji SATAKE	The University of Tokyo (IASPEI)
	Toshio YAMAGATA	Japan Agency for Marine-Earth Science and Technology (IAPSO)
Associate Members	Satoru TANAKA	Japan Agency for Marine-Earth Science and Technology (SEDI)

The 22nd Term of Science Council of Japan (2011-2014)

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	Toshitsugu YAMAZAKI	The University of Tokyo (IAGA)
Associate Members	Satoru TANAKA	Japan Agency for Marine-Earth Science and Technology (SEDI)
	Kouichi NISHIMURA	Nagoya University (IACS)

I. Activity report of the National Committee for Cryospheric Sciences (IACS)

Kouichi NISHIMURA
Chair of the National Committee for Cryospheric Sciences
Keisuke SUZUKI
Secretary General of the National Committee for Cryospheric Sciences

The present (22nd) term of the National Committee for the Cryospheric Sciences of Japan started in November 2011. The main agenda for the National Committee involved transmitting the information and activities of the International Association of Cryospheric Sciences (IACS) to its stakeholders in Japan, particularly the members of the Japanese Society of Snow and Ice (JSSI). JSSI is the main organization for snow and ice research in Japan and has nearly 900 members.
Further, the national committee announced and encouraged attendance at the international workshop and conferences organized by IACS.

Recent research activity highlights

1. Alpine Glaciers

Japanese glaciologists and geographers believed that there were no active glaciers in Japan. However, the research group of the Tateyama Caldera Sabo Museum have studied the surface flow velocity and ice thickness at the perennial snow patches in Mt. Tsurugi, central Japan, since 2009, finding that two of them are indeed active glaciers.

Studies on cryoconite, microbes, and their effect on surface albedo have been conducted in western China by a group from Chiba University, Japan since 2006, in collaboration with the Tien Shan Glaciological Station, Chinese Academy of Science. These researchers found a distinctive microbial community on the glacier: cyanobacteria, which are photosynthetic microbes, dominate the microbial community on the ablation surface and form a large amount of cryoconite on the surface. This cryoconite substantially reduces the surface albedo and likely affects the total ablation of the glacier. The dominance of cyanobacteria may be due to the abundant deposition of desert sands, which change the chemical conditions of meltwater to be favorable to cyanobacteria.

To evaluate the contribution of glacier runoff to river runoff, a new data set for altitudinal distributions of glacier area has been prepared for the Asian High Mountains. Only limited observation data on glacier fluctuation in the Asian High Mountains are available at present. However, the new glacier inventory established by this project will make it possible to estimate changes in glacier volume accurately.

2. Polar Glaciology

The changes occurring in the Arctic are both substantial and rapid, and many different parts of the Arctic climate system are involved. A new Japanese initiative, the "Arctic Climate Change Research Project," was launched within the framework of the GRENE (Green Network of Excellence) Program funded by the Ministry of Education, Culture, Sports, Science and Technology of Japan (MEXT) for 5 years starting in 2011. Four strategic research targets were established: 1. Understanding the mechanism of warming amplification in the Arctic; 2. Understanding the Arctic system for global climate and future change; 3. Evaluating the impacts of Arctic change on weather and climate in Japan; 4. Projection of sea ice distribution and Arctic sea routes. Over 300 scientists from 35 organizations are currently participating in the project, tackling all aspects of the Arctic climate systems.

At the National Institute of Polar Research (NIPR), the current main glaciology project is titled "Approaching 'the earth system' mechanisms through the past polar environmental changes." This project aims to predict the future of the Earth's environment by determining the past of the Antarctic ice sheet.

The project is a collaboration with geology-based scientists who investigate the growth/retreat history of the ice sheet in East Antarctica based on sediments and rocks near the coast. One important research method for clarifying the relationship between the elements composing "the Earth system" is the historical reconstruction of the past changes of each element and their chronology. Our recent activity includes Antarctic inland traverses to better understand the polar plateau, which contains an archive of the climate. Traverse teams have visited areas near Dome Fuji and further inland for glaciological surveys. Shallow (~100 m) firn cores were sampled, and firn air sampling was conducted at a few locations. Automatic weather stations have been installed. In the 2012/2013 field season, the area south of Dome Fuji will be investigated for a candidate location of a new permanent inland base. Accumulation environment and ice-sheet bed conditions have been investigated using ice sounding radars. Additional recent research has included a survey of ice shelves using the steam drill technique. The field team succeeded at penetrating the ice shelf using a steam drill to investigate the environment of the ice shelves. In the next several years, work will focus on the glaciological conditions near the coast. This research will include ice core drilling and surveys of Shirase Glacier.

II. Activity Report of the National Committee for Geodesy (IAGA)

Kosuke HEKI
Chair of the National Committee for Geodesy
Ryuichi ICHIKAWA
Secretary General of the National Committee for Geodesy

The period from 2011 to 2014 was unforgettable for Japanese geodesists because of the 11 March 2011 Tohoku-Oki M_w9.0 earthquake. Apart from the human tragedy of the event, the earthquake also stimulated vigorous research activities worldwide in various fields of earth sciences. For geodesy, the earthquake left unprecedentedly large geodetic signals in co- and postseismic crustal deformation, gravity change, disturbances in the upper atmosphere, etc. The earthquake also convinced geophysicists of the importance of a developing new geodetic technique: sea floor positioning. Below, we briefly review these activities and other geodetic research highlights during this period.

