Variability of H-Component of the Geomagnetic Field from Some Equatorial Electrojet Stations

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Abstract The hourly variation of the H-component of the geomagnetic field from ten MAGDAS observatories along the dip-equator was used to study the variation trend of solar quiet and solar disturbed variation. The variation in H with Sq (H) enhancement in all the ten stations which peak around local noon with steady similar pattern of variation in all the EEJ, are attributed to the enhanced dynamo action at these regions. The variation of Sq (H) was in the range of 20 to 170nT with peaks around 1200-1300LT. Generally, the magnitude of variation on disturbed days are higher due to ionospheric disturbances originating from the external drives such as space weather effects, storms etc. The results also confirmed the presence of counter electrojet, occurring in the morning and evening hours with the maximum amplitude of -25nT recorded during pre-sunset. The data also show that there is a longitudinal variability in the EEJ, with results showing strongest EEJ current in the South American Sector. Pronounced equinoctials maximum which is due to enhanced electron density at equinox was recorded on March and September with the magnitude between 40 to 140nT; a range of about 100nT.

Keywords: Geomagnetic field, Dip Equator, Electrojet

Introduction

The regular variation of the geomagnetic field is due to the Earth's rotation and its orbital movements around the sun, as well as the orbital motion of the moon. The diurnal variation also called solar daily variations is the most prominent of the regular variations. It is believed that electric currents flowing in the E-layer of the dayside ionosphere are the main cause of the diurnal variations. However, electric current in the Earth's crust, produced by electromagnetic induction also contribute to the variation (Lanza and Meloni , 2006). The regular diurnal variation depends on the time of year, solar activity and the geomagnetic latitude. Due to its relatively small intensities, the diurnal variation is only visible in magnetograms on days when there are no stronger magnetic disturbances in the magnetosphere.

Those days are called solar quiet days, S_q. The corresponding days, when the magnetic field is active are called solar disturbed day, or S_d (Lanza and Meloni, 2006). Other regular variations are the lunar variations which occur because the gravitation of the moon causes atmospheric tides (Jankowski and Sucksdorff 1996). The third is yearly variations possibly due to the Earth's orbital motion around the sun, and its tilting with respect to the plane of its orbits. According to the geomagnetic observations in Leivogur, the perturbation in the geomagnetic field also varies with the seasons of the year (Lanza and Meloni,2006).

The Equatorial electrojet is a narrow belt of intense electric current in the ionosphere confined to about $\pm 3^0$ around the dip equator. This is indicated on a magnetogram as an enhancement of the solar daily variation of the horizontal component of the magnetic field H and solar quiet day variation.

The first observation made about EEJ was in Huancayo (Peru) in 1922, attributed to a narrow ionospheric current of about 300Km in width flowing over the dip equator. During the daytime, eastward polarization field is generated by the global scale dynamo at the magnetic dip equator which give rise to a downward Hall current. Due to the presence of a non -conducting boundary a strong vertical polarisation field opposes the downward flow of the current. This field in turn gives rise to the intense Hall current which Chapman (1951) named EEJ. The EEJ phenomenon has been given various attention and has attracted many scientists in the past and recent times (Okeke and Hamano, 2000).

James and Rastogi (2002) studied the relationship between the day to day fluctuations in the horizontal geomagnetic field, H, at a chain of 13 stations within a narrow longitude belt in the Indo- Russian sector spanning from the equator to about 60^0 dip latitude. The day to day variability in the EEJ strength along the dip equator was also studied by (Adimula et al 2011).

Bartel and Jonhson (1940) as well Egedal (1947) discovered that the diurnal range of H at the stations near the equator peaks around the dip equator with assumption that the amplitudes of the daily variations in D and Z are not affected. Hourly mean values are used to study the morphological structure of the regular variation S_R of the earth's magnetic (H,D,Z) field component and to describe the EEJ during magnetically quiet days (Doumoya et al 1998). Rocket, array of magnetometers, radar, satellite and ionospheric soundings have also allowed the study of EEJ. In this paper, we employed a set of geomagnetic

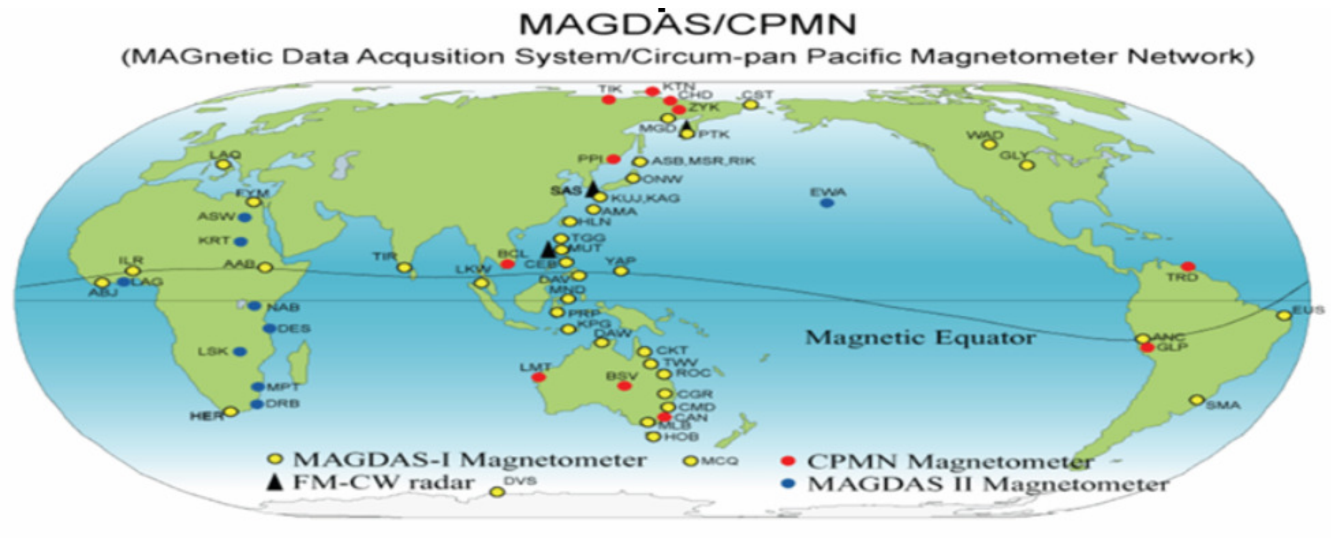

Figure 1: Global network of the MAGDAS magnetometers (Yumoto and the MAGDAS group 2007)

Table 1: Parameters of the Stations Used in Study

N	STATIONS	Code	Geographic latitude	Geographic longitude	Geomagnetic Latitude	Geomagnetic Longitude	Dip Lat
1	Ilorin	ILR	8.50	4.68	-1.82	76.8	-2.96
2	Lagos	LAG	-6.48	3.27	-3.04	75.33	-4.95
3	Ancon	ANC	-11.77	-77.15	0.77	354.53	0.74
4	Davao	DAV	7.00	125.40	-1.02	195.54	-0.65
5	Eusebio	EUS	-3.88	-38.43	-3.64	34.21	-7.03
6	Yap Island	YAP	9.50	138	1.49	209.06	1.70
7	Addis Ababa	AAB	9.04	38.77	0.18	110.23	0.57
8	Lang kawi	LKW	6.30	99.77	-1.23	170.06	-0.47
9	Cebu	CEB	10.36	123.91	2.53	195.06	2.74
10	Triunelvelli	TIR	8.50	77.0	-1.2	146.4	-0.2

data recorded by Magnetic Data Acquisition System (MAGDAS) to examine the solar daily variation in geomagnetic horizontal field intensities under quiet and disturbed conditions. A full description of MAGDAs system can be found in Yumoto, K. And the MAGDAS group (2007).

