Search for Predictors of Forbush Decreases

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Abstract.

Anisotropy of cosmic rays (CR) before a lot of Forbush decreases (FDs) was investigated by methods of the global survey and the "station ring" (SR) using the data of the world wide neutron monitor (NM) network. It has been found that predecreases and preincreases precede to the majority of FD onsets. They are anisotropic and characterized by the nonharmonical directional distribution. The longitudinal dependence change abruptly near the field line and depends on a character of the disturbance and its source. Appeared for a long time before FDs (up to day) these effects may be considered as the predictors of FDs.

1 INTRODUCTION.

The galactic cosmic rays (GCR) interact with transient moving in the space toward the Earth. They are the only agent provide the information about coming disturbed region well in advance. So, it is reasonable to study the behavior of GCR for searching of the FD precursors. Two mostly inherent effects of the GCR behavior before FDs stand out: 1) a preincrease of CR intensity caused by the GCR acceleration on the front of coming disturbance; 2) a predecrease conditioned by the magnetic connection between the Earth and low density regions behind the moving shock. These effects are anisotropic and manifest themselves in a different way on the various ground level CR stations.
These phenomena are well known for a long time [1], but only just now they are under intensive study [2,3,4]. We will try to show that precursors really exist in the numerous events and one can reliable sets off them from the current NM data.

2 METHODS AND DATA.

The methods of the global survey [5] and the "stations ring" (SR) were applied to analyze a great number of FDs. Hourly NM data of the stations with cutoff rigidity R_c<4 GV and latitudes <70° were used for the SR method. Shift of the effective position of station because of the Earth magnetic field was taken into account by using the coupling coefficients [6] for the flat rigidity spectrum up to 100 GV of the first harmonic. This method is a good addition to the global survey method and provides some advantages. For instance, it allows to obtain a different than harmonic longitudinal distribution of CR intensity, and it is less depended on an uncertainty of the model of isotropic and anisotropic variations. As a result the longitude-time distributions of the CR intensity were found for the time of different FDs and before their onsets. For each event the longitudinal sectors were selected according to dominant effect of the decrease and increase of CR intensity. The variations averaged by the stations within the corresponding sectors were analyzed jointly with a number of the space data.

3 RESULTS AND CONCLUSIONS.

The outstanding predecrease on 25-26.01.68 was studied in [4]. We examined it by the RS method. Figure 1 presents a view of this event in a different manner than in [4].

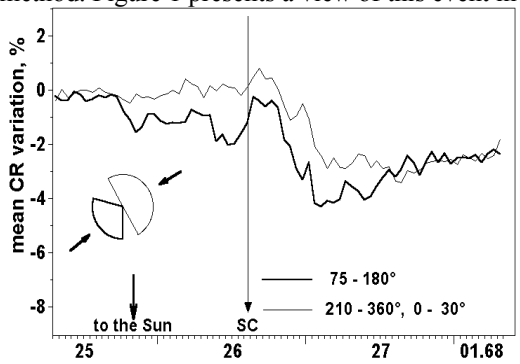

Fig. 1 CR variations in the different sectors on 25-27.01.1968

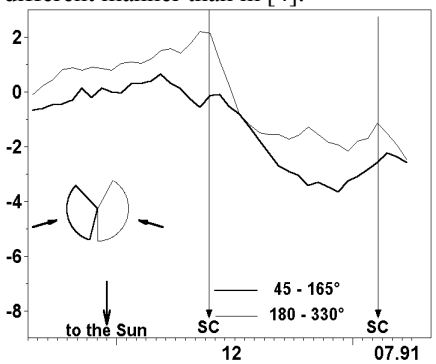

Fig. 2 CR variations in two different sectors on 12.07.91

The thick curve is the behaviour of GCR intensity averaged by the stations within the sector 75-180°. The upper curve corresponds to the region of 0-30°,210-360°. The predecrease started about 24 hours before the main FD onset and lasted all this time. The GCR appear to be scanning the approaching structure and carry the information about it along the magnetic field line entering the transient across the shock. This predecrease is unusual in many respects however the anisotropy at this time has a typical direction along the field lines. One can see similar pictures of the predecrease caused by the western and central solar flares for FDs on 11-12.07.91 (Fig.2), on 24-25.06.78 (Fig. 3) and for a number of others.

