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# Sunspots and geomagnetic disturbances during solar cycles 21, 22 and 23

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**Abstract.** The effect of solar and interplanetary turbulences on geomagnetospheric conditions leading to ninety seven (97) geomagnetic storms (GMSs) with $A_p \geq 50$ have been investigated using solar geophysical data (SGD) during the period 1978-99. It is observed statistically that maximum number of GMSs have occurred during the years of maximum solar activity. However, it is not necessary that maximum number of disturbed days should occur during the maximum solar activity period only. Somehow, exceptionally large number of disturbed days have occurred during the year 1991. Further, the occurrence of disturbed days varies with seasons as well. A peculiar result has been observed during the years 1982 and 1994, when sunspot numbers (SSNs) have decreased rapidly; whereas, the number of observed GMSs have increased.

## 1 Introduction

Sunspots appear to play main role in major solar and geomagnetic disturbances. The sunspot may divide or merge in a single spot or bipolar pair may rotate; such motion may produce a large flare. The occurrence of $H_{\alpha}$, X-ray solar flares and active prominences and disappearing filaments (APDFs) are also associated with various phases of sunspot cycles. 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 coronal mass ejections (CMEs) play an important role in interplanetary disturbances and may be responsible for non-recurrent geomagnetic storms (Gosling, 1993; Crooker, 1994). Occurrence of GMSs (recurrent and non-recurrent) varies with 11/22-year sunspot cycle. During solar activity maximum, major GMSs tend to non-recurrent and are predominantly associated with transient disturbances in solar wind arising from active regions of the Sun; whereas, during solar minimum activity period, most of the large GMSs are of recurrent type and are commonly associated with corotating flows in solar wind streams (Snyder et al., 1963). Some workers (Feynman, 1983; Wang and Sheeley Jr., 1997) have shown that the solar wind is a function of (i) latitudinal distance from the ecliptic plane and (ii) sunspot cycle, a part from mere sunspot numbers (SSNs). 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 field (IMF) strength B i.e.,VxB leading to geomagnetic disturbances causing GMSs (Sabbah, 2000). The electromagnetic and corpuscular radiations produce extra ionisation in the sunlit part of the Earth and produce geomagnetic disturbances causing GMSs. These geomagnetic disturbances are observed and represented by different geomagnetic indices $A_p$, $K_p$, equatorial index, $D_{st}$ and $A_E$ etc. Geomagnetic disturbances are driven by the interaction of solar wind with geomagnetosphere and the strength of this interaction depends on the solar wind parameters.

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## 2 Data Analysis

The relationship between solar and interplanetary disturbances causing GMSs and their association with various phases of 11/22-year sunspot cycle alongwith yearly and monthly distribution of disturbed days with $A_p \geq 50$ using SGD during the period 1978-99 has been investigated.

## 3 Results and Discussion

The classification of selected 97 significant GMSs with $A_p \geq 50$ in different varying ranges of horizontal component of Earth's magnetic field (H) value is presented in Table.

Annual mean values of SSNs and yearly distribution of the occurrence of GMSs for the period 1978-99 are plotted in Fig.1. Maximum SSNs and length of solar cycles 21st and 22nd are observed to be 164.5, 10.2 years and 158.1, 10 years respectively. It is observed that 60% GMSs have occurred during the maximum solar activity years 1979, 80 & 81; whereas, 13.3% GMS have occurred during the minimum solar activity years 1985 & 86 of 21st solar cycle. It is being further observed statistically that 77.6% GMSs and 0% GMSs have occurred during the maximum solar activity years 1989, 90 & 91 and minimum solar activity years 1995 & 96 respectively of 22nd solar cycle. Thus, it is evident that maximum number of GMSs occur during the maximum phases of each solar cycle. These observations show a close association between yearly occurrence of GMS and various phases of solar cycle. Somehow, a peculiar result has been observed during the years 1982 and 1994 when SSNs decrease rapidly; whereas, number of observed GMSs have increased. Thus, it is evident that the abrupt change has taken place in some of the solar features other than SSNs so as to produce large number of GMSs during these years.

A frequency occurrence histogram of yearly distribution of disturbed days ($A_p \geq 50$) have been plotted during the period of study in Fig 2. Solar output influences the Earth's magnetic field and produces geomagnetic disturbances at various locations. These disturbances, on the basis of daily average value of planetary index $A_p \geq 50$ have been investigated and 266 disturbed days during the period 1978-99 are observed. From this analysis, a peculiarity has been observed that it is not necessary that maximum number of disturbed days should occur during the maximum phases of solar cycles. Further, during the years 1982 and 1994, the SSNs decrease rapidly; whereas, number of disturbed days have increased. Exceptionally large number of disturbed days; such as 14.3% of the total number of disturbed days observed during the entire period of consideration i.e., 1978-99; have occurred during the year 1991 only, indicating that the Sun is being more violent during the year 1991. Further, occurrence of number of disturbed days does not show any symmetric association with SSNs.

## 4 Conclusions

From the rigorous analysis of data presented in the foregoing sections, the following conclusions have been drawn:

(i) Larger number of GMSs are observed during maximum solar activity and very less number of GMSs are observed during minimum solar activity years of solar cycles 21st & 22nd.

(ii) A peculiar result has been observed during the years 1982 and 1994 when SSNs decrease rapidly; whereas, number of GMSs increase.

(iii) It is not always necessary that maximum number of disturbed days should occur during the maximum phase of solar cycles only.

