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FUTA Journal of Research in Sciences

ISSN: 2315 8239

FUTA Journal of Research in Sciences, 2013 (2): 269-275

THE VARIATIONS OF PLASMA, FIELD PARAMETERS AND GEOMAGNETIC INDEX DURING GEOMAGNETIC STORM OF APRIL 2010

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ABSTRACT

This research is intended to communicate the results of inter-relationship that exist among the following interplanetary magnetic field (IMF) parameters: (B*z*, B*y*, B*t*) and the geomagnetic index (GI): (Ap, Kp, Dst, Ae) along side with the plasma parameters (T, P and V) during geomagnetic storm. The relationship between the field parameters, GI and plasma parameters with disturbance storm time index (Dst) was studied. A correlative study between the geomagnetic indices and the peak values of various plasma and field parameters during the geomagnetic storm of April 2010 were also presented. Our study shows that, while some of the parameters play active role in Dst morphology, some do not. An antiphase relation was observed in total field and Dst index. Hence mechanisms of the interplay between the parameters are also discussed.

Keywords: Geomagnetic storm and Disturbance storm time index, Dst.

INTRODUCTION

Our sun is an active star which ejects a constant stream of particles called the solar wind into space. From time to time, magnetic activity on its surface also launches fast-moving clouds of plasma called 'coronal mass ejections' or CMEs into space. When some of these clouds directed at the Earth arrive after travelling 93 million miles (150 million km), they cause intense disturbances in Earth's magnetic field. Since the 1800's, these disturbances have been called geo magnetic storms (GMS). During geomagnetic storms, the CME, plasma cloud and its magnetic field collides with the Earth's magnetic field, causing large transient magnetic disturbances. These disturbances can affect the Earth's magnetic field for as much as 2 days causing interference to communication, oil and gas, pipelines and others.

In the last few decades, different parameters have been standardized representing various facets of the solar activity occurring on the various layers of the surface of the sun that is, photosphere, chromosphere, corona and geomagnetic activity (Kumar and Yadav, 2002; Mishra *et al.,* 2005). Currently, the level of geomagnetic activity is measured by the following space weather parameters (Sunspot numbers (SSN), solar flares, coronal holes, geomagnetic Indices Ap, Kp, Dst etc) because of the important role they play in the study of solar-terrestrial relationships.

Three-hourly average values of the Dst, Ae and Ap geomagnetic activity indices have been studied by Saba *et al.* (1997) for 1 year duration each near the solar minimum year of 1974 and at the solar maximum of 1979. They found out that during solar maximum, seven intense GMSs (D*st* < -100 nT) occurred, whereas in 1974 only three were reported and the yearly average of AE is greater in 1974 than in 1979, the reverse seems to be true for the yearly average of Dst. Papitashvili *et al.,* (2000) studied solar cycle effects in planetary geomagnetic activity in which 27-days running averages of several plasma and field parameters (from OMNIWEB data base) are compared with equivalent Kp and Dst averages and concluded that changes in the magnitude rather than in direction are the cause of primary solar cycle variations in the IMF. Gonzalez e*t al.,* (1994) gave a brief review of magnetospheric and interplanetary phenomena at intervals with enhanced solar wind-magnetosphere interaction. It is assumed that the Sun-Earth interaction depends on solar wind. Intense GMSs is related to intense interplanetary magnetic field (IMF) and its southern component for a longer time (Gonzalez and Tsurutani, 1987). Gonzalez *et al.*, (1999) presented a brief study about the interplanetary origin of GMSs and found that two interplanetary structures are important for the development of storms; the sheath region just behind the forward shock, and coronal mass ejection (CME) ejected involving intense southward IMFs.

In this paper, an attempt has been made to examine the interrelationship and the effect of solar and interplanetary medium on the occurrence of moderate geomagnetic storm. Results are presented for the relationships between GI and several plasma and field parameters for GMSs of April 2010.

MATERIALS AND METHODS

Data Collection

The plasma data, geomagnetic index and field measurements of one hour time resolution were obtained from OMNIWEB. Data and quick plots of magnetic field, plasma parameters, geomagnetic indices, ionospheric particle parameters and many more in real time are available at OMNIWEB site and the detail information about the data supply in real time by OMNIWEB can be obtained at *omniweb.gsfc.nasa.gov/ow.html*. For this study, the following parameters are being used to study the storm of April 2010 as to what extent does these inter-planetary field parameters affect the occurrence of geomagnetic storm. Magnitude of average field vector also known as total magnetic field, B*t* (nT) of IMF, negative y-component of IMF, *By* (nT), negative z-component of IMF, *Bz* (nT) used in this study are in geocentric solar ecliptic (GSE) coordinate system. The plasma parameters used are: proton temperature, *T* (^{o}K), proton density, *D* (N/cm^{3}), plasma speed, *V* (km/s). Geomagnetic index: Kp, Dst, Ap and Ae.

