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Foreword

This is the Annual Report for the 2011 academic year (April 2011–March 2012), summarizing the research and educational activities, joint-use projects, and related committee activities at the Solar-Terrestrial Environment Laboratory (STEL).

Since the establishment of the STEL in 1990, research has been conducted on the structure and dynamic fluctuations of the Sun, the Earth, and the cosmic space between them. Additionally, nationwide studies have been promoted under Japan’s inter-university collaborative system. During the 2010 academic year, the Ministry of Education, Culture, Sports, Science, and Technology (MEXT) provided a new system of Joint Usage/Research Centers, including the STEL, as a successor to Japan’s inter-university collaborative system, from April 2010 to March 2016. During the second year (2011), we performed 176 collaborative studies, which are described in this report. The number of studies is significant for the size of our institute (only 30 faculty staff). It is worthy of special mention that the MEXT Young Scientists’ Prize of Commendation for Science and Technology and the Society of Geomagnetism and Earth, Planetary, and Space Sciences (SGEPSS) Tanakadate Award were received by staff members at our institute.

We have continued to advance the international research project Climate And Weather of the Sun-Earth System (CAWSES-II; 2009–2013), which was implemented by the Scientific Committee on Solar-Terrestrial Physics (SCOSTEP). The aim of the project is to understand the domain from the Sun to the Earth as a single complex system, including a comprehensive understanding of the mutual variability that occurs within this system over the short and long terms. The 6-year research project “Research on Space Storms and Atmospheric Variability in the Next Solar-maximum Period” was adopted as a special-fund program for education and research in the 2011 budgetary requests. This fund supports the joint-use research center where interdisciplinary research on space storms and atmospheric variations is conducted. Research goals include increasing safety and security for future space operations and exploring the variability of the terrestrial environment induced by solar activity. This joint-use research center is unique in the field of solar-terrestrial environment studies in Japan. Operations were performed on the interplanetary scintillation (IPS) phased-array antenna system called the “Solar Wind Imaging Facility;” millimeter-wave band radiometers for measuring ozone, water vapor, and chlorine monoxide in the middle and upper atmosphere; spectrometers for measuring methane and carbon dioxide; and a meteor radar and sodium lidar near the European Incoherent Scatter (EISCAT) radar bases, which were developed over the last few academic years. The Geospace Environment Modeling System for Integrated Studies (GEMSIS) is also progressing steadily.

We also participated in the “Inter-university Upper atmosphere Global Observation NETwork” (IUGONET) research project between April 2009 and March 2015. We cooperated with five Japanese universities and institutes (National Institute of Polar Research, Tohoku University, Nagoya University, Kyoto University, and Kyushu University) that have been leading sources of ground-based observations of the upper atmosphere for decades. The project is building a database system for our observational data. The metadata database (MDB) archiving this information is of great help to researchers who wish to efficiently obtain the various observational data that have been accumulated over many years.
The science goal of the project is to clarify the physical processes that control long-term variations in the upper atmosphere.

Cooperating with the Division of Particle and Astrophysical Science in the Graduate School of Science, we have promoted the Global COE (Centers of Excellence) Program “Quest for Fundamental Principles in the Universe” since 2008. The aim of this program is the comprehensive understanding of the elementary processes and structures that appear on various scales in space. We therefore have performed complementary operations among particle physics, astrophysics, and solar-terrestrial science to build major links from space to Earth. Another Global COE program, “From Earth System Science to Basic and Clinical Environmental Studies (BCES),” was started at Nagoya University in 2009, conducted by the graduate school of environmental studies. We also contributed to the BCES-GCOE program.

This year, we conducted research on such diverse topics as solar flare and solar wind; the magnetosphere, ionosphere, and thermosphere; the atmosphere near Earth’s surface layer; planetary magnetospheres; and planets outside our solar system. Using observations, simulations, and modeling techniques, we conducted advanced, energetic research in a wide range of fields. We hope this report helps to provide a full understanding of our activities and the current state of STEL.

June 2012

Y. Matsumi
Director
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1. Progress in Research

ATMOSPHERIC ENVIRONMENT

The chemical composition of the terrestrial atmosphere, which has evolved with life on Earth, is quite different from that of other Solar system planets. In recent years, the exhaustion of minor molecular species by human activity has destroyed the balance of the atmospheric environment, causing global warming, the destruction of the stratospheric ozone layer, and air pollution. In order to understand these phenomena more thoroughly, the Division of Atmospheric Environment is investigating: (1) the time variations and circulation of minor molecular constituents, (2) the fundamental processes of chemical reactions, and (3) the composition of aerosols and their influence on the atmospheric environment. To enhance our laboratory research and remote field observations, we are developing several original instruments and methodologies.

Observational and Laboratory Studies of the Upper and Middle Atmosphere

(1) Measurements of composition changes in the middle atmosphere at Syowa Station in Antarctica

The polar region is one of the most important sites for obtaining a better understanding of atmospheric dynamics and chemistry, such as variations in the chemical composition associated with the formation and breakdown of the polar vortex, heterogeneous reactions on polar stratospheric clouds, photochemical reactions, and dynamical transport by global circulation. Moreover, the polar area is a region where charged energetic particles penetrate the Earth’s magnetosphere. At the poles, composition changes caused by high-energy particle penetration are highly expected. We installed a ground-based millimeter-wave radiometer in January 2011 at Syowa Station in Antarctica to determine the mechanism behind the temporal and spatial variations of the chemical composition in the polar region’s middle atmosphere. We have been measuring the vertical distribution of ozone and nitrogen oxides (NO and NO₂) in the middle atmosphere since March 2011, in collaboration with the National Institute of Polar Research (NIPR). One scientist and one engineer from the Solar Terrestrial Environment Laboratory (STEL) worked at Syowa Station to construct and maintain the radiometer.

In January 2012, a major solar proton event occurred in which a proton flux with energy > 10 MeV (6300 pfu) was observed. The enhanced emission of NO, with an intensity of ~60 mK, was detected. The linewidth of the detected NO spectrum was estimated to be 1 MHz, suggesting that enhancement of the NO distribution occurred at an altitude > 60 km.
(2) Monitoring of the vertical distribution of ozone in the middle atmosphere with a millimeter-wave instrument at Rio Gallegos, Argentina

The Antarctic ozone hole that appears during the winter/spring seasons influences the chemical composition in the stratosphere, through dynamical and chemical processes that occur in the mid-latitude region of the southern hemisphere, at a time corresponding to breakup in the polar spring. The details of these mechanisms are still unclear, and further observational studies are highly desired. For this purpose, we installed a ground-based millimeter-wave radiometer at Rio Gallegos (52°S, 69°W, 40 m above sea level) with Centro de Investigacionese en Láseres y Aplicaciones (CEILAP) of Argentina, and have been measuring the vertical distribution of stratospheric ozone at 209 GHz since January 2011. To make continuous measurements of the vertical distribution of ozone more efficiently, we replaced the receiver system operating at the 209-GHz band to one that uses the 110-GHz band, due to the atmospheric opacity at 110 GHz and improved transparency of this frequency. We are currently working to improve the onsite data-reduction system.

In cooperation with CEILAP and the University of Punta Arenas, Chile, with support from the Japan Society for the Promotion of Science (JSPS) and the Japan International Cooperation Agency (JICA), we made preliminary measurements of the ozone distribution using a radiometer, a light detection and ranging (LIDAR) system, and balloon measurements. These measurements and comparisons among the results were presented at a lecture in the concluding seminar of the JICA project held at Rio Gallegos, August 2011.

(3) Continuous measurements of stratospheric chlorine monoxide (ClO) over the Atacama Highlands

The chemical composition in the middle atmosphere has changed significantly, according to environmental studies. Examples include the depletion of stratospheric ozone since the 1980s, which has been attributed to the emission of anthropogenic chlorine compounds

Left: Overview of Rio Gallegos Observatory in Argentina.
Right: Millimeter-wave radiometer operated at 110 GHz constructed in Nagoya.
from the ground, and global warming caused by the emission of greenhouse gases. As a result, temperature cooling of the middle atmosphere has induced changes in its chemical composition. Moreover, changes in the solar ultraviolet (UV) radiation also affect the chemical composition in the middle atmosphere through photochemical reactions. Recently, researchers discovered a sudden enhancement of the NOx concentration and decrease in the middle-atmosphere ozone, believed to be caused by the penetration of energetic particles associated with an increase in solar activity. To investigate these changes in the chemical composition of the middle atmosphere, we installed a millimeter-wave radiometer in the Atacama Highlands, Chile (23°S, 68°W, 4800 m above sea level), to measure the emission spectra of ozone, ozone-depleting molecules, water vapor, and their isotopes NO and NO2. The vertical profiles of these molecules were retrieved from the observed spectra, and the temporal variations as a function of altitude were obtained. Ground-based radiometer data indicated a diurnal variation of ClO in the upper stratosphere of the mid-latitude region. The obtained amplitude of the diurnal variation at 40 km was close to that observed in previous studies, although our measurement time frame was delayed by three hours (from sunrise) compared to previous work.

(4) Monitoring measurements of stratospheric and tropospheric minor constituents including greenhouse gases with infrared spectrometers

One of the most serious problems on atmospheric environment is global warming caused by monotonic increase of the greenhouse gases such as carbon dioxide (CO2) in the atmosphere, being predicted that global warming may be largely impacted on the Earth environment and human life-system in future. Since 1995, we have measured absorption spectra of stratospheric and tropospheric minor constituents such as ozone and carbon monoxide (CO) continuously by using two high-resolution Fourier transform infrared spectrometers (FTIRs) at Moshiri and Rikubetsu observatory. Since 2009, we have been measuring CO2 and methane (CH4) column-averaged mixing ratio. These data have been used to validate the GOSAT satellite, launched in January 2009. In November 2011, we had replaced the solar tracker to the newer one. In addition,
simultaneous measurements of CO₂ and CH₄ by using the FTIR and the compact optical spectrum analyzer (OSA) had been made for validation of the OSA measurement.

(5) Observations of planetary atmospheres with millimeter-wave telescopes

The chemical composition of a planet’s atmosphere reflects the origin and physical properties of the planet. Thus, both major and minor atmospheric constituents are equally important, and require spectroscopic methods for detection. Since 2010, we have been carrying out millimeter-wave observation of CS, CO, and HCN spectra for the atmospheres of Jupiter and Neptune (the Atacama Submillimeter Telescope Experiment (ASTE)), using a 10-m telescope in Chile. Our observations revealed a CO and HCN mixing ratio of ~1.0 ppmv and 1.0 ppbv, respectively, consistent with previous results. In contrast, CS emission was not detected in our observations, implying an upper-limit CS mixing ratio of ~0.01 ppbv. Derived from [CS]/[CO], this ratio was smaller than that observed at the Shoemaker–Levy 9 (SL9) comet collision with Jupiter by a factor of 2, implying that no collision event such as SL9 is likely for Neptune (over a 30-year time frame). Additionally, we have been measuring CO, HCN, and CS spectra with the Nobeyama Radio Observatory (NRO) 45-m telescope since 2011 to detect SO emission which may be related to volcanic activity.

In 2011, we started a project of continuous measurement of the planets’ atmospheres, using a portion of the Nobeyama Millimeter Array (NMA). We evaluated the tracking accuracy of the telescope, and succeeded in detecting CO-emission from the Martian atmosphere.
Observational and Laboratory Studies of the Lower Atmosphere

(1) Simultaneous balloon born measurements of CO$_2$ vertical profiles at three sites in the Tokyo metropolitan area

Emissions of CO$_2$ have increased dramatically over the past century as a result of the mass consumption of fossil fuels. This effect has been attributed to the expansion of industrial activities, resulting in a significant increase in atmospheric CO$_2$ concentration. CO$_2$ emissions from urban areas are an important part of the global carbon budget; however, the concentration estimations are based mainly on inventories of fossil fuel consumption and road traffic. To ascertain the CO$_2$ flux values from urban areas, detailed CO$_2$ measurements including vertical distributions are required.

In this study, simultaneous measurements of CO$_2$ vertical profiles were conducted using originally developed balloon-borne sounding systems (CO$_2$-sonde) at three sites on January 7, 2011 to evaluate CO$_2$ emissions from the Tokyo metropolitan area. The three sites, Isezaki (Gunma Pref.), Ichihara (Chiba Pref.), and Shirako (Chiba Pref.), where the balloon borne instruments were launched, are located upwind, inside, and downwind of the metropolitan area, respectively (left figure). The CO$_2$ sensors used a non-dispersed infrared-absorption spectroscopy (NDIR) technique that operated near 4.3 µm. The NDIR data were transmitted with temperature, humidity, and global-positioning system (GPS) data to a ground-based receiver (Meisei, RD-08AC) through a GPS rawin-sonde (Meisei, RS-06G) every second.

The CO$_2$ mixing ratio observed at Ichihara (near-source) was higher than that at Isezaki (windward) by 2–10 ppmv at lower altitude (<1 km); while that observed at Shirako (leeward) was higher than that observed at Isezaki (windward) by ~2 ppmv at an altitude of 1–2 km (right figure). These results can be reasonably explained by the emission and dispersion processes of CO$_2$ in the atmospheric boundary layer for the Tokyo metropolitan area (left figure). These data will prove to useful in the evaluation of CO$_2$ emissions from Tokyo, providing CO$_2$ transport models and a means of validating CO$_2$ total-column measurements from greenhouse-gas-observing satellites (GOSAT).

Left: Schematic diagram of the emission and dispersion processes of CO$_2$ in the Tokyo metropolitan area.
Right: Vertical profiles of the CO$_2$ mixing ratio obtained by balloon-borne CO$_2$-sonde instruments launched from three sites in Japan (Isezaki, Ichihara, and Shirako) on January 7, 2011.
Aerosols in the Earth’s troposphere consist of a complex mixture of mineral dust, inorganic salts, organic compounds, and soot particles. The impact of these aerosols on the climate depends on the physical and chemical properties of the aerosol, such as its size, shape, density, mixing state, and chemical composition. Therefore, accurate knowledge of these properties is essential for modeling climate forcing by aerosols. Particle density is a necessary parameter for particle mass and volume measurements. However, detailed examination of particle density distributions is still limited by filter-based techniques that can only provide an average density of internally and externally mixed particles.

In this work, real-time measurements of the effective density distributions and chemical properties of ambient particles were conducted on August 16–25, 2011 at the Higashiyama campus of Nagoya University. The effective ambient particle density, with a mobility diameter of 100 and 200 nm, was determined from the combined measurements from a differential mobility analyzer (DMA), an aerosol particle mass analyzer (APM), and a condensation particle counter (CPC), as shown in the left figure. Chemical properties of the aerosol were measured by a time-of-flight aerosol mass spectrometer (ToF-AMS). The density distributions and chemical compositions were measured every 30 min after passing through one of three lines controlling at 25, 100, and 300°C.

The right figure shows the average density distributions for 100 nm mobility diameter particles, measured for inlet temperatures of 25 and 300°C between 6:00 and 18:00 on Aug. 21, 2011. The ambient aerosols typically had two distinct density peaks: one at 0.7–0.9 g cm$^{-3}$ (peak 1), and the other at 1.2–1.6 g cm$^{-3}$ (peak 2). The changes in the peak areas after heating suggest that “peak 1” and “peak 2” consisted mainly of soot and volatile compounds (such as inorganic salts and organics), respectively. The effective density for peak 2 increased with increasing sulfate concentration, and decreased as the low-volatility oxygenated organic aerosol increased.

Right: Average density distributions for ambient particles with a mobility diameter of 100 nm, observed for inlet temperatures of (a) 25 and (b) 300°C, from 6:00–18:00 on Aug. 21, 2011.
Optical property measurements of aerosol during summer in Nagoya

Aerosol particles balance the radiation in the atmosphere by absorbing and scattering incident light. Black carbon (BC) particles are an important global warming agent, with radiation forcing similar in magnitude to CO₂. Internal mixing with other compounds tends to increase the light absorption of BC; however, the amount of absorption enhancement depends on factors such as the refractive index of BC and other coating materials, and the size and location of the BC core. Light-absorbing organic carbon (OC), referred to as “brown carbon”, involving humic-like substances (HULIS), organonitrates, and nitro-aromatics, has recently been proposed as a source of significant absorption, particularly for shorter-visible and UV wavelengths. However, observational studies of the enhancement of BC and OC light absorption are still limited.

In this work, by applying photoacoustic spectroscopy (PAS), the light-absorption enhancement of BC and the light absorption by OC were examined. Observations of the aerosol’s optical and chemical properties were conducted on August 16–25, 2011 at the Higashiyama campus of Nagoya University. The optical properties and chemical compositions were measured after the aerosol passed through lines controlling at 25, 100, and 300°C every 30 min. Absorption \( b_{\text{abs}}(\lambda) \) and scattering \( b_{\text{sca}}(\lambda) \) coefficients, at 405 and 781 nm, were measured using a three-wavelength photoacoustic soot spectrometer (PASS-3). The chemical composition of the aerosol was measured by the ToF-AMS.

The amplification factor \( F_A = \frac{b_{\text{abs}}(781 \text{ nm, 25°C})}{b_{\text{abs}}(781 \text{ nm, 300°C})} \), which represents the enhancement of light absorption of BC at 781 nm when light absorption by OC is negligible, is shown in the left figure. A coating consisting of volatile components enhanced the light absorption of BC by 10–40%. By comparing the wavelength dependence of the absorption coefficients with and without heating, the absorption coefficient at 405 nm for OC, \( b_{\text{abs,OC}}(405 \text{ nm, 25°C}) \), was estimated under the assumption that \( F_A \) did not depend on the wavelength. The right figure shows the \( b_{\text{abs,OC}} \) values and the total light absorption by the aerosol at 405 nm. Contribution of light absorption by OC, which was vaporized at 300°C, was found to be minimal during the summer months in Nagoya.

Left: Amplification factor \( F_A = \frac{b_{\text{abs}}(781 \text{ nm, 25°C})}{b_{\text{abs}}(781 \text{ nm, 300°C})} \).
Right: Absorption coefficients of all the aerosol particles and OC at 405 nm. All of the data are averaged over 6 h.
(4) Optical properties of diesel-exhaust particles

Diesel-exhaust particles (DEPs) are known as one of the main anthropogenic sources of BC and OC. The increased light absorption of BC due to an OC coating is referred to as the “lensing effect”. Light-absorbing OC has recently been proposed as a significant source of absorption for near-UV wavelengths. However, the contribution of the lensing effect and light-absorbing OC for DEPs is not well known, due to the difficulty in obtaining an accurate measurement of the light absorption of internally mixed BC particles and OC.

In this study, PASS-3 was used to investigate the optical properties of DEPs emitted from a diesel engine vehicle, running on a chassis dynamometer in an urban driving mode (JE05) and a constant speed mode (either idling or 70 km h$^{-1}$). The absorption and scattering coefficients of the DEP at 405, 532, and 781 nm were measured by the PASS-3 after passing through a dilution system and an inlet heater (left figure). The size distributions of the DEPs, before and after heating, were also measured by two scanning-mobility particle sizers (SMPS) during the constant mode experiments.

During the experiments using the JE05 mode, optical properties were measured with inlet heater temperatures of 20, 47, or 300°C. Enhancement of the scattering coefficient was observed during the high-speed driving period (~80 km h$^{-1}$, 1500–1700 s after start up) with an inlet temperature at 20°C. Enhancement of the scattering coefficient was not detected at 300°C, which indicated that the emission of OC compositions increased during this period. By comparing the wavelength dependence of absorption coefficients with and without heating, the OC contributions to the total light absorption at 405 and 532 nm during the high-speed driving period were estimated to be 16 ± 8% and <5%, respectively (right figure). Additionally, from the amplification factor at 781 nm ($F_A = b_{abs}(781 \text{ nm}, 25^\circ C) / b_{abs}(781 \text{ nm}, 300^\circ C)$), the light absorption of BC was enhanced by 15–20% during the constant speed mode, due to the OC coating.

Right: (a) vehicle speed and OC contribution to the total light absorption by DEPs at (b) 532 and (c) 405 nm during the transient cycle mode (JE05).
IONOSPHERIC AND MAGNETOSPHERIC ENVIRONMENT

Division of the Ionospheric and Magnetospheric Environment (Division 2) investigates the physical processes of energy transfer from the magnetosphere to the ionosphere and the thermosphere, and from the lower atmosphere to the upper atmosphere at various latitudes, on the basis of ground-based network observations using radio and optical equipment. Particles and fields in the magnetosphere and high- and low-latitude auroral phenomena are also studied. Studies using the European Incoherent Scatter (EISCAT) radars have provided new insights into auroral phenomena and the high-latitude lower thermosphere. Optical, radar, and GPS satellite observations have contributed greatly to an increased understanding of the ionosphere, thermosphere, and upper mesosphere. In 2011, a new group in Division 2, consisting of one professor and one assistant professor was established to develop satellite-borne plasma instruments.

Optical Mesosphere Thermosphere Imagers (OMTIs)

The Optical mesosphere thermosphere imagers (OMTIs) consist of five sky-scanning Fabry-Perot interferometers (FPIs), 13 all-sky CCD imagers, three tilting photometers, a spectral airglow temperature imager (SATI), and three airglow temperature photometers. These instruments are fully automated and measure nightglow emissions, neutral winds, and neutral temperatures at an altitude of 80–300 km. The OMTIs are located at several key points around the world: Shigaraki (34.8°N, 136.1°E), Rikubetsu (43.5°N, 143.8°E), Sata (31.0°N, 130.7°E) and Yonaguni (24.5°N, 123.0°E) in Japan; Chiang Mai (18.8°N, 98.9°E) in Thailand; Darwin (12.4°S, 131.0°E) in Australia; Kototabang (0.2°S, 100.3°E) in Indonesia; Resolute Bay (74.7°N, 265.1°E) and Athabasca (54.7°N, 246.7°E) in Canada; Magadan (60.1°N, 150.7°E) and Paratunka (53.0°N, 158.2°E) in Russia, and Tromsø (69.6°N, 19.2°E) in Norway.

