"Physics of Auroral Phenomena", Proc. XXXIII Annual Seminar, Apatity, pp. 49 - 52, 2011

Polar
Geophysical
Institute

MORNING – EVENING ASYMMETRY OF AURORAL PRECIPITATION DURING MAGNETIC STORMS

O.I. Yagodkina, V.G. Vorobjev, I.V. Despirak (*Polar Geophysical Institute, RAS, Apatity, Murmansk region, 184200, Russia)*

Abstract. Dynamics of the electron precipitation boundaries during magnetic storms on 10-11 January, 1997, 21-22 October, 2001 and 15-16 July, 2000 were investigated. The magnetic storms with a minimum in Dst of -80 nT, -200 nT and -300 nT, respectively were driven by interplanetary magnetic clouds. The locations of auroral precipitation boundaries from DMSP F10-15 spacecraft observations were compared to those obtained by means of empirical model (http://pgia-webapps-www/apm/). In this model the locations of different auroral precipitation regions depend on geomagnetic activity level expressed by the AL- and Dst indices. It is shown a good agreement between observed and calculated data in different MLT sectors that allowed using the model to examine the dynamics of auroral precipitation and creating the global pattern of precipitation. The significant latitudinal displacements of the diffuse auroral zone (DAZ) and the auroral oval precipitation region (AOP) along with the increase of magnetic activity were observed. During the magnetic storms the width of the DAZ precipitation in the evening sector (18-21 MLT) does not change significantly while the width of these precipitation in the morning sectors (03-06, 06-09 MLT) increase up to ~5º of latitude. The AOP region displays the opposite pattern: weaker widening of the precipitation in the morning sector than in the evening. In the evening sector about 10º expansion of the structured precipitation is observed. Differences in dawn-dusk widening (i.e., asymmetry) of the DAZ and AOP zones during magnetic storms are demonstrated.

Introduction

There are several empirical models of the auroral precipitation depending on geomagnetic activity level (McDiarmid et al., 1975, Spiro et al., 1982; Hardy et al., 1985). These models give the averaged precipitation features in fixed intervals of CGL and MLT. However the position of the region of the different precipitation types varies depending on magnetic activity level and MLT, so that averaging of different precipitation types with different and unknown rate of occurrence takes place. This defect is corrected in the models of Sotirelis and Newell (2000), based on data from 12 years and the eight DMSP satellites. However for selection of data according to the magnetic activity level authors used the latitudinal position of the ion isotropy boundary (b2i), which location was divided into several latitude intervals. Such model is difficult to use in practical purpose since the magnetic activity level is traditionally defined by the value of the AE (AL) and Dst indices. Thus, the existing auroral precipitation models obtained from satellite observations have a greater space-temporary resolution in contrast with our model, but they use as measures of magnetic activity either 3-hour Kp index, or 1-hour AE index. For practical purpose these models are rather difficult to use since they can give only rough estimation of the situations. It is impossible to use these models for more detailed studies, in particular, for study of the auroral precipitation during storms and substorms. The used here model (http://pgia-webapps-www/apm/) allows to construct the planetary distribution (geomagnetic latitude - local geomagnetic time) of different types of auroral precipitation depending on the level of geomagnetic activity determined by AL and Dst indexes. The following classification of the regions of electron penetrations suggested by Starkov et al. (2003) was used in our paper:

DAZ (diffuse auroral zone) is the region of diffuse precipitation, located equatorward an auroral oval and spatially coincided with a zone of diffuse aurorae. This is the zone of hard electron precipitation formed by the electrons injected into the near-Earth region on the night side and then drifted around the Earth. The typical energy of electrons here exceeds 1 keV.

AOP (auroral oval precipitation) is the region of structured precipitation, which equatorward boundary spatially coincides with the equatorial border of the oval of discrete auroral forms.

SDP (soft diffuse precipitation) is the region of soft diffuse precipitation poleward of the AOP region.

Aim of this study is the investigation of the electron precipitation boundaries and the creation of planetary pattern of auroral precipitation during magnetic storms driven by the magnetic clouds.

