

# The Interplanetary Causes of Intense Geomagnetic Storms and Their Solar Dependence Occurring During Solar Cycle 22, 23 and Rising Phase 24

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**ABSTRACT:** Solar transient eruptions are the main cause of interplanetary-magnetospheric disturbances leading to the phenomena known as geomagnetic storms. Eruptive solar events such as coronal mass ejections (CMEs) are currently considered the main cause of geomagnetic storms (GMS). GMS are strong perturbations of the Earth's magnetic field that can affect space-borne and ground-based technological systems. The solar-terrestrial impact on modern technological systems is commonly known as Space Weather. Part of the research study described in this thesis was to investigate and establish a relationship between GMS (with  $Dst \leq -110nT$ ) and their associated solar and interplanetary (IP) properties during solar cycle (SC) 22, 23 and rising phase of solar cycle 24. Solar and IP geo-effective properties associated with or without energetic solar features were investigated and used to qualitatively characterize intense storms. The results of this analysis specifically provide an estimate of the main sources of GMS during the period of solar cycle 22, 23 and rising phase of solar cycle 24.

**KEYWORDS:** coronal mass ejection, X-ray solar flares, Radio Burst, Interplanetary Magnetic Fields and Geomagnetic Storms.

## I. INTRODUCTION:

The geomagnetic field is influenced by several solar activity and interplanetary phenomena like sunspots, solar flares, coronal mass ejections (CMEs), magnetic clouds interplanetary shocks, disturbances in solar wind plasma. The major classes of solar activity tend to track the sunspot number during the cycle, including, radio burst, solar flares, filaments, and coronal mass ejections (CMEs) (Webb, D.F.et.al.1994). This activity is transmitted to Earth through the solar corona and its expansion into the heliosphere as the solar wind. The solar activity, solar flares and coronal mass ejections are most energetic solar events in the heliosphere and are widely recognized as being responsible for

production of geomagnetic disturbances in geomagnetic field. On significantly different spatial scales, flares and CMEs are two major manifestations of eruptive release of energy. It is considered that flares are related to small scale magnetic fields. CMEs, It is generally believed that long intervals of enhanced southward interplanetary magnetic field (IMF) and the high solar wind speed are the primary causes of intense geomagnetic disturbances, and that the solar sources of such geo-effective solar wind structures are usually CMEs (Webb, et.al.20010 .Evidence has been presented that the properties of the Earth-directed CMEs, such as the internal structure of the magnetic field, may determine whether or not a geomagnetic storm subsequently occurs (Burton, et.al.1975, Cane, et.al.2000).This suggests that the magnetic field serves as a link between flares, CMEs, and geomagnetic storms. As flares usually occur inactive regions, it is natural to ask if the configuration of magnetic field of active regions is an essential factor determining whether the related events are geo-effective. Several scientists have studied the coronal mass ejections and their effects on geomagnetic field and concluded that front side halo CMEs are geo-effective. Kim et al (2005) and the geo-effectiveness rate varied from <40% to >80%.Gopalswamy et al. (2009) analyzed 378 halo CMEs covering almost whole of solar cycle 23 and found that 71% of front side halos are geo-effective. On the other hand, Kim et al (2005) and Yermolaev.(2003) defined their halos as CMEs with  $W \geq 120^\circ$  and obtained the lower geo-effectiveness rate. In present investigation .In present investigation geomagnetic storms observed during the period of 23rd solar cycle has been analyzed with different solar and interplanetary parameters to know which of the solar and interplanetary parameters are geo-effective.

## II. DATA REDUCTION AND ANALYSIS

In this investigation data of Dst index have been used over the period of solar cycle 22, 23 and rising phase 24 to determine onset time, maximum depression time, magnitude of geomagnetic storms. This data has been taken from the NSSDC Omni web data system. 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 solar wind plasma parameters, interplanetary magnetic, hourly data of solar wind plasma parameters has 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>.)

