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Energy release between the tail magnetic reconnection and dipolarization regions and its role in the substorm onset

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The triggering mechanism of a substorm expansion onset is continually a major controversial issue in magnetospheric research. Various models, such as the near-Earth neutral line model and the current disruption model, have been proposed. These models "predict" different observational features in the initial process, its location, and the propagation direction of the resultant flows or waves. The critical issues for understanding the substorm onset mechanism include the relative timing and causal relationship between the magnetic reconnection and the current disruption as well as the processes midway between the regions of the two processes, such as fast earthward flows and waves. To solve these issues, we have performed statistical analyses and showed an overall picture of substorm-associated evolution of the near-Earth magnetotail. Namely, the magnetic reconnection occurs at X ~ -16 to -20 Re at least 2 min before onset to create a plasmoid tailward of X ~ -20 Re. Almost simultaneously with the magnetic reconnection, i.e., within 2 min, the dipolarization begins at X ~ -7 to -10 Re. Furthermore, we showed that the energy release occurs in the magnetic reconnection region and its surrounding regions, associated with substorm expansion onsets. Interestingly, the energy release is more significant between the regions of the magnetic reconnection and the initial dipolarization, rather than in the magnetic reconnection region, and is more widely seen than localized fast earthward flows. On the other hand, the energy increases in the initial dipolarization region at X $>$ -12 Re. In the present study, we discuss what a large amount of the released energy in the midway region is spent in, where it is transported, and what is its role in the substorm onset.

Keywords: substorm, magnetotail, energy release, energy transport, magnetic reconnection, dipolarization