



Relation between coronal mass ejections and solar activity in association with geomagnetic storms during 1996-2010

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Abstract: For planetary disturbance index ($AP \geq 50$) we have selected geomagnetic storms ($DST \leq -50$ nT) with sunspot number (R_z) and coronal mass ejections (Halo & Phalo) for the period of 1996-2010. It is found that the occurrence rate of total CMEs increases with solar activity and peak is observed around solar maximum. The occurrence rate of total CMEs have been found to be 2.85 per day, 3.82 CMEs/day and 1.18 CMEs/day have occurred during maximum and minimum solar activity years. We have observed 2.90 CMEs/per day during 23rd solar cycle & 3.28 CME/per day during rising phase of 24th solar cycle. Positive and strong correlation is found between halo, phalo CMEs with SSN (R_z). The GMSs are high positively correlated with halo CMEs and positively correlated with SSN(R_z). The average speed of partial halo CMEs are more correlated with SSN (R_z) as compared to halo CME speed.

Key Words: Coronal mass ejection, Sun spot numbers, Geomagnetic Storms, CMEs speed.

I. Introduction

Coronal mass ejections (CMEs) are the most impressive large scale phenomena occurring on the sun (Hindhausen et al 1984, Hindhausen 1993). They involve the ejection of up to 1013Kg of material seen as a large scale loop and tongue – shaped structures, into interplanetary space. These mass ejections carry a bulk of solar material at the speeds of 10-2000 Km/sec. The huge amount of energy involved in such ejection processes is believed to be stored in the magnetic fields surrounding mass ejections site. They are responsible for non recurrent disturbances in interplanetary medium, and their interaction with the earth's magnetosphere cause intense geomagnetic storms (Mac Queen 1980, Chertok 1993, Manoharan & Kundu 2003, Liemohn & Jazowski 2008). Many researchers have studied the solar cycle variation of different CMEs characteristics such as central latitude, total energy, velocity, measurement position angel (MPA) and central position angle (CPA) during times of solar maximum and minimum activity. In recent years, many workers have studied to understand the solar terrestrial relationships that are responsible for the occurrence of geomagnetic storms (Plunkett et al 2001, Wang et al 2002, Zhang et al 2003). However, we are still far from the final stages of quantitative understanding toward the goal of predicting the occurrence of geomagnetic storm from the knowledge of a coronal mass ejection and solar activity. A CME is said to be partial halo for which $MPA \geq 120^\circ$ and a CME is said to be a full for which MPA is equal to 360° . The definition of full halo CME or partial halo CME is based on the azimuthal extent of CMEs in LASCO field of view (Webb et al 2000). Howard et al (1982) are observed in LASCO images as full halo ($MPA=360^\circ$) or partial halo ($MPA>140^\circ$). The purpose of this paper is to study the relation between CMEs and solar activity in association of geo magnetic storms during 1996-2010.

II. Data analysis

We have used the CMEs data from large angle spectroscopic coronagraph (LASCO) on the solar and Heliospheric observatory (SOHO). For geomagnetic storms, geomagnetic disturbance index (Ap), sunspot numbers (R_z) data have been taken from solar geophysical data reports. Disturbance Storm Time ($DST \leq -50$ nT) index was obtained from site [http:// omniweb.gsfc.nasa.gov](http://omniweb.gsfc.nasa.gov). In the present study, we have studied the total CMEs, full halo and partial halo CMEs during 1996-2010. Angular width only 360° consider a full halo CMEs and angular width $\geq 120^\circ$ has been consider as partial halo CMEs.

