Global magnetosphere-ionosphere current system responsible for geomagnetic disturbances

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Storm-time geomagnetic disturbances on the ground are caused by magnetospheric and ionospheric currents, which are driven by the electric field associated with field-aligned currents (FACs). During the geomagnetic sudden commencement (SC), a fraction of the magnetopause current flows into the ionosphere along the geomagnetic field line, providing a dusk-to-dawn electric field responsible for the preliminary reverse impulse (PRI) of the SC. The PRI electric field is then transmitted to the equator instantaneously, causing two-cell Hall current vortices at high-mid latitudes, and a westward electrojet in the equatorial ionosphere. The equatorial currents are connected to the FACs by the Pedersen currents in mid latitude ionosphere. The PRI current is followed by the MI (main impulse) current driven by a dawn-to-dusk electric field in a minute, of which pattern is essentially the same as the PRI current in reversed direction. During storm/substorms, the southward IMF generates the Region-1 FAC, which carries the dawn-to-dusk convection electric field into the polar ionosphere. The polar electric field then drives ionospheric currents in the same way as that for the MI, resulting in coherent DP2 geomagnetic perturbations at high-equatorial latitudes. When the IMF turns northward or the southward IMF decreases its magnitude, the electric field changes its direction from dawn-to-dusk to dusk-to-dawn. This change in the electric field is caused by the overshielding electric field associated with the Region-2 FAC, which causes reversed Hall currents at high latitude surrounding the R2 FAC and a counter-electrojet at the dayside equator. The overshielding electric field becomes dominant during the substorm expansion phase, and at the beginning of storm recovery phase. Similar magnetosphere-ionosphere current system can be applied to explain the equatorial enhancement of PC5, Pi2 and so on. The electromagnetic energy responsible for the geomagnetic disturbances is transported to the equatorial ionosphere through the Earth-ionosphere waveguide, and a fraction of the energy leaks into the upper ionosphere and the inner magnetosphere. Thus, the magnetosphere-equatorial ionosphere current circuit is a path of electromagnetic energy transmission into the inner magnetosphere as well as to low latitude ionosphere.