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Geomagnetic Storms Associated with Higher Peak Value of IMFBz And Their Relation with Coronal Mass Ejections And Solar Wind Parameters

KEYWORDS: Geomagnetic storms .Coronal mass ejections,X-ray Solar Flares, Solar wind plasma parameters.

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ABSTRACT *An investigation of geomagnetic storms associated interplanetary magnetic field of higher peak values with observed between 1997 and 2010 with coronal mass ejections (CMEs) X-ray solar flares and solar wind plasma parameters was carried out. We found that majority 31(67.39%) of the geomagnetic storms are intense. Further it is found that 79.54% geomagnetic storms are associated with halo and partial halo coronal mass ejections. The association rates of halo and partial halo coronal mass ejections were found to be 85.71 and 14.28% respectively. It is also inferred that most of geomagnetic storms (79.82%) are associated with X-ray solar flares of different categories. The association rates of class X, class M, class C and class B X-ray solar flares are 13.33, 40.00, 28.88 and 20.00% respectively. Furthermore, it is concluded that these geomagnetic storms are closely related to disturbances in solar wind plasma parameters. Positive correlation with correlation coefficient 0.81and 0.79 has been found between magnitude of geomagnetic storms and maximum (peak) value and jump magnitude of average interplanetary magnetic field. The correlation coefficient of 0.83 and 0.60 between magnitude of geomagnetic storms and peak value and jump magnitude of associated jump in interplanetary magnetic field (JIMFBz) events has been obtained. Positive correlation with correlation coefficient 0.56 and0.50 is also found between magnitude of geomagnetic storms and peak value and jump solar wind plasma velocity. The correlation coefficient of 0.45 and 0.36 between magnitude of geomagnetic storms and peak value and jump magnitude of solar wind plasma pressure is also obtained.*

Introduction

The geomagnetic field is mainly influenced by the mass emission from the sun which has three components: the solar wind, coronal mass ejections (CMEs), and solar energetic particles (SEPs). CMEs propagate into the solar wind and drive shocks. Flares also accelerate particles, but generally over shorter duration and to lower intensity levels. When CMEs arrive at earth, they interact with earth's magnetosphere causing geomagnetic storms. These geomagnetic storms are not only related to coronal mass ejections (CMEs) but also shocks/sheath associated with them [Badruddin et al. 1986; Zhang & Burlaga, 1988; Venkatesan & Badruddin, 1990; Badruddin, 1998; Cane, 2000; Zhang et al. 2004; Kudela & Brenkus ,2004; Gopalaswamy, 2004]. Previous studies have observed a strong association between interplanetary CMEs and interplanetary shocks, interplanetary shocks and resulting geomagnetic disturbances [Srivastava & Venkatakrishnan, 2002]. Several investigators have studied different solar and interplanetary phenomena and inferred that CMEs are responsible for the most geoeffective solar wind disturbances and therefore the largest storms. Since the launch of SOHO, halo CMEs have been used to study the influence of earth-directed CMEs on geoactivity [Webb et al. 2000; St. Cyr et al, 2000; Cane & Richardson, 2003; Zhao & Webb, 2003] .The coronal mass ejections associated solar features and interplanetary counterparts of coronal mass ejections are responsible to produce intense geomagnetic disturbances, It is known that ICMEs moving faster than the solar wind speed produce preceding shocks, compressed solar wind, and interplanetary magnetic field (IMF), and generally larger interplanetary disturbances [Tsurutani et al., 1990; Gosling et al., 1991; Echer and Gonzalez, 2004, Echer et al, 2008]. Enhanced solar wind speeds and southward magnetic fields associated with interplanetary shocks and ejecta are known to be important causes of storms [Tsurutani, 1988] .Mcallister.et al [1997] have studied effects of solar and heliospheric phenomena on geomagnetic field. They have concluded that major geomagnetic storms, both recurrent and non recurrent, are the result of the combined effects of CMEs and CIRs. Echer, E et al [2004] have analyzed plasma and magnetic field parameter variations across fast forward interplanetary shocks during the last solar cycle minimum and observed that the solar wind velocity and magnetic field strength variation across the shocks are the parameters better correlated with Dst. Gopalswamy et al. [2008] have studied magnetic clouds ,coronal mass ejections and geomagnetic storms they have found that 86% magnetic clouds are associated with full and partial halos coronal mass ejections .The remaining 14% of magnetic clouds are associated with non-halo CMEs originating from close to the disk center. They have concluded that magnetic clouds associated with partial halo and halo coronal mass ejections are most potential candidates for production of geomagnetic storms .They have further concluded that magnetic clouds associated with non halo CMEs may also cause geomagnetic storms . Yurchyshyn et al [2004] have analyzed data for major geomagnetic storms and found a relationship between hourly averaged magnitude of the Bz component of IMF and projected speed of CMEs launched from the centre part of the solar disk, they have concluded that CMEs with V>1000km/s are capable of furnishing solar wind with negative magnetic field of high intensity causing extremely intense geomagnetic storms with Dst below -200nT. 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 nd 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. Veronica et al [2010] have performed an event by event study of 47 geomagnetic storms (GSs) that occurred during the ascending

