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DAYSIDE AURORAL DYNAMICS OBSERVED BY THE AGO NETWORK IN ANTARCTICA

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Abstract: Auroral dynamics in the dayside cusp/cleft and polar cap region have been studied using all-sky imaging data acquired at four Automatic Geophysical Observatories (AGOs) located at 70°–80° magnetic latitude in Antarctica during the period from April 5 to July 31, 1995. Poleward moving transient auroral forms with velocities of ~0.5 km/s and durations of ~10 min were frequently observed at the two AGO stations, P1 and P4, located at 80° magnetic latitude. The transient auroral forms moved poleward and westward in the pre-noon sector, while poleward and eastward in the post-noon sector. The luminosity of the auroral 630.0 nm emissions was found to be much higher than that of the auroral 427.8 nm emissions, implying that the energies of precipitating electrons exciting these auroral transients are very low. The WIND interplanetary magnetic field (IMF) data showed that these poleward moving transient auroral forms were strongly correlated with northward IMF ($Bz>0$) conditions. Since distinct back-scattered echoes of the HF radar at Halley Bay station were not observed when these transient aurora forms occurred, it is concluded that these auroras did not excite strong irregularities in the *F*-region. Thus, all these results taken together imply that these transient auroral forms are strongly related to the magnetopause boundary processes during northward IMF conditions.

1. Introduction

Recent studies of dayside auroral dynamics have demonstrated that poleward moving auroral forms are frequently observed near the cusp/cleft region in the ionosphere. Using meridian scanning photometer (MSP) data, FASEL *et al.* (1992) showed that these auroral transients were observed to brighten at the equatorward edge of the dayside auroral oval and fade as they move into the polar cap. FASEL (1995) showed that poleward moving auroral forms occurred mostly under southward interplanetary magnetic field conditions (IMF $Bz<0$). Therefore, these transient events were interpreted as a possible ionospheric signature of magnetic reconnection at the dayside magnetopause; *i.e.*, flux transfer events (FTEs) (FASEL *et al.*, 1992; KARLSON *et al.*, 1996; LOCKWOOD *et al.*, 1989). On the other hand, using MSP data and IMF and solar wind plasma data obtained by the IMP-8 satellite, SANDHOLT *et al.* (1994) showed that a sequence of these transient auroral events were found to be correlated with short pulses in solar wind dynamic pressure.

Though some ideas of the excitation mechanisms for these poleward moving auroral forms exist, studies of these auroral transient phenomena in the polar cap region have not been thoroughly carried out. OIEROSET *et al.* (1997) showed that high-latitude aurora activities observed near 77°–78° magnetic latitude are associated with the northward IMF ($Bz>0$) conditions. However, such auroral activities in the polar cap region are still unclarified. To investigate the sources of poleward moving auroral forms, it is necessary to observe the temporal and spatial development of these phenomena over a very wide region including the low latitude boundary layer (LLBL), cusp, plasma mantle and polar cap. The purpose of this study is to investigate the relationships between poleward moving auroral forms observed by a station network of Automatic Geophysical Observatories (AGOs) located at 70°–80° magnetic latitude in Antarctica and solar wind parameters obtained by the WIND satellite, and to clarify the characteristics of these phenomena.

2. Observations and Data

The AGO network is the first large-scale network of geophysical stations in Antarctica. The AGO network consists of six geophysical sites coded as P1, P2, P3, P4, P5, and P6. Illustrated in Fig. 1 is a polar map showing the locations of these AGO

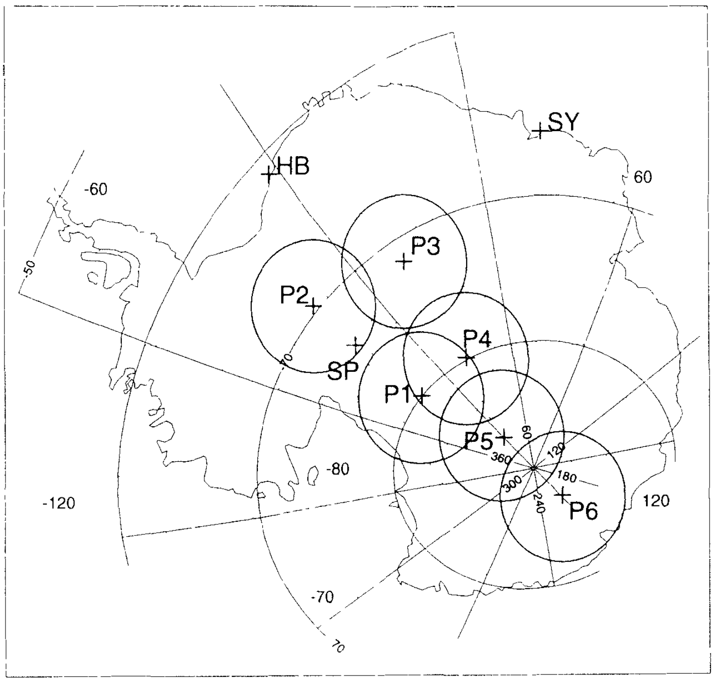

Fig. 1. Polar map showing the locations of the network stations in Antarctica. P1, P2, P3, P4, P5, and P6 are the AGO sites. HB, SP, and SY denote Halley Bay, South Pole and Syowa Stations. The solid (dashed) line corresponds to the geomagnetic (geographic) latitude and longitude.

