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Jay R. Johnson,
Andrews University, United States

*CORRESPONDENCE
M. Fraz Bashir,
frazbashir@epss.ucla.edu

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Editorial: Circulation of heavy ions and their role in regulating the near-earth plasma dynamics

M. Fraz Bashir[1]*, Elena Kronberg[2] and Lunjin Chen[3]

[1]Earth, Planetary, and Space Sciences, University of California, Los Angeles, Los Angeles, CA, United States, [2]Geophysics, Department of Earth and Environmental Sciences, University of Munich, Munich, Germany, [3]Department of Physics, University of Texas at Dallas, Richardson, TX, United States

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Editorial on the Research Topic
Circulation of heavy ions and their role in regulating the near-earth plasma dynamics

In recent years, the study of heavy ions in Earth's magnetosphere-ionosphere (M-I) system has gained increasing attention within the scientific community, for its profound impact on the dynamics of near-Earth space. The research, inspired by sessions at the American Geophysical Union Fall meetings in 2020–2023, has sparked a wave of new studies focusing on the circulation of heavy ions and their significant role in shaping near-Earth plasma dynamics.

The importance of this research lies in understanding the composition of ions, their sources and sinks, and how these factors regulate various magnetospheric processes. The studies span observational, theoretical, and modeling approaches, aiming to distinguish the ionospheric and solar wind sources of ions across different charge states and compositions. This editorial synthesizes insights from five recent papers that contribute to this burgeoning field.

Firstly, Godbole et al. reported observations from Poker Flat, Alaska, providing insights into ion upflow during pulsating aurora events. The study highlights the role of soft electron precipitation in generating 630.0 nm auroral emission, a less commonly observed phenomenon as observations of pulsating aurora are typically reported at 557.7 and 427.8 nm. These observations underscore the importance of ambipolar electric fields in contributing to ion outflow, a key factor in understanding heavy-ion circulation in the M-I system.

Secondly, Borovsky performed an analysis using the Tsyganenko T96 magnetic-field model revealing that the atmospheric loss cone for energetic particles in the magnetosphere is shifted due to finite-gyroradii effects. This shift leads to stochastic scattering of particles, notably protons and oxygen ions. This finding is crucial for ring current ion losses and the results of this study suggest a robustly shifted loss cone and stochastic scattering even in the dipolar magnetosphere which particularly impact the dynamics of the ring-current ion population.

Thirdly, Denton et al. developed analytical models of magnetospheric mass density and average ion mass up to L-shell equal to 10, using data from six spacecraft missions. The models, which factor in solar and geomagnetic conditions, emphasize the significance of various parameters, including solar EUV index, geomagnetic activity index, and solar wind dynamic pressure. This research offers a comprehensive understanding of mass density distribution and provides the magnetospheric community the models for quantifying heavy ion distribution under different solar and geomagnetic conditions that can be easily interpreted and used.

Fourthly, a review of nitrogen ion (N+) observations by Ilie et al., ranging from early low-altitude measurements to recent data from the Enhanced Polar Outflow Probe mission, sheds light on the presence of nitrogen ions alongside oxygen ions in the near-Earth plasma. This review calls for reevaluating the ionic composition in the ionosphere-magnetosphere system and cautions against oversimplifying interpretations of O+ measurements from current missions.

Lastly, Kozak et al. presented a study utilizing data from the Cluster-II mission examining the dynamics of ion fluxes and magnetic field changes in turbulent magnetotail dipolarizations. This study reveals that CNO + ions undergo more significant acceleration during dipolarization than protons and helium ions. This finding improves our understanding of the particle energization mechanisms in near-Earth space. The energetic particles can, for example, affect the plasma pressure and, therefore, the dynamics of the ring current dynamic.

In conclusion, these recent studies underscore the complexity and significance of heavy ions in regulating the near-Earth plasma dynamics. The collective efforts in this Research Topic pave the way for advanced understanding and modeling of heavy-ion circulation, influencing future spacecraft mission concepts and measurement techniques. As the scientific community continues to explore this Frontier, the insights gained will undoubtedly advance our knowledge of Earth's space environment and have broad implications in solar, ionospheric, and magnetospheric physics.

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