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STATISTICAL RELATION OF SOLAR FEATURES AND SOLAR WIND PLASMA PARAMETERS WITH INTERPLANETARY SHOCK RELATED GEOMAGNETIC STORMS

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ABSTRACT

We have studied geomagnetic storm ≤-80 nT, associated with interplanetary shocks, observed during the period of 2000- 2010 with coronal mass ejections and solar wind plasma parameters. We have found that most of the shock related geomagnetic storms are intense are severe. The association rates of moderate, intense and severe shock related geomagnetic storms have been found 21.88%, 59.38% and 18.75% respectively. Further it is observed that maximum of them (81.25%) are associated with coronal mass ejections. The association rates of halo and partial halo coronal mass ejections have been found 82.69% and 17.31% respectively. It is also concluded that majority of them are associated with radio bursts (71.88%). The association rates of type IV and type II radio bursts have been found 58.70% and 41.30% respectively. From the further analysis, positive co-relation has been found between magnitude of interplanetary shock related geomagnetic storms and magnitude of jump in solar wind plasma temperature ,velocity, pressure and peak value of interplanetary magnetic fields, southward component of interplanetary magnetic fields with correlation coefficient 0.33 between magnitude of interplanetary shock related geomagnetic storms and magnitude of jump in solar wind plasma temperature,0.40 between magnitude of interplanetary shock related geomagnetic storms and magnitude of jump in solar wind plasma velocity, 0.26 between magnitude of geomagnetic storms and magnitude of jump in solar wind plasma pressure,0.71 between magnitude of shock related geomagnetic storms and maximum (peak) value of average interplanetary magnetic field (JIMF),0.78 between magnitude of shock related geomagnetic storms and magnitude of maximum (peak) value of southward component of interplanetary magnetic field..

Keywords –Geomagnetic storms, interplanetary shocks**,** coronal mass ejections, solar wind plasma parameters.

