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Research Article

Features of Quiet-time Magnetic Field and Simple Approach to Estimate the Variability Strength of Equatorial Electrojet (EEJ) Current Intensity

Mustapha Abbas[1, *], Mohammed Bello Kaoje[1], Mukhtar Mohammad[2], Mukhtar Ibrahim Furfuri[1, 3], Arzika Yusuf Koko[1, 4], Aminu Muhammad[1], Asabe Audu Ibrahim[2]

[1]Department of Physics, Kebbi State University of Science and Technology, Aliero, Nigeria
[2]Department of Physics, Federal University of Agriculture, Zuru, Nigeria
[3]Department of Physics, Federal College of Education Technical, Gusau, Nigeria
[4]Department of Physics, Federal University Of Education, Kotangora, Nigeria

Abstract

It is a widely accepted fact that the quiet-time equatorial electrojet (EEJ) is a prominent narrow band of enhanced daytime eastward current flowing basically in the ionospheric E-region within $\pm 3°$latitude of the dip equator. Studies have shown over the years that at least two magnetic stations are required to estimate the daytime variability strength of the EEJ. One station must be situated within the EEJ strip (station whose EEJ strength is to be determined) and the other displaced just outside the EEJ influence. One of the open issues in estimating the strength of the EEJ has been the actual latitudinal distance of the off-equatorial station from the equatorial region. This has given rise to different schools of thought in estimating the variability strength of the EEJ. This paper outlined for the first time the latitudinal extent required of the off-equatorial station which is longitudinally aligned with the equatorial station and step-by-step procedure required for estimating the daytime equatorial electrojet and the latitudinal extent ideal for choosing the off-equatorial station aligned to the equatorial station. The result from this study will clarify on the latitudinal extent required for estimating the variability strength of the EEJ in the African sector and invariably provide to some extent the role of equatorial electrojet on the distribution of equatorial ionization at low latitude in this region.

Keywords

Ionosphere, Atmosphere, Equatorial Electrojet, Geomagnetic Field, Solar Quiet (Sq) Current

1. Introduction

One of the common and interesting features of the geomagnetic field variations that has attracted research workers both in the past and in recent times is the occurrence of regular daily variations apparently observed during absence or minimal solar-terrestrial disturbances [1, 2]. At the ground surface, the regular daily variations are most often referred to as

*Corresponding author: maphysik@yahoo.com (Mustapha Abbas)

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the geomagnetic daily variations or simply "Sq variations". The Sq variations are regular daily variations that gradually changes systematically with local time of the day. The Sq variations are generated when conducting plasma of solar thermal origin under the strong influence of electromotive force (EMF) caused by convective motion of air flow across the Earth's main field establishing currents and geomagnetic field variations at the ground surface. [3] earlier observed incredible enhancement of the northward component of the Earth magnetic field at Addis Ababa. Later, [4] explained this feature as a daytime phenomenon caused by intense band of eastward current flowing in the E-region of the ionosphere and named it equatorial electrojet (EEJ). The abnormal enhancement of the northward component of the Earth magnetic field posed a serious concern to the space community and the quest to understand the origin and electrodynamics processes became the centre of attraction. At the magnetic equator, the presence of daytime eastward polarization field caused by global scale ionospheric dynamo mechanism generates a downward Hall current [5]. A vertical polarization fields build-up which opposes the downward flow of current within a confined region bounded by non-conducting layers. This polarization field in turn gives rise to a intense Hall current globally known today as equatorial electrojet (EEJ). The equatorial electrojet (EEJ) is a strong band of current which under ideal atmospheric conditions flow eastward mainly during the sunlight hours within a confined latitudinal belt ± 3° dip latitude [4, 6]. Aside the EEJ current, there exist another current system known as the global Sq current. The Sq current extends from the magnetic equator to high latitude region. Hence, at the magnetic equator, the Sq variation is a combined effect of the prevailing eastward global Sq current and the EEJ current (that either flow eastward or westward). The global Sq current flow at an altitude 107 km while the EEJ current flows at slightly lower altitude 100 km in the E-region of the ionosphere, [7]. Hence, the incredible enhancement of the H-field at the magnetic equator reflect the combined effect of the global Sq current and the EEJ current intensities. In a situation, where the currents system are flowing in opposite direction such that the westward current exceeds the global eastward current, a full-fledge counter-electrojet (CEJ) identified by [8] would be established. This manifest as a sharp decrease in the horizontal component of the Earth magnetic field below the night-time or base level as earlier identified by e,g., [9, 10].

