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LARGE GEOMAGNETIC STORMS AND THEIR RELATION WITH CORONAL MASS EJECTIONS AND INTERPLANETARY MAGNETIC FIELD

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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 ≤ - 150 nT to Dst ≥-3560nT observed during the period of 1997-2006 with coronal mass ejections, interplanetary shocks and disturbances in interplanetary magnetic field. We obtained scatter plots between magnitude of geomagnetic storms, magnitude of maximum depression in Dst with magnitude and peak values of Interplanetary Magnetic Field (IMF) components Bz and total IMF B. We have found that 90.00 % geomagnetic storms are associated with halo and partial halo coronal mass ejections. We have found positive correlation between magnitude of geomagnetic storms and speed of associated coronal mass ejections. Further we have concluded that majority of the geomagnetic storms are associated with interplanetary shocks (90.00 %).From the study of geomagnetic storms with disturbances in interplanetary magnetic field. We have determined positive co-relation between magnitude of maximum depression in Dst and peak values of total IMF B and southward component of interplanetary magnetic field Bz with correlation coefficient 0.64, 0.62 respectively. Positive correlation has been also found between magnitude of geomagnetic storms and magnitude of total interplanetary magnetic field B and southward component of IMF Bz with correlation coefficient 0.58, 45 respectively.

KEY WORDS: Geomagnetic storms, halo and partial halo coronal mass ejections, interplanetary shocks

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. Several studies have shown that coronal mass injections (CMEs) are the most geoeffective solar phenomena (Brueckner et al., 1998; Cane et al., 2000; Gopalswamy et al., 2000, 2005; Wang et al., 2002; Webb et al., 2000; Zhang et al., 2003). Some workers 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. Shrivastava and Venkatakrishnan, (2004) 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 and originating from a favorable location, i.e. close to the central meridian and low and middle latitudes, are the most potential candidates for producing strong ram pressure at the earth's magnetosphere and hence intense geomagnetic storm. Several authors have pointed out the high probability of intense storms being triggered during the southward interplanetary magnetic field (IMF) passage (Kokubun et al., 1977; Tsurutani, 2001 Huttunen et al., 2002). Zhang et al., (2006) studied interplanetary causes of intense geomagnetic storms at different stages of the solar cycle, and their results agreed with results obtained by previous investigators. Lysatsky and Tan, (2003) 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 IMF Bz start to increase approximately 4or 5 hours after the maximum variation in plasma and IMF By. In this investigation we have studied large geomagnetic storms Dst ≤-150nT to≥350nT for the period of 1997 to 2006 with coronal mass ejections interplanetary shocks and interplanetary magnetic field to know the physical process mainly responsible to generate large geomagnetic storms.

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DATA PRESENTATION

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. The data of total interplanetary magnetic field B along with its southward component Bz, have also been taken from omni web data system. The data of CMEs are taken from SOHO, LASCO, and CME catalogue. Interplanetary shocks data are taken from the list of the shocks derived by PM group.

ANALYSIS AND RESULTS

The association between large geomagnetic storms ≤ 150 nT to≥ -350nT with coronal mass ejections (CMEs), interplanetary shocks, interplanetary magnetic field for the period 1997 to 2006 are given in table 1 and 2. From the data analysis it is observed that 18 out of 20 (90.00%) large geomagnetic storms are found to be associated with coronal mass ejections. We have further observed that the majority of related CMEs are halo CMEs. We have 18 large geomagnetic storms, which are associated with coronal mass ejections out of which 17 large geomagnetic storms (94.45%) are related to the halo coronal mass ejections. Only 01 (5.55%) large geomagnetic storms are found to be associated with partial halo coronal mass ejections. We have found positive correlation between magnitude of geomagnetic storms and speed of associated coronal mass ejections with correlation coefficient .57 and .62 between magnitude of maximum depression in Dst and speed of CMEs .From the further analysis it is observed that majority of these large geomagnetic storms are related to the interplanetary shocks and the related shocks are forward shocks, 18 out of 20(90.00%). From the study of