1. Geodetic works related to the 2011 Tohoku-oki earthquake

1.1 Synthetic Aperture Radar (SAR)

The Advanced Land Observing Satellite (ALOS, Daichi), launched in January 2006 and operated by the Japan Aerospace Exploration Agency (JAXA), stopped operation in May 2011, shortly after successfully obtaining two-dimensional images of the coseismic displacement of the 2011 Tohoku-oki earthquake using L-band SAR (PALSAR) [1]. Detailed analyses of the interferograms revealed that major active volcanoes and their surrounding areas experienced a coseismic subsidence of 5–15 cm [1]. The follow-on satellite ALOS-2 was launched in May 2014. This satellite detected the topographic changes of the Ontake Volcano, which erupted on 27 September 2014 and killed 57 hikers that were staying or walking around the summit.

1.2 Positioning with Global Navigation Satellite Systems (GNSS) networks

The nationwide array of continuous GNSS receivers GEONET (GNSS Earth Observation Network), operated by the Geospatial Information Authority of Japan (GSI), recorded eastward coseismic displacements of up to 5 meters at stations on the Pacific coast of the Tohoku District [2]. Coseismic subsidence in this area amounted to ~1 meter, causing significant landward retreat of the coastline. Postseismic movements still continue, but they do not appear to be recovering the coseismic subsidence. Large earthquakes excite free oscillations of the Earth, which are detectable with conventional sensing methods such gravimetry and strain/tilt measurements. After the 2011 Tohoku-oki earthquake, GEONET also detected free oscillation for the first time in terms of periodic surface displacements [3].

1.3 Sea floor positioning

Positioning of sea floor benchmarks using microwaves (between a vessel and satellites) and acoustic waves (between the sea floor and a vessel) has been conducted off the Pacific coast of the Japanese Islands for over ten years, mainly by three organizations: the Japan Coast Guard, Tohoku University, and Nagoya University. The importance of this activity became widely recognized due to the 2011 Tohoku-oki earthquake after the sea floor benchmark directly above the ruptured fault captured eastward coseismic movement exceeding 20 meters [4]. Some of the benchmarks have been showing rapid westward postseismic displacements, in the opposite direction to those of the GNSS stations on land [5]. These remarkable findings spurred the Japanese government to fund the deployment of multiple new sea floor geodetic stations.

1.4 Gravity changes

Satellite gravimetry by the Gravity Recovery and Climate Experiment (GRACE) captured the coseismic gravity changes of the 2011 Tohoku-oki earthquake [6]. The postseismic gravity changes of this earthquake and the two past M9 class earthquakes (2004 Sumatra-Andaman and 2010 Maule earthquakes) are characterized by the short-term (a few months) continuation of the coseismic drops on

the backarc side of the island arc and a long-term (years) slow gravity increase just above the ruptured fault [7].

2. International workshops on geodesy

From 2011 to 2014, Japanese geodesists hosted two international workshops sponsored by IAG. The first, the 18th International Workshop on Laser Ranging, was held in Fujiyoshida, Yamanashi, in November 2013 (LOC chair: Prof. T. Otsubo, Hitotsubashi Univ.). The workshop was attended by 150 participants from 27 countries. The second, the GENAH (Geodesy for Earthquake and Natural Hazards)-2014 (LOC chair: Prof. M. Hashimoto, Kyoto Univ.) workshop, took place in Matsushima, Miyagi, in July 2014. A total of 130 people from 16 countries attended this meeting, and many also participated in the post-workshop excursion to the coastal area of Miyagi, which was damaged by the 2011 Tohoku-oki earthquake tsunami.

3. Positioning and Navigation

3.1 QZSS for supplementation of GNSS for Urban or Mountainous Areas

The first satellite of the quasi-zenith satellite system (QZSS) MICHIBIKI was launched in September 2010. This satellite was injected into a quasi-zenith orbit over Japan with a central longitude of approximately 135E. In addition to the first satellite, which has maintained regular operations, three additional satellites are planned for launch in 2017–2019. These craft are expected to supplement the GNSS satellites for improved accuracy in positioning, especially in urban or mountainous regions.

3.2 Continuous GNSS Observation Network

GSI started to update the receivers of the GEONET stations to allow tracking not only of GPS, the American GNSS, but also of the Japanese QZSS, Russian GLONASS, etc. GEONET is composed of ~1200 permanent stations, and the majority of these stations were converted into multi-GNSS stations by 2012. Since 2014, the raw observation files in RINEX format have been uploaded to the data server more frequently (every hour in 2015). This procedure reduces the maximum latency of real-time data to one hour.

3.3 Very Long Baseline Interferometry (VLBI)

Major radio telescopes for VLBI have recovered from the damages caused by the 2011 Tohoku-oki earthquake. These installations include the Kashima 34-m antenna operated by the National Institute of Information and Communications Technology (NICT), the Tsukuba 32-m antenna operated by GSI, and the four radio telescopes for astrometry operated by the National Astronomical Observatory (NAO), Japan. GSI began operating a next-generation VLBI station with a 13-m telescope in Ishioka, Ibaraki, in the autumn of 2014.

4. Passing of Leading Geodesists

During the last four years, two leading scientists in geodesy have passed away: Ken'nosuke Hosoyama (Emeritus Staff of the International Latitude Observatory of Mizusawa) on 23 October 2014 and Yasujiro Wako (Emeritus Professor of National Astronomical Observatory) on 5 April 2011. Their passing reminds us of the glorious days of classical earth rotation studies in Mizusawa, Iwate, Japan.

References

[1] Takada, Y. and Y. Fukushima, Volcanic subsidence triggered by the 2011 Tohoku earthquake in Japan, Nature Geosci. 6, 637-641, 2013.

