Coronal Mass Ejections, Storms in Solar Wind Plasma Parameters and Magnetic Clouds In Relation With Intense Geomagnetic Storms

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Abstract.

Coronal mass ejections are most energetic solar events that eject huge amount of mass and magnetic fields into the heliosphere and are widely recognized as being responsible to generate storms in solar wind plasma parameters and geomagnetic storms in the magnetosphere of the earth. We have studied geomagnetic storms Dst ≤ - 100nT observed during the period of 1997-2006, with halo and partial halo coronal mass ejections associated with X-ray solar flares, interplanetary shocks, and magnetic clouds, which are interplanetary manifestations of coronal mass ejections. We have found that 84.93% geomagnetic storms are associated with halo and partial halo coronal mass ejections. The association rate of geomagnetic storms with halo and partial halo coronal mass ejections are found 74.91% and 25.81% respectively. The halo and partial halo coronal mass ejections, which are related to geomagnetic storms, majority of them are associated with X-ray solar flares (90.00%). Further we have concluded that majority of the geomagnetic storms are associated with forward shocks (88.16%) and some of them are related to magnetic clouds (50.74%) also. From the study of geomagnetic storms with storms in solar wind plasma parameters, we have determined positive co-relation between magnitude of geomagnetic storms and peak values of associated storms in solar wind plasma parameters with co-relation co-efficient .32 between magnitude of geomagnetic storms and peak values of associated storms in solar wind plasma temperature, .48 between magnitude of geomagnetic storms and peak values of associated storms in solar wind plasma velocity , .68 between magnitude of geomagnetic storms and peak values of associated storms in interplanetary magnetic field. We have concluded that halo and partial halo coronal mass ejections associated X-ray solar flares and related to forward shocks, magnetic clouds or both are very much effective in producing intense geomagnetic storms.

Keywords: Intense geomagnetic storms. Halo and Partial Halo Coronal Mass Ejections. Storms in Solar Wind Plasma Parameters.

I. INTRODUCTION

Geomagnetic storms are the significant perturbations of the earth's magnetosphere that occur when the interplanetary magnetic field (IMF) turns southward (Bz<o) and remains so for a prolong period of time [1, 2]. The two classes of geomagnetic storms [3] recurrent and non recurrent have been studied by R. Londi and G. Moreno [4] with coronal mass ejection and they have concluded that CMEs which are associated with enhanced solar soft X ray emission, are responsible for large fraction of geomagnetic storms. Crooker and Cliver [5] have concluded that the non-recurrent geomagnetic storms are caused by coronal mass ejections and coronal holes / streamer, ensemble. I.G. Richardson et al [6] have determined that intense geomagnetic activity often associated with CME related structure and intense geomagnetic storms are produced by coronal mass ejection at any stage of the solar cycle. Lyatsky.W and Tan. A[7] have studied geomagnetic storms with disturbances in solar wind plasma parameters. They have concluded that the averaged disturbances in solar wind, responsible for generating geomagnetic storms are associated with compression of ambient solar wind plasma and interplanetary magnetic field ahead of a high speed plasma flow. The magnetic field strength and plasma density start to increase, several hours before geomagnetic storm onset; however, the negative IMFBz start to increase approximately 4or 5 hours after the maximum variation in plasma and IMF By. Michalek, G: Gopalswamy N, et al [8] have studied geomagnetic storms with properties of halo coronal mass ejections (H-CMEs) and concluded that only fast halo CMEs with space velocity higher than 1000 km/s and originating from the western hemisphere close to the solar center could cause intense geomagnetic storms.. Magnetic clouds, interplanetary shocks, ejecta are the interplanetary manifestations of coronal mass ejections. Zhang and Burlaga [9] have studied geomagnetic storms with magnetic clouds and found that magnetic clouds can produce geomagnetic storms with the larger storms being associated with shock related clouds. The time of onset of the geomagnetic activity coincides with the arrival of magnetic clouds when the magnetic field is oriented southward at the cloud onset and it occurs later during the cloud when the magnetic field is oriented northward at the cloud onset.Richardson.et al. [10] Have investigated geomagnetic storm with coronal mass ejections, thy have determined that intense geomagnetic storm are produced by coronal mass ejections at any stage of solar cycle.. Shrivastava N. [11] has examined the solar origin of the geoeffective CMEs and their interplanetary effects, namely, solar wind speed, interplanetary shocks and the southward component of the interplanetary parameters. They have found that full halo CMEs associated with strong flares, are responsible for intense GMs .