## III. DATA ANALYSIS AND RESULT

We have analyzed intense geomagnetic storms magnitude  $\leq 110$  observed during the period of solar cycle 22,23 and rising phase of 24 with coronal mass ejections .For this investigation we have no direct observed CMEs data for the period of 1986-1995 for association for 49 events and for the period of 1997-2012 for four events . So we have no direct observed CMEs data for total 53 events for association hence we have used hard X- ray solar flares as a proxy data of CMEs for this period

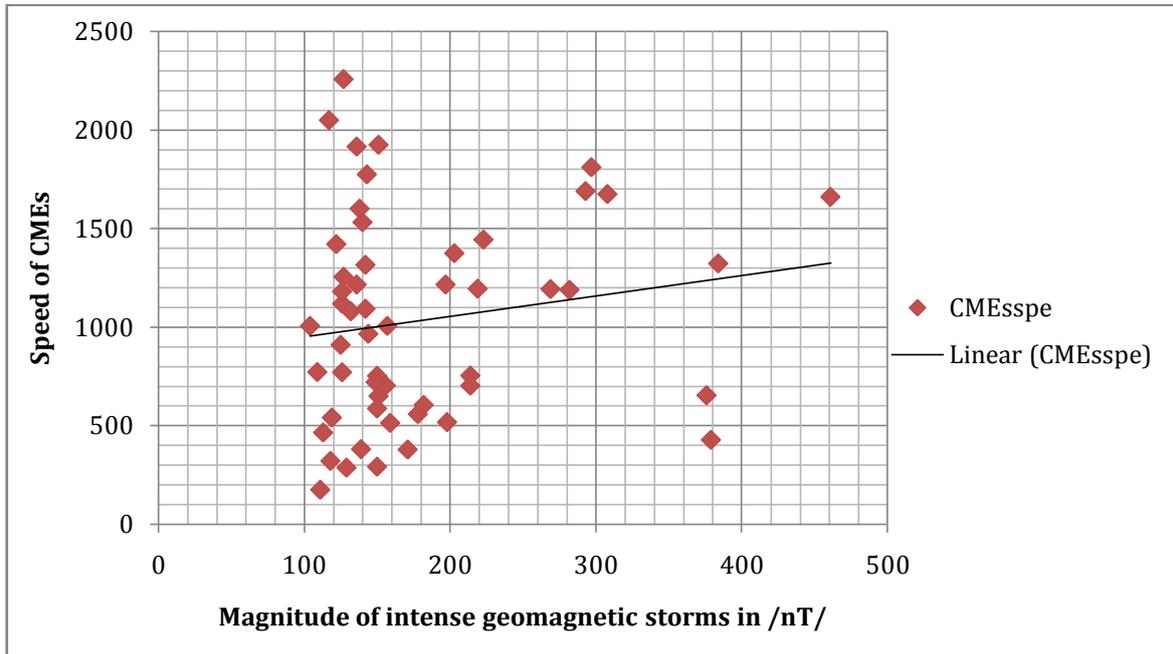
we have plotted scatter plot between magnitude of intense geomagnetic storms and speed of associated CMEs and the resulting scatter plot is shown in **Figure 1**.From the figure it is observed that there is positive correlation between these two

events. Positive correlation with correlation coefficient 0.16 has been found between magnitude of intense geomagnetic storms and speed of associated CMEs by statistical method.