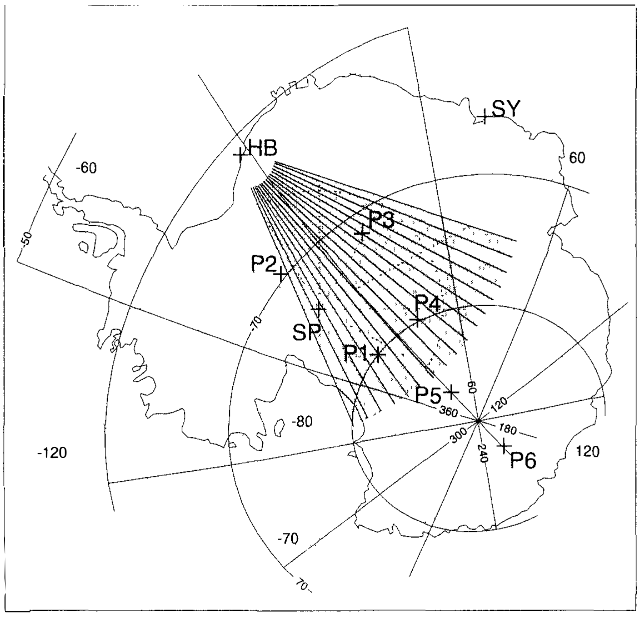

Fig. 2. Polar map showing the field of view of the HF radar at HB.

sites and several other key stations. The locations of AGO P1 (magnetic latitude $-80.1°$, magnetic longitude $16.8°$), P2 ($-69.8°$, $19.2°$), P3 ($-71.8°$, $40.1°$), P4 ($-80.0°$, $41.5°$), P5 ($-86.7°$, $29.4°$), and P6 ($-84.9°$, $215.3°$) were chosen to form two meridional arrays approximately 1.6 hours apart in magnetic local time covering latitudes from equatorward of the cusp to the polar cap (ROSENBERG and DOOLITTLE, 1994). Each AGO station has an all-sky imager (FOV$=170°$) operating simultaneously at two different wavelengths, 630.0 nm and 427.8 nm, at intervals of 2 min. A 500 km radius circle around each AGO site in Fig. 1 approximates the field of view at 200 km altitude of a 630.0 nm auroral imager. Magnetic local noon is ~1350 UT at P3 and P4, and ~1530 UT at P1 and P2, respectively.

In this study all-sky auroral imaging data obtained at AGO P1, P2, P3, and P4 were used. During a period from April 5 to July 31, 1995, we analyzed these data on April 21, April 30, May 1, May 23, May 25, June 27, July 2, July 24, and July 30. Solar wind and IMF data obtained by the WIND spacecraft were used to examine the relationship between auroral activities and interplanetary conditions. Halley Bay (HB) HF radar data were also analyzed to demonstrate possible ionospheric signatures associated with poleward moving transient auroras. Figure 2 shows the field of view of HF radar at HB. In this paper, all-sky imaging data, WIND data and HF radar data on July 2 and July 30 are presented.

3. Results

Figure 3a shows all-sky imaging data of 630.0 nm aurora emissions obtained at P4 between 0832 and 0842 UT on July 2, 1995. These figures show typical poleward

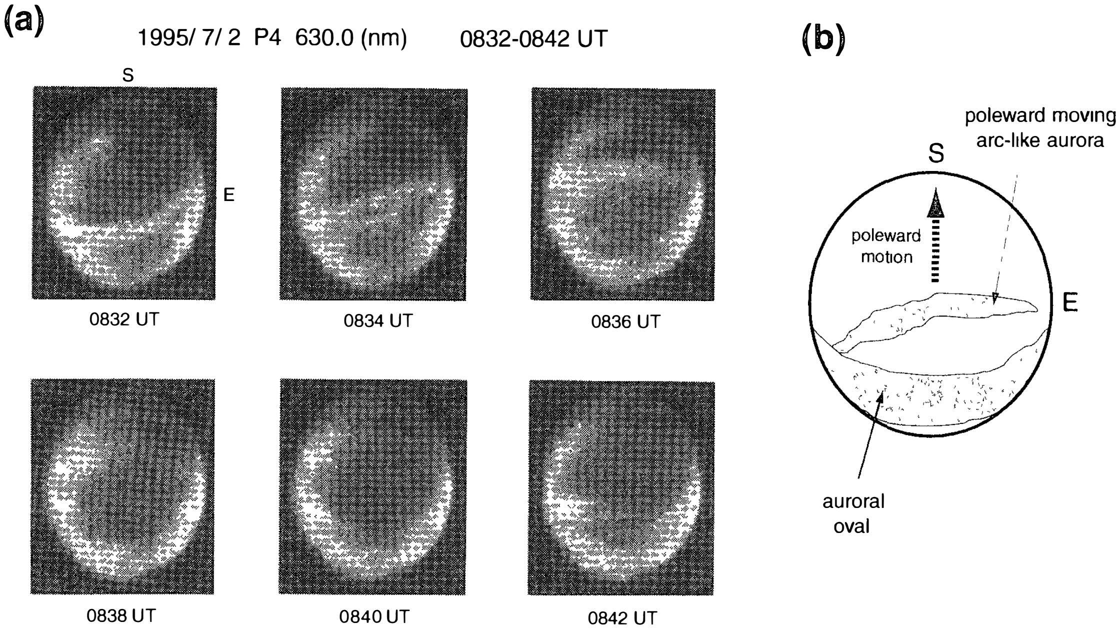

Fig. 3. (a) All-sky imaging data of 630.0 nm aurora emissions obtained at P4 from 0832 to 0842 UT on July 2, 1995. (b) Schematic illustration showing the motion of the poleward moving arc-like aurora.