Data used

To investigate the planetary distribution of auroral precipitation during the magnetic storms with a minimum in Dst - 80 nT on 10 January, 1997, - 200 nT on 21-22 October, 2001 and - 300 nT on 15-16 July, 2000 the DMSP F10-F15 observation data (OMNIWeb, http://nssdc.gsfc.noaa.gov), the AL- and Dst- indices (http://swdcdb.kugi.kyoto-u.ac.jp), and the empirical model (http://pgia-webapps-www/apm/) (Vorobjev and Yagodkina, 2005; Vorobjev and Yagodkina, 2007) were used. The solar wind and interplanetary magnetic field parameters were taken for the WIND satellite (http://cdaweb.gsfc.nasa.gov/cdaweb/istp_public/).

Results

We investigated the locations of auroral precipitation boundaries from DMSP F10-F15 spacecraft data and compared to those obtained by means of the empirical model. In Figure 1 the dynamics of the precipitation boundaries in the N- and S- hemispheres in the morning (a) and evening (b) MLT sectors for January 10-11, 1997 is shown. The top panels plot the variations of the AL- and Dst indices. We have considered the following precipitation boundaries: the poleward boundary of soft diffuse precipitation (SDP), the poleward boundary of auroral oval precipitation (AOPp), the equatorward boundary of auroral oval precipitation (AOPeq), and the equatorward boundary of the diffuse auroral precipitation (DAZeq). The universal time and latitudes (φ°, CGLAT) of the auroral precipitation boundaries are shown along the horizontal and vertical axes, respectively. The solid lines show the modeled boundary dynamics, and the marks indicate DMSP F10, F12 and F13 observations of investigated boundaries. As seen from Figure 1, boundary positions observed by the spacecraft experience considerable latitudinal variations at adjacent experimental points. Although the discrepancies between the experimental and calculated precipitation characteristics are sometimes considerable, the model calculations are generally in rather good agreement with the experiment. As we can see, the model calculations, which are the same in both hemispheres, are capable of filling the gaps in spacecraft measurements and to provide a more complete picture of precipitation boundary dynamics during magnetic storms.

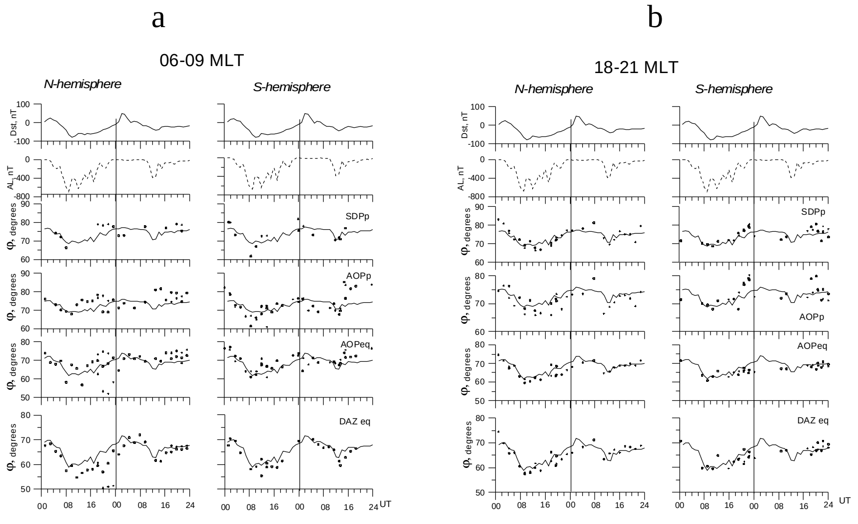

Figure 1. The variations of AL- and Dst indices, dynamics of the precipitation boundaries in the N- and S- hemispheres in the morning (a) and evening (b) MLT sectors. The solid lines indicate the model positions of the boundaries (DAZeq, AOPeq, AOPpol and SDPpol), the different symbols (•, + and ○) mark the boundary locations observed with the spacecraft DMSP-F10, 12, and 13, respectively.

The same investigations were made for two other geomagnetic storms and showed a good agreement between observed and calculated data.

