SSRG International Journal of Applied Physics
ISSN: 2350 – 0301 / https://doi.org/10.14445/23500301/IJAP-V9I1P104

Volume 9 Issue 1, 17-20, Jan-April 2022

Original Article

A Simple Approach to Estimate the Strength of Equatorial Electrojet using MAGDAS

Muka Peter Taiwo[1], Àlàgbé George Atilade[1]

[1]*Department of Pure and Applied Physics, Ladoke Akintola University of Technology, Ogbomoso, Oyo state Nigeria*.

Received Date: 02 March 2022
Revised Date: 05 April 2022
Accepted Date: 18 April 2022

Abstract*: This paper outlines a simple approach to estimating the strength of equatorial electrojet using the Magnetic Data Acquisition System (MAGDAS). The major parameters such as baseline values, hourly departures, correction for non-cyclic variation, and solar quiet used in describing the estimation of equatorial electrojet are discussed.*

***Keywords** - Baseline values, Electrojet, Geomagnetic latitude, Geomagnetic longitude, and Hourly departure.*

I. INTRODUCTION

The EEJ is a current flowing at the E-region altitude of the ionosphere. This phenomenon has been studied through different types of experiments. [1] investigated its vertical structure by using instruments inside rockets. Other properties such as the magnetic disturbances were examined above or below the magnetic meridian through chains of magnetometers crossing the magnetic dip equator. The study of equatorial electrojet began as far back as 1922 at Huancayo in Peru. The enhancement of the horizontal component of the Earth's magnetic field at the geomagnetic equator was produced by a narrow band of ionospheric current, which was named the equatorial electrojet (EEJ) in 1951[2].

The EEJ is a local reinforcement of the ionospheric conductivity in the direction parallel to the geomagnetic dip equator. This effect, known as the Cowling effect, is caused by establishing a strong electric field moving in a vertical direction in the equatorial region where the Earth's magnetic field lines are nearly horizontal. [3] observed that the current system associated with the daily geomagnetic variation occurs when the geomagnetic disturbances are minimal and is referred to as a global solar quiet (Sq) current system. EEJ is manifested by localized ionospheric currents and physical structures flowing at the dip equator with higher current intensities during the noontime, responsible for Sq variation. Several authors have studied different aspects of the variations of the solar quiet horizontal component, the variation of EEJ strength, and the correlation of EEJ between pairs of stations along the dip equator and far away from the equators. [4] and [5] observed that the daily variation of the geomagnetic field component at the equatorial station is due to the superimposition of the Sq current and the EEJ current flowing eastward at the lower altitude. [6] concluded that if Sq current and electrojet current are flowing opposite, the westward electrojet current has a higher intensity than the global eastward Sq current; it is called Counter Electrojet (CEJ). [7] studied the geomagnetic field variations from some EEJ stations. Their results show that there could be substantial day-to-day variability in the EEJ strength along the dip equator. That correlation between pairs of stations decreases as a function of increasing distance between them. The data also show a longitudinal variability in EEJ, with the strongest EEJ current in the South American sector and weakest in the Malaysian sector. [8] studied the variability strength of EEJ over Africa during low solar activity and observed that post-sunset counter-electrojet was greater than pre-sunrise, which is attributed to differences in photoionization. Figure 1 depicts the main processes taking place to produce EEJ. This paper gives a simple approach to estimating the strength of equatorial electrojet.

