Solar and Interplanetary Sources of Moderate Geomagnetic Storms During Solar Cycle 23 and 24

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Abstract

A geomagnetic storm is a comprehensive disturbance within Earth's magnetic field typically occurred due to anomalous circumstances within the solar wind plasma and interplanetary magnetic field (IMF) emissions caused by the different solar phenomenon. Moreover the magnitude of these geomagnetic effects largely depends upon the configuration and strength of potentially geo-effective solar/interplanetary features. In the present study the identification of 136 geomagnetic storms associated among disturbance storm time (Dst) decrease of more than -60 nT to -100 nT, have been made, which are observed during 1996-2012, the time period spanning over 23 and 24 solar cycle. We conclude that the main source of moderate storms were solar flares (B-class and M-class) however, a good number of these storms were also produced by CIR (Co-rotating interaction region).

Keywords: Solar flares, Sunspot number and geomagnetic storms.

1. Introduction

Geomagnetic storms frequently occurred because of atypical conditions inside the interplanetary magnetic field (IMF) and solar wind plasma emissions caused by different solar phenomenons (Akasofu 1983, Joselyn and McIntosh 1981). The study of these global disturbances of Earth's magnetic field is important in understanding the dynamics of the solar-terrestrial environment and because such storms can cause life-threatening power outrages, satellite damage, communication failure and navigational problems (Lakhina 1994 and Zhang 2016). It is a superior fact that the solar wind is regularly emanated from the sun's on the outside of corona and engulfs the whole heliosphere. It mostly consists of warm electrons and protons curving supersonically and caused due to very high coronal temperature serving ionized plasma toward the gravitation attraction of the Sun. The density and speed of this stream are highly erratic and depend exclusively upon the environment which has caused it to eject. The solar wind plasma carries with it magnetic field of the Sun, which when enter toward the interplanetary medium termed as Interplanetary Magnetic Field (IMF). The strength and direction of this magnetic field associated with solar wind speed depends upon its interaction among slow and fast solar wind originate from coronal holes and leads to produce co-rotating interaction region (CIR) (Akasofu 1983 and Kaushik et al 2000).

The rate of CMEs may determine how it geoeffective, but not speed itself is particularly geoeffective (Singh and Mishra 2015). Speed is a factor during the solar wind, which control the merging role on the boundary of magnetosphere, but its whole contribution to the storm strength while an electric field aspect be not large since speed varies much fewer than the further controlling parameters, such that the power of the southern magnetic field (Singh et al 2012). CMEs which are more rapidly than the solar wind are more geoeffective primarily because they compress southward fields in the vicinity of the leading edges (Kaushik and Shriastava 1999). CMEs are conscientious for the majority geoeffective solar wind disturbances. Though a CME enter into the Earth's atmosphere and it will be geoeffective. Further information CMEs can be found in the literature (Shea and Smart 1990; Tsurutani 1992; Crooker 2000 and Webb D 1995). There is a need and the ultimate objective of solar and terrestrial physics toward predicts the geoeffective CMEs. CME-associated flows tend to be responsible for the largest storms during the 23 solar cycles. This conclusion is reliable with other studies, (Forbes 2000). It was found that only ~13% of intense (Dst -100 nT) geomagnetic storms in 23 solar cycle were driven by streams, while the remaining involved CME-associated flows (ICMEs and/or upstream sheaths) (Dubey and Mishra). We also note that occasionally (Kaushik and Shriastava 1999, Badruddin 2006, Echer et al 2008, Balbeer et al 2011 and Gonzalez et al 2011. Singh and Mishra 2015. Lim et al 2019) both CME-associated flows and streams may be involved in the production of a storm, (Seo et al 2018, Singh et al 2012, Zhang et al 2007 and Burlaga et al 1987). However, for comprehensive quantitative representation a different geomagnetic index has been introduced. The disturbance storm time (Dst index) be the predictable measure of ring current strength and energy observed on the Earth's surface over low and moderate latitudes. The Dst value obtained beginning the longitudinal normal of H variations determine at middle along with low latitude observatories. It is the best display of the ring current intensities and a very susceptible index to characterize the degree of solar disturbance. Another geomagnetic index, auroral electrojet magnetic intensity index (A_{E)} (Dal et al 2006, Singh and Mishra 2019) is measured auroral electrojet intensity of the energy degenerate inside the ionosphere and energy of precipitating electrons on the auroral and polar regions. The planetary global indices Kp and Ap measured the global stage of geomagnetic field activity. The planetary index Ap represent the degree of worldwide geomagnetic variability on a daily basis and extensively used in various branches of science to describe the position of the geomagnetic field. The storm time variation also called geomagnetic storms deal with the different characteristics of geomagnetic storms and their association with solar behavior and interplanetary magnetic fields. These variations directly affect us and show adverse effects in satellites, communication systems and power losses.

