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ASSOCIATION OF RESIDUAL HORIZONTAL GEOMAGNETIC FIELD WITH INTERPLANETARY MAGNETIC FIELD PARAMETERS

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ABSTRACT: *The influence of IMF parameters on the depression of residual H – component of geomagnetic field at Mbour and Tamanrasset Geomagnetic Observatory stations was studied in 2004 and 2010. The measure of storm occurrence (Dst index) was used to select successful storm days. The effect of IMF parameters on residual H – component was investigated using filter analysis. The results showed very close correspondence of rapid changes in amplitudes between residual H – component and IMF parameters of solar wind velocity, proton density, B_z, VP and PB as examined in time and frequency domains. The quantitative relationship between residual H – component and IMF parameters of solar wind velocity, proton density, B_z, VP and PB was found to be 0.50, 0.55, 0.70, 0.60 and 0.63 respectively. This is direct evidence that B_z, PB and VP are more effective in causing geomagnetic fluctuations at equatorial low latitude stations.*

KEYWORDS: magnetosphere, residual field, storm, IMF parameters and noise interference

INTRODUCTION

Variations in the magnetic surroundings of the earth are of concern to scientists especially those studying space weather and climate change. Geomagnetic field extends from the inner core of the earth to a region known as the magnetosphere. The magnetosphere experiences disturbance during storm-time and this is suspected to be as a result of the intrusion of stream of charged particles coming from the sun surface or environment.

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Magnetic storm consists of three phases namely initial phase, main phase and the recovery phase. The storm is sometimes being initiated by sudden storm commencement (SSC) which is just a sharp jump in the horizontal magnetic field. This effect is experienced within the limit of initial phase of storm which sometimes dies off without producing storm (Rajni, Smita, Shailendra, Babita and Ajay, 2008). Some storms are not associated with sudden storm commencement (SSC) (Tsurutani, 2001). The diurnal variation is suspected to trigger off current that could cause substorms or main storm (Obiekezie, Obiadazie and Agbo, 2013). The main objective of this work is to investigate the influence of interplanetary magnetic field (IMF) parameters on horizontal component of ground magnetic field, at periods flanking low sunspot minimum. Magnetosphere reacts to the activities of the IMF parameters in diverse complexity (Rajni et al, 2008, Gonzalez et al, 1994). The common feature of geomagnetic storm is the growth and recovery of the ring current induced in the inner part of magnetosphere (Terada et al, 1998).

Off course magnetic storms have severe effects in this our civilized generation. These problems associated with intense or super storms can ordinarily be remedied by meteorological forecast or prediction of space events before time. Apart from the remedy, high energy radiating particles can cause cancer of the skin and electronic damages. Human beings will not be safe but because scientists are working tremendously to put space weather under control to reduce human risk and economic loss. The effect of storm is most effective when interplanetary magnetic field (IMF) moves in southward direction (Workshop Report of National Research Council of Academies, (2008), Bartels, Heck and Johnson, (1939).

Data and Method of Analysis

Two sets of data were used in this research. The first set involves disturbance storm (Dst) index and ground magnetic field horizontal component at two observatories – Tamanrasset (TAM) and Mbour (MBO) stations. Both of these stations are low latitude stations in Africa. The latitude and longitude of these observatories along with the observatory names and codes is giving in Table 1. These set of data are obtained from World Geomagnetic Data Centre website in Kyoto Japan. The months of successive storm as selected from the two years are shown in the table below.

Station name	Station code	Longitude	Latitude
Tamanrasset	TAM	17º	14º
Mbour	MBO	6º	23º

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Table 1: Station name, code and coordinates

S/N	Days	Month	Year	Component/parameters
1	25 – 27	July	2004	Dst, H - component and IMF parameters
2	4 – 5	August	2010	Dst, H - component and IMF parameters

Table 2: Selected days of storm in 2004 and 2010.

The second set of data involves the interplanetary magnetic field (IMF) parameters, which includes solar wind velocity (V), proton density (P), total magnetic field (B), product of V and P (VP), product of V and B (VB) product of P and B (PB). These data were downloaded from the OMNIWEB website.

