電磁流体シミュレーションを用いたサブストームの研究：低高度境界条件の影響

Global MHD simulation study on substorms: Influence of low altitude boundary condition

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A substorm is one of the most drastic disturbances taking place in the magnetosphere. The substorm is known to occur frequently when the interplanetary magnetic field (IMF) is southward and solar wind speed is high. It is believed that a substorm is essentially driven by the external condition, that is, the solar wind and IMF. Recently, some simulation results have shown that the ionospheric condition may affect the global magnetospheric convection. This may imply that in addition to the external condition (solar wind and IMF), the internal condition (ionospheric condition) is also a control factor to the characteristics of substorms. We investigated the characteristics of substorms by using global magnetohydrodynamics (MHD) simulation [Tanaka et al., 2010]. For given parameters of the solar wind and IMF, we repeated the simulation by changing the inner boundary of the simulation. In the global MHD simulation, the inner boundary is located at 2.6 Re. In the original setting, plasma pressure at the innermost grid was determined by $P_1=AP_2$, where P_1 and P_2 are the plasma pressures at the lowest grid and the second lowest grid, and A is a factor. When A is 1, the plasma pressure is the same at the lowest and the second lowest grids. This means that the pressure gradient force does not exist in between. When A is less than 1, there is a pressure gradient between them, and the plasma is accelerated toward the Earth. Finally, the plasma will be lost when it encounters the innermost boundary of the simulation. In the real situation, it represents the plasma loss process due to a recombination or charge exchange in the ionosphere. We obtained the following results. For given solar wind condition, the near-Earth reconnection region as identified by earthward and tailward plasma flows occurred at ~12 Re near the equatorial plane regardless of the value A. However, the earthward flow speed increases with decreasing the value A. When the value A is 0.6, the earthward flow speed was about 650 km/s, whereas when the value A is 1.0, it was about 260 km/s. As the value A increases, it became clear that high-pressure regions in the near-Earth plasma sheet extended toward the Earth after the reconnection, and that the magnitude of the current density and the magnetic field before the reconnection at ~12 Re increased. In this simulation, the magnetic diffusion takes place when the anomalous resistivity is large. The anomalous resistivity is a function of the current density and the magnetic field. It is thought that the condition at the inner boundary of the simulation may change the force balance that is responsible to the anomalous resistivity and the subsequent substorm dynamics. We will discuss the detail mechanism for the dependence of A on the earthward-tailward flow speed as well as the magnitude of auroral electrojets and field-aligned current.

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