A statistical study of near-earth magnetotail variations during substorm based on THEMIS data

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The energy imparted from the solar wind is stored as a form of magnetic energy in the magnetotail. When this process has progressed excessively, the energy release in which the magnetic energy is transferred to the kinetic energy of the particles begins. A part of physical mechanisms of this phenomenon called a substorm, is still not known.
In this study, we investigate the temporal and spatial development of the near-Earth magnetotail during substorms based on a superposed-epoch analysis of THEMIS data in the interval from November 2007 to April 2010, using a substorm onset as a time reference. To investigate the transport of the magnetic flux, we evaluated the ion flow velocity vector perpendicular to the magnetic field and perform the superposed epoch analysis for its three components. In addition, we carry out similar analysis by collecting data of positive and negative values of three velocity components separately to investigate relative timings of the flows with respect to the substorm onset.
The result shows that earthward flows increase just before the substorm onset, and tailward flows increase just after the onset in the region of -10 > X(GSM) > -12 Re (Earth radii). Furthermore, the fraction of the earthward flow events to the total events (earthward and tailward flow events) increases just before the onset, followed by increase of the fraction of tailward flow events. These results supports the validity of the NENL (Near-Earth Neutral Line) model and CCSR (Catapult Current Sheet Relaxation) model in which the earthward flows start earlier than the substorm onset. As for the increase of the tailward flows, it can be interpreted by reflection model proposed by Ohtani et al. (2009). Concerning the flows in Y-direction, they increase in the dawnward direction just before the onset, and duskward flows increase just after the onset in -10 > X(GSM) > -12 Re . It is possibly because our dataset contains more events in the dusk-side than those in the dawn-side, thereby, the initial flow is in the earthward and slightly dawnward directions reflecting the magnetic field structure in that region.
It is also found that immediately after the onset, it is found that the number of earthward flows becomes almost the same to the number of tailward flows in -8> X> -9Re. This can be the result of the ballooning instability which causes the current disruption (CD). Combining, this result with those forementioned, we can conclude that the NENL or CCSR model is more appropriate than the CD model to explain the onset of substorm.

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