29th International Cosmic Ray Conference Pune (2005) **00**, 101-104

Dependence of GMSs with H≤ 250 ϒ on solar feature's locations

M.P. Yadav
Department of Physics, Govt. Tilak P. G. College, Katni (M.P.), 483501, India
Presenter: M.P. Yadav (mp_yadav2005@yahoo.com), ind-yadav-mp-abs2-sh22-poster

Fifty-eight geomagnetic storm sudden commencement (SSCs) with planetary index (Ap) ≥ 20 and horizontal component of Earth magnetic field (H) ≤ 250 ϒ have been identified for the period 1979-1994 and their possible solar causes are looked upon. Solar features e.g., Hα, X-ray solar flares and active prominence and disappearing filaments (APDFs) have been found to occur more in lower helio latitude regions and produce interplanetary shocks that may lead to the occurrence of SSCs at the Earth. The major SSCs (65% of the fifty eight SSCs) are associated with coronal mass ejections (CMEs). Further, it is found that, there is symmetry in the distribution of APDFs in both northern and southern helio latitude regions. The delay time interval between the origination of solar events from the sun and the time of SSCs seen at the Earth is lying between 53 to 126 hours.

1. Introduction

Geomagnetic disturbances are generally represented by geomagnetic storms (GMSs), sudden ionospheric disturbances (SIDs) and ground level enhancement (GLEs). GMSs can be classified in two ways; such as storm gradual commencement (SGCs) and SSCs, SGSs arise from magnetically open long lived, high-speed solar wind streams (HSSWS) emitted from coronal holes and are usually small in magnitude. SSCs are associated with flare generated stream and are caused by shock waves propagating from the sun through the interplanetary medium. (Garcia and Dryer, 1987; Kumar and Yadav, 2002a). The transient phenomena at the sun surface and in the lower atmosphere such as flare, spray and eruptive prominence are often associated with huge mass motion. It is found that not all types of coronal transients generate CMEs (Gosling et al. 1979). Solar flares occur in magnetically complex regions; where the field often strongly sheared. The mechanism of energy release is associated with magnetic reconnection. Many workers have shown the association of different types of GMSs with solar flares (Lockwook, 1971; Garcia and Dryer 1987). The solar output in term of particle and field ejected into our interplanetary medium influences the geomagnetic field conditions. The radiant electro magnetic and corpuscular radiation produces disturbances at various locations such as polar, mid latitude and equatorial regions. These geomagnetic disturbances are measured by different geomagnetic indices AE, Kp or Ap and equatorial disturbance storm time (DST) index (Rangarajan, 1989; Garcia and Dryer 1987). The solar disappearing filaments (DFs) have linked with geomagnetic activity and also interplanetary shocks (Joselyn and Mc Intosh, 1981). The CMEs related shocks accelerate solar energetic particles (SEPs) causing large geomagnetic storms (Hewish and Bravo, 1986; Zhang et al, 2003). Geomagnetic Storms have been found to be particularly sensitive to the presence of an intense southward interplanetary magnetic field that allows efficient energy from the solar wind into the Earth magnetosphere through magnetic reconnection (Gonzalez and Tsurutani 1987). In this paper, an attempt has been made to unambiguously identify solar sources of geomagnetic storms basis on a comprehensive set of solar, interplanetary and geomagnetic observations. Further, GMSs and their association with various solar features have been investigated during the period of study.

2. Data Analysis

Fifty-eight geomagnetic SSCs with Ap ≥20 and H ≤ 250 ϒ have been identified for the period 1979-1994 by using solar wind plasma (SWP), interplanetary magnetic field (IMF) data from IMP-8 satellite and comprehensive solar geophysical data (SGD) reports. The SWP and IMF data are complied by King and Couzen in different volumes of interplanetary medium data book from national space science data center (NSSDC). On the basis of solar wind velocity (V) the solar features have been investigated 54 hrs ≤ Δt ≤ 125 hrs prior to the occurrence of GMSs at Earth from SGD reports. Here Δt is the delay time interval between the origination of solar events on the sun and the time of SSCs seen at the Earth at various locations.

