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A STATISTICAL STUDY ON CORONAL MASS EJECTION AND MAGNETIC CLOUD AND THEIR GEOEFFECTIVENESS

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ABSTRACT: A detailed investigation on geo effectiveness of Coronal Mass Ejections(CMEs) associated with Magnetic Clouds(MCs) observed during 1996-2009 is studied.The collected sample events are divided into two groups based on their association with CMEs related to geomagnetic storms Dst $\leq$ -50 nT eg 1.geoeffective events & 2.Non geo-effective events. Furthermore , most of the CMEs are of halo type occur mostly in western hemisphere. Halo and partial halo CMEs are likely to be the major cause of these GMSs of high intensity.There exist a weak anti-correlationship (R=0.54) for geoeffective events between CME speed (Vcme) and Dst index and relatively better correlation (R=0.54) and (R=0.16) 1.Between Vcme and solar wind speed (Vsw) 2.Dst index and solar wind speed whereas the correlation (R=0.16) between Dst indexand southward magnetic field component (Bz) is very poor. From our investigatios we have observed that the intense and long duration,southward magnetic field component(Bz) and fast solar wind speed are responsible for geomagnetic storms,and geomagnetic storms weakly depend on CME velocity.

KEYWORDS:Coronal Mass Ejections, Magnetic cloud and Geomagnetic storms.

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1. Introduction

In recent years a number of investigations have been carried out to understand the solar terrestrial relationship and to ascertain factors that are responsible for GMSs, Gopalswamy et al (2008)[1] and Kumar and Raizada (2008)[2]. It is believed that the GMSs are the response to interplanetary [IP] phenomena arising as a consequence of a solar event. The geospheric environment is highly affected by the Sun and its features such as Solar Flares [SFs], Active Prominences and Disappearing Filaments [APDFs], Coronal Holes [CHs], CMEs etc. Research since last three decades identifies CMEs as the energetic events in the heliosphere. CMEs from the Sun drive, Solar Wind (SW) disturbances in terms of magnetic field, speed and density which in turn causes geomagnetic disturbances at Earth.

Due to the effects of Solar flare and CME events, a GMS of longer than average duration may result. The intensity of GMSs is primarily decided by CMEs speed and strength of magnetic field it contains, Gopalswamy (2006)[3] and Cane et al (2000)[4] whereas according to Manoharan(2006)[5] primary factors determining the geoeffectiveness are : the direction of propagation of CMEs, its speed, size, density and further, orientation and strength of the magnetic field at the near Earth space. Intense GMSs are found to be mainly caused by CMEs (Zhang et al, 1996) [6] . The frequency of CMEs vary with sunspot cycle.

CMEs are large scale plasma and magnetic field structures moving away from the Sun into heliosphere (Gopalswamy, 2002)[7] . CMEs, which appear to surround the occulting disk of the observing coronagraph are known as halo CMEs (Howard et al, 1982) [8]. The CMEs with an apparent width of 360^o are taken as halo; whereas the CMEs with width $\leq 359^o$ and 120^o are taken as 'partial halo' (Loewe and Prolss, 1997[9] and Gopalswamy et al, 2007[10]) . CMEs that are observed in the solar wind near 1 AU are commonly called interplanetary coronal mass ejection [ICMEs].MC is the subset of ICMEs having a specific configuration in which the magnetic strength is higher than the average magnetic field. Halo CMEs have now been shown to be an important factor affecting the physical conditions in the entire Heliosphere, ability of CMEs to cause GMSs is known as geoeffectiveness which is measured in the terms of geomagnetic index such as the disturbance storm time of Dst . A MC is a transient event observed in the solar wind. It is defined as a region of enhanced magnetic field strength. smooth rotation of the magnetic field vector and low proton temperature(Burlaga et al, 1981)[11]. MCs are a possible manifestation of CMEs.