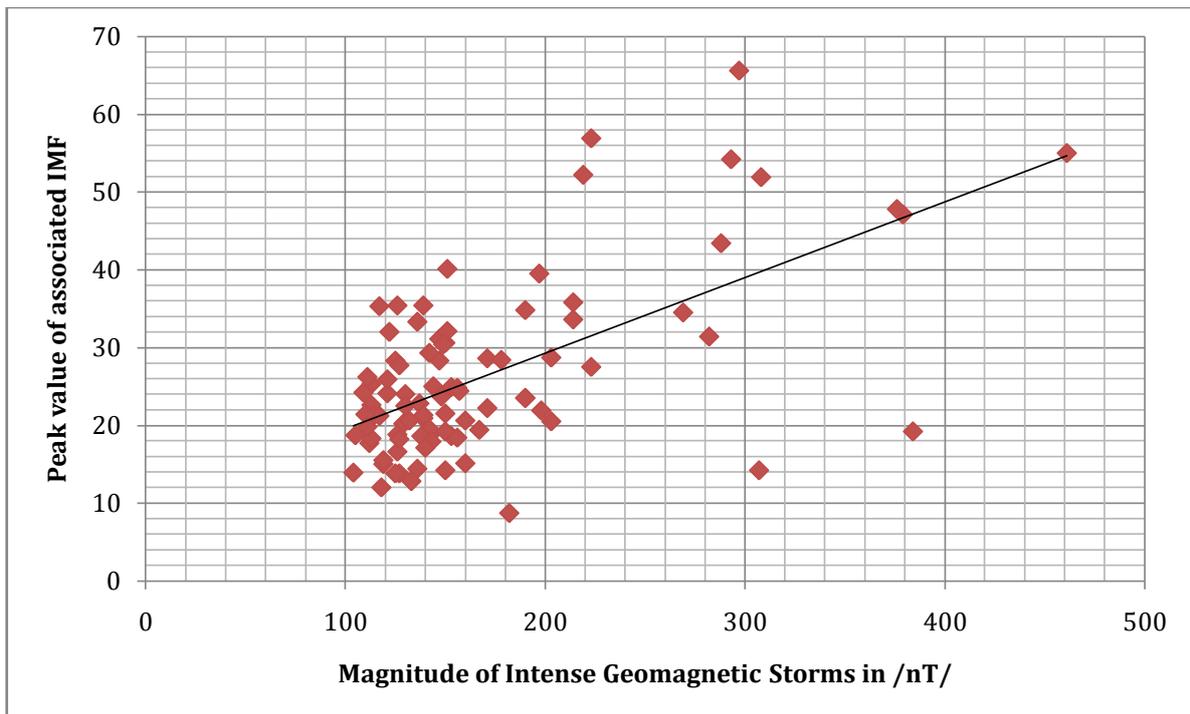
### Intense geomagnetic storms in relation with interplanetary magnetic field

The intense geomagnetic storms of selected criteria and associated disturbances in interplanetary magnetic fields for the period of solar cycle 22, 23 and rising phase 24 .From the data analysis of these events it is observed that we have 111 events of intense geomagnetic storms in which we have no data of disturbances in interplanetary magnetic fields for 18 events. Out of 93 events 91 (97.85%) intense geomagnetic storms have been found to be associated with disturbances in interplanetary magnetic fields .The occurrences of most of the intense geomagnetic storms have been between  $\pm 10$  h time lag between onset time of intense geomagnetic storms and start time of jump in interplanetary magnetic fields.

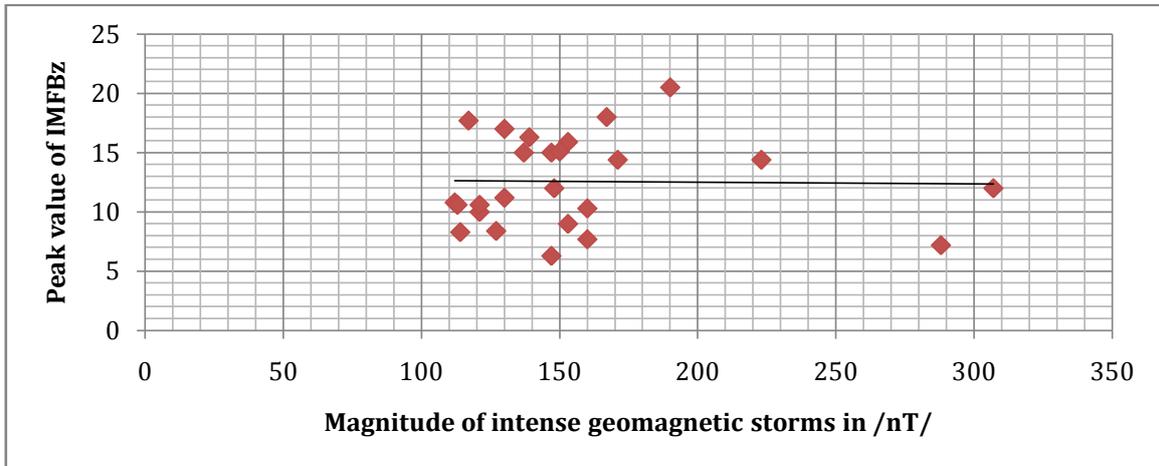
We have found some intense geomagnetic storms events which have higher magnitude but they are associated with such JIMF events which have relatively lower peak values of JIMF and vice versa. From the trend line of the scatter plot it is observed that there is positive correlation between magnitude of intense geomagnetic storms and peak value of associated JIMF events .Positive co-relation has been found between magnitude of intense geomagnetic storms and peak value of associated JIMF events. Statistically calculated co-relation coefficient is 0.61 between these two events for solar cycle 22, 23 and rising phase of solar cycle 24.



