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Substorm onset process: Ignition of auroral acceleration and related substorm phases

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The substorm onset process was studied on the basis of the vertical evolution of auroral acceleration regions derived from auroral kilometric radiation (AKR) spectra and Pi pulsations on the ground. The field-aligned auroral acceleration at substorm onset demonstrated two distinct phases. Low-altitude acceleration (h˜3000-5000 km), which accompanied auroral initial brightening, pre-breakup Pi2, and direct current of ultra-low frequency (DC-ULF) pulsation, was first activated and played an important role (pre-condition) in the subsequent substorm expansion-phase onset. Pre-breakup Pi 2 is suggestive of the ballooning-mode wave generation, and negative decrease in DC-ULF suggests increasing field-aligned current (FAC). We called this stage the substorm initial phase. A few minutes after this initial phase onset, high-altitude acceleration, which accompanied auroral breakup and poleward expansion with breakup Pi 1 and Pi 2 pulsations, suddenly broke out in an altitude range from 8000-16000 km. Thus, substorm expansion onset originated in the magnetosphere-ionosphere (M-I) coupling region, i.e., substorm ignition in the M-I coupling region. It is suggested that current disruption and subsequent violent energy release from the tail region take place after this ignition. Statistical investigations revealed that about 65% of earthward flow bursts observed in the plasma sheet were accompanied by enhanced low-altitude AKR, suggesting that flow braking of bursts causes FAC and resulting low-altitude field-aligned acceleration in the M-I coupling region. On the basis of these observations, we propose a substorm onset scenario in which FAC that originated from the braking of plasma flow bursts first enhances low-altitude acceleration (substorm initial phase onset), and then the increasing FAC induces current-driven instability in the M-I coupling region, which leads to high-altitude acceleration and resulting substorm expansion-phase onset.

Keywords: substorm, aurora, acceleration region, substorm onset