(1) Auroral observations

From 2005, we have conducted high-latitude aurora and airglow measurements using two all-sky imagers and an induction magnetometer and a proton photometer at Resolute Bay (magnetic latitudes: 83°) and Athabasca (62°). In 2011, we also conducted high time-resolution auroral observations and very low frequency/extremely low frequency (VLF/ELF) measurements at Athabasca and Fort Vermillion, Canada. Plasma patches at polar-cap latitudes, VLF/ELF waves in the inner magnetosphere, and isolated-proton auroras and related Pc1-geomagnetic pulsations at subauroral latitudes were investigated using data from these stations. Electron data obtained by the THEMIS and FAST satellites were analyzed to investigate magnetosphere-ionosphere coupling process associated with auroras.

(2) FPI development

Four new FPIs have been operated at Tromsø, Chiang Mai, Kototabang, and Darwin since March 2011 to measure winds and temperatures in the thermosphere at low- and mid-latitudes through airglow/aurora emissions at wavelengths of 630.0 nm. They form two pairs of geomagnetic conjugate measurements of thermospheric wind at low and middle latitudes. Investigations are under way on the F-region dynamo effects related to the equatorial plasma bubbles and on hemispheric coupling associated with the nighttime medium-scale traveling ionospheric disturbances.
Ionospheric Disturbances Observed by GPS Networks

Using densely-spaced GPS receivers in Japan, we investigated two-dimensional (2D) maps of the total electron content (TEC) with high spatial and temporal resolution. Approximately 7 min after the 2011 Tohoku Earthquake, an initial TEC disturbance was observed as a rapid TEC increase, followed by a large TEC decrease. We found that the location of the initial TEC disturbance was consistent with the large amplitude in the tsunami’s initial height, which was located ~170 km from the epicenter in the southeast direction. From this point, the TEC disturbances propagated outward at a velocity of $140 - 3500 \text{ m s}^{-1}$. These results suggest that the acoustic waves generated by the tsunami propagated into the ionosphere at the speed of sound, causing the TEC variations.

Observations of the Equatorial Thermosphere/Ionosphere over Indonesia

To study dynamic and electro-dynamic coupling processes in the equatorial atmosphere, we have operated an all-sky airglow imager, GPS receivers, a magnetometer, and VHF Doppler radar at Kototabang, Indonesia, since 2002. Continuous observations of field-aligned irregularities (FAIs) using the VHF Doppler radar revealed that F-region FAIs appeared frequently in the post-midnight between May and August during the solar minimum period. Five-beam measurements by the radar revealed zonal propagation of the F-region FAIs. We found that 46% (14%) of post-midnight FAIs propagated westward (eastward); zonal propagation was not discernible for the remaining 40% of post-midnight FAIs. The average velocity was approximately $50 \text{ m s}^{-1}$ westward. Although post-midnight FAIs could be associated with plasma bubbles, the high occurrence rate of westward-propagating post-midnight FAIs over Kototabang was not consistent with the average plasma-drift velocities observed at Jicamarca and Arecibo, indicating that not all post-midnight FAIs were associated with plasma bubbles. Because the zonal propagation velocity of post-midnight FAIs was comparable to medium-scale traveling ionospheric disturbances (MSTIDs) observed at mid-latitudes, some of the post-midnight FAIs over Kototabang could be mid-latitude FAIs coexisting with MSTIDs.
Left: Two-dimensional (2D) map of the total electron content (TEC) perturbations observed by the global positioning system (GPS) receivers.
Right: Spatial and temporal variations of the Doppler velocity of ground scatter echoes observed by the SuperDARN Hokkaido radar after the 2011 Tohoku Earthquake.

**SuperDARN Hokkaido HF Radar**

The Super Dual Auroral Radar Network (SuperDARN) Hokkaido High-Frequency (HF) radar at Rikubetsu, Hokkaido began continuous operation in December 2006. Because this radar is situated at a lower latitude than the preexisting SuperDARN radars, the dynamic-coupling processes in the high to mid-latitude upper atmospheres can be explored. During the past five years of operation, we observed a wide variety of interesting phenomena that occurred in the magnetosphere, ionosphere, thermosphere, and upper mesosphere. We studied the solar flare effects on the ionospheric disturbances represented by positive Doppler velocities of ground-scatter echoes. This was attributed to electron density changes that occurred in the D-region or lower E-region ionosphere that affected the radiowave pathlengths, as opposed to F-region electron-density changes, which would affect the reflection height. We also studied the characteristics of coseismic ionospheric disturbances (CIDs) having a propagation velocity of 3.5 to 6.2 km s$^{-1}$, which occurred 10 to 20 min after the 2011 Tohoku Earthquake. Additionally, we performed statistical analysis on near-range (<500 km) echoes, which are considered to contain upper-mesosphere echoes.

**Data Archives**

The following data archives are available to the public:

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Variation of neutral temperature observed by sodium LIDAR for the night of December 17, 2011. The time and height resolutions are 6 min and 2 km, respectively.

EISCAT Project Promotion: Synthetic Observations with Collocated Instruments in Northern Scandinavia

The EISCAT Scientific Association is an international organization concentrating on the operation of radar systems in northern Scandinavia. We accumulated a variety of instruments around the EISCAT radar site to conduct complementary and synthetic observations throughout the ionosphere, thermosphere, and mesosphere at high latitudes. In the 2011 fiscal year, 15 proposals for EISCAT special experiments were accepted by the Japanese EISCAT committee, and 14 of them were conducted in collaborations with NIPR. An FPI, four-wavelength photometer, proton imager, electron auroral camera, and multi-wavelength all-sky camera were operated automatically at Tromsø in 2011–2012 winter. A medium frequency (MF) radar at Tromsø and a meteor radar at Bear Island were operated automatically on a continuous basis to obtain wind data from 70 to 100-km altitudes. A sodium LIDAR system was also used during the winter at Tromsø. Synthetic observations with these radio and optical instruments allow us to study the energy budget and wind dynamics in the upper atmosphere at high latitudes.

Sodium LIDAR Observations at Tromsø

We conducted observations of neutral temperature at Tromsø using the sodium LIDAR for about 1900 hours from September 2011 to March 2012. We obtained ~812 hours of temperature data between 80 and 110 km. We operated the sodium LIDAR in a five-beam mode from September 21 to October 5, 2011, and October 22–26, 2011. Observations with a vertical (one-beam) mode were made from November 7, 2011 to March 13, 2012. Simultaneous observations with EISCAT ultra-high frequency (UHF) and/or very high frequency (VHF) radars were performed for ~20 nights. In particular, the 11-day run in January 2012 using the EISCAT-UHF radar was made under particularly good weather conditions.

Sporadic Sodium Layer Observed by Sodium LIDAR

High-time resolution measurements by the new Tromsø sodium LIDAR revealed short time-scale atmospheric waves as well as turbulence in the sporadic sodium layer. Sodium
LIDAR detected a large increase (ten times larger than normal) in the sodium density between 20:00 and 23:30 UT (21:00–24:30 LT) on January 11, 2011. Analyzing the 5s resolution data, we found short-period waves (e.g., wavelike structures of 7–11 min and 3 min) and turbulence in the frequency range of $10^{-4}$–$10^{-1}$ Hz.

**Variance of the Vertical Ion speed Measured with the EISCAT Radar**

The vertical component of the ion velocity measured with the EISCAT-UHF radar in the lower ionosphere (from 95 to 130 km) was characterized by notably large variances at oscillation periods of 2–8 minutes. Height profiles of variance of the vertical ion speed during geomagnetically disturbed periods indicated a peak at 120 km. This peak was well reproduced by a theoretical calculation assuming oscillations in the meridional component of the electric field. The statistical and theoretical calculations provided important insight into the magnetosphere–ionosphere coupling study.

**Database of EISCAT Radar and STEL Optical Instruments**

The analyzed data and quick-look figures are available for download from http://www.stelab.nagoya-u.ac.jp/~eiscat/data/EISCAT.html. A number of domestic and overseas researchers access and download these data for their scientific activities. The web page provides physical parameters, such as the electric field and ionospheric conductivity, together with general ionospheric parameters estimated with the EISCAT radar of UHF/VHF Tromsø radars and ESR 32 m/42 m radars at Longyearbyen. Furthermore, several long-run datasets such as DELTA-2 campaign (January 2009) and IPY one-year run (from March 2007 to March 2008) are also available. Six optical instruments are now in operation (March 2012): a digital camera, a four-channel photometer, a proton all-sky camera, a multi-wavelength all-sky camera, a Fabry-Perot interferometer, and a sodium LIDAR, which is presented above. These datasets are also available on the web.
A Comparative Study on the Structures and Dynamics of Auroras and the Fine Properties of Auroral Particles using the Reimei Satellite

Reimei satellite mission, starting the scientific observations at 650-km altitudes in the late 2005, has been providing us with the high-time/spatial resolution auroral data with the novel observation function realizing simultaneous conjunction measurements of the auroral emissions at the ionospheric altitudes and the auroral plasma particles in the topside ionosphere. The multi-spectral auroral camera (MAC) with 1.1-km resolution over a 70-km×70-km area at the auroral altitudes (110 km) are imaging a number of spatial distributions and time variations of auroras simultaneously with energy spectra of the energetic (10 eV−12 keV) plasma over the full-pitch angle range by auroral electron/ion energy spectrum analyzers (ESA/ISA). These features imply that the Reimei observations could reveal the closed correlation between the structures and variations of auroral arcs/bands and the precipitating electron components accelerated mainly by quasi-static field-aligned potential structures and kinetic (dispersive) Alfven waves above the Reimei orbit. The detailed comparisons based on these high-quality auroral image/particle data would derive the newest comprehensive knowledge which has not been obtained for several decades. The Reimei results indicate that rapidly varying inverted-V electron components are highly correlated with small-size active auroras like rotating auroral vortices, high-speed streaming shear-type arcs, flushing ray-type auroras, etc.

Development of Plasma/Particle Experiment Suite (PPE) for the Japanese Geospace Exploration Mission “ERG”

The terrestrial magnetosphere, especially inside the geosynchronous orbit, has been called Geospace, which is affected by the plasma particles and waves, the electric field and current, and the geomagnetic field. This region is quite important for the space infrastructure and also crucial for the space physics because a variety of particle acceleration/transport/loss processes occur and numerous high-energy/radiation belt particles are produced. Our Japanese community in the solar-terrestrial physics is starting up a new exploration mission, called “ERG (Energization and Radiation in Geospace).” For the space plasma/particle

An example of the 2-D distributions of auroral emissions, the electron energy distributions, and the field-aligned currents observed by the Reimei satellite.
observations in this mission, we have to establish/develop new experimental techniques. The \textit{in-situ} plasma/particle instrument suite should cover a wide energy range from \textasciitilde 10 eV up to a few of tens of MeV, especially for electrons. Many particle processes and the associated phenomena in the Geospace are activated through the energy coupling mechanisms among several plasma components with different characteristic energies. The ERG satellite, therefore, will carry several types of plasma/particle instruments, each of which could measure electrons/ions in the corresponding energy range efficiently using the electrostatic energy analyzers, the MCP/SSD/APD assemblies, and the scintillator/PMT unit. We, therefore, have been making the detailed design and conducting the space plasma/particle experiment (PPE) for our ERG mission.

\textbf{Development of the High Energy Particle instrument for Ions (HEP-ion) on BepiColombo-MMO}

In the past, Mercury has been investigated by Mariner 10 in 1970s. It discovered a dipole-type magnetic field and high-energy particle bursts through three times fly-by. Recently Messenger explored Mercury through three times fly-by in 2008–2009 and it has detected the substorms, but it has not detected any high-energy particle bursts. In order to reveal the structure and dynamics of the magnetosphere of Mercury, it is crucial to observe plasmas and high energy particles directly. Therefore, the next Mercury exploration, BepiColombo mission is planned to launch in 2014, which is a collaborate project between JAXA and ESA. Mercury Magnetospheric Orbiter (MMO), one of the two spacecraft of this mission, carries the High Energy Particle instrument for ions (HEP-ion) which has two techniques for high energy particle measurements, namely a Time-of-Flight (TOF) and a Solid-State Detector (SSD). They can measure velocity (v) and energy (E) of incoming ions respectively and the ion mass can be derived from v, E, so the ions are discriminated such as H, He, C–N–O, Na–Mg, K–Ca and Fe. Energy range is required from 30 KeV to 1.5 MeV. In order to measure these particles, the characteristics of the TOF unit of HEP-ion have been studied about electrical potential distribution and particle trajectories with numerical simulations. Additionally we calibrate its prototype model in our laboratory by using the high-energy ion beam line which provides 10 keV–150 keV ion beam of H\textsuperscript{+}, He\textsuperscript{+}, He\textsuperscript{++}, N\textsuperscript{+}. Its performance of a coincidence rate and mass resolution is checked by comparisons with the simulation results. The experiment results of a coincidence rate are consistent with simulations. As for mass
Left: Engineering model of the high-energy ion instrument for the Mercury magnetospheric exploration mission, which is set up with an attachment jig to a turn table in the vacuum chamber of the calibration facility for the performance test.
Right: Sweep frequency dependence of I-V characteristics. A hysteresis feature becomes smaller as the sweep frequency increases up to several kHz because of decreasing the impedance of the reference electrode sheath.

resolution, the results of experiments and simulations show good agreement and sufficient mass resolution in the energy range of 55 keV to 100 keV and we have obtained information of mass resolution from 100 keV to 1.5 MeV with simulations.

Concept Design of Atmospheric Neutral Analyzer for Terrestrial and Planetary Exploration

In order to understand the mean state, variability, and time evolution of terrestrial and planetary upper atmosphere, *in-situ* measurements of the composition and density of the neutral atmosphere and the detailed velocity distribution of individual species are indispensable. We are designing a new instrument called the Atmospheric Neutral Analyzer (ANA) to measure the detailed, mass-resolved 2 dimensional velocity distribution of neutral species, and to derive the corresponding density, mass composition, velocity and temperature from the measured distribution. The ANA is comprised of four sections; entrance aperture slit, ion accelerator, radio-frequency ion mass analyzer and imaging particle detector. We have completed the concept design of the instrument by conducting computer simulations and made appreciable progress toward building a prototype.

A Study on the Accuracy of Langmuir Probe Measurement from a Small Spacecraft

In Langmuir probe (LP) measurement from a small spacecraft, the current–voltage (I–V) characteristics are distorted and the derived electron temperature and density might be erroneous if the surface area ratio of a reference electrode to a probe is insufficient. In order to investigate the effect of finite electrode area ratio on LP measurements, we have carried out a laboratory simulation using a model sounding rocket in a vacuum chamber. By changing the frequency of sweep voltage applied to the probe, we have derived an equivalent impedance of the reference electrode sheath, which was the principal cause of distortion in I–V characteristics. In addition, the high-frequency sweep turned out to be effective to make LP measurements possible even when a sufficient surface area ratio cannot be achieved.
HELIOSPHERIC ENVIRONMENT

The research goal of the Division of the Heliospheric Environment is to understand the heliosphere within the context of the Earth’s environment. Our primary interest now is in the physical processes of the Sun, interplanetary space, the heliospheric boundary, and other astrophysical phenomena. In addition, we study the paleoenvironment of the heliosphere. We carry out our research using ground-based observations, satellite data, and computer simulations. The major subjects of our ground-based observations are cosmic rays, solar energetic particles, the solar wind, extra-solar planets and dark matter.

IPS Observations

We performed simultaneous interplanetary scintillation (IPS) observations at the Toyokawa, Fuji, and Kiso stations between April and November of 2011, using an upgraded system that was developed and installed in 2010. We determined the solar wind speeds from the three-station IPS observations for 2011. The IPS data are available to the public via http://stsw1.stelab.nagoya-u.ac.jp/ips_data.html. We found that the distribution of the solar wind speed for 2011 differed significantly from the data for 2009. Namely, the 2011 data showed that the polar fast winds declined, while the slow winds dominated at all latitudes. This fact suggests that the solar wind is quickly approaching the Cycle 24 maximum.

Long-Term Evolution of Solar Wind Density Fluctuations

We investigated the long-term variation in the global distribution of the solar wind speed, V, and density fluctuations, ΔNe, using our IPS data obtained during the period between 1997 and 2009. Here, we employed the time-sequence tomography method to determine the global distribution of V and ΔNe. We found that the global distribution of V significantly changed with the solar activity. Namely, the fast (slow) wind region diminished (enlarged) during the solar maximum, while the fast (slow) wind grew (declined) during the solar minimum. In contrast, such a clear dependence on the solar wind was not evident in the ΔNe data. Instead, we observed a marked drop in the ΔNe level for the period between the declining phase of Cycle 23 and the subsequent minimum. This drop occurred globally, and was ascribed to the weakening of the Sun’s polar magnetic field. We also investigated the relationship between V and ΔNe, and obtained a result consistent with ΔNe ∼ V^{−0.5} from our earlier studies. However, we observed that ΔNe for V < 350 km s^{−1} tended to deviate from the above relationship and exhibited a significant decrease. This suggests that the very low-speed (<350 km s^{−1}) solar wind has a different origin from other solar winds.

Collaborative Research on the Large-Scale Structure of the IMF (Project 1)

In association with the weak polar field in Cycle 24, different characteristics of the interplanetary magnetic field (IMF) structure have been observed. Cosmic-ray modulation serves as a useful tool for studying the large-scale structure of IMFs. A
and the Aichi Institute of Technology, formed an observation network to study muon cosmic rays (Geospace Center Project 1). In 2011, we began development of a new muon cosmic-ray detector in Mexico, in cooperation with the Shinshu University group.

**International Collaborations**

Between March and May of 2011, we were very pleased to host Dr. B. V. Jackson of the University of California, San Diego as a visiting professor to our group. During this period of time, we collaborated with Dr. Jackson on studies involving our IPS observations and the Solar Mass Ejection Imager (SMEI). The purpose of the study included elucidation of the relationship between loop-shaped density structures and the magnetic-flux rope, and the relationship between solar jets and interplanetary disturbances. Campaign observations of solar jets with Hinode, proposed last year by our research group and Dr. Jackson, were successfully made in June 2011. The solar wind prediction experiment is currently being conducted on a daily basis using the time-dependent tomography (TDT) technique developed by Dr. Jackson’s group. This program is available on the web site of the Community Coordinated Modeling Center (CCMC) of NASA, and can be run on a web server. This year, we installed the TDT program on our computers, and used it to evaluate the radio sources used in our IPS observations. As a result, we were able to identify the properties of the radio sources that optimized the IPS data.

**A Study of the Solar Wind Acceleration Mechanism**

Our important findings from our previous work revealed that the solar wind speed was highly correlated with the coronal magnetic parameters ($B/f$) during the 23rd solar minimum, where $B$ is the magnetic field strength and $f$ is the flux expansion rate. We examined this relationship between $V$ and $B/f$ using IPS and Kitt-Peak magnetogram observations from 1997–2009.

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**Left:** Distance–propagation speed diagram for 50 ICMEs identified by the Large Angle and Spectrometric Coronagraph (LASCO) experiment on board the Solar and Heliospheric Observatory (SOHO) spacecraft, IPS data, and in-situ observations from 1997–2009.

**Right:** Linear relationship between accelerations and differences in speed ($V-V_{sw}$) for fast ICMEs. Here, $V$ and $V_{sw}$ denote the radial speed of the ICME and the solar wind, respectively. The dash-dotted line indicates the least-squares best-fit line.
data observed during the 24th solar minimum (from 2008−2009). We found a similar dependency of $V$ on $B/f$; however, the slope of the regression line was steeper than that during the 23rd solar minimum. This result was compared with a theoretical model (Suzuki, 2006). The comparison indicated that the steepening of the dependency, attributed to the energy input from the solar surface that accelerates the solar wind, decreased during the 24th solar minimum.

A Study of the Kinematic Properties of ICMEs Identified using IPS Observations

Between 1997 and 2009, we identified 50 of the interplanetary coronal mass ejections (ICMEs) detected at intermediate distances from the Sun, by comparing the IPS data with a catalog of ICMEs [Richardson and Cane, 2010]. We analyzed their kinematic properties and determined that the radial speed of the ICME, $V$, converged on the background solar wind speed, $V_{bg}$, with increasing distance. Subsequently, we identified the equation $a = \gamma_1 (V - V_{bg})$ to explain the motion of fast ICMEs, where $a$ and $\gamma_1$ are the acceleration and a constant, respectively. These findings suggest that the motion of fast ICMEs is controlled by the hydrodynamic Stokes’ drag force.

Solar Neutron Telescope Study of Solar Particle Acceleration Mechanisms

One of the main goals of the Cosmic Ray Group in the Heliospheric Environment Division is to study the origin of cosmic rays and the mechanism by which cosmic rays are accelerated to high energies. Cosmic rays are used to probe the heliosphere, where a number of important dynamic processes occur, providing us with information not obtainable from satellites.

