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IONOSPHERIC CLOSURE OF THE SUBSTORM CURRENT WEDGE SYSTEM DEDUCED FROM THE VISIBLE AURORAL IMAGER ABOARD AKEBONO (EXTENDED ABSTRACT)

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An example of local auroral intensification event was analyzed. The auroral data were obtained with the VISible Auroral TV camera (ATV-VIS) aboard AKEBONO satellite. ATV-VIS can take a snapshot of a monochromatic (OI 557.7 nm) auroral image at every satellite spin period (about 8 s). The data were obtained on December 22, 1992 over North American area. Satellite altitudes were 2558 km–3994 km during the observation period of 0817:38 UT–0827:02 UT. In this period of only 564 s, ATV-VIS took 38 images. Spatial resolutions in its field of view (FOV) were 12 km–150 km depending on each viewing point. Ground magnetometer data were provided from Canadian Auroral Network for the Open Program Unified Study (CANOPUS), STEP Polar Network, INTERMAGNET, and WDC-C2 for geomagnetism.

From 0821:48 UT, a weak bright spot appeared in the auroral image. Its location was at about 72.0° corrected geomagnetic latitude (CMLAT) and 22.2 hr magnetic local time (MLT), and its peak intensity was about 10.0 kR. (Since there were no calibration for the intensity after launch, these values in this paper were based on the calibration data before launch.) Both its emission intensity and occupied area gradually increased, reached a peak value at 0825:01 UT (the peak intensity was 51.3 kR), and then decreased. During the increasing and decreasing stages, some kind of deformation of the bright area could be seen. Well corresponding to this auroral activity, ionospheric equivalent current deduced from the ground magnetometer data also developed and then declined during this period.

Figure 1 shows an auroral image taken at 0824:13 UT in the increasing stage. In Fig. 1, the colored area standing out from black background is the FOV of ATV-VIS. The bright area in the upper right corner in the FOV is an effect of the stray light, and the light on the lower left side is a contribution from the airglow at the limb of the earth. A bright island at around 72.0° CMLAT and 22.0 hr MLT is the intensified auroral activity mentioned above. It can be seen that a weak diffuse auroral region extended from the eastern side of the bright island to the lower latitudes, and then extended eastward to form a main diffuse auroral oval whose central location is at 67° CMLAT at 23 hr MLT. The diffuse auroral region showed a higher intensity as it shifted nearer to the bright island.

Figure 1 shows also the equivalent current vector at each station at the ATV-VIS observation time, for the deviation from the value at 0759 UT. Black or white small

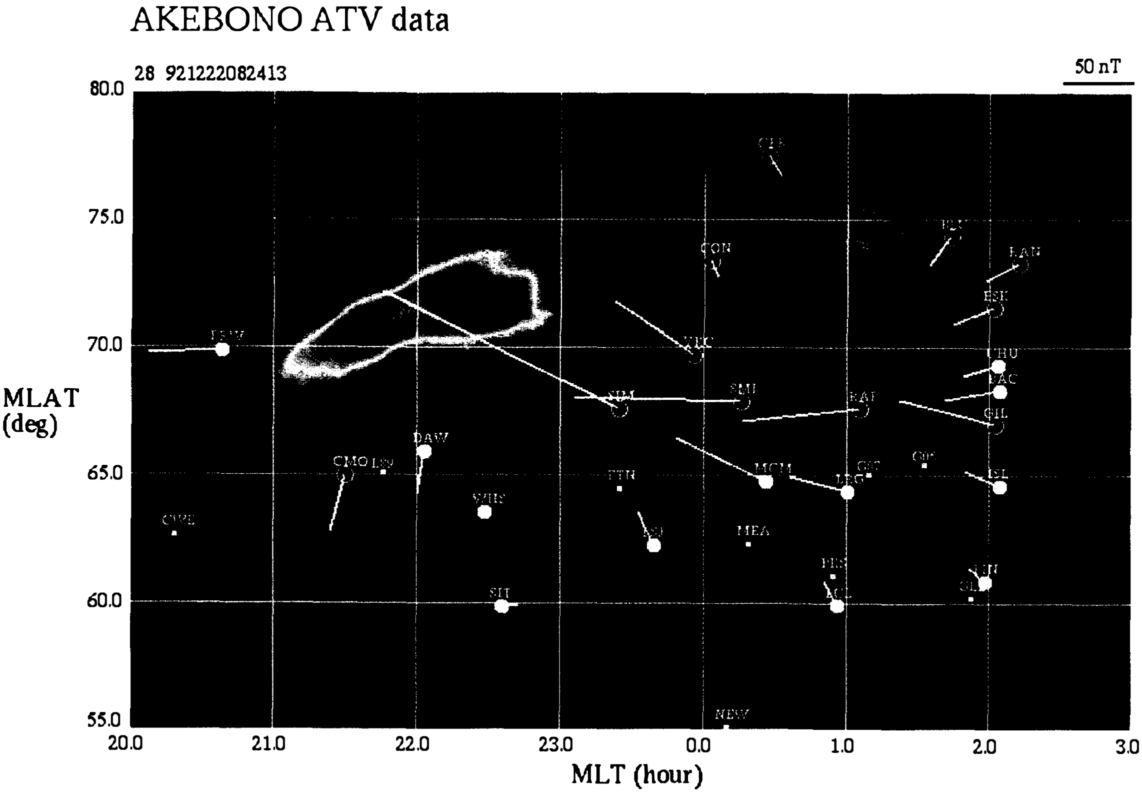

Fig. 1. Auroral image data combined with the equivalent current vectors for the ground magnetic field variation, after rotating the horizontal magnetic variation vector clockwise by 90°.

circle at each station shows the downward or upward deviation of the magnetic Z-component, respectively. It can be seen that a westward current flew from post-midnight side towards midnight almost along the main diffuse oval, and directed to the island on the pre-midnight side. The current was intensified with its westward flowing. The equivalent currents at BRW, CMO, and DAW directed outward from the island, and those at CON, CBB, BLC, RAN, and ESK directed toward the location around 68° CMLAT and 0.5–1.0 hr MLT, *i.e.*, higher latitude edge of the post-midnight main diffuse auroral oval. The currents at PIN, LCL, and FSJ directed westward and poleward, and that at SIT eastward.

