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The Impact of Solar Wind Disturbances on Cosmic Ray Intensity Variations

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ABSTRACT

The impact of solar wind disturbances on cosmic ray intensity variations has been studied. This was done using cosmic rays data from three neutron stations of SOPO, CLMX & MOSC, and solar wind data from 2000 to 2005. It was observed that solar activities give rise to a sharp depression in the intensity of cosmic ray variation known as Forbush decrease (FD). A manual approach was used to select the FDs. An epoch analysis was carried out on the selected FD dates using the R. program. Deviations were observed on the source event dates, giving rise to new FDs. The magnitude of the observed FD dates was determined. It was noticed that FD magnitude generally depends on the coordinates of the observing neutron stations. A correlation test was further carried out between (1) The FD magnitude of the three stations and (2) The FD magnitude and their corresponding solar wind data. A strong correlation of value cc = 0.932871 was seen between the FDs of SOPO and MOSC followed by the FDs of CLMX and MOSC of value cc = 0.8888257 and lastly the FDs of SOPO and CLMX of value cc = 0.7447626. This implies that observed FDs from neutron stations are coordinate-dependent. The result of the correlation test between FD magnitudes and solar activities shows that solar wind had a high and significant correlation with FD magnitude to the tune of (cc = 0.5381531). Based on the above arguments, it was confirmed that solar wind disturbances actually give rise to sudden depression in the intensity of cosmic rays known as Forbush decrease.
Keywords*:* Cosmic rays, Forbush decrease and Solar wind

INTRODUCTION

Solar wind (SW) is a stream of charged particles ignited from extremely hot corona in Sun [1]. They burst out in the interplanetary space, spreading frozen solar magnetic field along with it called Interplanetary Magnetic Field (IMF) [2]. Such solar-release can occur through different phenomena like solar flare, Coronal Mass Ejection, and Corotating Interaction Region (CIR) [3]. These charged particles couples with magnetosphere through electromagnetic and viscous interaction providing the energy and momentum inside the system [4]. The injected energy in coupled magnetosphere-ionosphere environments distort the geomagnetic activity of the system giving rise to the different phenomena such as geomagnetic storm, substorm, and aurora [4]. This distortion is known as solar wind disturbances [4].Cosmic rays are high energetic particles that arrive at the earth from the outer space [5]. They are grouped into primary and secondary cosmic rays. Firstly, primary cosmic rays are extremely energetic that even our highly improved machinery cannot attain or generate such level of energies [6]. They are sourced from the supernova explosions of the dying stars are the most probable sources of the cosmic rays [6]. These rays are the messengers of our universe giving us information about the building blocks of the universe and much more [6]. Secondly, secondary cosmic rays are low energy cosmic rays which are produced by the interactions between our earth's atmosphere and the highly energetic primary cosmic rays [6]. Cosmic rays can also be classified into two classes based on their sources: Galactic cosmic rays, coming from different parts of galaxies beyond our solar system and Solar cosmic rays coming from our own star which is the Sun [5]. The intensity and flux of the Galactic cosmic rays are much higher than the solar cosmic rays [6]. In fact, we get a few cosmic rays with relatively lower energies from our Sun [6]. It is generally believed that the solar daily variations of the cosmic ray intensity is due to a variation of the primary radiation incident on the earth's atmosphere [7]. When these radiations from the Sun enters the Earth, CMEs and their corresponding ICMEs associates with galactic cosmic rays that fill the interplanetary space [7]. GCRs are also modulated by the leading shock wave of the ICME and their following ejecta, which results in a reduced CR intensity known as Forbush decrease [8].

Forbush decrease is a short-term decrease in the galactic cosmic ray (GCR) flux which was first observed by S. Forbush [8]. It is one of the outstanding transient changes in cosmic ray (CR) flux, observed by ground-based neutron detectors [9]. FDs are referred to as a non-repetitive short-term decrease in Galactic cosmic ray (GCR) intensity presumed to be associated with large-scale perturbations in solar wind and the interplanetary magnetic field (IMF) [10]. Forbush decreases are generally divided into two recurrent and non-recurrent FDs. Whereas the recurrent FDs are induced by high-speed solar wind streams (HSSWs) from coronal holes which rotate together with the Sun, non-recurrent FDs are triggered by coronal mass ejections (CMEs) and their interplanetary extensions (ICMEs) [9]. However, these cosmic-ray intensity decreases are recorded at Earth by the neutron monitors (NMs) of the worldwide network [7]. Based on this, numerous neutron stations with different cutoff rigidities have been designed and introduced to enhance the detection and recording of FDs. It is observed that the peak of the decreases varies with the different cutoff rigidity, latitude, longitude and altitudes of each station [7]. This indicates how difficult it is for a cosmic ray particle to penetrate the Earth's magnetic field [7]. It has been argued that FD is the most spectacular variability in the GCR intensity which also appears to be the compass for investigators seeking solar terrestrial relationships [11]. FD is one of the mediator parameters required to be employed for understanding Sun–Earth weather connections. However, obtaining a large dataset of an FD is very important before any statistically reliable investigation can be carried out. Publications from the IZMIRAN group have investigated large FDs based on a semi-automated global survey method (GSM) [9]. However, other investigators select a few FD catalogs with the manual technique for their research [10, 11, 12, 13]. The problem lies on the similarity and differences found on the FDs obtained using these different methods. Therefore, Validation of FDs, selected by a manual, semi-automated or fully automated approach, is not a very common practice among CR scientists. In this paper, we intend to manually select FDs from the Climax and Moscow Neutron Monitor (NM) station from the year 2000 to 2005 and equally test the correlation between its amplitudes, solar wind data.

