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Radio Burst Related Geomagnetic Storms with CMEs, Interplanetary Magnetic Field and Solar Wind Disturbances

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Abstract:

In this work we have studied radio bursts (RB) related geomagnetic storms (GMS) Dst ≤ -90nT from 1997 to 2012. From the data analysis, we have found total number of radio bursts related geomagnetic storms ≤-90nT, are 42.Out of 42 geomagnetic storms 37(88.09%) geomagnetic storms are found to be associated with coronal mass ejections (CMEs). We have 37 geomagnetic storms, which are associated with coronal mass ejections out of which 25 geomagnetic storms (67.57%) are related to the halo coronal mass ejections. Out of 37 12(32.43%) geomagnetic storms are found to be associated with partial halo coronal mass ejection. Positive co-relation with co-relation coefficient 0.28 has been found between magnitudes of radio bursts related geomagnetic storms and speed of associated coronal mass ejections by statistical method. Further we have concluded that associated CMEs are closely related to jump in interplanetary magnetic field (JIMF) and solar wind disturbances parameters (temperature and pressure). Positive correlation have been found between peak value of jump in interplanetary magnetic field and speed of associated CMEs with correlation coefficient 0.31, 0.32 between magnitude of jump in interplanetary magnetic field and speed of CMEs. Positive co-relation has been found between speed of CMEs and peak temperature of (JSWT) events with co-relation co-efficient 0.38, 0.36 between magnitudes of JSWT events and speed of associated CMEs. Positive co-relation has been found between speed of CMEs and *peak value of (JSWP) events with co-relation co-efficient 0.40, 0.41 between magnitudes of JSWP events and speed of associated CMEs.*

Key words: Geomagnetic storms, CMEs, Interplanetary magnetic field, Solar wind plasma parameters.

INTRODUCTION

Coronal mass ejections (CMEs) are a key aspect of coronal and interplanetary dynamics .They can eject large amounts of mass and magnetic field into the heliosphere causing major geomagnetic storms and interplanetary shocks. Halo CMEs which appear as expanding, circular brightening that completely surround the coronagraphs occulting disks this suggests that these are normal CMEs seen in projection (Burkepile et al 2004) to be moving outward either toward or away from the earth. CMEs which have a larger apparent angular size than typical limb CMEs but do not appear as complete halos are called partial halo CMEs. Extensive observations from the Solar and Heliospheric Observatory (SOHO) mission's Large Angle and Spectrometric Coronagraphs (LASCO) have shown that full halos constitute ~3.6% of all CMEs, while CMEs with width ≥120° account for ~11% (Gopalswamy, 2004).

The occurrence of a geomagnetic storm depends upon the solar conditions, particularly the southward interplanetary magnetic field (IMF) component. Some researchers have suggested a relationship between geomagnetic storms and solar wind parameters (Weigel 2010).

The study of various geomagnetic indices with disturbances in different parameters of solar wind plasma indicates that geomagnetic activity is related to variety of solar wind plasma/field parameters via solar wind velocity, solar wind plasma density, magnetic field strength, its north-south component and various combinations of these parameters

(Akasofu, 1983). Several investigators have analyzed geomagnetic storms with different solar wind parameters (L. S vanguards1977 P. Perrault, 1978, Maezawa1979, P. T. Murayama1982, H. B. Garrat, 1974 M. I.Pudovkin 1980, W. D. Gonzalez et al 1994) and have inferred that disturbances in solar wind parameters play crucial role in generating geomagnetic storms. W.D. Gonzalez et al (1987) have concluded that there is strong relation between interplanetary magnetic field and geomagnetic storms.

In this work we have studied radio bursts related geomagnetic storms, (magnitude ≤-90nT) and associated disturbances in solar wind plasma parameters e.g. jump in solar wind plasma temperature (JSWT), jump in solar wind plasma pressure (JSWP), jump in interplanetary magnetic field (JIMF) and with coronal mass ejections.