Studies over the years have pointed out that to unravel the features of the variability strength of the EEJ current intensity, at least two stations are required such that one is located at the magnetic equator (whose EEJ current intensity is to be determined) and the other located just outside the equatorial zone within ±6-9° dip latitudes e.g., [11, 12]. On the basis of this several studies have been carried out on the longitudinal, latitudinal, seasonal and local time dependence of the EEJ current intensity. However, the general consensus with most of the previous studies is the station location at the magnetic equator (whose EEJ is to be determined). Contrary to this, the latitudinal position of the off-equatorial station caused a lot of controversies. This raised a lot of concerned as to what latitudinal extent is the off-equatorial station be located? Hence, this study is set to attempt the open question and put to rest the ambiguity surrounding the latitudinal extent required of the off-equatorial station in estimating EEJ current intensity in the East African region. On this note, we will explain in details earlier works done in estimating the variability strength of the EEJ current intensity in section 2. Subsequent sections are devoted to analysis procedures, results, discussions and conclusion.

2. Importance / Significance of the Present Work

Despite several years of studies on the variability strength of the equatorial electrojet current intensity using satellite and ground based magnetic field observations as cited above, there is still no clear concept on the necessary conditions required for estimating the EEJ strength and also the latitudinal extent between the station within the EEJ strip (whose EEJ strength is to be determined) and the other station outside the electrojet zone. This raised a lot of controversies resulting in different school of thoughts in estimating the variability strength of the equatorial electrojet current intensity. For instance [11, 12] reported that to estimate the variability strength of the EEJ current, two magnetic field observations are required. One station (whose EEJ strength is to be determined) must lie along the EEJ strip and the other station located just outside the electrojet zone at ±6-9° geomagnetic latitude. [13] study the diurnal variability of equatorial electrojet and its possible role on the day-to-day characteristics of the equatorial ionization anomaly over Indian and Brazilian sectors. They used the hourly difference of the H-field values from Alibag (dip lat. 13.1°) and Vassouras (dip lat. 15.3°) located outside the electrojet to estimate the variability strength of the EEJ at equatorial stations Tiruneveli and Sao Luiz in the India and Brazilian sectors respectively. In either case, the stations outside the electrojet zone (Alibag and Vassouras) are well above the regions earlier suggested by [11, 12] and their results are well established. In a different study, [14-18] deduced the variability of the EEJ current intensity at Trivandrum and Tiruneveli using an off-equatorial station Alibag (dip lat. 10.2°) and their result was well established. [19] estimated the variability strength of the equatorial counter-electrojet signatures and the influence of interplanetary magnetic field on the equatorial electrojet over Indian region. They used the off-equatorial station Hyderabad (dip lat. 12.79°) and Port Blair (dip lat. 4.77°) to deduce the strength of the equatorial electrojet current intensity at Vencode and Campbell Bay in the Indian region. Similarly, [7, 20] studied the occurrence of afternoon counter-electrojet over Indian longitude during solar minimum. They derived the EEJ current intensity at Trivandrum located at the magnetic equator with off-equatorial station Alibag (dip lat. 10.2°). [21] used the hourly difference of horizontal magnetic field at Huancayo (dip lat. -0.6°) and off-equatorial station San Juan (dip lat. 28.3°) for a period of 1997-2013 and another off-equatorial station Fuquene (dip lat. 18.2°) to infer variability strength of the EEJ current intensity in the American sector. The dip latitudes of the two off-equatorial stations (San Juan and Fuquene) used by these authors are quite large and well outside the prescribed latitudinal range suggested by [11, 12].

In the African sector [22] estimated the variability strength of the EEJ current over Ilorin (West Africa) using Maputo (dip lat. -35.98°) located at mid-latitude and not perfectly aligned longitudinally, but their result was well established. [9, 23] deduced the latitudinal profile of the strength of the equatorial electrojet current intensity at Addis Ababa along the equatorial region with respect to KRT (dip lat. 5.6°), Aswan (dip lat. 15.2°), Fayum (dip lat. 16.1°), Nairobi (dip lat. -10.6°) and Dares Salam (dip lat. -16.26°). The off-equatorial station Dares Salam used by these authors is not within the latitudinal range earlier suggested by [11, 12]. Recently, [24] conducted a monumental study on the spatio-temporal variability of the equatorial electrojet using long-term ground-observation that covers Indian, American, Asian and African sectors. In any of the region, the off-equatorial stations were carefully selected such that the dip latitude does not exceed 12.94° geomagnetic latitude.

