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Evolution and propagation of electric fields during magnetic impulses based on multiple observations

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Magnetic impulses triggered by the input from the solar wind lead to the variation of the particle and electromagnetic field. Sudden commencements (SCs), known as one of the most distinct magnetospheric disturbance phenomena, are triggered by the compression of the magnetosphere due to solar wind disturbances. Unlike magnetic storms and substorms, SCs can be identified as sharp magnetic variations on the global scale. Since SCs are isolated phenomena, their onset time and driver are relatively easy to identify. Several spacecraft observations of the electric field have indicated that the Alfven wave launching from the ionosphere toward the magnetosphere plays a crucial role in inducing the transient response of the electric field in the magnetosphere. However, this suggestion has not been tested sufficiently due to lack of the electric field observation in the ionosphere. Therefore, the interaction in the magnetosphere?ionosphere coupled system, such as the electric field propagation and energy transport process, is still an open issue.

Motivated by these issues, we try to investigate electric field characteristics associated with SCs by simultaneous multiple ground-based and spacecraft observations that can recently be utilized. We investigate the evolution and propagation of electric fields during SCs using in situ electric field data obtained by five THEMIS spacecraft and two Van Allen Probes (VAPs) spacecraft. We also investigate the propagation of electric fields to/in/from ionosphere with SuperDARN radar, HF Doppler radar, and ground magnetometer data. SC events are identified by the SYM-H index provided in OMNI database and geomagnetic field data. The event criteria were set as follows: (1) SCs occur from January 2013 to December 2014. (2) The amplitude of the SYM-H is more than 10 nT, and its rise time is less than 5 min. (3) Preliminary Impulse (PI) is recorded on high-latitude geomagnetic field (FSIM and FSMI stations).

We found 70 SC events satisfying these conditions. For all of them, both THEMIS and VAPs detect the enhancements of the electric field. The direction of the electric field is westward, which is consistent with that of the magnetospheric electric field observed by the Akebono satellite [Shinbori et al., 2004]. We found that the nightside magnetospheric electric field follows the dayside one within 5 s delay from the PI onset, despite the large distance between them (˜5-10 R_E). In the ionosphere, SuperDARN and HF Doppler radars detected the westward electric field during the PI phase. The PI onset time of ionospheric electric field is almost same (within 5 s) with the magnetospheric electric field detected by THEMIS and VAPs regardless of local time, which indicates the simultaneous response between magnetospheric and ionospheric electric fields. These results suggest that the electric field propagates from dayside to nightside magnetospheres via the ionosphere. That is, the dayside magnetospheric electric field propagates into the polar ionosphere along the magnetic field line, and then from polar toward low-latitude ionospheres at the speed of light between the ionosphere and ground propagation path. On the other hand, the ionospheric electric field propagates within 5 s toward the plasmasphere and inner magnetosphere (˜5-10 R_E). Although previous results have shown that the electric field associated with SCs is propagated into the magnetosphere by the Alfven wave along the magnetic field lines, the propagation velocity estimated by our observational results may be faster than the velocity of the Alfven wave.

In this paper, we report the validity of these data interpretation. We will also present the statistical results (i.e., the superposed epoch analysis) and the Poynting fluxes that play a crucial part in the energy transmission associated with the PI onset of electric fields, which is expected to clarify the propagation path of the electric field.