2. Data Analysis

During the period 1996 -2009 CMEs associated with magnetic clouds have been investigated. The data on magnetic Clouds is obtained from MFI table of MAG CLOUD'S (File://G:\MFI TABLE OF MAG CLOUD'S.htm) covering the above period and containing 110 events. The values of Dst indices are taken from world data center Japan (http://swdcwww.kugi.kyoto-u.ac.jp) . The data regarding the related CMEs (speed, width and acceleration) are taken from the online SOHO/LASCO CME catalog maintained by the CDAW data center (http://cdaw.gsfc. nasa.gov/CME_list). The data on Shocks is obtained from ACE Lists of Disturbances and Transients. Out of 110 events only 101 events are taken for our further analysis using the following selection criteria 1. The given CMEs information should be Clear 2. The days with data being not available are excluded from the analysis.

The above two selection criteria are used to select the clear events from which the properties of CMEs and their associated Magnetic Clouds can be studied clearly. The events are considered to be geoeffective if their Dst index $\leq$ -50 nT ,(Gopalswamy et al, 2007)[9] . The sample events are divided into two groups as follows; 1. Geoeffective events : It contains 54 events corresponding Dst index values $\leq$ -50nT 2. Nongeoeffective events: It contains the remaining 47 events.

RESULTS AND DISCUSSION

The CME speed listed in the LASCO CME catalog is measured from the height time measurements projected in the sky plane. So all the measured parameters will suffer from projection effects. No attempt has been made to correct the projection effects. The speed of the CMEs varies from few hundred Km/s to 2000 Km/s. The mean speed of nongeoeffective events is 468.51 Km/s and that of the geoeffective events is 787 Km/s.

The angular width is the angular extent between the two edge position angles of the CMEs in the sky plane. The width of the CME varies between 0^0 and 360^0. The mean width of the nongeoeffective events is 144.2^0 and that of the geoeffective events is 296.45^0 . In geoeffective events 74% are halo CMEs, while in nongeoeffective events only 26% are halo CMEs. Therefore, the geoeffective events are found to be wider than nongeoeffective events.

There exists a weak correlation between CME speed and Dst index for geoeffective events with an anti-correlation coefficient (R = - 0.23) as shown in Figure -1. Further there exists a weak correlation (R = 0.21) between Dst index and southward magnetic field component [B_Z] for geoeffective events as shown in Figure-2. The weak correlation indicates that the geoeffectiveness weakly depends on CME speed.

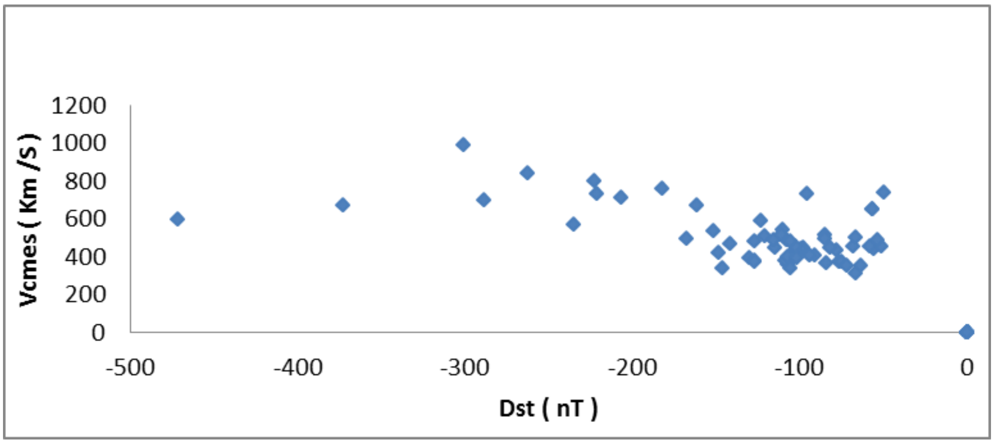

Figure – 1 : The scatter plot between V_{CMEs} and Dst have been plotted for Geoeffective events

