

Coronal Mass Ejections, Interplanetary Shocks In Relation With Forbush Decreases Associated With Intense Geomagnetic Storms

P.L.Verma¹, Nand Kumar Patel ² Mateswari Prajapati³

¹Department of Physics, Govt. Vivekanand P.G. College Maihar Satna M.P.India

²Research Scholar, A.P.S. University Rewa M.P.India.

³Research Scholar Govt.P.G.College Satna M.P. India.

E-mail: pl_verma2003@yahoo.com

Abstract. Coronal mass ejections (CMEs) are the most energetic solar events in which large amount of solar plasma materials are ejected from the sun into heliosphere, causing major disturbances in solar wind plasma, Interplanetary shocks, Forbush decrease (Fds) in cosmic ray intensity and geomagnetic storms. We have studied Forbush decreases associated with intense geomagnetic storms observed at Oulu super neutron monitor, during the period of May 1998-Dec 2006 with coronal mass ejections (CMEs), X-ray solar flares and interplanetary shocks. We have found that all the (100%) Forbush decreases associated with intense geomagnetic storms are associated with halo and partial halo coronal mass ejections (CMEs). The association rate between halo and partial halo coronal mass ejections are found 96.00% and 04.00% respectively. Most of the Forbush decreases associated with intense geomagnetic storms (96.29%) are associated with X-ray solar flares of different categories. The association rates for X-Class, M-Class, and C-Class X-ray solar flares are found 34.62%, 50.00% and 15.38% respectively. Further we have concluded that majority of the Forbush decrease associated with intense geomagnetic storms are related to interplanetary shocks (92.30 %) and the related shocks are forward shocks. We have found positive co-relation with co-relation co-efficient .7025 between magnitudes of Forbush decreases associated with intense geomagnetic storms and speed of associated coronal mass ejections. Positive co-relation with co-relation co-efficient 0.48 has also been found between magnitudes of intense geomagnetic storms and speed of associated coronal mass ejections.

1. Introduction

Coronal mass ejections (CMEs) are magnetized structures, which can affect the heliospheric conditions, producing large fluctuations in the heliospheric magnetic field. CMEs traveling at different speeds tend to merge into what are known as complex ejecta, which are seen often in the interplanetary medium during times of high solar activity. The increase of the magnetic field during the passage of ejecta at 1 AU is related to the GCR intensity decrease [6]. Cane H.V.[5] have studied cosmic ray intensity variations with coronal mass ejections and concluded that CMEs are large-scale phenomena that change the configuration of the interplanetary magnetic field (IMF) and clearly modulate the cosmic-ray intensity on short-term (few day) time scales.

Forbush decreases which falls under the category of asymmetric short term cosmic ray variations have been studied by several scientists are strongly associated with coronal mass ejections and the interplanetary shocks, magnetic clouds, ejecta which are interplanetary manifestations of coronal mass ejections decreases [17, 1, 3, 4, 10, 14, 7]. Zhang and Burlaga [17] concluded that relatively large decreases in cosmic ray intensity is associated with magnetic clouds that are preceded by a shock, whereas only a small decreases in cosmic ray intensity is associated with magnetic clouds that are not preceded by shock. Cane et al [3, 4] have inferred that the short-term



cosmic ray decreases are strongly associated with ejecta and shocks. Robert F. Penna et al [12] have investigate the relation between Forbush cosmic ray decrease recovery time and coronal mass ejection transit time between the Sun and Earth. Ifedili S.O [10] has studied two-step asymmetric cosmic ray intensity decreases (FDs) with coronal mass ejections magnetic clouds, interplanetary shocks and interplanetary disturbances, interplanetary magnetic field (magnitude and direction). Interplanetary coronal mass ejection (ICME) impacting on slow solar wind, there is a sheath upstream of the ICME led by a fast forward shock and the large IMF variations in this sheath, which sustained the Forbush decreases (FDs) in the cosmic ray intensity. P. Subhrmanayam et al [14] have studied asymmetric short term cosmic ray intensity decreases (FDs) with coronal mass ejections and inferred that these decreases (FDs) are associated with front side coronal mass ejections.

