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

Activity Reports on Geodesy and Geophysics in Japan for the Period from 2007 to 2010

JUNE 2011

JAPANESE NATIONAL COMMITTEE
FOR
GEODESY AND GEOPHYSICS

SCIENCE COUNCIL OF JAPAN

CONTENTS

Japanese National Committee for Geodesy and Geophysics

Foreword

Shiro IMAWAKI
Chair, Japanese National Committee for 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 (NCGG) was established by the Science Council of Japan (SCJ), which is the national adhering body of the IUGG. The SCJ completely reformulated itself in October 2005; the former structure, with more than 180 disciplinary committees, was reorganized into a structure with 30 disciplinary committees, including the Earth and Planetary Sciences (EPS) Committee. The EPS Committee covers all fields related to the earth and planetary sciences, including geophysics, geology, geography, and planetary sciences. The present Japanese NCGG was created as a subcommittee of the EPS Committee.

In conjunction with these changes, the Japan Geoscience Union (JpGU) was established in May 2005 to represent various societies of earth and planetary sciences. The JpGU now consists of 48 member societies covering geography, geology, geophysics, and space and planetary sciences. Details of these changes are given in the Foreword to our previous quadrennial report for the 2003–2006 period, issued in July 2007. The Union aims to promote the earth and planetary sciences as a whole through international partnerships, transmission of information to the public, research activities, and promotion of information exchange. The JpGU became a general incorporated association in December 2008. It has more than 7,000 registered individual Union members. Its annual spring meeting, held every year in May in Makuhari, east of Tokyo, offers more than 4,000 presentations and attracts more than 5,000 participants. The Japanese NCGG has maintained a close relationship with the JpGU.

In 2007, the International Association of Cryospheric Sciences (IACS) was established in the IUGG as its eighth association. The Japanese NCGG discussed how to respond to this international movement and decided to assign a national correspondent to IACS without establishing a new National Committee for IACS. Dr. Tetsuo Ohata of Japan Agency for Marine-Earth Science and Technology (JAMSTEC) was appointed as an Associate Member of the Japanese NCGG to serve as the IACS correspondent. The Japan Society for Snow and Ice (JSSI) is the scientific/technical society devoted to the geophysical study of snow and ice. The IACS correspondent will continue to maintain a close relation with the JSSI in order to promote cryospheric research in Japan at national and international levels.

We held the following important international meetings during 2007–2010. The international symposium “HydroChange 2008: From Headwaters to the Ocean: Hydrological Change and Watershed Management” was held in Kyoto during October 1–3, 2008. The international symposium “Fifty Years after IGY: Modern Information Technologies and Earth and Solar Sciences” was held in Tsukuba during November 10–13, 2008. The Seventh Asian Seismological Commission met in Tsukuba during November 24–27, 2008. The General Assembly of the International Association of Volcanology and Chemistry of the Earth’s Interior (IAVCEI) will be held in Kagoshima in 2013; our National Committee for Volcanology and Chemistry of the Earth’s Interior has been busy preparing it.

In Japan, fruitful scientific activities and events have occurred, of which selected examples are given below; details are provided in the following reports by individual committees. The lunar mission spacecraft SELENE, called *Kaguya* in Japanese, was launched in October 2007 and successfully finished its mission in June 2009. The spacecraft was developed by the Japan Aerospace Exploration Agency (JAXA) and obtained data on the lunar gravity field, global lunar topography, and lunar magnetic anomaly field. The mission was very productive and successful. The Greenhouse Gases Observing Satellite (GOSAT), called *Ibuki* in Japanese, was launched in January 2009 and has been acquiring data since February 2009. The satellite was developed by JAXA, the National Institute for Environmental

Studies, and the Ministry of the Environment to observe global distributions of carbon dioxide and methane. The Deep Sea Drilling Vessel *Chikyu* was delivered to JAMSTEC in July 2005. The vessel was designed to ultimately drill to the mantle in the Integrated Ocean Drilling Program (IODP). *Chikyu* has already finished tens of scientific drillings at three targeted areas: east, south, and west of Japan. Since 2006, JAMSTEC has been developing the Dense Oceanfloor Network System for Earthquakes and Tsunamis (DONET) in the To-Nankai region, south of Honshu, Japan. The system is a submarine-cabled real-time seafloor observatory network designed to establish the technology for large-scale real-time seafloor research and surveillance infrastructure for earthquake, geodetic, and tsunami observation and analysis. Its initial phase of installing 20 observatories will be completed in 2011.

After the reports of individual national committees for each discipline were compiled, Japan suffered extremely heavy damage from the 2011 Tohoku Earthquake, officially named the Great East Japan Earthquake. A quake of magnitude 9.0 occurred off the Pacific coast of Tohoku, Japan, on March 11, 2011, causing a catastrophic tsunami that hit the east coast of Japan and destroyed everything on the coast. More than 15,000 people were killed, and more than 9,000 are missing as of May 2011. The tsunami also caused severe problems at four nuclear power plants on the Fukushima coast, which are not yet under control as of May 2011. The details on how we handled those difficulties will be described in our next quadrennial report to be issued in 2015.

Membership
Japanese National Committee for Geodesy and Geophysics
Science Council of Japan

As of May 2011 (the 21st Term: from October 2008 through September 2011)

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	Dr. Kiyoshi SUYEHIRO	Integrated Ocean Drilling Program, Management International, Inc.

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	Dr. Kuniyoshi TAKEUCHI	International Centre for Water Hazard and Risk Management
Associate Member:	Dr. Kiyoshi SUYEHIRO	Japan Agency for Marine-Earth Science and Technology

I. *Activity Report of the National Committee for Geodesy*

Shuhei OKUBO
Chair of the National Committee for Geodesy
Yoichi FUKUDA
Secretary General of the National Committee for Geodesy

The period from 2006 to 2010 saw major progress in two space geodetic techniques in Japan: satellite-based L-band synthetic aperture radar (SAR) and the Japanese lunar mission. Both made significant and definitive contributions to advances in geodesy. Below we describe these two projects and other geodetic research highlights of the last four years.