To study the particle acceleration mechanisms associated with solar flares, neutron measurements are preferable to charged particle (e.g., proton), as the neutron is not
deflected by the IMF. The precise moment a neutron is emitted is determined from the neutron energy. We developed seven solar neutron telescopes on mountains at various longitudes to detect solar neutrons over an entire day. Adding to this network promoted by STEL, we plan to install Scintillator Bar (SciBar), which was used for the accelerator experiment at Fermi National Accelerator Laboratory (FNAL) in the U.S.A., on Sierra Negra, Mexico (97°W, 4600 m) as the new solar neutron telescope. This project is undertaken with the support of Kyoto University, the KEK group, and the Universidad Nacional Autonoma de Mexico. The new detector uses 15,000 scintillator bars to measure particle tracks. The new design will provide much higher energy resolution and better particle discrimination than the current solar neutron telescopes. This experiment is called SciCRT (SciBar for Cosmic Ray Telescope). In the 2011 fiscal year, we shipped SciBar from FNAL to the Instituto Nacional de Astrofísica, Óptica, y Electrónica (INAOE) in Mexico. All of the photosensors, electronics, and personal computers (PCs) were also sent to INAOE from Nagoya. The design of the structures to support the SciBar, which in total weighs 15 tons, was completed before the end of fiscal year 2011. We will begin cosmic-ray observation at INAOE in fiscal year 2012.

This work was performed in collaboration with Konan University, Nihon University, Chubu University, Shinshu University, the Tokyo Institute of Technology, Yamanashi Gakuin University, the National Astronomical Observatory of Japan, Ehime University, RIKEN, the Institute for Cosmic Ray Research (ICRR) at the University of Tokyo, ISAS/JAXA, Aichi Institute of Technology, and many institutions around the world.

Astrophysical Neutrinos and Cosmic-Ray Acceleration

We performed a search for solar flare neutrinos coincident with past big solar flares, using Super-Kamiokande atmospheric neutrino data. A 2.2-MeV gamma line, coincident with a solar flare, would indicate the acceleration period of protons or ions. This “gamma-ray tagging” method efficiently reduces the search window for neutrinos. 2.2-MeV gamma-ray emissions from the recombination of solar neutrons in the solar atmosphere were searched for in the typical large flare data and in RHESSI satellite data during the 2003 “Halloween events”. Gamma-ray-like events detected by the GEOTAIL low-energy particle experiments (GEOTAIL-LEP) were also searched to identify “proton acceleration” periods during the absence of RHESSI observation. As a result, we identified one neutrino event during the gamma-tagged period from the 2003 Halloween event. The expected rate of background atmospheric neutrinos was estimated to be 0.39 events. Thus, the observed number of neutrinos was consistent with that expected for background atmospheric neutrinos.

We have also made continuous efforts for the XMASS experiment, to detect weakly interacting massive-particle (WIMP) scattering using a liquid Xe detector. We studied features of the PMT after-pulse and its impact on the analysis, as well as the timing calibrations of the PMTs and the scattering and absorption parameters of the scintillation photons in the Xe detector.

These works are collaborations with ICRR, University of Tokyo.
**Cosmic-Ray Interaction-Focused Accelerator Experiment**

High-energy cosmic rays interacting with atmospheric molecules generate child particles resulting in particle clusters called “air showers.” By measuring air showers, high-energy cosmic rays have been studied by some large international collaborations. However, the compilation of observational results is affected by uncertainties in the interaction model. Therefore, we constructed an experiment, called the Large Hadron Collider forward (LHCf), whose results will reduce the interaction model uncertainties. The experiment uses the Large Hadron Collider (LHC) accelerator, where the most energetic particles are artificially generated. LHC was constructed at Conseil Europeen pour la Recherche Nucleaire (CERN) in Switzerland. It is a 14 TeV proton collider, corresponding to $10^{17}$ eV in the laboratory.

LHCf analyzed the data obtained from 2009–2010 experiments at the center of momentum energy of 7 TeV. The photon-energy spectra were published and compared with several model predictions. None of the models perfectly reproduced the data; however, the data were well bracketed in the model variations. The photon and neutral pion spectra for 0.9 TeV and 7 TeV collisions, respectively, were also analyzed and presented at several international workshops. We expect these results to be published in 2012. LHCf also considered the possibility of acquiring data at the LHC proton–Pb collision planned at the end of 2012. This proposal was presented to the LHC committee and approved, based on the importance of the p–Pb collisions required to understand p–air interaction and the feasibility of using an LHCf detector.

Photon energy spectra at 7 TeV proton-proton collisions measured by LHCf at two different emission angles. Experimental results (dots with errors) are compared with some model predictions indicated by lines. The model/data ratio is shown in the bottom.
LHCf continues to upgrade the radiation hard-detectors for the forthcoming high-energy collision at 14 TeV after 2014. One of the two detectors, constructed in 2011, was exposed to the heavy-ion beam at the Heavy-Ion Medical Accelerator in Chiba (HIMAC) to obtain the calibration data for all of the scintillator layers.

The LHCf experiment is conducted in collaboration with the Shibaura Institute of Technology, Waseda University, Kanagawa University, and institutions in the U.S.A., France, Italy, Switzerland, and Spain.

**Wide-Field Telescope Exoplanet Search**

When a dark object passes across the line of sight between a star and an observer, the light from the star is amplified by the gravitational field of the dark object. Under these circumstances, the dark object behaves like a lens. Accordingly, this technique is referred to as the gravitational microlensing method. The gravitational microlensing method is a very effective tool for searching for the Galactic dark matter candidates, such as massive compact halo objects (MACHOs) and extra-solar planets. The probability of finding MACHOs and exoplanets through gravitational microlensing is very low, and only one such detection is expected to occur per year per tens of millions of stellar observations.

To detect gravitational microlensing events effectively, it is most advantageous to observe a dense region of stars, such as the Large Magellanic Cloud, the Small Magellanic Cloud, or the Galactic Bulge, using a large-area CCD camera and a wide-field telescope. We installed a 1.8-m telescope and a large CCD camera with a very wide field of view (2.2 square degrees) in New Zealand and began observations in May 2005. Follow-up observations were performed with a 61-cm telescope.

![Exoplanet Discoveries vs. Snow Line](image)

Mass versus semi-major axis of the detected extra-solar planets. The crosses indicate planets found using the gravitational microlensing method.
In 2011, we detected 485 microlensing events and issued alerts to follow-up groups in real-time. We discovered four planetary systems. We also analyzed OGLE-2009-BLG-266 and found a Neptune-mass planet. Including this planet, 13 planets have been discovered using the microlensing method. From the analysis of MOA-2007-BLG-514, the host star of the lensing system exhibited properties of a possible massive stellar remnant. The mass ratio distribution of binary stars was obtained from analysis of the events between 2007 and 2010.

Members of the research team came from the School of Science of Nagoya University, Kyoto Sangyo University, the Tokyo Metropolitan College of Astronautical Engineering, the Nagano College of Engineering in Japan, the Carter National Observatory, the University of Auckland, Massey University, the University of Canterbury, Victoria University in New Zealand, and University of Notre Dame in the U.S.A.

Past Solar Activity by Radiocarbon Measurements

The intensity of the galactic cosmic rays entering the terrestrial atmosphere is affected by solar activity. Radiocarbon ($^{14}$C) is produced in the upper atmosphere by nuclear reactions initiated by cosmic rays. The half-life of $^{14}$C is 5730 years. Radiocarbon forms carbon dioxide, which circulates throughout the atmosphere, with a portion being transported into the biosphere. By measuring the concentration of $^{14}$C in biological samples, such as tree rings, it is possible to trace variations in cosmic-ray intensity and, consequently, variations in solar activity and space environment near the Earth during the years when $^{14}$C was absorbed by the sample.

We previously measured the concentration of $^{14}$C in tree-ring samples from periods corresponding to grand solar minima, when the solar activity was very weak for several decades to a hundred years. We found that the solar activity varied periodically even during the Maunder Minimum (1645–1715 AD), when sunspots almost disappeared. We found that the cycle lengths of the periodicity (Schwabe and Hale cycles) during the Maunder Minimum were 14 and 28 years, corresponding to the present cycle lengths of 11 and 22 years, and that the polarity of the solar magnetic field reversed alternately every solar cycle during the grand solar minima. In contrast, the cycle lengths in the Spoerer minimum (1416–1534 AD) were 11 and 22 years, as at present.

Radiocarbon concentration data have revealed large peaks for the 7th and 4th centuries BC, indicating grand solar minima. In 2011, we analyzed the variation in $^{14}$C concentration using a buried 300-year-old camphor tree from Kushima, Miyazaki, in southern Japan. We examined the 11-year and 16-year periodicities that occurred during the 4th century BC grand solar minimum, and submitted a scientific paper. Additionally, measurements of the $^{14}$C concentration in the 7th to 11th centuries were obtained from the tree rings of a Japanese cedar from Yaku Island. Cycle lengths of 11 years and 13 years were detected, which may relate to solar activity. We will continue acquiring higher-accuracy measurements. Meanwhile, we discovered a rapid increase in the radiocarbon concentration in the 8th century; discussions are underway to determine the cause.

This research was performed in collaboration with the Center for Chronological Research, Nagoya University.
Verification of the Cosmic Ray-Induced Cloud Formation Hypothesis

Observational data show a correlation between solar activity and global climate. The effect of solar ultraviolet radiation is, in general, considered to be the main mechanism for this correlation. However, a hypothesis has been submitted that atmospheric ions are created by secondary cosmic rays, which are produced by primary galactic cosmic-ray particles entering the Earth’s atmosphere, and that these control cloud formation in the lower troposphere. We conducted a preliminary experiment to test this hypothesis. In 2011, we constructed a full-scale, 75-L stainless steel reaction chamber that allows a flow of natural or synthetic air, to study ion production and aerosol-particle formation in the presence of variable air constituents, such as ozone and sulfur dioxide. A radiation source was substituted for cosmic-ray simulation.

This research was performed in collaboration with Japan Agency for Marine-Earth Science and Technology (JAMSTEC).

Gamma-Ray Observations of Cosmic-Ray Accelerators

Gamma-ray observations are considered to play a key role in the investigation of the origin of cosmic rays because the gamma rays are emitted by interactions of the cosmic-ray protons with the interstellar medium. Since its launch in 2008, the Fermi Gamma-ray Space Telescope has been instrumental in uncovering the nature of supernova remnants (SNRs), which are the prime candidates for cosmic-ray accelerators. In 2011, we observed two supernova remnants emitting TeV-gamma rays, RX J1713.7-3946 and RX J0852.0-4622. In RX J1713.7-3946, we observed a spectrum that was consistent with the gamma rays emitted by Compton up-scattering of electrons. In contrast, the gamma-ray spectrum from RX J0852.0-4622 was consistent with gamma rays emitted by the decay of $\pi^0$ mesons produced by the interactions of cosmic-ray nucleons with the interstellar medium. Conclusive results are still pending as we continue to collect statistics on the spectra to date.

The Fermi telescope is also sensitive to gamma rays produced by the annihilation of WIMP dark matter. Dwarf spheroidal galaxies provide a good environment to search for WIMPs, because they have a high concentration of dark matter compared with baryonic matter, which results in a low gamma-ray background. Studies of ten dwarf spheroidal galaxies yielded no significant gamma-ray signals from the WIMP annihilations, excluding the WIMP dark matter below 20 GeV/$c^2$, assuming the thermal-relic dark-matter hypothesis.

In addition analyzing existing Fermi gamma-ray data, we are also developing future gamma-ray instruments. We are the lead institution for the development of the Soft Gamma-ray Detector (SGD) onboard the International X-ray Astronomy Mission (ASTRO-H) to be launched by JAXA in 2014. We are now starting production of the SGD flight hardware. We are also collaborating with the SLAC National Accelerator Laboratory to develop custom-integrated circuits for the Cherenkov Telescope Array (CTA). Additionally, we intend to replace the conventional PMTs with silicon photosensors to improve the photon detection efficiency. Preliminary measurements indicate that the photon detection efficiency should be improved two-fold using silicon photosensors. The SGD and CTA cover the 40–600 keV and 0.01–100 TeV energy ranges, respectively, while Fermi covers 0.02–300 GeV.
INTEGRATED STUDIES

The Integrated Studies Division aims at tracing the flow of energy from the solar surface into the Earth’s upper atmosphere and its transformation on the way. The primary method of this research is to analyze data obtained from various points in the solar terrestrial environment. Data analysis of coupled Sun-Earth systems, such as solar flares, interplanetary disturbances, boundary processes, plasma convection, magnetic storms, substorms, radiation belts, and auroras, is complemented by computer simulations and modeling to improve the level of understanding. This is the purpose of the Geospace Environment Modeling System for Integrated Studies (GEMSIS). GEMSIS is developing functions for the science center of the Hinode satellite, as well as the Geospace project ERG, including the event list, the meta-data format such as the common data format (CDF), and integrated analysis tools.

GEMSIS-Sun – The goal of the GEMSIS-Sun group in GEMSIS phase 2 is “to understand systematically the processes related to solar flares, i.e., their energy storage, trigger, energy release, and particle acceleration.” To realize this goal, realistic solar flare models are currently being developed and compared with observational results, with large solar flares being of particular interest. This group is also responsible for the construction of the Hinode science database and its maintenance.

GEMSIS-Magnetosphere – The GEMSIS-Magnetosphere group developed the ERG science-center function at STEL. It is responsible for the concept design for the integrated data-analysis tools and a related database for effective research with various types of data, including those obtained from satellite observations, ground-based observations, and numerical simulations and models. In cooperation with ground-based network observation teams and the Inter-university Upper Atmosphere Global Observation Network (IUGONET) project, this group designed CDF files for magnetometer data and HF radar data. Plug-in software was created by this group for ease of use with the THEMIS Data Analysis Suites (TDAS). In the interest of worldwide collaboration on the THEMIS project, the group released the developed database and software to the science community.

GEMSIS-Ionosphere – The GEMSIS-Ionosphere group developed a means of calculating electric potentials and currents in the ionosphere from the Region-1 and -2 field-aligned currents and an ionospheric conductivity model. The group discovered that overshielding occurred at low latitudes, while the convection electric field was dominant at particular latitudes. During the negative sudden impulse (SI) event, the eastward ionospheric flow moved poleward periodically, based on SuperDARN observations. This group also found that overshielding occurred at the onset of substorms, and that the diffuse and broadband electrons intensified at the same time, as observed by ground magnetometers and satellites, respectively.

GEMSIS-Sun

(1) Comparison between particle acceleration modeling and multi-wavelength observations in a solar flare

The results of the particle acceleration model with Coulomb collision clearly showed that the height distribution of accelerated electrons depended on their energy (Minoshima et al., 2011).
This was attributed to the balance of the time-scales for the following three processes: Coulomb collision, bounce motion in the loop, and loop shrinkage. If this model is correct, then the 34 GHz looptop source should be located at a lower altitude than that of the corresponding 17 GHz source. However, we observed that the 34 GHz looptop source was located at a higher altitude in a solar flare than that of the 17 GHz source during the entire period of the flare. Also, the height difference reached a maximum at the flare peak time. This discrepancy suggests that there is another collisional process not included in the current model; this was confirmed by measurements of the 17 and 34 GHz decay-time scales.

(2) Solar flare research with high-speed imaging observations in visible lights

A new imaging system for observing solar flares was developed and installed on the Solar Magnetic Activity Research Telescope (SMART) at the Hida Observatory of Kyoto University as the joint research program with STEL. The system will be used to diagnose non-thermal particles, their acceleration site, and the trigger of flares by capturing the rapid temporal and spatial evolution of flare kernels observed in the solar chromosphere and photosphere at the onset of flares. The system simultaneously takes H-alpha and continuum images at a rate of 25 frames per second. The first-light images were taken in August 2011. Two white light flares were successfully observed on September 6 and 7, 2011.

(3) Hinode solar flare database

We are developing a complete flare catalogue including all solar flares that were observed with XRT/SOT/EIS on board Hinode. In 2011, the information of solar flares observed with Nobeyama Radio Heliograph was added. Soft X-ray, Ca II, and EUV images observed with Hinode and soft X-ray light curves observed with GOES are provided for each flare in the catalogue. The URL for this project is http://st4a.stelab.nagoya-u.ac.jp/hinode_flare/

(4) Database of non-linear force free fields calculated from Hinode magnetic field data

GEMSIS-Sun prepares database of non-linear force free fields (NLFFFs) of solar active regions. Three-dimensional structures of coronal magnetic fields are very important for understanding solar active phenomena (e.g., solar flares). It is, however, very difficult to observe coronal magnetic fields at present. Among the scientific subjects targeted in this

White-light flare (brightening in the boxed area) observed on 6 September 2011.
database are the solar flare trigger mechanism, the storage and release processes of magnetic field energy, and coronal mass ejections.

NLFFFs are calculated from high-quality vector magnetograms obtained by the solar optical telescope of Hinode. Over the course of this year, we studied the “preprocess” of vector magnetograms to obtain a more appropriate bottom boundary condition for the NLFFFs, in which the Lorentz force \((j \times B)\) was assumed to be zero. Using this technique, we reduced the area-integrated value of the Lorentz force at the bottom boundary to \(10^{-5}\) of the initial value.

(5) Study on the trigger mechanism of solar flares

Although the prediction of solar flares is an important issue for space-weather forecasting, the mechanism responsible for triggering solar flares is poorly understood, and the predictability is still largely limited. To overcome this problem, we recently performed systematic numerical simulations, in which more than 200 different magnetic-field configurations were examined to determine whether or not they were capable of triggering solar flares. As a result, we determined that solar flares can be triggered by the two different types of small magnetic fluxes, which have a magnetic component either opposite to the large-scale potential magnetic field or reversed to the magnetic shear. The simulations clearly indicated that magnetic reconnection between the small flux of those configurations and that of the pre-existing magnetic field can lead to large-scale eruption of a twisted magnetic flux and the intensive magnetic reconnection that causes the formation of flare loops. Additionally, we analyzed the magnetic configurations of four different active regions, in which major flares larger than the GOES-M5-class were observed by Hinode/SOT, and confirmed that all of the flares occurred under conditions that were consistent with the simulation results. The comparative study between simulations and observations suggested that the deterministic prediction of solar flares is possible with sophisticated analysis of the solar magnetic field.

(6) Theoretical study of coronal mass ejection morphology

ICMEs are often observed to travel much faster than the ambient solar wind. If the relative speed between the two exceeds the fast magnetosonic velocity, then a shock wave will form. The Mach number and the shock standoff distance ahead of the ICME leading edge is measured to infer the vertical size of an ICME in a direction perpendicular to the solar wind flow. We analyzed the shock standoff distance for 45 events that varied between 0.5 AU and 5.5 AU to infer their physical dimensions. We determined that the average ratio of the inferred vertical size to the measured radial width (i.e., the aspect ratio) of an ICME is \(2.8 \pm 0.5\). We compared these results to the geometrical predictions that forecasted an aspect ratio between 3 and 6. The geometrical solution varied with heliocentric distance and appeared to provide a theoretical maximum for the aspect ratio of the ICMEs. The minimum aspect ratio remained relatively constant at 1 (i.e., a circular cross-section) for all distances. These results suggest that possible distortions to the leading edge of the ICMEs occur frequently. However, these results may also indicate that the constants calculated in the empirical relationship to correlate the different shock fronts need to be modified, or perhaps both distortion considerations and a change in the empirical formulae are required.
(7) Area asymmetry of bipolar magnetic regions

We quantitatively defined the area asymmetry of bipolar magnetic fields in the photosphere of solar active regions. We selected 138 bipolar regions from magnetograms observed by the Michelson Doppler Imager (MDI) from April 23, 1996 to September 2, 2001. These regions were located in the southern hemisphere and around the solar meridian. We found that in 37% (51/138) of our events, the preceding polarity regions exhibited larger areas than the subsequent polarity regions. The average ratio of the areas (area of the subsequent polarity region/area to the preceding polarity region) was about 1.1, with a distribution between 0.5 and 2.5. Our results quantitatively confirmed our impression that in many bipolar regions, the areas of the preceding polarities were smaller than those of subsequent polarities.

(8) Hinode Science Center Project

The Hinode satellite, a state-of-the-art solar observatory in space, has made a significant contribution to the field of solar physics since its launch in September 2006. STEL initiated the new Hinode Science Center Project, in cooperation with the National Astronomical Observatory of Japan. This center was established to extend the interdisciplinary collaboration of solar physics and geospace sciences with Hinode’s data. The Hinode Science Centers at STEL are responsible for building and maintaining a secure data-center system that networks with all of Hinode’s data and the Hinode Science Center in the National Astronomical Observatory of Japan at Mitaka, Tokyo. The analyzing environments are duplicated at the two science centers.

GEMSIS-Magnetosphere

(1) Relationship between substorm-associated processes in the magnetotail and plasma sheet structure

Magnetic reconnection and dipolarization occur in the plasma sheet of the near-Earth magnetotail at the onset of a substorm expansion, and are thought to play a crucial role in substorm triggering. The key to understanding the triggering mechanism and causal relationships between these processes is determining in which structure of the plasma sheet these processes occur. To this end, we first studied the average structure of the plasma sheet using Geotail data. The statistics revealed that the characteristics of the plasma sheet, such as the values and gradients of the ion number density, temperature, pressure, flux, and magnetic field, distinctly change at a radial distance of ~10 to 12 \( R_E \). The magnetic configuration indicated that the earthward side corresponds to a transition area between dipole-like and taillike regions (the inner plasma sheet), while the tailward side corresponds to a taillike region (the outer plasma sheet). Taking into account these results, we then determined the locations of the substorm processes for events observed by the Geotail and THEMIS spacecraft. Our investigation revealed that magnetic reconnection occurs in the outer plasma sheet, while dipolarization is initiated in the inner plasma sheet. Based on these results, we discussed essential issues concerning the substorm triggering and development mechanisms, such as the behavior of fast earthward flows generated by magnetic reconnection and the expansion of the dipolarization region.
Example of an ultra-low frequency (ULF) simulation based on the GEMSIS ring-current (RC) model. The left panel shows the three-dimensional (3D) distribution of the bulk velocity (arrows and white lines) and the plasma pressure (colored region). The right panel shows the electron distribution in the equatorial plane; in this case, the electrons were launched from the initial \( L = 5 \) location and underwent drift-resonance with an ULF wave, with a period of 300 s and \( m = 2 \).