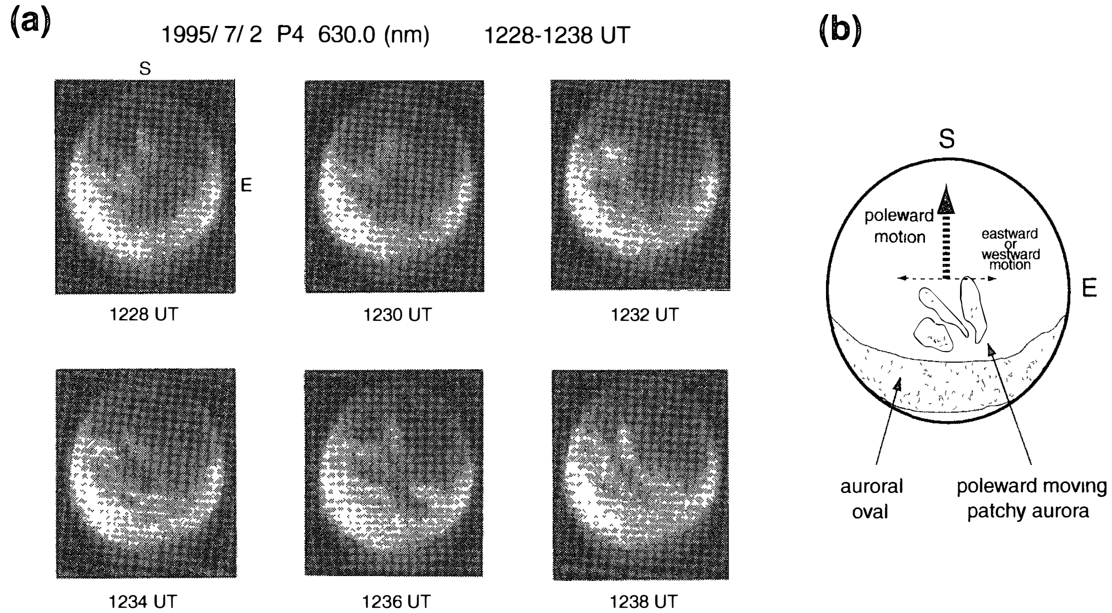

Fig. 4. (a) All-sky imaging data of 630.0 nm aurora emissions obtained at P4 from 1228 to 1238 UT on July 2, 1995. (b) Schematic illustration showing the motion of the poleward moving patchy aurora.

moving transient aurora observed in the time interval of 6–10 MLT. Most of these transient aurora have arc-like structures in the east-west direction. Though poleward moving auroras are also observed in the time interval of 14–18 MLT, their shape and motion are very similar to those in the time interval of 6–10 MLT. These transient auroras are found to appear first in the auroral oval or near the poleward boundary of

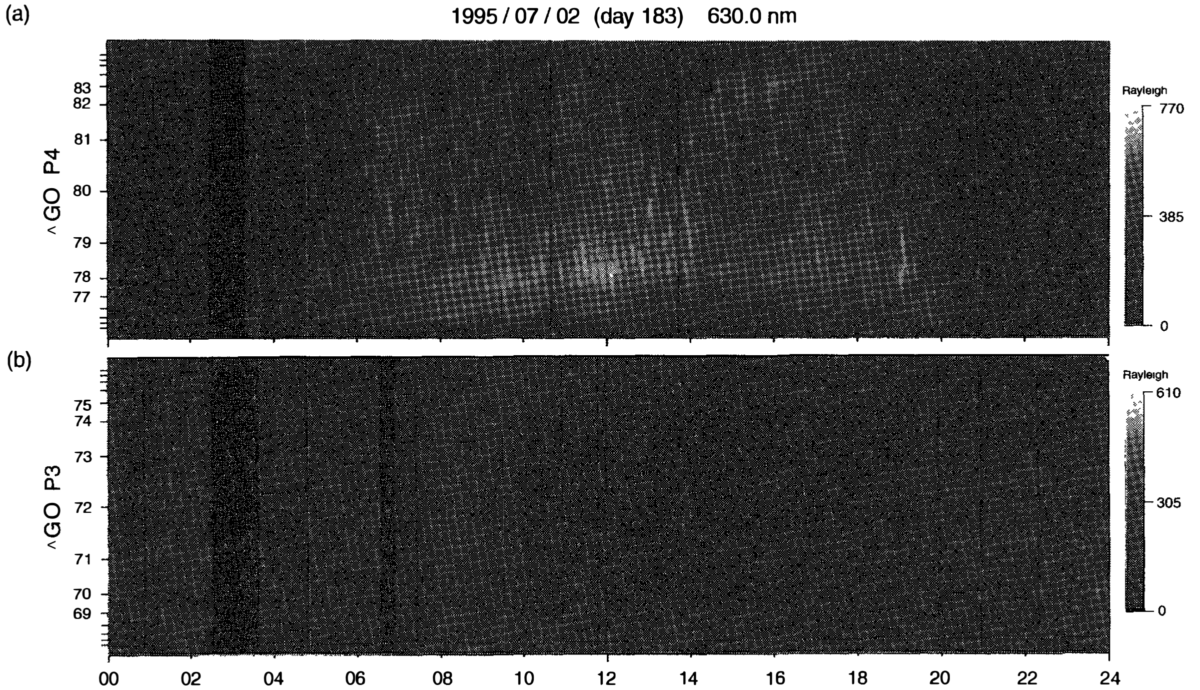

Fig. 5. *(a) Latitudinal keogram of 630.0 nm aurora observed at P4 on July 2 (day 183), 1995. (b) Same as (a) except for 630.0 nm aurora observed at P3.*

