The CHARACTERISTICS OF FORBUSH DECREASES OF COSMIC RAY INTENSITY

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ABSTRACT
Fifty-four Forbush decrease (Fd) events had been studied during a period of twenty years. It was found that there exist dependence between the amplitude of (Fd) event and the rigidity at the point of observation. The spectrum responsible for the Forbush decrease is found to have a power law with an exponent which depends on the profile of the event. (Fd) events can be classified into three different classes depending on the shape of its decreases and recovery.

keywords: *Cosmic Ray; Forbush Decrease; Rigidity.*

1. INTRODUCTION
Forbush decreases (Fds) is a transient and rapid decrease in the observed cosmic rays intensity followed by a gradual recovery typically lasting several day [1-2]. Forbush decreases occur when the sun releases an exceptionally large burst of matter and magnetic disturbance (magnetic cloud). The disturbance sweeps away some of the CR energetic particles in its path and prevents many CR energetic particles from entering the atmosphere. Various theories and models have been proposed by many investigators to explain Forbush decreases (Fds). Some of the models are based on enhanced drift while others are concentrated on diffusion of scattering models, both drift and scattering mechanisms suggest that the magnitude of Forbush decrease is proportional to the magnetic field strength and irregularities in the associated interplanetary disturbances [3]. The two step FDS are caused by the combination of shocks and CMEs, the first step is connected to the turbulent structure behind the shocks, and the second step is connected to the enhanced magnetic field and loop like field configuration of the CMEs [4]. The component related to the shock shows a gradual decreases and slow recovery while the ejecta component starts, with the ejecta arrival and the effects of superposition shocks and CMEs lead to the rather complex structure in the intensity profile of Fds. It is well known that coronal mass ejection events produce major disturbances in solar wind and interplanetary magnetic field. It has now been proved by recent studies of Fds with coronal mass ejections and the interplanetary shocks, magnetic clouds, ejecta which are interplanetary manifestations of coronal mass ejections that the Fds are strongly associated with CMEs [4-6] concluded that relativity large decreases in cosmic ray intensity is associated with magnetic clouds that are preceded by a shock, where as only a small decrease in cosmic ray intensity is associated with magnetic clouds that are not proceeded by shock. Badruddin [7] has reported that abrupt onset of decrease in intensity starts upon the arrival of certain shocks and decreases continue till the passage of post shock turbulent sheath. He has further determined that turbulent shocks are much more effective in producing Fds than non-turbulent shocks. He reported the halo CMEs are more effective transient modulator of CRI than other CMEs, and produces significant Fds. Cane *et al*. [8] have studied Fds for 30 years period with coronal mass ejection and found that 86% Fds are associated with CMEs and interplanetary shocks that they generate .They have further concluded that the depth of the FDS is dependent on the Helios longitude of the active region which ejected the associated CMEs. Cane, Richardson, Wibrengez [9] have inferred that the short term cosmic ray decreases are strongly associated with ejecta and shocks. According to [4], CMEs are plasma eruptions from the solar atmosphere involving closed field region, which are expelled into the interplanetary medium. The ICMES (interplanetary CME), term as “ejecta”, may generate shocks; when earth enters such a “shocks followed by ejecta” combination, the first step in the classical Fd is due to entry in the shocks .Thus both the shocks and CMEs are responsible for Fds. Kane [10] studied that all interplanetary disturbances having shocks and directed towards the earth are geoeffective giving at least a storm sudden commencement (SSC) and giving Dst (disturbance-storm time) index depressions in a wide range -10 to -500 nT. Gupta, Singh, Badruddin [11] have investigated the solar sources and features of interplanetary structures associated with big geomagnetic storm (GS) and large Fd events. They have concluded that shock associated CMEs can produce both large FdS and big GS. Fds and GS are likely to be closely correlated partially due to their common causes from solar and interplanetary disturbances. However, the magnitude, durations and time profiles of both phenomenon (Fd and GS) are related to the interplanetary structures and their associated feathers. Both increase with increasing interplanetary magnetic field and solar wind velocity. Recently, Shrivastava, Jot he, Singh [12] have reported that major solar flares occurring in western hemisphere of sun in association with

halo coronal mass ejection produce number of FD events. Barbashina *et al*. [13] found that the ratio of Forbush decreases in the fluxs of muons and neutrons have a ratio of approximately one to three.