INTRODUCTION

Geomagnetic storms are generally defined by periods of intense solar wind–magnetosphere (SW-M) coupling usually associated with extreme conditions in the solar wind (SW), such as coronal mass ejections (CMEs) or co-rotating interaction regions (CIRs). Coronal mass ejections (CMEs) are the energetic solar events in which huge amount of solar plasma materials are ejected into the heliosphere from the sun and generate large disturbances in solar wind plasma parameters and geomagnetic storms in geomagnetic field [Correiaa, 2005: Cane, 2000:Michalek, 2006: St. Cyr, 2000: Webb, 2000: Gopalswamy, 2006: Manoharan, 2006: Verma et al, 2009: Verma, 2012]. It is believed that the main cause of intense geomagnetic storms is the large IMF structure which has an intense and long duration southward magnetic field component, *Bz* [Tsurutani,et al, 1988 : Echer,et al, 2004]. They interact with the earth's magnetic field and facilitate the transport of energy into the earth's atmosphere through the reconnection process. .Correiaa and De Souza [2005] have presented the identification of solar coronal mass ejection (CME) sources for selected major geomagnetic storms in the geomagnetic field of geomagnetosphere. They have inferred that full halo CMEs originating from active regions associated with X-ray solar flares and propagating in the western hemisphere, cause strong geomagnetic storms. Michalek, G. et al [2006] have concluded that halo coronal mass ejections (HCMEs) originating from regions close to the center of the sun are likely to be geoeffective. They have showed that only fast halo CMEs (with space velocities higher than ~1000 km/s) and originating from the western hemisphere close to the solar center could cause intense geomagnetic storms. Gopalswamy [2009] have studied geoeffectiviness of halo and partial halo coronal mass ejections and concluded that the geoeffectiveness of partial halo CMEs is lower because they are of low speed and likely to make a glancing impact on earth rather than halo coronal mass ejections. Chao Yuea and Qiugang Zong [2011] have investigated interplanetary shocks associated with coronal mass ejections (CMEs) with geomagnetic storms and concluded that interplanetary shocks associated with coronal mass ejections (CMEs) have very profound effects on geomagnetic storms. They have investigated the role of the interplanetary shock properties and pre-conditions and presented a statistical study of 280 interplanetary shocks and their associated geomagnetic activities during 1998–2007. They have determined that perpendicular shocks can cause more intense geomagnetic activities compared with parallel ones under the same IMF pre-condition. Veronica et al [2010] have performed an event-by-event study of 47 geomagnetic storms (GSs) that occurred during the ascending phase of solar cycle 23 and found all geomagnetic storms are associated with the passage of a shock and an interplanetary coronal mass ejection (ICME). They have concluded on average, the most intense geomagnetic storms are caused by sheaths followed by sheath-ICME combinations and by ICMEs. They have obtained the correlation coefficients between the intensity of each geomagnetic storm (minimum Dst) and several solar wind parameters. They found that the well-known correlation between the geomagnetic storms intensity and the solar wind convicted electric field, Ey , stands for the geomagnetic storms caused by ICMEs (CC = −0.88) and sheath-ICME combinations (CC = −0.95) .They have found a very good correlation between the geomagnetic storms caused by sheaths and the total convicted electric field (SEy) (CC = −0.89). Hutchinson [2011] presented results of a superposed epoch analysis of geomagnetic storms over the last solar cycle. Geomagnetic storms, identified by means of their characteristic SYM-H evolution, are separated by size into weak ($-150 < \text{SYM-H} \leq -80$) nT, moderate ($-300 < \text{SYM-H} \leq -150$) nT, and intense ($\text{SYM-H} \leq -300$) nT categories and determined that intense storms were observed to be driven solely by coronal mass ejections (CMEs); moderate storms were dominated by CME onset, while only weak storms were driven by both CMEs and corotating interaction regions (CIRs) at a ratio of ∼2:1, respectively. Gonzalez, et al [2011] have presented a review on the interplanetary causes of intense geomagnetic storms (Dst≤-100 nT), that occurred during solar cycle 23 (1997-2005). They have reported that the most common interplanetary structures leading to the development of intense storm were magnetic clouds, sheath fields, sheath fields followed by a magnetic cloud and corotating interaction regions at the leading fronts of high speed streams. However, the relative importance of each of those driving structures has been shown to vary with the solar cycle phase. They have also studied super intense geomagnetic storm (Dst≤-250 nT) in more detail for solar cycle 23, and found that these storms are associated with magnetic clouds and sheath fields following interplanetary shocks. Eun-Young et al [2010] have investigated the interplanetary conditions of 82 intense geomagnetic storms from 1998 to 2006, and compared many different criteria of interplanetary conditions for the occurrence of the intense geomagnetic storms (Dst ≤ -100 nT). For this study, they have considered three types of interplanetary conditions as B_z conditions, $E_y$conditions, and their combination. They have suggested that three conditions are promising candidates to trigger an intense storm: $B_z \leq -10$ nT for >3 h, $E_y \geq 5$ mV/m for >2 h, and $B_z \leq -15$ nT or $E_y \geq 5$ mV/m for >2 h.

EXPERIMENTAL DATA

In this investigation hourly Dst indices of geomagnetic field have been used over the period 2000 through 2010 to determine onset time, maximum depression time, magnitude of geomagnetic storms. This data has been taken from the NSSDC Omni web data system which been created in late 1994 for enhanced access to the near earth solar wind, magnetic field and plasma data of Omni data set, which consists of one hour resolution near earth, solar wind magnetic field and plasma data, energetic proton fluxes and geomagnetic and solar activity indices. The data of coronal mass ejections (CMEs) have been taken from SOHO – large angle spectrometric, coronagraph (SOHO / LASCO) and extreme ultraviolet imaging telescope (SOHO/EIT) data. To determine disturbances in interplanetary magnetic, hourly data of average interplanetary magnetic field have been used, these data has also been taken from Omni web data (http;//omniweb.gsfc.nasa.gov/form/dxi.html)).

The data of X ray solar flares radio bursts, and other solar data, solar geophysical data report U.S. Department of commerce, NOAA monthly issue and solar STP data (http://www.ngdc.noaa.gov/stp/solar/solardataservices.html.) have been used. The data of interplanetary shocks have been taken from list of shocks observed wind satellites and list of transient and disturbances.

DATA ANALYSIS AND RESULTS

From the data analysis of shock related geomagnetic storms ,it is observed that most of the shock related geomagnetic storms are intense or severe geomagnetic storms .We have identified 64 shock related geomagnetic storms during the period of 2000-2010, out of which 50 shock related geomagnetic storms have been found either intense (59.38%) or severe (18.75%) geomagnetic storms .From the further analysis it is also observed that majority of the shock related geomagnetic storms 46 (71.88%) have been found to be associated with radio bursts. Out of 46 associated geomagnetic storms 19 (41.30%) are type II and 27(58.70%) geomagnetic storms are found to be associated with type IV radio bursts. From the analysis of shock related geomagnetic storms and coronal mass ejections it is observed that majority of the shock related geomagnetic storms are associated with coronal mass ejections (CMEs). We have 64 shock related geomagnetic storms in our list out which 52 (81.25%) are associated with coronal mass ejections. Out of 52 associated geomagnetic storms 09 (17.31%) geomagnetic storms have been found to be associated partial halo coronal mass ejections and 43(82.69%) with halo coronal mass ejections. Further it is observed that more than 50% (28) are associated with CMEs of higher speed having speed more than 1000km/s.

