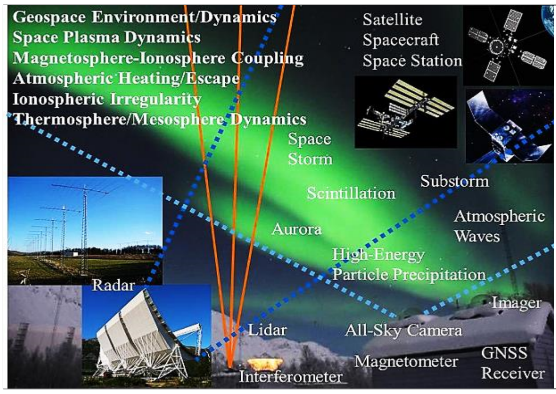
Division for Ionospheric and Magnetospheric Research



- 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 FY2019

Measurements of aurora and electromagnetic waves at subauroral latitudes (PWING Project)

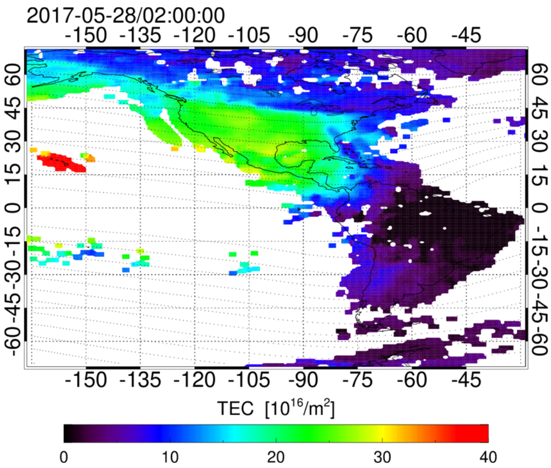
We operate aurora/airglow imagers and electromagnetic wave receivers under the PWING project at eight stations around the north pole, at MLATs of about 60° (in Canada, Russia, Alaska, Finland, and Iceland), to investigate plasma and wave dynamics in the inner magnetosphere. Various new results were obtained in FY2018. Using this longitudinal network, we found that the typical longitudinal extent of magnetospheric ELF/VLF waves is ~80 longitudinal degrees. This finding contributes to our quantitative understanding of high-energy electron acceleration in the radiation belts. By combining these ground-based network stations with the Arase satellite, we also obtain various interesting results in FY2019, including the propagation characteristics of magnetospheric ELF/VLF waves from the magnetosphere to the ground and the relationship between these waves and pulsating aurorae.

Upper atmosphere imaging using the optical mesosphere thermosphere imagers

The optical mesosphere thermosphere imagers (OMTIs) consist of five sky-scanning Fabry-Perot interferometers, 21 all-sky charge-coupled device imagers, three tilting photometers, and three airglow temperature photometers, which are used to investigate the dynamics of the mesosphere, thermosphere, and ionosphere. Various new results were obtained from OMTI measurements in FY2019. As an example, we obtained wavenumber spectra of small-scale gravity waves and medium-scale traveling ionospheric disturbances for more than 10 years, with their seasonal and long-term variations, using airglow images obtained at Magadan (Russia), Athabasca (Canada), Rikubetsu, and Shigaraki (both in Japan).

Ionospheric disturbances using GNSS receiver network

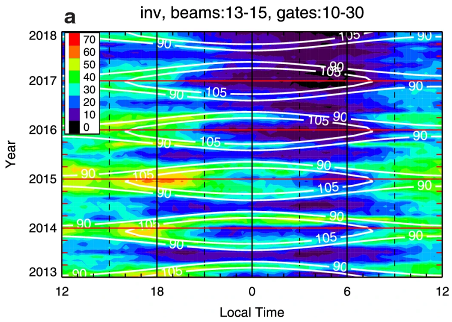
To clarify the characteristics of ionospheric disturbances during geomagnetic storms, we analyzed the total electron content data obtained from dense regional GNSS networks that were extended globally, and found new storm enhanced density (SED) generation characteristics. SED was believed to be generated by plasma transportation from low latitudes to high latitudes. However, we have shown that SED firstly appears at mid-latitudes and then extends to higher latitudes. Furthermore, we found that equatorial plasma bubbles, which are localized plasma depletions, extend to high latitudes, and reach 50 MLAT degrees during geomagnetic storms. These ionospheric disturbances could be caused by eastward electric fields induced during magnetic storm.



Map of Total Electron Content (TEC) during a geomagnetic storm. A plasma bubble can be seen as a TEC depletion extending from the low latitudes to the high latitudes.

SuperDARN Hokkaido HF radars

Using the SuperDARN Hokkaido HF East and West radars at Rikubetsu, Hokkaido, as well as other SuperDARN radars, we studied the statistical characteristics of Medium-Scale Traveling ionospheric Disturbances using the 3D-FFT algorithm, and SAPS occurrence. We also clarified the statistical occurrence characteristics of high-latitude ionospheric irregularities as a function of local time, season and solar activity.



Local time and seasonal distribution of the occurrence rates of ionospheric backscatter echoes in the polar cap region.

Promotion of FACTORS as the next space exploration mission for demonstrative integrated research on the space–Earth coupling system

The new space exploration mission, FACTORS, which is the next ERG (Arase) satellite mission led by our institute for terrestrial radiation belt exploration, is being promoted for simultaneous multi-point observations with multiple satellites in the near-Earth space and the terrestrial upper atmosphere. The following issues were particularly investigated, based on the FACTORS working group activities in ISAS/JASA: the international collaboration of three compact/micro satellite developments, cluster launch configurations for multiple satellites using an Epsilon rocket, and the science targets and observational objectives/techniques of the mission.

