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Study of Flare Related Intense Geomagnetic Storms with Solar Radio Burst and JIMF

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Abstract:

We have studied X and M-Class X -Ray solar flares related intense geomagnetic storms observed during the period of 2000-2006 with halo and partial halo coronal mass ejections, solar radio bursts and disturbances in solar wind plasma parameters. We have found that 82.45% X and M-Class X-Ray solar flare related intense geomagnetic storms are associated with halo and partial halo coronal mass ejections. The association rate of halo and partial halo coronal mass ejections are found 78.72 % and 21.27 % respectively. Further we have observed that 71.92% X and M-Class X-Ray solar flare related intense geomagnetic storms are associated with solar radio bursts. The association rate of type IV and type II radio bursts have been found 60.97 % and 39.03% respectively. From the study of X and M-Class X-Ray solar flare related intense geomagnetic storms with jump in interplanetary magnetic field, we have determined positive co-relation with co-relation co-efficient, 0.71 between magnitude of X and M-Class X-Ray solar flare related intense geomagnetic storms and peak values of associated jump in interplanetary magnetic field, 0.69 between magnitude of X and M-class X-Ray solar flare related intense geomagnetic storms and magnitude of jump in interplanetary magnetic fields.

Key words: Coronal Mass Ejections, X-Ray Solar Flares, Solar Radio Bursts, Intense Geomagnetic Storms, JIMF.

INTRODUCTION

The geospheric environment is highly affected by the solar active regions associated solar features and interplanetary parameters such as solar flare (SFs), active prominences disappearing filaments (APDFs), coronal holes, magnetic clouds, coronal mass ejections (CMEs), radio bursts interplanetary shocks and disturbances in solar wind plasma parameters . The active regions and related major classes of solar activity tend to track the sunspot number during the cycle, including, radio burst, calcium plages, solar flares, filaments, and coronal mass ejections (CMEs) (Webb and Howard, 1994). Several scientist have investigated relation between solar features and interplanetary parameters (Leamon et al. 2004, Bothmer and Schwenn 1994, Marubashi 1997, Zhao and Hoeksema 1998, Crooker 2000, McAllister and Martin 2000, Yurchyshyn et al. 2001, Luhmann et al. 2002 and Zhao and Webb 2003) and suggested that there is a straightforward relationship between the solar features and interplanetary parameters and it is inferred that geomagnetosphere is highly effected by solar active regions associated solar features and interplanetary parameters. Earth-directed CMEs are likely to impact the magnetosphere to cause geomagnetic storms in geomagnetosphere (N Gopalswamy, 2006, Manoharan 2006). The intensity of geomagnetic storms is primarily decided by the speed of CME and strength of magnetic field it contains (Gopalswamy, 2002, Cane, et al 2000), whereas according to Manoharan(,2006), primary factors determining the geoeffectiveness are the direction of propagation of CMEs, its speed, size, density, orientation and strength of the magnetic field at the near earth space. Intense geomagnetic storms are found to be mainly caused by CMEs (Landi and Moreno et al 1998, Zhang, et al 2003, Gopalswamy 2002, Cid, et al 2004, Gopalswamy, 2007, Michalek G.et al 2006, Correiaa, and de Souzaa 2005, Gopalswamy et al. 2008 , Gopalswamy 2009). Tsurutani et al 1988 and Echer et al 2004 have studied geomagnetic storms with interplanetary magnetic fields and inferred that the main cause of intense geomagnetic storms is the large IMF structure which has an intense and long duration southward magnetic field component, Bz .They interact with the earth's magetic field and facilitate the transport of energy into the earth's atmosphere through the reconnection process.