[2] Ozawa, S. et al., Coseismic and postseismic slip of the 2011 magnitude-9 Tohoku-oki earthquake, Nature 475, 363-377, 2011.

[3] Mitsui, Y. and K. Heki, Observation of Earth's free oscillation by dense GPS array: After the 2011 Tohoku megathrust earthquake, Sci. Rep. 2, 931, 2012.

[4] Sato, M. et al., Displacement above the hypocenter of the 2011 Tohoku-oki earthquake, Science 332, 1395, 2011.

[5] Watanabe, S. et al., Evidence of viscoelastic deformation following the 2011 Tohoku-Oki earthquake revealed from seafloor geodetic observation, Geophys. Res. Lett., 41, 5789-5796, doi:10.1002/2014GL061134, 2014.

[6] Matsuo, K. and K. Heki, Coseismic gravity changes of the 2011 Tohoku-Oki Earthquake from satellite gravimetry, Geophys. Res. Lett., 38, L00G12, doi:10.1029/2011GL049018, 2011.
[7] Tanaka, Y. and K. Heki, Long- and short-term postseismic gravity changes of megathrust earthquakes from satellite gravimetry, Geophys. Res. Lett., 41, 5451-5456, doi:10.1002/2014GL060559, 2014.

III. *Activity Report on the National Committee for Geomagnetism and Aeronomy (IAGA)*

Masato Nakamura
Chair of the National Committee for Geomagnetism and Aeronomy
Toshitsugu Yamazaki
Secretary General of the National Committee for Geomagnetism and Aeronomy

This report briefly reviews recent research activities (2011-2014) in geomagnetism, aeronomy, and related fields in Japan.

1. Earth and Planetary Interiors

The magnetic field around the Moon observed by the SELENE (Kaguya) spacecraft has been analyzed intensively. The radius of the highly electrically conducting lunar core was estimated to be approximately 290 km by a magnetic induction study. Distributions of magnetic anomalies at the lunar surface were obtained, and a possible reorientation of the lunar poles was proposed.

A geodynamo model in a magnetostrophic balance has been numerically simulated at a low Ekman number, indicating that large-scale structures appear as a result of the strong azimuthal (toroidal) magnetic field near the core-mantle boundary (CMB). A method to infer the toroidal field at the CMB from magnetic observations has been tested using numerical dynamo modeling.

Recent progress in paleomagnetic studies has been bolstered by paleointensity variations in older ages, remanent magnetization acquisition processes in sediments, and the widespread occurrence of biogenic magnetite. The Integrated Ocean Drilling Program and its successor, the International Ocean Discovery Program (IODP), have provided opportunities and materials for paleo- and rock magnetic studies. The Center for Advanced Marine Core Research, Kochi University, has supported paleo- and rock magnetic research in Japan through its nationwide joint-use system, which offers access to sophisticated instruments.

A multidisciplinary five-year project, “Normal Oceanic Mantle” (2010–2014), was conducted to study the lithosphere-asthenosphere system beneath the northwestern Pacific, including its electrical conductivity. A Network MT survey aimed at determining nationwide electrical conductivity distributions down to the upper mantle was continued in Japan. The 3D electrical conductivity was imaged to infer the fluid distribution deep in the crust and mantle in another multidisciplinary five-year project, “The Crustal Fluid” (2009–2013).

2. Sun, Solar Wind, and Magnetosphere

Geomagnetic conjugate observations of auroras have been conducted by the National Institute of Polar Research at Iceland and the Antarctic Syowa station for several decades. Recently, using new CCD cameras with high spatial resolution, these facilities have obtained conjugate features of auroral beads (voltex) structures at the initial brightening of auroral substorms, indicating that these bead structures are created in the source magnetosphere and are possibly related to the onset of auroral and magnetospheric substorms.

New high-speed (faster than 100 Hz) auroral imaging observations are being conducted by NIPR and the Solar-Terrestrial Environment Laboratory (STEL), Nagoya University at Fairbanks, Alaska and Athabasca, Canada. A loop antenna to measure ELF/VLF radio emissions was deployed at Athabasca, Canada by STEL, Athabasca University, and Kanazawa University in 2012. These observations show characteristics of the fast modulation of pulsating auroras and ELF/VLF chorus emissions that scatter electrons to cause the modulation of electron precipitation. Such nonlinear wave-particle interaction processes in the equatorial plane of the inner magnetosphere have been successfully simulated by the Research Institute for Sustainable Humanosphere (RISH), Kyoto University, and Tohoku University.

3. Upper Atmosphere

PANSY (Program of the Antarctic Syowa) Radar is the first MST/IS radar in the Antarctic region.

Construction started at Syowa Station in early 2011 and was recently completed. Japan has been a member of the EISCAT Scientific Association since 1996 and continues to make significant scientific contributions. Other big Japanese radars include the MU radar in Shigaraki and the Equatorial Atmosphere Radar in Indonesia, which continued to conduct experiments over this period. Routine ground-based network observation of the upper atmosphere, ionosphere, and magnetosphere has been conducted continuously. A second SuperDARN HF radar has conducted routine measurements of ionospheric plasma at subauroral latitudes at Rikubetsu since 2014. GAIA, an Earth atmosphere-ionosphere coupled model that seamlessly treats the neutral atmosphere and the ionosphere, is now used for studies of various phenomena. Observations from the Japanese Experiment Module (JEM) on ISS (International Space Station) started in 2012. ISS-IMAP (Imagers for Ionosphere, Mesosphere, upper Atmosphere, and Plasmasphere mapping) began imaging of the E- and F-region airglow and extra ultraviolet light from the plasmasphere. Additionally, the JEM-GLIMS (Global Lightning and sprIte MeasurementS on JEM-EF) started observations of lightning and transient luminous events. Several sounding rocket launches were also conducted: S-310-40 (December 2011) for LF/MF radio propagation in the ionosphere, S-520-26 (January 2012) for lithium-release neutral wind measurement, and S-520-27/S-310-42 (July 2013) for studies of the medium-scale TID.