III. Results and discussion

We have selected the yearly occurrence of geomagnetic storms ($DST \leq -50$ nT) for which ($Ap \geq 50$) and sunspot number during the period 1996-2010. We have also calculated the annually occurrence of halo, phalo and total CMEs during the study period. We have observed the 15629 CMEs for the period 1996-2010. Out of 15629 CMEs, 409 and 911 are the full and partial halo CMEs. The 3.82 CMEs/day have occurred during maximum solar activity years (1999-2003), whereas the 1.18 CMEs/day have occurred during minimum solar activity years (1996-1998). The per day occurrence rate of total CMEs has been found to be 2.85 for the period 1996-2010. A rate of 0.5 CMEs/day was observed by Hildner et al (1976) and Gopalswami et al (2002) from the OSO-7 coronagraph. Raychaudhari (2005) found that the 121.51 and 41.24 was the per month occurrence rate of CMEs during maximum and minimum activity years of 23rd sunspot cycle. The per day average occurrences

rate of total CMEs has been found to be 2.90 for 23rd solar cycle whereas the per day average occurrence rate of total CMEs has been found to be 3.28 for rising phase of 24th solar cycle.

Table 1 Shows annually occurrence of GMSs ($A_p \geq 50$) along with annually occurrence of CMEs and sunspot number during 1996-2010.

Year	No. of GMSs	Max. Dst	SSNs Rz	Total CMEs	Type of CMEs	No. of events	Average speed(km/s)
1996	1	-105	9	206	Halo Partial Halo	4 11	366 437
1997	3	-115	22	381	Halo Partial Halo	17 21	485.8 358.9
1998	8	-207	64	709	Halo Partial Halo	29 39	828.18 654.7
1999	7	-237	93	1011	Halo Partial Halo	27 120	890.4 575.57
2000	12	-301	120	1644	Halo Partial Halo	58 119	903.52 655.04
2001	13	-387	111	1498	Halo Partial Halo	63 150	1027.1 629.23
2002	10	-181	104	1691	Halo Partial Halo	52 127	1213.3 715.34
2003	16	-422	64	1127	Halo Partial Halo	30 71	1400.9 781.56
2004	7	-374	40	1101	Halo Partial Halo	40 77	857.23 627.63
2005	15	-247	30	1247	Halo Partial Halo	59 80	1297.1 508.75
2006	4	-162	30	1043	Halo Partial Halo	14 25	774.49 417.12
2007	0	NA	15	1344	Halo Partial Halo	3 12	830.67 431.75
2008	0	NA	3	863	Halo Partial Halo	1 13	143 375.69
2009	0	NA	3	647	Halo Partial Halo	1 2	276 260.5
2010	2	-81	0	1117	Halo Partial Halo	11 44	696.18 403.75
Total	98			15629	Halo Partial Halo	409 911	

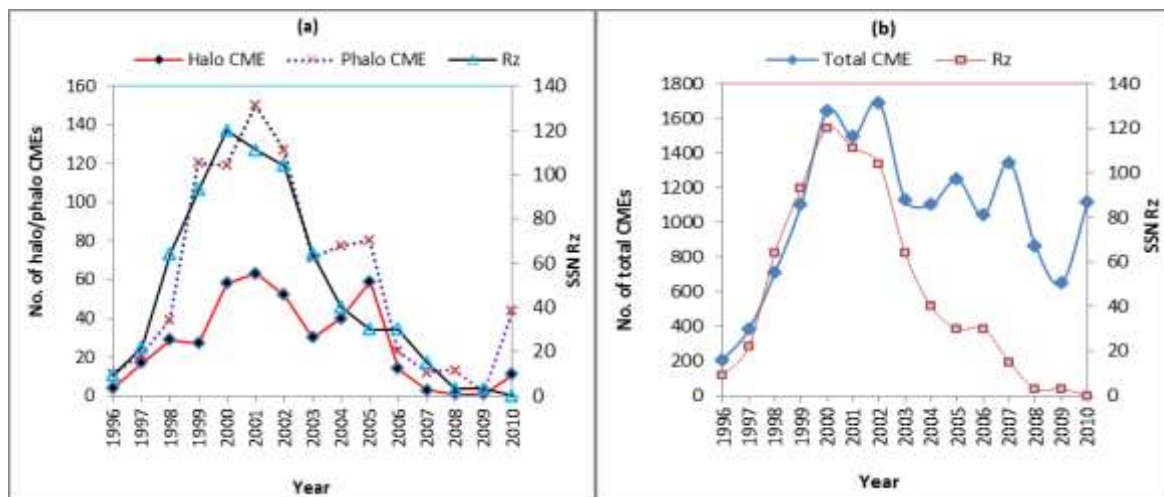


Fig.1(a),(b) shows annual occurrence rate of Halo, Phalo, and total CMEs with SSN (Rz) during 1996-2010.

