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Ground-based Optical Observations of Dayside Aurora in the Antarctic

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Abstract. Narrow field of view multichannel photometer measurements of aurora have been made at the Chinese Zhong Shan station (CGMLAT $74.5°$ S) in the Antarctic. Photometer recorded proton H_β, oxygen red (630.0 nm) and nitrogen N_2^+ emissions also in the vicinity of local magnetic noon. An afternoon optical event was observed during a 6-hour period of mainly southward IMF B_z on June 8th, 1999. In this case study the first results of photometer measurements of oxygen red (630.0 nm) emission and its behaviour are compared with IMF magnetic field data and some solar wind parameters. The location of the daytime red arc shows delayed changes as responce to IMF B_z-component variations. The changes may also be due to the substorm activity in the night side oval.

1 Introduction

The dayside auroras are related to the magnetospheric cusp or cleft processes taking place in the boundary layers of the magnetosphere. The role of the boundary layers in magnetospheric dynamics is partly unknown up to date. Satellites can provide spatially and temporally detailed particle and field measurements required to document these processes. An alternative method is to observe the projection of the magnetospheric cusp/cleft in the ionosphere in the form of the dayside auroras and compare them with different IMF and solar wind parameters.

The location, extent, dynamics and energy distribution of magnetosheath particles entering into the atmosphere along the magnetospheric cleft on the dayside can be determined by monitoring the optical signatures.

The motion of dayside auroral forms in relation to interplanetary conditions have been studied for a long time (e.g. Vorobjev et al. (1975); Horwitz and Akasofu (1977)). At present several features in the morphology and dynamics of the dayside auroras have been related to a multitude of solar wind and interplanetary magnetic field phenomena (e.g. Sandholt et al. (1996a); Sandholt et al. (1996b); Farrugia et al. (1995)). As the southward component of IMF increases, the dayside magnetopause moves earthward (Aubry et al. (1970); Maezawa (1974)), and the polar cusp shifts equatorward (Pike et al., 1974).The earthward displacement of the magnetopause also correlates with increasing geomagnetic activity (Meng, 1970), as do the equatorward shifts of the cusp and the dayside auroral oval.

Dayside auroras are optical ionospheric signatures in the dayside, i.e. up to $\pm$ 6 h from the magnetic noon. The dayside cusp/cleft aurora is the diffuse band where I(630.0 nm) $\gg$ I(557.7 nm). The red-line emission (630.0 nm) above 200 km is caused by the soft fluxes of magnetosheath particle precipitation, and its intensity during quiet conditions is normally below 1 kR. The dayside cusp aurora is faint or subvisual and its average height is 250 km. Most of dayside auroral observations in the Antarctic have until now been made at South Pole station (CGMLAT $74.9°$S).

The large-scale dynamics of the dayside auroras are mainly controlled by the IMF B_z component: a) During IMF $B_z <$ 0 conditions, the auroral intensity is particularly sensitive to the solarwind activity, which controls the efficiency of plasma transfer. b) When the IMF B_z vector turns to north, the auroral intensity decreases, and the auroras retreat poleward, indicating reduced plasma transport into the cusp/cleft region (Sandholt, 1994).

The geomagnetic latitudes of the dayside auroral forms are close to the cusp/cleft region, which corresponds to the auroral oval between about $70°$ and $80°$ MLAT ($B_z < 0$). Within the polar cap poleward of $75° - 80°$ MLAT appear sun-aligned auroras and theta-auroras especially when $B_z > 0$.