Materials and Methods

The year 2008 magnetic data was employed to achieve the desired objectives. Data were obtained from Magnetic Data Acquisition System (MAGDAS) facilities at the University of Ilorin, Ilorin (Geographic latitude: 8.50^{0}N, geographic longitude: 4.68^{0}E, geomagnetic latitude: -1.82^{0}S, geomagnetic longitude: 76.8^{0}S), Nigeria. The MAGDAS system chronicle data every second, minutes averages of the horizontal intensities from 10 stations along the dip equator were used. Table 1 shows the basic parameters of the station while fig. 1 presents the locations of the observatories.

The international Quiet days (IQDs) and international disturbed days (IDDs) were selected and used throughout the analysis. These days are the set of 5 quietest days and disturbed days based on magnetic activity index Kp. These days were published by Geosciences Australia (2013). The concept of local time is used throughout the analysis. The mean hourly values or the variation baseline is obtained from the 2 hours flanking local midnight. (Details explained by Rabiu et al, 2007). The daily departure, dH of the horizontal component of the H (nT) from the midnight value is shown in fig. 2 and fig. 3 for five quietest days and disturbed days in the year 2008.

Results of the Analysis

Figure 2 exhibits the quiet day solar daily variations of the horizontal intensity at various equatorial stations considered in the year 2008. Fiqure 3 shows daily hourly variations of the H-component on disturbed days which do not follow a regular trend. Figure 4 shows monthly variations of the horizontal component and Figure 5 is seasonal variation.

Discussion

The quiet and disturbed daily variation of dH for all the observatories are highlighted in fig. 2 and fig. 3. Monthly and seasonal variation were also considered. Deductions from the plots are as follows:

1. The buildup flank in the morning hours is steeper than that of the decay phase in the night hours. This also was documented by Rabiu et al (2009) in their magnetic field measurement using MAGDAS. Figure 2a, b, c and d show the daily variation of dH on the quietest day of the months. The figure shows that the electrojet strength peaks around 1200LT. On the month of March the electrojet is in

the range of 40 to 170nT; peaks around 1200LT, for June solstice EEJ is in the range of 30 to 110nT; peaks around 1200LT, for September the range is between 20 to 130nT; peaks around 1300nT, and for December the range is between 25 to 90nT; peaks around 1300LT. The electrojet strength in all the stations under considerations is in the range of 20 to 170nT with peaks around 1200 to 1300LT.

The current enhancement recorded is as a result of localized ionospheric currents flowing at the dip equator with higher current intensities during the time,(Okeke and Hamano ,2000).

The contrast in time for the peak electrojet across the entire months may be as a result of the sum total of the effects of the peak electron density and electric field. This agrees with the findings of Chandra et al (2000). The different variability in dH recorded could be attributed to the variabilities of the ionospheric processes and physical structure such as conductivity and wind, which are responsible for the S_q variation. These results are quite in agreement with the works of Adimula et al (2011), Matsushita (1969) and Onwumechilli (1960).

It could be observed that variability between two paired quiet consecutive days is quite different from any other two paired subsequent consecutive quiet days. For instance 07/03, 06/03 and 10/06, 13/06; it is observed that the variations are remarkably different from one another. Looking at figure 3a, on the 07/03 the variation is between 45nT to 160nT, the range is about 115nT; on 06/03 the variation is between 45nT to 105nT; the range is about 60nT. On 10/06, the variation is between 40nT to 85nT; the range is about 45nT. On 13/06, the variation is between 40nT to 79nT; the range is about 39nT. It is observed that dH between two consecutive quiet days could be very large and sometimes very small and occasionally there could be no contrast at all so dH shows remarkable day to day variability.

2. Alex et al (1992) discussed the abnormalities associated with certain characteristics of westward counter electrojet (CEJ) current which completely inhibits the equatorial enhancement of dH over the dip equator. Evidence of counter electrojet was seen in ANCON on March at 1600LT with the amplitude of about -20nT. CEJ were also observed at Addis-Ababa on 13/09 and 12/09. On 13/09 the amplitude is -18nT and was seen at 0700LT. on 12/09 CEJ was observed during morning and evening hours with different values. During the pre-sunrise period the value is -20nT and the time is 0800LT; for pre-sunset the value is -25nT and the time is 1500LT. The magnitude is greater during pre-sunset than the pre-sunrise. These depressions do not change the pattern of the diurnal variation at any station. Maximum variation around noon is still recorded. Adimula et al (2011) also obtained the same results.

On March, the maximum amplitudes for the stations vary from 40nT to 170nT; a range of about 130nT. On September, 20nT to 130nT; a range of about 110nT. On June, 20nT to 115nT; a range of about 95nT and December, 25nT to 90nT; a range of about 65nT. Figures 2a and 2c show that the EEJ is strongest in equinox (March and September) than in solstice (June and December). This is in line with the results of Adimula et al (2011) and Chapman and Rajarao (1965)

3. Figure 3 shows the daily hourly variation of the horizontal component on disturbed days. The variation does not follow a regular and consistent pattern. This is due to the ionospheric disturbances emanating from external source such as space weather effects, storm etc.

Generally, the magnitudes of the variations on disturbed days are greater than those of the quiet condition; this could be as a result of extra input of energy into the ionosphere (Rabiu et al 2007). For instance, on March the variation is between 20 to 190nT; (a range of about 170n) While in quiet condition the range is 130nT; (i.e from 40 to 170nT). The same trend is recorded for other months.

The variation is more disorganize in disturbed condition than in quiet condition. The first theoretical explanation was put by Chapman as due to up and down motion of the "ionospheric layer" whose conductivity was greater over the PM than over the AM hemisphere. Geomagnetic disturbances are associated imposition of a westward electric field over the electrojet region. During the periods of geomagnetic activity, ionospheric electric fields and current at low and equatorial latitudes are very different from those during quiet patterns (Rastogi, 1998).

4. The monthly average diurnal variability of the amplitude of dH of the EEJ is obtain by stacking diurnal hourly variations of each parameter over each of the month. Figure 4 shows monthly variation of dH. The variations were observed to present the same shape as that of H component daily variation.

