## Unified theory of substorm auroral sequence

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As the observational appearance, the substorm consists of four consecutive periods, the growth phase, the onset, the expansion phase, and the recovery phase [McPherron, 1970, 1979]. According to the development of these phases, various auroral forms occur sequentially in the ionosphere together with the corresponding auroral current system [Elphinstone et al., 1993; Kamide et al., 1996]. It is extensively studied how auroras and associated geomagnetic perturbations occur in the ionosphere. The problem is their origins in the magnetosphere. The key mechanism is the magnetosphere-ionosphere (M-I) coupling process realized by the exchange of the field-aligned current (FAC) between the ionosphere and the magnetosphere. Especially, the origin of arc type auroras must coexist with the source mechanism of the upward FAC. In this paper, we try to discuss the substorm mechanism recognizing that the generation process of the FAC has a crucial importance. We consider two main points to understand the generation of the FAC. The first point is to understand the FAC as the mechanism which transmits the motion from the magnetosphere to the ionosphere [lijima, 2000; Birn and Hesse, 2013; Tanaka, 2015]. In other words, if there is an arc aurora, we must identify the motion (shear) that should be transmitted. The second point is to understand the FAC as the energy supplier that compensates the ionospheric dissipation to maintain the convection. For this purpose, we must search for the dynamo that energize the FAC [Tanaka, 2007; Kikuchi, 2014; Tanaka et al., 2016]. These points are clarified from the global simulation which gives numerical solutions having an extremely high resolution. The substorm solution obtained from the high-resolution simulation reproduces the precise sequence of the substorm in the ionosphere. It can reproduce sequentially the quiet arc during the growth phase, initial brightening at the onset, and the westward traveling surge (WTS) during the expansion phase. It even reproduces the onset that starts from the equatorward side of the oval, two step development of the onset aurora, and the WTS that starts two minutes after the initial brightening. Then, we investigated the counter structures in the magnetosphere that correspond to each aurora in the ionosphere. The structure in the magnetosphere promoting the initial brightening is the near-earth dynamo in the inner magnetospheric region away from the equatorial plane. The near-earth dynamo is driven by the field-aligned pressure increase due to the parallel flow associated with the squeezing, combined with equatorward field-perpendicular flow induced by the near-earth neutral line (NENL). The dipolarization front is launched from the NENL associated with the convection transient from the growth phase to the expansion phase, but neither the launch nor the arrival of the dipolarization front coincides with the initial brightening. The arrival of flow to the equatorial plane of the inner magnetosphere occurs two minutes after the onset, when the WTS starts to develop toward the west. Looking at the present result that the onset is induced by the near-earth dynamo and the details of auroral sequence is understood from it, we cannot avoid to conclude that the current wedge (CW) is a misleading concept.

Keywords: Substorm aurora sequence, Field-aligned current, Near-earth dynamo