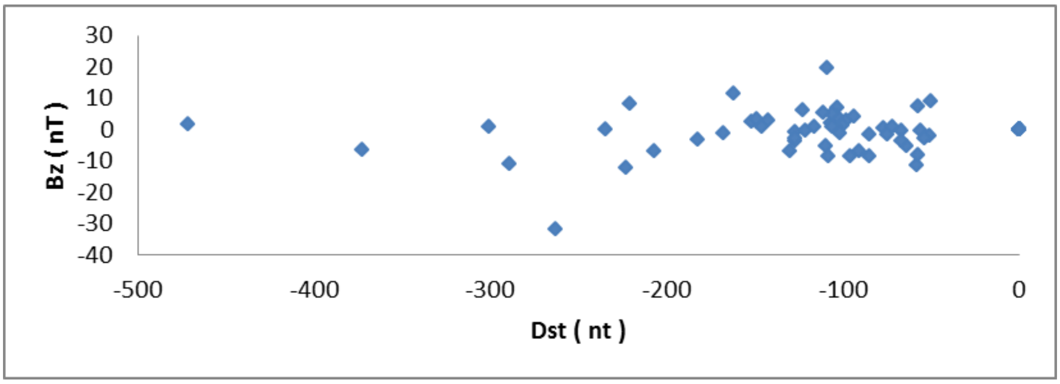

Figure – 2 : The scatter plot between Dst and B_Z have been plotted for Geoeffective events

The correlation between solar wind speed and Dst index for geoeffective events are shown in Figure -3. There exists a good anti-correlation between Dst index and solar wind speed (R = - 0.56) . The less scattering in the correlation plot shows that there exists a relationship between them and the geoeffectiveness depends on solar wind speed in the interplanetary medium. The fast solar winds are found to be associated with intense geomagnetic storm.

There exists a good correlation (R = 0.54) between CME speed and solar wind speed for geoeffective events . Thus , the CME speed in the interplanetary medium is affected by the solar wind speed. The fast CMEs are found to have more solar wind speed as shown in Figure – 4.

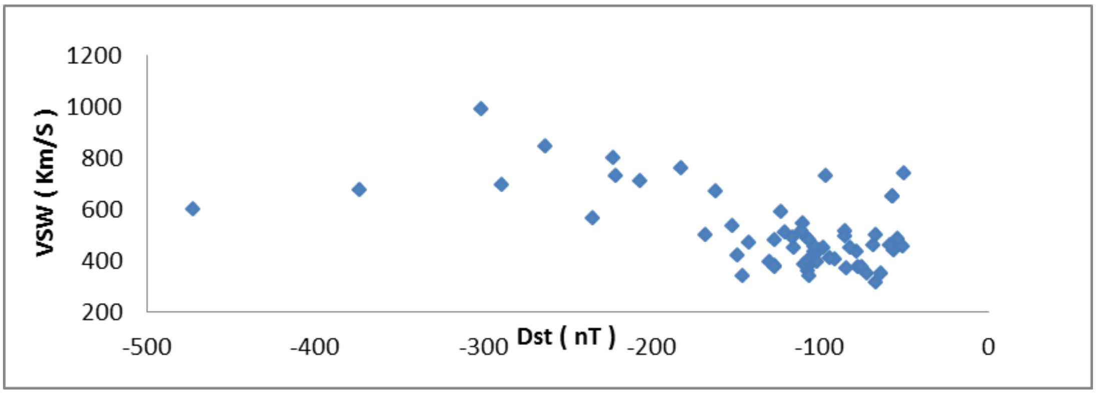

Figure – 3 : The scatter plot between V_{SW} and Dst have been plotted for Geoeffective events

