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Editorial: Space weather: magnetosphere ionosphere thermosphere (M-I-T) coupling

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Editorial on the Research Topic
Space weather: magnetosphere ionosphere thermosphere (M-I-T) coupling

The solar wind continuously interacts with Earth's near-space environment. A southward turning of the interplanetary magnetic field (IMF) Bz facilitates efficient energy transfer from the solar wind into the Earth's magnetosphere-ionosphere system, driving large-scale variations in plasma flows and electric currents. The magnetospheric/ionospheric currents and electric field variations lead to significant temporal and spatial disturbances in ionospheric dynamics at high latitudes. The high-latitude ionospheric disturbances propagate to mid- and low-latitude through global current systems, electric fields, and traveling atmospheric disturbances that impact the ionosphere-thermosphere dynamics. Therefore, the Magnetosphere-Ionosphere-Thermosphere (M-I-T) is a highly coupled and complex system.

A comprehensive understanding of the M-I-T system is essential for improving the reliability and safety of both ground- and space-based technological assets, navigation and communication systems. The Research Topic *"Space Weather: Magnetosphere-Ionosphere-Thermosphere (M-I-T) Coupling"* brings together studies that advance our understanding of the fundamental physical processes governing the M-I-T system under both quiet and disturbed space weather conditions.

Articles published in this Research Topic span topics such as the reduced geoeffectiveness of solar cycle 24, geomagnetic storm- and substorm-driven changes in ionospheric electrodynamics at low latitudes, the impact of solar flares on the ionospheric D-region, the relationship between STEVE and SAID, the automatic detection method and occurrence pattern of spread-F, direct observations of the effects of interplanetary shock impact angle on Geomagnetically induced currents (GICs), and the feasibility of using Total Electron Content (TEC) for predicting seismic activities. Brief highlights of each publication are provided below:

Fejer et al. reported unusually strong electrodynamic responses over the equatorial ionosphere during the 23–24 April 2023 geomagnetic storm. Plasma drift changes were driven by multiple processes during the storm. Nighttime observations showed large substorm-driven prompt penetration drifts superimposed on undershielding upward drifts. The observations of unusually large drifts and strong spread-F are not well reproduced by existing models. The study suggests considering the history of geomagnetic activity and incorporating improved magnetospheric convection models for better predictions of global ionospheric responses to magnetic storms.

Shipra et al. compared solar flare-associated cosmic noise absorption (CNA) at Maitri (Antarctica) and Abisko (Arctic) stations. The study examined the D-region ionospheric response to M- and X-class solar flares during 2014. Results show that solar flare-associated CNA (SCNA) strongly depends on solar zenith angle and flare intensity. A hemispheric asymmetry in SCNA was observed at similar latitudes and attributed to enhanced background ionization from prior particle precipitation. The study shows that to understand SCNA behavior at high latitudes, one needs to consider flare intensity, solar zenith angle, latitude, background ionospheric conditions, and radio wave frequency.

Oliveira et al. reported the first direct observations of interplanetary shock impact angle effects on GICs. The analysis involved 332 events from a dataset of over 600 shocks and examined their impact on GIC measurements from the Finnish natural gas pipeline system. Results show that moderate GIC peaks (>5 A) following shock impacts are associated with frontal shocks, likely driven by partial ring current intensifications in the dusk sector. However, intense GIC peaks (>20 A) occur several minutes later and are driven by energetic particle injections from the magnetotail, commonly associated with substorms.

Macho et al. investigated the relationship between STEVE and SAID during three events. Utilizing multi-instrument observations, the study verified the correlation between STEVE and SAID, as well as the temporal variation of SAID observed during STEVE events. Results show that SAIDs start before STEVE events, and SAIDs normally end during the maximum brightness of STEVE events.

Bhaneja et al. presented statistical analysis of F-region plasma irregularities (spread-F) over the low-latitude ionosphere. A new automated method using pattern recognition and edge detection was developed to identify spread-F conditions over the American, Atlantic, and Pacific sectors. Results show that low-latitude spread-F events occur during both solar minimum and maximum in all three sectors, with distinct seasonal patterns. Additionally, an algorithm was developed to detect the foF2 and hpF2 parameters that were validated using manually scaled ionograms and models.

Kiruthiga and Mythili assessed the use of ARMA and Cokriging (CoK) based models to forecast TEC variations before major earthquakes in Indonesia. The TEC data during 2004 Sumatra and 2012 Sulawesi earthquakes showed that the TEC anomalies 5–6 days prior to the events were strongly linked to seismic-induced electric fields than geomagnetic activity. Both models captured general trends in TEC, with ARMA showing higher sensitivity to short-term disturbances and CoK providing long-term predictions. The study highlights the potential of predictive models for TEC changes during seismic events.

Selvakumaran et al. investigated the reduced geoeffectiveness of solar cycle 24 by analyzing solar wind observations from multiple satellites. The number of intense and moderate geomagnetic storms in cycle 24 declined by approximately 80% and 40%, respectively. This reduction was attributed to lower heliospheric pressure, which caused CMEs to expand more than usual, diminishing their geoeffectiveness.

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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.

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The author(s) declare that no Generative AI was used in the creation of this manuscript.

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