Consideration of thermal ion upflow and outflow in the polar ionosphere

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Thermal ion upflow/outflow from the polar ionosphere has been observed for the last two decades by several satellite and radar measurements, and is classified into several categories. The polar wind outflow observed at 1 Re is known to be exceeding typically the escape velocity and moving toward the geomagnetic tail region, while in case of the auroral bulk upflow existing at low altitudes, the dominant O+ ions are gravitationally bound. We discuss an evolution of the ion upflow/outflow from low to high altitudes in the polar ionosphere by doing numerical calculation of the ion drift velocity with measured plasma temperature and density based on the momentum and continuity equations.

Thermal ion upflow/outflow from the polar ionosphere has been observed for the last two decades by several satellite and radar measurements, and is classified into several categories; polar wind, auroral bulk upflow, ion beam, conics, transversely accelerated ions and upwelling ions etc., in terms of the existing location and characteristic pitch angle/energy distribution.

The polar wind outflow such that the Akebono satellite observes at 1 Re is known to be exceeding typically the escape velocity and moving toward the geomagnetic tail region without an additional acceleration process, while in case of the auroral bulk upflow existing at low altitudes, a great part of the dominant O+ ions are gravitationally bound in the absence of further energization at higher altitudes. This scenario is empirically confirmed when one considers that the averaged ion flux of the auroral bulk upflow is approximately a factor of 10 larger than that of the polar wind.

It is not quite established what kind of acceleration process plays the important role in transporting the low-altitude upflow such as the auroral bulk upflow into the high-altitude regions where the escape velocity is attained. When one assumes that thermal ions are simply accelerated by the ambipolar electric field, the ion velocity parallel to the magnetic field can be estimated by the vertical gradient of plasma pressure. In other words, the velocity of upflowing ions can be obtained from the vertical distribution of temperature and density for electrons and ions. We discuss an evolution of the ion upflow/outflow from low to high altitudes in the polar ionosphere by doing numerical calculation of the ion drift velocity with measured plasma temperature and density based on the momentum and continuity equations. The result shows that the measured drift velocity is in good agreement with that estimated from the measured plasma temperature and density, which is an evidence that the ambipolar electric field is the important process for accelerating thermal ions at low-altitude polar ionosphere. This also suggests that the faster drifting ion upflow which is accelerated by larger electric field on the relatively steep gradient of the plasma pressure can reach higher altitudes and constitute a significant component of the ion outflow.