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RELATION OF COSMIC RAY INTENSITY AS REGISTERED BY GROUND-BASED DETECTORS TO SOLAR WIND PARAMETERS

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Abstract. Relation of cosmic ray intensity to solar wind parameters and geomagnetic activity has been examined by the superimposed epoch technique. Ground-based neutron monitor data for ten years were utilized. It was shown that the main factor affecting the cosmic rays is the interplanetary magnetic field (IMF) modulus |*B*|. A one-nanotesla increase in |*B*| leads to ~0.2% decrease of the monitor counting. After a strong sharp spike of |B| the monitor counting recovers with two characteristic times: ~12 hours and ~7 days. Correlation of high-latitude monitor data with the IMF northward component is revealed which can not be explained by the effect of geomagnetic cutoff rigidity decrease.

1. Introduction

Forbush [1937] found sporadic decreases in galactic cosmic ray (CR) intensity closely associated with magnetic storms. Later these phenomena were called Forbush decreases (FD). One of the first (and incorrect) explanations of FD was that the ring current growth during storms can lead to enhancement of geomagnetic rigidity cutoff and thus to a drop of the CR intensity [*Chapman*, 1937]. As shown by *Johnson* [1938], *Hayakawa et al*. [1950], *Treiman* [1953] (see also monographs by *Dorman* [1963] and *Dorman et al*. [1971]), the ring current causes not decrease but increase of CR intensity.

Morrison [1956] considered magnetic clouds ejected from the solar atmosphere to interplanetary space during solar flares as a possible cause of FD. *Parker* [1965] supposed that FD could originate due to interplanetary shock waves.

Belov et al. [1976] gave evidence of how CRs are affected first by magnetic cloud bow shock and then by the cloud body. Today many investigators consider FD to be a heliospheric phenomenon. *Belov and Ivanov* [1997] defined FDs as "CR variations caused by large-scale propagating disturbances of the solar wind". According to this view, FD occurs not only on the Earth surface but also beyond the magnetosphere.

It should be noted that the effect of geomagnetic cutoff variation on CR intensity was also verified. *Yoshida and Wada* [1959] revealed the global CR intensity increase related to magnetic storms, i.e. the phenomenon opposite to FD.

Thus cosmic ray behavior detected at the Earth surface is a complex function of interplanetary conditions and geomagnetic activity. There is no clear idea concerning the form of this function. In this paper we study relation of CR intensity detected by ground-based neutron monitors to the *Dst* index and solar wind parameters.

2. Data

We used hourly data of high-latitude neutron monitors in Apatity (the web-site http://pgi.kolasc.net.ru/CosmicRay) as well as in Thule, South Pole, and McMurdo (the web-site http://www.bartol.udel.edu/~neutronm) for 1980-1989 period. Hourly solar wind parameters as well as *Dst* indices were taken from the OMNI database.

3. Results

Fig. 1 shows the monthly averaged behavior of CR intensity and IMF modulus from 1980 to 1989. Strong anticorrelation of the two parameters in the course of the 11-year cycle of solar activity is evident.

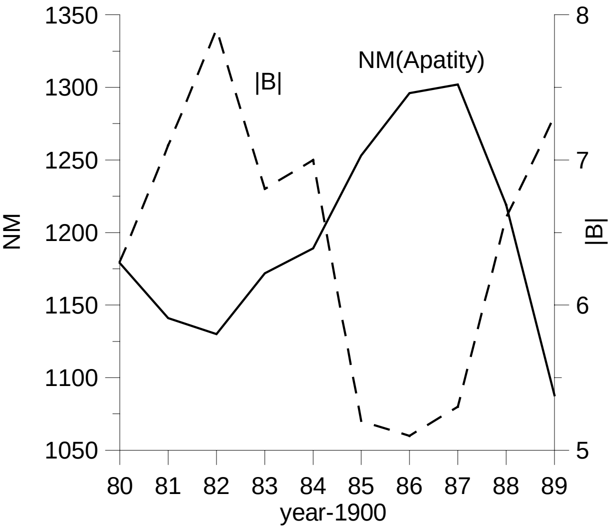

Fig. 1 Monthly averaged Apatity neutron monitor data (the solid line) and IMF modulus (the dashed line).

One can expect several characteristic times in response of CR intensity to a change in the IMF modulus |*B*|. We found this response in daily and hourly averaged data. Superimposed epoch technique was used, with minimum in neutron monitor counting chosen as a reference point. Fig. 2 shows that there are at least two characteristic recovery times of CR intensity after |*B*| returns to its normal value. One time is ~12 hours, the other is ~7 days.

