

Equinoctial Asymmetry of Horizontal Component of Solar Quiet Variation (SqH)

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Abstract
Intermagnetic data was used to obtained hourly values of solar quiet variation of horizontal component of geomagnetic field for 2009. The results obtained from the variability of the amplitude of the solar quiet SqH daily variation was examined. The SqH strength ranges between 90nT and 50nT at Adds Ababa and Guam with low strength values in other stations (Kakioka, Sodankyla, and Guam) around the local noon. The SqH are grouped into two 50nT-70nT and 70nT -90nT at Adds Ababa Kakioka, Sodankyla, Guam and Uppsala. For 50nT -70nT, It was observed that the SqH occurrence is higher in winter and summer at SqH1 (AAE) than spring and Autumn, while SqH2 (KAK) and SqH3 (SOD) has no values of occurrence of SqH. In SqH4 (GUAM), SqH occurrence is higher in Winter and Autumn than Spring and Summer. In SqH5 (UPP), five occurrence of SqH was noticed in winter while other seasons have no occurrence. While 70nT and 90nT, it was noticed that Spring and summer are enhanced in SqH than Autumn and Winter at SqH1 (AAE), with no value of SqH at SqH2, SqH3 and SqH5, while SqH4 with two occurrence of SqH in Autumn while other seasons have no occurrence. This implies that ionospheric conditions have a direct influence on the occurrence of SqH.
Keywords: solar quiet variation (SqH), Season variation and ionospheric condition

1.0 Introduction

The current in the ionosphere produce magnetic variation that can be observed at the ground and in space. The current associated with the ionospheric dynamo have regular smooth variation is known as solar quiet variation (*S*q) tends to be assigned to the variation observed when only quiet (or those classified as quiet) days are used. The Sq index is the daytime strength of the Sq dynamo current, which is as a results of current flowing in the E layer of the ionosphere caused by the dynamo action of the neutral winds and the induced telluric currents in the Earth’s upper mantle. These currents, in turn, generate magnetic field variations and can be used to obtain an equivalent electric current which is moving along the E region of the ionosphere, induced by solar radiation. The Sq composed of two large vortices flowing on the dayside of the Earth, counterclockwise in the northern hemisphere and clockwise in the southern hemisphere. The thermotidal and thermospheric forces cause electrically charged ions to move through Earth's magnetic field and produce current vortices at northern and southern hemispheres. There are other factors which contribute to the character of Sq variations, particularly in amplitude and phase (phase reflects the time at which the daily maximum amplitude occurs). These other factors include time of year, level of solar activity and, to a lesser extent, longitude of the survey.

Takeda (2002) described the effects of the solar activity on Sq from the correlation of the Sq amplitude with ionospheric conductivity and observed that the solar activity dependence in each month is mainly caused by the variation of the conductivity. The Sq field strongly varies as a function of latitude and longitude. It was also noted that the equivalent current systems Sq deduced from ground magnetic variations is only a proxy of real ionosphere electric currents (Thi Thu, 2011). The current intensity in the ionosphere depends on the ionization density as well as on the electric field. The daily, seasonal or solar cycle variation of the SqH could be primarily due to one of these parameters or due to the simultaneous effects of both. SqH occurs within 5° latitude centred on the dip equator. Chapman (1951) suggested the enhancement caused by a band of electric current of about 300 km in width flowing over the dip equator which was later named Equatorial electrojet.

Baker and Martyn (1953) proposed equatorial electrojet as the enhancement of the east-west ionospheric conductivity within a narrow latitude belt where the electric and magnetic fields are orthogonal to each other. The electrojet causes the large daily variation of the horizontal component of the magnetic field intensity recorded by ground based magnetometers sited along geomagnetic equator. If equatorial electrojet is a part of the global *S*q current system, modified close to the magnetic equator, the day to day variations in the strength of the equatorial electrojet should correlate with the corresponding variations in the strength of the *S*q currents at low latitudes outside the electrojet belt. Rastogi (1983) established that the long solar cycle variation of the range SqH at equatorial latitude is controlled mainly by corresponding variation of sunspot while season variation of SqH is controlled by the electric field.

James et al. (2008) examined the day-to-day variability of the horizontal component of the geomagnetic field along Indo-Russian chain of stations during midday and midnight hours in relations to the corresponding variations of Dst index. The correlation between ΔH and Dst index is around 0.8 for all latitudes. The slope of the regression line is about 1.0 during daytime but during the nighttime hours the slope is only around 0.5. Onwumechilli et al. (1973) showed a close relationship between the equatorial electrojet and polar magnetic variations on a day to day basis. Rastogi et al. (1994) established that the seasonal variation of the daily range of *H* shows equinoctial maxima at Trivandrum, Kodaikanal and Annamalainagar and slowly vanishes at stations further north. It was suggested that the equatorial stations are affected by the imposition of east-west electric field in addition to dynamo action of the earth's ionosphere.

