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INVESTIGATING THE VARIATIONS OF HORIZONTAL (H) AND VERTICAL (Z) COMPONENTS OF THE GEOMAGNETIC FIELD AT SOME EQUATORIAL ELECTROJET STATIONS

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ABSTRACT

This research is monitoring equatorial geomagnetic current which causes atmospheric instabilities and affects high frequency and satellite communication. It presents the variations of Horizontal (H) and vertical (Z) component of the geomagnetic field at some Equatorial Electrojet (EEJ) Stations during quiet days. Data from five (5) observatories along the magnetic equator were used for the study. Daily baseline values for each of the geomagnetic element H and Z were obtained. The monthly average of the diurnal variation and the seasonal variations were found. Results showed that the variations of the geomagnetic element of both H and Z differ in magnitudes from one stations to another along the geomagnetic Equator due to the differences of their geomagnetic latitude. The Amplitude curves for S_q (Z) are seen to be conspicuously opposite to that of S_q (H), and there is absence of CEJ in Z- Component but present in H- Components. The S_q values during the pre-sunrise hours are low compare to daytime hours. Minimum variations of dH was observed during June solstice and maximum variations was observed during Equinox season. This study shows that daily variations of (H) and (Z) occur in all the stations. The enhancement in H is as a result of EEJ current.

Keywords: Geomagnetic components, Magnetic Equator, Equatorial Electrojet, Variations

INTRODUCTION

Rabiu et al. (2007) examined the variability of equatorial ionosphere by using ground based geomagnetic field data of H and Z obtained at the equatorial station of Ibadan. The results showed that values of Sq daily variation rises from the early morning period to maximum at about local noon and falls to lower values towards evening, hence the ionospheric current responsible for the magnetic field variations was inferred to build up at the early morning periods and attain maximum intensities at about local noon .Previous studies on the longitudinal variability of the equatorial electrojet (EEJ) and the occurrence of its counter electrojet (CEJ) using the available records of the horizontal component H of the geomagnetic field simultaneously recorded in the year 2009 (mean annual sunspot number Rz = 3.1) along the magnetic equator in the South American, African, and Philippine sectors. The day to day variability of the geomagnetic field elements at the African longitudes has been studied for the year 1987 using geomagnetic data obtained from four different African observatories. The analysis was carried out on solar quiet days using hourly values of the H and Z, geomagnetic field values. The results of this study confirm that is a very changeable phenomenon, with a strong day-to-day variation. This day-to-day variation is seen to be superimposed on magnetic disturbances of a magnetospheric origin (Obiekezie, et al., 2013).

Under quiet geomagnetic conditions the variations of the three geomagnetic elements H, Z, and D from one day to the next in June, October, and December 1986 at eight Indian observatories from about 0° to 22° dip latitude was studied. The day to day variability was also measured by sequential Variability, (SV). In all the three months, the magnitude of day to day variability in H, Z, and D had a diurnal variation with maximum around local noon and minimum in the night. This is most likely Controlled by the diurnal variation of ionospheric conductivity. In the worldwide part of S_q (WS_q) zone, the SV in H, Z, and D was smaller in October than in June and December 1986, but SV(Z) is greater than SV(H) and SV(D) in all the three months. In the equatorial electrojet (EEJ) zone, the SV due to the EEJ alone in alone in H, Z, and D is greater in June than in October and December contrary to the seasonal variation of S_q (H) and S_q (Z) in the EEJ zone. The SV(D) due to the EEJ alone had a surprising large magnitude. There is evidence that the day to day variability of EEJ and the 〖WS〗_q are not in phase and consequently combine somewhat destructive within the EEJ zone (Okeke and Onwumechili., 1995).

Data and Method of Analysis

Magnetic data for 2008 was used for this study. Magnetic data Acquisition System (MAGDAS) of some stations within the magnetic equatorial belt which the University of Ilorin, Ilorin (geographic latitude: 8.470 N, geographic longitude: 4680 E, geomagnetic latitude :1.820S, geomagnetic longitude: 78.600 W), Nigeria is one of them. The geomagnetic field horizontal (H) and vertical (Z) components data in minutes are converted to hourly values using the MATLAB program. Hence hourly average of horizontal and vertical components was obtained. Stations along the geomagnetic equator were chosen because the aim is to investigate the variation of H and Z components of the geomagnetic field under quiet conditions at some selected geomagnetic observation along the magnetic equator. For each month of the year, there are ten (10) International quietest days (IQDs) and five (5) most disturbed (IDDs). Magnetic data for five (5) quietest days of each month for the year 2008 were used in this study (available at www.ga.gov.au). These days were considered based on magnetic activity index k_p . The k_p index for quietest days is within the range of 0-4. The concept of local time was used throughout the analysis as the stations might be few hours ahead of the Greenwich Meridian Time (GMT). Stations considered were indicated by white star color Figure 1. Table 1 shows the coordinates of the stations used in the study.

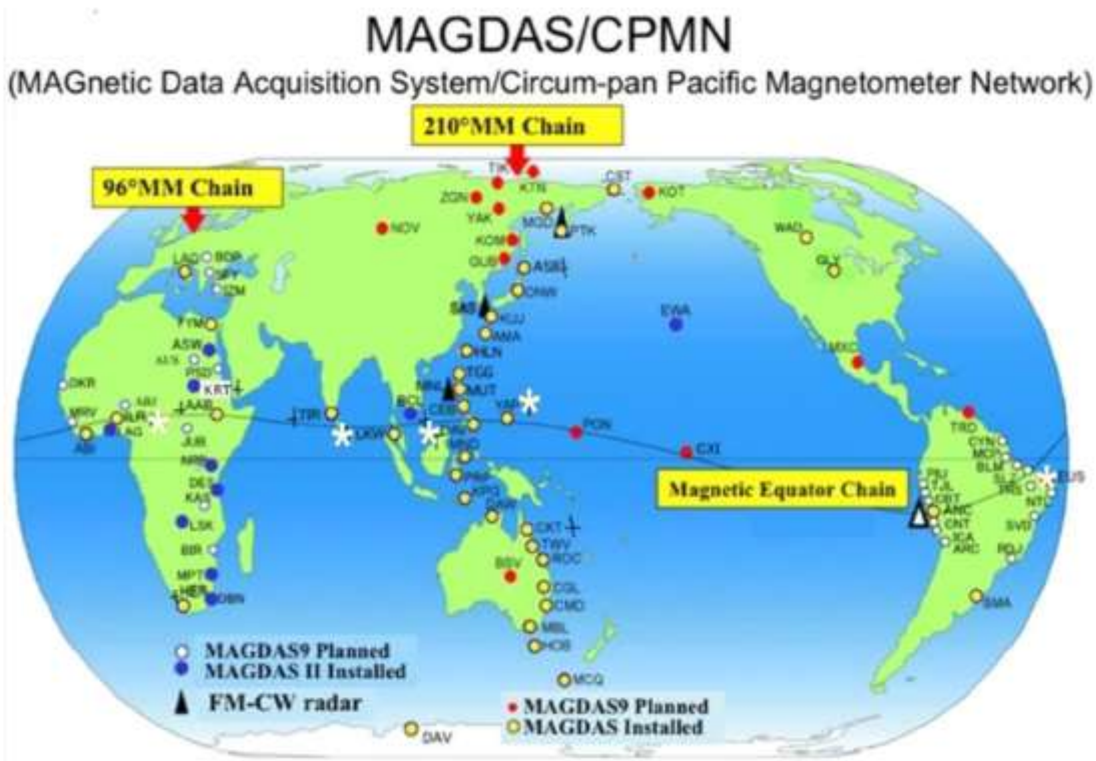


Figure 1: Distribution of the geomagnetic observatories used for the study (Source: Yumoto and MAGDAS Group, 2001)

Table 1: Coordinates of the Stations Used in the Study

S/N	Stations	Code	Geographic Latitude( )	Geographic Longitude( )	Geomagnetic Latitude (^{0})	Geomagnetic Longitude(^{0})	Dip latitude(^{0})
1	ILORIN	ILR	8.50	4.68	-1.82	76.80	-2.96
2	EUSEBIO	EUS	-3.88	-38.43	-3.64	34.21	-7.03
3	LANGKAWI	LKW	6.30	99.77	-1.23	170.06	-0.47
4	DAVAO	DAV	7.00	125.40	-1.02	195.54	-0.65
5	YAP ISLAND	YAP	9.50	138.08	1.49	209.06	1.70

The variation baseline was obtained from 2 hours flanking local midnight i.e. 24 hours local time (*LT*) and 1 hour local time. The daily baseline value for H_0 and Z_0 of both the geomagnetic element H and Z components is the mean value of the hourly values at these two hours. This is going to be of two Types i.e. the vertical component (*Z*) and the horizontal component (*H*).
For vertical component *(Z)* we have:

$$Z_0 = \frac{1}{2}(Z_{24} + Z_1) \quad (1)$$

Where Z_1 and Z_2 are values of geomagnetic element *Z* at 1hr *LT* and 24hr *LT* respectively and Z_0 is the daily baseline for the geomagnetic element *Z* which is the mean values of the hourly values at 24hr *LT* and 1hr *LT*. The daily baseline Z_0 for each station on each quiet day was subtracted from the hourly values Z_t to get the hourly departure from the midnight for a particular day. That is;

$$dZ = Z_t - Z_0 \quad (2)$$

Where $t = 1\ to\ 24$, dZ gives the measure of the hourly amplitude of the variation of *Z,* which is also the solar daily variation in Z ; and $S_q(Z)$ is dZ during quiet times. The monthly mean values were derived from the mean of the diurnal variation for the five quietest days in each month.
Similarly for the horizontal component *(H)*;

$$H_0 = \frac{1}{2}(H_{24} + H_1$$

$$dH = H_t - H_0$$

Where $t = 1\ to\ 24$, *dH* gives the measure of the hourly amplitude of the variation of *H,* which is also the solar daily variation in *H* and $S_q(H)$ is *dH* during quiet times.