Geomagnetic storms with disturbances in interplanetary magnetic Field

From the data analysis of shock related geomagnetic and associated disturbances in interplanetary magnetic field, we have observed that all the shock related geomagnetic storms are associated with jump in interplanetary magnetic field (JIMF) events. To see how the magnitude of shock related geomagnetic storms are correlated with the magnitude of JIMF events, we have plotted a scatter diagram between the magnitude of shock related geomagnetic storms and JIMF events in Fig.1. From the Fig It is clear that maximum shock related geomagnetic storms which have large magnitude are associated with such JIMF events which have relatively large magnitude. Positive co-relation has been found between magnitude of geomagnetic storms and maximum peak value of average interplanetary magnetic field of associated JIMF events. Statistically calculated co-relation co-efficient is 0.71 between these two events.

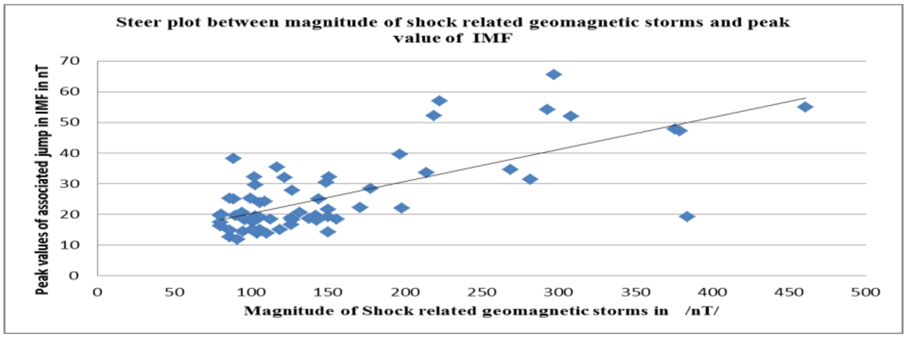

Figure-1- Shows scatter plot magnitude of shock related geomagnetic storms and peak value of JIMF events.

Geomagnetic storms with disturbances in southward component of interplanetary magnetic field

From the data analysis of shock related geomagnetic storms and associated jump in southward component of interplanetary magnetic field (JIMFBz), it is observed that all the shock related geomagnetic storms are associated with JIMFBz events. Further to see how the magnitude of geomagnetic storms are correlated with peak value of JIMFBz events, a scatter diagram have been plotted between the magnitude of geomagnetic storms and maximum peak value of JIMFBz events in Fig.2 .From the Fig it is clear that maximum geomagnetic storms which have large magnitude are associated with such JIMFz events which have relatively large peak value. Positive co-relation has been found between magnitude of geomagnetic storms and magnitude of maximum peak value of southward component of interplanetary magnetic field of associated JIMFBz events. Statistically calculated co-relation co-efficient is 0.78 between these two events.

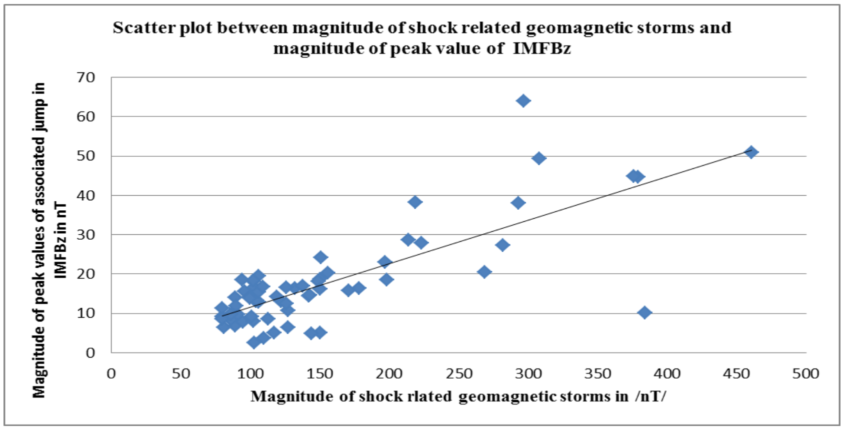

Figure -2-Shows scatter plot between magnitudes of shock related geomagnetic storms and peak value JIMFBz events