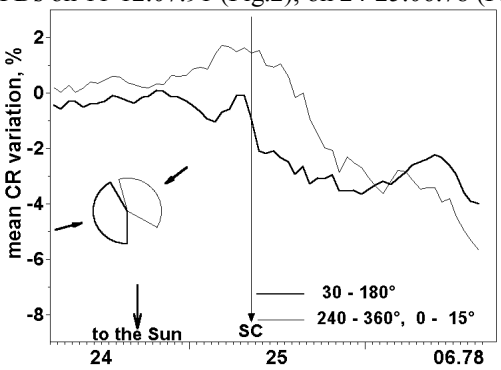

Fig. 3a.

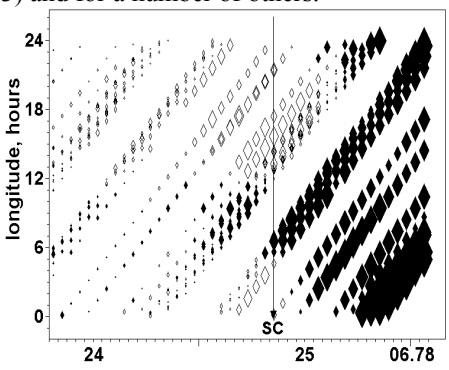

Fig.3b.

Figure.3b presents a longitude-time distribution of the effect on 25.06.78. The dark rhombuses mean the decrease and the light ones correspond to increase of GCR intensity. The size of rhombus is matched by the magnitude of effect. The vertical line marks the SSC. One can see the increase as well as the decrease some hours before the SSC only on the certain longitudes. The events caused by eastern disturbances give a little another picture. As an example, the behaviour of GCR on 4.04.91 after the eastern flare is shown in Fig.4. In this case the Earth was not connected with the transient region by the force lines but we observed the additional flux from the Sun within the sector 165-270°, probably, because of the particle acceleration on the shock.

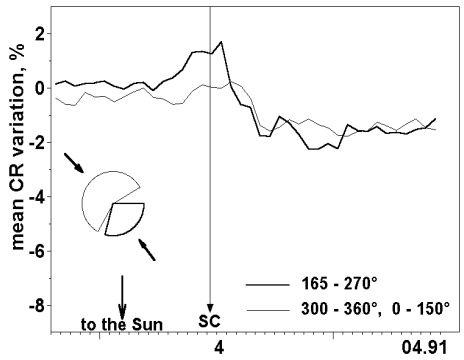

Fig. 4.

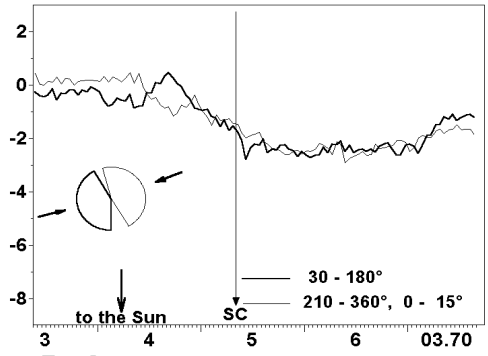

Fig. 5.

We see a more rare situation in Fig. 5. The predecrease was observed along of the force line outward the Sun (contrary to the usual) and probably it might be caused by the eastern interplanetary disturbance when the shock had already crossed the Earth orbit. Fig.6 presents another case. It looks like the usual predecrease but the unusual direction of the anisotropy from 165-300° sector, transverse to the field lines, has been observed. A possible explanation is: the Earth's magnetic force line doesn't enter the transient, but the adjacent lines (northern or southern) may contact this region and the resulting transverse gradient creates the Hall anisotropy and the decrease of CR intensity across field lines. The event on 15-17.08.70 caused by two transients is shown in Fig 7. We observe the predictors both before the first and second SSC although they occur differently and perhaps, indicate the different heliolongitudes of the flares.

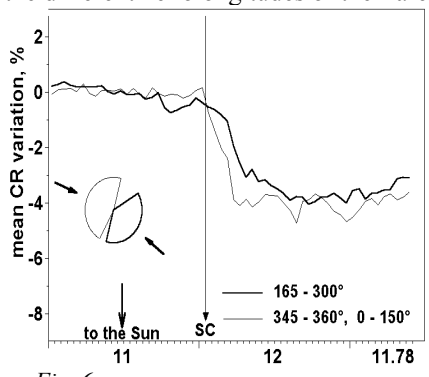

Fig. 6.

