Forbush Decreases In Relation with Halo and Partial Halo Coronal Mass Ejections and Storms in Solar Wind Plasma Parameters.

P.L. Verma*,G.P.Agrawal†,R.J.Prajapati,† †, A,Vishwkerma† †,A.Saxena‡ and J.P.Gupta§

**.Department of Physics, Govt. Vivekanand P.G. College Maihar, Satna (M.P)India.† Department of Physics, Govt. Vivekanand P.G. College Maihar, Satna (M.P)India ,† † Department of Physics,Bhuvans college Andheri Mumbai. † † Research Scholar Department of Physics A.P.S.University Rewa M.P.. ‡.Department of Physics,Govt.S.N.P.G.CollegeShahdolM.P.India, §.Department of Physics, Govt. P.G. College , Satna (M.P)India.*

Abstract

Coronal mass ejections (CMEs) are the dynamic events in which vast amount of solar plasma materials are expelled from the solar corona into interplanetary space and are responsible to generate storms in solar wind plasma parameters and Forbush decreases in cosmic ray intensity. We have studied Forbush decreases (Fds) magnitude ≥ 3%, obtained from the analysis of hourly count rate of cosmic ray particles recorded by oulu neutron monitor during the period 1997-2006 with coronal mass ejections, and storms in solar wind plasma parameters .We have found that 81.31% Forbush decreases are associated with coronal mass ejections (CMEs) and majority of them (78.37 %) are full halo coronal mass ejections (H-CMEs).The association rate of Forbush decreases with halo and partial halo coronal mass ejections are found 78.37%and 21.62 %respectively. We have further determined that halo and partial halo coronal mass ejections, which are related to Forbush decreases, majority of them are, associated with M and C class X-ray solar flares (77.02%). Positive co-relation with co-relation co-efficient .40 is found between magnitude of Forbush decreases and speed of associated coronal mass ejections. From the study of Forbush decreases with storms in solar wind plasma parameters, we have determined positive co-relation between magnitude of Forbush decreases and peak values of associated storms in solar wind plasma parameters with co-relation co-efficient .49 between magnitude of Forbush decreases and peak values of associated storms in solar wind plasma temperature, .25 between magnitude of Forbush decreases and peak values of associated storms in solar wind plasma density, .57 between magnitude of Forbush decreases and peak values of associated storms in solar wind plasma velocity .We have concluded that halo and partial halo coronal mass ejections associated with M and C class X-ray solar flares are very much effective in producing Forbush decrease in cosmic ray intensity.

Keywords:-Forbush decreases,Halo and Partial Halo Coronal Mass Ejections, Storms in Solar Wind Plasma Parameters.

I .INTRODUCTION

Forbush Decreases (FDs) are transient decreases in the counting rates of GCRs that last typically for about aweek.There are two basic types [1] of FDs. The first consist of recurrent decreases, with gradual onsets and more symmetric profiles. These are often associated with co rotating interaction regions in the solar wind[2]. FDs of the second type are marked by sudden onsets, reaching maximum depression in about a day, often in two stages [1], and followed by a gradual recovery. In both cases it is understood that the decreases in cosmic ray intensities result from large-scale (≥ 0.1 AU) increases in the interplanetary magnetic fields that modulate the scattering and convection of the GCRs [3,4,5].