RESULTS

Correlations between Geomagnetic Indices, Field and Plasma Parameters

The correlation coefficient between the geomagnetic indices is shown in Table 1. From these results, it is clear that Dst show strong negative correlation value with *Kp*, *Ae* and *ap* indices while *Ae*-index is well correlated (positive) with *Kp* and *ap* indices. These results depict an anti-phase relationship; positive enhancement in geomagnetic index (GI) results in increasing negative magnitude of Dst that eventually result in storm. GI revealed a strong linear positive correlation and this clearly indicate that the three indices considered (*Ae*, *Ap* and *Kp*) agree favourably well as good index and any of the index could be interchangeably used. Table 2 is the result of the correlation between *Dst* index and the field parameters. The *Dst* is weakly correlated with *Bt*, *By* but moderately strong when correlated with *Bz*. This result is in agreement with Manshilla (2008) where he found that peak D*st* is correlated to the maximum negative component of *Bz* of the IMF and better than the maxima of solar wind number density, *D* and solar wind speed, *V*.

Table 1: Correlation coefficient between D*st* and GI

	Dst	Kp	Ae	Ap
Dst	1			
Kp	-0.7607	1		
Ae	-0.8405	0.9175	1	
Ap	-0.7295	0.9191	0.8848	1

Table 2: Correlation coefficient between *Dst* and field parameters

	Dst	Bt	By	Bz
Dst	1			
Bt	-0.3835	1		
By	0.3188	-0.5045	1	
Bz	0.6084	-0.2486	0.4309	1

From Table 3, it is seen that *Dst* and V show anti-phase relation with strong negative correlation with *V*; whereas the correlation of *Dst* with *D* is moderately strong while correlation of *Dst* with *K* is weak. This result is similar to Yadav (2005).

