Abstract

We have investigated three aspects of ion upflow phenomena in order to understand the generation mechanisms of ion upflow. The first step was to investigate the relationship between ion upflow and particle precipitation which is different between several magnetospheric regions. The second step was to investigate the relationship between ion upflow and heating, from the macroscopic point of view. The third step was to investigate the characteristics of naturally enhanced ion-acoustic lines (NEIALs), which may be caused by plasma instabilities and are strongly related to ion upflow from the microscopic point of view.

We have examined the regions where dayside field-aligned (FA) ion upflows occur, based on a statistical analysis using approximately 170 simultaneous events between the EISCAT Svalbard radar (ESR) and the DMSP satellites. This systematic analysis for ion upflow has never been examined. We found that ion upflows occur not only in the cusp and cleft (the low-altitude portion of the low-latitude boundary layer (LLBL)) which have been considered as ion upflow regions, but also in the topside ionosphere connected to the mantle region. Ion upflows seldom occur either in the Boundary Plasma Sheet (BPS) or in the Central Plasma Sheet (CPS) in the dayside high latitudes. Almost all of the events in which the average FA ion velocity is more than 100 m s^{-1} are associated with sufficient soft electron precipitation (differential energy flux of electrons at 100 eV > 10^7 eV cm^{-2} s^{-1} sr^{-1} eV^{-1}). Although soft electron precipitation also sufficiently exists in the BPS, the ion velocities are mostly less than 100 m s^{-1}. The present results indicate that soft particle precipitation is the predominant energy source driving ion upflow in the topside ionosphere, but it works on ion upflow effectively in the higher latitude regions in the dayside and not in the BPS.

Plasma heating associated with FA ion upflow in the dayside topside ionosphere has been presented using data obtained simultaneously with the ESR and the EISCAT VHF radar. The FA ion upflows observed at an altitude of 665 km in the dayside cusp are associated with significant anisotropy of ion temperature, isotropic increases of electron temperature and enhancements of electron density. The anisotropy factor reaches maximum values of 1.7. There is no clear correspondence between the enhancements of the electric field strength and

the occurrence of the ion upflows. This is the first experiment to point out ion anisotropy independent of frictional heating. The ion upflow associated with perpendicular heating seems to closely correspond to NEIALs, because the FA ion velocity immediately changed around strong NEIALs.

The wave number (*k*)-dependence of the received power in high signal-to-noise ratio (SNR) conditions, occurring for NEIALs and for real satellites, has been investigated. These analyses help to specify generation mechanisms of NEIALs. In the case of NEIALs, we found that variations of the relative power between channels well above both the estimated and expected 1-sigma level occur over a signal pre-integrated profile, and a few profiles where the power radiated by NEIALs varies systematically with wavelength/wave number (*k*). This feature of NEIALs does not seem to be caused by the ESR system. Furthermore, power differences along one profile with NEIALs are obviously different from those of echoes from satellites at a similarly high SNR. The most plausible explanation we can suggest is that the *k*-dependence of the power in NEIAL events has its origin in the scattering medium itself. The frequency dependence of the power in NEIAL events and the characteristics of the enhanced peak heights can be well explained by the parametric decay of Langmuir waves [*Forme et al.*, 2001].

The results from these three investigations lead to the conclusion that the energy of soft electron precipitation is considered as the main source of the ion upflow. The energy of soft particle precipitation is supplied to the ions in the topside ionosphere via wave-particle interaction, such as wave-induced transverse ion heating, and upward parallel electric field due to anomalous resistively produced by plasma turbulence. Thus generation mechanisms of ion upflow must have the transversely ion heating and the upward acceleration by wave-particle interaction while the induced plasma waves decay. In addition to direct precipitation effects, namely enhanced ambipolar diffusion and heat flux, wave-particle interaction may hence play an important role in driving ion upflow.