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Geo-effectiveness of solar and interplanetary features during solar cycles 23 and 24

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Abstract: *The pivotal incentive of this work has been the analysis of the dependence of geomagnetic activity on solar characteristics and interplanetary (IP) indices. The geomagnetic storms (Dst ≤ -100nT to Dst ≤ -200nT), arising during solar cycle 23 and 24 (1996-2018) have been studied. The magnetic clouds, sheath fields, coronal mass ejections (CMEs) and solar flare regions are proclaimed to be the most frequent interplanetary structures activating the evolution of huge storms. However the relative importance of each of those driving structures has been shown to fluctuate with the phase of solar cycle. There is a candid interrelationship between the space weather in the near-earth environment and the distraction arising from the sun.*

Key Words: *Solar wind velocity, Average of Interplanetary Magnetic Field IMF (B), CMEs and Geomagnetic Storms.*

1. INTRODUCTION:

The consequential space weather effects through the integrated magnetosphere are due to powerful reciprocity of CMEs with the earth's environment. A geomagnetic storm is a major disturbance of earth's magnetosphere (Akasofu, 1963), when there is sufficient energy exchange from solar wind into the space surrounding of the earth. These storms arise due to fluctuations in solar wind which generates major variations in the currents, plasma and fields in earth's magnetosphere. Various geomagnetic storms and distinct sources of their origin have been proposed by numerous authors (Tsurutani et al 1988). The literature of (Chapman-1936; Murayama 1982; Oh and Yu 2004; Jatin Rathod et al. 2008 Kane 201; Singh and Mishra, 2015), have examined the phenomenon of geomagnetic storms and its demonstrations. From the observation of Hewish and Bravo (1986), it is clear that geomagnetic storms are strongly related to coronal holes as compared to solar flares. These storms are also linked with a magnetic cloud (Burlaga et al. 1987) and further carefully by Wilson(1987).

The influences of an interplanetary distortion giving rise to an abrupt variation in the geomagnetic components are known as Sudden Storm Commencement (Smith et al. 1986). Also there is a confirmation that the effect of interplanetary distortion in the magnetopause causes hydrodynamic waves moving through the magnetosphere towards our planet and SSC are resulted due to their isotropic modes. The geomagnetic storms have multidimensional importance i.e., their academic feature and the principal feature which occasionally can constitute a specific worry for mankind. The investigation of geomagnetic storms is helpful to inspect unfavorable effect in radio communication, radar observation, power grid, electric utilities, long distance pipelines and coexisting spacecrafts. There are usually two principal categories of geomagnetic storm- Storms and sub storms. Storms contribute more to space weather which are started off when intensified energy movement from the solar wind or interplanetary magnetic field to the magnetosphere leads into escalation of ring current. The ring current evolution can be kept track of with the dst index (Gonzalez et al. 1994; Bakare 2010; Kane 2014). The discharge of matter from the solar atmosphere into interplanetary space leads to the highest considerable space weather effects. A CME may contain a billion tons of mass which can be accelerated to many million miles per hour in a striking explosion. CMEs arising from near to the disk center considerably perturb the earth's environment and veeringly affect the earth (Gopalswamy 2006). The matter drained by each CME falls in a range of 10^{10} kg (Webb. 1995; Singh et al 2012). From the observation of Kahler(1992), if the CME is linked with flare, then it originates in the eruptive phase of the flare. CMEs and the flares are part of a same magnetic eruption process (Harrison 1995; Schreiber 1998; Zhang et al. 2001; Singh et al. 2012; Singh et al. 2013).

2. Data Sources and Selection Criteria:

In the current study, the geomagnetic storms (Dst ≤ -100 nT) associated with solar flares and coronal mass ejections occurring during solar cycle 21 to 24 have been investigated. The H_α solar flare data has been taken from the GOES satellite kept up by National Geophysical Data Center (NGDC) on daily basis. Generally the CMEs are noticed by the LASCO telescope. The website; http//www.cdaw.gsfc.gov.cmelist/. provides the properties of CMEs. The catalogue consists a record of all visible CMEs containing details of their date and time of their first appearance in the field of view of C2 Coronagraph, central position angle, angular width, speed, acceleration obtained from quadratic fitting etc. The Dst, solar wind, IMF, B_z data has been obtained from omniweb data.

3. Results and discussion:

From this investigation, the previous results have again been authenticated (Gonzalez et al. 1994, Dubey and Mishra, 2000; Singh and Mishra, 2015) that the parameter depicting long-term variation of sunspot activity occasionally displays unlike nature on short-term scale depending on local solar active regions and the related phenomenon. Since on daily basis these parameters are influenced differently at distinct times, so we have attempted the vital geomagnetic storms as a single event related with solar and interplanetary disturbances. The geomagnetic storms with Dst magnitude ≤ -100 nT occurring during last three decades have been taken into account.

