Substorm simulation: Current system and auroral structure

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Substorm is known to cause strong geomagnetically induced current (GIC) on the ground in the polar region. The GIC is primarily caused by the ionospheric current that is intensified by field-aligned current (FAC) during the substorm. On the basis of the result obtained by a global magnetohydrodynamic (MHD) simulation, we propose a scenario for the evolution of the current system associated with a substorm expansion. (1) Near-Earth neutral line releases magnetic tension in the near-Earth plasma sheet to compress plasma and accelerate it earthward. (2) Earthward, perpendicular flow is converted to parallel flow when flow braking takes place. (3) Plasma moves earthward parallel to a field line. The plasma pressure is additionally enhanced at off-equator. (4) Flow vorticities coexist near the off-equatorial high-pressure region. Resultant FAC is connected to the ionosphere, which may manifest initial brightening of aurora. The ionospheric current starts to increase. (5) Due to continued earthward flow, the high-plasma pressure region continues to expand to the east and west. (6) The ionospheric conductivity continues to increase in the upward FAC region, and the conductivity gradient becomes steeper. (7) The convergence of the Hall current gives rise to divergent electric field near the steep gradient of the conductivity. (8) Due to the divergent electric field, magnetospheric plasma moves counterclockwise at low altitude (as seen in the Northern Hemisphere). (9) The additional flow vorticity generates a localized upward FAC at low altitudes, which may manifest westward traveling surge (WTS) of aurora. As a consequence, the ionospheric current, conductivity, and the magnetospheric current system are redistributed. The evolution of the substorm depends on the solar wind condition as well as the magnetospheric condition. We will discuss the optimal condition that potentially causes the strong substorm.

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