It is imperative from the cited literatures that the off-equatorial stations used by these authors extended from the low to middle latitudes and in some cases the equatorial and off-equatorial stations are not perfectly longitudinally aligned e.g., [22] thereby raising concerned as to what off-equatorial latitude is required to estimate the variability strength of the EEJ current intensity. This study will provide clarification on the latitudinal extend of the off-equatorial station that is perfectly longitudinally aligned to an equatorial station when estimating the strength of the EEJ current in the East African sector. Prior studies have indicated that equatorial electrojet current is a complex electrodynamics mechanism with greater influence within and outside the equatorial region; the result from the present study would provide constraints on equatorial electrojet models and eliminate some of the ambiguous features associated with estimating the variability strength of the equatorial electrojet current over East African sector.

3. Materials and Method

3.1. Data and Method for Estimating EEJ Strength

Figure 1 show the location of the stations used in the study and Table 1 depict their coordinate systems. The concurrent quiet days record of the horizontal (H) magnetic field intensity at two magnetic observatories with one on the EEJ strip (whose EEJ current intensity is to be determined) and the other located just outside the EEJ strip are usually employed to deduced the variability strength of the equatorial electrojet current (EEJ). These field records are usually obtained during periods of minimal solar terrestrial magnetic disturbances.

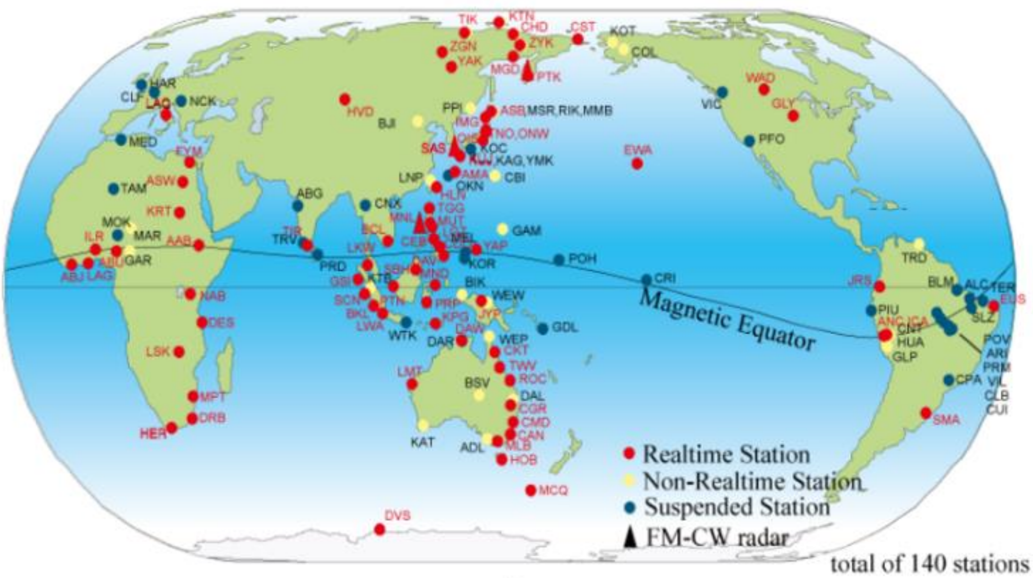

Figure 1. *Global MAGDAS map showing the locations of the stations used in the study.*

The quiet days can be visualized and carefully selected at the world data centre catalogue at hpp://wdc. kugi.kyoto-u.ac.jp. [6] earlier suggested the study of EEJ to be limited to days when the magnetic disturbances are minimal (quiet days) with magnetic activity index Ap ≤ 6. However, in this study we extended the Ap index to 8 (Ap=8) so as to study the effect of magnetic activity on the variability strength of EEJ current intensity. The days used in this study were carefully selected availability of concurrent data across the African stations.

The magnetic field records from Magnetic data Acquisition System (MAGDAS) are mostly in seconds and minute average records. Only the minutes average records are used in this study. It is worthy to note that the horizontal component (H) of the magnetic field record is used to characterize the strength of the equatorial electrojet. Hence, the averages of the minute records of the geomagnetic H element are process as shown in the data processing routine given in Figure 2.

Table 1. *List of intermagnet data stations and their coordinates system used in the study.*

		Geographic		**Geomagnetic**	
Station	**Code**	**Lat. (°*N*)**	**Lon. (°*E*)**	**Lat. (°*N*)**	**Lon. (°*E*)**
AdisAbaba	AAB	9.04	38.77	0.18	110.47
Khartoum	KRT	15.33	32.38	5.69	103.8
DareSalam	DES	6.47	39.12	-16.26	110.59
Nairobi	NAB	-1.16	36.48	-10.26	108.18
Hermanus	HER	-34.34	19.24	-42.24	82.28

