§9. Global Structure of the Substorm Depending on Magnetotail Reconnection Model

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Dynamical range is too wide for magnetic reconnection in the earth's magnetosphere, though that phenomenon is considered to play an important role in space phenomena such as substorm in the Earth's magnetosphere. Indeed modeling of anomalous resistivity is necessary in magnetohydrodynamic (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. We called the steady collisionless driven reconnection (SCDR) resistivity model As for other mechanism of resistivity, it is known that the growth of the drift kink instability (DKI) creates anomalous resistivity. Moritaka and Horiuchi estimated the effective resistivity based on the particle simulation data [4]. We perform substorm simulation by using the global MHD code developed by Tanaka et al. [1] with an effective resistivity model based on anomalous resistivity due to DKI and investigate applicability of the present effective resistivity model by comparing simulation results such as flux rope formation, the expected earthward and tailward flows generated by magnetic reconnections and the AEJ indices with our previous results[2]. Moritaka and Horiuchi demonstrated that the DK mode generates the anomalous resistivity and estimated the effective anomalous resistivity, $\eta_{\rm eff}$, estimated as

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

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 [4]. On the other hand, in the alternative SCDR resistivity model, the effective resistivity model is evaluated by

$$\eta_{\rm eff} = \left|\mathbf{v}\times\mathbf{B}\right|_{periphery} / \left|\mathbf{J}\right|_{center} \qquad (2)$$

where **B**, ***v*** and ***J*** are the magnetic field, the fluid velocity and the current respectively, and periphery and center mean the region apart from the reconnection point and the reconnection point respectively [2]. Figure 1 illustrates evolution of magnitude of the velocity on the Sun-Earth direction in the magnetotail. The horizontal and vertical axes represent the distance from the Earth and time, respectively. The blue region represents the earthward flow and the red region does the tailward flow. In addition, the green region is that of the slow velocity flow, and the region enclosed by the white circle indicates the region where the reconnection occurs. It is clearly seen that the reconnection point moves tailward. Note that the first reconnection point almost coincides with the timing of reconnection at almost 15 *Re* (the Earth radius) from the Earth at about 60 minute after the southward interplanetary magnetic field reached the bow shock. All simulations yield similar tailward speed of the reconnection points. A second reconnection appears in the SCDR and the constant resistivity models (see Panels C and D, respectively) at around 90 minute, which is absent in the DKII resistivity model. The maximum velocity is also similar among the four models, ranging from 440 km/sec (the constant resistivity) to 550 km/sec (the SCDR resistivity model) . Thus the time and place of reconnection and the speed of the reconnection point are determined by global conditions, whereas the emergence of multiple reconnections appears to depend on the resistivity model. We recognize that revaluation of the coefficient a is needed because of difference of normalization in PIC and MHD simulations, and we will carry out simulations with that coefficient.

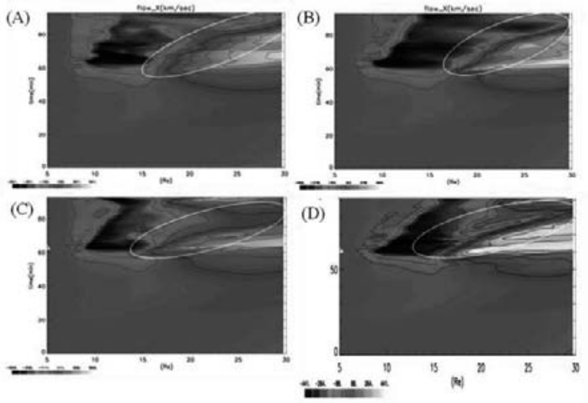

Fig. 1. Time evolution of the flow velocity on Sun-Earth direction in the magnetotail for (A) the DKII resistivity model with a=0.02, for (B) the DKII resistivity model with a=45, for (C) the SCDR resistivity model, and for (D) the constant resistivity model. The horizontal and vertical axes represent the distance from the Earth and time, respectively.

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2) Horiuchi R. and Den M. et al.: Plasma Phys. Control. Fusion 55 (2013).
3) Ishizawa, A. and Horiuchi, R.: Phys. Rev. Lett., **95** (2005) 045003.
4) Moritaka, T. and Horiuchi, R.: Phys. Plasmas **15** (2008) 092114.