4. Interdisciplinary activities and magnetic observatory

Ionospheric disturbances induced by the tsunami, as well as the large stress variations or strong ground motions associated with the Tohoku Earthquake, were studied by the high-resolution GPS-TEC network in Japan. The initial results were quickly published in *Earth Planets and Space* in 2012 (http://www.terrapub.co.jp/journals/EPS/toc/6412.html) (open access).

The International CAWSES-II Symposium was held in November 2013 at Nagoya University. Related papers are now being published in *Earth Planet Space* (http://www.earth-planets-space.com/series/ICS).

Kanozan Geodetic Observatory, at which the Geospatial Information Authority of Japan has conducted geomagnetic observations since 1956, became an unmanned station in April 2012. Kakioka Magnetic Observatory, operated by Japan Meteorological Agency, celebrated its 100th anniversary in January 2013. A method to convert the photographic records of Kakioka Magnetic Observatory to one-minute digital data has been developed, and these digitized data have been published sequentially since January 2013.

IV. Activity Report of the National Committee for Hydrological Sciences (IAHS)

Jumpei KUBOTA
Chair of the National Committee for Hydrological Sciences
Maki TSUJIMURA
Secretary General of the National Committee for Hydrological Sciences

The Japan National Committee for Hydrological Sciences promotes hydrological research and coordinates the national academic bodies related to terrestrial water studies. Japan now has 15 independent hydrological science societies: the Japanese Society of Limnology; the Japanese Association of Groundwater Hydrology; the Japanese Association of Snow and Ice; the Balneological Society of Japan; the Geochemical Society of Japan; the Japan Society of Civil Engineers; the Japanese Forestry Association; the Japan Society of Hydrology and Water Resources; the Japanese Association of Hydrological Sciences; the Erosion Control Engineering Society of Japan; the Society of Agricultural Meteorology of Japan; the Japanese Society of Irrigation, Drainage, and Reclamation Engineering; the Geothermal Research Society of Japan; the Japanese Geomorphological Union; and the Japanese Society of Physical Hydrology.

The Japanese committee of the International Association of Hydrological Sciences (IAHS) undertook the following three activities between 2011 and 2014.

1. Committee Meetings

The Japanese Committee of IAHS held four committee meetings on the following topics:

1st Meeting (23 May 2012 at Chiba): The mission of the committee was discussed, focusing on global communication of research by the Japanese hydrological community.

2nd Meeting (8 July 2012 at Kyoto): A proposal for an Open Discussion Meeting on Water was discussed.

3rd Meeting (16 August 2012 at Kyoto): A detailed agenda of the Open Discussion Meeting on Contributions by Japan for Global Water Research and Education (Japan Water 2012) was discussed.

4th Meeting (13 June 2013 at Tokyo): A summary of Japan Water 2012 was discussed. Issues and perspectives on the Letter Journal on Water in Japan were also discussed.

2. Japan Water 2012

The Japan Water 2012 meeting was held on 15 October 2012 at the Ministry of Education, Culture, Sports, Science and Technology Japan, organized by the National Committee for Hydrological Sciences and the IHP Working Group of the National Commission for UNESCO. The agenda of the meeting consisted of presentations on international trends in water research and education, presentations by institutes and universities on research and education programs, summaries of the activities of academic associations on water, presentations by key persons on human resource development in various sectors regarding career paths for water specialists, presentations by ministries and agencies concerned with water issues, and general discussion.

Approximately 80 participants participated in the meeting, coming from the Research Institute for Humanity and Nature; the University of Tokyo; Kyoto University; Nagoya University; the University of Tsukuba; Kyushu University; Hokkaido University; Yamanashi University; Gifu University; the Institute of Global Environmental Strategies; the National Institute of Advanced Industrial Science and Technology; the International Center for Water Hazard and Risk Management Under the Auspices of UNESCO; the World Bank; the Japan Agency for Marine-Earth Science and Technology; Suntory Holdings Limited; the Ministry of Education, Culture, Sports, Science and Technology; the Ministry of Environment; the Ministry of Land, Infrastructure, Transport and Tourism; and the Ministry of Agriculture, Forestry and Fisheries.

3. Special Session in the Japan Geoscience Union (JpGU) Meeting

The National Committee for Hydrological Sciences organized a Special Session titled “Issues and

Perspectives of Graduate Education and Career Paths for Water Specialists" on 21 May 2013 at Makuhari Messe, Chiba. Approximately 30 participants shared information on education programs at the graduate level related to water issues and sciences conducted by Kyoto University, Kyushu University, Kumamoto University, Yamanashi University, and the Research Institute of Humanity and Nature. The participants discussed the mission of this education, effective curriculum and coursework, quality control of students, and career paths for alumni.

