§12. Toward Multi-herarchy Modeling of Magnetosphere Simulation

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We study the effective resistivity model in macro-scale. Moritaka and Horiuchi [1] obtained the anomalous resistivity model induced in the instability during the wave-particle interaction by using two dimensional particle in cell (PIC) simulation. When applying their model to MHD framework, we derive that the additional coefficients are needed to use this model in as follows

$$\eta_{\mathrm{eff,MHD}} = a \times \left(\frac{d_i}{L}\right) \frac{\hat{\rho}_{0,MHD}}{\hat{\rho}_{(r=N),MHD}} \hat{B}_{0,MHD} \qquad (1)$$

where the coefficient a evolves from 0.02 to 0.1, the index MHD means the variables in MHD, 0 does in normalization, d_i is the ion inertial length, L is the radius of the Earth and B_o is a magnetic field at ion larmor radius scale distant from the current sheet. The variable $\hat{\rho}_{(r=N),MHD}$ is the density in neutral sheet and evolves and varies in space according to MHD equations. We carry out substorm simulation using a global MHD code [2] with the effective resistivity model given in Eq. (1). Magnetic reconnection during substorm

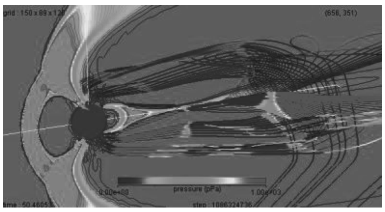

Fig. 1. Snapshot when magnetic reconnection occurred. Color contour and lines display plasma pressure and magnetic field.

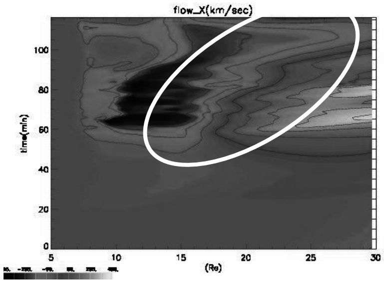

Fig. 2. Time evolution of velocity in the Sun-Earth direction. A white circle shows region of move of magnetic reconnection points.

could be reproduced as shown in Figs. 1 and 2, however, dependence of a was not found. We think this result is due to insufficient resolution of our global simulation, and continue studying this issue.

We extended Usami's MHD domain to a hierarchical mesh [3] that is controlled by Adaptive Mesh Refinement (AMR) technique (Ogawa et al. 2014[4]), aiming to connect the local PIC calculation with a global MHD simulation. In this study, we input external data that are derived from a global simulation of Earth's magnetosphere to our simulation. The input data decides the initial condition and the boundary condition. It leads to magnetic reconnection in the PIC domain. We present results in Fig. 3. The plots show density, pressure and v-component of velocity on the line of x=64, z=0.5 (upper) and the color contours display distributions of density (lower) on the plane of z=0.5 at t=20 (left) and t=99 (right). At t=20, density and pressure have some fluctuations, as flow toward the center region. Then the inflow meet in the centered PIC domain. Distribution of density and y-component of magnetic field at t=99 show indication of magnetic reconnection beginning. PIC noise can be seen in the PIC domain. It is well suppressed in the interface domain.

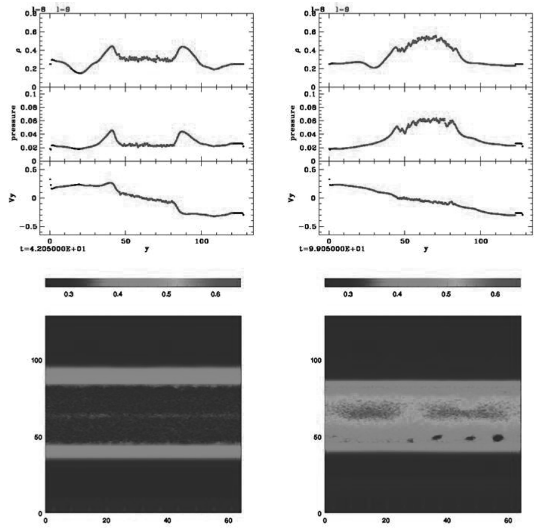

Fig. 3. Snapshots of multi-scale simulation of flux inflows using the connected PIC, uniform grid MHD and AMR-MHD models.

1) Moritaka, T. and Horiuchi, R.: Phys. Plasmas **15** (2008) 092114.
2) Tanaka, T., *J. Comput. Phys*. **111** 381 (1994).
3) S. Usami, R. Horiuchi, H. Ohtani, and M. Den, Phys. Plasmas **20**, 061208 (2013).
4) T. Ogawa, S. Usami, R. Horiuchi, M. Den, K. Yamashita, JPS Conf. Proc. **1**, 016013 (2014).