Study of Association of Geomagnetic Storms with Solar, Interplanetary and Other Geomagnetic Parameters

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Abstract

Geomagnetic storms are perturbations in the earth's magnetic fields. Geomagnetic storms which are measure by Dst indices are the signature of solar events. We classify geomagnetic storm in two categories on the basis of Dst value. I. Intense (Dst<-100 nT) II. Moderate (-75nT>Dst>-100nT). In present study 2080 Geomagnetic storm (Dst<-75nT) Observed during solar cycle 23 & ascending phase of solar cycle 24 (1996-2013) out of which 49.51% are intense and 50.49% are moderate. We use all these events of geomagnetic storm to derive the relationship with the solar activity for the period of 1996-2013. We found high and negative correlation (correlation coefficient -0.65) of Dst with solar parameters (SSN, Solar index) and IMF (correlation coefficient -0.82). We have also determined negative and high correlation between Dst & Ap(correlation coefficient -0.89) and Dst & Kp indices (correlation coefficient -0.89).

Key words: *Dst, SSN, Solar indices, IMF, Cosmic ray intensity, Kp & Ap indices.*

INTRODUCTION

Disturbances produced due to changes in the magnetic fields of sun and earth are known as solar activity & geomagnetic activity respectively. Both activities are linked are linked through the interplanetary medium lies between sun and interstellar medium. Activity of sun measured by powerful solar transient eruptions. Thus coronal mass ejection, solar wind stream, solar flares are accompanied by enormous energy and mass. Occurrence frequency and intensity of transient solar emissions vary with different phases of the solar cycle characterized by the number of sunspots on the photosphere. Solar maximum is dominated by powerful solar eruptions like solar flares and CME and the solar minimum is featured by coronal holes and fast wind stream (T surutani & Gonzolez 1998). Impact of these disruptive solar emissions on the earth's magnetosphere leads to sudden disturbances in the geomagnetic field known as geomagnetic storm(Rawat et al. 2007). Geomagnetic storms occur when the interplanetary magnetic field turns southward and remain southward for a prolonged period of time. In other words the geomagnetic storm is magnetic reconnection between southwardly oriented IMF B_Z component and the anti parallel geomagnetic field lines (Rawat et al. 2009 & references therein).
The variation of earth's magnetic field shows the time variation of magnetic elements of earth like angle of declination (Ø), angle of dip (θ) and horizontal component (H) of

magnetic field of earth. Values of the average global variation of the low latitude H component are represented by the Dst index, which is a good measure of the intensity of the ring current being the strength of the geomagnetic storms measured usually by the magnitude of the Dst index. Several scientists have studied interrelationship between solar parameters, interplanetary parameter and geomagnetic parameters with Dst (Gastava A. Mansilla). Gonzalez and B.T. Tsusutani (1987) found that the interplanetary causes of intense magnetic storm are long-duration, large and negative (-10nT) IMF B_Z events associated with interplanetary dusk word electric field>5 m V/m, that last for intervals> 3hr

B.T. Tsurutani et al studied the five largest magnetic storm occurred between 1971 to 1986 to determine their solar and interplanetary causes they found all of the events are associated with high speed solar wind streams led by collision less shocks the high streams are clearly related to identifiable solar flares. Burton et al (1975) gives a formula to predict the relationship between Dst index, velocity (flow) and density of solar wind as well as Bz component of IMF. Kane et al(2000) studied 83 events from 1996 to 1999 and found a high correlation (0.75) between Dst index and Bz. R.P. Kane(2005) noted that moderate or strong geomagnetic storm occurred only when solar wind speed was above ~ 350 km/s but above this limit he found in the plot of Dst Versus VxB_S (Product of V and southward component B_S of interplanetary magnetic field B) correlation better than that in the plot of Dst versus V However he suggested that estimate of V could certainly he useful to estimate the time when the storm would hit the earth. Gosling et al(1990) have investigated that strong geomagnetic storms ith Kp≥8 were caused by fast coronal mass ejections (CME's) at the sun during high solar activity. Fast CME's had produced solar wind shock disturbances at 1 AU associated with strong southward magnetic fields. Strong geomagnetic storms are analyzed by Elias and Silbergliet (2003) through the study of aa, AE and Dst indices strong geomagnetic strom where considered whenever aa>80 nT, Dst <-100nT, AE>600nT. Webb et al 2000 and Zhao & Webb 2003 showed that geomagnetic storms closely related with flares and CME's Yurchyshyn et al (2003) present data to establish relationship between Dst and Bz and found the hourly average Bz measured in the GSM system are correlated with the hourly averaged Dst index.

