"Physics of Auroral Phenomena", Proc. XXXIII Annual Seminar, Apatity, pp. 144 - 146, 2011

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LONG-TERM VARIATIONS OF ENERGETIC ELECTRONS AT LOW ALTITUDES

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Abstract. The charged particles under the Radiation belts at the small altitudes are few studied till now. The wide-used radiation models do not take into account such fluxes. The long-term variations of the electrons with energies of hundreds keV at L < 2 are discussed. The variations were studied using the NOAA POES series satellites data. These satellites are operating at ~ 800-km circle polar orbits. The variations of the average electron flux for more than 10 years (1998-2009) are presented.

The new effects were revealed at near-equatorial and middle-latitudinal regions:

- Seasonal semiannual variation of the quasi-trapped electrons flux;
- The average flux of the quasi-trapped electrons considerably increased in the previous solar cycle.

The electron flux variations were compared to different magnetospheric parameters. The results of the comparison are discussed below.

Introduction

This paper analyzes experimental data about the long-term variations of electron fluxes under the Radiation Belts. Charged particles' formations are observed at near-equatorial, low and middle latitude regions at L-values < 2. Electron flux enhancements under the Radiation Belts at L < 2 have been observed since early 1978 in a number of space experiments (Nagata et al., 1988; Voss et al., 1980). Later these fluxes were studied and some of their spatial and spectral characteristics were described in (Grigoryan et al., 2008). Nevertheless many questions concerning the structure, dynamics and sources of these electron flux formations in this region still remain open.

Experimental data

We need to study the long-term variations of the charged particles at the bottom of the inner radiation belt to understand completely their dynamics. The only way to make the continuous series of data is to use similar instruments in similar conditions for all the period. In the terms of space experiment it means either long living satellite or the series of identical satellites on the same orbits. Polar Operational Environmental Satellites of NOAA agency satisfy these conditions. At the table below one can see some details of POES missions. These satellites produce a continuous row of charged particles monitoring data since 1998 till nowadays (http://www.oso.noaa.gov/poes/index.htm and further on the links).

Table 1. NOAA series satellites.

№	Satellite index	Years of operation	Orbit details	Description
1	NOAA TIROS-N	1978-1981	Out of orbit	
2	NOAA POES-06	1979-1986	Out of orbit	Not all data
3	NOAA POES-07	1981-1985	Out of orbit	Not all data
4	NOAA POES-08	1983-1985	Out of orbit	Not all data
5	NOAA POES-10	1986-1991	Out of orbit	
6	NOAA POES-11	1988-2002	Out of orbit	Not all data
7	NOAA POES-12	1991-2002	Out of orbit	Not all data
8	NOAA POES-14	1995-2004	Out of orbit	
9	NOAA POES-15	Launched in 1998	807 km (curr.), 98.5°	Operating
10	NOAA POES-16	Launched in 2001	849 km (curr.), 99.0°	Operating
11	NOAA POES-17	Launched in 2002	810 km (curr.), 98.7°	Operating
12	NOAA POES-18	Launched in 2005	854 km (curr.), 98.7°	Operating
13	NOAA MetOp-2/A	Launched in 2006	817 km (curr.), 98.7°	Operating
14	NOAA POES-19	Launched in 2009	870 km (curr.), 98.7°	Operating

All the satellites carried onboard the same MEPED instruments that monitor the intensities of charged particle radiation at higher energies extending up to cosmic rays. Two identical electron telescopes are included in the instrument. One, termed the 0° electron detector, is mounted on the 3-axis stabilized NOAA spacecraft to view outward along the Earth-center-to-satellite vector. Whenever the satellite is poleward of a geographic latitude of about 35°, this detector monitors electrons in the atmospheric loss cone that will enter the Earth's atmosphere below the satellite. At lower geographic latitudes, this detector measures electrons that are geomagnetically trapped. The second electron telescope, called the 90° detector, is mounted to view in a direction approximately perpendicular to the 0° detector. At higher geographic latitude locations along the satellite orbit the 90° detector monitors electrons that are geomagnetically trapped since they will be reflected by the geomagnetic field at some point below the spacecraft The pair of electron telescopes provide 3 integral channels of electron data: $E_e > 30$ keV, $E_e > 100$ keV, and $E_e > 300$ keV. The proton mix in the channels out of the SAA is insignificant.

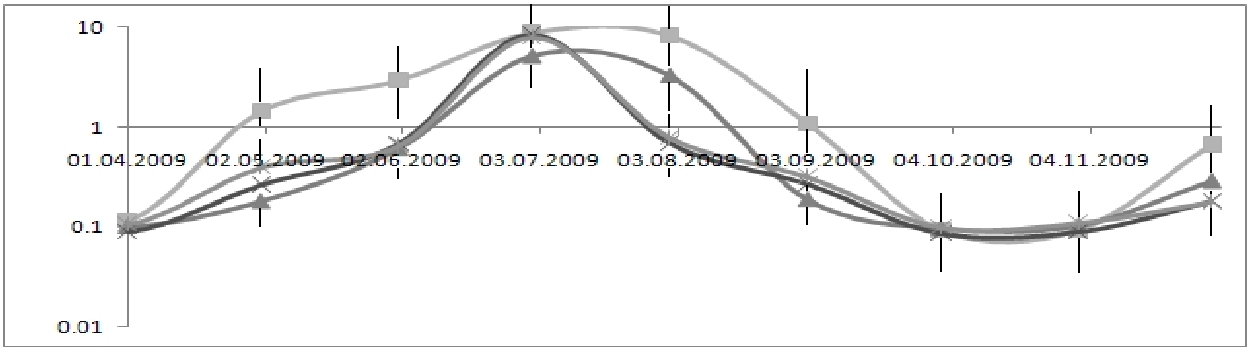

Fig. 1. NOAA-15 to MetOp-2 data comparison. Month averaging of > 30 keV, 0º-channel. The SAA region is excluded from the data set.