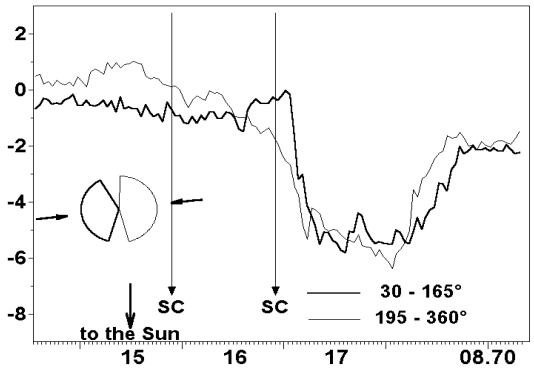

Fig. 7.

Fig.8a illustrates the longitudinal distributions of GCR effect in the event on 01.68 for different periods or during the process of development. The usual sinusoidal diurnal wave is visible (dotted line) a day before FD onset . The predecrease becomes evident yet at 17-23 hours on 25.01 (dashed line) and the distribution takes a quite peculiar form at 1-9 hours on 26.01. So, the predictor has revealed itself about 20 hours ahead of the FD onset. In Fig. 8b the similar distributions but for a number different events are presented. The listing of Fds is on the lower right. We see the similar distributions of GCR like in 8a, with the sharp transfer on the definite longitudes but with the different depths. It seems, the nonharmonical distribution with the abrupt transfer from minimum to maximum is typical for this kind of predictors. But sometimes the longitudinal dependence takes another form, for example on 4-5.03.70 (Fig. 8c). The quiet sinusoid is transformed before a shock to a complex curve with the abrupt change from maximum to minimum near the force line outward the Sun. For

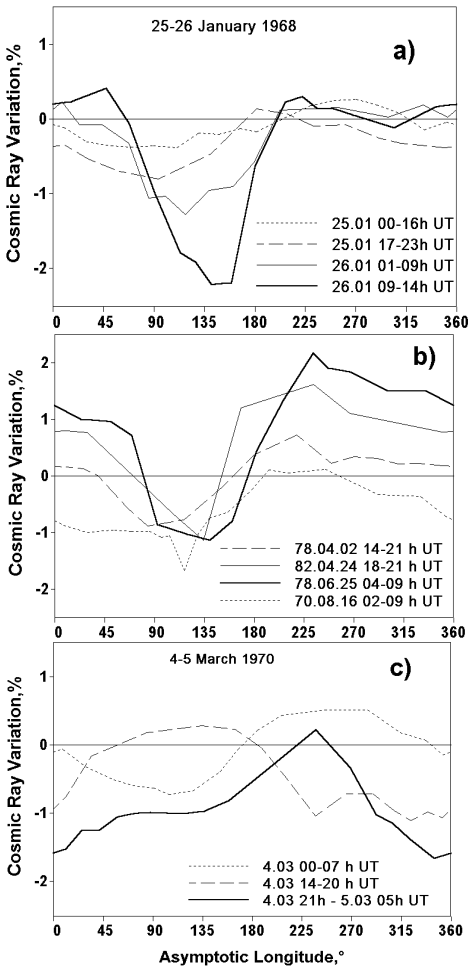

Fig. 8. CR longitudinal dependence in the different periods before FDs

all these predictors the coming structure provides the source as well as the sink of the CR, so the directions of the CR increase and decrease are very close to one another.

Using mentioned above events as the examples (actually we considered much more events) it can be argued that majority of FDs have the predictors revealed itself by different way in the CR behaviour some hours before the FD onset. The "station ring" method gives a good possibility to detect and study these predictors by NMs data. The predictors appear to be as various as FDs and depend on the heliolongitude of the flare similar to Fds [7]. The many of predictors have a peculiar nonharmonical longitude dependence of CR intensity with the abrupt transfer from minimum to maximum. These sharp transfers occur most probably within the 140-180° and 270-310° regions, near the usual direction of the magnetic field line. These results with the space data give a good possibility to investigate the structure of transients and character of their moving.

Acknowledgements. This work was supported by the federal program "Astronomy" and the Russian Foundation for Fundamental Research.

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