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# Seasonal Variation of Worldwide Solar Quiet of the Horizontal Magnetic Field Intensity

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**Abstract**

Numerous investigations have been carried out on many geomagnetic phenomena with a view of understanding the ionosphere. Solar Quiet (Sq) is caused by electric currents induced in the Earth by the external source. We studied the variations of Sq over the various seasons Winter (November, December, January and February), Summer (May, June, July, August), Autumn (September, October) and Spring (March, April), using data from 64 geomagnetic stations for the year 1996 across the globe. The seasonal variations were studied across various latitudes and longitudes. Results show that Sq(H) exhibits transient variations with varying amplitude according to seasons of the year.

**Keywords:** ionosphere, Solar Quiet (Sq), transient variations

## 1. Introduction

On the Earth, human beings strongly attached their survival to technologies. These technologies are numerous ranging from food security to human capacity development. The study of space phenomena strongly relies on the coupling of magnetosphere, ionosphere and the thermosphere. To mention a few, consistent studies by Matsushita and Campbell (1967); Onwumechilli and Ogbuechi (1962); Price (1969); Rabiu (1996); Bolaji et al. (2013) on these coupling have yielded outstanding information regarding unsuitable perturbations that have been taken into considerations, which makes our continuous living on Earth conducive. The influence of ionospheric currents known as solar quiet (Sq) currents of the ionosphere has played significant role of perturbations regarding the aforementioned coupling among magnetosphere, ionosphere and the thermosphere. Although, recent studies by Onwumechilli and Ogbuechi (1962); Rabiu (1996); Bolaji et al. (2013) on Sq currents were deduced from the horizontal (H) intensity of a geomagnetic field. But, the first study on the daily variation of Sq of the H intensity was carried out by Graham in 1722. During his study, he noted sluggish, regular and irregular changes of declination on different days. He observed that this irregular variability is sometimes larger and more rapid on some days and he referred to such variability as geomagnetic stormy days. From his study, he made suggestions by distinguishing between magnetically quiet, moderately disturbed and highly disturbed days. His studies reveal that daily variations of Sq are different from one day to another, which is based on classification of days into quiet, moderately disturbed and strongly disturbed periods. Different studies have shown that studying Sq variability during a very quiet period avail the opportunity to understand the morphologies of the ionosphere and its interaction with the magnetosphere. Campbell (1976) worked on the spectral characteristics of field variations during geomagnetic quiet conditions. From his work, he observed highest, moderate and enhanced spectral amplitudes at high latitude, low latitude and equatorial region, in that order. He further observed that spatial and temporal features of the spectral for quiet days are closely similar to that observed on geomagnetic disturbed days. Analysis of spherical harmonics that was initiated by Gauss (1839) was employed by Suzuki (1977) to study geomagnetic Sq field. He observed that universal time (UT) variability are made up of two parts;

the regular variations during quiet period (Sq) and the occasional variation during very disturbed period (irregular known as $S_R$, Maeda (1968)).

Mitra (1947); Schlapps (1968); Onwumechilli and Ogbuechi (1962); Rabiu (1996, 2002); Okeke and Rabiu (1998) have investigated Sq day-to-day variations at low and middle latitudes during very quiet period. Irrespective of latitudinal differences, Mitra (1947); Rabiu (1996, 2002); Okeke and Rabiu (1998) observed higher magnitudes of Sq of H during daytime period (0600-1800 local time, LT) compare to the nighttime hours (1900-0500 LT). They reported the effect of ionospheric dynamo from ionospheric conductivity as being responsible for the higher variability of Sq of h during daytime. Okeke and Rabiu (1998) and Rabiu (1996, 2002) suggested that these smaller Sq of H variability observed during nighttime hours (nocturnal period) are not from ionospheric sources, but, from non-ionospheric sources like magnetospheric and ring currents. Onwumechilli and Ogbuechi found that the amplitude of Sq depends on local time and the strength of Sq currents that enhanced at the dip equator. During International Geophysical Year (IGY), Schlapp (1968) participated in the investigation of worldwide day-to-day variability of Sq of H. He observed anisotropy phenomenon, a rapid and higher decrease in Sq of H magnitudes at the middle latitude (European stations) and lowest decrease at the equator. He suggested that variability with separation is faster at latitudes compare to longitudes. Ten (10) year after IGY, Greener and Schlapps (1978) investigated Sq of H day-to-day variability over Europe. They observed a greater coherent length in the east-west direction compare to north-south direction. They attributed that this greater coherence is due to a spatial coherence observed at middle latitude region in the order of 2000 Km.

