VARIATIONS OF ALTITUDINAL PROFILES OF TEMPERATURE, PRESSURE, AND WIND VELOCITY DURING FORBUSH-DECREASES FOR HIGH-LATITUDE STATIONS

Morozova A.L., Denisov E.V., Arkhipov S.N., Pudovkin M.I.
Institute of Physics, St.-Petersburg University, anita@geo.phys.spbu.ru

Abstract
The study presents results of analysis of altitudinal profile variations of atmospheric pressure, air temperature, and local wind velocity associated with Forbush-decreases of the galactic cosmic rays (GCR) intensity. The analysis is based on the data recorded at North-Atlantic high-latitude meteorological stations (Denmark, Greenland, Iceland, Faeroes, Jan Mayen) and shows that the effect strictly depends on location, predominant climate conditions as well as the weather conditions (cycloonic or anti-cycloonic) before the GCR events.

The influence of Forbush-decreases of the galactic cosmic rays (GCR) intensity on the atmospheric parameters (temperature, pressure, wind velocity etc.) in the low atmosphere has been studied before in some details (see e.g. Pudovkin et al. (1997), Stolov and Shapiro (1974)). It was shown that the effect is especially significant for high-latitude regions.

It was also shown that GCR and solar cosmic ray (SCR) events cause an appearance of cells with increased and decreased atmosphere pressure (Schuurmans, 1982). The existence of these cells could be explained by the influence of local climate features, such as predominant cycloonic or anti-cycloonic conditions, influence of ocean, orographic features etc. Therefore, a study of variations of meteorological parameters during GCR and SCR events for regions with unstable weather conditions (like the North-Atlantic region) is a matter of major interest.

Our previous study of variations of meteorological parameters in the North-Atlantic region presented in Morozova et al. (2002b) allowed us to conclude that significant variations of height profiles of pressure happen during Forbush-decreases.

In this paper we extend this analysis on variations of temperature and wind velocity height profiles. We also study how the weather conditions before the GCR events affect the character of variations of the atmosphere parameters.

Analysis of experimental data
To study the effect of solar activity on weather conditions in the North-Atlantic region we have used a dataset provided by the Danish Meteorological Institute (DMI). This dataset contains selected data from the database of
aerological soundings held at the DMI. These data include records of atmosphere pressure, temperature and wind velocity height profiles measured at local noon at ten meteorological stations situated in Iceland, Faeroes, Denmark, Jan Mayen and Greenland (see Figure 1).

![Map of meteorological stations in the North-Atlantic region](image)

**Figure 1.** The locations of the meteorological stations in the North-Atlantic region.

<table>
<thead>
<tr>
<th>N</th>
<th>Dates of Forbush-decreases of GCR</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Year</td>
</tr>
<tr>
<td>1</td>
<td>1978</td>
</tr>
<tr>
<td>2</td>
<td>1978</td>
</tr>
<tr>
<td>3</td>
<td>1978</td>
</tr>
<tr>
<td>4</td>
<td>1979</td>
</tr>
<tr>
<td>5</td>
<td>1981</td>
</tr>
<tr>
<td>6</td>
<td>1981</td>
</tr>
<tr>
<td>7</td>
<td>1982</td>
</tr>
<tr>
<td>8</td>
<td>1988</td>
</tr>
<tr>
<td>9</td>
<td>1991</td>
</tr>
<tr>
<td>10</td>
<td>1994</td>
</tr>
</tbody>
</table>

**Table.** List of the Forbush-decreases of GCR flux intensity used in the analysis

To study the variations of the meteorological parameters during Forbush-decreases we analyzed changes of height of some isobaric surfaces (p = 900, 700, 500 and 300 mbar) as well as temperature and wind velocity at these pressure levels.

At first, height profiles of all meteorological parameters have been interpolated to a uniform pressure scale. Then for each of the stations we used the superposed epoch method to calculate the average effect of Forbush-decrease on the height profiles of the meteorological parameters. The dates of Forbush-decreases in GCR fluxes with magnitude more than 2.5% during winter seasons have been used as "key dates" (see list of events in Table). The only GCR events that are isolated from other by at least 5 days were taken into consideration. Because of some gaps in the meteorological data the number of analyzed events changes with stations (from 6 to 10 events).

The results of this analysis are presented in Morozova et al. (2002a) as variations from mean values. In the paper it has been shown that the atmospheric parameters vary during at least the first 5 days after the events. In average, the GCR events are associated with a decrease of air pressure, temperature and wind velocity (excluding north-western and south-eastern parts of the North-Atlantic region).

To study the effect of initial weather conditions (weather condition before GCR events), which are the background for atmosphere parameter variations caused by cosmic ray events, we divided our "key dates" set in the two groups: group 1 – the Forbush-decreases occurred with a "cycloonic" background (the events with low surface pressure on the Greenland coast) and group 2 – the Forbush-decreases occurred with an "anti-cycloonic" background (the events with high surface pressure on the Greenland coast). The results of separate analysis of each group of GCR events show that the initial weather conditions dramatically define the character of the variations of the meteorological data:

- group 1. The air pressure, temperature and wind velocity increase in the eastern part and decrease in the western part of the region.
- group 2. On the contrary, the cosmic ray events of this group cause a decrease of air pressure, temperature and wind velocity in the eastern part and an increase of these parameters in the western part of the region.

