



Differential Transport of Nitrogen and Oxygen Ions from the Terrestrial Ionosphere to the near-Earth Region

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The presence of heavy ions has a profound impact on the temporal response of the magnetosphere to internal and external forcing, and plays a key role in plasma entry and transport processes within the terrestrial magnetosphere.

Numerous studies focused on the transport and energization of O^+ through the ionosphere-magnetosphere system; however, relatively few have considered the contribution of N^+ to the near-Earth plasma, even though past observations have established that N^+ is a significant ion species in the ionosphere and its presence in the magnetosphere is significant. In spite of only 12% mass difference, N^+ and O^+ have different ionization potentials, scale heights and charge exchange cross sections. The latter, together with the geocoronal density distribution, plays a significant role in the formation of ENAs, which in turn controls the energy budget of the inner magnetosphere, and the overall loss of the ring current. Therefore, the outflow of N^+ from the ionosphere, in addition to that of O^+ , affects the global structure and properties of the current sheet, the mass loading of the magnetosphere, and it leads to changes in the local properties of the plasma, which in turn can influence waves propagation.

This study involves an integrated computational view of geospace, that solves and tracks the evolution of all relevant ion species, to systematically assess their regional and global influence on the various loss and acceleration mechanisms operating throughout the terrestrial magnetosphere. We employ the newly developed Seven Ion Polar Wind Outflow Model (7iPWOM), which in addition to tracking the transport of H^+ , He^+ and O^+ , now solves for the heating and transport of N^+ , N_2^+ , NO^+ and O_2^+ in Earth's polar wind. The 7iPWOM is coupled with a two-stream model of superthermal electrons (GLObal airglow, or GLOW) to account for the attenuated radiation, electron beam energy dissipation, and secondary electron impact. We show that during various solar conditions, the polar wind outflow solution using 7iPWOM improves significantly when compared with OGO observations.

In addition, numerical simulations using the kinetic drift Hot Electron Ions Drift Integrator (HEIDI) model suggest that the contribution of outflowing N^+ to the ring current dynamics is significant, as the presence of N^+ alters the development and the decay rate of the ring current. Electron transfer collisions are far more efficient at removing N^+ the system, compared with the removal of O^+ ions. Synthetic TWINS-like mass separated ENA images show that the presence on nitrogen ions in the ring current, even in small amounts, significantly alters the ENA fluxes, and the peak of oxygen ENA fluxes can vary for up to an order of magnitude, depending on the magnetosphere composition. These findings can explain recent observations of faster than expected decay of high energy oxygen ions, as measured by the RBSPICE instrument on board of the Van Allen Probe spacecraft. We speculate that the abundance of oxygen has been mis-estimated, as it is likely that some of the oxygen measurements to actually be include comparable abundances of nitrogen ions.