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The Effect of 27-Day Solar Rotation on Earth Magnetosphere

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Abstract:

In this paper we present the results of an investigation of the sequence of events from the Sun to the Earth that ultimately led to the geomagnetic activity. We observed from that the good correlation between geomagnetic index Dst and B x V has been observed to be 0.77. The long-term variation of 27 day has shown average correlation between interplanetary and geomagnetic parameters for cycles 22, 23 and 24. The correlation coefficient between solar wind speed with geomagnetic indices Kp, Ap and Dst for the cycles 22, 23 and 24 is found to be 0.69, 0.65 and 0.57 respectively. The origins and outcome of life on Earth are intimately connected to the way the Earth responds to the Sun's variations. The solar activity and the space magnetic storms affect in various ways earth's magnetosphere. Solar conditions are constructive for the progress of electromagnetic disturbances in geospace, which can effectively influence the performance and reliability of space and ground-based technological systems. As the sphere of the human environment and exploration continues to expand towards space, understanding the effects of our active Sun, becomes day after day more important. This paper studied present understanding of the dynamics of the solar- terrestrial environment and its impacts on the earth's magnetosphere.

***Key Words*: Sunspot Number, Solar Wind Plasma, Total Average Magnetic field B and Geomagnetic stroms.**

Introduction

Geomagnetic activity variations are observed with the 27-day solar rotation period, however, there have been very few studies on the relative contributions on the 27 day variation. In this section we have tried to obtain more physical insight into these issues by analyzing geomagnetic data over more than a solar cycle with interplanetary parameters. Changes in solar EUV radiation are produced by the non uniform distribution and motion of EUV radiation sources, such as active regions; over the Sun surface as well as the random fluctuation of radiation intensity. As the Sun rotates with a quasi-27 day period, the solar EUV flux measured at 1 AU shows a variation with a broad spectral peak between about 22 and 32 days (Pap et al., 1990; Kane et al., 2001; Kane, 2002, Woods et al., 2005; Ma et al., 2007). Similarly, there are also quasi-27 day variations in solar wind and interplanetary magnetic field (IMF) as solar active regions near solar maximum and corotating interaction regions (CIRs) near solar minimum rotate with the Sun. The lifetime of solar active regions and CIRs can last longer than one solar rotation period. These recurrent variations have been noticed in solar wind and IMF produce periodic geomagnetic activity of 27-days when solar wind and IMF interact with the magnetosphere (Schreiber, 1998; Parker, 2005, Ma et al., 2012).

Solar plasma disturbance originating on the Sun, such as coronal mass ejection (CMEs), is major factor in determining disturbance in the near-Earth environment. Large scale solar coronal mass ejection (CMEs) travels through the inner heliosphere at the speed of up to 1000 Km/s, reaching the space environment of Earth within one to three days and carrying with them to the potential for major geomagnetic disturbance (Hundhausen et al. 1997; Gosling et al. 1990 and Singh et al. 2012). Coronal mass ejections release huge quantities of matter above the surfaces of the sun near the corona and emission of electromagnetic radiation does refer to the solar flare. The ejected plasma consists of primarily electrons and protons, but may contain small quantities of heavier elements such as helium, oxygen and iron. It is associated with enormous changes and disturbances in the coronal magnetic field. When the ejection is directed towards the Earth and reaches it as an interplanetary coronal mass ejection (ICME), the shock wave of the travelling mass of solar energetic particles causes a geomagnetic storm that may disrupt the Earth's magnetosphere, compressing it on the day side and ending the night side magnetic tail. When the magnetosphere reconnects in the nightside, it creats power on the order of terawatt scale, which directed back towards the Earth's upper atmosphere. Solar activity comprising sunspots and other phenomena is strongly related to the disturbance in the Earth's magnetic field, giving rise to various effects in the Earth's upper atmosphere [Muscheler et al. 2007; Usoskin et al. 2009, Gopalswamy et al. 2010;]. Shocks occur in the solar atmosphere (the corona) during solar flares and other manifestations of solar activity. Flares and coronal mass ejections can inject energy and material into the solar wind driving travelling interplanetary shocks which propagate out through the solar system. The solar wind has high speed and low speed streams, coming from different source regions on the sun. Shocks can form at the interface between a slow stream being overtaken by a fast stream. In more exotic astrophysical bodies one finds jets of material from active galactic nuclei (AGN), and there are probably shocks formed at the interface between the jet material and the interstellar medium. In supernovae massive amounts of energy are

