COSMIC RAY VARIATION INFLUENCE ON THE DURATION OF ELEMENTARY SYNOPTIC PROCESSES

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Abstract. In this study we consider the influence of galactic and solar cosmic ray variations on the durations of elementary synoptic processes (ESPs) in the Northern hemisphere. It was revealed that the sharp decreases of the galactic cosmic rays intensity, known as Forbush decreases, resulted in an increase of the durations of the ESPs related to the meridional form of the atmospheric circulation as well as in a decrease of the durations of the ESPs for the western and eastern forms of the circulation. It was shown that the bursts of solar protons cause an increase of the durations of the ESPs related to the western and meridional forms, whereas no changes of the ESP duration for the eastern circulation form were found. The detected variations of the durations of elementary synoptic processes may be explained by an influence of solar and galactic cosmic ray variations on the evolution of baric systems at middle and high latitudes of the Northern hemisphere.

Introduction

Studies of elementary synoptic process (ESP) characteristics play an important role in meteorology, because many long-time weather forecasts are based on the analysis of the type and duration of ESPs. The definition of an elementary synoptic process was proposed by Russian meteorologist G.Ya. Vangengeim. According to his definition, ESP is a period when the main characteristics of a particular synoptic situation remain constant over a larger part of the globe. The mean duration of a ESP is usually 3–5 days.

A variety of elementary synoptic processes is divided into 3 groups, which are related to the different atmospheric circulation forms: the eastern form, the meridional form and the western form. This classification is based on a similar geographic distribution of pressure fields and a similar character of processes of their formation, as well as on a similarity of the directions of prevailing wind systems and of the main intrusions of air masses. The eastern atmospheric circulation form is characterized by the development of stable waves of big amplitude in the pressure field with the gradients directed along the latitude. The characteristic feature is a formation of high and warm anticyclones, mainly over the continents, which block the movement of air masses from west to east. Considerable zonal wind components also directed from west to east are observed over the Atlantic and the Pacific oceans. Meridional exchange of air masses becomes more intensive. The meridional atmospheric circulation form is characterized by intrusions of low cold Arctic anticyclones in Europe through Scandinavia. High and warm anticyclones arise over the eastern part of the Atlantic. One can observe a filling of the Icelandic low and a weakening of cyclogenesis near Greenland. Meridional exchange of air masses intensifies. The western atmospheric circulation form is characterized by a strengthening of the movement of cyclones and anticyclones in the zonal flow from west to east. Temperature and pressure gradients between high/middle and high/low latitudes start increasing. Meridional exchange of air masses weakens.

In the work by Veretenenko and Thejll [2004] an intensification of cyclone regeneration near Greenland was found after energetic solar proton events. Artamonova and Veretenenko [2010] revealed an intensification of stationary blocking anticyclone formation over the North-Eastern Atlantic, Europe and Scandinavia during Forbush decreases of galactic cosmic rays (GCR). These results suggest that cosmic ray variations may affect the evolution of cyclones and anticyclones over the North Atlantic and Europe and, as a consequence, the duration of ESPs which are characterized by the development of these baric systems. On the other hand, Veretenenko and Pudovkin [1993] found an intensification of zonal circulation after solar proton events and a weakening of zonal circulation during Forbush decreases of GCR. These results also allow us to assume that the variations of solar and galactic cosmic rays may influence the duration of ESPs related to different forms of atmospheric circulation. So, in this work we study the variations of the ESP duration associated with Forbush decreases of GCR and solar proton events.

Experimental data analysis

To study the effects of GCR variations on the ESP duration, we selected 48 Forbush decreases of GCR with amplitude $\delta N/N > 2{,}5\%$ using the data of Apatity Neutron Monitor (67°N, 33°E) for the period 1980-2006. To exclude a possible influence of solar proton bursts, we selected those events which were not accompanied by intensive solar proton fluxes (i.e., with the intensity $I > 100$ proton·cm^{-2}·s^{-1}·sr^{-1} for particles with energy $E_p > 10$ MeV) during the period ±3 days around the Forbush decrease onset. The list of 48 solar proton events (SPEs) with energy of particles $E_p > 90$ MeV for the period 1980-1995 was taken from [Veretenenko and Thejll, 2005]. Both Forbush decreases and solar proton events were considered for the cold half of the year (October - March), because this period is characterized by a significant increase of the surface temperature contrasts and, as a consequence, by an intensification of cyclonic activity at middle latitudes. Two sets of elementary synoptic processes observed during the Forbush decreases and SPEs were selected, the catalog by Vangengeim (published in 1964 and continued up to now) being used, and the mean distributions of the ESP durations associated with Forbush-decreases and solar proton events were calculated.