1. L-band SAR

The Advanced Land Observing Satellite (ALOS, a.k.a. Daichi) was launched in January 2006 and has been operated by the Japan Aerospace Exploration Agency (JAXA). This satellite is equipped with a phased array L-band SAR (PALSAR). Owing to the nature of the L-band signal, which penetrates vegetation on the land surface, the ALOS PALSAR provides fundamental datasets for monitoring the variability of the solid Earth, such as crustal deformation caused by seismic and volcanic activities. For example, the Geospatial Information Authority of Japan (GSI) analyzed crustal deformation caused by the Niigataken Chuetsu-oki Earthquake of 2007 using InSAR data. Uplift motion associated with episodic growth of fault-related folds was discovered [1].

2. Selenodesy

The Japanese lunar mission SELENE (a.k.a. Kaguya) was launched in September 2007 and ended in June 2009. Three selenodetic mission instruments were onboard: RSAT (a satellite-to-satellite Doppler tracking system) and VRAD [very long baseline interferometry (VLBI) radio sources] for gravity field recovery, and LALT (a laser altimeter) for global topographic observation. The tracking data provided by RSAT revealed detailed gravity features on the far side of the moon. Tracking of VRAD by both international and domestic VLBI stations contributed to improved orbital consistency. A global lunar topographic map with a spatial resolution finer than 0.5° was derived from LALT. New datasets for lunar gravity and topography have been released from the SELENE Level 2 database and used for geophysical research on crustal thickness and structure and compensation states of impact basins [2].

3. Positioning and Navigation

3.1 Supplementation of GPS for Urban or Mountainous Areas

The quasi-zenith satellite MICHIBIKI was launched in September 2010. It has been injected into a quasi-zenith orbit over Japan with a central longitude of about 135°E. The satellite is now subject to initial functional verification and is expected to supplement the GPS satellites for improved accuracy in positioning, especially in urban or mountainous regions.

3.2 Continuous GPS Observation Network

The GSI modernized its strategy for routine analysis of the Japanese continuous GPS observation network (GPS Earth Observation Network System: GEONET), the world's largest regional GPS network, which serves not only geodesy but also meteorology, seismology, volcanology, and ionospheric sciences. The new analysis strategy (Version 4) adopts (1) estimation of the atmospheric gradient, (2) absolute antenna phase center models, (3) the coordinate system International Terrestrial Reference Frame 2005 (ITRF2005), (4) a new method for calculating the fixed point, and (5) a new correction method for ionospheric delay. The quality of the estimated coordinates was significantly improved by adopting the new strategy [3].

3.3 VLBI

The National Institute of Information and Communications Technology (NICT) succeeded in developing technology for real-time transmission of VLBI data over an intercontinental baseline, which enables rapid derivation of the Earth rotation parameter UT1 [4].

The GSI operates the Tsukuba 32-m VLBI station (TSUKUB32) and the Tsukuba VLBI data processing facility for international VLBI sessions [5].

4. Analysis of GRACE data

Monthly gravity data from the Gravity Recovery and Climate Experiment (GRACE) were analyzed to reveal that 40–50 Gt of mountain glaciers are lost from the Himalayas and major mountain belts in central Asia [6]. A fairly large uncertainty is caused by a possible contribution from glacial isostatic rebound, separability from groundwater loss in northern India, and climate fluctuations on decadal timescales. This result suggests that, contrary to the prediction of the Intergovernmental Panel on Climate Change (IPCC), the Himalayan glaciers may not be gone within 30 years.

A postseismic gravity (geoid height) change was detected for the first time ever using GRACE monthly gravity data taken before and after the 2004 Sumatra–Andaman earthquake [7].

5. Marine Geodesy

The Japan Coast Guard and The University of Tokyo observed seafloor crustal movements using the GPS/acoustic method and detected a coseismic slip associated with the 2005 Off-Miyagi Prefecture Earthquake (M7.2), postseismic slip until early 2007, and then recovery of coupling [8]. These observations indicate temporal changes in the coupling state in the seismogenic zone associated with plate subduction.

6. Passing of Leading Geodesists

During the last four years, several leading scientists in geodesy passed away: Yoshifumi Tomoda (Member of National Academy of Japan, Emeritus Professor of University of Tokyo) on December 17, 2007; Takeshi Dambara (Former Professor, Shizuoka University) on August 6, 2009; Hiromichi Suzuki (Former Deputy Director of Geographical Survey Institute) on May 28, 2010; and Yoshiteru Kono (Emeritus Professor, Kanazawa University) on November 22, 2010. The passing of these leading scientists reminds us of the glorious days of classical geodesy, in particular gravimetry.

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II. *Activity Report of the National Committee for* Geomagnetism and Aeronomy

Toshihiko IYEMORI
Chair of the National Committee for Geomagnetism and Aeronomy
Toshitsugu YAMAZAKI
Secretary General of the National Committee for Geomagnetism and Aeronomy

We report here on the International Association of Geomagnetism and Aeronomy (IAGA-) related research activity in Japan during 2007–2010 in four areas: Earth and planetary interiors; Sun, solar wind, and magnetosphere; upper atmosphere; and interdisciplinary activities, new space programs, and reorganizations. The following is a summary of what has been accomplished over the last four years in each of these areas.

1. Earth and Planetary Interiors

The magnetic field around the Moon has been successfully observed by the lunar magnetometer (LMAG) on the SELENE (Kaguya) spacecraft from October 29, 2007 to June 10, 2009. On the basis of the nominal observations for the first 14 months at an altitude of ~100 km, we obtained full-coverage vector maps of the lunar magnetic anomaly field at 100 km altitude. The maps show not only strong magnetic anomalies in several regions but also weak anomalies over most of the lunar surface. The Kaguya and previous observations indicate that the weak anomalies are likely to originate from lunar crustal magnetism, suggesting the existence of an ancient global magnetic field such as a dynamo field on the early Moon.