(2) Study of global distribution of ULF waves in the inner magnetosphere based on the GEMSIS-RC model

To understand the dynamics of the inner magnetosphere during the geospace storms, the GEMSIS-Magnetosphere team developed a new physics-based model for the global dynamics of the ring current (GEMSIS-RC model). Coupled with the Maxwell equations, the GEMSIS-RC model is a self-consistent, kinetic, numerical simulation code for solving the five-dimensional collisionless drift-kinetic equation for ring-current (RC) ions in the inner magnetosphere. We applied the GEMSIS-RC model to the simulation of the global distribution of ultra-low frequency (ULF) waves to test its capability of describing fast time-scale phenomena. Two cases, without and with plasmapause, were compared in the simulation domain. The results showed that the existence of plasmapause strengthened the ULFs outside the plasmapause and widened the magnetic local time (MLT) region where the \( E_r \) (toroidal) component was excited by the given \( E_\phi \) (poloidal) component. The comparison between runs with and without RC ions showed that the existence of the hot RC ions deformed and amplified the original sinusoidal waveforms. The GEMSIS-RC model was able to reproduce the rapid radial transport of relativistic electrons by drift resonance, with a drift period of 600 s, as theoretically expected.

(3) Fine structure of the energy spectrum associated with a pulsating aurora

We studied the fine structure of the energy spectrum associated with a pulsating aurora event, using Reimei data. We found that continuous precipitation at 1 keV almost always occurred during the pulsating aurora event. We conducted a simulation study on the chorus wave-particle interactions, considering the lower- and upper-band chorus frequency structures. Lower-band chorus waves consisted of the rising tone elements, with repeat periods of a few hundred ms, while the upper-band chorus waves exhibited a continuous structure. As a result, we successfully reproduced the precipitation of keV electrons that caused the pulsating aurora. The keV-electron precipitation had internal modulations, with periods of a few hundred ms.
In contrast, the stable precipitation at 1 keV was due to the upper-band chorus waves. The results indicated that typical chorus-frequency structures can produce the observed pulsating aurora, suggesting that chorus waves may be their primary source.

**GEMSIS-Ionosphere**

(1) Two satellite observations of precipitating electrons associated with auroral breakup

We compared auroral electrons several minutes before and after an auroral breakup. FAST passed the breakup location 6 min before the breakup and observed diffuse 10-keV electrons. The diffuse electrons were accompanied by broadband electrons below 1 keV, which were attributed to Alfvén waves. Seven minutes after the breakup, a Defense Meteorological Satellite Program (DMSP) satellite crossed the onset arc. The DMSP satellite observed inverted-V type electrons at the surge horn, which were 15° west of the initial breakup location. These results suggest that the evolution of diffuse electrons to inverted-V electrons is associated with waves.

(2) Ionospheric electric-field pattern controlled by field aligned currents deduced by a global ionospheric potential solver

Using the global ionospheric potential solver GEMSIS-POT, we investigated how the ionospheric electric field changed from an undershielding condition to an overshielding condition as the field aligned current (FAC) distribution changed. Calculations were
performed by changing $I_{R2}/I_{R1}$, the ratio of current intensities of region 2 (R2) and region 1 (R1) FACs, and by moving the R2-FAC relative to the fixed R1-FAC. The results are summarized as follows. (1) With increasing $\delta L_{T_{R2-R1}}$ (the local time difference between the R1 and R2-FAC peaks), the efficiency of the shielding by the R2-FAC increased but the associated potential skewed to the nightside. (2) The turning point at which the ionosphere transitioned from undershielding to overshielding varied between an $I_{R2}/I_{R1}$ ratio of 0.7–0.8. (3) With increasing $\delta L_{T_{R2-R1}}$, the shielding effect weakened around noon, where the R1-potential intruded on the low-latitude region; however, the R2-potential remained dominant at the other local times. These results suggest that the actual ionosphere cannot be unambiguously classified as either undershielding or overshielding. To describe the ionospheric condition more accurately, we suggest the use of new classification terms, i.e., “complete overshielding” and “incomplete overshielding.” Here, we define complete overshielding as the situation in which the overall ionosphere on the equatorial side of the auroral region is dominated by the R2-electric field, which is the same as the original and strict definition of overshielding. Incomplete overshielding refers to the situation in which the ionosphere is locally but not globally dominated by the R2-electric field. We suggest that overshielding or undershielding identification should be based not only on observations from a limited local time sector, but from the ionosphere as a whole.

(3) Variation of ionospheric plasma convection associated with a negative SI

Spatial–temporal evolution of ionospheric plasma convection, associated with a negative sudden impulse (SI) signature on ground magnetograms, has been examined in detail using SuperDARN HF radar, magnetometers, and satellite observations over the ground measurements. We recently discovered that transient eastward flows in the ionosphere shifted poleward in the sub-auroral region with finite latitudinal widths of several degrees. These results were quantitatively consistent with the poleward propagations of geomagnetic variations, observed directly under ionospheric flows. The fact that the poleward-shifting eastward flow was observed repeatedly with decreasing speed implied that a sudden expansion of the magnetosphere, inducing an SI signature on the ground, produced global-damping oscillation of the magnetosphere with a rapidly decreasing amplitude. As a result, the electric field and current generated in the ionosphere due to the magnetospheric oscillation was interpreted by the radar and ground magnetometers as a magnetosphere–ionosphere-coupling process.

(4) Equatorial counterelectrojet developed at the onset of the substorm

It has been well recognized that substorms are initiated by the formation of a current wedge between the plasma sheet and the ionosphere. However, by analyzing isolated substorms with magnetometer-array data and SuperDARN convection maps, we deduced that the overshielding electric field and currents develop at the subauroral-to-equatorial latitudes at the onset of substorms, a few minutes earlier than the formation of the substorm current wedge. The results indicated that both R1- and R2-FACs were generated; however, the R2-FACs were strong enough to produce a reverse current at the subauroral latitude and a counterelectrojet (CEJ) at the dayside equator. Thus, we can conclude that the substorms begin with the intensification of the R2-FACs CEJ in the inner magnetosphere.
Simulation Studies

(1) Particle simulations of perpendicular collisionless shocks

A full particle simulation study was carried out to study microinstabilities generated in self-consistently excited perpendicular collisionless shocks. The 2D simulation with a high ion-to-electron mass ratio showed that the modified two-stream instability could be generated by the interaction of incoming and reflected ions with electromagnetic whistler-mode waves propagating in a direction quasi-perpendicular to the ambient magnetic field. The properties of the excited whistler-mode waves were consistent with a linear dispersion analysis based on the simulated velocity distribution functions. We also found that the excited waves had an electron-scale wavelength in the shock-normal direction and an ion-scale wavelength in the shock-tangential direction. This suggests that the electron-scale microturbulence and the ion-scale shock structures are coupled to each other by a modified two-stream instability.

(2) Dissipation of the Poynting flux in the pulsar wind

Pulsar winds are thought to be strongly magnetized, highly relativistic winds that emanate from rotating neutron stars. In contrast, observations of nebulae suggest that pulsar winds are weakly magnetized winds at the termination shock. This problem, known as the sigma problem, has been a long-standing unresolved issue of pulsar physics and may have some relevance to general-relativistic astrophysics problems. Using a newly developed, one-dimensional, relativistic two-fluid code for plasma pairs, we investigated the relativistic pulsar-wind termination shock that interacts with a pulsar wave emitted from an obliquely rotating pulsar. The pulsar wave was modeled as a circularly polarized, sinusoidal, magnetic shear wave, which is a stationary structure (in entropy mode) as measured in the fluid rest frame. In a realistic parameter regime, the pulsar-rotation frequency can be so high that it is greater than the local proper plasma frequency at the termination shock. In this case, we determined that the upstream wave was converted into electromagnetic waves of very large amplitude. The subsequent decay of these electromagnetic waves led to the dissipation of the incoming Poynting flux. We feel that this dissipation process provides a plausible solution to the sigma problem.

(3) Three-dimensional magnetohydrodynamic simulation of super magnetic storms

We succeeded in executing a global three-dimensional magnetohydrodynamic (3D MHD) simulation of super-magnetic storms for pure southward or northward IMF orientation, when the solar wind and IMF occur under extreme conditions (e.g., density of 200 cc$^{-1}$, velocity of 2000 km s$^{-1}$, and an IMF of 200 nT). Bow shock, magnetopause, and the near-Earth neutral line excite the formation of strong vortices. These intermittently occurring vortices produced during magnetopause and magnetic reconnection create a turbulent structure in the plasma sheet. The characteristic features for extreme conditions are well understood in comparison with the simulation results for intermediate and normal conditions. The position of the bow shock, stagnation distance, and near-Earth neutral line was 4.5 $R_e$, 3.0 $R_e$, and $-2.5 R_e$, respectively. A very large vortex train formed in the flank magnetopause, resulting in streamer-like turbulence in the plasma sheet.
2. Geospace Research Center

“Geospace” refers to the solar-terrestrial environment, which begins with the Earth and extends outward to encompass the Earth’s atmosphere and the Sun. Geospace is very dynamic, as it receives energetic particles and electromagnetic emissions from the Sun. In geospace studies, it is essential to treat the Sun, the Earth, and the space between them as a single entity. The Geospace Research Center was established in April 2004 by combining the Center for Joint Observations with Data Processing and Observatories. The purpose of the Geospace Research Center is to coordinate and promote joint research projects on dynamic processes in geospace, including studies of energy flow and transformations of the solar–terrestrial system. The Center consists of a Management Section, a Research Projects Section, four observatories, and two stations.

The Center coordinates regular research projects and databases in the field of solar-terrestrial science. A system for constructing STE databases was developed in cooperation with three Center projects. We constantly evaluate and investigate the network database system to conform to the latest trends in flexible data access.

(1) Database production

In the 2010 fiscal year, 12 database-production collaborations were approved and carried out. The Super Dual Auroral Radar Network (SuperDARN) database, part of the global HF radar network project, was compiled at the Solar-Terrestrial Environment Laboratory. This database is open to the Japanese SuperDARN community, which consists of scientists who have registered with the Japanese SuperDARN joint research program led by the National Institute of Polar Research. The data are distributed from the University of Saskatchewan in Canada in the form of a portable HDD. SuperDARN data use is in accordance with the SuperDARN PI agreement.

(2) Computational joint research programs

Computational joint research projects were successfully performed through the use of the Fujitsu FX1, HX600, and M9000 supercomputer systems at the Information Technology Center, Nagoya University. A total of 23 groups used the supercomputer for simulations/modeling of the solar-terrestrial environment, as well as for other scientific calculations. Also, a new DELL PowerEdge R815 supercomputer system at STEL has started operations. Large-scale kinetic simulations such as full particle simulations of collisionless shocks and Vlasov simulation of unmagnetized astrophysical objects are performed using this system.

(3) Symposia/workshops

On September 15–16, 2011, the Workshop on Solar, Terrestrial, and Planetary (STP) Simulation Techniques was held at Kyushu University. Thirteen presentations were given on implicit numerical schemes for plasma electromagnetic fluid simulations and hybrid particle-in-cell simulations. Also, on March 1–3, 2012, the Workshop on Solar-Terrestrial Environment (STE) simulation was held at Hiroshima University. Seven invited talks were given on global kinetic simulations of the magnetosphere, fusion plasmas, astrophysical shocks, and
numerical schemes for computational fluid dynamics (CFD). Eight oral presentations were given on the magnetosphere, the ionosphere, plasma waves in the inner magnetosphere, collisionless shocks, magnetic reconnection, and Vlasov simulation techniques.

(4) Inter-university Upper atmosphere Global Observation NETwork (IUGONET) project

The Inter-university Upper atmosphere Global Observation NETwork (IUGONET) is a six-year (2009–2014) research project supported by the Special Educational Research Budget (Research Promotion) from the Ministry of Education, Culture, Sports, Science, and Technology (MEXT), Japan. Five Japanese universities/institutes, National Institute of Polar Research (NIPR), Tohoku University, Nagoya University, Kyoto University, and Kyushu University, collaborate to extend our own ground-based observation network for the upper atmosphere and to build the virtual information center of upper atmospheric science by connecting the IUGONET universities/institutes with the multi-point information exchange system. We also develop and share a metadata database (MDB) of our observational data to facilitate distribution of the observational data that we have accumulated for decades, leading to more intense collaborations in research.

STEL plays an active role in carrying out the IUGONET project by organizing the project-promotion group consisting of the staff of the Geospace Research Center and the project steering committee, joined by representatives from the research groups in the laboratory. In collaboration with other IUGONET universities/institutes, we hold regular on-line meetings utilizing the video conference system and web meeting system installed by this project. These meetings are held to discuss project promotion and the development of our database system. In FY 2011, we continued to collect metadata from our original data based on the IUGONET metadata format. We also developed official-release versions of the MDB system and the data analysis/visualization software common to the IUGONET universities/institutes, called iUgonet Data Analysis Software (UDAS). The collected metadata were archived in the MDB system. The official release of the MDB and the UDAS is planned to begin early in the next fiscal year. All these achievements and resources have been made available to the public on the IUGONET website (http://www.iugonet.org).

Projects

The Geospace Research Center has completed the following four special research projects in cooperation with research groups in the laboratory and with domestic and overseas co-researchers.

Project 1: Study of the Evolution of Three-Dimensional Heliospheric Structure and Particle Acceleration in the Peculiar Solar Activity Cycle

Solar cycle 24 has some characteristics that differ from earlier cycles, such as the very infrequent occurrence of sunspots, the weak polar magnetic field, and the reduction in the dynamic pressure of the polar fast solar winds. In Project 1, we aim to characterize the evolution of the 3-dimensional heliospheric structure in this peculiar cycle, in collaboration with Japanese and foreign researchers. We also intend to describe particle acceleration from heliospheric observations in this cycle. During this year, we addressed the following subjects:
(1) Survey of the interplanetary magnetic field structures using cosmic-ray modulation observations

Cosmic-ray modulation observations are useful for studying the IMF structure. We established the Global Muon Detector Network (GMDN), which includes Nagoya, Hobert (Australia), Sao Martinho (Brazil), and Kuwait City, in collaboration with Professor K. Munakata’s group at Shinshu University. To reveal the precise nature of the large-scale IMF structure with such a global observation network, cosmic rays emanating from all directions in the full sky must be measured continuously. However, there is an observation gap over the region between North America and the Southwest Indian Ocean. To fill this gap in the GMDN coverage, we have developed a new detector for muon cosmic-ray observations in Mexico. Muon-detection circuits will be attached to the solar neutron telescope “SciCR”, which will operate at Mt. Sierra Negra (4600 m above sea level) in Mexico. In 2011, we transferred the muon detection circuits to Mexico, and assembled them. The work to connect wavelength-shifting fibers to plastic scintillator bars is currently underway. We expect to start muon cosmic-ray observations in Mexico next year. We began preliminary observations of muon cosmic rays at Mt. Sierra Negra using a miniature detector.

We also conducted a study of cosmic-ray intensity variations and CMEs using the muon detectors of the GRAPES-3 air shower experiment at Ooty, India, in collaboration with Professor H. Kojima (Aichi Institute of Technology) and Professor Y. Hayashi (Osaka City University). This muon detector has a huge area (560 m² at present and 980 m² in the future), enabling us to determine muon intensity distribution at high angular resolution. In 2011, we studied the following: (1) the relationship between cosmic ray intensity and solar wind speed, (2) the spatial distribution of the Forbush decrease and its temporal evolution, and (3) the shadows of the Sun and Moon.

(2) Study of the 3D solar wind structure using the multi-station IPS system

Interplanetary scintillation (IPS) observations have been made over a long time period at STEL using a multi-station system composed of four large antennas at Toyokawa, Fuji, Kiso, and Sugadaira. These observations have been used to reveal the evolution of the 3D solar wind structure. We need to improve antenna sensitivity to achieve advanced spatial resolution for IPS observations. Recently, the IPS antenna at Toyokawa was upgraded with a more sensitive system called the Solar Wind Imaging Facility, Toyokawa (SWIFT), and IPS observations with SWIFT have been carried out on a daily basis since 2008. In 2010, we upgraded the observation systems at Fuji and Kiso to collect IPS data simultaneously with the SWIFT. Using the upgraded systems, we performed simultaneous IPS observations at Fuji, Kiso, and Toyokawa between April and November 2011, and derived solar wind speeds from the IPS data. We are performing work to restore the drive system of the Kiso antenna.

(3) Exploring 3D properties of the heliosphere with an international collaboration of space-borne and IPS observations

We collaborated with the UCSD group on the study of 3-D reconstructions of the solar wind using computer tomography. We invited Dr. B. V. Jackson of UCSD to STEL as a visiting professor during March–May 2011. We performed a collaborative analysis of IPS and Solar Mass Ejection Imager (SMEI) observations to examine the relationship between loop-shaped
density enhancements and magnetic flux ropes. We also made a collaborative study of the jet phenomenon using Hinode and IPS observations. In June 2011, we conducted campaign observations of the jet phenomenon using Hinode, SMEI, and the STEL-IPS system.

**Project 2: Coupling Processes of Space Plasma and Charged/Neutral Atmosphere based on Global Ground and Satellite Observations**

This project aims to elucidate the coupling processes of space plasma and the charged/neutral atmosphere in the geospace region by coordinating new global experiments from ground network instruments and satellites. Using the advantage of ground experiments for long-term measurements, we also investigate the effects of the solar 11-year activity cycle on the Earth’s atmosphere.

(1) Aurora and airglow measurements in the Canadian arctic

Two all-sky cooled charged-coupled device (CCD) imagers, a filter-tilting meridian-scanning proton aurora-photometer, and an induction magnetometer have been continuously operated at Resolute Bay (74.7°N, 265.1°E) and Athabasca (54.7°N, 246.7°E), Canada, since 2005. High-time resolution auroral and VLF/ELF observations were carried out in February 2012 at Athabasca and Fort Vermillion. This enabled us to study the polar cap patches, VLF/ELF waves in the inner magnetosphere, and proton auroras associated with the Pc1 geomagnetic pulsations. These data are available at the following website: http://stdb2.stelab.nagoya-u.ac.jp/canada/index.html.

(2) Satellite mission ERG planning

Project 2 supports the Energization and Radiation in Geospace (ERG) satellite mission to investigate the dynamics and particle acceleration of the inner magnetosphere. The ERG mission is the first candidate of the second ISAS small-satellite mission. In 2011, we continued developing the ERG-associated ground network measurements and related database in collaboration with Project 4. A domestic ERG conference was held in March 5–6, 2012, in the Tohoku University.

(3) SuperDARN Radar in Hokkaido

Routine observations of the ionosphere, thermosphere, and mesosphere by the SuperDARN HF radar in Hokkaido were continued in fiscal year 2011. This year, efforts focused on the echo disappearance associated with solar-flare events, showing that the rapid Doppler velocity observed at the disappearance was caused by plasma-density enhancement in the D-region, rather than by that in the F-region. Analysis was also performed on dispersive ionospheric waves propagating with velocities of $3.5-6.2$ km s$^{-1}$ for $\sim$10–20 min after the 2011 Tohoku Earthquake.

(4) Sodium LIDAR observations of the mesosphere and lower thermosphere

To measure mesospheric temperatures and winds at the EISCAT Tromsø site, a high-power sodium-LIDAR system was installed in 2009. In 2011, routine lidar measurements were started for (1) collaborative measurements with the EISCAT radar for ion and neutral
temperatures, (2) measurements of atmospheric waves with periods of 4–10 hours, and (3) measurements of the sporadic sodium layer. The first five-beam measurements were also carried out in 2011.

(5) Leading activities for the CAWSES-II Task Group 4 (TG4)

The international project “Climate And Weather of the Su–Earth System-II (CAWSES-II)” has been carried out under the Scientific Committee On Solar-Terrestrial Physics (SCOSTEP) for 2009–2013. The Task Group 4 (TG4) activity, “What is the geospace response to various inputs from the lower atmosphere,” of CAWSES-II is strongly related to Project 2. In 2011, Project 2 members took leadership roles in carrying out TG4 activities by issuing TG4 newsletters (three times), keeping TG4 mailing lists for more than 200 international scientists, and organizing the TG4 workshops at the Committee on Space Research (COSPAR) meeting in Australia (July 2011), the International Symposium on Equatorial Aeronomy (ISEA)-13 in Peru (March 2012), and the international Climate and Weather of the Sun–Earth System (CAWSES)-II/International Space Weather Initiative (ISWI) session at the Japan Geoscience Union (JPGU) meeting (May 2011).

(6) Development of a new receiver of EISCAT radar

We have developed a new high-resolution receiver for the EISCAT radar to obtain ionospheric parameters. The receiver was tested during October 2011 at the EISCAT Tromsø site, on a meteor-ionized atmosphere.

**Project 3: Effect of Solar Activity on the Global Environment**

Solar activity influences the global environment in various ways. We intend to verify the effect of variations in solar activity on the global environment from the past to the present, clarifying their elementary processes. We will continue to develop this project in the second Midterm Plan (which began in 2010) as well as in the first plan.

We will elucidate variation in solar activity in the past by measuring radioisotopes to understand long-term solar variation over several decades. To clarify the mechanism of solar activity influence on the global environment, we will observe the variations occurring in the present atmosphere with infrared radiation and millimeter-wave radiometers. We will investigate their elementary processes in laboratory experiments using laser systems. Additionally, we have begun a study to investigate the possible relationship between atmospheric ionization due to cosmic rays (which are affected by solar activity) and cloud formation and, therefore, the global climate.

