"Physics of Auroral Phenomena", Proc. XXVI Annual Seminar, Apatity, pp. 70-73, 2003

Polar Geophysical Institute

RESULTS OF THE ANALYSIS OF ELECTRON PRECIPITATION EVENTS OBSERVED IN THE POLAR ATMOSPHERE

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Abstract

Numerous Electron Precipitation Events (EPEs) were observed at high-latitude stations (Olenya, Tixie Bay, Norilsk) during long-term balloon cosmic ray measurements performed by Lebedev Physical Institute in 1957- 2002. From analysis of the data it can be concluded: (1) the energetic electron precipitation is widely extended over longitude; (2) the events typically occur 1-2 days after geomagnetic Sudden Storm Commencements. We have also examined correlation of the EPEs with electron fluxes (at the energy range >2 MeV) at geostationary orbit as well as with Dst and AE indices.

Introduction

Numerous Electron Precipitation Events (EPEs) were recorded in the northern and southern polar atmosphere during the long-term balloon cosmic ray observations in 1957-2002. Both the long-term cosmic ray balloon experiment and method of electron precipitation event analysis are described in detail in [1-10]. The EPEs in the atmosphere are associated with precipitation of energetic electrons with energies from a few hundreds keV up to a few MeV. The principle characteristics of the EPEs and their occurrence rate in relation to solar activity cycle and seasonal effect were studied in [5-10]. In this paper we interpret the data obtained at high-latitude stations in terms of longitudinal extension of energetic electron precipitation region and correlation of the EPEs with the electron fluxes (energies >2 MeV) at geostationary orbit as well as with Dst and AE indices.

Data

Table 1 presents a list of high-latitude stations of cosmic ray balloon measurements in the atmosphere. The data obtained at these stations were used in the analysis. It is seen from the table that most of the events were observed at Olenya station, which is due to Olenya's position in the northern auroral region (see Table 1, columns 2 and 3) and a very long time of observations (column 6) in this site. Besides, the EPEs were recorded at the auroral stations Tixie Bay and Norilsk but in a smaller number because of shorter time of observations. The EPEs are not typically observed at locations outside the auroral zone. Thus no events were registered at Barentzburg and Vostok (we note, however, that the time of measurements here was rather short; see columns 6 and 7). Only 11 EPEs were registered at Mirny during ~ 40 years of observations. Energetic electron precipitation at Mirny could occur due to an occasional latitudinal extension of the southern auroral zone deep into the polar region.

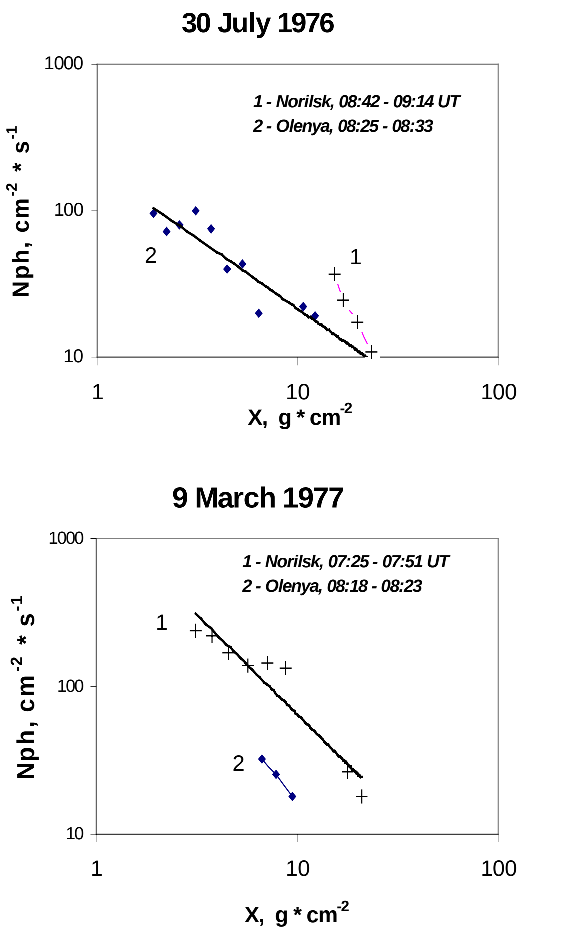
Simultaneous observations of the EPEs at different locations are very important to estimate a longitudinal extent of energetic electron precipitation region. The problem is that simultaneous balloon position at the same altitude at different stations during the EPE event is a very rare occasion. Table 2 presents a comparative statistics of electron precipitation events observed simultaneously at the two pairs of stations: Olenya-Norilsk and Olenya-Tixie. In spite of small statistics of the events recorded at Norilsk and Tixie, it is possible to conclude that (1) the events recorded at Norilsk were also observed at Olenya in ~30 % of the cases, and, vise versa, the events observed at Olenya were registered at Norilsk in ~ 23 % of the cases; (2) ~50 % of the events recorded at Tixie were also detected at Olenya, but only in ~20 % of the cases the electron precipitation events at Olenya were "seen" at Tixie. The simultaneous occurrence of the EPEs indicates that the energetic electron precipitation sometimes is widely extended over longitude (~80º).