The CME and the high-speed solar wind stream (HSS) are known to be the source of considerable consequences in the near- earth space accelerating magnetospheric (auroral and ring current) particles to higher energies and this particle precipitation into the atmosphere is enhanced specifically in upper thermosphere and mesosphere region. However, the electric current and fields are kept up and generated by magnetospheric particle precipitation which also affects the charged and neutral atmosphere below. The effects show dependence on the behaviour of the interplanetary disturbance and quite different for CMEs and HSS. The geomagnetic storms have been categorized into three phases- the initial phase, the main phase and the recovery phase. The intensification of solar wind behind the shock wave gives rise to initial phase. This is a quasi-steady state proceded by sudden storm commencement. The main phase of geomagnetic storms is followed with the sudden ionospheric disturbances while the recovery phases follow with the active main phase. There is a gradual entire comeback of H-field back to pre storm level. The time period of recovery phase is always larger than that of the main phase. Fig 1 depicts the net number of higher geomagnetic storms analyzed for the mentioned period is 120, related CMEs with geomagnetic storms is 69, associated with CMEs and flares is 40 and associated only with flares is 11.

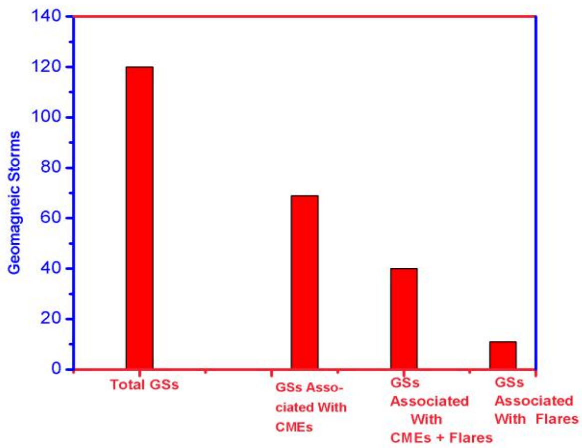

Figure 1: Shows the large Geomagnetic storms and their association with CMEs, CMEs + Flares and flares.

3.1 Geomagnetic storms of June 2015

We have investigated the behaviour of the influences during many events by analyzing the sketches of all the interplanetary variables to get an additional perception on the efficacy of various indices. The association of various solar and interplanetary indices with major and moderate geomagnetic storms has been studied by many workers (Singh and Mishra). These events have been dispensed on the basis of the magnitude and behavior of the profile in each case. The solar wind velocity has an ascending tendency with velocity fluctuating in the range 550-650 km/s (56 cases) which in some cases has been observed increasing to about 750 km/sec and even occasionally ~ 850 km/sec in some unusual cases during June 2015 event, fig 2. These events were basically front side but lacking visible surface signatures, and were backside events having universal effects for example dismissal set up by global waves (Mc Cosmos et al. 1991)

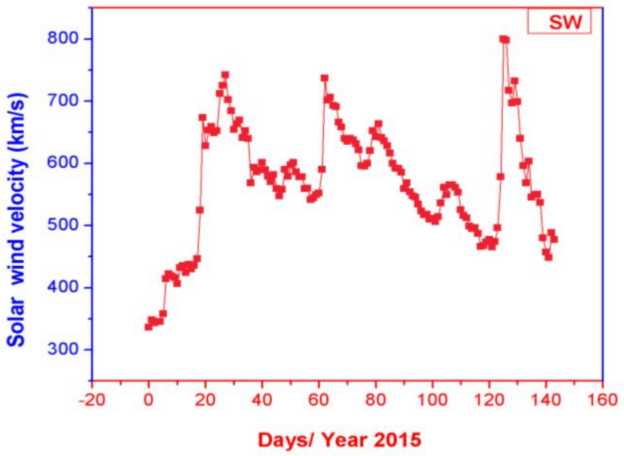

Figure 2: Shows the variation of solar wind velocity during 22 June to 28 June in year 2015

Also a sudden variation in z-component of B from northward to southward is observed. The negative B_z value, its magnitude and duration have a considerable benefaction for the evolution of geomagnetic storms (Kane 1977). The changes in B_z component is found significantly getting negative value showing that there is a geomagnetic storm.

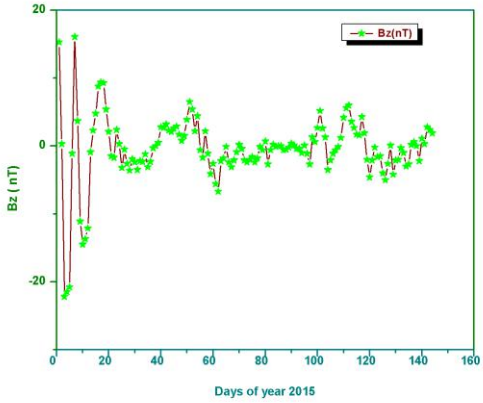

Figure 3: Shows the variation of Bz component of IMF during 22 June to 28 June in year 2015.