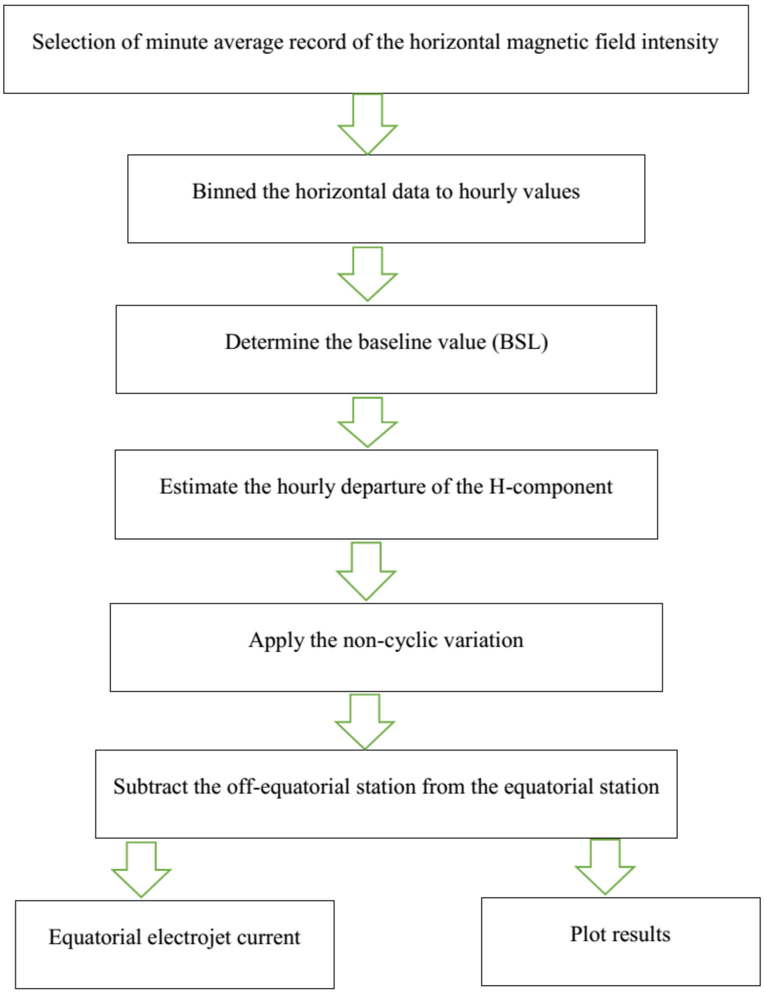

Figure 2. *The flow diagram for estimating the variability strength of the equatorial electrojet current.*

3.2. Hourly Horizontal Magnetic Field Values

For this particular study, it is assumed that the magnetic field records measured by the magnetometer are in minute average records and the concept of local time (LT) is employed. The 1-min average field records should be binned to hourly averages as indicated in Figure 2 and this reduced the data to 24 hourly values for each particular day. This can be achieve using the simple relation given in (1):

$$H_{values} = \frac{H_1+H_2+\cdots+H_{60}}{60}, \frac{H_{61}+H_{62}+\cdots+H_{120}}{60}, \frac{H_{1381}+H_{1382}+\cdots+H_{1440}}{60} \quad (1)$$

Where H_1, H_2,...H_{1440} represent the minute values of the horizontal component of the magnetic field intensity. This process should be carried out on each particular day under consideration. The averages of the minute records of the horizontal magnetic field intensity for the pair of stations are taken at 1 hr centered on local time of each station. This is achieved by simply assuming that if the station say is 1 hr ahead of Greenwich Mean Time (GMT), therefore, 1200 UT correspond to 1300 LT at the station. The hourly values are obtained as expressed in equation (1).

3.3. Baseline Values (BLV)

The baseline is specifically defined as the average of four (4) hours flanking local midnight (0100 LT, 0200 LT, 2300 LT and 2400 LT), respectively. The baseline value for a station is usually deduced by simply calculating the hourly values of the 4 hrs flanking the local midnight (0100, 0200, 2300 and 2400 LT hrs) for each station. Hence, BLV values of the horizontal component of each station can be obtained using the relation below:

$$BLV = \frac{H_{0100} + H_{0200} + H_{2300} + H_{2400}}{4} \quad (2)$$

the H_{0100}, H_{0200}, H_{2300} and H_{2400} are the hourly values of the H-component at 0100, 0200, 2300 and 2400 hr LT respectively. The baseline values (BLV) should be further corrected to the nearest whole number in Nano-Tesla (nT) unit.