However, studies on Sq of H are not limited to diurnal, spatial, temporal and day-to-day variability. Studies on Sq of H have also been conducted regarding seasons with respect to solar cycle, annual and semi annual variability. For example, Yacob and Rao (1965) studied the solar cycle and annual variations of Sq (H) at Alibag in India, a low latitude region. They observed a higher magnitude of Sq of H during the summer months, which is equivalent to June (J) season and a lowest magnitude during the winter months, which is equivalent to December (D) season. Maeda (1968) and Suzuki (1973) observed that Sq current intensities at J-season and equinoctial periods are almost equal over American sector. Santarelli et al. (2007) investigated geomagnetic daily variation of Sq of H at Mario Zucchelli station, Antarctica in Italy, a middle latitude station. Using fourteen years of magnetic data, they found a higher magnitude of Sq of H during J-season and a lower magnitude of Sq of H during D-season. Rastogi (1992) and Onwumechilli et al. (1994) have studied geomagnetic field variations of Sq of H at India stations, a low latitude sector. They observed maxima magnitudes of Sq of H during equinoctial months and the lowest magnitudes of Sq of H at noon hours during J-season, which indicates a semi-annual variability as well. Further effort by Vestine (1954) suggested that the meridional ionospheric wind blowing from summer to winter hemispheres explains the annual variation of Sq of H and that of Olson (1970b) postulated a single current system flowing on the magnetopause as the explanation regarding the daily, semi-annual and annual variations of Sq of H. Recently, Yamasaki et al. (2011) worked on the intensity variations of the equivalent Sq current system along the 210° magnetic meridian in Asia using data base of Magnetic Data Acquisition System (MAGDAS). They observed higher magnitudes during J-season compare to D-season. They found that the total current intensity (J total) variability are mainly controlled by solar radiation activity and the impact of seasonal and day-to-day effects are about half of the solar activity contributions as well. Pham Thi Thu et al. (2011) also studied the Sq field characteristics at Phu Thuy, Vietnam, during solar cycle 23 and comparison its variability with Sq field at other longitudinal sectors. Their results show that Sq fields exhibit equinoctial and diurnal asymmetry. These indicate that the seasonal variation of the monthly mean of X-component exhibit a semi-annual signature having two equinoctial maxima. On global scale, Takeda (1999) excluded assumption of north-south symmetry on the time variations of global geomagnetic Sq field in year 1964 and 1980. He observed that the intensity of the vortex in the year 1980 (a solar maximum year) was almost twice as large as that of year 1964 (a solar minimum year). He observed that in the year 1980, the intensity of Sq was varying with a period of about 10-15 days such that the phase is advanced with respect to earlier universal time or to the east side of the globe. He then suggested that the intensity in the two hemispheres vary out of phase with respect to one another and ignores seasonal variability.

Although, the aforementioned literatures have shown that several studies on Sq of H variability have been conducted regionally, but, without any consideration regarding coordinated seasonal variability. Hence, this shortcoming is due to shortage of coordinated observatories, otherwise, owing to increasing geomagnetic observatories either singly or through collaborative efforts, it worth conducting investigation on seasonal variability of Sq of H. In this work, 64 observatories across the world accommodating the northern and southern hemisphere during a very quiet period (1996) will be investigated.

## 2. Methodology

The geomagnetic data employed for this study were retrieved from International Real-time Magnetic Observatory Networks (INTERMAGNET) shown in Figure 1. INTERMAGNET is a global network of geomagnetic observatories, where the Earth magnetic field intensities are being monitor. The data from 64 stations at different latitudinal and longitudinal zones in the year 1996, a low solar active year were used for this study. A year data that was recorded simultaneously from each zone are investigated. The year 1996, being a low solar active period during the solar cycle 22 has an annual sunspot number of 8.6. This annual sunspot number of 8.6 implies that the year 1996 has lesser geomagnetic disturbances coupled with higher number of spotless days in reference to sunspot number. These are stronger indicators that solar quiet (Sq) studies during this year (1996) will give better morphologies about its variability compare to year with higher sunspot number and geomagnetic disturbances. The reason is that the best period to study Sq variability is during period with no or lesser disturbances in the ionosphere. Hence, the choice for international quiet days (IQDs) within the year 1996, otherwise, disturbed days could be involved. The Geosciences Australia at www.ga.gov.au/oracle/geomag/iqd/_form.jsp contains list of IQDs that was described as the quietest days in a month. The most five quietest days were selected from each month of the year 1996 to study geomagnetic intensity of the horizontal (H) component.

The encrypted recorded INTERMAGNET H component data in minutes are decoded and converted to hourly values using codes writing with MATLAB® program. These H geomagnetic field intensities hourly values of the most five quietest days were taken from each month over all the 64 stations. For Sq of H component computation, the baseline value of H ($H_o$) was define as the average value of H component near local midnight between 2400 local time (LT) and 0100 LT. This is expressed mathematically as follows:

$$H_o = \frac{H_{01} + H_{24}}{2} \tag{1}$$

Where $H_{01}$ and $H_{24}$ are the hourly values of H component at 0100 LT and 2400 LT, respectively. The hourly departure ($\delta H$) is equal to the residual value after subtracting a day $H_o$ value from each hourly value of H component. That is,

$$\delta H_t = H_t - H_o \tag{2}$$

This $\delta H$ is the equivalent to the Sq of H, where t = 1 to 24 hours. These analyses are carried out on all quietest five days in a month over all the year 1996 and across all stations under investigation. The deduced Sq of H are further corrected for non-cyclic variations, a phenomenon where the value at 0100 LT is not different from the value at 2400 LT. This method has been employed by Vestine (1947) and Rabiu (2002). For seasonal variation, the hourly values for five quietest days in each month were averaged. This average result to a monthly mean that was then classified into four seasons; winter (November, December, January and February), summer (May, June, July, August), autumn (September, October) and spring (March, April). These estimated seasonal values were then plotted with surfer 8 application to generate the worldwide three dimensional plots results that will be discuss later. However, using the capability of Surfer 8 application, some zones where INTERMAGNET geomagnetic stations did not exist, which could have indicated absence of data-points on the seasonal plots were interpolated. The 64 geomagnetic observatories under investigation are tabulated below.