Fabrication and initial experimental checks of technical developments in an engineering model of a double-shell type electrostatic energy analyzer for next-generation in-situ observations of space plasmas

For the miniaturization/mass-reduction/power-saving of space plasma energy analyzers and their possible applications in micro-satellites and CubeSat, we completed a detailed design, created an engineering fabrication, and performed initial experimental checks of a double-shell type electrostatic energy analyzer enabling the simultaneous measurement of ions and electrons with one sensor head, using our charged-particle beamline facility. After the mechanical design and fabrication of the double-layered collimator and double-dome electrostatic analyzer, we compared experimental results with those of a numerical simulation and confirmed that the performance requirements and design objectives were almost achieved.

Maintenance of the charged-particle beamline calibration system as the developmental facility for particle analyzers in future space exploration missions

The charged-particle beamline facility was maintained in a clean room of our institute, which is crucial for the development of new particle analyzers for the future geospace and terrestrial upper atmosphere exploration. Following monitoring system developments for two-dimensional cross-sections and energy-angle distributions, we realized the prompt switching between the ion and electron beam emissions, the intensity/cross-section enlargements of the beams, and the electron flux enhancements, by tuning the cubic Helmholtz coils, and calibrating the two-dimensional particle imaging detector.

Promotion of EISCAT and EISCAT_3D projects

We proceeded with the EISCAT project in collaboration with NIPR: (1) we performed nine EISCAT SP experiments for Japanese colleagues; (2) we proceeded with the EISCAT_3D project, the master plan 2020 "Study of coupling processes in the solar–terrestrial system" has been selected as one of the 31 most important big projects; and (3) we had a special session for the master plan 2020 in JpGU2019. We have also operated the sodium LIDAR, a photometer, an MF radar, and a meteor radar in northern Scandinavia, and have collaborated with Japanese and foreign colleagues in studies on atmospheric stability, gravity waves, sporadic sodium layers, and vertical winds.

Oxygen density enhancement and EMIC waves in the inner magnetosphere

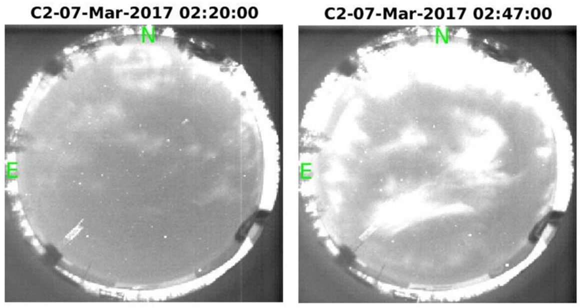
The O^+ density is sometimes enhanced in a limited range of altitudes in the deep inner magnetosphere, and is named the oxygen torus. We investigated the longitudinal structure of the oxygen torus using simultaneous observations from the Arase and Van Allen Probe satellites. We found that the oxygen torus is localized to the dawn sector, indicating a crescent-shaped torus. It was newly found that an electromagnetic ion cyclotron (EMIC) wave in the H^+ band appeared coincidently with the oxygen torus. The linearized dispersion relation for EMIC waves shows that the growth rate increases in the oxygen torus than in the adjacent regions in the plasma trough and the plasmasphere. We conclude that the oxygen torus in the inner magnetosphere may play an important role in the excitation of EMIC waves.

Development of a magnetometer system using a 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 (±70,000 nT). Experimental observations showed that the MI sensors can detect geomagnetic variations with amplitudes of ~1 nT, which were also detected with a fluxgate magnetometer. We developed an instrument for ground measurements including MI sensors, a Raspberry Pi-based data logger, an A/D converter, and so on, which is only ~1/10 of the usual cost of a fluxgate magnetometer. We also developed an onboard instrument for a future sounding rocket.

International collaboration to study the impacts of EEP on atmospheric minor species

Energetic electron precipitation (EEP) can modify the density of atmospheric minor species, such as NO_x and O_3, which affect the atmospheric temperature and dynamical field through chemical reactions. We have 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. This year we analyzed data from the high-speed EMCCD all-sky camera operated by the Japanese team in Sodankylä (Finland) and the meridional chain of the riometer in Finland, to investigate pulsating aurorae and lower ionospheric ionization. We found that the EEP energy flux tends to increase in the lower latitude parts of the pulsating aurora, coinciding with the enlargement and intensification of patch-like pulsating aurorae. This result was presented at the CHAMOS meeting in Finland.



All-sky images taken with the high-speed EMCCD camera operated in Sodankylä, Finland. The aurorae in the left image are characterized by darker and smaller patches than those shown in the right image, which was taken in a period of EEP flux enhancement at lower latitudes in the auroral appearance.

SDI-3D project

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 temperature of a horizontal plane of 1,000-km diameter. In 2018, we established an international team of researchers from Japan, Scandinavian countries, and the US. This team started the “SDI-3D” project, which aims to deploy three SDIs in the same areas as EISCAT_3D, which may be operational in 2022. To progress this project, an international exchange program (or cross-appointment system) was conducted between Nagoya University and the University of Oulu (Finland) in 2018 (a first at Nagoya University), and a faculty member stayed in Oulu for three months in 2019. We officially participated in administrative-level meetings with the MoU, which were conducted by institutes to integrate the ground-based observation networks in Finland, Norway, and Sweden.

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/
Wp geomagnetic index	http://www.isee.nagoya-u.ac.jp/~nose.masahito/s-cubed/