3.4. Hourly Departure of H-component

The hourly departure of horizontal magnetic field intensity is approximately equal to the solar quiet of H-component (S_qH_t) and is usually obtained by simply subtracting the BLV value say for a particular day from each of the hourly values of that same particular day. This is expressed as;

$$S_qH_t = H_t - BLV \quad (3)$$

Where t is the local time in hours and usually ranged from 0100 LT hr to 2400 LT hrs. S_qH_t is the solar quiet value for a particular hour and H_t is the corresponding hourly H-component value of that same hour respectively. Hence, the resulting values should be subjected to noncyclic variation.

3.5. Correction for Noncyclic Variation

Careful observation of the S_qH_t obtained in equation (3) shows a conspicuous differences exist between the 1st and 24th hourly values for each particular day. This anomaly is corrected by applying non-cyclic variation technique. This implies that the S_qH_t values obtained should be further corrected for non-cyclic, a procedure such that the value at 0100 LT hr is the same as the value at 2400 LT hr [25] This non-cyclic variation can be achieve by simply making little linear adjustment on the daily hourly values such that the S_qH_t value at 0100 LT, 0200 LT….., 2400 LT are considered as; N_1, N_2, ……., N_{24}.

$$\Delta_X = \frac{N_1 - N_{24}}{23} \quad (4)$$

Where N_1, N_2 …N_{24} represent the hourly values of ΔH at 01:00 LT, 02:00 LT ….24:00 LT. The linear adjusted value for each hour is given as:

$$N_1 + 0\Delta_X, N_2 + 1\Delta_X, \ldots \ldots \ldots \ldots N_{24} + 23\Delta_X \quad (5)$$

The linearly adjusted values are expressed in the relation below;

$$\Delta H_t\,(N) = N_t + (t-1)\Delta_t \quad (6)$$

Hence, the corrected non-cyclic hourly departures give the solar daily variation of H component. This solar daily variation is approximately equal to solar quiet daily variation SqH for magnetic elements H during quiet periods.

3.6. Estimation of Variability Strength of EEJ Current

At this point, the H-component values of the off-equatorial station obtained using the relation 6 is subtracted from the equatorial station (whose EEJ strength is to be determined) using the relation;

$$\Delta H_{EEJ\ strength} = \Delta H_{Equator} - \Delta H_{off-equator} \quad (7)$$

Where $\Delta H_{off-equator}$ represent the processed H-component of the magnetic field records off-equatorial station but perfectly longitudinally aligned to the equatorial station $\Delta H_{Equator}$. $\Delta H_{EEJ\ strength}$ gives the variability strength of the equatorial electrojet and the result is plotted against local time of the magnetic observatory.

4. Results

Figure 3 (panel a) show the local time hourly amplitudes of solar quiet of H-field (SqH) on February 6 2011 along 96° MM in the African sector. At the top of the Figure is the Ap index that depict the level of magnetic activity. The Ap index for this day is 3 (Ap=3) which implies that the day is very quiet and makes it more convenient to characterized with some degree of certainty the behavior of SqH variations. From the Figure, it is apparently seen that SqH steadily increase from midnight (2400 LT) seen across all the latitudes. The night-time increase in SqH is a phenomenon that is only peculiar to maximum solar activity and not a common event during low solar activity. This is because during maximum solar activity the ionosphere is able to sustained its ionization for a prolong period of time after solar activity effect seized to occur due to absence of continuous thermal heating of the upper atmosphere. Similar features have been reported in the American sector during maximum solar activity by [26].

