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Atmospheric pressure variations at extratropical latitudes associated with Forbush decreases of galactic cosmic rays

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Abstract

Changes of troposphere pressure associated with short-time variations of galactic cosmic rays (GCRs) taking place in the Northern hemisphere's cold months (October–March) were analyzed for the period 1980–2006, NCEP/NCAR reanalysis data being used. Noticeable pressure variations during Forbush decreases of GCRs were revealed at extratropical latitudes of both hemispheres. The maxima of pressure increase were observed on the 3rd–4th days after the event onsets over Northern Europe and the European part of Russia in the Northern hemisphere, as well as on the 4th–5th days over the eastern part of the South Atlantic opposite Queen Maud Land and over the d'Urville Sea in the Southern Ocean. According to the weather chart analysis, the observed pressure growth, as a rule, results from the weakening of cyclones and intensification of anticyclone development in these areas. The presented results suggest that cosmic ray variations may influence the evolution of extratropical baric systems and play an important role in solar-terrestrial relationships.

Keywords: Cosmic rays; Forbush decreases; Pressure variations; Baric system dynamics

1. Introduction

The connection of solar variability and the lower atmosphere is a very interesting and controversial question. Many various hypotheses have been suggested how the Sun can influence the Earth's weather and climate and a number of forcing agents which can transfer solar disturbances into the Earth's atmosphere have been considered, such as cosmic rays (Ney, 1959; Dickinson, 1975; Tinsley and Deen, 1991), solar irradiance (Kristjansson et al., 2002), solar ultraviolet fluxes (Haigh, 1996, 1999), interplanetary electric fields (Tinsley, 2008). Among these forcing agents solar and galactic cosmic rays seem to play a rather important part, because they have sufficient energy to penetrate the stratosphere/upper troposphere heights and, at the same time, their fluxes are strongly modulated by solar activity (e.g., Tinsley et al., 1989).

The evidences of solar and galactic cosmic ray influence on atmospheric pressure and baric system dynamics on different time scales can be found in a number of works. Tinsley and Deen (1991) revealed a decrease of vorticity area index (VAI, the index which characterizes the cyclone intensity) associated with short-time decreases of galactic cosmic rays (GCRs), so called Forbush decreases, mainly at the latitudes ~40–65°N over oceans in winter time. Tinsley (1988) found the latitude shift of cyclone tracks in the North Atlantic associated with cosmic ray flux variations on the decadal time scale. Pudovkin et al. (1997) showed that Forbush decreases were accompanied by a noticeable increase of pressure at the high-latitudinal station Sodankylä (Finland), with the maximum being observed on the 3rd–4th days after the event onsets. Veretenenko and Thejll (2004, 2005) showed that sharp increases of solar proton flux (so called solar proton events or SPEs) result in the intensification of cyclone regeneration in the North Atlantic near the south-eastern Greenland coasts. Veretenenko and Thejll (2013) found also a noticeable intensification of cyclonic activity over oceans at middle latitudes

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in both hemispheres on the days following the energetic SPE onsets. The effects are most pronounced in October–March for the Northern hemisphere and in April–September for the Southern hemisphere, i.e., in the cold part of year for the hemisphere under study. Artamonova and Veretenenko (2011) revealed a pronounced intensification of 'blocking' anticyclone formation on the 3rd–4th days after Forbush decrease onsets over the North Atlantic, Scandinavia and the north of the European part of Russia in the cold half of year. Noticeable changes in the duration of macrosynoptic processes (i.e., natural time intervals when the position of main baric systems and the direction of main air flows remain constant over a large part of the globe) associated with short-time variations of solar and galactic cosmic rays were found by Artamonova and Veretenenko (2013). It should be stressed that studying characteristics of macrosynoptic processes is very important, because many long-time weather forecasts are based on the analysis of the type and duration of these processes (Vangengeim, 1952). The results mentioned above suggest that solar and galactic cosmic ray variations may affect the evolution of extratropical baric systems and play an important role in solar-terrestrial relationships.

