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Characterization of the geomagnetic H-component for a paired station in Africa

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This scientific research investigates the quiet days variation, Sq(H) of H-component of geomagnetic field for the paired stations: Aswan (ASW: G.G.Lat.24.09^{0}N, G.G.Lon.32.89^{0}E and G.M.Lat.15.20^0, G.M.Lon.104.24^0),Durban (DRB: G.G.Lat.29.86^{0}S, G.G.Lon.31.02^{0}E and G.M.Lat.39.21^0, G.M.Lon.96.1^0) located along the 96^0 MM (magnetic meridian) using the ten international quietest days' geomagnetic data from MAGDAS for the year 2009 (a low activity year).The study reveals that sq(H) shows predominantly the diurnal, monthly and seasonal variations of the geomagnetic H-component during the quiet days year round. With maximum amplitude of sq(H) in ASW and minimum in DRB. Meanwhile, the CEJ seen as negative depressions in the H-component of earth field at DRB are all salient physical processes in this study. Further data analysis also revealed many other interesting characteristics for the Sq(H) over African sector paired station. The conclusion drawn from the study shows that the geomagnetic field variations in the northern hemisphere are higher due to solar activities in the region. The Northern Hemisphere is tilted toward the sun, so this area of the Earth receives more direct sunlight during the day than the Southern Hemisphere does. The Southern Hemisphere, on the other hand, is tilted away from the sun and thus receives the sun's rays at an angle, which significantly explains why there is a consistent decrease when it reaches the Durban station (southern hemisphere station), hence the solar activity of the sun influences the Earth's magnetic field, and the upper atmosphere(ionosphere).

Keywords: Geomagnetic field, Ionosphere, MAGDAS, Hemispheric asymmetry.

1. Introduction

The magnetic field is produced as a result of the motion of convection currents of the molten iron which in turn produces an electric current, the convection currents are a result of the molten iron in the Earth's outer core and the resultant effect of convection current currents are caused by heat escaping from the outer core of the earth through a natural process called geodynamo [1]. The geomagnetic field comes from both the inner and outer of the Earth and is divided into stable and variable fields. The stable field is produced by the core dynamo current of the inner Earth and the crustal field produced by earth's crustal magnetic rocks while the variable field is produced by the current systems in the magnetosphere, ionosphere and their induction currents [2]. The variable field extends out into space, where it interacts with a stream of fast-moving charged particles emanating from the Sun.

Geomagnetic field components exhibit two rare variations which are a solar quiet day or Sq variation and rapid irregular fluctuation known as geomagnetic disturbances or storms [2],[3]. Non-polar latitude records showed Sq smooth regular variation. However, the Sq signature tends to be overshadowed and not recognized due to the advent of storms but distinguish itself with a periodic occurrence of 24 h [4]. Solar quiet day or Sq variation of geomagnetic H- component Sq(H) is a regular daily solar variation that takes place in the absence of solar-terrestrial disturbances [1]. The Sq(H) are due to the consequences of dynamo current in the upper ionosphere at a height of 100 km above earth surface [5]. The day-to-day and seasonal variations of Sq(H) has been studied by several scientists. [6],[7]-[8] are few examples.

However, research on the geomagnetic field variation in the African sector remains important due to the orientation of the horizontal geomagnetic field over the continent. The geomagnetic field varies longitudinally from one sector to another within the same equatorial belt

[9]. In this study, hemispheric variation of the geomagnetic field for two selected stations located in the Northern and Southern part of Africa was investigated using geomagnetic H-component obtained from the MAGDAS network in order to study the characteristics of Sq(H) of the two stations.

2. Data and Methodology

The data set used in this research work was obtained from the Magnetic Data Acquisition System (MAGDAS) observatories (http://magdas2.serc.kyushu-u.ac.jp/realtime). This represents the minute averaging of the horizontal (H) intensities from the listed stations from the northern and southern hemispheres. The geographical and geomagnetic locations of the stations are shown in Table1.

