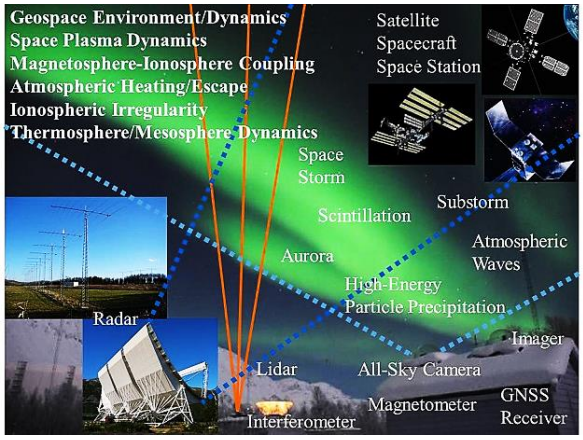
9-1. Research Divisions
Division for Ionospheric and Magnetospheric Research



Research topics and keywords

- Understanding the process of energy transfer from the solar wind to the magnetosphere and ionosphere
- Understanding the magnetosphere–ionosphere–thermosphere coupled system
- Ground-based and network observation
- Space and planetary exploration

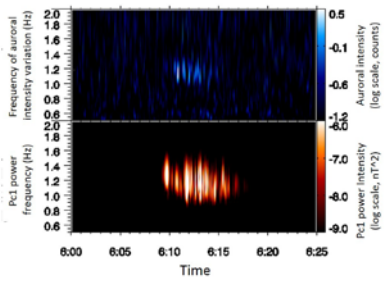
Introduction to Division for Ionospheric and Magnetospheric Research

The plasma and energy carried by the solar wind to the Earth and other planets exert physical effects on the magnetosphere and ionosphere, known as geospace. We study these effects and associated phenomena with international cooperation, primarily, through various observational approaches using ground-based instruments; for example, European Incoherent Scatter (EISCAT) radars, High-Frequency (HF)/Very High Frequency (VHF) radars, Global Navigation Satellite System (GNSS) receivers, high-sensitivity passive/active optical instruments, magnetometers, and instruments onboard satellites/spacecraft, which are developed in our division. We also lead the way to future space exploration missions based on our expertise.

Main Achievements in FY2017

1. Measurements of aurora and electromagnetic waves at subauroral latitudes

Since 2016, under the PWING project, we have operated aurora/airglow imagers and electromagnetic wave receivers at stations in Canada, Russia, Alaska, Finland, and Iceland around the North Pole at magnetic latitudes of about 60o to investigate the dynamics of plasma and waves in the inner magnetosphere. Same frequency oscillations at ~1 Hz were identified in the Pc1 geomagnetic pulsations (EMIC waves) and intensity variations of isolated proton aurora. We also reported clear differences in ELF/VLF wave features at stations separated by ~30 degrees of longitude, indicating the localization of these wave sources in the inner magnetosphere.



Dynamic spectra of (top) intensity variations of isolated proton aurora.and (bottom) power of the Pc1 geomagnetic pulsations (EMIC waves).

2. Study of the upper atmosphere using optical imaging instruments

To investigate the dynamics of the mesosphere, thermosphere, and ionosphere, we routinely operate Optical Mesosphere Thermosphere Imagers (OMTIs), which consist of five sky-scanning Fabry-Perot interferometers (FPIs), 17 all-sky charge-coupled device (CCD) imagers, three tilting photometers, and three airglow temperature photometers. Plasma bubble occurrence over Africa has been studied statistically using an all-sky airglow imager operated in Nigeria.

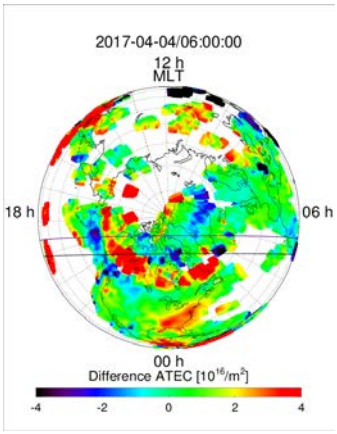
3. Response of the ionosphere and thermosphere to solar flares

Solar flares enhance solar EUV and X-ray radiation to rapidly increase the plasma density in the dayside ionosphere. We improved the GAIA, a coupled global model of the ionosphere and atmosphere, to investigate plasma density

depletion in the low latitude evening ionosphere after an intense solar flare, and found that the flare increases the plasma density in the dayside ionosphere to develop an eastward ionospheric current. Part of the current flows into the nightside to generate an electric field near the sunset terminator; this electric field transports plasma from low to high latitudes, which decreases the low latitude plasma density.