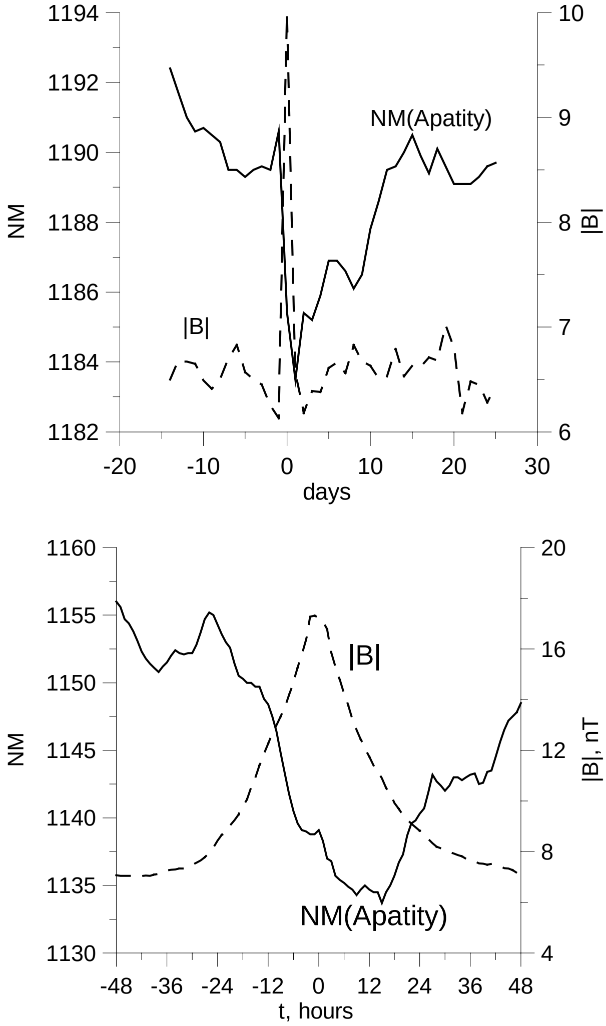

Fig. 2 Response of the Apatity neutron monitor (the solid line) to a spike of the IMF modulus (the dashed line), based on daily (top) and hourly (bottom) data.

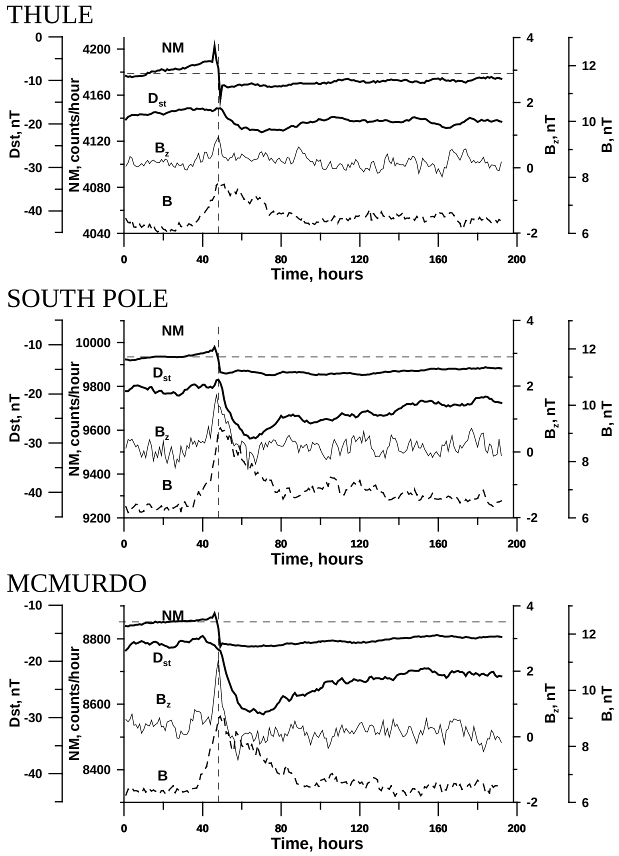

Fig. 3 Averaged behavior of CR intensity (NM) registered by three ground-based detectors, *Dst* index, IMF B_z component, and IMF modulus $|B|$.

The curves in Figs. 3 and 4 were obtained by superimposed epoch technique, with minimum in neutron monitor counting chosen as a reference point. Fig. 3 illustrates the behavior of CR intensity at three observatories (Thule, South Pole, and McMurdo), as well as *Dst* index, IMF B_z component, and IMF modulus $|B|$. One can see, that a Forbush decrease of about 1% is accompanied by a geomagnetic depression with $Dst_{min} \approx -30$ nT, an increase in the northward IMF by ~1 nT, and growth of the IMF modulus by ~2 nT. The recovery phase of FD is much longer than that for other three parameters.