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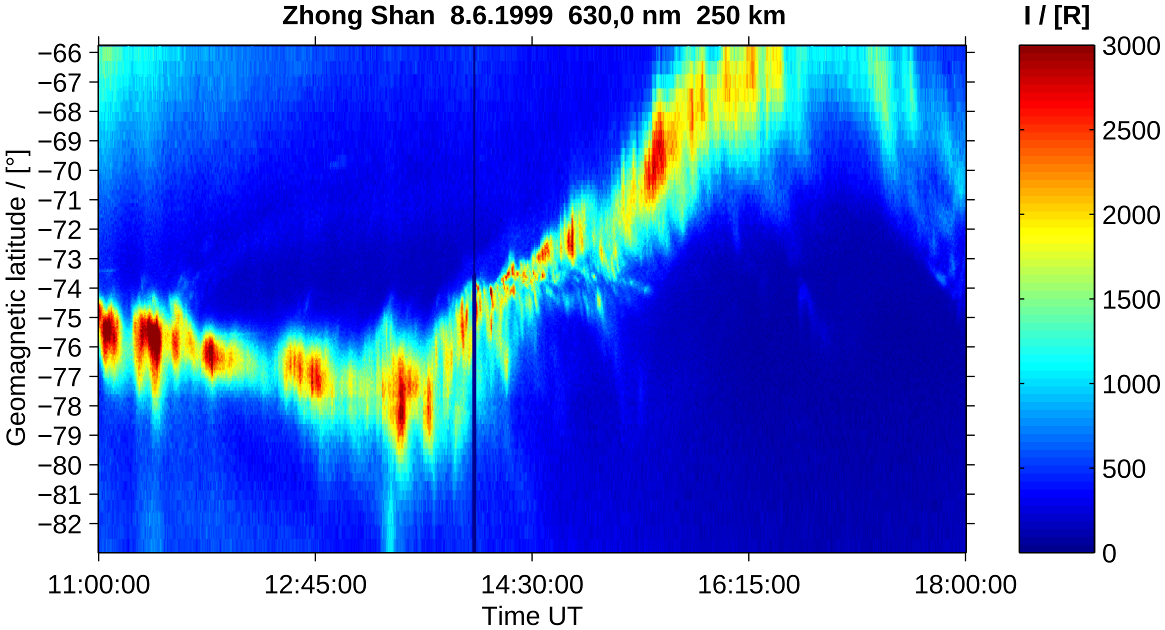

Fig. 1. This figure shows the position of red 630.0 nm aurora as a function of time from 1100 UT until 1800 UT. The intensity of the emission is coded by the colors. The red aurora appears rather stable at geomagnetic latitude of $-76°$ for several hours during afternoon. After 1400 UT it gradually moved down to $-70°$ and below.

2 Data presentation

2.1 Photometric auroral observations

One of the stations in the Antarctic which satisfies the requirements of dayside auroral observations is Chinese station Zhong Shan (69.37° S, 76.38° E; CGMLAT 74.5° S). Magnetic noon (12 MLT) is there at about 10.30 UT. During the darkest months, in June and July, it is possible to measure daytime aurora due to the geometry of the geographic and geomagnetic poles and the auroral oval. Figure 1 shows auroral photometer observations from Zhong Shan for the interval 1100-1800 UT, on June 8, 1999. Intensity of oxygen red emission (630.0 nm) is plotted as a function of geomagnetic latitude. The 630.0 nm emission is highly sensitive to low-energy (100-500 eV) electrons through the excitation of atomic oxygen at F-layer altitudes.

A relative intense red auroral emission (2.7 kR) was located poleward of the zenith, at the geomagnetic latitude of -75– -76° just after noon during the time interval of 1100-1145 UT. A more intense transient auroral form (3.5 kR) appeared somewhat higher latitude at 1128 UT. These two reasonable intense auroral emissions are probably consequences of abrupt directional discontinuities of IMF B_z during the time period of 0940-1030 UT. One more intense transient auroral form (2.6 kR) was located further poleward (-76 °) at 1156 UT.

On ACE satellite B_z rushed negative around 12 UT, but the time delay to ionosphere is at least one hour. A poleward motion continued and gradual weakening of the transient (10 min) auroral emissions occured during interval of 1145-1320 UT. Fairly intensive emission (2.3 kR) at 1328 UT was located further poleward (-77 – -78 °). On the other hand the weaker poleward boundary (1.5kR) extented to geomagnetic latitude of -80° and higher at 1320 UT. It may be an indication of the theta-aurora in the polar cap.

An obvious equatorward motion of the whole auroral belt started about 1340 UT when B_z reached a value of -6 nT on ACE. The equatorward motion continued up to 1700 UT, even if B_z turned positive at 1600 UT. During this period there were numerous brightenings of short-lived individual auroral forms and their simultaneous excursions poleward. The most prominent brightening (2.7kR) at 1530 UT was located at geomagnetic latitude of -68 – -70 °.

After 1630 UT the luminosity of auroras decreased clearly and after 1700 UT they moved again poleward and faded out. At that time the aurora was partly outside of the field of view of the station. The poleward excursions of the aurora as well as the overall eguatorward drift were presumably caused largely by the IMF variations preceeding them. The AE index (not shown here) increased (100-800 nT) during the period of the equatorward drift at 1400 UT indicating substorm activity in the nightside ionosphere. Some of the auroral motion may have been associated rather with the substorm activity than directly with the IMF variations.

