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Halo Coronal mass Ejections: The Cause of Large Forbush Decreases and Geomagnetic Storms

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Abstract

Coronal mass ejections (CMEs) are the solar events which carry large amounts of plasma and magnetic fields into the heliosphere and are responsible for interplanetary shocks, geomagnetic disturbances in earth's magnetosphere and Forbush decreases in cosmic ray intensity. We have studied large Forbush decreases magnitude ≥8.00% observed during the period of 1997-2006, with coronal mass ejections, interplanetary shocks, magnetic clouds and geomagnetic storms. We have found that all the large Forbush decreases are associated with coronal mass ejections, majority of them are halo coronal mass ejections (H-CMEs) (94.44%).Halo coronal mass ejections (H- CMEs), which are related to Forbush decreases, are associated with strong X-ray solar flares of category X, M and C class with association rate of 23.52%, 58.82%, 17.64% respectively. We have further determined that vast majority of the Forbush decreases (95.00%) are associated with interplanetary shocks and the related shocks are forward shocks. The interplanetary shocks which are related to Forbush decreases, 52.63% of them are related to magnetic clouds and most of the magnetic clouds (80.00%) are of excellent or good quality. The start time of 90.00% magnetic clouds are found after the arrival time of interplanetary shocks. We have further determined that Forbush decreases which are associated with halo coronal mass ejections (H-CMEs), 94.11 %of them are associated with geomagnetic storms and 73.68% of them are intense geomagnetic storms. The onset time 84.21% geomagnetic storms are found after the onset time of Forbush decreases. We have concluded that halo coronal mass ejections (H-CMEs) associated with X-ray solar flares and related to interplanetary shocks, magnetic clouds or combination of both are mainly responsible for large Forbush decreases in cosmic ray intensity and geomagnetic storms in earth's magnetosphere.

Keywords:-Forbush decreases, Halo Coronal Mass Ejections, , Geomagnetic storms.

I.INTRODUCTION

Coronal mass ejections (CMEs) are major solar events that eject large amount of mass and magnetic fields into heliosphere .The more energetic CMEs are typically accompanied by flares, which accelerate massive particles. Some CMEs propagate towards the earth, and are called "halo" CMEs, because of their appearance in coronograph images. Such earth-directed CMEs expand and propagate in interplanetary space, transforming into what are commonly called interplanetary CMEs [1,2]. Fast CMEs often propagate through the solar wind at super-Alfvenic speeds, driving shocks ahead of them [3]. The shocks driven by CMEs are frequently responsible for driving large geomagnetic storms [4,5,6,7].and Forbush decreses in cosmic ray intensity [8,9,10,11,12,13,14,15,] .The role of CMEs and their near-earth counterparts in causing Forbush decreases at the earth has been well documented [12]. It is now fairly well known that magnetic clouds are well correlated withForbush decreases [16,17,18,19,20,21] for the opposite viewpoint, some authors assume that the Forbush decrease is entirely due to the magnetic cloud [22,23,24]. In this investigation, we have associated large Forbush decreases with halo coronal mass ejections, interplanetary shocks, magnetic clouds and geomagnetic storms for the period 1996-2006 and an attempt has been made to know the role of halo coronal mass ejections, their interplanetary manifestations in producing large geomagnetic storms and Forbush decreases in cosmic ray intensity .

II. 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 ≥8.00%.

Hourly Dst indices of geomagnetic field have been used over the period 1997 through 2006 to determine onset time, maximum depression time, magnitude of geomagnetic storms. This data has been taken from the NSSDC omni web data system.. The magnetic cloud data are taken from the table of magnetic clouds determined by WIND/MFI group (http://gsfc.nasa.gov/mfi/mag_cloud_publ.html). The data of CMEs and shocks have been taken from the list of shocks derived by PM/MTOF group from the SOHO observations, shocks arrival derived by the IPS group from ACE observations, shock arrival derived by WIND group from WIND observations SOHO, LASCO, CME catalogue which consists all CMEs manually identified since 1996 from large angle and spectrometric coronagraph (LASCO) on board the solar and hemispheric observatory misson (SOHO).(http://umtof.edu/pm/shocks.html,www.lmsal.com/cgidiaposon/www_getcme_list_sh,htpp://pwg.gsfc.nasa.gov/wind/current_listIPS.html).

