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Coronal Mass Ejection: theirs sources and geomagnetic disturbances

S. Naitamor

Centre de Recherche en Astronomie Astrophysique et Geophysique, chemin de l'observatoire, BP 63 Bouzareah, Algeria; e-mail: snaitamor@yahoo.com

Abstract. I present a statistical study of CMEs (type Halo and Partial Halo) theirs solar surface sources and geomagnetic disturbances from January 1997 to September 2004. From all front side CMEs I have identified 208 events issued from the southern quadrant and 200 events from the northern quadrant. Theirs surface sources are 149 C flare, 176 M flare, 60 X flare and 23 filaments and prominence respectively. For geomagnetic disturbances studies I used the Dst data delivered by Kyoto University, and I selected events with Dst less than -50. By using Bz-Vcme and Dst-Bz plots, we can estimate the Bz component of the magnetic field and storm level of an event with given CME speed

Key words. CME, Flares, Geomagnetic disturbances

1. Introduction

Geomagnetic storms are disturbances in the earth magnetosphere that occur when the interplanetary magnetic field (IMF) component Bz becomes southward. Large storms can still cause significant damage to space and ground based installation. Sever geomagnetic storms occur when IMF imposes long periods of the southward component (Bz) with large magnitude. Coronal Mass Ejection (CMEs) and corotating interaction regions (CIRs) are considered to be two major solar sources of geomagnetic disturbances. There is considerable interest to predict magnetic field orientation, speed and arrival time of the perturbation at the near earth space. Several authors have attempted to link the near-sun observations of CMEs with their interplanetary counterparts to asses their geomagnetic effects and estimate the travel time to 1AU (Webb et al. 2000; Gopalswamy et al. 2001a; Yurchyshyn al. 2003). In this study, I have identified surface disk sources of 408 CMEs (PH and complete halo) events between January 1997 and September 2004. For the correlation study, I have selected events with Dst values was ¡ -50nT. The data used in this study are described in the second section, the results are presented in the third section and I finish with conclusion and remarks.

Send offprint requests to: S. Naitamor

2. Data selection

For CMEs information and properties I have used the LASCO CME catalog. The events studied her have angular width greater than 120. The speed of CME used in this study is that obtained by linear fit to the height time profile. To identify the associated surface activity of each event, I used the NOAA preliminary report and forecast of solar geophysical data and LASCO C2/EIT 195Å movies. I searched for disk activity within a time window starting 3 hours before and until the time that the leading edge of the event was first observed in the Lasco C2 coronagraph at height of 1.0Rs above the limb. For ICMEs parameters, I used the ACE hourly averaged data of Bz component of the interplanetary magnetic field in GSM system, and ICME speed at Coordinate Data Analysis Web-page. Dst values of geomagnetic storms are given in the World Data Center for Geomagnetism in Kyoto University.

3. Results

3.1. CMEs sources and locations

The total number of identified CMEs is 408 event, 208 event in the southern quadrant and 200 in the north. The results show a growth of the CMEs number while approaching a solar cycle maximum where south quadrant activity is dominant. From April 1999 and up to April 2001 CMEs number increase to the maximum value and north quadrant sources dominate. After April 2001 the activity remain high for the rest of the period where the south quadrant sources return to dominate, see figure 1. Figure 2 shows the different activities associated with the front side CMEs. Major sun disk activities are M flare class (176 events), C flare class (149 events) and X flare class (60 events).

Figure 3 shows the speed distribution of all events for the three flare classes, it is shown that majority of very fast CMEs have X flare class sources.

3.2. Front side CMEs geomagnetic disturbances

To study the relation between CMEs and geomagnetic storms, I searched all events with Dst values less than -50. When the ICME speed is known and assuming a linear expansion of the interplanetary plasma material from the sun to 1AU, we can estimate the time onset time of the CME. The CME searched her must be front side, having angular width greater than 120 and have a source region near sun disk center (40). In figure 4 and 5 are presented for the 74 CMEs flares sources events Bz(nT) and Dst(nT) parameters. In the solar minimum the geomagnetic perturbations are less and are between moderate and intense storms. During maximum activity of the cycle, the number of perturbation increase with major to sever storming classes. Is also shown that the largest event of this period occurred on 20 November 2003, after the solar maximum.