2.2 Interplanetary magnetic field (IMF) observations

Figure 2 shows ACE-satellite IMF magnetic field B_z-component for June 8, 1999. From 7 UT to ∼12 UT the IMF was

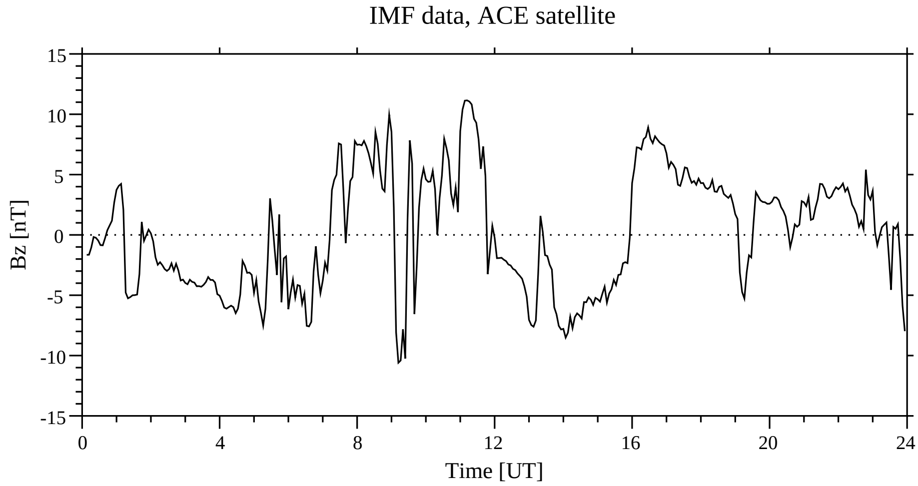

Fig. 2. Interplanetary magnetic field variations are shown for the day June 8th, 1999. The B_z component is northward during 7 - 12 UT. It turns southward around 12 UT and back to northward again at 1600 UT. The position of the red daytime arc does not clearly follow the IMF variations.

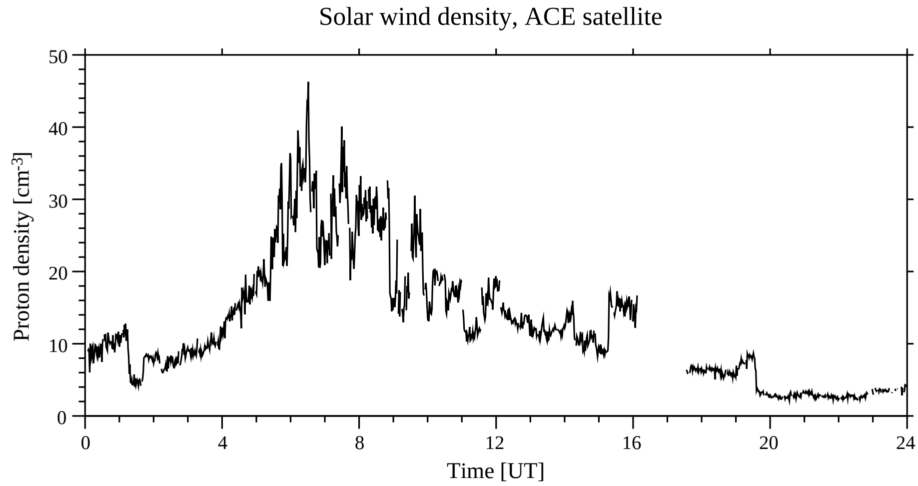

Fig. 3. The proton density in solar wind measurements by ACE satellite is plotted as a function of time during the day 8th June 1999. The density had high values (up to 47 cm^{-3}) during 5 - 9 UT, but it fluctuated around 14 protons cm^{-3} during the time interval of 11-16. There is a data gap between 1620 - 1730 UT. The density decreased to 6 protons cm^{-3} after the data gap.

