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Statistical Study of Geomagnetic Storms and their Classification during Solar Cycle-23

Balveer S. Rathore[1*], Subhash C. Kaushik[1,2], K.K. Parashar[1], Rammohan S. Bhadoria[1] and Preeti Kapil

[1]School of Studies in Physics, Jiwaji University,
Vidya Vihar, Gwalior, M.P., India
[2]Departrment of Physics, Government Autonomous Excellent College,
Datia, M.P., India
**Corresponding Author E-mail: balveer_singhra@yahoo.co.in*

Abstract

A geomagnetic storm is a global disturbance in Earth's magnetic field usually occurred due to abnormal conditions in the interplanetary magnetic field (IMF) and solar wind plasma emissions caused by various solar phenomenon. A study of 220 geomagnetic storms associated with disturbance storm time (Dst) decreases of more than -50 nT to -300 nT, observed during 1996-2007, the span of solar cycle 23. We have been analyzed and studied them statistically. We find yearly occurrences of geomagnetic storm are strongly correlated with 11-year sunspot cycle, but no significant correlation between the maximum and minimum phase of solar cycle-23 have been found. It is also found that solar cycle-23 is remarkable for occurrence of Intense geomagnetic storm during its declining phase. The detailed results are discussed in this paper.

Keywords: Geomagnetic Storm, Interplanetary magnetic field (IMF), Disturbance storm time (Dst), Solar Cycle.

Introduction

Geo-magnetic storms generally occurred due to abnormal conditions in the interplanetary magnetic field (IMF) and solar wind plasma emissions caused by various solar phenomenons'. The study of these worldwide disturbances of Earth's magnetic field are important in understanding the dynamics of solar-terrestrial environment and furthermore because such storms can cause life threatening power outrages, satellite damage, communication failure and navigational problems.

Since the beginning of the space age, the cause of geomagnetic activity has been sought in a number of correlative studies (Akasofu 1983). It is suggested that geomagnetic, activity is related to variety of interplanetary plasma/field parameter: Solar wind velocity V. interplanetary magnetic field (IMF) B and Bz (Gonzalez et al. 1989, Sabbah 2000). Strong geomagnetic disturbance is associated with passage of magnetic cloud (Zhang and Burlaga 1988; Gonzalez et al. 1994), which causes geomagnetic storms. It is known that interaction between slow and fast solar wind originating from coronal holes leads to create co-rotating interaction region (CIR). Geomagnetic disturbance are generally represented by geomagnetic storms and sudden ionosphere disturbance (SIDs). Geomagnetic storms are caused by interplanetary (IP) shocks or stream interfaces associated with high speed solar wind streams (HSSWS) (Howard et al. 1985, Webb and Howard 1994). These are associated with Coronal holes, which occur in Polar Regions or higher latitude. Fast CME produce transient IP shocks, which cause storm sudden commencement at earth. Geomagnetic storms are associated with isolated disappearing filaments (Joselyn and McIntosh 1981). The occurrence of prominences and flares are also associated with varying phases of sunspot cycle leading to the geomagnetic storms. The strength of IMF and its fluctuations have also shown to be most important parameter affecting the geomagnetic field condition (Gonzalez et al. 1989). South direction of IMF, allows sufficient energy transfer from the solar wind into the Earth magnetosphere through magnetic reconnection.

In this paper the statistical study has been performed to analyze these geomagnetic storms recorded by various geomagnetic observatories with Dst values without their interplanetary caused. Further we compare occurrence of geomagnetic storms during maximum and minimum phase of solar activity period of solar cycle-23.

Selection criteria and Data analysis

The disturbances in the geomagnetic field are caused by fluctuation in the solar wind impinging on the earth. The disturbances may be limited to the high-latitude polar region, unless the interplanetary magnetic field (IMF) carried by the solar wind has long periods (several hours or more) of southward component (Bz <0) with large magnitudes (greater than 50nT). The occurrence of such a period stresses the magnetosphere continuously, causing the magnetic field disturbance to reach the equatorial region. The degree of the equatorial magnetic field deviation is usually given by the Dst index. This is the hourly average of the deviation of H (horizontal) component of the magnetic field measured by several ground stations in mid-to low-latitudes. Dst = 0 means no deviation from the quiet condition, and Dst ≤ -50nT means large storms.

We have analyzed the events represented by maximum Dst decrease and selected by using the selection procedure of Loewe and Prolss (1997). A list of magnetic storms, based on the Dst indices provided by the World Data Center for Geomagnetism, Kyoto, Japan is being compiled for this study for the period 1996-2007. As the study period refers to the interval solar cycle 23. We have used the Omni Web Data Results (www.omniweb.gsfc.nasa.gov) (Couzens & King 1986, King 1997, King & Papitashvili 1998).

Result and Discussion

The 11-year solar activity cycle has been studied for a very long time Sunspot data is known to possibly data back to the ancient Chinese astronomers however the sun-earth connection is relatively new. The fact that the solar activity is directly related to space weather and geomagnetic activity does rise and fall along with the solar activity, In the whole period (1996-2007) of solar cycle-23, Solar cycle contains one maximum peak, where sunspot number is maximum and the period of that peak is termed as solar maximum activity phase. So, the maximum phase of solar cycle-23 has been measured during the year 2000 whereas the periods 1996-99 and 2001-07 are the periods of minimum phase of solar activity.