Table 1: Association of Geomagnetic Storms with interplanetary Magnetic Field

Geomagnetic storms					IMFB (nT)					IMFBz (nT)		
S. No.	Date	Onset time in dd(hh)	Maximum Dec. time in dd(hh)	Magnitude in nT	Start time in dd(hh)	Maximum jump time in dd(hh)	Maximum IMF in nT	Magnitude in nT	Start time in dd(hh)	Maximum jump time in dd(hh)	Maximum IMFin nT	Magnitude in nT
1	03.05.98	03(21)	04(05)	-156	03(17)	04(04)	38.9	35	03(17)	04(04)	-19.5	-17.7
2	25.09.98	25(00)	25(09)	-203	24(21)	25(00)	28.7	18.8	25(00)	25(02)	-18.4	-27.1
3	22.09.99	22(20)	22(23)	-173	22(11)	21(18)	28.4	16.9	22(19)	23(20)	-18.5	-28.9
4	22.10.99	22(00)	22(06)	-214	21(18)	22(05)	35.8	17.8	21(23)	22(05)	-28.2	-24.6
5	06.04.00	06(17)	07(00)	-273	06(15)	06(22)	31.4	24.5	06(16)	06(21)	-22.1	-20.8
6	24.05.00	24(01)	24(08)	-164	23(15)	24(02)	34.1	26.8	24(01)	24(02)	-24.1	-31.1
7	15.07.00	15(18)	16(00)	-258	15(13)	15(20)	51.9	42.1	15(17)	15(20)	-49.3	-48.8
8	12.08.00	12(05)	12(09)	-148	11(18)	12(09)	33.6	23.9	12(05)	12(06)	-26.4	-24.6
9	17.09.00	17(20)	17(23)	-197	17(15)	18(00)	39.5	33.5	17(19)	17(21)	-23	-30.6
10	04.10.00	04(04)	05(13)	-141	04(05)	05(05)	26.3	10.4	04(05)	05(05)	-24.6	-25.4
11	11.04.01	11(15)	11(23)	-269	11(13)	11(23)	34.5	28	11(14)	11(21)	-17.7	-18.3
12	21.10.01	21(17)	22(21)	-173	21(16)	21(22)	28.4	21.3	21(16)	21(18)	-12.8	-7.8
13	05.11.01	05(19)	06(06)	-298	05(12)	06(03)	65.6	55.9	05(18)	06(03)	-61	-62.2
14	24.11.01	24(06)	24(16)	-223	24(05)	24(10)	56.9	49	24(06)	24(07)	-13.1	-15.3
15	07.09.02	07(12)	08(00)	-153	07(11)	07(17)	22.9	15.8	07(11)	07(17)	-22.3	-21.7
16	01.10.02	01(06)	01(16)	-150	30(16)	30(23)	25.1	10.3	01(05)	01(12)	-13.7	-20
17	17.08.03	17(18)	18(15)	-150	17(13)	18(01)	22	13.4	17(15)	18(09)	-17.4	-17.3
18	26.07.04	26(22)	27(13)	-165	26(21)	27(04)	26.1	21.4	26(21)	27(00)	-11	-14
19	15.05.05	15(06)	15(08)	-186	15(02)	15(09)	54.2	48.4	15(05)	15(06)	-41.2	-48.6
20	24.08.05	24(09)	24(11)	-194	24(05)	24(09)	52.2	42.4	24(09)	24(10)	-40.9	-42.2

geomagnetic storms and disturbances in interplanetanetary magnetic field it is concluded that geomagnetic field is greatly influenced by interplanetary magnetic field. We have plotted scatter plot between magnitude of geomagnetic storms and magnitude of disturbances in total interplanetary magnetic field B. Magnitude of maximum depression in Dst and peak value of total interplanetary magnetic field B. Magnitude of geomagnetic storms and magnitude of disturbances in southward component of interplanetary magnetic field Bz. Magnitude of maximum depression in Dst and magnitude of maximum depressed value of southward component of interplanetary magnetic field Bz.

The resulting scatter plots are shown in figure 1,2,3,4,5 and 6. From the figures it is observed that the magnitude of geomagnetic storms and maximum depression in Dst shows positive correlation with magnitude and peak value of IMFB and magnitude.The magnitude of geomagnetic storms also shows positive correlation with magnitude of variation in Bz and maximum depression in Bz. We have also calculated correlation coefficient statistically and found positive correlation between magnitude of geomagnetic storms and magnitude of disturbances in total interplanetary magnetic field with correlation coefficient .58, magnitude of geomagnetic storms and magnitude of disturbances in southward component of interplanetary magnetic field Bz with correlation coefficient .45. Positive correlation has also been found between magnitude of maximum depression in Dst and peak value of total interplanetary magnetic field B and magnitude of maximum depression in southward component Bz with correlation coefficient .62 between magnitude of maximum depression in Dst and peak value of total interplanetary magnetic field Band .64 between magnitude of maximum depression in Dst and magnitude of maximum depression in southward component of interplanetary magnetic field Bz .We have also observed

Table 2: Association of Geomagnetic Storms with Coronal Mass Ejections and Interplanetary Shocks