Figure 2 illustrates the global pattern of auroral precipitation in the CGL – MLAT coordinates and the indices of geomagnetic activity during storm on 10-11 January 1997. The dashed lines mark the four time intervals - the calm (a), the growth (b), the main (c), and the recovery (d) magnetic storm phases, for which the planetary distributions are shown. In the calculations, the 1-hour indices of magnetic activity (AL and Dst) were used. From Figure 2 we can see a significant displacement to lower latitudes of the zones of auroral precipitation and a change in the size of the precipitation zones with magnetic activity increasing. In the main storm phase (maximum of magnetic activity) the region of soft auroral precipitation (SDP) located poleward of the AOP disappeared.

In Figure 3 the displacement of the boundaries (a) and changes in the size of the precipitation zones (b) in the morning (06-09 MLT –solid lines) and evening (18-21 MLT – dashed lines) sectors are presented in detail. At the top of the Figures, the AL (solid line) and Dst (dashed line) indices of magnetic activity and in Fig. 3a the behavior of the poleward and equatorward boundaries of AOP and of the equatorward boundary of DAZ are shown. The maximum displacement of the AOP in the main phase of the first storm is about 5^0 CGL for both sectors; the displacement of the equatorial DAZ is about 9^0 CGL. The position of the precipitation boundaries is controlled by the level of magnetic activity in the auroral zone and by the intensity of magnetic storms. Figure 3b displays the change in the AOP and the DAZ width for two MLT sectors. As we can see, the width of the DAZ precipitation in the evening sector (18-21 MLT) does not change significantly, while in the morning sector (06-09 MLT) the DAZ expands up to about 5^0 of latitude. The AOP region displays an opposite pattern: weak widening of the precipitation region in the morning sector (about 1^0 of latitude) and expansion of the structured precipitation region in the evening sector. Such pattern in the auroral precipitation is observed for both storms on 10 and 11 January and defined by both the magnetic activity (AL-index) and storm intensity (Dst variations). Thus, during two magnetic storms under a long-lasting depression of the Dst index, a significant latitudinal displacement of the DAZ and the AOP region was observed. The expansion of the DAZ precipitation occurred in the morning sector and the AOP region expanded in the evening sector.

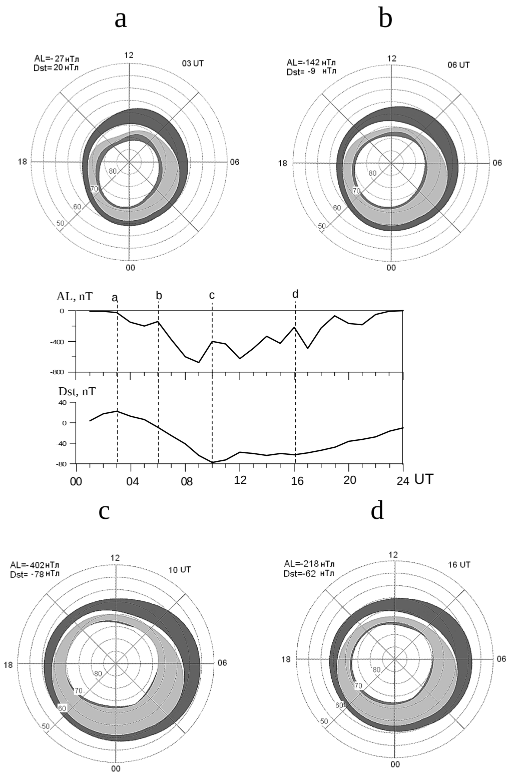

Figure 2. The dynamics of the global precipitation for four time intervals marked by the dashed lines.

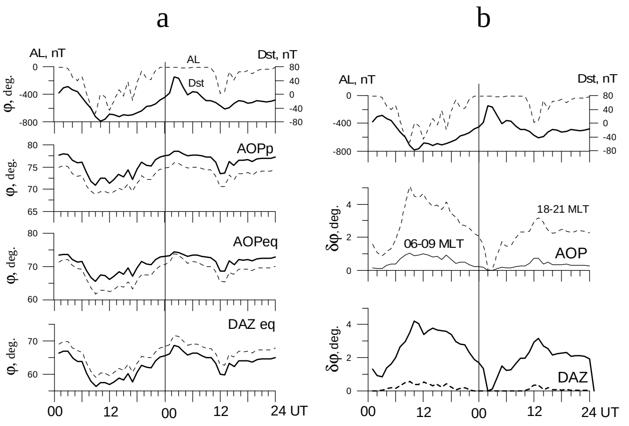

Figure 3. The boundary displacements (a) and the changes of the size of the precipitating zones (b) in the morning (solid lines) and in the evening (dashed lines) sectors on January 10-11, 1997.