The amplitude at these stations increases regularly from dawn and then decreases towards dusk. Higher values are seen during equinoctial months of March and September while lower values are seen in solstice (June and December). On March, (equinox) the variation is between 55 to 140nT; a range of about 85nT. For June (solstice) the variation is between 40 to 90nT; a range of about 50nT.

5. The seasonal variation of dH was also examined. Obtaining the seasonal variation means averaging the monthly means for Lloyd's seasons. On quiet conditions, seasonal variation occurred in all the EEJ stations selected with equinoctial maximum and solstitial minimum. For instance Eusebio(EUS) south of the magnetic equator displayed maximum variation in J-Solstice with least variation in D- season. Ancon (ANC) located at south of

Daily variation in H component of the geomagnetic field for 5 IQD's of March 2008

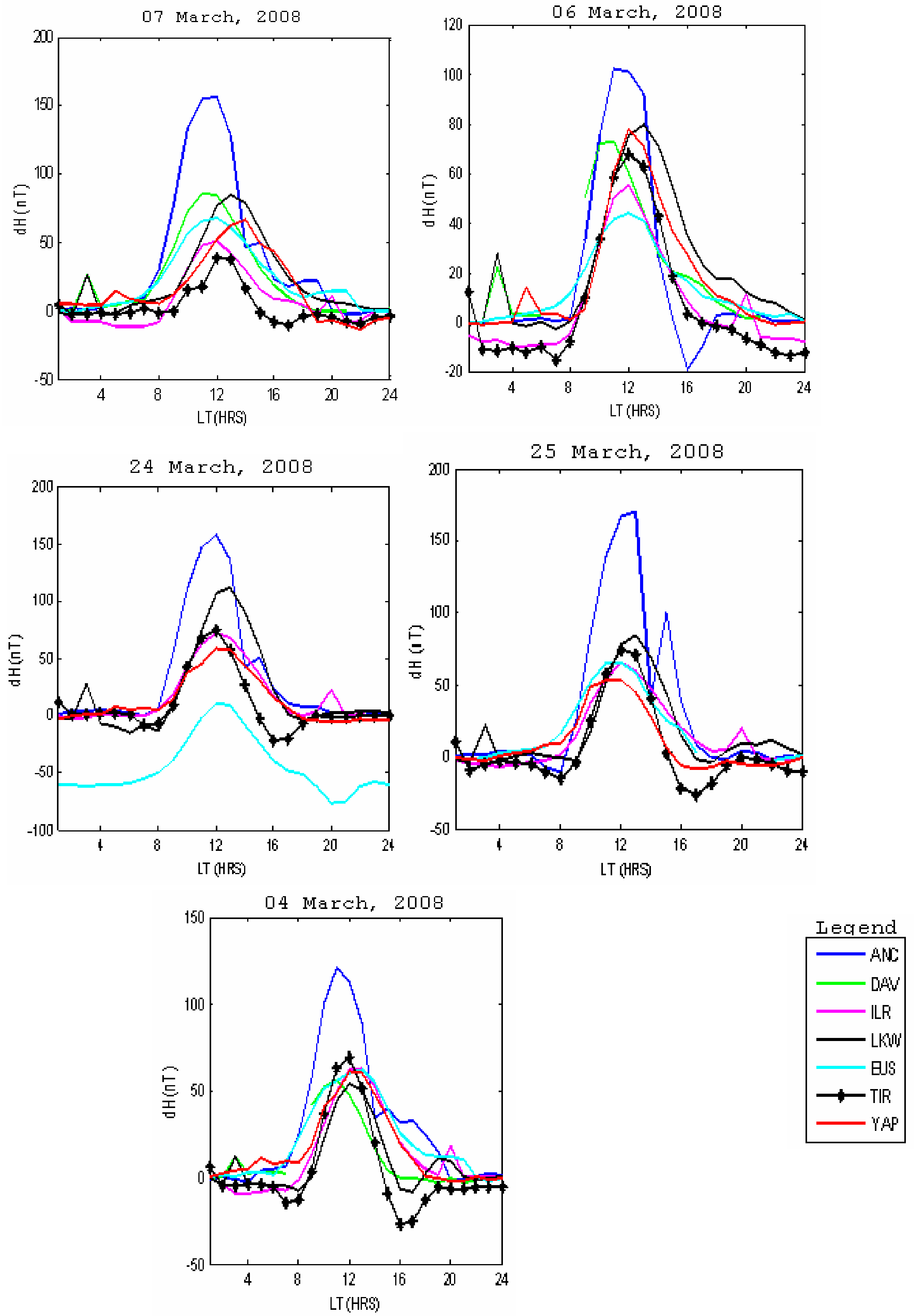

Fig. 2a: Quiet day variation of the horizontal component of the magnetic field dH for March 07, 06, 24, 25 and 04, 2008.

