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Editorial: Near-earth electromagnetic environment and natural hazards disturbances

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Editorial on the Research Topic
Near-earth electromagnetic environment and natural hazards disturbance

Throughout history, human communities have faced consistent threats from natural hazards like earthquakes, volcanic eruptions, and tsunamis. Yet, scientists strive to understand the process behind hazard formation and to predict their occurrences. Since the 1980s, space technology has allowed satellites to capture abnormal electromagnetic (EM) emissions, plasma density irregularities, and energetic particle precipitations near seismic fault zones, volcanic belts, and tsunami-prone coasts. Extensive efforts have been dedicated to rock-rupture processing experiments and ground-space comparative studies. EM precursors have shown promising potential for short-term earthquake prediction. In 2004, France launched the DEMETER satellite, operational until 2010, followed by China's China Seismo-Electromagnetic Satellite (CSES) in February 2018, focusing on earthquake monitoring from space.

This Research Topic serves two main purposes. Firstly, it validates and calibrates data from ground-based instruments and satellite platforms to explore the space's EM environment including the EM field, plasma parameters, energetic particle flux, and distributions. Secondly, it emphasizes cross-disciplinary studies of natural hazard monitoring, including earthquakes, volcanoes, etcetera. By combining modeling and observation, the goal is to develop innovative methodologies for studying natural hazards and the interconnected mechanisms of the Lithosphere-Atmosphere-Ionosphere system.

This first volume includes nine contributions which will be excellent references to the future works focused on the Research Topic.

Liu et al. proposed a spatial analysis method to extract the disturbances of CSES electron density (Ne) before earthquakes. An example was taken from the 5 August 2018 Indonesia Mw6.9 earthquake. A superposed epoch and space approach was applied to the Ne anomalies during Mw ≥ 6.0 global earthquakes for more than 2 years. It was found that 1) relative to the epicenters, seismo-ionospheric disturbances are more obvious in the equator direction than those in the polar direction; 2) the anomalies within 300 km distance from the epicenter are significant 11, 3, and 2 days before earthquakes; 3) the influence region of the anomalies associated with earthquakes enlarges with the magnitude increase, and the stronger magnitude is, the earlier disturbance appears. The results would support the electric field pathway as the main channel of lithosphere–atmosphere–ionosphere coupling.

He et al. examined ionospheric total electron content (TEC) anomalies before the 2011 Mw9.0 Tohoku-oki earthquake in Japan using Global Navigation Satellite System data from northern Australia. They found that TEC anomalies in Australia began approximately 41.5 min before the earthquake, closely matching the timing observed in Japan. These anomalies appeared on the same longitude as northeastern Japan, supporting the theory that ionospheric electric fields redistributed electrons before significant earthquakes. However, the anomaly in Australia was shifted about 500 km southward, indicating differences in the underlying physical mechanisms between the two hemispheres.

Chu et al. simulated the variation of geomagnetic cutoff rigidities from 1965 to 2025, which quantify Earth's magnetic field's shielding effect on energetic particles with data from the International Geomagnetic Reference Field model and energetic particles' windows (EPWs). Results revealed a relationship between cutoff latitude and the background magnetic field intensity, but it's not a simple linear one. Changes in cutoff rigidities and the geomagnetic field are asymmetric on the global scale. The weakening of the geomagnetic field shifts cutoff latitudes toward the equatorial region in the southern hemisphere, while the situation in the northern hemisphere is less predictable. In the northern hemisphere, EPWs decrease by about 0.03% per year, while in the southern hemisphere, they increase by approximately 0.05%–0.12% per year. The positions of EPWs do not align precisely with geomagnetic poles or magnetic dip poles, being closer to geomagnetic poles.

Yan et al. analyzed the correlation between electron density (Ne) and temperature (Te) in the ionosphere, by using simultaneous observations from four satellites: CSES, Swarm A, Swarm B, and the CHAMP satellite. Results from all four satellites indicated a generally consistent negative correlation between Ne and Te. However, The negative correlation between Ne and Te becomes weaker or even reverses into a positive correlation after Ne exceeds a certain threshold. The slope of the correlation also varies with season and magnetic latitude, reflecting the seasonal and MLat-dependent features.

Jianing et al. studied the in-orbit magnetic field data from CSES and Swarm satellites, aiming to assess data consistency through cross-comparison. Their approach involved analyzing data from two satellites passing close to each other in a relatively short timeframe within a specific spatial location, with criteria for geomagnetic quiet periods based on the Kp index. The study visualized differences between in-orbit data and model values, examining variations in data over time and with changes in geomagnetic latitude.

Huang et al. analyzed CSES data to investigate the characteristics of artificial source signals that are transmitted from ground-based artificial source stations. The research aimed to pinpoint the position and intensity of the strongest points within these two regions by examining the power-spectrum density of the electric field recorded by CSES over the NWC transmitter. The analysis focused on a specific frequency of 19.8 kHz with a bandwidth of 200 Hz. The "strongest point" was defined as the location with the highest power spectral density within a range of ± 10° around the NWC transmitter. The study uncovered several noteworthy statistical characteristics related to these strongest points, with variations influenced by factors such as day/night, location, and different components of electric field vectors.

Wang et al. based on CSES observations, reported three notable disturbing steps in the space environment: Electromagnetic radiation from solar flares reaches Earth at the speed of light, followed by solar energetic charged particles, and finally, coronal mass ejections (CMEs) and geomagnetic storms. The analyzed disturbance cases are all associated with solar proton events (SPEs). The observations confirm that the data quality of the high-energy particle package (HEPP) from CSES is highly reliable and accurate and is highly advantageous to monitor the variation of energetic particles and X-rays in the radiation belt of the Earth during solar activities.

Wu et al. studied high-resolution electromagnetic field intensity data from the DEMETER satellite to detect harmonic electromagnetic radiations in the ionosphere, specifically above extra-high voltage and ultra-high voltage power plants in China. The highest frequency recorded was around 8,850 Hz. The origins of these radiations are likely associated with nonlinear devices such as converters or geomagnetic disturbances. A simple physical model explains how these radiations propagate from the Earth's surface to the ionosphere.

Yang et al. address the critical Research Topic of "communication blackout" during reentry for sharp-coned vehicles. While previous research mainly focused on EHF (extremely high frequency) communication for blunt-coned vehicles, this study explores EHF communication for sharp-coned vehicles. The study models the EHF communication system, considering modulation modes (2ASK, 2PSK, and 2FSK). Key findings indicate that transmission coefficient increases with carrier frequency, channel gap decreases over time, phase shift stabilizes with higher carrier frequency, and bit error rate (BER) varies based on factors like antenna placement, carrier frequency, and modulation mode.

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Conflict of interest

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