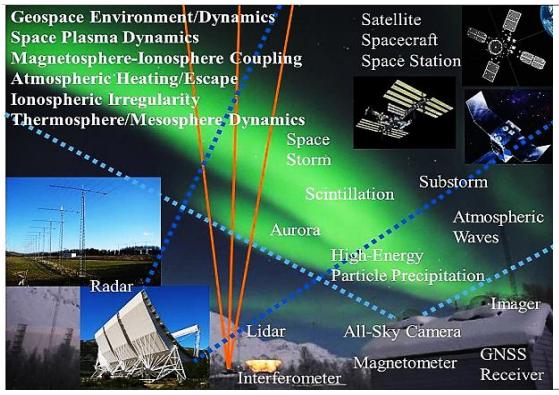
Division for Ionospheric and Magnetospheric Research



- Energy transfer from the solar wind to the magnetosphere and ionosphere
- Magnetosphere-ionosphere-thermosphere coupled system
- Ground-based and network observation
- Space and planetary exploration

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 the 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.

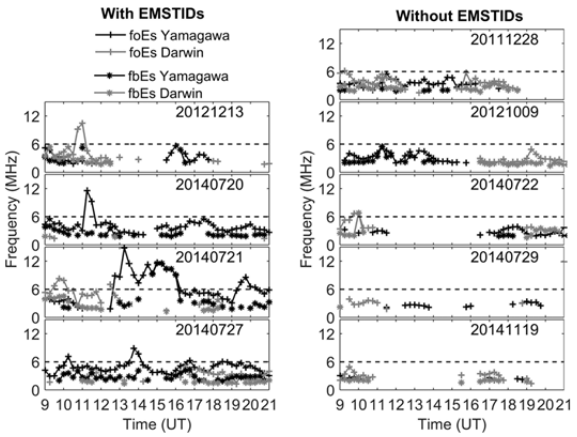
Main Activities in FY2018

PWING Project: Measurements of aurora and electromagnetic waves at subauroral latitudes

The PWING project operates aurora/airglow imagers and electromagnetic wave receivers at eight stations in Canada, Russia, Alaska, Finland, and Iceland around the North Pole at magnetic latitudes of about 60° to investigate the dynamics of plasma and waves in the inner magnetosphere. Various new results were obtained in FY2018. Using this longitudinal network, we found that the Pc1 geomagnetic pulsations (electromagnetic ion cyclotron waves) occur simultaneously over 13-h local times (~200°longitudes) at the arrival of the corotation interaction region (CIR) of the solar wind. We also found using simultaneous measurements by the Arase and Van Allen Probe satellites, that this wave contributes to a rapid loss of radiation belt electrons after the start of a CIR-associated storm.

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 comprise five sky-scanning Fabry-Perot interferometers (FPIs), all-sky charge-coupled device (CCD) imagers, three tilting photometers, and three airglow temperature photometers. Various new results were obtained in FY2018. As an example, we conducted simultaneous measurements of nighttime medium-scale traveling ionospheric disturbances (MSTIDs) and the sporadic *E* layer, as well as thermospheric neutral wind,

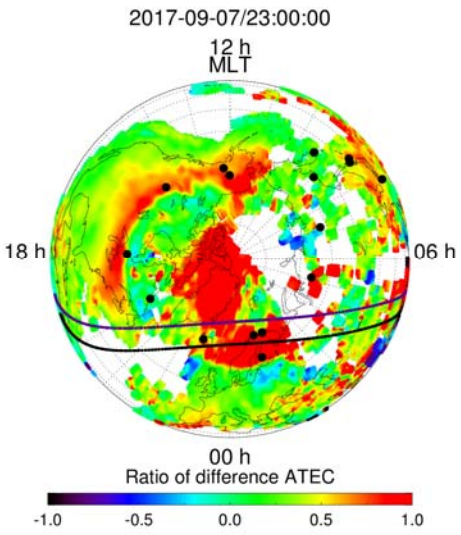


The values of foEs and fbEs, which indicates intensity of the sporadic *E* layer, for the nights with MSTIDs (left, 4 events) and without MSTIDs (right, 5 events). The values of foEs are clearly stronger for the nights with MSTIDs.

using OMTIs and ionosondes at northern and southern hemispheres in Japan and Australia, respectively. We successfully showed that the sporadic *E* layer contributes significantly to the generation of nighttime MSTIDs together with Perkins instability in the ionospheric *F* layer.