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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. 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 co rotating interaction regions at the leading fronts of high speed streams.

II-Experimental Data

In this investigation hourly Dst indices of geomagnetic field have been used over the period 197 to 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.

III-Data analysis and results

From the data analysis geomagnetic storms associated with higher peak values of IMFBz observed during the period of 1997-2010,it is observed that most of the geomagnetic storms are intense or severe geomagnetic storms .We have identified 46 such geomagnetic storms during the period of 1997-2010 out of which 02(4.34%) are modrate,31(67.39%) are intense and 13(28.26%) are severe geomagnetic storms. From the further analysis it is observed that majority of the geomagnetic storms are associated with interplanetary schocks. We have 46 geomagnetic storms out of which 43(93.47%) are associated with interplanetary shocks and related shocks are forward shocks .From the analysis of geomagnetic storms and coronal mass ejections it is observed that majority of the geomagnetic storms are associated with coronal mass ejections (79.54%).The association rates of halo and partial halo coronal mass ejections have been found 85.71% and 14.28% respectively. From the analysis of selected geomagnetic storms and associated X-ray solar flares, it is observed that the 97.82 % the geomagnetic storms are associated with X- ray solar flares of different categories .The association rates of X, M,C and B class solar flares have been found 13,40,28.88 and 20.00% respectively.

Geomagnetic Storms with Disturbances in Interplanetary Magnetic Field.

From the data analysis of geomagnetic and associated disturbances in interplanetary magnetic field, we have observed that all the geomagnetic storms are associated with jump in interplanetary magnetic field (JIMF) events. To see how the magnitude of geomagnetic storms are correlated with the magnitude of JIMF events, we have plotted a scatter diagram between the magnitude of geomagnetic storms and JIMF events in Fig.1 From the Fig.1 it is clear that maximum 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 magnitude of average interplanetary magnetic field of associated JIMF events. Statistically calculated co-relation co-efficient is 0.79 between these two events. Further to see how the magnitude of geomagnetic storms are correlated with the peak value of JIMF events, we have plotted a scatter diagram between the magnitude of geomagnetic storms and peak value of JIMF events in Fig.2 From the Fig 2 It is clear that maximum geomagnetic storms which have large magnitude are associated with such JIMF events which have relatively large peak values of IMF .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 0.81 between these two events.

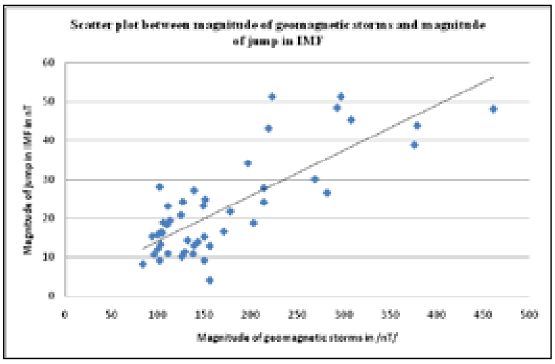

Figure-1- Shows scatter plot magnitude of geomagnetic storms and magnitude of JIMF events.

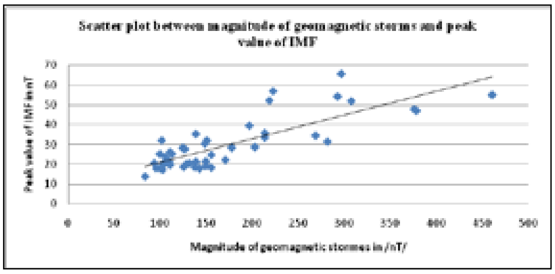

Figure-2- Shows scatter plot magnitude of geomagnetic storms and peak value of JIMF events.