RESULTS AND DISCUSSION

Daily Variation S_q of *H* for 2008

The result shows a steady increase in *dH* at pre-sunrise reaching a peak around local noon almost in a regular pattern and decrease at post-sunset. These features are in conformity with the works of Rastogi and Iyer (1976). The $S_q(H)$ variation pattern agrees with the earlier works of Onwumechilli (1960) and Mtshushita (1969) and can be attributed to the variabilities of ionospheric processes and physical structure such as conductivity and wind structure, which are generally responsibility for $S_q\ (H)$ variation. The variation during the daytime which is always higher than nighttime for all the stations is attributed to the afore mentioned ionospheric process and as well as enhancement dynamo action at their respective regions (Onwumechili, 1997). Figure 2 shows the hourly plots of $S_q(H)$ of the stations. The buildup flank in the morning hours is steeper than that of the decay phase in the night hours. This was also observed and documented by *Rabiu et al.,* (2009) and Akpaneno & Adimula, (2015) in their magnetic field measurement using MAGDAS. The daily variations of are characterized by maximum day time (0700 to 1700 LT) magnitude, minimum pre-sunrise (0500 to 0600 LT) and night time (1700 to 2400 LT) magnitude, from all the plots in Figure 2. The variational trends is observed between Stations may be attributed to the difference in their latitudinal location (Obiekezie *et al;* 2013*)*. This result is quite in agreement with the work of Bolaji *et al* (2013) and that of Akpaneno and Adimula (2015). In Figure 4 *LKW* shows the maximum of *dH* 110 nT on 9th October and peak around 1200 LT, minimum at 70 nT on 25th October and peaks around 1100 LT. In this Figure the amplitude of *LKW* is seen to be higher than *EUS, ILR, DAV* and *YAP* (*H)* Amplitudes. This high amplitude could be as a result of influence of Equatorial electrojet current (EEJ). The EEJ current is an east-west current which is seen flowing positive in the morning thus, causing an enhancement in the (*H)* values of station within the EEJ region. This work is quite in agreement with the work of Obiekezie *et al (*2013). Apart from this maximum and minimum value of (*H)* observed from the pre sun-rise towards the sun rise period, they are characterized with counter electrojet (CEJ). The CEJ is the local time variation of (*H)* below zero. Around this period, the CEJ normally occur in both pre sunrise and pre sunset which is 0700 LT to 0800 LT for pre sunrise and 1600 LT to 1700 LT for pre sunset. The CEJ magnitude of S_q was ranged between - 1 to -31 nT. The highest value -31 nT was seen on 02/08 at 0700 LT. Generally, the magnitudes of variation were found to be larger before midnight than before sunrise hours. This depicts that the conductivities are still low before sunrise and the neutral wind pattern due to the solar thermal heating is not present. This absence of solar thermal heating causes the ionospheric conductivity to be weaker during pre-sunrise hours over all the days throughout the year 2008. These observations have been previously reported by Bartel and Johnson (1940), Onwumechilli (1967), Rastogi (1974), Okeke and Hamano (2000), Rabiu *et al* (2007,2009) and Akpaneno and Adimula (2015) that values during the pre-sunrise hours are lower compare to daytime hours. The CEJ occurred on 09/10, 18/10 and 25/10 respectively. On 09/10 CEJ events occurred in the pre sun rise period at *LKW* and *DAV*. *LKW* show the minimum CEJ magnitude of -8 nT and peaks around 0800 LT while *DAV* show the maximum CEJ at -10 nT and Peak around 0700 LT. On 18/10, the CEJ occur in both pre sun rise and pre sunset. At the pre sun rise *DAV* show the maximum values of *dH* at -8 nT and peak around 0700 LT, *YAP* show the minimum at -3 nT and peak around 0700 LT. But at pre- sunset both of the stations take the maximum at -19 nT, peaks around 1600 LT. On 25/10 *LKW* take its maximum at -2 nT and peaks around 0800 LT in the pre sun rise. On 24/10 the during the pre-sunrise hour range from 1 to 5 nT which has a maximum values. It is observed in this Figure that *LKW* has the highest magnitude of 110 nT on 09/10 while *ILR* lowest magnitude of 48nT on 27/10 and peaks around 1200 LT and 1000 LT respectively. Figure 2(b), *DAV* show the maximum *dH* at 100nT on 29th September and peak around 1100 LT, minimum of 70 nT on 13th September and peak around 1100 LT. The CEJ occur on 21/09,24/09 and 29/09, on 21/09 CEJ took place in both pre sun rise and pre sun set which are *LKW* and *YAP*, *YAP* show the maximum *dH* at -10 nT and peak around 0700 LT, *LKW* show the minimum of -9 nT and also peak around 0700 LT. On 24/09, *YAP* show the maximum CEJ at -9 nT and peak around 0700 LT and also has the maximum during the pre-sunrise hours range from 1 to 5 nT. It is observed that *DAV* has the highest magnitude at 100 nT on 29/09 and *ILR* lowest magnitude at 42 nT on 12/09 and peaks at 1200 LT and 1100 LT. The variations between two paired quiet consecutive days is quite different from any other two paired subsequent consecutive quiet day as reported by Akpanano and Adimula (2015). For instance, on 09/10, 25/10 and 12/09, 29/09; it is observed that the variations are remarkably different from one another. Looking at Figure 2(a), on 09/10 the variation is between 45 nT to 110 nT, the range is about 65 nT; on 25/10, the variation is between 60 nT to 90 nT, and the range about 30 nT.

Figure 2 (b), on 12/09, the variation is between 42 nT to 79 nT; the range is about 37 nT. On 29/09, the variation is between 88 nT to 100 nT; the range is about 12 nT. It is observed that *dH* between two consecutive quite days could be very large and sometimes very small and occasionally there could be no contrast at all, so *dH* show remarkable day to day variability of Equinox season. These observations have been previously reported by Akpaneno and Adimula (2015). Figure 2(c) *LKW* show the maximum *dH* at 80 nT, on 2nd August, and peak around 1200 LT, while *ILR* show the minimum *dH* at 30 nT on 30th August, and peak around 1000 LT. It was observed that the *dH* during the Equinox Months is higher than solstice Months. For instance, on 09/10, *DAV* with maximum of 110 nT for Equinox Months while on 02/08 *LKW* with amplitude of 80 nT. It was observed that, latitudinal positions of the station also affected the magnetic field variability.

Daily Variation S_q of Z for 2008

The amplitude curves for S_q (*Z)* are seen to be conspicuously opposite to that of S_q (*H)*, and there is absent of CEJ. Figure 3 shows the hourly plots of S_q (Z) for some of the stations. The daily variation of are characterized by maximum day time 0800 to 1400 LT magnitude, and minimum pre sunrise 0700 to 0900 LT and night time 1700 to 2400 LT magnitudes for all the plots. In Figure 3 (d), it was observed that *dZ* during the Equinox Months is also higher than the solstice Months. It was also observed that, latitudinal positions of the station also affected the Magnetic field variability.

Monthly Variation of S_qH

The Monthly mean presented in Figure 4 shows the longitudinal variations. *DAV* records its highest value of *dH* with value of 98 nT and peaks around 1100 LT while *ILR* with lowest value of 50 nT and peaks around 1000 LT; for Equinox Months (October and September). The CEJ occur in the pre sunrise hour which has the value of -30 nT and peaks around 0800 LT (*LKW),* for June solstice, *LKW* show the maximum *dH* at 70 nT and peaks around 1200 LT while *ILR* minimum of 30 nT and peaks around 0700 nT hours.*DAV* has the maximum *dH* at 80 nT and *LKW* minimum of 30 nT both of them peaks around 1200 LT which is for December solstice. The highest *dH* values is 98 nT *DAV* occurring during Equinox Months and the lowest value at 70 nT which is *LKW* during the Solstice Months (August and December). It was observed that the Latitudinal position of the stations also affected the magnetic field variability. For instance, Table 1 *DAV* and *LKW* are on a very close meridian, But *DAV* exhibit higher magnetic field amplitude than *LKW*, this is because DAV which has geomagnetic latitude of -1.02° is closer to the magnetic equator than LKW with geomagnetic Latitude of -1.23° .

Monthly Variation of S_qZ

Figure 5 shows the monthly mean variation of *Z,* which for Equinox season *YAP* show the maximum *dZ* at -38 nT and peaks around 1200LT, *YAP* shows the highest value at -28 nT for June solstice and peak around 1100 LT. December solstice *YAP* has the highest value of *dZ* at -20nT and peaks around 1200 LT. The highest *dZ* values is -38 nT *YAP* occurring during the Equinox Months and lowest value is -20 nT for the same station. It was also observed that the latitudinal position of the station also affected the magnetic field variability.