Geomagnetic cutoff rigidity are quantitative measure of the shielding provided by the earth`s magnetic field. More precisely, geomagnetic cutoff rigidities predict the energetic particle transmission through the magnetosphere to a specific location as a function of direction [14]. The rigidity dependence of Fds has been determined using neutron intensity rates with cut-off rigidities from 1.19-11.39 GV.

2. DATA AND ANALYSIS

In the present investigation hourly count of cosmic ray, recorded by a world-wide network of neutron monitors during the solar cycles 20-21 (1969-1988) for five stations has been used to investigate Forbush decreases (Fds). The stations under our consideration cover a rigidity range 1.19-11.39 GV as shown in table 1. In this analysis, we have selected only those Fd`s, which have amplitude greater than 3%.

Table 1 List of neutron monitor stations

Stations	Geographical (degree)			Cutoff Rigidity (GV)
	Lat.(λ)	Long.(η)	Alt.(m)	
Kerguelen	-49.35	70.25	0	1.19
Washington	38.9	77.08	1.91	1.24
Kiev	50.72	30.30	12	3.62
Room	41.9	12.52	60	6.32
Norikura	36.10	137.50	2876	11.39

3. RESULTS AND DISCUSSION

Fifty-four events of Forbush decreases (Fds) had been studied, these events had been classified into four groups according to their shape. These groups are the group (A) contains decreases starting with sharp-drop of intensity and displaying a main phase less than one day before the recovery. The recovery phase takes two or three days. This group is a sharp-sharp event. Group (B) contains decreases starting with sharp drop and recovery phase from 4to10 days .This class is found to be of more occurrence. This group is a sharp-slow event. Group(C) a slow-drop of intensity taking place during a period of 3-4 days and recovery within 2-3days. This group is defined as slow-sharp events. Finally, group (D) is a slow-slow events are similar to group (C) during the drop and take about 4-5 days during recovery. The period of the event is started two days before the event and ends two days after the event. Figure 1a represents the relation between sunspot number and the occurrence of the Fd events. This figure shows that the frequency of the events is much more during the period of maximum solar activity than that during minimum solar activity. Figure 1b shows the correlation between Fds events and sunspot number which shows a positive correlation with coefficient 0.613 which indicates dependence between Fd events and sunspot number. The amount of cosmic ray intensity during the main phase of decrease depends on the latitude of the recording station [15]. This drop of intensity has maximum value at the pole and minimum value at the equator.

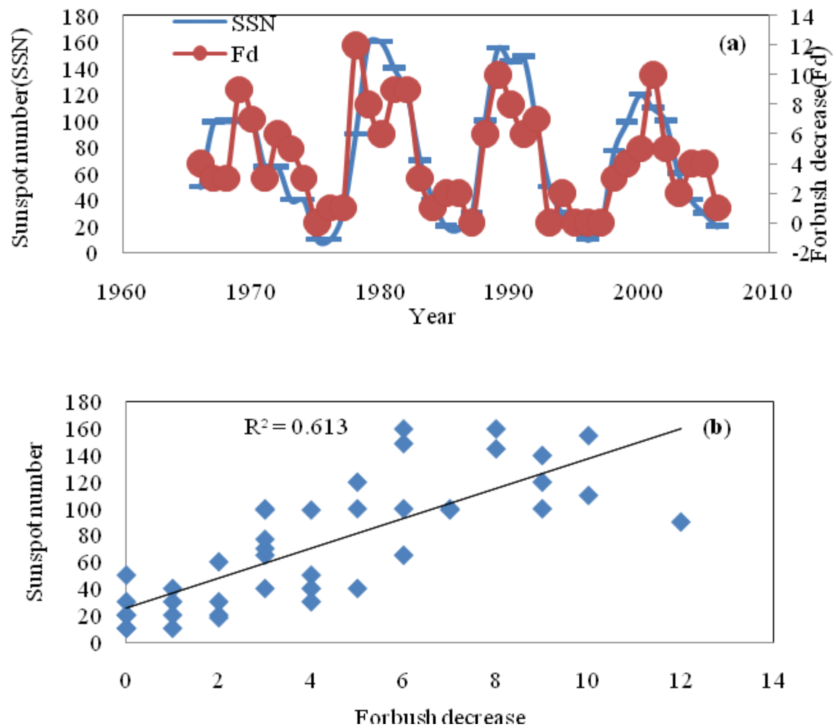

Figure. 1 (a) Shows the yearly frequency of occurrence of Fd events along with Yearly mean values of sunspot numbers and (b) Association of magnitude of FDs magnitude with sunspot numbers.