MATERIALS

The major materials used for this work are the data of cosmic ray intensity and solar wind from the year 2000 to 2005 that was obtainedfromhttp://cr0.izmiran.ru/mosc/ and http://www.nmdb.eu respectively through the SOPO, CLMX and MOSC Neutron Monitor (NM) networks. Journal publications and R. statistical program were also used.

METHODS

Forbush decrease event dates were generated from onset journal publications.

The cosmic rays count from Moscow (MOSC) NM of the corresponding selected FD dates were displayed and arranged using text editor. The epoch analysis approach was used to identify the main phase and the recovering phase of the FD events in each date using R. program. The magnitude of each corresponding FD was determined. The FD dates, their computed magnitudes and solar wind data were recorded and presented in the in tables 1, 2 and 3. These processes were repeated for the data of cosmic rays from Climax (CLMX) and South Pole (SOPO) Neutron Monitor from the year 2000 to 2005 respectively. A correlation test was also carried out between: (1) FD magnitude of the three neutron station and (2) FD magnitudes and solar wind.

RESULTS

The selected FD dates and their corresponding magnitudes for the three CR stations of CLMX, SOPO and MOSC are shown in table 1, 2 and 3 below. The variation of Fig. 1-3 explains the application of epoch analyses for the selected FD dates. These dates were picked from table 1, 2 and 3. Thess Figs. 1-3 shows the FD onset count, the minimum decrease and the recovering phase of the selected FD dates for an event in each selected years from 2000 - 2005.

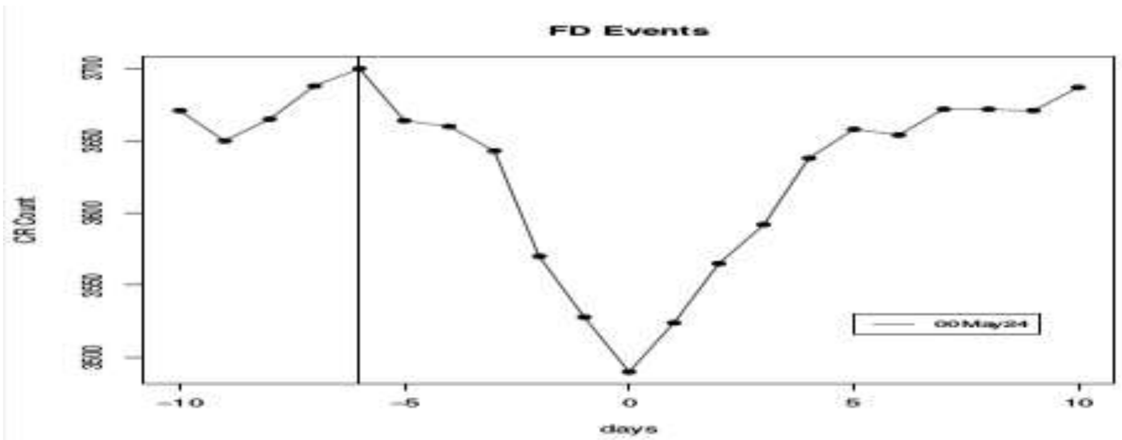

Fig. 1: Epoch analysis of FD of 24-05-2000 from CLMX station.