Several investigators have studied geomagnetic storms with various solar features, solar wind parameters and inferred that CMEs are responsible for the most geoeffective solar wind disturbances and, therefore the largest geomagnetic storms. R - Landi and G - Moreno et al [13] have investigated the role of the coronal mass ejections in producing non recurrent geomagnetic storms in period 1969-1974. They have concluded that coronal mass ejections associated with chromospheric flares, accompanied by type IV radio emission, are the most effective in perturbing the geomagnetic field. N. Gopalswamy et al [9] have studied geoeffectiveness, speed, solar source, and flare association of a set of 378 halo coronal mass ejections (CMEs) of solar cycle 23 (1996-2005). They have compiled the minimum Dst values occurring within 1 - 5 days after the CME onset. They have compared the distribution of such Dst values for the subset of halo CMEs: — disk halos, limb halos, and back side halos CMEs. Defining that a halo CME is geoeffective if it is followed $Dst \leq -50$ nT, moderately geoeffective if $-50\text{nT} < Dst < -100\text{nT}$, and strongly geoeffective if $Dst \leq -100\text{nT}$, they have found that the disk halos are followed by strong geomagnetic storms, limb halos are followed by moderate storms, and back side halos are not followed by significant storms. Badruddin; Singh, Y. P. [2] have studied the subset of CMEs, called interplanetary magnetic clouds (MCs), observed in the heliosphere and their associated features (shock/sheath, IR and HSS). Best-fit equations representing the relation between level of the geomagnetic activity and interplanetary plasma/field parameter have been obtained. Zhao, et al [16] studied the source locations of 130 solar flares associated with type II radio burst events and interplanetary shocks observed by L1 spacecraft during February 1997-August 2002. They have investigated the relative positions between the flare sources, the heliospheric current sheet (HCS), and the Earth. They have found that (1) Solar flares are usually distributed within $[S30^\circ, N30^\circ]$ in heliographic latitude and $[S30^\circ, N30^\circ] \times [E10^\circ, W30^\circ]$ are the predominant source region on the solar disk that includes the majority of geoeffective solar flares. Michalek, G. et al [11] have concluded that halo coronal mass ejections (HCMEs) originating from regions close to the center of the sun are likely to be geoeffective. They have showed that, only fast halo CMEs (with space velocities higher than ~ 1000 km/s) and originating from the Western Hemisphere close to the solar center could cause intense geomagnetic storms. Echer, E et al [8] have analyzed plasma and magnetic field parameter variations across fast forward interplanetary shocks during the last solar cycle minimum (1995-1996, 15 shocks), and maximum year 2000. They have observed that the solar wind velocity and magnetic field strength variation across the shocks are the parameters better. Verma P.L. et al [15] have studied geomagnetic storms $Dst < -50$ nT observed during the period of 1997-2006, with halo and partial halo coronal mass ejections associated with X-ray solar flares of different categories and concluded that they have concluded that majority of the observed geomagnetic storms are found that halo and partial halo CMEs associated with X ray solar flares are most potential candidates for production of geomagnetic storms.

2. Experimental Data

In this work hourly data of oulu super neutron monitor have been used to determine Forbush decreases in cosmic ray intensity. The data of different types of coronal mass ejections have been taken from SOHO – large angle spectrometric, coronagraph (SOHO / LASCO) and extreme ultraviolet imaging telescope (SOHO/EIT) data. The data of interplanetary shocks are taken from shocks arrival derived by WIND group from WIND observations, ACE list of transient and disturbances. The data of X ray solar geophysical data report U.S.Department of commerce, NOAA monthly issue and ftp://ftp.ngdc.noaa.gov/STP/SOLAR_DATA/ftp://ftp.ngdc.noaa.gov/STP/SOLAR_DATA/SOLAR_FLARES/FLARES_XRAY/data have been used.