The aim of the study is to investigate the variation of SqH at Addis Ababa, Kakioka, Sodankyla, Guam and Uppsala using the date corresponding to quiet days taken from 2009. The season variation of SqH for the five stations was also examined.

2.0 Methodology

2.1 Data Analysis

The INTERMAGNET provides a good data base from an array of magnetometers for the study of the temporal and spatial variation of the magnetic field strength across the globe. It provides the horizontal components of the Earth's magnetic field (H), as well as the northward and eastward components (X, Y) where used. The five international solar quiet days of each month of the year were employed in this study. The baseline for the quiet day variations is to use the five quietest days for each month for each magnetic observatory. The mean values of H were evaluated for all the months of the years 2009 for the five international quiet days. Table 1 presents stations with geographic and geomagnetic latitude where data are collected. Data were available from January-December 2009 except August 2009.

Table 1. Geographic and Geomagnetic Coordinates of Intermagnet Stations Used in the Study.

Stations	Code	Geographic Latitude	Geographic Longitude	Geomagnetic Latitude	Geomagnetic Longitude
Addis Ababa	AAE	09.3	38.76	0.18	11.80
Kakioka	KAK	36.23	140.19	27.37	208.75
Sodankyla	SOD	67.36	26.62	63.42	107.24
Guam	GUAM	13.58	144.87	5.61	215.55
Uppsala	UPP	59.90	17.35	58.3	106.9

The values for the SqH variations were obtained by subtracting from the observatory hourly means, a trend determined by the two local midnight levels on each side of the quiet day. The local midnight level was computed as a four hourly mean centered on local midnight.

It was noted that the Sq electric field at low latitudes outside the electrojet belt can cause a larger current over the magnetic equator due to increased electric conductivity (Baker and Martyn, 1953). Morning depression is clearly seen across the stations but it does not seem to alter the trend of the daily variation at any of the day. The daily variation of SqH of AAE and GUAM shows a maximum variation around 1100hr LT-1300hr LT but more significant at AAE than GUAM. It was also noted that the SqH activity is stronger in AAE as it is closer to the magnetic dip equator. In Figure 1, the average daily variation of the SqH observed at Addis Ababa with respect to GUAM for January to December ranges from 30nT and 90nT just before noon at about 1100 LT.

Figure 1. Daily variation of SqH at AAE, KAK, SOD GUAM and UPP on the five quiet days from January –December 2009.

2.2 Seasonal Variation of SqH

Several years ago three mechanisms were proposed to cause the seasonal variation of geomagnetic activity. Firstly, the axial hypothesis established the fact that the geomagnetic variation was associated with changes of the Earth heliographic latitude. Secondly hypothesis is referred to as equinoctial hypothesis; it focuses on the angle when the dipole is perpendicular to the solar wind flow, increase in geomagnetic activity will occur at the equinoxes, (McIntosh, 1959). Thirdly, Russell and McPherron's (1973) approach assumed that interplanetary magnetic field IMF lies in its typical parker spiral configuration on solar equatorial plane, the southward component of the interplanetary magnetic field in the geocentric solar magnetospheric (GSM) coordinate system is increased when the angle between the z axis of GSM coordinate and the solar equatorial plane is minimum near the equinoxes. The southward component of interplanetary magnetic field is maximum in early April and October.

Many other researchers studied the variations of the Sq, including Hibberd (1985) that examined the annual, semi-annual and even the whole solar cycle. Stening (1971) examined seasonal variations and longitudinal inequalities of the electrostatic-field in the ionosphere by looking at its electric conductivity and the Earth's main magnetic field. Takeda (2002) showed solar activity dependence of the Sq amplitude, and explained this effect through the ionospheric conductivity. Also Takeda (2002) compared the amplitude of the Sq for the same value of conductivity. The seasonal variation is seemingly due to differences in neutral winds or to the magnetic effect of the field-aligned current (FAC) flowing between the two hemispheres generated by the asymmetry in the dynamo action. The FACs are controlled by interplanetary magnetic fields (IMF) and its electric fields can directly penetrate to the equatorial ionosphere (Sastri, 1988).

Figure 2: Seasonal variation of SqH1, SqH2, SqH3,SqH4 and SqH5 for AAE,KAK, SOD, GUAM and UPP respectively.

