Statistical Analysis of Coronal Mass Ejections

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ABSTRACT

The paper describes the statistical study of the correlation of CME parameters with the geomagnetic storm index Dst. An attempt is made to understand which is the most effective parameter producing the storm. It has been seen that southward component of Interplanetary Magnetic Field (Bz) and Initial Speed play important role in geoeffectiveness of a CME.

1. Introduction

Coronal Mass Ejections are major event occurring on the Sun that affect terrestrial atmosphere and produce sequence of events that are referred to as Space Weather. Jadav et al., (2005) have presented the space weather aspects of a large halo CME on 4 April 2000, which appeared to be associated with 2F/C9.7 flare in AR8393. The statistical study of effectiveness of different solar wind and interplanetary parameters on geomagnetic storm generation was studied by Srivastava and Venkatkrishnan (2004). In this paper, a statistical study of correlations of the storm index D_{st} with solar wind and interplanetary parameters is presented.

2. Experimental data:

In order to understand the propagation of CMEs through the interplanetary medium their travel time is studied as a function of the initial speed of the CME. The travel time is measured as the time between the appearance of the CME on the coronagraph and time of onset of the geomagnetic storm. Figure 1 shows the variation of travel time with initial speed. Positive slope of linear fit with a constant of 0.29 indicate that both initial speed and Dst index are positively correlated with each other. Figure 2 of Dst and Southward Component of Interplanetary Magnetic Field if with R = 0.80 is very highly correlated and implies that this parameter is the most important among all CME related parameters.
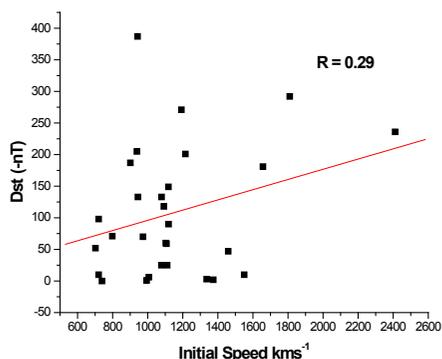

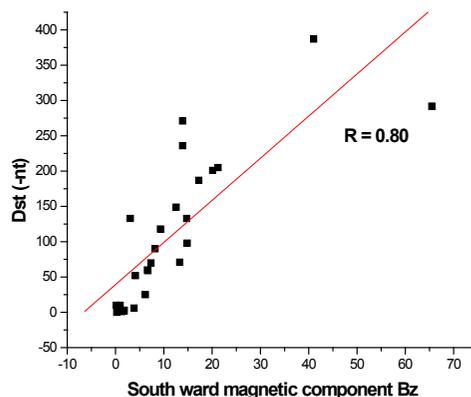**Figure 1: Correlation plot of Dst and Initial Speed of CME (km/s).**

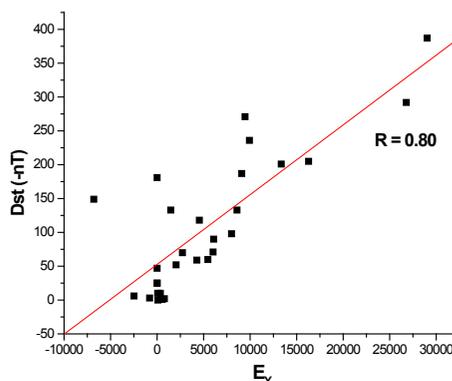**Figure 2: Correlation plot of Dst and Southward Component of IMF, B_z (nT).**

Figure 3: Correlation plot of Dst and Interplanetary Electric Field.