4. Special Sessions in the IAHS/IAPSO/IASPEI Joint Assembly

The members of the National Committee for Hydrological Sciences contributed as conveners, presenters, and commission members in the IAHS (International Association of Hydrological Sciences)/ IAPSO (The International Association for the Physical Sciences of the Oceans)/ IASPEI (International Association of Seismology and Physics of the Earth Interior) Joint Assembly "Knowledge for the Future," held in Gothenburg, Sweden from 22 to 26 July 2013. The IAHS organized 4 symposiums and 11 workshops at the assembly.

V. Activity Report of the National Committee for Meteorology and Atmospheric Sciences (IAMAS)

Hisashi NAKAMURA
Chair of the National Committee for Meteorology and Atmospheric Sciences
Jinro UKITA
Secretary General of the National Committee for Meteorology and Atmospheric Sciences

The main organization for the Japanese research community in the fields of meteorology and atmospheric sciences is the Meteorological Society of Japan (MSJ), which has a current membership of approximately 3,800. All members of the National Committee for Meteorology and Atmospheric Sciences (the Committee, hereafter) have been appointed by the Science Council of Japan (SCJ) under close communication with the MSJ.

The current (23rd) term of the Committee began its activities in October 2014 with the selection of members, enabling close communication with the MSJ in the areas of reviewing academic and research activity in meteorology and atmospheric sciences and planning for the promotion of future activity in the field. The Committee also handles international affairs related to the International Association of Meteorology and Atmospheric Sciences. The following report summarizes the main activities of the Committee since October 2011, when the preceding Committee (22nd term) was organized.

1. Overview

The MSJ has played a central role in fostering the advance of meteorological research in Japan and opening new research areas in cooperation with related academic societies and research organizations, both domestically and internationally. The MSJ has encouraged communication among member scientists by sponsoring scientific workshops and symposia, including its semiannual general assemblies; by publishing its bulletin, international journals, and research monographs; and by disseminating the latest scientific knowledge to the general public at an open symposium in each general assembly and at summer school every year. The MSJ is now strengthening its ties with the Japan Geoscience Union (JpGU).

2. Highlights on recent activities

Some of the novel outcomes from research activity and promotion in conjunction with domestic and international projects such as the World Climate Research Program (WCRP) and International Geosphere–Biosphere Program (IGBP) are summarized below:

- The core set of coordinated climate model experiments for the fifth phase of the Coupled Model Intercomparison Project (CMIP5) was conducted on the upgraded Earth Simulator using two state-of-the-art coupled general circulation models (CGCMs): the MIROC (from the AORI-NIES-JAMSTEC) and the MRI-CGCM. The results from those climate simulations significantly contributed to the Fifth Assessment Report (AR5) of the Intergovernmental Panel on Climate Change (IPCC). A next-generation, high-resolution atmospheric modeling project is now in progress using a newly developed petaflop supercomputer (the K computer) of the AICS. The project strongly emphasizes super-high resolution simulations with a global cloud-resolving model (NICAM) and large-data ensemble data assimilation and forecast.
- Substantial progress has been made in the area of satellite observations through several projects, including the Greenhouse gases Observing SATellite (GOSAT), Global Precipitation Measurement (GPM), Global Change Observation Mission (GCOM), and Advanced Land Observing Satellite (ALOS). GOSAT-1, which measures concentrations of carbon dioxide and methane, was launched on 23 January 2009 and has been operating properly since that point. Its successor, GOSAT-2, is also under development. The Global Precipitation Measurement (GPM) mission is an international network of satellites that provide next-generation global observations of rain and snow. Its current core satellite, the GPM Core Observatory, employs two sensors, the dual-frequency Precipitation Radar (DPR) and the GPM Microwave Imager, and was successfully launched on 28 February 2014. Contributing to the

Global Earth Observation System of Systems (GEOSS), the GCOM consists of the GCOM-W and GCOM-C, which aim to make continuous global-scale observations on changes in water (hydrological) cycle and climate, respectively. The first satellite of the GCOM-W, which uses the Advanced Microwave Scanning Radiometer 2 (AMSR2), was launched on 18 May 2012. The ALOS-2, which uses a new L-band SAR, was launched on 24 May 2014. After the initial calibration-validation phase, this satellite has been in successful operation. Other satellite projects, such as the GCOM-C for measuring the carbon cycle and radiation budget and the EarthCARE for taking cloud and aerosol measurements, are in development for future launches.

- The construction of the PANSY radar, the first Antarctic Mesosphere-Stratosphere-Troposphere incoherent scatter (MST/IS) radar, began in December 2010 at Syowa Station and was completed in April 2012. The radar has been in operation almost continuously since that point. The adjustment of the full system was finished in January 2015, and continuous observations will occur over the next 13 years, covering a full solar cycle.
- Extensive discussions were conducted within the research community, under the leadership of the SCJ, to establish a roadmap for effectively organizing large-scale national research projects and identifying particular research areas that will be of increasing importance in the future. Specifically, under the leadership of the SCJ, the MSJ led intensive discussions within the community to select and prioritize national projects that require large-scale funding from the Ministry of Education, Culture, Sport, Science and Technology (MEXT). The MSJ has placed the highest priority on establishing a research aircraft for the science community, as well as high priority on climate prediction and projection.

VI. Activity Report of the National Committee for the Physical Sciences of the Oceans (IAPSO)

Toshio Yamagata
Chair of the National Committee for the Physical Sciences of the Oceans
Toshiyuki Hibiya
Secretary General of the National Committee for the Physical Sciences of the Oceans

The current National Committee for the Physical Sciences of the Oceans of the Science Council of Japan took over the activities of the previous committee on 1 October 2014. We report below some of the outcomes from Japanese research activities in physical and chemical oceanography during 2011–2014.