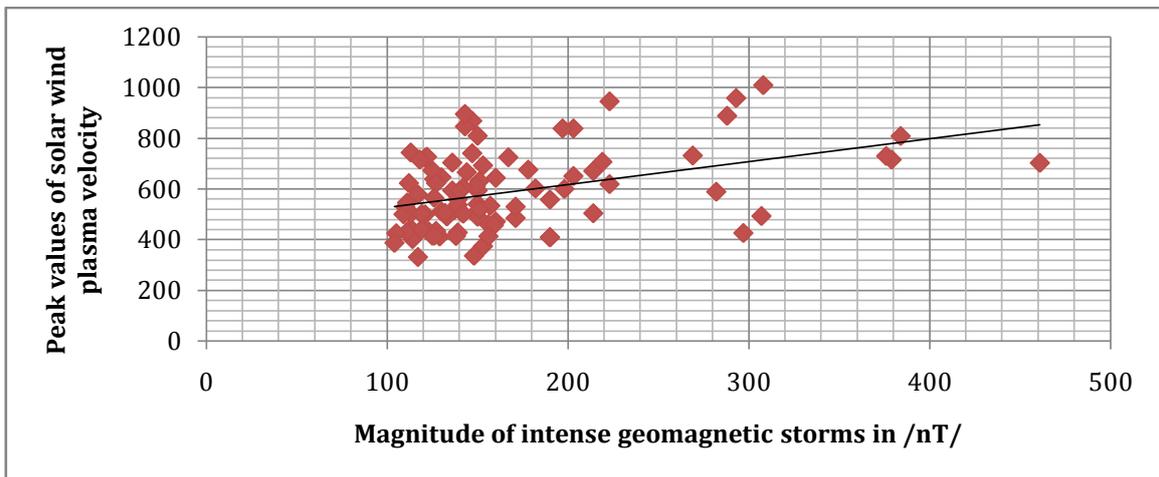
**Figure 1:** The figure shows scatter plot between magnitude of intense geomagnetic storms and speed of associated CMEs.



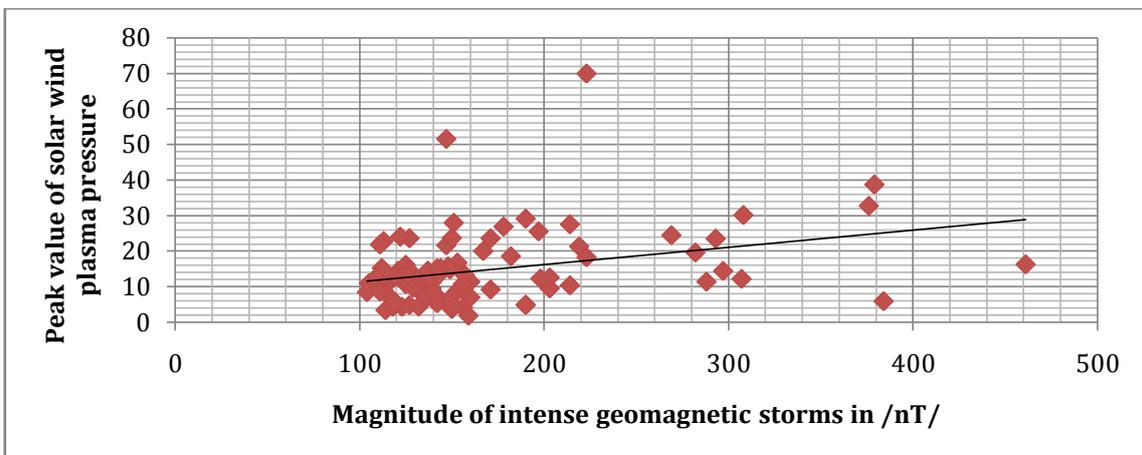
**Figure 2:** Shows Scatter plot between magnitude of intense geomagnetic storms and peak value of IMF for solar cycle 22, 23, and rising phase of solar cycle 24.



