Proc. NIPR Symp. Upper Atmos. Phys., 1, 185-191, 1988

POLAR CAP ARCS AND THEIR RELATIONSHIP TO IMF AND GEOMAGNETIC ACTIVITY

Kazuo MAKITA[1], Syun-Ichi AKASOFU[2] and Ching-I. MENG[3]

[1]Faculty of Technology, Takushoku University, Tatemachi, Hachioji-shi, Tokyo 193
[2]Geophysical Institute, University of Alaska, Fairbanks, Alaska 99775, U.S.A.
[3]Applied Physics Laboratory, Johns Hopkins University, Johns Hopkins Road, Laurel MD 20707, U.S.A.

Abstract: From four months DMSP auroral image data, various kinds of polar cap arcs are examined and they may be categorized fundamentally four typical polar cap arcs. The first one is the bright arcs which occur during strong northward IMF period. The second one is poleward leap arcs which occur during the recovery phase of a substorm. The third one is multiple faint arcs which occur during the strong northward IMF period and the fourth one is very faint sun-aligned arcs which occur during a magnetically quiet period. The first and the second polar cap arcs may be originated from the plasma sheet particles. On the other hand, the third and the fourth arcs may not be related to plasma sheet particles but magnetosheath particles. Although the first and the third arcs are seen during the period of a strong northward IMF, the magnitude of geomagnetic activity for the first one is larger than that for the third one. It seems that magnetospheric energy release may be also another important factor for the auroral dynamics.

1. Four Types of Polar Cap Arcs

From the examination of DMSP auroral image data, we categorized four types of polar cap arcs. The characteristics of these four types of arcs are examined and described in the following.

(1) Bright arcs during the large northward IMF period

Bright discrete arcs occasionally extend from the night side auroral oval to the polar cap region. Figure 1 shows a typical example of such arcs. The top panel of the auroral image was obtained during the period from 1019 to 1044, January 15, 1983. In this interval, a moderate geomagnetic activity was in progress, and the hourly average value of AE index during this particular period was 224 nT. From this image, auroral activity was found to be high, especially in the midnight sector. However, there was no bright arc which extended to the polar region in this period. The second image was taken 100 min after the first image. Geomagnetic activity in this period became weak and the hourly average value of AE was 163 nT. In this image, one can see a group of arcs, which extended from the night side auroral oval, at the center of polar cap region. Auroral activity in the dawn and the dusk auroral oval became weak during this period. The hourly average value of IMF from 12 to 13 UT was $B_T=18.0$, $B_x=-12.3$, $B_y=9.0$ and $B_z=6.4$ nT, respectively. Although the geomagnetic activity became weak in this interval, large geomagnetic disturbances