1. The Kuroshio and Kuroshio Extension

Japanese scientists have been making steady progress in the study of the long-term variability of the Kuroshio and Kuroshio Extension (KE). Covariation of the dynamic state of the Kuroshio Extension and the path of the Kuroshio south of Japan has been identified. The effects of these variations on the atmospheric conditions in this region and the sea level variation along the coast of Japan have been clarified. The predictability of these variations, which is intimately related to the large-scale wind field variation and its adjustment processes, has been actively studied. Several numerical modeling and observational efforts have been directed to understanding submesoscale phenomena, which have been ubiquitous in this region.

2. Midlatitude Air-Sea Interactions

From 2010 to 2015, a Japanese nationwide project on the topic “Hot Spots in Climate Systems” has been conducted in collaboration with projects in the US, France, and China. Nearly 100 scientists and graduate students participated in the project to improve the understanding of air-sea interactions on the marginal sea, ocean basin, and planetary scales. The studies in this project examined topics ranging from subsurface ocean dynamics to variability in the stratosphere. The impacts of sea surface temperature fronts on the mean and variability of clouds, storm tracking, and further atmospheric circulation, including its annular mode, have been detected in observational data and/or numerical models. Possible ocean-to-atmosphere feedbacks have been found in summer and autumn seasons, as well as in winter.

3. North Pacific mode waters and their variability

Taking advantage of the accumulation of relatively dense Argo profiling data over the northwestern North Pacific, a great deal of research has been conducted on mode waters, including Subtropical Mode Water and Central Mode Water. Remarkable outcomes include that (1) mode water formation and distribution are heavily influenced by mesoscale eddies, as has been suggested by previous numerical studies; (2) the deeper pycnocline associated with an anticyclonic eddy fosters the formation of thicker mode water; (3) the interannual-to-decadal modulation of eddy activity along the Kuroshio Extension causes significant temporal variations in mode water formation and its spreading.

4. The Tropical Pacific and Indian Oceans

Intensive studies on the evolutionary mechanisms of dominant climate modes in the tropical Indo-Pacific region and their influences on global and regional climate conditions have been conducted, including asymmetric characteristics in the Indian Ocean Dipole (IOD) events and inter-basin influences between the IOD and El Niño/Southern Oscillation. A regional climate phenomenon occurring off the coast of northwestern Australia, called the Ningaloo Niño/Niña, has been recently identified. Both the local air-sea interaction effects and the remote effects of El Niño/La Niña events from the Pacific have been shown to be important in the evolution of the Ningaloo Niño/Niña. High-quality data from Japanese surface moorings in the tropical Indo-Pacific region continue to be disseminated to the wider research community.

5. Polar Oceans

The Cape Darnley Polynya, which has the second highest ice production in the Antarctic Ocean, has been identified as the missing source of the Antarctic Bottom Water (AABW). This fourth AABW, called the Cape Darnley Bottom Water, migrates westward and ultimately constitutes part of AABW in the Weddell Sea, representing 10%–30% of Atlantic AABW production. A series of research expeditions in the western Arctic Ocean by the *Mirai* and *Oshoro* during 2012–14 has revealed several important processes in this ice decline sea, such as the enhanced role of eddies in biological pumping from wide shelves to deep basins.

6. Ocean Mixing

The turbulent mixing caused by various energy sources has been examined in various regions. The global distribution of energy conversion rates from barotropic to baroclinic tides has been numerically clarified in the limit of zero horizontal grid spacing. Tidal interactions with fine-scale (~1 km) rough bottom bathymetry have been found to efficiently generate high wavenumber internal waves subject to local dissipation, inducing abyssal mixing with intensity and vertical decay scale in a trade-off relationship with each other. Microstructure measurements have been conducted near mixing hotspots in the deep ocean to assess the fine-scale parameterizations of turbulent dissipation rates. The performance of several turbulence closure models for the surface mixed layer has been assessed using large eddy simulation and global general circulation models under various sea-surface conditions.

7. Coastal and Marginal Seas

A part of the research project "Hot Spots in Climate Systems" was conducted to uncover atmosphere-ocean coupled processes at the regional scale over the East Asian marginal Seas. Synoptic-scale atmospheric processes (e.g., extratropical cyclones) have been found to be frequently modulated over the marginal seas due to oceanic fronts, the Kuroshio path, phytoplankton bloom, etc. Recent ocean reanalysis products (e.g., JCOPE2 and DREAMS) have provided useful boundary conditions for modeling coastal waters. For example, a forecast of Kyucho events (sudden intrusions of Kuroshio water) into the Seto Inland Sea has been conducted using a fine-resolution numerical model, along with JCOPE2 data, as a one-way nested system.

8. Data Assimilation Research

Ocean data assimilation studies in Japan have focused primarily on developing new technologies and societal applications. Application areas include coastal disaster prevention, seasonal-interannual prediction, fishing field prediction, and estimation of the drift/dispersion of marine debris and nuclear matter. International activities in collaboration with JCOMM/GODAE Ocean View, CLIVAR/GSOP, JCOMM/ET-OOFS, JCOMM/TT-MEER, and GOOS/TPOS2020 have also been performed. This activity includes the estimation of the drift/dispersion of marine debris from the 2011 Great Tohoku Tsunami in Japan, international intercomparison of ocean reanalysis data, and observation of system evaluation experiments in the tropical Pacific.