Daily variation in H component of the geomagnetic field for 5 IQD's of June 2008

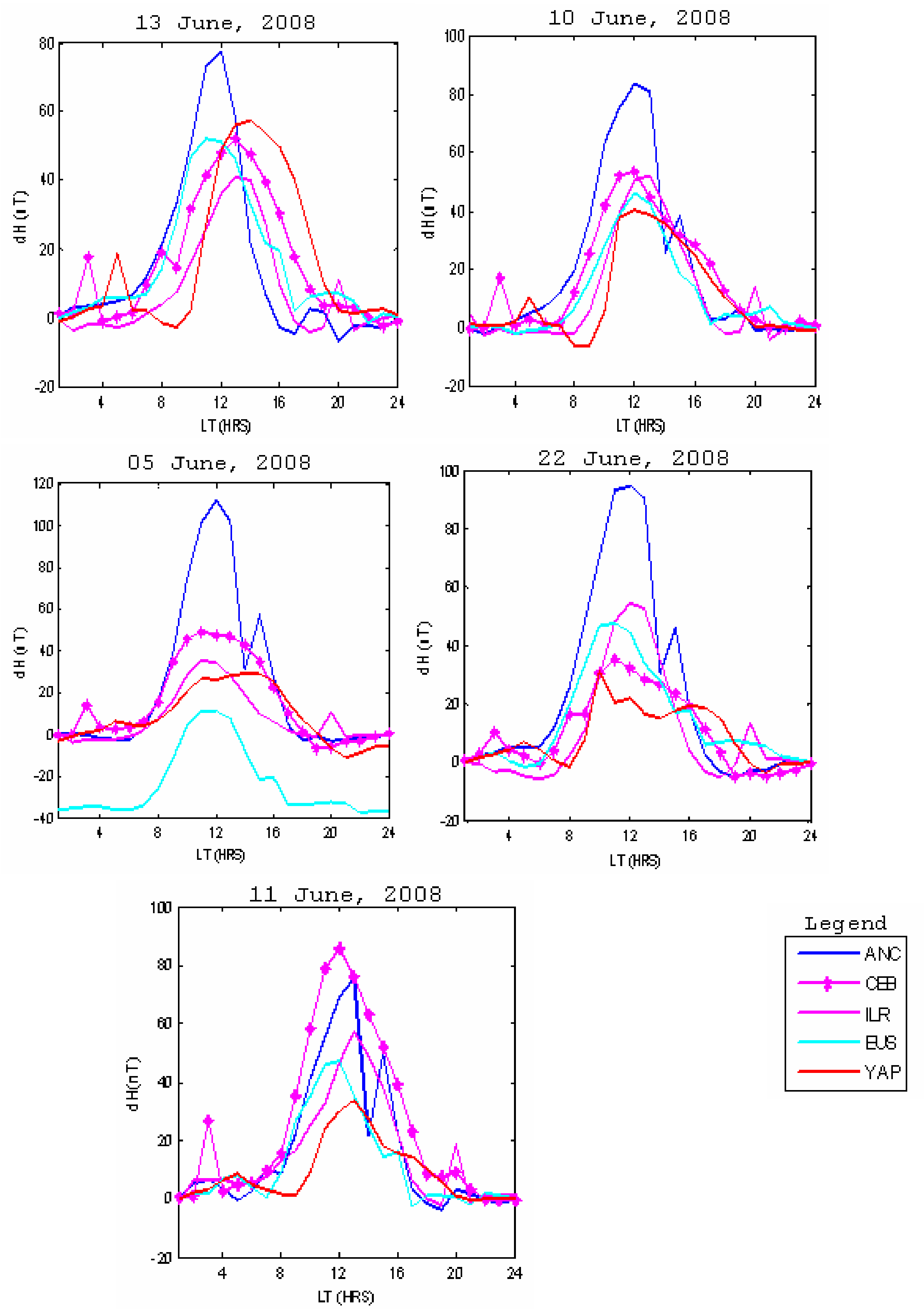

Fig. 2b: Quiet day variation of the horizontal component of the magnetic field dH for June 13, 10, 05, 22 and 11, 2008.

Daily variation in H component of the geomagnetic field for 5 IQD's of September, 2008

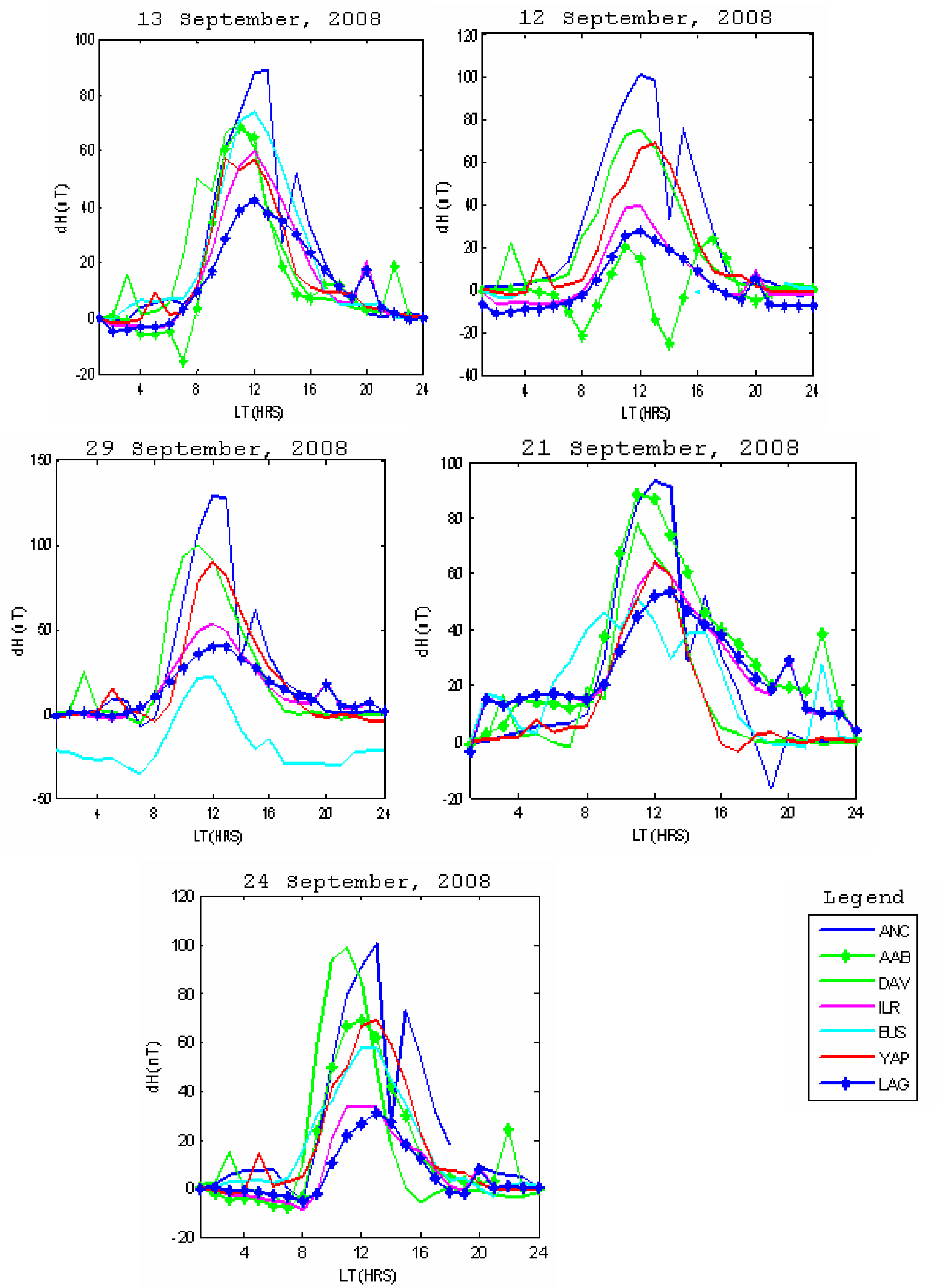

Fig. 2c: Quiet day variation of the horizontal component of the magnetic field dH for September 13, 12, 29, 21 and 24, 2008.

Daily variation in H component of the geomagnetic field for 5 IQD's of December, 2008

