Long-Term Datasets for the Understanding of Solar and Stellar Magnetic Cycles
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Study of solar flares associated with Geoeffective CMEs

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Abstract. We study 30 solar flare events associated with coronal mass ejections (CMEs) that produced geomagnetic storms as measured in Dst index. Our study reveals that the magnitude of Dst index is significantly associated with maximum solar wind speed, peak of B_z component of the IMF and the product of peak B_z and solar wind speed (minimum and maximum). From our investigations, it can be inferred that CMEs travel with higher speed in the beginning and their speed reduces as they reach L1 location.

1. Introduction

Geomagnetic storms are major disturbances in the Earth's magnetosphere that occur when the interplanetary magnetic field turns southward and remains so for a prolonged period of time (Tsurutani *et al.* (1992)). Reconnection between the southward directed components of the solar wind carried magnetic field (B_z) and the northward magnetic field can occur (Dungey (1963)) at the dayside magnetopause, resulting in the transfer of significant amounts of energy from the solar wind into the Earth's magnetosphere. As a consequence of this there occurs a westward (ring) current as evidenced by a decrease in the induced magnetic field over equatorial magnetic stations, and a large decrease in the Dst index (Jain *et al.* (2010)). Geomagnetic storms are associated with Earth directed coronal mass ejections (CMEs). CMEs originating from regions close to the central meridian of the Sun and directed toward Earth cause the most severe geomagnetic storms (Gopalswamy *et al.* (2007), Ameri, & Valtonen (2017)).

2. Observation and Results

Coronal Mass Ejections (CMEs) occurred during the period of 2010 to 2017 and associated with geomagnetic storms quantified as disturbed storm time (Dst) $\leqslant -25$ nT are considered for the current investigation. The CME data is obtained from the Large Angle and Spectrometric Coronagraph Experiment (LASCO) on board the Solar and Heliospheric Observatory (SOHO). Dst index is taken from the WDC Kyoto.

We have analyzed the solar effects on geosphere for 30 events. For example, the solar wind speed, B_z component of interplanetary magnetic field (IMF) and solar wind proton density (Fig. 1-a,b,c) for a Halo CME event that occurred on the 25 February 2014 at 01:25:50 UT with a speed of 2147 km/s. The $IMF - B_z$ turns southward on 27 February 2014 at 18:53 UT with value −15 nT and proton density increased to 31 #/cc on this day. The strength of the ring current is known to be dependent on two components (i) the B_z and (ii) the solar wind speed. So, we take the product of these two components (Fig. 1-d). It reveals association with Dst index (Fig. 1-e). The product ($B_z.SW_v$) dip turns negative on 27 February 2014 at 19 UT with −6046 nT. km/s. The storm occurred on 28 February 2014 at 00 UT with Dst index −94 nT. Shown in Fig. 1 (f-i) is the variation of Dst index

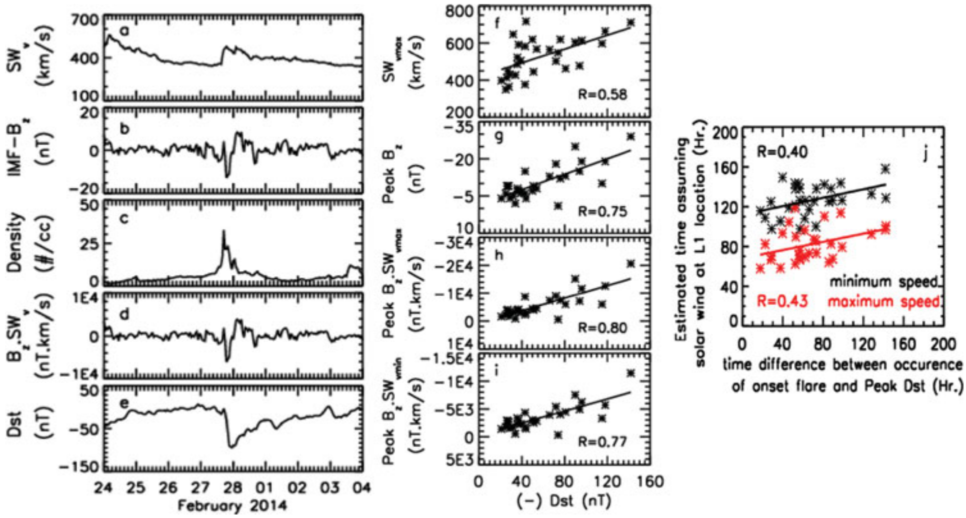

Figure 1. *(a-e)*: Variation of (a) solar wind speed, (b) B_z component of interplanetary magnetic field (IMF), (c) ion density, (d) product of $B_z.SW_v$ and (e) Dst index during flare event on 25 Feb 2014. *(f-i)*: Dst index as a function of (f) SW_{vmax}, (g) peak B_z, (h) product of peak $B_z.SW_{vmax}$ and (i) product of peak $B_z.SW_{vmax}$ for 30 selected solar flare events. *(j)*: Comparison between estimated times for particles to reach the Earth by considering the minimum and maximum solar wind speed at L1 location and the time difference between occurrences of flares and the corresponding peaks in the Dst index for 30 selected events.

as a function of maximum solar wind speed (SW_{vmax}), peak B_z, product of peak B_z and SW_{vmax}, and, product of peak B_z and SW_{vmin} for all 30 events under study. The Dst index is highly correlated with the Bz component (R=0.75), while intermediately correlated (R=0.58) with SW_{vmax}. The speed-magnetic field products ($B_z.SW_{vmax}$ and $B_z.SW_{vmin}$) also had very high correlation (R=0.80 and R=0.77 respectively) with Dst index. Further, we have also calculated the time difference between peak Dst time and flare onset time, and plotted against the minimum and maximum time taken for the arrival of particles closer to the Earth (L1 location) by considering the solar wind speed at L1 location ((1AU/SW_{vmax}) and (1AU/SW_{vmin})) (Fig. 1-j). It may be noted that the estimated time delay is greater than that observed. This clearly indicates that the solar wind speeds are greater than those measured at L1 location.

3. Conclusion

Our sample of 30 events reveal that flare and CME both occurred nearly simultaneously (within one hour). CMEs originated in the western (10), central (15) and eastern (5) meridians were geoeffective. The B_z component of the IMF and solar wind speeds are important for formation of the ring current/geomagnetic storm as reflected in the Dst index.

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