§5. Toward Multi-herarchy Modeling of Magnetosphere Simulation

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Substorm includes wide dynamical range phenomenon such as magnetic reconnection in the magnetotail and dipolarization of the Earth's magnetic field. It is well known that magnetic reconnection is controlled by micro physics and magnetic field is described by magnetohydrodynamic (MHD) equations. We study the way to model anomalous resistivity in MHD framework, and typical one is given by a parameter which is adjusted to observation results [1]. Horiuchi, Den, Tanaka et al. [2] proposed physically based resistivity model, based on the ion meandering orbit effect obtained by PIC simulation results of collisionless driven reconnection in the steady state [3] for MHD framework. Other mechanism of resistivity is due to the growth of the drift kink instability (DKI). Moritaka and Horiuchi demonstrated that the DK mode generates the anomalous resistivity and estimated the effective anomalous resistivity, η_{eff} estimated as [4].

$$\eta_{\mathrm{eff}} = a \times \eta_{\mathrm{Hall}} = a \times \frac{B_o}{eN_o} \qquad (1)$$

where B_o and N_o are constant magnetic field, normalization factor of the magnetic field, and the density at the neutral sheet in the initial profile, respectively. The coefficient a evolves, i.e., a=0.02～0.1 according to the growth of the DKI. It is noted that this evaluation is in PIC simulations. We derived that the additional coefficients are needed to use this model in MHD framework as follows

$$\eta_{\mathrm{eff,MHD}} = a \times \left(\frac{d_i}{L}\right) \frac{\hat{\rho}_{0,MHD}}{\hat{\rho}_{(r=N),MHD}} \hat{B}_{0,MHD} \qquad (2)$$

where the index MHD means the variables in MHD, 0 does normalization, d_i is the ion inertial length and L is the radius of the Earth. The variable $\hat{\rho}_{(r=N),MHD}$ is the density in neutral sheet. and evolves and varies in space according to MHD equations. We will evaluate this resistivity model by global magnetosphere simulation in near future.

The grid structure can give the most important influence on the performance of the global simulation. Recently Tanaka developed simulation code, named the REPPU (REProduce Plasma Universe) code, which grid system has no apparent singularity [5]. Figure 1 shows the simulation results of the AU, AL indices with wave phenomena on the ground. This code can also reproduce the sudden increase of the AL clearly at onset of substorm.

We need to fill the gap between micro scale and macro scale toward multi-hierarchy modeling of magneto -sphere simulation. Indeed the gap is too large to connect those scales directly, so we insert Adapted Mesh Refinement (AMR) scheme [6] in REPPU code. As the first step, we begin with the solar wind model simulated by REPPU code. We treat supersonic velocity region of the solar wind because of ease of test calculation for connection of two codes. Figure 2 displays color contour of solar wind velocity on an equational plane of a 3D AMR MHD simulation on Cartesian mesh. Sun locates (x,y)=(32,-20); outside the simulation box. The initial condition and the y-lower boundary condition are input from REPPU code in which Sun locates the center of its simulation box. It shows smooth connection from REPPU code to AMR code.

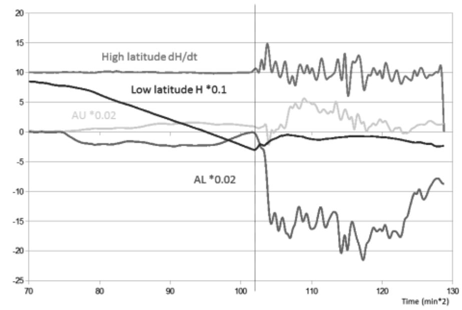

Fig. 1. Ground magnetic perturbations derived from the global MHD simulation. These are the AU, AL indices, with waves named high-latitude Pi2, low-latitude Pi2 and the low-latitude positive bay.

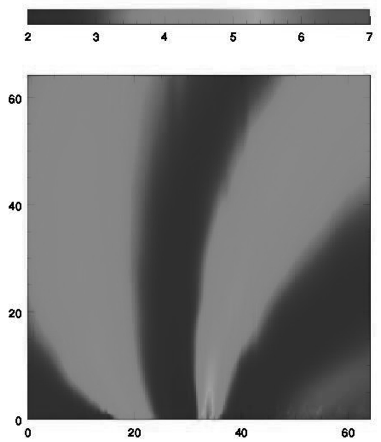

Fig. 2. Test simulation of connection between AMR and REPPU code. Color contour indicates the solar wind velocity.

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