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Editorial: Cold-ion populations and cold-electron populations in the Earth's magnetosphere and their impact on the system

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Editorial on the Research Topic
Cold-ion populations and cold-electron populations in the Earth's magnetosphere and their impact on the system

This Research Topic is the offshoot of an on-line workshop "*The Impact of Cold-Plasma Populations in the Earth's Magnetosphere*" that was held September 28—2 October 2020. The workshop was originally scheduled as an in-person meeting for June 1–4, 2020 in Los Alamos, New Mexico, United States. A growing realization of the importance of cold electrons in the Earth's magnetosphere-ionosphere system led the Research Topic Editors to change "cold plasma" to "cold ions and cold electrons" when creating the title of this Research Topic. The Research Topic highlighting illustration appears in Figure 1.

There are several "cold" populations of ions and electrons in the Earth's magnetosphere, where "cold" indicates low energy. The cold populations have temperatures that are typically less than a few-hundred eV, and often as low as 1 eV and less. Cold-ion populations and cold-electron populations are extremely difficult to measure in the Earth's magnetosphere, and their properties, evolutions, and controlling factors are poorly understood (cf. Delzanno et al., 2021). They are sometimes referred to as the "hidden populations" (Olsen, 1982), but they are known to have multiple impacts on the behavior of the global magnetospheric system. These impacts are extensively reviewed in Delzanno et al. (2021): they include (a) the reduction of the dayside reconnection rate and consequently the reduction of solar-wind/magnetosphere coupling, (b) alteration of the growth rate and saturation amplitudes of plasma waves resulting in alterations of the energization rates of the radiation belts, (c) changes in plasma-wave properties resulting in changes in the loss rates of the ring current and radiation belts, (d) changes in the mass density of the magnetosphere resulting in changes in ULF waves and the radial diffusion of the radiation belts, (e) increases of the mass density in the magnetosphere which increases the growth rate of Kelvin-Helmholtz waves on the magnetopause, (f) spatial and temporal structuring of the aurora, (g) altering magnetotail reconnection, (h) changing spacecraft charging, and (i) acting as sources for warm and hot magnetospheric populations.

This Research Topic contains 17 papers that are a combination of Original Research articles, Review articles, and Perspective articles addressing a wide variety of cold-ion

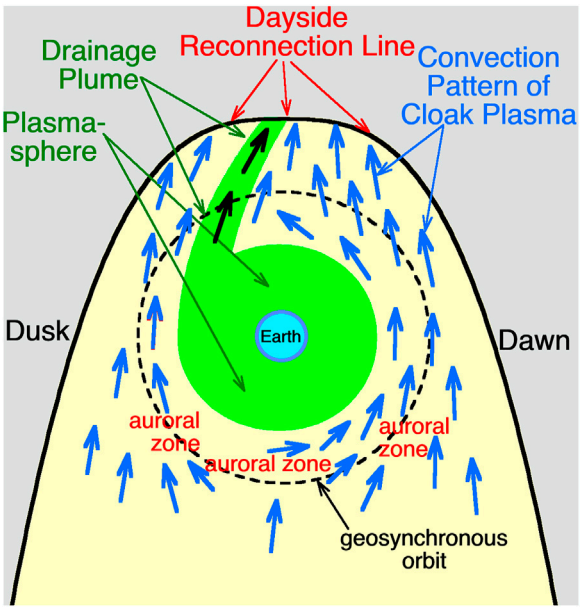

FIGURE 1
A sketch of some of the low-energy populations in the equatorial plane of the magnetosphere during geomagnetically active times. Indicated in green is the plasmaspheric drainage plume flowing into the dayside reconnection line and indicated in blue is the warm plasma cloak flowing into the dayside reconnection line. Geosynchronous orbit is indicated as the dashed black circle.

and cold-electron Research Topic for magnetospheric physics. The 17 papers address the sources of the cold-particle populations, the cold-particle impact on the operation of the magnetosphere-ionosphere system, and measurement techniques for cold electrons and cold ions.

The production of cold-ion populations in the magnetosphere is addressed in a number of papers. Li et al. examine extensive plasma-wake observations of ion outflows from the high-latitude ionosphere into the magnetosphere. Krall and Huba examine the effect of the neutral upper atmosphere's thermal composition and winds on the ion outflow from the ionosphere into the magnetosphere. Borovsky et al. present calculations of the production rates of cold protons in the magnetosphere directly from physical processes ionizing the Earth's cold neutral-hydrogen geocorona.

The properties of cold-particle populations in the Earth's magnetosphere were addressed in several of the Research Topic papers. Lin and Ilie looked at the properties of various molecular-ion populations in the magnetosphere, populations that may be important during times of high geomagnetic activity. Foster and Erickson examined warm and hot oxygen ions in the vicinity of the dayside plasmaspheric drainage plume with implications for localized oxygen outflow from the ionosphere. Takahashi and Denton reviewed critical magnetoseismic observations of the mass densities of ion populations in the magnetosphere; these mass densities impact the properties of ULF waves and can be responsible for mass loading dayside reconnection. Pierrard et al. reviewed improved models of the plasmasphere in the inner magnetosphere: such plasma models are important for the modeling plasma waves in the magnetosphere. Ripoll et al. (2023) reviewed a variety of electron-density models for their usefulness to radiation-belt physics. For cold electrons, Peterson discussed rare measurements of low-energy electrons in the magnetosphere that originated from the ionosphere/atmosphere and elucidated some of the complexities of understanding low-energy-electron dynamics.

Pertaining to the evolution of cold ions in the Earth's magnetospheric system, Usanova reviewed the energy exchange between cold-ion populations and hot-ion and hot-electron populations *via* electromagnetic ion-cyclotron (EMIC) waves and the resulting heating of the cold ions. Chappell et al. reviewed the evolution of cold ions of ionospheric origin becoming critical hot-ion populations in the magnetosphere, in comparison with the more-often-considered solar-wind ion sources of magnetospheric ions.

The physical interactions in the magnetospheric system impacted by cold populations were examined by several papers. Lee et al. reviewed several new results pertaining to EMIC waves and the observed populations of cold ions in the magnetosphere. Norgren et al. investigated the impact of cold ions on magnetic reconnection processes and the properties of cold ions in the outflow jets of reconnection. Li et al. investigate observations of field-aligned beams of cold ions in magnetotail reconnection outflows where the cold ions entered into the outflow jets.

The structuring of the nightside pulsating aurora by structure in the cold plasma of the nightside magnetosphere was reviewed by Liang et al. and the structuring of the dayside diffuse aurora by structure in the cold plasma of the dayside magnetosphere was reviewed by Han.

Finally, Maldonado et al. review measurement techniques for cold ions and cold electrons used in the past and outline innovative methods that could be used in the future.

Author contributions

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

References

Delzanno, G. L., Borovsky, J. E., Henderson, M. G., Resendiz Lira, P. A., Roytershteyn, V., and Welling, D. (2021). The impact of cold electrons and cold ions in magnetospheric physics. *J. Atmos. Sol. Terr. Phys.* 220, 105599. doi:10.1016/j.jastp.2021.105599

Olsen, R. C. (1982). The hidden ion population of the magnetosphere. *J. Geophys. Res.* 87, 3481–3488. doi:10.1029/JA087iA05p03481

Ripoll, J.-F., Pierrard, V., Cunningham, G. S., Chu, X., Sorathia, K., Hartley, D., et al. (2023). Modeling of the ele tron plasma density for radiation belt physics. *Front. Astron. Space Sci.* 2023, 1096595. doi:10.3389/fspas.20XX.744344