4. Temporal and spatial variations of the plasmasphere and ionosphere using GNSS receiver network

To clarify the characteristics of temporal and spatial variations of the plasmasphere and ionosphere during the development and decay of geomagnetic storms, and their physical mechanism, we collected new GNSS receiver data in the Canadian and Nordic regions, and developed a database of long-term TEC observations, and an analysis tool. The analysis results with these products show that an enhanced TEC region appears in the longitudinal direction in the auroral zone during the main phase of geomagnetic storms. The enhanced TEC region expands to lower latitudes as geomagnetic storms develop. Furthermore, a decreased TEC region corresponding to the mid-latitude ionospheric trough appears at the lower latitude of the auroral zone. The location of the mid-latitude ionospheric trough almost coincides with the plasmapause detected by the Arase satellite traveling in the inner magnetosphere.



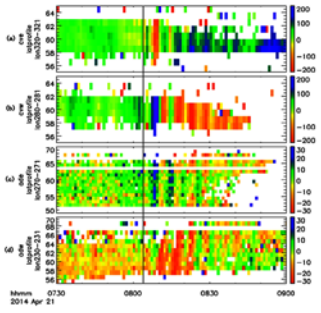
TEC map in the northern hemisphere in geomagnetic coordinates.

5. Study on lunar plasma environment

A tenuous region called the wake forms behind the Moon in the solar wind, and plasma entry/refilling into the wake is a fundamental problem in lunar plasma science. We have investigated, in detail, signatures of ions and electrons around the lunar wake boundary using the Kaguya (SELENE) data. We have proposed a new model of the wake boundary close to the Moon, taking into account the three-dimensionality of solar wind proton motions. This new model explains electron signatures around the wake boundary detected by Kaguya at an altitude ~100 km from the lunar surface.

6. SuperDARN Hokkaido HF Radars

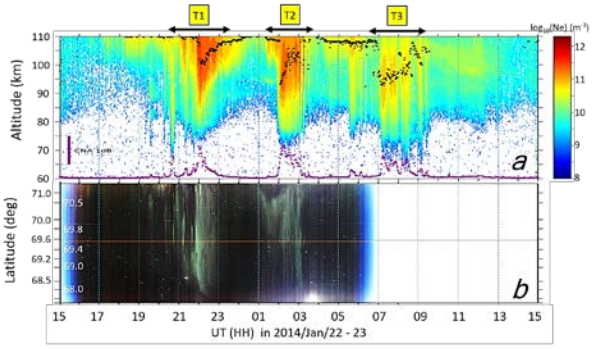
Using the SuperDARN Hokkaido HF East and West radars at Rikubetsu, Hokkaido, we studied the statistical characteristics of Sub-Auroral Polarization Streams (SAPS) and the relationship with ionospheric conductivity determined by the solar zenith angle. We also used worldwide SuperDARN radar data to study the characteristics of ionospheric electric field oscillations following sudden changes in solar wind dynamic pressure.



SuperDARN observation of electric field oscillations following a sudden change in solar wind dynamics pressure.

7. EISCAT project promotion: synthetic observations with collocated instruments

The EISCAT Radar Scientific Association is an international organization concentrating on operation of radar systems in northern Scandinavia. We combined a variety of instruments around the EISCAT radars to conduct complementary and synthetic observations throughout the ionosphere, thermosphere, and upper mesosphere. In FY2017, 13 proposals for EISCAT special experiments were accepted by the Japanese EISCAT committee, and 10 of these were conducted in collaboration with the National Institute of Polar Research (NIPR). Several optical instruments, including the Na Lidar, the FPI, the 5 wavelengths photometer, and several all-sky cameras were operated automatically at the EISCAT Tromsø site. An international session on “Study of coupling processes in the



(a) The electron density measured with the EISCAT radar repeatedly increases with aurora substorms, decreasing its lowest height of ionization. This means that energy of precipitation electrons increases with time.
(b) enhancement of the electron density associate with evolution of auroral patches [Oyama et al., 2017].

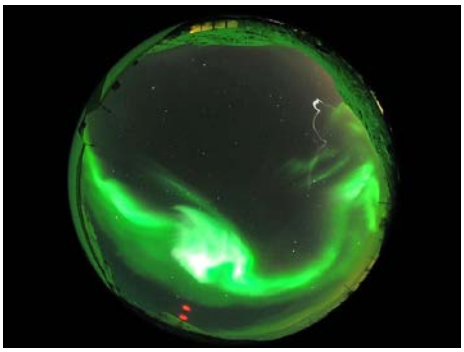
solar-terrestrial system", related to the EISCAT_3D project, was organized at the Japan Geoscience Union (JpGU) 2017 with the Research Institute for Sustainable Humanosphere (RISH), Kyoto University and NIPR. The 18th EISCAT symposium was held at NIPR in May 2017.

8. International collaboration to study impacts of the EPP on the atmospheric minor components

Energetic particle precipitation (EPP) can modify the density of atmospheric minor components such as NO_x and O_3, which affect the atmospheric temperature and dynamical field through chemical reactions, and we organized an international collaborative team to study this topic. We analyzed data from ground-based instruments such as the EISCAT radar and optical cameras and instruments onboard satellites, and presented EPP with the appearance of auroral patches.