We conducted research on the topics described below to investigate how solar activity affects Earth’s environment: (1) Past solar activity and its influence on Earth’s climate, (2) Influence of solar activity on atmospheric minor constituents, (3) Elementary processes of atmospheric reaction by solar activity in the global environment, and (4) Verification of cloud formation by cosmic rays. In addition, the Second International Nagoya Workshop on the relationship between solar activity and climate change was held at Nagoya University in January 2012.
(1) Past solar activity and its influence on the Earth’s climate

Radiocarbon ($^{14}$C) is produced in the upper atmosphere by nuclear reactions initiated by galactic cosmic rays. Variations in past cosmic ray intensity and solar activity can be studied by measuring concentrations of atmospheric radiocarbon produced by galactic cosmic rays under the influence of solar activity. To study past solar activity periodicities, we measured radiocarbon concentrations in annual tree rings, at a high degree of accuracy, from periods of solar activity minima, such as the Maunder Minimum and the Spoerer Minimum, and also from periods of normal solar activity. To date, we have found that the periodicity in the Maunder Minimum was 14 years rather than the current 11 years. We aim to investigate the periodicity of the solar activity through the past three thousand years. The measurements were performed with accelerator mass spectrometers (AMS) at Nagoya University.

In 2011, we analyzed the results of radiocarbon concentration measurements on a camphor tree from Kushima, Miyazaki, in southern Japan. The tree was estimated to be buried in the 4th century BC, which is considered to be a time when one of the solar grand minima occurred. Detailed analysis of the 4th century BC samples confirmed a $3\sigma$ statistical significance for a solar cycle periodicity of 16 years, which is longer than the 11 years observed at the present time, and even longer than the Maunder Minimum results. An understanding of the mechanisms behind the longer periodicities in solar grand minima is needed. We also measured radiocarbon concentration in tree rings from the 7th century BC, which may have been a characteristic period of solar activity, and will continue the measurements to examine variations in solar-cycle periodicity. Additionally, we measured radiocarbon concentrations from the 7th to 11th centuries AD, and found a period of 13 years around a small solar activity minimum, indicating that the elongation of the Schwabe-cycle period is common in some types of solar activity minima. We discovered a sharp increase in the radiocarbon concentration in the 8th century. The cause of this variation in concentration is currently under investigation.

Another measurement of beryllium 7 was conducted in several stations around the world in collaboration with Yamagata University to trace how cosmogenic nuclides behave in atmosphere and how they respond to the current variation in solar activity. An air sampler was set at high altitude on Mt. Chacaltaya, Bolivia, in the southern hemisphere, and successive measurements continue with cooperation of the local institution. An observatory in Iceland, which is at high latitudes in the northern hemisphere, was renewed, and thus a network is forming. The sun is getting active and these measurements will be continued.

(2) Influence of solar activity on atmospheric minor constituents

This sub-theme focuses on the study of the influence of solar activity on the atmospheric composition change based on monitoring observations of millimeter-wave and infrared molecular spectral lines. We also work on developing and improving the observational instruments used to carry out these monitoring observations.

Continuous measurements of ozone, chlorine monoxide (ClO), and other minor constituents using millimeter-wave spectral radiometers operated in the Atacama Highlands, Chile ($23^\circ$S, $68^\circ$W, 4800 m above sea level), and Rio Gallegos, Argentina ($52^\circ$S, $69^\circ$W, 40 m above sea level), have been carried out. The observed data are the fundamental dataset for studying
long-term and annual variations in atmospheric compositions in the middle atmosphere. The ClO vertical distribution and its temporal variation were analyzed based on the millimeter-wave data obtained in the Atacama Highlands. The diurnal variation in ClO in the upper stratosphere was derived for the first time from ground-based observations. These data were compared with and validated by those measured by the Aura/Microwave Limb Sounder (MLS) and the Japanese Experiment Module/Superconducting Submillimeter-Wave Limb-Emission Sounder (JEM/SMILES) onboard the International Space Station (ISS).

To study the ion–molecule chemistry caused by energetic particle precipitation and its influence on the chemical composition of the middle atmosphere in the polar region, we installed a newly developed, power-saving, superconductive millimeter-wave spectral radiometer at Syowa Station in Antarctica in January 2011, for continuous observation of ozone, NO, and NO₂. During the January 2012 when a solar proton event with a flux of 6300 pfu for >10 MeV occurred, we detected enhanced NO emission with a peak intensity of 60 mK, suggesting an enhancement of NO distribution at the altitude above 60 km.

We have measured absorption spectra of stratospheric and tropospheric minor constituents such as ozone and carbon monoxide (CO) continuously using a high-resolution Fourier-transformed infrared spectrometer (FTIR) at Moshiri observatory. Since 2008, CO₂ and CH₄ column-averaged mixing ratios (XCO₂ and XCH₄) have been measured, and the CO₂ and CH₄ dataset were used for GOSAT data validation. In 2011, we replaced the new solar tracker on the Moshiri FTIR system, and we evaluated the tracking accuracy of the solar tracker system at Moshiri. We also installed a new instrument to measure XCO₂ and XCH₄ using a compact optical spectrum analyzer (OSA) in Nagoya to verify measurement accuracy.

(3) Elementary processes of atmospheric reaction by solar activity in the global environment

In laboratory experiments as an aid to model calculations, we are attempting to clarify interaction processes to reveal the effect of intensity variations in solar UV radiation, which is a remarkable expression of solar activity variation. In 2011, we detected chlorine atoms Cl(2P₃/2), and investigated atmospheric reaction processes between organic molecules and chlorine atoms. The intensity variations in solar UV radiation can change the formation and loss processes of the organic compounds. These data help to clarify the chemical processes of organic compounds in the troposphere. The reaction processes of Cl atoms with several unsaturated organic molecules were studied. We developed an instrument for the measurements of atmospheric aerosols, and investigated the optical and chemical properties of aerosols to reveal their climate effects. Also, using a new laser spectroscopic method for stable isotope ratio measurements of carbon dioxide CO₂ with a response of a few seconds, we have studied the photosynthesis of some plants and the temporal variation in isotope ratios of CO₂ in the ambient air in Nagoya city.

(4) Verification of cloud formation initiated by cosmic rays

An experiment intended to verify a hypothesis of cloud formation by galactic cosmic rays is being conducted in collaboration with JAMSTEC. The experiment is intended to clarify the relationship between solar activity and the global climate. This year, measurements of
atmospheric ionization and aerosol formation by ionizing radiation were started using a rather large metal chamber. It was shown that ionizing radiation and UV radiation affect aerosol formation. More detailed experiments on aerosol formation will be carried out using various radiation sources and synthetic air to examine the change in aerosol formation rate.

(5) The Second International Nagoya Workshop on the Relationship between Solar Activity and Climate Changes

We organized “The Second International Nagoya Workshop on the Relationship between Solar Activity and Climate Changes”, which was held on January 16–17, 2012. We invited several foreign speakers, including J. Lean, A. Scaife, and L. Svalgaard, as well as Japanese researchers. The following topics were discussed in detail: variation of the sunspot activity and heliospheric environment, variation of solar irradiation and its impact on climate, solar variability in the paleoclimate, influence of galactic cosmic rays on cloud and climate, solar impact on the upper atmosphere, and solar impact on the stratosphere and troposphere.

We will continue to move forward with these four research subjects in our activities. By connecting these subjects, we will elucidate the variations in solar UV radiation and particle fluxes and reaction processes by UV radiation as well as particles in the stratosphere and the middle atmosphere and their influence on the global environment, and we will explore the relationship between past solar activity and climate change.

Project 4: Geospace Environment Modeling System for Integrated Studies – phase II: Investigation of Particle Acceleration and Regional Coupling Processes during Geospace Storms

“Geospace” represents the near-Earth space where the influence of Earth is noticeable. Geospace storms, which often take place during a solar maximum, are drastic variations in the space environment caused by dynamic solar activities such as CMEs. During geospace storms, enhanced regional couplings in the solar–terrestrial system and dynamic energy and mass transport are known to occur. These result in changes in the Earth's radiation belt and in various space weather phenomena. However, the mechanisms responsible for the dynamic variation are far from understood. The GEMSIS project aims to understand the physical mechanisms of the particle acceleration and regional couplings in the solar–terrestrial system during geospace storms based on observation-based integrated models. Another important task of the project is the development of a science center function for geospace studies that facilitates close collaborations among satellite observations, ground-based observations, and theories, simulations, and models by providing integrated data analysis tools and a combined database.

The GEMSIS project has been carried on by three working teams (GEMSIS-Sun, -Magnetosphere, and -Ionosphere). We report on the research activities of each working team below.

(1) GEMSIS-Sun working team

The goal of the GRMSIS-Sun group in the GEMSIS phase 2 is ‘to understand systematically the whole processes in solar flares, i.e., energy-store, trigger, energy-release, and particle acceleration’. In order to realize this, we are developing realistic solar flare models and
comparing them to observational results of solar flares, especially large solar flares. The research activities in this year are described below.

a) Non-linear force-free magnetic field in the solar corona
Magnetic fields in the solar corona are the energy source of explosive energy-release phenomena such as solar flares and CMEs. Accurate calculations of realistic coronal magnetic fields are vital to understanding the physical processes behind these phenomena. Thus, a database of coronal magnetic fields becomes useful for various solar physics studies. Our final goal is to develop a database of coronal magnetic fields for all active regions observed with Hinode/SOT. To realize this, we are developing the modeling code to derive non-linear force-free magnetic fields in the solar corona using photospheric magnetic field data observed with Hinode/SOT and SoHO/MDI.

b) Numerical modeling of energetic particles in solar flares
Based on the drift-kinetic theory, we developed a model for particle acceleration and transport in solar flares. Using this model, we investigated the height distribution of coronal electrons by focusing on the energy-dependent pitch-angle scattering. In this situation, the electron heights are energy dependent: intermediate-energy electrons inhabit higher altitudes, whereas lower- and higher-energy electrons populate lower altitudes. This implies that the intermediate-energy electrons are inhibited from following the shrinking field lines to lower altitudes because pitch-angle scattering causes efficient precipitation of these electrons into the footprint and their subsequent loss from the loop. This result is qualitatively consistent with the position of the above-the-loop-top hard X-ray (HXR) source that is located above coronal HXR loops emitted by lower-energy electrons and microwaves emitted by higher-energy electrons.

c) Research on solar flare particle acceleration using ground-based and satellite observations
During a solar flare, a large number of electrons are accelerated in the corona. Some of these electrons precipitate into the footprint of a flare loop and emit HXRs and microwaves. At the same time, some are trapped in the flare loop and then emit the same emissions around the apex of the flare loop. We focus on the latter emissions because they are closely related to the acceleration and transportation processes of electrons below the magnetic reconnection site. We analyzed the temporal and spatial variations of loop-top sources of an M-class flare observed on July 27, 2005 using 17-GHz and 34-GHz data taken by the Nobeyama Radio Heliograph. We had expected that the 34-GHz loop-top microwave source would be located at a lower altitude than that of the 17-GHz source because the higher-energy electrons that emit 34-GHz microwave radiation can penetrate to lower altitudes with fewer collisions during transport. However, our results indicated that the 34-GHz loop-top source was located at a higher altitude than the 17-GHz source during the entire flare period. It was also found that around the peak time of the flare, the height difference between the 17-GHz and 34-GHz loop-top sources increased. This result suggests that another acceleration/scattering process may exist.

d) Hinode flare catalog
We are developing a complete flare catalog, including all solar flares that were observed with the X-ray telescope (XRT), solar optical telescope (SOT), and extreme-UV imaging spectrometer (EIS) on board the Hinode satellite. More than 3000 events have occurred during the Hinode operation period (from 2006 to the present), and about half of them were observed with Hinode. All of them are listed in the catalogue. Soft X-ray, Ca II, and EUV images observed with Hinode and soft X-ray light curves observed with GOES are provided for each flare in the catalogue. This Hinode flare catalog is expected to be used by a large
number of researchers for flare analyses, especially for statistical studies and event searches. The URL for this project is http://st4a.stelab.nagoya-u.ac.jp/hinode_flare/

(2) GEMSIS-Magnetosphere working team

Aiming at understanding the dynamics of the inner magnetosphere during geospace storms, the GEMSIS-Magnetosphere working team has addressed the development of new physics-based models for the global dynamics of the ring current (GEMSIS-RC model) and the radiation belt (GEMSIS-RB model). We are also developing a high-resolution global MHD simulation code, which enables us to study MHD turbulence in the interactions of the solar wind with the magnetosphere. Integrated data analysis studies on topics such as the supply mechanisms of ring-current ions and relativistic electron accelerations are also conducted using various types of space-based and ground-based geospace observations. Some results are applied to studying the forecasting of radiation belt variations. Other ongoing research includes the concept design for an integrated data-analysis tool and a related database for effective research with various types of data, including those obtained from satellite observations, ground-based observations, and numerical simulations and models.

a) Development of GEMSIS ring-current model

We developed a numerical simulation model for ring-current particles as part of our ongoing effort to understand the geomagnetic storms that produce the strongest disturbances in geospace. We derived a new set of equations that incorporates the coupling between the electromagnetic field and drift-approximated particles in a self-consistent manner. A numerical simulation code solving the new equations (a five-dimensional kinetic equation and the Maxwell equation) is being developed. We have demonstrated that the new code is capable of describing the propagation of MHD waves, changes in the particle drift path due to the self-consistent coupling that cannot be reproduced in conventional models.

b) Development of GEMSIS radiation belt model

We developed a three-dimensional relativistic test-particle code and used it to calculate the trajectories of relativistic electrons in the outer radiation belt. We examined the evolution of the outer belt electrons associated with the enhancement of the solar wind dynamic pressure. As a result, we confirmed the drift loss of relativistic electrons by magnetopause shadowing (MPS), and we found a split in the outer radiation belt. This occurs because some electrons in the outer part of the outer belt can be trapped. The split in the outer belt depends on the large magnetic tilt angle. These findings suggest that a realistic magnetic field model is essential for understanding the dynamics of the outer radiation belt.

c) Response of the magnetotail to sudden changes in solar wind pressure

The impact of sudden changes in solar wind pressure results in various global and dynamic changes in the magnetosphere. Using GEOTAIL data, we studied the response of the plasma sheet in the magnetotail to sudden enhancements of the solar wind pressure and discussed the effect on the occurrence of substorms. On the basis of the specific entropy in particular, we showed that the plasma sheet compression due to the sudden enhancement in solar wind pressure is nearly adiabatic, in contrast to the nonadiabatic substorm-associated processes. Another important issue is the question of whether a sudden enhancement in solar wind pressure triggers a substorm. We showed that the northward magnetic field in
the plasma sheet tends to increase in association with the compression, implying that the lateral magnetotail compression suppresses the triggering of substorm expansion onsets.

d) Geospace data analysis
The GEMSIS-Magnetosphere group studies various geospace phenomena, such as aurora and radiation belts, using data from many satellites (REIMEI, GEOTAIL, FAST, GOES, THEMIS, etc.). As an example, we investigated a possible mechanism for the solar-cycle variations in the outer radiation belt, considering two typical types of magnetic storms categorized in accordance with solar wind drivers: coronal mass ejections (CMEs) and corotating interaction regions (CIRs). Large flux enhancements in the inner portion of the outer belt tend to occur during the recovery phase of great storms driven by CMEs, whereas large flux enhancements in the outer portion and at geosynchronous orbit tend to occur during the recovery phase of relatively moderate storms driven by CIRs. CMEs and CME-driven storms occur during solar activity maxima, whereas CIRs and CIR-driven storms occur during the solar declining phase, which controls the solar-cycle variations in the outer radiation belt.

e) ERG Science Center preparation
In cooperation with ground-based network observation teams and the IUGONET project, we designed CDF files for magnetometer data and HF radar data. Plug-in software to use these data easily on THEMIS Data Analysis Suites (TDAS) was also developed. We started a limited release of part of the developed database and the software to domestic researchers for test use.

(3) GEMSIS-Ionosphere working team

a) Rapid decay of ring current and formation of the main oval of proton aurora
A rapid decay of the storm-time ring current was investigated by means of a simulation using realistic magnetic field and electric field models with pitch angle scattering due to the field line curvature (FLC) together with the charge exchange and adiabatic cone loss. When all three loss processes were included, the Dst (Sym-H) index showed rapid recovery, with an e-folding time of ~6 h, which is consistent with observations. Precipitating proton flux agreed fairly well with the data based on the proton aurora observed by the IMAGE satellite. Fairly good agreement between the simulation and observations may imply that FLC scattering is sufficient to account for the rapid recovery of the ring current as seen by Dst (Sym-H).

b) Proton aurora associated with magnetic impulse events
Auroral hydrogen emission at 486.1 nm (proton aurora) associated with a magnetic impulse event (MIE) was observed for the first time by the all-sky imager installed at the South Pole Station (~74.3° MLAT). Optical observations at the South Pole Station showed a clear spot-like brightening of proton auroral emissions associated with MIEs. These proton aurora spots were ~300–500 km in length and ~150–200 km in width at an altitude of 150 km and lasted for ~1–2 minutes. The spot drifted antusunward with a speed of ~3–5 km s⁻¹, but did not always drift. The proton precipitation may be a result of the adiabatic change in the proton’s pitch angle in the magnetosphere or the direct penetration of solar wind protons.

c) Auroral Substorm Current System
The spatial distribution of field-aligned currents (FACs) was studied for an intense substorm. We first estimated the height-integrated ionospheric Hall and Pedersen conductances from ultraviolet images taken by the Polar satellite. To derive FACs, we then employed Ohm’s
law for the ionosphere, applying a magnetic inversion method to the input conductances and
ground magnetic field data. As a result, we found that the Hall FACs connected to the
ionospheric Hall currents were anti-correlated with the Pedersen FACs connected to the
ionospheric Pedersen currents. Such anti-correlations were observed near the poleward and
the equatorward edges of the auroral westward currents. This result indicates that the
auroral current system, including the Cowling channel (that is, the auroral westward
currents), were enhanced by the polarization electric field in this particular event.

d) Overshielding electric fields associated with quasi-periodic DP2 fluctuations and substorms
Based on the magnetometer network and Hokkaido radar data, we deduced that the
overshielding electric field plays a significant role in the quasi-periodic DP2 fluctuation events,
which become dominant at the equator when the IMF turns northward. The comprehensive
ring-current model verified the development of the Region-2 field-aligned currents responsible
for the overshielding. Using high to equatorial magnetometer arrays, we have shown that
overshielding occurs at the onset of substorms. Based on global MHD simulations, the cause of
the substorm-associated overshielding was confirmed to be the magnetic field dipolarization.

e) Upward Poynting flux from the ionosphere to the inner magnetosphere
Based on spacecraft observations, the electric field associated with the preliminary impulse
of the geomagnetic sudden commencement was found to be transmitted from the ionosphere
to the inner magnetosphere, with an upward flow of the Poynting flux. The upward
Poynting flux matches the Earth–ionosphere waveguide model in which the polar electric
field propagates to low latitudes at the speed of light, and the ionospheric electric field
further propagates upward into the inner magnetosphere.

f) Anomalous occurrence of the preliminary impulse of geomagnetic Sudden
Commencement (SC) in the South Atlantic Anomaly (SAA) region
We found that the preliminary reverse impulse (PRI), which is rarely seen in low latitudes,
frequently appears (occurrence probability of 80%) near the center of the South Atlantic
Anomaly (SAA) region. From calculations of ionospheric conductivity derived from the
IRI-2007 and NRLMSISE-00 models, we showed that the height-integrated conductivity
was more enhanced in the SAA region, where the ambient magnetic field intensity was weak.
The significant enhancement of the PRI occurrence is caused by the increased ionospheric
conductivity in this region.

Observatory

The Geospace Research Center has carried out routine ground-based observations of various
physical and chemical phenomena in the solar-terrestrial environment from its own
observatories located at Moshiri, Rikubetsu, Fuji, and Kagoshima. These long-term
observations are performed in conjunction with similar observations from stations located at
Kiso and Sugadaira.

Moshiri Observatory

The Moshiri Observatory (44.4°N, 142.3°E) is located in Hokkaido. Because of its
advantageous location, the observatory plays a significant role in the study of the
solar-terrestrial environment.
(1) Atmospheric research

The Moshiri Observatory is far from large cities and relatively free from local pollution. Thus, it is well suited for the study of the tropospheric chemistry of relatively clean air. Stratospheric ozone declined globally at a rate of a few percentage points per decade in the 1980s and 1990s. In Japan, the greatest ozone decrease occurred over Hokkaido. Stratospheric species such as O₃, HCl, and ClONO₂ have been measured since 1996 using a high-resolution FTIR spectrometer system. In 2010, a new computer-controlled solar tracker was installed, and its tracking accuracy was estimated in 2011. Stratospheric NO₂ and ozone column amounts have been observed since March 1991 by a ground-based visible spectrometer. The observations were performed as part of the Network for the Detection of Atmospheric Composition Change (NDACC). FTIR measurements also provided useful information on some important tropospheric trace gases. Column amounts of CO, C₂H₆, and HCN were measured using FTIR data. The column amounts of these species showed strong seasonal variations. In-situ measurements of ozone, CO, and hydrocarbons were performed in collaboration with Tokyo Metropolitan University and analyzed using the FTIR data. We recently installed an InGaAs detector and remote-control software on the FTIR spectrometer to measure the column-averaged dry-air molar fraction of atmospheric carbon dioxide (CO₂) and methane (CH₄), important greenhouse gases in global warming. This was used to validate data from the GOSAT satellite, launched in January 2009. Additionally, the instrumental functions of the compact OSA were estimated to improve its measurement accuracy of CO₂ and CH₄.