Table 3: Correlation coefficient between D*st* and plasma parameters

	Dst	D	V	K
Dst	1			
D	0.5117	1		
V	-0.7565	-0.5998	1	
K	-0.3942	-0.3499	0.73	1

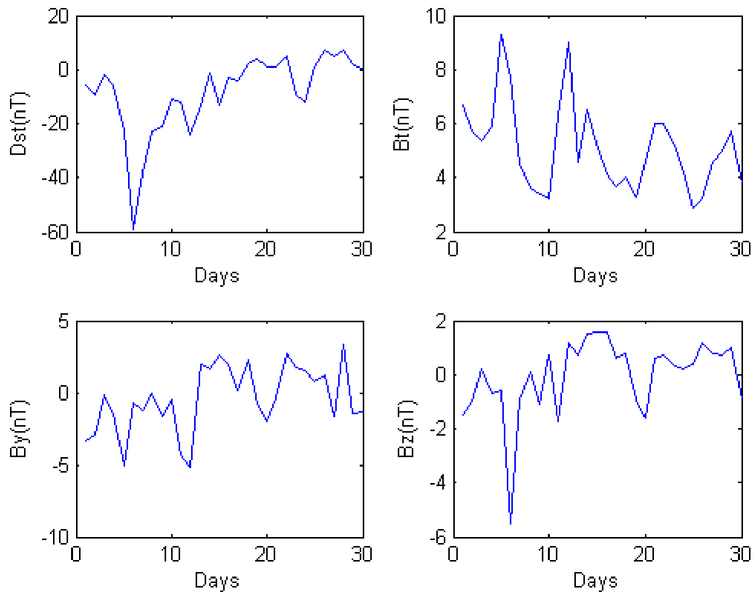

Figure 1: The graph of *Dst* and *Bt, By and Bt* for the month of April 2010

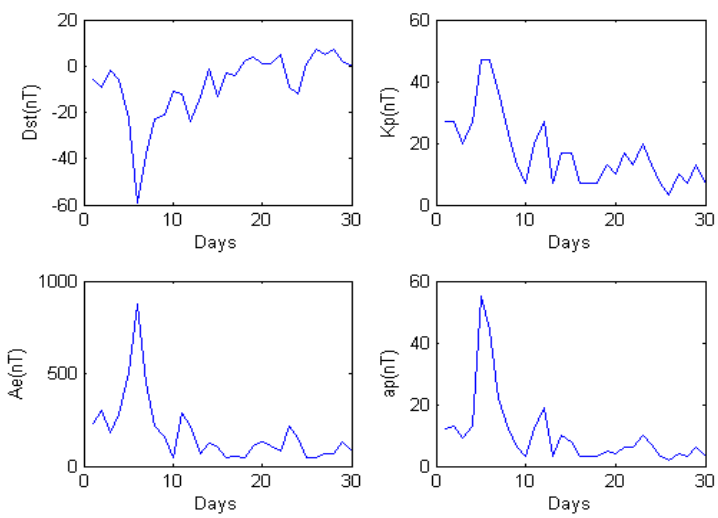

Figure 2: The graph of *Dst* and *Kp, Ae and ap* for the month of April

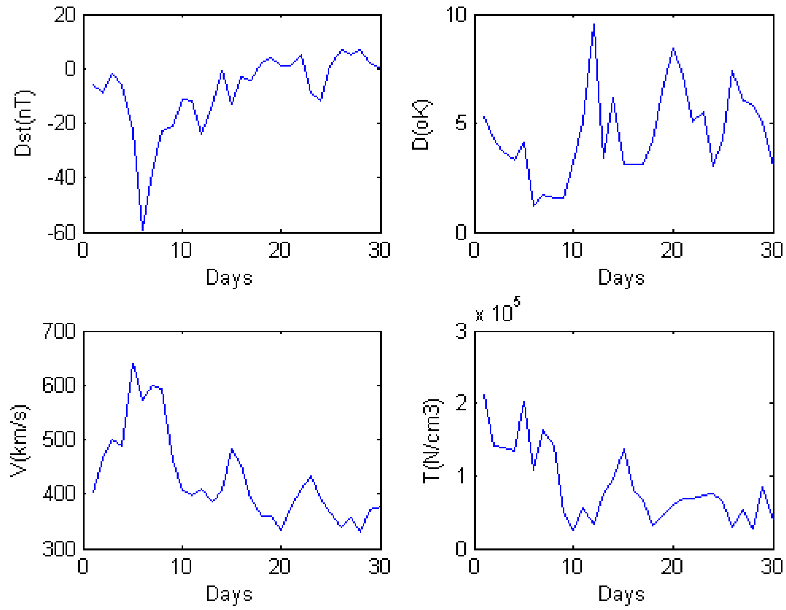

Figure 3: The graph of *Dst* and *D, V and T* for the month of April 2010

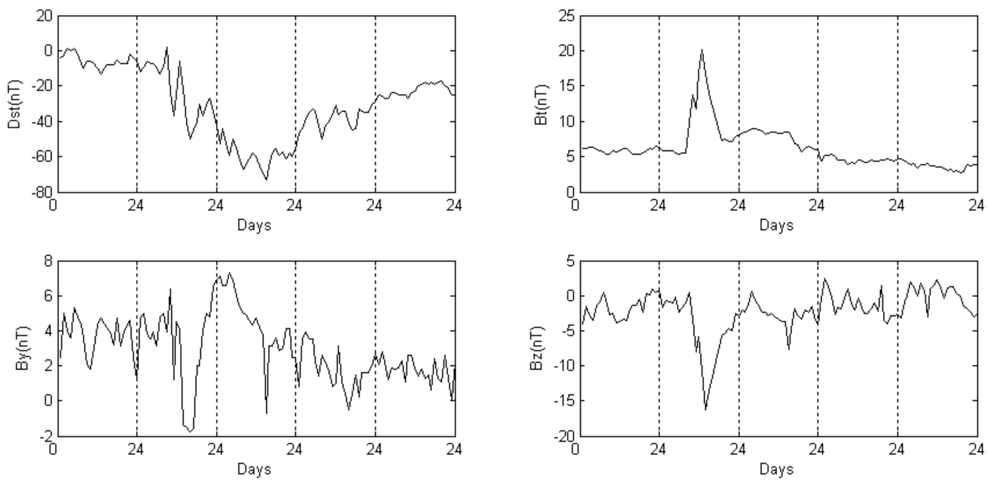

Figure 4: The graph of *Dst* and field parameters showing the sudden commencement, main phase and recovery phase of April 2010 storm (4^{th} - 8^{th}April 2010)

