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Effect of Geomagnetic Storms and Their Association with Solar Wind Velocity during 1996-2016

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ABSTRACT

In the present study we shows the results on interplanetary causes of large geomagnetic storms (Dst ≤ -100nT to Dst ≤ -200nT), that occurred during solar cycle 23 and 24 (1996–2016). Space weather in the near-earth environment is directly associated to disturbances originating at the Sun. It is found that total number of large geomagnetic storms (Dst≤-100nT) were observed 88. WE conclude that large storms associated with CMEs were 43, associated with CMEs and solar flares (B-class and M-class), and however associated with only flare is 27. However, the relative importance of each of those driving structures has been shown to vary with the solar cycle phase.

Keywords: Solar wind velocity, IMF, CME's and geomagnetic storms.

I. INTRODUCTION

The geomagnetic storms are a sequence of varying magnetospheric response to the varying conditions in interplanetary space which are caused by coronal magnetic storms. A variety of geomagnetic storms and several sources of their origin have been suggested by many authors [2]. The phenomenon of the geomagnetic storm and its manifestation has been discussed in the literature [3-8]. Strong interaction of CMEs with Earth's environment causes serious space weather effect through the coupled magnetosphere system. A geomagnetic storm is a global disturbance of the earth's magnetic field [1] and usually occurs in response to abnormal conditions in the IMF and solar wind.

Hewish and Bravo [9] found that geomagnetic storms are more associated with coronal holes than the solar flares. Burlaga et al. [10] have concluded that these are associated with either a magnetic cloud which is also confirmed by [11].

The impacts of an interplanetary irregularity causing a sudden change in the geomagnetic components are called sudden commencements [12]. It is accepted that the impact of the interplanetary irregularity on the magnetopause causes hydromagnetic waves which travel through the magnetosphere towards the Earth as also into the tail and their isotropic modes give the SSC. The importance of studying geomagnetic storms is basically two fold. One refers to their academic aspect and the other involves principal aspects that in some cases can represent a particular concern for mankind. The study of geomagnetic storms is useful to explore adverse effect in radio communications, power grid, radar observations, electrical utilities, long-distance pipelines and synchronous spacecraft. Geomagnetic activity can be divided in to two main categories, storms and sub storms. Storms, the main contributors to space weather, are initiated when enhanced energy transfer from the solar wind/ IMF to the magnetosphere leads in to intensification of ring current. The ring current development can be monitored with the Dst index [13-15].

Some of the most dramatic space weather effects occur in association with eruption of material from the solar atmosphere into interplanetary space. These eruptions are known as coronal mass ejections, (CMEs). A large CME can contain 10^{16} grams (a billion tons) of matter that can be accelerated to several million miles per hour in a spectacular explosion. CMEs originating from close to the disk center significantly perturb earth's environment and they directly impact the earth [16]. Each CMEs are drain the solar mass in the range of 10^{10} Kg [17-19] pointed out if the CME is associated with flare then the CME originates in the explosive phase of the flare. Gosling [20] showed that solar flares play no fundamental role in causing geomagnetic disturbances. Flares and CMEs are part of the same magnetic eruption process [21-25]. Characterictics of flares associated with CMEs has been discussed in the literature [26-28].

II. Selection Criteria and data analysis

In the present study, we have analyzed the Geomagnetic storm with Dst magnitude ≤-100nT and their relationship with solar flare, and coronal mass ejections, occurred during solar cycle 21 to 23. The daily observed H-α solar flare data has been taken from the GOES Satellite which is supported by National Geophysical Data Center (NGDC). CMEs are routinely observed by the LASCO telescope on board the SOHO satellite. The extrapolated CMEs onset time is close to the associated type II and IV bursts. The properties of CMEs are collected from the data available through website; http//www.cdaw.gsfc.gov.cmelist/. The catalog contains a list of all visible CMEs with information of their date and time of the first appearance in the field of view of c_2 coronagraph, central position angle, angular width, speed acceleration obtained from quadratic fitting etc, and the Dst, solar wind, IMF, Bz data has been taken from the omni web data.

III. Results and Discussion

The study has once again confirmed the earlier results [29-31] that the indices which are associated with long term variation of sunspot activity sometimes show different behaviour on short term scale depending on local solar active regions and associated phenomena. Since these individual indices on a day to day basis, are affected different at different time, hence we have tried to study the major geomagnetic storms as an individual event associated with solar and interplanetary disturbances. Here we have selected only those geomagnetic storms whose Dst magnitude ≤ -100 nT, occurred during the last three decades.

The largest interplanetary disturbances, in particular the coronal mass ejections (CME) and the high-speed solar wind streams (HSS) are known to cause dramatic effects in the near-Earth space, accelerating magnetospheric (in particular, auroral and ring current) particles to higher energies and enhancing particle precipitation into the atmosphere, especially in the mesosphere-upper thermosphere (MLT) region. Moreover, magnetospheric particle precipitation maintains and produces electric currents and fields that also affect the charged and neutral atmosphere below. The effects are found to depend on the nature of the interplanetary disturbance and to be very different for CMEs and HSSs.

