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Evolution of several space weather events connected with Forbush decreases

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Abstract. In our recent paper (Dorotovič *et al.* 2008a) we focused on a study of the Forbush decrease (FD) of January 17–18 and 21–22, 2005. It was shown that the corresponding recovery time can depend on the density of high-energy protons in the CME matter. In this paper we identified several additional events in the period between 1995 and 2007. We found that the majority of FDs studied is accompanied by an abrupt count increase in the proton channel P1 and by a simultaneous decrease in the channel P7 (GOES). However, the analysis of temporal evolution of all FDs did not confirm the hypothesis on different recovery time after FD as a function of the energy distribution of the particles penetrating into radiation belts of the Earth.

Keywords. ISM: cosmic rays, Sun: flares, solar-terrestrial relations, Earth

1. Introduction

More or less regular CR variations of different duration, connected with the length of the solar activity cycle (11-year), the length of the solar rotation (27-days) or related to the rotation of the Earth (24 hours) are interrupted by the sporadic ones – a sudden decrease with slow recovery, FD – Forbush Decrease and an abrupt increase with immediate decrease, GLE – Ground Level Event. Both events are related to the occurrence of solar flares and transient events. Geoeffectivity of some solar events was investigated e.g. by Koskinen & Huttunen (2006), Wang & Wang (2006), Bochníček *et al.* (2007) and Valach *et al.* (2007).

The occurrence of FDs in the period between 1995 and 2007, i.e. in the 23rd cycle of solar activity, was analyzed in this paper. We use, data from the Neutron Monitor (NM) at Lomnický štít and observations from satellites WIND, ACE, SOHO, and GOES for a better description of complex evolution of the selected FDs. The second section describes the input data and methods of processing; results and consequent conclusions are presented in the third section.

2. Data used and their processing

We used the data from the NM at Lomnický štít for the period of 1995 – 2007 as basic input for the analysis. The data from other neutron monitors (Oulu, Haleakala, and South Pole) were used for verification of temporal evolution of CR in certain periods. We defined the following criteria for the selection process:
1) A total decrease in NM counts at Lomnický štít is at least 2% (in normalization of each year to 100%).
2) A decrease occurs at all stations.

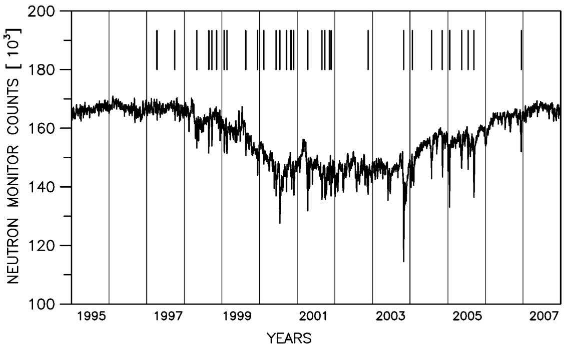

Figure 1. Temporal evolution of cosmic radiation level from NM at Lomnický štít in the period between 1995 and 2007 together with an indication of FDs studied.

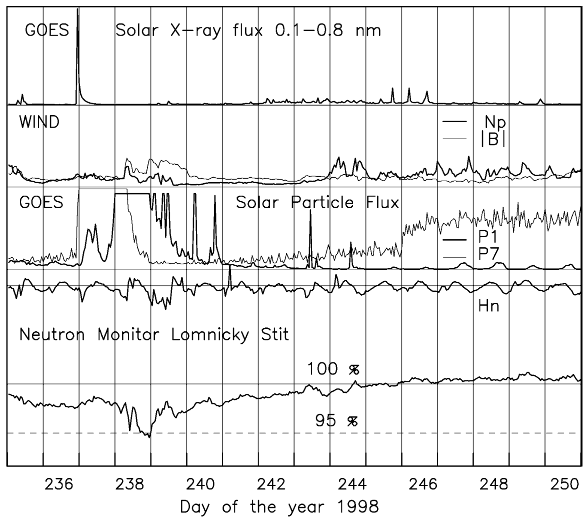

Figure 2. FD on the 238th day (26 August) in 1998: temporal evolution of NM measurements with a resolution of 1 hour (the bottom part of the y-axis), from top: solar X-ray flux (GOES), proton density n_p and interplanetary magnetic field intensity $|B|$ (ACE), proton fluxes P1, P7 and magnetic field component H_n (GOES).

Conditions in the heliosphere between the Earth and the Sun were determined using the data on proton density and magnetic field from the observatories WIND (till 1998), ACE (since 1998), and GOES (proton channels P1: 0.4 – 4.0 MeV and P7: 165 – 500 MeV). The GOES data on solar X-ray flux in the range of 0.1 – 0.8 nm were used for identifying a flare together with its importance.

According to the defined criteria and using the described data we were able to select 34 events in the considered period. The temporal distribution of individual events is shown in Fig. 1. Fig. 2 shows an example of our analysis.

3. Results and discussion

Because the shape of the evolution of individual FDs varies significantly, we decided to define the following types of a FD according to its recovery phase:

A – a classical evolution, i.e. an abrupt decrease and a slow uniform recovery;

B – non-uniform recovery, interrupted by an increase and a decrease;

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C – decrease and increase on the same day followed by a second slower decrease and a gradual recovery to the initial level;
D – similar evolution as B, but the interval between the first decrease and increase is longer;
E – decrease to a certain level, then a longer persistent period followed by an abrupt increase to the initial level.

A table with basic properties of studied FDs and detailed description of results can be found in the paper of Dorotovič *et al.* (2008b). We briefly summarize our conclusions as follows:
1) Only in one case out of 34, the origin of FD cannot be connected with a flare in X-ray flux. In many cases (22 of 34) the corresponding flare was followed by a halo type CME.
2) The depth of decrease is maximally 7%, each year being normalized separately.
3) Most FDs are of type A − 14 events; type B − 10 events, type C − 8 events, D and E types − 1 event each.
4) Almost in all cases FD is related to an increase of n_p and $|B|$ at the WIND and ACE satellites. However, there are 7 of 34 cases when this increase follows only after the FD.
5) P1 counts during FD strongly increase, in maximum to 3 – 4 orders of magnitude higher than the quiet value, and P7 decreases. The decrease in P7 is often superimposed by a burst in this energetic range, which usually occurs immediately after the flare or is caused by a flare different from that which caused the FD studied (Fig. 2). Almost each FD is connected with an increase in P1. However, not each increase of P1 causes an FD.

4. Concluding remarks

FD is usually accompanied by an abrupt count increase in the channel P1 and by a simultaneous decrease in the channel P7, often as far as the threshold values of the instrument. This finding can be considered as the main result of the analysis of FD evolution. Then an impression arises that during FD the protons of the primary CR are absorbed on the low-energy protons indicated in the channel P1 and simultaneously also the protons from channel P7.

The analysis of the temporal evolution of FD did not confirm the hypothesis published in the paper by Dorotovič *et al.* (2008a) on different recovery time after a FD as a function of the energy distribution of the particles penetrating into radiation belts of the Earth. There are two reasons: 1) in most cases, the recovery time cannot be determined owing to other variations occurring during the recovery period and 2) the channel P7 is either overloaded due to a previous burst or is at a threshold value.

Acknowledgements

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