The activity of SqH for the period of 50nT to 70nT and 71nT and 90nT was considered in this study where SqH1, SqH2, SqH3, SqH4 and SqH5 represents Addis Ababa, Kakioka, Sodankaya, Guam and Uppsala respectively. Aslo the seasonal periods used in this study are: Winter (November, December, January, and February), Summer (May, June, July, August), Autumn (September, October), Spring (March, April).

3.0 Discussion of the Results

From the Figure 1, the solar quiet variation of the H component (SqH) is high in Addis Ababa (AAE) along the electrojet region as a result of equatorial electrojet EEJ phenomena than other stations (KAK, GUAM, SOD and UPP) for all the months of the year 2009. The SqH is found around the local noon, when the sun is vertically overhead (see Figure 1). It was also noticed that morning depression is clearly seen across the stations. The daily variation of SqH of AAE and GUAM shows a maximum variation around 1100hr LT-1300hr LT but more significant at AAE than GUAM. The SqH activity is stronger in AAE as it is nearer the magnetic equator. The average daily variation of the SqH observed at Addis Ababa with respect to Guam for January to December 2009 ranges from 90nT and 60nT around the 12 noon. The geomagnetic disturbance during the day often intensified at the equatorial electrojet with respect to low latitudes, reflecting penetration of electric field to the equator. Changes in day to day geomagnetic disturbance are not only noticed during disturbance days but also observed at the quiets days. These changes may be as a result of propagation condition for tides entering the dynamo region from below, also some condition from planetary waves that are able to propagate to ionospheric heights. Chapman and Bartels (1940) revealed that changes in day to day amplitude of SqH are controlled by changes in the ionization. But the variability of the current system is determined by the irregularities in the convection system in the relevant layers of the Ionosphere.

Several suggestions were also raised as possible causes of diurnal and seasonal variations; recent result shows that ionospheric conductivity plays a crucial role in particle precipitation and substorm generation. Auroral and geomagnetic activities are associated with low ionospheric conductivity. When both auroral zones are in darkness, the conductivity in conjugate nightside auroral zones is minimum at equinoxes (Lyatsky and Hamza, 2001). Low ionospheric conductivity may be one of the major causes of the asymmetry in seasonal variation of SqH. Also the distance between the Earth and Sun changes with season. The stronger enhancement of SqH at the magnetic equator (AAE) is evident caused by equatorial electrojet. From Figure 2a, SqH are grouped into 50nT - 70nT, it can be seen that the SqH occurrence is higher in winter and summer at SqH1 (AAE) than spring and Autumn, while SqH2 (KAK) and SqH3 (SOD) has no values of occurrence of SqH. In SqH4 (GUAM), SqH amplitude is larger in Winter and Autumn than Spring and Summer. In SqH5 (UPP), five occurrence of SqH was noticed in winter while other seasons have no occurrence.

In Fig 2b, between 70nT and 90nT, it was noticed that Spring and summer are enhanced in SqH than Autumn and Winter at SqH1 (AAE), with no value of SqH at SqH2, SqH3 and SqH5, while SqH4 with two occurrence of SqH in Autumn while other seasons have no occurrence. The influence of the SqH currents is enhanced at low latitudes when compared to high and mid-latitudes. The difference in the asymmetry of the geomagnetic field might be responsible for the difference in the latitudinal response of SqH even the season. The seasonal variation is attributed to seasonal shift in the mean position of the Sq current system and the electrodynamics effects of local winds. The vertical daytime ExB drift velocity in the ionospheric F region is inferred to have seasonal variation (Rabiu et al., 2007). The asymmetry behavior of the geomagnetic field at the northern and southern hemisphere causes the asymmetry in the ionospheric conductivity.

The results of this study confirm that *S*q (H) is a very changeable phenomenon, with a strong season variation, and that it is superimposed on magnetic disturbances of a magnetospheric origin that affect the determination of the true *S*q (H) variation. It may be as a result of the product of both the electron density and the electric field.

4.0 Conclusion.

The study examined the solar quiet variation of the H component (SqH), it was observed that SqH value is high in Addis Ababa (AAE) along the electrojet region as a result of equatorial electrojet EEJ phenomena than other stations (KAK, GUAM, SOD and UPP) for all the months of the year 2009. Also noticed that SqH is found around the local noon, when the sun is vertically overhead. The activity of SqH for the period of 50nT to 70nT and 70nT and 90nT was considered in this study where SqH1, SqH2, SqH3, SqH4 and SqH5 represents Addis Ababa, Kakioka, Sodankaya , Guam and Uppsala respectively. From Figure 2a, it was observed that the SqH amplitude is larger in winter and summer at SqH1 (AAE) than spring and Autumn, while SqH2 (KAK) and

SqH3 (SOD) has no values of occurrence of SqH. In SqH4 (GUAM), SqH amplitude is larger in Winter and Autumn than Spring and Summer. While in Figure 2b, it was noticed that Spring and summer are enhanced in SqH than Autumn and Winter at SqH1 (AAE), with no value of SqH at SqH2, SqH3 and SqH5, while SqH4 with two occurrence of SqH in Autumn while other seasons have no occurrence. This implies that ionospheric conditions have a direct influence on the occurrence of SqH.

