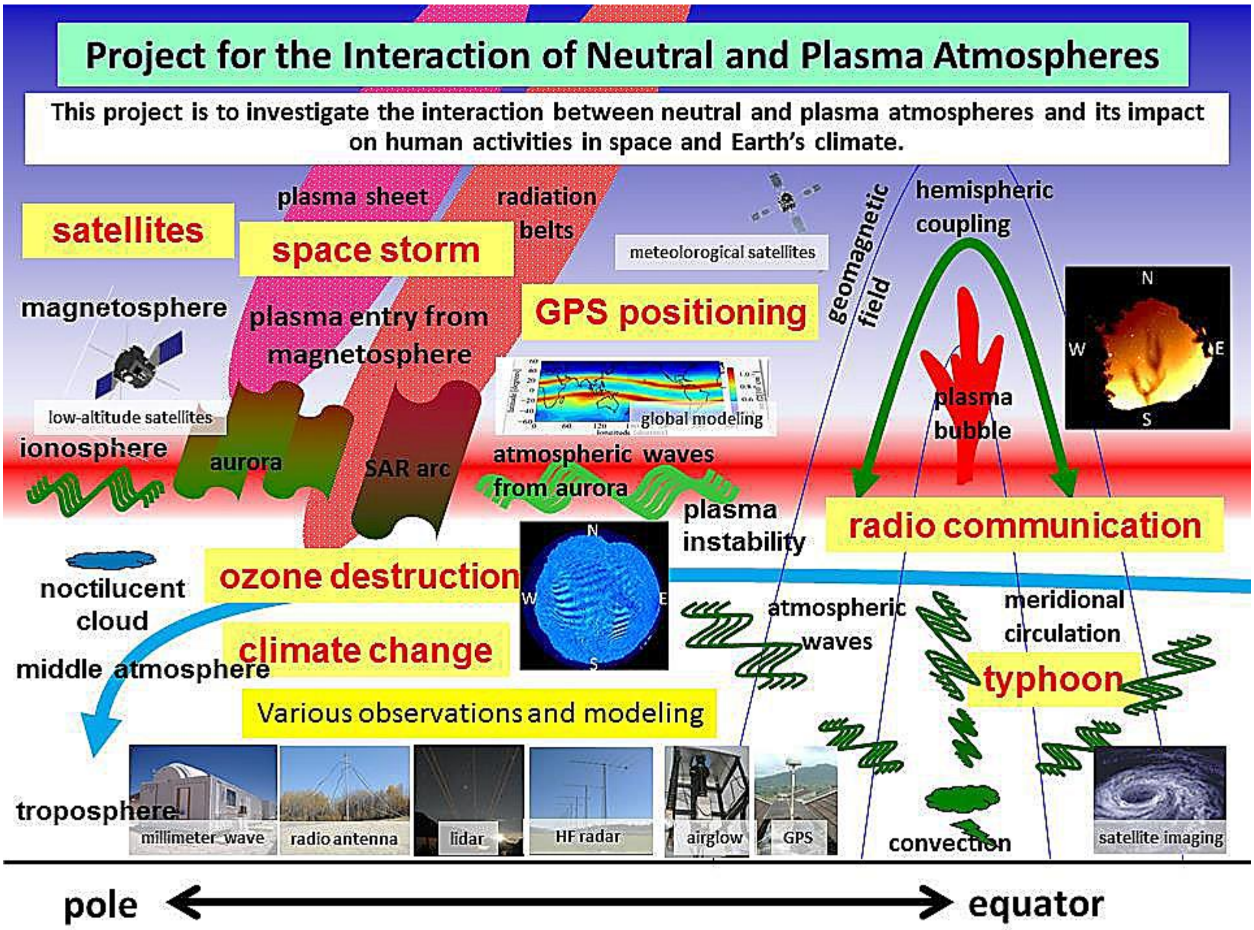
9-3. Interdisciplinary Researches
Project for the Interaction of Neutral and Plasma Atmospheres

Introduction to Project for the Interaction of Neutral and Plasma Atmospheres

The Earth's atmosphere is partly ionized because of solar ultraviolet emissions, forming the ionosphere. Ionospheric plasma affects human activities in space such as radio communications and GPS positioning. The consequences of climate change appear significantly in the upper atmosphere and ionosphere. As shown in the figure below, neutral-plasma interaction processes in the upper atmosphere and ionosphere can be observed as various phenomena occurring from high to low latitudes. The aurora in the polar region is caused by precipitation of high-energy plasma, which heats the upper atmosphere, and generates atmospheric waves and disturbances that propagate toward low latitudes. On the other hand, ionospheric plasma instability, known as plasma bubbles, occurs in the equatorial upper atmosphere, causing interference with satellite-ground communications and GPS positioning. These phenomena can be measured by various ground-based remote-sensing instruments, such as airglow imagers, magnetometers, radars and lidars, and millimeter wave telescopes. This interdisciplinary project investigates the interaction of neutral and plasma components of the Earth's atmosphere using various ground remote sensing techniques and *in situ* satellite measurements, as well as global and regional high-resolution modeling of the neutral-plasma interaction, and contributes to the reliable use of space by humans.