**Figure 3:** Shows Scatter plot between magnitude of intense geomagnetic storms and peak value of IMFBz for solar cycle 22.



**Figure 4:** shows Scatter plot between magnitude of intense geomagnetic storms and peak value of jump in solar wind plasma velocity for solar cycle 22, 23 and rising phase 24.



**Figure 5:** Shows Scatter plot between magnitude of geomagnetic storms and maximum jump in solar wind plasma pressure solar cycle 22,23 and rising phase 24.

### **Intense geomagnetic storms in relation with southward component of interplanetary magnetic fields. (IMFBz)**

The intense geomagnetic storms of selected criteria and associated disturbances in southward component of interplanetary magnetic fields for the period of solar cycle 22, 23 and rising phase 24. From the data analysis of these events it is observed that we have 111 events of intense geomagnetic storms in which we have no data of disturbances in southward component of interplanetary magnetic fields for 23 events. Out of 88 events 86 (97.72 %) intense geomagnetic storms have been found to be associated with jump in southward component of interplanetary magnetic fields. The occurrences of most of the geomagnetic storms have been between  $\pm 10$  h time lag between onset time of intense geomagnetic storms and start time of jump in interplanetary magnetic fields.

We have plotted a scatter diagram between magnitude of geomagnetic storms and peak value of associated jump in IMFBz Fig.3. From the fig it is clear that, most of the intense geomagnetic storms which have higher magnitude are associated with such JIMFBz events having lower peak value but these two events do not have any fixed proportion, We have found some intense geomagnetic storms events which have higher magnitude but they are associated with such JIMFBz events which have relatively higher peak values of JIMFBz and vice versa, from the trend line of the scatter plot it is observed that there is weak negative correlation between magnitude of intense geomagnetic storms and peak value of JIMFBz events. Negative co-relation has been found between magnitude of intense geomagnetic storms and peak value of associated JIMFBz events. Statistically calculated co-relation coefficient is -0.02 between these two events for solar cycle 22.

### **Intense geomagnetic storms in relation with solar wind plasma velocity**

The intense geomagnetic storms of selected criteria and associated disturbances in solar wind velocity for the period of solar cycle 22, 23 and rising phase 24. From the data analysis of these events it is observed that we have 111 events of intense geomagnetic storms in which we have no data of disturbances in solar wind plasma velocity for 18 events out of 93, 92 (98.9 %) intense geomagnetic storms have been found to be associated with jump in solar wind plasma velocity. The occurrences of most of the geomagnetic storms have been between  $\pm 10$  h

time lag between onset time of geomagnetic storms and start time of jump in solar wind velocity.

We have found some intense geomagnetic storms events which have higher magnitude but they are associated with such JSWV events which have relatively lower jump values and vice versa. . From the trend line of the scatter plot it is observed that there is positive correlation between magnitude of intense geomagnetic storms and peak value of JSWV events. Positive co-relation has been found between magnitude of intense geomagnetic storms and peak value of associated JSWV events. Statistically calculated co-relation coefficient is 0.41 between these two events for solar cycle 22, 23 and rising phase of solar cycle 24.

