Response of the equatorial ionosphere electron density during moderate geomagnetic storms over Accra, Ghana using the Low-Cost Global Navigation Satellite System (GNSS) Receiver measurements

Solomon Otoo Lomotey [1], Babatunde Rabiu [2,5], Bruno Nava [3], Anton Kashcheyev [4], Patrick Essien[6] , Nana Ama Browne Klutse[7], Olivier Obrou [8], Daniel Okoh [5], Christine Amory-Mazaudier[9], Ebenezer Agyei-Yeboah [10], Obafeye Aderonke [2,5], Golekamang Thaganyana [11], Sam-Quarcoo Dotse [1], Teshome Dugassa Feyissa[12], Valence Habyarimana [13]

United Nations
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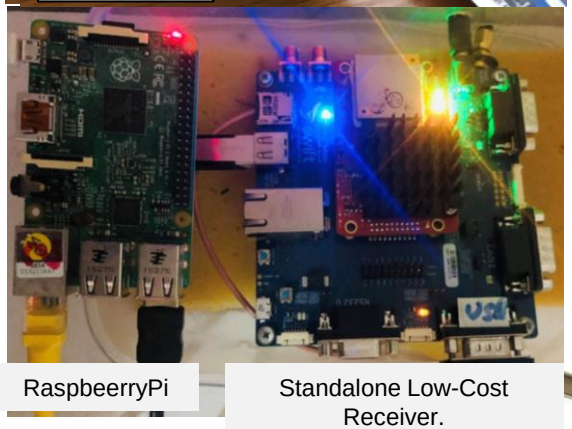
[1] University of Environment and Sustainable Development, School of Built Environment (SBE), Department of Smart Technology, PMB, Somanya, Eastern, Ghana
[2] United Nations African Regional Centre for Space Science and Technology Education-English (UN-ARCSSTE-E), Ile-Ife, Osun State, Nigeria.
[3] Abdus Salam International Center for Theoretical Physics, Trieste, Italy..
[4] University of New Brunswick, Fredericton, Canada
[5] Center for Atmospheric Research, National Space Research and Development Agency, Nigeria
[6] University of Cape Coast , Department of Physics, Cape Coast, Ghana.
[7] University of Ghana, Department of Physics, Legon, Accra, Ghana.
[8] Universite de Cocody UFR SSMT Laboratoire de Physique de l-Atmosphere Boulevard de l-Université Abidjan COTE D'IVOIRE
[9] Laboratoire de Physique des Plasmas , Universite Pierre et Marie Curie Sorbonne Universities , 75252 , Paris Cedex, France.
[10] Laboratory of Physics and Astronomy, UNIVAP, Sao Jose dos Campos, Brazil.
[11] University of Bath, Department of Electronic and Electrical Engineering , Claverton Down, Bath BA2 7AY.
[12] Space Science and Geospatial Institute| Entoto Observatory and Research Center , Addis Baba (Finfine), Ethiopia.
[13] Department of Physics, Mbarara University of Science and Technology, Mbarara, Uganda.

Solomon Otoo Lomotey (PhD)
Email: Lomoteys@gmail.com
University of Environment and Sustainable Development (UESD)
Somanya,
Eastern Region, Ghana.

INTRODUCTION

GNSS Antenna



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Standalone Low-Cost Receiver.

The effort to acquire a low-cost GNSS receiver at the Abdus Salam International Centre for Theoretical Physics (ICTP), Trieste, on October 14, 2022, was spearheaded by Prof. Babatunde, the Executive Director of UN-ARCSSTE-E, as depicted in the photographs on the right. Under the direction of Drs. Bruno Nava and Anton Kashcheyev, the ICTP collaborated on this.

Furthermore, the GNSS receiver was successfully installed on November 11, 2022, in Accra, Ghana. It has been gathering data since November 2022, as seen in the picture taken by Dr. Solomon Otoo Lomotey during the installation procedure.