Dependence of recovery of CR intensity in Thule on FD amplitude is shown in Fig. 4. The relaxation time of CR is several days and reveals no pronounced relation to the amplitude. The dependence of the IMF modulus on AF is non-linear. While the 1% FD are caused by ~1-nT enhancement of |B|, the 2% FD requires ~4-nT

4. Discussion

Relation of FD to the IMF modulus is quite expectable due to investigations by *Morrison* [1956], *Parker* [1965], *Belov et al.* [1976], *Belov and Ivanov* [1997]. Two relaxation times (~12 hrs and ~7 days) were not clearly distinct in earlier studies. Some forecast models operate with characteristic times as large as several months [*Belov et al.,* 2001].

Relation of neutral monitor counting decrease to the northward IMF found also by *Shadrina et al.* [2002] is rather peculiar. The symmetry principle implies that the cause of the effect can not be in interplanetary space because both northward and southward IMF directions are identical with respect to CR modulation. Therefore, one should search for the origin of the effect inside the magnetosphere. Storm time electric currents could enhance CR intensity as noted by *Johnson* [1938], *Hayakawa et al.* [1950], *Treiman* [1953], *Dorman* [1963], *Dorman et al*. [1971]. Since these currents grow with increase of the southward IMF, it is evident that the northward IMF is more favorable for the Forbush decrease. However, it is unclear why the northward IMF in Fig. 3 occurs only at the beginning of the storm, whereas the storm time electric currents flow during both beginning and recovery phases of the storm. Another difficulty is the fact that atmospheric cutoff rigidity for high-latitude stations is ~1 GV which is considerably lower than the geomagnetic cutoff rigidity, so that the station must not respond to a change of geomagnetic threshold. The relation of CR to the northward IMF can be caused by some specific features of CR anisotropy.

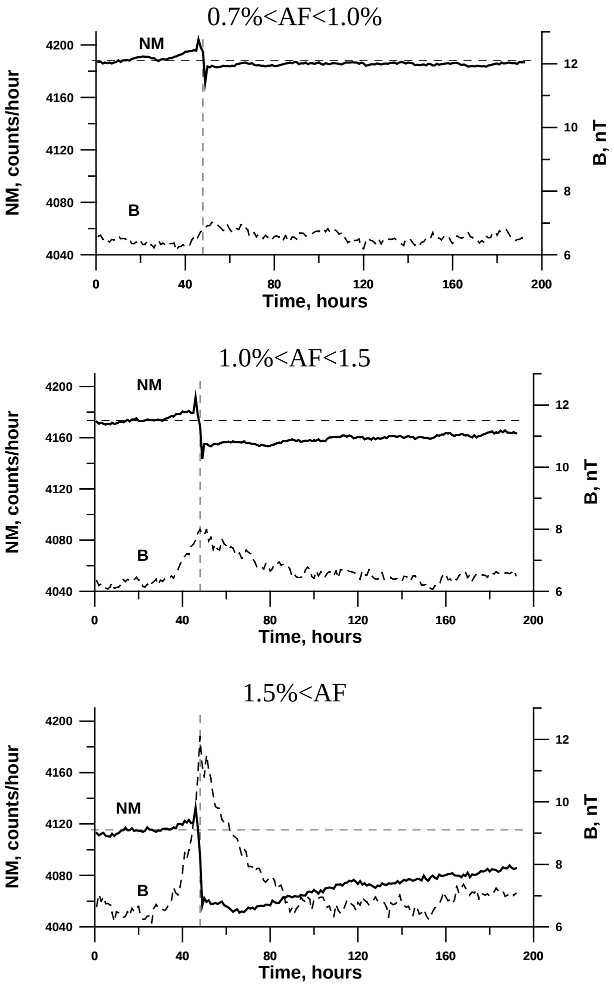

Fig. 4. Average behavior of cosmic ray intensity in Thule (the solid line) and IMF modulus |*B*| (the dashed line) for three amplitudes of the Forbush decrease (AF).

5. Conclusions

1) The Forbush effect registered as a decrease of galactic cosmic rays at the Earth surface is controlled mostly by the IMF modulus. After a sharp spike in the IMF modulus the cosmic ray counting recovers with two characteristic times, ~12 hours and ~7 days.

2) An additional contribution to the ground Forbush effect is due to the IMF northward component.

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