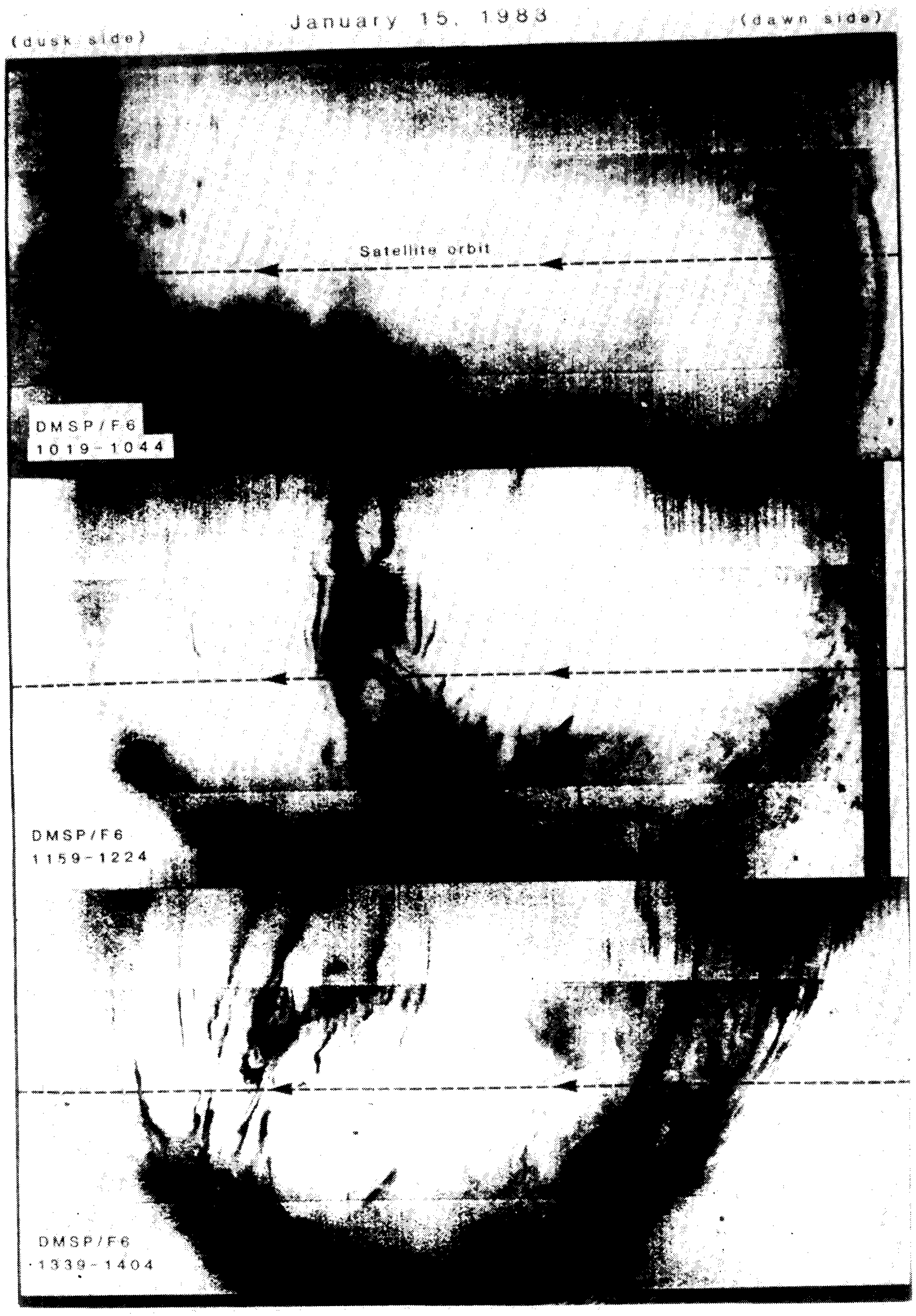

Fig. 1. Three auroral image data obtained by DMSP/F6 satellite. In the middle panel, bright discrete arcs extend from the night side oval to the polar cap. Such polar cap arcs move to the evening side in the bottom panel. These auroras appear during a large northward IMF period.

($AE \sim 300$ nT) were observed about one hour before this event. In the bottom image, multiple bright arcs are seen near the dusk sector. The bottom auroral image data was obtained after 100 min of the second image. It seems that the bright arc system

