STUDIES ON LARGE GEOMAGNETIC STORMS DURING SOLAR CYCLES 22-23

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ABSTRACT

The set of 158 intense geomagnetic storms associated with Dst index 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.

Keywords: *Geomagnetic storms, Dst index, Solar cycles, Main phase, Recovery phase*

ABSTRAK

Badai geomagnet besar dengan indeks Dst lebih kecil dari 100 nT dalam siklus matahari ke 22 dan ke 23 berjumlah 158 kejadian. Telah dilakukan pengolahan data dan analisisnya sepanjang siklus ke 22 dan saat aktivitas maksimum pada siklus ke 23. Selain itu, juga dibahas kejadian badai geomagnet besar dalam periode tersebut dengan berbagai karakteristiknya, seperti keterkaitannya dengan siklus matahari dan variasi musim. Hasil yang diperoleh menunjukkan bahwa kemunculan badai geomagnet tahunan berkorelasi sangat kuat dengan siklus bilangan *sunspot*, tetapi tidak menunjukkan korelasi yang signifikan dengan fase maksimum dan minimum dari siklus matahari. Durasi fase awal paling dominan adalah antara 0-2 jam, sedangkan durasi fase utama dan fase pulih masing-masing antara 7-12 jam dan 2-3 hari. Dari variasi musiman terlihat bahwa puncak terjadinya badai geomagnet besar adalah pada bulan April dan Oktober.

Kata kunci: *Badai geomagnet, Index Dst, Siklus matahari, Fase utama, Fase pulih*

1   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 magnetograms, shows the time variation of horizontal component (H), declination (D), and vertical component (Z). However, for global quantitative representation various geomagnetic indices have been introduced. The disturbance storm time (Dst) index is the conventional measure of ring current intensity and energy observed at earth's surface over low and moderate latitudes. The Dst index, deriving from hourly horizontal magnetic variations recorded in a network of near-equatorial geomagnetic observatories, is mostly used since 1957. It is the best indicator of the ring current intensities and a very sensitive index to represent the degree of solar disturbances. The strength of geomagnetic storms is indicated by the Dst index indicating the amount of solar wind energy penetrating the Earth's ionosphere. Geomagnetic storms are usually classified by Dst index as intense storms (Dst $\leq$ -100 nT), moderate storms (-100 < Dst < -50) and minor storms (Dst $\geq$ 50). In terms of time sequence a geomagnetic storm can be described to three phases: initial phase, main phase, and recovery phase (Gonzalez et al., 1994). The main phase is characterized by a large decrease of Dst. 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.

2   DATA ANALYSIS

The general characteristics of all those intense geomagnetic storms, which are compiled in Table 2-1 are described here. Hourly Dst indices for this work are obtained from the World Data Center C2 at Kyoto University database (http:// swdcdb.kugi.kyoto-u.jp/dstdir) and from National Space Science Data Center (NSSDC) database (http://nssdc.gsfc.nasa.gov/omniweb). The time associated with storm sudden commencement (SSC) was obtained from National Geophysical Data Center (NGDC) database(ftp;//ftp.ngdc.noaa. gov/STP/SOLARDATA/SUDDENCOMMENCEMENT/STORM2.SS/. 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

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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 of 1986-1988,1992-1999 and 2001-2002 are the periods of minimum phase of solar activity, whereas the period of 1989-1991 and 2000 are taken as the period of maximum phase of solar activity. Generally, solar cycle contains one maximum peak, where sunspot number (SSN) 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. The maximum phase of 22nd solar cycle has been measured during the period of 1989-1991. 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 as below,