3. Data Analysis and Results

Forbush decreases associated with intense geomagnetic storms, coronal mass ejections and interplanetary shocks during the period of 1998 to 2006 are listed in table.

Table 1 Association of Forbush decreases with intense geomagnetic storms, coronal mass ejections and interplanetary shocks for the perid of 1998 to 2006

(Fds)					Shocks	CMEs			SOLAR FLARES	
date	Onset set timedd (hh)	mag %	Onset set timedd (hh)	Mag nitud e in nT	Shock	Date time dd(hh)	Type H/P	Speed K/s	Date time dd(hh)	Class
01.05.98	01(20)	6	02(04)	-214	01(22)	29(16)	H	1602	29(29)	M-68
25.08.98	25(12)	8	26(09)	-171	26(07)	nd	nd	nd	24(22)	X10
24.09.98	24(12)	10	25(00)	-203	24(24)	nd	nd	nd	23(07)	M-71
08.11.98	08(04)	7	08(20)	-126	08(05)	05(21)	H	1118	06(15)	M-17
07.04.00	07(00)	3	06(16)	-282	na	04(17)	H	1199	06(02)	M-18
15.07.00	15(12)	12	15(15)	-308	15(15)	14(11)	H	1674	14(11)	X-57
17.09.00	17(12)	8	17(20)	-197	na	15(22)	H	537	16(04)	M-59
28.10.00	28(00)	7	28(21)	-126	28(10)	25(08)	H	948	25(09)	C-40
06.11.00	05(12)	7	06(10)	-134	06(10)	03(18)	H	643	03(20)	C-53
26.11.00	26(12)	8	26(22)	-127	26(08)	24(05)	H	1298	24(05)	X-20
19.03.01	19(03)	4	19(11)	-150	19(11)	18(02.26)	H	785	16(10)	C-54
11.04.01	11(12)	8.5	11(15)	-269	11(14)	09(16)	H	1198	09(16)	M-79
17.08.01	17(16)	7	17(17)	-102	17(11)	15(24)	H	1575	14(10)	C-97
25.09.01	25(20)	8	25(22)	-102	25(20)	23(20)	H	478	23(11)	M-11
21.10.01	21(16)	5	21(16)	-178	21(17)	19(170)	H	901	19(16)	X-16
06.11.01	05(12)	12	05(19)	-297	06(02)	04(17)	H	1810	04(16)	X-10
24.11.01	24(12)	10	24(06)	-223	24(06)	22(20)	H	1443	22(20)	M-38
29.10.03	29(00)	25	29(06)	-384	29(06)	28(11)	H	2686	28(10)	X-172
21.01.04	21(16)	8	22(05)	-144	22(01)	20(00)	H	1074	20(07)	M-61
26.07.04	26(16)	10	26(23)	-150	26(23)	23(16)	H	824	23(17)	M-22
07.11.04	07(08)	12	07(10)	-150	07(03)	07(17)	H	1759	07(16)	X-20
08.05.05	08(06)	6	07(20)	-126	07(19)	06(17)	H	1128	06(11)	M-13
15.05.05	15(00)	7	15(05)	-293	15(02)	13(17)	H	1689	13(16)	M-80
23.08.05	23(20)	7	24(08)	-219	24(06)	22(01)	H	1194	22(01)	M-26
11.09.05	11(00)	12	11(02)	-127	11(01)	09(20)	H	2257	09(19)	X-62
14.12.06	14(18)	10	14(21)	-143	14(14)	13(02.54)	H	1931	13(02)	X-34