Let us give in more detail the methods of the ESP selection and the calculation of the mean distribution of the ESP duration for undisturbed conditions. We selected the current ESP, if a Forbush decrease or a SPE coincided with the two first days of the ESP. In the case when a Forbush decrease or a SPE coincided with the two last days of the ESP, we selected the next ESP. The mean distribution of the ESP durations for undisturbed conditions was calculated using the Monte-Carlo simulation method. We generated 1000 sets of 48 randomly selected key dates when no Forbush-decreases or energetic solar proton events were observed during the cold half of the year (October - March) for the period 1980-2006. On the base of these data the mean distribution of the ESP durations was calculated.

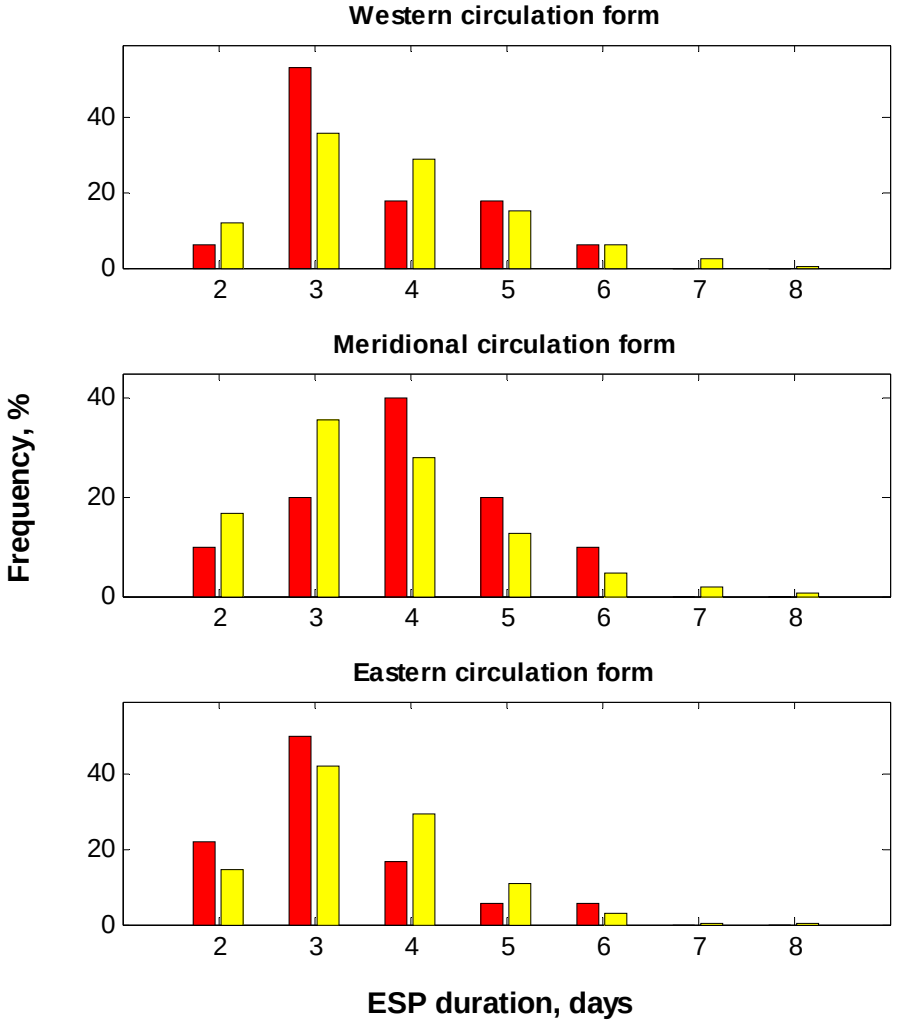

Fig. 1 Distribution of the ESP durations during Forbush decreases of galactic cosmic rays (red bars) and the mean distribution of ESP durations for undisturbed conditions in the period 1980-2006 (yellow bars).

