Geoeffectiveness of Solar Features

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Abstract

An attempt has been made to locate the solar features and their effectiveness causing the storm sudden commencements (SSCs) type geomagnetic storms (GMSs) with $D_{st} < -100$ nT on Earth. Twenty four GMSs have been investigated using solar wind Plasma (SWP) data, interplanetary magnetic field (IMF) data and solar geophysical data (SGD) during the period 1986–93. It is observed statistically that X-ray, Hα solar flares and active prominences and disappearing filaments (APDFs) which have occurred within lower heliographic latitudinal zones are associated with larger number of GMSs at Earth. Furthermore, the maximum number of GMSs are associated with solar flares of lower importance (SF). The lower importance in association with some specific characteristics such as, location, region, duration of occurrence of event may also cause such type of GMSs. It is found that CMEs, causing GMSs which occur at low heliolatitude are related with eruptive prominences, X-ray events, optical and Hα solar flares and type IInd and IV radio bursts.

1. Introduction

Geomagnetic disturbances are generally represented by geomagnetic storms (GMSs), sudden ionospheric disturbances (SIds) and ground level enhancements (GLEs). GMSs are distinguished in two kinds; such as, storm gradual commencements (SGCs) or storm sudden commencements (SSCs). GMSs are caused by magnetically open, long lived, high speed solar wind streams (HSSWS) produced from solar coronal holes (Sheeley (Jr.) and Harvey, 1981; Feynman and Gu, 1986); Hα, X-Ray solar flares (Garcia and dryer, 1987; Kumar and Yadav, 2002A); isolated disappearing filaments (Cane et al, 1986). The occurrence of flares and prominences are associated with varying phases of sun spot cycle. The solar output in terms of particle and field ejected out into interplanetary medium influences the geomagnetic field conditions (Webb, 1992). The radiant electromagnetic and corpuscular radiation produces extra ionization in the sun lit part of the earth and produces disturbances at various locations; such as, polar, mid latitude and equatorial regions. These disturbances are observed and represented by different geomagnetic indices (Rangarajan, 1989) like AE, K_p or A_p and equatorial index

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D_{st}. Tsurutani et al, 1992 have shown that extreme values of southward interplanetary magnetic field (IMF) are the key causal role of GMSs. The product of solar wind velocity (**V**) and interplanetary magnetic field (**B**); i.e. VxB is more effective parameter in the development of GMSs (Sabbah, 2000).

2. Analysis of Data

All those geomagnetic storms which are associated with $D_{st} < -100$ nT during the period Jan. 1986 – Dec. 1993 are being considered and are found to be 24 in number. The position of Hα, X-ray solar flares and APDFs (Solar geophys. data Reps. 1986–93) have been noted 54 to 121 hours prior the occurrence of GMSs at Earth depending upon the solar wind velocity, V (Couzens and King 1986, 1989, 1994).

3. Results and Discussion

A frequency occurrence histogram of Hα solar flares with heliolatitude/ longitude associated with GMSs have been plotted in Figs 1 (a, b). From Fig (1a), it is evident that 60% Hα solar flares occurred in northern helio latitude and 40% in southern heliolatitude are associated with GMSs. At the helio latitude $(0\text{–}40)^0$ N to $(0\text{–}40)^0$S, there is concentration of 100% of the total Hα solar flares are associated with GMSs and no Hα solar flares have occurred beyond 40^0N and 40^0S. It is quite apparent from Fig 1(b) that 45% Hα solar flares occurred in eastern heliolongitude and 55% Hα solar flares occurred in western helio-longitude are associated with GMSs. Again 70% of total Hα solar flares occurred with helio-longitude lying between $(0\text{–}40)^0$E to $(0\text{–}40)^0$W are associated with GMSs. Thus, it may be deduced from here that Hα solar flares occurred within lower helio latitude/ longitude are associated with large number of GMSs (Kumar and Yadav, 2002b). Frequency occurrence histogram of X-ray solar flares heliolatitude/longitude associated with GMSs have been plotted in Fig (2a, b). From Fig 2a, it is observed that 67% and 33% X-ray solar flares have occurred in northern and southern heliolatitude range respectively. At heliolatitude in the range (0–40)°N to (0–40)°S, there is a concentration of 100% of the total X-ray solar flares associated with GMSs and no X-ray solar flares have occurred beyond 40°N or 40°S associated with GMSs. It is quite apparent from Fig 2b that 55% and 45% of X-ray solar flares occurred in eastern and western heliolongitude zones respectively are associated with GMSs. It is further observable from Fig 2b that 78% of the total X-ray solar flares occurred in helio longitude range (0–40)°E to (0–40)°W are associated with GMSs. Thus it may be inferred from here that X-ray solar flares occurred within lower heliographic latitude/longitude are associated with large number of GMSs (Kumar and Yadav, 2002b). Frequency occurrence histogram of APDFs with different helio-latitude/longitude associated with GMSs have been plotted in Fig 3 (a, b). It is observed from fig 3(a) that 55% and 45%