Seasonal Variation of S_q of H for 2008

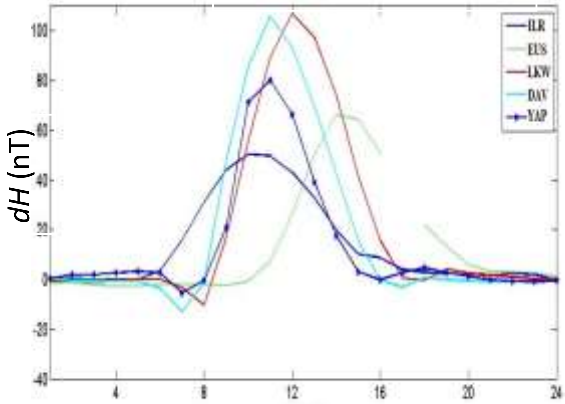
Figure 6 shows that *dH* displayed Seasonal variation across the longitudes. The result for the variation of *dH* during E- Season. It was observed that the amplitude of *dH* is highest at *YAP* reaching about 90 nT at 1200 LT, followed by magnitude of 83 nT at *DAV*. A West African station, *ILR* displayed a lower variation in comparison to other station used. This shows that the amplitude of *dH* increased with increasing longitude, except at *LKW* which had a lower amplitude than *EUS*. Some CEJ events were recorded at *LKW* in the pre- sunrise hours. During J- Season, *DAV* was observed to be the highest at about 1200 LT with amplitude of 70 nT while *ILR* and *EUS* had the minimum *dH* and a CEJ about -30 nT at 0600 LT was observed at *LKW* station. For D- Season *YAP* exhibited the maximum *dH* amplitude and peak at 1200 LT with 80 nT followed by a magnitude of 68 nT *DAV*. A West African station, *ILR* displayed a lower variation in comparison to other stations used.

Seasonal Variation of S_q of *Z* for 2008

Figure 7 shows that *dZ* displayed Seasonal variation across the longitudes. The result for the Variation of *dZ* during E- Season is that, *ILR* and *LKW* exhibited the maximum *dZ* amplitude were *ILR* peak at 1100 LT with -20 nT while *LKW* peak at 1200 LT with -20 nT. Whereas *YAP* had the minimum *dZ* amplitude. It was also observed that the latitudinal position of stations also affected the magnetic field variability.

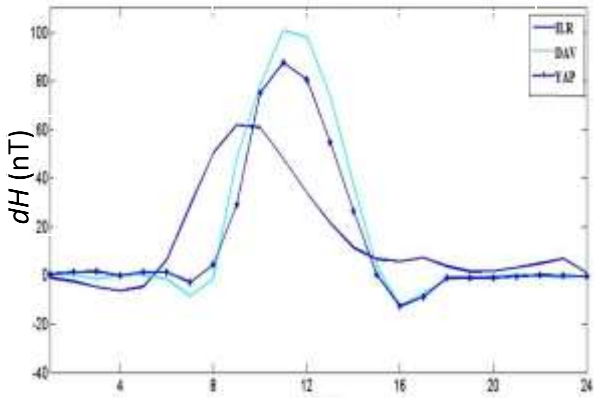
The seasonal variation of *H)* in general terms has a higher value during equinoctial season than in the solstices. The possible mechanisms responsible for this pattern are the presence of greater solar dynamo processes in the Equinoctial months. Chapman and Raja Rao (1965) and Chandra *et al.* (1971) also reported greater equinoctial maxima from their observed seasonal variations.

09 October 2008



Local Time (Hrs)

18 October 2008



Local Time (Hrs)

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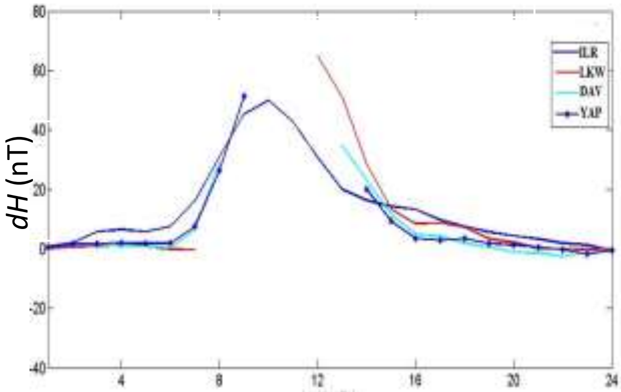

Local Time (Hrs)

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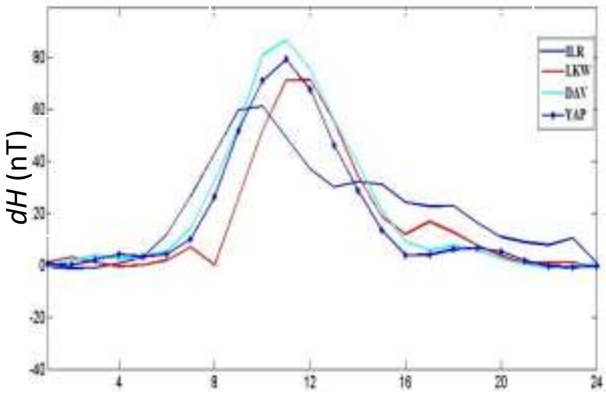

Local Time (Hrs)

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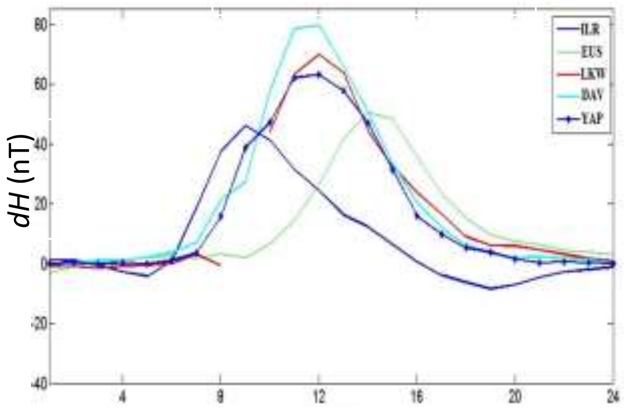


Local Time (Hrs)

Figure 2 (a): quiet day variation of the horizontal component of the magnetic field *dH* for october 09,18,24,25 and 27, 2008.