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

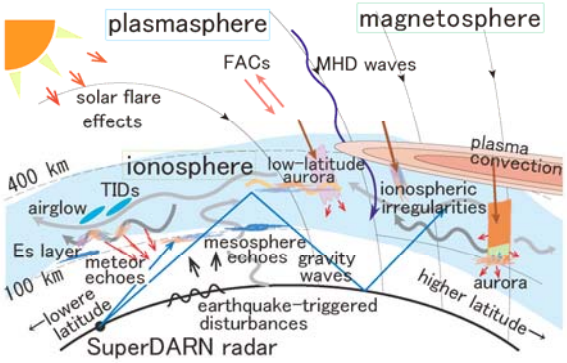
To clarify the characteristics of temporal and spatial variations of the plasmasphere and ionosphere during the development and decay of geomagnetic storms, as well as their physical mechanism, we collected the GNSS data obtained from dense regional GNSS networks extended globally and developed a database of long-term total electron content (TEC) observations, and an analysis tool. The analysis results with these analysis environments showed that an enhanced TEC region appears in the high-latitude regions from noon to afternoon within an hour after the onset of the main phase of geomagnetic storms. The enhanced TEC region expands to lower latitudes as geomagnetic storms develop. This observational fact suggests that the generation mechanism of the storm-time-enhanced TEC region is different from that of Storm Enhanced Density (SED) proposed previously. We also found that TEC perturbations caused by daytime MSTIDs decrease in case of sudden stratospheric warming. This result suggests that daytime MSTIDs can be caused by secondary gravity waves generated by the dissipation of the primary gravity waves in the stratosphere and mesosphere, where the zonal wind is intense.



Global TEC map in the northern hemisphere in geomagnetic coordinates.

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 and geomagnetic activity. We also completed writing a comprehensive review paper on the mid-latitude SuperDARN, which was published in Earth and Planetary Science.



Schematic of natural phenomena that can be studied by SuperDARN radars (from mid-latitude SuperDARN review paper).

Investigation of FACTORS as the next-generation space exploration mission for the space–Earth coupling system

Toward the next-generation space exploration mission, FACTORS, for the space–Earth coupling system after the ERG (Arase) satellite mission led and realized by our institute for the terrestrial radiation belt exploration, we investigated the science subjects, the observational objectives and techniques, and the engineering subjects on the formation flight, the cluster launch method, and the operation of multiple satellites. Through these research activities, the formal working group for FACTORS has been approved and established in ISAS/JAXA.

Innovative design of double-shell-type energy analyzer as a next-generation technical development for *in situ* observations of space plasmas

For the miniaturization and mass reduction of the space plasma energy analyzer, we have been developing a double-shell-type energy analyzer that enables simultaneous measurements of ions and electrons with one sensor head. We designed the shapes of the collimator and the double dome-shaped electrodes so that the electrons and ions with targeted energies could be detected, and conducted numerical simulations to investigate the performance and characteristics of the analyzer. We confirmed that the electrons and ions can be analyzed with the same sensor head by only applying a negative high voltage to the electrodes.