It has now been proved by the recent studies of Forbush decreases with coronal mass ejections that the decreases are strongly associated with CMEs. The role of CMEs and their near-earth counterparts in causing Forbush decreases at the earth has been well documented by Cane.H.V. [1] Fast CMEs often propagate through the solar wind at super-Alfvenic speeds, driving shocks ahead of them. The shocks driven by CMEs are frequently responsible for driving Forbush decreses in cosmic ray intensity [1,6,7,8 ,] Cane et al[9] have studied Forbush decreases for 30 years period with coronal mass ejection and found that 86% FDs are associated with CMEs and interplanetary shocks that they generate. Badruddin [10,11] has reported that abrupt onset of decrease in intensity starts upon the arrival of certain shocks and decrease continue till the passage of post shock turbulent sheath. He has further determined that turbulent shocks are much more effective in producing Forbush decreases than non-turbulent shocks. He also reported that halo CMEs are more effective transient modulator of cosmic ray intensity than other CMEs and producs significant Forbush decreases. P. Subramanian et a l [12] have inferred that Fds are associated with front side halo coronal mass ejections (CMEs) and near-Earth magnetic clouds. The associated Forbush decreases are expected to have significant contributions from the cosmic-ray depressions inside the CMEs/ejecta. Belov et al [13] have studied Forbush decreases with interplanetary disturbances. They have concluded that magnitude of FDs is directly proportional to Hm, Vm where Hm maximum disturbance value for the interplanetary magnetic field strength is and Vm is maximum solar wind velocity. In this investigation an attempt has been made to determine the role of halo and partial halo coronal mass ejections in producing Forbush decrease and to co-relate the magnitude of FDs with peak values of solar wind plasma temperature, density and velocity during the associated solar wind disturbances.

II .EXPERIMENTAL DATA

In this investigation hourly count rate of cosmic ray, recorded by oulu neutron monitor over the period 1997 through 2006 has been used to determine Forbush decreases (FDs). The oulu neutron monitor (NM) is situated in Northern Finland (65.05ºN, 25.47ºE). The local vertical geomagnetic cut off rigidity is about .8GV and the neutron monitor in oulu is one of the most stable and reliable stations of the world neutron monitor Network. In this work we have selected only those FDs, which have decrease greater than 3.0%. The hourly data of solar wind plasma velocity, density and temperature have been used over the period 1997 through 2006 to determine peak values of solar wind plasma velocity, proton density and temperature. These data have been taken from the NSSDC omeni web system. The data of CMEs have been taken from SOHO, LASCO, CME catalogue, which consists all CMEs manually, identified since 1996 from large angle and spectrometric coronagraph (LASCO) on board the solar and heliospheric observatory mission (SOHO).

Table-1Association of Forbush decreases with CMEs and Peak Values of Solar Wind Plasma parameters.