Table 2-1: 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

3 RESULT AND DISCUSSION

3.1 Characteristic of Intense Geomagnetic Storms

The occurrence rate shows that the majority of intense geomagnetic storms occurred during the maximum phase. Figure 3-1 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.
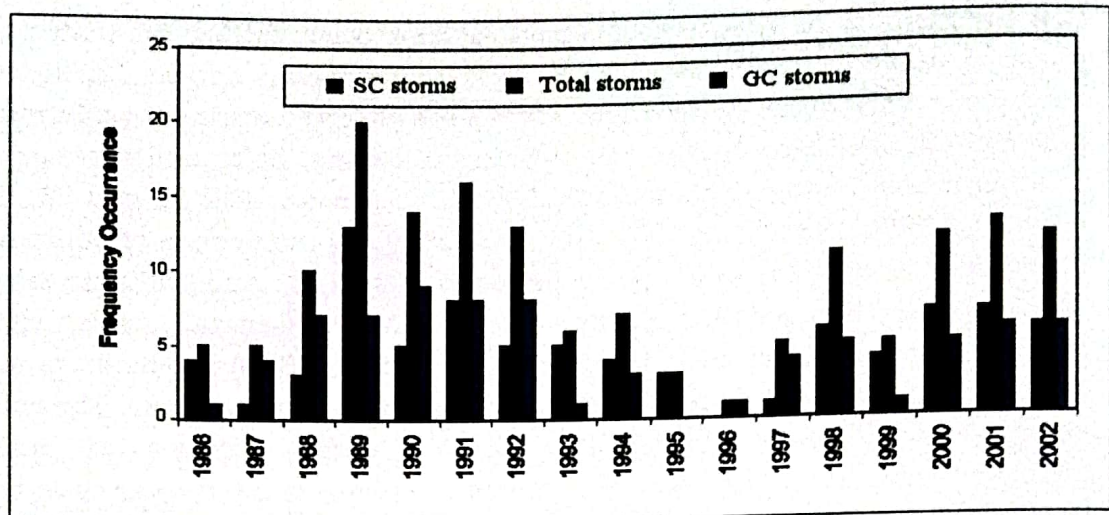
Figure 3-1: Frequency histogram of geomagnetic, sudden and gradual commencement storms observed during solar cycle 22 and 23

The onset time of geomagnetic storms is generally coincident with the time of SSCs (Gonzales et al., 1992), though it is not always an essential condition. Zhu and Wada (1983) observed that the Dst 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 Dst 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.

3.2 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 3-2 shows the compiled plots for these durations. For the study of the initial phase duration, the number of such storm events has

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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 (1977).
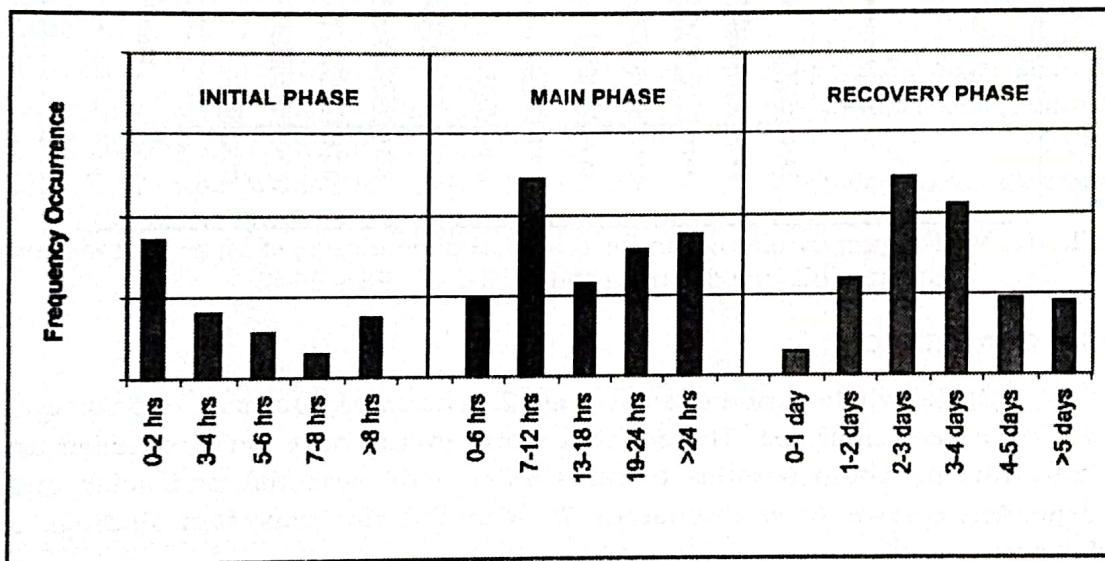

Figure 3-2: Frequency histogram for *initial*, *main* and *recovery phase* durations