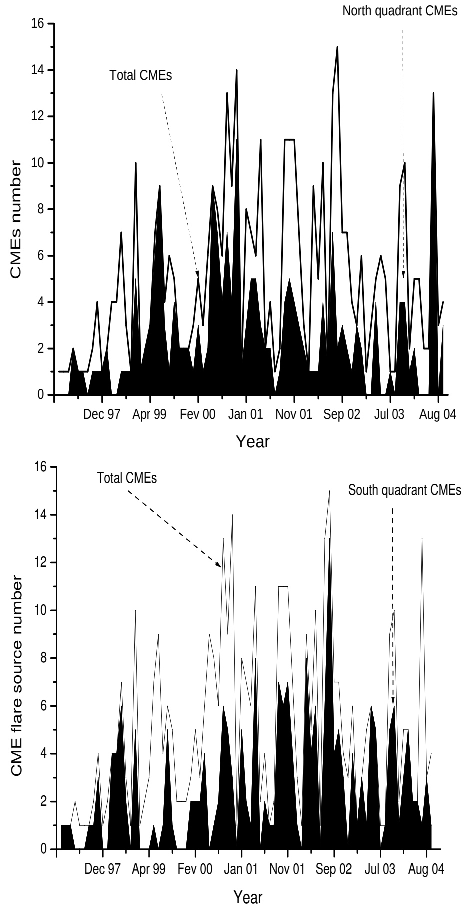

Fig. 1. CMEs number of north and south quadrant sources

$$V_{ICME} = 341.83 + 0.292 * V_{CME} \quad (1)$$

In figure 6 I have presented the Bz(nT)-CME speed dependence. Majority of fast CME

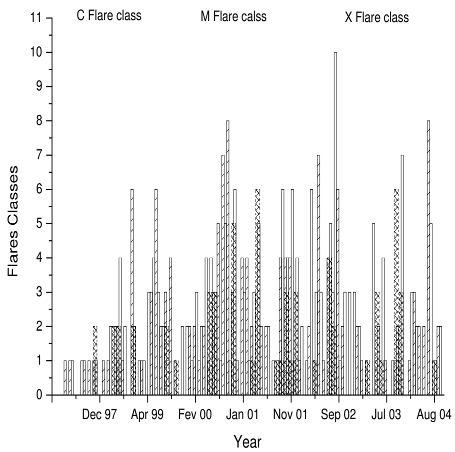

Fig. 2. front side activity associated with CMEs

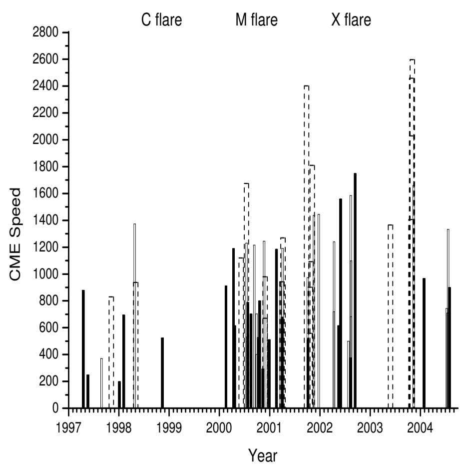

Fig. 3. CMEs speed distribution for all front side events.

have a strong Bz component and the dependence can be described by the relation:

$$B_z = -2.72 - 0.0148 * V_{cme} - 1.17310^{-6} * V_{cme}^2 \quad (2)$$

Figure 7 shows the variation of Dst(nT) index with Bz(nT) component of the IMF. It shows clearly that CMEs with strongly southward Bz produce sever geomagnetic storms. The Dst-B_z relation is given by:

$$Dst = 8.6 - 318.92 Ln(-Bz/4.52) \quad (3)$$

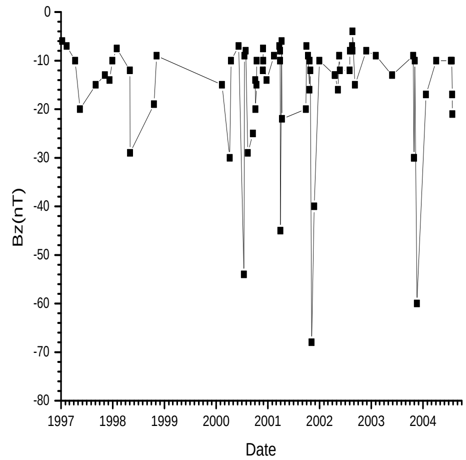

Fig. 4. Bz values for selected events.