A geodynamo at much lower Ekman numbers has been numerically simulated. The results show scale separation between the velocity and magnetic fields and sheet-like convective motions aligned with the rotation axis, although the magnetic field thus produced under the condition of fixed temperature at the core–mantle boundary (CMB) is weaker than that of the Earth. A laterally uniform heat flux at the CMB, on the other hand, leads to large-scale convective motions, which generate a strong dipole-type magnetic field. The pattern of heat flux at the CMB also influences the magnetic field strength.

Paleomagnetic and rock-magnetic studies of sediments and volcanic rocks of various ages and places were conducted. Progress includes paleomagnetic evidence for the geodynamo at 3.45 Ga; accumulation of absolute paleointensity data using the double heating technique of the Shaw method with low temperature demagnetization (LTD–DHT Shaw method) and the microwave method; an argument for the possibility of geomagnetic field modulation by changes in eccentricity; evidence for postdepositional remanent magnetization acquisition lock-in depth of ~15 cm based on paleointensity estimation using ^{10}Be; and environmental applications of rock magnetism using new proxies. The 2009 Kochi International Workshop on Paleo, Rock, and Environmental Magnetism was held during February 5–6, 2009, at Kochi University.

The Integrated Ocean Drilling Program (IODP) has provided valuable material for paleomagnetic studies. The riser drilling vessel *Chikyu*, operated by Japan for the IODP, started scientific drilling in 2007. The nonriser drilling vessel *JOIDES Resolution*, operated by the United States, resumed operation in 2009 after a three-year refurbishment. Many paleomagnetists from Japan participated in the IODP expeditions and have been conducting paleomagnetic studies, including paleointensity variations since ~40 Ma and high-resolution paleomagnetic records in the Antarctic Margin and Bering Sea. An international (Japan, United States, Australia) ocean bottom electromagnetic experiment was conducted in the Marianas subduction zone, across which an array of about 40 electromagnetic sites was deployed and a 2D conductivity model in the upper mantle was obtained.

The multidisciplinary five-year project “The Stagnant Slab” was conducted from 2004 to 2008. Data from long-term (up to three years) deployment of ocean bottom electromagnetometers, as well as those from the Ocean Hemisphere Observation Network and existing observatories, were analyzed to reveal the electrical conductivity of the slab stagnating in the mantle transition (MT) zone of the western Pacific subduction zone. An interpretation of the resulting 3D image of electrical conductivity was attempted in

association with seismic tomography and mineral physics to examine the presence of water in the transition zone. A networked MT survey that compiled the electrical conductivity distributions of the crust and upper mantle was conducted in Japan. Intensive studies in tectonically active environments were also conducted by magnetotelluric and aeromagnetic surveys to explore the crustal structures and their relation with local and regional tectonic activities. In another multidisciplinary five-year project, "The Crustal Fluid," initiated in 2009, the 3D electrical conductivity is imaged to infer the fluid distribution deep in the crust. In volcanic studies, several efforts were made to develop and apply electrical, magnetic, and electromagnetic methods of monitoring.

Theoretical studies of the electromagnetic field generation mechanism of earthquakes and seismic waves were further developed, and several physical models were proposed. Monitoring efforts were continued in order to detect electromagnetic signals related to earthquakes.

2. Sun, Solar Wind, and Magnetosphere

Successful observations with the Japanese solar imaging satellite Hinode revealed many fine structures in the lower solar atmosphere with unprecedented high spatial resolution, providing important information on the solar wind heating mechanism, which is still unknown. The fine structures of the magnetic field in coronal holes and active regions are also being revealed. The STEL at Nagoya University constructed a new large interplanetary scintillation (IPS) antenna, which began observations of the 3D structure of the solar wind and coronal mass ejections (CMEs) with improved spatial and temporal resolution using IPS tomography. Numerical simulations of the space weather between the Sun's photosphere and the Earth have begun. Research into more realistic data-driven models of the solar corona and heliosphere has been advanced by exploiting the unprecedented high-resolution observations of Hinode as well as the IPS technique.

The Global Muon Detector Network (GMDN) has succeeded in observing a clear cosmic ray precursor of a large CME impact on the Earth in December 2006. This precursor was recorded almost one day before the CME impact. A collaboration with the Tibet air shower experiment revealed for the first time the changes in the Sun shadow (the shadow cast by the Sun in the high-energy cosmic ray flux) in strong correlation with solar activity, suggesting the influence of the strong magnetic field near the Sun on cosmic ray trajectories.

THEMIS, a five-spacecraft mission to explore substorm physics, was launched in 2007. The Japanese community has made substantial contributions to this mission. In the THEMIS era, many Japanese scientists are participating in the data analysis effort. A domestic forum for data users has been established so that a student who has just started to inspect the THEMIS data can accelerate his or her study smoothly by communicating with senior scientists. Geotail data are still frequently referred to in the course of THEMIS data analysis.

Onboard the Japanese lunar orbiter Kaguya are a plasma instrument and a magnetic field detector that provide information on the plasma environment around the Moon. Now with ion data providing the complete information on the plasma environment below an altitude of 100 km, various new phenomena are being discovered in the Kaguya data. This will provide an impetus to the study of plasma–surface interactions, which have various planetary magnetospheric applications.

The Japanese scientific microsatellite Reimei has measured small-scale auroral features since its successful launch in 2005 into a Sun-synchronous polar orbit at an altitude of 640 km. It carries a three-CCD monochromatic auroral camera and electron and ion spectrometers for obtaining simultaneous image-particle measurements of small-scale aurora. These data allow us to study the one-to-one correspondence between auroras and precipitating electrons at a scale of down to 1 km for various types of auroras such as multiple arc, pulsating, and black auroras.