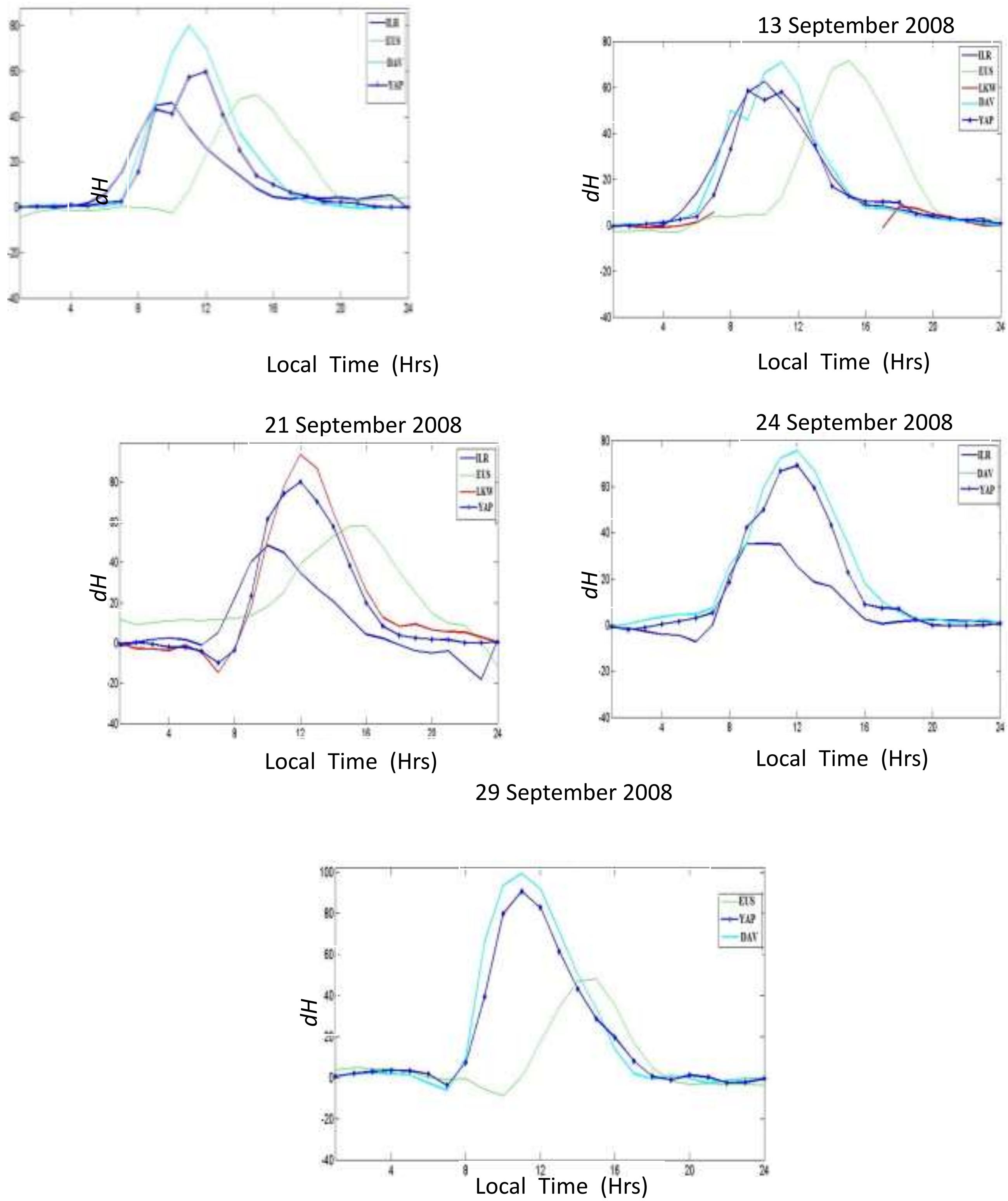
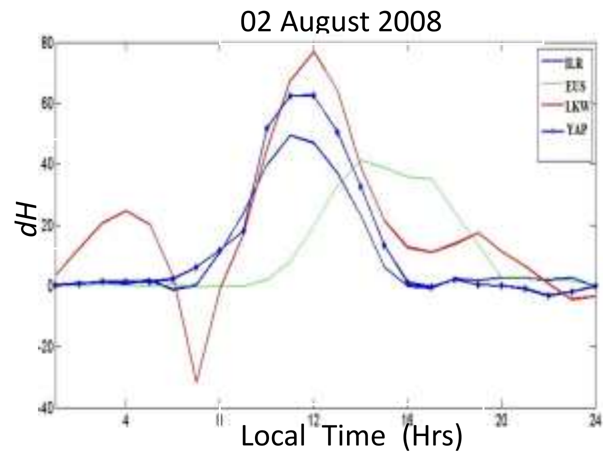
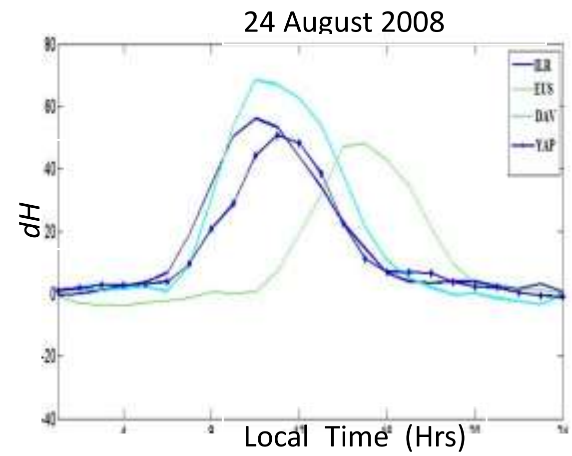
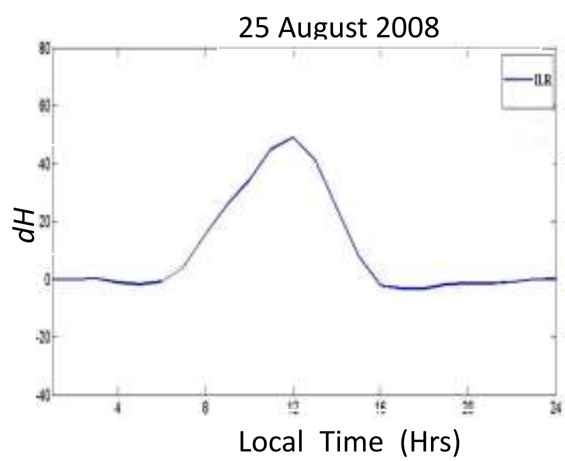
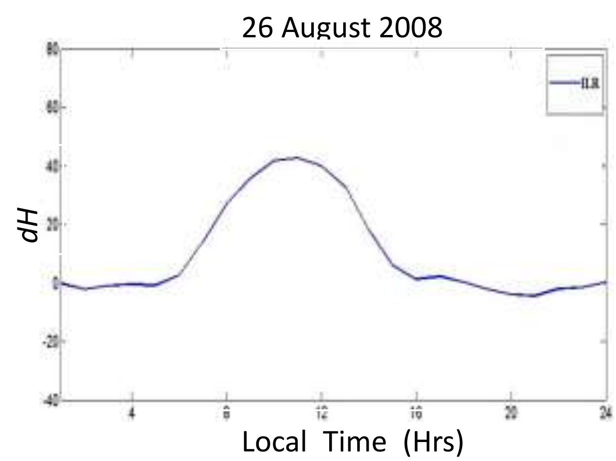


Figure 2 (b): quiet day variation of the horizontal component of the magnetic field *dH* for September 12,13,21,24 and 29, 2008.









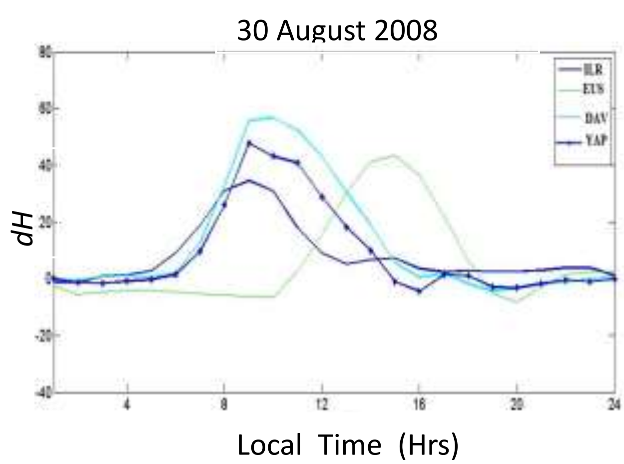
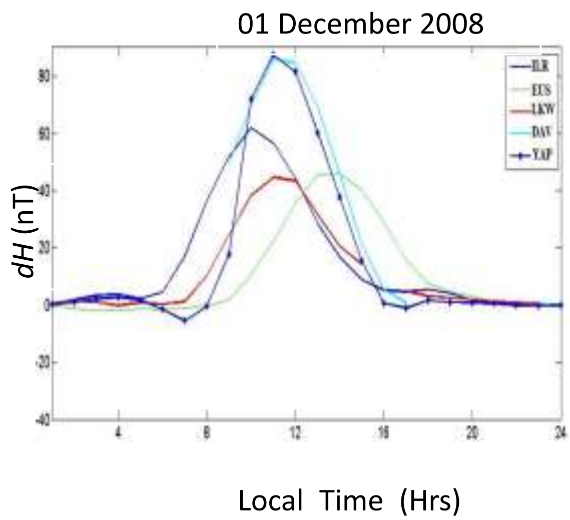
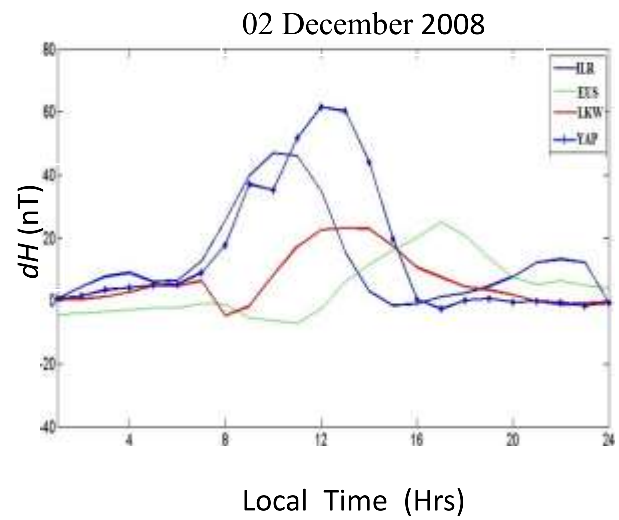
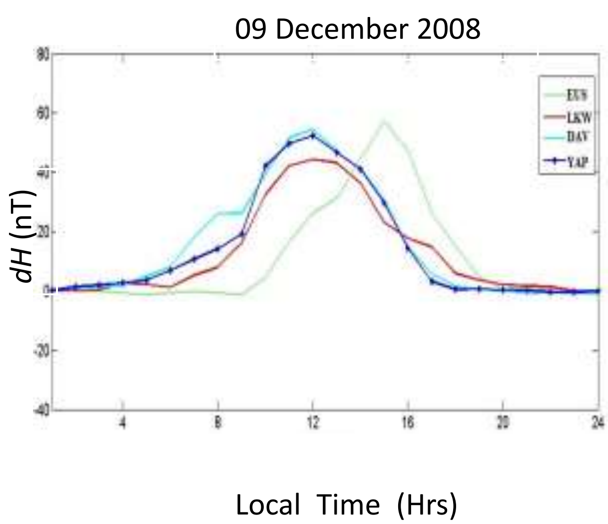
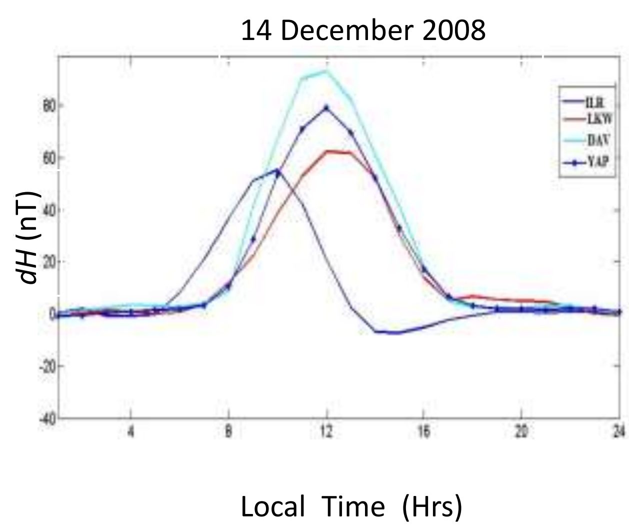


Figure 2 (c): quiet day variation of the horizontal component of the magnetic field *dH* for August 02,24,25,26 and 30, 2008.









