Superposed Epoch Study of the Substorm Triggering in the Earth's magnetotail (II)

Shinobu Machida[1]; Yukinaga Miyashita[2]; Kan Liou[3]; Akimasa Ieda[4]; Daisuke Nagata[5]; Tsugunobu Nagai[6]; Takahiro Obara[7]; Yoshifumi Saito[8]; Toshifumi Mukai[9]

[1] Dept. of Geophys., Kyoto Univ.; [2] ISAS/JAXA; [3] JHU/APL; [4] STEL, Nagoya Univ.; [5] Dept. of Geophysics, Kyoto Univ.; [6] Tokyo Institue of Technology; [7] NICT; [8] ISAS; [9] JAXA

http://www-step.kugi.kyoto-u.ac.jp/~machida/

Time development of near-Earth magnetotail during substorms has been investigated by multi-dimensional superposed-epoch analysis with Geotail data according to the method described in a paper by Machida et al. [JGR, 25291, 2000]. The start time of each substorm was determined by auroral data obtained by Polar and Image spacecrafts, and key parameters derived from plasma, magnetic field and electric field data were sorted in the X(GSM) - Z(estimated) coordinates, in which we assume that an event with higher plasma-beta should be located closer to the plasma-sheet center.

The result shows that the earthward flows exist in the plasma-sheet boundary layer from -20Re to -30Re in X prior to the substorm onset. This flow is a foundation of the boundary layer model of substorm. The Poynting flux toward the plasma sheet center also enhances in the lobe region from -10Re to -15Re in X. This Poynting flux is a necessary condition for the thermal catastrophe model although it was the AC field in that model, but what we found is the Poynting flux of DC filed. Interestingly, earthward flow in the central plasma sheet between -13Re and -20Re in X starts about 4 min before the onset.

After t = 0, i.e., the auroral break-up, the dipolarization and the tailward flows with southward magnetic fields of plasmoid start. Those variations are predicted by the current disruption model, the ballooning instability model, and the near-Earth neutral line model. The initial location of the total pressure decrease is obscured but it seems to start in the central plasma sheet from -10Re to -20Re in X at t ~-4 min. And, this variation propagates to the surrounding regions successively.

We could confirm various variations which relevant models of substorm are based on or predict. However, none of them can perfectly explain our results. Thereby, we propose a new model, in which the Poynting flux toward the plasma sheet center enhances the JxB force, resulting in the earthward motion of highly stretched closed field lines about 4 min before the onset. This earthward flow induces the ballooning instability or other instability to cause the current disruption. The formation of the magnetic neutral line is a natural consequence of the present model, namely, the relaxation of a highly stretched sling-shot current sheet produces the enhanced duskward electric field at its tailward edge, which is the boundary between the sling-shot current with large stress and the Harris-type current sheet with little stress. Further, induced flows toward the current sheet center around the boundary may enhance the formation of the magnetic neutral line and the efficiency of the magnetic reconnection.