From the data analysis given in table it is observed that the total number of Forbush decreases associated with intense geomagnetic storms is 26. The onset time of all the associated intense geomagnetic storms are found after the onset time of Forbush decreases. We have found positive correlation with correlation coefficient .48 between magnitude of Forbush decreases and magnitude of associated geomagnetic storms. From the data analysis of Forbush decreases associated with interplanetary shocks it is concluded that majority of the Forbush decreases associated with intense geomagnetic storms are also related to interplanetary shocks. We have 26 Forbush decreases in our list out of which 24 (92.30%) are found to be associated with interplanetary shocks. It is also observed that the related shocks are forward shocks. The onset time of majority of the Forbush decreases are found at ± 10 hours time lag between onset time of Forbush decreases and arrival time of interplanetary shocks. From the data analysis of Coronal mass ejections and selected Forbush decreases, we have determined that all the Forbush decreases are found to be associated with coronal mass ejections. We have 26 Forbush decreases in our list in which, we have no data of CMEs for association for two events. 24 out of 24 Forbush decreases are found to be associated with coronal mass ejections. Out of these associated Forbush decreases 23 out of 24 are found to be associated with halo coronal mass ejections and one is related to partial halo coronal mass ejections. The association rates of halo and partial halo CMEs are found 96.00% and 04.00% respectively. Positive co-relation with correlation coefficient .7025 have been found between magnitudes of Forbush decreases associated with intense geomagnetic storms and speed of associated coronal mass ejections. From the data analysis of Forbush decrease and X ray solar flares we have observed that the most of the Forbush decreases associated with intense geomagnetic storms (96.29%) are associated with X-ray solar flares of different categories. The association rates for X-Class, M-Class, and C-Class X-ray solar flares are found 34.62%, 50.00% and 15.38% respectively.

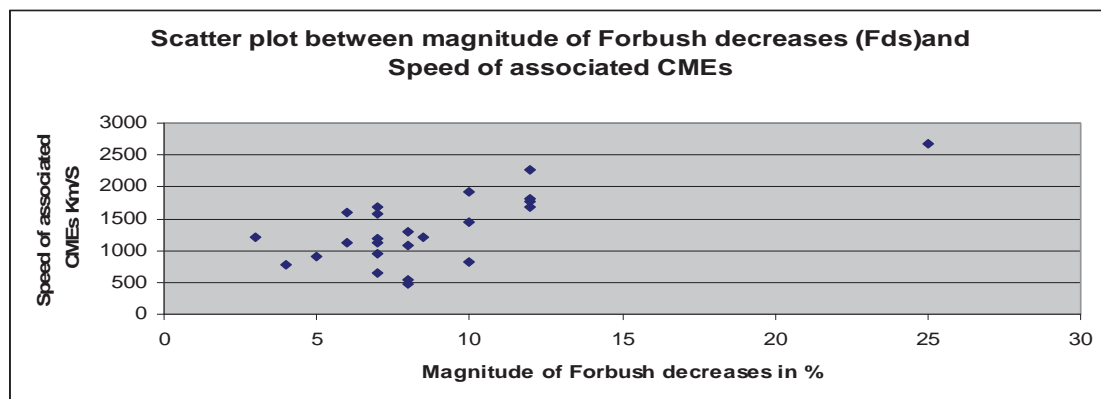


Figure 1 Shows Scatter plot between Magnitude of Forbush decrease associated with intense geomagnetic storms and speed of associated CMEs