Geomagnetic Storms with Disturbances in Southward Component of Interplanetary Magnetic Field.

From the data analysis of geomagnetic storms and associated jump in southward component of interplanetary magnetic field (JIMFBz), it is observed that all the geomagnetic storms are associated with JIMFBz events. Further to see how the magnitude of geomagnetic storms are correlated with magnitude of JIMFBz events, a scatter diagram has been plotted between the magnitude of geomagnetic storms and magnitude of JIMFBz events in Fig.3 .From the Fig 3 it is clear that maximum geomagnetic storms which have large magnitude are associated with such JIMFz events which have relatively large magnitude of IMFBz events. Positive co-relation has been found between magnitude of geomagnetic storms and magnitude of southward component of interplanetary magnetic field of associated JIMFBz events. Statistically calculated co-relation co-efficient is 0.30 between these two 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.4 .From the Fig 4, 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 0.83 between these two events.

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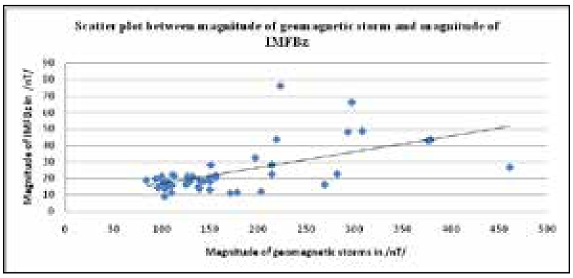

Figure-3- Shows scatter plot magnitude of geomagnetic storms and magnitude of JIMFBz events.

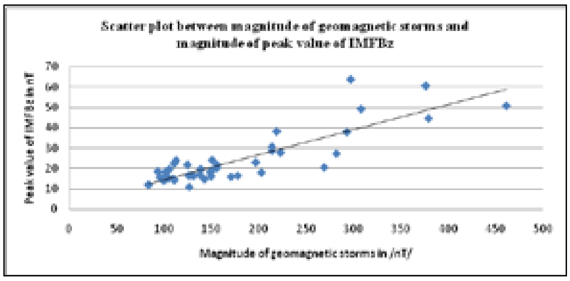

Figure-4- Shows scatter plot magnitude of geomagnetic storms and magnitude of peak value of JIMFBz events.

Geomagnetic Storms with Disturbances in Solar wind Velocity

From the data analysis of geomagnetic storms and associated jump in solar wind plasma velocity (JSWV), it is observed that all 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 has been plotted between the magnitude of geomagnetic storms and magnitude of JSWV events in Fig.5. From the Fig 5, it is clear that maximum 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 0.50 between these two events. Further to see how the magnitude of geomagnetic storms are correlated with peak value of JSWV events, a scatter diagram has been plotted between the magnitude of geomagnetic storms and magnitude of JSWV events in Fig.6. From the Fig 6, it is clear that maximum geomagnetic storms which have large magnitude are associated with such JSWV events which have relatively large peak values. Positive co-relation has been found between magnitude of geomagnetic storms and peak value of jump in solar wind velocity. Statistically calculated co-relation co-efficient is 0.56 between these two events.

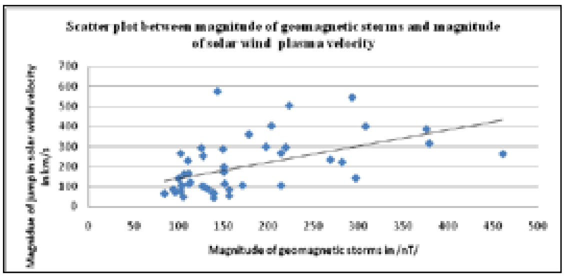

Figure-5- Shows scatter plot magnitude of geomagnetic storms and magnitude of JSWV events

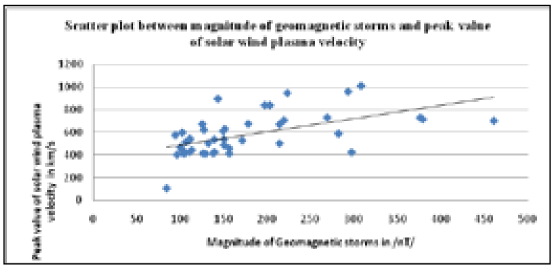

Figure-6- Shows scatter plot magnitude of geomagnetic storms and peak value of JSWV events.