The recovery period of Fd may be approximate to the form

$$\Delta I=\Delta I_0 e^{-t/\lambda} \qquad (1)$$

where $\lambda=1/t_0$ is the recovery constant which is a mean value for the rate of recovery after a cosmic ray decrease and its value differs from case to another. ΔI is the intensity deviation from the reference level I_0, which is the mean intensity during a quiet period chosen close before the decrease. Such period must not contain irregularities as increases or decreases. ΔI_0 is the deviation at the midpoint (T_0) of a quiet internal (between T_1 and T_2) during the recovery. Table 2 shows the value of λ for four types of Fds. There is no big difference between the values of λ for all groups and the characteristics recovery time of these Fds is found to be rigidity independent.

Table 2 The values of λ for different types of Forbush decreases

Station / Event	Norikura (R_0=11.39GV)	Room (R_0=6.32GV)	Kiev (R_0=3.62GV)	Wash (R_0=1.24GV)	Kergulen (R_0=1.19GV)
	Group(A)				
30-8-1970	0.038	0.034	0.035	0.034	0.033
23-11-1982	0.030	0.030	0.030	0.032	0.033
20-7 -1988	0.028	0.026	0.027	0.0276	0.023
	Group(B)				
23-3-1969	0.029	0.025	0.023	0.025	0.022
30-4-1978	0.024	0.048	0.016	0.013	0.024
1-6-1978	0.032	0.030	0.030	0.027	0.028
25-7-1980	0.036	0.033	0.031	0.032	0.026
18-12-1980	0.033	0.031	0.026	0.022	0.032
11-11-1981	0.039	0.035	0.031	0.034	0.031
9-1-1983	0.037	0.031	0.032	0.028	0.028
3-11-1986	0.023	0.034	0.026	0.023	0.027
	Group(C)				
26-1-1971	0.032	0.027	0.024	0.020	-
	Group(D)				
8-3-1978	0.025	0.025	0.02	0.017	0.021
2-4-1979	0.024	0.023	0.021	0.022	0.025
14-9-1979	0.013	0.011	0.010	0.007	0.009
22-7-1981	0.018	0.018	0.016	0.012	0.014

Since the count rate of neutron component of cosmic ray at the stations under consideration are characterized by the threshold rigidity *R*, the dependence of the intensity drops during Fds and the rigidities are shown in Figure 2.

