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NORTH-SOUTH ASYMMETRY IN THE SELECTED PARAMETERS OF SOLAR WIND IN THE NEAR EARTH'S SPACE

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Abstract

Cosmic ray fluxes as measured in the polar atmosphere demonstrate a certain north-south asymmetry. In search of plausible asymmetry sources, some parameters of solar plasma in the near Earth's space, such as solar wind velocity and density, interplanetary magnetic field strength, etc., were examined. It was found, that the observed solar wind velocity and density depend on the Earth's heliolatitude leading to the seasonal effect in these parameters. The asymmetry in the solar wind velocity may reach up to ~30 % in March and September and certainly contribute to the well-known seasonal variation in geomagnetic and auroral phenomena. Asymmetry value varies in the course of the 11-year solar cycle being large around solar activity minimum and negligible around solar maximum.

1. Introduction

Long-term balloon observations of cosmic rays in the polar atmosphere being performed by Lebedev Physical Institute (LPI) in the Murmansk region and Mirny observatory (the Antarctic) reveal a certain North-South asymmetry. In order to clarify the asymmetry origin, we examined data on solar wind velocity, interplanetary magnetic field strength, and some other parameters of solar wind plasma in the near Earth's space. In particular, we considered the asymmetry in distributions of these parameters relative to the heliospheric current sheet. Difference between the solar wind velocity dV northwards and southwards of the heliospheric current sheet clearly demonstrated a seasonal effect in accordance with changes in the Earth's heliolatitude [*Svirzhevskaya and Svirzhevsky*, 2003]. It was found that similar difference of solar plasma density dn also depends on the Earth's heliolatitude. However, the dV and dn values changed during a year in the opposite phase. The found heliolatitude dependences varied in a course of the 11-year solar cycle in such a way that the seasonal effects were large in the periods of solar activity minimum and negligible in the periods of solar maximum. *Lyatsky et al*. [2001] estimated the seasonal variation in the solar wind velocity as rather small and usually less than 50 km/s. It may be true for the seasonal variation averaged over the 11-year cycle. However, as we show in this work, in years around solar minimum the difference between the dV values in March and September, when the Earth's heliolatitude reaches its maximum, is sometimes as large as 100–150 km/s.

The pronounced seasonal effect in a number of geomagnetic and auroral phenomena is well-known for a long time. The activity increases in the periods of the spring and autumn equinoxes. In particular, precipitation of magnetospheric electrons into the atmosphere as observed in the LPI balloon cosmic ray experiment is most often in March and September-October [*Makhmutov et al*., 2003]. Fluxes of 0.5–5 MeV magnetospheric electrons enhance around the equinoxes in the wide range of the L-shells ($L = 3.5$–6), even under extremely quite solar condition, the electron flux increases being strongly correlated with increases in the solar wind velocity [*Baker et al*., 1997]. The mechanisms of electron acceleration leading to their flux enhancement are still unclear but their relation to changes of the solar wind velocity is undoubted. Processing of the solar wind OMNIweb data undertaken in this work shows that the difference between solar wind velocities in the adjacent sectors of the heliospheric magnetic field may reach values of 100–150 km/s in periods of the spring and autumn equinoxes. The Earth gets into the regions where the solar wind velocity is higher (lower) each time when crossing the sector boundary, several times during one solar rotation, even in absence of the high speed solar wind flows. The difference between solar wind velocities in adjacent sectors may lead to regular changes in the size of the magnetosphere because of changes in the dynamic pressure of the solar wind $nV^2/2$. The latter may cause regular acceleration of particles in the magnetosphere and elevation of geomagnetic and auroral activity in the equinoctial periods.

2. OMNIweb data processing

The OMNI-files [http://nssdc/gsfc.nasa.gov/omniweb/] were used as the initial data on solar plasma parameters. The monthly averaged values of the solar wind velocity V and density n in the northern and southern hemispheres of the heliosphere were calculated. The heliospheric current sheet was considered as the boundary between the northern and southern hemispheres. Further, the differences between monthly meanings $dV = V_n - V_s$ and $dn = n_n - n_s$ were taken in such a way that a parameter with the subindex n refers to the region northwards of the heliospheric current sheet and that with the subindex s southwards of the heliospheric current sheet. The dV and dn values were taken as the quantitative characteristics of the North-South asymmetry in the solar plasma characteristics under study.