Table 1. The station and their locations

Station	Abbreviations	Country	Geographical		Geomagnetic	
			Lat (°)	Lon (°)	Lat (°)	Lon (°)
Aswan	ASW	Egypt	24.08	32.89	15.20	104.24
Durban	DRB	South Africa	-29.86	31.02	-39.21	96.10

The data are the minute averages of H, the geomagnetic north-south component that was converted to hourly values, recorded at each station located in the northern and southern hemispheres. The geographical and geomagnetic locations of these stations are shown in Table 1. The ten (10) internationally quiet days (IQDs) in each month for the year 2009 was selected for this analysis. These ten international quiet days (IQDs) are the ten quietest days of the month as classified on the planetary magnetic index Kp. Baseline values (BAL) were calculated by averaging the value of 4 hrs flanking the local midnight (0100, 0200, 2300 and 2400 LT). Many researchers, including [2],[6] and [10] have used this approach.

The BAL value for the H- component is thus given by

$$\mathrm{BAL(H)} = \frac{\mathrm{H}_{23} + \mathrm{H}_{24} + \mathrm{H}_{01} + \mathrm{H}_{02}}{4} \qquad (1)$$

where $\mathrm{H}_{23}, \mathrm{H}_{24}, \mathrm{H}_{01}$ and H_{02} are the hourly values of H - component at 23-, 24-, 01- and 02-hours LT. The operation of Eqn. (1) above was carried out for each of the geomagnetic stations considered at their local time.

The solar quiet amplitude Sq(H) for a particular hour t, was deduced by subtracting the baseline, BAL(H), for a particular day from each of the hourly values H_t for that particular day H_t.

$$\mathrm{Sq(H)} = \mathrm{H_t} - \mathrm{BAL(H)} \qquad (2)$$

where, $t = 01$ to 24 LT

The local time (LT) for the selected stations was utilized throughout the analysis.

3. Results and Discussion

The results of the diurnal monthly variation of the geomagnetic H- component for Aswan (ASW) and Durban (DRB) stations are shown in Figures 1 and 2 respectively. The red line in Figure 1 and 2 represents the monthly average of the hourly values of Sq(H) for the ten quietest days of the months at the two stations considered. For our description henceforth, the mean of the Sq(H) hourly values for each hour of all the ten quiet days of a month is termed hourly value for each month. The results of the hourly values of Sq(H) for ASW station in Figure (1) reveal that the diurnal variation of Sq(H) presents the same trend in every month of the year 2009 at a different magnitude. A pre-noon peak can be observed for all the month between 0800h – 1000h LT with values within 18 to 20 nT. The morphology of the diurnal monthly variations of Sq(H) for ASW show a regular increase in amplitude from dawn to a pre-noon peak value before gradually decreasing to a minimum daytime value. This value remains nearly zero through the nighttime period. The higher Sq(H) observed before noon hour and minimum Sq(H) observed in the nighttime is as a result of the continuous solar heating of the upper atmosphere [2]. The peak value noted for ASW can be attributed to the equatorial intensification due to daytime solar activity as photo-ionization and minimum loss rate. The absence of solar radiation at night suggest that the nighttime variation came from non-ionospheric sources (e.g., Magnetosphere etc.).

Figure 2 shows the diurnal monthly variations of Sq(H) at DBR station. The morphology of the Sq(H) at DBR indicates an increase from a nearly baseline value around dawn to a pre-noon peak of ~8 nT at 0800h LT in all months. It gradually reduces to -10 nT around 1400h LT across all the months. The depression observed around local noon at DRB in all the months is attributed to phenomenon known as counter electrojet (CEJ) [2]. CEJ is a geomagnetic phenomenon whose attributes are seen during the geomagnetic quiet conditions as a negative depression in the magnitude of the geomagnetic H-component during the noon hours [12].

Figure 3 depicts the Month-to-Month diurnal variations of Sq(H) at ASW and DRB stations for a month each in the four seasons, where January represents a month in December solstice, April represents a month in March equinox, June represents a month in June solstice and August for the month in September equinox. It can be observed that the monthly Sq(H) variations for the two stations during the selected months (i.e., January, April, June and August) indicate that ASW presents maximum Sq(H) variation magnitude than DRB in all the months. The peak recorded between the hours of 1000h -1100h LT at ASW in January, April, June and August are 18 nT, 28 nT, 32nT and 21 nT respectively. However, the maximum value of Sq(H) in DRB is between 6 to 13 nT within the hours of 0700h to 0800h LT. The minimum Sq(H) variation for ASW and DRB are -12 nT (April) around 1700h LT and -16 nT (August) at about 1400h LT respectively. There are daytime occurrences of CEJ as depression, observed in all the months considered at DRB and most prominent in August with a magnitude of about -16 nT.