We launched CO₂ instrument balloons in Moshiri and measured the vertical profiles of CO₂ concentration. To ascertain the global and geophysical flux values of CO₂ and their seasonal and inter-annual variation, detailed CO₂ measurements including vertical distribution are required. However, the monitoring sites for CO₂ are mainly ground-based nowadays, and air flight measurements are performed only in restricted areas and seasons. We are developing balloon-borne instruments that can measure the vertical distribution of CO₂ anywhere in the world under any weather conditions, such as ozonesondes. The instruments can be used for the validation of the greenhouse monitoring satellite GOSAT.
Furthermore, the instruments will accumulate new scientific knowledge on the global distribution of greenhouse gases and their temporal variations, and on the mechanism of the global carbon cycle and its effect on the climate. This will prove useful in predicting future climate change and assessing its impact.

(2) Ionospheric and magnetospheric research

a) Magnetic field observations
Routine measurements of magnetic field variations have been conducted using a fluxgate magnetometer with a sampling rate of 1 s and an induction magnetometer with a sampling rate of 64 Hz. The data for these magnetometers are available on the web page at http://stdb2.stelab.nagoya-u.ac.jp/div2/data.html. These data are accessed about 2000 times per year.

b) Electromagnetic wave observations
ELF/VLF emissions were recorded at Moshiri Observatory using a 20-kHz computer-aided digital recording system with a 43-m tower antenna. Using a spectrum-fitting procedure, ionospheric D-layer height can be estimated from the spectral shape of the tweek emissions in the ELF/VLF dynamic spectrum. We investigated the dynamic variations in D-layer heights during geomagnetic storms in collaboration with researchers at Chiba University.

c) Optical observations
Routine measurements of low-latitude auroras were performed using a three-channel northward-looking photometer (automated operation). Twenty low-latitude aurora events were observed at Rikubetsu and Moshiri during the last solar maximum period (1999–2004). Since the aurora events of 2004, low-latitude auroras have not been observed. In collaboration with the Komazawa University, a routine measurement of noctilucent clouds has been carried out since 2010.

Rikubetsu Observatory

The Rikubetsu Observatory (43.5°N, 143.8°E, geomagnetic L-value: 1.5) is located on the eastern part of Hokkaido. A large number of sunny days, light rainfall (688 mm annual average) and snowfall (145 mm annual average), and mild winds (1.6 m/s average) render site ideal for observing the middle atmosphere and low-latitude auroras. From this observatory, we study atmospheric minor constituents related to stratospheric ozone depletion using radio, infrared, and optical instruments; low-altitude auroral phenomena using high sensitivity all-sky cameras and photometers; and ionospheric disturbances and atmospheric gravity waves using optical instruments, and magnetometers.

After several years of preliminary observations, the Rikubetsu Observation Point was established in 1997 and is jointly operated by STEL and the National Institute for Environmental Studies (NIES). As of April 1, 2003, the observation point was upgraded, officially becoming the Rikubetsu Observatory. The National Institute of Information and Communications Technology (NICT), Tohoku Institute of Technology, and Yokohama National University later joined in our observations. Employing infrared and optical spectroscopic analysis, this observatory plays an important role in the NDACC Network. In 2006, a new large HF radar (Hokkaido-Rikubetsu HF radar) was built in Pontomamu, 15
The offices and observation room of the Rikubetsu Observatory are located within the Rikubetsu Space and Earth Science Museum, in Hokkaido. It began its steady operation in December 2006. This HF radar is the second mid-latitude SuperDARN radar in the world and the first in Asia.

(1) Study of the relationship between atmospheric minor constituents and the stratospheric ozone

Synthetic monitoring of variations in the composition of the middle atmosphere in northern Japan was carried out using a visible spectrometer, a FTIR spectrometer, and a millimeter-wave-band radiometer in collaboration with NIES.

With the aid of an FTIR spectrometer, we performed highly accurate measurements of seasonal variations in ozone, HCl, and CO by measuring the spectral absorption lines present in solar background radiation. Additionally, we derived the total amount of ozone and NO from the intensity of scattered light observed by a visible spectrometer. The mixing ratio of ozone at each altitude can also be obtained by measuring the radiation spectrum of atmospheric ozone using a millimeter-wave spectroscopic radiometer. The millimeter-wave radiometer was transferred from NIES to STEL in 2011, and STEL has been in charge of its ozone-monitoring operation since then.

(2) Study of mesospheric gravity waves by observing low-latitude auroras and airglow

We have been observing low-latitude auroras and airglow emissions using a highly sensitive all-sky camera, meridian-scanning photometers, an airglow temperature photometer, and a fluxgate magnetometer. In 2011, the propagation of large-amplitude ionospheric disturbances from the Tohoku Earthquake off the Pacific coast was detected by the Hokkaido-Rikubetsu HF radar. This reveals the detailed characteristics of the propagation of coseismic ionospheric disturbances following a giant earthquake with very high temporal (8 s) and spatial (22.5 km) resolution.

The observed data are available on our homepage at:
Optical data: http://stdb2.stelab.nagoya-u.ac.jp/omti/index.html
Magnetometer data: http://stdb2.stelab.nagoya-u.ac.jp/mn210/index.html
HF radar data: http://center.stelab.nagoya-u.ac.jp/hokkaido/index.html
IPS antennas at Fuji (left) and Kiso (right).

Fuji Observatory and Sugadaira and Kiso Stations

Solar wind observations are performed using the IPS method. The solar wind observation system consists of four stations: Fuji, Sugadaira, Kiso, and Toyokawa. Fuji Observatory (35.4°N, 138.6°E), located at the foot of Mt. Fuji at an altitude of 1015 m, is the key station of the four-station system. It was established in 1978 for solar wind observations. The Sugadaira and Kiso stations were established in 1978 and 1993, respectively. An asymmetric cylindrical parabolic antenna operating at 327 MHz is installed at each station except Toyokawa. The antenna consists of parabolic frames with stainless steel wires stretching through the frames to form a 2000 m² parabolic reflector. The IPS observations with these antennas are carried out every day on a routine basis, except during winter. Each station is fully automated and remotely controlled from Nagoya through an Internet connection. The 2010 upgrades to the observation systems of the Fuji and Kiso antennas allowed simultaneous IPS data collection from these antenna systems and the Toyokawa antenna for a given source. Between late April and early November 2011, we carried out three-station IPS observations using the upgraded systems to determine the solar wind speeds. The observations ended in early November due to a serious problem with the Kiso antenna driving system; restoration work is currently underway. Observations of the Jovian decimetric radiation were also made using the Fuji and Kiso antennas under a collaborative research program.

Construction of a new antenna dedicated to IPS observations was started in 2006 at Toyokawa and completed in 2007. The new antenna is a meridian-transit-type cylindrical parabola with a 106 m NS and 38 m EW physical aperture. It operates at 327 MHz, as do the other antennas. IPS observations were performed on a daily basis in 2011 with the Toyokawa antenna, without any significant interruption.

Kagoshima Observatory

Routine observations of the ionosphere and the upper atmosphere have been carried out at the Kagoshima Observatory (31.5°N, 130.7°E, geomagnetic L-value: 1.2) which is located at Tarumizu near the active Sakurajima volcano in the southern region of Kyushu Island. An additional remote station is operated at Sata (31.0°N, 130.7°E), about 70 km south of the Kagoshima Observatory. The following instruments are in automatic operation:
The Kagoshima Observatory central office (left) and the Sakurajima volcano (right).

- ELF/VLF radio emission receiver (Tarumizu)
- 40 kHz standard radio signal receiver (Tarumizu)
- Fluxgate magnetometer (Tarumizu)
- Induction magnetometer (Tarumizu and Sata)
- All-sky CCD imager (Sata)
- Airglow temperature photometer (Sata)

Routine observations of ELF/VLF emissions were performed for two minutes every 30 minutes using an analog recording system (1976–2006) and a digital recording system (after 2007). Using a spectrum-fitting procedure, we can estimate ionospheric D-layer height from the spectral characteristics of two atmospheric emissions in the ELF/VLF band. We investigate dynamic variations in D-layer heights in collaboration with Chiba University. To investigate the climatological changes in ELF/VLF emissions associated with 11-year solar cycle variations, we began to digitize the analog tape archives recorded at Kagoshima Observatory over a 31-year period (1976 to 2006). A list of all the tapes was provided on the website at http://stdb2.stelab.nagoya-u.ac.jp/vlf/index.html. Up to 2011, we finished digitizing the ELF/VLF tape data for the geomagnetically quiet days of each month from 1976 to 2006 and active days of each month from 1976 to 1985.

The observatory is one of the key stations of the magnetometer chain along the Japanese meridian, and observations of geomagnetic field variations have been carried out since 1989. Summary plots of one-minute averaged data are found at http://stdb2.stelab.nagoya-u.ac.jp/mm210/. In 2011 a new induction magnetometer was installed at Tarumizu by the University of Electro-Communications to investigate atmospheric related to lightning discharge.

At Sata, observations of nighttime airglow emission from the upper atmosphere were carried out using an all-sky imager (since July 2000) and an airglow temperature photometer (since December 2003). A network telephone line is used for near-real-time monitoring of optical measurements. These optical data are available at http://stdb2.stelab.nagoya-u.ac.jp/omti/. The induction magnetometer at Sata has continued observation of high frequency (~0.1–10 Hz) geomagnetic pulsations since July 2007. The data from the induction magnetometer are available at http://stdb2.stelab.nagoya-u.ac.jp/magne/index.html.
3. Publications and Presentations

Published Papers (January 2010-March 2012)

Papers (in refereed journals)


Fujita, S., T. Kikuchi, and T. Tanaka, State transition of the magnetosphere-ionosphere compound system due to a northward turn of the interplanetary magnetic field revealed from a global


Hara, T., K. Seki, Y. Futaana, M. Yamauchi, M. Yagi, Y. Matsumoto, M. Tokumaru, A. Fedorov, and


Jackson, B. V., M. S. Hamilton, P. P. Hick, A. Buffington, M. M. Bisi, J. M. Clover, M. Tokumaru, and


Menjo, H., O. Adriani, L. Bonechi, M. Bongi, G. Castellini, R. D’Alessandro, A. Faus, K. Fukui, M.


Tanaka, Y., A. Shinbori, M. Kagitani, T. Hori, S. Abe, Y. Koyama, H. Hayashi, D. Yoshioka, T. Kono,


### International Conferences

The Solar-Terrestrial Environment Laboratory has been represented in academic year 2011 at various international conferences.

<table>
<thead>
<tr>
<th>Title</th>
<th>Country/Region</th>
<th>Date</th>
<th>Number of Presentations</th>
</tr>
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<tbody>
<tr>
<td>CCAPP Symposium 2011</td>
<td>U.S.A.</td>
<td>April 4–6, 2011</td>
<td>1</td>
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<tr>
<td>NDACC-IRWG/TCOON Meeting</td>
<td>U.S.A.</td>
<td>May 23–27, 2011</td>
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<td>ISTS 2011</td>
<td>Japan</td>
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<td>IAP Seminar</td>
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<tr>
<td>User Meeting and Summer School “Cavity Enhanced Spectroscopy”</td>
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<td>2011 Joint CEDAR-GEM Workshop</td>
<td>Mexico</td>
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<tr>
<td>AGU Chapman Conference: Dynamics of the Earth’s Radiation Belts and Inner Magnetosphere</td>
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<tr>
<td>10th International School for Space Simulations (ISSS-10)</td>
<td>Canada</td>
<td>July 24–31, 2011</td>
<td>3</td>
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<tr>
<td>FQMT11</td>
<td>Czech</td>
<td>July 25–30, 2011</td>
<td>1</td>
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<tr>
<td>Asia Oceania Geosciences Society (AOGS) Meeting 2011</td>
<td>Taiwan</td>
<td>August 8–12, 2011</td>
<td>8</td>
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<tr>
<td>32nd International Cosmic Ray Conference</td>
<td>China</td>
<td>August 11–18, 2011</td>
<td>8</td>
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<tr>
<td>30th General Assembly of the International Union of Radio Science (URSI)</td>
<td>Turkey</td>
<td>August 13–20, 2011</td>
<td>1</td>
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<tr>
<td>International Space Plasma Symposium (ISPS) 2011</td>
<td>Taiwan</td>
<td>August 15–19, 2011</td>
<td>5</td>
</tr>
<tr>
<td>The 1st ICSU World Data System Conference-Global Data for Global Science</td>
<td>Japan</td>
<td>September 3–6, 2011</td>
<td>2</td>
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<tr>
<td>15th EISCAT Workshop</td>
<td>China</td>
<td>September 5–9, 2011</td>
<td>1</td>
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<tr>
<td>International Symposium on Recent Observations and Simulations of the Sun-Earth System II (ISROSES-II)</td>
<td>Bulgaria</td>
<td>September 11–16, 2011</td>
<td>2</td>
</tr>
<tr>
<td>Workshop on Physical Processes in Non-Uniform Finite Magnetospheric Systems — 50 Years of Tamao’s Resonant Mode Coupling Theory</td>
<td>Japan</td>
<td>September 12–15, 2011</td>
<td>3</td>
</tr>
<tr>
<td>2011 International Conference on Storms, Substorms, and Space Weather</td>
<td>China</td>
<td>September 18–23, 2011</td>
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<tr>
<td>International Workshop on Space Weather in Indonesia</td>
<td>Indonesia</td>
<td>September 18–25, 2011</td>
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<tr>
<td>Japan-Korea Space Weather Workshop 2011</td>
<td>Korea</td>
<td>September 29–October 1, 2011</td>
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<tr>
<td>American Association for Aerosol Research (AAAR) 30th Annual Conference</td>
<td>U.S.A.</td>
<td>October 3–7, 2011</td>
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<tr>
<td>KAS Fall Meeting 2011</td>
<td>Korea</td>
<td>October 4–6, 2011</td>
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<tr>
<td>The Fifth Hinode Science Conference</td>
<td>U.S.A.</td>
<td>October 10–15, 2011</td>
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<td>Event</td>
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<tr>
<td>KMIIN</td>
<td>Japan</td>
<td>October 24-26, 2011</td>
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<tr>
<td>The 16th WMO/IAEA Meeting on Carbon Dioxide, Other Greenhouse Gases,</td>
<td>New Zealand</td>
<td>October 25-28, 2011</td>
<td>1</td>
</tr>
<tr>
<td>and Related Measurement Techniques (GGMT)</td>
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<tr>
<td>6th Symposium on the Science by Astronomical Earth Observatory</td>
<td>Japan</td>
<td>October 31-November 2,</td>
<td>1</td>
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<tr>
<td>(Chimondai) &amp; International Workshop of Interactive Research Center of</td>
<td></td>
<td>2011</td>
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<tr>
<td>Science</td>
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<tr>
<td>The 2011 NDACC Symposium</td>
<td>France</td>
<td>November 7-10, 2011</td>
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<tr>
<td>ISSI meeting</td>
<td>Switzerland</td>
<td>November 7-11, 2011</td>
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<tr>
<td>International Conference for High Performance Computing, Networking,</td>
<td>U.S.A.</td>
<td>November 12-18, 2011</td>
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<tr>
<td>Storage and Analysis 2011 (SC11)</td>
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<tr>
<td>HEAP2011</td>
<td>Japan</td>
<td>November 13-15, 2011</td>
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<tr>
<td>AGU Fall Meeting 2011</td>
<td>U.S.A.</td>
<td>December 5-9, 2011</td>
<td>17</td>
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<tr>
<td>EDS2011</td>
<td>Vietnam</td>
<td>December 15-21, 2011</td>
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<tr>
<td>GCOE Winter School/Workshop</td>
<td>Japan</td>
<td>December 16-18, 2011</td>
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<tr>
<td>The 3rd Workshop on Climate and Environment between Nanjing University</td>
<td>China</td>
<td>December 24-25, 2011</td>
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<tr>
<td>and Nagoya University</td>
<td></td>
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<tr>
<td>The 2nd Nagoya Workshop on the Relationship between Solar Activity</td>
<td>Japan</td>
<td>January 16-17, 2012</td>
<td>1</td>
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<tr>
<td>and Climate Changes</td>
<td></td>
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<tr>
<td>14th Takayama Seminar Held Jointly with JSPS-NRF-NDFC A3 Foresight</td>
<td>Japan</td>
<td>January 27-28, 2012</td>
<td>1</td>
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<tr>
<td>Program Seminar</td>
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<tr>
<td>UHECR 2012</td>
<td>Switzerland</td>
<td>February 13-16, 2012</td>
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<tr>
<td>International Symposium on Aerosol Studies Explored by Electron</td>
<td>Japan</td>
<td>February 16-17, 2012</td>
<td>2</td>
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<tr>
<td>Microscopy -How can electron microscopy improve atmospheric models?-</td>
<td></td>
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<tr>
<td>NIPR Symposium on Conjugate Aurora and SuperDARN - Past, Present</td>
<td>Japan</td>
<td>February 16-17, 2012</td>
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<tr>
<td>and Future</td>
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<td></td>
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<tr>
<td>The 1st AOSWA Workshop</td>
<td>Thailand</td>
<td>February 22-24, 2012</td>
<td>1</td>
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<tr>
<td>GEMSIS International Workshop 2012</td>
<td>Japan</td>
<td>March 12-14, 2012</td>
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<tr>
<td>ISEA 13</td>
<td>Peru</td>
<td>March 12-16, 2012</td>
<td>3</td>
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<tr>
<td>19th Meeting of the ALOMAR Science Advisory Committee</td>
<td>Germany</td>
<td>March 13-14, 2012</td>
<td>1</td>
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<tr>
<td>MST13 Workshop</td>
<td>Germany</td>
<td>March 19-23, 2012</td>
<td>1</td>
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<tr>
<td>Inner Magnetosphere Coupling (IMC) -2 Workshop</td>
<td>U.S.A.</td>
<td>March 19-23, 2012</td>
<td>6</td>
</tr>
</tbody>
</table>
4. Staff

Organization

Director

Deputy Director

Research Divisions

Division I: Atmospheric Environment

Division II: Ionospheric and Magnetospheric Environment

Division III: Heliospheric Environment

Division IV: Integrated Studies

Division for Visiting Scientists

Management Section

Research Projects Section

Moshiri Observatory

Rikubetsu Observatory

Fuji Observatory

Kagoshima Observatory

General Affairs Division

Accounting Division
Staff List

Director
Yutaka Matsumi

Deputy Director
Kanya Kusano

Research Divisions

Division I: Atmospheric Environment
Yutaka Matsumi Professor
Akira Mizuno Professor
Tomoo Nagahama Associate Professor
Tomoki Nakayama Assistant Professor

Division II: Ionospheric and Magnetospheric Environment
Kazuo Shiokawa Professor
Masafumi Hirahara Professor
Satonori Nozawa Associate Professor
Yuichi Otsuka Assistant Professor
Shin-ichiro Oyama Assistant Professor

Division III: Heliospheric Environment
Yoshitaka Itow Professor
Hiroyasu Tajima Professor
Munetoshi Tokumaru Professor
Yutaka Matsubara Associate Professor
Kimiaki Masuda Associate Professor
Takashi Sako Assistant Professor

Division IV: Integrated Studies
Takashi Kikuchi Professor
Kanya Kusano Professor
Satoshi Masuda Associate Professor
Kanako Seki Associate Professor
Akimasa Ieda Assistant Professor
Geospace Research Center

Tatsuki Ogino  Director, Professor
Fumio Abe    Associate Professor
Nozomu Nishitani  Associate Professor
Yoshizumi Miyoshi  Associate Professor
Ken’ichi Fujiki  Assistant Professor
Takayuki Umeda  Assistant Professor

Observatories

Moshiri Observatory
Yutaka Matsumi  Director, Professor

Rikubetsu Observatory
Akira Mizuno  Director, Professor

Fuji Observatory
Munetoshi Tokumaru  Director, Professor

Kagoshima Observatory
Kazuo Shiokawa  Director, Professor

Administrative Section

Tetsuya Taniguchi  Administrative Director
Shin’ichiro Matsuoka*  Director of General Affairs Division
Hideki Ito  Director of General Affairs Division
Minoru Takeda*  Director of Accounting Division
Katsumi Hikiji  Director of Accounting Division

General Affairs Division
General Affairs Section
Masao Yamamori  Section Chief

Research Promotion Section
Takao Tanase  Section Chief

Personal Section
Keisuke Matsuura  Section Chief

Accounting Division
Accounting Section
Supplies Section
Management Section
Technical Center (Solar-Terrestrial Environment Laboratory)

Yasuo Kato
Yasusuke Kojima
Tetsuya Kawabata
Yasushi Maruyama
Yuka Yamamoto
Yoshiyuki Hamaguchi
Takayuki Yama	
zaki
Tomonori Segawa
Ryuji Fujimori

Visiting Foreign Staff

<table>
<thead>
<tr>
<th>Name, Title</th>
<th>Permanent Affiliation</th>
<th>Period of Stay</th>
</tr>
</thead>
<tbody>
<tr>
<td>Veenadhari, B. P. Associate Professor</td>
<td>Indian Institute of Geomagnetism, India</td>
<td>February 18, 2011–July 22, 2011</td>
</tr>
<tr>
<td>Takahashi, H. Senior Research Staff</td>
<td>INPE, Brazil</td>
<td>April 20, 2011–July 20, 2011</td>
</tr>
<tr>
<td>Thayyil, J. P. Associate Professor</td>
<td>University of New Brunswick, Canada</td>
<td>August 30, 2011–December 6, 2011</td>
</tr>
<tr>
<td>Koustov, A. V. Professor</td>
<td>University of Saskatchewan, Canada</td>
<td>August 31, 2011–November 30, 2011</td>
</tr>
<tr>
<td>Amm, O. Senior Scientist</td>
<td>Finnish Meteorological Institute, Finland</td>
<td>March 2, 2012–May 31, 2012</td>
</tr>
<tr>
<td>Sydora, R. D. Professor</td>
<td>University of Alberta, Canada</td>
<td>March 12, 2012–June 11, 2012</td>
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Visiting Staff