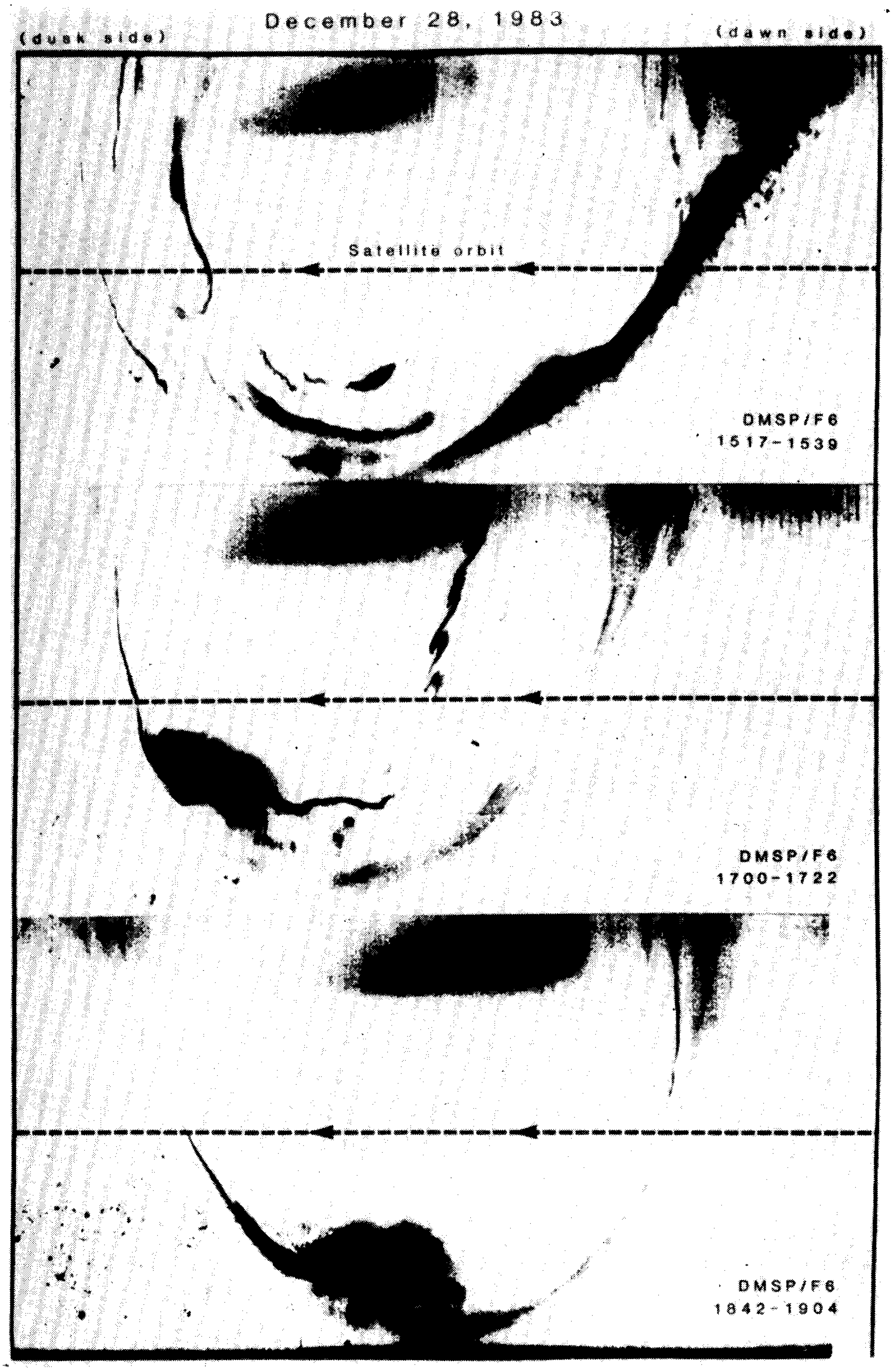

Fig. 2. The poleward leap aurora after the onset of substorm the top panel. It moves to the polar cap region and becomes a bright discrete arc in the middle and panels.

in the middle panel moved to the dusk region in this interval.

(2) Bright arcs related to the poleward expansion

After the onset of a substorm, poleward leap auroras can occasionally be seen. These auroras extend to the high latitude side of auroral oval and become bright polar cap arcs. Figure 2 shows a typical example of this kind. The image on the top was obtained from 1520 to 1540, December 28, 1983. In this period, the geomagnetic activity was low and the hourly average value of AE from 15 to 16 UT was 131 nT. Severe geomagnetic disturbances ($\sim$500 nT) were seen during the interval from 13 to 14 UT. It was noted that there were several bright multiple arcs near the higher latitude side of the nightside auroral oval. These arcs gradually moved to the poleward side apart from the stable auroral oval region. The middle panel shows the auroral image obtained at the next orbit from 1700 to 1722. In this period the geomagnetic activity became low and the hourly average value of AE was 74 nT. One can seen that the auroral luminosity during the auroral oval became weak and a bright discrete arc extended to the center of polar cap. Although there was 205 min time lag between the top and the bottom image data, it may be thought that the polar cap arc in the middle image was related to the poleward leap aurora in the top image.

The hourly average values of IMF from 16 to 17 UT was $B_T=5.0$, $B_x=3.1$, $B_y=-1.8$ and $B_z=3.2$ nT, respectively. It shows that these arcs due to the poleward leap of expanded aurora are seen during a period of small northward IMF and also a quiet period of recovery phase. In the bottom panel, there was no polar cap arc and the auroral activity was recognized only near midnight along the auroral oval.