Development of the monitoring system for the beamline calibration systems for particle analyzers in future space exploration missions

In the development of the new particle analyzers for the future terrestrial upper atmosphere explorations, we need to perform calibration tests of the analyzers using indoor beamline calibration systems. In doing so, we are developing a monitoring system for the beamline calibration systems. In this monitoring system, 2D cross-sectional distribution and energy-angle distribution of the ion beam used for the calibration of the particle analyzers can be measured. We performed performance tests of the beamline monitoring system using the beamline owned by our laboratory and acquired a 2D cross-sectional distribution profile and an energy-angle distribution profile.

International collaboration to study impacts of the EPP on 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. We organized an international collaborative team to study this topic, and analyzed data from ground-based instruments such as the EISCAT radar and optical cameras and instruments onboard satellites. For estimating the 2D map of EEP from the optical measurements, we analyzed data from the EISCAT radar and the collocated spectrograph. Then we concluded that the emission line at 844.6 nm would be more suitable for energy estimation than that at 777.4 nm, which might be mixed with other emissions sensitive to higher-energy electrons.

New five-wavelength photometer

A new five-wavelength photometer was developed and installed at the EISCAT Tromsø site (69.6°N, 19.2°E) in January 2017. The photometer consists of two units: an optical unit, and a control unit together with a PC. The photometer can simultaneously observe auroral emissions with five wavelengths. A uniqueness of the present system is its capability of precise pointing, which enables pointing the photometer at the field-aligned position using a star image obtained with a coaxial digital camera. Another uniqueness of the system is its capability of taking data at a sampling rate of 400 Hz. Some preliminary results including correlations between 427.8 and 557.7 nm, 630 nm, 777.4 nm, and 844.6 nm are presented. These comparisons are not significant unless all the five wavelength emissions emanate from exactly the same volume (i.e., magnetic zenith) in the ionosphere, which the present system has.

SDI-3D project: Development of SDI

The scanning Doppler imager (SDI) is a ground-based Fabry-Perot Doppler spectrometer, operating in an all-sky imaging mode with a separation scanned etalon to resolve Doppler spectra at heights of 90–400 km. Even a single

station can estimate the horizontal wind vector and the temperature on the horizontal plane of 500 km diameter. We established an international team in 2018 with researchers of Japan, Scandinavian countries, and US. This team has started the "SDI-3D" project, which aims at developing three SDIs and deploying them in the same area as that for EISCAT_3D, which may start operation in 2022. For progressing this project, an international exchange program (or cross-appointment system) was concluded between the Nagoya University and University of Oulu (Finland) as the first case in Nagoya University. We participated in administrative-level meetings, organized by institutes to integrate the ground-based observation network in the areas of Finland, Norway, and Sweden. We asked them cooperation requests for achieving the SDI-3D project goal and obtained their consent.

Longitudinal structure of oxygen density enhancement in the inner magnetosphere

In the early 1980s, it was discovered that the O^+ density is sometimes enhanced in a limited range of altitude in the deep inner magnetosphere (~10,000- to 30,000-km altitude). This O^+ density enhancement was originally named the oxygen torus, which implies azimuthal symmetry of the density enhancement. However, its longitudinal structure remains poorly known. We investigated the longitudinal structure of the oxygen torus for the first time using simultaneous observations from the Arase and Van Allen Probe A satellites. We found that the oxygen torus does not extend over all longitudes but is localized to the dawn sector, indicating a crescent-shaped torus.

Development of a magnetometer system using Magneto-Impedance sensor

The magneto-impedance (MI) effect was discovered about 25 years ago, and a micro-sized magnetic sensor that utilizes this effect has now become commercially available. We made some modifications to the commercially available MI sensors as they can cover the range of the geomagnetic field. Experimental observations of geomagnetic field variations with the MI sensors were conducted at an observation site. The results showed that the MI sensor recorded geomagnetic variations with amplitudes of ~1 nT, which were also detected with a fluxgate magnetometer. This suggests that MI sensors are useful for researches in geomagnetism or space physics, although they are much less expensive than fluxgate magnetometers.

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
Reimei satellite data	http://reimei.stelab.nagoya-u.ac.jp/