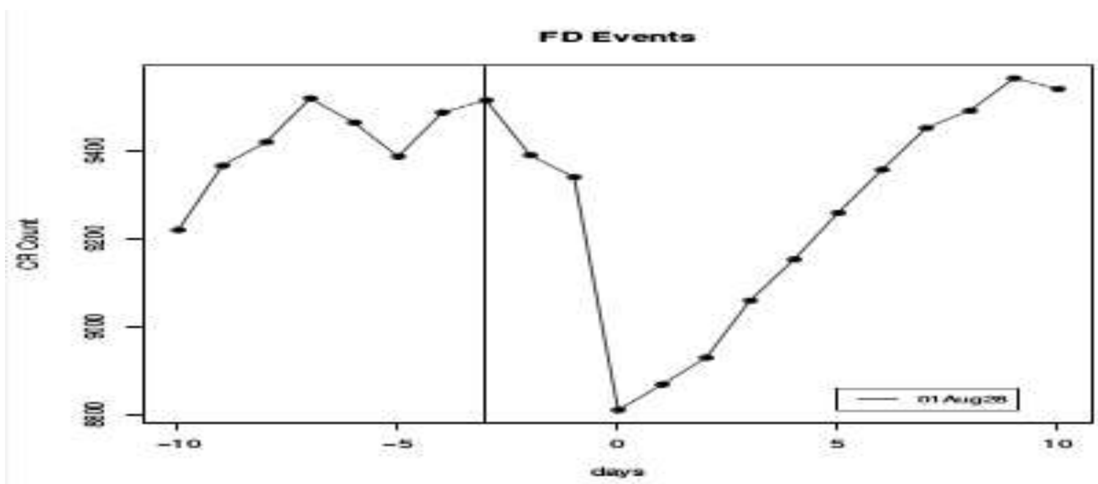

Fig. 2: Epoch analysis of FD of 28-08-2001 from SOPO station.

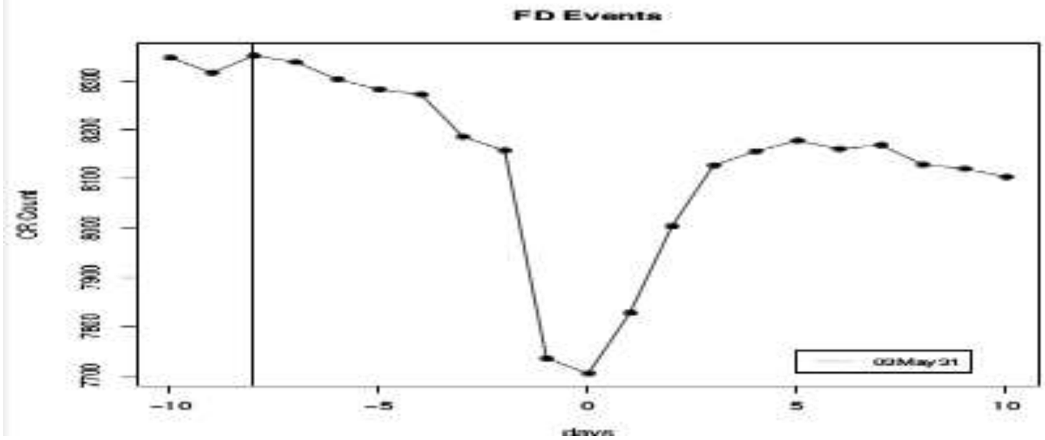

Fig. 3: Epoch analysis of FD of 31-05-2002 from MOSC station.

Tables 1, 2 and 3 shows the determined FD magnitude for SOPO, CLMX and MOSC neutron stations with their corresponding solar wind data.

Table 1: Determined FD magnitude for CLMX station and their corresponding IMF and Solar wind data.