9. Marine Biogeochemical Study

An interdisciplinary research project, "The New Ocean Paradigm on its Biogeochemistry, Ecosystem, and Sustainable Use" (NEOPS), was launched to establish new ocean provinces in the Pacific Ocean based on a better understanding of ecosystems and biogeochemical cycles. To understand the large-scale distribution of trace elements and their isotopes in the marine environment, Japanese-GEOTRACES cruises have been conducted in the North and the South Pacific, the Southern Ocean, and the Sea of Japan. Individual key topics, such as ocean acidification and biogeochemical cycles of radioactive elements related to the Fukushima accident, have been studied by Japanese biogeochemical scientists.

VII. Activity Report of the National Committee for Seismology and Physics of the Earth's Interior (IASPEI)

Kenji SATAKE
Chair of the National Committee for Seismology and Physics of the Earth's Interior
Satoru TANAKA
Secretary General of the National Committee for Seismology and Physics of the Earth's Interior

During the last four years (2011–2014), Japan continued its active research program in seismology and its applications to seismic hazards. Many of the efforts were related to the 2011 Tohoku Earthquake, the largest event in Japan's written history of earthquake records.

1. Devastating Earthquake

On 11 March 2011, the Tohoku Earthquake (M 9.0) and tsunami severely impacted northeastern Japan (Tohoku area), causing approximately 18,000 deaths and missing and over 6,000 injuries. The huge tsunami, with run-up heights of nearly 40 meters, caused over 95% of the deaths. The tsunami also caused core damage to and the release of radioactive material from the Fukushima Nuclear Power Station, forcing the evacuation of 150,000 persons in Fukushima Prefecture. From a seismological point of view, the Tohoku earthquake was one of the most studied great earthquakes, with data available from dense regional seismic networks, global seismic networks, and geodetic networks. Several important features of the earthquake included 1) a huge fault slip (30 to 60 meters) on the shallow portion of the megathrust close to the Japan Trench, 2) high frequency strong motions generated not from the areas of large slip but from the deeper down-dip portion of the fault plane, and 3) possible slow slips detected before the main shock.

2. Seismological Society of Japan (SSJ)

After the 2011 Tohoku Earthquake, the SSJ held a special symposium titled "Problems of current earthquake science – As revealed by the 2011 Tohoku Earthquake –" at its 2011 fall meeting and published a monograph (in Japanese). Furthermore, SSJ expressed new action items in 2012 in which the importance of outreach activities was emphasized. The year 2013 was the 90th anniversary of the Great Kanto Earthquake and the 100th anniversary of Prof. John Milne's death. A seminar on the 1923 Kanto Earthquakes was held in the epicentral area, Yokohama. The John Milne exhibition – Father of Japanese Seismology – was held at the National Museum of Nature and Science in Tokyo and included a visit from the Emperor and Empress of Japan. The 2014 SSJ meeting was held in Niigata for the 50th anniversary of the 1964 Niigata Earthquake. Prof. Kei Aki confirmed a double couple focal mechanism and first calculated the seismic moment for this earthquake. Many SSJ members have discussed the relationship of earthquake research and social applications such as safety policy for nuclear power plants.

3. National Projects

The Ministry of Education, Culture, Sports, Science and Technology (MEXT) launched in 2014 the new project "Earthquake and Volcano Hazards Observation and Research Program," which is a renewal of a five-year program formally known as "The Earthquake and Volcanic Eruption Prediction Research Project." The new project emphasizes the role of researchers in public safety. The Headquarters for Earthquake Research Promotion in MEXT, which was established after the 1995 Kobe earthquake, continues to promote scientific activities, fund research budgets, and official evaluate the monthly seismicity and long-term likelihood of earthquakes. This committee produced the latest revision of the National Seismic Hazard Maps for Japan in 2014 and published numerous ground motion scenarios of potential large earthquakes. The Central Disaster Management Council in the Cabinet Office continues its planning for disaster management for future large earthquakes. The Japan Meteorological Agency continues to operate a successful early warning system that covers the entire country. In operation since 2007, it has issued warnings of a few to tens of seconds before strong shaking for large earthquakes, including the 2011 Tohoku event, with very few false alarms.

4. Large Research Projects

The construction of the Dense Oceanfloor Network system for Earthquakes and Tsunamis (DONET) off the eastern coast of the Kii Peninsula, a part of the source area of the expected Nankai earthquake, was completed in 2011. To extend the observation area, DONET2 is being constructed off the western coast of the Kii Peninsula and to the east of Shikoku Island. After the 2011 Tohoku Earthquakes, the construction of the Seafloor Observation Network for Earthquakes and Tsunamis along the Japan Trench (S-net) was initiated. To understand this great earthquake, the Japan Trench Fast Drilling Project (JFAST) in 2012–2013 drilled boreholes to the plate boundary fault for geological and geophysical observations. The obtained drilling cores and temperature measurements in the borehole provided explanations for the low friction and large displacement of the fault that were largely responsible for the devastating tsunami.

MEXT and the Japan Society for the Promotion of Science (JSPS) have funded several other large projects, including high-pressure mineral experiments, seismological and geodetic observations at the seafloor, deep sea drilling, and studies on fluid in the crust for seismological research.

5. Asian Seismological Commission (ASC) and Activities of Other Societies

Prof. K. Hirahara stepped down as ASC President in 2012, and Dr. T. Yokoi started to serve as a Bureau member in 2013. SSJ recognizes that successful methods for short-term earthquake prediction are likely not possible in the near future; however, the Earthquake Prediction Society of Japan was founded independently in 2014 to pursue prediction research.

