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Geomagnetic Storms and Their Correlative Study With Solar Wind and IMF Parameters During Solar Cycle 23

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Abstract: *Geomagnetic storms are caused due to atypical conditions occurring in the interplanetary magnetic field and solar wind plasma emissions and the strength of these geomagnetic storms depends upon the potentially geo-effective solar or interplanetary parameters. In the present paper, our observation consists of more than 200 geomagnetic storms and the disturbance storm time (Dst) decrease of more than -50 nT to less than -300 nT was observed, which are scrutinized during solar cycle 23. This analysis has been carried out on the statistical basis between the dst strength and peak value acquired by solar wind plasma parameters and interplanetary magnetic field (IMF) along with its components . The Dst index values and the wind measurements have been taken on hourly basis using various satellites. The sults obtained depicted the strong correlation of geomagnetic storms with the 11 year sunspot cycle. The IMF B has been found strongly geo-effective during the main phase of magnetic storms, and more considerable at the time of storm peak, which is additionally granted by southern component of IMF Bz, vindicated by previous findings. The dst and solar wind velocity are strongly correlated as compared to IMF, Bz and ion density. It has been substantiated that geomagnetic storm intensity shows a more significant correlation with the total magnetic field strength of the IMF than with its southward component.*

Keywords: *Geomagnetic storms, Interplanetary magnetic field, Disturbance storm time (Dst), Solar cycle.*

1. INTRODUCTION:

The unusual condition in the IMF and solar wind plasma eruptions gives rise to geomagnetic storms[1,2] . The investigation of these global distortions of the earth's magnetic field help to describe the dynamics of solar-terrestrial environment and in addition these storms can cause satellite damage, communication failure, navigation issues, etc[2-4]. The cause of geomagnetic activities has been pursued through different studies from the beginning of the space age .It is assumed that geomagnetic activity has a close association with a number of interplanetary plasma or field parameters, eg solar wind velocity V, IMF B and Bz [1,2,4]. Moreover the geomagnetic disturbance is also related to magnetic cloud giving rise to intense and severe GMSs [5,6]. There is an uninterrupted flow from the sun's corona swamping the whole heliosphere. It constitutes hot electrons and protons flowing supersonically caused by the immensely high temperature of the sun's corona thus makes the ionized plasma to control the gravitational attraction of the sun. There is a fluctuation in the density and the speed of this flow depends upon the conditions due to which it was caused to erupt. The magnetic field of the sun is associated with solar wind, and after going into it is called IMF.

Geomagnetic dist6urbances are usually indicated by geomagnetic storms and sudden ionospheric disturbances(SIDs). The disturbances originated at solar atmosphere, interplanetary shocks and stream interfaces related with high speed solar wind streams(HSSWS)[8,9]. They are related with coronal holes, happenining in polar regions. Transient IP shocks are generated by CME, giving rise to storm sudden commencement at earth. Prominences and flares are also related with the changing phases of solar cycles causing geomagnetic storms . The strong IMF and its variations have also considerable effect on geomagnetic field conditions. There is an ample energy transport from solar wind into geo-magnetosphere through magnetic reconnection permitted by south direction of IMF[12-14].

Generally GMS lasts for few days , however the recovery phase of geomagnetic storm sustains for two weeks or even for larger time period called as High- Intensity long-duration continous AE activity –events(HILDCAE). Tsurutanc and Gonzalez (1987), suggested that the uninterrupted injections to the ring current occurs during these events in such a way that the ring current does not decompose quickly [15-18]. According to studies, these geoeffective events are related with CMEs , solar flares , SEPs and solar wind transients as well[19-22], which in turn considerably generate depressions in the earth's ring current and the CRI is also attuned, giving rise to Forbush decrease events and ground based events as well [23,24].

In the present work , we have carried out the statistical analysis to examine the geomagnetic storms noticed by different geomagnetic observatories spotted using Disturbance storm time index (Dst). The geomagnetic activity is measured in terms of Dst index as it indicates the depressions in the ring current due to its interaction with plasma structures originating from solar surface. So many solar parameters have been studied which were possibly geoeffective taking place during solar activity period of SC-23.