Figure 4 demonstrates the fluctuation of Dst on daily basis during geomagnetic storms, 23 June, 2015 (Dst peak magnitude (–220nT). Murayamo (1982) however analyzed that there is a correlation between negative Dst and dynamic pressure in phase with ring current expedition which was freshly established by Fenrich and Luhman (1998). However this dependence was not found much effective. The presence of peak magnitude was observed in June 23 (2015) and on 28 June, 2015 it recovered to its normal level. The above mentioned geomagnetic storm was found to be related with 4B flare/ CME (speed 1042 km/sec) taking place during the decreasing phase of solar cycle 24 and being an extraordinary characteristic.

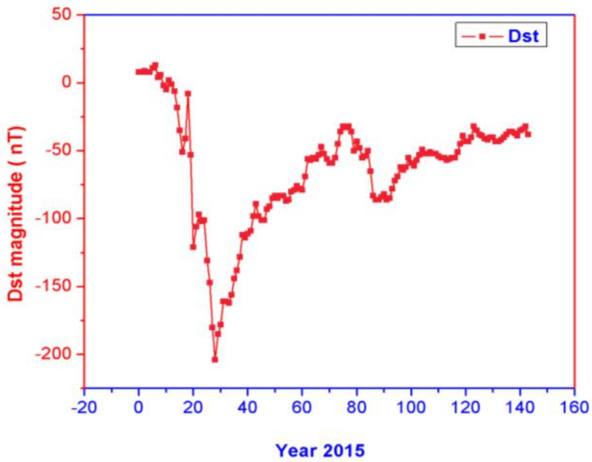

Figure 4: Shows the geomagnetic storms during the time period of 22 June to 28 June in year 2015.

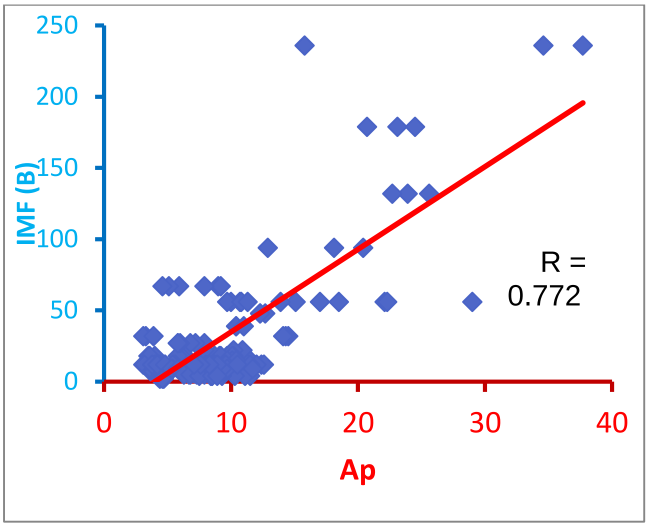

Figure 5: Correlation plots of geomagnetic index Ap with total average interplanetary magnetic field IMF (B) field during the period 22-28 june, 2015.

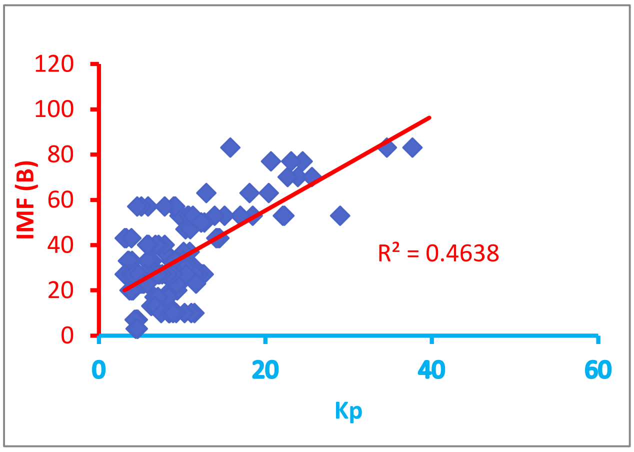

Figure 6: Correlation plots of geomagnetic index Kp with total average interplanetary magnetic field IMF (B) during the period 22-28 june, 2015.

4. CONCLUSION:

From the above discussion, main consequences have been summed up from the investigation of the geomagnetic storms (Dst < -100 nT) and their association with interplanetary parameters during the year 1996 to 2018 as follows

The total number of large geomagnetic storms (Dst< -10nT) analyzed were 120 and that related with CMEs were 69, and related with CMEs and flares (B-class and M-class) are 40, and that linked only with flares were 11.

We have analyzed the significant geomagnetic storms noticed on 14 April 2006 and their association with interplanetary parameters. The correlation coefficient of Kp and Ap parameters with B has been found to be r = 0.681 and r = 0.772 respectively. The perceptible relationships are indispensable for exemplary investigations and space weather phenomenon. The geomagnetic storm intensity has been found well correlated with the net magnetic field of IMF rather than B_z

Component of IMF, density and solar wind velocity.

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