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Multiple Poleward Propagating Auroral Events in the 15-16 MLT Sector

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Abstract. Four intervals of postnoon aurora observations were analyzed together with the interplanetary magnetic field variations. There were several clear reversals of the sign of the z-component of the interplanetary magnetic field (IMF), which is known to have an effect on the dayside auroras. The data from the low altitude satellites of DMSP series were used to study the features of electron precipitations related to the auroral arcs. A possible connection between the dayside and nightside auroras was discussed.

1 Introduction

It is widely accepted that dayside auroras are an ionospheric manifestation of the processes in the regions related with the magnetopause: boundary plasma sheet (bps), low latitude boundary layer (llbl), cusp and, probably, mantle. For this reason dayside auroras are regarded as a powerful tool for the investigation of solar wind - magnetosphere interaction. The nightside auroras are caused by the processes in the magnetotail. Due to the difference in the processes ruling the auroras in the dayside and in the nightside, the similar auroral phenomena may be caused by different reasons. For instance, the aurora displacement along the meridian in the dayside is controlled by the sigh of the IMF vertical component, whereas in the night the auroras demonstrate such behaviour at different phases of auroral substorm. The question is what rules the morning and evening auroras as both the dayside and nightside processes may influence on the aurora dynamics in these MLT sectors.

In the northern hemisphere the latitudes above 75 N are the place where dawn and dusk auroras can be observed. But regular registrations are complicated there due to hard climate. For this reason most of the papers have a form of "case study" (Sandholt et al., 1998) and the limited data set hinders the generalization of the interpretation. So, the nature of the dayside auroras is still not understood. The aim of this paper is to extend the statistics on the morphology and dynamics of postnoon auroras. We concentrate on the auroral response to variations of the IMF and on the features of precipitating electrons in the vicinity of auroras.

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2 Instrumentation and methods of investigation

In this study we analyzed the data of television registrations of auroras from Barentsburg high-latitude observatory (BAB, 78,05 N 14,12 E). To study the aurora dynamics the TV records were digitized to get a temporal resolution of one frame per second and the keograms along the magnetic meridian were constructed.

The ionospheric convection was observed by the HF-radar located in Hankasalmi (HANK). The vector velocity was derived from single radar azimuth scan data using the algorithm described in Ruohoniemi et al. (1989).

The WIND and ACE satellites provided the solar wind data. Below we will use the WIND data corrected on the transit time from the observation of the variation by the satellite to their arrival at the magnetopause. To calculate this time we used the algorithm discussed by Hairson and Heelis (1995). On December 28 we had a possibility to check our calculations by comparing the transit time (which was about of 70 minutes) with time lag of sudden impulse on the ground relatively sudden impulse in the solar wind. This gives an uncertainty of the transit time of about 5 minutes.

The spectrograms from DMSP satellites were used as well.

3 Dynamics of postnoon arcs

Most of the dayside auroras are rayed arcs. This irregularity hindered the investigation of the arc dynamics. So, we had to concentrate on the meridional movement, which was inferred from the equatorial edge of auroras clearly seen in the keograms. In the Fig. 1 we present two keograms together with the variations of interplanetary magnetic field.