2. **Selection criteria Data and Methodology:**

The changes in solar wind striking our planet is the cause of disturbances in the geomagnetic field. This disturbance is restricted to the upper-latitude polar regions until the IMF taken by the solar wind has prolonged periods of southward component ($B_z < 0$) having huge magnitudes [2,4]. The magnetosphere gets strained due to the occurrence of such periods , thus letting the magnetic field disturbance to the equatorial region. The extent of equatorial magnetic field deviation is represented by Dst which is the hourly average of the deviation of horizontal component(H) of the magnetic field evaluated at various ground stations in mid to low latitudes. The value of Dst = 0 means zero deviation from quiet condition, Dst $\leq$ -50nT indicates magnetic storms[3,4]. A catalougue of magnetic storms based on Dst indices afforded by the world data center for geomagnetism, Kyoto, Japan through its world wide web(also from omni web data source maintained by National Geophysical Data Center NGDC: http://www.ngdc.noaa.gov/stp/SOLAR/ftpsatenvir.html) is being assembled for this analysis for the period 1996-2007. The omni web data results (www.omniweb.gsfc.nasa.gov) have been used. The data has been obtained from online sources deliverd by WDC through its web (NOAA): http;//www.noaa.gov/), Geostationery Operational Environment Satellite(GOES): (http://goes.ngdc.noaa.gov/).

We correlate the results of one data series with that of the other at several lags and leads. It helps to spot variables being the main indicators of subsequent variables. This technique of two time-series data sets involves several calculations of correlation coefficient(r) by time-shifting the one data set reative to the other data set. This shift is known as a "lag" and the lag tine is usually a sampling period of two time-series data sets. The papers and books e.g., Goshtasby et al., 1984 ; Lewis, 1995; Qureshi, 2003 [33-36]

3. Observations:

It is a fact that space weather is is directly related to solar activity and there is an increase and decrease in geomagnetic activity with solar activity. There are two maximas in solar cycle 23. The maximum SSN and duration of that peak is known as maximum activity phase[37-39]. The maximum phase of solar cycle 23 is during the year 2000 and 1996-99 and 2001-07 is the minimum phase as shown in the figure 1

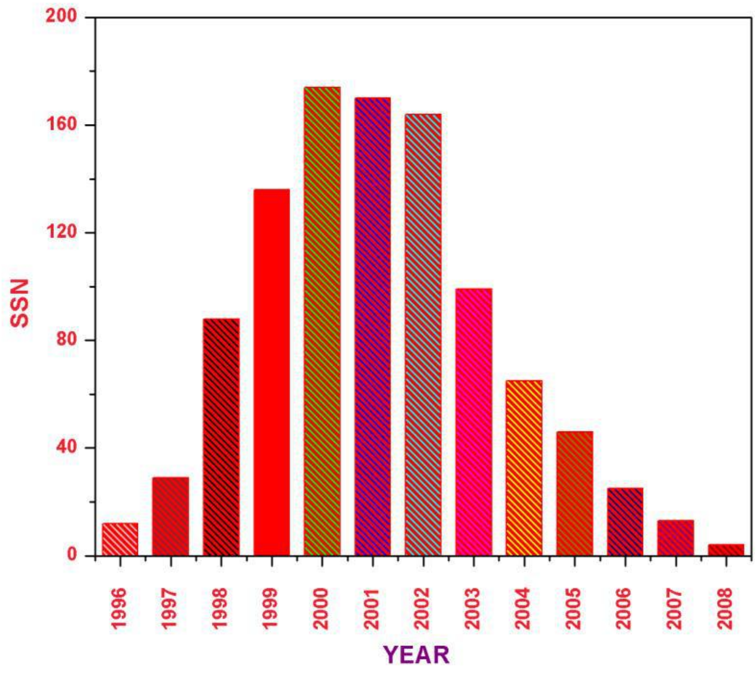

Fig. 1 Average number of sunspot per year during 1996-2007.