The cause of geomagnetic storm can be determined by correlation study between solar interplanetary and geomagnetic parmaters. We investigated various solar interplanetary and geomagnetic parameters for complete solar cycle 23 and ascending phase of 24 (1996-2013)

The aim of statistical study presented in this paper is to analyzed association of geomagnetic storms which is represented by Dst value with different solar activity interplanetary parameters and other geomagnetic parameter.

Data and Method:

In this investigation a list of geomagnetic storm based on the Dst indices provided by the world data centre for geomagnetism Kyoto, Japan through its world wide web (and also from the Omni web data source maintained by national geophysical data centre (NGDC)) (http:/www.ngdc.noaa.gov/stp/solar/ftpsatenvir.html) is being compiled for this study for the period (1996-2013) which cover the solar cycle 23 and ascending phase of 24. In this study and correlative analysis, we have taken data of solar, interplanetary and geomagnetic parameters from website of Omni web and solar geophysical data book to derive correction of geomagnetic disturbances with solar, interplanetary and geomagnetic parameters. Observed daily values of parameters used to find monthly & then yearly mean values of all considered parameters. Now statistical method used to find the correlation between yearly mean values of all parameters.

Results and Discussion:

Coronal mass ejection (CME's) are the major causes for the large geomagnetic storm (Dst<-100nT) (Bruechner et a 1998 , Cane et al 2000 Gopalswamy et al 2000,2005 Wang et al 2002 Webb et al 2000 Zhang et al 2003). High speed streams(HSS) in co rotating interaction regions(CIR's) cause only moderate to weak storms (-100nT<Dst<-50nT) Gonzalez et al (2001) studied the interplanetary causes of intense geomagnetic storms (Dst<-100nT) and found that magnetic clouds, sheath fields, sheath field followed by a magnetic cloud and corotating interaction regions leading high speed streams were the most common interplanetary structures to the development of an intense storm.Disturbances of the near earth environment are measured by various parameters such as aa (Mayaud 1973), Planetary equivalent amplitude Ap (Bartels et al 1939) and Dst (Sugiuara 1964) indices. Variation in solar activity are traced by measuring sunspot number (Hoyt and Schattel 1998) solar index and solar flare indices (ozguc et al 2003) total solar irradiance (Lean et al 1995), in this study we relate solar parameters (SSN & Solar index) interplanetary parameters(IMF,Bz and flow) and geomagnetic parameters (Kp and Ap) with the intense geomagnetic storm(Dst≤-100nT)