deposited in a very short time and shocks are formed as the supernova remnant (SNR) loads up material as it expands away from the newly formed pulsar. In fact' the interplanetary magnetic field is the extension of solar magnetic fields which could not be held static due to the tremendous energy of the solar corona and comes out along with the solar wind in the form of frozen in spiral magnetic lines of force. The high speed solar plasma interacts with Earth magnetic field and creates disturbance in the magnetosphere. Injection of the solar wind energy into magnetosphere produces variations of geomagnetic field at Earth. The IMF is a weak field, varying in strength near the Earth from 1 to 37 nT, with an average value of ~6 nT. The IMF is the term for the solar magnetic field carried by the solar wind among the planets of the solar system. When the IMF and geomagnetic field lines are oriented opposite or antipallel to each other, they can merge or reconnet resulting in the transfer of energy, mass, and momentum from the solar wind flow to magnetosphere. The strongest coupling with the most dramatic magnetospheric effects occurs when the Bz component is oriented southward. Disturbances created by solar plasma and field sometimes become responsible for adverse effects on satellites, communications, electric power and pipelines. Numerous severe storms occurred during the maximum phase of the solar activity and are mostly associated with CMEs (Srivastava 2005; Zhang et al. 2006; Singh et al. 2012). Most CME initiation models today are based on the premise that CMEs and flares derive their energy from the coronal magnetic field. The currents that build up in the corona as a result of flux emergence and surface flows slowly evolve to a state where a stable equilibrium is no longer possible. Once this happens, the field erupts. If the eruption is sufficiently strong and the overlying fields not too constraining, plasma is ejected into interplanetary space. If strong magnetic fields exist in the erupted region, then bright, flare-like emissions occur. The latter is true, even if the field does not erupt (Gopalswamy et al 2007)

Several authors have studied the geoeffectiveness of magnetic clouds for longer time intervals (Gosling et al. 1991; Echer et al. 2005) and of other interplanetary structures for several levels of the intensity of magnetic storms, also involving superstorms (Gonzalez et al. 1994, 1999, Srivastava 2005; Zhang et al. 2006; Richardson et al. 2006; Gonzalez et al. 2007 and Singh et al. 2015) Solar energetic transients, i.e. flares and coronal mass ejections (CMEs), occur rather spontaneously, and we have not yet identified unique signatures that would indicate an imminent explosion and its probable onset time, location, and strength.

On the Magnetosphere it has been suspected that "northward turnings" of the solar wind magnetic field can trigger magnetospheric substorms (Rostoker, 1983; Hsu and McPherron, 2006) but see Morley and Freeman (2007) and for evidence against this. These northward turnings occur as solar wind current sheets pass the Earth, and solar wind current sheets typically have co-located velocity shear layers. Hence, sudden wind shear effects may have been hidden in these previous studies of solar wind triggering by sudden magnetic field changes, but the effects of the wind shears were not separately studied. Assessing the separate importance of magnetic field changes and velocity-vector changes on the stability of the magnetosphere should be done. A solar wind discontinuity with the proper orientation can interact with the Earth's bow shock to produce a "hot flow anomaly" (Thomsen et al., 1986; Schwartz et al., 2000) wherein solar wind ions that reflect off the bow shock travel upstream inside the discontinuity

and produce a rapid pressure expansion of the discontinuity's current sheet (Burgess, 1989; Koval et al., 2005]. Hot flow anomalies are known to produce large transient outward displacements of the magnetopause (Borovsky 2012).