Zhang et al (2007) have studied, 88 major geomagnetic storms (Dst < -100 nT) that occurred during 1996-2005. They have found that 53 (60%),) S-type, in which the storm is associated with a single ICME and a single CME at the Sun ,24 (27%), M-type, in which the storm is associated with a complex solar wind flow produced by multiple interacting ICMEs arising from multiple halo CMEs launched from the Sun in a short period; and 11 (13%), C-type, in which the storm is associated with a CIR formed at the leading edge of a high-speed stream originating from a solar coronal hole (CH).Echer, E et al (2004) 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 correlated with Dst. They have also observed that during solar maximum, 36% of interplanetary shocks are followed by intense (Dst≤-100 nT) and 28% by moderate (-50≤Dst <-100 nT) geomagnetic activity. During solar minimum, 13% and 33% of the shocks are followed by intense and moderate geomagnetic activity, respectively .Chao Yuea nd Qiugang Zong (2011) have investigated interplanetary shocks associated with coronal mass ejections (CMEs) with geomagnetic storms and concluded that interplanetary shocks associated with coronal mass ejections (CMEs have very profound effects on geomagnetic storms. C. Oprea1 et al (2013) have studied solar and interplanetary parameters and found that the superposed epoch analysis revealed the strong dependence of the geomagnetic storm intensity on the southward component of the interplanetary magnetic field, Bz, which leads to magnetic reconnection between the IP structures and Earth's front-side magnetic field. This strong dependence between the storm intensity and Bz has been well established by the past studies (Wu and Lepping, 2002; Srivastava and Venkatakrishnan, 2004; Echer et al., 2008).In this investigation X and M class solar flare related intense geomagnetic storms observed during the period of 2000-2006 have been studied with coronal mass ejections, radio bursts and disturbances in solar wind plasma parameters to know the physical process mainly responsible generate intense geomagnetic storms .

DATA SOURCES

In this study geomagnetic storms associated with X and M class X-ray solar flares have been studied with coronal mass ejections, radio bursts, and JIMF observed during the period of 2000-2006. To determine geomagnetic storms hourly data of Dst index has been used and these data has been taken from Omni web data (http;//omniweb.gsfc.nasa.gov/form/dxi.html). The data of coronal mass ejections (CMEs) have been taken from SOHO – large angle spectrometric, coronagraph (SOHO / LASCO) and extreme ultraviolet imaging telescope (SOHO/EIT) data. The data of solar radio bursts and X-ray solar flares are taken from STP solar data (http://www.ngdc.noaa.gov/stp/solar/solardataservices.html).