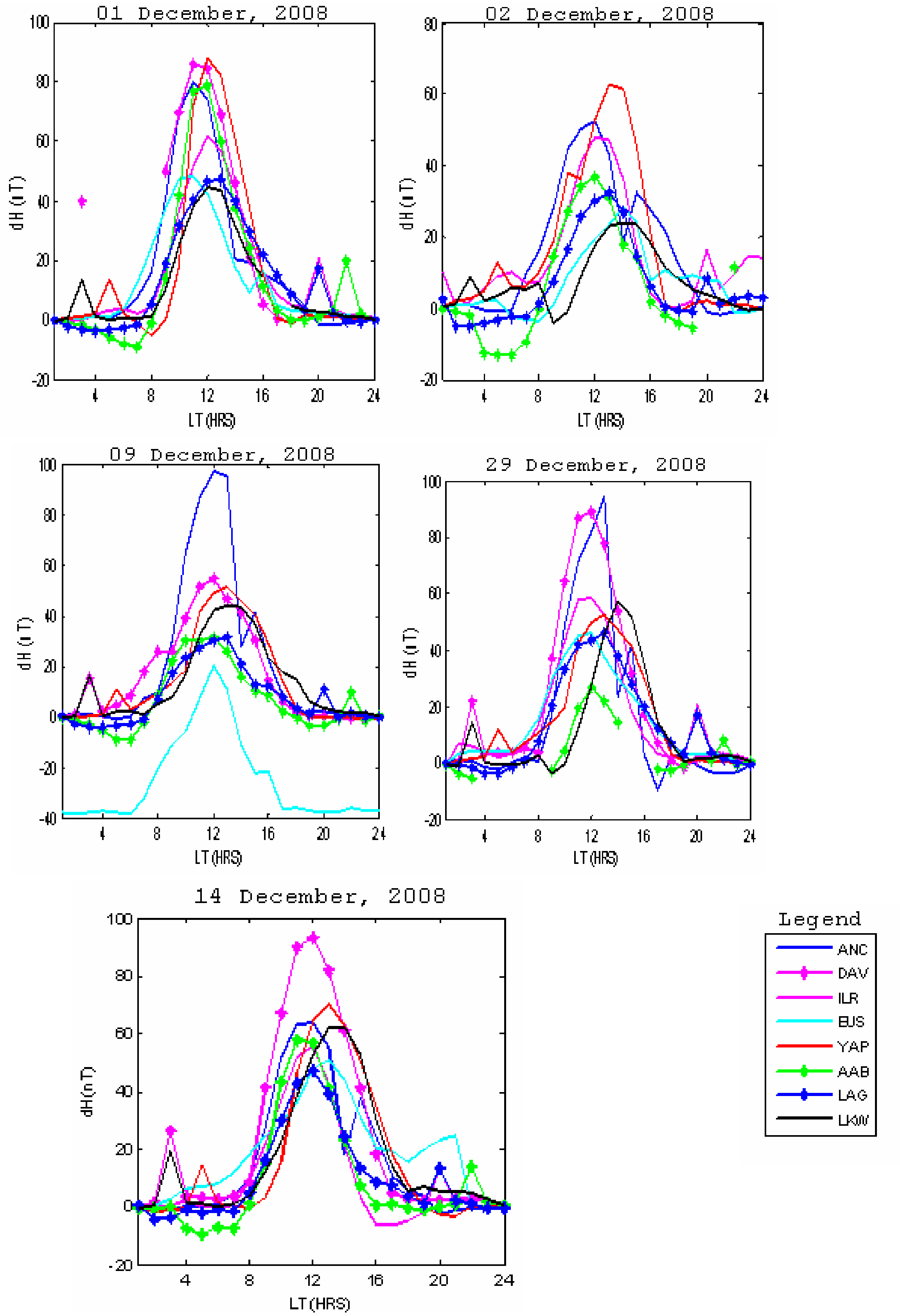

Fig. 2d: Quiet day variation of the horizontal component of the magnetic field dH for December 01, 02, 09, 29 and 14, 2008.

Daily variation in H component of the geomagnetic field for 5 IDD's of March, 2008

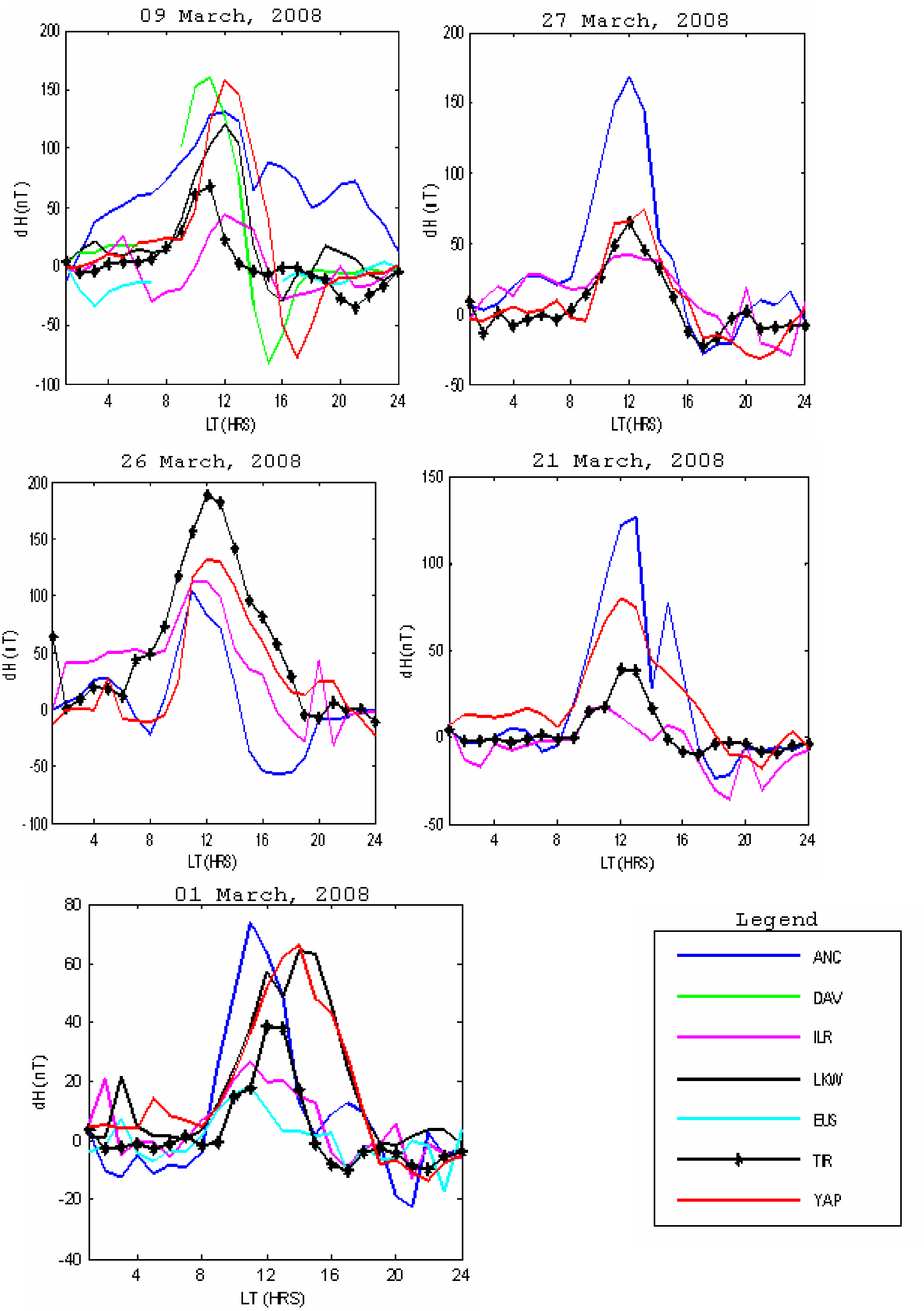

Fig. 3a: Disturbed day variation of the horizontal component of the magnetic field dH for March 09, 27, 26, 28 and 01, 2008.