The points marked by L89, G06, and G07 in Fig. 1 are the foot points of the geosynchronous satellites, LANL-1989-046, GOES-6, and GOES-7, respectively, projected with Tsyganenko 1989 (T89) model (Tsyganenko, 1989) for $Kp=2$ condition.

Magnetometer data from mid- and low-latitude stations showed a substorm expansion phase onset at 0759 UT followed by the second activation onset at 0812 UT. GOES-7 magnetometer data showed that small dipolarization variations occurred at around those times. X- and Y-components of the magnetometer data from mid- and low-latitude stations showed that the substorm current wedge (SCW) system seemed to be centred at the meridian around 23.0–23.5 hr MLT, and the downward field-aligned current (FAC) of the SCW system are located around 1.0–1.5 hr MLT. Despite no clear onset signature both on the ground and with satellites during the observation period of ATV-VIS, it can be thought that the auroral intensification event observed by ATV-VIS is associated with an intensification of the FAC of the SCW system during the late phase of the substorm starting from 0759 UT.

Equivalent current pattern produced by upward and downward FACs and westward ionospheric electrojet current system under the condition of an enhanced ionospheric conductivity at the auroral zone had been discussed in many papers (*e.g.*, FUKUSHIMA, 1969, 1971), and equivalent current patterns were shown with models for a break-up aurora (BAUMJOHANN *et al.*, 1981) and for a westward traveling surge (WTS) (OPGENOORTH *et al.*, 1983). These modeling results also showed that the upward FAC region is to be localized at the western edge of the longitudinally elongated zone of enhanced conductivity and the downward one is widely distributed on the eastern side. Observationally, an intense upward FAC was actually observed at the front of the WTS by DMSP satellite (BYTHROW and POTEMRA, 1987). Referring to these papers, it is very reasonable to attribute the bright island in Fig. 1 to a localized upward FAC region and the equivalent current patterns at CMO and DAW reflect mainly the effect of the FAC. As for the downward FAC region, it is to be locate on the high latitude side of the post-midnight diffuse auroral oval, judging from the equivalent current pattern at CON, CBB, BLC, RAN, and ESK, which should reflect mainly the effect of the FAC. This upward and downward FAC pair will constitute the SCW system as mentioned above. An essential difference between the previous theoretical and modeling works and our observation is in that the downward FAC center seems to be located at the high latitude side or outside of the region of enhanced conductivity in our case. There were some reports showing that the upward and downward FACs of the SCW system located far from the main diffuse oval (OPGENOORTH *et al.*, 1980; PELLINEN *et al.*, 1995). If we follow the progressive development of the equivalent current pattern after the initial onset at 0759 UT, it can be easily supposed that the ionospheric conductivity gradually changed with time. We now presume that the diffuse auroral region (*i.e.*, enhanced conductivity region) would be created by the precipitation of the injected electrons drifting by the enhanced dawn-to-dusk electric field in the current disruption process which must be closely related with the formation of the SCW system. In other words, the FAC location and intensity and the conductivity enhancement are to be closely related with one another. A more realistic model calculation including such a mutual interrelationship will be done in the future for understanding the time-development of the ionospheric closure of the SCW system.

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References

BAUMJOHANN, W., PELLINEN, R. J., OPGENOORTH, H. J. and NIELSEN, E. (1981): Joint two-dimensional observations of ground magnetic and ionospheric electric fields associated with auroral zone currents: current systems associated with local auroral break-ups. Planet. Space Sci., **29**, 431–447.

BYTHROW, P. F. and POTEMRA, T. A. (1987): Birkeland currents and energetic particles associated with optical auroral signatures of a westward traveling surge. J. Geophys. Res., **92**, 8691–8699.

FUKUSHIMA, N. (1969): Equivalence in ground geomagnetic effect of Chapman-Vestine's and Birkeland-Alfven's electric current-systems for polar magnetic storms. Rep. Ionos. Space Res. Jpn., **23**, 219–227.

FUKUSHIMA, N. (1971): Electric current systems for polar substorms and their magnetic effect below and above the ionosphere. Radio Sci., **6**, 269–275.

OPGENOORTH, H. J., PELLINEN, R. J., MAURER, H., KÜPPERS, F., HEIKKILA, W. J., KAILA, K. U. and TANSKANEN, P. (1980): Ground-based observations of an onset of localized field-aligned currents during auroral breakup around magnetic midnight. J. Geophys., **48**, 101–115.

OPGENOORTH, H. J., PELLINEN, R. J., BAUMJOHANN, W., NIELSEN, E., MARKLUND, G. and ELIASSON, L. (1983): Three-dimensional current flow and particle precipitation in a westward traveling surge (observed during the Barium-GEOS rocket experiment). J. Geophys. Res., **88**, 3138–3152.

PELLINEN, R. J., PULKKINEN, T. I., HUUSKONEN, A. and GLASSMEIER, K.-H. (1995): On the dynamical development of the downward field-aligned current in the substorm current wedge. J. Geophys. Res., **100**, 14863–14873.

TSYGANENKO, N. A. (1989): A magnetospheric magnetic field model with a warped tail current sheet. Planet. Space Sci., **37**, 5–20.

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