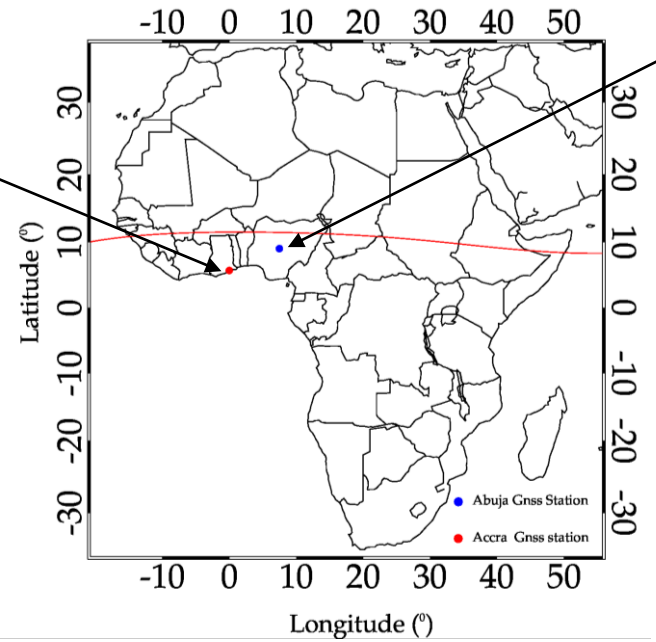


Figure 1: Map of Africa, showing the location of the Low-Cost GNSS receiver (green circle dot) in Accra $(5.7^0N, 0.04^0E)$, and Abuja $(7.4^0N, 9.04^0E)$ blue circle dot ,

- The two maps (Figures 2.0 and 3.0) show that the Eastern part of Africa has a lower number of GNSS receiver stations than the Western sector.
- However, virtually no receivers are visible over Ghana, in contrast to the fewer stations in Nigeria. This data gap across Ghana and the entire western sector poses major challenges to research on space weather and ionospheric studies.
- This current study investigated the response of moderate geomagnetic equatorial ionosphere over Accra.

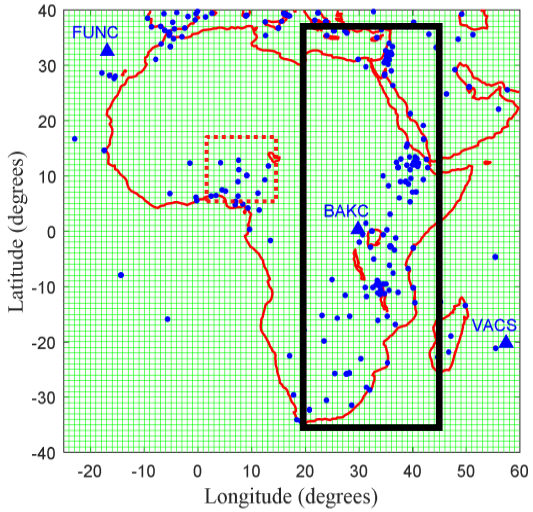
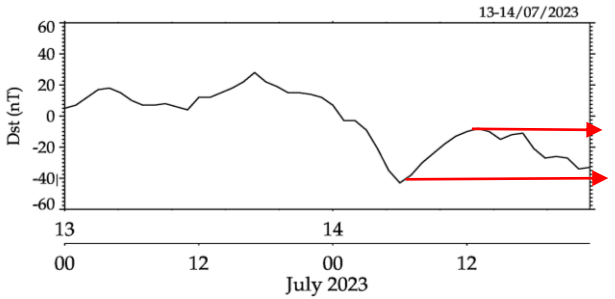


Figure 2.0:Map of Africa showing the locations of GPS receivers . The black short-dash lines is Nigerian sector OKOH ET AL. 2019.