Two years (2004 and 2010) of data having Dst index occurrence and flanking the recent solar minimum were downloaded and the days of occurrence of storm were inspected and selected as shown in Table 2. The choice of this time window is to investigate the storm effect on the geomagnetic field component when the activities of the sun are low. This is done to eliminate other extraneous effects coming from the sun. Universal time (UT) was employed throughout this study. The baseline values of H – component and selected IMF parameters were calculated as the average of the values of the hours flanking the mid-night,

$$H_0 = \frac{H_{00}+H_{01}+H_{22}+H_{23}}{4} \quad 1$$

Where $H_{00,}$ $H_{01,}$ $H_{22,}$ and $H_{23,}$ are the hourly values of H - component and selected IMF parameters for at 0000, 0001, 2200 and 2300 hourly UT respectively, H_0 = baseline value.

The change in H_0 (ΔH_O) for any hour, t, is the difference between the hourly values of $H_{t,}$ and the baseline (H_0).

$$\therefore \quad \Delta H_0 = H_t - H_0 \quad 2$$

Where $t = 0, 1, 2, 3, \dots \dots . 23$ hours, ΔH is the change in the H – component during the quiet time and disturbed time.

The international quiet days and disturbed days were selected based on the planetary magnetic index as published by the Australian Geosciences website. The residual horizontal geomagnetic field was determined by the expression {(Disturbed – Quiet) – Dst cos λ_m} for the two stations. Where λ_m is the magnetic latitude of a station.

The residual component field for each of the stations as well the IMF parameters was each plotted against the universal time on a separate graph. This is done as to view and identify any correspondence of events. A better way of viewing the data is in frequency domain referred to as spectral analysis. This was done using MATLAB software. The basis of spectral analysis is the Fourier analysis equation of the form;

$$Y_t = A_n sin\,(2\pi\, ftn + Q_n) \qquad 3$$

Where $Q_n = tan^{-1}\left({}^{a_n}/_{b_n}\right)$, $A_n = \sqrt{a_n^2 + b_n^2}$, $t = 1, 2, \ldots \ldots \ldots 24,\; n = 1 \ldots \ldots 6$

Regression analysis using Excel package was also done to obtain the quantitative relationship between the residual horizontal geomagnetic field component and each of the selected IMF parameters.

RESULTS AND DISCUSSIONS

Observation for the Event of 25th – 27th July, 2004.

Figs. 1b and 1c are the residuals of horizontal (H) component of Mbour (MBO) and Tamanrasset (TAM) stations. This follows from the subtraction of quiet days and adjusted Dst index from the disturbed H – component for each of the stations. The Dst index which is the measure of storm occurrence is shown in fig. 1a. The IMF parameters in-line with the residual fields of solar wind velocity, product of V and P (VP) and B_z which are respectively shown in figs. 1d, 1g and 1j.