2. Selection Criteria and data Selection

In the present study, we have studied correlation of long-term variation between interplanetary and geomagnetic parameters for cycles 22, 23 and 24. The correlation coefficient between solar wind speed with geomagnetic indices Kp, Ap and Dst for the cycles 22, 23 and 24 were discussed. We have also select the correlation coefficient between Bz-component of IMF with geomagnetic indices Ap, Kp and Dst, and correlation between geomagnetic index Dst and B x V has been analysed.

The relationship between solar activity and geomagnetic indices in solar cycle 22 to 24 has been analysed. The significance of the geomagnetic Ap, Kp index in tracking long-term solar activity has been documented in the literature [8]. For this purpose we have selected data of 27 day values of geomagnetic activity (Kp Indices, Ap Indices and Dst Indices) have been taken from web site (www.geomag.bgs.ac.uk/daaservice/dat). The 27 day variation values of international SSN, Bz-component of interplanetary magnetic field (IMF) and solar wind speed (V) data have been downloaded from the National Geophysical Data Centre web site (htt://www.ngdc.noaa.gov/stp/SOLAR/ftpsunspotnumber.html).

3. Results and Discussion

The effect of geomagnetic activity is very complicated. A large amount of joule heating is deposited at high latitudes during geomagnetically active periods. This causes upwelling of molecular rich air in the auroral region and down welling of atomic rich air at middle and low latitudes and thus changes in thermospheric composition and plasma density (Burns et al., 1991). Geomagnetic storms can also produce penetration electric fields and enhance neutral wind circulation that alters global ionospheric plasma distribution and density (Lei et al., 2008a; Wang et al., 2008, 2010). The relationship of Kp and solar wind speed is clearly seen in **(fig. 1).** It is observed from (**fig. 2, 3** and **4)** that the good correlation between total interplanetary magnetic field IMF (B) and geomagnetic index Kp, Ap and Dst has been observed to be 0.74, 0.75 and 0.70 during the cycles 22, 23 and 24 respectively. Positive correlation coefficient has been observed between SSN with geomagnetic indices Kp, Ap, and Dst respectively **(fig. 5, 6** and **7).**

The long-term variation has shown average correlation between interplanetary and geomagnetic parameters for cycles 22, 23 and 24. The correlation coefficient between solar wind speed with geomagnetic indices Kp, Ap and Dst for the cycles 22, 23 and 24 is found to be 0.69, 0.65 and 0.57 respectively **(fig. 8, 9** and **10).** We have also obtained the correlation coefficient between Bz-component of IMF with geomagnetic indices Ap, Kp and Dst, positive correlation is found as depicted in **fig. 11, 12** and **13.** It is observed from **(fig. 14)** that the good correlation between

geomagnetic index Dst and B x V has been observed to be 0.77.

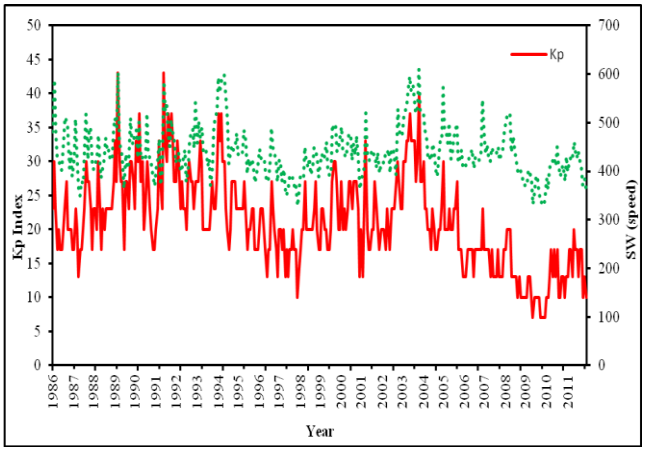

Fig. 1:Shows the relationship between Kp index with interplanetary parameter SW (speed) for 27-day variation during the period 1984 to 2012.