3. Results and Discussion

Akasofu and Yoshida (1967), Lockwood (1971) and Pudovkin and Chertkov (1976) have shown the association of different types of GMSs with solar flares. The associations of GMSs with Hα, X ray solar flare and active prominences and disappearing filaments have been studied. A frequency histogram of Hα solar flares with heliographic latitude/longitude associated with GMSs have been plotted in Figure 1(a,b). It is observable from Figure 1(a) that 43% Hα solar flares occurred in northern heliolatitude and 57% Hα solar flares occurred in southern heliolatitude are associated with GMSs. At that heliolatitude in the range $(0\text{-}30)^0$N to $(0\text{-}30)^0$S, there is concentration of 96% of Hα solar flares are associated with GMSs. It is observable from Figure 1(b) that 49% and 51% Hα solar flares occurred in eastern and western heliolongitudinal zones are associated with GMSs. Further, 70% Hα solar flares are associated with GMSs at the heliolongitude in the range $(0\text{-}60)^0$E to $(0\text{-}60)^0$W. Thus, it may be derived from here that the Hα solar flares occurred with in lower heliographic latitudes are associated with large number of GMSs. A frequently occurrence histogram of X-ray solar flares with helio-latitude/longitude associated with GMSs have bee plotted in Figure 2(a,b). It is observable from Figure 2(a) that 59% and 41% X-ray solar flares occurred in northern and southern helio-latitude are associated with GMSs. At the helio latitude in the range $(0\text{-}30)^0$N to $(0\text{-}30)^0$S, there is concentration of 90% of X-ray solar flares are associated with GMSs and no X-ray solar flares have occurred beyond 40^0N or 40^0S. From Figure 2(b), it is evident that 48% and 52% X-ray solar flares occurred in the eastern and the western helio-longitudes respectively are associated with GMSs. Further, 78% X-ray solar flares occurred at the helio-longitude in the range $(0\text{-}60)^0$E to $(0\text{-}60)^0$W are associated with GMSs. Thus X-ray solar flares occurred with in lower heliographic latitude are associated with GMSs (Dubey and Mishra 1998, Kumar and Yadav, 2002a, 2002b, 2003). Figure 1 and 2 shows the asymmetry in the distribution of events associated with SSCs (Yoshida and Akasofu 1965). This means that shocks effect in certainly asymmetric, because draping field lines around the ejecta leads to an asymmetry in the post shock compression region (Cane,1988). A frequency occurrence histogram of APDFs with helio-latitude associated with GMSs has been plotted in Figure 3(a,b). It is evident from Figure 3(a) that 50% of APDFs occurred in each northern and the southern helio-latitude respectively are associated with GMSs. The most effective zone for producing GMSs are lying between $(20\text{-}30)^0$N and $(20\text{-}30)^0$S. In the helio-latitude range $(0\text{-}30)^0$N and $(0\text{-}30)^0$S, there is concentration of 89% of APDFs associated with GMSs. No APDFs occurred beyond 60^0N and 60^0S in association with GMSs. Further 3(b) shows that 44% and 56% APDFs occurred in the eastern and the western helio-longitude are associated with GMSs respectively which shows asymmetry in distribution. Furthermore, 61% APDFs occurred at the heliographic longitude in the range $(0\text{-}60)^0$E and $(0\text{-}60)^0$W are associated with GMSs. A peculiarity has been observed that 14% of APDFs occurred in helio-longitude range $(80\text{-}90)^0$ W are associated with GMSs. Thus, it may be inferred that APDFs, occurred within lower heliographichal latitude are associated with GMSs on Earth (Kumar and Yadav, 2002a, 2002b). While 34.5% GMSs are associated with other solar features. Finally, the association of solar features GMSs has been investigated. Out of 58 GMSs, the 27,36,38 GMSs are associated with solar flares (Hα and X-ray),

APDFs and CMEs respectively. Thus we conclude that 65.5% GMSs are associated with CMEs (Hewish and Bravo, 1986; Webb, 1995; Zhang et at 2003) alone, while 34.5 GMS are associated with other solar features. Three GMSs are not associated with any solar features which shows that some solar features occurring on the backside of the solar disc are also contributing this cause. In many cases the transit time between the explosion on the sun and maximum geomagnetic activity causing GMSs is lying between 53 Hrs to 126 Hrs (Bruckner et al, 1998; Gopalswami et al, 2000; Cane et al, 2000; Zhang et al., 2003). It is found that CMEs related events are not always accompanied with high-speed solar wind streams.

