Two-step evolution of auroral acceleration and pseudo-/full-substorms

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The auroral substorm morphology documented by Akasofu [1964] has been widely accepted: the expansion phase of auroral substorm is characterized by a sudden brightening of auroral arc (Stage I) which is followed by its rapid poleward motion in a few minutes (Stage II). A sudden brightening (Stage I) which is not followed by poleward expansion and global development in the auroral latitude and longitude (Stage II) is called pseudobreakup. These two stages of auroral substorm onset imply that auroral substorm onset is composed of two-step evolution of auroral particle injection and/or acceleration process. From this viewpoint, geophysical differences between pseudobreakups and full substorms have been studied. Results from these many studies suggested that there exist no significant physical differences between pseudo-substorms and full-substorms in the magnetosphere and on ground. It rather seems that there is a phenomenological continuum of states between the small pseudobreakups and large substorms. Ohtani et al. [2002] suggested that an unknown condition is necessary to develop from pseudo-breakup to the full substorm, even when the magnetic flux transport is sufficient from the tail region.

An abrupt particle acceleration along auroral field lines, that is, the sudden formation of a parallel electric field in the magnetosphere-ionosphere (M-I) coupling system, is essential to complete the substorm onset process. In this paper, we examine the pseudobreakup/full-substorm problem focusing on the particle acceleration in the M-I coupling region, where the field-aligned auroral acceleration shows two types evolution at substorm onset as recently shown by Morioka et al. [2009] referring the dynamical behaviors of auroral kilometric radiation (AKR).

The result showed that Stage I (initial brightening) and II (breakup and poleward expansion) correspond to the activation of the low-altitude acceleration region and breakout of the high-altitude acceleration region, respectively. Cases when only the low-altitude acceleration is activated without the breakout of the high-altitude one are the pseudo-substorm. In other word, the breakout of the high-altitude acceleration region in the M-I coupling region divides the substorm into pseudo-substorm and full-substorm. Further analysis suggests that when the field aligned current during the initial brightening becomes stronger, it leads to the current driven instability in the M-I coupling region which induces the breakout of the high-altitude acceleration.