Recovery Phase of the storm Moderate geomagnetic storm (i.e., -43nT)

Figure 4.0:Time series of geomagnetic storm (Dst.) index plotted as function day/Hour for the days 13 and 14 July, 2023.

Analysis to detect possible irregularities generations

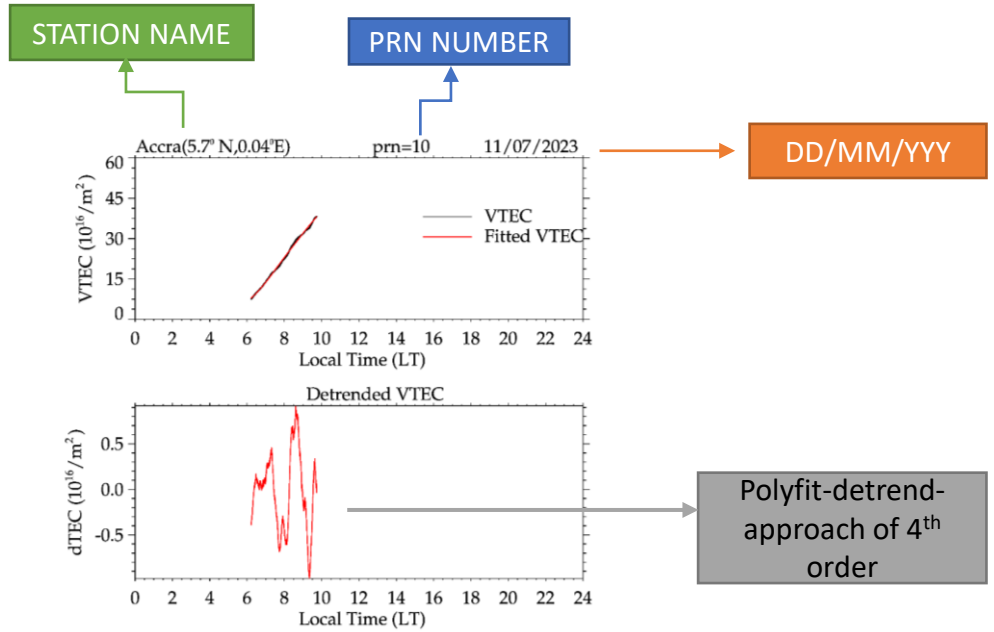


Figure 1:GPS VTEC before (black) and after removing outliers using median and MAD filtering technique (red line) on the 11th July 2023 over Accra (5.7°N, 0.04°E) for PRN 10.

- VTEC data was fitted to a fourth-order polynomial over all receiver station to remove the diurnal variability. The fitted VTEC was subtracted from the corresponding VTEC to produce a detrended TEC (ΔTEC) time series for each PRN.
- A similar method to detrend VTEC data has been used by Valladares et al. (2009), Valladares and Hei (2012), Habarulema et al. (2013, 2016, 2018) and Katamzi and Habarulema (2014).

Estimation of Rate of Tec Index (ROTI)

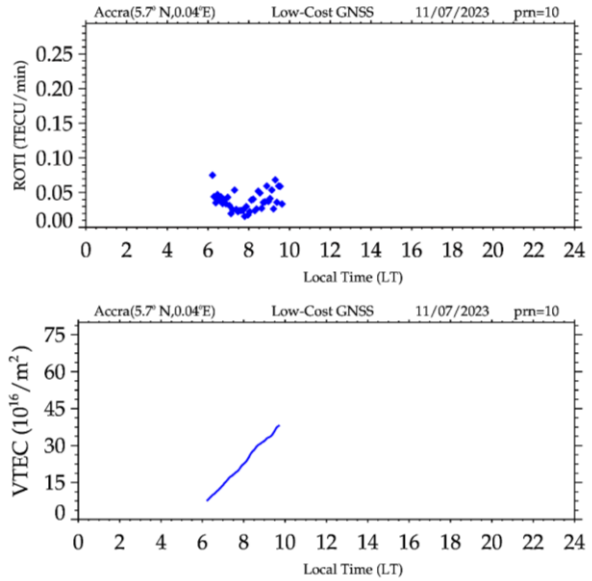


Figure 2 :TEC rate of change index (ROTI) on the 11th July 2023 over Accra (5.7°N, 0.04°E) for PRN 10.

