

## Low-frequency waves in the near-Earth magnetotail before substorm dipolarization onsets

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Dipolarization which occurs in the near-Earth magnetotail is an important process for understanding the substorm triggering mechanism. In the present study we have investigated low-frequency waves that were observed at  $X \sim 10$  Re before substorm dipolarization onsets. First, we analyzed Geotail data for 43 substorm events. We find that there are small-amplitude Alfvén and slow-mode magnetosonic waves with a period of 1-2 min from at least 10 min before dipolarization onset. These waves substantially grow after onset. The amplitude of the waves before onset is relatively large in the off-equator plasma sheet and the plasma sheet boundary layer, while it is smaller at the equator and in the lobe. We also analyzed multi-point observations from THEMIS. Based on these results, we discuss the relationship between the low-frequency waves, dipolarization, and substorm expansion onset.

Keywords: substorm, magnetotail, dipolarization, low-frequency waves