On the figure 1 the comparison of detectors inter-calibration is shown. To compare the data of each channel were averaged by month, at L < 1.2 with SAA region excluded from the data set. The data from different satellites are in good agreement, indicating that the quality of inter-calibration of instruments on different satellites is high enough. The discrepancy shown is explained by the difference in heights of vehicles (up to 50 km), as well as the fact that satellites N15, N17, M02 work in the morning local time, and satellites N16, N18, N19 – in the evening.

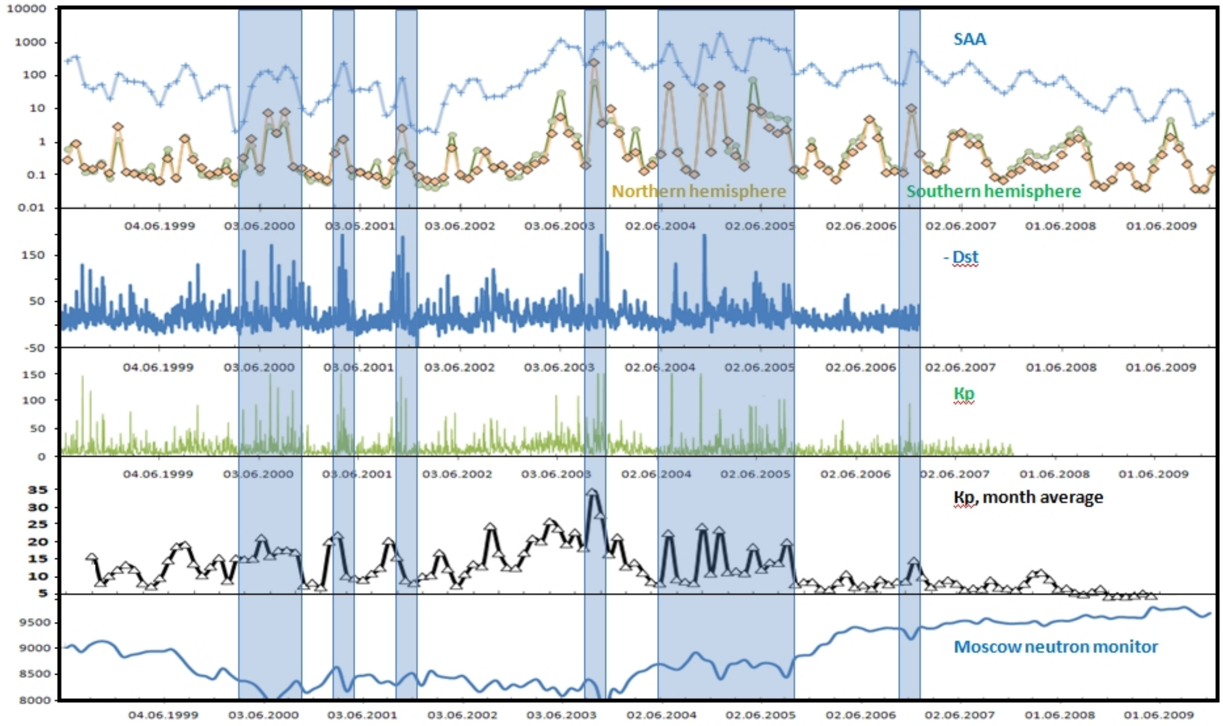

Fig. 2. The comparison of the electron flux and the magnetosphere parameters. Dst and Kp shows magnetospheric events. The CR average rate is shown on the bottom graph.

After the inter-calibration the long period of time was studied using the data. On the figure 2 (a) one can see 3 curves of the electron flux at $L < 1.2$. The 0º-channel, $E_e > 30$ keV is shown at 3 areas as an example. SAA means the border o Southern-Atlantic Anomaly at ~800 km altitudinal slice. The difference between the northern and the southern hemispheres is quite low that tells us about the symmetry of the particles loss process. Indeed, the loss of a radiation belt particles is determined by interaction with VLF waves, and this interaction process occurs mainly near the equator. The fluxes in SAA subside to the solar activity cycle minimum, while the fluxes under the belt remain approximately the same level, experiencing variations twice a year.

The vertical columns point some of the important geomagnetic events. The connection between the electron flux increases and high-level geomagnetic activity is beyond doubt. However, the relationship between the electron flux at $L < 1.2$ and Dst and Kp indexes in quiet geomagnetic conditions have not been found. On fig. 2 (e) it is shown the average rate of GCRs by Moscow neutron monitor station (*http://helios.izmiran.troitsk.ru/cosray/main.htm* and further on the links). The semiannual variations cannot be generated also by the cosmic rays variations.

Conclusion

There are still many questions about the behavior of the electrons deep under the radiation belts. The long-term downward trend from 2005 till the end of 2009 is largely coincides with the behavior of the radiation belts electrons. The decrease in their fluxes can be explained by a small number of substorms in that period, and as a result, a small number of incoming particles in the belt. The semiannual variation is to reduce the flux of electrons in the loss cone in summer and winter and increase the number of quasitrapped particles at the same time. This variation appears at $L < 2$. It is best seen in years 2006 to 2009 when quite geomagnetic conditions gave the least interference in the electron fluxes.

The causes of these variations have yet to learn. More information will be get during the increase phase of the new solar cycle. The work in this direction will continue.

References

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http://helios.izmiran.troitsk.ru/cosray/main.htm (Moscow neutron monitor data)

http://www.oso.noaa.gov/poes/index.htm (NOAA POES satellites, instrument description, current status, databases)