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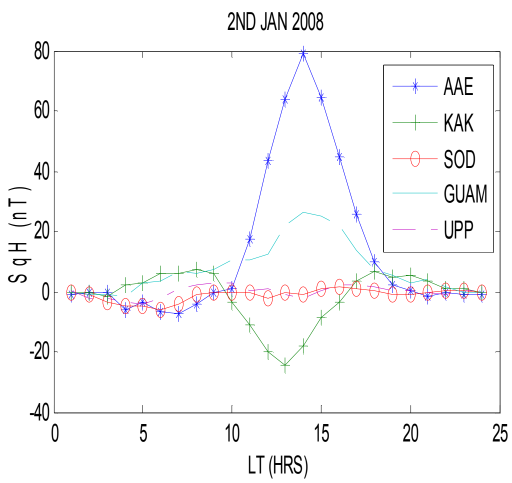
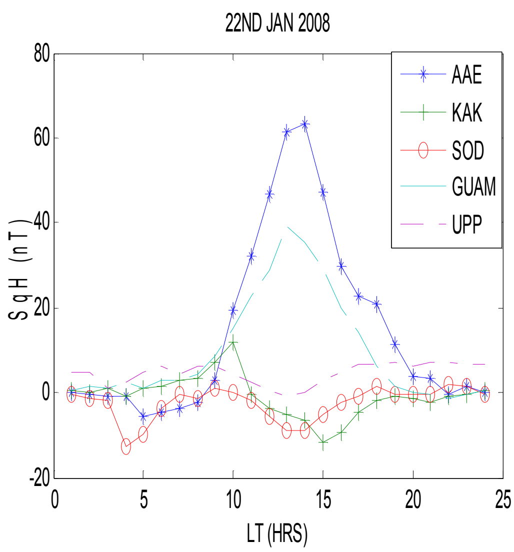
Figure Captions





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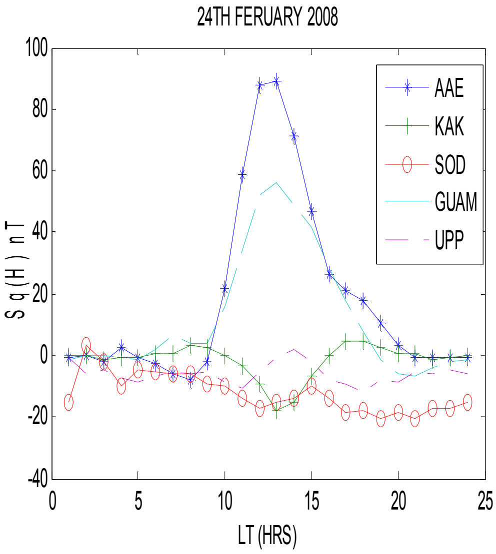