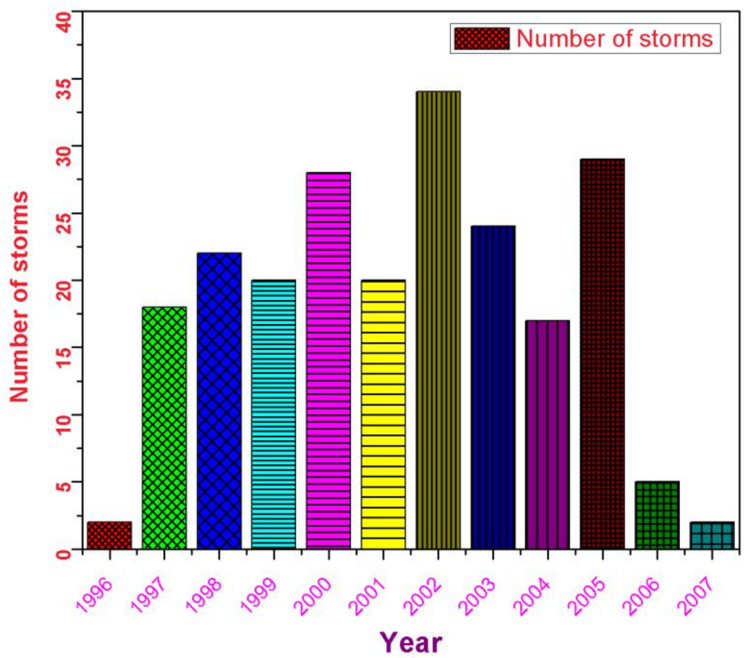

Fig. 2 The total number of storm days per year during 1996 to 2007.

In the current work, the Dst data has been used to register the number and severity of geomagnetic storms for SC-23. . The plots have been drawn depicting occurrence of GMSs during the year and the intensity of their severity . For Dst ≤-50nT ,210 geomagnetic storms have been observed during 1996-2007. The figure 1shows the mean sunspot number for the respective year and figure 2 depicts the days of more severe GMSs with dst ≤-50 nT and the resultant number of stormy days per year are also shown..

The above figures show the GMSs and SSN . The least number of storms occurred in year 1996.(solar minimum year) is 2 and the maximum number of GMSs have occurred in year 2002. The year 2000 is the maxima of SC 23 while the year 2007 represents its minimum sunspot activity for its declining phase, and in the year 2003 and 2005 higher number of GMSs have been observed.

We have categorized GMSs on the basis of their Dst magnitude in four classes according to Loewe and Prolss [9], a geomagnetic storm is weak (Dst ≤ -50nT), moderate (-100nT< Dst ≤ -50nT), intense (Dst ≤ -100nT) , and severe (Dst ≤ -200nT).

4. Results and discussion:

It was reinvigorated by Shwenn (2006) elaborately the relation of solar processes with the space weather phenomenon. The influence of solar activity on the middle atmosphere was revitalized by Dameris and Pawson (2002) and some contentious results were observed . The experiments with two types of numerical model examined the atmospheric reaction to variations in solar forcing were revitalized . One is mechanistic -model simulations and the second is general circulation model-one detects that feeble changes produced spreading upto the magnetosphere are connected by electromagnetic fields and currents . The comprehension of this fact has brought about the concept of Global Electric Circuit (GEC) to elaborate the electromagnetic environment of the earth's atmosphere. The combination of solar wind –magnetosphere –ionosphere creates an important component of GEC. Lakhina (1994in upper atmosphere can give rise to oscillations in lower atmosphere and the next one shows that modulation of middle atmosphere dynamics is feasible .

The different regions of our planet near space environment) revitalized the solar wind –magnetosphere-ionosphere combining processes taking attention on the non-linear particle dynamics in the magnetotail [3]. Several mechanisms based on non-linear particle dynamics . linear prediction filtering techniques, phase space reconstruction techniques and dynamical analogue models of geomagnetic activity are revived.