Table No 1Association of Forbush decreases with CMEs, Interplanetary Shocksand Magnetic Clouds.

	FORBUSH DECREASES			GOMAGNETIC STORMS		SHOCK		MAGNETIC CLOUD			CMES			SOLAR FLARE	
S.N.	date	Onset set timedd (hh)	Mag nitu de in %	Onset set timedd (hh)	Mag nitu de in nT	Shock Arrival time dd(hh)	Tfds -Tsh (hh)	Start time dd(hh)	End time dd(hh)	Qua lity	Start time dd(hh)	Type H/P	Speed K/s	Start time dd(hh)	**Class**
1	25.08.98	25(00)	8.0	26(11)	-143	NA	NA	NA	NA	NA	ND	ND	ND	23(09)	M-22
2	24.09.98	24(04)	10.0	25(00)	-203	24(23)	-19	25(10)	26(13)	2	ND	ND	ND	23(07)	M-71
3	08.11.98	08(12)	8.0	08(20)	-126	08(04)	8	08(23)	10(01)	1	05(02)	H	460	07(11)	M-24
4	12.12.99	12(12)	8.0	12(08)	-77	12(15)	-3	NA	NA	NA	11(20)	p	348	10(02)	C-37
5	08.06.00	08(12)	8.0	08(15)	-89	08(09)	3	NA	NA	NA	06(16)	H	1130	05(14)	M-15
6	15.07.00	15(08)	10.0	15(15)	-308	15(14)	-6	15(06)	15(14)	2	14(10)	H	1815	14(10)	X-5.7
7	17.09.00	17(08)	8.0	17(20)	-197	17(17)	-9	18(01)	18(15)	3	15(22)	H	537	16(04)	M-59
8	04.04.01	04(16)	8.0	04(16)	-59	04(14)	2	04(20)	05(08)	1	01(11)	H	1683	01(11)	M-55
9	11.04.01	11(12)	12.0	11(15)	-269	11(15)	-3	12(07)	12(17)	2	09(15)	H	2974	09(16)	M-69
10	06.11.01	06(00)	11.0	05(19)	-297	06(01)	-1	NA	NA	NA	03(19)	H	457	03(20)	C-38
11	24.11.01	24(04)	10.0	24(06)	-223	24(06)	-2	24(15)	25(13)	3	21(14)	H	518	21(14)	C-47
12	29.05.03	29(08)	9.0	NA	NA	29(12)	-4	NA	NA	NA	27(07)	H	509	27(22)	X-1.3
13	22.01.04	22(00)	8.5	22(05)	-144	22(01)	-1	NA	NA	NA	20(00)	H	1074	20(07)	M-61
14	27.07.04	27(00)	10.0	27(02)	-148	26(22)	2	NA	NA	NA	25(15)	H	1366	25(14)	M-22
15	07.11.04	07(04)	12.0	07(20)	-376	07(02)	2	08(03)	08(16)	2	04(10)	H	719	04(08)	C-63
16	15.05.05	15(00)	10.0	15(05)	-293	15(02)	-2	15(05)	15(22)	2	13(17)	H	1689	13(16)	M-80
17	16.07.05	16(12)	8.0	17(06)	-77	17(01)	-13	17(15)	18(03)	2	13(14)	H	1390	13(14)	M-50
18	24.08.05	24(08)	8.0	24(08)	-219	24(06)	2	NA	NA	NA	22(02)	H	1194	22(00)	M-26
19	10.09.05	10(20)	11.5	10(13)	-61	11(01)	-5	NA	NA	NA	09(20)	H	2693	09(19)	X-6.2
20	14.12.06	14(10)	8.0	14(00)	-138	14(14)	-4	NA	NA	NA	13(02)	H	1931	14(21)	X-1.5