EXPERIMENTAL DATA

In this investigation hourly Dst indices of geomagnetic field have been used over the period 1997 to 2012 to determine onset time, maximum depression time, magnitude of geomagnetic storms. This data has been taken from the NSSDC Omni web data system which 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 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. To determine disturbances in interplanetary magnetic field, hourly data of average interplanetary magnetic field have been used, these data has also been taken from Omni web data (http;//omniweb.gsfc.nasa.gov/form/dxi.html)). The data of X ray solar flares radio bursts, and other solar data, solar geophysical data report U.S. Department of commerce, NOAA monthly issue and solar STP data (http://www.ngdc.noaa.gov/stp/solar/solardataservices. html.) have been used.

Table-1: Association of RB related GMS, CMEs, IMF and plasma parameters

Geomagnetic Storms Dst≤-90nT			Coronal Mass Ejections			IMF		Solar Wind Temperature		Solar Wind Presure	
S.No.	Date	Magnitude of GMS	Date	Type	Speed of CMEs in Km/S	Maximum Jump in IMF	Magnitude of jump in IMF	Maximum jump in Temp	Magnitude of jump in temp	Maximum jump in pressure	Magnitude of jump in presure
1	10.04.1997	-102	07.04.1997	Halo	878	22.1	18.7	695175	682940	9.71	8.47
2	15.05.1997	-115	12.05.1997	Halo	464	25.6	22.9	158816	149663	10.19	8.85
3	02.05.1998	-203	29.04.1998	Halo	1374	20.4	14.1	420844	326112	19.97	18.5
4	25.06.1998	-111	na	na	na	14.1	2.2	100414	90890	8.92	7.71
5	19.10.1998	-111	15.10.1998	Halo	262	26.5	23.5	107812	101724	21.85	19.53
6	07.11.1998	-139	04.11.1998	Halo	523	35.4	29.3	223059	215560	6.66	5.28
7	13.11.1998	-132	10.11.1998	Partial	286	20.2	15.1	26988	10454	9.79	9.07
8	17.02.1999	-128	na	na	na	26.9	23.6	470460	451763	5.09	4.55
9	28.02.1999	-94	na	na	na	19.8	15.3	154621	131728	15.34	14.33
10	12.09.1999	-103	10.09.1999	Partial	1467	13.6	10.1	416852	369034	14.52	13.49
11	21.10.1999	-257	19.10.1999	Partial	753	35.8	14.3	525759	511615	27.54	25.69
12	22.01.2000	-98	18.01.2000	Halo	739	18.1	14.3	165657	153520	3.38	2.07
13	24.05.2000	-164	22.05.2000	Halo	649	7.5	1.7	468151	454891	27.97	26.61
14	15.07.2000	-308	14.07.2000	Halo	1674	51.9	46.9	352419	256112	32.53	28.13
15	15.09.2000	-221	12.09.2000	Halo	1053	10.4	7.1	137342	117359	5.49	4.54
16	24.09.2000	-191	22.09.2000	Partial	378	11.8	8.6	495695	451456	3.26	2.72
17	13.10.2000	-100	11.10.2000	Partial	799	20.5	14.9	118307	90615	11.05	10.27
18	10.11.2000	-102	08.11.2000	Halo	474	10.3	5	2228444	2189449	8.98	5.48
19	23.03.2002	-107	22.03.2002	Halo	1750	13.9	9.8	116154	82810	5.25	4.58
20	17.04.2002	-149	15.04.2002	Halo	720	30.4	25.1	56069	19374	3.61	1.23
21	11.05.2002	-103	08.05.2002	Halo	614	13.4	7.3	262009	230600	4.39	2.85
22	23.05.2002	-172	21.05.2002	Partial	853	38.2	33.4	1217894	1201690	4.55	1.97
23	01.08.2002	-98	29.07.2002	Partial	360	15.7	9.9	121706	110074	7.53	7.05
24	04.09.2002	-179	na	na	na	18.9	4.1	257857	234281	4.84	2.5
25	30.09.2002	-179	26.09.2002	Partial	178	25.1	18.3	112901	98361	3.91	1.91
26	16.06.2003	-152	14.06.2003	Partial	875	14.4	8	232052	208048	3.66	3.35
27	10.07.2003	-128	na	na	na	13.9	9.3	67327	50406	6.66	6.06
28	28.10.2003	-382	27.10.2003	Partial	1322	19.3	10.9	1108866	1042274	6.3	6
29	20.11.2003	-417	18.11.2003	Halo	1660	55.8	53.3	505060	455915	17.18	15.68
30	22.07.2004	-115	20.07.2004	Halo	710	18.9	14.2	240584	167781	6.04	5.56
31	24.07.2004	-201	22.07.2004	Partial	899	21.9	16.3	455138	447032	12.99	12.69
32	07.11.2004	-415	04.11.2004	Halo	653	47.8	45	750946	694860	34.07	33.19
33	07.01.2005	-94	05.01.2005	Halo	735	22.3	18.3	126165	101870	26.1	24.57
34	16.01.2005	-117	15.01.2005	Halo	2049	35.3	31.9	1078838	1059288	53.67	51.9
35	07.05.2005	-275	05.05.2005	Halo	1180	16.6	10.7	845807	793666	14.68	13.21
36	28.05.2005	-155	26.05.2005	Halo	586	19	17	210877	195777	11.46	10.28
37	10.07.2005	-100	09.07.2005	Halo	1540	9.8	2.2	297954	271207	6.49	5.95
38	24.08.2005	-248	22.08.2005	Halo	2378	52.2	48.7	2666957	2640465	30.98	30.14
39	14.12.2006	-155	13.12.2006	Halo	1774	17.9	14.3	213495	194741	13.45	12.81
40	07.03.2012	-140	05.03.2012	Halo	1531	17.1	13.7	364927	353785	8.32	7.12
41	4/23/2012	-119	19.04.2012	Partial	540	15.5	11.6	327270	307084	12.88	11.95
42	17.06.2012	-151	14.06.2012	Halo	987	40.1	37.2	192576	156565	4.4	3.74