The Space Environment Research Center (SERC) of Kyushu University has deployed Magnetic Data Acquisition System (MAGDAS) magnetometers at 54 stations along the 210 and 96 magnetic meridians and along the magnetic dip equator, and has installed three FM–CW radars along the 210 magnetic meridians in order to understand changes in the electromagnetic and plasma environment in geospace and the coupled Sun–Earth system. An international collaboration RapidMag (AARI, JHU/APL, NICT, IDG, and WDC for Geomagnetism, Kyoto) has been successfully established for the acquisition of near-real-time magnetometer data from Russian auroral zone stations to improve the auroral electrojet index.

3. Upper Atmosphere

A new general circulation model, the Ground-to-topside model of the Atmosphere and Ionosphere for Aeronomy (GAIA), was developed in Japan. The model includes atmospheric processes in the entire atmosphere, coupling processes from the atmosphere to the ionosphere, their reverse effects, and dynamo processes of the ionosphere, all in a self-consistent manner.

By using European Incoherent Scatter Scientific Association (EISCAT) radars at Tromso and Longyearbyen, ion upflows, the 3D current system, pulsating auroras, and lower thermospheric wind dynamics have been studied. A sodium lidar began operation in October 2010 at the EISCAT Tromso site (69.6°N, 19.2°E) to measure the neutral temperature at 80–110 km altitude with a 10-min time resolution. A new meteor radar began regular operation at Bear Island (74.5°N, 19.0°E) on November 1, 2007 in collaboration with the University of Tromso.

Ionospheric waves and irregularities in midlatitude areas were studied by various measurements performed by the GPS-TEC network, the SuperDARN Hokkaido Radar, an imager and an Fabry–Pérot interferometer for observing the airglow, and the middle and upper atmosphere (MU) radar. The MU radar observed unique enhancement of E-region irregularities during the partial solar eclipse of July 22, 2009.

Various satellites are used to study the upper atmosphere. Careful analysis of data from the ultrasensitive accelerometer of CHAMP revealed an equatorial neutral-atmosphere anomaly and wave-4 structures in the thermosphere, which shed new light on the coupling processes between the atmosphere and the ionosphere. The ISUAL instrument on the FORMOSAT-2 satellite was used to detect the structures of medium-scale traveling ionic disturbances from space. A DELTA-2 rocket campaign was conducted on January 26, 2009. The JAXA sounding rocket S-310-29 was launched from Andoya, Norway, and successfully measured neutral winds and plasma parameters around an auroral breakup event. The EISCAT IS radar, operated during the DELTA-2 period, fortunately observed a sudden stratospheric warming event in January 2009. A lithium release experiment for measuring thermospheric wind velocity was successfully conducted at Uchinoura, Japan, on September 2, 2007.

The budget for the Mesosphere–Stratosphere–Troposphere/IS (MST/IS) radar at Syowa Station in the Antarctic (PANSY) was approved in FY2009, and construction started in late December 2010. The PANSY radar will operate with a limited system for tropospheric observation in 2011 and with the full system beginning in 2012; the operation will continue for 13 years, including a full solar cycle. The observation network for studies of the equatorial and low-latitude ionosphere was expanded in the Asian sector. The Equatorial Atmosphere Radar (EAR), SEALION (ionosonde network), OMTI (optical instrument network), GPS TEC and scintillation receivers, and satellite-beacon receivers were deployed in Indonesia, Thailand, Vietnam, and surrounding countries.

The International Symposium on Coupling Processes in the Equatorial Atmosphere (CPEA Symposium) was held in March 2007 at Kyoto University. An International Reference Ionosphere workshop was held in November 2009 at Kagoshima University. The International Symposium on the 25th Anniversary of the MU radar was held in September 2010 at Kyoto University; it reviewed the scientific achievements attained by the MU radar since 1984 and discussed the ongoing research on the atmosphere and ionosphere.

4. Interdisciplinary Activities, New Space Programs, and Reorganizations

The international symposium “Fifty Years after IGY: Modern Information Technologies and Earth and Solar Sciences” was held in Tsukuba during November 10–13, 2008. In association with the Scientific Committee on Solar–Terrestrial Physics (SCOSTEP) program Climate and Weather of the Sun–Earth System (CAWSES, 2004–2008), the International CAWSES Symposium was hosted in Japan at Kyoto University in October 2007. An interdisciplinary workshop for space weather research, “The Basic Study of Space Weather Prediction,” was held in 2009 in Kyoto to wrap up the results of the project. The Inter-university Upper atmosphere Global Observation NETwork (IUGONET), a multidisciplinary geoinfomatic approach for clarifying the mechanisms of long-term variations in the upper atmosphere, began in 2009; this six-year research project will build a metadata database of ground-based observations of the upper atmosphere.

The next space mission to be flown by the Japanese community is the Energization and Radiation in

Geospace (ERG) mission, a small science satellite of the Institute of Space and Astronautical Science, JAXA, for studying the inner magnetosphere. In parallel with the preparations for the mission itself, a science center is being established at the STEL that will seamlessly provide various research tools. A project to launch an optical imager and lightning detectors to the International Space Station (ISS) has begun, and the ISS-IMAP and ISS-GLIMS instruments are now under development.

The Hachijo Hydrographic Observatory was closed on March 31, 2009; it conducted geomagnetic observations on Hachijo Island for 31 years beginning in 1978. The Kanoya and Memambetsu magnetic observatories have become unmanned stations beginning in April 2011.

III. Activity Report of the National Committee for Hydrological Sciences

Makoto TANIGUCHI
Chair of the National Committee for Hydrological Sciences
Kinpei ICHIYANAGI
Secretary General of the National Committee for Hydrological Sciences

The Japan National Committee for Hydrological Sciences plans future hydrological research and coordinates national academic bodies related to land–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 2007 and 2011.

1. Committee Activities

The previous Japanese committee of the IAHS (chair: Dr. Masayoshi Nakao; secretary general: Dr. Kazuhisa Chikita) was replaced in October 2008; Dr. Makoto Taniguchi (Research Institute for Humanity and Nature), who is the vice president of the International Committee on Ground Water, became the chair of IAHS Japan, and Dr. Kinpei Ichiyanagi (Kumamoto University), who is the secretary of the International Committee on Tracers, became the secretary general. The 15 members of the Japanese committee of the IAHS meet at least once a year under the Science Council of Japan (SCJ) to discuss hydrological research activities in Japan.