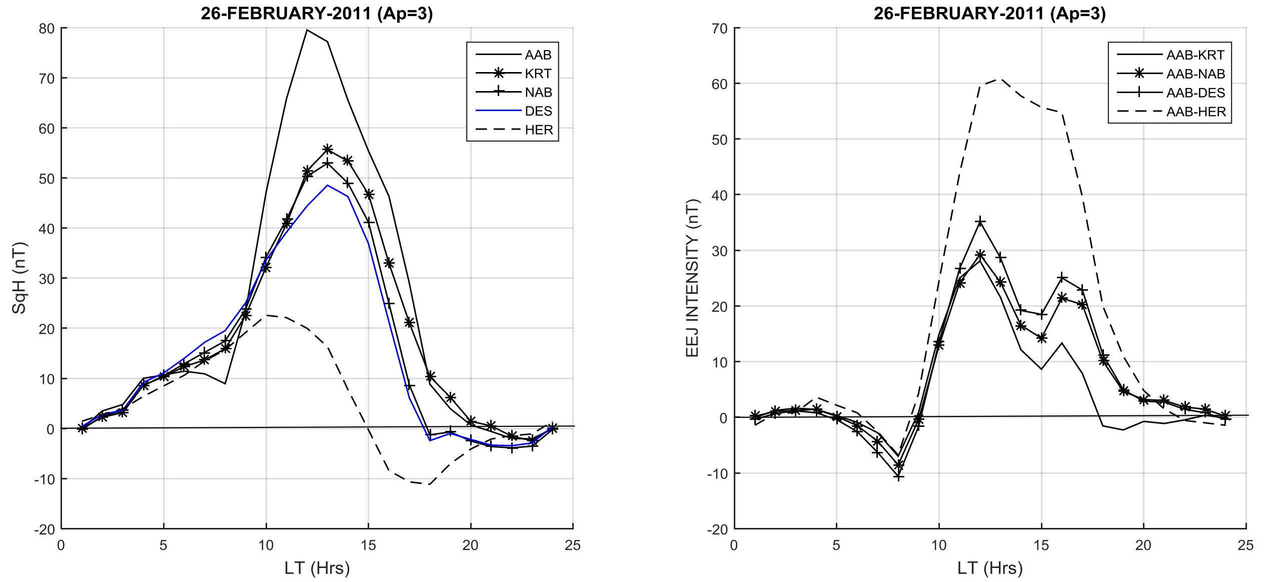

Figure 3 *Variability of SqH across Africa and EEJ intensity at AAB on 26-Feb, 2011.*

The increase in SqH amplitudes that started at midnight (2400 LT) hrs indicate that even at night-time hours the ionosphere is not completely shut down but depict some level of ionization. The occurrence of night-time positive amplitudes during low solar activity is a strong indication that it is not solar activity bound. This shows that the positive SqH amplitudes observed in the American sector by [26] during maximum solar activity can as well be observed even during low solar activity. The reduced SqH magnitudes at HER with positive value∼ 21 around 1000 LT and flip its direction afterwards suggest that HER is closer to the southern hemisphere Sq focus latitude in the African sector (see Figure 3). Other stations equatorward of HER had their peaks at different local times indication of possible influence of variable ionospheric neutral wind system. The latitudinal profile of the SqH show highest magnitude ∼79 nT around 1200 LT at AAB. The greater daytime SqH magnitudes at AAB compared to other stations suggest stronger influence of the equatorial electrojet current that arise from cowling conductivity bounded by non-conductive layer within the E-region of the ionosphere [5, 10, 27]. Other stations exhibit higher magnitudes ∼55, 52 and 49 nT seen around 1300 LT at KRT, NAB and DES respectively. These latitudinal variations of SqH are typical features of an ideal Sq current system whose intensity decreases with increasing latitude from the equator to the focal latitude. Generally, the daytime positive SqH magnitude seen across all the stations arise from stronger eastward current intensity. The slowly changes of SqH with local time is due to changes in ionization caused by changes in solar radiation with local time of the day. It may thus be concluded that the little depression in AAB around 0800 LT seen in Figure 3 (panel a) and its subsequent negative amplitudes with respect to other stations as shown in Figure 3 (panel b) is a strong indication of an effect of counter-electrojet event caused by a band of westward equatorial electrojet current during these particular hours [28].

However, after these daytime peaks, SqH reached their based level at different local time seen earlier (1800 LT) at NAB and DES and 2 hours latter (2000 LT) at AAB and KRT. The reason for reaching their base level at different local times may likely be associated to latitudinal variability in ionospheric electric field. Careful observation of Figure 3 (panel a) reveals a notable decrease of SqH around 0800 LT at the equatorial station AAB and completely absent at other stations located outside the electrojet zone. This shows that the depression in SqH observed at AAB is strictly an equatorial electrojet phenomenon bounded within ±3° dip latitude. The slight depression but unable to go beyond the base level at AAB around 0800 LT (see Figure 3 panel a) is an evidence of stronger global eastward Sq current intensity over the westward current (counter-electrojet) at this particular hour of the day, hence result to partial counter-electrojet (PCEJ).

In a quest to study the pattern and latitudinal extent of the off-equatorial station required to estimate the variability strength of the equatorial electrojet current intensity, the variability strength of the EEJ intensity for every 1 hrs local time are deduced and illustrated in Figure 3 (panel b). It is apparent that the variability of EEJ current intensity at AAB with respect to KRT shows a typical equatorial electrojet characteristic. The partial counter-electrojet that appeared in Figure 3 (panel a) manifest as a full-fledge counter-electrojet when the global Sq current effect is removed. Similar regular occurring pattern of EEJ current intensity at AAB with respect to other stations was also observed as shown in Figure 3 (panel b). It is interestingly observed that the EEJ current intensity at AAB with respect to all the stations show similar pattern at every local time, exception of HER (see Figure 3 panel b). For example, the latitudinal magnitude of EEJ current at AAB with respect to all the stations seems not to show any significant difference exception of HER. In fact, the EEJ intensity at AAB relative to the HER located closer to the Sq focus latitude exhibit a different pattern reflecting the fact that it is not suitable for characterizing the variability strength of the EEJ current intensity at AAB. The overall result seems to point to the fact that during low solar activity the variability of EEJ current intensity at AAB in the East African sector cannot be estimated with respect to HER. This due to the fact that HER is closer to the Southern hemisphere Sq focus with reduce intensity and slight phase variation that when used as off-equatorial station in the estimation of EEJ strength does not reflect the true features of the EEJ current intensity as depicted in Figure 3 (panels a and b).