Gopalswamy.N.et al [12] have studied geoeffectiveness, speed, solar source, and flare association of a set of 378 halo coronal mass ejections (HCMEs) of solar cycle 23 (1996-2005). 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. They have concluded that disk halos and limb halos CMEs are very much effective in producing geomagnetic storms. In this investigation an attempt has been made to know the role of coronal mass ejections (CMEs)interplanetary shocks, magnetic clouds, which are interplanetary manifestations of coronal mass ejections and disturbances in solar wind plasma parameters in producing geomagnetic storms.

II. DATA AND ANALYSIS

In this investigation 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 which has been created in late 1994 for enhanced access to the near earth solar wind, magnetic field and plasma data of omni data set, which consists of one hour resolution near earth, solar wind magnetic field and plasma data, energetic proton fluxes and geomagnetic and solar activity indices. 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)onboardard(SOHO)..(http://umtof.edu/pm/shocks.html,www.lmsal.com/cgidiapo-son/www_getcme_list_sh,htpp://pwg.gsfc.nasa.gov/wind/current_listIPS.html). The solar wind plasma parameter data has also been taken from NSSDC omni web datasyatem.

TABLE NO 1 Association of intense geomagnetic storms with coronal mass ejections, interplanetary shocks, magnetic clouds and solar wind plasma parameters.

S. No.	Geomagnetic Storms			Coronal Mass Ejections								
	Date	Onset set timedd (hh)	Magnitude in nT	Date	Time dd(hh)	Typ eH/P	Associated Solar Flares	Peak Temperature in degree Kelvin	Peak velocity in Km/s	Peak IMF	shocks	clouds
1	21-04-97	21(12)	-101	NA	NA	NA	NA	43958	422	13.9	NA	ND
2	15-05-97	15(04)	-113	12/5/1997	12(05)	H	C-13	341122	444	35.3	15 (01)	15 (09)
3	03-09-97	3(18)	-103	30/08/97	30(07)	H	B-55	123020	415	17.3	03 (08)	ND
4	01-10-97	1(02)	-100	28/09/97	28(010	H	NA	187187	490	13.8	01 (01)	01 (16)
5	10-10-97	10(17)	-109	6/10/1997	06(15)	P	NA	124070	449	13.8	10 (16)	10 (24)
6	06-11-97	6(23)	-105	4/11/1997	04(06)	H	X2.1	179980	468	15.8	06 (22)	07 (15)
7	22-11-97	22(10)	-106	NA	NA	NA	C-16	415513	524	26.6	22 (09)	22 (15)
8	17-02-98	17(14)	-105	12/2/1998	12(16)	P	B-33	56091	416	21.3	18 (08)	ND
9	10-03-98	10(13)	-110	NA	NA	NA	C-11	NA	529	21.4	NA	ND
10	02-05-98	2(09)	-203	29/04/98	29(07)	H	M-68	420844	651	18.9	01(22)	02(12)
11	06-08-98	6(02)	-139	ND	ND	ND	ND	41563	428	21.3	06(07)	ND
12	26-08-98	26(11)	-143	ND	ND	ND	ND	2092158	847	18.9	26(07)	ND
13	25-09-98	25(00)	-203	ND	ND	ND	ND	907650	839	28.7	25(00)	25(10)
14	19-10-98	19(02)	-111	15/10/98	15(10)	H	M-24	179467	430	26.2	18(20)	19(05)
15	07-11-98	7(11)	-139	4/11/1998	04(08)	H	C-1	331265	537	12.6	07(08)	ND
16	08-11-98	8(20)	-126	5/11/1998	05(20)	H	M-84	151837	639	35.4	08(05)	08(23)
17	13-11-98	13(00)	-129	10/11/1998	10(06)	P	C-33	63578	412	20.2	13(02)	ND
18	13-01-99	13(11)	-105	ND	ND	NA	C-69	80074	425	18.7	13(11)	ND
19	18-02-99	18(03)	-125	ND	ND	NA	M-32	518339	673	28.3	18(03)	18(14)