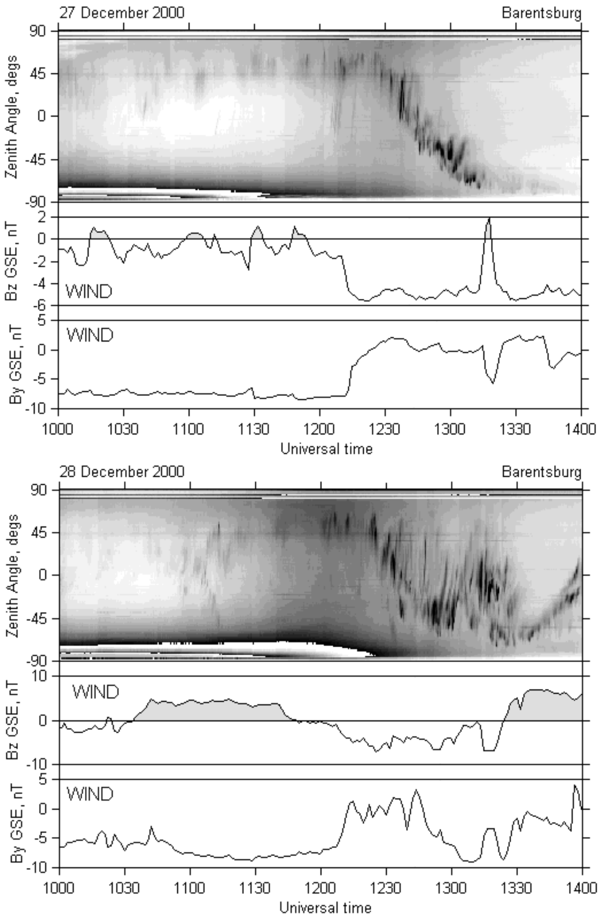

Fig. 1. Postnoon aurora response to the IMF variations.

On December 27, 2000 Bz varied around zero for more than two hours and decreased rapidly to the value of -5 nT near 1210 UT. The auroras occupied the part of the sky north of zenith while Bz was small. The southward turning was accompanied with auroral intensity enhancement and fast equatorward drift outside the TV camera field of view at the velocity $\sim$ 200 m/s. The time delay between the IMF turning and aurora response was about of 20 minutes.

There were several changes of sign of Bz between 10 UT and 14 UT on December 28, 2000. At the beginning of the interval Bz was slightly negative and auroras were very faint. Approximately 30-35 minutes later Bz became positive, the intensity of auroras increased and they moved poleward at the velocity 50 m/s. The southward turning of Bz after 1130 UT was accompanied with one more auroral intensification. Fifteen minutes later the auroras started to drift equatorward at the velocity of 200 m/s. Near 1325 UT Bz turned to the north again. The auroras responded by a decrease of intensity and fast poleward displacement (150 m/s) ten minutes later. During the first reversal, the By component stayed strong negative while during two others it was near zero.

The analysis of all the events shows that the arc systems start to move poleward after northward turning of the IMF Bz, whereas the southward turning is accompanied with equatorward aurora displacement. This is not a new result (see, for instance, Horwitz and Akasofu (1997)). The finding is that the response time of auroras seems to depend on the sign of IMF By component. Namely, it is 5-20 minutes for positive By and more than 30 minutes for negative By. We have also found that the arc velocity is faster for rapid Bz variations (150-200 m/s against 50 m/s for gradual decrease or increase of Bz).

The movement of every arc in the series does not depend on the IMF conditions. For all events considered the arcs moved poleward.

Table 1. List of events.

Date	UT	MLT	Peak energy	Domain
17.12.00	10:07	14:06	1 keV	bps
28.12.00	12:23	15:10	3 keV	bps
27.12.00	12:37	15:32	600 eV	bps
27.12.00	12:28	16:26	4 keV	bps
29.12.00	12:09	15:10	10 keV	bps
17.12.00	12:58	16:40	2 keV	bps

4 Magnetosphere domains

There were several cases of DMSP crossings of TV camera field of view during the intervals under consideration. The spectrograms analysis allowed us to define the position of postnoon multiple arcs with the respect to the boundaries of magnetospheric domains as well as the distribution and the energy of electron precipitations in the arc vicinity. To compare with satellite data, the auroras were mapped at the ionosphere altitude.

An example of the DMSP F15 pass through the TV camera field-of-view is presented in Fig. 2, bottom. The TV frame is mapped at 150 km altitude above Earth's surface (Sergienko and Ivanov, 1993) and shows the form of auroras at the moment when satellite was above the system of arcs. Thin white lines are geomagnetic meridian and parallell. Thin white arrow indicates the fragment of satellite trajectory. Convection velocity is shown with open arrow. White star marks the position of the satellite at 12:37:46 UT. As seen from the spectrogram in Fig. 2, top, the arcs were within the boundary plasma sheet (bps) around this moment. Electron precipitation near the arc have the form of "inverted V" with peak value near 600 eV.