The Rate of TEC (dTEC/dt) calculation

$$ROT = \frac{TEC_k^i - TEC_{k-1}^i}{(t_k - t_{k-1})}$$

$\Delta t = t_k - t_{k-1} = 1$ min.

TEC rate of change index (ROTI)

$$ROTI = \sqrt{\langle ROT^2 \rangle - \langle ROT \rangle^2}$$

- TEC rate of change index (ROTI), which is considered to be a proxy for the S4.

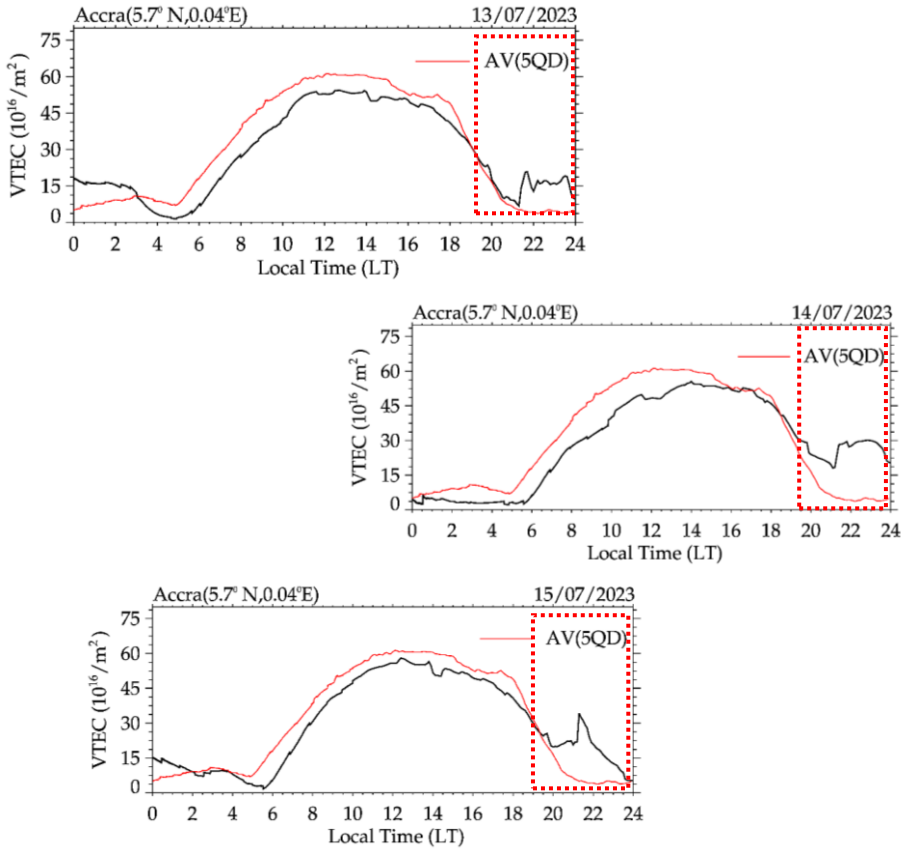


Figure 3.0: VTEC diurnal variation from the days 13th –14th July, 2023 and 5 quiet days (5QDs) average variations of VTEC (red solid line)

- **Figure 3.0 illustrates how the VTEC maximum (~55 TECU) varied throughout the day at approximately noon local time (12:00 LT). This behavior represents the typical pattern of the daytime ionospheric profile and is linked to the direct combination of EXB drift velocity and solar radiation (Kelley, 2012).**
- **But after nighttime, there is also a noticeable abrupt increase in the VTEC (~20 TECU) between 20:00 and 24:00 LT (seen by rectangle red dashed lines).**