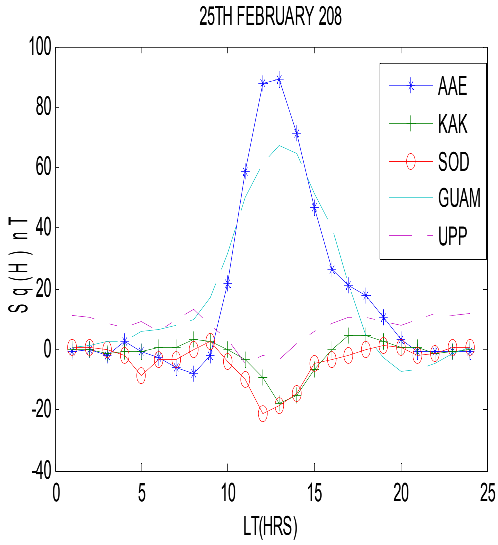

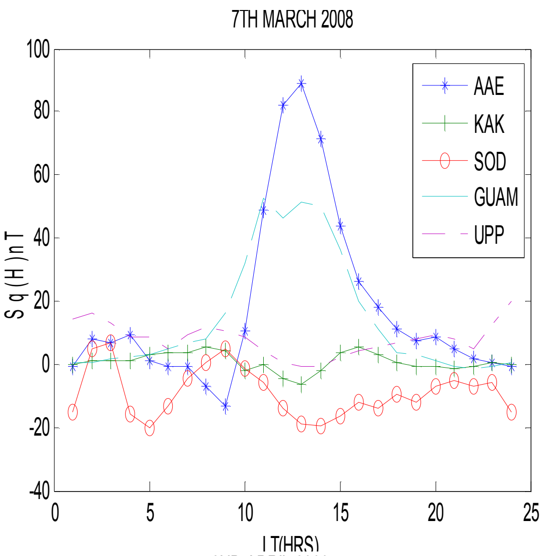

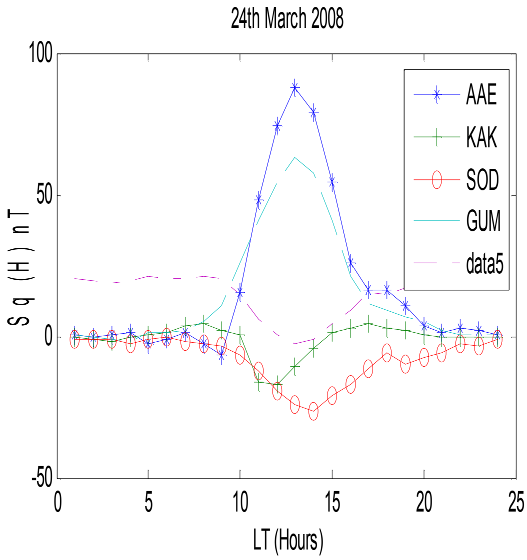

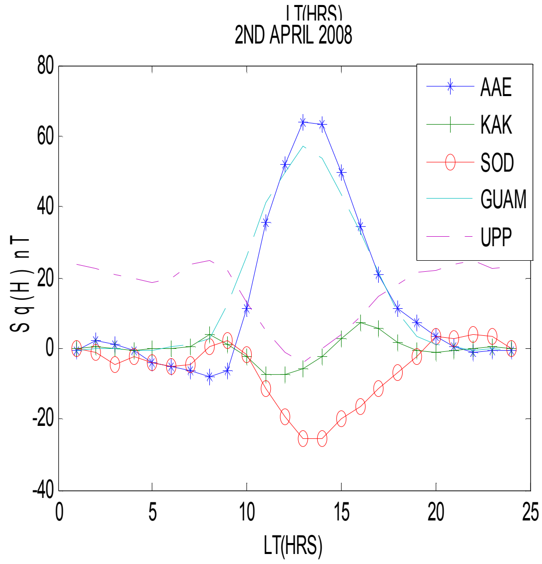

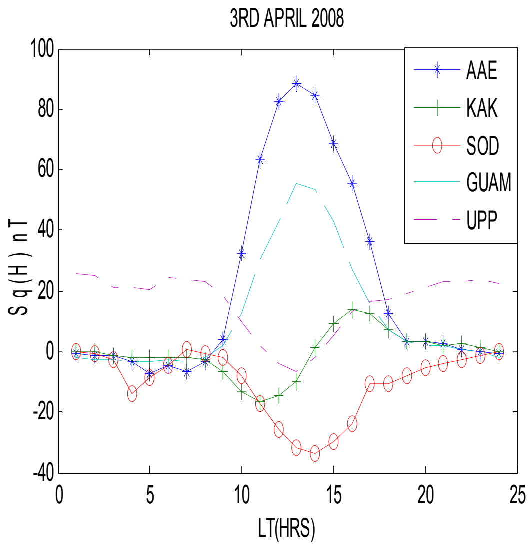

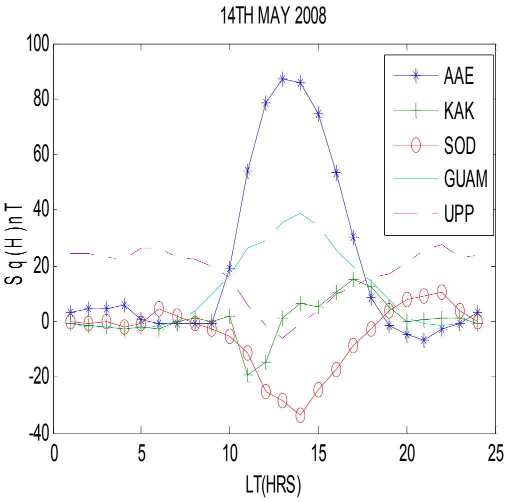
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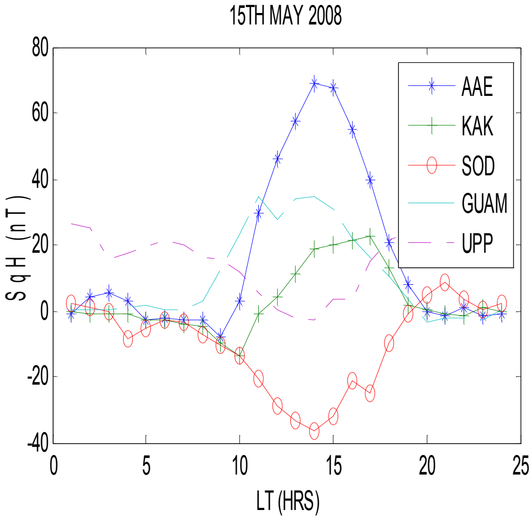