The crossings of the sector boundary are determined by the change in the direction of the $B\varphi$ (azimuthal) component of the interplanetary magnetic field. The $B\varphi$ direction within 45° – 225° (135° on average) in the GSE coordinate system refers to the "away" sector, while the $B\varphi$ direction within 225° – 45° (315° on average) refers to the "towards" sector. The "towards" sector may be situated both northwards and southwards of the heliospheric current sheet depending on the phase of the 22-year solar magnetic cycle. Relation between the sector directivity and the northern (southern) hemispheres of the heliosphere for various periods is given in Table.

Table. Directions of the interplanetary magnetic field in 1960–2000.

Hemisphere	1963–1970	1971–1980	1981–1989	1990–2000
N	$B\varphi$ towards	$B\varphi$ away	$B\varphi$ towards	$B\varphi$ away
S	$B\varphi$ away	$B\varphi$ towards	$B\varphi$ away	$B\varphi$ towards

Processing of the data on the solar wind velocity gave the results presented in Fig. 1. In addition to the solar wind velocity dV, the Earth's heliolatitude is shown being changed from -7.2° (6 March) to +7.2° (7 September). In the 60-ies and 70-ies, a correlation between dV and the Earth's heliolatitude is rather absent (with exception for 1976–1977), but in 1985–1988 and 1994–1996 it is quite good. In periods around solar activity maximum, dV values are smaller and any correlation with the Earth's heliolatitude vanishes.

The plasma density difference dn also clearly depends on the Earth's heliolatitude (Fig. 2). However, the changes in dV and dn are shifted in phase by 180°. The high negative correlation between dn and the Earth's heliolatitude is typical for the years around solar activity minimum: 1976–1979, 1985–1989, 1995–1998. The correlation is kept high during longer time periods than the high positive correlation between the Earth's heliolatitude and dV.

3. Discussion and conclusions

It is obvious that the dependence of dV and dn on the Earth's heliolatitude is caused by the latitude gradients in the solar wind velocity V and density n in the heliosphere between the heliospheric current sheet and the heliospheric high latitudes. In the years of low solar activity, the V values increase and the n values decrease while receding from the heliospheric current sheet. In the years of high solar activity the gradients vanish and the correlation with the Earth's heliolatitude is absent. As it has become clear in the post-Ulysses time, a gradient in V during the high solar activity periods disappears throughout the heliosphere [*Smith and Marsden*, 2003]. It should also be noted that at the same time the heliospheric current sheet tilt increases up to 70° and it could no longer be considered a boundary between the northern and southern heliospheric hemispheres.

The main conclusions of this study are as follows:

1. There exist seasonal variations in the difference between values of the solar wind velocity (dV) and density (dn) northwards and southwards of the heliospheric current sheet. The highest dV and dn are observed when the Earth's heliolatitude is highest.
2. The dV and dn dependence on the Earth's heliolatitude varies during the 11-year solar cycle. The seasonal effects are large in the periods of low solar activity and negligible in the periods of high solar activity.