Research topics of the project for the interaction of neutral and plasma atmospheres.

Main Achievements in FY2017

In FY 2017, we operated 12 international collaborative studies, eight domestic collaborative projects, and 22 meetings under ISEE. Various scientific results have been obtained through these collaborative projects.

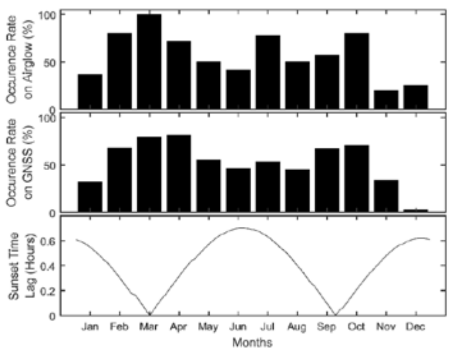
For polar disturbances, we studied the thermospheric wind response to poleward-moving auroral arcs at the beginning of auroral substorms. Using data from a sounding rocket, the EISCAT radar, a Fabry-Perot Interferometer (FPI), and an all-sky camera during the DELTA-2 campaign in January 2009, we found that the thermospheric winds at altitudes of ~120 km are affected by the arc at a distance 70 km from the arc, but not affected 160-200 km away from the arc. This indicates that thermospheric disturbances associated with substorm aurora are localized in a limited region. We also installed a millimeter-wave receiver at Tromsø, Norway, to measure ozone and other atmospheric minor components. Operation of the receiver was stopped on December 2017 due to a fault with the FFT processor. We are repairing this and will recommence continuous observation soon.

Photo of the auroral arc. The auroral Joule heating and Lorentz force cause heating and acceleration of the thermosphere.

The new scientific satellite ERG was launched by ISAS/JAXA in December 2016, to investigate wave-particle interactions between high-energy electrons and ions in the inner magnetosphere. We have conducted several ERG -ground campaign observations in FY 2017. From the combined ground-satellite measurements, including EISCAT and newly installed high-speed EMCCD cameras, we identified precipitation of keV-MeV electrons associated with VLF chorus waves. An ISEE researcher was hired by Oulu University in Finland through a cross appointment, and will conduct collaborative research related to this interdisciplinary project.

It is essential to develop velocity-mass spectrometers for neutral particles and ambient ions to conduct *in-situ* observations of energy transport due to collisions between charged and neutral particles in the terrestrial upper atmosphere and related upper atmospheric variations, which also means that appropriate particle beamlines must be constructed as calibration facilities. We are currently building two types of particle beamline in our laboratory for tests and calibrations across wide energy ranges, corresponding to those of plasma particle measurements in near-Earth space. We developed interface and control software programs, mechanical interface devices and components in vacuum, and conducted initial operations of the beamline monitoring system, to obtain sensor calibration data using the beamline monitoring system for measuring and controlling the beam flux and energy-angle dispersions.

At middle and low latitudes, we have succeeded in obtaining the statistical characteristics of plasma bubble appearance in West Africa using an airglow imager and a GNSS receiver at Abuja, Nigeria. We have also obtained the ionospheric D-region height variation estimated from the cut-off frequencies of a tweek atmospheric in Vietnam and Japan (Sata), and are continuing measurements using 5 FPIs in Norway, Japan, Thailand, Indonesia and Australia. The FPI is unique since it is the only instrument that can monitor winds and temperatures in the thermosphere at altitudes of 200–300 km from the ground through the Doppler shift and the spectrum width, respectively, of airglow emissions. The long-term variation of gravity waves and medium-scale traveling ionospheric disturbances were investigated using 16-year airglow images obtained at Shigaraki, Japan.



Seasonal variation of (top panel) plasma bubble observed in airglow images and (middle panel) scintillation of GNSS radio signal obtained at Nigeria. The bottom panel shows the time difference of sunset between the northern and southern hemispheres in the Nigerian meridian, which affects the occurrence of the plasma bubble.