Forbush Decreases		Temperature	Density	Velocity	CM E	Speed K/s	Solar Flares		Forbush Decreases				CM E		
date	Magnitude in %	Peak Tem in Deg k	Peak-DeninN/cc	PeakVe in km/s	TypeH/P	K/s	Class	Date.	Mag in %	Peak Tem in Deg k	Peak DeninN/cc	PeakVe in km/s	TypeH/P	SpeedK/s	Flare
24.02.97	3	103334	8.2	501	p	290	B-72	17.08.01	7	316649	27.8	599	H	625	C-23
14.03.97	3	149958	15	425	NA	NA	NA	28.08.01	5	360302	12.9	568	H	1433	X-5.3
10.04.97	5	206960	32.4	547	H	905	C-68	11.10.01	7	563212	24.7	534	H	973	M-14
03.09.97	3	123020	21.5	415	H	551	M-14	21.10.01	5.8	529177	21.9	676	H	558	X-1.6
07.11.97	3	374718	23.4	460	H	785	X-2.1	06.11.01	11	102333	45.7	721	H	457	C-38
22.11.97	4	415513	32.4	524	H	150	C-16	13.11.01	3	NA	NA	NA	P	187	M-16
28.01.98	3	108446	13.4	408	H	693	M-13	24.11.01	10	246407	43.9	948	H	518	C-47
01.05.98	5	420844	14.5	651	H	1374	M-68	30.12.01	6	NA	NA	NA	H	2239	X-3.4
04.05.98	5	987658	23.5	833	H	542	X-1.1	10.01.02	5	497423	12.4	642	H	2210	C-72
15.05.98	4	120982	28.2	402	P	1130	C-72	19.01.02	3	117926	30.6	451	NA	NA	M-15
05.06.98	5	543945	15.5	646	H	1802	B-70	20.03.02	3.5	345889	19	576	H	989	M-10
06.07.98	3	396647	11.4	632	ND	ND	M-12	22.03.02	3	193208	5.5	454	H	603	C-57
25.08.98	8	2E+06	8.8	847	ND	ND	M-22	08.04.02	3	NA	NA	NA	P	488	C-19
24.09.98	10	907650	9	839	ND	ND	M-71	17.04.02	5.5	396426	33.6	611	H	742	M-37
08.11.98	8	151837	24.4	639	H	460	M-24	23.05.02	5.5	1217894	23	871	H	1611	M-15
23.11.98	4	242479	22.3	512	NA	NA	X-3.7	17.07.02	5	315419	14.4	519	H	1151	X-3.0
25.12.98	3	626114	14.6	514	NA	NA	X-1.0	19.07.02	5	471256	3.5	501	H	1636	M-18
18.02.99	6	518339	12.7	673	NA	NA	M-32	01.08.02	3.5	311710	11.5	524	P	608	M-47
22.01.99	7	616310	4.4	655	ND	ND	M-52	06.08.02	3	NA	NA	NA	P	1279	X-1.0
22.05.99	4	116827	4.4	NA	P	938	C-24	15.08.02	3	359985	2.5	624	P	431	M-18
13.07.99	3.5	43539	8.4	301	P	866	C-30	10.11.02	7	203583	40.6	630	H	1977	M-46
22.08.99	3	NA	NA	NA	P	248	M-18	17.11.02	7	171363	8.7	494	H	1250	C-64
15.09.99	4.5	499533	5.4	621	P	520	C-49	18.11.02	3.5	NA	NA	NA	H	1185	C-64
12.12.99	7.5	691431	10.9	686	NA	NA	C-37	26.11.02	3.5	496229	17.2	592	H	1187	C-46
11.02.00	5.5	256885	9.4	505	H	1079	M-13	26.01.03	3	NA	NA	NA	NA	NA	M-19
20.02.00	3	221321	30.1	343	H	728	M-25	20.02.03	3	301784	10	668	NA	NA	C-10
29.03.00	3.5	203766	6.2	520	NA	NA	M-31	20.03.03	3	654097	3.3	806	H	1042	X-1.5

08.06.00	8	962327	19.5	772	H	1130	M-15	29.05.03	9	605923	36	737	H	509	X-1.3
25.06.00	3	186551	7.5	511	P	847	M-30	28.10.03	2.5	1044292	7	809	NA	NA	X-1.2
15.07.00	10	2E+06	20.1	1010	H	1815	X-5.7	15.11.03	7	645479	8.3	712	H	1225	B-41
07.09.00	3	325382	4.3	469	P	485	C-30	20.11.03	5.5	534783	17.6	703	H	1660	M-32
14.09.00	3.5	40979	22.3	NA	H	1839	M-10	06.01.04	6.5	678522	5.2	723	NA	NA	M-69
17.09.00	8	920581	32.8	893	H	537	M-59	22.01.04	8.5	585976	17.1	666	H	1074	M-61
03.10.00	3.5	150416	13.3	461	P	586	M-22	12.04.04	3.5	316828	4.7	490	H	1276	C-96
13.10.00	3	112746	23.4	469	P	457	C-23	22.07.04	5	581133	15.5	672	H	906	M-86
28.10.00	5	6E+06	39.3	415	H	948	C-40	27.07.04	10	492162	10.8	653	H	1366	M-22
06.11.00	6	458587	17.5	609	H	643	C-32	13.09.04	6	360712	23.6	577	H	1328	M-48
26.11.00	7	631551	35.7	623	H	614	C-54	07.11.04	12	808505	64.5	730	H	719	C-63
03.03.01	3	220207	11.4	511	P	362	B-48	05.12.04	5	225157	ND	435	H	1216	M-15
27.03.01	5.5	371410	25	629	H	1185	M-17	27.12.04	3	222878	7.5	559	NA	NA	C-18
04.04.01	8	1E+06	6.8	767	H	1683	M-55	08.05.05	6	662109	14.2	804	H	1180	C-78
08.04.01	7	337569	12	781	H	1390	M-84	15.05.05	10	959643	17.6	959	H	1689	M-80
11.04.01	12	849339	24.7	732	H	2974	M-69	16.07.05	8	206479	13.9	491	H	1390	M-50
28.04.01	7	834771	9.1	724	H	1171	M-78	24.08.05	7.5	456378	26.2	707	H	1194	M-26
03.05.01	3	20509	11	NA	NA	NA	M-18	10.09.05	12	406951	7.2	1035	H	2693	X-6.2

