A journey of energy from solar wind to polar ionosphere as viewed from global MHD simulation

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The Sun emits different forms of energy to interplanetary space. The most significant form is the solar electromagnetic radiation that arrives at Earth's atmosphere directly. The second and third ones are the solar wind kinetic energy and the magnetic energy of the interplanetary magnetic field (IMF), which are the ultimate sources of the energy consumed in the polar ionosphere. Despite of numerous studies, the pathway and the conversion of the solar wind energy (including the solar wind kinetic energy and the magnetic energy of IMF) into the polar ionosphere are not well-known. The results obtained by the global magnetohydrodynamics (MHD) simulation suggest that the development of dynamo is a key in understanding the energy transfer and conversion. When the solar wind is supersonic, the first dynamo appears in the bow shock, which converts the solar wind kinetic energy to the internal energy and the magnetic energy. When the IMF is southward, the second dynamo appears in the mantle region, which converts the internal energy to the kinetic energy and the magnetic energy. The mantle dynamo is closely associated with the generation of the Region 1 field-aligned currents (FACs). A line integral of the Poynting flux, which is called a S-curve, shows a spiral with its center moving toward the polar ionosphere. The spiral shape is a manifestation of the magnetospheric convection, and the earthward displacement is caused by a twist of the flux tube associated with the FACs. When the near-Earth reconnection takes place in the plasma sheet, the third dynamo appears in the inner magnetosphere, which generates Region 1-sense FACs known as substorm current system. The fourth dynamo appears in the low-altitude magnetosphere when the ionospheric Hall current is partially blocked. The upward FAC associated with the forth dynamo is related to the westward traveling surge in the MHD simulation. However, the upward FAC is connected to the divergent (not convergent) Pedersen current, which is different from conventional wisdom. The EISCAT_3D observations are expected to resolve this problem, and provide insightful information about the interface between the magnetosphere and the ionosphere during the transient phenomena, such as an auroral expansion.

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