The geomagnetic storms preceded by sudden commencement have been divided in to three phases, the initial phase, main phase and recovery phase. The initial phase is caused by an enhancement of solar wind behind the shock wave. It is quasi steady state proceeded by sudden storm commencement. The main phases of geomagnetic storms follow with the sudden ionospheric disturbances. The recovery phases of geomagnetic storm follow with the active main phase. It consists of slow quite return of H field back to pre storm level. It is also noted that recovery phase duration is always higher than the main phase duration. In **Fig. 1** shows the total number of large geomagnetic storms observed during said period is 88, associated CMEs with geomagnetic storms is 43 and associated CMEs + flare are 18 and associated with only flare is 27.

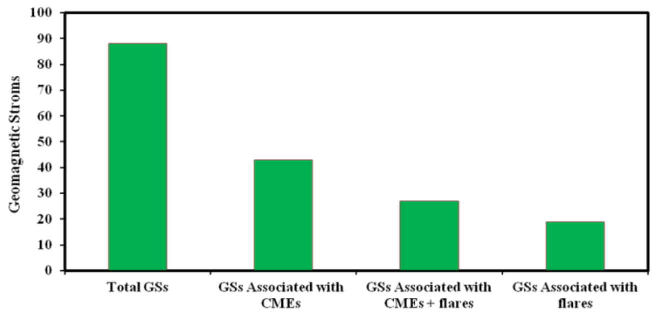

Figure 1. Shows the large Geomagnetic Storms and their association with CMEs, CMEs + Flares and Flares.

Geomagnetic storm of 15 December 2006

To obtain further insight on the effectiveness of various parameters, we have analysed the nature of effects during various events through an examination of the profiles of all the interplanetary variables. Earlier many workers have studied the major geomagnetic storms and their association with different solar & interplanetary features [24]. Solar and interplanetary disturbances causing moderate geomagnetic storms [22]. The events have been distributed according to the magnitude and nature of the profile in each case. The changes in these parameters have been grouped in different slots of magnitudes.

During the geomagnetic storm, the solar wind velocity has an increasing tendency with change of velocity in the range up to 550 to 650 km/sec (56 cases) which in some cases rises to about 650 – 750 km/sec and rarely sometimes ≈ 900 km/sec during the event of 15 Dec. 2006 Fig.2. Whether these CMEs were actually frontside events but lacked visible surface signatures, were backside events with global consequences such as expulsions triggered by global waves [19].

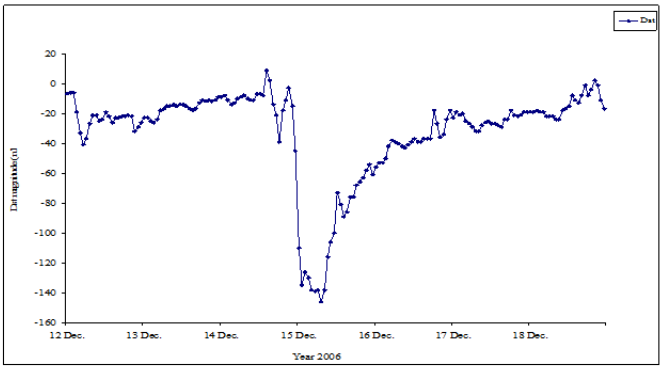

Figure 2. Shows the variation of solar wind velocity during 12 Dec. to 18 Dec. in year 2006.

There is also abrupt change in Bz component from northward to southward. Not only negative Bz or B average is responsible for development of MGS but also its magnitude and duration contribute significantly [16 and 32]. Fig. 3 shows the variation in Bz component during the some event. The southward Bz component becomes prominently negative indicating the geomagnetic storm occurrence [33].

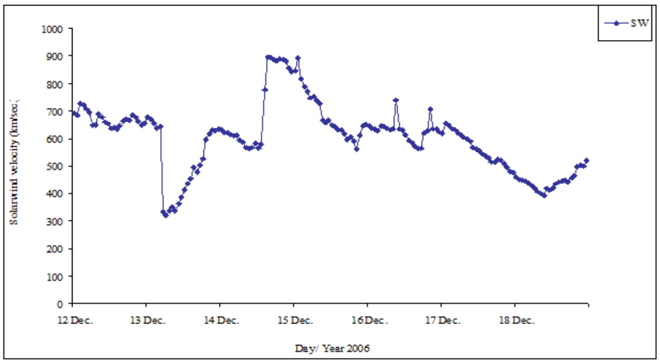

Figure 3. Shows the geomagnetic storms during the time period of 12 Dec. to 18 Dec. in year 2006