III .ANALYSIS AND RESULTS

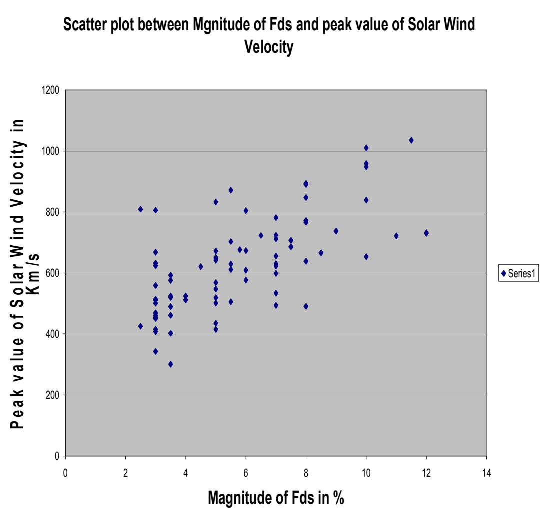

Figure1. Shows scatter plot between magnitudes of Forbush decreasesand peak values of solar wind plasma velocity showing positive correlation with correlation coefficient .57.

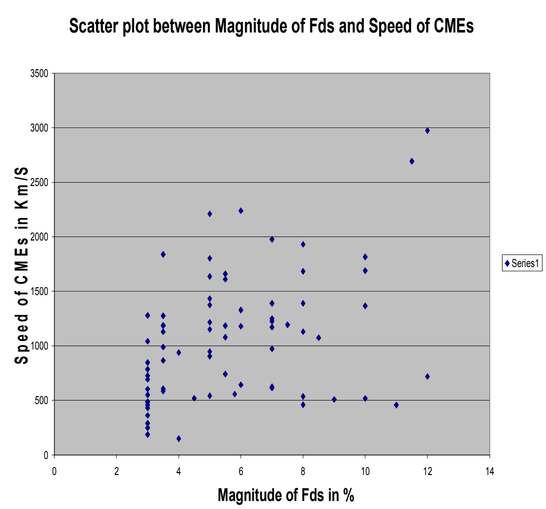

Figure 2. Shows scatter plot between magnitudes of Forbush decreasesand speed of CMEs howing positive Correlation with correlation coefficient .40.