RESULT AND DISCUSSION

From the data analysis of radio burst related geomagnetic storms, it is observed that most of the radio burst related geomagnetic storms are intense or severe geomagnetic storms. We have identified 42 radio burst related geomagnetic storms during the period of 1997-2012, out of which 37 radio burst related geomagnetic storms have been associated with coronal mass ejections. Out of 37 associated geomagnetic storms 12(32.43%) geomagnetic storms have been found to be associated partial halo coronal mass ejections and 25(67.57%) with halo coronal mass ejections(Figure-1). Further we have found the positive correlation with correlation coefficient of 0.28

between magnitudes of radio bursts related geomagnetic storms and speed of associated coronal mass ejections (Figure-2). Further it is observed that 35% (13) are associated with CMEs of higher speed having speed more than 1000km/s.

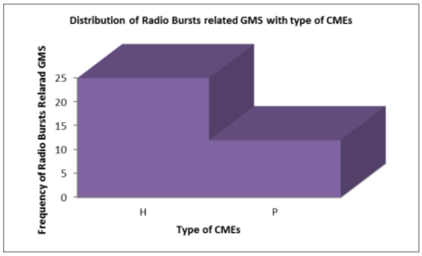

Figure-1- Distribution of radio bursts related geomagnetic storms with coronal mass ejections.

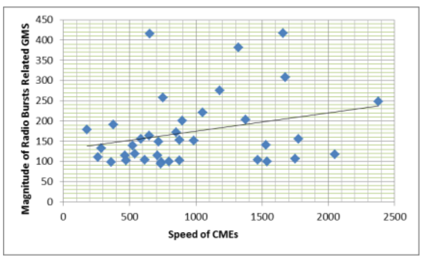

Figure-2- The scatter plot between speed of CMEs and magnitude of radio bursts related geomagnetic storms.