(3) Multiple faint arcs

Multiple faint arcs occur during geomagnetically quiet period with a large northward IMF. Figure 3 shows a typical example of this kind of aurora. The image on the top was obtained from 0630 to 0653, November 11, 1983. Geomagnetic activity was small in this period and multiple faint auroral arcs were seen in the polar region. The middle image was obtained in the period from 0810 to 0833 UT. One can recognize multiple faint arcs over the polar cap region. In this interval, the geomagnetic activity was small and AE index was less than 90 nT. It is interesting to note that these faint multiple arcs are seen during a period of large northward IMF. Actually, the hourly average value of IMF from 06 to 07 UT was $B_T=11.9$, $B_x=-7.9$, $B_y=0.7$ and $B_z=7.8$ nT respectively. This IMF condition was similar to the previous (1) event. However, the geomagnetic activity in this period was very low ($AE<100$ nT). The bottom panel data was obtained from 0950 to 1013. Although the quality of auroral image was poor, multiple faint arcs were also seen in the polar cap region.

(4) Faint arcs

Very faint arcs are occasionally seen in the polar cap during the geomagnetically quiet period. Figure 4 shows an example of such event. The top panel shows the auroral image data obtained from 0827 to 0850 UT. Very faint auroral arcs were seen near the center of polar region. In this interval, the geomagnetic activity was extremely low ($AE\sim30$ nT). The middle image also shows a similar arc. This auroral image was obtained during the interval from 1150 to 1213 UT, and faint arcs were seen in the dawn sector. The geomagnetic activity in this period was still very low ($AE\sim30$ nT). The bottom panel also shows a quiet period auroral image data, obtained from 2050 to 2113 UT. One can see very faint arcs in the center of polar cap. The hourly average value of IMF during the interval from 11 to 12 UT was $B_t=7.0$, $B_x=6.1$, $B_y=0.8$ and $B_z=3.0$ nT, respectively.