The distribution of the ESP durations during Forbush decreases of galactic cosmic rays compared with the distribution of the ESP durations for undisturbed conditions are presented in Fig.1. One can see an increase of the ESP durations related to the meridional circulation form and a reduction of the ESP duration related to the western and eastern circulation forms. In Fig.2 the distribution of the ESP duration during solar proton events and the mean distribution of the ESP duration for undisturbed conditions are shown. As it is seen from the figure, the bursts of solar protons result in an increase of the ESP durations related to the western and meridional forms of the atmospheric circulation, whereas no changes of the ESP durations are observed for the eastern circulation form.

The detected variations of the ESP durations may be explained by an influence of solar and galactic cosmic rays on the evolution of baric systems at middle and high latitudes. In the previous work [Artamonova and Veretenenko, 2010] it was shown that Forbush decreases are accompanied by an increase of the life-time and intensity of blocking anticyclones over north-eastern part of the Atlantic, Europe and Scandinavia. It is known that the meridional form of the atmospheric circulation is characterized by the development of baric systems namely of such a type. An increase of anticyclone activity during Forbush decreases may be a reason for an extension of the ESP duration for the meridional form of the atmospheric circulation (the most frequent duration for this form gets equal to 4 days, whereas in the absence of Forbush-decreases it equals to 3 days). On the other hand, the western and meridional forms of atmospheric circulation are characterized by a significant cyclone activity over the Atlantic Ocean. A weakening of cyclonogenesis during Forbush decreases in the same region may be a reason for shorter ESPs (more ESPs lasting 3 days in comparison with the undisturbed level) which are related to the western and meridional circulation forms.

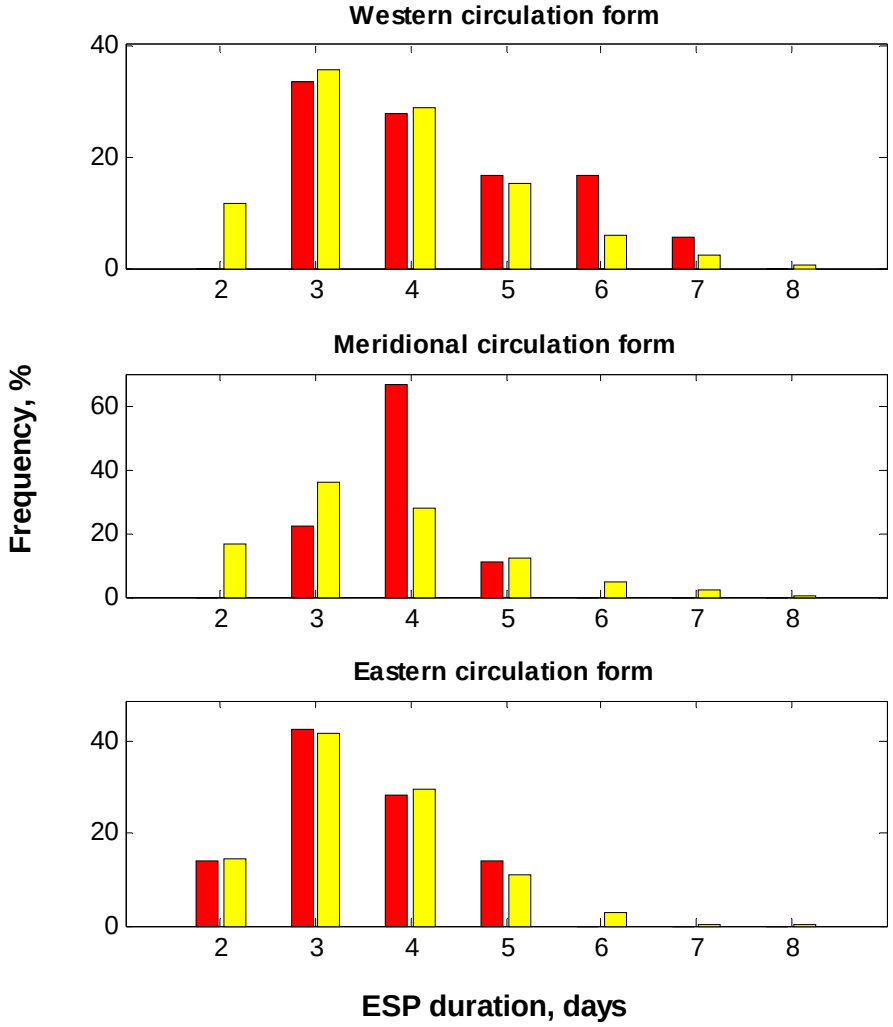

Fig. 2 Distribution of the ESP durations during solar proton events (red bars) and the mean distribution of ESP durations for undisturbed conditions in the period 1980-2006 (yellow bars).