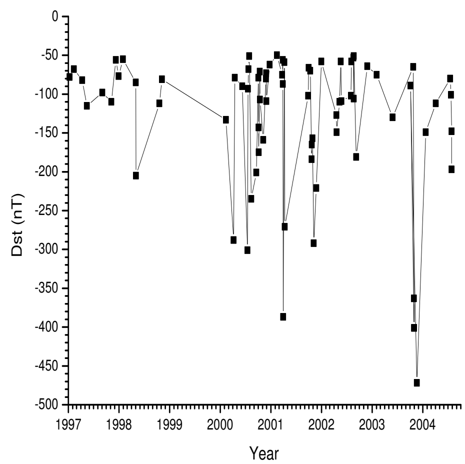

Fig. 5. Dst values for selected events.

4. Conclusions

Webb et al. (2000) studied halos CMEs from December 1996 to June 1997; they found that earth directed CMEs were associated with shocks, magnetic clouds and geomagnetic storms 3-5 days later. Especially Halo CMEs occurred in active region within 0.5Rs of sun center are an excellent indicator of increased geoactivity at earth. (Wang et al. 2002) identified 132 earth directed CMEs for a period between Mars 1997 to December 2000. They found that 45 percent of the total 132 CMEs caused geomagnetic storms with Kp¿5. In their

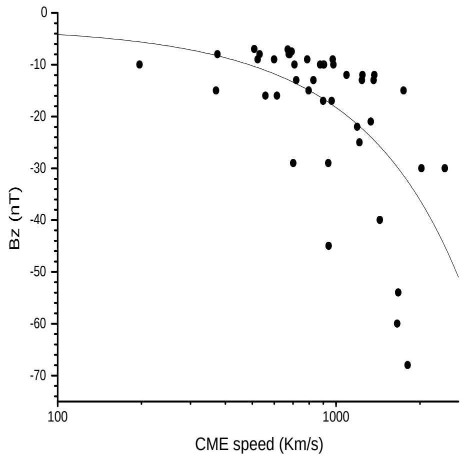

Fig. 6. B_z component as function with CME speed.

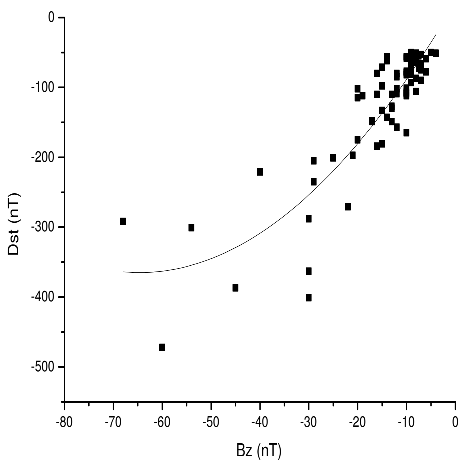

Fig. 7. Dst versus B_z for the selected events.

statistics the CMEs distribution is asymmetric about the central meridian. More than 60 percent events occurred on the west. The CME initial location scattered in latitude [S40, N40] and in longitude [E40, W70]. The average transit time of geoeffective halo CMEs is 75 hours. Wu et al. (2002) investigated geomagnetic storm activity during periods of 135 magnetic clouds from 1965 to 1998. They found that the Dst index correlates well with both the Bz component of the IMF and the rectified electric field VBs but does not correlate well with solar wind speed, indicating that role of magnetic cloud speed in predicting storm intensity is a minor one. Depending on the solar wind speed, they found that the correlation coefficient for Dst versus Bz increase dramatically when solar wing speed increase. Yurchyshyn al. (2003) studied the relationship between the projected speed of CMEs and the hourly averaged magnitude of Bz component of the IMF. They found a correlation coefficient of 0.78 between Bz values halo CME speed. They also found a third polynomial relationship between Dst index and Bz, the correlation coefficient is 0.82. Note that their Dst-Bz fit is only reliable in the range $-40 \leq Bz \leq 0nT$. In this study, the CMEs occurrence has the same rate in north and south quadrant of the solar disk, related surface activities are 149 C flare, 176 M flare, 60 X flare, 23 filaments and prominence. From all identified events the geoeffective CMEs scattered in latitude [S40, N40] and in longitude [E50, W60]. These results also show that 62 percent events occurred on the west and 38 percent events in the east. Therefore CMEs which occur in the west part of the sun disk can affect the earth geomagnetosphere. The mean speeds of each flares-CMEs class are: 1391.38 km/s for X class flare 1012.91 km/s for M class and 751.56 for C class. For space weather application I have selected front side CMEs which are around 30 in latitude. According to Yurchyshyn al. (2003) the Bz-Vcme dependence can be expressed by the following relation:2

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