Table 1. Study locations with their latitude and longitude

| S/N | STATION | NAME | COUNTRY | CO-LATITUDE (DEG) | LONGITUDE (DEG/E) |
|---|---|---|---|---|---|
| 1 | ABK | ABISKO OBSERVATORY INFORM | SWEDEN | 21.64 | 18.82 |
| 2 | ALE | ALERT OBSERVATORY INFORM | CANADA | 7.50 | 297.65 |
| 3 | AMS | AMSTERDAM ISLAND OBSERVATORY | FRANCE | 127.80 | 77.57 |
| 4 | BDV | BUDKOV OBSEVATORY INFORM | CZECH REPUBLIC | 40.92 | 14.02 |

| | | | | | |
|---|---|---|---|---|---|
| 5 | BEL | BELSK OBSERVATORY INFOR | POLAND | 38.16 | 20.79 |
| 6 | BFE | BRORFELDE OBSERVATORY INFOM | DENMARK | 34.37 | 11.67 |
| 7 | BLC | BAKER LAKE OBSERVATORY INFOM | CANADA | 25.67 | 263.97 |
| 8 | BNG | BANGUI OBSERVATORY INFORM | CENTRAL AFRI REP | 85.67 | 18.566 |
| 9 | BOU | BOULDER OBSERVATORY INFORM | USA | 49.86 | 254.76 |
| 10 | BRW | BARROW OBSERVATORY INFORM | USA | 18.62 | 203.38 |
| 11 | BSL | BAY ST.LOUIS OBSERVATORY INFORM | USA | 59.60 | 270.60 |
| 12 | CBB | CAMBRIDGE BAY OBSERVATORY INFO | CANADA | 20.88 | 254.97 |
| 13 | CLF | CHAMBON LA FORET OBSERVATORY | FRANCE | 41.98 | 2.27 |
| 14 | CMO | COLLEGE OBSERVATORY INFORM | USA | 25.14 | 212.16 |
| 15 | CNB | CANBERRA OBSERVATORY INFORM | AUSRALLIA | 125.31 | 149.36 |
| 16 | CZT | CROZET OBSERVATORY INFORM | FRANCE | 136.43 | 51.86 |
| 17 | DLR | DEL RIO OBSERVATORY INFORM | USA | 60.51 | 259.08 |
| 18 | DRV | DUMONT d' URVILLE | FRANCE | 156.67 | 140.01 |
| 19 | ESK | ESKDALEMUIR OBSERVATORY INFORM | UK | 34.70 | 356.80 |
| 20 | EYR | EYREWELL OBSERVATORY INFORM | NEW ZEALAND | 133.42 | 172.35 |
| 21 | FCC | FORT CHURCHILL OBSERVATORY | CANADA | 31.24 | 265.91 |
| 22 | FRD | FREDERICKSBURG OBSERVATORY | USA | 51.80 | 282.63 |
| 23 | FRN | FRESNO OBSERVATORY INFORM | USA | 52.91 | 240.28 |
| 24 | FUR | FUERSTENFELDBRUCK OBSERVATORY | GERMANY | 41.84 | 11.28 |
| 25 | GDH | GODHAVN OBSERVATORY INFORM | DENMARK | 20.75 | 306.47 |
| 26 | GLN | GLENLEA OBSERVATORY INFORM | CANADA | 40.36 | 262.88 |
| 27 | GNA | GNANGARA OBSERVATORY INFORM | AUSRALIA | 121.80 | 116.00 |
| 28 | GUA | GUAM OBSERVATORY INFORM | USA | 76.42 | 144.87 |
| 29 | HAD | HARTLAND OBSERVATORY | UK | 39.00 | 355.50 |