9. International collaboration to study thermospheric responses to the substorm onset arc

Auroral morphological and brightness change is regulated by a sequence involving sudden explosive illumination, which is known as auroral substorm onset. The onset triggers energy flow from the magnetosphere to the polar ionosphere, and its dissipation modulates the upper atmosphere. One of the outstanding questions in this field concerns what area receives the energy and how the upper atmosphere changes through this energy input. We analyzed data taken during a coordinated experiment (DELTA-2 in January 2009) with a sounding rocket, the EISCAT radar, a Fabry-Perot interferometer (FPI) and optical cameras. The two wind measurements with the rocket and FPI revealed that, although wind speeds within about 70 kilometers of the auroral arc increased sharply as the substorm gained intensity, winds between 160 and 200 kilometers away from the arc's edge were not affected. This result was published in JGR Space Physics (Oyama et al., 2017), and chosen as an article for the Eos Research Spotlight.



An all-sky image with the breakup aurora (bottom) and a trail of the luminescent puff released from the rocket (top right). Credit: National Institute of Polar Research, Japan.

10. Evaluation of a method to derive ionospheric conductivities using two auroral emissions (428 and 630 nm) measured with a photometer at Tromsø (69.6°N)

We evaluated a photometric method for derivation of ionospheric conductivities based on simultaneous observations by a photometer (field-of-view = ~1.2°), a digital camera, and the EISCAT UHF radar (field-of-view = ~0.7°) operated at Tromsø, Norway (69.6°N, 19.2°E), for two nights on October 10 and 11, 2002. We compared height-integrated Pedersen and Hall

conductivities with a post-integration time of 10 sec derived from EISCAT UHF radar observations and photometer observations with wavelengths of 427.8 and 630.0 nm. In general, good agreement in temporal variations of the height-integrated Pedersen and Hall conductivities was found between EISCAT and photometer values. We conclude that the photometric method using wavelengths of 427.8 and 630 nm can capture temporal variations of the conductivities well, but unavoidable underestimations of the Pedersen (about 30–40%) and Hall (about 50–60%) conductivities are involved.

11. Development of a suprathermal ion energy-mass spectrometer for a Japanese sounding rocket experiment mission to observe the terrestrial polar ionosphere

We performed final calibrations of the suprathermal ion energy-mass spectrometer for the sounding rocket experiment mission (SS520-3) of ISAS/JAXA to observe the terrestrial polar ionosphere, which had an original planned launch window in December, 2017. Using the suprathermal ion beamline at ISEE, at Nagoya University, several ion species (H^+, He^+, N^+, etc.) with energies of 10–500 eV were produced in the ion source and emitted to the spectrometer for checking energy, angle and mass separation resolutions, which were confirmed to be of intended performance. We also carried out simulated solar irradiance tests with deuterium emissions and confirmed that the countermeasure performance for reducing dark count noises caused by solar ultra-violet emissions in the spectrometer was sufficient. (The launch of SS520-3 has been postponed to 2018 because of rocket common bus system problems.)

12. Investigation on mass spectrometry methods for future neutral particle analyzers

We are currently constructing a new type of neutral particle mass/energy analyzer for future terrestrial/planetary upper atmospheric explorations. While we have, thus far, developed the analyzer using a method applying a Bennett type high-frequency mass spectrometer, there are various technical problems in realization. We are therefore investigating the feasibility of an analyzer using a spectrometer with a time-of-flight method through numerical simulations of particle trajectories.

13. Construction of beamline monitoring systems for the developments of future particle analyzers

We are currently constructing beamline systems for calibration of new types of particle analyzers for future terrestrial/planetary upper atmosphere explorations. We have conducted performance tests on the newly developed beamline monitoring system using the beamline facilities in our institute and at ISAS/JAXA, and initial operation tests to obtain two-dimensional cross section profiles of the beam fluxes with compensating time variations through software programing in the system.

14. Data Archives

The following data archives are available to the public:

Database	Web site
OMTIs	http://stdb2.isee.nagoya-u.ac.jp/omti/
GPS scintillation	http://stdb2.isee.nagoya-u.ac.jp/QL-S4/
VHF (30.8 MHz) radar	http://stdb2.isee.nagoya-u.ac.jp/vhfr/
SuperDARN Hokkaido radar	http://cicr.isee.nagoya-u.ac.jp/hokkaido/
210-mm magnetic field data	http://stdb2.isee.nagoya-u.ac.jp/mm210/
ISEE magnetometer network	http://stdb2.isee.nagoya-u.ac.jp/magne/
ISEE VLF/ELF data	http://stdb2.isee.nagoya-u.ac.jp/vlf/
EISCAT radar, Sodium Lidar, MF/Meteor radar, Optics	http:// www.isee.nagoya-u.ac.jp/~eiscat/data/EISCAT.html