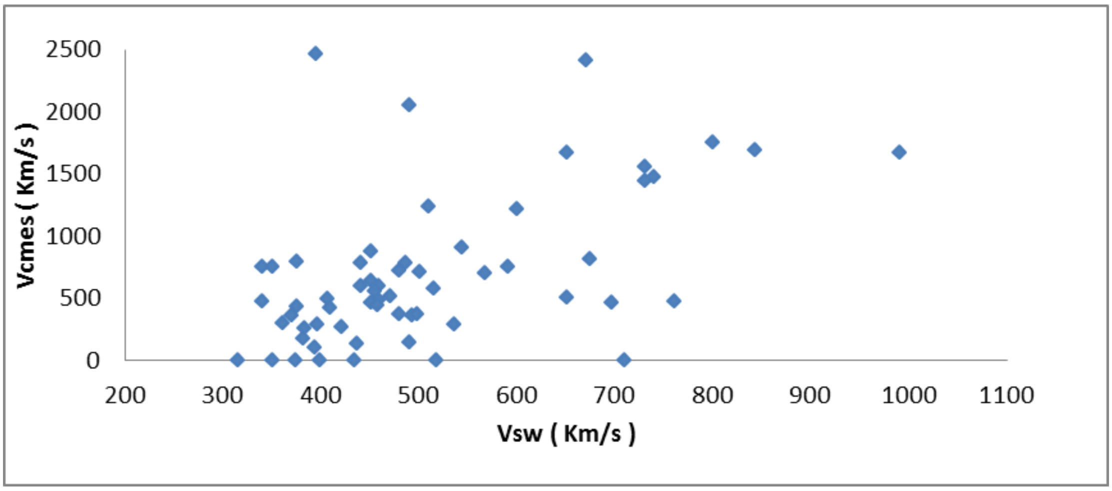

Figure –4 : The scatter plot between V_{SW} and V_{CMEs} have been plotted for Geoeffective events

There exists a weak anti-correlation between CME speed and Dst index for nongeoeffective events with an anti-correlation coefficient (R = - 0.36) as shown in Figure -5 . Further there exists a weak correlation (R = 0.24) between Dst index and southward magnetic field component [B_Z] for geoeffective events as shown in Figure-6.

The anti-correlation between solar wind speed and Dst index for nongeoeffective events are shown in Figure -7. There exists a good correlation between Dst index and solar wind speed (R = -0.38).There exists a weak correlation (R = 0.29) between CME speed and solar wind speed for nongeoeffective events as shown in Figure – 8 .

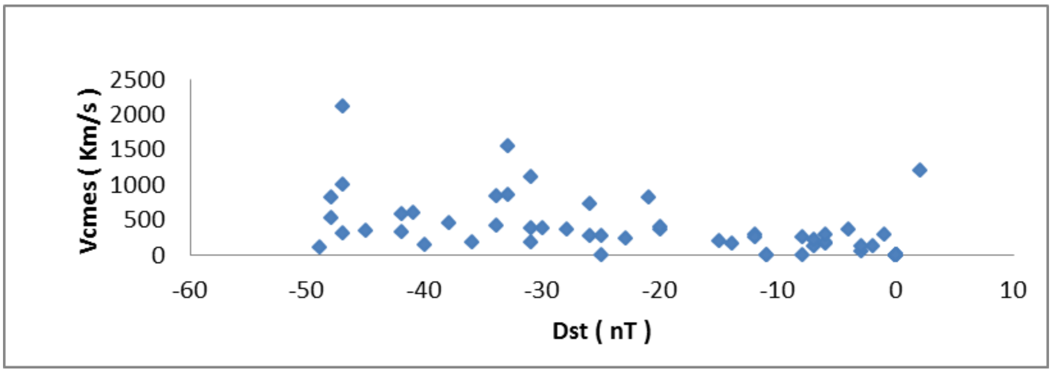

Figure – 5 : The scatter plot between V_{CMEs} and Dst have been plotted for Nongeoeffective events