VIII. Activity Report of the National Committee for Volcanology and Chemistry of the Earth's Interior (IAVCEI)

Setsuya NAKADA
Chair of the National Committee for Volcanology and Chemistry of the Earth's Interior
Eisuke FUJITA
Secretary General of the National Committee for Volcanology and Chemistry of the Earth's Interior

From 2011 to 2014, several volcanic eruptions occurred in Japan, including those at Shinmoe-dake, Kirishima during January to September 2011 and at Ontake in September 2014. The number of casualties and missing persons from the Ontake eruption reached over 60 despite its small scale. Nishinoshima, Izu-Ogasawara Bonin started its submarine eruption, continuing the extension of its lava field over the sea surface and enveloping the old island. The activation of several Japanese volcanoes during these years may reflect the effects of the Tohoku-Oki earthquake. Sakurajima has continued its explosive activity since 2008.

1. Volcanological Society of Japan (VSJ)

The VSJ published volumes 56–59 of its scientific journal (Bulletin of the Volcanological Society of Japan). The society hosted the IAVCEI Scientific Assembly in Kagoshima in July 2013; 1,069 participants attended from 43 countries and gave a total of 1,209 presentations. The assembly was supported by Kagoshima City and Prefecture as one of the 100-year anniversary events commemorating the Taisho Sakurajima eruption.

VSJ established the "Asian Consortium of Volcanology" (ACV) in 2014, collaborating with societies in Indonesia (CVGHM), the Philippines (PHIVOLCS), Singapore (EOS), and the USA (USGS). The main task of ACV is helping young volcanologists in Asian countries share knowledge through their professional training in representative observatories on active volcanoes.

2. National Project for Predicting Volcanic Eruptions

In the period of 2011–2014, the national research project "Observation research program for forecasting earthquake and volcanic eruption" (2009–2013) was replaced by the "Earthquake and Volcano Hazards Observation and Research Program" (2014–2018). This new program pays more attention to low-frequency, large-scale hazards and multidisciplinary research involving the fields of disaster science and social science, drawing from the lessons of the 2011 Tohoku-Oki earthquake disaster. The Japan Meteorological Agency (JMA) continued to strengthen its observation network of 47 volcanoes in Japan and the operating Volcanic Alert Level on 30 volcanoes. The National Research Institute for Earth Science and Disaster Prevention (NIED) also continued to strengthen its volcanic observation network (V-net).

3. Study of Eruption Forecasting

We faced difficulties in forecasting eruptions at several volcanoes. Regarding Shinmoe-dake volcano, small phreatic eruption events had occurred for 2.5 years before the subplinian events on 26 and 27 January 2011, and ground deformation started approximately 1 year before. However, we could not predict the imminent climactic event.

Another example of the difficulty of forecasting eruptions was a phreatomagmatic event that occurred at Kuchinoerabu Volcano on 3 August 2014, after 34 years' quiescence. Monitoring on this volcano has detected abnormal changes over the previous 15 years, including seismic swarms and crustal expansions in 2004, 2006, and 2008. The eruption potential was considered to be very high. However, the onset of the eruption was not forecasted in a timely manner, although it was shown after the eruption that the tiltmeter had recorded the expansion of the summit crater approximately 1 hour prior to the eruption.

The phreatic eruption at Ontake volcano occurred at approximately noon on a hot Saturday (27 September 2014), when many climbers were enjoying beautiful, colorful fall scenery and taking lunch

around the top of the volcano. Abnormal seismic activity was observed on 10 and 11 September but was less significant than the precursory seismicity of previous eruptions. It was shown later that volcanic tremors and crustal deformation, the latter of which suggested the faint expansion of the summit area, had been observed approximately 11 minutes and 7 minutes, respectively, prior to the eruption. These observations may imply the possibility of predicting phreatic eruptions in the near future. However, it is believed that weak and unsystematic signals are difficult to use as the precursors of small eruptions, even if monitoring instruments are densely placed near the crater.

Another important volcanic issue in Japan over this period was monitoring for caldera eruptions in relation to the regulation of nuclear power plant (NPP) operations. The tsunami associated with the 2011 Tohoku-Oki earthquake affected the Fukushima Daiichi NPP sites; the resultant power shortage caused failure in the cooling of nuclear fuels, leading to the nuclear reactors' meltdown. Following this accident, all Japanese NPPs were stopped. Before these sites were reopened, the Nuclear Regulation Authority (NRA) of Japan established new safety guideline for evaluating volcanic activity in which monitoring was introduced as the key to forecasting large-scale eruptions that may affect the facilities. Strong arguments were repeated among industry-NRA officials, volcanologists, and the public on the possibility of monitoring. The VSJ organized a committee that discussed nuclear power issues within society, commenting that it is highly difficult to monitor large-scale eruptions with sufficient lead time.

4. Others

An innovation program of the MEXT Grant-in-Aid for Scientific Research, “Geofluids; nature and dynamics of fluids in subduction zones,” was conducted during 2009–2013. This project examined the fluid dynamics and magma evolution around subduction zones using seismological, geodetic, electromagnetic, and experimental petrological approaches.

The Geological Survey of Japan, AIST, has hosted the annual Asia-Pacific Region Global Earthquake and Volcanic Eruption Risk Management (G-EVER) consortium since 2012. Two bilateral international projects, SATREPS, sponsored by JICA-JST, were conducted or are planned for the future: “Enhancement of Earthquake and Volcano Monitoring and Effective Utilization of Disaster Mitigation Information in the Philippines” in the Philippines (2010–2014), and “Integrated Study on Mitigation of Multimodal disasters caused by Ejection of Volcanic Products” in Indonesia (2014–2018).