(iv) Exceptionally large number of disturbed days have occurred during the year 1991 only. Further, the occurrence of disturbed days varies with seasons as well.

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**Table :** Classification of GMSs on the basis of horizontal component of Earth's magnetic field (H)

| S. No. | Category | H range ($\gamma$) | Number of GMSs |
|---|---|---|---|
| 1. | Severe | $H \geq 400$ | 38 |
| 2. | Moderately severe | $250 < H < 400$ | 32 |
| 3. | Moderate | $H \leq 250$ | 27 |

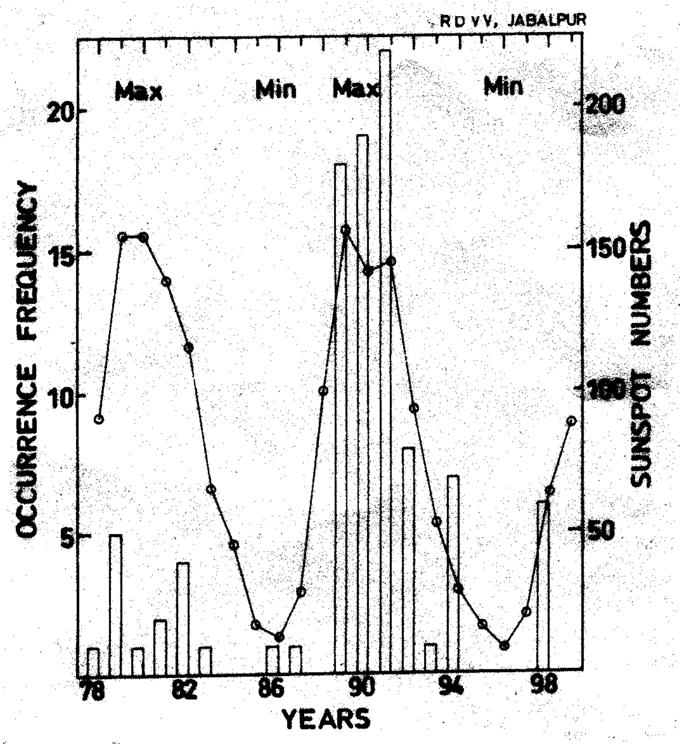


Fig 1. The occurrence frequency of GMSs histographically and SSNs plotted for the period 1978-99.

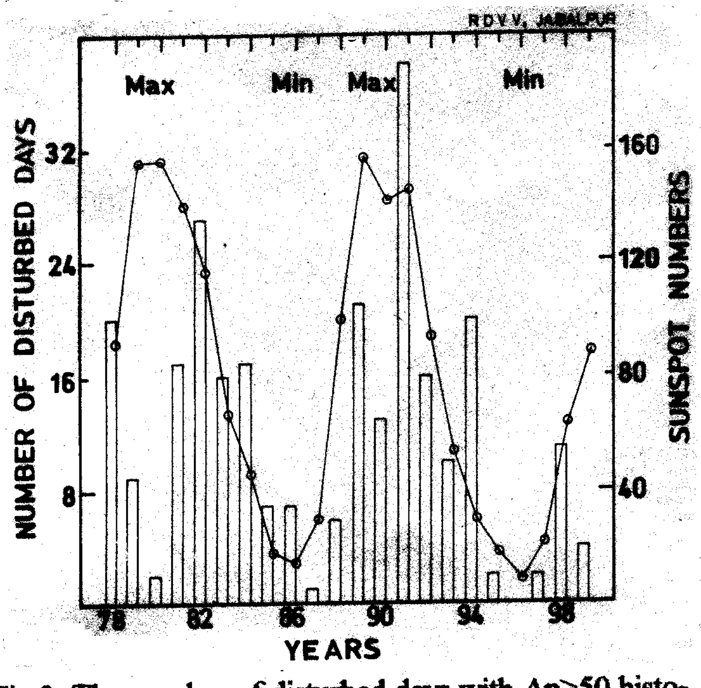


Fig 2. The number of disturbed days with Ap>50 histographically and SSNs plotted for the period 1978-99.

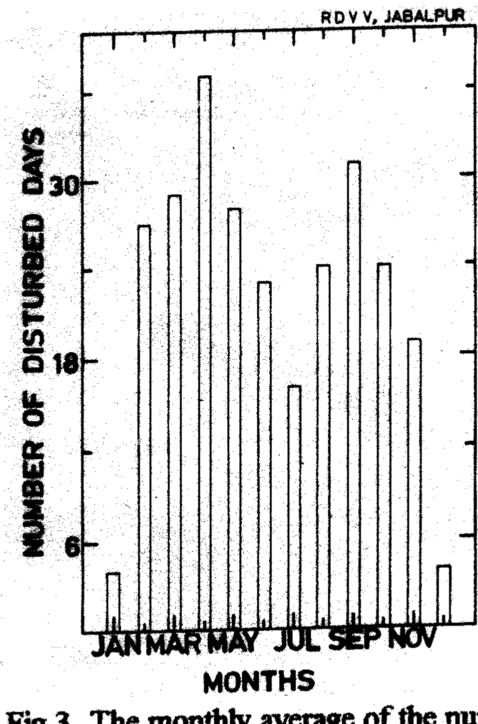


Fig 3. The monthly average of the number of disturbed days with Ap>50 for the entire period 1978-99 plotted histographically.