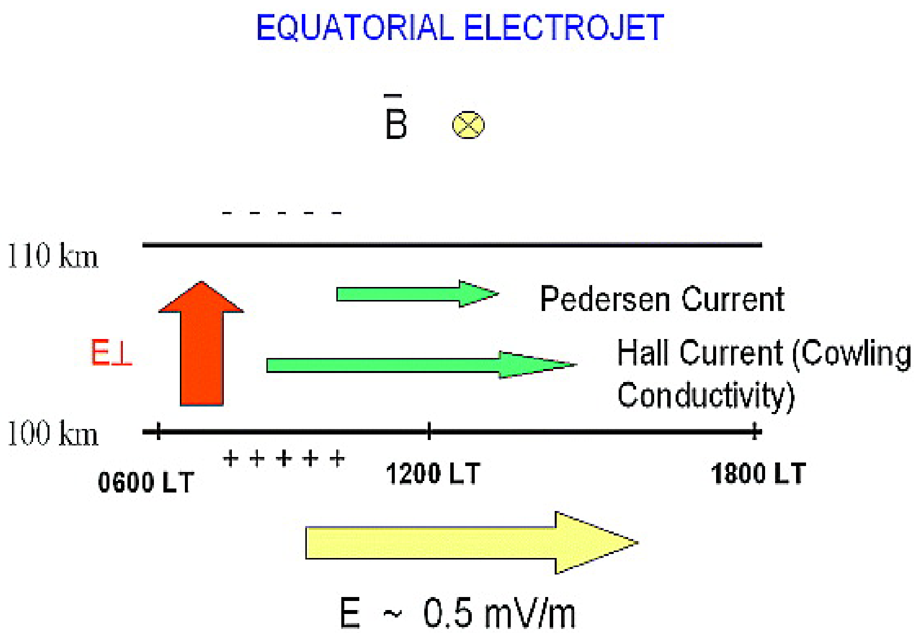

Fig. 1 Schematic diagram of equatorial electrojet electric fields and current systems [9]

II. METHOD OF ESTIMATION

The Magnetic Data Acquisition System is the most straightforward method for estimating the intensity of EEJ. MAGDAS is made up of a ground magnetometer data unit powered by a solar power unit that includes a solar panel, inverter, battery, and a wireless internet link.

When estimating the strength of EEJ, one station must be closer to the equator, with a value of 3°, and the other must be farther away from the equator, with a value of around 9° [10]. When estimating the strength of EEJ, we do not select stations at random. The coordinates for latitude and longitude must be known. We must consider the five quiet days once a month. The quiet days can be found on the Kyoto World Data Center for Geomagnetism's website. The letters q1, q2, q3,..., and q10 represent it. The first five days begin with the letter q1 and end with q5.

A code on Seasonal Variation, H plot, and 24-hourly value must be written in the form of a function. Following the creation of the code, the next step is to debug each function in MATLAB to the subplot. Finally, now that we have all the parameters write some code to estimate the EEJ. Before calculating the EEJ, the Sq(H) in nanoTesla must be determined. The Sq currents will subtract from the EEJ data at the stations. The electrojet current will be the remnant.

III. PROCEDURE

The first step in determining the strength of equatorial electrojet is to select the five most magnetically quiet days from the International Quiet Days (IQD) according to the classification of the planetary geomagnetic index, K_p, for each of the equatorial stations, i.e., stations located within $\pm 3^{\circ}$ of the magnetic equator and stations that are far away from the equator at approximately $\pm 9^{\circ}$. These stations must have similar geomagnetic longitude.

A. Midnight Baseline

Baseline values are defined as the average of the 4 hours flanking local midnight (23, 24, 1, 2, hours) [10]. The baseline should be calculated for both the required stations by taking the last hourly value the same over the average values. Maputo is regarded as one of the stations far away from the magnetic equator; since Maputo is UTC+2hours ahead of Greenwich Mean Time, then 2hours have to be deducted from 24hours local time. The starting point of Maputo from the baseline is 22hours.

Consequently, the baseline for Maputo,

$$H_O = \frac{H_{22}+H_{21}+H_2+H_1}{4} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

The same procedure applies to other stations, provided they are of the same longitude. For instance, for Ilorin, since Ilorin is UTC+1, the baseline is obtained as

$$H_O = \frac{H_{23}+H_{22}+H_2+H_1}{4} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(2)}$$

B. Hourly Departure

The hourly departure from the baseline is generated by subtracting the baseline values for a particular day from the same day's hourly values [11].

$$\Delta H_t = H_t - H_\circ \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\text{(3)}$$

Where t = 01, 02, 03, 24 (hours)

C. Correction for non-cyclic variation

A process whereby the values of ΔH at 0100LT are different from those of ΔH at 2400LT is said to be a non-cyclic variation [12] & [13]. The hourly departure is further corrected for this reason. This is done by making a linear adjustment in the daily hourly values of ΔH; V_1, V_2,……. V_{24}. The best way of achieving this is to consider the hourly departure values of ΔH at 01LT, 02,.24LT such that

$$\Delta c = \frac{V_{01} - V_{24}}{23} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(4)}$$

Therefore, the linear adjustment values at these hours will be:

$$V_1 + 0\Delta, V_2 + 1\Delta c,\ V_3 + 2\Delta c \ldots\ldots\ldots V_{23} + 22\Delta c,\ V_{24} + 23\Delta c \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(5)}$$

The hourly departure corrected for non-cyclic variation gives H's solar quiet daily variation.