Figure 4 represents the seasonal variation of Sq(H) at ASW and DRB. The seasonal Sq(H) variation peak value is observed at ASW during the March equinox (February, March and April) at about 1000h LT with a magnitude of 31 nT. The minimum seasonal Sq(H) variation was observed at DRB during the December solstice (November, December and January) at around 0800h LT and magnitude of 6 nT. It was also noted that there exists an asymmetry in the daytime value of seasonal Sq(H) variation at ASW and DRB. It was more pronounced during the June solstice and September equinox, whereby the time of maximum seasonal Sq(H) variation in ASW almost corresponds to the corresponding occurrence of counter electrojet (CEJ), a depression in horizontal intensity at DRB. Both stations show a unique night time nearly baseline values.

The correlation between Sq(H) at ASW and DRB were computed for each of the hours as shown in Figure 5. The relationship between the observed values of Sq(H) variation at the two stations revealed that their correlation, $r = 0.43$. The obtained poor r value can be attributed to the asymmetry effect on the two stations. The major contributor to the observed asymmetry between ASW and DRB is the difference in the pre-noon peak values and the occurrence of CEJ at DRB stations.

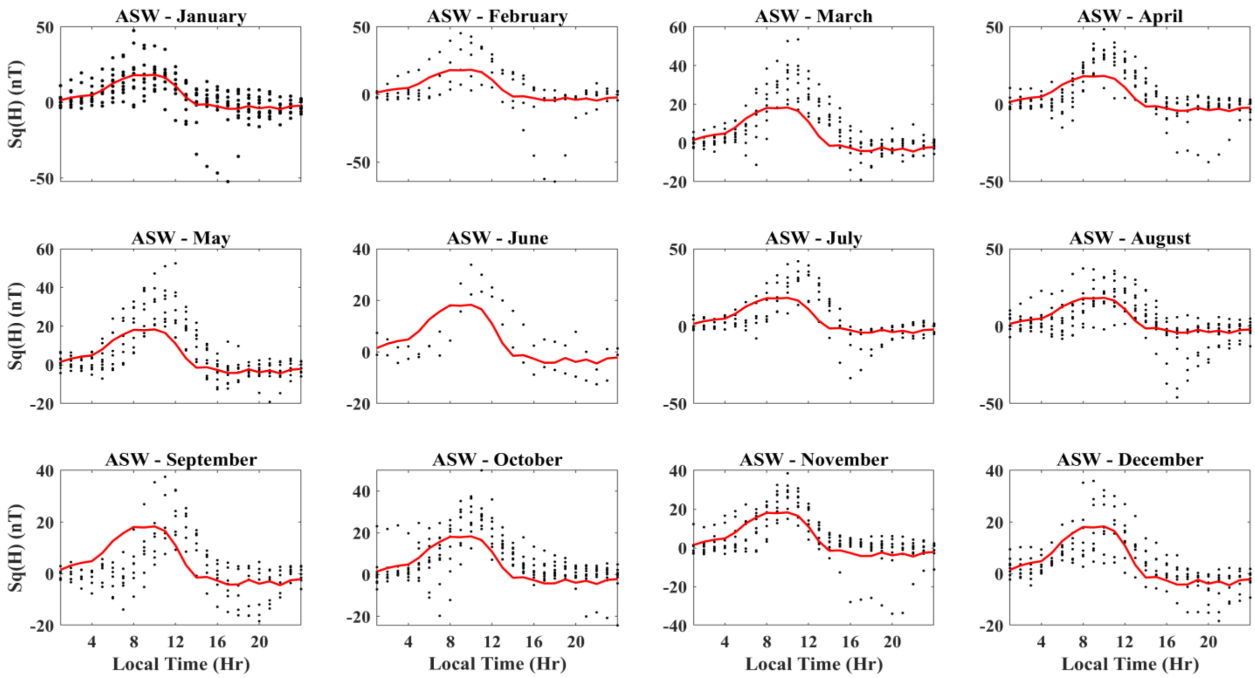

Figure 1. Monthly Diurnal Variation of Sq(H) over Aswan.The dotted points represent he daily values of Sq(H) and the red thick line represents the diurnal average value of Sq(H)