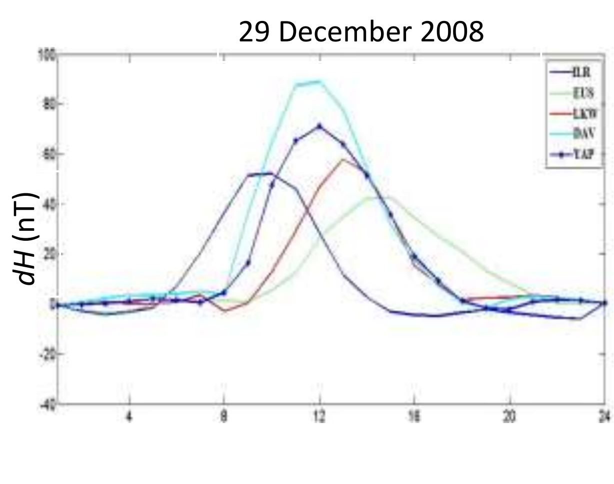


Figure 2 (d): quiet day variation of the horizontal component of the magnetic field *dH* for December 01,02,09,14 and 29, 2008.

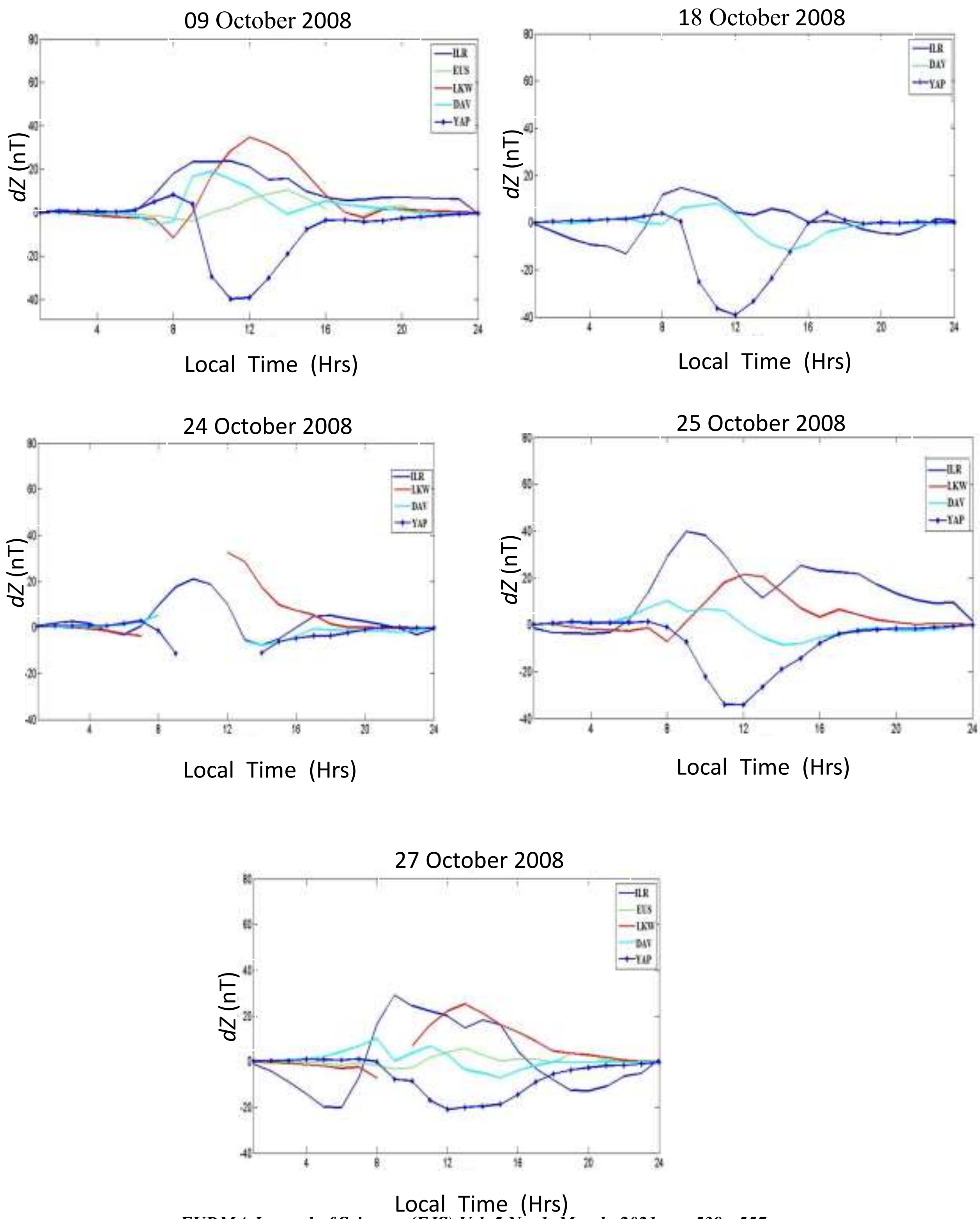
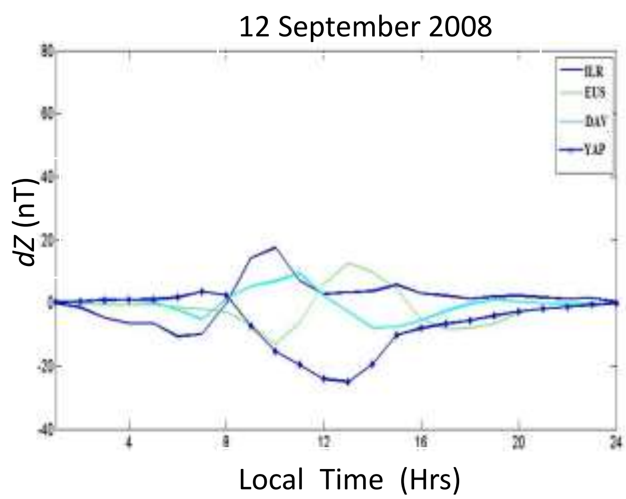
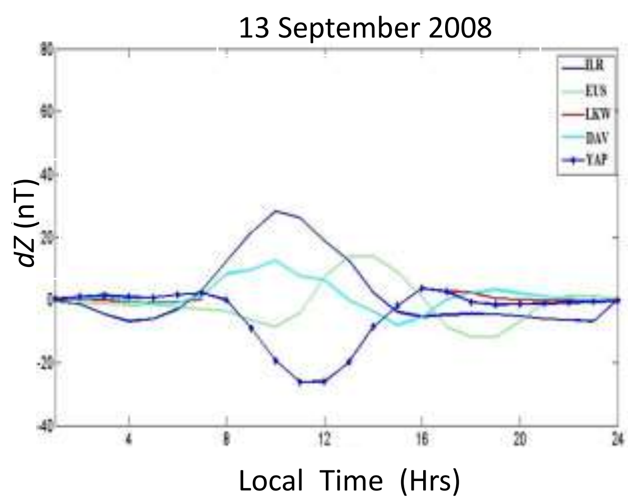
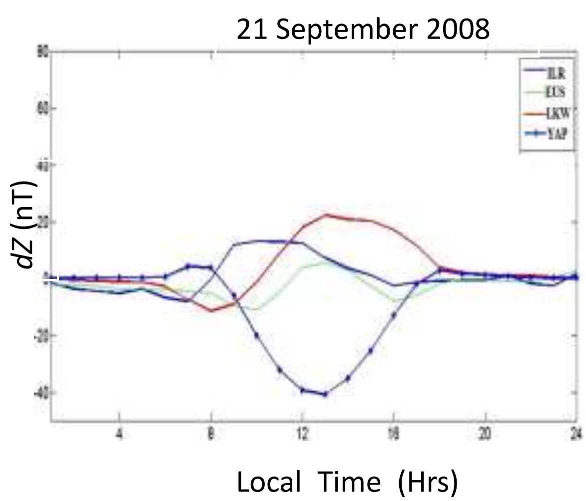
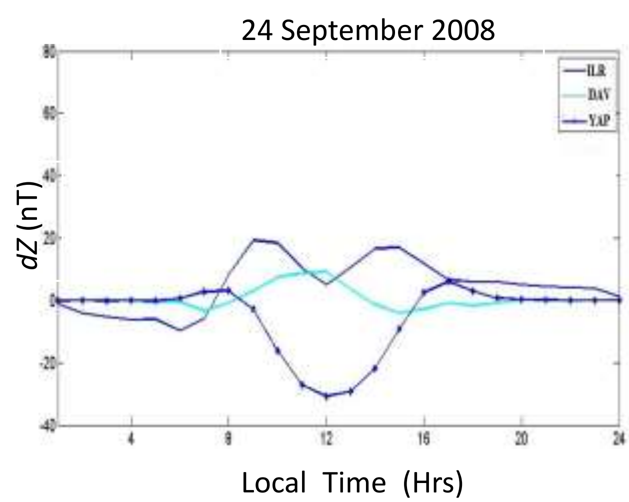


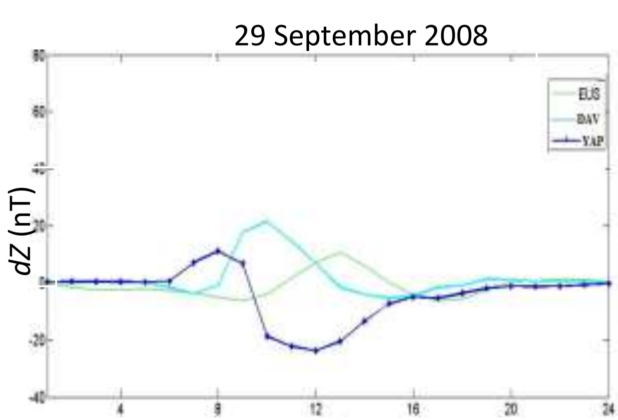
Figure 3 (a): quiet day variation of the horizontal component of the magnetic field *dZ* for October 09,18,24,25 and 27, 2008.