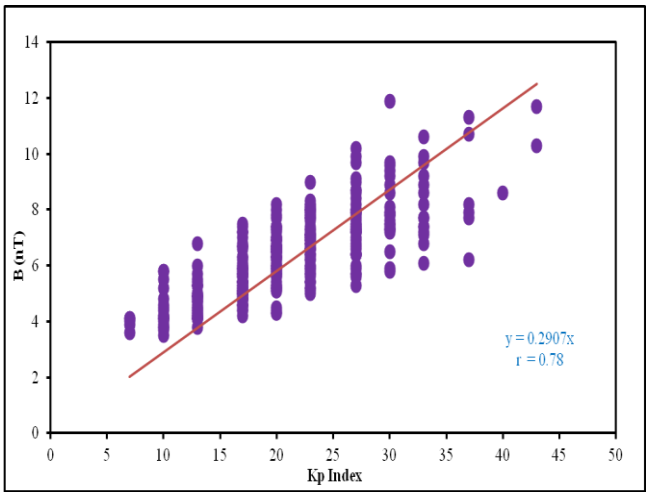

Fig. 2: Shows the correlation coefficient between IMF B(nT) and Kp index for 27-day variation during the period 1986 to 2012.

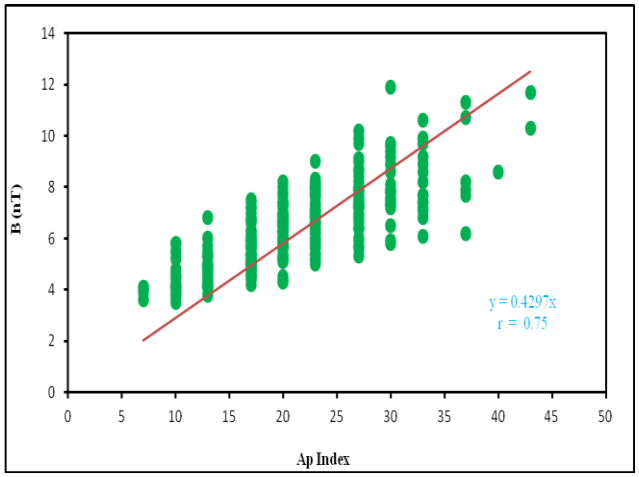

Fig. 3: Shows the correlation coefficient between IMF B(nT) and Ap index for 27-day

variation during the period 1986 to 2012.

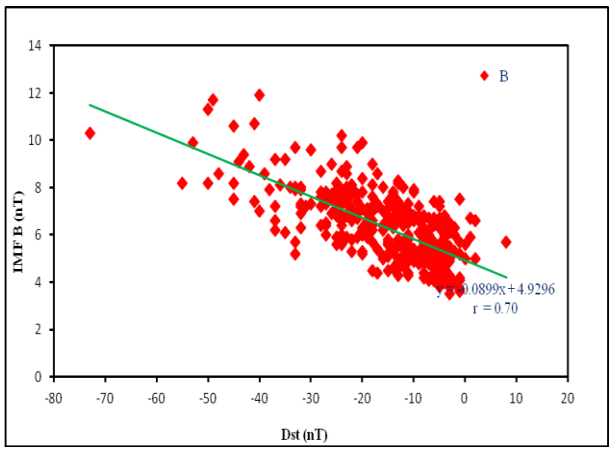

Fig. 4: Shows the correlation coefficient between IMF B(nT) and Dst index for 27-day variation during the period 1986 to 2012.