Solar Parameters and Geomagnetic Storm

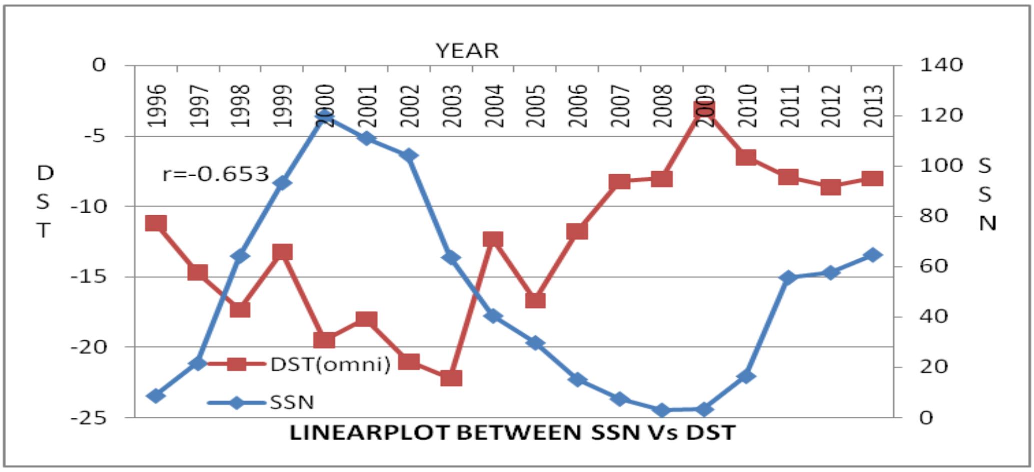

Figure 1. Linear plot between SSN Vs Dst

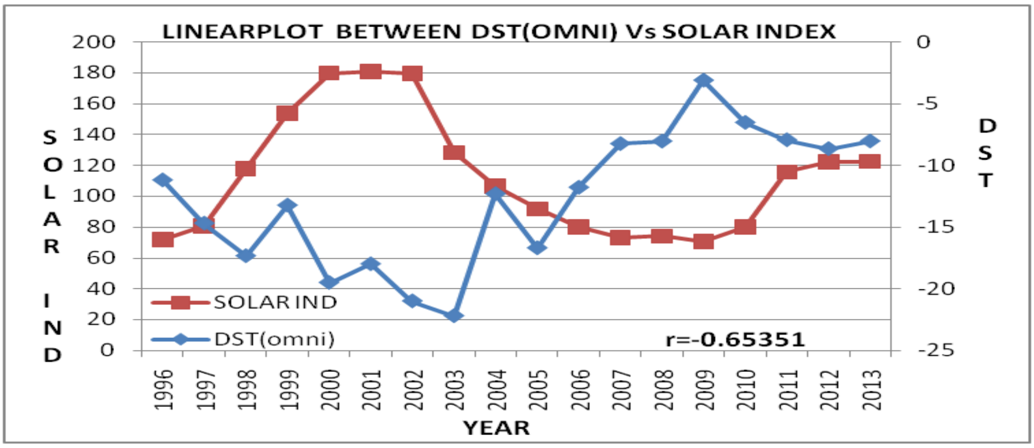

Figure 2. Linear plot between Dst Vs Solar index

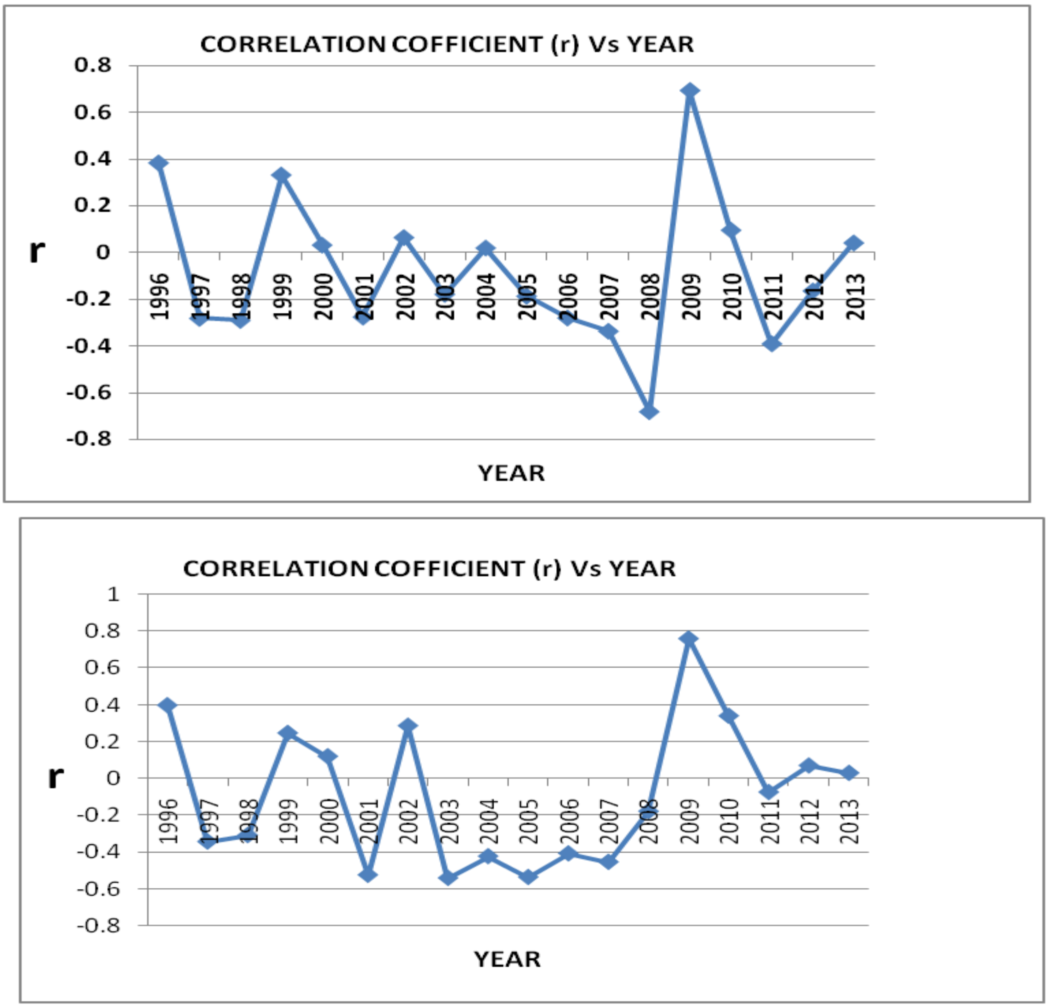

Figure 4. Variation of r of Dst and Solar index

Statistical relation of geomagnetic storm with solar parameters (SSN & index)-In this study we have associated intense geomagnetic storm (Dst≤-100nT) observed during the period 1996-2013 with sunspot number and solar index. Fig (I) shows that negative correlation with correlation coefficient -0.65 has been found between magnitude of intense geomagnetic storm that is Dst value and SSN. This represents that SSN may be strong indicator of producing intense geomagnetic storm. Fig 3 shows that correlation coefficient dst and SSN varies with time. We observe maximum deviation 0.3 in correlation coefficient during 1996-2013.

Fig. 2 shows that solar index and Dst indices are related negatively with correlation coefficient

-0.65 this represent that solar index is also a good indicator of producing geomagnetic storm. Fig. 4 shows that correlation coefficient between solar index and Dst varies with time. We observe maximum deviation 0.2 in correlation coefficient between them during 1996-2013.