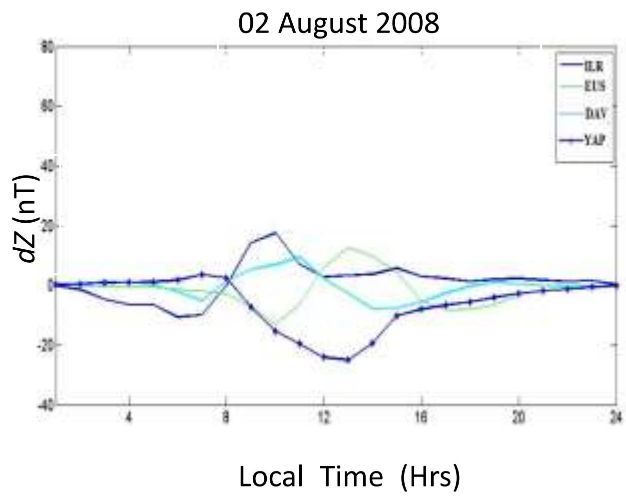


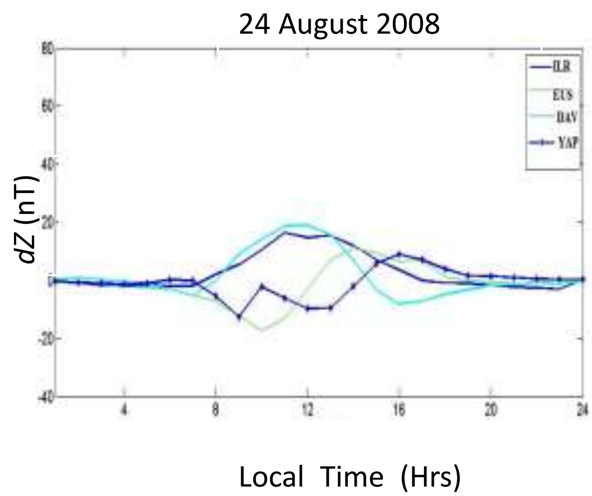


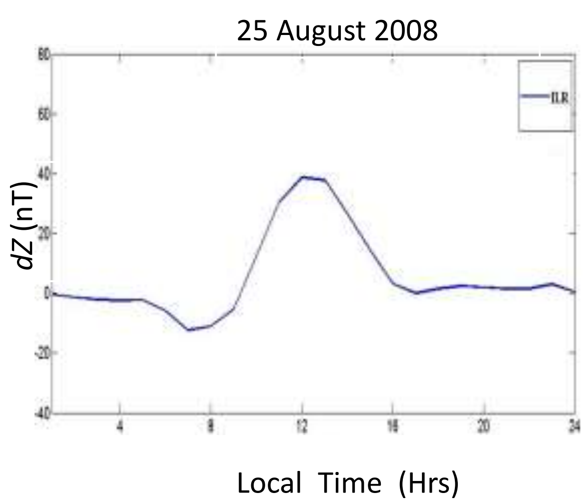


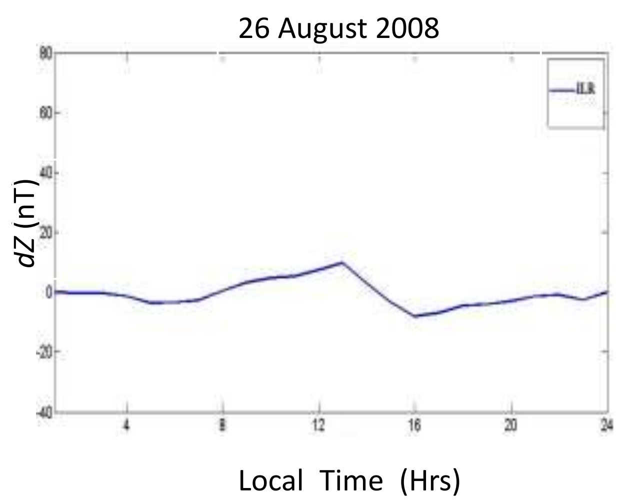
Local Time (Hrs)

Figure 3 (b): quiet day variation of the horizontal component of the magnetic field *dZ* for September 09,18,24,25 and 27, 2008.









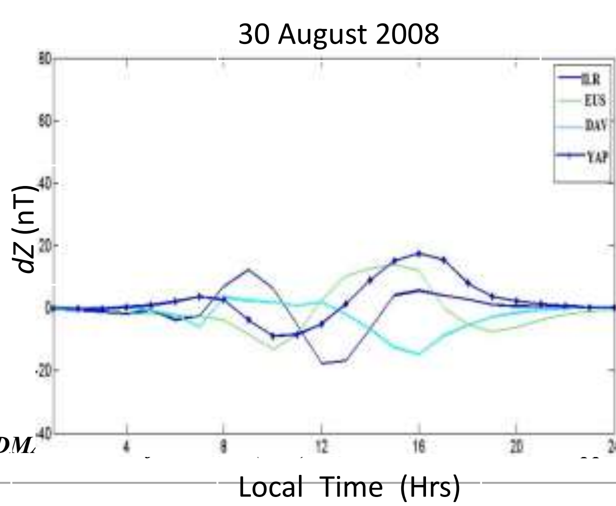
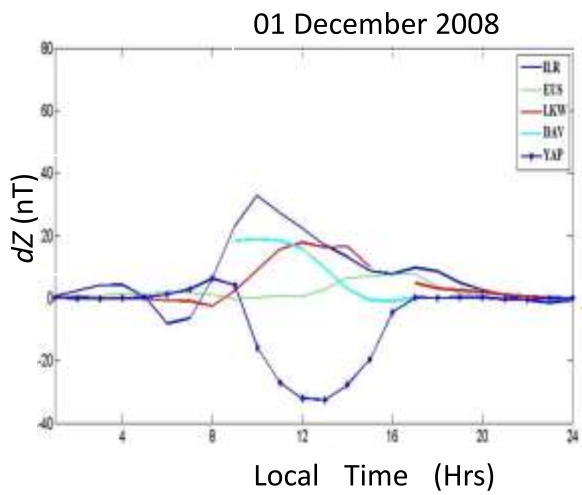
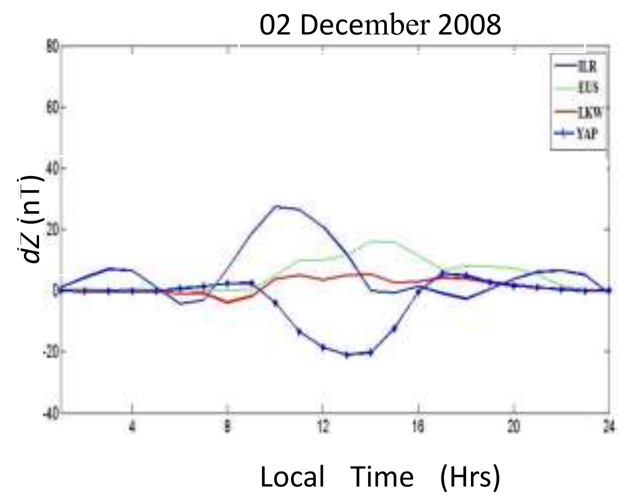
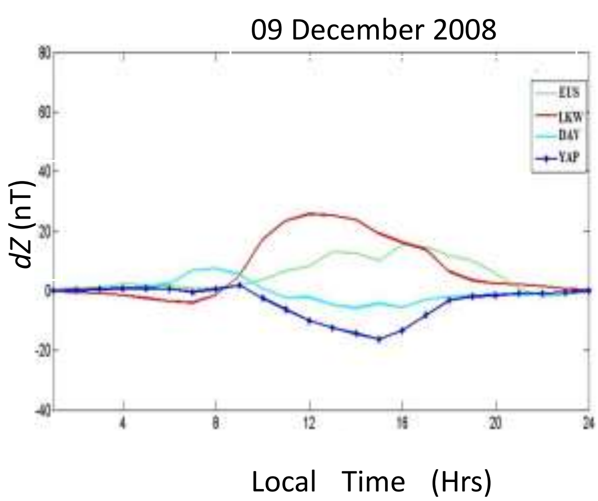
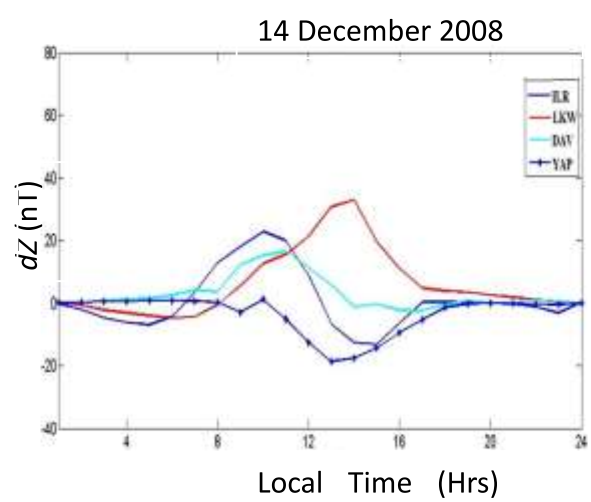


Figure 3 (c): quiet day variation of the horizontal component of the magnetic field *dZ* for August 02,24,25,26 and 30, 2008.