The statistical analysis of the association of Forbush decreases with coronal mass ejections shows that majority of the Forbush decreases are found to be associated with coronal mass ejections .We have 91 Forbush decreases ≥ 3%, out of which 74(81.31%) of the Forbush decreases have been found to be associated with coronal mass ejections. we have found that out of 74 associated Forbush decreases, 16(21.62%) Forbush decreases are found to be associated with partial halo CMEs where as 58 (78.3 7%) Forbush decreases are found to be associated with full halo CMEs. Coronal mass ejections, which are related with geomagnetic storms, are also associated with solar flares of different categories. In this study 74 Forbush decreases are found to be associated with CMEs in which all CMEs are associated with X-ray solar flares of different categories. 13(17.56%) CMEs are associated with X class, 35(47.29%) CMEs are associated with M class,22 (29.72%) CMEs are associated with C class and 4(5.40%) CMEs are found to be associated with B class X-ray solar flares. Mejority of the CMEs are related to Mand C class X ray solar flares .From the study of magnitude of Forbush decreases and speed of associated coronal mass ejections, we have found positive correlation with correlation co-efficient .40 between magnitude of Forbush decreases and speed of associated coronal mass ejections. From the study of Forbush decreases with storm in solar wind plasma parameters i.e. jump in solar wind temperature (JSWT), jump in solar wind density (JSWD) and jump in solar wind velocity (JSWV), it is inferred that Forbush decreases of higher magnitudes are found to be associated with such JSWT events, which have relatively higher peak values. We have determined positive correlation between magnitude of Forbush decreases and peak values of associated JSWT events. Statistically calculated correlation co-efficient is .49 between these two events. Positive correlation is found between magnitude of Forbush decreases and peak value of associated JSWD events. Statistically calculated correlation co-efficient is .25between these two events .Forbush decreases of higher magnitudes are found to be associated with such JSWV, events which have relatively higher peak values of velocity. Positive correlation has been found between magnitude of Forbush decreases and a peak value of associated JSWV events, statistically calculated co-relation co-efficient has been found .57.

IV .CONCLUSION

From our study, 74out of 91 Forbush decreases have been found to be associated with CMEs.Out of these 74 associated Forbush decreases, 16(21.62%) Forbush decreases are found to be associated with partial halo CMEs where as 58 (78.37%) Forbush decreases are found to be associated with full halo CMEs. The halo and partial halo CMEs are found to be related with X-ray solar flares of different categories. All CMEs are associated with X-ray solar flares, majority of them are related to M and C class solar flares. From these results, it is concluded that halo coronal mass ejections and partial halo coronal mass ejections of higher speed associated with strong X-ray solar flares are mainly responsible to generate.Forbush decreases in cosmic ray intensity. The positive correlation between magnitude of Forbush decreases and peak values of jump in solar wind temperature, density and velocity suggests that magnitude of Forbush decreases depends upon the peak values of disturbances in solar wind parameters.

REFERENCES

[1] H.V. Cane, Space Science Rev., 93, 55 (2000).

[2] I.G. Richardson, Space Science Rev., 111, 267 (2004).

[3] E.W. Cliver et al., Astrophys. J., 592, 574 (2003).

[4] G. Wibberenz et al., J. Geophys. Res., 107, (All), 1353, doi:10.1029/2002JA009461 (2002).

[5] A.V. Belov et al., Proc. 28th ICRC, 6, 3581 (2003).

[6]Belov, A.V., et al 2001 c proc. 27th ICRC 2001.

[7]Robert F.Penna, Alice, QuillenJ.Geophys.Res.Vol.110, A09s052005

[8]P.L.Verma Proc.30th ICRC Merida Mexico2007

[9]Cane H.V.I.G. Richardson and T.T. Von Rosenving (1996). J. Geophys. Res. 10(A10) 21-561, 21572

[10]Badruddin (2001) Proc. ICRC 2001.

[11]Badruddin (2003) proc. 28th ICRC 2003,

12]Subramanian, P.; Antia, H. M.; Dugad, S. R.; Goswami, U. D.; Gupta, S. K.; Hayashi, Y.; Ito, N.; Kawakami, S.; Kojima, H.; Mohanty, P. K.; Nayak, P. K.; Nonaka, T.; Oshima, A.; Sivaprasad, K.; Tanaka, H.; Tonwar, S. C.; The Grapes-3 Collaboration

Astronomy and Astrophysics, Volume 494, Issue 3, 2009, pp.1107-1118

[13]Belov, A.V. Eroshenko, E.A. olenever, V, A, et al 2001 c proc. 27th ICRC 2001.