TITLE - The Study of Large geomagnetic storms observed during Of Period 1986-2002

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Abstract

The set of 158 intense geomagnetic storms associated with $\mathbf{D}_{st}$ decreases of more than 100 nT, observed during solar cycle 22 and 23, In the covers whole period of solar cycle 22 and maximum part of solar cycle 23, have been analyzed. The selected storm events have been compiled and their various characteristics features as well as seasonal and solar cycle dependence have been discussed. We find yearly occurrence of intense storm are strongly correlated with 11-year sunspot cycle, but no significant correlation's between the maximum and minimum phases of solar cycle have been found. It is also found that best initial phase duration lies between 0-2 hours. The main and recovery phase duration's lies between 7-12 hours and 2-3 days respectively. The seasonal shows a cyclic variation peaking around April and October months.

Introduction

Geomagnetic storms are large disturbances in the geomagnetosphere, often persisting for several days are more. During geomagnetic storms, the magnetic field measured at the earth's surface is perturbed by strong electric currents flowing within both the magnetosphere and the ionosphere, the aurora brightens and extended to low magnetic latitudes, and intense fluxes of energetic charge particles are generated within the magnetosphere. The variation of earth's magnetic field, usually expressed through magneto grams, shows the time variation of declination (**D**), vertical component (**Z**) and horizontal component (**H**). However, for global quantitative representation various geomagnetic indices have been introduced. The disturbance storm time ($\mathbf{D}_{st}$) index is the conventional measure of ring current intensity and energy observed at earth's surface over low and moderate latitudes. The $\mathbf{D}_{st}$ values are obtained from the longitudinal average of **H** variations measured at middle and low latitude observatories. It is the best indicator of the ring current intensities and a very sensitive index to represent the degree of solar disturbances.

The aim of the statistical study presented in this paper is to analyze various characteristics of intense geomagnetic storms and which defines better aspects to understand history of geomagnetic storms.

General characteristic of intense geomagnetic storms

The general characteristics of all those intense geomagnetic storms, which are compiled in Table 1 are described here. Out of the selected 158 intense geomagnetic storm events, 82 are sudden commencement type and rest 76 are gradual commencement type. Generally, it is believed that the majority of intense geomagnetic storms occur during the maximum phase of sunspot cycle because many solar active regions appear during this time, while a few of the geomagnetic storms are observed during the minimum phase of sunspot cycle due to the presence of coronal holes and some other solar activities. Of the whole period (1986-2002) of solar cycle 22 and 23, the periods 1986-88,1992-99 and 2001-02 are the periods of minimum phase of solar activity, whereas the period 1989-91 and 2000 are taken as the period of maximum phase of solar activity. Generally, solar cycle contains one maximum peak, where sunspot number is maximum and the period of that peak is termed as solar maximum activity phase. The solar cycle 22 exceptionally, among other 22 solar cycles, contains two peaks during the year 1989 and 1991. So, the maximum phase of 22nd solar cycle has been measured during the year 1989-91. In this period (1986-2002), the occurrence rates of total number of intense geomagnetic storms, sudden commencement storms and gradual commencement storms during maximum and minimum phases of above mentioned period have been calculated and are summarized in below.

Table - Occurrence rates for different types of geomagnetic storms observed during maximum and minimum phases of solar cycle 22 and 23.

Storm type	Occurrence rate during	
	Maximum phase	Minimum phase
Large storms	15.5	7.38
Sudden commencement storms	8.25	3.76
Gradual commencement storms	7.25	3.61

The occurrence rate shows that the majority of intense geomagnetic storms occurred during the maximum phase. Figure 1 shows the occurrence frequencies of sudden commencement storms, total number of large geomagnetic storms and gradual commencement storms, during the period 1986-2002. The plot shows occurrence of intense storm are strongly correlated with SSN, but no significant correlation between the maximum and minimum phases of solar cycle and the yearly occurrence of sudden and gradual commencement storms has been found.