Figure 4 is another diurnal variation of SqH and the variability of EEJ current intensity obtained on March 15-17, 2011. These days are very quiet with Ap index equals to 1, 1, and 6 as shown at the top of the Figure. As shown on the Figure, SqH amplitudes at HER exhibit typical behavior of an ideal station located poleward of the Sq focus with persistent negative amplitudes at every local time on March 15, 2011 (see Figure 4 panel a). Similar features are also observed the next day (March 16, 2001) but only around (1200-2000 LT) hrs. On March 17, 2011, SqH showed a dawn-side positive SqH magnitude that became negative around 1300 LT at HER. The SqH variation pattern at HER for these days March 15-17, 2011 shows the north-south fluctuation in the position of the southern hemisphere Sq focus around HER latitude. Aside these features, SqH are characterized by night-time negative amplitudes that extended to around 0800 LT across all the stations exception of HER as shown in Figure 4 (pane a). Generally, SqH exhibit daytime latitudinal profile with greater intensity at AAB located at the magnetic. The daytime peak intensity reached ~ 90, 59, 57 and 56 nT at AAB, KRT, NAB and DES on March 15, 2011. However, with increase in magnetic activity as indicated at the top of each panel, these peaks increased with increase in magnetic activity and reached ~ 130, 87, 81 and 84 nT at AAB, KRT, NAB and DES seen on March 17, 2011. It is obvious that the increase in magnetic disturbances does not yield any significant influence to the phase of the quiet-time daily variation but cause considerable increase in the SqH magnitude as observed in Figure 4 (panel a). Our result is invariance with earlier studies over the Indian and American sectors by [28]. Generally, the SqH peaks were observed around (1200-1300 LT) hrs. Their greater magnitudes around these periods is due to continuous solar thermal heating of the upper atmosphere (ionosphere) caused by prevailing wind system with minimal loss rate around 1200 LT hrs. Our result is in conformity with those of [5, 25-27] that also observed higher intensity of Sq current intensity around local noon.

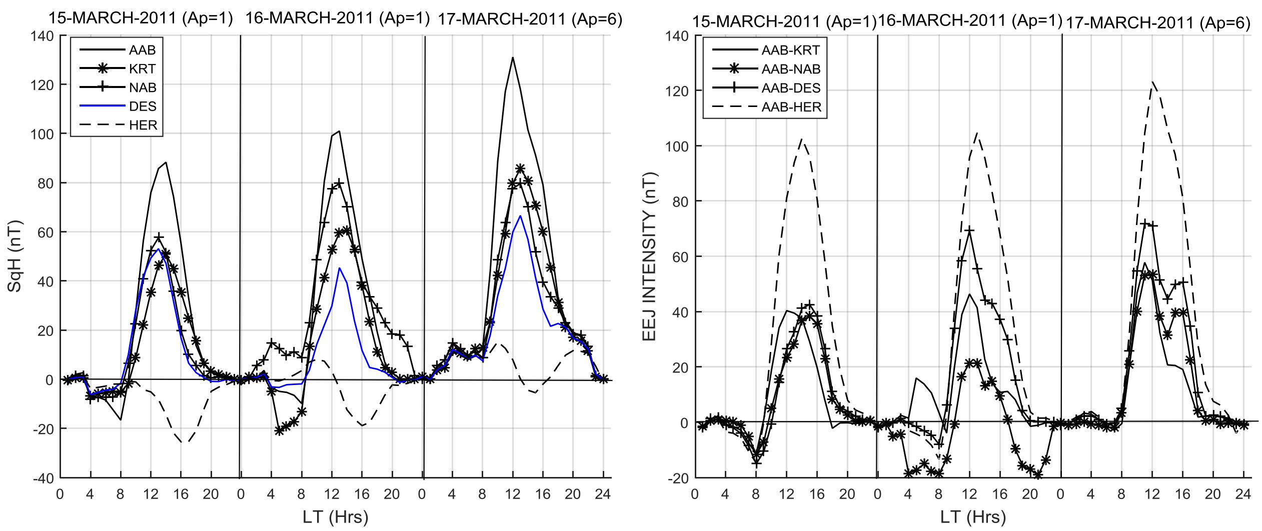

Figure 4. *Variability of SqH across Africa and EEJ intensity at AAB on 15-17 March, 2011.*

