電離圏起源イオンの磁気圏大循環

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Synthetic understanding of global circulation of ionospheric ions

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Outflows of ionospheric ions contribute mass, momentum and energy to the magnetosphere. Observational evidence indicates that the magnetospheric pressure can be dominated by singly charged oxygen ions of ionosphere origin during large magnetic storms when outflow rate is high and the convection electric field is strong enough, while the pressure consists mostly of protons during quiet periods. The pressure is responsible for the magnetic inflation and generation of field-aligned currents. Changes in the magnetospheric ion composition also alter significantly EMIC wave growth. The EMIC wave is known to be an important source for pitch angle scattering of 1-2 MeV electrons. To understand the magnetosphere-ionosphere coupling from the plasma circulation point of view, it is necessary to consider basic processes regarding outflows, transport and acceleration of the ionospheric ions. We investigated the ultimate fate of outflowing suprathermal ions that originate from the polar ionosphere by launching ions from various physical and velocity space regions. The tracing was performed in empirical electric and magnetic fields until the ions reach one of the four boundaries; the magnetopause, the distant tail, the ring current region (L-shell of 5), and the atmosphere. An empirical model of the outflowing ions based on 11-year data from Akebono/SMS enables us to calculate quantitatively number of ions that reach each of the destinations. Input parameters of this model are invariant latitude (ILAT), magnetic local time (MLT), altitude, Kp, sun spot number and day of year. Output of this model is the density, temperature and parallel velocity of H+, He+ and O+. After incorporating the empirical model with the particle tracing, we found that the final destination depends crucially on the initial velocity, pitch angle, ILAT, MLT, Kp and sun spot number, as well as magnetic configurations and the convection electric field in the magnetosphere. For a given ionospheric condition, we found that when the near-earth magnetic field is dipolar, only 10-30 % of outflowing O+ ions reach the ring current region. When the near-earth magnetic field becomes tail-like, 40-60 % of them reach the ring current region and contribute to an enhanced ion flux distribution in the ring current region, which is similar to the observation in terms of a spectral shape. However, a crude estimation indicates that the calculated differential flux in the ring current region is much smaller than observed by a factor of 400. More robust modeling efforts together with precise and direct observation of the ion composition near the earthward boundary (such as Akebono and ePOP) and in the heart of the ring current (such as ERG, RBSP and Orbitals) will resolve the discrepancy and improve our understanding of the ionosphere-magnetosphere coupling.