For the magnetic storms of moderate (October 21-22, 2001; a, b) and strong (July 15-16, 2000: c,d) intensities the displacement of the boundaries and changes in the size of the precipitation zones in the morning and evening sectors are more expressively and presented in Fig. 4.

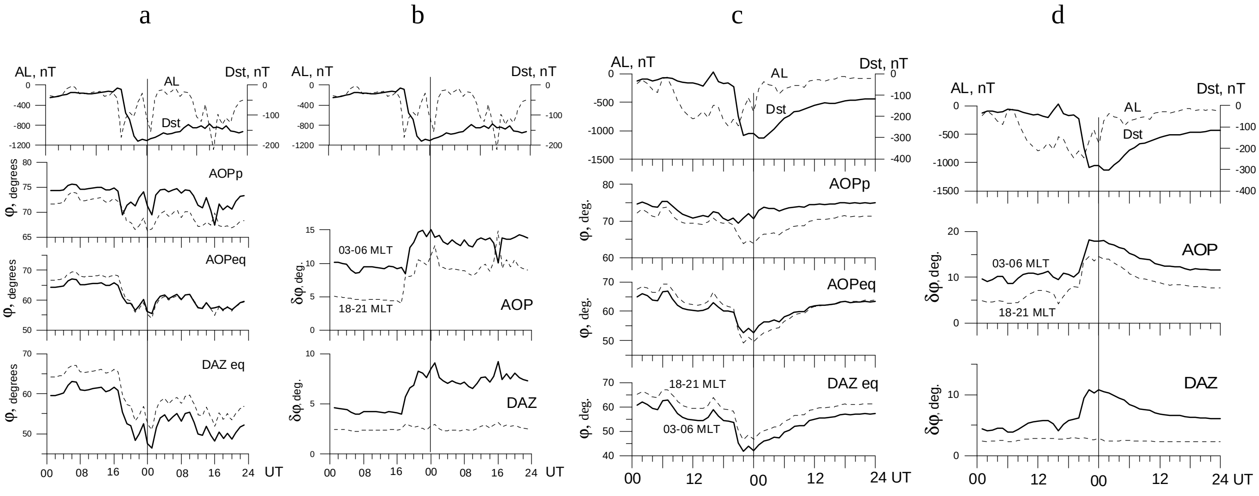

Figure 4. The boundary displacements (a, c) and the changes of the size of the precipitating zones (b, d) in the morning (solid lines) and in the evening (dashed lines) sectors for October 21-22, 2001 (the moderate storm) and July 15-16 2000 (the strong storm).

As can see from Figure 3 and Figure 4 the displacement of the boundaries to lower latitudes and the zone broadening increase with the geomagnetic activity growth. During the magnetic storms the width of the DAZ precipitation in the evening sector (18-21 MLT) does not change significantly while the width of these precipitation in the morning sectors (03-06, 06-09 MLT) increase up to ~5º of latitude. The AOP region displays the opposite pattern: weaker widening of the precipitation in the morning sector than in the evening. In the evening sector about 10º expansion of the structured precipitation is observed. Figures 2, 3 and 4 demonstrate the differences in dawn-dusk widening (i.e., asymmetry) of the DAZ and AOP zones during magnetic storms.

Discussion and conclusions

The present study presents the model pattern of the global auroral precipitation during magnetic storms driven by magnetic clouds. The auroral boundary positions in the morning and in the evening MLT sectors were studied in detail for two different auroral regions: the diffuse auroral zone (DAZ) and the structured auroral oval precipitation (AOP). It is shown that there is a significant shift of the auroral boundaries in both sectors depending on the storm intensity. For the strong magnetic storm on July 15-16, 2000 the DAZ boundary was located at 40^0 CGL and for the weak storm on 10-11 January 1997 it was located at about 60^0 CGL. It is shown that the width of DAZ did not change in the evening sector and it extended up to 10^0 in the morning one. It is found different expanding of the AOP region in both sectors for the different intensity storms. For the moderate and the strong storms the expansion the AOP region was observed in both sectors and for the weak storm the significant expansion was only in the evening sector.