2. IAHS Scientific Assembly

The 8th International Association of Hydrological Sciences (IAHS) Scientific Assembly & 37th International Association of Hydrogeology (IAH) Congress *(http://www.appliedhydrology.org/iahs/)* was held in Hyderabad, India, during September 6–12, 2009. About 70 Japanese hydrologists attended the IAHS/IAH joint congress. During the congress, Yukiko Hirabayashi, Shinjiro Kanae, and Seita Emori from Japan received the 2009 Tison Award for their paper "*Global projections of changing risks of floods and droughts in a changing climate*" (http://iahs.info/hsj/530/hysj.53.4.754.pdf), which was published in the *Hydrological Sciences Journal* in August 2008.

The IAHS red book No. 329 (ISBN 978-1-907161-00-1, 318+x pp), *Trends and Sustainability of Groundwater in Highly Stressed Aquifers*, edited by Makoto Taniguchi, Alyssa Dausman, Ken Howard, Maurizio Polemio, and Elango Lakshmanan, was published as the Proceedings of the JS2 symposium in Hyderabad, India, in September 2009.

3. Organizing the IAHS Symposium in Japan

The international symposium HydroChange 2008 was held in Kyoto, Japan, during October 1–3, 2008. It was organized by the IAHS, the Research Institute for Humanity and Nature (RHIN), and the Global Water System Project (GWSP) and cosponsored by the European Observatory of Mountain Forests and the International Association of Headwater Control. More than 180 hydrologists attended the symposium to discuss issues in 11 sessions. The proceedings of the symposium were published as the book *From Headwaters to the Ocean* from CRC Press.

Another international symposium, "Groundwater as a Key for Adaptation to Changing Climate and

Society," was held on November 14, 2010 in Kyoto, Japan. It was organized by UNESCO's International Hydrological Programme (IHP); the IAHS; the RIHN; Nagoya University's HyARC; Kyoto University's DPIR; and the Ministry of Education, Culture, Sports, Science and Technology of Japan. More than 140 people joined the symposium and discussed global groundwater problems and adaptation to the changing climate and society in Asia.

IV. *Activity Report of the National Committee for* *Meteorology and Atmospheric Sciences*

Teruyuki NAKAJIMA
Chair of the National Committee for Meteorology and Atmospheric Sciences
Hisashi NAKAMURA
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), with a current membership of nearly 3,900. Until the major reorganization of the Science Council of Japan (SCJ) in 2005, all members of the National Committee for Meteorology and Atmospheric Sciences (the Committee, hereafter) had been appointed by the executive committee of the MSJ for a term of three years. The current Committee for the 21st term has been organized with members selected by a new selection rule set by the SCJ under close communication with the MSJ. The Committee aims to review academic and research activity in meteorology and atmospheric sciences and to propose plans for activating and promoting future activity in the field. The Committee also handles international affairs related to the International Association of Meteorology and Atmospheric Sciences.

1. Overview

The MSJ has played a central role in Japan in fostering the advance of meteorological research 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. Further exploitation of atmospheric sciences is also being created by the Section of Atmospheric, Ocean, and Environmental Sciences, formed after the reorganization of the Japan Geoscience Union (JpGU) in 2009.

2. Recent Activity Highlights

Some of the novel outcomes from the activities of research and research promotion, including domestic and international projects related to the World Climate Research Program (WCRP) and International Geosphere–Biosphere Program (IGBP), among others, are listed below:

- Twentieth-century simulations and 21st-century global warming projection experiments have been conducted on the Earth Simulator by using high-resolution state-of-the-art coupled general circulation models (CGCMs), including MIROC (from CCSR-NIES-FRCGC) and MRI-CGCM, for contribution to the fifth assessment of the Intergovernmental Panel on Climate Change (IPCC). A national next-generation high-resolution modeling project initiated by the Advanced Institute for Computational Science (AICS) will use their petaflops supercomputer.

- Substantial progress has been made in the Earth observation satellite projects GPM, EarthCARE, GCOM/C, GCOM/W, and HIMAWRI-8 and -9. The Greenhouse Gases Observing Satellite *Ibuki* was successfully launched in January 2010 and is currently performing observations with the Fourier Transform Spectrometer (TANSO-FTS) and the Cloud and Aerosol Imager (TANSO-CAI).

- The budget for the Mesosphere–Stratosphere–Troposphere incoherent scatter (MST/IS) radar at the Syowa Station in the Antarctic (PANSY) was approved in FY2009, and construction began in late December 2010. PANSY radar operation will begin with a limited system for tropospheric observation in 2011 before full system operation, including stratospheric observation, begins in 2012. The operation will continue for 13 years, including a full solar cycle.

• An SCJ symposium was held in 2010 to discuss how to improve the IPCC assessment system.

• Under the leadership of the SCJ, extensive discussion has begun within the research community regarding the establishment of a roadmap for effectively organizing nationwide projects and specifying particular research areas that are expected to be of increasing importance in the future.

V. *Activity Report of the National Committee for the Physical Sciences of the Oceans*

Masaaki WAKATSUCHI
Chair of the National Committee for the Physical Sciences of the Oceans
Yutaka MICHIDA
Secretary General of the National Committee for the Physical Sciences of the Oceans

The present (21st term) National Committee for the Physical Sciences of the Oceans of the Science Council of Japan began its activities in October 2008. This report briefly reviews the recent progress (2007–2010) in physical and chemical oceanography in Japan in several research fields. All committee members contributed to the preparation of this document.