In this research paper the statistical study have been performed to investigate these geomagnetic storms recorded with different geomagnetic observatories recognized with the facilitate of the disturbance storm time index (Dst). This Dst index is taken as an indicator of geomagnetically distressed conditions, as it represents the depression inside the ring current as a outcome of its relations among the plasma signature having their ancestry originated on the solar shell or from several exotic environment. We have investigated different solar parameters/interplanetary magnetic field mechanism that were probably geoeffective and appeared throughout the solar-activity period of 23 solar cycles.

2. Data Selection

In the present study we have analyzed in detail all those moderate geomagnetic storms which are associated with Dst decreases of less than -60 to -100 nT and are observed during the period 1996-2012. If the magnitude of a storm (Dst value) recurs for several consecutive days/hours, then the last day/hour taken as the storm's day. A set of moderate geomagnetic storms connected with Dst between -60 to -100 nT are presented. We have analyzed the association of storms with different solar and interplanetary disturbances and their correlation between them. The hourly values of the geomagnetic index have been obtained by Solar Geophysical Data (Prompt Comprehensive report) of the U.S. Department of Commerce, NOAA and Omni web data.

3. Results and Discussion

Moderate geomagnetic storms are often associated with CMEs or IP shocks in the solar wind resulting from the interaction between high-speed and low-speed plasma streams (Richardson et al 2006, Singh et al 2016 and Lim et al 2019). A CME produces a disturbance in the solar wind preceded by a shock wave. Interplanetary space probes encountering such disturbances have recorded increased solar wind speeds, densities and rapidly varying magnetic fields. When these interplanetary disturbances reach the Earth, they give rise to geomagnetic storms. Storms driven by CME-associated flows have an occurrence rate that generally follows the solar activity cycle but may be temporarily depressed for a period around solar maximum. As the storm size increases, CME-associated flows contribute to a larger fraction of events. The transfer of energy and plasma from Sun to Earth is also interesting. Throughout the heliosphere, the solar wind plasma carrier embedded within its solar magnetic field lines. The transfer of energy, momentum and mass from the Sun to Earth for several solar perturbations under a variety of interplanetary configuration is also a major scientific objective. The long-term monthly mean sunspot numbers are shown in fig. 1 According to our selection criteria 136 moderate geomagnetic storms (Dst≤-60 to -100nT) have been observed during the sunspot cycle 23 and 24 (fig. 2). The maximum number of B-class flare had been observed three years after sunspot maxima which does not follow the phase of solar cycle 23 (fig. 3), which indicates the unexpected deviation from solar maxima and minima. Near the minimum phase, a few of the geomagnetic storms are observed due to the presence of coronal holes and some other solar activities. Maximum geomagnetic storms had been observed one year after sunspot maxima which do not completely follow the phase of solar cycle 23. Moderate geomagnetic storms (Dst ≤-60 to -100nT) and C- class flare shown in fig. 4. The moderate geomagnetic storms and 41 M-class flares have been observed which follow the different phases of cycle 23 and 24 (fig. 5). The occurrence of X-class flare is maximum in the year 2002 (two years after sunspot maxima) and does not follow the phase of solar cycle 23 associated with moderate geomagnetic storms. Fig. (6).



Fig. 1: Shows the Monthly mean sunspot number for period 1944 to 2012 which cover the solar cycle 18 to 24.



Fig. 2: Shows the sunspot number and moderate geomagnetic storms (Dst \leq -60 to -100nT) during the period 1996 to 2012.



Fig. 3: Shows the sunspot number and Occurrence of B-Class Flare associated with the moderate GMSs during the period 1996 to 2012.



Fig. 4: Shows the sunspot number and occurrence of C-class flares associated with moderate geomagnetic storms (Dst ≤-60 to 100nT) during the period 1996 to 2012.



Fig. 5: Shows the sunspot number and occurrence of M-class flares associated with moderate geomagnetic storms (Dst ≤-60 to 100nT) during the period 1996 to 2012.



Fig. 6: Shows the sunspot number and occurrence of X-class flares associated with the moderate geomagnetic storms (Dst \leq -60 to-100 nT) during the period 1996 to 2012.

4. Conclusion

The variation of the interplanetary magnetic field (IMF) and increases into the velocity and density of solar plasma particle prominent the magnetosphere outcome in geomagnetic storms. Geomagnetic storms has seen on the face of the Earth as perturbations during the components of the geomagnetic field, caused via electric currents flowing inside the earth's magnetosphere and upper atmosphere. The main confront to solar-terrestrial physicist is to recognize which solar and interplanetary method caused the geomagnetic activity. Solar output during the solar plasma and magnetic field expelled out into the interplanetary medium consequently generate the perturbation inside the geomagnetic field.

We have summarized important results derived from the analysis of the geomagnetic storms (of magnitude <-60nT to <-100 nT, and their relationship with interplanetary parameters for the period 1996 to 2012 we have found that 11.7% (16/136) moderate storms (Dst \leq -60 to -100nT) were associated with CIR (Co-rotating interaction region). We conclude that the main cause of moderate storms were solar flares (B-class and M-class). Dst decreases with increasing magnetopause shielding currents, a measure of magnetospheric compression produced by an increase in solar wind velocity. These quantitative relationships are invaluable for modeling studies and space weather phenomena.

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