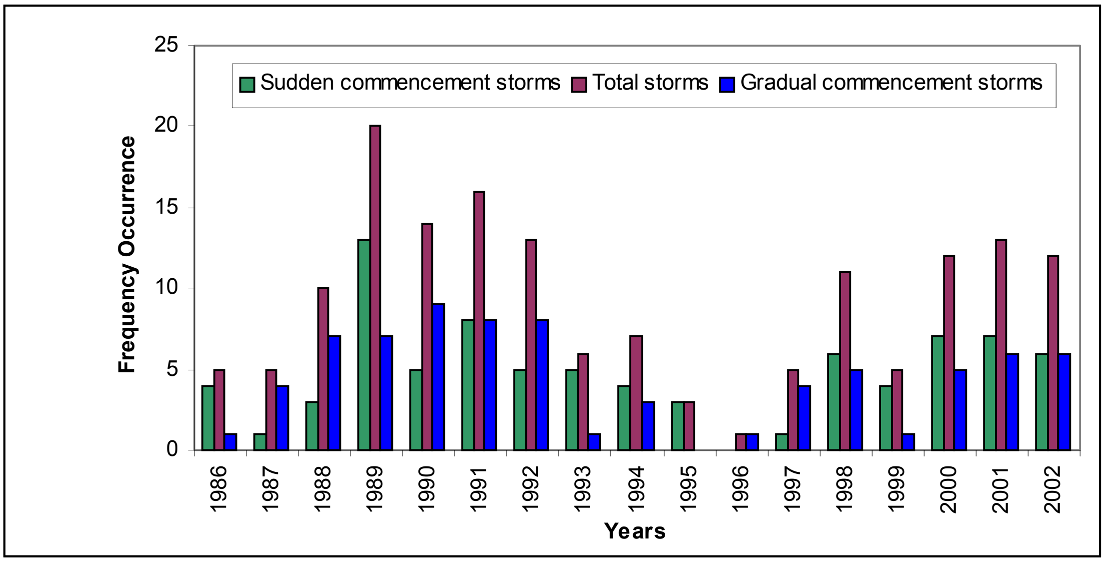

Fig. 1- Frequency histogram of geomagnetic, sudden and gradual commencement storms observed during solar cycle 22 and 23.

The onset time of geomagnetic storms is generally coincident with the time of SSCs (Ref. 2), though it is not always an essential condition. Zhu and Wada[3] observed that the $\mathbf{D}_{st}$ value is minimum at about 10-20 hours after the occurrence of SSC. Moreover, a number of SSCs were not found to be associated with any significant change in the $\mathbf{D}_{st}$ magnitude. In the present selected study period 52% large geomagnetic storms were associated with SSCs. It is also observed that, in most of the cases, the onset of main phase just follows SSC. For the selected SSCs associated intense storm events, the most probable value of time difference between SSC and onset of main phase is found to vary from 0-2 hours, when the storms associated with SSC show faster recovery in comparison to the storms that are not associated with SSC.

Variation of initial, main and recovery phase durations

A standard classical geomagnetic storm can be divided into three phases, namely initial phase, main phase and recovery phase. The initial phase is caused by an enhancement of solar wind behind the shock wave. It is a quasi-steady state preceded by sudden storm commencement. The main phase of the geomagnetic storm is characterized by the decrease in **H**-component of earth's magnetic field and followed with the sudden ionosphere disturbances (SIDs) and ring current system. The recovery phase of geomagnetic storm follows with the active main phase. It characterized by a slow and quiet return of **H**-field back to pre-storm level. In this study, the best fit initial, main and recovery phase durations have been analyzed for selected storm events. Figure 2 shows the compiled plots for these durations. For the study of the initial phase duration, the number of such storm events has been selected whose initial phase duration varies in the time intervals of 0-2, 3-4, 5-6, 7-8 and > 8 hours. Similarly, for the main phase, time intervals of 0-6, 7-12, 13-18, 19-24 and > 24 hours have been selected. Generally, the recovery phase of storms takes more time, so the time intervals varying in the range of 0-1, 1-2, 2-3, 3-4, 4-5 and > 5 days have been chosen. From these plots, it is clear that the best initial phase duration lies between 0 and 2 hours. The main phase duration for maximum number of intense storms lies between 7-12 hours. The recovery rate depends on magnitude and main phase gradient of storms. In this study, recovery phase duration lies between 2-3 days. Further, it is also found that the main phase duration is always less than the recovery phase duration and the storm associated with SSC shows faster recovery in comparison to other storm that is not associated with SSC. This result is in good agreement with the findings of Kane[1] and Shukla[4].