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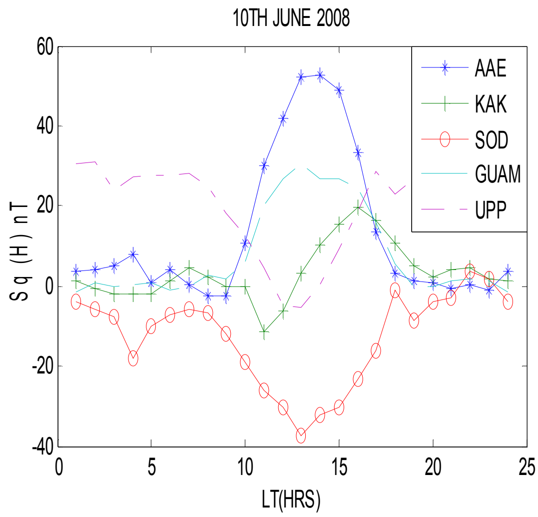
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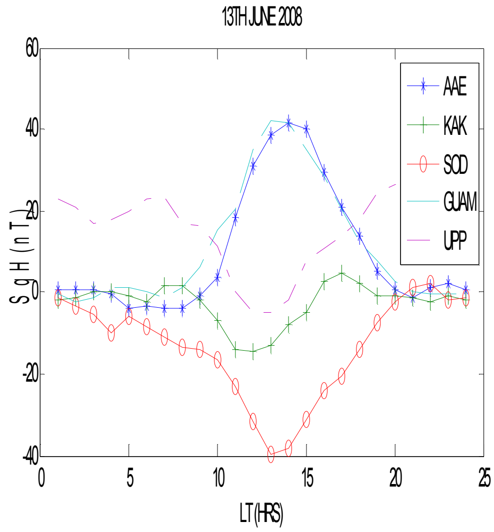
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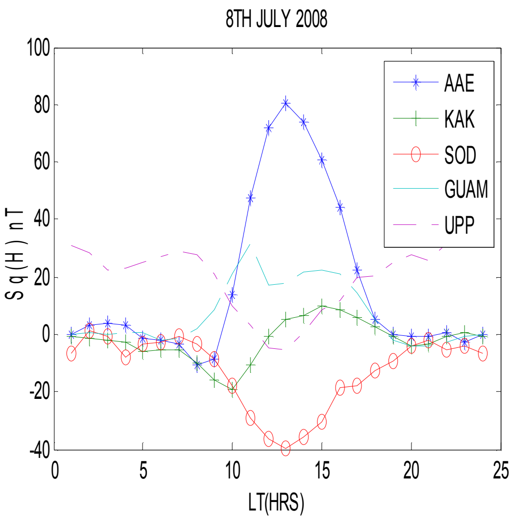