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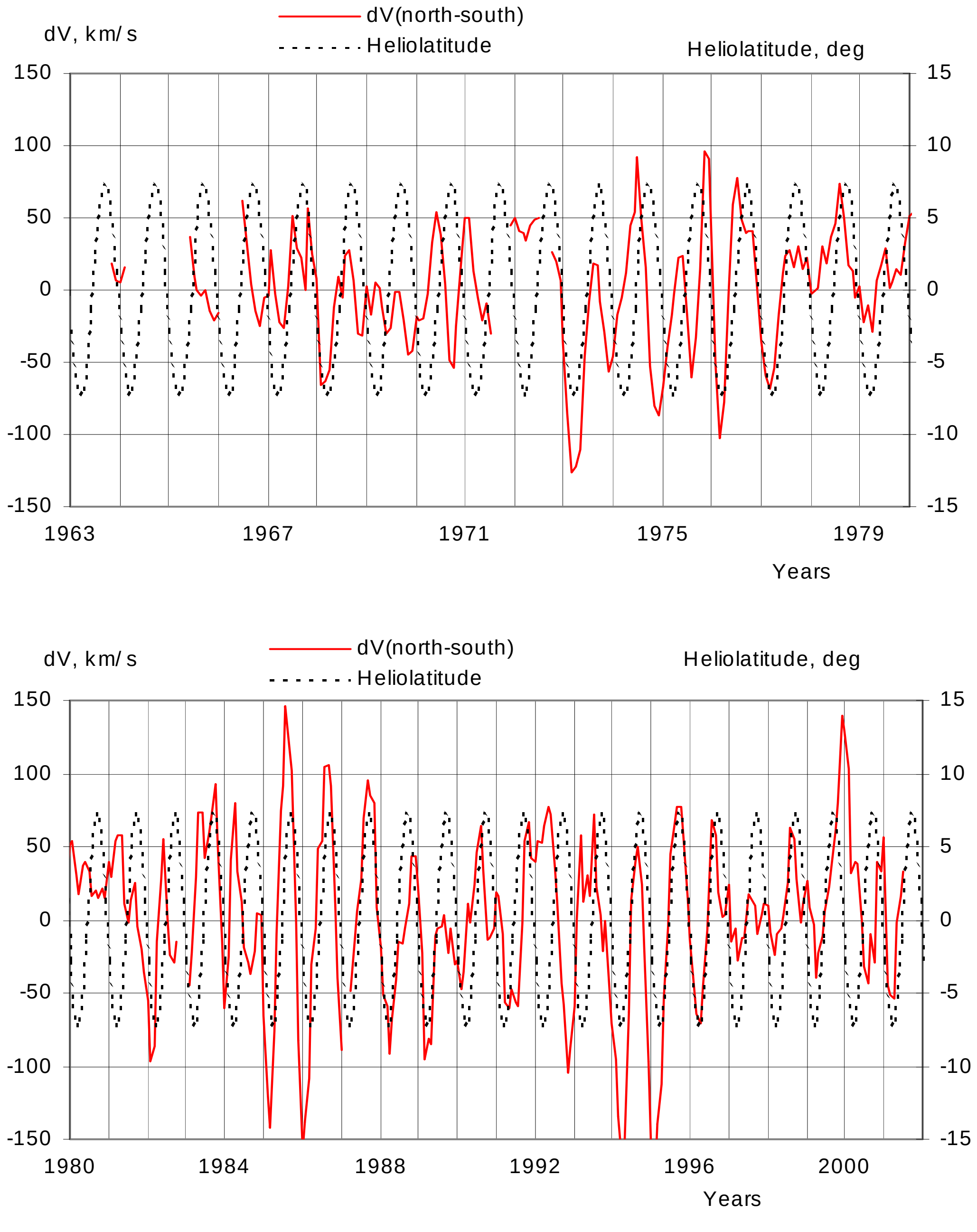
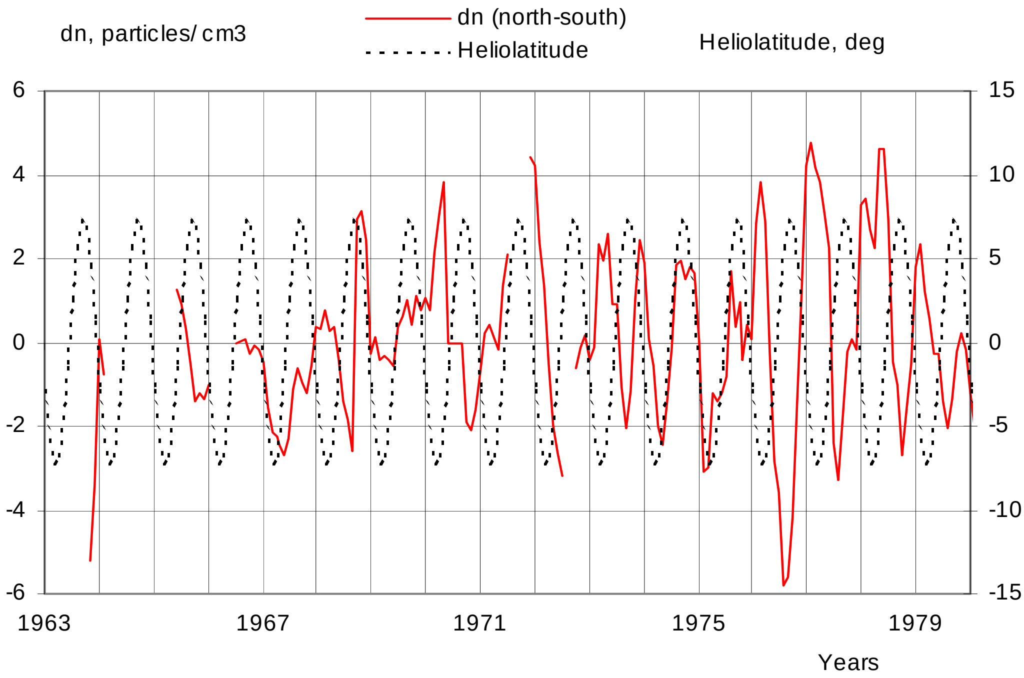