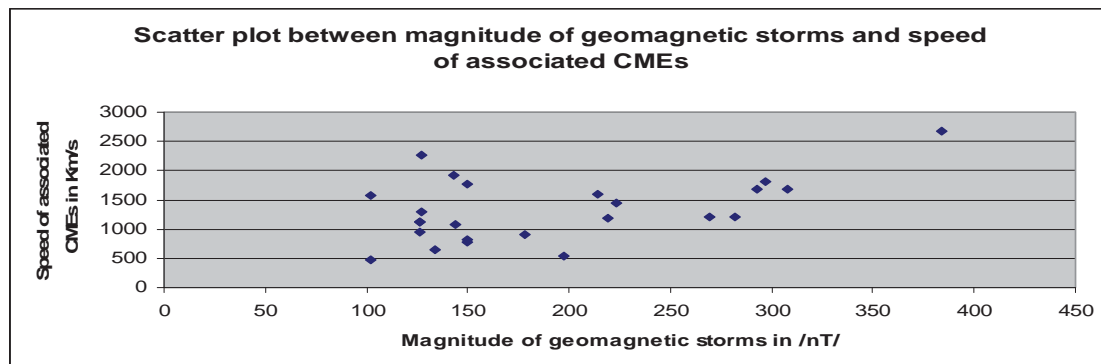


Figure 2 Shows Scatter plot between Magnitudes of intense geomagnetic storms and speed of associated CMEs

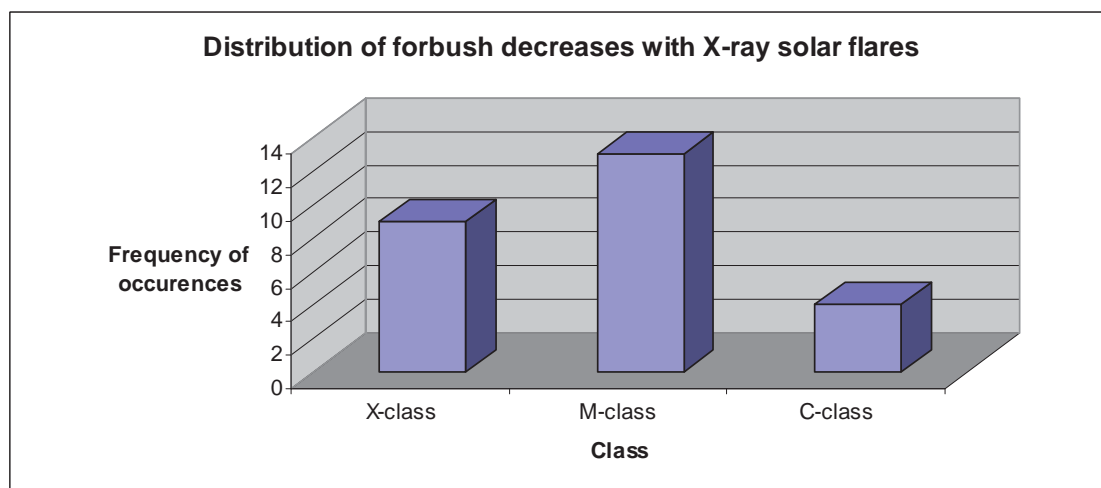


Figure 3 Shows distribution of Forbush decreases associated with intense geomagnetic storms and associated X ray solar flares

4. Conclusion

From our study we have found that Forbush decreases associated with intense geomagnetic storms are associated with halo and partial halo coronal mass ejections (CMEs). The association rate between halo and partial halo coronal mass ejections are found 96.00% and 04.00% respectively. Most of the Forbush decreases associated with intense geomagnetic storms (96.29%) are associated with X-ray solar flares of different categories. The association rates for X-Class, M-Class, and C-Class X-ray solar flares are found 34.62%, 50.00% and 15.38% respectively. Further we have concluded that majority of the Forbush decrease associated with intense geomagnetic storms are related to interplanetary shocks (92.30 %) and the related shocks are forward shocks. We have found positive co-relation with co-relation co-efficient .7025 between magnitudes of Forbush decreases associated with intense geomagnetic storms and speed of associated coronal mass ejections. Positive co-relation with co-relation co-efficient 0.48 has also been found between magnitudes of intense geomagnetic storms and speed of associated coronal mass ejections. From the above results it is concluded that Forbush decreases associated with intense geomagnetic storms are closely related with halo coronal mass ejections associated

with X ray solar flares of different categories and interplanetary shocks .Hence These Fds are caused by halo coronal mass ejections associated with hard X ray solar flares and interplanetary shocks that they generate.

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