20	22-09-99	22(18)	-182	19/09/99	19(17)	P	C-49	320171	602	28.4	22(12)	21(21)
21	22-10-99	22(00)	-214	19/10/99	19(050	P	C-29	525759	504	20.2	21(15)	ND
22	11-02-00	11(07)	-132	8/2/2000	8(10)	H	M-13	256885	505	10.1	11(03)	ND
23	06-04-00	6(16)	-282	4/4/2000	4(16)	H	C-97	345986	589	31.4	06(16)	ND
24	24-05-00	24(00)	-151	22/05/00	22(02)	H	C-63	468151	631	34.1	24(17)	ND
25	15-07-00	15(15)	-308	12/7/2000	12(13)	H	X-19	1501458	1010	51.9	15(15)	15(06)
26	12-08-00	12(01)	-214	9/8/2000	9(16)	H	NA	400136	671	33.6	11(09)	12(06)
27	17-09-00	17(20)	-197	15/09/00	15(22)	H	C-14	920518	839	39.5	17(17)	18(02)
28	03-10-00	3(23)	-156	21/10/00	2(04)	H	C-44	29535	461	18.4	03(01)	03(17)
29	13-10-00	13(14)	-100	9/11/2000	9(24)	H	C-67	265699	469	18	12(22)	13(18)
30	28-10-00	28(01)	-126	25/10/00	25(08)	H	C-40	157899	415	18.8	28(10)	28(23)
31	05-11-00	5(10)	-150	31/11/00	3(18)	H	C-32	487233	594	ND	06(09)	ND
32	10-11-00	10(07)	-102	8/11/2000	8(05)	H	C-52	2228444	910	13.8	10(06)	ND
33	26-11-00	26(22)	-127	23/11/00	23(06)	H	C-54	631551	623	27.7	26(11)	ND
34	19-03-01	19(11)	-150	18/03/01	18(02)	H	B-58	NA	490	18.3	19(11)	19(23)
35	31-03-01	31(04)	-379	29/03/01	2910	H	X-17	704151	716	46.9	31(01)	ND
36	11-04-01	11(15)	-269	9/4/2001	916	H	M-79	849339	732	34.5	11(14)	12(08)
37	18-04-01	18(01)	-106	15/04/01	1514	P	X14.4	301239	518	23.8	18(01)	ND
38	22-04-01	22(00)	-106	18/04/01	1803	H	C-22	70688	388	15.1	21(15)	22(01)
39	17-08-01	17(17)	-102	14/08/01	1416	H	NA	316649	599	10.3	17(12)	ND
40	21-10-01	21(16)	-178	19/10/01	1901	H	X16	529177	676	28.4	21(17)	ND
41	31-10-01	31(14)	-104	30/10/01	3003	P	C-60	190892	502	19.5	28(03)	ND
42	05-11-01	5(19)	-297	3/11/2001	320	H	C-38	66992	387	13.9	31(14)	31(21)
43	24-11-01	24(06)	-223	22/11/01	2221	H	M-38	135790	426	21.6	06(02)	ND
44	17-04-02	17(11)	-149	15/04/02	1504	H	M-12	2464027	946	56.9	24(05)	24(16)
45	11-05-02	11(13)	-103	8/5/2002	814	H	C-28	396426	611	30.4	17(11)	18(04)
46	01-08-02	1(23)	-105	29/07/02	2924	P	C-12	224668	441	18.8	11(11)	ND
47	18-08-02	18(22)	-110	16/08/02	1613	H	M-52	311710	524	14.1	01(05)	01(12)
48	04-09-02	4(02)	-102	NA	NA	NA	M-10	571733	573	13.8	18(19)	ND
49	06-09-02	6(09)	-159	5/9/2002	517	H	C-52	257857	442	16.3	04(18)	ND
50	01-10-02	1(04)	-156	NA	NA	NA	NA	124893	457	NA	NA	ND
51	21-11-02	21(02)	-122	19/11/02	1903	P	C-49	112901	413	25.1	NA	ND
52	27-05-03	27(23)	-118	26/05/03	2618	P	M-10	503038	727	10.2	20(11)	ND
53	16-06-03	16(10)	-136	15/06/03	1523	P	X13	320258	716	12	NA	ND
54	10-07-03	11(00)	-109	NA	NA	NA	X3.6	249171	594	11.2	NA	ND
55	17-08-03	17(17)	-171	14/08/03	1420	H	C-46	529872	360	12.8	NA	10(20)
56	28-10-03	28(06)	-384	27/10/03	2708	P	M-27	236723	530	22.2	17(14)	18(12)
57	20-11-03	20(02)	-461	18/11/03	1808	H	M-39	1044292	809	18.2	28(02)	ND
58	22-01-04	22(05)	-144	21/01/04	2104	H	C-12	534783	703	55.8	20(07)	20(11)
59	11-02-04	11(10)	-107	NA	NA	NA	m-12	585976	666	19.2	22(01)	ND
60	03-04-04	3(14)	-113	29/03/04	2901	P	B-61	100962	702	16.5	NA	ND
61	22-07-04	22(20)	-106	20/07/04	2014	H	M-86	121421	504	10.2	03(09)	04(03)
62	24-07-04	24(11)	-198	23/07/04	2316	H	M-22	981133	672	18.9	22(10)	22(15)
63	30-08-04	30(02)	-119	NA	NA	NA	B-46	479820	600	21	24(06)	24(13)
64	07-11-04	7(20)	-376	NA	NA	NA	M-40	59302	440	13.2	29(10)	29(19)