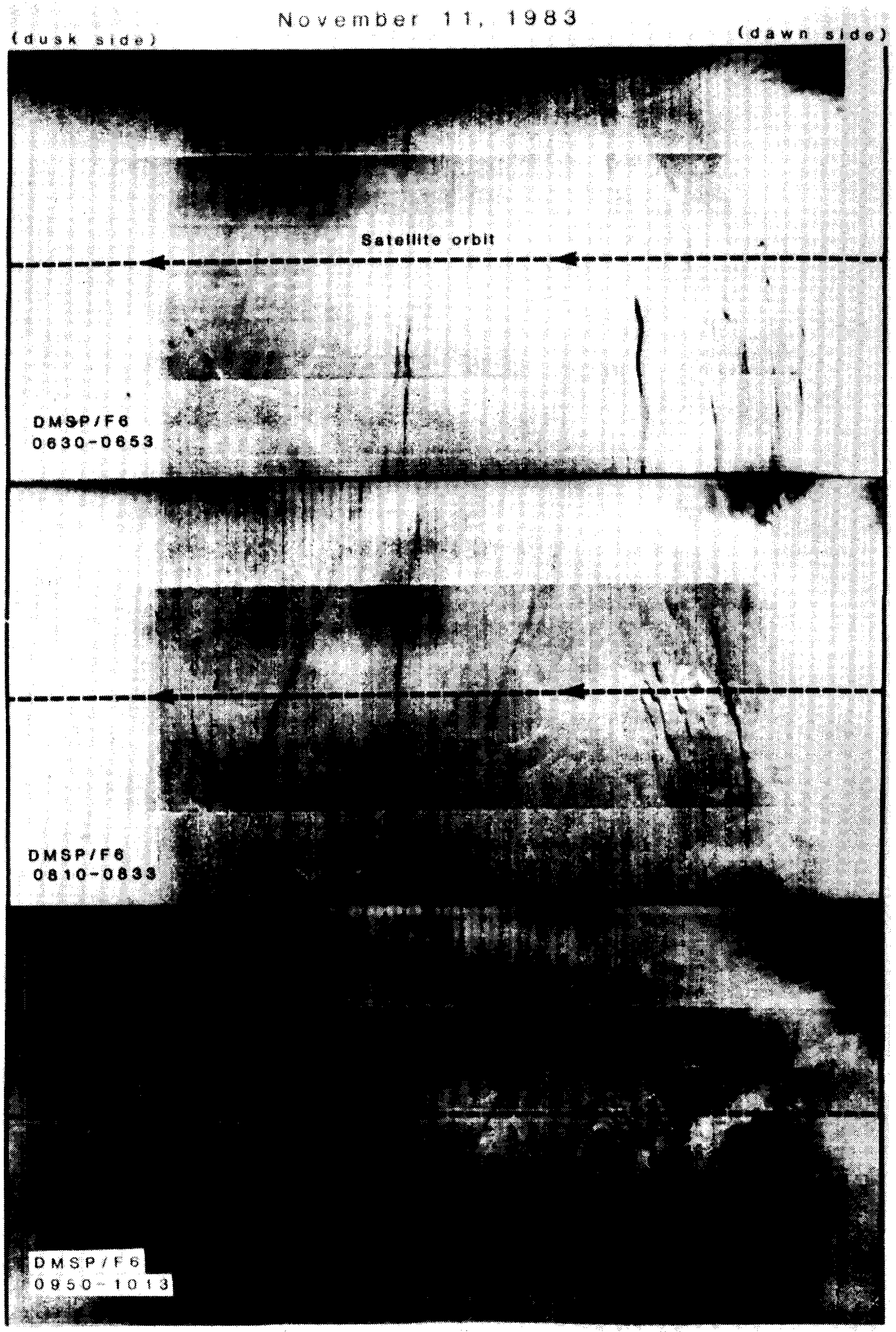

Fig. 3. Multiple discrete arcs obtained during a geomagnetically quiet period with a large northward IMF.

2. Summary and Conclusion

On the basis of DMSP auroral image data obtained in January, October, November and December in 1983 and also in January 1984, we illustrated four typical types