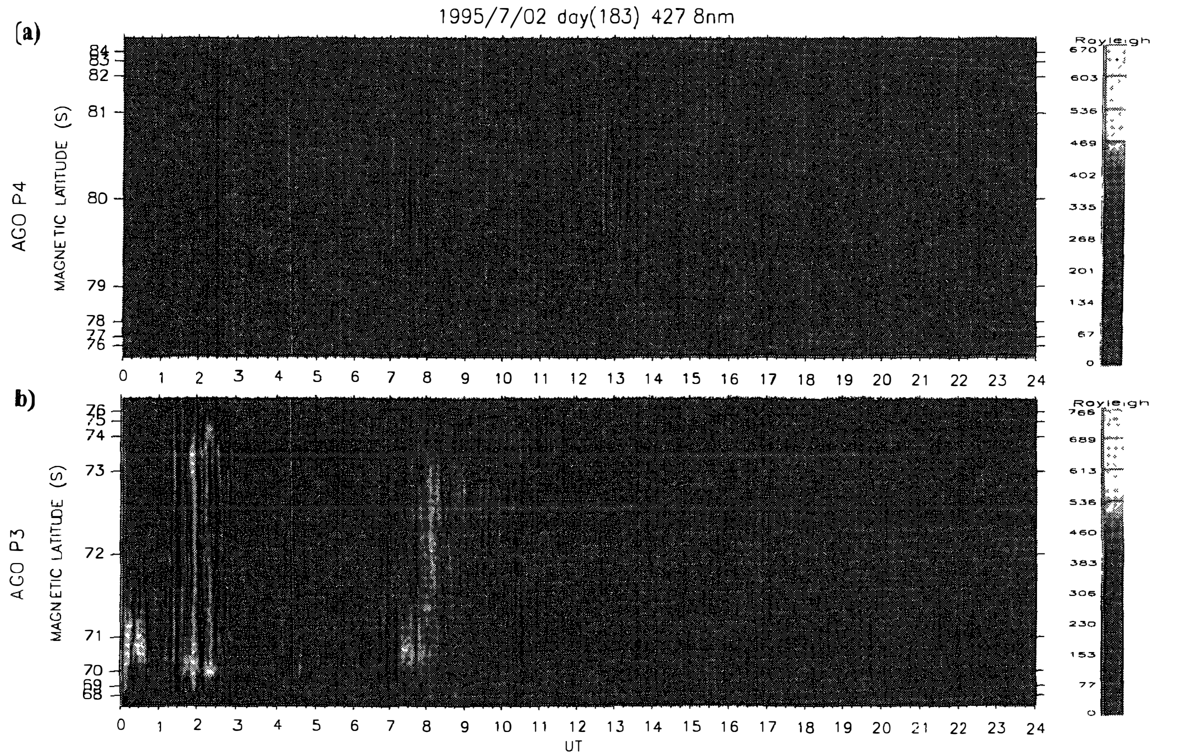

Fig. 6. *(a) Latitudinal keogram of 427.8 nm aurora observed at P4 on July 2 (day 183), 1995. (b) Same as (a) except for 427.8 nm aurora observed at P3.*

the auroral oval, and then they travel into the polar cap. Figure 3b is the schematic illustration showing the motion of these transient aurora. On the other hand, poleward moving transient, patchy aurora are frequently observed in the time interval of 10–14 MLT. Figure 4a shows all-sky imaging data obtained at P4 between 1228 and 1238 UT on July 2, 1995. Patchy auroras are usually formed at the poleward edge of the auroral oval first, then move poleward. These aurora sometimes move not only poleward but also eastward or westward simultaneously. Figure 4b schematically shows the motion of these poleward moving patchy auroras.

Figures 5a and b show the latitudinal keograms of 630.0 nm aurora emissions observed at P4 and P3 on July 2 (day 183), 1995, respectively. These keograms were obtained by extracting the pixels along the magnetic meridian from all-sky image data. From this figure, it is obvious that poleward moving auroral forms were frequently observed in the region from 78° to 85° magnetic latitude and in the time interval between 0600 and 2000 UT (between 0410 and 1810 MLT).

Figures 6a and b show the keograms of 427.8 nm aurora emissions observed at P4 and P3 on July 2, 1995, respectively. Though poleward moving transient auroras were also observed in the region from 79° to 81° in the morning hours until 1400 UT (1210 MLT), such auroral movements were not observed in the afternoon hours. The