To estimate a significance of the described above variations of the meteorological parameters we have used the Student criterion. Figures 2 – 4 show the results of the statistic analysis of the meteorological parameters. Figure 2 presents variations of height of isobaric surface p = 500 mbar, Figures 3 – 4 show variations of air temperature and wind velocity at this pressure level. Data for all GCR events (both group together) are shown on Figures a, data for group 1 are shown on Figures b, data for group 2 are shown on Figures c. In these Figures the regions of decrease (or increase) of corresponding parameters with significance more than 80% are shadowed.
Figure 2. Regions of increase and decrease of the height of the isobaric surface $p = 500$ mbar during 5 days after a GCR event with significance more than 80% and more than 90%; all events (a), group 1 (b), group 2 (c) – see text for comments.

Figure 3. Regions of increase and decrease of the atmosphere temperature at the isobaric surface $p = 500$ mbar during 5 days after a GCR event with significance more than 80% and more than 90%; all events (a), group 1 (b), group 2 (c) – see text for comments.
Results

The statistic analysis of variations of meteorological parameters during Forbush-decreases for the North-Atlantic region has shown that the atmospheric parameters vary significantly at least for the first 5 days after the events. This effect depends on the geographical location of a given meteorological station as well as on the weather conditions (cyclonic or anti-cyclonic) before the GCR events.

In average all GCR events are associated with a decrease of air pressure and temperature. Wind velocity significantly decreases in the south-eastern part of the region (on the 5th day) and increases in the central and western part of the region (on the 2nd and the 4th - 5th days).

The separate analysis of both groups of GCR events shown that the character of the variations of the meteorological data depends on the initial weather conditions:

— **GCR events from group 1**: events with "cyclonic" weather conditions (*surface pressure falls*). The GCR events are associated with a significant decrease of air pressure and temperature in the western part of the region. Wind velocity decreases in the eastern part of the region (on the 2nd - 4th days).

— **GCR events from group 2**: events with "anti-cyclonic" weather conditions (*surface pressure rises*). The events are associated with a significant decrease of air pressure and temperature in the eastern part of the region, and a slight increase of air pressure in the western part of the region on the 1st-3rd days. Wind velocity decreases in the most eastern part of the region and increases in the central and western part of the region.

These data show that the influence of GCR events on meteorological parameters in the North-Atlantic region is a stabilization of weather conditions that taken place before Forbush-decreases. During GCR events started at period of low surface pressure measured on the Greenland coast (*group 1*) the further decrease of atmosphere pressure takes place (see Figure 1b). Contrary, during GCR events started at period of high surface pressure on the Greenland coast (*group 2*) the further increase of atmosphere pressure takes place (see Figure 1c).

Some uncertainty in the variations of wind velocity could be explained by a fact that we have analyzed only the absolute value of the wind velocity and not considered the wind direction, whereas it is well know that the wind direction seriously changes during Forbush-decreases of the GCR intensity (see e.g. Pudovkin and Babushkina, 1992; Pudovkin and Veretenenko, 1996). Due to considerable difficulties of statistical treatment of vector variables the analysis of wind direction requires an additional study.

Acknowledgement

The Danish Meteorological Institute is gratefully acknowledged for the supplied meteorological data. Authors are deeply grateful to Dr. P. Thejll (DMI)
for stimulating discussion. This work was supported by the Russian Foundation for Basic Research, grant No 00-15-98555.

References


Труды международной конференции. ГАО РАН, Пуловко, 17-22 июня 2002

ОБ «ИСТОРИИ» СОЛНЕЧНОЙ АКТИВНОСТИ НА БОЛЬШОЙ ВРЕМЕННОЙ ШКАЛЕ

Наговицын Ю.А.
Главная (Пулковская) астрономическая обсерватория РАН,
Санкт-Петербург; nag@gao.spb.ru

Abstract
The multi-scale approach to study of the “History” of Solar Activity in the Past is proposed. Based on the available data the investigation of solar activity process for four time scales 100, 1000, 10000 and 10^{9} years is offered. Some new facts of “the history of the Sun” are discussed.

В последние времена связаны с фиксируемыми сильными изменениями земного климата широко дискутируется вопрос об относительной роли в этих изменениях техногенных и солнечно-обусловленных факторов. Исследования же солнечно-земных связей на этот предмет как необходимый атрибут должны содержать достоверные и разнообразные сведения о различных характеристиках солнечной активности (СА) за большой промежуток времени. В этой работе мы остановимся на некоторых аспектах нашего подхода к изучению долгопериодного поведения СА — создания удовлетворительной базы данных о ее «Истории».

Специфика наших знаний об истории какого-либо природного процесса такова, что чем дальше мы углубляемся в прошлое, тем меньше объемом фактических данных мы располагаем — происходит естественное рассеяние (потеря) информации. Поэтому, если изучаемый процесс обладает развитой частотной структурой, на первый взгляд кажется, что мы обречены на худшее описание более длинных вариаций по сравнению с короткими. Однако, с другой стороны, для описания длинных вариаций априори и требуется меньше информации, чем для коротких. Хорошей аналогией для понимания этого является практика вейвлет (или какого-либо подобного)-преобразования: при увеличении масштаба вейвлета в 2 раза требуемая плотность мережек изучаемого ряда может быть в 2 раза меньшей. Таким образом, для принципиального описания процесса для всего набора временных шкал мы можем использовать различные по качеству ряды: более детальные и качественные для малых масштабов, более грубые — для больших. Подобная "логарифмическая логика" и определяет основу нашего подхода к задаче адекватного описания солнечной активности: мы изучаем этот процесс на нескольких временных