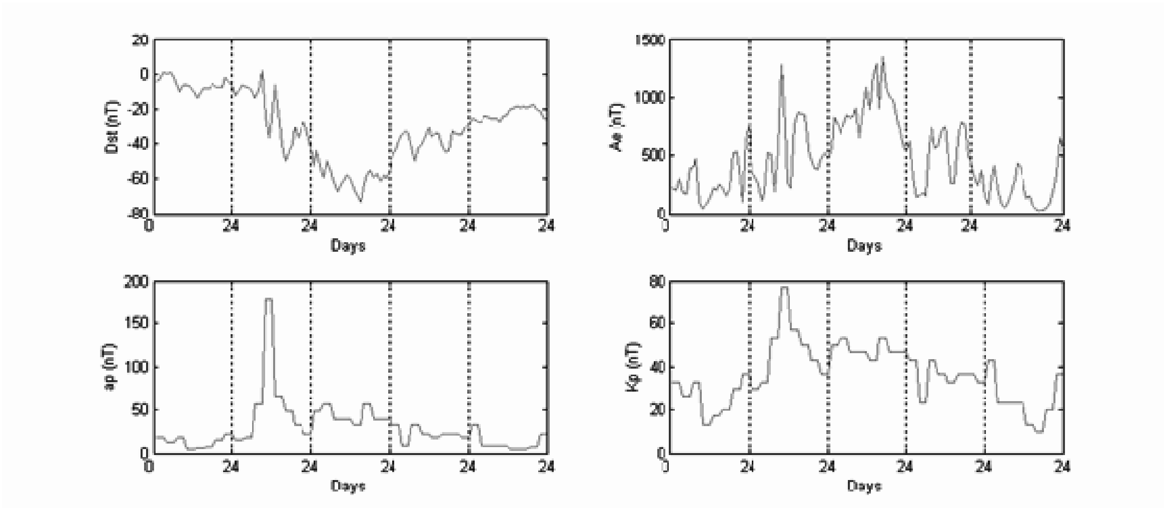

Figure 5: The graph of D*st* and geomagnetic index (GI) showing the sudden commencement, main phase and recovery phase of April 2010 storm (4th - 8th April2010)

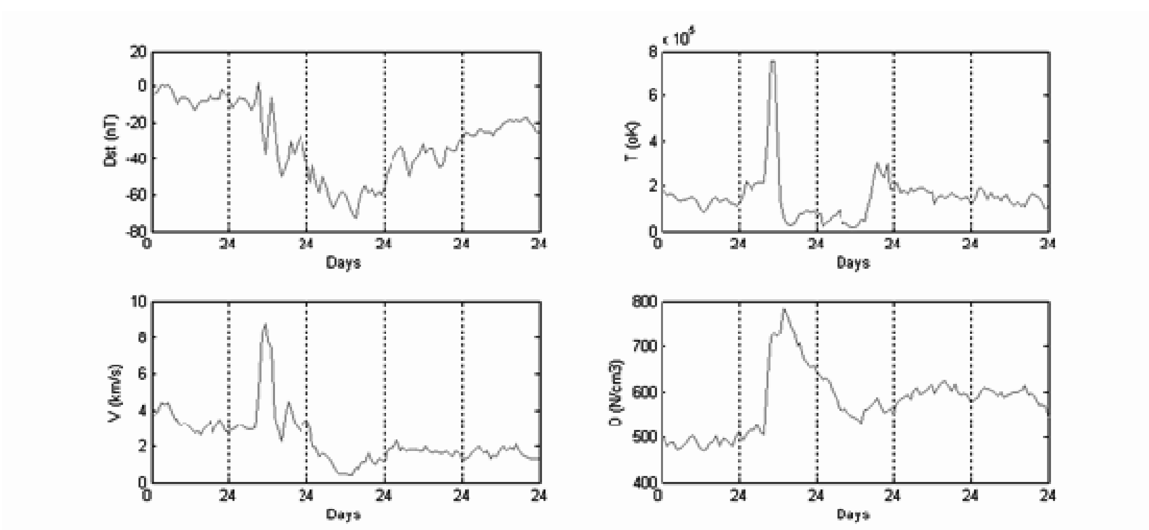

Figure 6: The graph of D*st* and plasma parameters showing the sudden commencement, main phase and recovery phase of April 2010 storm (4th - 8th April 2010).