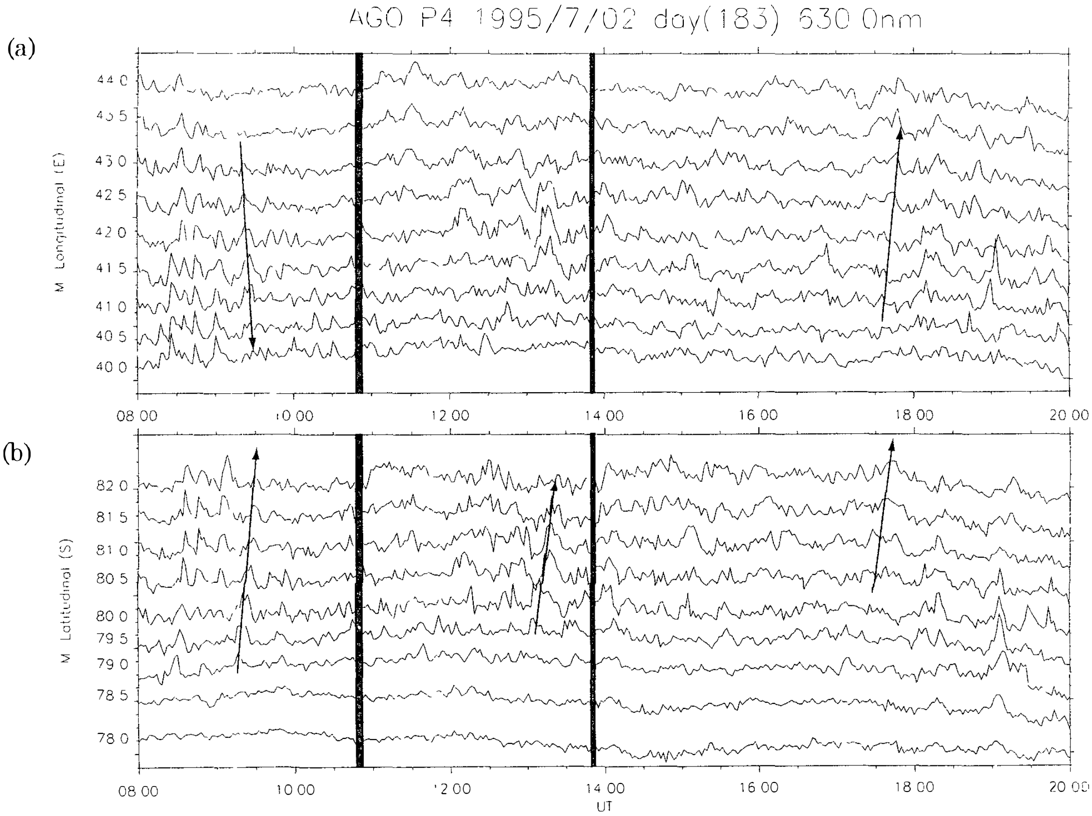

Fig. 7. (a) Plots of the relative intensity of 630.0 nm auroral emissions observed at P4 at different longitude. (b) Same as (a) except for 630.0 nm auroral emissions at different latitude.

luminosity of the auroral 630.0 nm emissions was much higher than that of the auroral 427.8 nm emissions. This fact implies that the energies of precipitating electrons exciting these auroral transients were very low.

Figures 7a and b show the time-variation in the intensity of 630.0 nm auroral emission observed at P4 for different longitudes and latitudes from top to bottom, respectively. These diagrams were constructed from the longitudinal and latitudinal keograms. Arrows in these figures indicate the direction of the transient auroral motion. From Fig. 7b, it is seen that transient auroras appear near ~79.0° magnetic latitude first at the poleward edge of the auroral oval, and then they move poleward. Furthermore, most of transient auroras observed in the morning sector move westward, whereas they move eastward in the afternoon sector as shown in Fig. 7a.

A cross spectral analysis of the 630.0 nm auroral luminosity at different latitudes and longitudes is useful for estimating velocities of these moving auroras. Figure 8a shows a cross spectrum of these time series of the auroral intensity at 81.0° and 80.5° magnetic latitude between 0800 and 0900 UT shown in Fig. 7b. This spectrum is calculated by the maximum entropy method (MEM) with a data window of 60 min and a frequency resolution of 0.04 mHz. Figures 8b and c show coherences and phase relations of the time series between 81.0° and 80.5° in magnetic latitude. From these

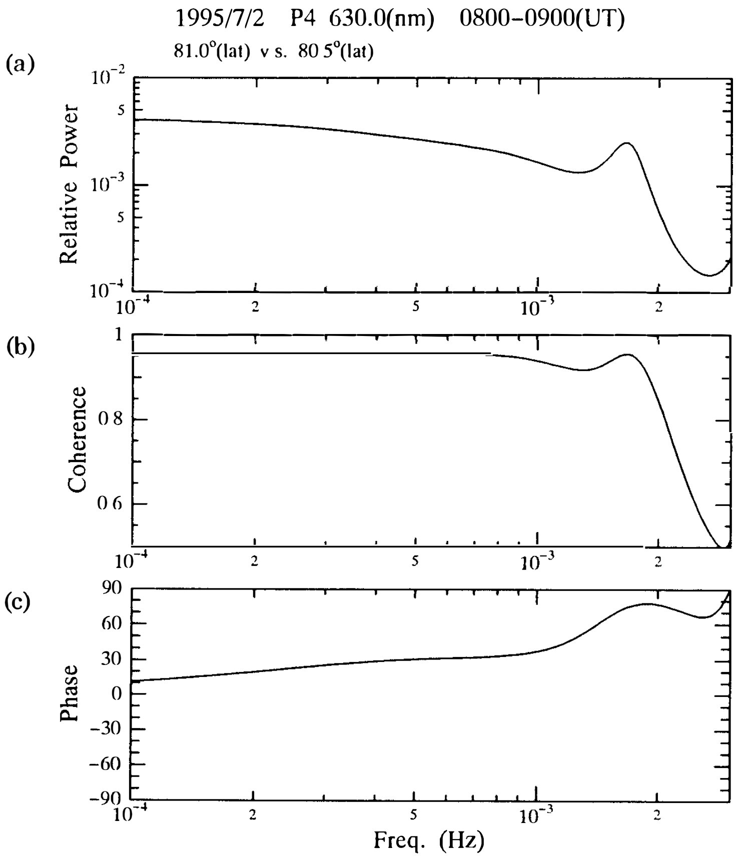

Fig. 8. (a) Cross spectrum of time series of the auroral intensity at 81.0° and 80.5° magnetic latitude observed at P4 from 0800 to 0900 UT. (b), (c) Coherence and phase relation.