Table 1. List of high-latitude stations of ballooning and their characteristics: geographic and geomagnetic coordinates, geomagnetic cutoff rigidity (R_c), McIlwain parameter (L) ('-' means that the station is situated in the region of open geomagnetic field lines), period of measurements, total number of launches in the site ($N_{lauches}$) and launching rate, total number of electron precipitation events recorded (N_{epe}).

Station	**Coordinates**		**R_c (GV)**	**L (R_E)**	**Period of measurements**	**$N_{launches}$ (launching rate)**	**N_{epe}**
	Geogr.	**Geomag.**					
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Olenya	68º57'N 33º03'E	65º07', 132º21'	0.6	5.6	08/1957 - 12/2002	~ 12000 (~ everyday)	471
Mirny	66º34'S 92º55'E	-77º40', 143º24'	0.03	-	03/1963 - 12/2002	~ 10000 (~ everyday)	10
Tixie-Bay	71º36'N 128º54'E	65º48', 215º22'	0.53	5.9	02/1978 - 10/1987	1186	17
Norilsk	69º00'N 88º00'E	64º05', 179º55'	0.6	5.2	11/1974 - 06/1982	757	11
Barentzburg	78º36'N 16º24'E	75º03', 114º89'	0.06	-	05/1982 - 07/1983	59	0
Vostok	78º47'S 106º87'E	86º47', 53º74'	0	-	01 - 02/1980	33	0

Table 2. Comparative statistics of EPEs recorded at Olenya, Norilsk and Tixie Bay.

Combination of stations		**Period of measurements**	**Number of EPEs recorded at the Station 1**	**Number of simultaneous launches at the Station 2**	**Number of EPEs recorded simultaneously at the Station 1 and 2**
Station 1	**Station 2**				
Olenya	***Norilsk***	11/1974 - 06/1982	89	13	3
Norilsk	***Olenya***	11/1974 - 06/1982	11	10	3
Olenya	***Tixie***	02/1978 - 10/1987	145	47	9
Tixie	***Olenya***	02/1978 - 10/1987	17	16	9