Geomagnetic storms with disturbances in solar wind plasma velocity

From the data analysis of shock related geomagnetic storms and associated jump in solar wind plasma velocity (JSWV), it is observed that 63 out of 64 geomagnetic storms are associated with JSWV events. Further to see how the magnitude of geomagnetic storms are correlated with magnitude of JSWV events, a scatter diagram have been plotted between the magnitude of shock related geomagnetic storms and magnitude of JSWV events in Fig. 3. From the Fig it is clear that maximum shock related geomagnetic storms which have large magnitude are associated with such JSWV events which have relatively large magnitude. Positive co-relation has been found between magnitude of geomagnetic storms and magnitude of jump in solar wind velocity. Statistically calculated co-relation co-efficient is 0.40 between these two events.

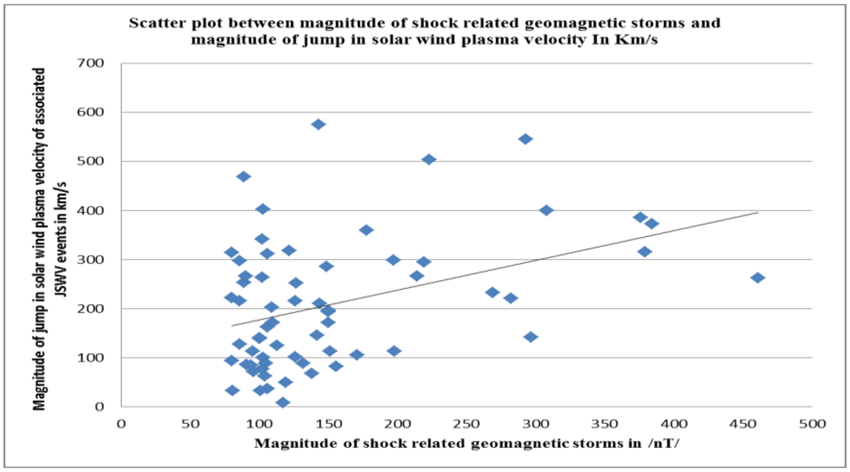

Figure-3- Shows scatter plot magnitude of shock related geomagnetic storms and magnitude of solar wind plasma velocity

Geomagnetic storms with disturbances in solar wind plasma temperature

From the data analysis of shock related geomagnetic storms and associated jump in solar wind plasma temperature (JSWT), it is observed that 62 out of 64 geomagnetic storms are associated with JSWT events. Further to see how the magnitude of geomagnetic storms are correlated with magnitude of JSWT events, a scatter diagram have been plotted between the magnitude of shock related geomagnetic storms and magnitude of JSWT events in Fig. 4 .From the Fig it is clear that maximum shock related geomagnetic storms which have large magnitude are associated with such JSWT events which have relatively large magnitude. Positive co-relation has been found between magnitude of geomagnetic storms and magnitude of jump in solar wind temperature .Statistically calculated co-relation co-efficient is 0.33 between these two events.

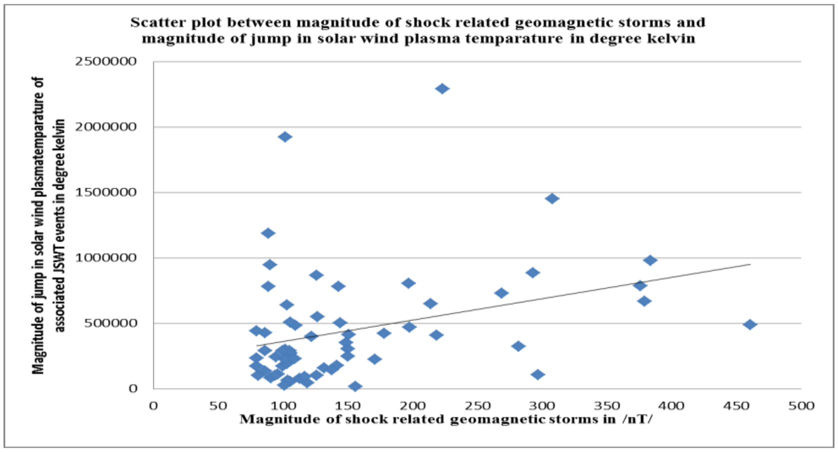

Figure-4 Shows scatter plot magnitude of shock related geomagnetic storms and magnitude of solar wind plasma temperature