Correlation between Peak value of IMF Associated with RB related GMS and speed of CMEs

To know the statistical behavior of (JIMF) events of selected criteria with speed of associated CMEs a scatter plot has been plotted between peak value of jump in interplanetary magnetic field (JIMF) and speed of associated CMEs (Figure-3). From the scatter plot, it may be inferred that there is moderate positive correlation between peak value of IJMF events and the speed of associated CMEs with co-relation co-efficient 0.31 between these two events.

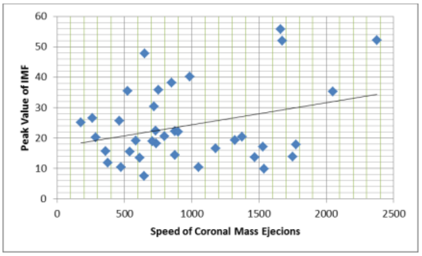

Figure-3– The scatter plot between speed of CMEs and peak value of associated JIMF events associated with RB related GMS.

Correlation between magnitudes of IMF Associated with RB related GMS and speed of CMEs

To know the statistical behavior of magnitude of JIMF events of selected criteria with speed of associated CMEs a scatter plot has been plotted between magnitudes of jump in interplanetary magnetic field (JIMF) and speed of associated CMEs the resulting plot is shown in figure 4. From the figure it is inferred that, most of the JIMF events having higher magnitude are associated with such CMEs which have higher speed but these two events do not have any fixed proportion, We have found some JIMF events which have higher magnitude but they are associated with such CMEs events which have relatively slow speed and vice versa. From scatter plot, it may be inferred that there is moderate positive correlation between magnitude of IJMF and the speed of associated CMEs. Positive co-relation has been found between speed of CMEs and magnitude of associated JIMF events. Statistically calculated co-relation co-efficient is 0.32 between these two events.

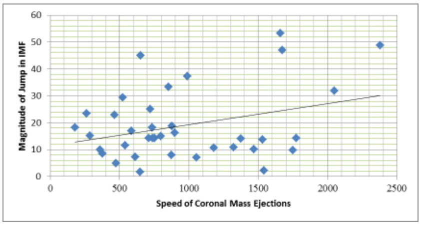

Figure-4- The scatter plot between magnitude of JIMF associated with RB related GMS and speed of CMEs.

Correlation between Peak value of JSWT Associated with RB related GMS and speed of CMEs

To know how the peak value of JSWT events is correlated with speed of coronal mass ejections, we have plotted a scatter diagram between the speed of CMEs and peak value of associated JSWT events fig.5. From the fig it is clear that, most of the JSWT events having higher peak value are associated with such CMEs which have higher speed, but these two events do not have any fixed proportion. From the trend line of the figure it is inferred that there is moderate positive correlation between peak value of JSWT events and speed of associated CMEs. Positive co-relation has been found between speed of CMEs and peak temperature of (JSWT) events with co-relation co-efficient 0.38

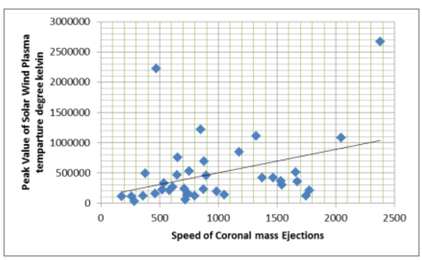

Figure-5- The scatter plot between speed of CMEs and peak value of jump in solar wind plasma temperature (JSWT) associated with RB related GMS.

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Correlation between magnitudes JSWT Associated with RB related GMS and speed of CMEs

To see how the magnitudes of JSWT events are correlated with speed of CMEs we have plotted a scatter diagram between magnitude of jump in solar wind plasma temperature (JSWT) events and speed of associated CMES shown in fig.6. From the observation of trend line of the fig, it may be inferred that there is moderate positive correlation between magnitude of JSWT events and speed of CMEs has been found with co-relation co-efficient 0.36 between these two events.