Figure 1. Difference between the solar wind velocity northwards and southwards of the heliospheric current sheet $dV = V_n - V_s$ (3-monthly running averages, solid curve) and the Earth's heliolatitude relative to the helioequator (dotted curve) in 1963–2001.



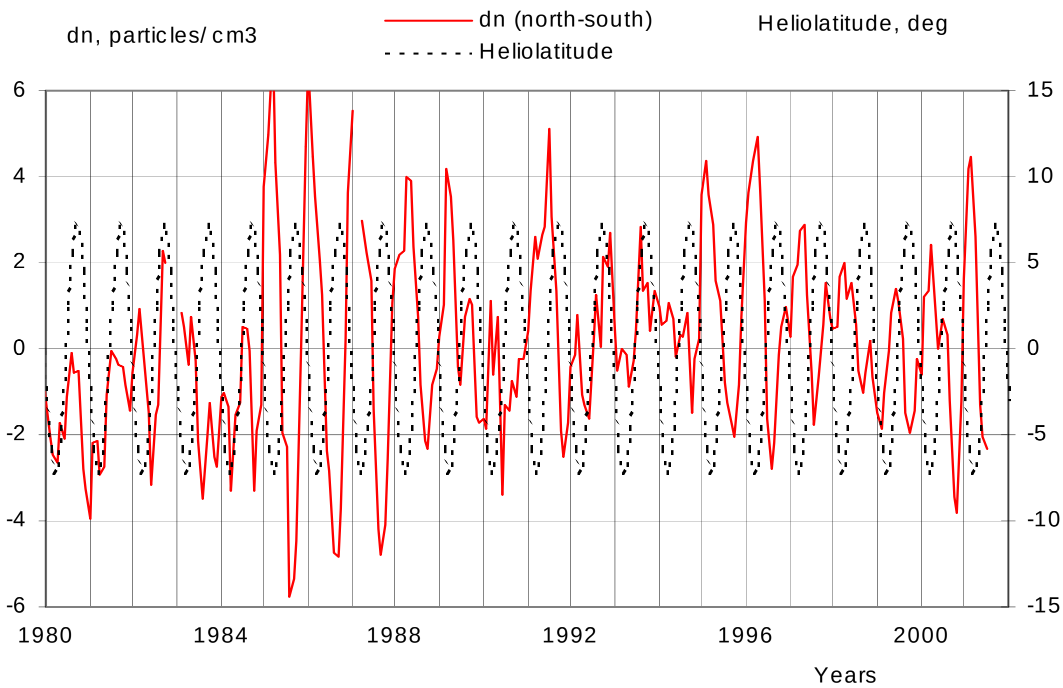


Figure 2. Difference between the solar wind density northwards and southwards of the heliospheric current sheet $dn = n_n - n_s$ (3-monthly running averages, solid curve) and the Earth's heliolatitude relative to the helioequator (dotted curve) in 1963–2001.