	X and M Class Related Intense Geomagnetic storms, Associated Solar Features and IMF									
	Geomagnetic storms			**IMF**			**CMEs**		**SF**	**Radio bursts**
S. NO.	Date	Onset time in dd(hh)	Magnitude in nT	Start time in dd(hh)	Maximum IMF	Magnitude in nT	types H/P	Speeds km/sec.	Class	Type
1	11.02.00	11(07)	-132	11(23)	20.6	14.3	H	1079	M-13	II
2	06.04.00	06(16)	-282	06(10)	31.4	26.5	H	1188	M-10	II
3	24.05.00	24(00)	-151	23(15)	32.1	24.8	H	649	M13	IV
4	15.07.00	15(15)	-308	15(08)	51.9	45.2	H	1674	X-57	II
5	12.08.00	12(01)	-214	11(17)	33.6	24.1	H	702	M11	II
6	17.09.00	17(20)	-197	17(14)	39.5	34.1	H	1215	M-59	IV
7	03.10.00	03(23)	-156	03(00)	18.4	12.9	P	703	M-10	II
8	13.10.00	13(14)	-100	12(19)	18	12	H	798	M15	II
9	28.10.00	28(21)	-126	28(18)	18.8	10.1	H	770	M11	II
10	05.11.00	05(10)	-150	04(23)	14.2	4.8	H	291	C-32	na
11	10.11.00	10(07)	-102	10(05)	17.8	8.2	H	474	M74	IV
12	26.11.00	26(22)	-127	26(08)	27.7	24.2	H	1254	X-23	II
13	19.03.01	19(11)	-150	19(09)	21.5	15.2	H	752	M11	II
14	31.03.01	31(04)	-379	30(21)	47.1	43.8	H	427	M-17	IV
15	11.04.01	11(15)	-269	11(09)	34.5	30.1	H	1192	M-79	IV
16	18.04.01	18(01)	-106	17(23)	23.8	18.9	P	1199	X-144	IV
17	22.04.01	22(00)	-106	21(21)	15.1	9.6	P	1160	M41	na
18	17.08.01	17(17)	-102	17(07)	32.1	28	H	1575	M10	II
19	21.10.01	21(16)	-178	21(13)	28.4	21.7	H	558	X-16	II
20	28.10.01	28(01)	-142	27(22)	19.5	12.8	H	1092	X-13	IV
21	31.10.01	31(14)	-104	31(18)	13.9	7.8	P	1005	M30	IV
22	05.11.01	05(19)	-297	05(12)	65.6	51.2	H	1810	X-10	IV
23	24.11.01	24(06)	-223	24(04)	56.9	51.2	H	1443	M-38	II
24	17.04.02	17(11)	-149	17(07)	30.4	23.2	H	720	M-12	IV
25	11.05.02	11(13)	-103	11(05)	19.4	13.3	H	614	M14	na
26	01.08.02	01(23)	-105	01(01)	14.4	7.4	P	360	M12	IV
27	18.08.02	18(22)	-110	18(18)	13.8	9.1	H	1585	M-52	II
28	04.09.02	04(02)	-102	03(07)	18.9	9.1	na	na	M10	na
29	06.09.02	06(09)	-159	na	na	na	P	513	M10	II
30	01.10.02	01(04)	-156	01(06)	24.8	4	na	na	M31	na
31	21.11.02	21(02)	-122	20(22)	32	22.2	P	938	M14	na
32	27.05.03	27(23)	-118	27(04)	12	3.5	na	na	M14	na
33	16.06.03	16(10)	-136	15(17)	14.4	5	P	1215	M-15	IV
34	11.07.03	11(00)	-109	11(03)	12.8	3.5	na	na	M20	na
35	17.08.03	17(17)	-171	17(00)	22.2	16.5	H	378	M12	na
36	28.10.03	28(06)	-384	28(01)	19.2	9.6	P	1322	M-27	IV
37	20.11.03	20(02)	-461	20(05)	55	48.1	H	1660	M-45	IV
38	22.01.04	22(05)	-144	21(21)	25	19.7	H	965	M-61	II
39	11.02.04	11(10)	-107	11(09)	21.2	13.6	na	na	M12	na
40	03.04.04	03(14)	-113	03(23)	18.3	10.1	na	na	M15	na
41	22.07.04	22(00)	-106	22(14)	18.9	10.4	H	710	M-86	IV
42	24.07.04	24(11)	-198	24(05)	21.9	16.3	na	na	M22	na
43	30.08.04	30(02)	-119	29(23)	15	5.9	na	na	M14	na
44	07.11.04	07(20)	-376	07(12)	47.8	38.8	H	653	M93	IV
45	16.01.05	16(20)	-117	17(07)	35.3	31.1	H	2049	M-86	IV
46	21.01.05	21(19)	-103	21(15)	29.5	24.8	H	2020	X-13	IV
47	07.05.05	07(20)	-126	07(12)	16.6	10.7	H	1180	M13	II
48	15.05.05	15(05)	-293	15(01)	54.2	48.4	H	1689	M-80	IV
49	20.05.05	20(04)	-101	20(06)	15	5.7	P	405	M18	IV
50	29.05.05	29(22)	-150	29(01)	19.2	9.1	H	586	M11	IV
51	12.06.05	12(17)	-109	12(07)	24.2	18.6	na	na	M10	na
52	10.07.05	10(11)	-100	10(02)	25.2	15.7	H	683	M-49	IV
53	24.08.05	24(08)	-219	24(04)	52.2	43.1	H	1194	M-26	IV
54	31.08.05	31(12)	-138	31(03)	18.6	10.8	H	1600	M16	na
55	11.09.05	11(02)	-127	10(21)	18.2	13	H	2257	X-62	IV
56	14.04.06	14(10)	-111	13(14)	19.8	10.9	na	na	M12	na
57	14.12.06	14(21)	-143	14(11)	17.9	13.9	H	1774	X-34	IV

DATA ANALYSIS AND RESULTS

From data analysis of X and M class X-ray solar flare related intense geomagnetic storms and coronal mass ejections listed in Table 1 it is observed that most of the X and M class X-ray solar flare related intense geomagnetic storms are associated with halo and partial halo coronal mass ejections (CMEs) .We have 57 X and M class X-ray solar flare related intense geomagnetic storms out of which 47 are associated with coronal mass ejections (CMEs). The association rate of halo and partial halo coronal mass ejections are found 78.72 % and 21.27 % respectively. Further we have observed that 73.68% X and M-Class X-Ray solar flare related intense geomagnetic storms are associated with solar radio bursts. We have 57 X and M-Class X-Ray solar flare related intense geomagnetic storms out of which 41 are associated with type IV and type II solar radio bursts. The association rate of type IV and type II radio bursts have been found 60.97 % and 39.03% respectively.

