Global evolution and propagation of electric fields during sudden impulses using satellites and ground-based observations

*Naoko Takahashi[1], Yasumasa Kasaba[1], Yukitoshi Nishimura[2], Takashi Kikuchi[3,4], Atsuki Shinbori[3], Tomoaki Hori[4], Nozomu Nishitani[4]

1.Dep. Geophysics Graduate School of Science Tohoku University, 2.University of California, Los Angeles, 3.Research Institute for Sustainable Humanosphere, Kyoto University, 4.Institute for Space-Earth Environmental Research, Nagoya University

Sudden impulses (SI) are triggered by compression of the dayside magnetosphere, leading to fast mode wave propagation in the equatorial plane. Broadband fast mode waves generated in the magnetosphere propagate tailward from the dayside magnetopause, and the abrupt compression of the dayside magnetosphere induces Alfven wave propagation toward the polar ionosphere along magnetic field lines. Then the ionospheric electric field penetrates from polar toward low-latitude ionosphere at speed of light. These propagation processes have been supported by previous event and statistical studies using multi-point observations. However, there are few papers that performed a statistical analysis of the precise temporal evolution of the SI-associated MHD waves, particularly using satellites in the inner magnetosphere or ionosphere. Further, it is known that the Poynting flux plays a crucial role in the electromagnetic energy transport, but the detailed propagation path is still an open issue.
Motivated by these issues, we investigate global evolution and propagation of electric fields using in-situ satellites and ionospheric radars. In order to clarify the magnetospheric response, we obtain the magnetospheric electric and magnetic field data from THEMIS (5 probes) and Van Allen Probes (2 probes). Magnetospheric magnetic field data obtained from GOES 13 and 15 are also referred to. We identify the ionospheric response using the C/NOFS satellite, SuperDARN (high latitude) and HF Doppler (mid latitude) radars.
Seventeen events occurred from October 2012 to December 2014 show that both THEMIS and Van Allen Probes detect the westward electric field regardless of the local time. We also find time delay of onsets between dayside and nightside magnetospheric electric fields. In a representative event on 17 March 2013, the onset time of the dawnside electric field (~4.8 h LT, L~4) is 24 s later than the dayside one (~10.4 h LT, L~7). The nightside electric field (~1.8 h LT, L~5.5) starts to decrease 32 s after the onset of the dawnside electric field. These time lags can be explained by the fast mode wave propagation in the equatorial plane. However, in the eveningside, the onset of the nightside magnetic field (~19 h LT) is 20 s later than that of the midnight one. In the ionosphere, C/NOFS (~11 h LT) and HF Doppler radar (~15 h LT) detects the dusk-to-dawn electric field 19 s later than the onset of the midnight electric field. Although SuperDARN radar cannot detect the precise onset time due to the normal scan mode with time resolution of 1 min, we find the dusk-to-dawn electric field observed as the negative peak of the line-of-sight velocity. Since the ionospheric electric field propagates globally and simultaneously, it is speculated that the nightside ionospheric electric field also responds with 19-s delay from the onset of the nightside magnetospheric electric field. Estimated Poynting fluxes are directed toward the ionosphere along field lines, which indicates the Alfven wave propagation toward the ionosphere in both the dayside and nightside. Therefore, the possible propagation path is as follows: first, the fast mode wave propagates from dayside to nightside magnetospheres in the equatorial region through the dawnside, and then the Alfven wave propagates from the magnetosphere toward the ionosphere.
On the basis of such individual events, we statistically derive the spatial distribution of the time response of magnetospheric electric fields. In the dayside, the magnetospheric electric field

responds more gradually as the L-value of satellites becomes smaller. The estimated propagation velocity in the dayside is ~600-900 km/s, which is consistent with the fast mode wave speed. In the nightside, however, the post-midnight electric field responds faster than the pre-midnight one. The asymmetric distribution with respect to the midnight meridian may be associated with the plasmapause location.