Geomagnetic Storms with Disturbances in Solar wind Plasma Pressure

From the data analysis of geomagnetic storms and associated jump in solar wind plasma pressure (JSWP), it is observed that all 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 has been plotted between the magnitude of shock related geomagnetic storms and magnitude of JSWP events in Fig.7. From the Fig 7, it is clear that maximum 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 coefficient is 0.36 between these two events. Further to see how the magnitude of geomagnetic storms are correlated with peak value of JSWP events, a scatter diagram has been plotted between the magnitude of geomagnetic storms and magnitude of JSWP events in Fig.8. From the Fig 8 it is clear that maximum geomagnetic storms which have large magnitude are associated with such JSWP events which have relatively large peak values. Positive co-relation has been found between magnitude of geomagnetic storms and peak value of jump in solar wind plasma pressure. Statistically calculated co-relation co-efficient is 0.45 between these two events.

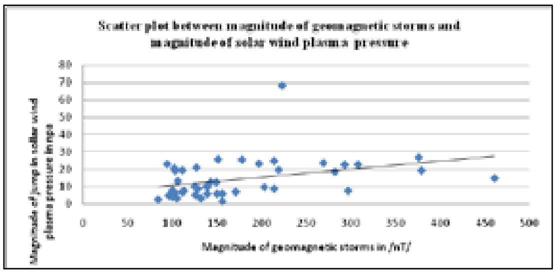

Figure-7- Shows scatter plot magnitude of geomagnetic storms and magnitude of JSWP events

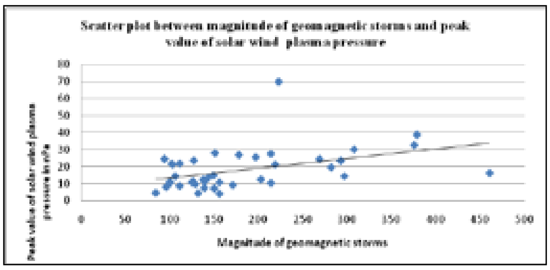

Figure-8- Shows scatter plot magnitude of geomagnetic storms and peak value of JSWP events.

IV-Conclusion

From our study we have identified 46 geomagnetic storms associated with higher peak vlue of IMFBz , in which most of the such geomagnetic storms are intense are severe. The association rates of moderate, intense and severe geomagnetic storms are 02(4.34%), 31(67.39%) and 13(28.26%) respec-

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tively. We found that 79.54% geomagnetic storms are associated with halo and partial halo coronal mass ejections. The association rates of halo and partial halo coronal mass ejections have been found to be 85.71 and 14.28% respectively. Further we have obtained that majority of the geomagnetic storms (93.47%) are associated with interplanetary shocks and shocks are forward shocks. From the analysis of geomagnetic storms and X-ray solar flares, it is concluded that all the geomagnetic storms are associated with X-ray solar flares of different categories. The association rates of X,M, C, and B class solar flare have been found 6,18,13 and 09 respectively. From the further analysis, positive co-relation has been found between magnitude of geomagnetic storms and magnitude of jump in solar wind plasma ,velocity, pressure, interplanetary magnetic field, southward .component of interplanetary magnetic field, and peak value of solar wind plasma ,velocity, pressure interplanetary magnetic field, southward component of interplanetary magnetic field, pressure, with correlation coefficient 0.50 between magnitude of geomagnetic storms and magnitude of jump in solar wind plasma velocity , 0.56 between magnitude of geomagnetic storms and peak value of solar wind plasma velocity. 0.36 between magnitude of geomagnetic storms and magnitude of jump in solar wind plasma pressure, 0.45 between magnitude of geomagnetic storms and peak value of solar wind plasma pressure. 0.79 between magnitude of geomagnetic storms and magnitude of jump in interplanetary magnetic field (JIMF) 0.81 between magnitude of geomagnetic storms and peak value of JIMF. 0.30 between magnitude of geomagnetic storms and magnitude of jump in southward component of interplanetary magnetic field (JIMFBz),0.83 between magnitude of geomagnetic storms and magnitude of peak value of IMFBz .From the above results it is concluded that majority of the geomagnetic storms associated with higher IMFBz are intense or severe and closely related to coronal mass ejections, X- ray solar flares and disturbances in solar wind plasma parameters and play key role to generate intense and severe geomagnetic storms.

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