Some reliable predictors of the intensity of Geomagnetic Storms

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Abstract: During the period 1996-2005 Intense, Major and Minor Geomagnetic Storms (GMSs) have been investigated. It is observed that the maximum solar wind velocity and the maximum decrease in the IMF Bz component are not the binding conditions for the intensity of the GMSs to occur. It is observed that for Intense, Major and Minor GMSs the product of solar wind velocity (Vsw) with Bz min (i.e. Vsw.Bzmin); product of linear velocity of CMEs (Vcme) with Bzmin (i.e. Vcme.Bzmin) and the product of coronal intensity with Dst (i.e. CI.Dst) are better predictors for the GMSs in comparison to the individual parameters.

Introduction

The geospheric environment is highly affected by the Sun and its features which are responsible for some large/small geomagnetic storms [1,2] and Corotating Interaction Regions (CIRs) produced by High Speed Solar Wind Streams (HSSWS) in the interplanetary medium [3-6].

CMEs are the key causal link to solar activity that produces GMSs [7]. CMEs are large-scale magnetoplasma structures that erupt from the Sun and propagate through the interplanetary medium with speeds ranging from only a few kms-1 to nearly 3000 kms-1. CMEs carry typical 1015 g of coronal material [8]. CMEs originating on the visible solar disk are known as earth directed CMEs. GMSs occur when the IMF associated with CMEs (ICMEs) impinges upon the Earth's magnetosphere and reconnects. There is statistical evidence favoring the association of GMSs with magnetic clouds produced by CMEs [9,10].

Data spanning 21 years made it possible to recognize some of the coronal holes are almost are permanently visible on solar poles, except at the time of the maximum of the solar cycle, when polarity inversion occurs. High-speed solar wind particles streaming out of the hole and streaming towards the earth results in to striking the Earth's magnetic field and triggering the GMSs [11,12]. The coronal intensities are given in millionths of intensity of the solar disk (coronal units) streaming towards the earth results in to striking the Earth's magnetic field and triggering the geomagnetic storms.

The GMSs generally occur 1 to 4 days later than onset /explosion of the solar features on the solar disk [13,14]. It is generally accepted that the initial phase of the resulting geomagnetic storm is triggered by an increase in the plasma pressure accompanied by an increase in the density and speed of the solar wind at and behind the interplanetary shock. The main phase is governed on the other hand, by the southward component of the Interplanetary Magnetic Field (IMF) [15].

In recent years, a number of investigations have been carried out to understand the solar terrestrial relationship and to ascertain factors that are responsible for geomagnetic storms. [16-20]. Several studies of the solar interplanetary sources of geomagnetic storms show that the increase in the speed of solar wind i.e., Vsw and the magnitude of the southward component of the embedded magnetic field i.e., Bz are the key interplanetary parameters that determine the geoeffectiveness of CMEs [21].

In the present analysis the sudden storm commencements (SSCs) and the minimum Dst of the

SSC day for categorizing the GMSs have been considered. Geomagnetic events are characterized by the Disturbance storm time (Dst) index measured in terms of nano Tesla (nT). A storm is said to be Intense if (Dst<-100nT), Major if (-50nT>Dst≥-100nT) and Minor if (-20nT≥Dst≥-50nT).

Data Analysis

In the present data analysis from the period July 1996 to Jan 2005, geomagnetic storm events are characterized by the minimum Dst index of the SSC day. Solar Geophysical and Interplanetary Data and SOHO/LASCO CME catalog are used to study the manifestations of CMEs causing the GMSs. The total magnetic field and the southward component of IMF values, which are important for understanding the development of geomagnetic storms. The values of Dst indices are obtained from the geomagnetic activity web page of the World Data center, Japan (available at http://swdcwww.kugi.kyoto-u.ac.jp). On the basis of solar wind velocity (Vsw), CMEs have been investigated such that $1 \leq \Delta t \leq 5$ days prior to the occurrence of GMSs on the earth. Here the time Δt taken by the solar wind in reaching the earth from the sun depend upon Vsw.

Results and Discussion

Earlier studies suggest that the geoeffectiveness of solar wind depends upon the speed and the embedded southward magnetic field [22]. It is the coupling between the solar wind plasma, and the magnetic field orientation that defines the magnitude of a geomagnetic storm. The variation of Bz plays a crucial role in determining the amount of solar wind energy, which is transferred to the magnetosphere [23,24]. It is observed that the maximum solar wind velocity is not the binding condition for the intensity of occurrence of GMSs. Similarly the maximum decrease in the IMF Bz component is also not a binding condition for the intensity of the GMSs to occur. It is also observed that Intense and Major GMSs occur even when the value of the IMF Bz is even larger than –10nT. Thus, it seems that the relationship pointed out by Tsurutani and Gonzalez [24] is not the binding condition for the Intense GMSs to occur where Bz <-10nT. The Pearson's correlation coefficient between Dst and Bz for all types of GMSs from July1996 to Jan 2005 has been found to be 0.97. Whereas, Wu and Leeping [25] using hourly average OMNI data for 135 events from 1965 to 1998 have obtained the correlation to be 0.86 and Cane et al [26] have obtained the correlation to be 0.74 for the period 1996 to 1999 for 83 events. A very good correlation between Dst and Bz for the solar cycle 23 reveals that the Bz and Dst play an important role in the occurrence of GMSs.

For Intense, Major and Minor GMSs the product of Solar Wind Velocity (Vsw) with Bzmin (i.e.,Vsw. Bzmin) and Linear fit speed of CMEs (Vcme) with Bzmin (i.e., Vcme.Bzmin) and the product of coronal intensity with Dst (i.e., CI. Dst) are presented in Table 1. It is observable from the Table that the values of these products along with Dst are largest minimum for Intense GMSs followed by Major and Minor GMSs respectively. Thus, one it is deduced from here that product of the Bz with solar wind velocity Vsw and Vcme that is (Vsw.Bzmin) and (Vcme.Bzmin), and the product of coronal intensity with Dst (CI. Dst) of the SSC day are the reliable predictors of the intensity of the GMSs.

	INTENSE	MAJOR	MINOR
Dst	-182	-61	-25
Bz	-10.4	-10.9	-7.3
CI	2551	3559	1441
Vsw	403	334	466
Vcme	815	539	452
Vsw.Bz	-4191.2	-3640.6	-3401.8
Vcme.Bz	-8476	-5875.1	-3299.6
CLDst	-464282	-217099	-36025

Table 1: Significance of Bz , Dst, Vsw and Vcme on GMSs during the period July 1996 to Jan 2005

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Conclusions

It is observed that the maximum solar wind velocity and the maximum decrease in the IMF Bz component are not the binding conditions for the intensity of the GMSs to occur. It is observed that for Intense, Major and Minor GMSs the product of solar wind velocity (Vsw) with Bz min (i.e. Vsw.Bzmin); product of linear velocity of CMEs (Vcme) with Bzmin (i.e. Vcme.Bzmin) and the product of coronal intensity with Dst (i.e. CI.Dst) are better predictors for the GMSs in comparison to the individual parameters.

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