Daily variation in H component of the geomagnetic field for 5 IDD's of June, 2008

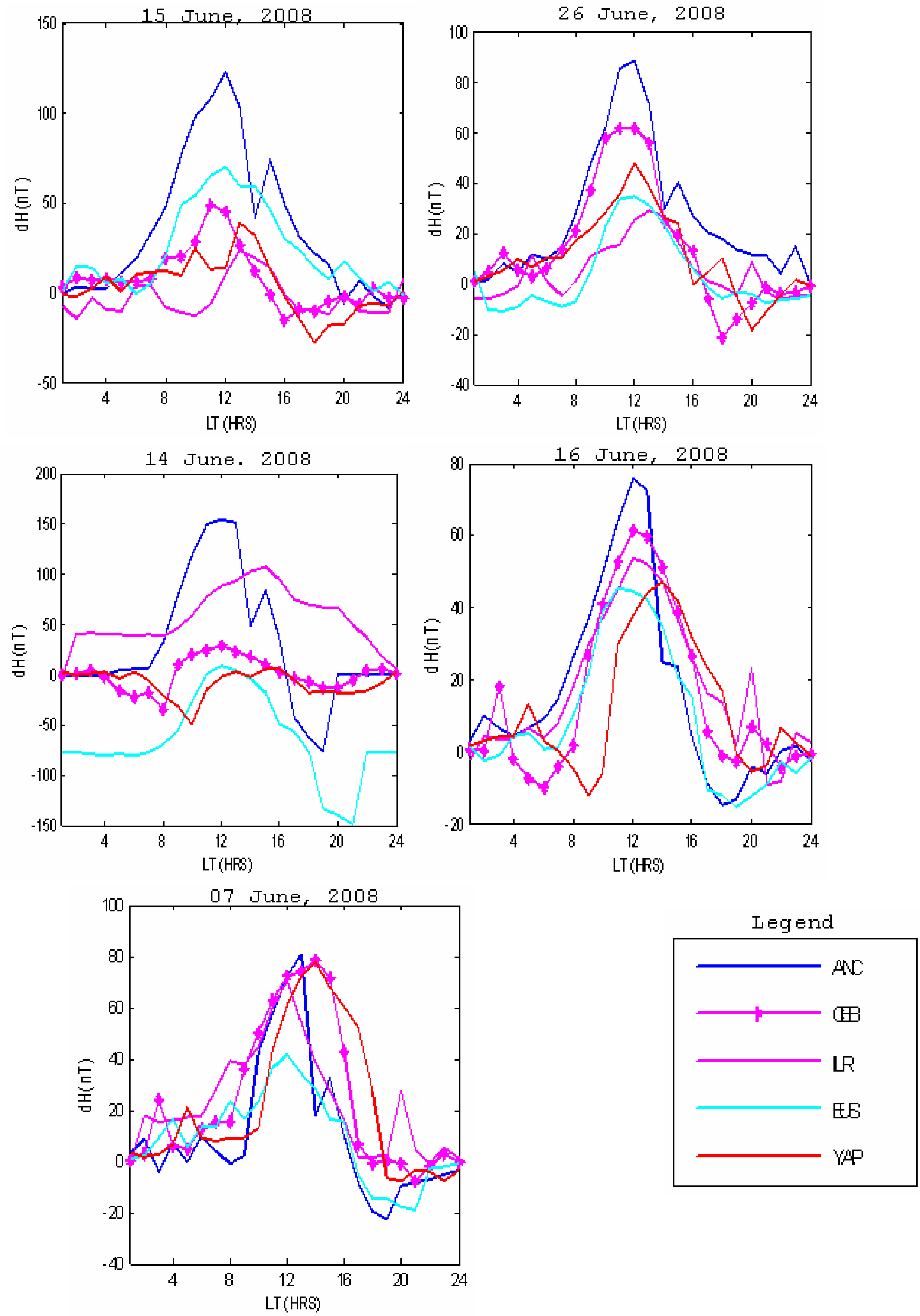

Fig. 3b: Disturbed day variation of the horizontal component of the magnetic field dH for June 15, 26, 14, 16 and 07, 2008.

Daily variation in H component of the geomagnetic field for 5 IDD's of September, 2008