Geomagnetic Storms with Disturbances in solar wind plasma pressure

From the data analysis of shock related geomagnetic storms and associated jump in solar wind plasma pressure (JSWP), it is observed that 62 out of 64 geomagnetic storms are associated with JSWP events. Further to see how the magnitude of geomagnetic storms are correlated with magnitude of JSWP events, a scatter diagram have been plotted between the magnitude of shock related geomagnetic storms and magnitude of JSWP events in Fig. 5 .From the Fig it is clear that maximum shock related geomagnetic storms which have large magnitude are associated with such JSWP events which have relatively large magnitude. Positive co-relation has been found between magnitude of geomagnetic storms and magnitude of jump in solar wind plasma pressure. Statistically calculated co-relation co-efficient is 0.26 between these two events.

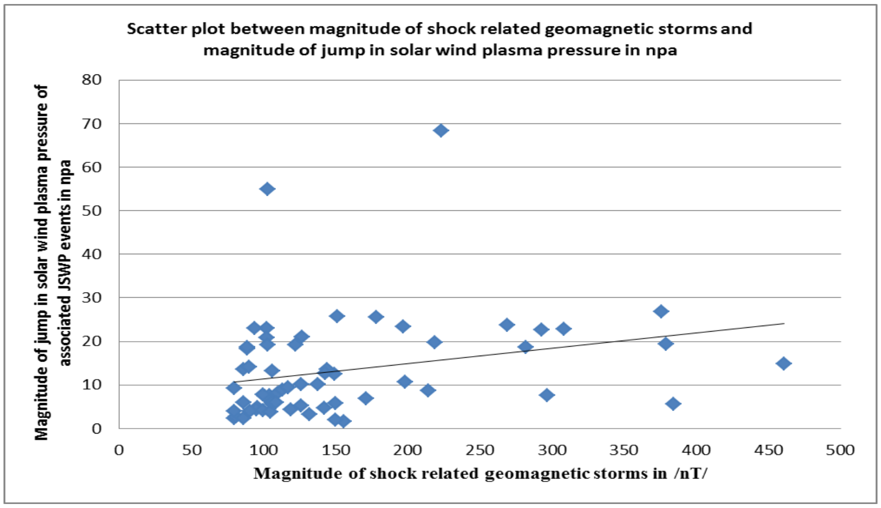

Figure-5- Shows scatter plot magnitude of shock related geomagnetic storms and magnitude of solar wind plasma pressure

CONCLUSION

From our study we have identified 64 shock related geomagnetic storms found that most of the shock related geomagnetic storms are intense are severe. The association rates of moderate, intense and severe shock related geomagnetic storms are 21.88%, 59.38% and 18.75% respectively. Further it is found that majority of the (81.25%) interplanetary shock related geomagnetic storms are associated with coronal mass ejections. The association rates halo and partial halo coronal mass ejections have been found 82.69% and 17.31% respectively. Further it concluded that interplanetary shocks shock related geomagnetic storms are associated with radio bursts (71.88%). The association rates of type IV and type II radio bursts are 58.70% and 41.30% respectively. From the further analysis, positive co-relation has been found between magnitude of interplanetary shock related geomagnetic storms and magnitude of jump in solar wind plasma temperature ,velocity, pressure and peak value of interplanetary magnetic fields, with correlation coefficient 0.33 between magnitude of interplanetary shock related geomagnetic storms and magnitude of jump in solar wind plasma temperature,0.40 between magnitude of interplanetary shock related geomagnetic storms and magnitude of jump in solar wind plasma velocity, 0.26 between magnitude of interplanetary shock related geomagnetic storms and magnitude of jump in solar wind plasma pressure,0.71 between magnitude of shock related geomagnetic storms and maximum (peak) value of average interplanetary magnetic field (JIMF),0.78 between magnitude of shock related geomagnetic storms and magnitude of maximum (peak) value of southward component of interplanetary magnetic field. From the above results it is concluded that shock related geomagnetic storms are closely related to coronal mass ejections, radio bursts and disturbances in solar wind plasma parameters and these solar and interplanetary parameters play crucial role to generate intense and severe geomagnetic storms.

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