figures, it is estimated that the period of the transient aurora is 625 s since the cross spectrum show a distinct spectral peak at ~1.6 mHz with high coherence (~0.9). From Fig. 8c, it is evident that the phase of the 625 s peak is delayed by 75 degrees. These facts imply that the transient aurora moved poleward. Since the travel time of the aurora from 80.5° to 81.0° magnetic latitude is estimated to be about 130 s, the velocity of the moving aurora is estimated to be 0.44 km/s. Using this method, it is found that the transient auroral forms traveled poleward with velocities of ~0.5 km/s and durations of ~10 min on average. This analysis also showed that the transient auroral forms

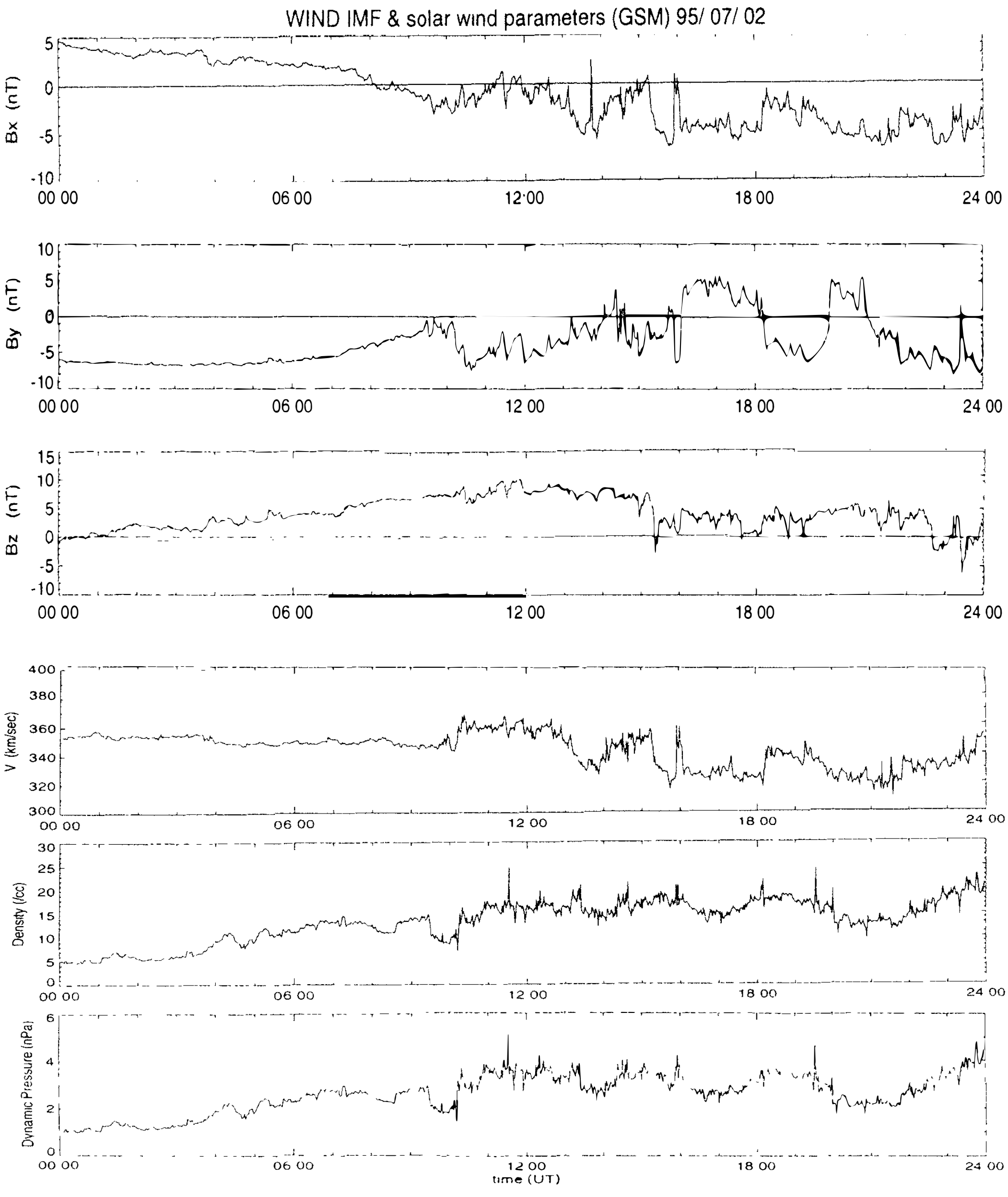

Fig. 9. Interplanetary conditions measured by the WIND spacecraft on July 2, 1995. From top to bottom, IMF Bx, By, Bz, solar wind velocity, number density and derived solar wind dynamic pressure.

moved poleward and westward during 6–10 MLT, while poleward and eastward in the post-noon sector of 14–18 MLT.

