Solar and Interplanetary Disturbances causing Moderate Geomagnetic Storms

M.P. Yadav[1] and S. Kumar[2]
(1) Department of Physics, Govt. Tilak P. G. College, Katni (M.P.) 483501, India.
(2) Department of P.G. studies & Research in Phys. and Elec., R. D. University, Jabalpur (M.P.) 482001, India.

Abstract

The effect of solar and interplanetary disturbances on geomagnetospheric conditions leading to one hundred twenty one moderate geomagnetic storms (MGSs) with planetary index, $A_p \geq 20$ and horizontal component of earth's magnetic field, $H \leq 250\gamma$ have been investigated using solar geophysical data (SGD), solar wind plasma (SWP) and interplanetary magnetic field (IMF) data during the period 1978–99. It is observed statistically that 64%, 36%, MGSs have occurred during maximum and minimum phase of solar cycle 21^{st} and 22^{nd} respectively. Further, it is observed that Hα, X-ray solar flares and active prominences and disappearing filaments (APDFs) have occurred within lower helio latitude region associated with larger number of MGSs. No significant correlation between the intensity of GMSs and importance of Hα, X-ray solar flares have been observed. Maximum number of MGSs are associated with solar flares of lower importance of solar flare faint (SF). The lower importance in association with some specific characteristics i.e. location, region, duration of occurrence of event may also cause MGSs. The correlation coefficient between MGSs and sunspot numbers (SSNs) using Karl Pearson method, has been obtained 0.37 during 1978–99.

1. Introduction

Sunspot appears to play key causal role in major solar and geomagnetic disturbances. The occurrence of Hα, X-ray solar flares and active prominences and disappearing filaments (APDFs) are also associated with various phases of sunspot cycles. Geomagnetic disturbances are represented by geomagnetic storms, sudden ionospheric disturbances (SIDs) and ground level enhancements (GLEs). Sudden commencements and gradual commencements (GCs) are caused by two types of solar wind streams (Feynman and Gu, 1986). Geomagnetic storms are also caused by interplanetary shocks (I P Shocks) or streams interfaces which in turn are caused by occurrences on the sun, associated with high speed solar wind streams (HSSWS). These are associated with coronal holes, which occur in

pp. 3655–3659

polar regions or high latitude (Sheeley (Jr) and Harvey, 1981). Fast Coronal mass ejections (CMEs) produce transient I P shocks which cause sudden storm commencement (SSC) at earth (Gosling, 1993; Hundhausen, 1993; Webb, 1995). The solar output in term of particle and field ejected out into interplanetary medium influences the geomagnetic field conditions (Kahler, 1992; Gosling, 1993). It has been observed that the CMEs play an important role in interplanetary disturbances and may be responsible for non-recurrent geomagnetic storms (Gosling, 1993 ; Crooker, 1994). The north-south component (B_z) of IMF, plays a dominant role in determining the amount of solar wind energy to be transferred to the magnetosphere to produce geomagnetic storm (Tsurutani et al, 1992). Recently, it is observed that geomagnetic activity during the declining phase of solar activity is highly related to high values of the product of solar wind velocity (**V**) and interplanetary magnetic filed (IMF) strength **B** i.e. **VXB** leading to geomagnetic disturbances causing GMSs (Sabbah, 2000). In this paper, an attempt has been made to examine the effects of solar and interplanetary transients that may cause MGSs. Further, the MGSs and their association with various phases of sunspot cycles and different interplanetary and solar features have been investigated for the period of study.

2. Data Analysis

All those geomagnetic storms which are associated with $A_p \geq 20$ and H $\leq 250\gamma$ during the period Jan. 1978 – Dec. 99 are considered and are found to be 121 in number. For this study, solar wind plasma (SWP) and interplanetary magnetic field (IMF) data from IMP–8 satellite are used. These data are compiled by King and Couzens in different volumes of interplanetary medium data book from national space science data center (NSSDC). The possible association of geomagnetic storms with solar features has been investigated during the period Jan 1978 – Dec 93. For associations of geomagnetic storms with solar features, solar geophysical data (SGD) have been used for the period 78–99. On the basis of solar wind velocity (**V**), solar features have been investigated such that $1 \leq \Delta t \leq 5$ days prior to the occurrence of MGSs on the earth. Here, the time (Δt) taken by the solar wind in reaching the earth from the sun will depend upon the V.

3. Results and Discussion

Annually sunspot numbers (SSNs) and occurrence of Moderate geomagnetic storms have been plotted histographically in Fig 1. The correlation coefficient between yearly occurrence of MGSs and SSNs has been calculated using Karl Pearson method and found to be 0.37. This result shows an association between yearly occurrence of MGSs and SSNs (Kumar and Yadav, 2001). It is observed statistically that 69% and 31% MGSs have occurred during the maxi-

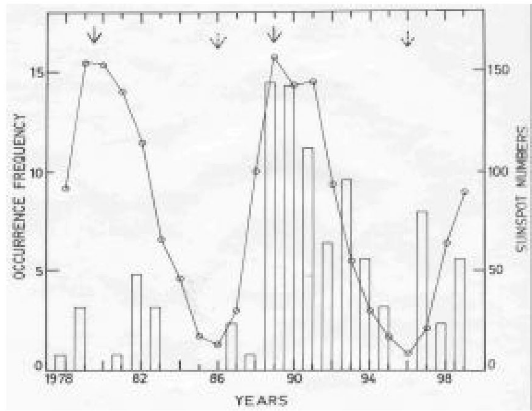

Fig. 1. The occurrence frequency of moderate geomagnetic storms (MGSs) histographically and SSNs plotted for the period 1978–99.

