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Editorial: Space- and ground-based observations of ELF (extremely low frequency)/VLF (very low frequency) electromagnetic waves and their propagation mechanisms

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Editorial on the Research Topic
Space-and ground-based observations of ELF (extremely low frequency)/VLF (very low frequency) electromagnetic waves and their propagation mechanisms

A large number of anthropogenic and natural ELF (Extremely Low Frequency)/VLF (Very Low Frequency) electromagnetic (EM) waves can be observed on the ground and in space. The ELF/VLF EM waves in the atmosphere could propagate not only in the earth-ionosphere waveguide but also penetrate through the Earth's ionosphere and into the magnetosphere to interact with energetic electrons in the radiation belts via gyroresonance (Helliwell, 1965) and induce electron precipitation onto the ionosphere (Helliwell et al., 1973). Conversely, EM waves originating from the magnetosphere can also propagate to and affect the ionosphere (Bortnik et al., 2011; Chen et al., 2017).

In recent years, many spacecrafts operating in near-Earth space such as CSES, GOES, Cluster, THEMIS, the Van Allen Probes, Arase, and Swarm, combined with ground-based observatories such as the MAGDAS, SuperMAG, and INTERMAGNET networks, are utilized to study the characteristics of these EM waves. Meanwhile, many models have also been developed to study the upward and downward propagation mechanisms of the EM wave (Starks et al., 2008; Lehtinen and Inan, 2009; Bortnik et al., 2011; Chen et al., 2017). Therefore, the main goal of this Research Topic is to study the EM waves observed by different

satellite and ground-based equipments to get more understanding of these waves and their origins.

In this Research Topic on "*Space- and ground-based observations of ELF (Extremely Low Frequency)/VLF (Very Low Frequency) Electromagnetic waves and their propagation mechanisms*", we present 4 original research articles describing the propagation characteristics of EM waves from VLF transmitter, nuclear electromagnetic pulse (NEMP) and earthquakes, and discussing the correlation between the geomagnetic Z component solar quiet variation (SqZ) component and the total electron content (TEC).

Xia et al., investigate the latitudinal dependence of four ground VLF transmitters wave power in the inner magnetosphere. Their results reveal significant latitudinal dependence of the wave power: the wave power is minimized near the equator and increases as the latitude increases, which both have been observed by ERG/Arase and Van Allen Probes satellites and their ray-tracing simulation also confirmed this conclusion. The study on the wave power distribution of VLF transmitters will be useful to estimate the energetic electron loss caused by VLF transmitter emissions in the inner magnetosphere. Wei et al. proposed an effective method to calculate the NEMP propagation in the ionosphere, and pointed out that this method can be used for the design of the space-based NEMP detectors and satellite-ground docking experiments. Yang et al. proposed an EM waves anomaly automatic detection algorithm based on empirical mode decomposition. They found a correlation between 2,329 earthquakes of magnitude not less than 5.0 and ultra-low frequency disturbances in the electric field, which may provide a possible way for the application of electromagnetic monitoring satellites in earthquake prediction. Niu et al. concluded that the Sq field and ionosphere are both strongly controlled by solar activity. However, the relationship between SqZ and ionospheric TEC is similar in both solar-minimum and solar-maximum years, indicating that their relationship depends not on the Sun but on local position, especially latitude. They indicated that it is reasonable to use the Z component for geomagnetic modeling in geomagnetically assisted navigation.

Collectively, this group of papers provides updated information on the physics of EM waves from different sources. We thank the authors for their excellent contributions and hope that this Research Topic leads to new methods and ideas for investigating the EM waves in the ionosphere and magnetosphere, as well as promoting the EM waves in space for science and engineering applications.

Author contributions

SZ: Writing–original draft. XS: Writing–review and editing. CZ: Writing–review and editing. ZX: Writing–review and editing. HP: Writing–review and editing. LL: Writing–review and editing.

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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

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