S/N	DATE	FD MAG.(%)	IMF	SW (kms-1)	S/N	DATE	FD MAG.(%)	IMF	SW (kms-1)
1	08-02-2000	-1.9	4.4	566.63	40	23-05-2002	-4.48	17	620.89
2	13-02-2000	-4.2	6.21	559.15	41	30-07-2002	-4.64	7.54	420.17
3	21-02-2000	-1.2	14.3	421.15	42	02-08-2002	-5.61	12.1	487.71
4	01-03-2000	-2.5	7.65	477.62	43	20-08-2002	-5.62	7.19	477.88
5	25-03-2000	-2.8	4.84	610.33	44	23-08-2002	-0.91	8.77	402.26
6	04-04-2000	-1	9.16	383.51	45	26-08-2002	-0.91	10.2	359.74
7	08-04-2000	-1.1	4.68	528.98	46	28-08-2002	-1.39	8.9	449.68
8	03-05-2000	-4.1	6.23	515.08	47	06-11-2002	-1.44	7.05	567.44
9	09-05-2000	-1.8	5.92	342.83	48	12-11-2002	-4.58	12.4	566.53
10	15-05-2000	-2.8	9.09	413.64	49	19-11-2002	-6.63	11.5	391.74
11	24-05-2000	-5.8	13.7	634.72	50	23-12-2002	-2.21	10.1	530.22
12	09-06-2000	-8.4	10.2	604.48	51	27-01-2003	-4.29	8.75	499.26
13	21-06-2000	-2	4.63	358.62	52	11-04-2003	-4.01	5.13	650.32
14	24-06-2000	-1.6	11.4	547.85	53	31-05-2003	-9.89	6.3	687.78
15	16-07-2000	-17	21.8	797.57	54	11-06-2003	-1.19	4.25	633.65
16	06-08-2000	-3.1	5.98	511.79	55	16-06-2003	-1.19	10.2	500.67
17	12-08-2000	-4.5	25	597.34	56	23-06-2003	-6.16	7.46	502.01
18	25-08-2000	-0.9	7.53	394.17	57	31-10-2003	-22.4	15.9	1004.3
19	18-09-2000	-6.3	19.2	741.14	58	07-11-2003	-6.53	5.8	504.51
20	29-09-2000	-6.6	5.46	375.06	59	18-11-2003	-5.32	4.5	378.27
21	07-10-2000	-1.8	5.91	389.04	60	21-11-2003	-5.3	9.6	511.39
22	29-10-2000	-6.6	13.8	379.22	61	24-11-2003	-2.75	9.08	552.39
23	07-11-2000	-4.8	20.2	507.37	62	10-12-2003	-0.68	7.58	757.52
24	29-11-2000	-8.8	9.25	509.38	63	10-01-2004	-7.87	11.3	550.98
25	09-01-2001	-5	4.03	400.92	64	25-01-2004	-7.5	9.93	471.09
26	24-01-2001	-2.5	5.33	431.67	65	24-07-2004	-5.02	16.9	558.35
27	05-03-2001	-1.9	10.7	492.67	66	27-07-2004	-9.72	17.4	880.28
28	12-04-2001	-9.3	15.1	657.48	67	10-11-2004	-11.8	18.4	550.98
29	29-04-2001	-6.6	7.65	591.32	68	04-01-2005	-4.88	5.69	700.91
30	28-08-2001	-6.3	7.47	517.72	69	19-01-2005	-9.84	12.6	818.28
31	26-09-2001	-7.9	7.47	517.72	70	21-01-2005	-5.04	10.2	689.41
32	30-09-2001	-2	11.8	518.16	71	09-05-2005	-5.37	8.37	386.56
33	02-10-2001	-1.9	7.45	495.69	72	17-06-2005	-3.62	7.23	602.86
34	12-10-2001	-5.4	11.4	497.58	73	13-07-2005	-5.09	6.89	556.18
35	06-11-2001	-6.1	11.1	413.01	74	17-07-2005	-6.23	10	453.66
36	25-11-2001	-8.6	11.5	645.57	75	07-08-2005	-3.48	5.16	643.91
37	03-01-2002	-6.6	5.85	339.79	76	25-08-2005	-3.42	5.32	650.81
38	22-03-2002	-6.8	7.51	443.36	77	13-09-2005	-14.3	5.99	709.43
39	25-03-2002	-6.6	15.4	433.15					

Table 2: Determined FD magnitude for SOPO station and their corresponding IMF and Solar wind data.

