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Solar and interplanetary causes of large geomagnetic storms

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Abstract : The geomagnetic storms and their association with various solar and interplanetary causes have been reported by various authors for last solar cycle In the present time, an important paradigm shift such that the coronal mass ejection (CME)s and not the flares are considered the causal link with solar activity and produces large geomagnetic storms Coronal holes are also responsible for recurrent geomagnetic storms. The geomagnetic storms are highly correlated with solar wind velocity and strength of the southward component of the interplanetary magnetic field (Bs)' In the present study, we have examined all those large geomagnetic storms which are associated with the Storm Time Index (Dst) decrease of more than 100 nT and their association with different type of solar and interplanetary causes during the period 1986–1995, in the light of new shifted paradigm

Keywords : Geomagnetic storms, solar and interplanetary causes, coronal mass ejections.

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The outstanding disturbances that are recorded on the ground magnetograms, caused by the transient, radiative and corpuscular emission from solar surface are known as geomagnetic storms. The association between large solar flares, Interplanetory (IP) shocks and sporadic geomagnetic storms has long been recognized. Solar disappearing filaments (DFs) have been linked with geomagnetic activity [1,2] and also IP shocks [3–5]. In recent times, a new concept has been developed that CMEs are the agents driving IP shocks and large geomagnetic storms. The CMEs related shocks accelerate solar energetic particles (SEPs) events associated with major IP disturbances. An important paradigm shift such that the CMEs and not flares are considered the key causal link with solar activity and to be drive all large geomagnetic storms and the associated effects, such as auroral displays, has come up in the literature [6–9]. The CMEs are vast structures of solar plasma and magnetic fields which are expelled from Sun into the heliosphere and make a prime link between solar and geomagnetic activity. Our present study aims at to examine the association of large geomagnetic storms with solar and interplanetary causes and a comprehensive analysis of sudden and gradual commencement of storms on the basis of two case histories, are shown graphically.

Coronal mass ejections are spectacular manifestation of solar activity in which $10^{15} - 10^{16}$ gms of solar materials are suddenly propelled outward into interplanetary space. There is a controversy about origin of CMEs. Some investigators [6–8] found that CMEs arise from large scale, closed magnetic structures usually associated with radio bursts, flares, DFs and sometimes interplanetary disturbances, while others [10,11] argued that CMEs originated from coronal holes. So there is a controversy about origin of CMEs *i.e.* whether CMEs are associated with flares like phenomena or associated with coronal holes. At the present time, it is believed that few CMEs were accompanied by H-alpha flares, those CMEs were much faster than CMEs without flares and were nearly always accompanied by type II and IV metric radio bursts. CMEs may be associated with filament eruptions and DFs. It is wellknown that flares and DFs are well associated with CMEs but the most common association is with eruptive prominences rather than flares.

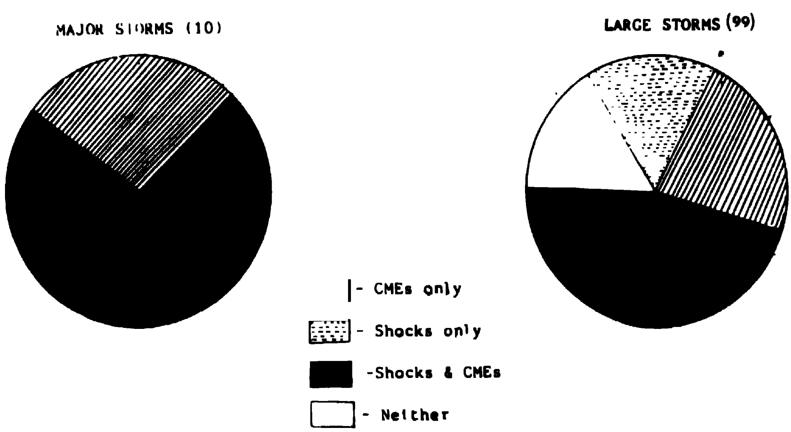

Figure 1. Pie charts illustrating the association of major and large type geomagnetic storms with solar and interplanetary disturbances.

The activity which recurs approximately in 27 days are known as recurrent geomagnetic activity. The recurrent geomagnetic activity is most significant in the declining phase of even numbered solar cycle [12]. These recurrent geomagnetic disturbances were associated with solar coronal holes observed by OSO-7 [13]. The recurrent geomagnetic disturbances are observed due to long-lived high speed streams originated from the coronal holes.