1. Study of the Kuroshio and Kuroshio Extension

The Kuroshio system is important in the heat transport and dissipation of energy input by winds. Interest in the Kuroshio Extension (KE), which used to be a less-studied area in the Kuroshio system, has expanded worldwide, and a well-defined decadal variability has been identified. Progress in Japan has been made with the aid of high-resolution numerical simulations. The decadal variability of the KE jet has been shown to be in phase with that of large-scale winds despite their nonlinearity. The separation latitude of the Kuroshio from the coast also depends on large-scale winds rather than coastal topography, which appears to be consistent with altimetry data. Observational and modeling studies of the impacts of sea-surface temperature fronts in the KE on the atmosphere and on mode water formation are also underway.

2. Midlatitude Air–Sea Interactions

Studies of the influence of midlatitude oceanic frontal zones on the atmosphere have accelerated during 2007–2010; US-CLIVAR organized a western boundary current (WBC) working group to synthesize them. In this active field, Japanese scientists have led studies of the following topics: in situ observations that demonstrated physical processes in the feedback; findings that this feedback penetrated the upper troposphere; numerical experiments showing that a sea surface temperature (SST) frontal zone can enhance atmospheric disturbances, which form storm tracks and westerly jets aloft; and decades-long eddy-resolving oceanic general circulation model integrations to reveal the basic mechanisms and properties of variations in the WBC system, e.g., the KE.

3. Research on the Tropical Pacific and Indian Oceans

Intensive studies with a tropical moored buoy array in the Indian and Pacific Oceans showed that the Indian Ocean Dipole (IOD) is an inherent air–sea coupled climate mode in the Indian Ocean that interacts with the El Nino–Southern Oscillation in the Pacific domain. Three consecutive IOD events on June 07, 2008 were observed extensively by the Japanese buoys; the data reveal the importance of subsurface ocean variability before IODs. El Nino–Modoki in the Pacific Ocean appears more frequently than before. This newly identified climate mode is considered to be important in association with sea-level rise in tropical islands and a distinct teleconnection pattern to midlatitude climate systems, which differs from that during El Nino events.

4. Study of Polar Oceans

Extensive Japanese International Polar Year projects have been conducted in both polar oceans. In the Southern Ocean, a cooperative project between Australia and Japan on the deep WBC over the eastern flank of the Kerguelen Plateau based on a two-year coherent mooring array showed that northward bottom-water (Antarctic Bottom Water) transport in this region is comparable to that from the Weddell Sea. In the Arctic, anomalous warm-water inflow from the Bering Sea is suggested as an initial trigger for the abrupt sea-ice decrease in the Pacific Arctic Ocean since the late 1990s. It may have contributed to the strengthening of wind-driven current and sea-ice motion, which fragments sea ice and accelerates melting

in the Pacific Arctic Ocean.

5. Deep-Water Warming in the Pacific

Full-depth hydrographic observations and analysis of changes in the deep ocean have been conducted in Japan. The distribution of recent bottom-water warming in the Pacific has been shown using hydrographic data from the World Ocean Circulation Experiment's Hydrographic Program and its revisit cruises. An assimilation system for investigating bottom-water warming has been developed; it successfully revealed recent bottom-water warming and clarified the mechanisms of rapid transfer of heat from the Antarctic to the deep layers of the North Pacific.

6. Recent Surface-Layer Salinity Change Detected in the Argo Float Data

Over 3,000 Argo floats observe and cover the global ocean, enabling the study of basin-scale variations in surface-layer salinity. Changes in the global surface-layer salinity were investigated using Argo float data with annual mean climatology reconstructed from historical salinity data from 1960 to 1989. The surface-layer salinity distributions in the Argo data and the climatology showed similar patterns, with low values in subpolar and tropical regions and higher values in the subtropics. Recent Argo data indicate that the contrast between low and high salinity intensified in all areas except the subpolar North Atlantic. The intensified contrast in the surface-layer salinity was maintained over several recent years. Estimations of evaporation and precipitation changes using a simple method based on the surface-layer salinity changes were attempted. The estimations indicated a high probability that the global hydrological cycle had increased in the past 30 years.

7. Marine Biogeochemical Study

A research project as a part of Safety of Life at Sea, "Linkages in Biogeochemical Cycles between the Surface Ocean and Lower Atmosphere" (the Western Pacific Air–Sea interaction Study, or WPASS) was funded by the Ministry of Education, Culture, Sports, Science and Technology and launched in July 2006 as a five-year project with more than 70 members and international collaborators. W-PASS aimed to achieve quantitative understanding of the key biogeochemical interactions and feedback between the ocean and the atmosphere in the western North Pacific. As an international project of GEOTRACES, a study of the marine biogeochemical cycles of trace elements and their isotopes was established in 2004; a Japanese marine geochemistry group participated in establishing and advancing the project, and related cruises were conducted to perform observations in the Indian Ocean during 2009–2010. A related study was also conducted during 2006–2008 and revealed that the subpolar marginal sea, the Sea of Okhotsk, plays a significant role in controlling biogeochemical processes in the North Pacific through the Fe supply.

8. Data Assimilation Research

Following the recent development in satellite and in situ Earth-observing systems, ocean data assimilation studies in Japan have focused primarily on new scientific and societal applications during the last decade. In particular, a 4D-VAR data assimilation system using a coupled ocean–atmosphere model has been developed to a level sufficient to define the dynamical state of the global climate on seasonal to interannual scales. The estimation of climate processes during 1996–1998 shows considerably improved representations and forecasts of several key events in the tropical Pacific and Indian Ocean sector, e.g., a roughly two-year lead-time prediction of the 1997–1998 El Nino event. Furthermore, the system has successfully identified rapid warming of abyssal North Pacific waters and revealed a fast teleconnection (within four decades) between changes in the surface air–sea heat flux off the Adelie Coast of Antarctica and the bottom-water warming in the North Pacific through the action of internal waves, as noted in Section 5. In addition, the Japan Meteorological Agency has developed the second generation of operational systems for ocean weather and ocean climate (El Nino and seasonal) forecasting, an international network for solving operational issues under GODAE and JCOMM/ET-OOFS, and an inter-comparison of reanalysis under CLIVAR/GSOP. These results demonstrate the superiority of data-assimilation systems in Japan in understanding the nature of climate variability.