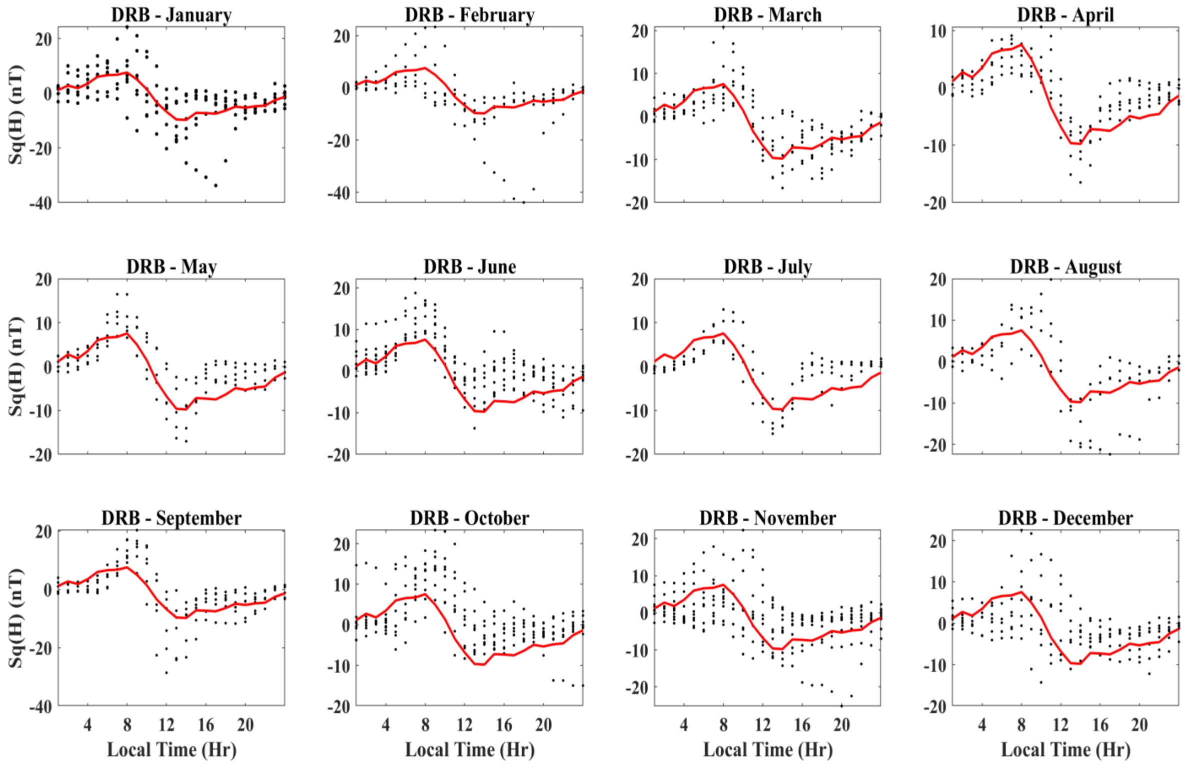

Figure 2. Monthly Diurnal Variation of Sq(H) over Durban. The dotted points represent he daily values of Sq(H) and the red thick line represents the diurnal average value of Sq(H)

