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Solar and Interplanetary Disturbances causing Moderate Geomagnetic Storms

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Abstract. The effect of solar and interplanetary disturbances on geomagnetospheric conditions leading to 121 moderate geomagnetic storms (MGS) have been investigated using the neutron monitor, solar geophysical and interplanetary data during the period 1978–99. Further, the duration of recovery phase has been observed to be greater than the duration of main phase in most of the cases of MGS. It has further been noted that Ap-index increases on sudden storm commencement (SSC) day than its previous day value and acquires maximum value on the day of maximum solar activity. Generally, the decrease in cosmic ray (CR) intensity and Dst begins few hours earlier than the occurrence of MGS at Earth. Furthermore, negative Bz pointing southward plays a key causal role in the occurrence of MGS and the magnitude and the duration of Bz and Bav also play a significant role in the development of MGS. The solar features Hα, X-ray solar flares and active prominences and disappearing filaments (APDFs) which have occurred within lower helio-latitudinal/helio-longitudinal zones produce larger number of MGS. Solar flares seem to be the major cause for producing MGS.

Key words. Solar flares—active prominences and disappearing filaments—sunspot numbers—geomagnetic storms.

1. Introduction

Geomagnetic disturbances are generally represented by geomagnetic storms, sudden ionospheric disturbances (SIDs) and ground level enhancements (GLEs). During the geomagnetic storms, it has been observed that horizontal component of Earth's magnetic field (H) may attain a maximum value in few to several minutes, the rise is quicker at noon ($\simeq$ 2 min) than that at mid night ($\simeq$ 5 min). The change of the magnetic field during Storm Sudden Commencements (SSCs) (Burlaga and Ogilvie 1969) is step like and oscillatory.

The impact of an interplanetary irregularity causing a sudden change in the geomagnetic components are called SSCs (Smith *et al.* 1986). 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. Almost all the observable features of the solar atmosphere owe their existence to the sunspot magnetic field (Kane 1976). Hewish & Bravo (1986) found that geomagnetic storms are more associated with coronal holes than the solar flares. Burlaga *et al.* (1987) have concluded that these are associated with either a compound stream or a magnetic cloud which is also confirmed by Wilson (1987). Further, co-rotating interaction regions and some other phenomena has also been observed to cause GMSs.

Recently, it has been shown that CMEs without considering solar flares are the key causal link with solar activity and produce geomagnetic storms (Webb 1995). Data available from Skylab mission suggest that the coronal holes, CMEs, Eruptive Prominences and Disappearing Filaments (EPDFs) have causal link with solar activity and energy emitting regions and they produce geomagnetic storms. In this paper, a detailed analysis of moderate geomagnetic storms (MGS) has been presented and an attempt has been made to understand the relationship between solar and interplanetary causes with MGS.

2. Data analysis

In order to examine the relationship between solar and interplanetary causes with MGS in a statistical way, we have considered 121 MGS during the period January 1978 to December 1999. Because of limited space, only four typical cases of MGS observed have been listed in the Table 1. In the present study, MGS are considered with horizontal geomagnetic field component, H $\leq 250\gamma$ (Pandey and Kohli 1982) and Ap $\geq$ 20. The data from neutron monitoring stations have also been analysed. The hourly solar wind velocity (V) data is taken from interplanetary medium data books, available up to period December 1993. These data are measured through IMP-8 satellite (Couzens & King 1986, 1989, 1994). The positions of associated Hα solar flares, X-ray solar flares and APDFs have been noted 1 to 6 days prior to the occurrence of MGS at Earth depending upon Solar Wind velocity (V) (Solar Geophys. Data Reps., 1978–99).

3. Salient features of MGS observed

The initial phase of storm starts after abrupt change in Bz component either from N to S or from S to N. The main phase of storm starts after sudden increase in V and the average IMF (Bav). There is also abrupt change in Bz component from northward to southward. Not only negative Bz or Bav is responsible for development of MGS but also its magnitude and duration contribute significantly (Kane 1977). It is deduced from the plots of all the events that the durations of the initial, main and recovery phases are lying between 20–52 hours, 5–20 hours and 21–30 hours respectively. Further, it is observed in case of individual events that the duration of the recovery phase is always larger than the duration of main phase as is clear from the plot of January 1990.

A peculiar result has been observed during the years 1983 and 1994 when Sunspot numbers (SSNs) decrease very rapidly while number of MGS increases (Fig. 1). It is observed that 48% MGS are produced by eastern X-ray solar flares; whereas 52% MGS are produced by western X-ray solar flares. Further, 78% MGS are associated with X-ray solar flare at the heliographic longitude in the range 0–60°E and 0–60°W. Remaining 22% are distributed over the range 60–90°E and 60–90°W. Thus, X-ray

Table 1. List of MGS with their respective solar features.