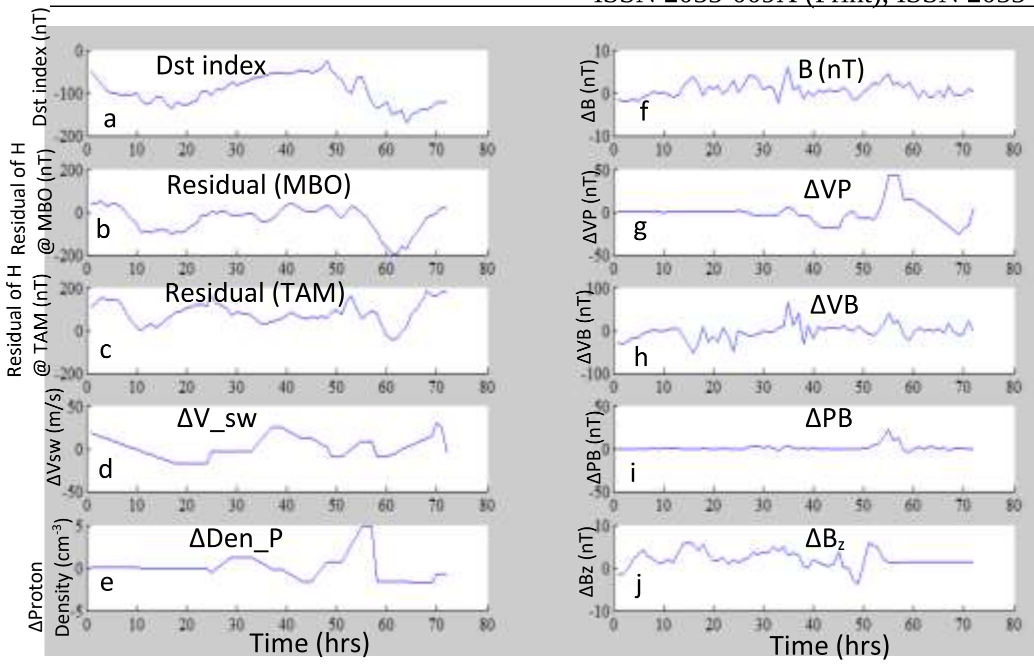

Fig. 1: Variation of (a) Dst index and the hourly mean of (b) residual H – component in MBO,
(c) residual field at TAM, (d) V_sw, (e) Den_P, (f) B, (g) VP, (h) VB, (i) PB, and (j) B_z
of IMF for the storm days of 25th – 27th July, 2004.

There was observed sudden storm commencement (SSC) in the corrected H – components at the two stations. This is in-line with the Dst index which is regarded as the measure of storm occurrence. The main phase of the storm was seen to occur at noon time of the first day (25th July, 2004) of storm with Dst index reaching the peak at -150nT. Another main phase of the storm was also observed on the third day of the storm event (27th July, 2004) at -175nT of Dst index value. Each of the storms was followed by slow recovery. Thus the change in H – components at both stations is very similar to changes in Dst index. The maximum decrease of residual H – component at MBO and TAM are -200nT and -95nT respectively.

It is interesting to observe that residual H – component of geomagnetic field at both stations show decreasing trend similar to Dst index sharing same period of occurrence. In this regard the Dst index is however not responsible for the fluctuation of the residual field observed at MBO and TAM but suspected to be coming from distant sources. The solar wind velocity, VP and B_z are seen to have similar fluctuating structure with residual fields

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at both stations. Thus, it is obvious that fluctuation observed at the residual field is associated with the activities of the solar wind parameters especially the solar wind velocity, VP and B_z. This remarkable similarity of events calls for further studies to ensure if the cause of the fluctuation on the H – component is coming from local or upstream sources.

Observation for the Event of 4th – 5th August, 2010.

Fig. 2 presents the Dst index during the storm event, residual H fields of both stations under study and IMF parameters of solar wind velocity, proton density, total B, VP, VB, PB and B_z respectively. The residual H – components at both stations and IMF parameters are aligned each, one by one for clearer visibility of their individual spectrum. A close look at the residual H component and the selected IMF parameters revealed similarities of events between H – component at both stations and IMF parameters. Maximum downward peaks of residual fields at both stations occurred at about 1200hrs on the first day of storm being 4th August, 2010.