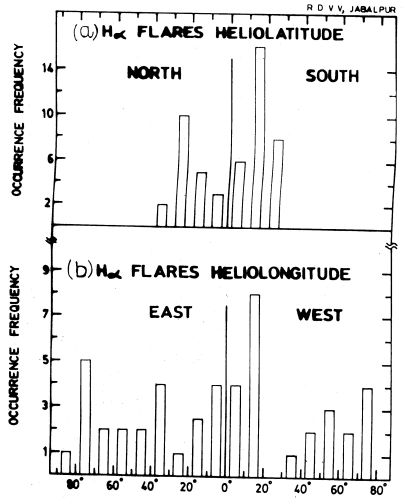

Figure 1. Occurrence frequency histogram of Hα solar flares Associated with GMS with helio latitude/longitude has been plotted during the 1979-1994 has been plotted during the 1979-1997

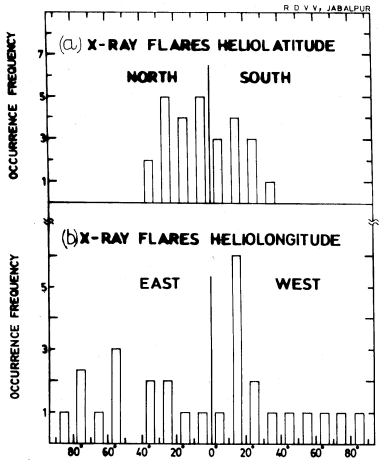

Figure. 2. Occurrence frequency histogram of X- Ray solar flares associated with GMSs with helio latitude/longitude

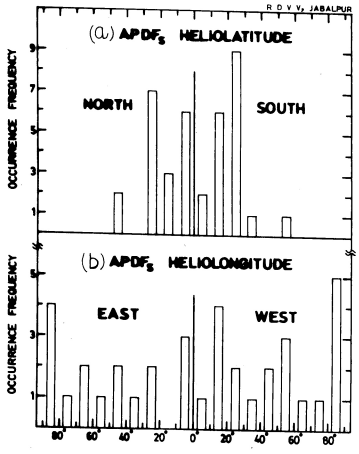

Figure 3. Occurrence frequency histogram of APDFs with helio latitude/longitude associated with GMS has been plotted during the 1979-1994

4. Conclusions

1. Hα, X ray solar flares have occurred within lower helio graphic occurred within lower helio graphic latitude $(0\text{-}30)^0$N and $(0\text{-}30)^0$S are associated with maximum number of GMSs. No. Hα, X-ray solar flares have occurred beyond 40^0 N or 40^0S.
2. In heliolatitude range $(0\text{-}30)^0$N and $(0\text{-}30)^0$S, 89% of APDFs are associated with GMSs, where as there is almost equal distribution of the APDFs in both northern and southern hemisphere.
3. Statistically, it is found that 65.5% GMSs are associated with CMEs alone. This result is consistent with Hewish and Bravo (1986), Webb (1995) and Zhang et al., 2003 observation and inconsistent with Grarcia & Drayer (1987) result.
4. CMEs are more related with APDFs than other solar features and they occur at low helio latitude. It is observed that CMEs related GMSs are not always associated with HSSWSs.
5. In many events, the delay time interval between the origination of solar events from the sun and the time of SSCs seen at Earth is lying between 53 hrs to 126 hrs.

5. Acknowledgements

The authors are highly indebted to various experimental groups, in particular, Professor J. H. King for providing the data.

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