| | | | | | |
|---|---|---|---|---|---|
| | | INFORM | | | |
| 30 | HER | HERMANUS MAGNETIC OBSERVATORY | SOUTH AFRICA | 124.43 | 19.23 |
| 31 | HON | HONOLOLU OBSERVATORY INFORM | USA | 68.68 | 202.00 |
| 32 | IQA | IQALUIT OBSERVATORY INFORM | CANADA | 26.25 | 291.48 |
| 33 | KAK | KAKIOKA OBSERVATORY INFORM | JAPAN | 53.77 | 140.18 |
| 34 | KOU | KOUROU OBSERVATORY INFORM | FRANCE | 87.79 | 307.27 |
| 35 | LER | LERWICK OBSERVATORY INFORM | UK | 29.90 | 358.80 |
| 36 | LOV | LOVO OBSERVATORY INFORM | SWEDEN | 30.66 | 17.82 |
| 37 | MBC | MOULD BAY OBSERVATORY INFORM | CANADA | 13.69 | 240.64 |
| 38 | MBO | MBOUR OBSERVATORY INFORM | SENEGAL | 75.62 | 343.03 |
| 39 | MEA | MEAOOK OBSERVATORY INFORM | CANADA | 35.38 | 246.65 |
| 40 | MMB | MEMAMBETSU OBSERVATORY INFORM | JAPAN | 46.10 | 144.20 |
| 41 | NAQ | NARSARSUAQ OBSERVATORY INFORM | DENMARK | 28.84 | 314.56 |
| 42 | NCK | NAGYCENK OBSERVATORY INFORM | HUNGARY | 42.37 | 16.72 |
| 43 | NEW | NEWPORT OBSERVATORY INFORM | USA | 41.74 | 242.88 |
| 44 | NGK | NIEMEGK OBSERVATORY INFORM | GERMANY | 37.93 | 12.68 |
| 45 | NUR | NURMIJARVI OBSERVATORY INFORM | FINLAND | 29.49 | 24.66 |
| 46 | OTT | OTTAWA OBSERVATORY INFORM | CANADA | 44.60 | 284.45 |
| 47 | PAF | PORT-AUX-FRANCAIS OBSERVATORY | FRANCE | 139.35 | 70.26 |
| 48 | PBQ | POSTE-DE-LA-BALEINE OBSERVATORY | CANADA | 34.72 | 282.26 |
| 49 | PHU | PHUHUY OBSERVATORY INFORM | VIETNAM | 68.97 | 105.95 |
| 50 | PPT | PAMATAI OBSERVATORY INFORM | FRANCE | 107.57 | 210.41 |
| 51 | RES | RESOLUTE BAY OBSERVATORY INFOR | CANADA | 15.31 | 265.10 |
| 52 | SBA | SCOTT BASE OBSERVATORY INFORM | NEW ZEALAND | 167.85 | 172.78 |
| 53 | SIT | SITKA OBSERVATORY | USA | 32.94 | 224.67 |

| | | | | | |
|---|---|---|---|---|---|
| | | INFORM | | | |
| 54 | SJG | SAN JUAN OBSERVATORY INFORM | USA | 71.89 | 293.85 |
| 55 | SOD | SODANKYLA GEOPHYSICAL OBSER | FINLAND | 22.63 | 26.63 |
| 56 | STJ | ST. JOHN'S OBSERVATORY INFORM | CANADA | 42.41 | 307.32 |
| 57 | AMS | TAMANRASSET OBSERVATORY INFO | ALGERIA | 67.21 | 5.53 |
| 58 | TAN | TANANARIVE OBSERVATORY INFORM | MADAGASCAR | 108.92 | 47.53 |
| 59 | THL | THULE OBSERVATORY INFORM | DENMARK | 12.53 | 290.77 |
| 60 | THY | TIHANY OBSERVATORY INFORM | HUNGARY | 43.10 | 17.54 |
| 61 | TUC | TUCSON OBSERVATORY INFORM | USA | 57.75 | 249.17 |
| 62 | VIC | VICTORIA OBSERVATORY INFORM | CANADA | 41.48 | 236.58 |
| 63 | WNG | WINGST OBSERVATORY INFORM | GERMANY | 36.26 | 9.07 |
| 64 | YKC | YELLOW KNIFE OBSERVATORY INFOR | CANADA | 27.52 | 245.52 |

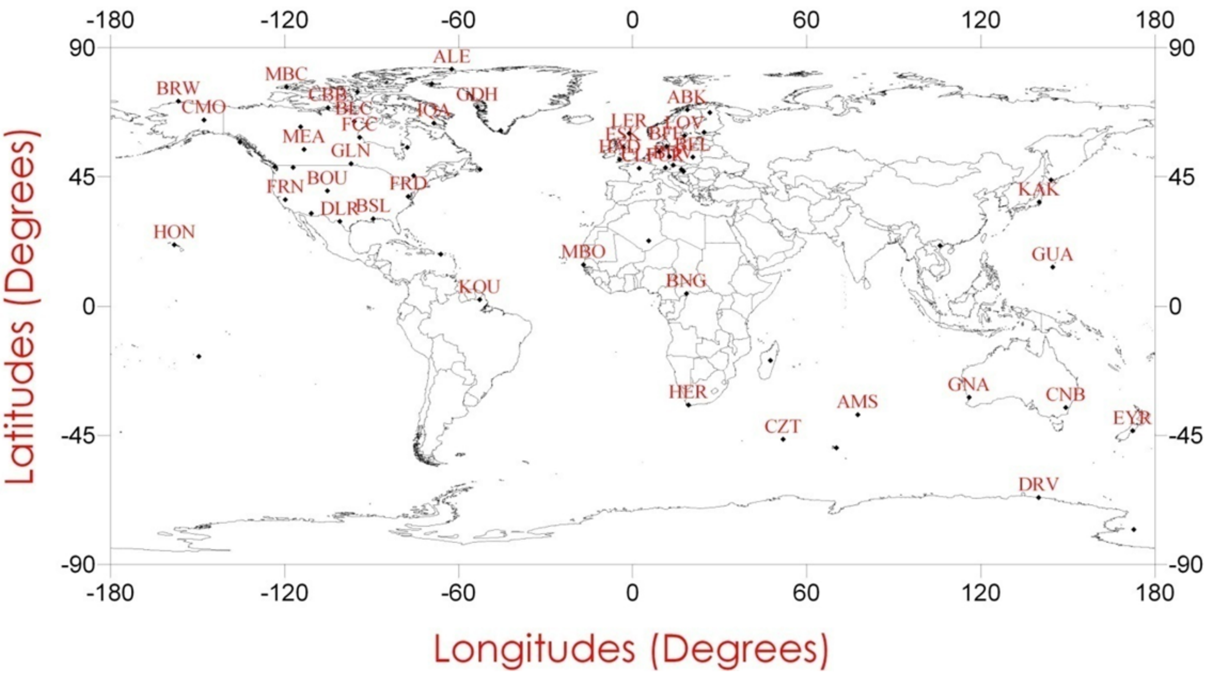


Figure 1. Map of the world showing locations of the 64 observatories used in the research