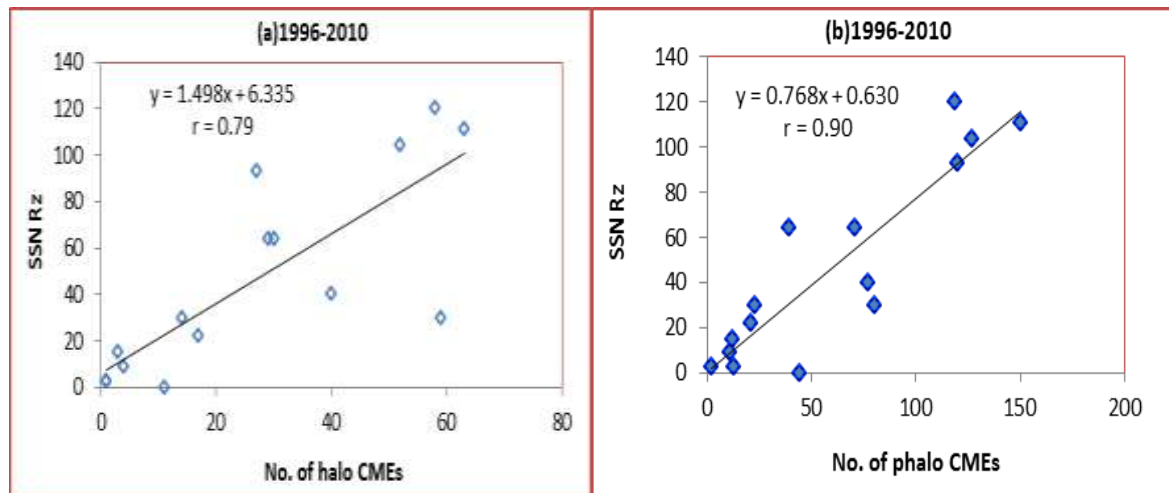


Fig. 2 (a), (b) shows the cross correlation between the annual occurrence rate of Halo and PHalo CMEs with annual average of SSN (Rz) during the period 1996-2010.

