Evolution and propagation of electric fields during magnetic impulses based on multi-point observations

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Sudden commencements (SCs) are one of the abrupt magnetospheric disturbance phenomena. They are triggered by a compression of the dayside magnetosphere, leading to fast mode wave propagation in the equatorial plane. On the other hand, the compression induces Alfven waves that propagate toward the polar ionosphere along magnetic field lines, and then ionospheric electric fields propagate toward low-latitude ionosphere at speed of light. Each propagation process is individually supported by MHD simulations and ground magnetic field data. Several direct observations have also provided evidence of the fast mode or Alfven wave propagation, but spatial and temporal evolutions of these propagations are not well known. For the latter process, a previous study using the Cluster satellites shows that upward Poynting fluxes transport electromagnetic energy toward the nightside magnetosphere. However, whether such upward Poynting fluxes are launched from the ionosphere or converted from fast mode waves has not been confirmed yet.

Motivated by these issues, we investigate evolution of the electric field in the magnetosphere-ionosphere coupled system using multiple satellites and ground-based observations during SCs. We use magnetospheric electric and magnetic field obtained by THEMIS (5 probes), Van Allen Probes (2 probes). Magnetometer data from GOES 13 and 15 are also used. We also obtain the ionospheric electric field data from SuperDARN (high latitude) and HF Doppler (mid latitude) radars. SC events are identified by the SYM-H index provided in the OMNI database and geomagnetic field data. The event selection criteria are set as follows: (1) SCs occurred 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) A Preliminary Impulse (PI) is recorded in geomagnetic field data at the subauroral region.

Seventeen SC events satisfying these conditions show that the magnetospheric electric field responds within 1 s to the magnetospheric magnetic field. These events also show the time delay of the onsets between dayside and nightside magnetospheric electric fields. For example, we find a clear SC signature on March 17, 2013. The SC onset time of the dawnside electric field (˜4.8 h LT, L˜4) is 20 s later than the dayside one (˜10.4 h LT, L˜7). The nightside electric field (˜1.0 h LT, L˜5.5) starts to decrease after 35 s of the SC onset of the dawnside electric field. These propagation times can be explained by the fast mode wave propagation in the equatorial plane. At the midnight sector, however, the magnetospheric electric field responds simultaneously independent of the L-value. In addition, the SC onset of the nightside electric field (˜21 h LT) is 15 s later than that of the midnight one although they are detected in the same L-value, which suggests that there may be a dawn-dusk asymmetry of the electromagnetic energy propagation time in the inner magnetosphere. In the ionosphere, both SuperDARN and HF Doppler radars detect a westward electric field at ˜15 h LT about 1 min after the onset of the dayside magnetospheric electric field, which is consistent with the Alfven velocity from the dayside magnetosphere to the polar ionosphere.

We will clarify the spatial evolution of both fast mode and Alfven waves by statistical studies, and evaluate the possible propagation path of the electromagnetic energy associated with SCs to the ionosphere and inner magnetosphere.