As for solar proton events, Veretenenko and Thejll [2004] revealed that North Atlantic cyclones near Greenland regenerate more intensively after energetic solar proton bursts. It results in an increase of the duration of the ESPs for the western circulation form. We can see more ESPs with duration of 6-7 days in comparison with undisturbed conditions. Forbush decreases of GCR following solar proton events result in an increase of the ESP duration for the meridional circulation form. At the same time, the duration of ESPs for the eastern circulation form remains without considerable changes.

Discussion

This investigation showed that Forbush decreases of GCR and solar proton events may influence the duration of elementary synoptic processes by changing the intensity of cyclonic and anticyclonic activity over the North Atlantic, Europe and Scandinavia. The results obtained are in good agreement with the variations of zonal pressure at middle and subpolar latitudes [Pudovkin and Babushkina, 1992] as well as with the variations of zonal circulation intensity during Forbush decreases and solar proton events [Veretenenko and Pudovkin, 1993].

It should be noted that cyclonic and anticyclonic activity at middle latitudes, i.e., formation, development and movement of extratropical baric systems (cyclones and anticyclones) are closely related to the structure of the thermo-baric field of the troposphere (divergence or convergence of isohypses) and the temperature contrasts in the frontal zones [Matveev, 2005]. Thus, an intensification of cyclonic/anticyclonic activity suggests changes of these factors associated with cosmic ray variations under study and these changes, in turn, create more favorable conditions for the development of cyclones/anticyclones in the North Atlantic region. A possible mechanism of the effects observed in the evolution of mid-latitudinal baric systems may involve radiative forcing of cloudiness changes as well as latent heat release [Tinsley, 2008] with the consequent effects in the troposphere temperature field and, then, in the atmospheric circulation.

Conclusions

Investigation of durations of elementary synoptic processes according to the classification by Vangengeim was carried out taking into account an influence of solar proton events and Forbush decreases of galactic cosmic rays on the baric system dynamics at high and middle latitudes. An increase in the ESP duration for the western and meridional circulation forms were detected on the days following the onsets of solar proton events with energy of particles $E_p > 90$ MeV. During Forbush decreases of GCR with the amplitude $\delta N/N > 2{,}5$ % an increase in the ESP duration for the meridional form and a reduction in the ESP duration for the western and eastern circulation forms were detected.

It was shown that the detected changes in the ESP durations are caused by the influence of cosmic ray variations under study on the development of North-Atlantic baric systems. These changes of ESPs result from an intensification of stationary blocking anticyclones over the East Atlantic, Europe and Scandinavia during Forbush decreases of GCR and of cyclone regeneration near Greenland after solar proton events.

The results obtained seem to be of importance for meteorological forecasts based on the analysis of the type and duration of elementary synoptic processes.

References

Artamonova, I.V. and S.V. Veretenenko (2010), Galactic cosmic ray variation influence on baric system dynamics at middle latitudes, *J. Atmos. Sol.-Terr. Phys*, doi:10.1016/j.jastp.2010.05.004

Pudovkin, M.I. and S.V. Babushkina (1992), Influence of solar flares and disturbances of the interplanetary medium on the atmospheric circulation, *J. Atmos. Sol.-Terr. Phys.*, 54(7/8), 841–846.

Matveev, L.T. and U.L. Matveev (2005), *Clouds and vortices – the basis of fluctuations of weather and climate,* St.Petersburg, RGGMU, 327 pp.

Tinsley, B.A. (2008), The global atmospheric electric circuit and its effects on cloud microphysics*, Rep. Prog. Phys.,* 71(6), 66801-66900.

Vangengeim, G.Ya. and A.A. Girs (1964) *The catalog of macrosinoptical processes by classification of Vangengeim,* AARI, Leningrad.

Veretenenko, S.V. and M.I. Pudovkin (1993), Effects of cosmic ray variations in the circulation of lower atmosphere, *Geom. and aeronomy,* 33(6), 35-40.

Veretenenko, S.V. and P. Thejll (2004), Effects of energetic solar proton events on the cyclone development in the North Atlantic, *J. Atmos. Sol.-Terr. Phys*., 66, 393–405.

Veretenenko, S.V. and P. Thejll (2005), Cyclone regeneration in the North Atlantic intensified by energetic solar proton events, *Adv.Space Res.,* 35, 470-475.