## 3. Results

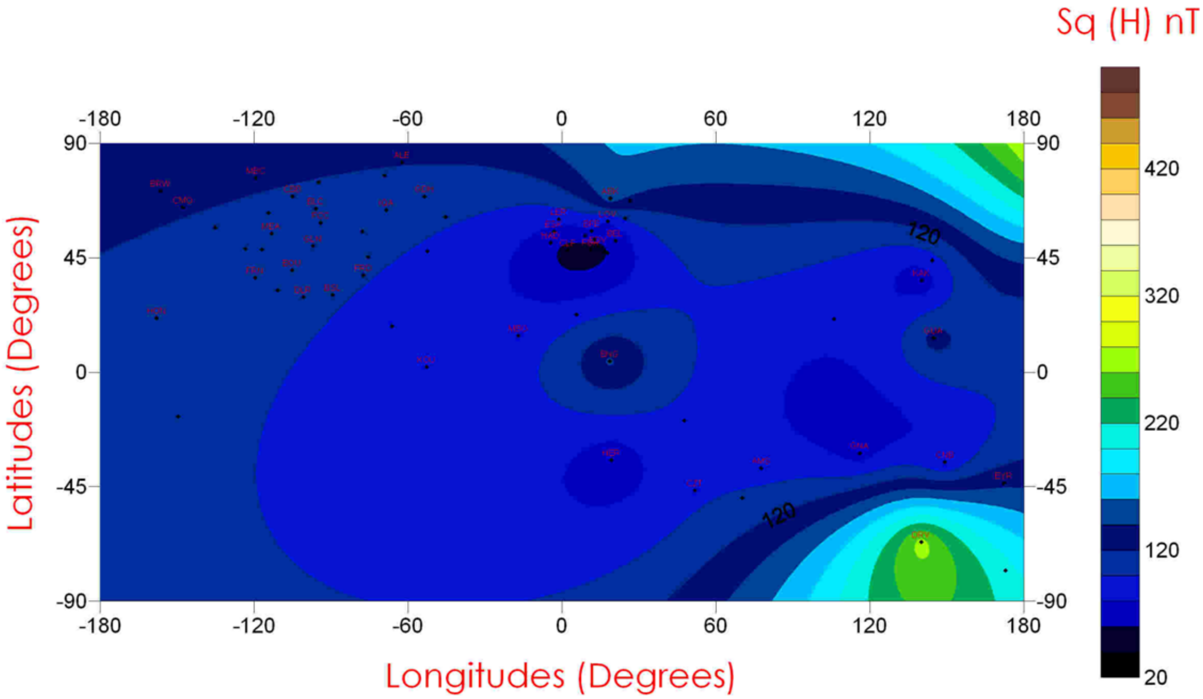


Figure 2. Sq (H) during E- season

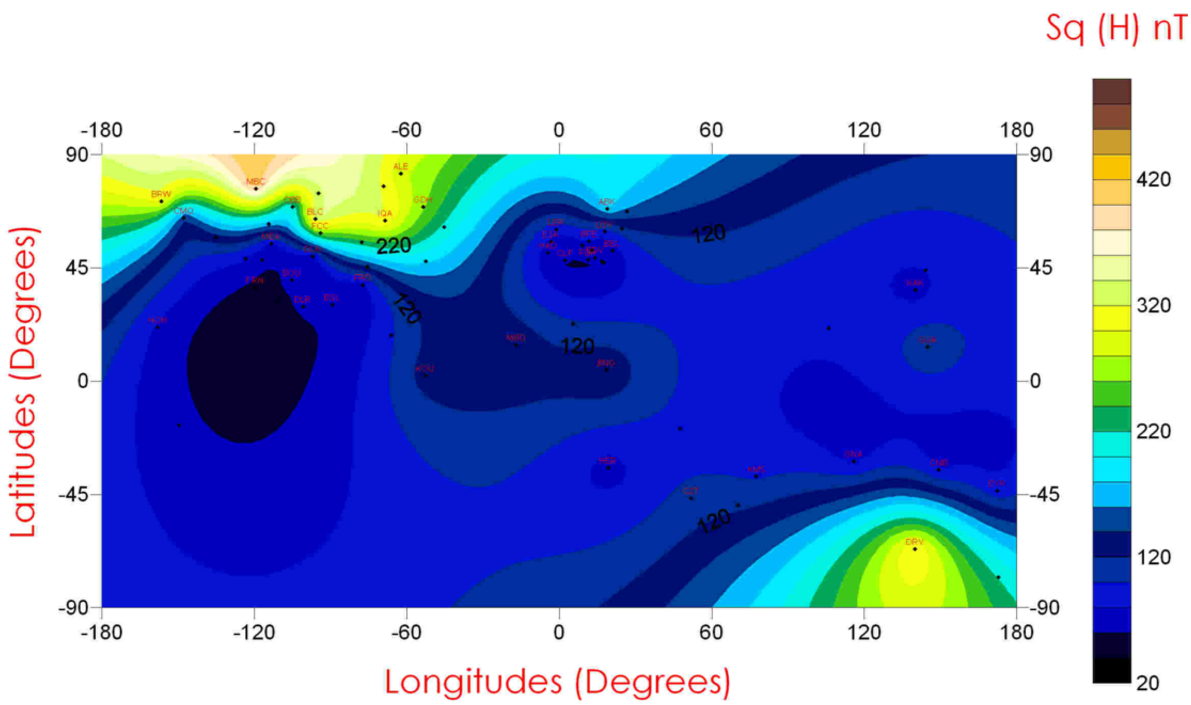


Figure 3. Sq (H) during E- season (Autumn)