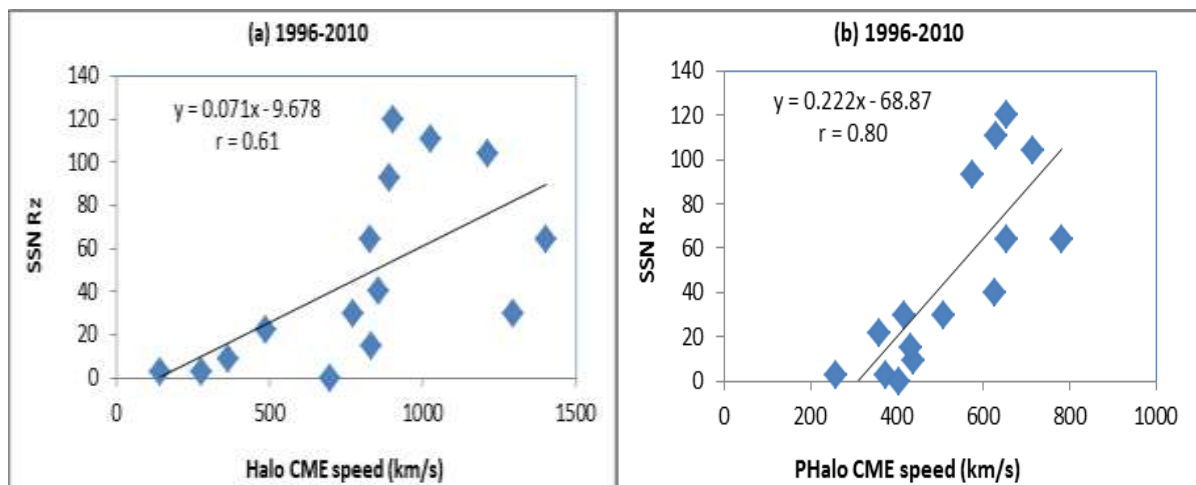


Fig. 3(a), (b) shows the cross correlation between the annual average speed of Halo, PHalo CMEs with annual average of sunspot numbers for the period 1996-2010.

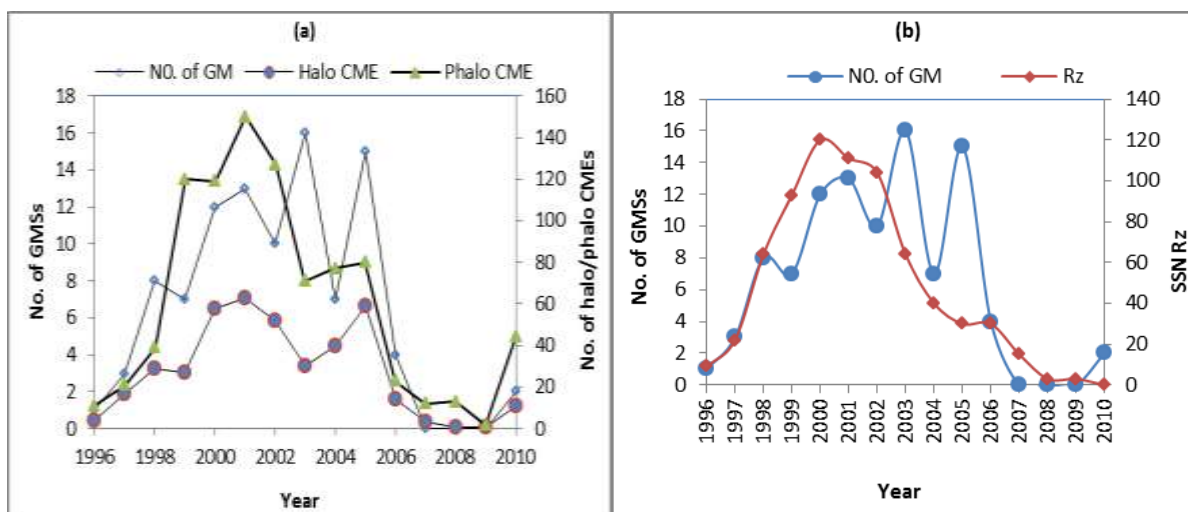


Fig. 4 (a), (b) shows variation of annual occurrence rate of GMS along with annual occurrence rate of Halo, Phalo CMEs and SSN(Rz) for the period 1996-2010.