S/N	DATE	FD MAG.(%)	IMF	SW (kms-1)	S/N	DATE	FD MAG.(%)	IMF	SW(kms-1)
1	25-03-2000	-2.41	4.84	610.3	42	28-08-2002	-1.55	8.9	449.68
2	03-05-2000	-4.38	6.23	515.1	43	06-11-2002	-3.67	7.05	567.44
3	09-05-2000	-2.05	5.92	342.8	44	12-11-2002	-3.3	8.04	566.53
4	24-05-2000	-7.39	13.68	634.7	45	18-11-2002	-8.07	9.04	378.27
5	09-06-2000	-9.47	10.22	604.5	46	27-11-2002	-1.98	10.04	535.96
6	20-06-2000	-2.26	6.3	377.3	47	23-12-2002	-3.68	11.04	530.22
7	24-06-2000	-1.92	11.35	547.9	48	27-01-2003	-5.12	12.04	499.26
8	26-06-2000	-0.93	11.49	513.2	49	02-02-2003	-2.38	13.04	504.98
9	13-07-2000	-6.82	11.14	577.5	50	31-03-2003	-3.21	14.04	551.41
10	16-07-2000	-17.19	21.79	797.6	51	05-04-2003	-0.81	15.04	489.24
11	29-07-2000	-1.26	8.84	458.6	52	11-04-2003	-4.19	16.04	650.32
12	06-08-2000	-3.59	5.98	511.8	53	31-05-2003	-10.8	17.04	687.78
13	12-08-2000	-2.63	24.96	597.3	54	11-06-2003	-1.16	18.04	633.65
14	29-08-2000	-1.26	6.82	596.7	55	23-06-2003	-6.61	19.04	502.01
15	30-08-2000	-1.26	4.96	575.8	56	27-07-2003	-1.86	20.04	673.04
16	03-09-2000	-1.87	6.77	412.7	57	10-08-2003	-0.59	22.04	608.44
17	18-09-2000	-7.62	19.17	741.1	58	18-08-2003	-2.56	21.04	466.18
18	29-10-2000	-7.12	13.75	379.2	59	25-10-2003	-6.73	23.04	536.4
19	07-11-2000	-5.4	20.16	507.4	60	31-10-2003	-27.4	24.04	1004.3
20	11-11-2000	-1.45	7.23	802.7	61	18-11-2003	-6.31	25.04	378.27
21	29-11-2000	-9.33	9.25	509.4	62	21-11-2003	-2.81	26.04	511.39
22	28-03-2001	-5.36	8.87	606.3	63	10-12-2003	-1.06	27.04	757.52
23	01-04-2001	-4.98	7.51	743.5	64	10-01-2004	-6.37	28.04	550.98
24	09-04-2001	-5.37	8.61	617.5	65	25-01-2004	-9.11	29.04	471.09
25	12-04-2001	-9.84	15.1	657.5	66	24-07-2004	-5.73	30.04	558.35
26	16-04-2001	-13.63	3.95	591.3	67	27-07-2004	-7.74	31.04	880.28
27	29-04-2001	-8.01	7.65	591.3	68	10-11-2004	-13.3	32.04	550.98
28	18-08-2001	-5.73	11.79	515.5	69	28-12-2004	-3.63	33.04	430.9
29	23-08-2001	-1.41	4.5	486.2	70	04-01-2005	-5.44	34.04	700.91
30	28-08-2001	-7.64	7.47	517.7	71	19-01-2005	-18.1	35.04	818.28
31	26-09-2001	-9.09	7.47	517.7	72	22-01-2005	-4.48	36.04	758.45
32	02-10-2001	-3.19	7.45	495.7	73	09-05-2005	-6.45	37.04	386.56
33	12-10-2001	-6.34	11.37	497.6	74	17-06-2005	-5.9	38.04	602.86
34	06-11-2001	-8.05	11.06	413	75	13-07-2005	-5.7	39.04	556.18
35	25-11-2001	-9.27	11.54	645.6	76	17-07-2005	-12.2	40.04	453.66
36	03-01-2002	-9.46	5.85	339.8	77	02-08-2005	-3.3	41.04	479.41
37	24-03-2002	-7.98	12.3	440.6	78	05-08-2005	-5.37	42.04	429.41
38	15-05-2002	-4.08	6.27	409.1	79	07-08-2005	-3.61	43.04	643.91
39	23-05-2002	-5.31	17.02	620.9	80	25-08-2005	-6.66	44.04	650.81
40	02-08-2002	-7.63	12.06	487.7	81	12-09-2005	-7.07	45.04	867.54
41	20-08-2002	-6.82	7.19	477.9					

Table 3: Determined FD magnitude for MOSC station and their corresponding Solar wind data.

S/N	DATE	FD MAG.(%)	IMF	SW(kms-1)	S/N	DATE	FD MAG.(%)	IMF	SW(kms-1)
1	24-03-2000	-1.7	4.84	610.33	33	28-05-2002	-0.9	5.6	659.3
2	30-03-2000	-0.9	5.23	442.38	34	02-08-2002	-5.1	12.06	487.71
3	03-05-2000	-3.2	6.23	515.08	35	20-08-2002	-3.7	7.19	477.88
4	08-05-2000	-1.4	9.85	357.99	36	28-08-2002	-1.7	8.9	449.68
5	15-05-2000	-1.6	9.09	413.64	37	12-11-2002	-1.7	12.38	566.53
6	24-05-2000	-5.5	13.68	634.72	38	18-11-2002	-5.1	9.32	378.27
7	09-06-2000	-6.7	10.22	604.48	39	23-12-2002	-1.9	10.08	530.22
8	20-06-2000	-1.3	6.25	377.26	40	27-01-2003	-3.6	8.75	499.26
9	24-06-2000	-1.9	11.35	547.85	41	11-04-2003	-3.4	5.13	650.32
10	26-06-2000	-0.9	11.49	513.26	42	31-05-2003	-7.9	6.3	687.78
11	16-07-2000	-13	21.79	797.57	43	11-06-2003	-0.6	4.25	633.65
12	06-08-2000	-2.2	5.98	511.79	44	23-06-2003	-8	7.46	502.01
13	12-08-2000	-1.7	24.96	597.34	45	24-06-2003	-4.8	8.53	538.71
14	09-09-2000	-1.4	6.93	399.59	46	04-07-2003	-1.1	6.55	728.94
15	18-09-2000	-5.1	19.17	741.14	47	31-10-2003	-18	15.85	1004.3
16	29-10-2000	-5.3	13.75	379.22	48	17-11-2003	-3.6	6.03	749.71
17	02-11-2000	-5.4	3.54	365.63	49	24-11-2003	-3.2	9.08	552.39
18	07-11-2000	-3.7	20.16	507.37	50	01-12-2003	-1.1	6.7	444.38
19	11-11-2000	-0.9	7.23	802.73	51	10-12-2003	-1.3	7.58	757.52
20	29-11-2000	-6.1	9.25	509.38	52	10-01-2004	-6.5	7.58	757.52
21	20-03-2001	-2	18.03	398.12	53	25-01-2004	-6.7	9.93	471.09
22	28-03-2001	-3.8	8.87	606.26	54	27-07-2004	-0.9	17.37	880.28
23	01-04-2001	-3.4	7.51	743.48	55	10-11-2004	-10	18.35	550.98
24	05-04-2001	-3.4	7.47	613.81	56	19-01-2005	-14	12.59	818.28