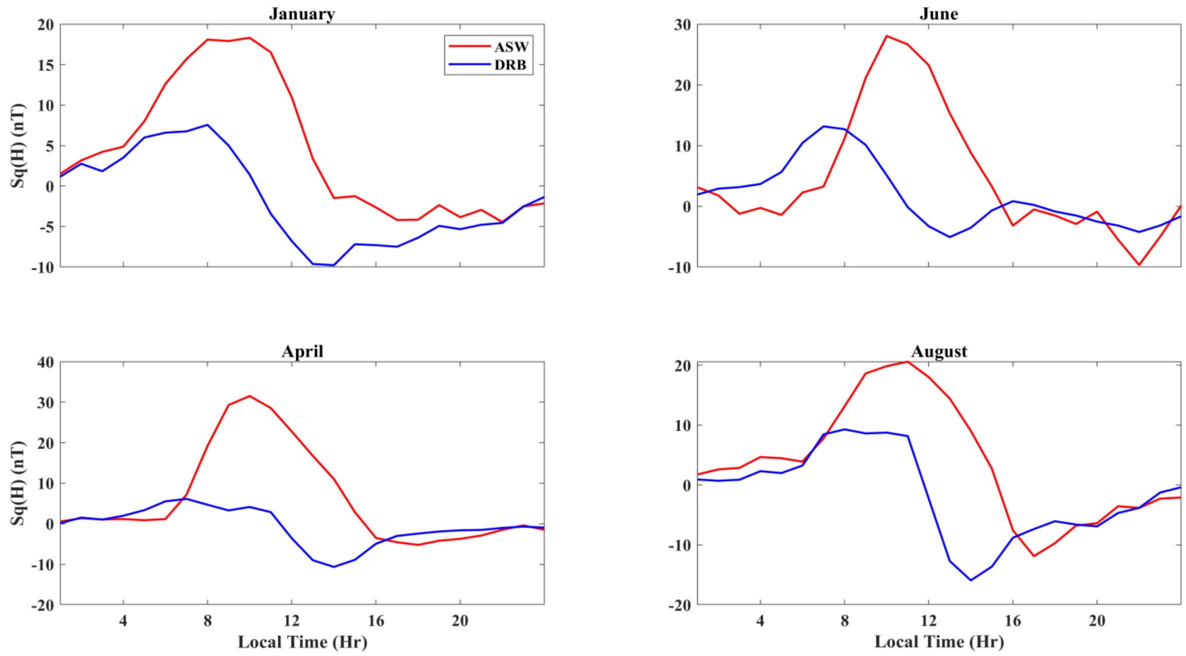

Figure 3. Month-Month Variation of Sq(H) for Aswan and Durban

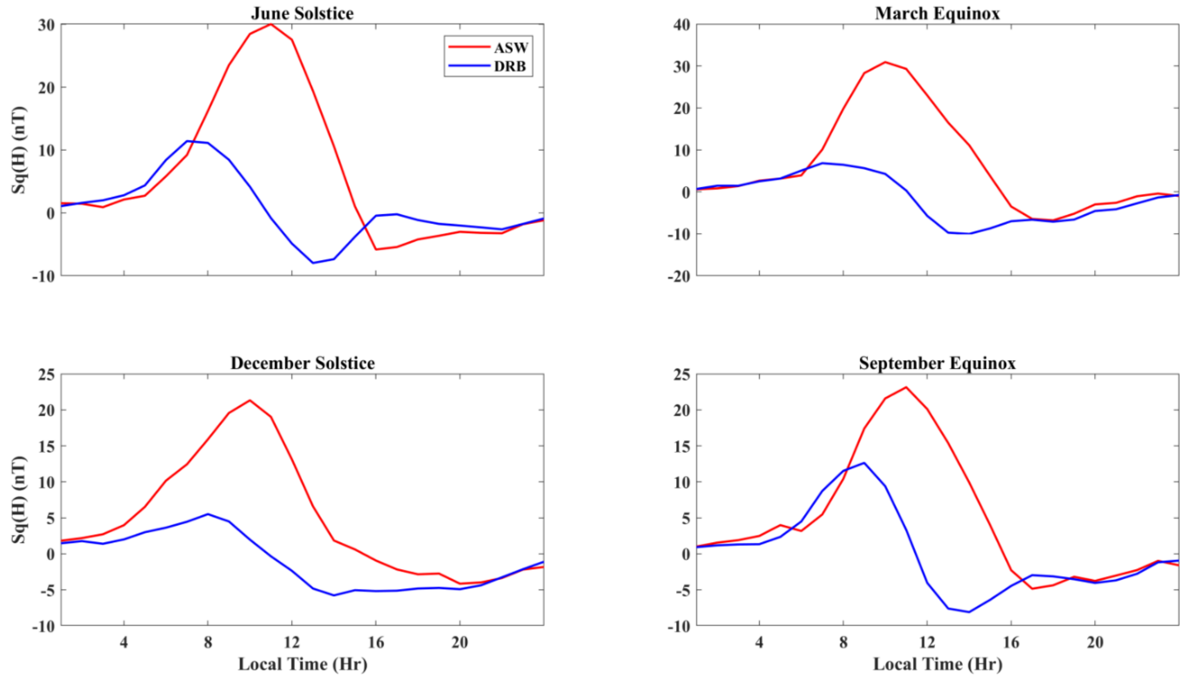

Figure 4: Seasonal Variation of Sq(H) for Aswan and Durban.