Geomagnetic Storms					Shocks	CMEs		
S. No.	Date	Onset time in dd(hh)	MaximumDec. time in dd(hh)	Magnitude in nT	Start time in dd(hh)	Date	types H/P	Speeds km/sec.
1	03.05.98	03(21)	04(05)	-156	03(18)	01(23.40)	H	657
2	25.09.98	25(00)	25(09)	-203	24(23)	nd	nd	nd
3	22.09.99	22(20)	22(23)	-173	23(09)	20(06.06)	H	604
4	22.10.99	22(00)	22(06)	-214	21(15)	19(05.50)	P	753
5	06.04.00	06(17)	07(00)	-273	06(16)	04(16.32)	H	1188
6	24.05.00	24(01)	24(08)	-164	24(17)	22(01.50)	H	649
7	15.07.00	15(18)	16(00)	-258	15(14)	14(10.54)	H	1674
8	12.08.00	12(05)	12(09)	-148	11(18)	09(16.30)	H	702
9	17.09.00	17(20)	17(23)	-197	17(17)	16(05.18)	H	1215
10	04.10.00	04(04)	05(13)	-141	05(03)	02(03.50)	H	525
11	11.04.01	11(15)	11(23)	-269	11(14)	09(15.54)	H	1192
12	21.10.01	21(17)	22(21)	-173	21(17)	19(01.27)	H	558
13	05.11.01	05(19)	06(06)	-298	06(02)	03(19.20)	H	1810
14	24.11.01	24(06)	24(16)	-223	24(05)	22(20.30)	H	1443
15	07.09.02	07(12)	08(00)	-153	Na	05(16.54)	H	1903
16	01.10.02	01(06)	01(16)	-150	Na	Na	Na	Na
17	17.08.03	17(18)	18(15)	-150	17(14)	14(20.06)	H	378
18	26.07.04	26(22)	27(13)	-165	26(23)	23(16.06)	H	824
19	15.05.05	15(06)	15(08)	-186	15(02)	13(17.12)	H	1689
20	24.08.05	24(09)	24(11)	-194	24(06)	22(01.31)	H	1194

Na-Not associated

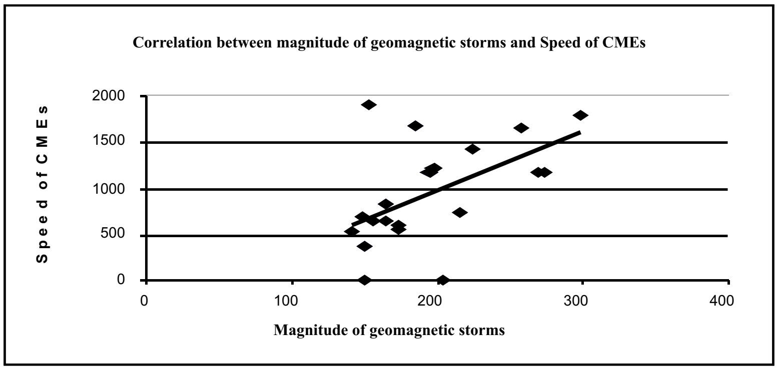

Figure 1 :Shows scatter plot between magnitude of geomagnetic storms and speed of Associated CMEs with correlation coefficient .57

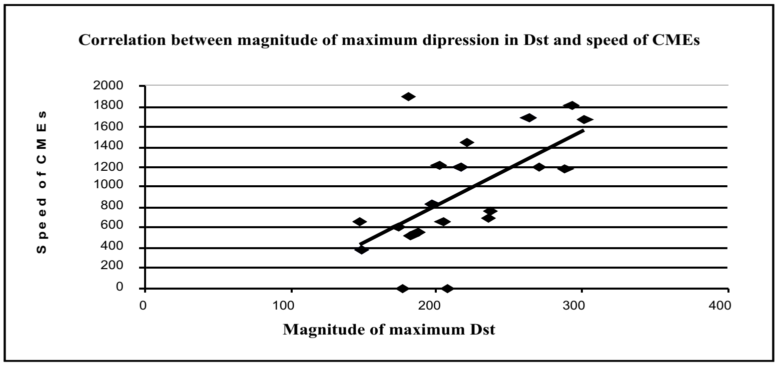

Figure 2: Shows scatter plot between magnitude of maximum depression in Dst and speed of CMEs with correlation coefficient .62

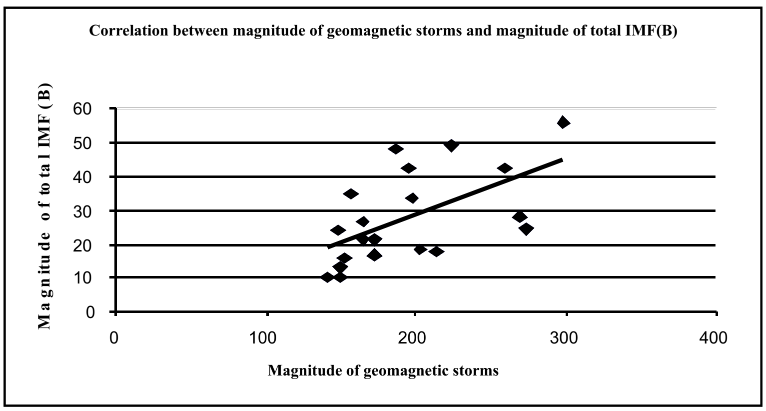

Figure 3: Shows scatter plot between magnitude of geomagnetic storms and magnitude of total IMF (B) with correlation coefficient.58