25	09-04-2001	-4.5	8.61	657.48	57	22-01-2005	-4.7	10.22	689.41
26	12-04-2001	-7.9	15.1	657.48	58	09-05-2005	-4.9	8.37	386.56
27	07-11-2001	-6.3	6.45	627.14	59	16-05-2005	-5.6	10.21	628.53
28	25-11-2001	-8.3	11.54	645.57	60	17-06-2005	-2.9	7.23	602.86
29	03-01-2002	-6.9	5.85	339.79	61	17-07-2005	-8.9	10.01	453.66
30	24-03-2002	-6.9	12.3	440.64	62	07-08-2005	-4.1	5.16	643.91
31	24-04-2002	-5.3	7.14	487.38	63	25-08-2005	-4	5.32	650.81
32	23-05-2002	-3.2	17.02	620.89	64	13-09-2005	-12	5.99	709.43

The correlations are grouped into two phases. Phase one shows the correlation of FD magnitude between the three stations while phase two shows the correlation between the FD magnitudes of the three stations and their corresponding solar wind data. Pearson r correlation method was used for the correlation test. Table 4 contains the correlation values between the three stations of SOPO, CLMX and MOSC.

Table 4: Correlations between the FDs of the three neutron stations

S/No	Stations Correlation	Correlation Value
1	SOPO VS CLIMX	0.7447626
2	SOPO VS MOSC	0.932871
3	CLIMAX VS MOSC	0.8888257

Table 5 contains the correlation values between the FDs of the three stations of SOPO, CLMX and MOSC with their corresponding solar wind data.

Table 5: Correlations between the FDs of the three neutron stations and solar wind

S/No	Correlation Test	Correlation Value
1	SOPO VS SW	0.3640701
2	CLMX VS SW	0.5381531
3	MOSC VS SW	0.3366304

Figs. 4, 5 and 6 shows the correlation plots between FDs of SOPO & CLMX, SOPO & MOSC and CLMX and MOSC stations respectively.