Where t is known to be the local time ranging from 01 to 24, the hourly departures corrected for non-cyclic variation give the solar daily variation in H. Sq(H) denotes the solar quiet daily variation in H.

D. Horizontal Components of Geomagnetic Field

The Subtraction of the H components inside and outside the dip equator yields an H value, which is needed to eliminate the Dst ring current component and the global Sq current of H. The ionospheric electrojet current is proportional to the remnant H value, resulting in an east-west electric field. This eastward electric field could be caused by the Sq Wind dynamo system or a high-latitude electric field penetration. [14] discovered an east-west. overhead current during the daytime within a narrow latitude belt about 130 kilometers above the magnetic dip equator, where the geomagnetic field is horizontal. [15] dubbed this the Equatorial Electrojet. [16] observed an abnormally large horizontal (H) component of the geomagnetic field at Huancayo compared to the [17] current system, based on data from mid-latitudes. [18] observed that the daily variation of the geomagnetic field component at the equatorial station is due to the superimposition of the Sq current and the EEJ current flowing eastward at the lower altitude. The daily variation of the geomagnetic field component at the equatorial station was caused by the superimposition of the Sq current and the EEJ current flowing eastward at a lower altitude. [19] concluded that when Sq and EEJ currents flow in opposite directions, and the westward EEJ current exceeds the global eastward Sq current. This is referred to as Counter Electrojet (CEJ). The intensity of the geomagnetic field has been observed to vary from sector to sector within the equatorial zone. [20] discovered that the daily ranges of H at equatorial stations peak around the dip equator. The magnitude of Sq is time-dependent, and the strength of Sq current is enhanced at the dip equator [21–22].

[23] investigated the geomagnetic field variation of SqH at the India station, located in a low latitude sector. They observed maximum SqH magnitudes during equinoctial months and lowest SqH magnitudes at noon hour during J season, indicating a semi-annual variability in the range of the SqH seasonal variation that depicts EEJ characteristics. However, recent research has shown that Sq currents can be deduced from the horizontal (H) intensity of a geomagnetic field by [24]; [25]; [26]. Graham, however, conducted the first study on the daily variation of Sq of the H intensity in 1722. During his research, he observed slow, regular, and irregular changes in declination on different days. He discovered that this irregular variability could be larger and more rapid.

VI. CONCLUSION

A simple approach to estimating EEJ has been discussed. Particular stations close to and away from the geomagnetic equator have been used as references.

REFERENCES

[1] Sampath S. and T. S. G. Sastry, Results from in Situ Measurements of Ionospheric Current in the Equatorial Region I, J. Geomag Geoelectr. 31 (1979) 373-379.

[2] Chapman S, The Equatorial Electrojet as Detected from the Abnormal Electric Current Distribution above Huancayo, Peru and Elsewhere, Arch. Meteorol. Geophys. Bioclimatol. 44 (1951) 368-390

[3] Abbas M, Abidin Z Z, Jushoh M H, Bolaji O S, and Yoshikawa, Features of Horizontal Magnetic Field Intensity Over the Northern Island of Malaysia, Indian J Phys. 93(10) (2019) 1247-1257

[4] Richmond AD, Equatorial Electrojet—I. Development of a Model Including Winds and Instabilities, Journal of Atmospheric and Terrestrial Physics. 35(6) (1973) 1083-1103.

[5] Onwumechili CA, The Equatorial Electrojet Gordon and Breach Science Publishers. (1997).

[6] Gouin P, Mayaud PN, A Proposal for the Possible Existence of a Counter Electrojet at Magnetic Equatorial Latitudes, Annual of Geophysics (France). 23 (1967) 41-47

[7] Adimula IA, Rabiu Yumoto K, The Magdas Group, Geomagnetic Field Variation for some Equatorial Electrojet Stations, Sun and Geosphere. 6(2) (2011) 45-49.

