Tailward flows in the near-Earth plasma sheet around substorms

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Tailward flows in the plasma sheet are sometimes observed even in the near-Earth region (from Xgsm [Re] = -8 to -15), which have not been explained by conventional substorm models. In order to understand the cause and effect of these flows in the framework of substorms, we have investigated features of the perpendicular flows in the plasma sheet measured by GEOTAIL in terms of their occurrence positions, durations, relative timings to substorm onsets, motions, and structures. The timing of the auroral onset determined by Polar/UVI images has been used. We have so far found (1) the tailward flows are observed ubiquitously in the near-Earth plasma sheet and their average flow directions are approximately along the Xgsm axis, (2) their occurrence rate significantly rises after substorm onsets, and (3) the tailward flows are often preceded by earthward flows. The result (3) suggests that the tailward flows represent reflection of earthward flows or passage of vortical flows. Regarding the possibility of reflection, we have statistically estimated the length of traveling path of these flows, that is, the distance from GEOTAIL to the reflection point, as a function of the satellite position. As a result, the travel path length decreases as the observing position (i.e., at GEOTAIL) approaches the Earth, but thus estimated reflection point approaches the Earth as the observing position approaches the Earth; this is unreasonable, suggesting that reflections do not occur at a fixed point in the near-Earth region. As for the possibility of vortical flows, we have applied the minimum variance method to these flows. The result suggests that these flows may correspond to the vortices in the plasma sheet for some events. We have estimated a scale and a motion of a vortex during a large substorm. The result shows that it is difficult to interpret this vortex to be a part of the wedge current system.