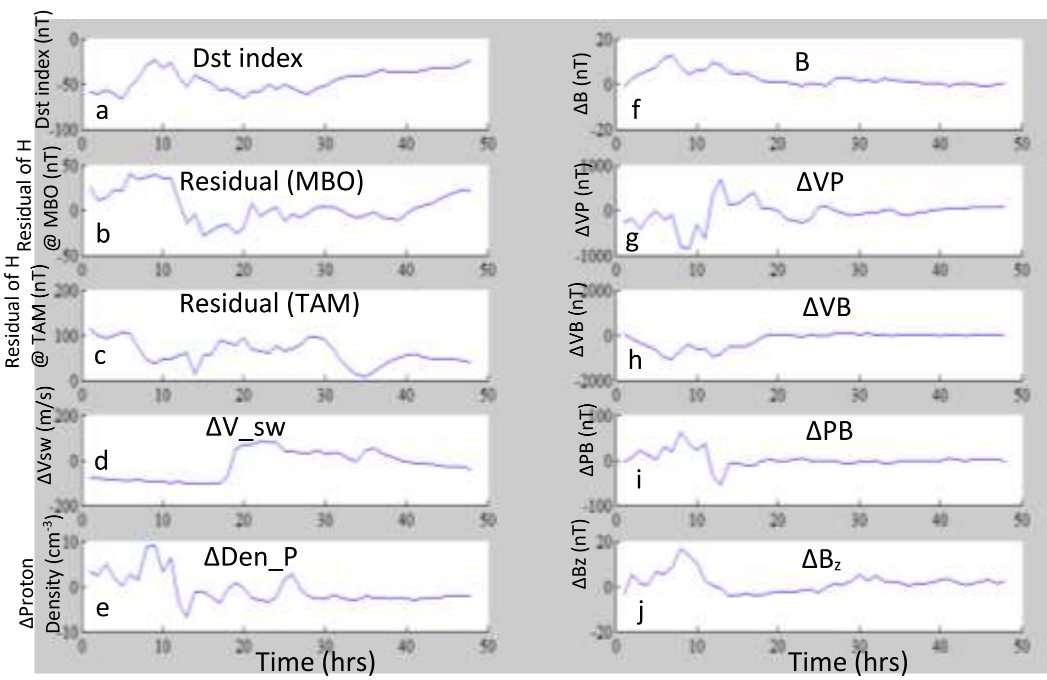

Fig. 2: Time series of hourly (a) Dst index and the hourly mean of (b) residual H – component in MBO, (c) residual field at TAM, (d) V_sw, (e) Den_P, (f) B, (g) VP, (h) VB, (i) PB, and (j) B_z of IMF for the storm days of 4th – 5th of August, 2004.

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Solar wind velocity, proton density, VP and PB have similar trend of events with the residuals whereas B_z showed a corresponding rise that matches the same effect of storm event as observed on residual H – component within the same period. It is interesting to observe similarities between residual ground magnetic field at both stations and IMF parameters especially the solar wind velocity, proton density, VP, PB and B_z because it is in-line with the previous results of the considered storm events.

Generally, the observed maximum negative peaks on the amplitudes of H – component at MBO and TAM in time domain is seen to correspond with the maximum amplitudes of the interplanetary magnetic field (IMF) parameters of solar wind velocity, proton density, VP, PB and B_z in almost all the events. Dst index for all the events indicates clearly that there was occurrence of storm for each of the event periods and the trend of amplitudes at each time align with the residuals of H – component at both stations. Normally ground magnetic field data are usually mixed with unwanted signals and after removing the noise interference from the H – components, the amplitudes of signals still persistently displayed features signatory to storm. It is interesting to observe that initial phase, main phase and recovery phase of each of the storm events is seen to be more visible. The amplitude of H – component in MBO and TAM maintained the same amplitude shape. It is also observed that solar wind velocity, proton density, VP, PB and B_z have more common regular amplitude structure with the residual H – component at both stations than the other selected IMF parameters. Sudden storm commencement (SSC) was seen to be experienced in some storm events and this is suspected to be as a result of sudden sharp intrusion of solar wind into the ground magnetic field. The time domain of all the parameters was transformed into frequency domain to investigate further if the cause of variation of the H – component is due to distant or local effect. Fortunately, it is obvious to observe that the maximum rise in the amplitudes of H – component in the frequency domain is observed to have corresponding features with IMF parameters of solar wind velocity, proton density, VP, PB and B_z as was also observed in time domain. The storm effect is observed to be more rapid in the noon hours and sometimes recovers late in the night. There was no significant change in amplitude of H – component signatory to storm that was observed in the morning hours. The regression analysis between the IMF parameters and residual H – component completely revealed effective dependence of the depression of H – component on IMF parameters of solar wind velocity, proton density, VP, PB and B_z. The value of the correlation coefficient (r) between residual H-component and solar wind velocity was found to be 0.5 on the first storm event considered. The value of 'r' for proton density, VP, PB and B_z are found to be 0.59, 0.60, 0.63 and 0.70 respectively. However, it is observed here that B_z, the product of V and P (VP) as well as the product of P and B (PB) are more

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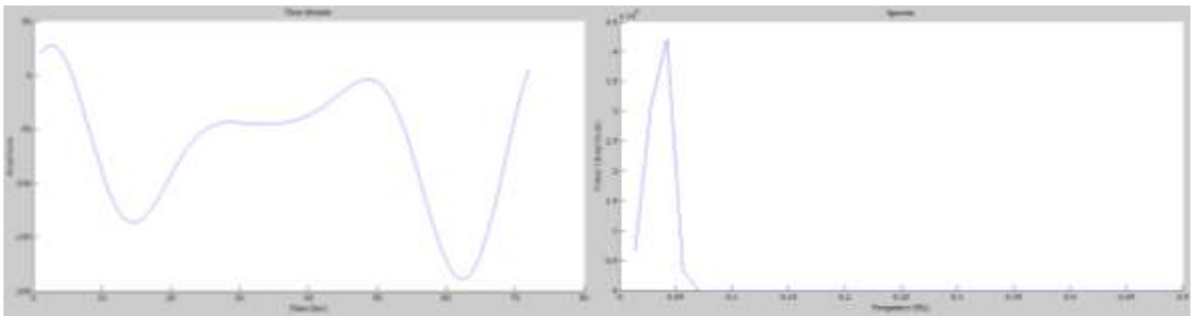
effective in triggering geomagnetic field disturbance. This is in agreement with Jaya et al, (2010) and Vichare and Alex, (2006).