mum and minimum phases of 21st solar cycle respectively. It is further observed statistically that 59% and 42% MGSs have occurred during the maximum and minimum phases of 22nd solar cycle respectively. Somehow, a peculiar result has been observed during the year 1993, when SSNs have decreased very rapidly; whereas, the MGSs have increased significantly. The number of MGSs are maximum during the solar maximum activity year i.e. 1989–91. Akasofu and Yoshida (1967) ; Lockwood (1971) and Pudovkin and Chertkov (1976) have shown the association of different types of geomagnetic storms with solar flares. Frequency occurrence histogram of MGSs with importance of Hα, X-ray solar flare have been plotted in Fig 2 (a,b). It is observed from Fig 2(a, b) that 53%, 18%, 16% MGSs are associated with Hα solar flare of importance SF, SN and $\geq$1 bright (1B) respectively ; whereas 67%, 7% and 7% MGSs are associated with X-ray solar flare of importance SF, SN and $\geq$ 1B respectively. Thus we conclude that maximum number of MGSs are associated with importance of solar flare faint (SF) of each Hα and X-ray solar flares during the period 1978–93. This result is consistent with Kumar and Yadav (2002a, b) result. No significant correlation between intensity of geomagnetic storms and importance of Hα, X-ray solar flares have been observed. Somehow, solar flare of lower importance in association with some other specific characteristics i.e. location, duration of event, region may also cause the occurrence of MGSs (Klassen et al, 1999 ; Kumar and Yadav, 2002a, b; 2003).

The association of MGSs with solar features i.e. Hα, X-ray solar flares, ADPFs and CMEs have been plotted in Venn diagram 3. It is quite apparent from Fig 3 that out of 90 MGSs ; 49, 27, 43, 12 MGSs are associated with Hα, X-ray solar flares, APDFs and CMEs respectively. Thus, we conclude that maximum number of MGSs are associated with solar flares (Hα & X-ray) as compared to other solar features. This result is consistent with Garcia and Dryer (1987) and

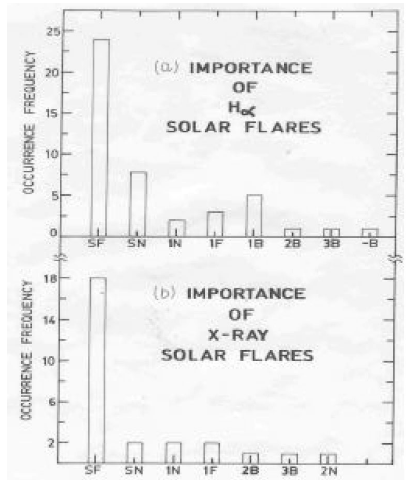

Fig. 2. The occurrence frequency of (a) Hα and (b) X-ray solar flares importance plotted histographically during 1978–93.

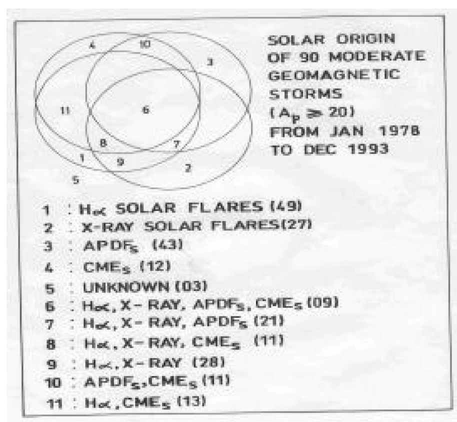

Fig. 3. Venn diagram showing the solar origin of 90 moderate geomagnetic storms with $A_p \geq 20$ with H$\leq 250\gamma$ during the period Jan 1978 to 1993.

Kumar and Yadav (2002a, b) and inconsistent with Hewish and Bravo (1986) and Webb (1995) observations. Further, 03 MGSs are not associated with any solar features. This shows that some solar features occurred on the backside of the solar disc are likely to contribute for this cause.

4. Conclusions

From the rigorous analysis of data, the following conclusions are drawn:

(i) It is observed statistically that, 64%, 36% MGSs have occurred during maximum and minimum phases of 21^{st} and 22^{nd} solar cycles respectively.

(ii) No significant correlation between intensity of MGSs and importance of

Hα, X-ray solar flares have been observed. Maximum number of MGSs are associated with importance SF of each Hα, X-ray solar flares. Solar flares with lower importance in association with some other specific characteristics i.e. location, region, duration of event may also produce MGSs.

(iii) MGSs are associated more with solar flares. This result is consistent with Garcia & Dryer (1987), Kumar and Yadav (2002a, b) and inconsistent with Hewish and Bravo (1986) and Webb (1995) result.

(iv) The correlation coefficient between MGSs and SSNs has been obtained to be 0.37 during the period 1978–99, which shows an association between MGSs and SSNs.

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