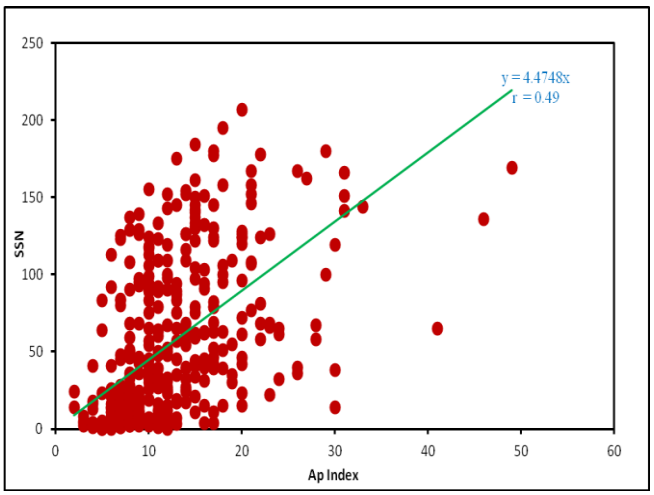

Fig. 5: Shows the correlation coefficient between SSN and Ap index for the 27-day variation during the period 1986 to 2012.

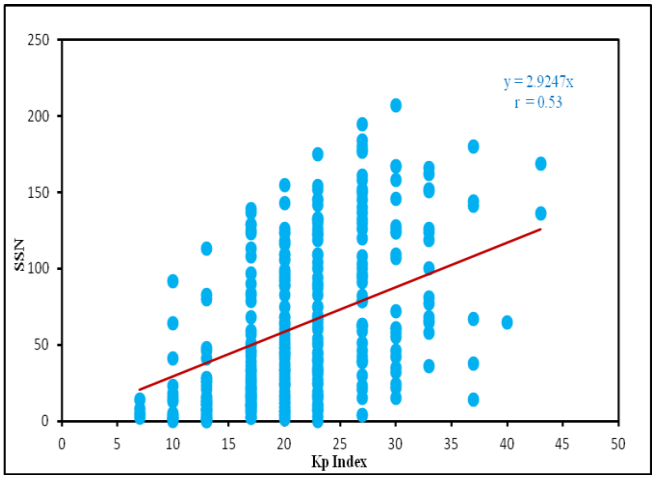

Fig. 6: Shows the correlation coefficient between SSN and Ap index for the 27-day variation during the period 1986 to 2012.

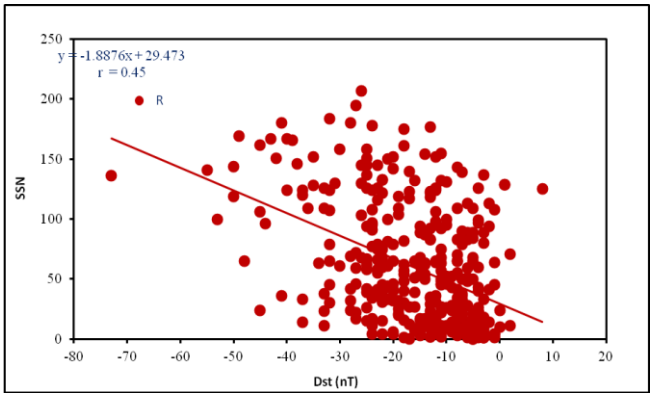

Fig. 7: Shows the correlation coefficient between SSN and Dst index for 27-day variation during the period 1986 to 2012.

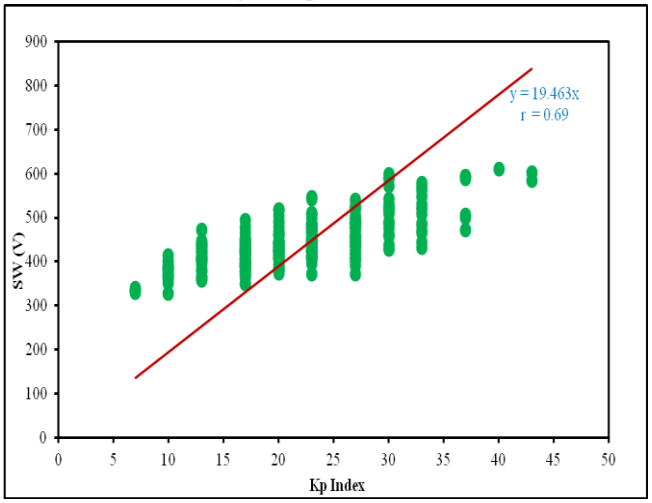

Fig. 8: Shows the correlation coefficient between SW (speed) and Kp index for the 27-day variation during the period 1986 to 2012.