Figure 9 shows the IMF and solar wind parameters obtained by the WIND spacecraft on July 2, 1995. Plotted parameters are *Bx*, *By*, *Bz* in geocentric solar magnetospheric (GSM) coordinates, solar wind velocity, number density and derived solar wind dynamic pressure from top to bottom, respectively. At this time the WIND spacecraft was located at ~203 R_E upstream of the Earth. The solar wind velocity was very slow in the range from 310 km/s to 370 km/s. Using an average solar wind velocity of ~340 km/s in the GSM-X direction, the travel time of the solar wind from the spacecraft location to the Earth's magnetopause is estimated to be ~60 min. Therefore, the time interval of the auroral transients between 0600 and 2000 UT corresponds roughly to the time interval between 0500 and 1900 UT for the WIND data. In this time interval, the *Bx* component of the IMF was mostly negative and the *By* component changed from negative to positive, whereas the *Bz* component was positive. This fact indicates that the poleward moving transient auroral forms occur during northward IMF conditions.

Figure 10 shows plots of the back-scattered echo power (unit of dB), line-of-sight velocity (unit of m/s) and Doppler spectral width (unit of m/s) measured by the beam 8 of the HF radar at HB on July 2, 1995. The HF radar data in the range from ~2300 to 3500 km are approximately the back scattered echoes from the region where transient auroral forms were observed by the AGO network. It is found that distinct back-

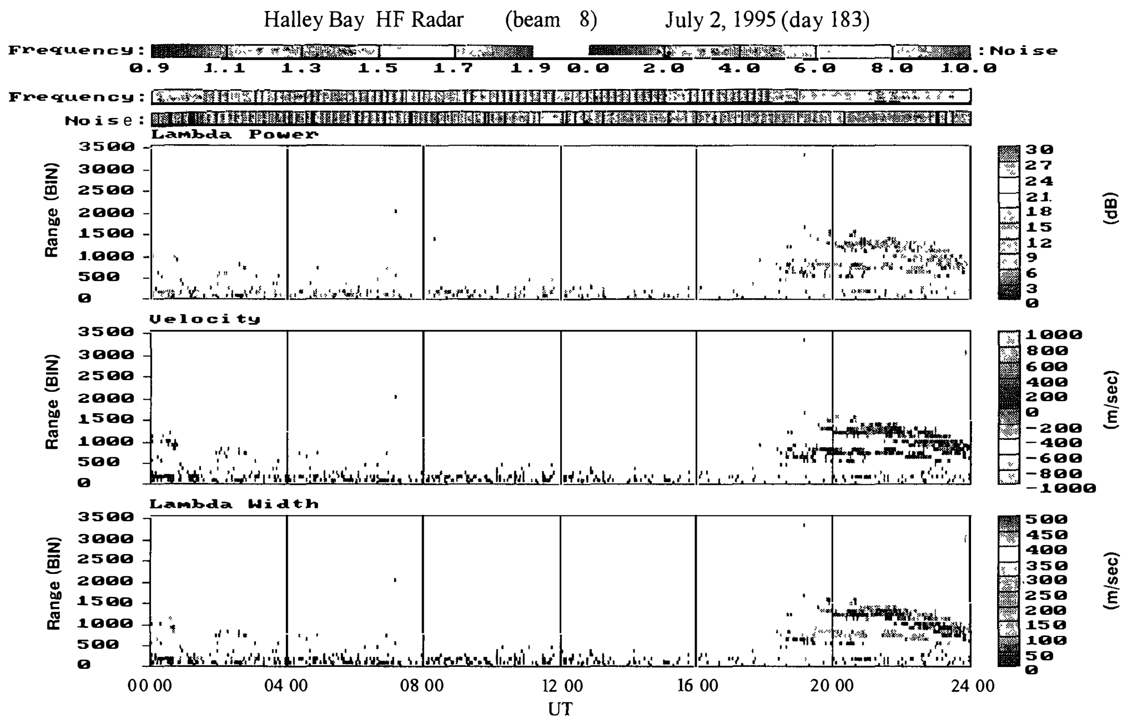

Fig. 10. Plots of the HF radar (beam 8) data obtained at HB on July 2, 1995. Each plot shows the back-scattered echo power (in dB), line-of-sight velocity (in m/s) and Doppler spectral width (in m/s) from top to bottom, respectively.

scattered echoes of the HF radar were not observed when these transient aurora forms were observed. This fact implies that these aurora did not excite strong irregularities in the *F*-region.

Poleward moving transient aurora observed by AGOs and the interplanetary condition measured by the WIND spacecraft on July 30 (day 211), 1995 were also examined. Figure 11a shows IMF *Bx*, *By*, *Bz* measured by the WIND spacecraft on July 30, 1995, respectively. The WIND spacecraft was located at ~45 R_E between 0800