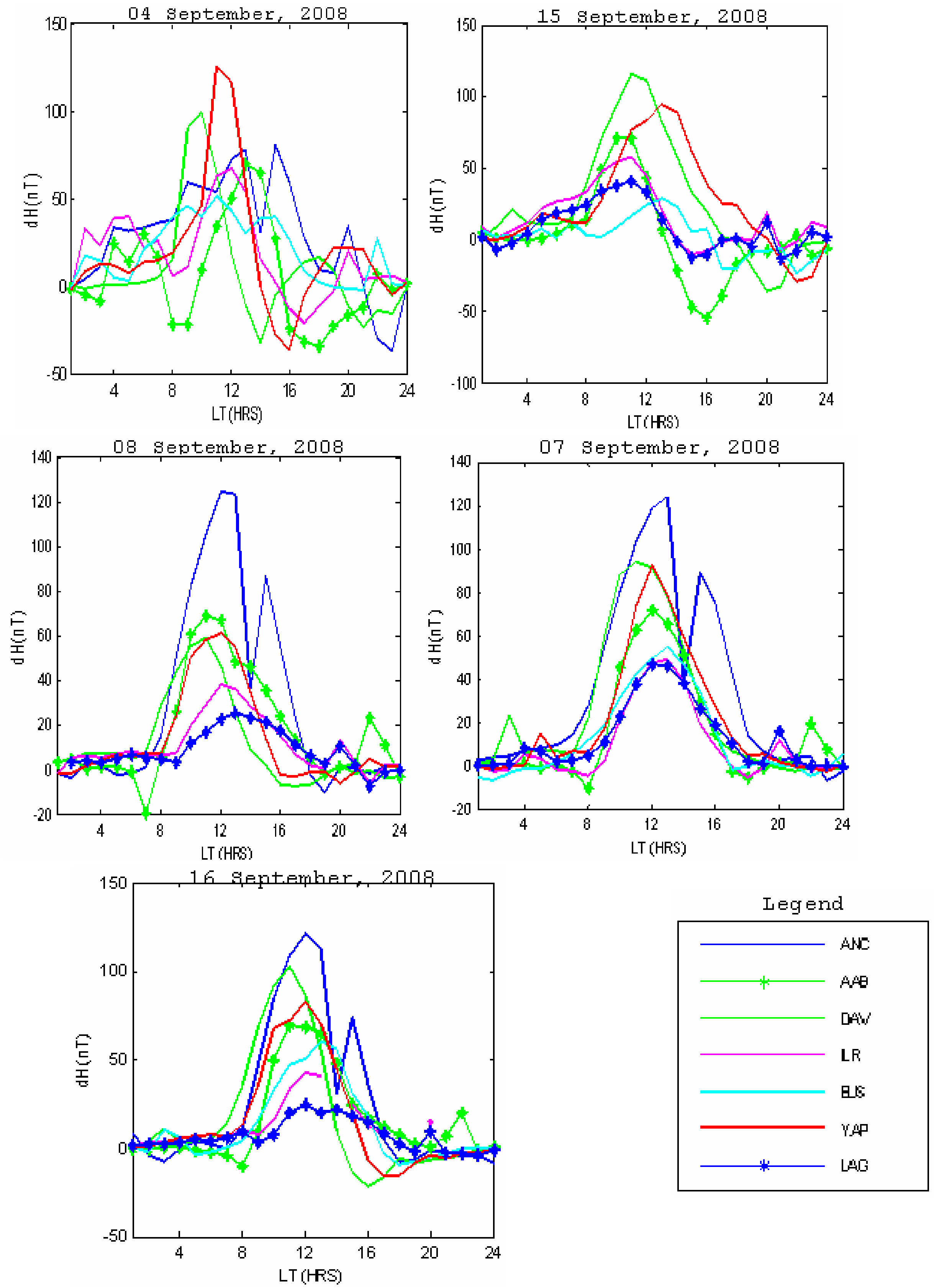

Fig. 3c: Disturbed day variation of the horizontal component of the magnetic field dH for September 04, 15, 08, 07 and 16, 2008.

Daily variation in H component of the geomagnetic field for 5 IDD's of December, 2008

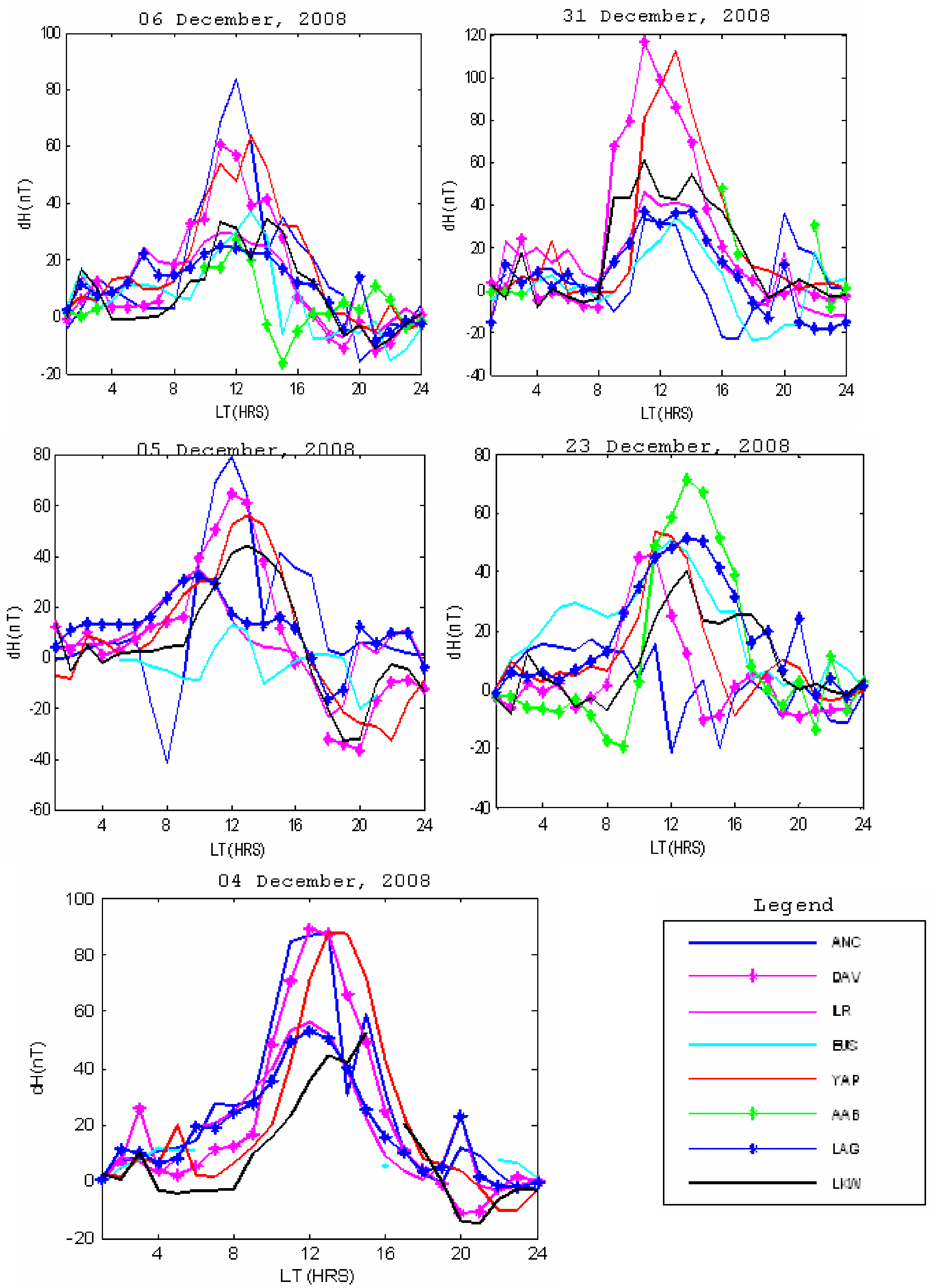

Fig. 3d: Disturbed day variation of the horizontal component of the magnetic field dH for December 06, 31, 05, 23 and 04, 2008.

Monthly variation in H component of the geomagnetic field for March (Equinox), June (Solstice), September (Equinox) and December (Solstice) for 2008