The power spectra of the residuals of ground magnetic field of the events in 2004 and 2010 are shown in figs. 3 - 12 below. The residual of ground magnetic field together with selected solar wind parameters were then transformed from time domain to frequency domain using fast Fourier transform (fft) technique with time window of 48 hours and 72 hours depending on the duration of each storm. This gave the opportunity for the display of discrete frequencies occurrence for each of the respective events. The calculations were done using MATLAB software. It was observed that the maximum amplitudes of the



residual H – component at both stations were seen to correspond with most of the IMF parameters.

Fig. 3: Time domain and power spectral density of residual H component at MBO station during 25th – 27th July, 2004.

Residual (MBO)

Residual (MBO)

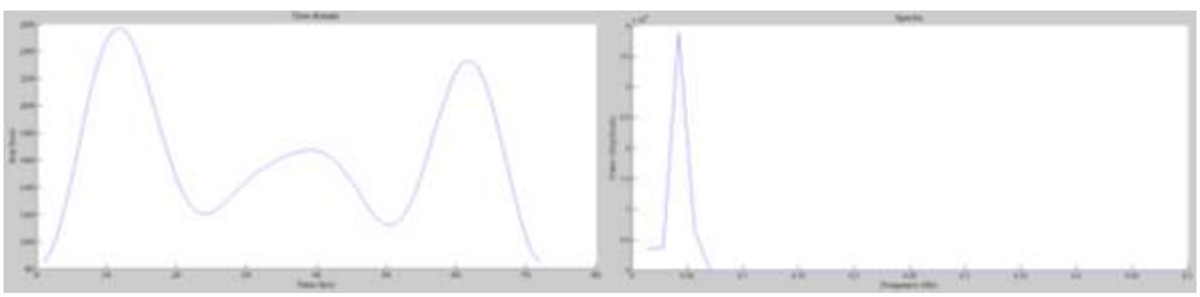


Fig. 4: Time domain and power spectral density of res. H at TAM for 25th – 27th July, 2004.

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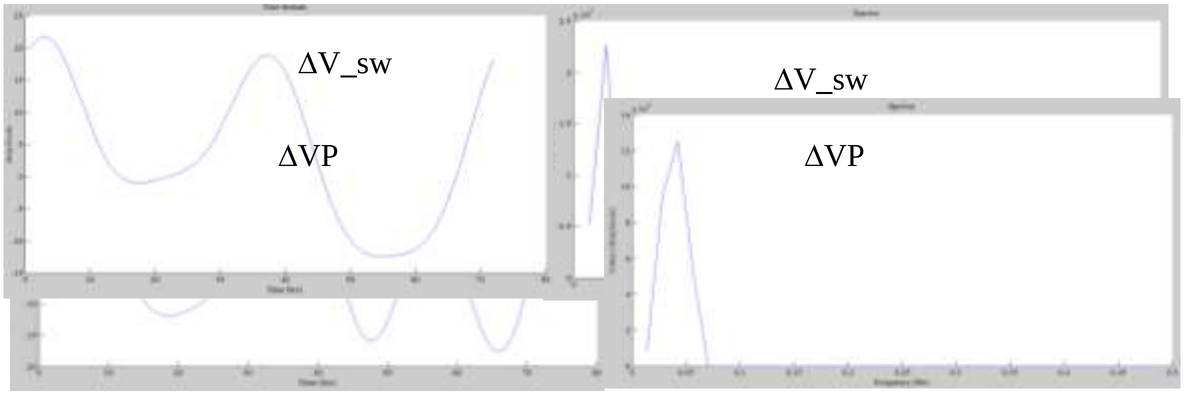

Fig. 5: Time domain and power spectral density of solar wind velocity for 25th – 27th July, 2004.

Fig. 6: Time domain and power spectral density of VP for 25th – 27th July, 2004.

