Quick transmission of electromagnetic energies into the magnetosphere through the ionosphere

Yukitoshi Nishimura[1]; Takashi Kikuchi[2]; Atsuki Shinbori[3]; Yuji Tsuji[4]; Tomoaki Hori[3]; Shigeru Fujita[5]; Takayuki Ono[6]; Wygant John[7]

[1] STEL, Nagoya University; [2] STEL; [3] Solar-Terrestrial Environment Laboratory, Nagoya Univ.; [4] Particle and Astrophysical Sci.,Nagoya Univ; [5] Meteorological College; [6] Department of Astronomy and Geophysics, Tohoku Univ.; [7] University of Minnesota

The transient response of convection electric fields in the magnetosphere and ionosphere is investigated using direct measurements of electric fields by CRRES, THEMIS and Cluster spacecraft. The Poynting flux associated with a sudden commencement is analyzed in order to evaluate existence of quick energy transmission toward the magnetosphere through the ionosphere.

Large-scale electric fields earthward of the inner edge of the electron plasma sheet show a quick response simultaneously with southward turning of the IMF. A statistical study using 165 events of southward and northward turning of the IMF confirms a prompt response within 5 min for 80% of events. A coordinated observation of the electric field by the CRRES and Akebono spacecraft shows a simultaneous increase in the dawn-dusk electric field. It strongly suggests that the quick response of large-scale electric fields occurs in a wide region of the inner magnetosphere. A quick response associated with southward turning of the IMF is also identified in in-situ magnetic fields and ionospheric electric fields. The concurrent response in the ionosphere and magnetosphere indicates that southward turning of the IMF initiates simultaneous (less than 1 min) enhancements of the ionospheric electric field, large-scale electric field in the inner magnetosphere, and the current system in the magnetosphere and ionosphere.

In contrast, a quick response of large-scale electric fields is not identified in the electron plasma sheet even below the geosynchronous altitude. A statistical study using the CRRES data reveals a large time lag of more than 30 min until the response of large-scale electric fields. Amplitudes of the electric field are significantly weaker than earthward of the electron plasma sheet, and no obvious correlation is identified with the solar wind electric field, while the electric field earthward of the electron plasma sheet well correlates with the solar wind electric field. Multipoint observations by the THEMIS spacecraft confirm that only the spacecraft earthward of the electron plasma sheet measures a prompt response, and a time lag of ~10 min is identified in the electron plasma sheet.

The remarkable difference in the response of electric fields indicates a presence of a different mode of the response of large-scale electric fields in the electron plasma sheet and magnetically conjugated auroral ionosphere.

Detecting Poynting fluxes associated with Alfven waves is essential to prove the instantaneous energy transmission process via the ionosphere. The Cluster spacecraft in the lobe measures field-aligned Poynting fluxes propagating upward during the preliminary impulse of a sudden commencement. Waveguide equations are solved in order to estimate the amount of the Poynting flux propagating from the ionosphere. The magnitude of the Poynting flux and time delay after the onset of the preliminary impulse detected on the ground, are quantitatively explained by the leakage of the Poynting flux from the ionosphere-ground waveguide. The theoretical calculation supports the idea that ionospheric electric fields are transmitted toward the magnetosphere as upward Poynting fluxes carried by Alfven waves and alter the magnetospheric convection pattern.

Upward Poynting fluxes are also observed associated with southward turning of the IMF. Transmission of electromagnetic energies from the ionosphere toward the magnetosphere is thus a common process for geomagnetic phenomena related to the global field-aligned current system.