Interplanetary Parameters and Geomagnetic Storm

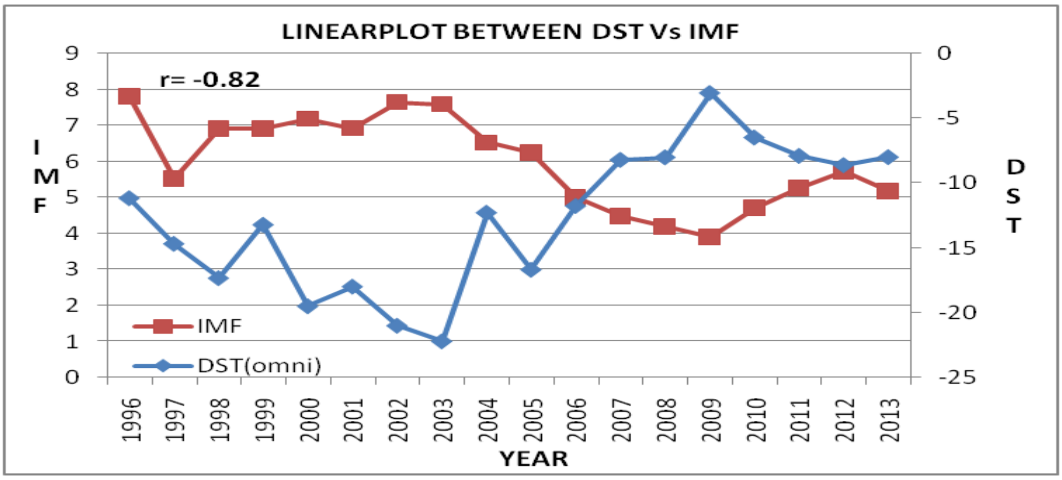

Figure 5. Linear plot between Dst and IMF

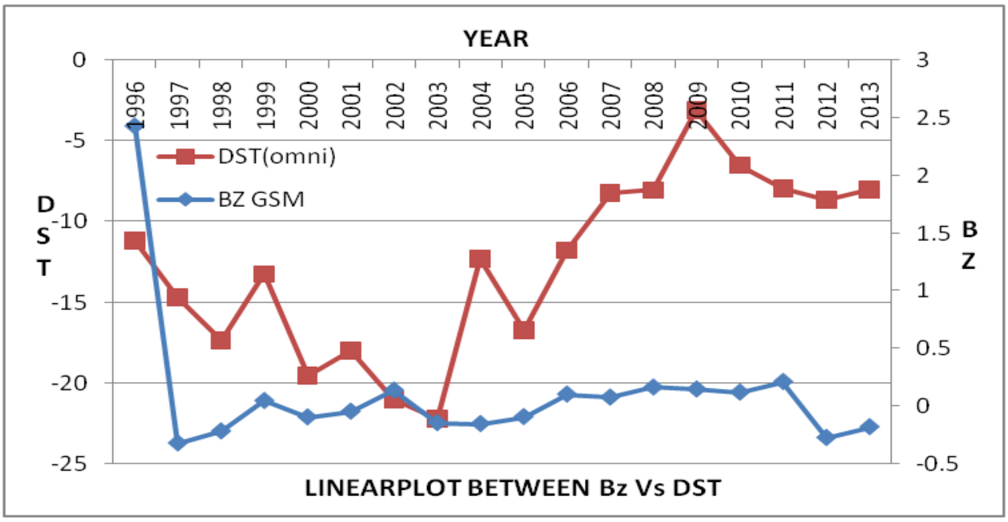

Figure 6. Linearplot between Bz and Dst

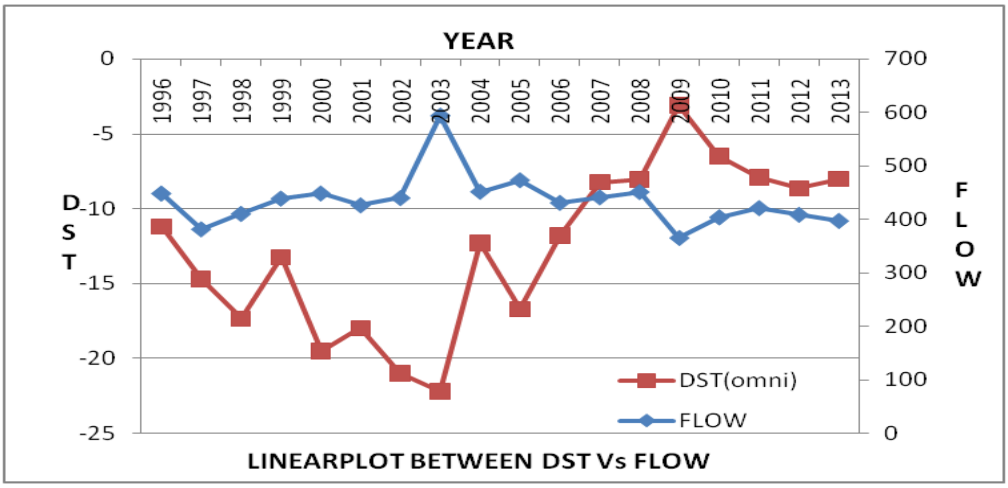

Figure 7. Linearplot between Dst Vs Flow

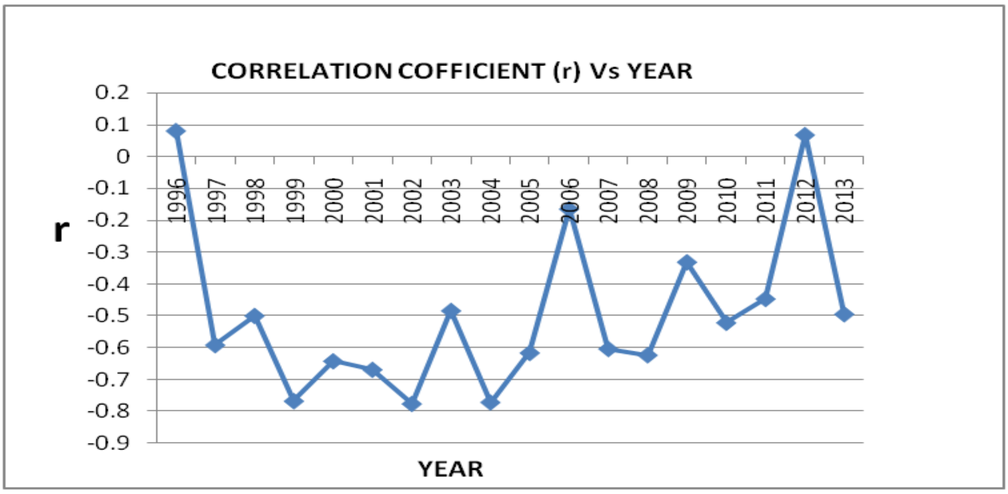

Figure 8. Variation of r of Dst and IMF

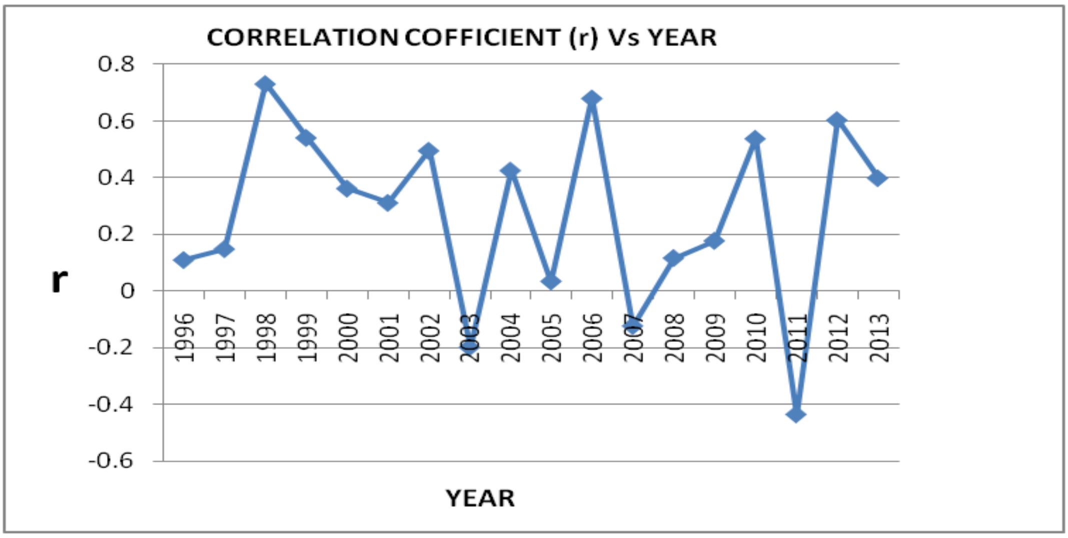

Figure 9. Variation of r of Dst and Bz

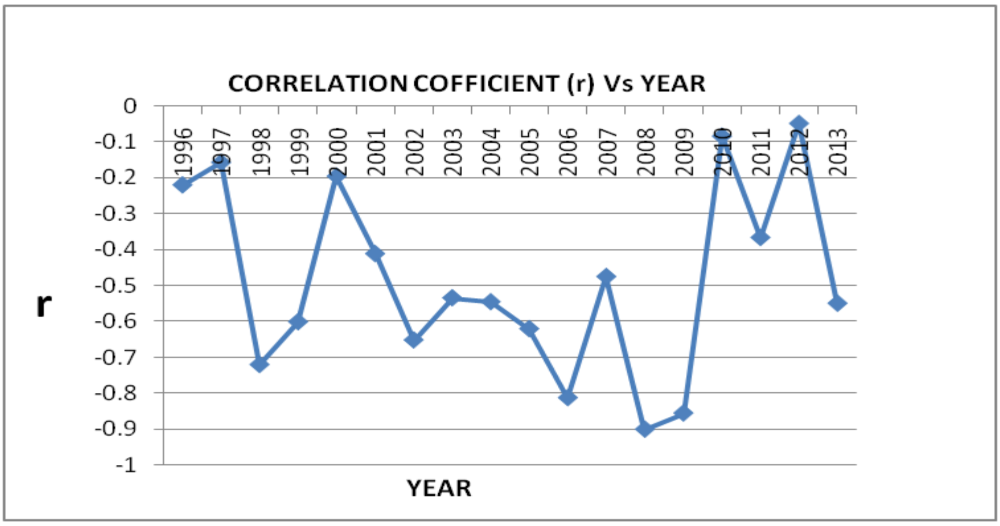

Figure 10. Variation of r of Dst and FLOW

Statistical relation of geomagnetic storm with interplanetary parameters(IMF, Bz & flow): In this study we have associated intense geomagnetic storm (Dst≤-100nT) observed during the period 1996-2013 with IMF B, Bz & flow. Fig 5 show that negative correlation with correlation coefficient -0.85 has been found between magnitude of intense geomagnetic storm that is dst value and IMF B. This represent that IMF may be strong indicator of producing intense geomagnetic storm. Fig.8 shows that correlation coefficient between them varies with time during 1996-2013.

Fig 6 shows that southward component IMF Bz and dst indices are related positively with correlation coefficient 0.16 this represent that solar index IMF Bz is not a good indicator of producing geomagnetic storm. Fig 9 shows that correlation coefficient between them during 1996-2013.

Fig 7 shows that flow and dst indices are related negatively with correlation coefficient -0.58 this represent that flow is also a good indicator of producing geomagnetic storm. Fig 10 shows that correlation coefficient between flow and dst varies with time. We observe maximum deviation 0.2 in correlation coefficient between them during 1996-2013.

