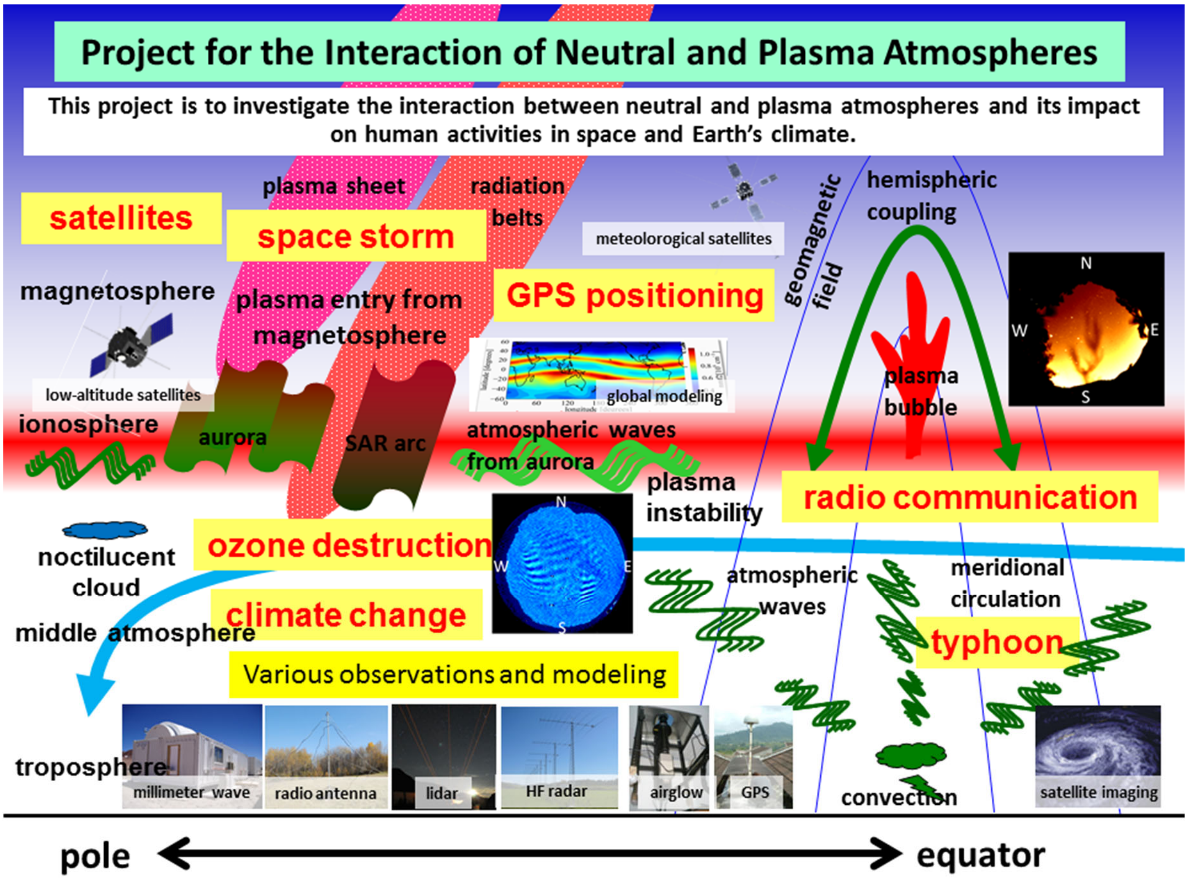
Project for the Interaction of Neutral and Plasma Atmospheres

The Earth's upper 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 significant 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 regions is caused by the precipitation of high-energy plasma, which heats the upper atmosphere and generates atmospheric waves and disturbances that propagate toward low latitudes. However, ionospheric plasma instabilities, known as plasma bubbles, occur in the equatorial upper atmosphere, interfering with satellite–ground communication and GPS positioning. These phenomena can be measured using various ground-based remote-sensing instruments, such as airglow imagers, magnetometers, radars and lidars, and millimeter-wave telescopes. This interdisciplinary project investigates the interactions between the 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 neutral–plasma interactions. The project contributes to the reliable use of space by humans and to our understanding of possible plasma effects on the Earth's climate change.