Date of MGS	SSC (UT)	H (γ)	V (km/sec)	Date/time (UT) of solar events location	Possible association of MGS with solar events											
					Hα solar flares				X-ray solar flares				APDFs			
					Lat. deg.	CM deg.	Imp	Region	Lat. deg.	CM deg.	Imp	Region	Lat.	CM deg.	Imp	Region
24.1.90	2115	240	660	Jan 22/0839	S 09	E 73	SF	59 00	–	–	–	–	N 08	W 19	–	58 99
01.8.90	0742	164	375	Jul 26/2106	N 13	W 19	SF	61 62	N 13	W 20	SF	61 77	S 27	W 53	–	–
02.4.91	2001	209	543	Mar 30/1825	S 08	W 76	SF	65 61	–	–	–	–	S 22	W 37	–	65 55
09.2.93	1156	180	703	Feb 07/0908	–	–	–	–	–	–	–	–	–	–	–	–

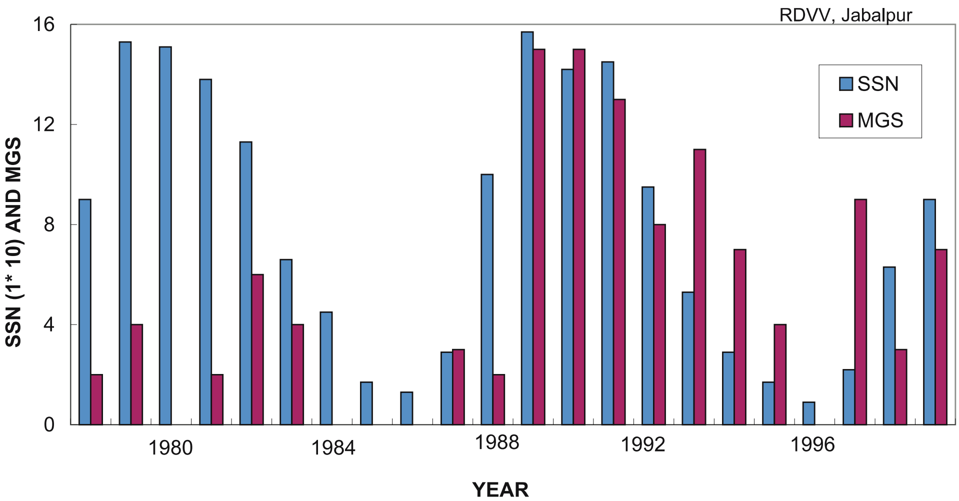

Figure 1. Frequency occurrence histogram of yearly distribution of MGS and their association with SSN.

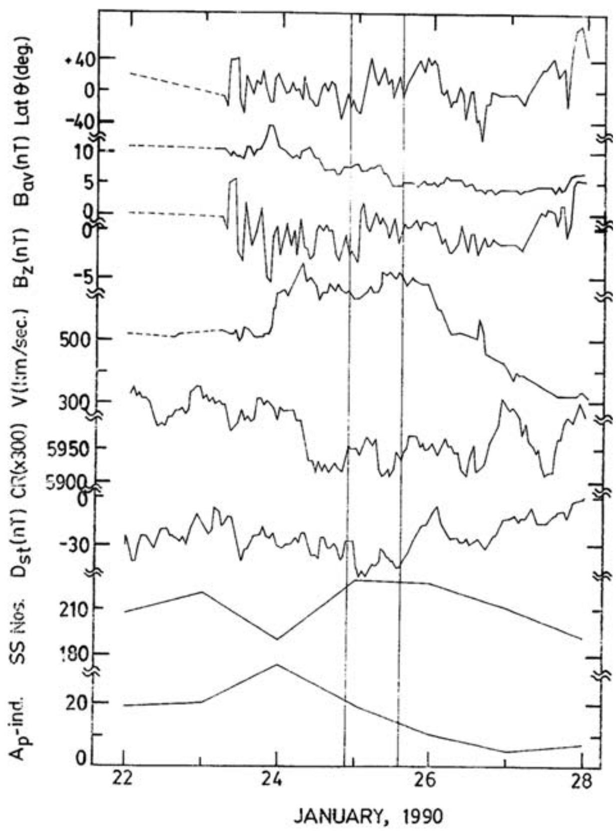

Figure 2. IMF and SWP parameters, i.e., latitude, θ (deg); Bav (nT); Bz (nT); V (km/sec); CR intensity; Dst (nT); SS nos. and Ap index have been plotted during the period 22–28 January 1990 for the 24th January 1990 event.

solar flare occurring within lower heliographic latitude and longitude are able to produce a strong configuration of closed magnetic field regions which cause fast IP shocks in the interplanetary medium and MGS on the Earth.

On the higher latitude and longitude Hα, X-ray solar flares do not produce fast IP shocks. There is equal distribution of APDFs in both northern and southern hemispheres; however, in helio-latitude range 0–30°N and 0–30°S, 89% of APDFs are associated with MGS. 03 MGS out of 121 investigated, are not associated with any solar features. This shows that some solar features occurring on the back side of the solar disc are also contributing for this cause. Interplanetary Magnetic Field (IMF) and Solar Wind Plasma (SWP) parameters along with CR intensity recorded at Deep River neutron monitoring station, Dst, SSNs and Ap indices have been depicted in Fig. 2 for the MGS of January 1990. Figure 2 also shows the beginning and ending boundaries of interplanetary magnetic cloud affecting these parameters.

4. Conclusions

- In solar cycle 21, 69% of MGS occurred during maximum phase and 31% during minimum phase whereas, in solar cycle 22, 59% of MGS occurred during maximum phase and 41% during minimum phase. Thus, maximum number of MGS have occurred during the maximum phase of solar cycle.
- Hα, X-ray solar flares, occurred within lower heliographic latitude 0–30°N and 0–30°S and longitude 0–60°E and 0–60°W, produce maximum number of MGS. On the higher helio-latitude beyond 40° and helio-longitude beyond 60°; Hα, X-ray solar flares do not produce fast IP shocks. A few number of less intense geomagnetic storms are associated with these zones.
- Fast and slow IP shocks are associated with different properties of Hα, X-ray solar flares and APDFs, e.g., NOAA region, location (helio-latitude/helio-longitude), duration and shape of solar event.
- 54.4%, 30% and 47% MGS are associated with Hα, X-ray solar flares and APDFs respectively.

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