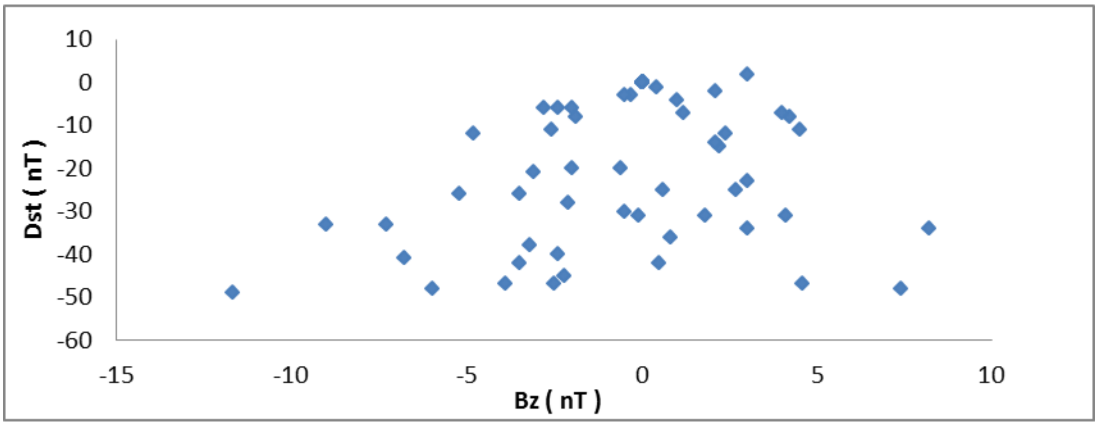

Figure –6 : The scatter plot between Dst and B_Z have been plotted for Nongeoeffective events

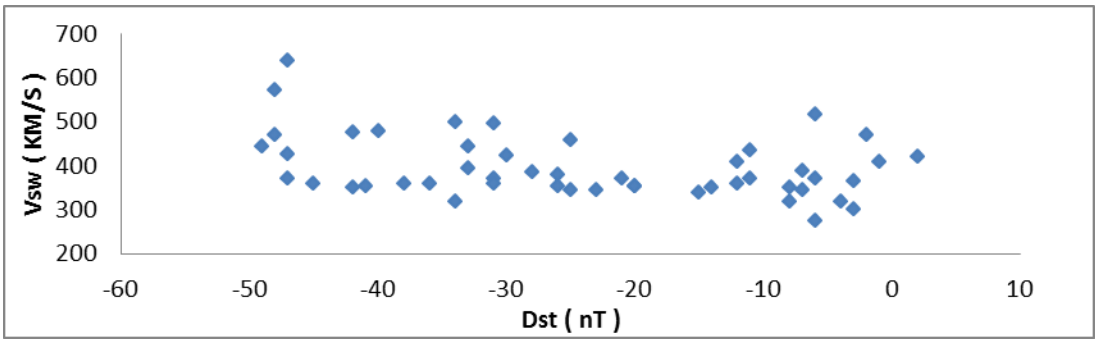

Figure – 7 : The scatter plot between V_{SW} and Dst have been plotted for Nongeoeffective events

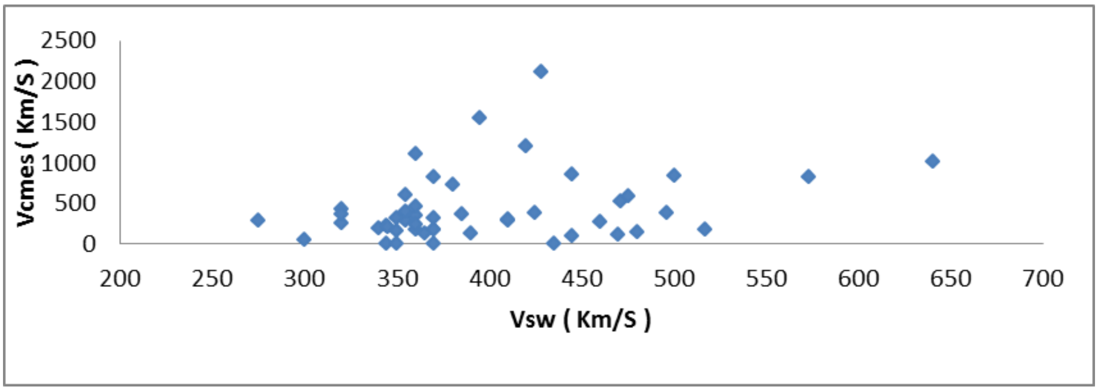

Figure – 8 : The scatter plot between V_{SW} and V_{CMEs} have been plotted for Nongeoeffective events

Speed of MCs seem to be one of the important parameters responsible for the occurrence of GMS. There exists a good anti-correlation (R = - 0.64) between magnetic cloud velocity and Dst index . Geoeffective MCs generally have high speed. Speed of MCs appear to have greater impact on the minimum value of Dst attained during a GMS. Furthermore , it has been observed that the MCs are about 47% RH and 53% LH that have occurred.