Hewish and Bravo [10] have shown that the solar source region were always accompanied by coronal holes and suggested that the transient activity at the hole boundaries could produce interplanetary shocks. The coronal holes are low density regions

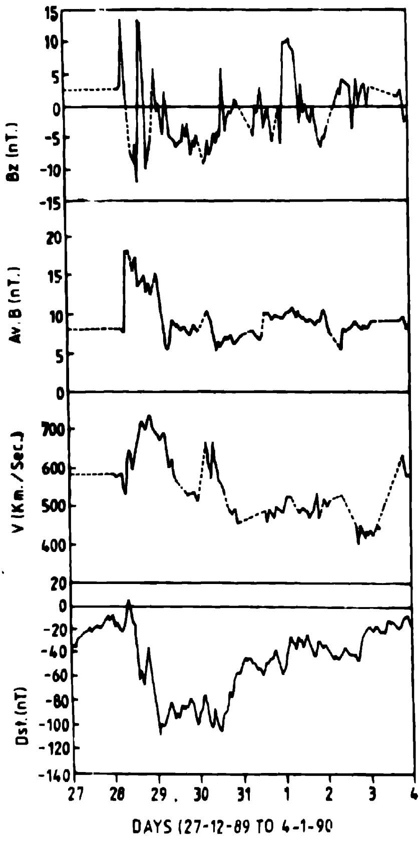

Figure 2. Association of geomagnetic storms with different interplanetary parameters observed during Dec 29, 1989 to Jan. 04, 1990 (Dashed line shows the data gap)

and the high speed streams originated from the coronal holes, can freely stream off from them which are characterized by open fields lines [14]. The relationship between coronal holes, high speed solar wind streams and geomagnetic disturbances was further developed by Legrand and Simon [15]. The coronal holes are major producer of recurrent geomagnetic storms It was confirmed that the high speed streams are originated in the coronal holes and are strongly influenced by the solar cycle [16]. The maximum number of gradual commencement type of storms are associated with coronal holes.

The strength of the interplanetary magnetic field (IMF) and its fluctuations have been shown to be the most important parameters affecting the geomagnetic field variations. The most of the interplanetary shock waves originate at or near the Sun, in the form of an active region and consequently, the entire shock disturbances engulf the Earth, the various phases of geomagnetic storms are produced [17]. The exact measurement of geomagnetic field variations are capable of remote sensing the nature of the solar wind, IMF and *vice versa*.

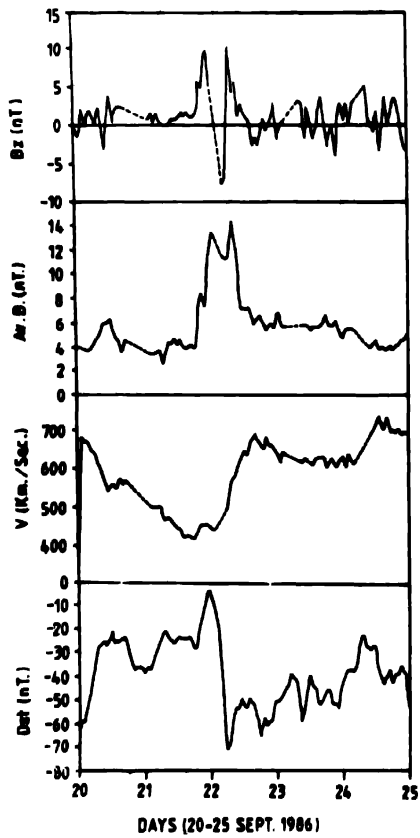

Figure 3. Association of geomagnetic storms with different interplanetary parameters observed during Sept 22–25, 1986 (Dashed line . . shows the data gap)

In this communication, we have considered solar and interplanetary causes of all those large geomagnetic storms, which are associated with the Dst decrease of more than 100 nT during the period (1986–1995). There were 99 such type of storms. The geomagnetic storms are often preceded by abrupt increase in the northward component of Earth's magnetic field, called sudden commencement, which are well correlated with IP shocks. These shocks driven by fast CMEs produce sudden commencement of storms. Out of the 99 selected storms, we have noticed, 51 are sudden commencement type storms. Fast CMEs produce transient IP shocks which causes sudden commencement at the Earth. We have studied about these causes for 10 major storms associated with the Dst decrease of more than 250 nT and 99 large storms associated with the Dst decrease of more than 100 nT and found that maximum number of these type of geomagnetic storms are associated with fast CMEs and interplanetary shocks. The different types of geomagnetic storms and their association with solar and interplanetary causes are shown in Figure 1 by pie diagram.

For different types of geomagnetic storms, their magnitudes and phases are highly correlated with interplanetary parameters. For better understanding of these causes, a sudden commencement geomagnetic storm observed during Dec. 29, 1989–Jan. 04, 1990 associated with fast CMEs and shock compression and another gradual commencement storm observed during Sept. 22–25, 1986 identified with coronal holes, and their association with interplanetary parameters are shown in Figures 2 and 3. From these plots, we have noticed that in the case of sudden commencement type of geomagnetic storm, initial phase of storm starts after abrupt change in northward component and the main phase of geomagnetic storm starts after sudden increasing in solar wind velocity (V) and IMF magnitude (B); and when northward component is suddenly turned to southward. The gradual commencement storm IMF magnitude (B) and southward component (Bs)) shows similar trends as sudden commencement storm, but the solar wind velocity (V) increase slowly with the main phase of the storm.

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