So, in this work we continue our previous investigation of baric system evolution in the course of short-time variations of galactic cosmic rays taking place in the cold half of year for the Northern hemisphere (October–March). We expand the studied area to the whole globe and consider pressure variations in both hemispheres in the course of these Forbush decreases of GCRs. The areas of most prominent pressure deviations are compared with the climatic positions of the main atmospheric fronts and the distribution of geomagnetic cutoff rigidities.

2. Experimental data and their analysis

For this investigation the same list of Forbush decreases in GCRs was used as in our previous work (Artamonova and Veretenenko, 2011). We analyzed 48 Forbush decreases with the amplitude exceeding 2.5% relative to the undisturbed level according to the Apatity neutron monitor data (67°N, 33°E) for the period 1980–2006. We selected only those events which were not accompanied by intensive solar proton fluxes during three days around the event onset, as solar proton bursts may produce the opposite effect on the troposphere (Pudovkin and Veretenenko, 1995). The distribution of amplitudes of the Forbush decreases under consideration is presented in Fig. 1. As it is seen from Fig. 1, the amplitudes of most part of these events (∼60%) vary in the range 2.5–3.5%, whereas the number of strong events with the amplitude over 5% is not very high because the beginnings of strong Forbush decreases are often superimposed with solar proton bursts and do not satisfy the selection criteria.

The events were considered for the cold period in the Northern hemisphere (October–March), because in this half of year temperature gradients in the troposphere are high and, as a consequence, cyclonic activity is most intensive. The daily averaged values of geopotential (gp) heights (GPH) of the 1000 hPa level (corresponding practically to the sea level) were taken from the NCEP/NCAR 'reanalysis' archive (Kalnay et al., 1996). The superposed epoch analysis (SPEA) was used to calculate mean pressure deviations from the undisturbed level, which was obtained by averaging the geopotential height data over 10 days before the event onset. The day of the event onset was considered as the zero day. The results of SPEA calculations for the days around the onsets of the Forbush decreases under study are presented in Fig. 2.

As it is seen from Fig. 2, there are no noticeable deviations of pressure before the Forbush decrease onset and on the zero day. On the +1 day relative to the Forbush decrease onset a slow pressure growth takes place over Scandinavia and the northern part of Russia along the southern coast of the Arctic Ocean. During the next two days the area of pressure growth gets bigger. It spreads to the west over the North Atlantic up to the south-eastern coasts of Greenland and to the east up

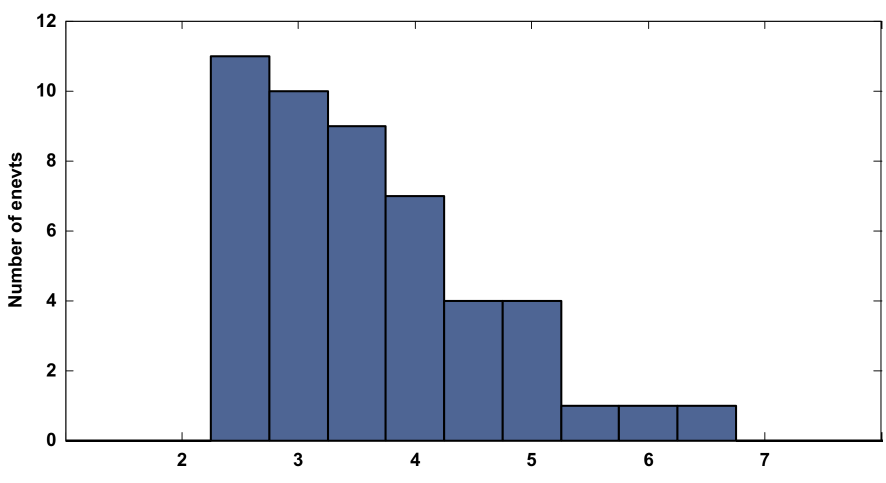

Fig. 1. Distribution of the amplitudes for 48 Forbush decreases under study.

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