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

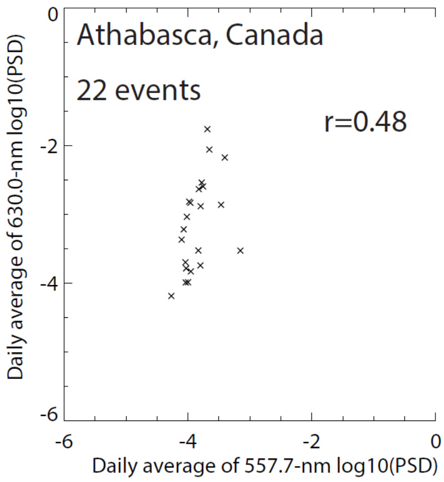
Main Activities in FY2019

In FY2019, we conducted nine international collaborative studies, nine domestic collaborative projects, and 20 domestic meetings under ISEE. Various scientific results have been obtained through these collaborative projects.

Polar aurora as an indicator of plasma–atmosphere interactions (photo taken at Athabasca, Canada on October 4, 2019, during an ERG-ground campaign observation).

As mentioned in the previous paragraph, the interaction of neutral and plasma components is an essential and important issue for understanding the partially ionized atmosphere, or the ionosphere and thermosphere. We are expecting a dramatic improvement in ground-based ionospheric measurement accuracy with the initiation of EISCAT_3D in Scandinavia in 2022. However, as the measurement of neutral components in the thermosphere is theoretically impossible for EISCAT_3D, preparations for diagnosing neutral components or the thermosphere are perceived as an urgent issue. The international project team (SDI-3D: established in 2018 by Japan, the US, Finland, Sweden, and Norway) has made budget requests to deploy three SDIs, which are capable of measuring thermospheric wind vectors and temperatures within 1000 km2. Collaboration between the EISCAT_3D and the three SDIs in Scandinavia will create an ideal environment for studying the coupled polar ionosphere–thermosphere system with state-of-the-art ground-based instruments. We newly developed a multi-frequency millimeter-wave spectrometer to simultaneously observe spectral lines of O_3, CO, NO, NO_2, and HO_2 within a 230–255 GHz range. At the end of FY2020, the new spectrometer was shipped and is now being re-assembled at Syowa station to start steady monitoring of those atmospheric molecules. The new scientific satellite Arase (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 FY2019. From the combined ground–satellite measurements, including EISCAT and newly installed high-speed EMCCD cameras, several interesting results, especially concerning wave–particle interactions, have been reported in various scientific journals, including *Nature*, *Nature Communications*, and *Nature Scientific Reports*. An ISEE researcher was hired by the University of Oulu in Finland through a cross-appointment and will conduct collaborative research related to this interdisciplinary project.

At middle- and low latitudes, various scientific results have been obtained in FY2019, mainly using multi-point ground-based airglow and GNSS observations. As an example, we studied atmospheric gravity waves (AGWs) and medium-scale traveling ionospheric disturbances (MSTIDs) using more than 10 years of airglow images obtained in Canada, Russia, and Japan. We show positive correlations between the power of the AGWs in the mesosphere and MSTIDs in the ionosphere, suggesting the generation of MSTIDs by AGWs from the lower atmosphere A 3-dimensional Fourier analysis of these airglow images also provided wavenumber spectra and their latitudinal, longitudinal, local time, and solar activity dependences in the mesosphere and ionosphere.



Positive correlation between the power of the atmospheric gravity wave in the mesosphere and medium-scale traveling ionospheric disturbances in the ionosphere, obtained at Athabasca, Canada.