Geomagnetic Parameters and Geomagnetic Storm

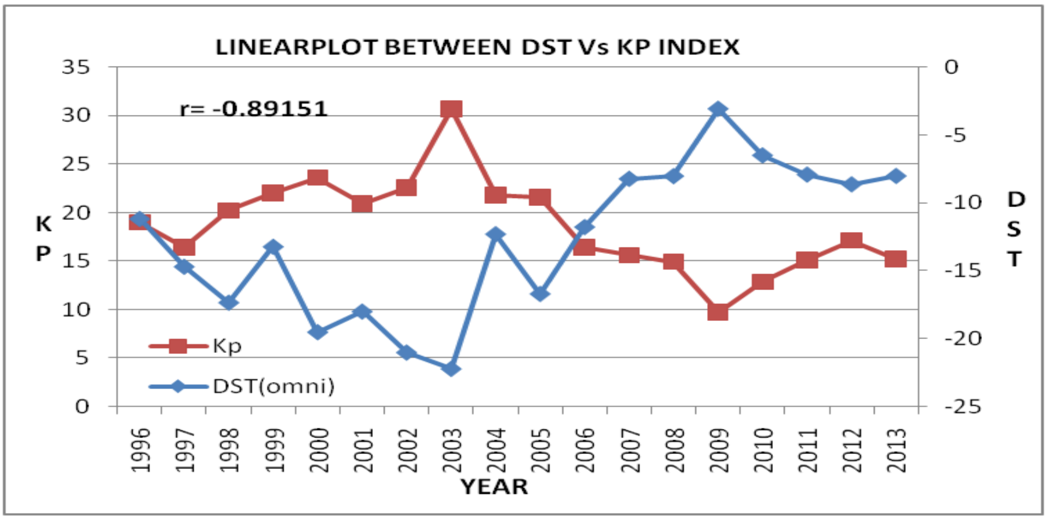

Figure 11. Linear plot between Dst and Kp Index

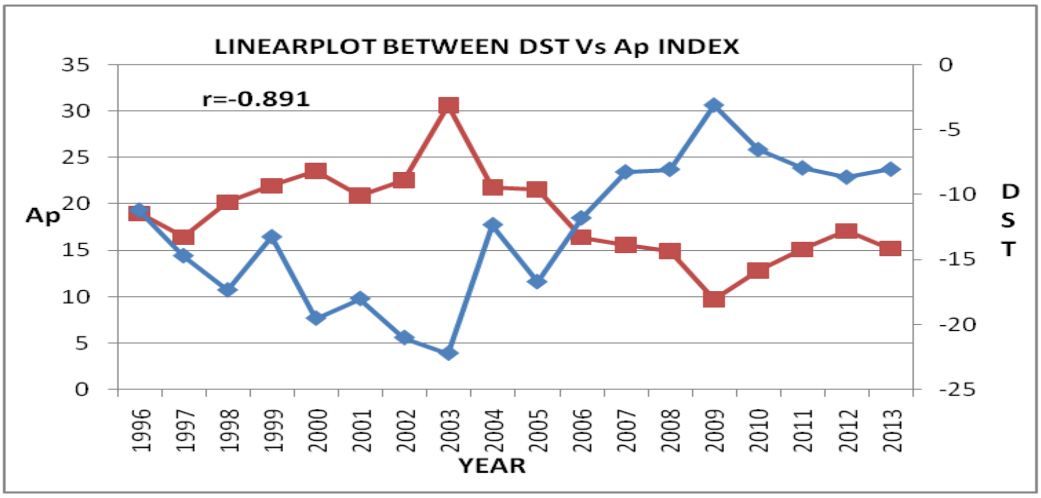

Figure 12. Linearplot between Dst Vs Ap Index

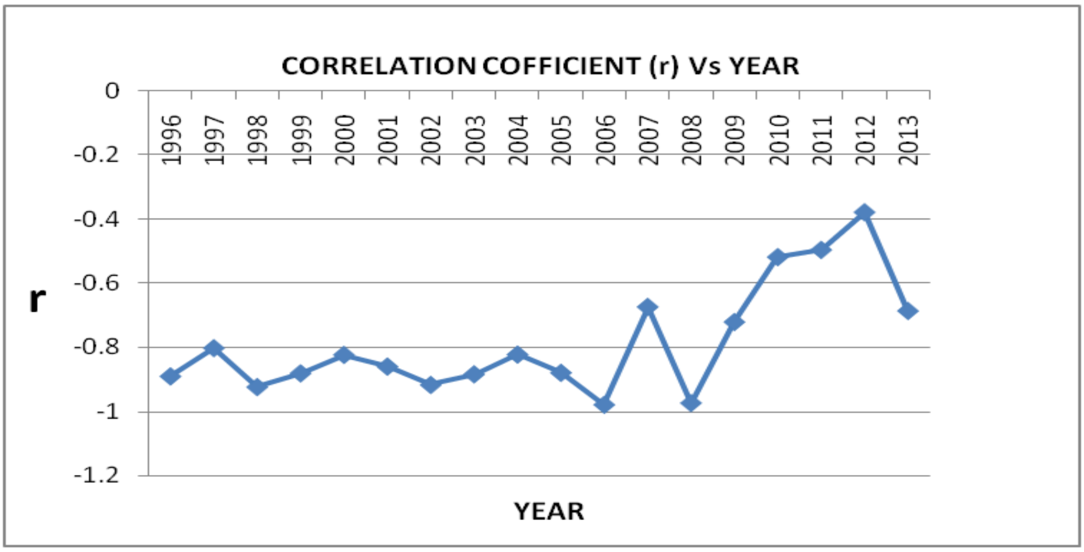

Figure 13. Variation of r of Dst and Kp

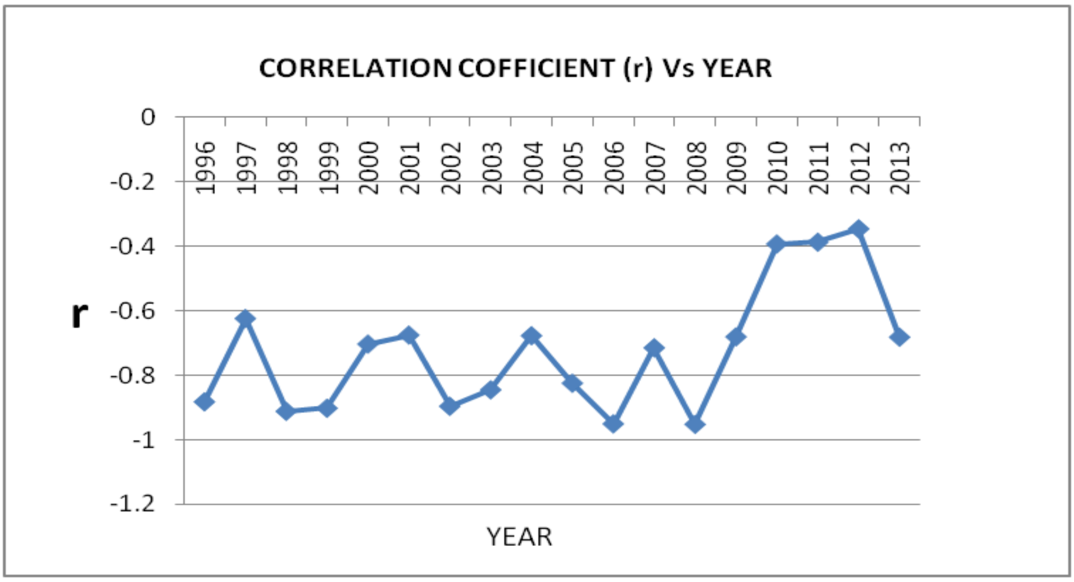

Figure 14. Variation of r of Dst and Ap

Statistical relation of geomagnetic storm with geomagnetic parameters (Kp & Ap)

Fig 11 shows that planetary index (Kp) and dst indices are related negatively with correlation coefficient -0.89. This represents that Kp is also a good indicator of producing geomagnetic storm. Fig 13 shows that correlation coefficient between Kp and Dst varies with time. We observe maximum deviation 0.2 in correlation coefficient between them during 1996-2013.

Fig 12 shows that planetary equivalent amplitude (Ap) and dst indices are related positively with correlation coefficient 0.8 this represent that Ap is also a good indicator of producing geomagnetic storm. Fig 14 shows that correlation coefficient between them varies with time during 1996-2013.

Conclusion:

1. SSN and solar indices both are equally important parameters to predict intense geomagnetic storm because they have same correlation coefficient (-0.65) in long term study (1996-2013)
2. IMF B is better indicator of geomagnetic storm with respect to Bz and flow.
3. Planetary index (Kp) and planetary equivalent amplitube (Ap) both are equally important parameters to predict intense geomagnetic storm because they have same correlation coefficient(-0.89) in long term study (1996-2013)
4. Sun is the source of energy that produce disturbance in interplanetary medium and therefore control the geomagnetic thus solar activity play main role to produce geomagnetic storm.

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