Abstract

Main purpose of this study is to analyze auroral substorm evolution in detail as possible as we can, by using the global auroral observation by the AKEBONO UV imager (ATV-UV) and the local auroral observation by the ground-based instruments (meridian scanning photometer (MSP) and all-sky SIT-TV camera) at Syowa and Asuka stations in Antarctica. Austral winter in 1989 is our target period because the simultaneous observations by the ATV-UV and the MSP/SIT-TV were accomplished only during this period. We have searched such an event where the global auroral substorm evolution was observed by the ATV-UV with a sufficiently long period from the initial brightening, and the local auroral substorm signature, poleward expansion, was observed by the MSP and SIT-TV camera at Syowa and/or Asuka stations. Only one such event, on June 6-7, 1989, was found. We have analyzed the evolution during the growth phase to middle of the expansion phase in the special event in detail.

Through the period from the late growth phase to the middle of the expansion phase, it was found that a characteristic auroral activity, which we called the NPSBL (Near Plasma Sheet Boundary Layer) aurora, should play an important role in the auroral substorm evolution. The NPSBL aurora clearly appeared around the ionospheric PSBL region a few minutes before the onset, and was clearly intensified a few minutes after the onset. It continued to exist around the same location until the local further poleward expansion. The local further poleward expansion started with a significant intensification and a significant enlargement of the latitudinal width of the poleward-most auroral activity. The initial rapid poleward expansion of the bulge started at lower latitudes well away from the NPSBL aurora, and was suddenly slowed around the latitudes of the NPSBL aurora, which was true both in the global auroral evolution and the local auroral poleward expansion.

It was also found that there were three distinct stages in the auroral bulge evolution. The Stage-1 was characterized by a rapid poleward and rapid azimuthal expansion in a short time. The next Stage-2 was characterized by a very slow poleward and nearly symmetric slower azimuthal expansion. The last Stage-3 was characterized by a sudden re-activation of the rapid poleward and rapid azimuthal expansion. Such a three-stage evolution was also found in the local poleward expansion. Simultaneous observations by the ATV-UV and MSPs at Asuka and Syowa stations revealed that the global auroral bulge expansion during the Stage-3 proceeded as a successive azimuthal propagation of such a local three-stage evolution. The NPSBL aurora played an important role in the three-stage evolution.

We have searched similar events of the local poleward expansion as shown in the detailed study of the special event, and found the total 13 events in the MSP data in 1989. In all the 13 events, similar evolution of the NPSBL aurora, and its similar association with the stepwise three-stage evolution were found. The statistical study of the 13 events suggests that such features (the NPSBL aurora and the three-stage evolution) should appear when the initial poleward expansion occurs at sufficiently lower latitude region around midnight hours.

Other several important findings in the detailed study of the special event are as follows.

1. It was found that the evolution of the nightside convection during the growth phase was closely associated with the evolution of the FEM (Fast Equatorward Moving) arc. Toward the onset, both the FEM arc and peak velocity of the return flows of the two-cell convection moved equatorward from around the PSBL region to lower latitudes.
2. The UV auroral breakup occurred around the demarcation region of the two-cell convection in a pre-midnight localized area at a little higher latitudes of the FEM arc around the poleward edge of the proton main oval.
3. A clear waveform of the initial Pi2 pulsations was observed only during the Stage-1, and was significantly damped afterward.
4. Intensification of the Pi1B pulsations was delayed from the Pi2 onset by about 80 sec, and the initial Pi1Bs were damped during the transition phase from the Stage-1 to Stage-2.
5. The negative and positive potentials of the substorm current wedge (SCW) system should be located at equatorward-westward and poleward-eastward sides of the bulge, respectively, from the beginning of the bulge formation. Hence the central part of the bulge did not correspond to the central location of the negative potential from the beginning.
6. The SCW system showed a stepwise evolution, being closely associated with the three-stage evolution of the auroral bulge.
7. During the local third stage, the bright electron emission region was bifurcated into the poleward expanding part and the equatorward moving part. The pulsating auroral activity appeared in the equatorward part soon after the bifurcation.
8. The proton auroral emission co-existed with the electron emission within the bulge during the period from the local first stage to the second stage, and almost disappeared soon after the bifurcation of the electron auroral region during the local third stage.
9. The increase of the energetic particle flux at geosynchronous orbit, observed on the eastern side of the bulge, also showed a stepwise evolution.

Based on these observations and a great amount of previous works by other researchers, we have discussed the substorm evolution in the magnetosphere.