65	16-01-05	16(20)	-117	13/01/05	1324	P	C-68	808505	730	46.4	07(02)	08(03)
66	21-01-05	21(19)	-103	20/01/05	2007	H	X7.1	184011	578	9.5	17(07)	ND
67	07-05-05	7(20)	-126	5/5/2005	521	H	C-78	918810	565	16.6	07(19)	ND
68	15-05-05	15(05)	-293	13/05/05	1317	H	M-80	959643	959	54.2	15(02)	15(06)
69	20-05-05	20(04)	-101	17/05/05	1703	P	M-18	54918	473	15	20(04)	20(07)
70	29-05-05	29(22)	-150	26/05/05	2615	H	B-75	270337	540	17	19(09)	ND
71	12-06-05	12(17)	-109	9/6/2005	915	P	C-10	474130	500	23.4	12(07)	12(16)
72	10-07-05	10(11)	-100	7/7/2005	717	H	M-49	308733	466	25.2	10(03)	ND
73	24-08-05	24(08)	-219	22/08/05	2202	H	M-26	456378	707	52.2	24(06)	ND
74	31-08-05	31(12)	-138	29/08/05	2911	H	NA	190393	414	18.6	30(19)	ND
75	10-09-05	10(13)	-127	9/9/2005	920	H	X6.2	NA	NA	18.2	11(01)	ND
76	14-04-06	14(0)	-111	12/4/2006	1217	H	NA	367605	546	19.8	NA	ND

III. RESULTS

The association between intense geomagnetic storms < –100nT and coronal mass ejections (CMEs), interplanetary shocks, magnetic clouds,and disturbances in solar wind plasma parameters for the period 1997 to 2006 are given in Table No.1. From the data analysis it is observed that 62out of 73 (84.93%) intense geomagnetic storms < –100nT are found to be associated with coronal mass ejections. We have 76 intense geomagnetic storms in our list in which the CME data for association is available for 73 geomagnetic storms. We have further observed that the majority of related CMEs are halo CMEs.We have sixty two intense geomagnetic storms, which are associated with coronal mass ejections out of which 46 intense geomagnetic storms (74.19%) are related to the halo coronal mass ejections. Only 25.81% intense geomagnetic storms are found to be associated with partial halo coronal mass ejections. We have also determined that the coronal mass ejections, which are related to geomagnetic storms, are also related to the X-ray solar flares of different categories. Out of 62associated CMEs, 08(12.90%) are related with X-class, 17(27.42%) are related with M-class, 26(41.93%) are found to be related with C-class and 05(8.060%are found to be associated with B class X-ray solar flares. From the further analysis it is observed that mejority of these intense geomagnetic storms are also related to the interplanetary shocks and the related shocks are forward shocks,67out of 76(88.16%).We have observed that Intense geomagnetic storms which are related to interplanetary shocks some of them are also related to magnetic clouds. We have 67geomagnetic storms which are related to shocks in whish 34 are also related to magnetic clouds 50.74%., From the study of geomagnetic storms with storm in solar wind plasma parameters i.e. jump in solar wind temperature (JSWT), jump in solar wind density (JSWV) and jump in interplanetary magnetic field, it is inferred that geomagnetic storms of higher magnitudes are found to be associated with such JSWT,JSWVanand jump in interplanetary magnetic field events, which have relatively higher peak values of temperature,velocity and interplanetary magnetic field . . We have determined positive correlation between magnitude of geomagnetic storms and peak values of associated JSWT events. Statistically calculated correlation coefficient is .32 between these two events. Positive correlation has been found between magnitude of geomagnetic storms and peak values of of associated JSWV events, statistically calculated co-relation co-efficient have been found.48. Large positive correlation has been found between magnitude of geomagnetic storms and peak values of interplanetary magnetic field with correlation coefficient.68

IV. CONCLUSION

From our study 62 out of 73 intense geomagnetic storms < -100nT have been identified as being associated with coronal mass ejections and 90%of them are related to X-ray solar flares (CMEs). .67out of 76(88.16%)are identified as being associated with interplanetary shocks .It is observed that Intense geomagnetic storms which are related to interplanetary shocks some of them are also related to magnetic clouds .We have 67geomagnetic storms which are related to shocks in whish 34 are also related to magnetic clouds 50.74%.. These results are suggesting that the X-ray solar flares related coronal mass ejections associated with magnetic clouds, shocks or both are very much effective in producing major geomagnetic storms. The positive correlation between magnitude of geomagnetic storms and peak values of solar wind temperature, velocity, and interplanetary magnetic fields suggests that disturbances in solar wind parameters play also crucial role in producing intense geomagnetic storms

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