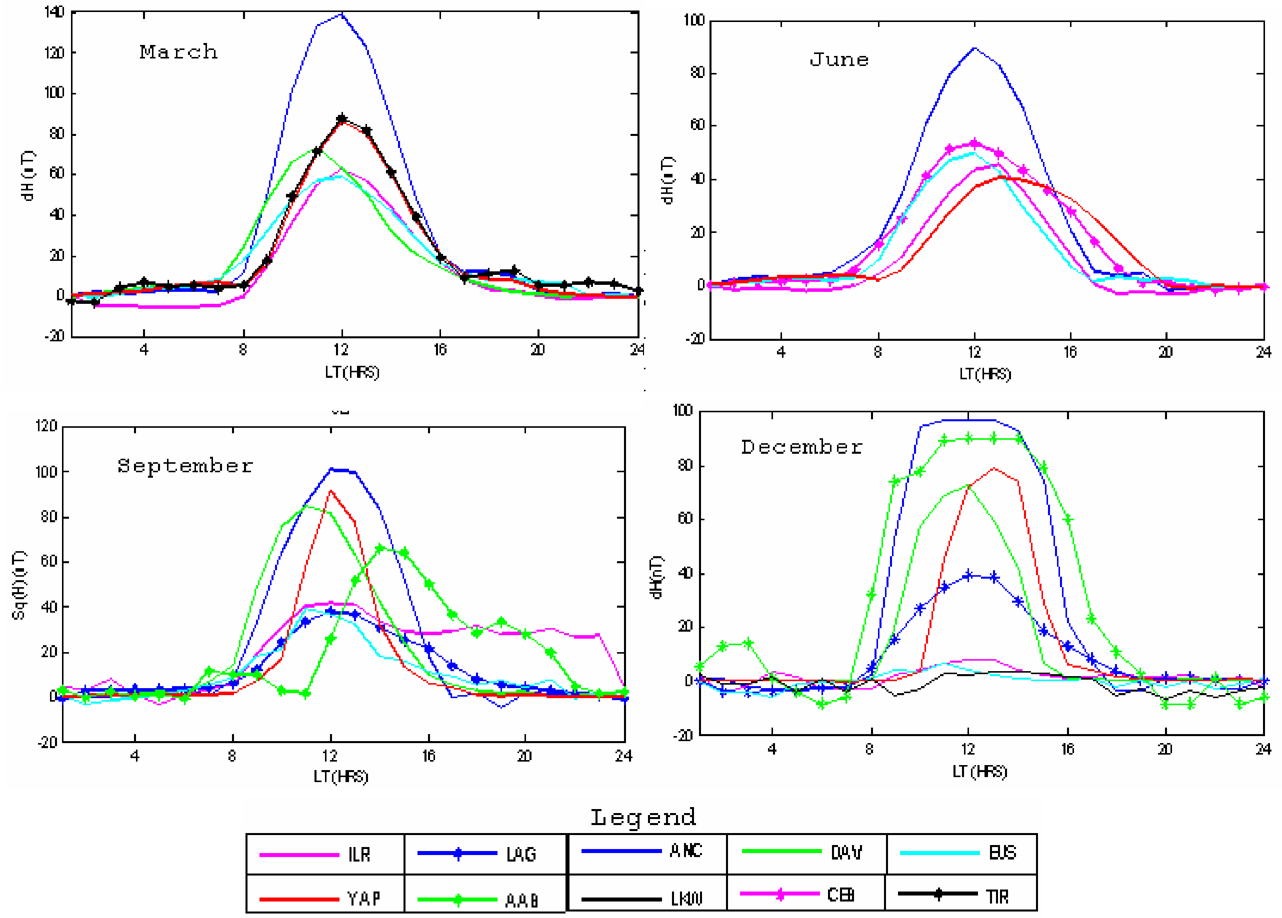

Fig.4: Monthly variation in H component of Geomagnetic field under quiet condition

magnetic equator also display equinoctial maximum of about 23nT with least variation in J-season. This result shows that EEJ is strongest in ANCON (South American Sector). This is a line with the work of Adimula et al (2011). The seasonal change in the Sq variation is attributed to a seasonal shift in the mean position of the Sq current system of the ionospheric electrojet (Hutton, 1962). The electrodynamics effect of local winds can also account for seasonal variability, since the winds are subjected to day to day and seasonal variability.

Conclusions

The diurnal variation in geomagnetic field studied during quiet and disturbed conditions show enhancement in H-component in all the 10 observatories considered. These variations peak around local noon with steady similar trend recorded during quiet days. These trends are attributed to enhanced dynamo action at these regions. Ionospheric processes and physical structure such as winds and conductivity are also responsible for the s_q variations. The variational trend recorded during disturbed conditions are disorganized compared to quiet conditions. This is as a result of ionospheric disturbances originating from the external sources such as space weather effects and storms. Pronounced equinoctial maximum which is due to enhanced electron density at equinox was recorded to be between 40 to 140nT; a range of about 100nT. Seasonal change in s_q variation was also recorded with ANCON located in South American Sector showing equinoctial maximum of 23nT with least variation in J-season. Counter Electrojet was recorded during morning and evening period.

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Seasonal variation in 2008 (Quiet Condition)

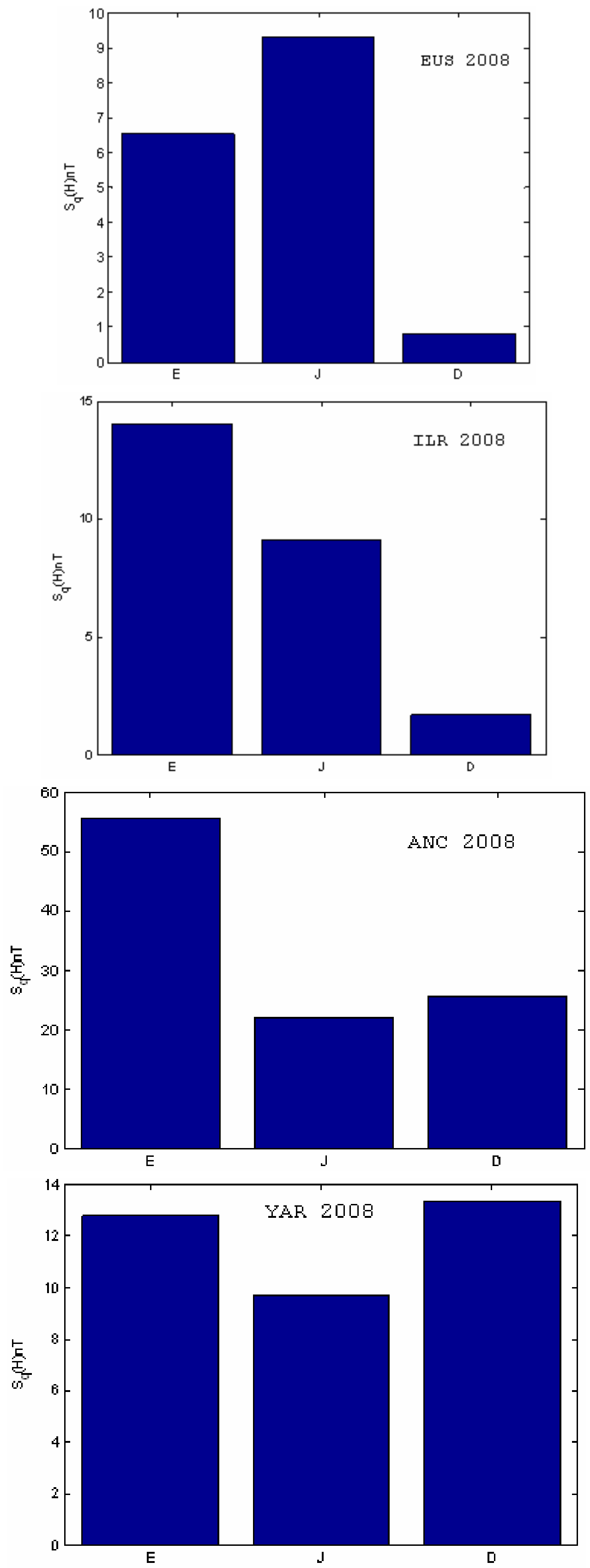

Fig.5: Monthly variation in H component of geomagnetic field under quiet condition

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