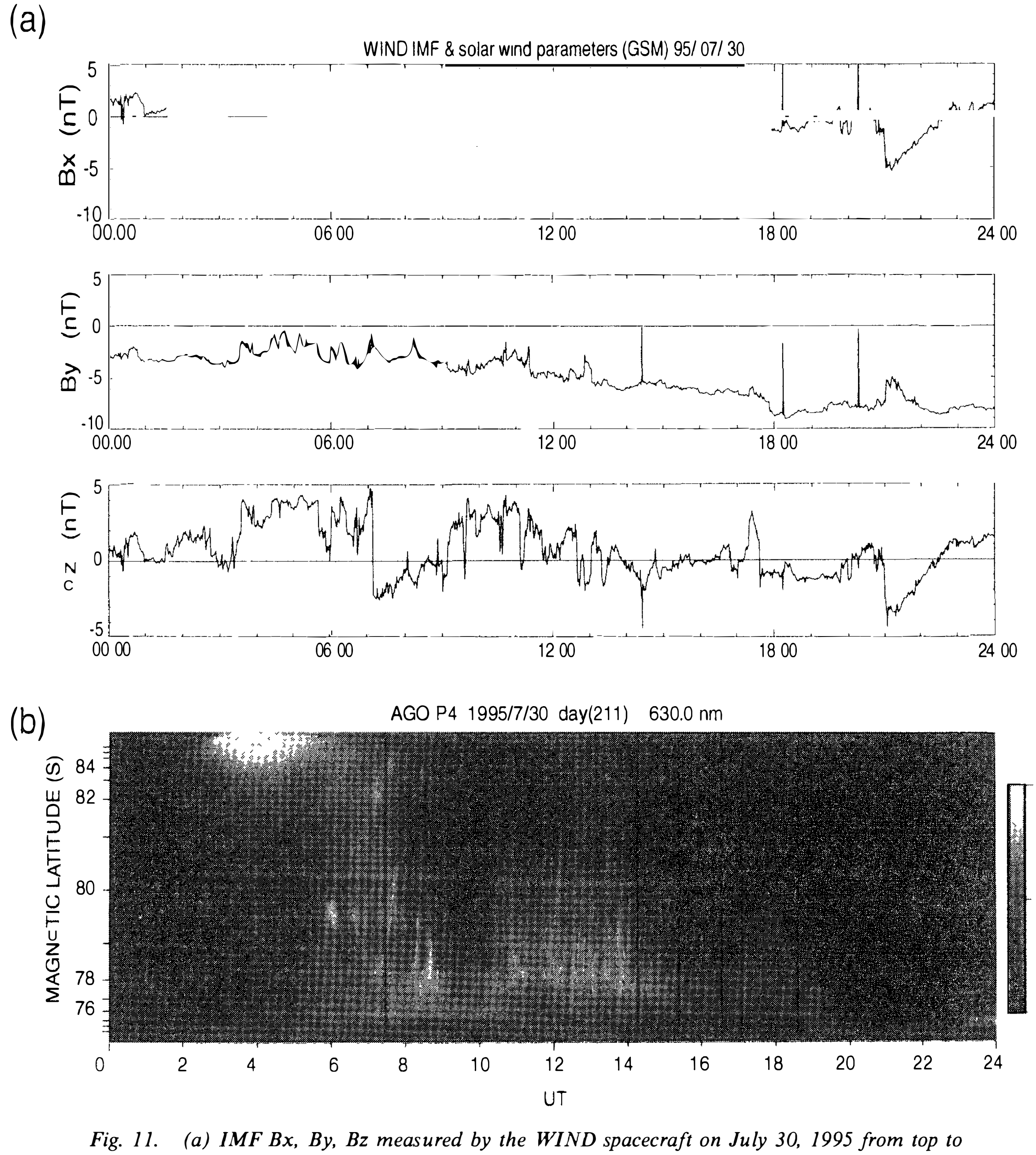

Fig. 11. (a) IMF Bx, By, Bz measured by the WIND spacecraft on July 30, 1995 from top to bottom, respectively. (b) Latitudinal keogram of 630.0 nm aurora observed at P4 on July 30 (day 211), 1995.

and 2000 UT. Considering the average solar wind velocity of ~330 km/s, the travel time from the WIND location to the magnetopause is ~11 min. Though IMF Bx was slightly negative and By was negative between 0800 and 2000 UT, IMF Bz was positive in the three time intervals, before 0705 UT, from 0905 to 1350 UT, and from 1705 to 1740 UT. Figure 11b shows the keograms of 630.0 nm aurora emissions observed at P4 on July 30, 1995. From this figure, it is seen that poleward moving auroras were observed before 9 UT and from 1020 to 1520 UT. Though there is ~1 hour time lag from the onset of the poleward moving of the transient auroras to the positive turning of IMF Bz, these transient auroras seem to be highly correlated with northward IMF conditions.

4. Discussion

We analyzed all-sky auroral imaging data obtained at AGOs on nine different days in 1995. Though Karlson *et al.* (1996) and Fasel *et al.* (1992) showed that transient auroral events are related with southward IMF conditions, it was found that most of transient auroral evens in this study occurred in northward IMF conditions. As shown in Section 3, it was also found that these transient auroras are found to appear in the auroral oval or near the poleward boundary of the oval first, and then travel into the polar cap with velocities of ~0.5 km/s and durations of ~10 min in average. Transition from auroral oval to polar cap would mean transition from closed to open field lines (*i. e.*, reconnection). So, it is speculated that these transient auroral forms observed by the AGOs are related with reconnection under northward IMF conditions. Sandholt *et al.* (1994) pointed out that the transient auroras observed near the cusp/cleft region are correlated with short solar wind dynamic pressure variation under negative IMF conditions. As shown in Fig. 9, weak solar wind dynamic pressure pulses were observed by the WIND spacecraft. So, these pressure variations may play some role to excite these transient auroras. To identify this, it is necessary to check the solar wind data observed near the magnetopause since such short-lived features in the solar wind measured by the WIND spacecraft at ~203 R_E ahead the Earth may not be indicative of a large-scale solar wind structure that can cause a demonstrable effect on the magnetosphere.

Acknowledgments

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