### **Intense geomagnetic storms in relation with solar wind plasma pressure**

The intense geomagnetic storms of selected criteria and associated disturbances in solar wind pressure for the period of solar cycle 22,23 and rising phase 24. From the data analysis of these events it is observed that we have 111 in which we have no data for 19 events of disturbances in solar wind plasma pressure for association. Out of 92 events 90 (97.83%) geomagnetic storms have been found to be associated with jump in solar wind pressure. The occurrences of most of the geomagnetic storms have been between  $\pm 10$  h time lag between onset time of geomagnetic storms and start time of jump in solar wind pressure.

We have found some intense geomagnetic storms events which have higher magnitude but they are associated with such JSWP events which have relatively lower peak values and vice versa. . From the trend line of the scatter plot it is observed that there is positive correlation between magnitude of intense geomagnetic storms and peak value of JSWP events. Positive co-relation has been found between magnitude of intense geomagnetic storms and peak value of associated JSWP events. Statistically calculated co-relation coefficient is 0.33 between these two events for solar cycle 22, 23 and rising phase of solar cycle 24.

## **IV. RESULTS AND CONCLUSIONS**

Conclusions of the results obtained from the analysis of different solar features such as coronal mass ejections, solar flares, radio bursts, interplanetary shocks, solar wind disturbances and observed intense geomagnetic storms  $Dst \leq -110$  nT during the period of solar cycle 22, 23 and rising phase of 24. The important findings are as follows:

### 1. Intense geomagnetic storms in relation with Coronal Mass Ejections

Majority of the intense geomagnetic storms have been found to be associated with coronal mass ejections (74.77 %). We have 111 intense geomagnetic storms in which 87 intense geomagnetic storms (78.39%) has been found to be associated with coronal mass ejections. From the further analysis of intense geomagnetic storms and type of associated CMEs of available data we observed that 26.42% intense geomagnetic storms have been found to be associated with P type CMEs and 73.58 % intense geomagnetic are found to be associated with H type CMEs.

### 2. Intense geomagnetic storms in relation with interplanetary magnetic Field

Most of the intense geomagnetic storms (97.85%) observed during the period of solar cycle 22, 23 and solar cycle 24 have been found to be associated with disturbances in interplanetary magnetic field.

Positive correlation with correlation coefficient 0.61 has been found between magnitude of intense geomagnetic storms and peak value of associated JIMF events of interplanetary magnetic field for the period of solar cycle 22, 23 and rising phase 24.

Positive co-relation has been found between magnitude of intense geomagnetic storms and peak value of associated JIMF events. Statistically calculated co-relation co-efficient is 0.34 between these two events for solar cycle 22,

Positive correlation with correlation coefficient 0.64 has been found between magnitude of intense geomagnetic storms and peak value of associated JIMF events of interplanetary magnetic field for the period of solar cycle 23 and rising phase 24.

### 3. Intense geomagnetic storms in relation with solar wind velocity

Most of the intense geomagnetic storms (98.92 %) observed during the period of solar cycle 22,23 and solar cycle 24 have been found to be associated with disturbances in solar wind plasma velocity.

Positive correlation with correlation coefficient 0.41 has been found between peak value of associated JSWV events in solar wind plasma velocity and magnitude of associated intense geomagnetic storms for the period of solar cycle 22, 23 and rising phase 24.

### 4. Intense geomagnetic storms in relation with solar wind pressure

Most of the intense geomagnetic storms (97.83%) observed during the period of solar cycle 22,23 and solar cycle 24 have been found to be associated with disturbances in solar wind plasma pressure.

Positive correlation with correlation coefficient 0.33 has been found between peak value of associated JSWP events in solar wind plasma pressure and magnitude of associated intense geomagnetic storms for the period of solar cycle 22, 23 and rising phase 24.

Positive correlation with correlation coefficient 0.41 has been found between peak value of associated JSWP events in solar wind plasma pressure and magnitude of associated intense geomagnetic storms for the period of solar cycle 23 and rising phase 24.

Positive correlation with correlation coefficient 0.26 has been found between magnitude of jump in solar wind plasma pressure and magnitude of associated intense geomagnetic storms for the period of solar cycle 22, 23 and rising phase 24.

Positive correlation with correlation coefficient 0.34 has been found between magnitude of jump in solar wind plasma pressure and magnitude of associated intense geomagnetic storms 23 and rising phase 24.

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