Abstract

Ions in the ionosphere drift through the process of the cross product of the electric and magnetic fields, momentum transfer from neutrals to ions through collisions, and diffusion caused by the pressure gradient mainly along geomagnetic field lines. At high latitudes, the electric field and precipitating particles originated in the magnetosphere significantly affect motions of ions. Motions of ions during geomagnetically active intervals can disturb those of neutrals in the auroral thermosphere through collisions between ions and neutrals. For example, wavelike structures in the motions of neutrals at oscillation periods from a few tens minutes to a few hours are generated by enhancements of plasma flow, or the electric field [*Hunsucker*, 1982 and references therein]. For more than four decades, wavelike structures such as gravity waves in the thermosphere have been the subject of many theoretical and experimental studies on thermospheric and ionospheric motions during auroral activity. There are, however, many unresolved aspects of the wavelike structures in the auroral ionosphere and thermosphere. Two of them are, (1) dynamical coupling of plasma motions and neutral winds in the presence of wavelike structures in short time-scale (10-90 min) in the auroral ionosphere, and (2) relationships between wavelike structures and ionospheric disturbances in association with auroral arcs. We conduct three analyses on these topics using data observed mainly with the European Incoherent Scatter (EISCAT) radar, a scanning Fabry-Perot interferometer (FPI), and an all-sky auroral camera:

- Dynamical coupling between oscillations of ions and neutrals in short time-scale from simultaneous observations between the EISCAT radar and the scanning FPI (λ = 630.0 nm),
- Statistical analysis of the ion velocity, along the geomagnetic field line, observed with the KST (Kiruna-Sodankylä-Tromsø) EISCAT radar and ESR (EISCAT Svalbard Radar),
- Relationship between wavelike structures and ionospheric disturbances in association with auroral arcs using data from simultaneous observations between the EISCAT radar and the all-sky auroral camera.

Field-aligned velocities of ions and neutrals in almost the same volume in the *F*-region have been obtained at the same time with the EISCAT radar and the scanning FPI during the night of 8 February 1997 at Tromsø, Norway. Our observation is the first experiment simultaneously using optical and radio techniques for targeting short-time-scale oscillations of ions and neutrals in the auroral *F*-region. In general, it is difficult to obtain optical data of sufficient quality, but the field-aligned velocities obtained during this campaign have good quality with

time-resolution of about 1.5 min and can be used to investigate dynamical coupling between oscillations of ions and neutrals in short time-scale. The summary of the EISCAT–FPI comparison is that the amplitude and the phase of $U_{//\mathrm{FPI}}$ have been correctly estimated using EISCAT radar data as long as the height range covered by EISCAT radar data in use overlaps the emission layer. It is concluded that the plasma oscillations observed with the EISCAT radar at different heights in the *F*-region are due to the motion of neutrals.

The main conclusion of the statistical study of the field-aligned ion motions using KST radar and ESR data is that diurnal variations in the field-aligned ion motion are likely driven by a large-scale pressure gradient of the temperature of neutrals. Sporadic/burst upward ion motions along geomagnetic field lines are observed during enhancements of southward electric field. Plasma diffusion velocities during large upward ion-motion events are significantly smaller than the magnitude of the observed upward velocity, which suggests that neutral winds in the *F*-region should strongly affect the generation of the large upward ion velocities. However, we do not yet understood the driving mechanisms of those upward ion motions and the relation between motions of neutrals and ionospheric heating caused by enhancement of the electric field.

The simultaneous observations using the EISCAT radar and the all-sky camera were conducted in northern Scandinavia on 1 March 1995 and revealed wavelike structures of the neutral-wind velocity in the auroral *F*-region and ionospheric disturbances in association with auroral arcs. Although we cannot find conclusive evidence that the observed oscillations are gravity waves (GWs), the wave parameters, such as frequency, phase, and wavelength, of observed oscillations are typical of those for medium-scale GWs according to *Hunsucker* [1982]. From the wave parameters, we estimate when and where the observed oscillations have been generated using the dispersion relation for GWs. Around the estimated position and time, the auroral arc extended in an almost zonal direction according to all-sky auroral images obtained at Kilpisjärvi. This implies that geomagnetic activity at high latitudes is important to generate GWs, as indicated by previous theoretical studies.