Solar zenith angle dependence of composition, velocity and temperature of ion outflows

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Recent satellite observations and simulations have clarified that (especially O^+) ion outflows from the ionosphere play an important role in abrupt changes in the ion composition in the plasma sheet and ring current during geomagnetic storms. The energy of outflowing ions is an important factor to understand the transport path of the ions to the magnetosphere. To clarify how strongly ionospheric conditions (sunlit or dark) affect ion outflows, we investigated solar zenith angle (SZA) dependence of composition, velocity and temperature of outflowing ions above 10 eV using the data obtained by the FAST satellite at 3000-4150 km altitude from 7 January 1998 to 5 February 1999.

We discriminated ion beam events from non-beam (related to transverse heating) events, and studied separately. At this altitude range, almost all of beam events were observed under ionospheric dark conditions. For the beam events, the O^+/H^+ flux ratio does not depend on SZA (average: ~0.25), while the flux ratio decreases with increasing SZA for the non-beam events. Since the flux ratio of ion beams reflects the ion composition at the lower end of the auroral acceleration region, the averaged flux ratio indicate the typical ion composition at the lower end of the auroral acceleration region. The ion composition below ~3000 km is probably not suitable to develop the auroral acceleration region under sunlit conditions.

For the non-beam events, the parallel streaming energy and temperatures (perpendicular and parallel) of ions tend to increase with increasing SZA. This result indicates that the solar illumination affects energization of outflowing ions at least below 3000 km altitude. Under dark conditions, the parallel streaming energy and the parallel temperature of ions in the non-beam events often exceeded ~10 eV, while those rarely exceeded 10 eV (~1 eV in most of cases) under sunlit conditions. The perpendicular ion temperature in the non-beam events was mostly ~10-30 and ~15-200 eV under sunlit and dark conditions, respectively. Our previous study showed that ion outflows (especially O^+) with large fluxes, which would have a large impact for the magnetospheric physics, occur mostly under sunlit conditions. Thus, the solar illumination enables the ionosphere to cause ion outflows with large fluxes, while it would suppress energization of ions at least below ~3000 km altitude.

Additionally, we found that the outflowing ion number flux positively correlates with the parallel streaming energy of ions under sunlit conditions, while no clear correlation between the outflowing ion number flux and perpendicular or parallel ion temperatures. Thus, it is expected that there is a physical connection between the parallel streaming energy and the ion number flux under sunlit conditions, and it is important to clarify how the ions gain the parallel streaming energy (~several eVs) below ~3000 km altitude for understanding of the driving mechanism of ion outflows with large fluxes. Weak parallel electric fields and/or perpendicular heating at low altitudes in the cusp/cleft and the auroral zone would be the candidate. Since the parallel streaming energy is very small (below ~10 eV), detailed ion measurements that include the energy range below ~10 eV are essential in future for further investigation at least below ~3000 km altitude.