In figure 3, Dst is plotted against Interplanetary Electric Field during CME propagation towards the Earth. This is also in good correlation with Dst index. While Figure 4 of Interplanetary Wind Density is also in correlation with Dst Values. Figure 5 is of Dst versus Ram pressure which is derived from Speed and Density whose correlation (0.588) is less than magnetic field.
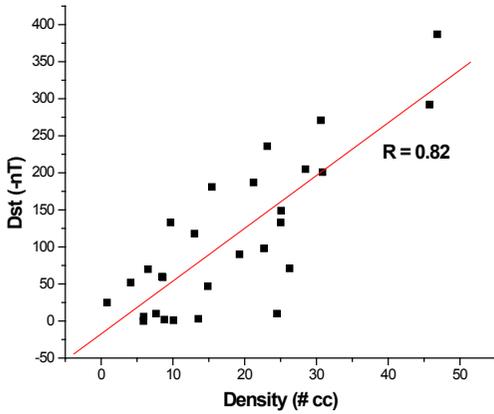
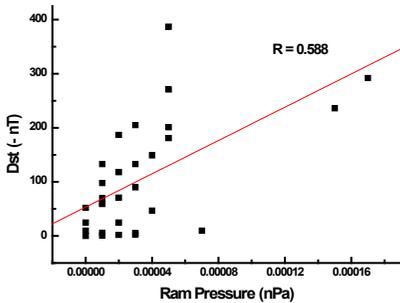**Figure 4: Correlation plot of Dst and Proton Density (#/cc).**

Figure 5: Correlation plot of Dst and Ram Pressure (nPa).

An attempt is also made here by taking initial speeds of Coronal Mass Ejections and their travel time towards the Earth. This time is taken between emergence from LASCO/C2 and time at Dst minimum. This exercise was done to understand whether higher speed results into more geoeffective storms.
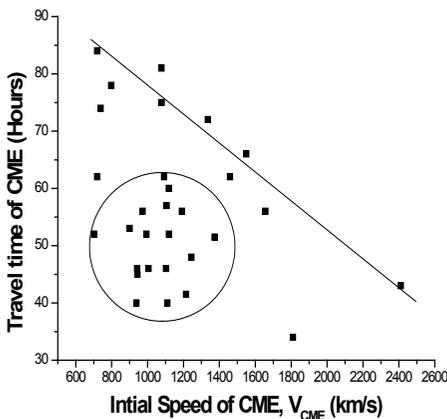

Figure 6: Plot of Travel time (Hrs) vs. Initial Speed (km/s) of CMEs.

In this figure, some points are aligned along a straight line with negative slope showing decrease of travel time with increasing speed but the number of points below the line indicates the acceleration or deceleration process of CMEs as they interact with the background solar wind in the interplanetary medium.

5. Discussion and conclusion:

St Cyr et al (2000) performed a detailed study of CMEs observed by LASCO from January 1996 to April 1998, and identified 92 halo or partial halo CMEs out of a total of 841. Based on EIT observation 40 of them were identified as originating on the front side of the disc as viewed by SOHO's vantage point at L1. There were 20 severe geomagnetic storms during the same period, 14 (70%) of which were preceded by front-side halo CMEs. These results confirm that factors other than the occurrence of a CME, directed towards Earth, that are important in determining the level of geomagnetic activity. The most important parameters determining the geoeffectiveness of a CME are the speed of the ejecta and strength and orientation of the magnetic field. Srivastava and Venkatkrishnan (2004) reported correlation studies of various CME parameters with storm index. They found that magnitude of geomagnetic storms depends on the ram pressure because a high ram pressure leads to the compression of the magnetic cloud and intensifies the southward component of B_z. However, our correlation studies indicate that the correlation for ram pressure was quite less than for density. Thus the interaction between the CME / solar wind and magnetosphere is very complex and varies from event to event. A large number of cases need to be studied before any meaningful statistical association, especially for the purpose of space weather prediction, can be drawn.

REFERENCE

1. Jadav, R.M., Iyer, K.N., Joshi, H.P., and Hari Om Vats, Coronal mass ejection of 4 April 2000 and associated space weather effects, Planet. & Space Sci., 53, 671-679, 2005. || 2. Srivastava N. and Venkatkrishnan P., Solar and Interplanetary sources of major geomagnetic storms during 1996-2002, J. Geophys. Res., 109, A10103, doi:10.1029/2003JA010175, 2004. || 3. St. Cyr. O. C., et al., Properties of coronal mass ejections: SOHO LASCO observations from January 1996 to June 1998. J. Geophys. Res, 105, 18169, 2000.