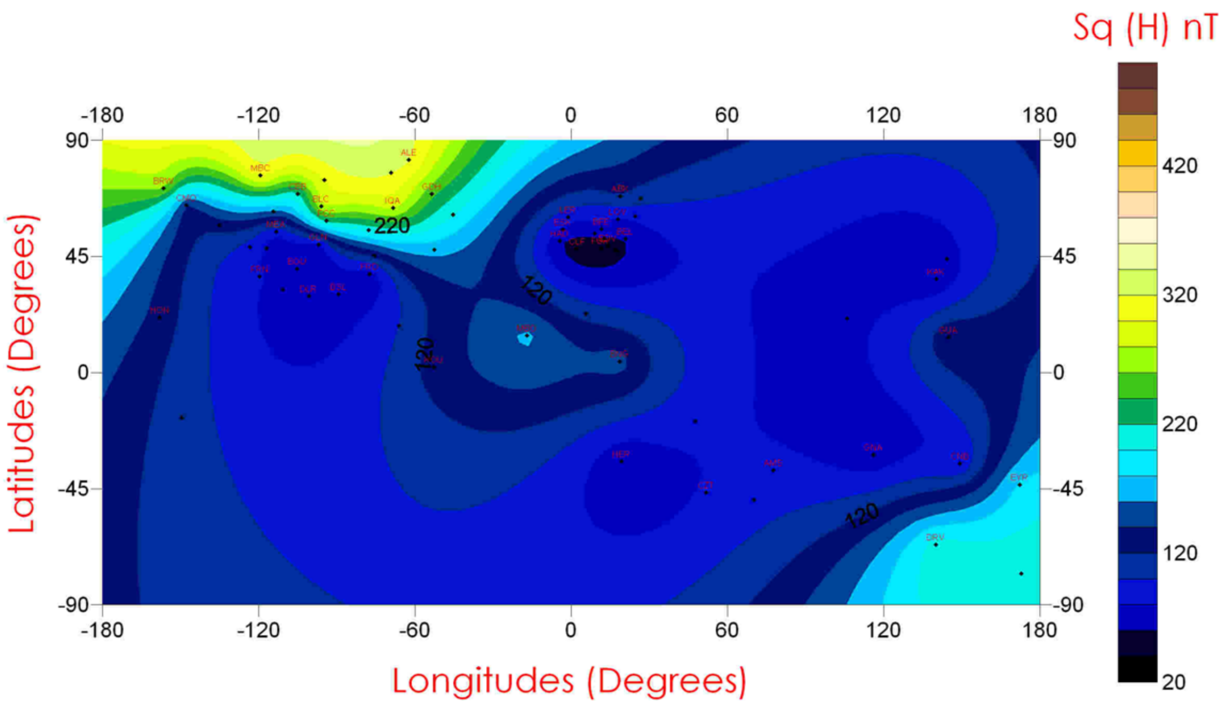


Figure 4. Sq (H) during E- season(Spring)

