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Comparative study of SWP and IMF parameters with DST ≤ - 100 nT in association with large geomagnetic storms

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-abs1-sh2.1-oral

We have studied 10 years (1986-1996) solar wind plasma (SWP), interplanetary magnetic field (IMF) and solar geophysical data with equatorial disturbance storm time (DST) index ≤ - 100 nT. The eighty only geomagnetic storms (GMSs) are identified and a correlative study has been performed. GMSs are highly correlated with sunspot numbers (SSNs). Statistically, it is found that 60% GMSs have occurred during maximum activity years. It has been found that DST index and solar wind velocity (V) is highly correlated as compared to DST and the average value of IMF (B) or DST and the northward or southward component of IMF (Bz). It is also observed that slope of the regression line between DST and V is more as compared to the slope of DST and Bav or DST and Bz. Statistically, it is noticed that 70% of the GMSs are associated with southward component of IMF (Bz) alone, shows that IMF toward south for the solar wind to interact directly with magnetosphere as one necessary condition for the development of geomagnetic effect causing GMSs seen at the Earth. Furthermore, it is observed that the product of V and B directly modulates the geomagnetic activity.

1. Introduction

The geoeffictiveness of various solar and interplanetary phenomena such as interplanetary (IP) shocks, turbulent sheath, ejected plasma clouds from solar flares/coronal mass ejection (CMEs) co-rotating high speed solar wind stream (HSSWS) from coronal holes and interaction region/stream interfaces have been of considerable interest to the solar terrestrial physics (STP), The field of solar terrestrial physics (STP) has greatly advanced in the last 45 years. The sun has been continuously observed by using ground based detectors which are important measuring devices to study the sun and its continuously varying out puts, which modulate cosmic rays as well as produce disturbances in geomagnetic field may lead to cause the occurrence of geomagnetic storms at various locations of the Earth. In fact continuous measurement of the solar variability has been found to be of great importance. Actually, in the last few decades, different parameters have been standardized representing various facets of the solar activity occurring on the various layers of sun surface i.e. photosphere, chromosphere, corona and geomagnetic activity (Rangarajan, 1989; Kumar and Yadav, 2002; Mishra et al., 2005). Currently, many solar IMF and geomagnetic parameters are available for the investigation of solar terrestrial relationship. These are SSNs, solar flares, coronal holes, V, B, geomagnetic Indies Ap, Kp, DST etc. The level of magnetic disturbance or geomagnetic activity is measured by these geomagnetic indices. Geomagnetic activity can be divided into two main categories, namely storms and substorms. Storms, the main contributors to space whether, are initiated when enhanced energy transfer from the solar wind/interplanetary magnetic field into the magnetosphere leads into intensification of ring current. The ring current development can be monitored with the DST index (Gonzalez et al., 1994). According to classical substorm injection hypothesis, ring current is enhanced via energization and injection of plasma sheet particles from the tail towards the inner magnetosphere during substorms, which are typical for storm times. However, this view has been under attack for some time now and according to the recent workers by Iyemori and Rao (1996) and Siscoe and Petschek (1997), the substorm expansion phases act as energy dissipation term and the south ward IMF as an input term in the energy balance equation. Recently, geomagnetic activity during the declining phase of solar activity is related to high values of V and B. The value of V x B directly modulates the geomagnetic activity. The product V x B is more important for geomagnetic activity rather than IMF alone (Sabbah, 2000). Also the correlation between geomagnetic activity indices and interplanetary plasma/field parameters such as, V, B, southward field component, Bz and their various functions have been explored (Akasofu, 1983; Baker, 1986), but a unique relationship is still lacking which may ultimately lead to unambiguous understanding of magnetospheric phenomena. Although, there has been substantial growth in our knowledge of solar and interplanetary causes of geomagnetic storms, there are still unanswered questions that must be addressed and solved to predict the occurrence of storms (Tsurutani and Gonzalez, 1995). In this paper, an attempt has been made to examine the cause and effect of solar and interplanetary transients causing GMSs.

2. Data Analysis

All those GMSs which are associated with equatorial DST index $\leq$ - 100 nT during the period 1986-1996 are being considered and found to be 80 GMSs in number. For this study, SWP, IMF data from IMP-8 satellite and solar geophysical data (SGD) are being used during the period of study. SWP and IMP data are compiled by King and PapitaShivlli (1986, 1989, 1994) in different volumes of interplanetary medium data book from National Space Science Data Center (NSSDC).