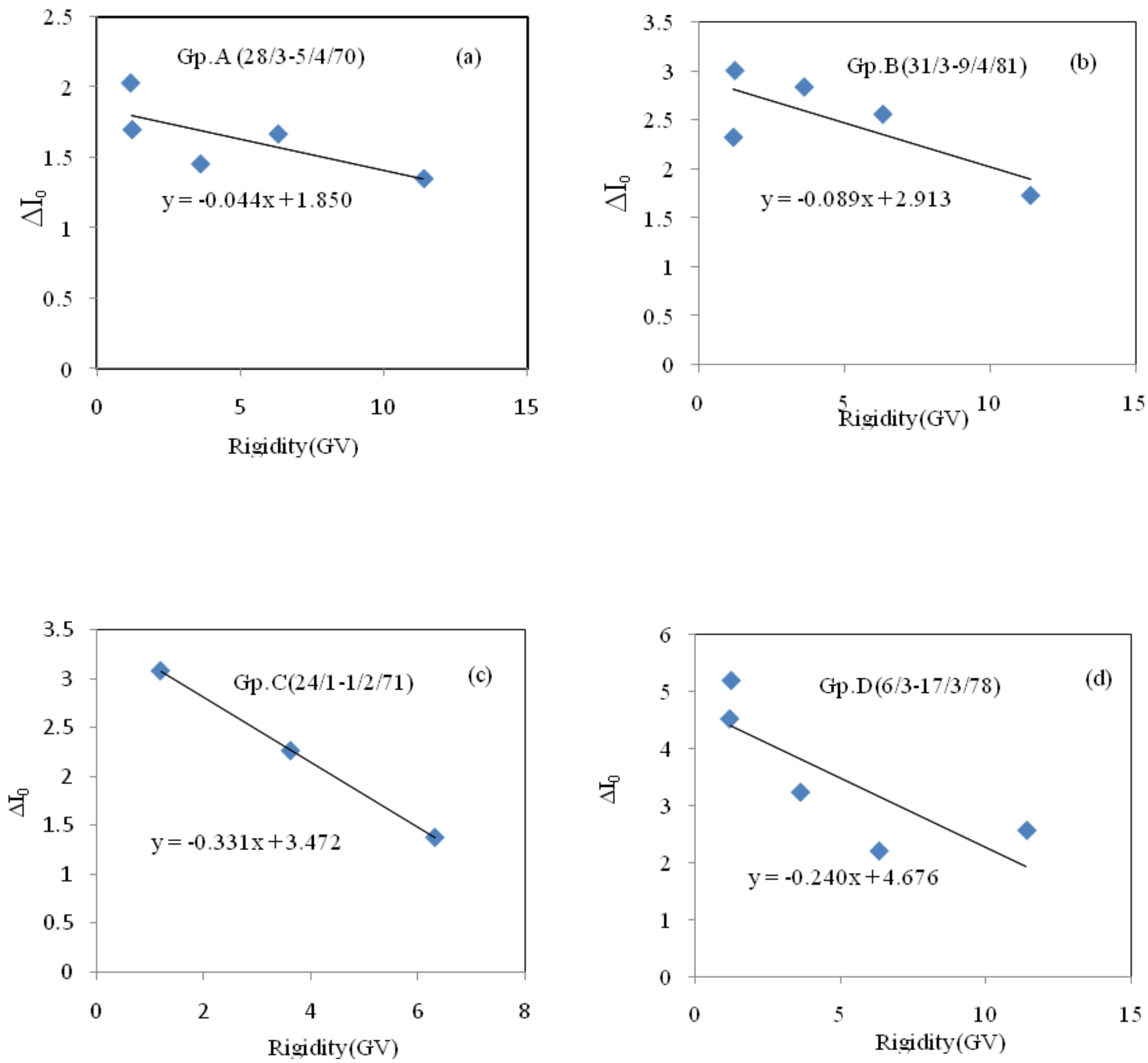

Figure 2 The rigidity dependence of mean intensity drop for four FD groups

The intensity rigidity formula which describe the rigidity dependence in the region 1.19-11.39 GV is considered to have a first degree dependence of the form

$\Delta I_0(R) = C + C_1 R$ (2)

where R is the threshold rigidity and $\Delta I_0(R)$ is the normalized intensity, the values of the regression coefficients C and C_1 will depend on the shape of the event. The straight line given can represent the dependence of the main intensity drop during a decrease on the threshold cut-off rigidity in the rigidity range 1.19-11.39 GV. By using the straight line as representing the rigidity dependence of $\Delta I_{0,}$ a comparison between the four groups of decreases can be made. Group (B) and group (D) are similar, while group (C) shows high rigidity dependence than that for the other groups, and group (A) has minimum rigidity dependence. This means that group (B) and group (D) may be considered as one group. This result can be detected from the values of C and C_1 of the fitted line presented in table 3.

Table 3 Represents the values of C and C_1 for all FD groups.

Groups	C	C_1	Average C	Average C_1
A	3.935 1.776	-0.193 -0.085	2.856	0.139
B	2.987 2.958 10.981 3.108 2.435 3.269	-0.170 -0.126 -0.639 -0.147 -0.148 -0.183	4.789	-0.236
C	3.472	-0.331	3.472	-0.331
D	4.676 2.694 6.118 5.219	-0.241 -0.111 -0.293 -0.281	4.677	0.232

The variation primary spectrum *ΔD/D* of the primary intensity can be represented by

$$\Delta D/D = aR^{-b} \quad (3)$$

where *R* is the primary rigidity and "*a*"& "*b* "are constants which may differ from event to another [16]. According to studies of [17], the constants "*a*" and "*b*" are found to differ from one shape to another of Forbush event (Figure.3).