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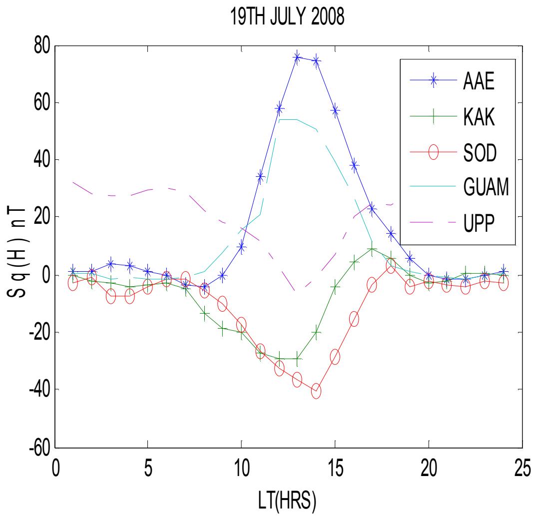
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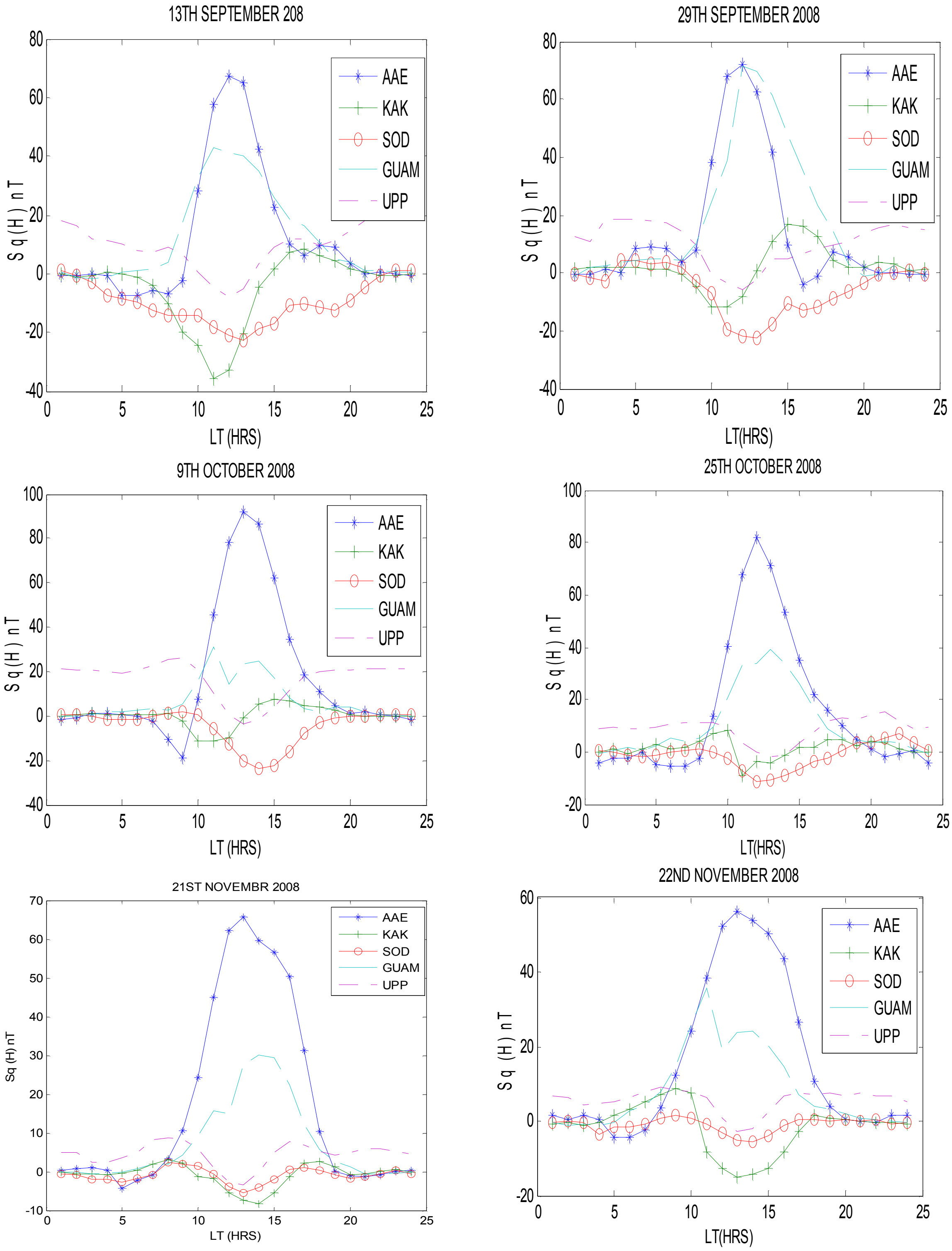
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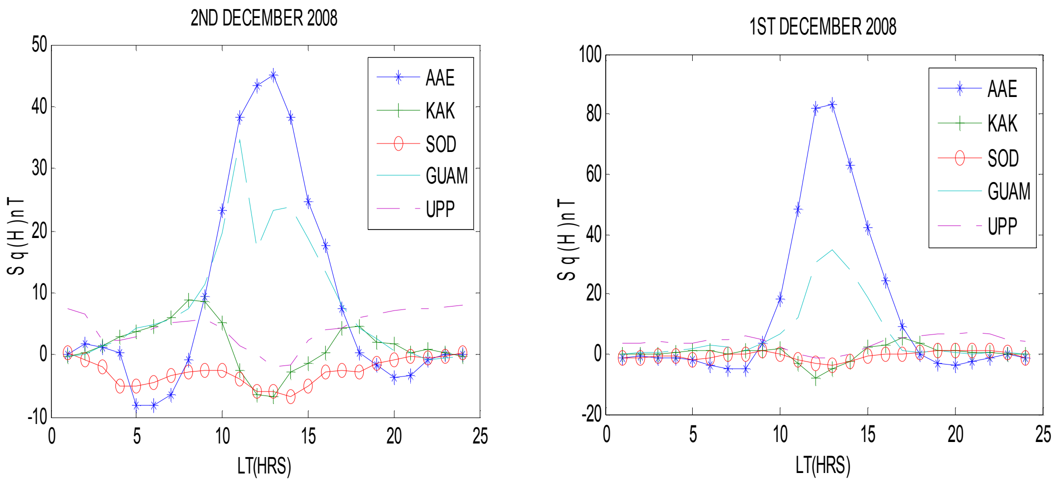
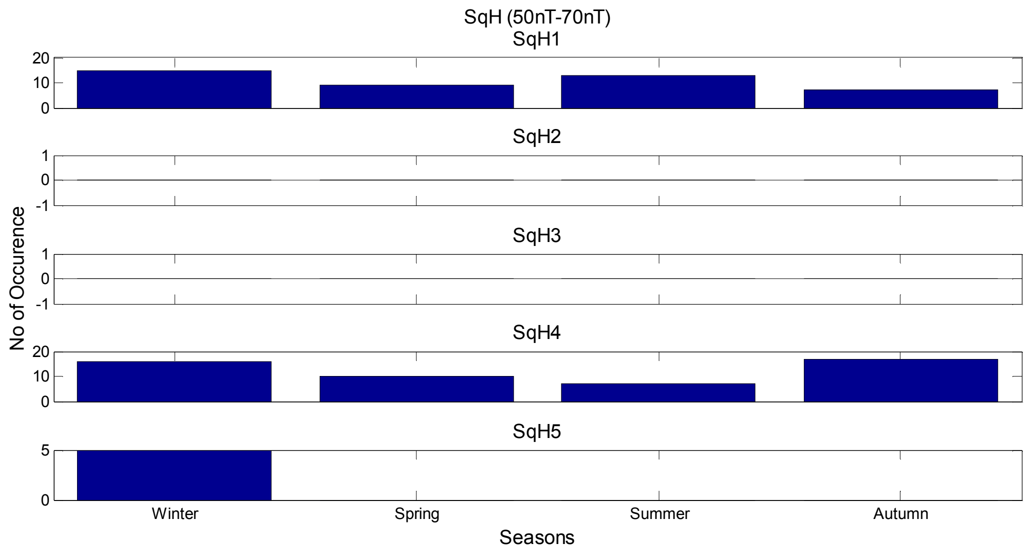