Only 5 C-class flare has been observed during solar cycle 23 which follows the sunspot cycle. Large geomagnetic storms (Dst≤-100nT) and 11 C- class flares have been observed for the period 1996 to 2016 **(fig. 4).** In phase with the ring current excursion, however, Murayama [9] found a correlation between negative Dst and dynamic pressure, which was recently confirmed by Fenrich and Luhmann [20] but this dependence of storm strength on dynamic pressure is weak. Peak magnitude occurred at 7 UT on 15 Dec. 2006, and recovered to normal level on 18 Dec. 2006. At last this geomagnetic storm has been found to be associated with the 4B flare / CME (Speed 1042 km/sec.) This event has occurred during the declining phase of solar cycle 23, which is a remarkable feature [33, 34].

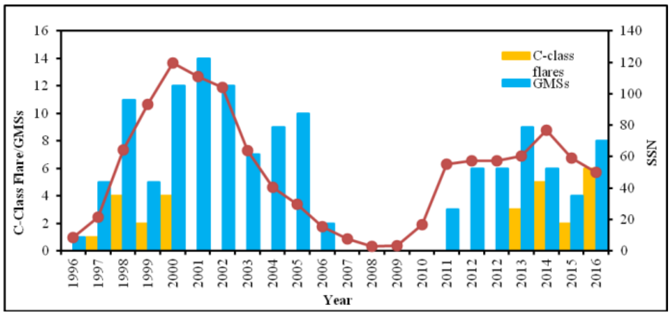

Figure 4. Shows the sunspot number and occurrence of C-class flares associated with moderate geomagnetic storms (Dst ≤-60 to 100nT) during the period 1996 to 2016.

The maximum number of B-class flare has been observed three year after sunspot maxima, which do not totally follow the phase of solar cycle 23 (fig. 5), which indicates the unexpected deviation from solar maxima and minima. Total 88 large geomagnetic storms (Dst≤-100nT) occurred during the maximum phases of both the solar cycle (fig.6)

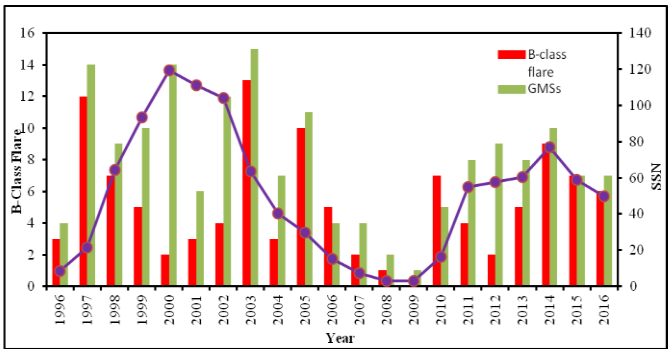

Figure 5: Shows the sunspot number and Occurrence of B-Class Flare associated with the moderate GMSs during the period 1996 to 2016.

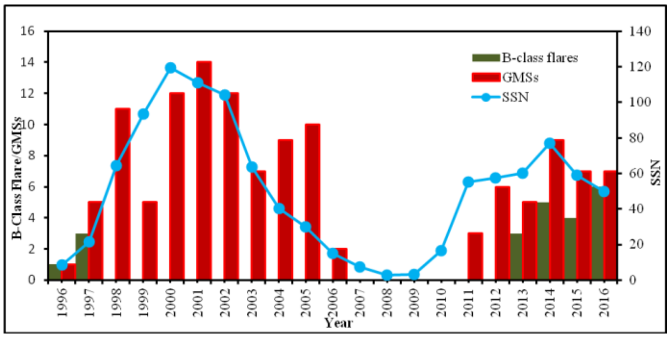

Figure 6 : Shows the sunspot number and occurrence of B-class flares associated the large geomagnetic storms (Dst ≤-100 nT) during the period 1996 to 2016.

IV. CONCLUSION

On the basis of results and discussion, we have summarized important results derived from the analysis of the geomagnetic storms (of magnitude <-100 nT) and their relationship with interplanetary parameters for the period 1996 to 2012 as follows:

It is found that total number of large geomagnetic storms (Dst≤-100nT) were observed 88. WE conclude that large storms associated with CMEs were 43, associated with CMEs and solar flares (B-class and M-class), and however associated with only flare is 27.

Major Geomagnetic storms observed on14 April 2006 have been studied and their relationship with interplanetary parameters has also been discussed. The total average interplanetary magnetic field (B) has good correlation with Kp and Ap Indices with Correlation Coefficient r = (0.59) and (0.58) respectively. These quantitative relationships are invaluable for modeling studies and space weather phenomena. t has been verified that geomagnetic storm intensity is correlated well with the total magnetic field of IMF better than southward component Bz of the IMF, density and solar wind velocity.

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