<table>
<thead>
<tr>
<th>Name, Title</th>
<th>Permanent Affiliation</th>
<th>Period</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kawahara, T. Associate Professor</td>
<td>Shinshu University</td>
<td>April 1, 2011–March 31, 2012</td>
</tr>
<tr>
<td>Kodera, K.</td>
<td></td>
<td>April 1, 2011–March 31, 2012</td>
</tr>
<tr>
<td>Obara, T. Professor</td>
<td>Japan Aerospace Exploration Agency</td>
<td>April 1, 2011–March 31, 2012</td>
</tr>
<tr>
<td>Shibasaki, K. Professor</td>
<td>National Astronomical Observatory of Japan</td>
<td>April 1, 2011–March 31, 2012</td>
</tr>
<tr>
<td>Tanaka, T. Professor Emeritus</td>
<td>Kyushu University</td>
<td>April 1, 2011–March 31, 2012</td>
</tr>
<tr>
<td>Tsuneta, S. Professor</td>
<td>National Astronomical Observatory of Japan</td>
<td>April 1, 2011–March 31, 2012</td>
</tr>
<tr>
<td>Watanabe, T. Professor Emeritus</td>
<td>Ibaraki University</td>
<td>April 1, 2011–March 31, 2012</td>
</tr>
<tr>
<td>Narusawa, Y.</td>
<td>Mitsubishi Heavy Industries, Ltd.</td>
<td>January 1, 2012 – March 31, 2012</td>
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</table>
### Research Assistant Professor

<table>
<thead>
<tr>
<th>Name</th>
<th>Period</th>
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<tbody>
<tr>
<td>Hori, T.</td>
<td>From May 1, 2009</td>
</tr>
<tr>
<td>Suzuki, S.</td>
<td>From August 1, 2010</td>
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<tr>
<td>Shimoyama, M.</td>
<td>From November 1, 2011</td>
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</table>

### Researcher (Postdoctoral Fellows)

<table>
<thead>
<tr>
<th>Name</th>
<th>Period</th>
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<tbody>
<tr>
<td>Nishioka, M.</td>
<td>From April 1, 2010-August 31, 2011</td>
</tr>
<tr>
<td>Teramoto, M.</td>
<td>From April 1, 2011</td>
</tr>
</tbody>
</table>

### Researcher

<table>
<thead>
<tr>
<th>Name</th>
<th>Period</th>
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</thead>
<tbody>
<tr>
<td>Miyashita, Y.</td>
<td>From April 1, 2009</td>
</tr>
<tr>
<td>Nakamizo, A.</td>
<td>From April 1, 2010</td>
</tr>
<tr>
<td>Yamamoto, T.</td>
<td>From April 1, 2010</td>
</tr>
<tr>
<td>Isono, Y.</td>
<td>August 1, 2010-March 31, 2012</td>
</tr>
<tr>
<td>Fukui, A.</td>
<td>August 1, 2011-September 30, 2011</td>
</tr>
<tr>
<td>Yagi, M.</td>
<td>From January 1, 2012</td>
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### Researcher (Global COE)

<table>
<thead>
<tr>
<th>Name</th>
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<tbody>
<tr>
<td>Mitsuka, G.</td>
<td>From April 1, 2009</td>
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<tr>
<td>Tsuda, T.</td>
<td>From April 1, 2009-March 31, 2012</td>
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<tr>
<td>Hasegawa, M.</td>
<td>From March 1, 2012</td>
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### Japan Society for the Promotion of Science (JSPS) Research Fellowship for Young Scientist

<table>
<thead>
<tr>
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<tr>
<td>Nishimura, Y.</td>
<td>April 1, 2009-September 20, 2011</td>
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<td>Tsuji, Y.</td>
<td>April 1, 2010-March 31, 2012</td>
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<tr>
<td>Miyake, N.</td>
<td>April 1, 2010-March 31, 2012</td>
</tr>
<tr>
<td>Okumura, A.</td>
<td>October 1, 2011-August 31, 2012</td>
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</table>

### JSPS Postdoctoral Fellowship Program (Short-term)

<table>
<thead>
<tr>
<th>Name (Country)</th>
<th>Period</th>
</tr>
</thead>
</table>
5. Management System

The Solar-Terrestrial Environment Laboratory was established to conduct comprehensive research on the solar-terrestrial environment. To accomplish this goal smoothly, the Laboratory has a system of three operating committees.

The Advisory Board is to advise the Director on the overall management of the Laboratory matters and future plans. The Laboratory refers issues on cooperative research to the Cooperative Committee, and technical details are considered by the Technical Committee which has representatives from each of the Research Divisions.

Committee System
Advisory Board

The Advisory Board for the 2010 academic year is as follows:

T. Ono  Professor, Graduate School of Science, Tohoku University
T. Kajita  Director, Institute for Cosmic Ray Research, University of Tokyo
H. Kumagai  Vice President, National Institute of Information and Communications Technology
T. Sakurai  Deputy Director, National Astronomical Observatory of Japan
Y. Sasano  Director, Center for Global Environmental Research, National Institute for Environmental Studies
N. Sato  Deputy Director, National Institute of Polar Research
T. Tsuda  Director, Research Institute for Sustainable Humanosphere, Kyoto University
M. Nakamura  Research Director, Space and Astronautical Science, Institute of Japan Aerospace Exploration Agency
M. Hoshino  Professor, Graduate School of Science, University of Tokyo
K. Yumoto  Director, Space Environment Research Center, Kyushu University
N. Sugiyama  Professor, Graduate School of Science, Nagoya University
A. Kono  Professor, Graduate School of Engineering, Nagoya University
T. Shibata  Professor, Graduate School of Environmental Studies, Nagoya University
Y. Matsumi  Professor, Solar-Terrestrial Environment Laboratory, Nagoya University
A. Mizuno  Professor, Solar-Terrestrial Environment Laboratory, Nagoya University
K. Shiokawa  Professor, Solar-Terrestrial Environment Laboratory, Nagoya University
Y. Itow  Professor, Solar-Terrestrial Environment Laboratory, Nagoya University
T. Kikuchi  Professor, Solar-Terrestrial Environment Laboratory, Nagoya University
T. Ogino  Professor, Solar-Terrestrial Environment Laboratory, Nagoya University
6. Collaborative Research Activities

Collaborative Research Program

One of the major functions of the Solar-Terrestrial Environment Laboratory is to promote and conduct collaborative research on Solar-Terrestrial Science with scientists from universities and institutes outside the Laboratory. These research programs are carried out using laboratory instruments, software/databases and facilities. The Laboratory’s contact persons are indicated below:

Instruments

<table>
<thead>
<tr>
<th>Instrument</th>
<th>Contact Person</th>
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</thead>
<tbody>
<tr>
<td>Fourier Transform Infrared (FT-IR) Spectrometer for Atmospheric Composition Measurements (Moshiri and Rikubetsu)</td>
<td>T. Nagahama</td>
</tr>
<tr>
<td>Visible Wavelength Spectrometer for Atmospheric Composition Measurements (Moshiri and Rikubetsu)</td>
<td>T. Nagahama</td>
</tr>
<tr>
<td>Heterogeneous Atmospheric Reaction Analysing System (Nagoya)</td>
<td>Y. Matsumi</td>
</tr>
<tr>
<td>Instrument for Stable Isotope Ratios of Atmospheric Carbon Dioxide Using a Mid-IR Laser Absorption Apectroscopy Technique (Nagoya)</td>
<td>Y. Matsumi</td>
</tr>
<tr>
<td>Instrument for Atmospheric Nitrogen Oxide and Ozone Concentrations (Nagoya)</td>
<td>Y. Matsumi</td>
</tr>
<tr>
<td>STEL Magnetometer Network</td>
<td>K. Shiokawa</td>
</tr>
<tr>
<td>Optical Mesosphere Thermosphere Imagers (Rikubetsu, Shigaraki, Sata, and Overseas OMTI Stations)</td>
<td>K. Shiokawa</td>
</tr>
<tr>
<td>SuperDARN Hokkaido Radar</td>
<td>N. Nishitani</td>
</tr>
<tr>
<td>Sodium LIDAR (Tromsø)</td>
<td>S. Nozawa</td>
</tr>
<tr>
<td>The UHF (327 MHz) Antenna for Interplanetary Scintillation Observations (Fuji and Kiso)</td>
<td>M. Tokumaru</td>
</tr>
<tr>
<td>Solar Neutron Telescope (Norikura Observatory, Institute for Cosmic Ray Research, the University of Tokyo)</td>
<td>Y. Matsubara</td>
</tr>
<tr>
<td>Ultra Low Level Spectrometer for Beta-Ray Counting</td>
<td>K. Masuda</td>
</tr>
<tr>
<td>Multi-Directional Cosmic Ray Muon Telescope (Nagoya)</td>
<td>F. Abe</td>
</tr>
<tr>
<td>GEDAS (Geospace Environment Data Analysis System)</td>
<td>S. Masuda</td>
</tr>
<tr>
<td>Three-Dimensional Image Processing System (Nagoya)</td>
<td>T. Ogino</td>
</tr>
<tr>
<td></td>
<td>T. Umeda</td>
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Software/Database

<table>
<thead>
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<th>Contact Person</th>
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</thead>
<tbody>
<tr>
<td>Atmospheric Composition Data by FT-IR Measurements (Moshiri and Rikubetsu)</td>
<td>T. Nagahama</td>
</tr>
<tr>
<td>NO\textsubscript{2} and O\textsubscript{3} Data by Visible Wavelength Spectrometer Measurements (Moshiri and Rikubetsu)</td>
<td>T. Nagahama</td>
</tr>
</tbody>
</table>

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EISCAT Database (Longyearbyen, Tromsø, Kiruna, and Sondakylä)  
S. Nozawa

All-Sky Auroral Data (Canada, Alaska, and Siberia)  
K. Shiokawa

Coordinated Magnetic Data Along 210° Magnetic Meridian  
K. Shiokawa

STEL Magnetometer Data  
K. Shiokawa

Database of the Optical Mesosphere Thermosphere Imagers  
K. Shiokawa

VLF/LF Wave Data (Moshiri and Kagoshima)  
K. Shiokawa

VHF Radar/GPS Scintillation (Indonesia)  
Y. Otsuka

SuperDARN Hokkaido Radar Data  
N. Nishitani

Interplanetary Scintillation Data  
M. Tokumaru

Solar Wind Speed Data  
M. Tokumaru

Cosmic Ray Intensity Database  
F. Abe

Algorithm for Modeling of Ionospheric Electric Fields and Currents  
A. Ieda

Solar Flare Database  
S. Masuda

Magnetospheric Environment Database (FAST Satellite)  
K. Seki

MHD Simulation on the Magnetospheric Environment  
T. Ogino

Numerical Simulation Codes for Plasma Kinetics  
T. Umeda

Facilities

Computer System for Solar-Terrestrial Environmental Research  
(TSupercomputer System)  
T. Ogino

Facilities at Moshiri Observatory  
Y. Matsumi

Facilities at Rikubetsu Observatory  
A. Mizuno

Facilities at Kiso Station  
M. Tokumaru

Facilities at Fuji Observatory  
M. Tokumaru

Facilities at Kagoshima Observatory  
K. Shiokawa

Contact Person

Symposia/Workshops

The Solar-Terrestrial Environment Laboratory sponsors topical symposia/workshops to provide a forum for stimulating discussions on Solar-Terrestrial Science. Each year proposals for conducting such symposia are called for. The following meetings have been approved by the Cooperative Committee, and held in academic year 2011:

<table>
<thead>
<tr>
<th>Title, Convener</th>
<th>Location</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Workshop on Substorm Onset Mechanism, Y. Miyashita</td>
<td>Nagoya</td>
<td>August 22, 2011</td>
</tr>
<tr>
<td>Mesosphere-Thermosphere-Ionosphere Workshop, Y. Otsuka</td>
<td>Fukuoka</td>
<td>August 29–31, 2011</td>
</tr>
<tr>
<td>The 1st ICSU World Data System Conference, T. Ogino</td>
<td>Kyoto</td>
<td>September 3–6, 2011</td>
</tr>
</tbody>
</table>
Workshop on Physical Processes in Non-Uniform and Finite Magnetospheric Systems - 50 Years of Tamao’s Resonant Mode Coupling Theory, S. Fujita

Workshop on STP Simulation and Modeling Techniques, K. Fukazawa

Modeling and Data Assimilation in the Ionosphere and Magnetosphere, S. Nakano

Studies of the Magnetosphere-Ionosphere Convection System, K. Hashimoto

Paper-Writing Workshop for Studies of Upper Atmosphere, Ionosphere, and Magnetosphere, K. Shiokawa

The 17th Symposium on Atmospheric Chemistry, T. Nakazawa

STE Events Report and Analysis Workshop, S. Watari

Mid-Latitude HF Radar Workshop, N. Nishitani

Symposium on Aerosol Research for Young Scientist, T. Nakayama

Workshop on Mm-Wave and THz Detection Technology, H. Ogawa

STE Workshop, S. Watari

Workshop on Space Plasma Waves, T. Hada

Solar and Stellar Physics: Their Synergy and Future, T. Sekii


The 2nd Nagoya Workshop on the Relationship between Solar Activity and Climate change, Y. Matsumi

Solar Activities and Civilizations, M. Yokoyama

Current Status of Earth Science Metadata and Their Use, H. Hayashi

16th Workshop on Lidar Observation of Atmosphere, C. Nagasawa

STE Simulation Workshop: Status and Prospect of Plasma Multiscale Simulation, T. Miyoshi

Workshop on the Inner Magnetosphere, T. Ono

GEMSIS International Workshop, K. Seki

GEMSIS-Sun Workshop 2011, S. Masuda

Workshop on Regional Network for Space Weather Observation and Education, M. Shinohara

Symposium on Electromagnetospheric Physics, H. Kawano

STE Events Report and Analysis Workshop, S. Watari

Substorm and Related Topics, T. Tanaka

Space Weather and Cosmic Ray Modulation, K. Munakata

EISCAT Meeting, Y. Ogawa

Workshop on Physical Processes in Non-Uniform and Finite Magnetospheric Systems - 50 Years of Tamao’s Resonant Mode Coupling Theory, S. Fujita

Workshop on STP Simulation and Modeling Techniques, K. Fukazawa

Modeling and Data Assimilation in the Ionosphere and Magnetosphere, S. Nakano

Studies of the Magnetosphere-Ionosphere Convection System, K. Hashimoto

Paper-Writing Workshop for Studies of Upper Atmosphere, Ionosphere, and Magnetosphere, K. Shiokawa

The 17th Symposium on Atmospheric Chemistry, T. Nakazawa

STE Events Report and Analysis Workshop, S. Watari

Mid-Latitude HF Radar Workshop, N. Nishitani

Symposium on Aerosol Research for Young Scientist, T. Nakayama

Workshop on Mm-Wave and THz Detection Technology, H. Ogawa

STE Workshop, S. Watari

Workshop on Space Plasma Waves, T. Hada

Solar and Stellar Physics: Their Synergy and Future, T. Sekii


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STE Events Report and Analysis Workshop, S. Watari

Substorm and Related Topics, T. Tanaka

Space Weather and Cosmic Ray Modulation, K. Munakata

EISCAT Meeting, Y. Ogawa
Reports from Collaborative Research

Proceedings

<table>
<thead>
<tr>
<th>Title</th>
<th>Date of Publication</th>
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<tr>
<td>Proc. of 17th Symposium on Atmospheric Chemistry</td>
<td>October, 2011</td>
</tr>
<tr>
<td>Proc. of Symposium on the Mesosphere, Thermosphere, and Ionosphere</td>
<td>November, 2011</td>
</tr>
<tr>
<td>Proc. of 16th Workshop on Lidar Observation of Atmosphere</td>
<td>March, 2012</td>
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Committee on STER

The principal activities of the Committee on Solar-Terrestrial Environmental Research (STER) in Japan are to organize workshops, which promote collaborative work in related research areas. Two workshops were held in the 2011 academic year:

<table>
<thead>
<tr>
<th>Title</th>
<th>Date</th>
<th>Location</th>
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<tbody>
<tr>
<td>STE Events Report and Analysis Workshop</td>
<td>October 21, 2011</td>
<td>National Institute of Information and Communications Technology</td>
</tr>
<tr>
<td>STE Events Report and Analysis Workshop</td>
<td>March 15, 2012</td>
<td>Kyushu University</td>
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CAWSES Space Weather Database in Japan

The Scientific Committee on Solar-Terrestrial Physics (SCOSTEP), which carried out the STEP program (1990–1997), the S-RAMP program (1998–2002) and the Climate And Weather of the Sun-Earth System (CAWSES) program (2004–2008) is conducting the CAWSES-II program for 2009–2013 in order to understand the short-term (space weather) and long-term (space climate) variability of the integrated solar-terrestrial environment during the period for solar maximum from solar minimum, and its societal applications. In 2011, for the short term variability (Space Weather) of the CAWSES-II, “CAWSES-II Space Weather International Collaborative Research Database in Japan” has been constructed as an infrastructure of national cooperative research as our country positively participates. URL: http://center.stelab.nagoya-u.ac.jp/cawses/cw2/index_e.html
7. International Relations

Academic Exchange

Because of the nature of Solar-Terrestrial Science, it is essential that the Laboratory put international cooperative research programs forward. The total number of signed agreements is 20 as of April, 2012. The essence of the Agreement for Academic Exchange program is to promote international collaboration in observations, data analyses, and theoretical studies; exchange of researchers including graduate students; and exchange of information on research projects, planning, and publications.

<table>
<thead>
<tr>
<th>Institution</th>
<th>Country</th>
<th>Establishment</th>
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<tbody>
<tr>
<td>Indonesian National Institute of Aeronautics and Space</td>
<td>Indonesia</td>
<td>May 31, 1988</td>
</tr>
<tr>
<td>National Institute of Water and Atmospheric Research</td>
<td>New Zealand</td>
<td>July 26, 1989</td>
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<tr>
<td>Geophysical Institute, University of Alaska Fairbanks</td>
<td>U.S.A.</td>
<td>July 16, 1990</td>
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<tr>
<td>Department of Physics, University of Oslo</td>
<td>Norway</td>
<td>November 23, 1990</td>
</tr>
<tr>
<td>Chacaltaya Cosmic Ray Observatory, Faculty of Sciences, Universidad Mayor de San Andres, La Paz</td>
<td>Bolivia</td>
<td>February 20, 1992</td>
</tr>
<tr>
<td>Centre for Geophysical Research, University of Auckland</td>
<td>New Zealand</td>
<td>December 7, 1992</td>
</tr>
<tr>
<td>Space Environment Center, National Oceanic and Atmospheric Administration</td>
<td>U.S.A.</td>
<td>December 15, 1992</td>
</tr>
<tr>
<td>National Geophysical Data Center, National Oceanic and Atmospheric Administration</td>
<td>U.S.A.</td>
<td>January 5, 1993</td>
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<tr>
<td>Swedish Institute of Space Physics</td>
<td>Sweden</td>
<td>March 25, 1993</td>
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<tr>
<td>Faculty of Science, University of Tromsø</td>
<td>Norway</td>
<td>October 8, 1993</td>
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<tr>
<td>Department of Geophysics, Finnish Meteorological Institute</td>
<td>Finland</td>
<td>October 21, 1994</td>
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<td>Haystack Observatory, Massachusetts Institute of Technology</td>
<td>U.S.A.</td>
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<td>Yerevan Physics Institute</td>
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<td>October 18, 1996</td>
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<tr>
<td>National Institute for Space Research</td>
<td>Brazil</td>
<td>March 5, 1997</td>
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<tr>
<td>Center for Astrophysics and Space Sciences, University of California at San Diego</td>
<td>U.S.A.</td>
<td>December 22, 1997</td>
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<tr>
<td>Faculty of Science, University of Canterbury</td>
<td>New Zealand</td>
<td>July 30, 1998</td>
</tr>
<tr>
<td>Institute of High Energy Physics, Chinese Academy of Sciences</td>
<td>China</td>
<td>February 20, 2001</td>
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<tr>
<td>Polar Research Institute of China</td>
<td>China</td>
<td>November 11, 2005</td>
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<tr>
<td>Institute of Cosmophysical Research and Radiowave Propagation, Far Eastern Branch, Russian Academy of Sciences</td>
<td>Russia</td>
<td>April 14, 2007</td>
</tr>
<tr>
<td>Institute of Solar-Terrestrial Physics (ISTP), Siberian Branch of the Russian Academy of Sciences</td>
<td>Russia</td>
<td>October 28, 2008</td>
</tr>
</tbody>
</table>
# International Collaboration

## A. Major International Projects

<table>
<thead>
<tr>
<th>Research Subject</th>
<th>Collaborating Country (Countries) or Organization(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CAWSES (Climate and Weather of the Sun-Earth System) II</td>
<td>SCOSTEP</td>
</tr>
<tr>
<td>Consolidation of a Measurement Station for Atmospheric Composition Change at the Southern End of South America, Rio Gallegos</td>
<td>Argentina</td>
</tr>
<tr>
<td>Study of the Polar Ionosphere and Magnetosphere Using HF Radar Network</td>
<td>U.S.A., U.K., France, South Africa, Australia, Canada, Italy</td>
</tr>
<tr>
<td>Space Weather Study of the Solar Wind -Magnetosphere-Ionosphere-Thermosphere Coupling</td>
<td>Korea</td>
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<tr>
<td>Japan-Korea Space Weather Workshop 2011: Current Status and Prospect of Space Weather Modeling and Observation</td>
<td>Korea</td>
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## B. International Collaborative Projects

<table>
<thead>
<tr>
<th>Research Subject</th>
<th>The Other Party (Parties)</th>
</tr>
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<tbody>
<tr>
<td>Arctic Ozone Chemistry</td>
<td>NIWA; New Zealand</td>
</tr>
<tr>
<td>Laboratory Studies on Atmospheric Fate Processes of Hydrofluorocarbons</td>
<td>Ford Research Laboratory; U.S.A.</td>
</tr>
<tr>
<td>Laboratory Studies on Elementary Reactions of Atmospheric Minor Constituents</td>
<td>University of Bristol; U.K.</td>
</tr>
<tr>
<td>Application of the Cavity Ring Down (CRD) Spectroscopy to Atmospheric Measurements</td>
<td>Geophysical Institute, University of Alaska Fairbanks; U.S.A.</td>
</tr>
<tr>
<td>Studies of Important Chemical Reactions in the Troposphere and Stratosphere</td>
<td>The Australian National University; Australia</td>
</tr>
<tr>
<td>Study of Chemical Reaction Dynamics in the Upper Atmosphere</td>
<td>Harvard-Smithsonian Center for Astrophysics; U.S.A.</td>
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<tr>
<td>Observational Study of Atmospheric Minor Molecules in Atacama, Chile</td>
<td>University of Chile; Chile</td>
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<tr>
<td>An Observational Study for Stratospheric Ozone Depletion in Mid-Latitude Region Related to the Antarctic Ozone Hole</td>
<td>Laser and Applications Research Center (CEILAP); Argentina</td>
</tr>
<tr>
<td>Magnetic Conjugate Observations of Midlatitude Thermospheric Disturbances</td>
<td>IPS Radio and Space Service; Australia</td>
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<tr>
<td>Variation of the Thermosphere and Ionosphere owing to the Energy of Atmospheric Waves</td>
<td>LAPAN; Indonesia</td>
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<tr>
<td>High-Sensitive Imaging Measurements of Airglow and Aurora in the Canadian Arctic</td>
<td>University of California; U.S.A.</td>
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<tr>
<td>Global Observation of Airglow Rotational Temperature in the Mesopause Region</td>
<td>University of Calgary; Canada</td>
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<td>INPE; Brazil</td>
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Ionosphere and Upper Atmosphere Research, Observations and Monitoring

Ground and Satellite Measurements of Geospace Environment in the Far-Eastern Russia

Research and Development of the Low-Energy Electron Instrument Onboard the ERG Satellite

Research and Development of the Plasma/Particle Instrument Suite for the Mercury Magnetospheric Exploration Mission

Chiang Mai University; Thailand

Institute of Cosmophysical Research and Radiowave Propagation, Far Eastern Branch, Russian Academy of Sciences; Russia

National Cheng Kung University; Taiwan

CESR-CNRS, CETP-IPSL; France

Institute for Solar Physics of the Royal Swedish Academy of Sciences; Sweden

Rutherford Appleton Laboratory; U.K.