The results of all satellite passes are summarized in Table 1. All passes showed inverted V structures above the arcs. The peak energy did not exceed 10 keV and it decreased toward noon. In all cases the multiple arcs were observed inside the boundary plasma sheet.

5 Discussion

Our results show that the dynamics of the arc system is controlled by IMF variations whereas the individual arcs in the

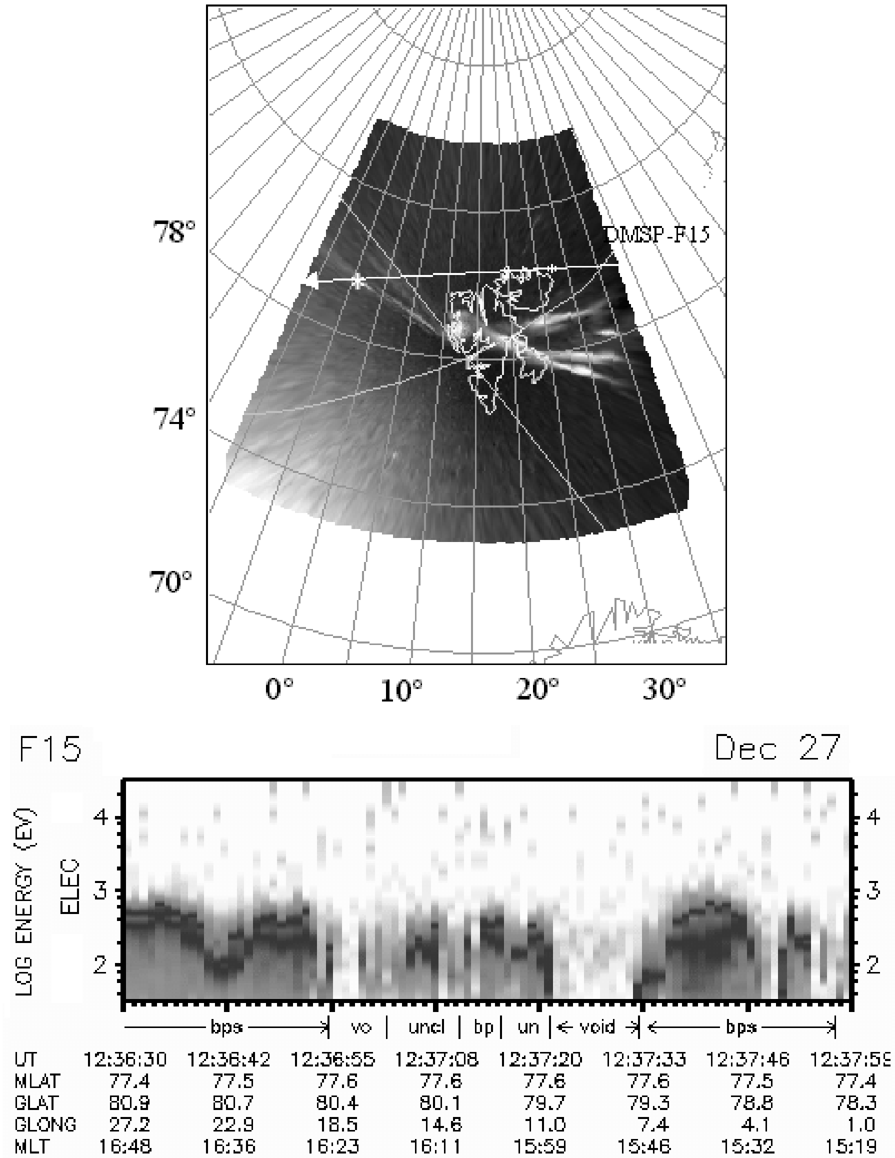

Fig. 2. Bottom panel: DMSP F15 pass through TV camera field of view; top panel: the spectrogram along the fragment of F15 trajectory marked with white line in the bottom panel.

series behave irrespectively from the IMF conditions.