The dawn-dusk widening (asymmetry) of the auroral precipitation regions was found during the main and the recovery phases of the magnetic storms under investigation. The most significant widening of the precipitation zones occurred during the moderate and strong magnetic storms. Newell et al. (1998) explained such asymmetry by changes in the configuration of the geomagnetic tail under storm conditions. They showed that magnetic field inclination (the extent to which the magnetotail is stretched) strongly controls the b2i latitude and that the magnetic field is more depressed and stretched at dusk than at dawn, and asymmetry increases with increasing magnetotail stretching. This asymmetry is consistent with the rotation of the symmetry line of the b2i (MLT) curve toward premidnight hours and suggests the growth of a so-called “partial ring current” system with increasing activity.

In the studies of Vorobjev and Yagodkina (2003, 2005), a simultaneous displacement to the equator of the DAZeq, AOPeq and the isotropization boundary (b2i) in the nightside sector, which is dependent on the AL and Dst indices, was demonstrated. Judging by a significant displacement of these boundaries during the storms under investigation we can suggest an enhanced magnetotail stretching and development of the dawn-dusk asymmetry.

Acknowledgements. The paper was supported by the RFBR Grants 09-05-00818 and Program No. 4 of the Russian Academy of Science. The study is part of a joint Russian -Bulgaria project “The influence of solar activity and solar wind streams on the magnetospheric disturbances, particle precipitations and auroral emissions” of PGI RAS and STIL-BAS under the program for fundamental space research between RAS and BAS.

References

Hardy, D.A., Gussenhoven, M.S., Holeman, E., 1985. A statistical model of auroral electron precipitation. Journal of Geophysical Research 90 (5), 4229–4248.

McDiarmid, I.B., Burrows, J.R., Budzinski, E.E., 1975. Average characteristics of magnetospheric electrons /150 eV to 200 keV/ at 1400 km. Journal of Geophysical Research 80 (1), 73–79.

Newell, P.T., Sergeev, V.A., Bikkuzina, G.R., Wing, S., 1998. Characterizing the state of the magnetosphere: testing the ion precipitation maxima latitude (b2i) and the ion isotropy boundary. Journal of Geophysical Research 103, 4739-.4746.

Newell, P.T., Burke, W.J., Sanchez, E.R., Meng, C.-I., Greenspan, M.E., Clauer, C.R., 1991. The low-latitude boundary layer and boundary plasma sheet at low altitude: prenoon precipitation regions and convection reversal boundaries. Journal of Geophysical Research 96, 21013-21023.

Sotirelis, T., Newell, P.T., 2000. Boundary-oriented electron precipitation model. Journal of Geophysical Research 105 (A8), 18655–18673.

Spiro, D.J., Reiff, P.Y., Maher, L.J., 1982. Precipitating electron energy flux and auroral zone conductances—an empirical model. Journal of Geophysical Research 87 (10), 8215–8227.

Starkov, G.V., Rezhenov, B.V., Vorobjev, V.G, Feldstein, Ya.I., 2003. Planetary distribution of auroral precipitation and its relation to the zones of auroral luminosity. Geomagnetism and Aeronomy 43 (5), 609-619.

Vorobjev, V.G., Yagodkina, O.I., Starkov, G.V., Feldstein, Ya.I., 2003. A substorm in midnight auroral precipitation. Annales Geophysicae 21 (12), 2271–2280.

Vorobjev, V.G., Yagodkina, O.I., 2005. Effect of magnetic activity on the global distribution of auroral precipitation zone. Geomagnetism and Aeronomy 45(4), 438-444.

Vorobjev, V.G., Yagodkina, O.I., 2007. Auroral precipitation dynamics during strong magnetic storms. Geomagnetism and Aeronomy 47(2), 185-192.