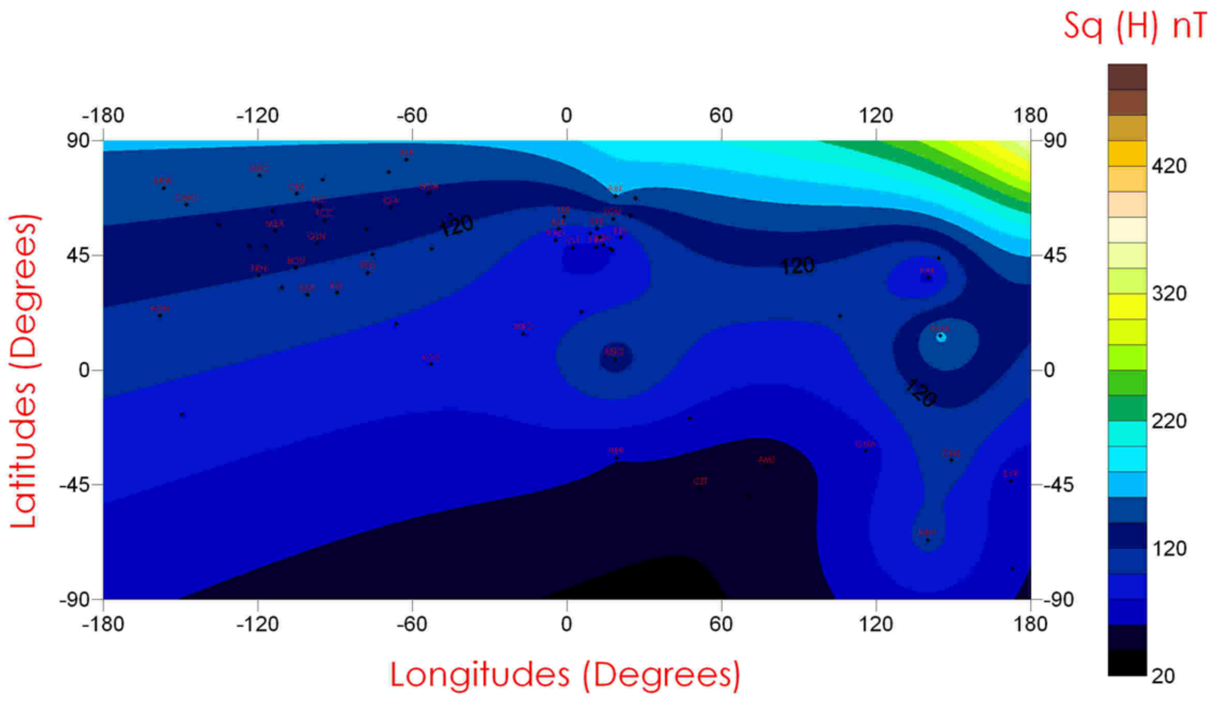


Figure 5. Sq (H) during J- season (June Solstice)

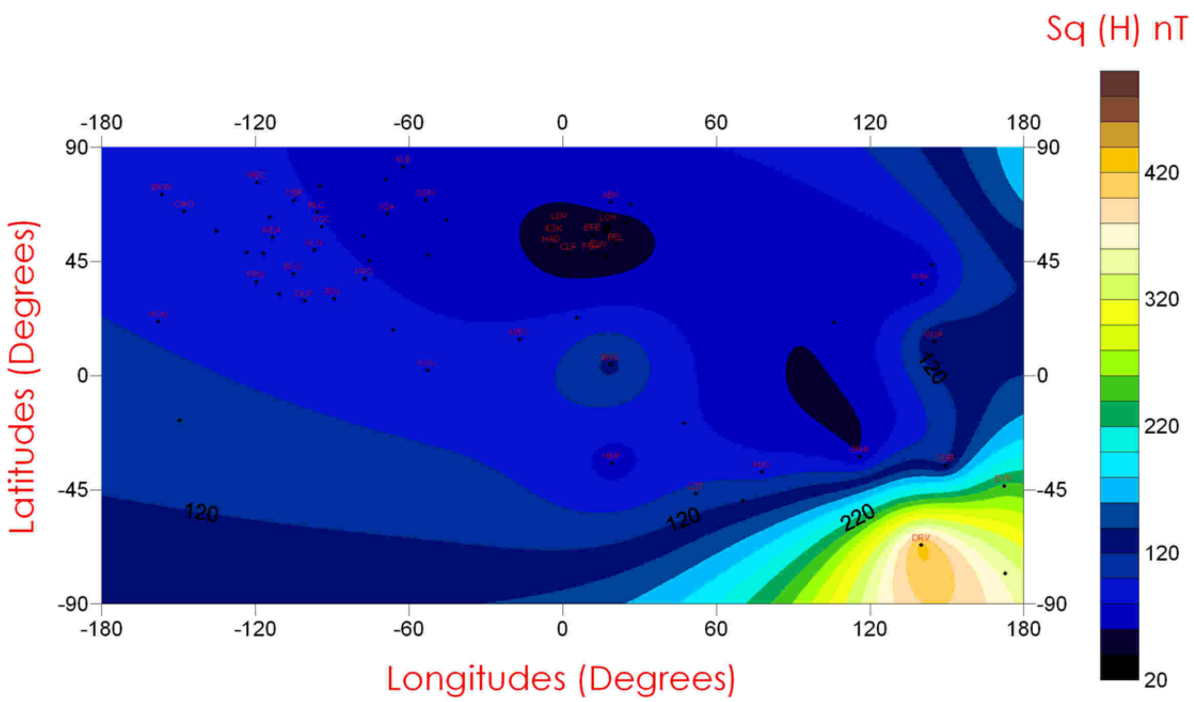


Figure 6. Sq (H) during D- season (December Solstice)