The reaction of arc system may be explained by reconnection. Under the northward (southward) IMF, the reconnection should cause expansion (contraction) of the polar cap, which appears as relative shifts of the boundary plasma sheet regime. The arc system repeats the bps movement. Under the positive By condition the reconnection occurs in the afternoon sector that is nearly to the observation point. Therefore, the auroras reaction occurs earlier than for negative By, when the reconnection area is in the morning sector far from the Barentsburg. The individual arc behavior is apparently determined by magnetospheric generator processes. In the paper by Shiokava et al. (1997), the multiple arcs in the dawn were associated with the substorm activity in the nightside. In this case the ionosphere convection might be a reason of their appearance in this MLT sector. To check this, we have studied the character of the azimuth propagation of the high-latitude arcs in the nightside ionosphere. There the arcs are rather uniform and their azimuthal expansion may be easy traced from the motion of their westward or eastward edge.

It was found that the direction of the arc expansion (from East to West) is consistent with the convection flow. However, convection velocity is 2-3 times less than the arc velocity, which is 1.5-2 km/s.

The MLT distribution of the events considered is shown in Fig. 3. Arrows indicate the direction of arc propagation along azimuth. It is seen that the arcs propagate away from local midnight. For the events when the position of the POLAR satellite allowed to obtain the images of the auroras in the vicinity of observational point, the arc propagation corresponded to the arc flow from an auroral bulge visible near the midnight meridian.

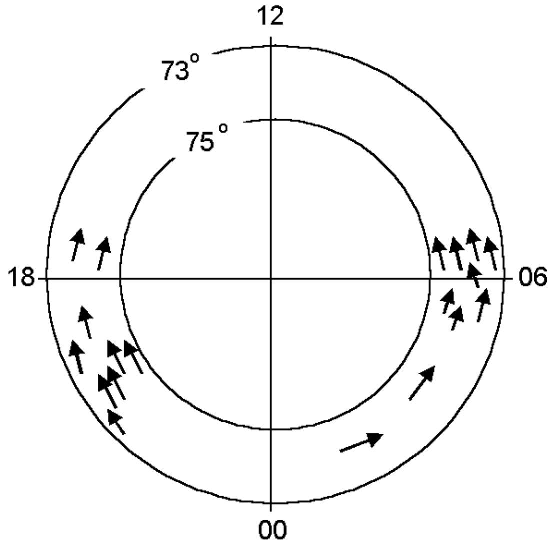

Fig. 3. The MLT distribution of the arc velocity.

We think that the convection instability discussed by (Kozlovsky and Lyatsky, 1994) is the most probable mechanism responsible for the appearance of the arcs in the late postnoon hours. This instability is a modification of the interchange instability. It develops in the nightside plasma sheet and may give rise to plasma structures oriented in the ionosphere both along and at a certain angle to the meridian. The former is seen as the WTS. The latter are stretched toward noon and form the postnoon multiple arcs.

6 Summary

We have analyzed several intervals of television observations of postnoon auroras together with the solar wind and DPSP satellite data. The main findings are the following: multiple arcs are the dominating form of postnoon auroras. The latitudinal propagation of the system of arcs is controlled by both z- and y- components of IMF, whereas every arc in the system moves poleward independently on the sign of Bz. The arcs forming the series are observed inside the ionospheric projection of the boundary plasma sheet and do not leave it while they move poleward. The arcs are associated with electron precipitation of inverted V type with peak energy of 0.6-4 keV for the rayed arcs and 2-10 keV for homogeneous arcs. The energy of the precipitation responsible for the rayed arcs has a tendency to decrease toward the noon. The features of the latitudinal propagation of the arc system may be explained in the frame of the dayside reconnection. But the reconnection, as well as other kinds of magnetopause instabilities, may not be regarded as a candidate mechanism of multiple arc formation. We think that postnoon arcs are the result of the expansion of the nighside auroras toward the earlier MLT hours.

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