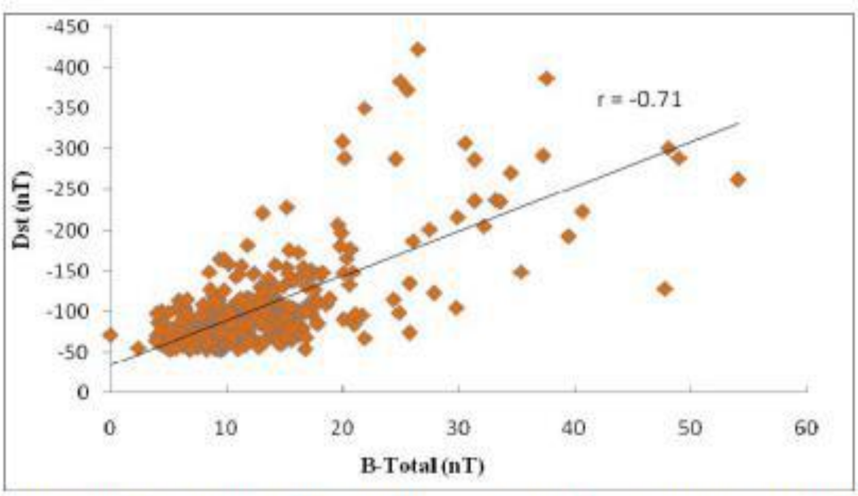

Fig. 3. presents the Interplanetary magnetic field versus the maximum of negative Dst.

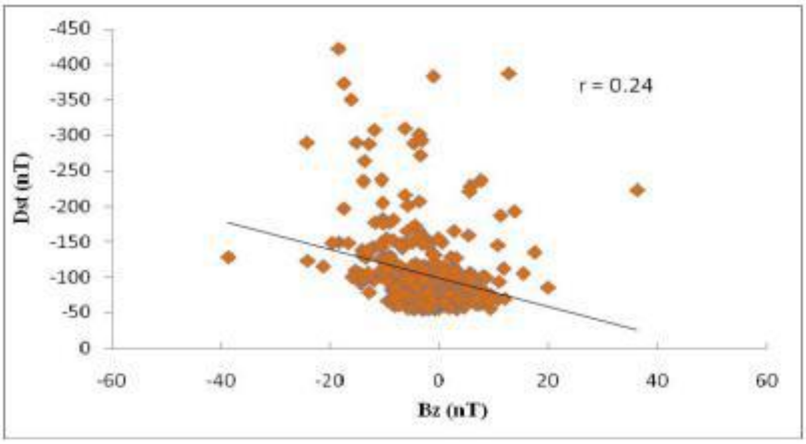

Fig. 4. presents the maximum of interplanetary negative Bz (southward) versus the maximum of negative Dst.

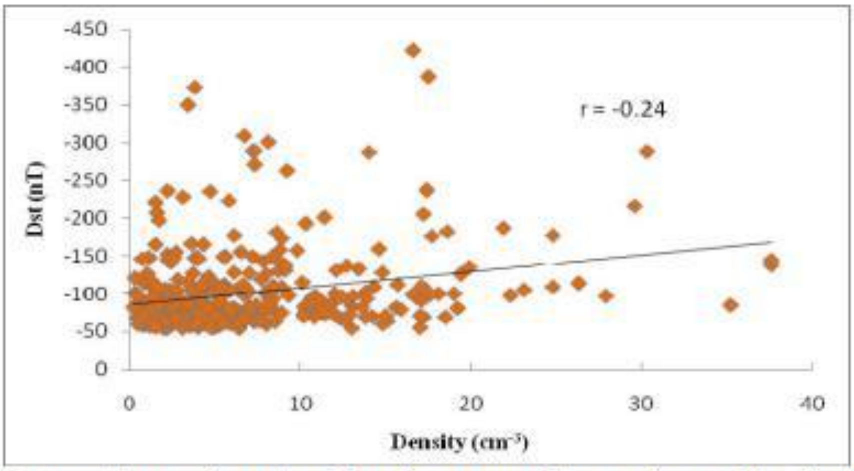

Fig. 5. shows the peak proton density versus the maximum Dst (negative)