3.2 Seasonal Dependence of Large Geomagnetic Storms

The occurrence rate of large geomagnetic storms displays a pronounced semi-annual variation. Russel and McPherron (1973) 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 (Crooker and Siscoe, 1986; Crooker, et al., 1992, Saroso, 2006; Gonzales et al., 2007). 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. (1992) have shown that 30-40% of geomagnetic disturbances occur during the equinoctial months of March and September and ≤ 5% occur during the solstitial months June and December, and proposed the major increase in the

Russell-McPherron 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 3-3. It is seen that the semi-annual variation of large storm events shows a cyclic variation peaking around April and October.
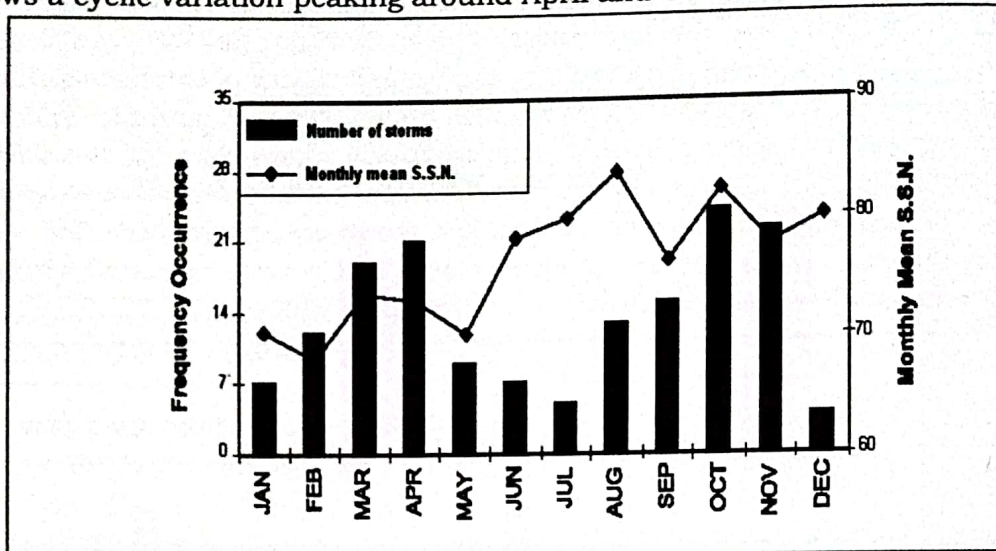

Figure 3-3:Frequency histogram for seasonal dependence of large geomagnetic storms, observed during the period of 1986-2002

4 CONCLUSION

Of the 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 can list the important findings as follows:

- 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.
- The 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. 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.
- The semi-annual variation of large storm events shows a cyclic variation peaking around April and October months.

Kyoto University, Space Physics Interactive Data Resource, as well as National Geophysical Data Center, and National Space Science Data Center.

REFERENCES

Crooker, N. U. and Siscoe, G. L., 1986. *Physics of the Sun*, edited by P. A. Sturrock, Reidel, Massachusetts, 193.

Crooker, N. U., Cliver, E. W. and Tsurutani, B. T., 1992. J. Geophys. Res. Lett. 19, 429.

Gonzalez, W. D., Echer, E., Clua-Gonzalez, A. L., and Tsurutani, B. T., 2007. Geophys. Res. Lett., 34, L06101, doi:10.1029/2006GL028879.

Gonzalez, W. D., Gonzalez, A. L. C., Mendes O. (Jr) and Tsurutani, B. T., 1992. EOS Trans AGU, 180.

Gonzalez, W. D., Joselyn, J. A., Kamide, Y., Kroehl, H. W., Rostoker, G., 1994. J. Geophys. Res. 99, 5771–5792.

Kane, R. P., 1977. J. Geophys. Res., 82, 561.

Russell, C. T. and McPherron, R. L., 1973. Space Science Review, 205.

Saroso, S., 2006. *Proc. of International Conference on Mathematics and Natural Sciences,* Bandung, Indonesia, 1277-1280.

Zhu, B. Y. and Wada, M., 1983. *Proceedings of 18 International Cosmic Ray Conference*, Bangalore, India, MG-6-16, 213.