From the data analysis of geomagnetic storms and associated disturbances in interplanetary magnetic fields listed in Table1, it is observed that most of the geomagnetic storms (98.24%) have been found to be associated with disturbances in interplanetary magnetic fields. We have 57 geomagnetic storms out of which 56 are associated with jump in interplanetary magnetic fields.

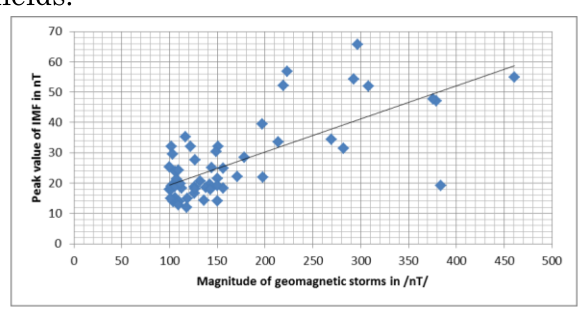

Figure-1-Scatter plot between magnitude of geomagnetic storms and peak value of IMF showing positive correlation with correlation coefficient 0.71.

To know the statistical behavior of geomagnetic storms and peak value of associated JIMF events a scatter plot has been plotted between magnitude of geomagnetic storms and peak value of associated JIMF events and the resulting plot is shown in Figure 1. From the Figure it is inferred that, most of geomagnetic storms having higher magnitude are associated with such JIMF which have relatively higher peak value but these two events do not have any fixed proportion, We have found some geomagnetic storms which have higher magnitude but they are associated with such JIMF events which have lower values of peak IMF and vice versa. Positive correlation with correlation coefficient 0.71 has been found between magnitude of geomagnetic storms and peak value of IMF of associated JIMF events.

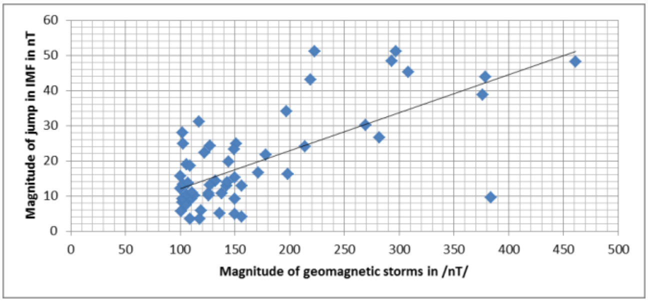

Figure-2-Scatter plot between magnitude of geomagnetic storms and magnitude of jump in IMF showing positive correlation with correlation coefficient 0.69.

To know the statistical behavior of geomagnetic storms and magnitude of jump of associated JIMF events a scatter plot has been plotted between magnitude of geomagnetic storms and magnitude of jump of associated JIMF events and the resulting plot is shown in Figure 2. From the Figure it is inferred that, most of geomagnetic storms having higher magnitude are associated with such JIMF events which have relatively higher magnitude but these two events do not have any fixed proportion, We have found some geomagnetic storms which have higher magnitude but they are associated with such JIMF events which have lower magnitude of IMF and vice versa. Positive correlation with correlation coefficient 0.69 has been found between magnitude of geomagnetic storms and magnitude of associated JIMF events.

CONCLUSION

From our study we have found that 82.45% X and M-Class X-Ray solar flare related intense geomagnetic storms are associated with halo and partial halo coronal mass ejections. 71.92% X and M-Class X-Ray solar flare related intense geomagnetic storms are associated with solar radio bursts. From the study of X and M-Class X-Ray solar flare related intense geomagnetic storms with jump in interplanetary magnetic field ,large positive co-relation with co-relation co-efficient, 0.71 has been found between magnitude of X and M-Class X-Ray solar flare related intense geomagnetic storms and peak values of associated jump in interplanetary magnetic field, 0.69 between magnitude of X and M-class X-Ray solar flare related intense geomagnetic storms and magnitude of jump in interplanetary magnetic fields. From these results it is concluded that coronal mass ejections, solar radio bursts and associated JIMF events are responsible to generate X and M Class X-ray solar flare related intense geomagnetic storms.

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