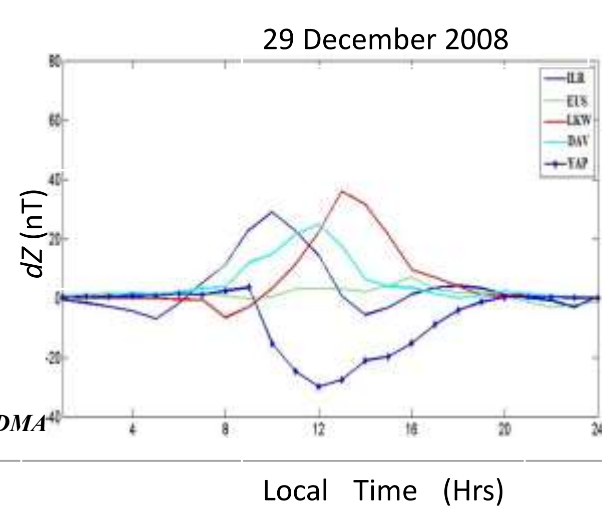


Figure 3 (d): quiet day variation of the horizontal component of the magnetic field *dZ* for December 01,02,09,14 and 29, 2008.

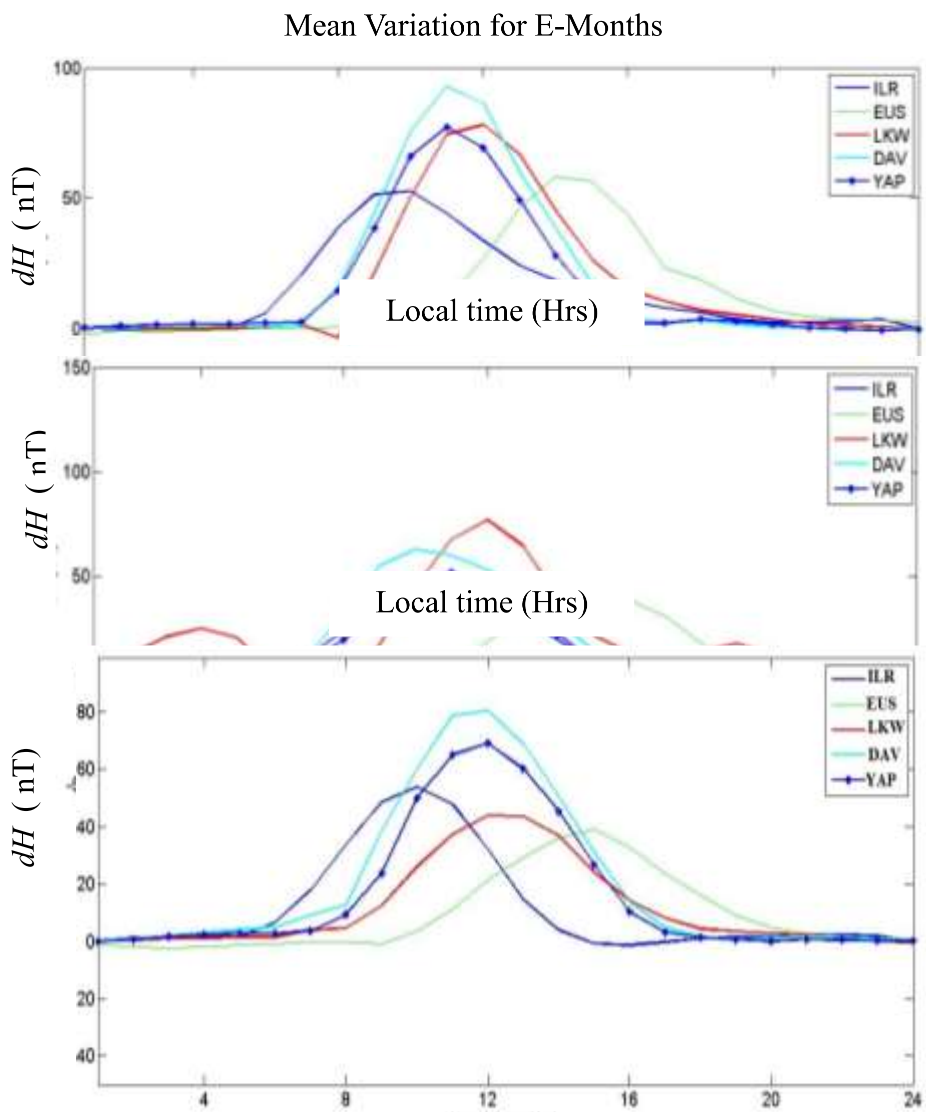
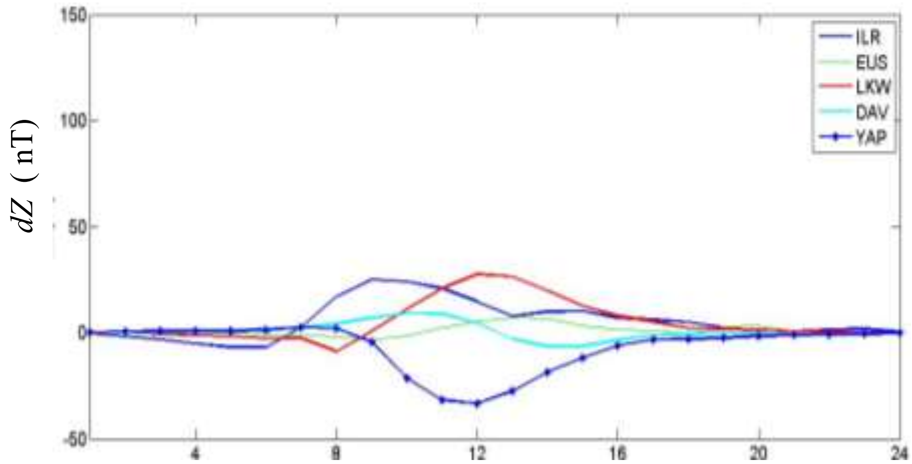


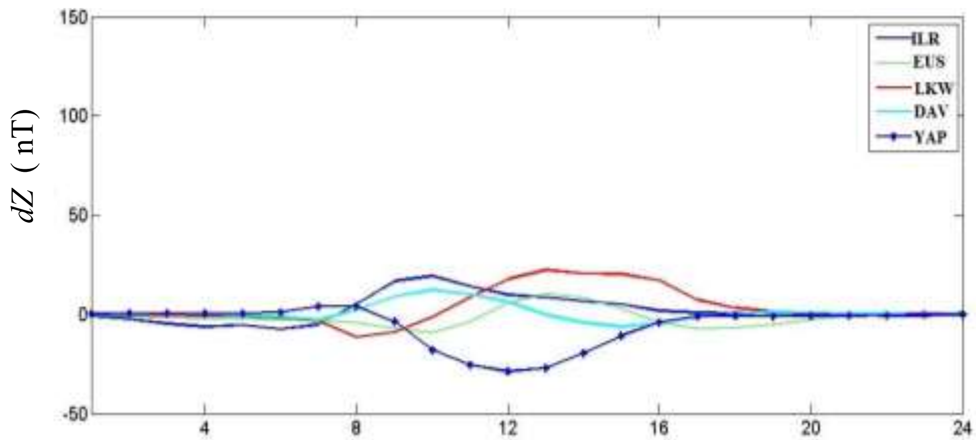
Figure 4: monthly variation for *H* components of geomagnetic field under quiet condition

Mean Variation for E- Months



Local time (Hrs)

Mean Variation for J-Months



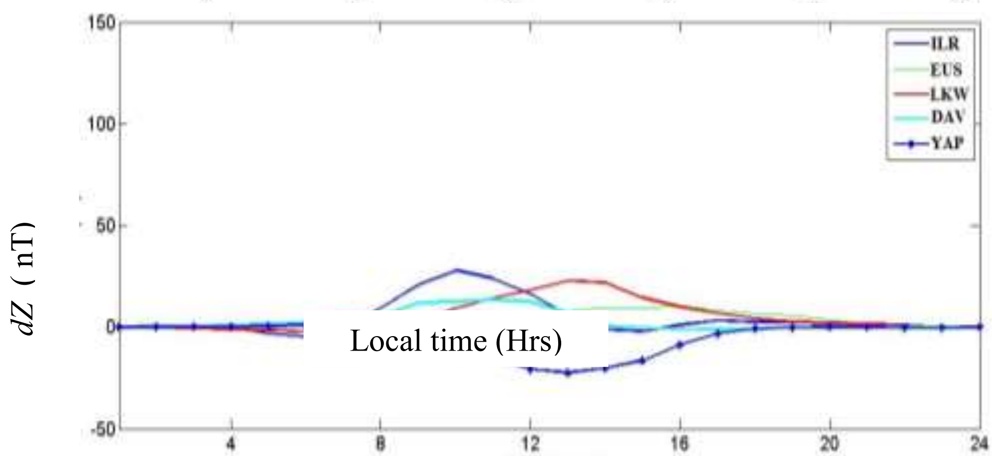


Figure 5: monthly variation of *Z* component of the geomagnetic field under quiet condition.