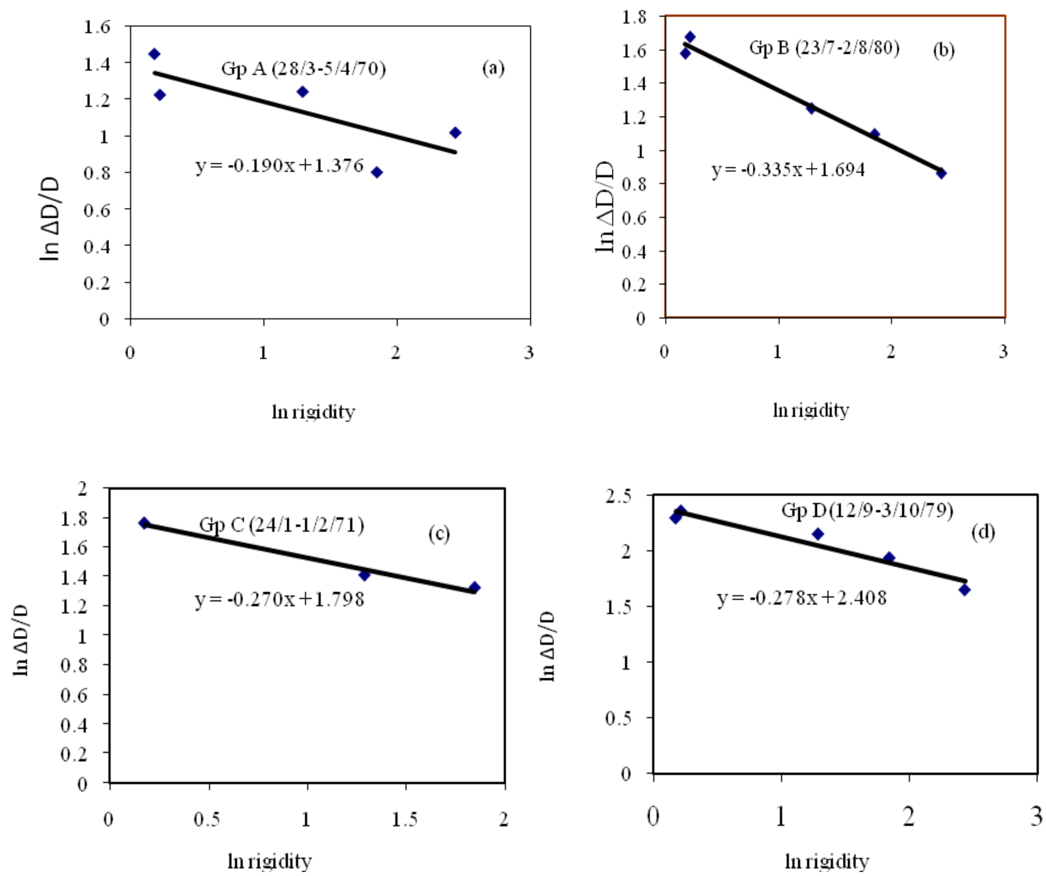

Figure.3 The variation primary spectrum ΔD/D of the primary intensity with rigidity for different groups of FD.

The value of "*b*" is found to depend on solar activity. This constant "*b*" is found, to change from 0.19 for group (A) to 0.335 for group (B) while for group (C) and group (D) have approximately the same value. This result represents an indication about the classification of the Fd events into three classes only

Table 4 Example of the values of the constants "a" and "b".

	Group A	Group B	Group C	Group D
a	3.959	5.441	6.037	11.112
b	0.190	0.335	0.270	0.278

The constant *"a"* of the spectrum responsible for the Fd events is found to change from 3.959 for group (A) to 11.112 for group (D) (table 4). Accordingly the variation primary spectrum $\Delta D/D$ can be represented by

$\Delta D/D= 3.959R^{-0.190}$ for sharp-sharp events

$\Delta D/D=11.112R^{-0.278}$ for the rest of the events

The spectrum responsible for the Fd is found to have a power law with exponent varying from 0.190 to 0.335 depending on the shape of the event. This result confirms that obtained by [13] for muon component which is one third that for neutron component.

4. CONCULUSION

The effect of geomagnetic cut-off rigidity on the profile of Forbush decreases for the period of 1969 to 1988 (cycles 20, 21) had been studied. The results indicate that the Forbush decreases have rigidity dependence. Forbush decreases are found to be of a higher occurance during maximum solar activity period. The value of recovery rate λ of each group is quiet different depend on the shape of the event and independent on the rigidity. The spectrum responsible for the Forbush decrease is found to have a power law with an exponent which depends on the profile of the event. (Fd) events can be classified into three different classes depending on the shape of its decreases and recovery.

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