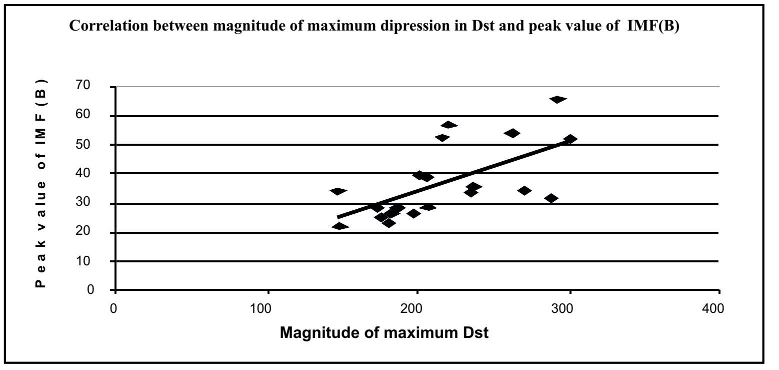

Figure 4: Shows scatter plot between magnitude of maximum depression in Dst and peak values of IMF (B) with correlation coefficient.64

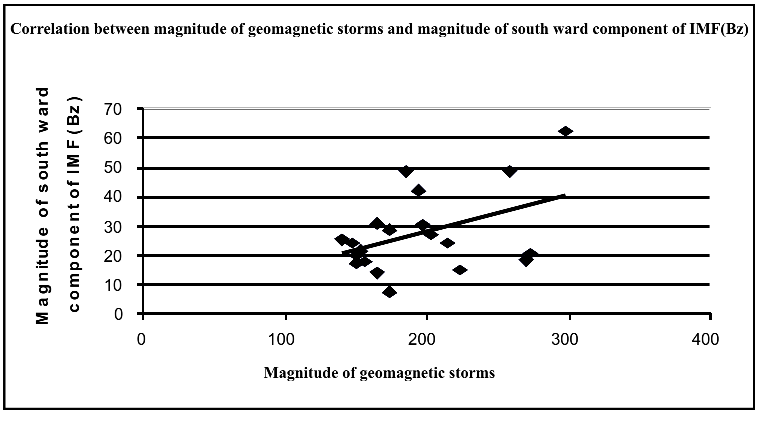

Figure 5: Shows scatter plot between magnitudes of geomagnetic storms and magnitude of southward component of IMF (Bz) with correlation coefficient .45

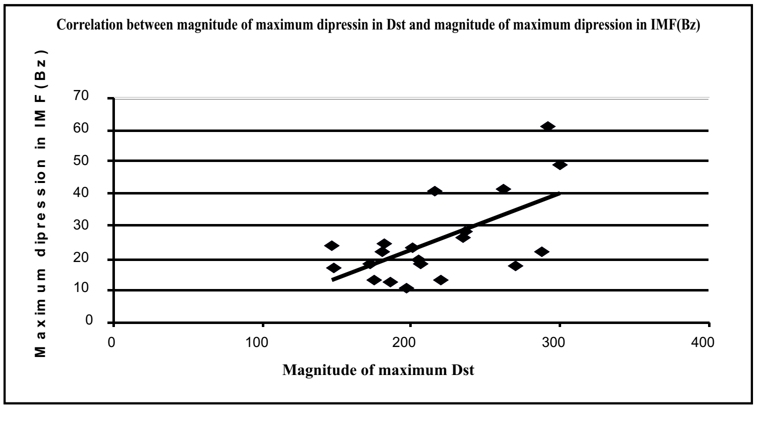

Figure 6 :Shows scatter plot between magnitude of maximum depression in Dst and magnitude of maximum depression in IMF (Bz) with correlation coefficient .62

onset time of large geomagnetic storms follow the that start time of disturbances in interplanetary magnetic field .

CONCLUSION

This scenario provides a general view of the effect of coronal mass ejections and IMF on the magnetosphere. In conclusion; we found that there are definite relationships between the halo coronal mass ejections speed of coronal mass ejections disturbances in IMF, and the ground-based geomagnetic indices Dst. Large variations in the Dst index are related not only to southern Bz but also to significant temporal variations in Bz and total interplanetary magnetic field E. Since the start time of disturbances in total interplanetary magnetic field are found before the onset time of large geomagnetic storms so start time of IMF B may be used to forecast large geomagnetic storms .

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