## 4. Discussion

Figures 2 to 5 show worldwide seasonal variations of solar quiet field of the horizontal intensities, Sq (H) during E-season (Autumn), E-season (Spring), J-season (June Solstice) and D-season (December Solstice). In Figure 2, during Autumn E-season, magnitudes of Sq (H) at the western longitude (60°W – 180°W) are in the range between ~ 240 nT and ~ 440 nT at high latitude around 60°N to 90°N. On the same western longitude (60°W – 180°W) at the middle latitude (30°N – 60°N), Autumn E-season magnitudes of Sq (H) were observed to significantly reduce to between ~ 60 nT and ~ 180 nT. Although, around the low latitude (0°N – 30°N), the Sq (H) magnitudes further reduce to ~ 20 nT and ~ 40 nT, but, between the western zone (~ 60°W) and eastern zone (~ 58°E) through the equator (0°) to the low latitude (0°S – 30°S) at southern hemisphere, the Autumn E-season magnitudes of Sq (H) were observed to slightly increased to between the range of ~ 120 nT and ~ 140 nT. Beyond the low latitude to high latitude at the southern hemisphere around 60°W – 180°W, the Autumn E-season magnitudes of Sq (H) are between ~ 40 nT and 60 nT. Minimal Autumn E-seasonal magnitudes of Sq (H) in the range of ~ 60 nT to ~ 130 nT were observed from the high latitude (northern hemisphere) to middle latitude in the southern hemisphere through the low latitude around 60°E – 180°E. Gradual increments were observed from the middle latitude in the southern hemisphere around 60°E – 180°E to the high latitude. These gradual increments were in the range of ~ 170 nT to ~ 320 nT, with the highest magnitude of ~ 320 nT observed at high latitude and the lowest magnitude of ~ 170 nT observed at the middle latitude. The signature of Spring E-seasonal variability in Figure 3 is similar to that of Autumn E-seasonal variability (Figure 2). Irrespective of similarity in their patterns of variability, the Autumn E-season Sq (H) magnitudes are always greater than the Spring E-season Sq (H) magnitudes. For instance, at 60°N to 90°N around 60°W – 180°W, reduced Spring E-season Sq (H) magnitudes in the range of ~ 220 nT to ~ 300 nT were observed compare to Autumn E-season Sq (H) magnitudes in the range of ~ 240 nT to ~ 440 nT. At the high latitude of the southern hemisphere around 120°E – 180°E, reduction in Sq (H) magnitudes of Spring E-season were as well observed compare to higher Sq (H) magnitudes of Autumn E-season. Around 120°E – 180°E, these reductions have consistent value of ~ 220 nT compare to Autumn E-seasonal magnitudes in the range between ~ 170 nT and ~ 320 nT. The surprised increment in equinoctial Sq (H) magnitude at the equatorial region within the low latitude indicates re-injection of ionospheric current, which was reported by Chapman (1951) as being initiated by equatorial electrojet current (EEJ). This comparison between Autumn and Spring E-seasonal magnitudes at all latitudes and longitudes shows that Sq (H) seasonal magnitudes during Autumn is always higher than that of Spring period.

Figure 4 shows worldwide variability of Sq (H) magnitudes during J-season (June solstice) ranging between ~ 20 nT and ~ 180 nT across all latitudes and longitudes. Highest values in the range of ~ 80 nT – ~ 140 nT were observed at all equatorial regions within low latitude across all longitudes. Lowest values in the range of ~ 20 nT – ~ 40 nT were observed at southern hemisphere of the high latitude around 150°W – 110°E and crept slightly into the middle latitude around 60°E – 110°E. An exception was observed at northern hemisphere of high latitude between 60°E and 180°E. This exception is an attribute of increments at northern hemisphere of high latitude between 60°E and 180°E. These increments of Sq(H) magnitudes during June solstice were gradual around 45°N and 60°E and with highest magnitudes of ~ 320 nT between 90°N and 180°E. A worldwide Sq(H) variability pattern similar to June solstice was observed from D-season (December solstice), but, in opposite pattern regarding increments of Sq(H) magnitudes. This opposite pattern regarding increments of Sq(H) magnitudes was initiated around 43°S and extended with continuous increments to the southern hemisphere of high latitude around 8°E – 180°E. The highest Sq(H) magnitude during December solstice between 50°S and 130°E of the southern hemisphere of high latitude was ~ 440 nT. In contrast to June solstice between 90°N and 180°E, reduced Sq(H) magnitude of ~ 160 nT was as well observed.

Although, previous work of Campbell (1976) has shown highest magnitude of Sq(H) at high latitude compared to other latitudes. However, he could not distinguish Sq(H) magnitudes between the northern and southern hemisphere. He attributed this highest Sq(H) magnitude at high latitudes to their closeness to the polar cap that easily accesses any available release energies from magnetospheric sources. Our results have shown high magnitudes of Sq(H) at high latitude compare to other latitudes. The highest value of ~ 440 nT was observed at the southern hemisphere during D-season. The Sq(H) magnitudes were moderate at equatorial zone and sometimes enhanced and at the middle latitude, Sq(H) magnitudes are lower. Similar results have been reported by Yacob and Rao (1965); Maeda (1968); Suzuki (1973); Santarelli et al. (2007); Pham Thi Thu et al. (2011); Yamazaki et al. (2011). At middle and equatorial latitudes, they observed a higher magnitude of Sq(H) during the summer months, which is equivalent to June (J) season and a lowest magnitude during the winter months, which is equivalent to December (D) season. But, at the southern hemisphere of high latitude, summer period is experience when the northern hemisphere of the high latitude is in winter period. Hence, the highest magnitude of Sq(H) observed at the southern hemisphere of high latitude during D-season.

In conclusion, the study has shown the existence of seasonal variation of worldwide Sq(H) with the following characteristics:

1) Solstitial asymmetry: the December solstice Sq(H) magnitude (~ 440 nT) and located at the high latitudes south eastern part of the globe is greater than June solstice Sq(H) magnitude (~ 320 nT) located at the high latitudes north eastern part of the globe.

2) Equinoctial asymmetry: the autumn Sq(H) magnitude (240 nT – 440 nT) at the high latitudes North western and (220 nT – 320 nT) at the high latitude south eastern part of the globe is greater that the spring Sq(H) magnitude ( 220 nT – 300 nT) at the high latitudes north western part of the globe and 220 nT at the high latitudes south western part of the globe.

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