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Observation and simulation study on the response of the Earth's magnetosphere and ionosphere at the occurrences of the GLE events

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Solar energetic particles (SEPs) are composed of protons, electrons, and heavy ions with energies ranging from hundreds of keV to MeV, and they are observed in the heliosphere. Large-scale SEP events are one of the most critical phenomena in terms of space weather. They pose a risk of radiation exposure to humans and equipment in space. SEPs are accelerated in magnetic reconnection regions and by coronal mass ejection (CME)-driven shocks in the solar corona[1,2]. After the acceleration process of the SEPs in the corona region, they propagate along solar magnetic fields into the interplanetary space. During the propagation, they are affected by solar wind and heliospheric magnetic fields, and they can interact with other activities in the heliosphere. The temporal and spatial variations of SEPs strongly depend on physical quantities of source activities, magnetic connectivities between the sources and the photospheric magnetic footpoints of spacecraft, and the conditions in the interplanetary space[1,2,3].
SEP events are mainly observed in-situ measurements in space. However, a few large and fast SEPs are detected on the ground, called ground level enhancement (GLE). In this study, we examine 19 GLE events during solar cycle 24 and 25. The sources are mostly located in the western regions, and the other two events are located at E09° and E08°. They are associated with X-class flares except for two events (M-class). The CME speeds range from 700 km/s to 3200 km/s. Out of the 19 events, 13 have pre-CMEs, leading to a decrease in the Dst index when GLE events precipitate into the ground. In this study, we specifically conducted simulations for the event that occurred on 2012 May 17, which corresponds to this case. We investigate the response of the Earth's magnetosphere and ionosphere using the 3D global MHD simulation for the GLE event. We present the relations between the characteristics of GLEs, associated solar activities, and the state of Earth's magnetosphere as well as the ionosphere. This work was supported by the National Research Foundation (NRF) of Korea under grant no. NRF-2020R1I1A1A01074877 and NRF-2023R1A2C1008051.

References

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