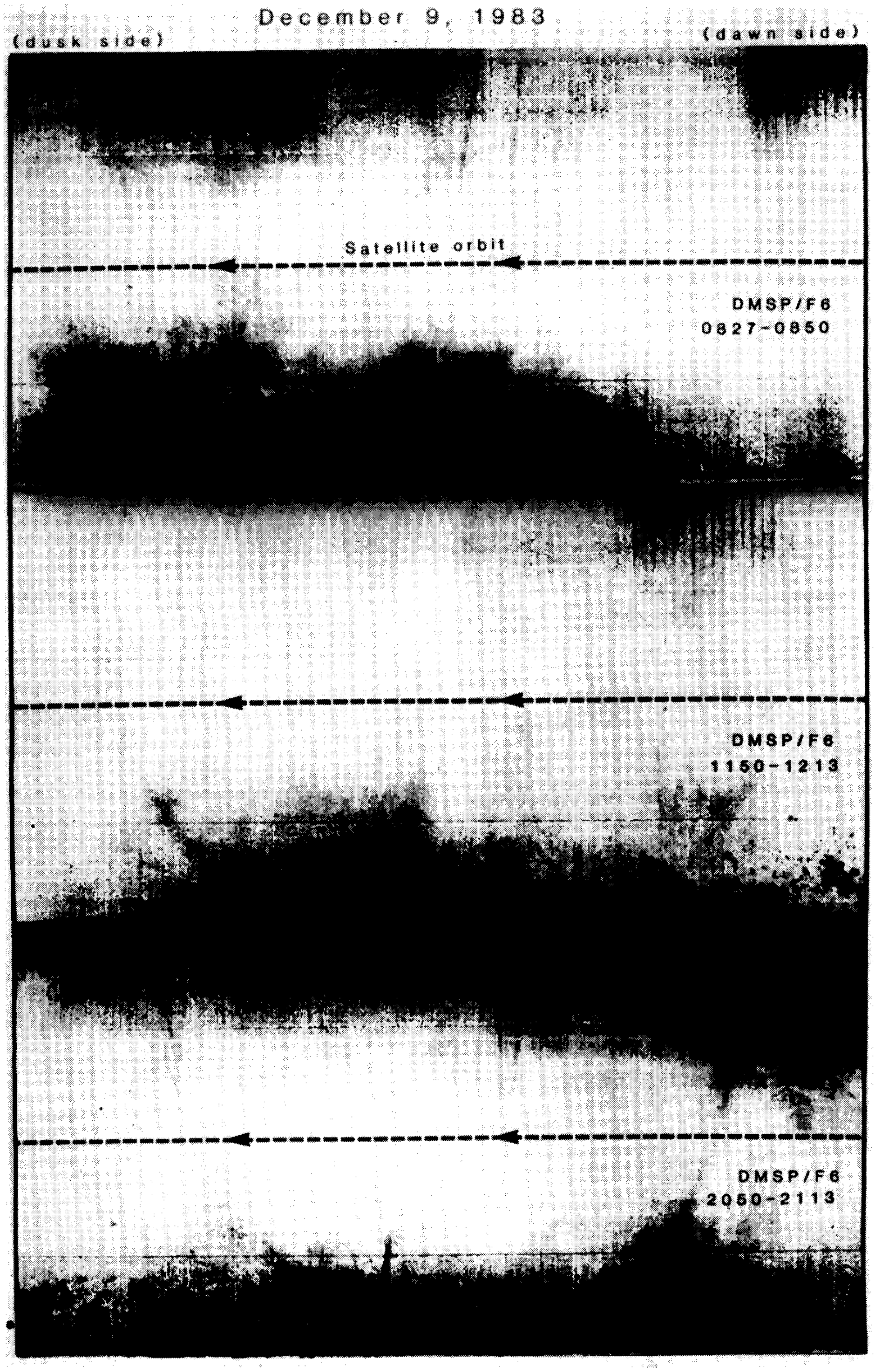

Fig. 4. Very faint auroral arcs seen in the polar cap, when a global auroral activity is low even along the auroral oval.

of polar cap arcs. Most of these four types of polar cap arcs are seen during the period of northward IMF. The characteristics of these polar arcs are summarized as follows.

The first one is a very bright arc of aurora observed when IMF was strong and northward. The particle precipitation associated with this auroral arc is similar to that of the auroral oval, and these particles may be originated from the plasma sheet (FRANK *et al.*, 1986). It is noted that the auroral activity is not so low in this period, although IMF is strongly northward. These results may suggest that the amount of energetic electrons in the plasma sheet is still conserved during the northward IMF condition and thus it can be seen electron precipitations in the polar cap region as well as in the auroral oval.

The second type of polar cap arc is related to the poleward expansion of auroral oval. The differences between the first and the second ones are the condition of IMF and magnetosphere. Namely the second type arc is observed after the onset of substorm and is accompanied by a poleward leap aurora suggested by HONES (1985). These poleward leap aurora is a bright polar cap arc and it becomes gradually disappeared in the high latitude region.

The third one is multiple faint arcs, which occur during the period of a strong northward IMF. When these kinds of multiple faint arcs are observed, the geomagnetic activity in the auroral oval is very low. The precipitating electron energy may be low, less than one keV, and the characteristics of energy spectra seem to be similar to that of magnetosheath electrons rather than that of a plasma sheet electrons.

The fourth type of arc occurs during extremely quiet period. The luminosity of this arc is very faint and the magnitude of IMF value is also low. This condition may correspond to the ground state of magnetosphere.

Our analysis indicates that the appearance condition of these four types of polar cap arcs are quiet different one another. It is necessary to study these polar cap auroras and their relationship to particle precipitation and also IMF condition, in order to understand auroral dynamics over the polar cap.

References

FRANK, L. A., CRAVEN, J. D., GURNETT, D. A., SHAWHAN, S. D., WEIMER, D. R., BURCH, J. L., WINNINGHAM, J. D.. CHAPPEL, C. R., WAITE, J. H., HEELIS, R. A., MAYNARD, N. C., SUGIURA, M., PETERSON, W. K. and SHELLEY, E. G. (1986): The theta aurora. J. Geophys. Res., **91**, 3177–3224.

HONES, E. W., Jr. (1985): The poleward leap of the auroral electrojet as seen in auroral images. J. Geophys. Res., **90**, 5333–5337.

(*Received May 30, 1987; Revised manuscript received October 5, 1987*)