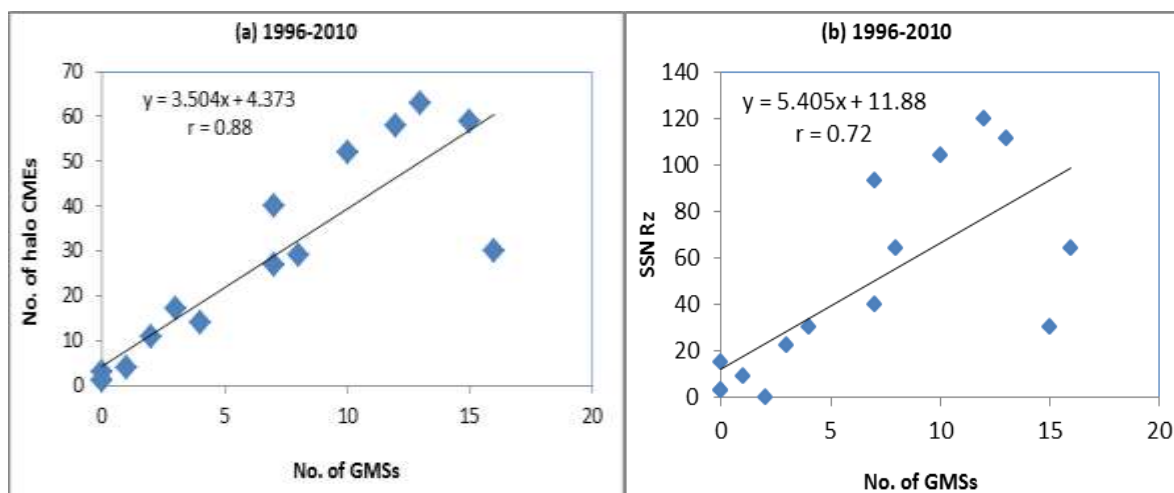


Fig. 5(a), (b) shows the cross correlation between the annual occurrence rate of GMS with annual occurrence rate of Halo CMEs and sunspot numbers for the period 1996-2010.

The annual occurrence rate of halo, partial halo and total CMEs with R_z have been plotted in fig 1(a),(b) respectively. It is apparent from fig 1(a), (b) that the maximum numbers of halo and partial halo CMEs have occurred during maximum activity years of 23rd solar cycle. The cross correlation between annual occurrence of halo, partial halo CMEs with R_z have been plotted in fig 2(a),(b) respectively for the period 1996-2010. The correlation coefficient of halo and partial halo CMEs with SSN (R_z) are found to be 0.79 and 0.90 respectively. Fig 3(a),(b) shows cross plot between annual average speed of halo/phalo CMEs with annual average of SSN(R_z) during study period. The correlation coefficient of halo, phalo CMEs speed with SSN (R_z) are 0.61 and 0.80 respectively. The annual occurrence of geomagnetic storms with halo, partial halo CMEs and SSN (R_z) have been plotted in fig 4(a),(b) respectively for the period 1996-2010. It is apparent from fig 4(a),(b) that maximum number of GMSs have occurred during maximum solar activity years. One peculiar result has been observed during years 2003, 2005, when GMSs increase whereas SSN (R_z) decrease which shows that the sunspot numbers are not only key casual of GMSs. It seems that some other phenomena are occurring on the solar disk which may be responsible for occurrence of geomagnetic storms. The cross correlation between the annual occurrence rate of GMSs with halo CMEs have been plotted in fig 5(a) for the period 1996-2010. The Karl Pearson's correlation coefficient and slope of regression line between the GMSs and halo CMEs have been found to be 0.88 and 3.504 respectively which shows that the SSN (R_z) and GMSs are strongly correlated. The cross correlation of GMSs with SSN (R_z) have been plotted in fig 5(b) for the period 1996-2010. The correlation coefficient GMSs with SSN (R_z) have been found to be 0.72.

IV. Conclusions

From the rigorous study, the following conclusions have been drawn:

1. Maximum number of halo, partial halo and total CMEs have occurred during maximum solar activity years.
2. The occurrence rate of total CMEs increases with solar activity and peak is observed around solar maximum activity years.
3. Partial halo CMEs are strongly correlated to SSN(R_z) as compared to halo CMEs.
4. Maximum number of GMSs have occurred during maximum activity years and are high correlated with SSN(R_z) with correlation coefficient 0.72.
5. The per day occurrence rate of the total CMEs have been found to be 2.85 for the period 1996-2010 while 3.82 CMEs/day and 1.18 CMEs/day have occurred during maximum and minimum solar activity years.
6. We have observed 2.90 CMEs/day during 23rd solar cycle and 3.28 CMEs/day have occurred during rising phase of 24th solar cycle.
7. We have also observed number of CMEs (halo & phalo) are directly correlated with the magnitude of geomagnetic storm.
8. During maximum solar activity period more CME are found with their maximum speed 1400 km/s. It is also evident during these period more GMS are observed. The average speed of phalo CMEs are more correlated with SSN (R_z) in comparison to halo CMEs.

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