Magnetospheric dynamo driving the nightside Region 2 field-aligned current system

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The importance of field-aligned currents connecting the magnetosphere and ionosphere is widely recognized. In order to stimulate steady-state plasma convection in the ionosphere, energy must be supplied continuously from the magnetosphere to the ionosphere by field-aligned currents. In the magnetosphere side of the current system, there exists a "dynamo" in which electromagnetic energy is produced from other sources. In spite of this recognition, it was not until the advent of global magnetohydrodynamic (MHD) simulation that we started to gradually understand the physical processes of the magnetospheric dynamo. Global numerical simulations revealed that in the magnetosphere plasma thermal energy is much higher than flow kinetic energy, indicating that the energy source of the field-aligned currents is mainly plasma thermal energy. Recently, we have learned that one dynamo process is the "expanding slow mode" disturbances (Watanabe et al., 2014), and we now have a consensus that the Region 1 field-aligned current system can be interpreted in terms of the expanding slow mode. However, this mechanism seems not applicable to the nightside Region 2 FAC system. The purpose of this study is, using MHD formulation, to interpret the physical processes of the Region 2 dynamo on the nightside, in prospect of generalizing the theory of the magnetospheric dynamo. The magnetospheric dynamo is defined as the region in which the dot product of the current density vector (J) and the electric field vector (E) is negative ($J.E < 0$). Using Poynting's law, Faraday's law, and Ohm's law (with no use of equation of motion), the dynamo condition can be expressed in terms of the spatial variation of the magnetic field. Keeping in mind that we are considering a high beta region in which the magnetic field is relatively strong, the spatial structure of the magnetic field is assumed to determine the physics in the system. For formation of a dynamo, either (1) the magnetic pressure increases in the convection frame, or (2) the magnetic tension and plasma convection are in opposite directions. By considering the equation of motion separately, condition (1) indicates that the plasma pressure is sustained by the magnetic pressure, which is interpreted by the expanding slow mode disturbances mentioned above. This mechanism applies to the Region 1 system. Meanwhile, condition (2) indicates that the plasma pressure is sustained by the magnetic tension, which is considered to be applicable to the nightside Region 2 system. The latter process has never been focused in the past, and in this study we describe physical processes of this tension-driven dynamo.

Keywords: field-aligned current, dynamo, Region 2