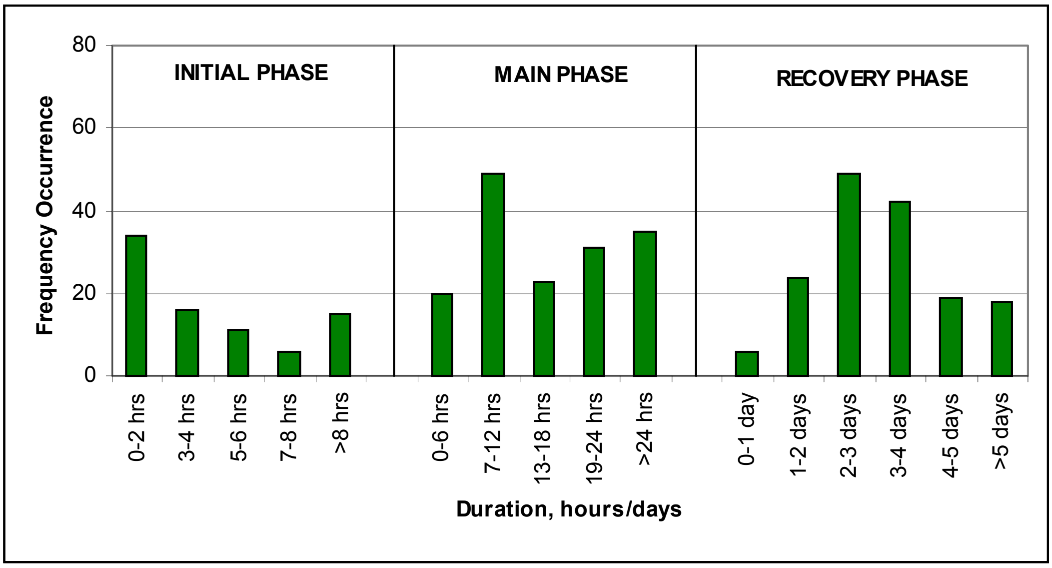

Fig. 2- Frequency histogram for initial, main and recovery phase durations.

Seasonal dependence of large geomagnetic storms

The occurrence rate of large geomagnetic storms displays a pronounced semi-annual variation. Russell-McPherson effect suggests that the geoeffectiveness of the causative eruptive solar events has a seasonal dependence. The semi-annual variations of geomagnetic activity have been analyzed by a number of methods[5,6]. It is usually treated as a statistical effect and attributed to a mechanism that gives stronger solar wind-magnetosphere coupling, on the average, in spring and fall. Crooker et al.[7] have shown that 30-40% of geomagnetic disturbances occur during the equinoctial months of March and September and $\leq$ 5% occur during the solstitial months June and December, and proposed the major increase in the Russell-McPherron[8] polarity effect through a systematic pattern of shock compression and draping the ecliptic fields preceding the driver gas of coronal mass ejections. The seasonal dependence of selected storm events are shown in Figure 3. It is seen that the semi-annual variation of large storm events shows a cyclic variation peaking around April and October.

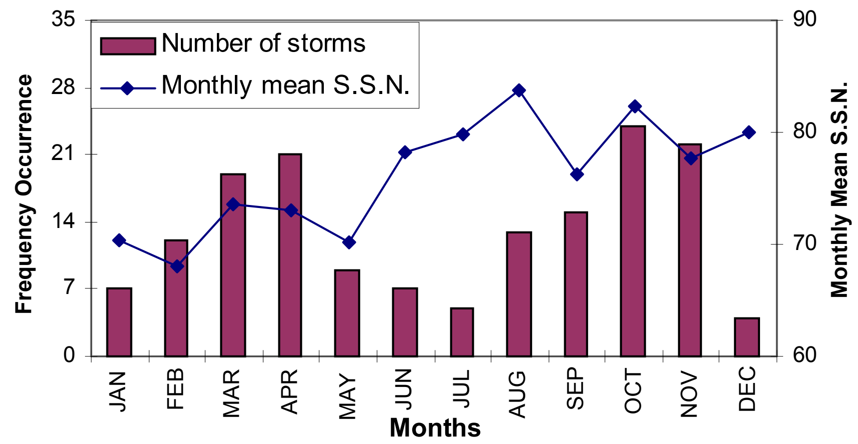

Fig. 3- Frequency histogram for seasonal dependence of large geomagnetic storms, observed during the period 1986-2002.

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