Figure 4 (panel b) shows the latitudinal variability of the EEJ current intensity at AAB with respect to all the stations considered in the study. It is generally observed from the Figure that the EEJ current intensity at AAB relative to KRT exhibit similar current intensity at AAB with respect to NAB, and DES. Similarly, the strength of the EEJ current intensity at AAB with respect to KRT showed dusk-side enhancement apparently seen around 1600 LT. similar dusk-side enhancement are conspicuously seen at AAB with respect to NAB and DES stations but completely absent at AAB with respect to HER. By interpretation, the structure of the evening EEJ current intensity at AAB with respect to KRT, NAB, and DES thus revealed that the F-region pre-reversal enhancement (PRE) suggested by [28] will be strengthened, hence more plasma would be lifted to a height with minimal loss rate, a condition that is not apparently seen when EEJ intensity at AAB is estimated with respect to HER. This again justifies that the H-field values at HER is not suitable for estimating the variability strength of EEJ at AAB.

It is also evident from Figure 4 (panel b) that the variability of EEJ current intensity reached at $AAB_{equator}$-$KRT_{off\text{-}equator}$= ~ 40 nT, $AAB_{equator}$-$NAB_{off\text{-}equator}$=39 nT, $AAB_{equator}$-$DESoff\text{-}equator$=39 nT, and $AAB_{equator}$-$HER_{off\text{-}equator}$=101 nT. These amplitudes were observed to increase with solar magnetic activity to about $AAB_{equator}$-$KRT_{off\text{-}equator}$ = ~49 nT, $AAB_{equator}$-$NAB_{off\text{-}equator}$=48 nT, $AAB_{equator}$-$DES_{off\text{-}equator}$=57 nT, and $AAB_{equator}$-$HER_{off\text{-}equator}$=122 nT suggesting the strong influence of magnetic solar activity on the intensity of EEJ current system. The magnitude of the EEJ current intensity at AAB with respect to all the stations falls within the same reasonable range exception of HER. This again clarifies that HER cannot be used as a reference latitude for estimating the variability strength of the EEJ current at the East African sector. This shows that the quiet horizontal magnetic field records up to the latitude of DES can be used to infer the variability strength of the EEJ current in the East African sector. Also from Figure 4 (panel b) the day-to-day variations in the magnitude and phase of the EEJ current intensity exist even among similar quietest days. Such variation may be attributed to changes in wind system and ionospheric conductivity [9].

5. Conclusions

The ground-based horizontal component of the Earth magnetic field record along 96°MM allows us to study the features of the quiet-time variability of SqH and EEJ variability current intensity. The following conclusions may be drawn from the study:

1. SqH shows a persistent night-time variations that steadily increase from midnight (2400 LT) hrs across all the latitudes indication that the night-time increase in SqH is not only peculiar to maximum solar activity but can thus be observed even during low solar activity.
2. Our study revealed that even at nigh-time the ionospheric conductivity is not completely shut-down but exhibit a persistent nigh-time conductivity that are much smaller than the daytime conductivity.
3. The persistent increase in SqH magnitudes with increasing magnetic activity indicates an additional more energy as magnetic activity increases in contrast to earlier observation that reported reduced magnetic field variations e.g., Rastogi, 1988.
4. The persistent differing nature of the EEJ current both in phase and magnitude at AAB with respect to HER in any of the day considered suggest HER is not an option when estimating the variability strenght of EEJ current intensity in the East African sector.

Abbreviations

EEJ	Equatorial Electrojet
Sq	Solar Quiet
LT	Local Time
PCEJ	Partial Counter-equatorial Electrojet
EMF	Electromotive Force

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Author Contributions

The conceptualization of the work was done by Mustapha Abbas and the data curation and formal analysis were carried out by Mustapha Abbas and Mukhtar Ibrahim Furfuri. The methodology was designed by Mustapha Abbas and the software application was done by Mukhtar Mohammad and Mohammad Bello Kaoje. The manuscript was written by Arzika Yusuf Koko and Aminu Mohammed and revised by Asabe Bulus Ibrahim. The review and editing was done by Mustapha Abbas.

All authors have read and agreed to the published version of the manuscript.

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Data Availability Statement

The magnetic field data used in this study were obtained directly from Magnetic Data Acquisition System (MAGDAS) and the magnetic indices that support the findings of this study can be obtain at:
https://wdc.kugi.kyoto-u.ac.jp/kp/index.html#LIST

Conflicts of Interest

The authors declare no conflicts of interest.

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