In this activity, we have used Dst data, that record the number and severity of geomagnetic storms during a solar cycle-23. We have plotted this data and we can give answer several question having to do with how often geomagnetic storms occur during the year, and the frequency of their severity. Firstly we have investigated 220 geomagnetic storms with Dst ≤ -50 nT, are occurred during 1996 to 2007. During this period 220 geomagnetic storms have been found to satisfy selection criteria and will compare with sunspots cycle-23 and we have classified geomagnetic storms with respect to their Dst magnitude in four categories according to Loewe and Prolss (1997), a geomagnetic storm can be weak (Dst > -50nT), moderate (-100nT < Dst ≤ -50nT), intense (Dst ≤ -100nT), and severe (Dst ≤ -200 nT).

Figure 1 gives the averaged sunspot number for that year and in figure 2 number of days in which geomagnetic storms were more severe than Dst < -50 nT and shown are the total number of storm days per year. Here, we have analyzed about 220 geomagnetic storm occurred during period 1996-2007. The number of geomagnetic storm observed in each year along with the sunspot number is shown in fig.1 and fig.2. From fig.1 it is evident that in the year 1996 (Solar minimum year) only 2 geomagnetic storm have occurred. It is also found that maximum numbers of geomagnetic storm have occurred in year 2002, while year 2000 is the maxima of the solar cycle-23, the year 2007 represents minimum sunspot activity during the descending phase of solar cycle-23, in the year 2003 and 2005, the large numbers of geomagnetic storm have occurred.

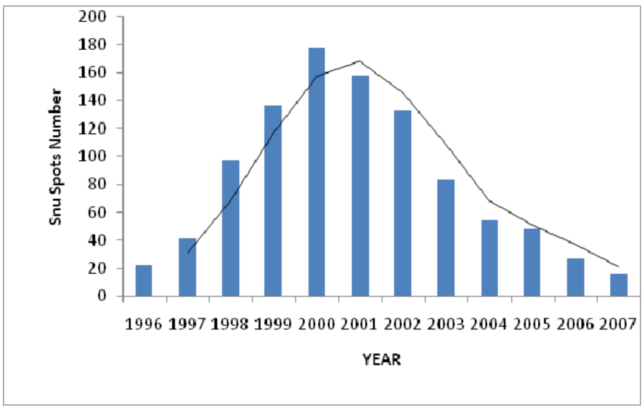

Figure 1: Average number of sun spots per year during 1996-2007.

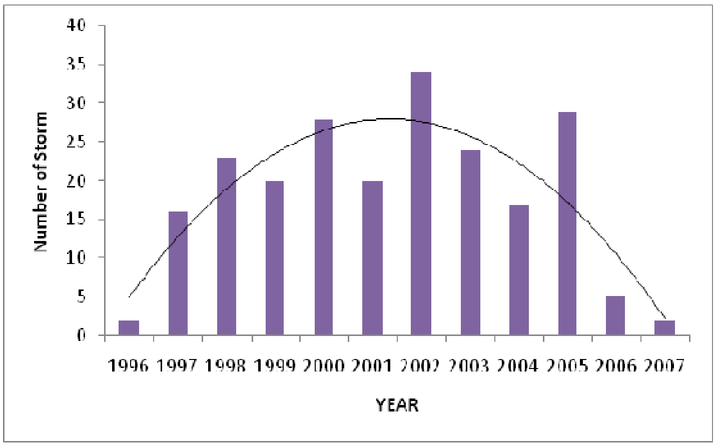

Figure 2: The total number of storm days per year during 1996-2007.

However the exact time span and intensity are up for dispute our data in figure 2 shows that the second descending phase geomagnetic peak occurs only 18-24 months after solar maximum. This data also shows that the descending phase peak seems to be larger, which means more activity occurs during that period, than the ascending phase peak. Therefore no significant correlation between the maximum and minimum phases of solar cycle and yearly occurrence of geomagnetic storm has been found.

Based on 220 geomagnetic storms (Dst magnitude <-50nT) occurred during year 1996 to 2007, we have classified geomagnetic storms with respect to their Dst magnitude in three categories.

Table 1: Shows the occurrence of the Geomagnetic storms with their classification as per year

Year	Moderate (-100nT□Dst ≤ -50nT)	Intense (-200nT □ Dst ≤ -100nT)	Severe (Dst ≤ -200nT)
1996	01	01	00
1997	12	06	00
1998	13	07	02
1999	15	04	01
2000	16	08	04
2001	07	10	03
2002	21	13	00
2003	18	04	02
2004	10	06	01
2005	20	07	02
2006	03	02	00
2007	02	00	00

Table 1 shows the occurrence of the geomagnetic storms with their classification as per year. Under the selection criteria 138 moderate geomagnetic storms, 67 intense geomagnetic storms and 15 severe geomagnetic storms have been observed.

Conclusion

The maximum phase of solar cycle-23 has been measured during the year 2000 whereas the periods 1996-99 and 2001-07 are the periods of minimum phase of solar activity. Which clearly follow the phase of sunspots cycle.

It is evident that in the year 1996 (solar minimum year) only 2 geomagnetic storm have occurred. It is also found that maximum number of geomagnetic storm have occurred in year 2002 while year 2000 is the maxima of the solar cycle-23, the year 2007 represent minimum sunspot activity during the descending phase of solar cycle-23

The largest geomagnetic storm of solar cycle-23 occurred on 20 November 2003, with a Dst index of -472 nT and the large numbers of geomagnetic storm have occurred in the year 2003 and 2005, which do not exactly follow the phase of solar cycle and show complex behavior.

It is believed that the majority of intense geomagnetic storm occur during the maximum phase of sunspot cycle because many solar active region appear during this time while a few of the geomagnetic storms are observed during the minimum phase of sunspot cycle, which do not exactly follow the phase of solar cycle and show complex behavior.

No significant correlation between the maximum and minimum phase of solar cycle and yearly occurrence of intense and great storms has been found.

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