APDFs occurred in northern and southern helio-latitude respectively and most effective zones were APDFs are lying between $(0–40)^0$N to $(0–40)^0$S. At helio latitude $(0–40)^0$N to $(0–40)^0$S, there is concentration of 100% of the total APDFs are associated with GMSs. No APDFs have occurred beyond 40^0N and 40^0S associated with GMSs. Thus, it may be inferred from here that APDFs, occurred within lower helio latitudinal zones are associated with large number of GMSs. It is quite apparent from Fig 3(b) that 65%, 35% APDFs have occurred in eastern and western helio longitude respectively. It is observable from 3(b) that 55% of the total ADPFs occurred in helio longitude range between $(0–50)^0$E to $(0–50)^0$W are associated with GMSs. A peculiar result has been observed that 30% APDFs have occurred in helio latitude range $(80–90)^0$E only that of total APDFs of entire period of consideration. The association of GMSs with importance of Hα, X-ray solar flares during the period 1986–93 have been plotted in Fig 4(a, b) respectively. From Fig 4(a), it is quite apparent that 85% of Hα Solar flares with importance $\leq$ 1N are associated with GMSs. Further, it is evident from Fig 4(a) that maximum number of Hα Solar flares are associated with importance SF; somehow, no significant correlation between magnitude (intensity) of GMSs and importance of Hα solar flares is observed. It is apparent from Fig 4(b) that 83% of X-ray solar flares with importance $\leq$ 1N are associated with GMSs. Further, it is quite apparent from Fig 4(b) that maximum number of X-ray solar flares with importance solar flare faint (SF) are associated with larger number of GMSs. Somehow, no significant correlation between magnitude (intensity) of GMSs and importance of X-ray solar flares have been observed. Some times the Hα, X-ray solar flares of lower importance in association of some other specific properties i.e. position, duration, region etc may also cause GMSs (Kumar and Yadav, 2002b).

Finally, the association of solar features with GMSs having Dst ≤ -100nT have been investigated during the period 1986–93 and plotted in Venn diagram in Fig 5. It is quite apparent from Fig 5 that 72% of Hα, 69% X-ray solar flares and 72% APDFs occurred during the period are associated with GMSs separately. Statistically, it is observed that GMSs are more associated with solar flares. This result is consistent with Garcia and Dryer (1987), Kumar and Yadav (2002a, b) and inconsistent with Hewish and Bravo (1986), Webb (1995) observations.

4. Conclusions

From the rigorous analysis of data, the following conclusions are drawn:

(i) Hα, X-ray solar flares occurred in lower helio latitude and longitude produce larger number of GMSs. APDFs occurred with in lower helio latitude are associated with large number of GMSs. No GMS is produced by Hα, X-ray solar flares beyond 40^0N and 40^0S.

(ii) The maximum number of GMSs are associated with solar flares of lower importance i.e. SF during the period 1986–93. Thus, the solar flares with

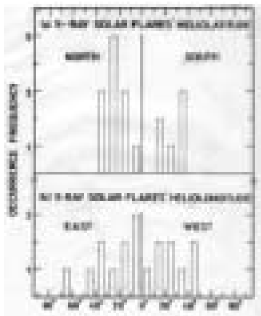

Fig. 1. The occurrence of Hα-ray solar flares helio (a) latitude and (b) longitude plotted histographically during 1986–93.

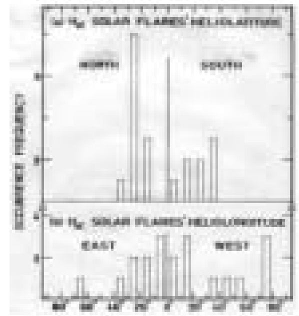

Fig. 2. The occurrence of X-ray solar flares helio (a) latitude and (b) longitude plotted histographically during 1986–93.

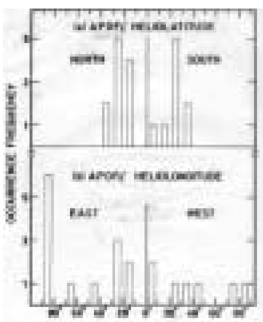

Fig. 3. The occurrence of APDFs solar flares helio (a) latitude and (b) longitude plotted histographically during 1986–93.

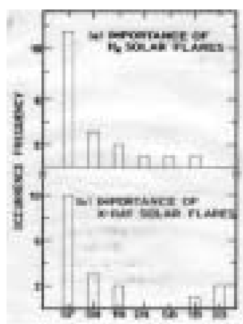

Fig. 4. The occurrence frequency of (a) Hα and (b) X-ray solar flares importance plotted histographically during 1986–93

Fig. 5. Solar origin of 24 geomagnetic storms with Dst$\leq$ -100 nT have been plotted using Venn diagram during the period Jan 1986 – Dec 93.

lower importance in association with some other specific properties, i.e. position, duration, region may also cause GMSs.

(iii) GMSs are more associated with solar flares than other solar features. This result is consistent with Garcia and Dryer (1987), Kumar and Yadav (2002a, b) and inconsistent with Hewish and Bravo (1986), Webb (1995) observations.

5. Acknowledgements

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

6. References

1. Sheeley (Jr) N.R., Harvey J.W. 1981, Solar Phys. 70, 237
2. Feynman J., Gu. X.Y. 1986, Rev. Geophys. 24, 650
3. Garcia H.A., Dryer M.1987, Solar Phys. 109, 119
4. Kumar S., Yadav M. P. 2002a, Bull. Astr. Soc. India 30, 859
5. Cane H.V., Kahler S.W., Sheeley (Jr.) N.R. 1986, J. Geophys. Res. 91, 13321
6. Webb D.F. 1992, The solar sources of CMEs in eruptive solar flares, Edited by
7. Svestka et. al. (Springer verlag. Newyork) 234
8. Rangarajan G. K. 1989, Geomagnetism (India) 3, 324
9. Tsurutani B.T., Gonzalez W.D., Tang Lec F. 1992, Geophys. Res. Lett.19, 73
10. Sabbah I. 2000, Geophys., Res. Lett. 27, 13
11. Solar Geophys. Data Reps (1986–93).
12. Couzens David A., King Joseph 1986, 1989, 1994, Interplanetary medium data book supp. 3A, 4, 5
13. Kumar S., Yadav M.P. 2002b, Indian Journal of Radio & space Phys. 31, 190
14. Hewish A., Bravo S., Sol. Phys. 91, 169
15. Webb D.F. 1995, Rev. Geophys. suppl., 577