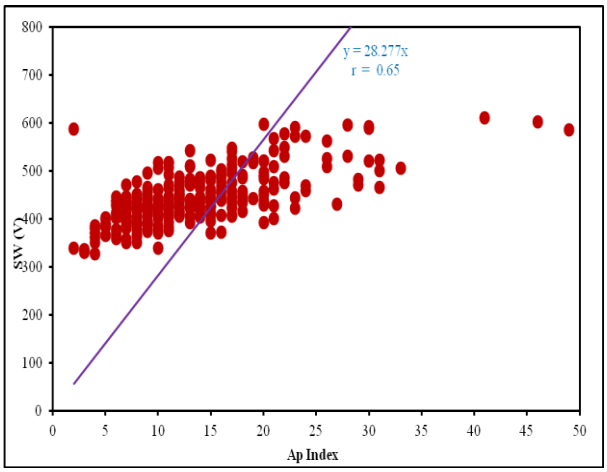

Fig. 9: Shows the correlation coefficient between SW (speed) and Ap index for the 27-day variation during the period 1986 to 2012.

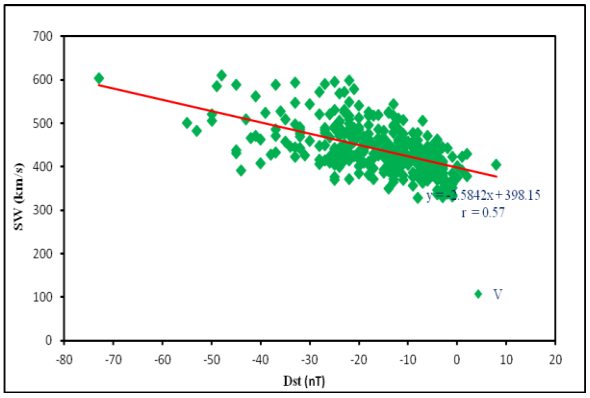

Fig. 10: Shows the correlation coefficient between SW (speed) and Dst index for the 27-day variation during the period 1986 to 2012.

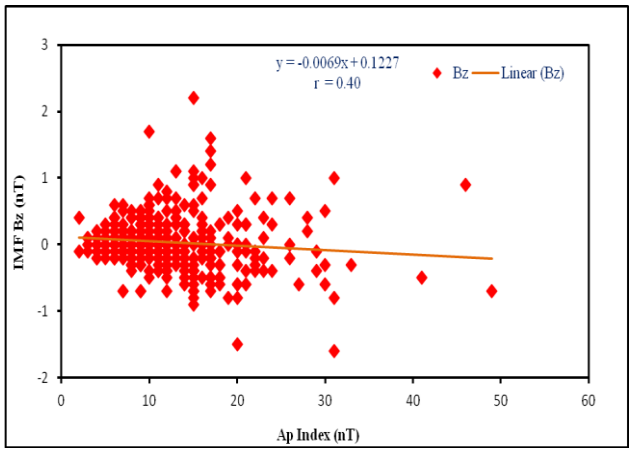

Fig. 11: Shows the correlation coefficient between IMF Bz(nT) and Ap index for 27-day variation during the period 1986 to 2012.

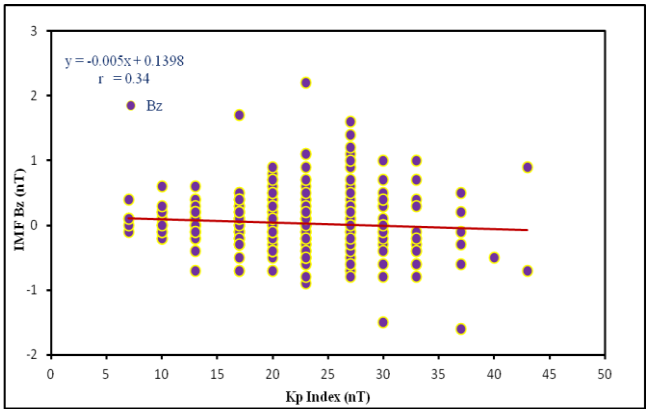

Fig. 12: Shows the correlation coefficient between IMF Bz(nT) and Kp index for 27-day variation during the period 1986 to 2012.