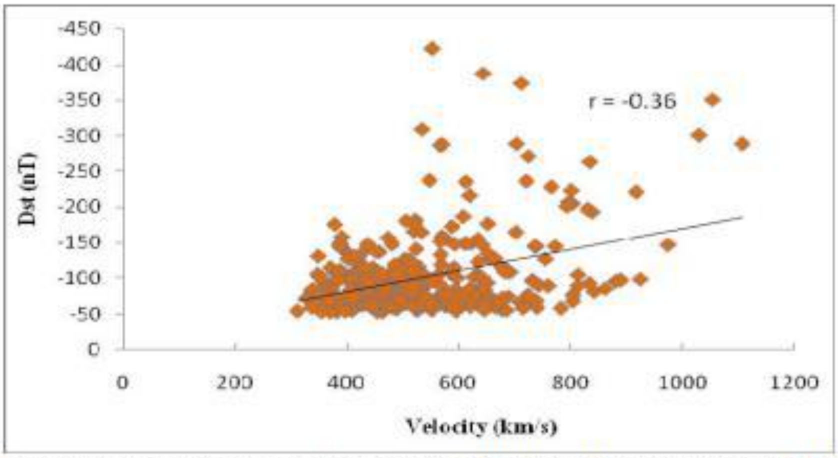

Fig. 6. presents mamimum values reached by the solar wind speed V versus negative Dst (max.)

Figure 3 shows the correlation of IMF versus maximum of negative Dst . It has been statistically found that the occurrence of more intense GMSs(negative Dst $\sim \leq 250$) is lower. A linear correlation between B_{av} and Dst has been plotted and depicts that the intensity of GMSs is highly dependent on B_{av} and the correlation coefficient has been found to be equal to -0.71

Figure 4 represents the maximum of interplanetary negative Bz (southward component) versus the maximum of negative Dst . A linear correlation has been found between Bz and and Dst and thus it is clear that cc is 0.24. This may be because Bz has considerable growth mainly during or before initial phase of GMSs not during main phase.

No strong correlation is observed between Dst and density during the main phase and it does not mean that Bz is geo-ineffective

Figure 5 depicts that the peak proton density versus the maximum Dst (negative). There is not an explicit relation between these two indices so it is concluded that more intense GMSs are not inevitably connected with larger values of solar density. So it implies that the probability intensity of a GMS is not evaluated by the rise of density so the correlation coefficient between these two is -0.24

Figure 6 shows the maximum values which the solar wind speed can attain versus negative Dst (max). There is a high scatter with a vast range of velocities varying between 400 to 900 km/s. The more intense GMSs (Dst <-350.nTpeak) are not related with greater solar wind speeds . The correlation coefficient between the two parameters is -0.36

5. CONCLUSION:

The year 2000 has been the maximum phase of SC-23 while the duration between 1996-99 has been observed as the periods of minimum phase of solar activity. It is evident that the year (2001 to 2007 is the solar minimum year), only 2 GMSs are observed. And the largest number of GMSs occurred in the year 2002 and the year 2002 is the maxima of SC-23 and the year 2007 is its minimum during its declining phase. In 2003, the largest number of GMS was observed with Dst index of -472.nT and the larger number of GMSs have been observed in the year 2003 and 2005, not following the phase of solar cycle thus depicting complex behavior. It has also been observed that the bulk of intense GMSs were found during the maximum phase of SC due to the existence of several solar active areas seen for this time where as less GMSs are observed during main phase of SC.

In this work, we have considered the peak values of several parameters which are further interconnected with the peak depression in the geomagnetic disturbed condition. Also in this work, the correlation coefficient between B_{av} and the strength of GMS has been found to be equal to … and a strong dependence of strength of GMS with B_{av} has been observed. In the previous research, strength of GMS was found highly dependent on Bz but here it is very low. So in this work , we have found Bz is not significantly at peak at the time of Dst peak value which indicates time delay between B_z and Dst peak

Also it has been confirmed that GMS intensity shows high correlation with B_{av} as compared to Bz of IMF, density and solar wind velocity.

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