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主 論 文 の 要 旨

論文題目　**Study of substorm onset processes in the magnetosphere and the ionosphere using satellite and ground-based observations (衛星と地上観測を基にした磁気圏と電離圏におけるサブストーム開始プロセスに関する研究)**

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論 文 内 容 の 要 旨

Substorms are fundamental geomagnetic and auroral disturbances with time scales of 2–3 h. Among various substorm models, the location and mechanism of substorm onsets are still under debate. In this thesis, we focused on the onset mechanisms of substorms in the magnetosphere and the ionosphere, as well as how the Earth's upper atmosphere can be affected at substorm onsets. We analyzed data obtained from satellite and ground-based instruments, and applied various empirical models. The contents can be divided into the following four topics.

Firstly, we focused on the substorm onset mechanism in the magnetosphere. For the first time, we statistically studied severe magnetic fluctuations in the near-Earth magnetotail at 6–12 R_E, which may cause substorm-associated tail-current disruption. We used the magnetic field data with a sampling rate of 4 Hz obtained by the Time History of Events and Macroscale Interactions during Substorms E (THEMIS-E) satellite for 2013–2014. We identified 3322 severe magnetic fluctuation events, and found that their occurrence rates are 0.00312 %, 0.0312 %, and 0.0675 % at 6–8, 8–10, and 10–12 R_E, respectively in the near-Earth tail. These severe magnetic fluctuations occurred near the substorm onsets or during the expansion phase of substorms. We also found that the speed of plasma flow increases before the severe magnetic fluctuations. We discussed how both the inside-out and outside-in substorm models can explain these features.

Second, we investigated the spectral property of these severe magnetic fluctuations. We used the measurements of THEMIS-D and E for 2008–2018. Because magnetic field dipolarization is a signature of substorm onset, we further extracted 36 dipolarization events with severe magnetic fluctuations. We calculated the power spectral density (PSD) of magnetic fluctuations during these dipolarization events, and found that the steepness of the spectral slope increases with increasing frequency for almost all the events. We showed the average PSDs of magnetic fluctuations sorted by (a) the distance to the neutral sheet and (b) ambient magnetic field intensity. In all groups, the slopes of average PSDs becomes steeper abruptly from below ~$10^{-1.3}$ Hz to above ~$10^{-1.3}$ Hz (0.05 Hz). We also see a clear increase of the slope at 0.05–0.1 Hz in case of larger ambient magnetic field intensity, implying that the magnetic fluctuations have a relatively strong power near the ion gyrofrequency and may contribute to the non-magnetohydrodynamics (non-MHD) effect in ion motion.

Thirdly, we focused on the ionospheric and thermospheric processes at substorm onsets. We studied the high-latitude thermospheric wind variations at local substorm onsets at Tromsø, Norway. We obtained four events, whose wind measurements were obtained at altitudes of 200–300 km by a Fabry-Perot interferometer (FPI). All events showed eastward increases of zonal winds at local substorm onsets. For meridional winds, these events showed southward increases except for those at midnight. The observed wind variations (< 49 m/s) were much smaller than the typical plasma convection speed in the auroral zone. Therefore, we speculate that the wind-induced ionospheric current at local substorm onsets does not provide strong feedback to the development of substorm expansion phase in the magnetotail. We then discussed the possible causes of the observed wind variations.

Finally, we also investigated the average winds in the thermosphere during geomagnetically quiet times. We used wind measurements for 2009–2015 obtained by the same FPI at Tromsø. On average, the zonal wind shows a westward increase before the midnight compared with winds expected from diurnal tides. A maximum speed of 100 m/s occurs at both the dusk and dawn sides. The meridional wind has a diurnal-tide structure with a minimum value of -130 m/s near the midnight. We also reported occasional large wind deviations (> 100 m/s) from the average winds even during geomagnetically quiet time. We then applied these quiet-time average winds to the previous event study in the third topic, and concluded that the substorm-associated winds with shorter time period are the main contributors to the observed thermospheric wind variations at local substorm onsets.

The results of these four topics indicate: (1) Substorm onset is unlikely to be caused by severe magnetic fluctuations in the near-Earth magnetotail or thermospheric wind variations at high latitudes, although we did not completely deny the scenarios of substorm onset by inside-out and magnetosphere-ionosphere coupling (MIC) substorm models. (2) At local substorm onsets, high-latitude thermospheric wind can be affected by various phenomena, and is dominated by substorm-associated energy input from the magnetosphere, such as plasma convection.