DISCUSSION

The Variation of Plasma, Field Parameters and Geomagnetic index with Dst

Figures (1-3) shows the hourly plots of Dst with GI, field and plasma parameters. From Figure 1, after the sudden storm commencement (SSC) on day 5, April 2010; the Dst index rapidly increases negatively following the southward turning of *Bz* component of IMF and reached a maximum value on 6^{th} of April 2010 indicating the main phase of the storm. The *Bz* component of the IMF oscillated rapidly for several hours then turned north for several hours and finally turned to south on April 7, 2010. This observation is in agreement with the results of Kane and Echer (2007) who found that during the geomagnetic storm, the larger negative Bz gives the stronger negative Dst.

Figure 2 shows the graph of *Dst, Kp, Ae and ap* for the month of April 2010. The graphs show that during sudden commencement of the storm, a rapid increase in the value of *ap* and *Kp* were observed indicating a storm is approaching. This implies the *kp* and *ap* index could be used as parameters to predict the occurrence of geomagnetic storm. However, during the main phase of the storm, *Ae* increases positively as Dst increases negatively.

In Figure 3, a sudden increase in the solar wind speed occurred around 06:00 UT on April 5, 2010 indicating the arrival of GMS, at 08:00UT. The T and D value also increases at this time. Following the sudden commencement of the storm, *Ds*t value increased rapidly on day 6 of April 2010 showing the main phase of the storm. On day 7, the storm has fully recovered.

The Storm Phase

Figures (4-6) show the plot of Dst with field, GI and plasma parameters during the sudden commencement of the storm noticed on day 5 of April 2010, the main phase on day 6 of April 2010 and the recovery phase on day 7 of April 2010. From Figure 4, the sudden commencement is seen on the 5^{th} of April 2010 at 11:00UT; as this sudden increase in Dst value, a corresponding increase in *Bz* was observed. This is because *Bz* allows sufficient energy transfer from the solar wind into the Earth's magnetosphere through magnetic reconnection. Looking at the main phase of the storm, on 6^{th} of April 2010, at 07:00UT, the Dst value recorded is -67nT. The main phase lasted for 7hours where another increase is seen in the value of Dst to -73nT at 14:00UT after which the storm gradually recovered. The recovery phase lasted till the 8^{th} day. Figure 5 is the graph of Dst and GI showing different phases of the April 2010 storm. As explained above for Dst, it was noticed that GI, the *kp* and *Ae* increases rapidly. During the commencement of the storm, geomagnetic indices (*kp, Ae* and *Ap*) considered show positive peak signifying the storm commencement. At main phase only *Ap and kp* index return to their original level of variation while *Ae* show another peak during the main phase of the storm.

Considering Figure 6, solar wind number density, *D*, solar wind speed, *V* and proton temperature, *T* increases rapidly during the sudden storm commencement signifying that a storm is approaching and the behaviour is similar to GI.

CONCLUSIONS

Looking at the relationship between Dst index, geomagnetic indices (GI), field and plasma parameters. The main conclusions can be summarized as follows:

- From table 1, it can be seen that the peak values of all three GI parameters are highly correlated with each other with correlation coefficient value R $\geq$ 0.8 while Dst show a strong negative linear relationship when correlated with the GI parameters. This suggests an anti-phase interrelationship between the storm index and GI. Among the plasma field parameters, only D show fairly positive linear relationship with Dst index with R value of 0.51 while V exhibit strong negative relationship as shown in Table 3
- The result from Table 2, revealed that the peak value of Dst index show strong and positive correlation (R = 0.61) with peak value of Bz. This could be as a result of similar sources of variation in Dst and Bz
- Peak value of Dst index is well correlated with peak values of V (Table 3).
- From the above observations it can be concluded that the peak values of GI are in good correlation with Dst and hence these parameters are most useful for predicting GMSs.
- Comparative analyses of correlation coefficients of Dst with field parameters show that Dst index is more correlated with Bz which is in agreement with some existing results on Dst and V, such as Yadav (2005).

- The Ae and ap index could be used as parameters to predict the occurrence of geomagnetic storm
- Finally, the study of GMSs and behaviour of plasma and field parameters during the storm of April 2010 yields new information about the origin of GMSs and their effect on the Earth's atmosphere.

ACKNOWLEDGEMENT

The authors are highly grateful to OMNIWEB (omniweb.gsfc.nasa.gov/ow.html) for providing real time interplanetary indices data used in the study and also Space Physics Laboratory, Federal University of Technology, Akure.

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