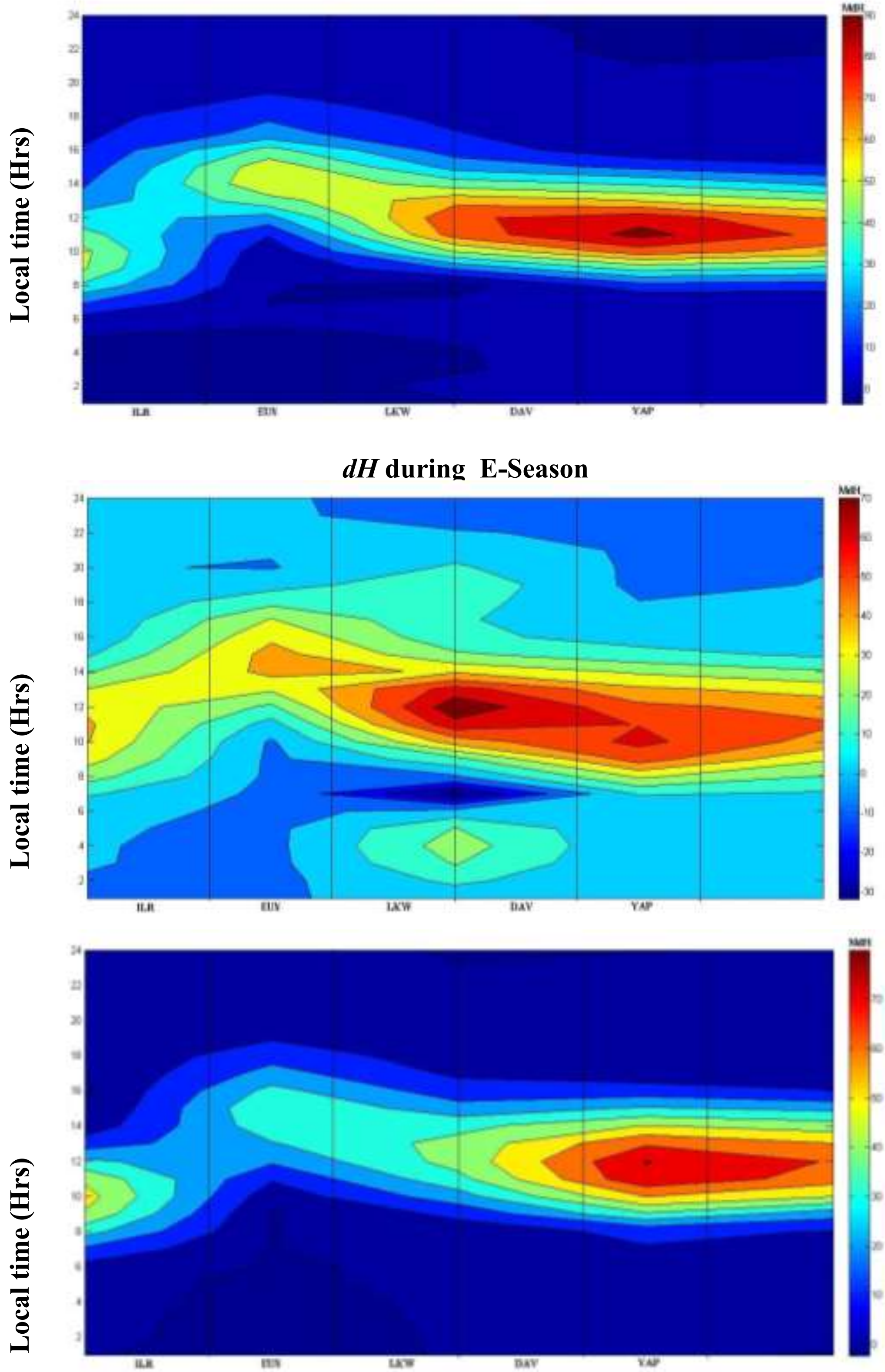


Figure 6: seasonal variation of *H* component of geomagnetic field under quiet condition

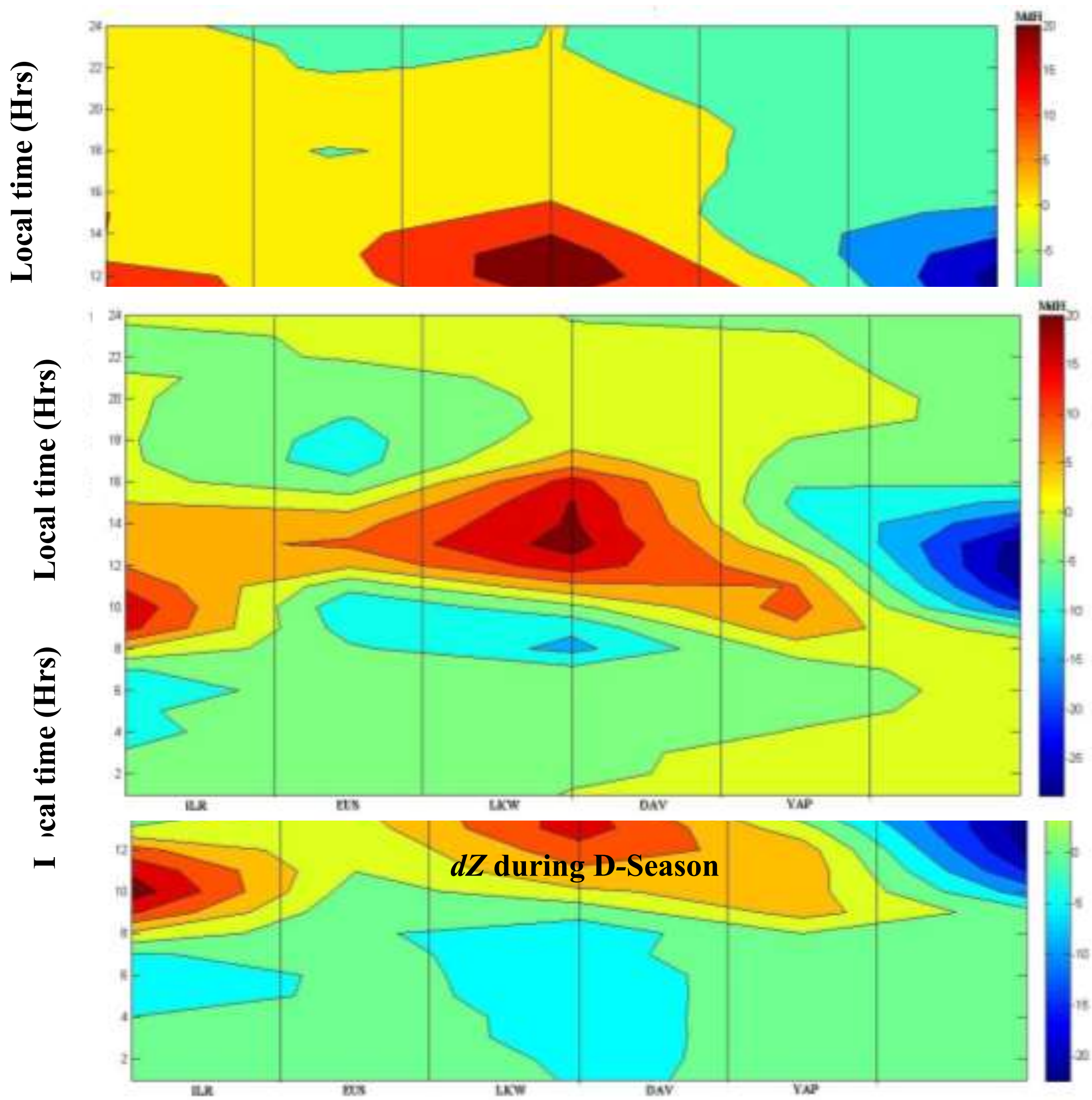


Figure 7: seasonal variation of *Z* component of geomagnetic field under quiet condition

CONCLUSION

Conclusively, it was observed from the results of this study that the longitudinal geomagnetic field variation during solar quiet condition was obtained for the 5 selected stations along the magnetic equator through which the diurnal transient, monthly and seasonal variation was successfully studied. The stations along the specified longitude was seen to differ where the minimum variations for *dH* was observed during June solstice at *LKW* 70 nT observatory, and maximum variations was observed during Equinox season at *DAV* 98 nT observatory, which are also having the highest longitudinal variation of *dH*, while for *dZ* with the minimum variations was observed during the December solstice at *YAP* -20 nT observatory, and the maximum variation was observed during Equinox season at *YAP* -38 nT observatory which are also having the highest longitudinal variations of *dZ*. Therefore it is concluded from the results gotten that the variations value at equinoxes is higher than at solstices which is in conformity and agreement with the work of Akpaneno and Adimula (2015) and is due to the presence of greater solar dynamo processes in the Equinoctial months.

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