VI. Activity Report of the National Committee for Seismology and Physics of the Earth's Interior

Kenji SATAKE
Chair of the National Committee for Seismology and Physics of the Earth's Interior

During the last four years (2007–2010), the Japanese seismological community has conducted seismological research and contributed to international activities. Several damaging earthquakes occurred in Japan but provided invaluable seismological data.

1. Asian Seismological Commission (ASC)

The Seventh ASC meeting was held in Tsukuba, Japan, jointly with the annual meeting of the Seismological Society of Japan (SSJ). A total of more than 800 people participated, including 230 foreign participants from 40 countries and regions. Dr. Kazuo Hirahara was elected president of the ASC.

2. Seismological Society of Japan (SSJ)

The SSJ made a financial contribution to the above ASC meeting, including supplying travel funds for foreign participants. The SSJ also contributed financially to the International Committee for the Preservation of WWSSN and Historical Seismograms (ICPWHS). The SSJ published a special volume of Zisin (*The Journal of the Seismological Society of Japan*), *Seismology in Japan: Present State and Seeds for the 21st Century*, consisting of 57 review papers (in Japanese). The SSJ also published *The Science of Earthquake Prediction* in 2007, which was translated into Chinese.

3. Damaging Earthquakes and Tsunami

On March 25, 2007, the Noto-hanto earthquake (M6.9) occurred near the tip of the Noto peninsula on the Japan Sea coast, causing one death and 356 injuries. On July 16, 2007, the Niigata-ken Chuetsu-oki earthquake (M6.8) occurred off the Niigata prefecture in the Japan Sea, causing 15 deaths and 2346 injuries. A large ground acceleration (more than 1000 gal) was observed. The Kashiwazaki–Kariwa Nuclear Power Station (NPS), the largest NPS in the world, is located 16 km from the epicenter. No fatal damage occurred, but operation was suspended for about two and a half years after the earthquake. On June 14, 2008, the Iwake-Miyagi Nairiku (inland) earthquake (M7.2) occurred in northern Honshu, causing 23 casualties and 426 injuries. An extremely large peak ground acceleration (4,000 gal) was recorded at a nearby strong-motion station. On July 24, 2008, an intermediate-depth (110 km) earthquake (M6.8) occurred in Iwate prefecture, and on August 11, 2009, an earthquake (M6.5) occurred in Suruga Bay, Shizuoka prefecture, in the region of the anticipated Tokai earthquake. Both earthquakes were located within a slab, and each caused one death. The Chilean (Maule) earthquake (M8.8) in February 2010 caused tsunami damage in Japan, but there were no human injuries or casualties.

4. National Projects

The earthquake and volcanic eruption prediction research project started in 2009 as a new national five-year project. Earthquake and volcanic eruption predictions, both of which have long histories and have contributed to better observation and understanding of earthquakes and volcanoes, were merged for better understanding of earthquake and volcanic eruption processes in subduction zones.

The government's Headquarters of Earthquake Research Promotion (HERP) has been conducting monthly evaluations of seismic activity, long-term evaluation of earthquakes in subduction zones and active faults, and updates of national seismic hazard maps in Japan. The HERP also funds several national projects such as active fault surveys, a dense ocean-floor network system for earthquakes and tsunamis, and multidisciplinary and multi-institutional research projects on multisegment subduction-zone earthquakes in the Nankai trough, the high strain rate zone, and earthquake disaster mitigation in the Tokyo metropolitan area.

The Japan Meteorological Agency started an Earthquake Early Warning service in October 2007,

which has issued warnings for more than 100 earthquakes in the last three years.

5. Few Research Topics

While it is impossible to cover all the seismological research conducted in Japan, it may be noteworthy to mention a few topics. Small-scale repeating earthquakes have been identified in various places in the subduction zone along the Kuril–Japan trench, and forecasts and estimations of the slip rate on the plate boundary have been made. Along the Nankai trough in southwestern Japan, several types of low-frequency earthquakes and episodic creeps, namely low frequency tremors, very low frequency earthquakes, and short-term slow slip events, have been identified, and their characteristics have been studied. In addition, the recurrence pattern of great earthquakes has been reproduced by dynamic simulation of the subduction zone, and a seafloor observation system connected by submarine cables (Dense Oceanfloor Network System for Earthquakes and Tsunamis, DONET) is being constructed to monitor earthquakes and tsunamis.

Several projects and studies have examined the physics of the Earth's interior. A comprehensive stagnant slab research project included imaging by seismic tomography, seafloor observations, high-temperature/-pressure experiments, and numerical simulation of mantle convection. The seismic velocity structure of the deeper part of active faults and the seismogenic zone of the subducted plate have been clarified by intense seismic observations, reflection surveys, and scattered wave data.

VII. Activity Report of the National Committee for Volcanology and Chemistry of the Earth's Interior

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

The level of volcanic activity during 2007–2010 was as low as that during the previous term (2003–2006). Small volcanic eruptions occurred at some volcanoes (e.g., Asama, Sakurajima, Miyakejima). Small eruptions occurred at Asama in August 2008 and February 2009, and faint ashfall was observed in Tokyo during the latter. Sakurajima, which began an explosion in the Showa crater on February 6, 2008, exhibited continued explosive activity; pyroclastic flows descended up to 1.5 km from the crater, and 750 and 1000 explosive eruptions occurred in 2009 and 2010, respectively.

1. Volcanological Society of Japan (VSJ)

The VSJ, a nonprofit organization with about 1000 members, published volumes 52–55 of its scientific journal (*Bulletin of the Volcanological Society of Japan*). A special issue, "Fuji Volcano" (490 pp, in Japanese), summarizing recent research results including those of disaster science, was published in 2007. The VSJ and Shimabara city (Nagasaki) hosted an international conference of the International Association of Volcanology and Chemistry of the Earth's Interior (IAVCEI), "Cities on Volcanoes 5," in November 2007, which 600 scientists and about 1,400 nonscientists including local residents, attended. The VSJ's proposal to hold the IAVCEI Scientific Assemblage at Kagoshima in 2013 was approved by the IAVCEI in 2008.