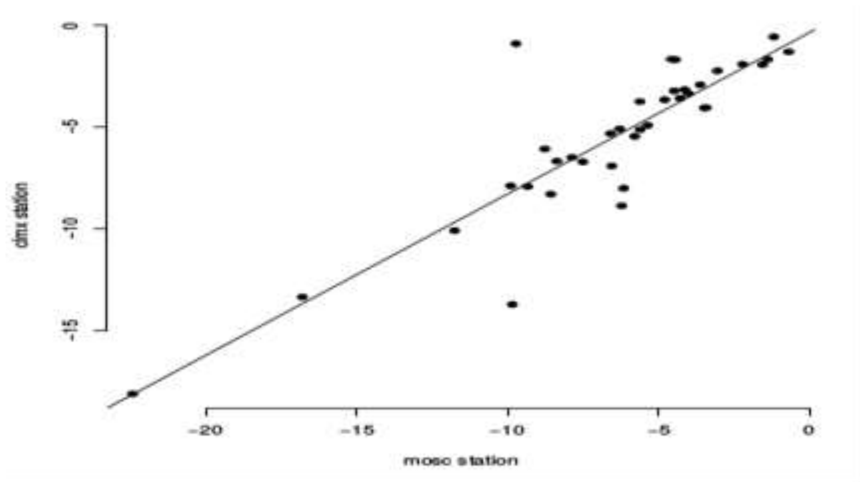

Fig. 4: Correlation plot of CLMX and MOSC FDs

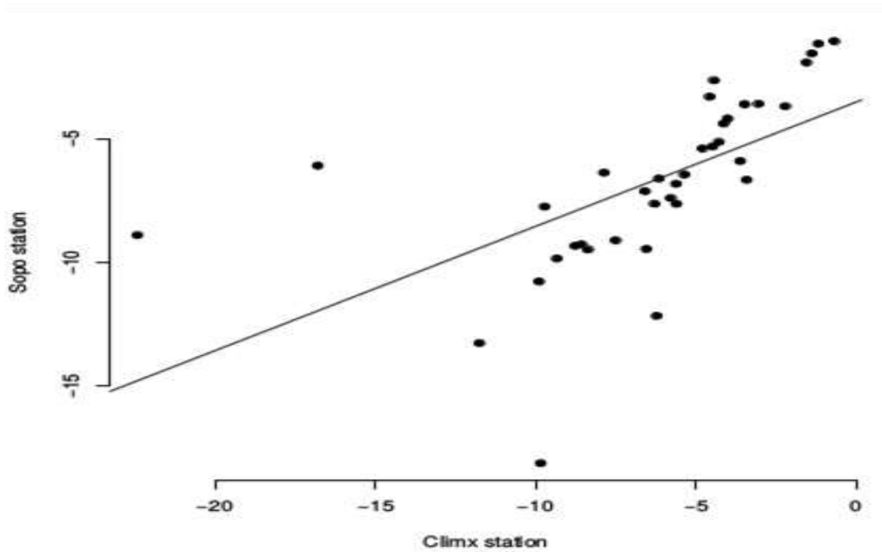

Fig. 5: Correlation plot of SOPO and CLMX FDs

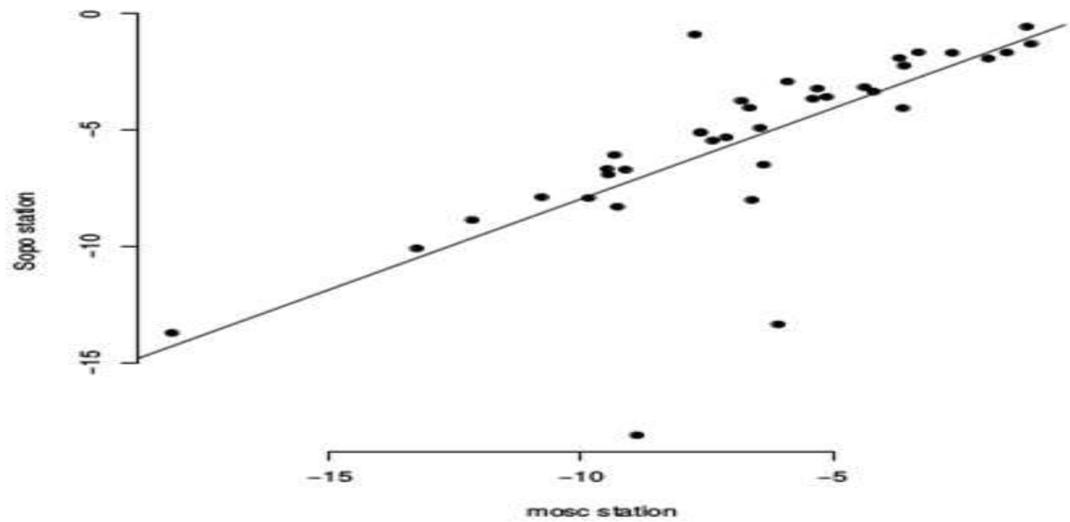

Fig. 6: Correlation plot of SOPO and MOSC FDs

DISCUSSION

Previous study of FDs have identified two methods of FD key event selection which are commonly used by researchers conducting epoch analysis. These methods of FD selections are (i) the use of data from a CR station, and (ii) compiling dates from the literature. Numerous investigators employs these same techniques. For instance, [14], identified 22 large FDs between 2000 and 2005 using Climax data. They validated the dates of these events by comparing them with FD days found in another two station, the Oulu and Moscow stations. An event is said to be an FD if the CR data are equal to or lower than 5% below the 90-day running mean. Table 1, 2 and 3 above shows our FD dates selected and computed from literature. The FDs of [15] were used as source event dates which forms the basis of our event selection. A total of 77, 81 and 64 events were observed in CLMX, SOPO and MOSC neutron stations respectively as shown in the tables. Similarities and variations were observed in the comparison on the event date selection of the two tables. Some event dates were observed to tally with that source dates which forms the basis of our event selection. A total of 53 FDs were seen to be similar with the source event dates for SOPO while CLMX and MOSC neutron stations recorded 62 and 41 similar events respectively. A total of 29 FDs were newly generated for SOPO, while CLMX and MOSC recorded 15 and 23 events respectively. These dates that are similar validates our result. The non-similar dates are the new FDs generated by this study. However, slight variations were also detected on the observed FD dates. It was noticed that the dates recorded in the source event dates are not really the exact date of the FD event, rather some days away from or before the supposed epoch time/day. For instance, the event of 25-03-2000 was observed as 24-3-2000 in MOSC station while both SOPO and CLIMX observed the same event on 25-03-2000. Also, the event of 20-06-2000 as recorded by both SOPO and MOSC station was seen on 21-06-2000 by CLMX station. However, the event of 30-05-2000 is not seen as an FD event based on our analyses. This variation in dates are been traced to onset date time of events. The magnitude of an FD is the strength/size of the depression in cosmic ray intensity variation. Tables 1, 2 and 3 equally shows the determined FD magnitudes for neutron stations of CLMX and MOC. Previous research have shown that the magnitude of FDs depends on the latitudes of neutron monitors. For instance, [16,17], suggested that FDs are longitudinal and latitudinal dependence. The magnitude of the FD consistently increased from lower latitude NMs, the CLMX station (39.37 ◦ N), to higher latitude stations, the station in SOPO (90.00 ◦ S). For instance the magnitude of the event of 03-01-2002 are -6.55% and -9.46% for CLMX, and SOPO neutron stations respectively. While the SOPO station recorded the highest depression followed by CMX station, MOSC station recorded the least depression. This signifies that the magnitude of the event for SOPO station is the highest followed by CLMX and finally MOSC which is the least. While large FDs tend to show a clear deep depression, the small events do not really show a very deep depression. These small FDs are sometimes seen to be the non-simultaneous [18, 19, 20]. FDs that are not usually observed by all the stations. [21], suggested that these small events are affected by diurnal anisotropy unlike the large ones. A comparison of Table 1, 2 and 3 shows that MOSC detected fewer FDs (64 FDs) than the rest of the stations. A