Figure 1. Daily variation of SqH at AAE, KAK, SOD GUAM and UPP on the five quiet days from January –December 2009.

(a)



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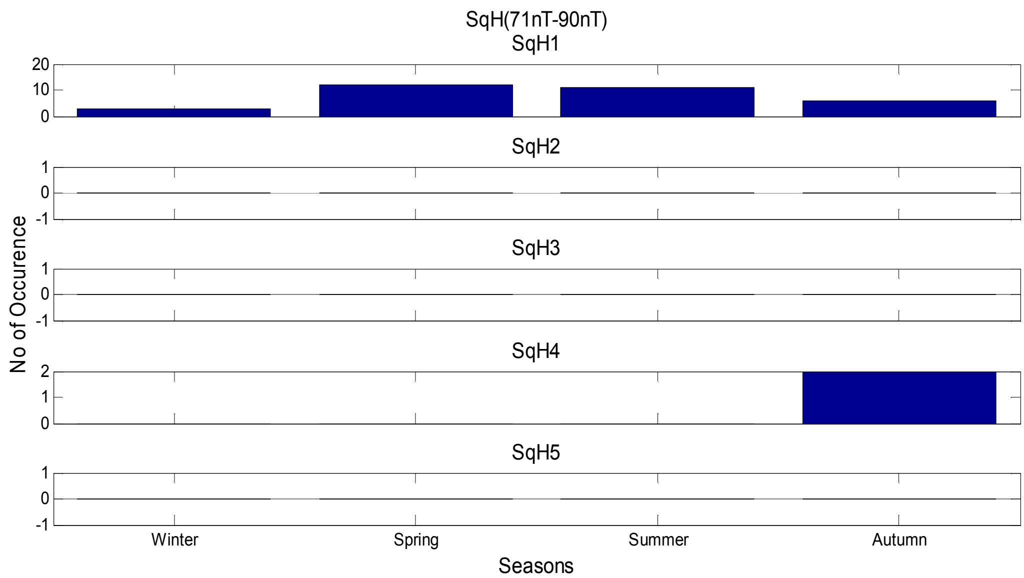

Figure 2: Seasonal variation of SqH1, SqH2, SqH3,SqH4 and SqH5 for AAE,KAK, SOD, GUAM and UPP respectively.