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Roles of the near-Earth tail in energy storage and release processes during substorms

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The magnetic energy in the lobe is $P_b V$, where P_b is the magnetic pressure in the lobe and V is the volume encircled by the tail current. A change in the magnetic energy as a result of energy storage and release is possible in two ways: (1) both P_b and V are changed, which is the traditional view of the growth phase of substorms and plasma sheet thinning for energy storage, and (2) only V is changed. The latter way of the energy storage and release was recently found by five-point THEMIS observations on 8 April 2009 substorm. By estimating a radial profile of the plasma pressure during the plasma sheet thinning, it can be shown that with no increase in the total pressure, the energy storage is possible by the inward penetration of the current sheet. In addition to that, this new type of the thinning can explain the formation of the near-Earth neutral line or the weak magnetic field region. Detailed analyses of this new type of thinning and extended case studies using THEMIS, Geotail and GOES were performed to understand the role of the near-Earth tail in the growth phase of substorms. It should be stressed that some of widely adapted presumptions for the near-Earth tail analysis and understanding require severe cautions. First, the assumption of one dimensional geometry or a pressure balance, i.e. negligible tension force, are not appropriate, while isotropic MHD force balance is valid. Second, spatial profiles of the magnetic field and current requires cautions: the equatorial field has a local minimum and current density is non-uniform. Finally, when the traditional thinning was observed during the growth phase, the plasma sheet evolved in a non-monotonic way. In the late growth phase, the increasing trend in the total pressure ceased and became constant in time. Overall, this study suggests that the new type of the current sheet thinning is a leading factor for the substorm onset.

Keywords: substorm, magnetotail, plasma sheet, multi-spacecraft analysis