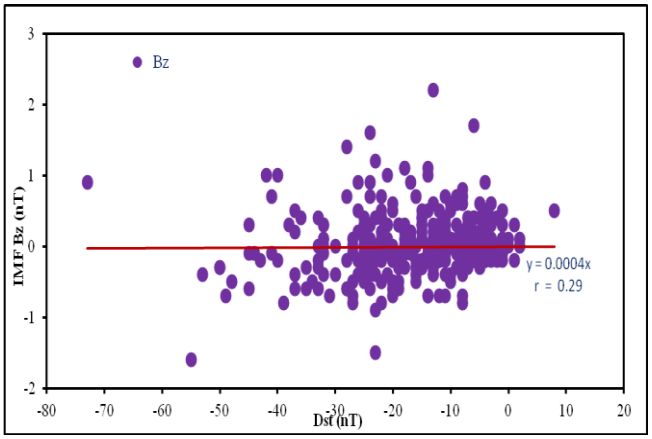

Fig. 13: Shows the correlation coefficient between IMF Bz(nT) and Dst index for 27-day variation during the period 1986 to 2012.

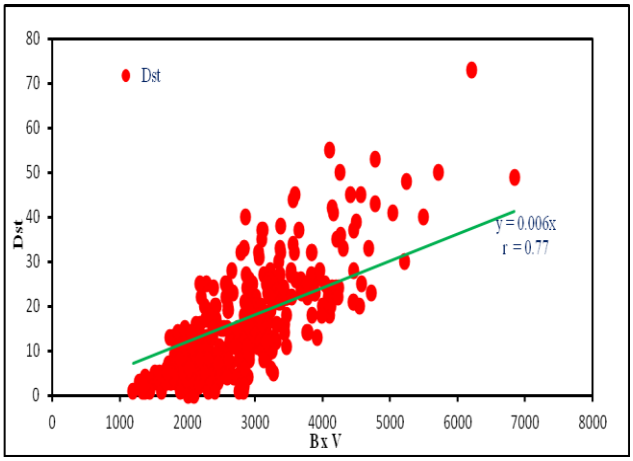

Fig. 14: Shows the correlation coefficient between geomagnetic index Dst and B x V index for 27-day variation during the period 1986 to 2012.

3 Conclusion

In this paper we considered geomagnetic indices indicate various solar and interplanetary characteristics and their corresponding geomagnetic effects. For each event, peak Dst values as well as date and time of their occurrences has been analysed. Dst decreases with increasing magnetopause shielding currents, a measure of magnetospheric compression produced by an increase in solar wind velocity. Connection between the variation of the solar magnetic field and the solar wind velocity at Earth as determined by the Sun's rotation and dipole tilt and the heliographic location of Earth, geomagnetic activity derived from the time varying geometry of the Sun and Earth was successful in predicting the time variation of the geomagnetic Ap index in selected years. The model accurately predicts the strong semi-annual effect in the ~27 day component of geomagnetic activity, with strongest effect at equinox and with weakest effect at solstice. Thus the expectation is that near equinox the correlation would be higher than the average correlation obtained over the entire year. The variation in geomagnetic activity at this time would be unrelated to solar rotation due to the effect of synoptic weather.

We conclude therefore that, it appears that a significant influence of ~27 day geomagnetic

activity on cloud and temperature predictably occurs during years around solar minimum and at times around equinox it would be interesting to examine if this could assist in long term weather prediction. The solar magnetic field and the solar wind velocity contain significant components at harmonics of the 27 day solar rotation period.

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