close observation of Tables 10 suggests that the FDs detected by MOSC are mostly small FDs. The fewer FDs detected by MOSC cannot be attributed to data gap as the station was in operation throughout the year. The station in CLMX ranks second (76 FDs) with regard to fewer FD detections. Table 3 implies that the magnitude of the largest FD detected by this MOSC station is −6%, whereas other stations, except for MOSC, measured larger decreases as well as a greater number of FDs. Much more can be noted from Tables 1, 2 and 3. It is interesting to note that in addition to the fact that the number of FDs detected by these stations varies appreciably, the dates of observation of these events are not the same, even for stations that tend to detect close number of FDs. SOPO and CLMX, for example, measured close number of FDs (81 and 77 FDs respectively).

Research has identified that the FD magnitude observed at stations with close latitude are bound to have a strong positive correlations. FDs have also been seen to correlate with solar activities. [22], stated that they analyzed FDs at three high latitude stations (NWRK, MCMC and SOPO). Although they did not indicate the outcome of their comparison nor the implication on the result obtained, the general underlying assumption among researchers conducting FD-based correlation/regression or epoch investigation is that FDs that are simultaneous at two or more stations are strong events. Between the year 2000 and 2005, [23] selected 22 FDs using CLMX data and following the same approach, they simply stated that their FD event days were compared with those at Oulu and Moscow NMs and by extension, they assumed that their FDs are consistent, or rather simultaneous. Table 4 shows the result of the correlation test between FD magnitudes of the three stations of SOPO, CLMX & MOSC. The strong correlation of value cc = 0.932871 seen between SOPO and MOSC is an indication that the FDs observed in this two stations are highly simultaneous. These high level of simultaneity is traced to the latitudinal closeness of the two stations (90.00^{o}S,55.47^{o}N) for both SOPO and MOSC stations. However, the correlations of two stations of SOPO and CLMX of value cc = 0.7447626 which was less correlated compared to SOPO and MOSC is an indication that the two stations are not as close in latitude as SOPO and MOSC. Fig. 4, 5 and 6 which shows the correlation plots between the FDs of the three stations indicates that the higher the cluster of the plotted points within the line of best fit, the more positive significant of the correlation.

Research has shown that correlation exist between FD magnitude and solar activities. [24], reveals that the correlation between FD magnitude and the product of the magnetic field enhancement and the SW speed increase is better than correlations for the two SW parameters treated separately. Therefore, we analyzed correlations of FD magnitudes with solar wind data to find out whether solar activities is relevant on FDs. Table 5 shows the result of a correlation test between FD magnitudes of the three stations of SOPO, CLMX and MOSC with solar wind. A stronger correlation was observed between FD magnitude and solar wind for all the three stations. For instance, the correlation of FD magnitudes of SOPO station and solar wind is cc = 0.3640701. This signifies that solar wind disturbances gives rise to FDs. The highest correlation was also observed between the FD magnitudes of CLMX station and solar wind. These good correlations obtained for SW and FD magnitudes shows that FDs are generated by solar activities.

CONCLUSION

It is concluded that solar wind disturbances gives rise to cosmic ray intensity variation which generates a sharp decrease in cosmic ray intensity known as Forbush decrease.

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