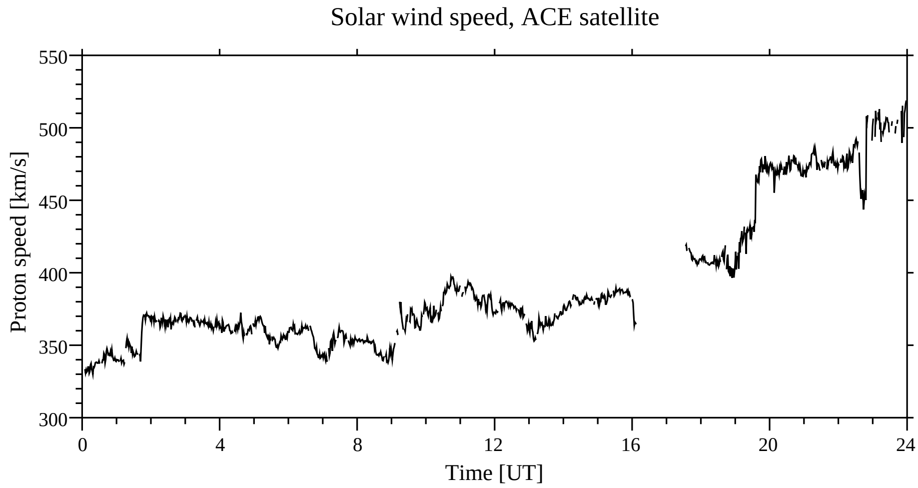

Fig. 4. The proton velocity in solar wind, measurements by ACE satellite, is plotted as a function of time during the day 8th June 1999. The velocity is fairly constant, 380 km/s, during the period of 11 - 16 UT when the daytime aurora has been observed. After the data gap 1610 - 1730 the speed had somewhat higher value, 410 km/s.

strongly northward except for two southward excursions between 9-10 UT. A sudden and brief reorientation took place at ∼1145 UT. From ∼1200 to 1600 UT, IMF B_z was generally negative except for a short directional discontinuity of the magnetic field at 1330 UT. The switch back to strongly positive IMF B_z values took place abruptly at 1600 UT.

During the time interval of 1030-1200 UT the IMF B_z was mostly positive between 0 - 10 nT. During the period of 1200-1300 UT the auroras moved poleward by one degree (from -76° to -77°). Taking into consideration the time delay of about one hour this motion corresponds reasonable to the earlier results as Aubry et al. (1970) or Maezawa (1974).

2.3 Some solar wind parameters

Solar wind plasma data indicate that the solar wind proton speed and density in period 1100-1600 UT were fluctuating around 380 km/s and 14 cm^{-3} respectively. Proton density peaked 47 cm^{-3} earlier, at 0630 UT and proton speed increased gradually up to 560 km/s toward the midnight.

No clear correlation between daytime auroral location and solar wind parameters were found in this event. With solar wind speed of 400 km/s the delay for solar wind signals to arrive from ACE satellite (X_{GSE} = 230 R_E) to the magnetopause by assuming their convection along the Sun-Earth line is about 60 min. The travel of solar wind from magnetopause into the ionosphere takes 2-3 minutes and yet another delay for the ionosphere to respond (estimated at 10-15 min, Freeman et al. (1990)) creates a further delay of signals.

3 Discussion and Conclusions

The Zhong Shan station is a new place for measuring dayside aurora. This case study reports first results of our scanning auroral photometer measurements. The most important conclusion is that our recordings between 1100-1800 UT are ionospheric signatures of dayside postnoon aurora, because the Zhong Shan station's CGMLAT is $74.5°$ S and local magnetic noon 10.30 UT.

Transient, active auroral forms, with a recurrence period of 10 min occurred and their intensities were 0.5 - 5 kR. Poleward motion of shortlived individual auroral arcs occur nearly coincident in time with the equatorward shifts.

Our event of June 8th, 1999 did not show any clear correlation between the position of the daytime auroral band and the IMF B_z-variations. During the positive excursion of B_z-component the intensity of the red emission decreased. At the same time the daytime aurora had its most poleward position. After 1600 UT, when B_z turned positive, the daytime red emission had shifted to geomagnetic latitudes of -66 – -69°, but the main part of the aurora was outside the field of the photometer.

In this event the dominant daytime red auroral emission lasted to ∼16 UT, which is typical for daytime aurora. The change of the geomagnetic latitude is partly due to the diurnal motion of the oval, partly due to other reasons. More complete data set is needed in order to study more carefully the relation between the intensity and latitude of the daytime auroras and IMF or solar wind parameters.

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