III. ANALISIS ANDRESULTS

The statistical analysis of the association of Forbush decreases with coronal mass ejections, interplanetary shocks, magnetic clouds and geomagnetic storms shows that all of the Forbush decreases are associated with coronal mass ejections. We have 20 Forbush decreases magnitude ≥8.00%, the available data of CMEs for association are18. From the data analysis of Forbush decreases and coronal mass ejections, we have found that out of 18 associated Forbush decreases, 01(5.55%) Forbush decrease is found to be associated with partial halo CMEs where as 17 (94.44%) Forbush decreases are found to be associated with full halo CMEs. Halo coronal mass ejections, which are related with Forbush decreases, are also associated with solar flares of different categories. In this study 17out of 18 Forbush decreases are found to be associated with H-CMEs in which all H- CMEs are associated with X-ray solar flares of different categories. 23.52% H-CMEs are associated with X class, 58.82%H- CMEs are associated with M class, 17.64% H-CMEs are associated with C class X-ray solar flares. To know the relation between magnitude of Forbush decreases and speed of associated coronal mass ejections, we have plotted a scatter diagram between magnitude of Forbush decreases and speed of associated coronal mass ejections .The resulting scatter plot is shown in fig 1.from the figure, it is clear that there is medium positive correlation between magnitude of Forbush and speed of associated coronal mass ejections, statistically calculated correlation coefficient is.38 From the further analysis it is observed that these Forbush decreases are also related to the interplanetary shocks and the related shocks are forward shocks. We have 20 Forbush decreases in our list out of which 19(95.00%)are found to be associated with interplanetary shocks . From the further analysis it is observed that Forbush decreases wich are related to interplanetary shocks some of them are also related to magnetic clouds .We have found 19 Forbush decreases which are related to interplanetary shocks out of these 10 Forbush decreases are also found to be associated with magnetic clouds of different qualities. In the related magnetic clouds 20.00% magnetic clouds are of excellent quality, 60.00 % magnetic clouds are of good quality, 20.00% magnetic clouds are of poor quality. The start time of 90.00% magnetic clouds are found after the arrival time of interplanetary shocks. We have further determined that Forbush decreases which are associated with halo coronal mass ejections (H-CMEs), 94.11 %of them are associated with geomagnetic storms and 73.68% of them are intense geomagnetic storms. The onset time 84.21% geomagnetic storms are found after the onset time of Forbush decreases.

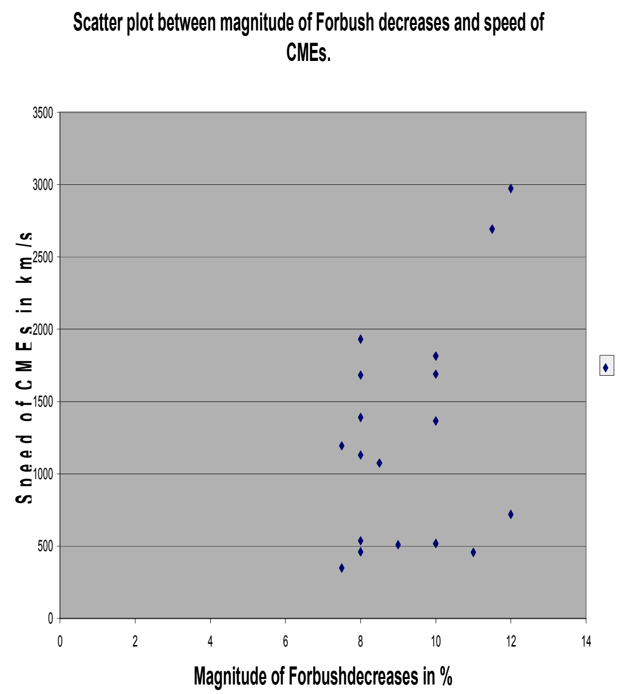

Figure1. Shows scatter plot between magnitude of Forbush dcreases and speed of associated H-CMEs showing positive correlation with correlation coefficient .38

IV.CONCLUSIONS

From our study 17 out of 18 Forbush decreases ≥8.00%, have been identified as being associated with halo coronal mass ejections (CMEs), related to X-ray solar flares. 19out of 20 as being associated with interplanetary shocks and out of these 19, 10 are as being associated with magnetic clouds. 16out of 17 as being associated with halo coronal mass ejections and geomagnetic storms giving an association rates 94.44%,with halo coronal mass ejections 95% with interplanetary shocks52.63 with shocks magnetic clouds both and 94.11%with halo coronal mass ejections and geomagnetic storms respectively. These results are suggesting that the halo coronal mass ejections related X-ray solar flares associated with magnetic clouds, shocks or both are very much effective in producing Large Forbush decreases in cosmic ray intensity, geomagnetic storms in geomagnetic field.

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