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Editorial: New insights into high-energy processes on the Sun and their geospace consequences

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Editorial on the Research Topic
New insights into high-energy processes on the sun and their geospace consequences

The Sun releases an enormous amount of energy during explosive solar activities, such as solar flares and coronal mass ejections (Webb and Howard, 2012; Aschwanden et al., 2017; Benz, 2017). The solar corona can be heated up to tens of millions of degrees and a large number of charged particles can be accelerated to nearly the speed of light (Desai and Giacalone, 2016; Reames, 2017). Heated plasmas and high-energy particles increase solar radiations across the entire electromagnetic spectrum, from radio to gamma-ray wavelengths, which can have a profound effect on the Earth's upper atmosphere immediately after about 8 minutes. These create additional ionization and heating in the Earth's upper atmosphere, leading to radio blackout, GNSS signal interferences and tracking loss, increased drag on spacecraft, as well as affecting the global electric circuit (GEC), and many other phenomena (Bothmer and Daglis, 2007; Buzulukova and Tsurutani, 2022; Tacza et al., 2022). Recent studies have demonstrated that the solar flare effects can extend to the Earth's magnetosphere via electrodynamic coupling (Liu et al., 2021; Liu et al., 2024). When the high-energy particles propagate through the interplanetary medium and arrive at the vicinity of the Earth, known as solar energetic particle (SEP) events, they can pose hazardous radiation threats to astronauts and spacecraft electronics in space (Vainio et al., 2009; Shea and Smart, 2012).

This Research Topic aims to collect scientific contributions on high-energy processes on the Sun and their geospace consequences. Eight research articles and one review are contained in this electronic book, focusing on multi-wavelength observations of solar flares, acceleration and transport of energetic particles, and impacts of solar eruptions on the coupled magnetosphere–ionosphere–thermosphere system.

Qiu proposed that brightening-dimming sequences in the lower solar atmosphere can be used to identify the properties of magnetic reconnection or plasma expansion of overlying magnetic structures in the corona. This novel method was examined by the observations of two eruptive flares.

Kuznetsov et al. presented a detailed analysis of an M-class solar flare on 2023 March 6 utilizing the combined observations in microwave and hard X-ray (HXR) from the Siberian Radioheliograph (SRH) and the HXR Imager on board the Advanced Space-based Solar Observatory (ASO-S/HXI). They further modeled the microwave emission in the 3D reconstructed flare loop using the GX simulator, which can provide spatial and spectral diagnostics of energetic electrons.

Kong et al. modeled the propagation of energetic electrons in the flare loop by numerically solving the particle transport equation. They highlighted the effects of turbulent pitch-angle scattering on the trapping/precipitation and anisotropic distribution of energetic electrons in solar flares. The simulation results help us understand the observation signatures of nonthermal HXR and microwave emissions and the excitation of coherent solar radio bursts.

Tang et al. investigated the impact of the evolution of the electron energy spectrum and velocity distribution as they propagate along the flare loop on the electron cyclotron maser instability/emission, one of the known radiation mechanisms of coherent radio bursts.

Reames reviewed how the abundance of elements can provide unique insights into the origin of SEPs in both impulsive and large gradual SEP events. The review discussed the observed properties of four sources of SEPs and the associated physical processes, including magnetic reconnection in solar jets and the seed particles for particle acceleration at CME-driven shocks.

Shalchi discussed the particle transport equation that includes the physics of pitch-angle scattering by magnetic turbulence. A new approach was developed to obtain the solutions of the equation, indicating that the two-dimensional subspace approximation is equivalent to using the telegraph equation.

Zhou et al. developed a three-component MHD model to study the evolution of the solar wind from 1 to 150 AU in the heliosphere, and the numerical simulation results were compared with the observations from New Horizons, Voyager 1 and 2. They highlighted the effects of Anomalous Cosmic Rays (ACRs) on shock-like structures of the solar wind in the outer heliosphere.

Zhang and Wang investigated a moderate geomagnetic storm in 2022 associated with a huge geohazard event of the Tonga volcano eruption. They utilized GPS total electron content (TEC) and numerical simulations from the Thermosphere Ionosphere Electrodynamic General Circulation Model (TIEGCM) to understand the plasma responses of the ionosphere-thermosphere coupled system.

Qiao et al. presented the forecast of ionospheric F2 layer (foF2) at low latitudes using deep learning models. The Informer–foF2 model demonstrates better prediction performance in predicting variations from several hours up to 48 h, compared to the widely used long short-term memory model.

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