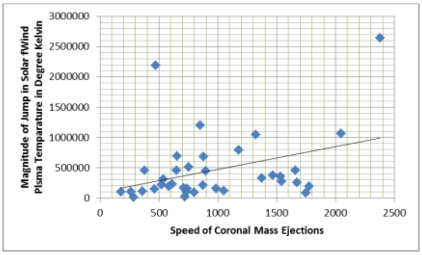

Figure -6 –The scatter plot between magnitude of JSWT Associated with RB related GMS and speed of CMEs.

Correlation between Peak value of JSWP Associated with RB related GMS and speed of CMEs

In this section we have selected those jumps in solar wind plasma pressure (JSWP) events which are associated with radio bursts related geomagnetic storms and studied statistical behavior of these events with coronal mass ejections. To see how the peak value of JSWP events are correlated with coronal mass ejections. We have plotted a scatter diagram between the speed of CMEs and peak value of associated JSWP events fig.7. From the fig it is clear that, most of the JSWP events having higher peak value are associated with such CMEs which have higher speed but these two events do not have any fixed proportion, We have found some JSWP events which have higher peak value but they are associated with such CMEs events which have slow speed and vice versa. The trend line of the scatter plot it is clear that there is moderate positive correlation between these two events. Statistically calculated co-relation co-efficient is 0.40 between these two events.

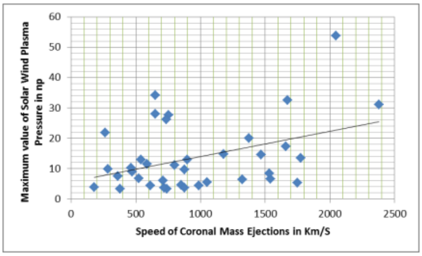

Figure-7- The scatter plot between speed of CMEs and peak value JSWP events Associated with RB related GMS.

Correlation between magnitudes of JSWP Associated with RB related GMS and speed CMEs

To see how the magnitudes of JSWP events are correlated with speed of CMEs we have plotted a scatter diagram between magnitude of jump in solar wind plasma pressure (JSWP) and speed of associated CMES shown in fig .8. The trend line of the scatter plot shows moderate positive correlation between the two events. Positive co-relation has been found between magnitudes of JSWP events and speed of CMEs, Statistically calculated co-relation co-efficient is 0.41 between these two events.

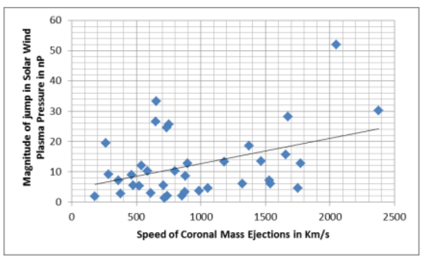

Figure -8- The scatter plot between magnitudes of JSWP Associated with RB related GMS and speed of CMEs.

CONCLUSION

From our study we have identified 42 radio burst related geomagnetic storms. Further it is found that majority of the (88.09%) radio burst related geomagnetic storms are associated with coronal mass ejections. The association rates halo and partial halo coronal mass ejections have been found 67.57% and 32.43% respectively. From the further analysis, positive co-relation with co-relation coefficient 0.28 has been found between magnitudes of radio bursts related geomagnetic storms and speed of associated coronal mass ejections. From the further analysis, positive correlation have been found between peak value of jump in interplanetary magnetic field and speed of associated CMEs with correlation coefficient 0.31, 0.32

between magnitude of jump in interplanetary magnetic field and speed of CMEs. Further it is concluded that there is a positive correlation between peak value of jump in solar wind plasma temperature (JSWT) and speed of associated CMEs with correlation coefficient 0.38, 0.36 between magnitude of jump in solar wind plasma temperature and speed of associated CMEs, 0.40 between peak value of jump in solar wind plasma pressure (JSWP) and speed of associated CMEs, 0.41 between magnitude of jump in solar wind plasma pressure and speed of associated CMEs. From the above results it is concluded that radio burst related geomagnetic storms are closely related to coronal mass ejections, radio bursts and disturbances in solar wind plasma parameters these solar and interplanetary parameters play crucial role to generate intense and severe geomagnetic storms.

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