2. National Project for Predicting Volcanic Eruptions

The five-year national project for predicting volcanic eruptions was combined with that for predicting earthquakes in 2009; the two national projects had been independently developed since 1974 and 1964, respectively. They have identical Earth science backgrounds, use the same infrastructure for monitoring and observation, and are supported by the same Earth scientist communities, especially in local universities.

The Japan Meteorological Agency (JMA) launched the Volcanic Warning and Advisory service in December 2007 and has issued about 70 warnings and advisories with Volcano Alert Levels on activated volcanoes (e.g., Miyakejima, Asama, Sakurajima, and Kirishima). The Volcano Alert Level scheme made it possible for local municipalities to plan for volcanic disaster mitigation: level 1 (normal), level 2 (no access to the crater), level 3 (no access to the volcano), level 4 (preparation for evacuation), and level 5 (evacuation).

The Ministry of Education, Culture, Sports, Science and Technology (MEXT) and the JMA launched the Foundational Volcanic Observation Network in 2009. Systems consisting of a borehole-type seismometer, a tiltmeter, and GPS were installed at 47 active volcanoes. As a general policy, the JMA is in charge of volcano monitoring, whereas universities and national institutes provide their own observation data to the JMA. This new network was intended to replace older instruments with more effective and less expensive data acquisition infrastructure and to promote data circulation among researchers.

3. Study of Eruption Forecasting

Although we can detect abnormal phenomena leading to eruptions and forecast eruptions on the basis of monitoring data, the magnitude, mode, and progress of the eruptions are still unknown. To minimize forecasting failures and achieve real-time evaluation of the activity, the preparation of eruption scenarios for active Japanese volcanoes has begun. These scenarios are event trees that show probabilities on the basis of historical and geological records of eruptions, geophysical–geochemical monitoring archives, and

geophysical–geochemical models.

A comprehensive project was conducted at Sakurajima to reveal the accumulation and ascension of magma. The results of seismic, GPS, electromagnetic, and geochemical monitoring and repeat experiments suggest that the volumes of magma accumulated in the shallow reservoir beneath Sakurajima and supplied from the deeper reservoir have both increased, along with an increasing contribution from juvenile materials, since October 2009. Comprehensive observations were also conducted at Suwanosejima and Asama to model the source mechanism of repeating explosive eruptions associated with bubbling, migration, and rupturing of gas in the conduit.

A new technique using muons, or muonography, yielded important information on the magma process in the shallowest conduit. Measuring the muon path lengths and absorption along different paths yields the density distribution inside the volcano. The use of muonography in conjunction with other observations such as gravitational measurements becomes very useful in modeling the eruption process in the conduit.

4. Other National Projects

University researchers conducted a challenging project on a Grant-in-Aid from MEXT (2009–2013), titled "Geofluid: Nature and Dynamics of Fluids in Subduction Zones." This project focuses on the dynamics of deep fluids liberated from subducting plates and studies related phenomena (e.g., magmatism, seismicity, crustal deformation, metamorphism, hot spring activity, and ore formation) from many perspectives by geophysical observations of deep-seated rocks (seismic tomography and magnetization transfer imaging); materials science of fluids, including high-pressure experiments and molecular dynamics studies of the chemistry and physical properties of fluids and the microstructure of fluid-bearing rocks; and forward modeling coupled with geochemical inversion of fluid flow, magma genesis, and ore formation. The final goal of this project is to establish a universal model for geofluid dynamics that explains the circulation of fluids throughout the subduction zones and its effects on the active Earth.

5. International Activities

Universities conducted observational studies of volcanoes in Indonesia, the Aleutians, Taiwan, and other areas by international collaboration through various agreements with foreign universities and national organizations. The project "Multidisciplinary Hazard Reduction from Earthquake and Volcanoes in Indonesia" started in 2009 under the Japan Science and Technology Agency (JST) and Japan International Cooperation Agency (JICA). As a feasibility study for this project, the Asian International Symposium on Modeling Volcanic Eruptions for Volcanic Hazard Assessment was held in Bandung in November 2008. A collaboration with the Indonesian Center of Volcanology and Geological Hazard Mitigation (CVGHM) on the JST–JICA project targets laboratory volcanoes including Semeru, Talang, Guntur, Batur, and Kelud. Sinabung, in northern Sumatra, was added after its first historical eruption in August 2010. A group of Japanese volcanologists was dispatched to Merapi volcano after receiving an official request from the Indonesian president in November 2010, when the Merapi eruption caused more than 300 casualties.

The National Research Institute for Earth Science and Disaster Prevention (NIED) conducted research on Iwojima Caldera with the US Geological Survey and on the project "Development of Hazard Mitigation Methods for Volcanic Lava Flow" in conjunction with the Japan–Italy agreement with the Istituto Nazionale di Geofisica e Vulcanologia (INGV). The Geological Survey of Japan (GSJ), part of the National Institute of Advanced Industrial Science and Technology, collaborated with the Geological Survey of Austria in aeromagnetic and gravitational surveys to reveal the shallow subsurface structure of Italian volcanoes. The GSJ collaborated with the INGV and Italian universities to model gas-emitting processes on the basis of observations of volcanic eruption plumes and with CVGHM to study caldera-forming eruptions in Indonesia.

Universities, the NIED, and the JMA have conducted a group-training course on volcanology under the auspices of the JICA. The NIED dispatched a specialist to Ecuador and the Philippines to advance volcanic observation techniques. The JMA collaborated with the Philippine Institute of Volcanology and Seismology on volcano monitoring.

The Tokyo Volcanic Ash Advisory Center of the JMA, reported volcanic ash information in the area from Kamchatka to the Philippines and contributed to safe flights of aircraft.