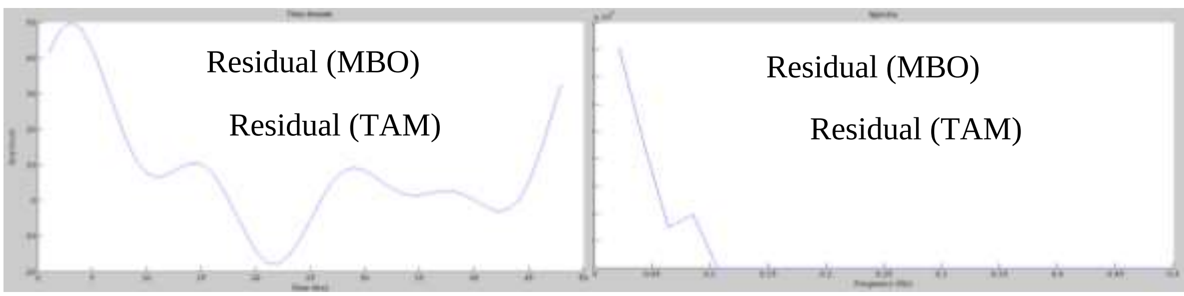

Fig. 7: Time domain and power spectral density of res. H at MBO for 4th – 5th August, 2010.

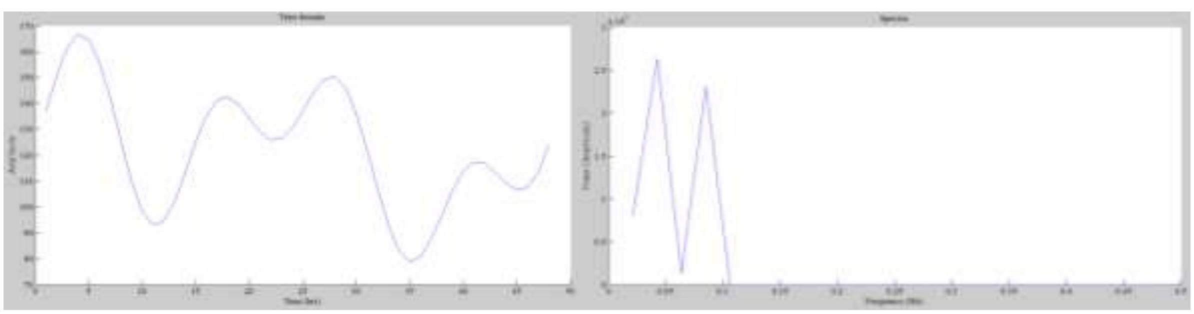

Fig. 8: Time domain and power spectral density of res. H. at TAM for 4th – 5th August, 2010.

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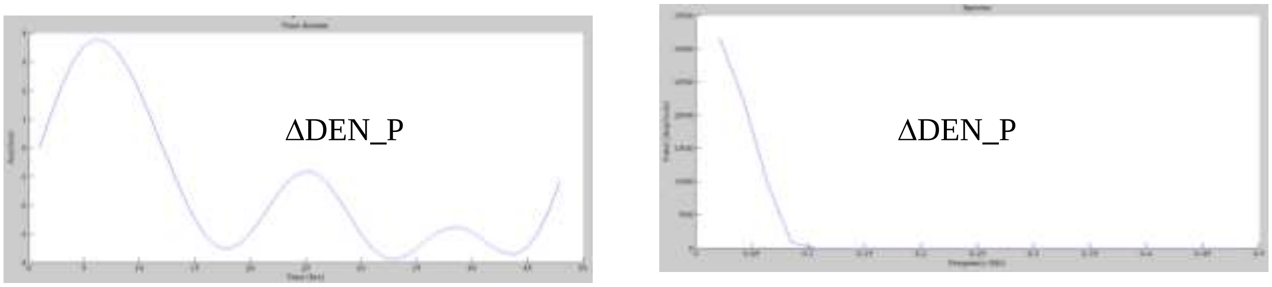

Fig. 9: Time domain and power spectral density of proton density for 4th – 5th August,20