Boston University; U.S.A.

University of Bern; Switzerland

Study of the Polar Upper Atmosphere Using the EISCAT Radars and Other Instruments

Collaborative Study Using the EISCAT Radars

Observations of Interplanetary Disturbances Using the International IPS Network

Study of 3-D Solar Wind Structure and Dynamics Using Heliospheric Tomography

A Search for Dark Objects Using the Gravitational Microlensing Effect

University of Tromsø; Norway

EISCAT Scientific Association

EISCAT Group; U.K.

Tata Institute of Fundamental Research; India

National Centre for Radio Astrophysics; Mexico

UCSD/CASS; U.S.A.

University of Auckland; New Zealand

University of Canterbury; New Zealand

Victoria University of Wellington; New Zealand

Massey University; New Zealand

University of Notre Dame; U.S.A.

Research Institute of Physics, University of San Andres; Bolivia

Yerevan Physics Institute; Armenia

Institute of High Energy Physics, Chinese Academy of Sciences; China

University of Bern; Switzerland

University of Hawaii; U.S.A.

National Autonomous University of Mexico; Mexico

Research on Origin of Cosmic Rays with Fermi Satellite

Stanford University; U.S.A.

SLAC National Accelerator Laboratory; U.S.A.

NASA/GSFC; U.S.A.

U.S. Naval Research Laboratory; U.S.A.

UCSC; U.S.A.

Sonoma State University; U.S.A.

University of Washington; U.S.A.

Purdue University; U.S.A.

Ohio State University; U.S.A.

University of Denver; U.S.A.

CENS; France

CNRS; France

École Polytechnique; France

INFN; Italy

Italian Space Agency; Italy

IFSI; Italy

Royal Institute of Technology; Sweden

Stockholm University; Sweden
Research on Origin of Cosmic Rays with Soft Gamma-ray Detector Onboard ASTRO-H Satellite
Stanford University; U.S.A.
CENS; France

Study in Cosmic Neutrinos by Using a Large Water Cherenkov Detector
Boston University; U.S.A.
Brookhaven National Laboratory; U.S.A.
UCI; U.S.A.
Duke University; U.S.A.
George Mason University; U.S.A.
University of Hawaii; U.S.A.
Indiana University; U.S.A.
Los Alamos National Laboratory; U.S.A.
University of Maryland; U.S.A.
State University of New York; U.S.A.
University of Washington; U.S.A.
Chonnam National University; Korea
Seoul National University; Korea
Sungkyunkwan University; Korea
Tsinghua University; China
University of Warsaw; Poland

Study in Interaction of Very High Energy Cosmic Rays by Using Large Hadron Collider
University of Florence; Italy
Catania University; Italy
École Polytechnique; France
CERN; Switzerland
University of Valencia; Spain
Ernest Orlando Lawrence Berkeley National Laboratory; U.S.A.

Study of Dark Matter and Solar Neutrinos Using a Liquid Xenon Detector
Seoul National University; Korea
Sejong University; Korea
Korea Research Institute of standards and Science; Korea

Research on Origin of Cosmic Rays with CTA (Cherenkov Telescope Array)
DESY; Germany
Max-Planck-Institut; Germany
Heidelberg University; Germany
CENS; France
École Polytechnique; France
University of Paris; France
INFN; Italy
IFSI; Italy
University of Barcelona; Spain
Complutense University; Spain
University of Zurich; Switzerland
Durham University; U.K.
University of Leicester; U.K.
University of Leeds; U.K.
SLAC National Accelerator Laboratory; U.S.A.
Argonne National Laboratory; U.S.A.
University of Washington; U.S.A.
Iowa State University; U.S.A.
UCLA; U.S.A.
UCSC; U.S.A.
University of Chicago; U.S.A.
Smithsonian observatory; U.S.A.

Research on Particle Acceleration in the Solar Corona through the FOXSI Rocket Experiment
UCB; U.S.A.
Stanford University; U.S.A.
NASA/MSFC; U.S.A.

Study of Indirect Dark Matter Searches
Ohio State University; U.S.A.
Study of the Geospace Environment Variation with GEMSIS
RBSP Project
Modeling Study of Inner Magnetosphere
Study on Trigger Mechanism of Solar Flares
Study on Structure and Dynamics of Coronal Mass Ejections
Modeling of Solar Wind-Magnetosphere Coupling
Cross-Scale Coupling in the Earth’s Magnetosphere
Nonlinear Waves in Space Plasmas

Visitors

Short-Term Visitors (April 2010 – March 2011)

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<th>Name</th>
<th>Permanent Affiliation</th>
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<tr>
<td>Bhasakara Pantula, V.</td>
<td>Indian Institute of Geomagnetism</td>
<td>India</td>
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<tr>
<td>Noé, L.</td>
<td>Hawaii University</td>
<td>U.S.A.</td>
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<tr>
<td>Pearce, J. K.</td>
<td>University of Queensland</td>
<td>Australia</td>
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<tr>
<td>Scholl, I. F.</td>
<td>Hawaii University</td>
<td>U.S.A.</td>
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<td>Khan, H. K.</td>
<td>Kyung Hee University</td>
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<td>Cheng, F.</td>
<td>National Cheng Kung University</td>
<td>Taiwan</td>
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<td>Scaife, A.</td>
<td>Met Office Hadley Centre</td>
<td>U.K.</td>
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<td>Shrivastava, A.</td>
<td>Jiwaji University</td>
<td>India</td>
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<tr>
<td>Kaushik, S. C.</td>
<td>Jiwaji University</td>
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<td>Svalgaard, L.</td>
<td>Stanford University</td>
<td>U.S.A.</td>
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<td>Lean, J.</td>
<td>Naval Research Laboratory</td>
<td>U.S.A.</td>
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<td>Enghoff, M. B.</td>
<td>Danish Technical University</td>
<td>Denmark</td>
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<td>Damiani, A.</td>
<td>Santiago de Chile University</td>
<td>Chile</td>
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<td>Kim, B.</td>
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<td>Cho, I.-H.</td>
<td>Korea Astronomy and Space Science Institute</td>
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<tr>
<td>Vanhamaki, H.</td>
<td>Finland Meteorological Institute</td>
<td>Finland</td>
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Seminars by Visitors

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<th>Country/Region</th>
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<tr>
<td>Noé, L.</td>
<td>Hawaii University</td>
<td>U.S.A.</td>
<td>April 13, 2011</td>
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<td>Jackson, B.V.</td>
<td>UCSD</td>
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<td>April 20, 2011</td>
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<td>Pearce, J. K.</td>
<td>University of Queensland</td>
<td>Australia</td>
<td>June 2, 2011</td>
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<td>Takahashi, H.</td>
<td>IMPE</td>
<td>Brazil</td>
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<td>Bhasakara Pantula, V.</td>
<td>Indian Institute of Geomagnetism</td>
<td>India</td>
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<td>Khan, H. K.</td>
<td>Kyung Hee University</td>
<td>Korea</td>
<td>July 28, 2011</td>
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<tr>
<td>Thayyil, J. P.</td>
<td>Indian Institute of Geomagnetism</td>
<td>India</td>
<td>September 20, 2011</td>
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<tr>
<td>Koustov, A. V.</td>
<td>University of Saskatchewan</td>
<td>Canada</td>
<td>October 28, 2011</td>
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<td>Abbreviations</td>
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<tr>
<td>APL:</td>
<td>Applied Physics Laboratory</td>
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<td>CASS:</td>
<td>Center for Astrophysics &amp; Space Sciences</td>
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<td>CAWSES:</td>
<td>Climate and Weather of the Sun-Earth System</td>
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<td>CENS:</td>
<td>Centre d’Études Nucléaires de Saclay</td>
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<td>Centre d’étude des Environnements Terrestre et Planétaires</td>
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<td>CERN:</td>
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<td>CNRS:</td>
<td>Centre National de la Recherche Scientifique</td>
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<td>CESR:</td>
<td>Centre d’Etude Spatiale des Rayonnements</td>
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<td>DESY:</td>
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<td>Istituto di Fisica dello Spazio Interplanetario</td>
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<td>Johns Hopkins University</td>
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<td>Los Alamos National Laboratory</td>
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<td>Lembaga Panerbangan Dan Antariska Nasional</td>
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<td>SCOSTEP:</td>
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</table>
8. Education

Solar-Terrestrial Environment Laboratory offers primarily graduate programs, but also provides opportunities for both undergraduate and postdoctoral experience. The members of the academic staff offer graduate and undergraduate courses.

Graduate Programs

The Laboratory has a graduate course program for Solar-Terrestrial Science, as part of the Graduate School of Science, Nagoya University. It also cooperates with the Department of Electrical Engineering and Computer Science, Graduate School of Engineering, in teaching/training graduate students in related disciplines of Solar-Terrestrial Science. Graduates are enrolled in Doctoral (D) programs. Academic members are responsible for guiding the progress of the students’ thesis work. They also offer the teaching of core and topical courses.

The Number of Graduate Students Since 2007

<table>
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<tr>
<th>Graduate School of Science</th>
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<th>2011</th>
<th>2012</th>
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| Total             | 57   | 56   | 63   | 73   | 79   | 77   |
Graduate School of Science

<table>
<thead>
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<th>Field/Topics</th>
<th>Faculty Members</th>
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<tbody>
<tr>
<td>Solar-Terrestrial Chemistry</td>
<td>Y. Matsumi, Professor</td>
</tr>
<tr>
<td></td>
<td>A. Mizuno, Professor</td>
</tr>
<tr>
<td></td>
<td>T. Nagahama, Associate Professor</td>
</tr>
<tr>
<td></td>
<td>T. Nakayama, Assistant Professor</td>
</tr>
<tr>
<td>Solar-Terrestrial Relationships</td>
<td>M. Hirahara, Professor</td>
</tr>
<tr>
<td></td>
<td>K. Kusano, Professor</td>
</tr>
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<td>T. Kikuchi, Professor</td>
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<tr>
<td></td>
<td>S. Masuda, Associate Professor</td>
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<tr>
<td></td>
<td>S. Nozawa, Associate Professor</td>
</tr>
<tr>
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<td>Y. Otsuka, Associate Professor</td>
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<td>K. Seki, Associate Professor</td>
</tr>
<tr>
<td></td>
<td>A. Ieda, Assistant Professor</td>
</tr>
<tr>
<td></td>
<td>S. Oyama, Assistant Professor</td>
</tr>
<tr>
<td>Solar-Terrestrial Physics</td>
<td>Y. Itow, Professor</td>
</tr>
<tr>
<td></td>
<td>H. Tajima, Professor</td>
</tr>
<tr>
<td></td>
<td>M. Tokumaru, Professor</td>
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<td></td>
<td>F. Abe, Associate Professor</td>
</tr>
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<td>K. Masuda, Associate Professor</td>
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<tr>
<td></td>
<td>Y. Matsubara, Associate Professor</td>
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<tr>
<td></td>
<td>K. Fujiki, Assistant Professor</td>
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<td></td>
<td>T. Sako, Assistant Professor</td>
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Graduate School of Engineering

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<thead>
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<th>Field/Topics</th>
<th>Faculty Members</th>
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<tbody>
<tr>
<td>Space Electromagnetic Environment (Space Information Technology)</td>
<td>T. Ogino, Professor</td>
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<tr>
<td></td>
<td>Y. Miyoshi, Associate Professor</td>
</tr>
<tr>
<td></td>
<td>T. Umeda, Assistant Professor</td>
</tr>
<tr>
<td>Space Electromagnetic Environment (Space Observations)</td>
<td>K. Shiokawa, Professor</td>
</tr>
<tr>
<td></td>
<td>N. Nishitani, Associate Professor</td>
</tr>
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</table>

Undergraduate Education

Based on demand, the faculty of the Solar-Terrestrial Environment Laboratory offers numerous undergraduate courses in the School of Science, the School of Engineering, and in other departments and at other universities in the adjacent area.

During the 2011 academic year, the following courses were offered:
- Astrophysics and Space Science
- Experimental Physics
- Physics Experiments
- Introduction to Physics
- Astrophysics and Space Physics
- Solar-Terrestrial Science
- Electromagnetic Wave Engineering
- Electric Circuit with Exercise
- Experiments on Electrical and Electronic Engineering
- Introduction to Electrical’Electronic and Information Engineering
- Mathematics with Exercises
9. Research-Related Activities

Several facilities, including a computer network, are available to facilitate research on the solar-terrestrial environment.

Computer / Network

The computer system for Solar-Terrestrial Environmental Research was upgraded in December 2010 as the core computer/network system of STEL, which consists of a supercomputer with a theoretical peak performance of 20 TFlops and disk arrays with a total capacity of 280TB, a large RAID storage with a total capacity of 360 TB, Sun workstations, and high-speed network. These computers and the network are successively used for computer experiments/simulation, data analysis, database generation, and communications.

The video teleconferencing system, which uses a TCP/IP internet connection, was introduced in 2004, and used for remote teleconferencing and lecturing between Toyokawa and Higashiyama. In an effort to upgrade the “Gigabit Network” program for 2000–2003, we joined the JGN2 project of the National Institute of Information and communications Technology (NICT) in cooperation with Kyoto University, Ehime University, Kyusyu University, and NICT. The JGN2 project is a four-year program (2004–2007) of high speed computer network available in Higashiyama from the 2006 fiscal year. The research title of the project is “Common Usage of Geospace Environment Information Using High Speed Networks” and it is aimed at applying high speed networks to geospace study throughout 2007. A new research project of NICT, JGN2plus, began in 2008 and the widely distributed file system and 10G bps high speed network were introduced in 2010. A new research project of NICT, JGN-X, began in 2012. We installed the latest version of the distributed file system, called Gfarm2, and used the space-science cloud-computing environment (OneSpaceNet) of the NICT.
10. Public Service

Outreach Activities

In cooperation with local governments where laboratory observatories exist, STEL has made all possible efforts to connect its research activities to society using its outreach program, with the motto “advanced intellectual property to social services”. In fiscal year 2002, the Ministry of Education, Culture, Sports, Science and Technology (MEXT) embarked on a program to support outreach activities at selected national universities including Nagoya University. The purpose of this comprehensive program was to promote a two-way partnership between universities and local governments, and communities. After the MEXT’s three-year program, the STEL program was incorporated from 2005 into one of the president’s budget programs at Nagoya University, and has been continuing in fiscal year 2011.

Since Rikubetsu Town, Hokkaido, and STEL started the Community Cooperative Committee in March 2003, they have held regular meetings on the planning and management of social services every year. In fiscal year 2011, the committee whose members are the mayor and related staff of Rikubetsu Town and several staff of STEL, met with representatives of Hokkaido University, the Kitami Institute of Technology, the National Institute for Environmental Studies, and the National Institute of Polar Research. In the meeting, all members agreed that together they would promote a broad range of social cooperative services.

Our activities for fiscal year 2011 were as follows:

Lectures and classes:
STEL delivers lectures to local schools in Rikubetsu Town every year. This year, special classes were given on December 1, 2011 at Rikubetsu Elementary School and Rikubetsu Junior High School, with a theme “disaster, radioactivity, and nature”, taking into account the East-Japan Earthquake that occurred earlier in the year. Dr. Yuki Sadaike (Institute of Seismology and Volcanology, Hokkaido University) talked about disaster, based on her own experience during the Okushiri Tsunami. Prof. Kimiaki Masuda (STEL, Nagoya University) explained radioactivity and its relationship to natural radioactivity and human beings. Mr. Toshio Ushiyama (photographer and environmental counselor) showed many pictures of stars and aurorae taken personally. All of the lectures were well received by the children and left them with a strong impression and appreciation of science.

Public outreach events:
“Antarctic classroom” was opened at the Rikubetsu Astronomical Observatory on September 10, 2011. Following the opening address by Prof. Yosuke Kamide, director of the Observatory, Prof. Akira Kadokura, Head of the 50th Japanese Antarctic Research Expeditions, National Institute of Polar Research, gave a lecture entitled “Japanese Antarctic Observation”. The Observatory and Syowa Station in Antarctica was then connected by internet so that they could communicate with each other. From Syowa Station, many members, including Ms Yasuko Isono, STEL Researcher working there over the winter, participated in the discussion to introduce the public to Antarctica and their current living conditions there. The discussion was followed by a quiz.
From Rikubetsu, many children of Rikubetsu Elementary School and their parents answered the quiz and asked questions.

On December 3, 2011, an event was carried out to celebrate the completion of a new planetarium program, “Snowflake – Snow is a letter from the heaven”, at the Rikubetsu Astronomical Observatory. After speeches by the Mayor of Rikubetsu Town and a producer of the program, Prof. Yasushi Fujiyoshi from the Institute of Low-Temperature Science, Hokkaido University, a supervisor for the program, gave a lecture entitled “How clouds and snow are produced”. The participants enjoyed the program.

Booklets:
We have produced many issues of booklets related to solar-terrestrial science, and distributed these booklets to the public at open houses, conferences, and poster exhibitions. This research has been presented to people in understandable terms to reach a broad range of society. The booklets are prepared by the Rikubetsu Astronomical Observatory, Toyokawa Geospace Hall, and Public Relations Office of Nagoya University. The booklets are available to the public at the homepage of STEL, with nearly two million accesses recorded per year. Current titles include the following:

- Aurora, Sun and Solar Wind, Planets, Ozone, Cosmic Rays, Global Warming,

Additionally, we have produced a series of comics, “What is --- !?”, which are easier for children and the general public to understand. The booklets were distributed at the following meetings and conferences in the fiscal year 2011:

- JPGU 2011 (Makuhari, May 21–27, 2011)
- STEL Open House and University Festival: Public Lecture (Nagoya, July 4, 2011)
- Nagoya University Home Coming Day (Nagoya, October 15, 2011)

These distributions are considered to be important contributions of STEL in providing research content to the community and promoting public interest in general natural science.

New Home Page:
A new homepage for STEL (http://www.stelab.nagoya-u.ac.jp/index.php.ja) was launched to provide up-to-date information to the public. In particular, “Hot Topics” and “Photo of the Month” links have been set up. This allows the activities of STEL and cutting-edge research results to be transmitted to the public as the data become available.
11. Facilities

Library

The laboratory library provides substantial coverage of space physics and geophysics as well as basic physics, chemistry, and mathematics. The present collection contains 13,404 books, supplemented by data reports and preprints. The Library has subscriptions to 134 journals from around the world.

<table>
<thead>
<tr>
<th>Books</th>
<th>Journals</th>
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<td></td>
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<td>Foreign</td>
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Properties

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<th>Location</th>
<th>Site (m²)</th>
<th>Building (m²)</th>
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① Moshiri Observatory
② Rikubetsu Observatory
③ Sugadaira Station
④ Kiso Station
⑤ Fuji Observatory
⑥ Kagoshima Observatory

Solar-Terrestrial Environment Laboratory

Toyokawa Branch