Furthermore , the effect of CMEs (i.e.; halo as well as partial halo) to cause GMSs of varying nature is investigated . It is found that 53% halo and 47% partial halo CMEs are responsible for GMSs. Thus , it may be deduced that CMEs having Position Angle [PA] greater or equal to 120^0 have higher probability of reaching the Earth than other CMEs of having PA less than 120^0 .

It is observable from here that MCs having a velocity greater than 400 Km/s are mostly responsible for

GMSs. Thus, it is deduced that MCs velocity also play an important role in the prediction of GMSs.

3 . CONCLUSIONS

We have analyzed 101 CMEs associated with MCs observed during 1996 – 2009. The sample events are divided into two groups based on the CMEs association with Dst ≤ - 50 nT as (i)geoeffective events and (ii) nongeoeffective events . The results of our study are summarized as follows: It may be deduced that CMEs having Position Angle [PA] greater or equal to 120^0 have produced geomagnetic storms and CMEs velocity is also a good predictor of geomagnetic storms. The velocity of CMEs has been found to play major role in deciding the strength of GMSs along with other parameters like angular width, direction of motion etc. It is expected that ones with more speed leads to more disturbance in magnetosphere, which in turn causes intense GMSs. The CMEs with less speed leads to weak GMSs. Most of the geoeffective CMEs have occurred in western hemisphere.

The magnetic clouds having velocity greater than 400 km/s are mostly responsible for GMSs. Magnetic cloud velocity has significant correlation with Dst and it is also one of the important parameter for prediction of the GMSs.

The anti-correlation between CME speed and Dst is weak for geoeffective event (R = - 0.23) and weak for nongeoeffective event (R = - 0.36) .The correlation between Dst index and solar wind speed is good for geoeffective events (R= 0.56) and weak anti-correlation for nongeoeffective event (R= - 0.38) . The correlation between Dst index and southward magnetic field component [Bz] is weak for geoeffective events (R = 0.21) and for nongeoeffective event (R = 0.24) . The correlation between CME speed and solar wind speed is good for geoeffective events (R = 0.54) & is weak for nongeoeffective events (R = 0.29) .

The geoeffective events are found to be associated with intense geomagnetic storm with mean Dst index (-128.55 nT). The nongeoeffective events are found to be associated with weak geomagnetic storm with mean Dst index (-23.979 nT). Furthermore, the effect of CMEs (i.e; halo as well as partial halo) . There exists a weak correlation between (i) CME speed and Dst index with an anti-correlation coefficient of R = - 0.36 as shown in Figure –9 (ii) Dst index and southward magnetic field component [Bz] with a correlation coefficient of R= 0.16 as shown in Figure – 10 . There exists a good correlation between(i) Dst index and solar wind speed/Magnetic Clouds velocity with a correlation coefficient of R= 0.64 as shown in Figure - 11