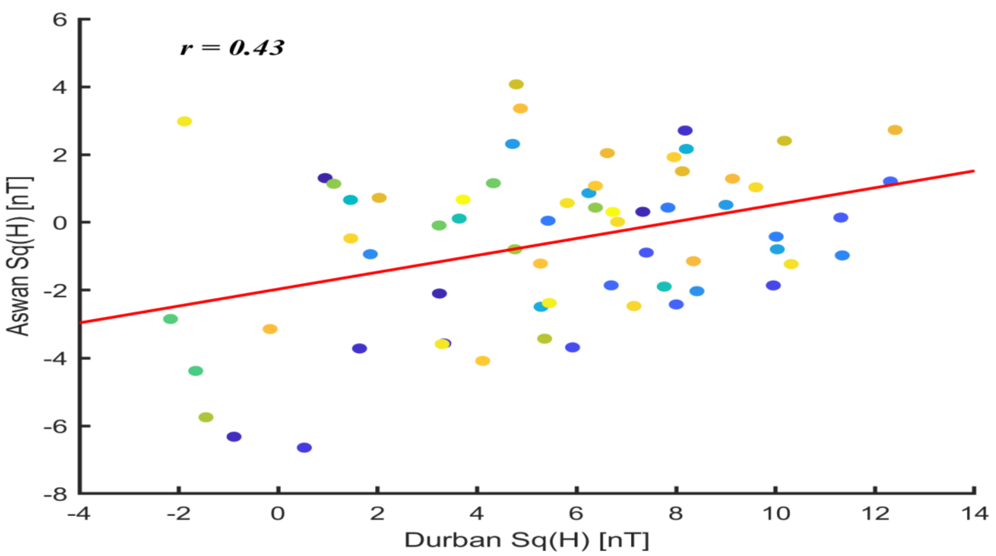

Figure 5: Scattered Plots of Sq(H) Showing correlation between Aswan and Durban.

4. Conclusion

This study affirmed that there is Sq variation in horizontal component of the earth magnetic field on quiet days year-round. The magnitudes are greater during the daytime hours than the night time hours. This is mainly due to the variability of the ionospheric processes and physical structure such as conductivity and wind structure. The conclusion drawn from the study shows that the geomagnetic field variations in the northern hemisphere are higher due to solar activities in the region.

1. The maximum and minimum Sq(H) amplitude observed in ASW and DRB respectively are as a result of their latitudinal position difference
2. Maximum Sq(H) before noon and minimum Sq(H) at night time are due to the continuous heating of the upper atmosphere.
3. March equinox and June solstice Sq(H) variation were maximum at ASW
4. There is a weak correlation ($r = 0.43$) between the two stations (ASW and DRB).

5. The diurnal variation is present in the horizontal component of the earth magnetic field during the quiet days the year-round. The pre-noon magnitudes are greater than the post-noon magnitude. This is accounted for by ionospheric processes such as solar conductivity and wind structure.
6. The high amplitude noticed for ASW can be attributed to the location of the station around the equatorial latitude and as such EEJ (equatorial electrojet) current which is an eastward current flowing positive in the morning resulted in the enhancement in Sq(H) values recorded for ASW.
7. The low Sq(H) values observed for DRB as well as the pronounced depression in all the months of the year are due to the hemispherical difference because DRB is found in the southern hemisphere.

Maximum Sq(H) recorded in this work is at ASW, a station at the northern hemisphere of the magnetic equator than DRB a southern hemisphere station. This variation is attributed majorly the asymmetric of north-South of the photo ionization processes.

Conflict of Interest

The author declares that there is no conflict of interest.

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