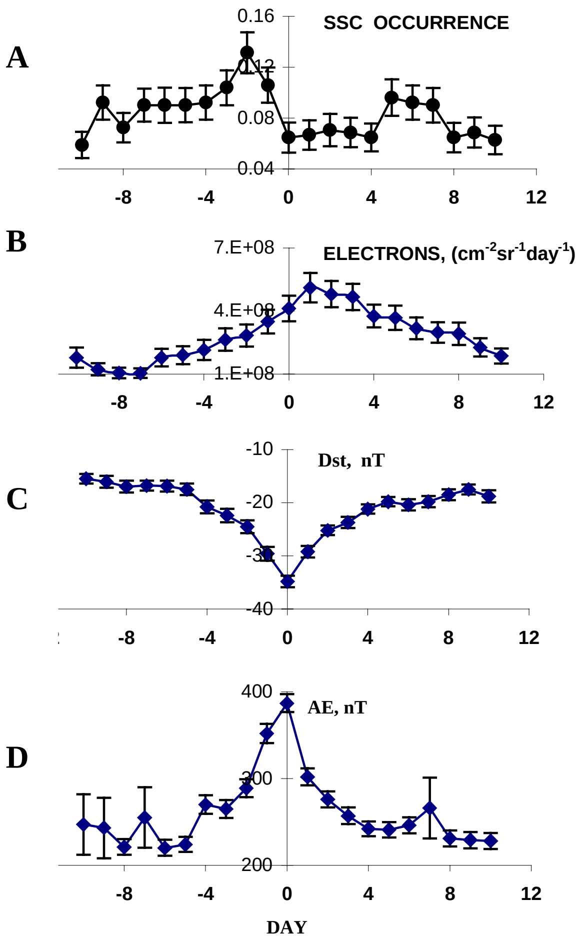


Fig.1 Photon absorption spectra recorded at Olenya and Norilsk during the electron precipitation events on 30 July 1976 and 9 March 1977

Fig. 2 From top to bottom: the results of superimposed epoch technique application to the Sudden Storm Commencements (SSC) daily occurrence rate, daily electron fluences (E>2 MeV) observed at geostationary orbit onboard GOES, daily Dst- and AE –indices. The 0-day corresponds to the day of electron precipitation event as observed at Olenya.
The *rms* of the data are shown by vertical bars.

Figure 1 shows the photon absorption spectra in the atmosphere obtained at Olenya and Norilsk during the precipitation events on 9 March 1977 and 30 July 1976. We note that the observations at these stations during the events are not quite simultaneous but significant fluxes of very energetic photons were recorded in both sites.

Geomagnetic disturbances and EPE observations in the atmosphere

We analyzed the available geomagnetic data on Sudden Storm Commencements (SSC), daily fluences of relativistic electrons observed by GOES satellite at geostationary orbit, equatorial Dst- index and auroral electrojet AE– index [11]. We found that only about 13 per cent of the EPEs occurred on the day when the SSC was recorded. Then we applied superimposed epoch technique to the SSC and EPE data. The day of EPE registration at Olenya was chosen as a zero day and the daily SSC occurrence rate for 11 days before and 11 days after the zero day was examined. The results obtained are presented in Fig. 2. It is clearly seen that the EPE is most probable ~2 days after the geomagnetic Sudden Storm Commencements (panel A). Fig. 2 (panel B) shows that the EPEs occur most frequently when the electron fluxes at geostationary orbit is greater than $2{\cdot}10^{8}$ $cm^{-2}sr^{-1}day^{-1}$.

The results related to Dst and AE indices show that electron precipitation events often occur during the main phase of geomagnetic disturbance when the -Dst and AE indices are increased (panels C and D). This is consistent with the suggestion that the electrons suffer strong acceleration in the magnetosphere one-two days after the SSC [12, 13], when low energy electron population previously injected in the course of substorm is accelerated up to high energies (several MeV).

Results

Numerous Electron Precipitation Events (EPEs) were observed at high-latitude stations (Olenya, Tixie Bay, Norilsk) during long-term balloon cosmic ray measurements performed by Lebedev Physical Institute in 1957- 2002. Analysis of the data enables to conclude that (1) energetic electron precipitation is widely extended over longitude (~ 80º), i.e. in about 50 per cent of cases the events recorded at Tixie were also detected at Olenya, in ~20 per cent of cases the EPEs observed at Olenya were “seen” at Tixie; (2) the EPEs mostly occur 1-2 days after the geomagnetic Sudden Storm Commencement as follows from increased relativistic electron flux (daily fluence) observations onboard GOES at geostationary orbit.

Acknowledgments. This work is partly supported by Russian Foundation for Basic Research grants no. 02-02-16262, 01-02-16131, 03-02-31002, and grant INTAS 2000-752.

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