

Solar and interplanetary signatures of intense geomagnetic storms during 1997–2000

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Abstract. During the ascending phase of the recent solar cycle, the solar and interplanetary signatures of coronal mass ejections (CMEs) observed by Large Angle Spectrometric Coronagraphs (LASCO) aboard SOHO, have been examined. These CMEs were responsible for causing intense geomagnetic storms ($Dst \leq -100$ nT) on the earth. In this paper, the relationship of these CMEs with halos, long-duration events, flares and eruptive prominences have been studied. In addition, investigation of the role of the initial expansion speeds of halos in determining the time of their arrival at the earth has also been made.

Key words : coronal mass ejection, geomagnetic storm

1. Introduction

Geomagnetic activity observed at the earth is generally attributed to the occurrence of CMEs on the Sun and their associated interplanetary shock waves or to high speed solar wind streams. CMEs are large expulsions of material from the sun, which are often associated with solar prominences or flares. They travel into interplanetary medium and if directed towards the earth, can reach the earth in 3-5 days. Therefore, to understand solar-terrestrial relationship and address the important question, i.e. whether geo-effectiveness can be predicted, one needs to investigate multi-instrument data-sets, both ground and space based. With the advent of Solar and Heliospheric Observatory (SOHO), we now have a better opportunity to track a CME, in particular with Large Angle Spectrometric Coronagraphs (LASCO) which have imaging capability from 1.1 to $30 R_{sun}$ and Charge, Element and Isotope Analysis System (CELIAS) which is capable of detecting interplanetary shocks associated with CMEs. In this paper, the solar and interplanetary signatures of CMEs observed by LASCO and CELIAS have been examined. The data-set includes all the CMEs observed during January 1997 - June 2000 which were responsible for causing intense geomagnetic storms ($Dst \leq -100$ nT) on the earth, in the ascending phase of the recent solar cycle.

2. Geo-effective CMEs during 1997-2000

From the examination of LASCO and ground-based data, it was found that 30 CMEs occurred on the sun which gave rise to intense geomagnetic storms, during 1997-2000. Table 1 gives the connection between shocks/solar ejecta and geomagnetic storms of various strengths defined by Dst and Kp index.

Table 1. Statistics for geo-effective events.

Storm intensity	No. of CMEs	Dst index	Kp index	Shock association
Very Intense	6	$\text{Dst} \leq -150$	$8 \leq \text{Kp} \leq 9$	100%
Intense	24	$\text{Dst} \leq -100$	$5 \leq \text{Kp} \leq 7$	55%

The location of onset of CMEs appears to be quite important as all the events originate near central meridian and at low latitudes with only 3 exceptions. Further, out of 6 very intense events, 4 had strong association with 3B, X class flares and 2 events with eruptive prominences. On the other hand, out of 24 intense events, 15 had strong association with 2B, C and M class flares and 9 were associated with eruptive prominences. Three very long duration events (LDEs) of about 6, 14, 28 hours were observed with very intense events in contrast to 10 cases of LDEs of 3-5 hours in case of intense events. 48% of the total number of events occurred as full halos (360°) while 43% were associated with partial halos ($> 180^\circ$) and 9% had no association with halos at all.

Travel time of CMEs towards the Earth : Using pairs of good images from LASCO-C2 and C3, the speed of outermost front was determined. The *travel time* of a CME was defined as the time difference between the first appearance in LASCO-C2 and the arrival of the associated shock at SOHO as observed by CELIAS on SOHO. It was found that the average travel time for most of the CMEs is 80 hours. Only for exceptionally fast CMEs, where initial expansion speeds at around $20 R_{\text{sun}}$, exceeded 1000 km/s, the travel time may drop to less than 50 hours. This implies that the arrival time of the CME at the earth does not depend much on the initial expansion speed of the halo.

3. Results

Our results show that

1. At the ascending phase of solar cycle the rate of geo-effective event ($\text{Dst} < -100$ nT) is approximately 1 per month.
2. 90% of geo-effective events examined were associated with halos. However, the strength and type of the associated storm depends on magnetic topology of the ejecta or cloud.
3. For predicting the travel time from sun to earth, one can use Brueckner's rule (Brueckner et al. 1998), i.e., assume 80 hours. This implies that fast CMEs generally undergo deceleration. However for a few exceptional cases of fast CMEs, travel time might reduce to 50 hours.

References

Brueckner G.E., Howard R.A., Koomen M.J., Korendyke C.M., et al. 1995, Solar Phys., 357