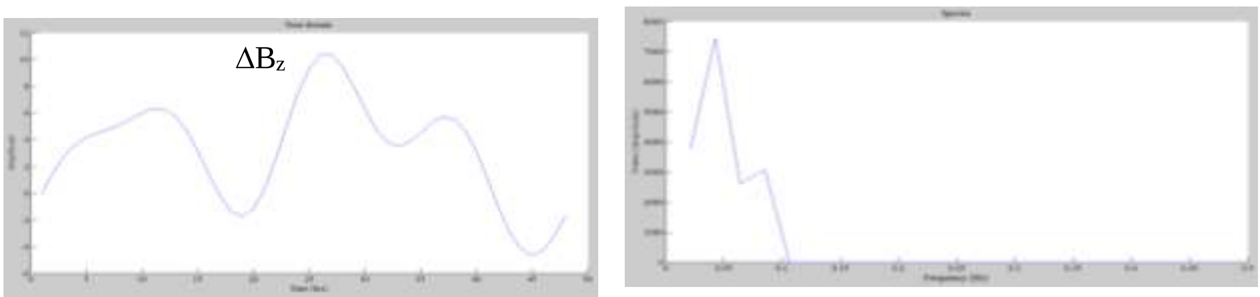

Fig. 10: Time domain and power spectral density of B_z for 4th – 5th August, 2010.

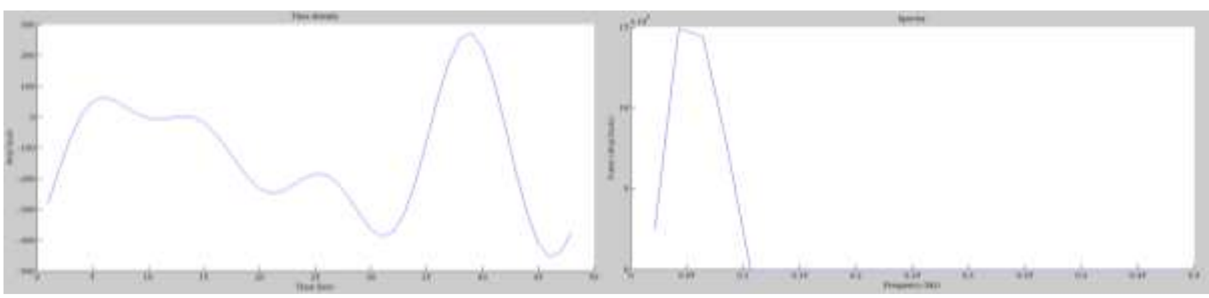

Fig. 11: Time domain and power spectral density of VP for 4th – 5th August, 2010.

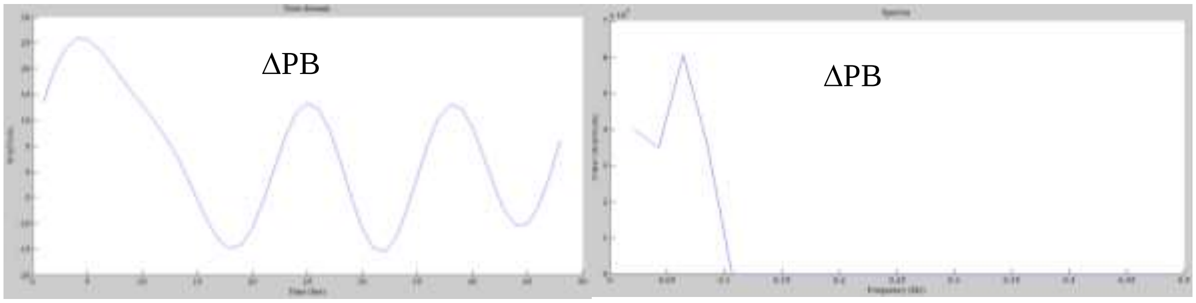

Fig. 12: Time domain and power spectral density of PB for 4th – 5th August, 2010.

SUMMARY/CONCLUSION

Investigation of the influence of the interplanetary magnetic field (IMF) parameters on horizontal component of geomagnetic field was carried out in two stations in Africa within the low latitude. There was observed decreasing trend in amplitudes of residual H – component at both stations. The IMF parameters were observed to have the same shape with residual field at the same time.

From the results, it was confirmed that the interplanetary magnetic field parameters are actually responsible for the depression of horizontal component of geomagnetic field. Based on the observations from time domain, frequency domain and the regression analysis; it was deduced that the activities of IMF parameters significantly fluctuate the horizontal component of geomagnetic field especially the Bz, product of V and P (VP) and product of P and B (PB).

Acknowledgement

Two sets of data used for this research were obtained from World Geomagnetic Data Centre Website in Kyoto Japan and OMNIWEB Website. My supervisor Professor G. A. Agbo played a key role on this research and references are made on this work, we say thank you to all.

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