3. Results and Discussion

For most of the studies in the field of STR, initially the sunspot numbers were used. In the last 25 years many other solar indices have also been routinely published in the SGD and hence these other solar indices have also been used for various investigators of STR (Kumar and Yadav, 2002). Daily, monthly and annually mean value of SSNs are calculated for the period 1986-1996. The coefficient of correlation between occurrence of GMSs and SSNs has been calculated using Karl Pearson's method and found to be 0.8. Thus, we conclude that GMSs are highly correlated with SSNs. Yearly distribution of the occurrence of GMSs and their association with yearly SSNs has been plotted for the period 1986-1996 in Fig1. Statistically, it is observed that 60% GMSs have occurred during maximum activity years. Figure 1 demonstrates that maximum number of GMSs have occurred when SSNs are maximum. One peculiar result has been observed during 1994, when SSNs decreases while number of GMSs increases significantly. The cross correlation coefficient between DST versus V; DST versus Bav and DST versus Bz have been found to be 0.96, 0.67 and 0.62 respectively. Thus, we conclude that DST is highly correlated with V as compared to Bav, Bz. The sources of GMSs have been investigated by many researches (Cane et al., 1987; Cane et al. , 1996; Webb et al., 2000). We have also investigated the sources of 80 GMSs. Out of 80 GMSs, 40 and 08 GMSs are associated with transient disturbance and co-rotating flow respectively, while sources of 32 GMSs are uncertain. 38 and 11 large GMSs are associated with shocks and magnetic cloud respectively while the association of 31. GMSs are uncertain. 36 and 06, GMSs are associated with negative and positive polarity of IMF (B) respectively. 06 GMSs are associated with either negative or positive polarity of IMF. Polarity of 30 GMSs are uncertain. Thus we conclude that maximum number of large GMSs are associated with negative polarity of B. IMF towards south allows sufficient energy transfer from the solar wind into the Earth's magnetosphere through magnetic reconnection. This result is similar to Dungey, 1961, Fairfiel & Cahill 1966 and Gonzalez & Tsurutani, 1987 result. Thus a storm is an interval of time when a sufficient intense and long lasting interplanetary convection electric field lead through a substantial energization in the magnetosphere, ionosphere system to an intensified ring current strong enough to exceed some key threshold of the quantifying storm time DST index. The electric field mentioned, is composed of V and southward IMF (Bz), of these, the magnetic field is found to be more important, indicating that the mechanism for the energy transfer includes magnetic field merging. The large storms are generally related to CMEs from the sun (Gosling et al. 1991). In these cases, the related enhancements of accompanied by southward IMF direction result into storm sudden commencement (SSCs). We have found different trend of regression lines between DST, V; DST, Bav; DST, Bz and is depicted in Figure. 2. It is apparent from Figure 2 that slop of regression line between DST, V is more as compared to DST, Bav and DST, Bz. The progression of weaker relationship between DST, Bz is not understood presently. However in future studies this fact seems to be quite important in understanding the choice of solar and IMF parameters for studies to terrestrial phenomena.

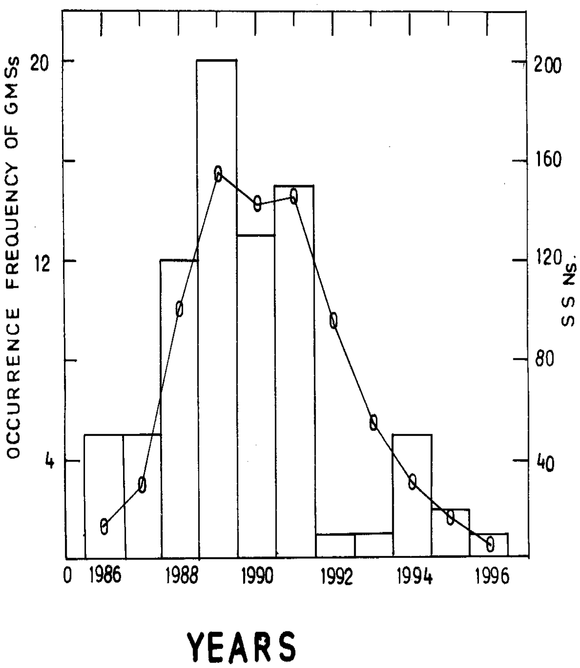

Figure 1 Occurrence frequency with SSNs has been plotted histographically during the year 1986 1996

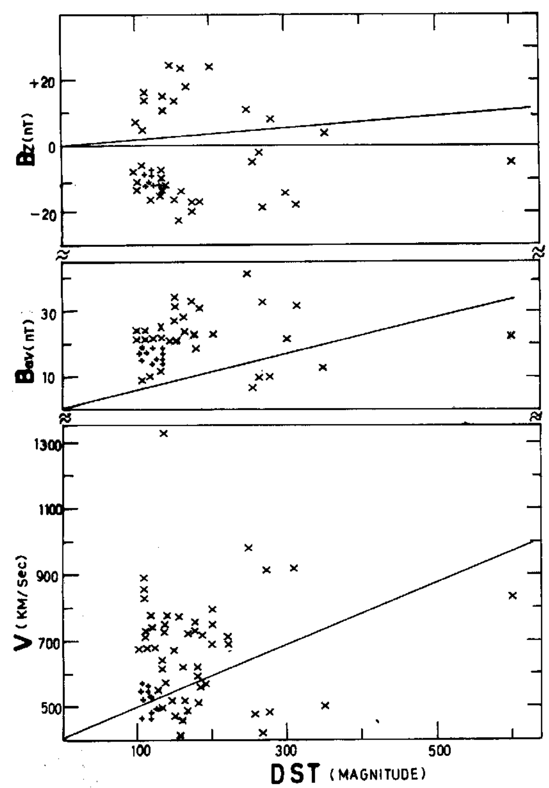

Figure 2 V,Bav, Bz, with DST and their regression lines have been potted. For the period 1986-1996

4. Conclusions

1. GMSs are highly correlated with SSNs and correlation coefficient has been found to be 0.8. Statically, it is found that 60% GMSs have occurred during maximum activity years.
2. It has been observed that DST and V are highly correlated and correlation coefficient has been found to be 0.96 as compared to DST, Bav and DST, Bz.
3. Slope of regression line between DST, V is more as compared to DST, B or DST, Bz.
4. Statistically, it is observed that 70% of GMSs are associated with southward component of IMF (Bz) alone. Furthermore, it is observed that the product of V and B directly modulates the geomagnetic activity.

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