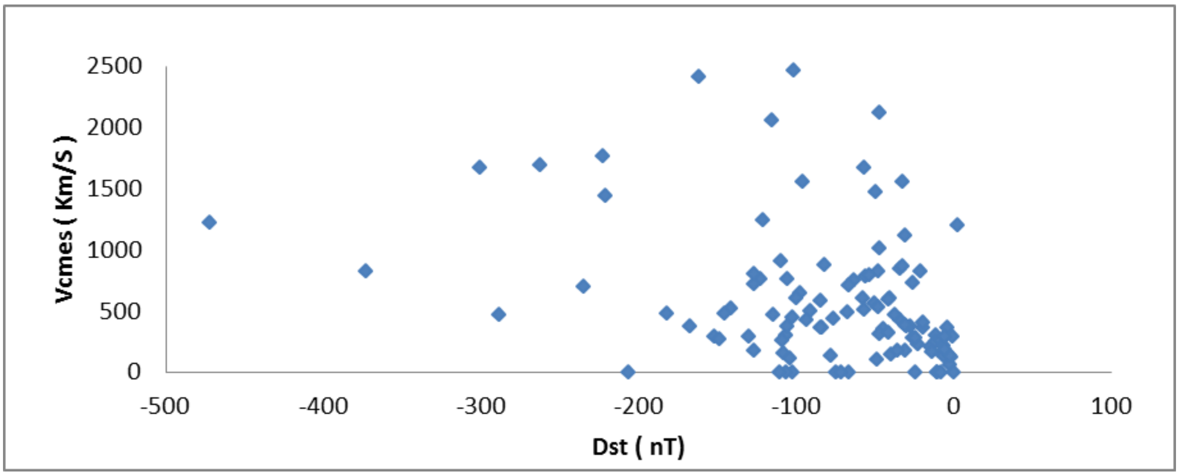

Figure –9 : The scatter plot between V_{CMEs} and Dst have been plotted

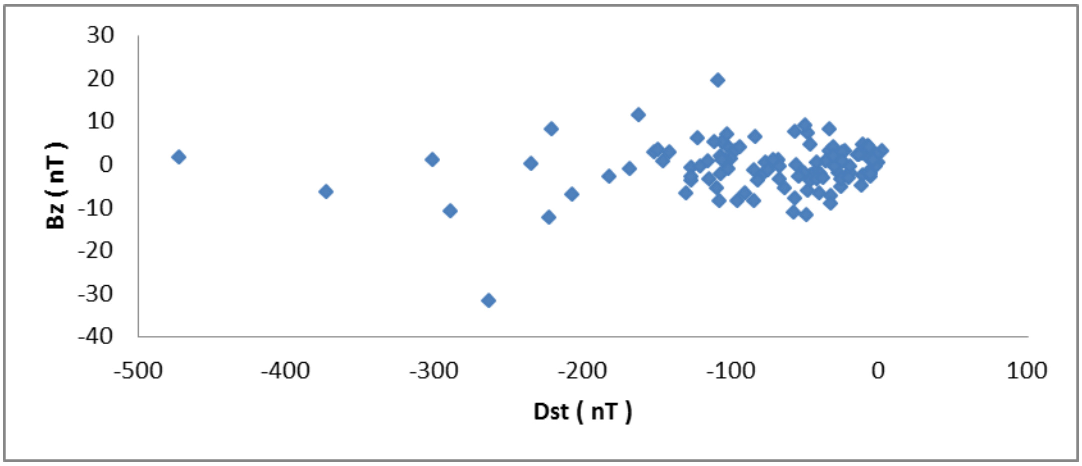

Figure –10 : The scatter plot between Dst and B_Z have been plotted

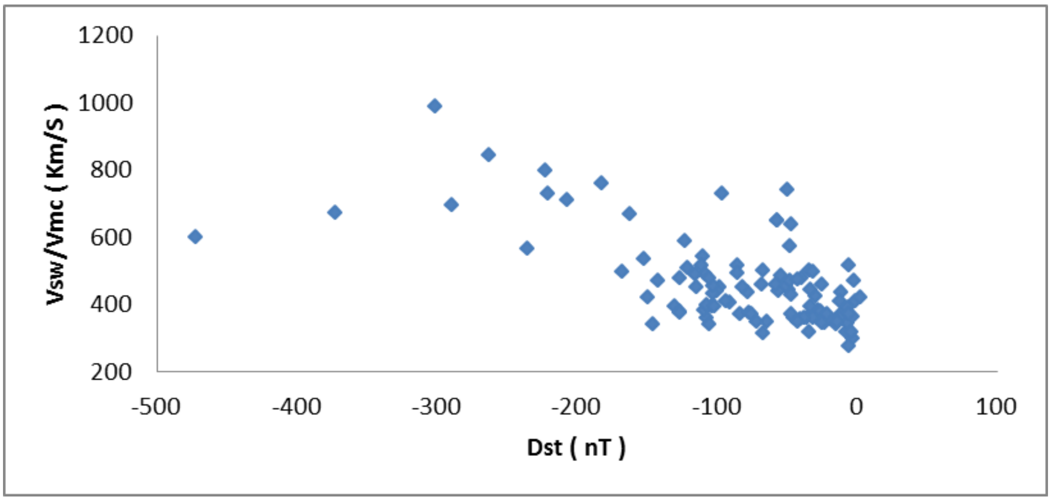

Figure – 11: The scatter plot between Magnetic Clouds Velocity (V_{SW} / V_{MC}) and Dst have been plotted

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