[8] Abbas M, Salihu M, Variability Strength of the Equatorial Electrojet over Africa during Low Solar Activity, International Journal of Marine, Atmospheric and Earth Sciences. 2(1) (2014) 28-40

[9] Anderson D. N, A. Anghel K, Yumoto M, Ishitsuka, and E Kudeki, Estimating Daytime Vertical E × B Drift Velocities in the Equatorial F-Region Using Ground-Based Magnetometer Observations, Geophys. Res. Lett. 29(12) (2002) 1596. doi:10.1029/2001GL014562

[10] Eastern Africa GNSS & Space Weather Capacity Building Workshop Advanced School/Workshop. (2021) 21–25.
[11] Rabiu A. B, Mamukuyomi A. I, and Joshua E. O, Variability of Equatorial Ionosphere Inferred from Geomagnetic Field Measurement, Bulletin Astronomy Society India. (2007) 1-12.
[12] Okeke F.N, C.A Onwumechili, and A.B. Rabiu, Day to Day Variability of Hourly Geomagnetic Amplitudes in Low Latitude, Geophys. J. Int. 134 (1998) 484-500.
[13] Rabiu A.B, Geomagnetic field variations at the Middle Latitudes, Ph.D. Thesis, University of Nigeria, Nsukka. (2000).
[14] Egedal J, Magnetism and Atmospheric Electricity, Journal of Terrestrial Physics. 52 (1947) 449–451.
[15] Chapman S, The Equatorial Electrojet as Detected from the Abnormal Electric Current Distribution above Huancayo and Elsewhere, Arch. Meteorl. Geophys. Bioclimatol. A4 (1951) 368-392.
[16] McNish AG, Bull 10, Int. Assoc. Magn. Transaction of Edinburgh Meeting, Copenhagen. (1937) 271–280.
[17] Chapman S, The Solar and Lunar Diurnal Variations of Terrestrial Magnetism. Phil. Trans. Roy. Soc. A(218) (1919) 1–118.
[18] Richmond A. D, The Computation of Magnetic Effects of Field-Aligned Magnetospheric Currents, J. Atmos. Terr. Phys. 36 (1974) 245 – 252. https://doi.org/10.1016/0021- 9169(74)90044-0
[19] Mayaud P. N, The Equatorial Counter Electrojet. A Review of its Geomagnetic Aspects. J. Atmos. Terr. Phys. 39 (1977) 1055-1070. https://doi.org/10.1016/0021- 9169(77)90014-9
[20] Fang T.-W, Richmond A, Liu J.-Y, Maute A, Lin C.-H, Chen C.-H, & Harper B, Model Simulation of the Equatorial Electrojet in the Peruvian and Philippine Sectors, Journal of Atmospheric and Solar-Terrestrial Physics. 70(17) (2008) 2203-2211. https://doi.org/10.1016/j.jastp.2008.04.021
[21] Bartels J, and Johnson H, Geomagnetic Tides in Horizontal Intensity at Huancayo. J. Geophys. 45 (1940) 264-308. https://doi.org/10.1029/TE045i003p00269
[22] Onwumechili C. A, Study of the Return Current of the Equatorial Electrojet, J. Geomag. Geoelectr. 44(1) (1989) https://doi.org/10.5636/jgg.44.1
[23] Onwumechili CA, In: Eds. Matsushuita S, and Campbell W. H, Physics of Geomagnetic Phenomena. Academic Press, New York. 1 (1967) 425-507. https://doi.org/10.1016/B978-0-12-480301-5.50014-8
[24] Onwumechili C. A, & Ogbuehi P. O, Fluctuations in the Horizontal Geomagnetic Field. J. Atmos. Terr. Phys. 24 (1962) 173-190.
[25] Rabiu A. B, Nighttime Geomagnetic Variations at Middle Latitudes, Nigerian Journal of Physics. 8s (1996) 35-37.
[26] Bolaji O. S, Adimula I. A, Adeniyi J. O, & Yumoto K, Variability of Horizontal Magnetic Field Intensity over Nigeria during Low Solar Activity, Earth-Moon Planets, an International Journal of Solar System Science. (2013). http://dx.doi.org/10.1007/s11038-012-9412-0.