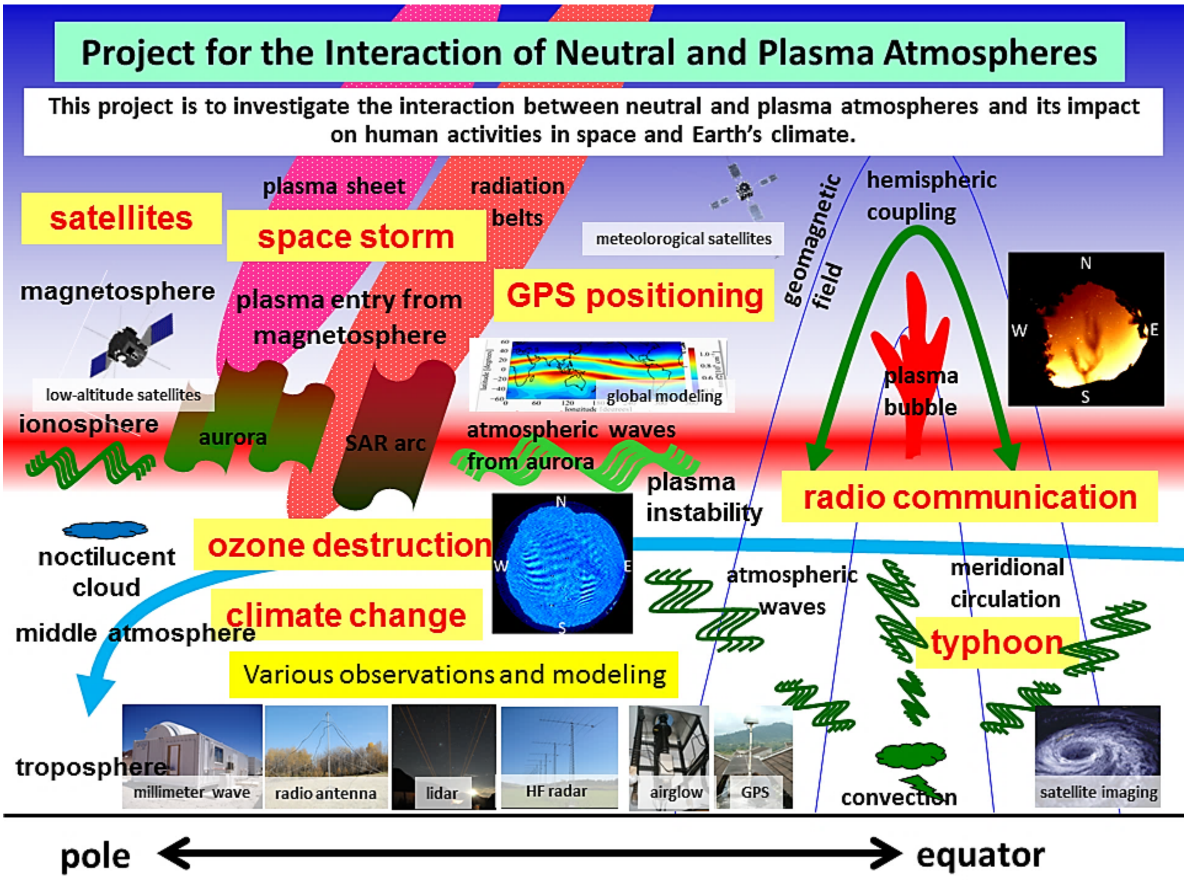
Project for the Interaction of Neutral and Plasma Atmospheres

The ionosphere is part of the Earth's upper atmosphere and is partly ionized by solar ultraviolet emissions. The peak altitudes of plasma density in the ionosphere are 300–400 km, where most low-altitude space vehicles fly. Thus, ionospheric plasma significantly affects human activities in space, such as radio communications and positioning by Global Navigation Satellite System (GNSS). The consequences of climate change are 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 GNSS positioning. These phenomena can be measured using various ground-based remote-sensing instruments, such as airglow imagers, magnetometers, radars, 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, and global and regional high-resolution modeling of neutral–plasma interactions. The project contributes to the reliable use of space by humans and our understanding of possible plasma effects on Earth's climate change.



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

Main Activities in FY2020

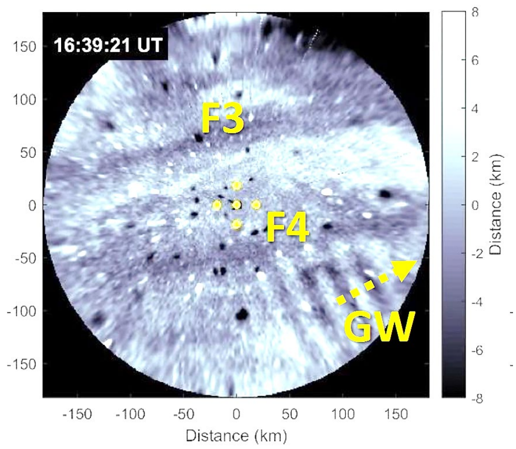
Polar aurora as an indicator of plasma–atmosphere interactions (after Shiokawa et al., 2020).

In FY2020, we conducted 14 international collaborative studies, 13 domestic collaborative projects, and 22 domestic meetings for the ISEE. Various scientific results have been obtained from these collaborative projects.

The interaction of neutral and plasma components is an essential and important issue for understanding the partially ionized atmosphere, ionosphere, and thermosphere. We expect 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, preparation for diagnosing neutral components or the thermosphere is 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 that are capable of measuring thermospheric wind vectors and temperatures within 1000 × 1000 km^2. This proposal was approved by the National Science Foundation in the USA in the summer of 2020. Collaboration between the EISCAT_3D and the three SDIs in Scandinavia will create an ideal environment for studying coupled polar ionosphere–thermosphere systems with state-of-the-art ground-based instruments. We 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 steadily monitor these 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 FY2020. From the combined ground–satellite measurements, including EISCAT and newly installed high-speed EMCCD cameras, interesting results, especially concerning stable auroral red arcs and wave–particle interactions, have been reported in various scientific journals. Collaborative researches have been made with University of Oulu in Finland through a cross-appointment related to this interdisciplinary project.

Using multi-point airglow imaging measurements, exciting scientific outputs were obtained in FY2020. As an example, collaborative measurements of an airglow imager and a sodium lidar were conducted in Tromsø, Norway. The formation of a sporadic sodium layer was observed to be associated with the passage of mesospheric tidal bores in airglow images.



OH airglow images obtained at Tromsø, Norway, on December 19, 2014. North is upward and east is to the right. Northward-propagating east-west tidal bore (F3 and F4) and eastward-propagating gravity waves (GW) are simultaneously observed associated with a sporadic sodium layer appearance measured by a collocated sodium lidar (after Narayanan et al., 2021).