Response of Moderate geomagnetic Storm

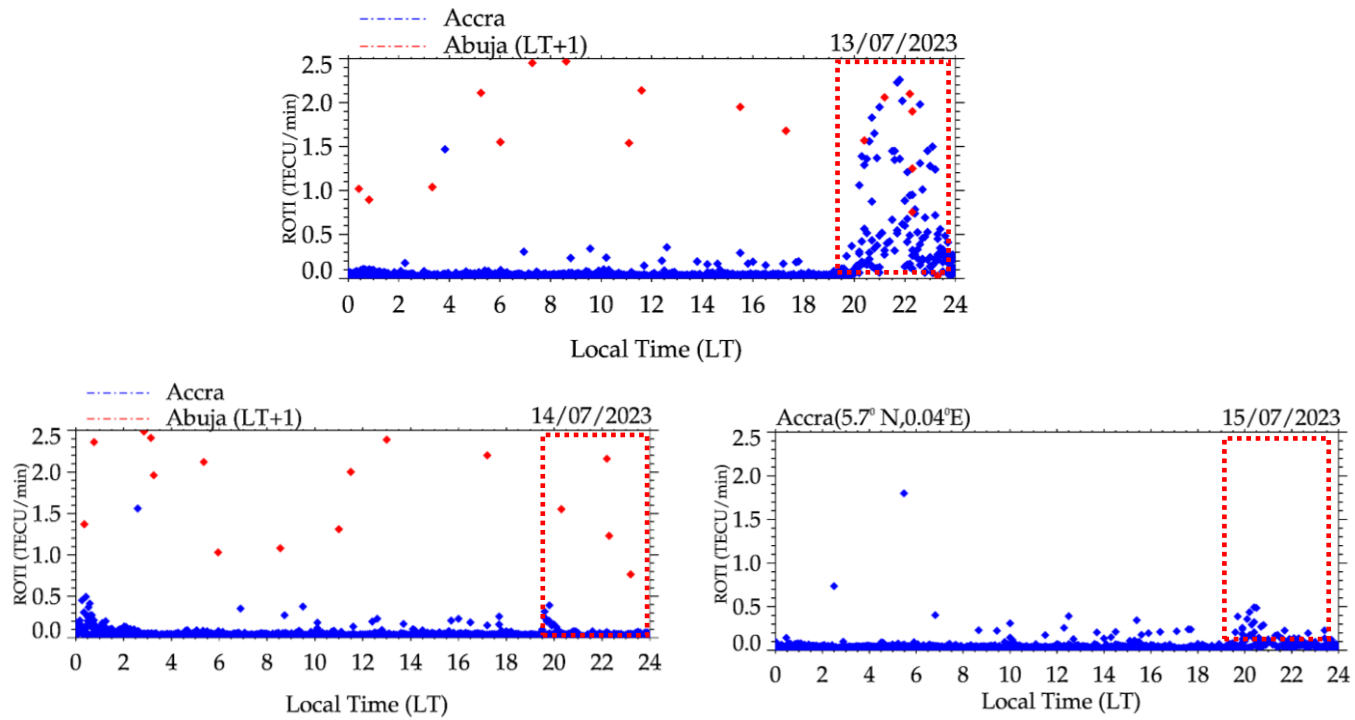


Figure 4.0: The TEC rate of change index (ROTI), which is considered to be a proxy for the S4 index, for the days 11th-17th July, 2023.

- **Figure 4.0 likewise showed a similar pattern, although in contrast to Figure 3.0, the diurnal profile of the VTEC significantly increased during the post-sunset hours.**
- **This observation, however, cannot be explained by a single GNSS station situated in the south crest region of the equatorial ionization anomaly (EIA).**

Spectral Analysis

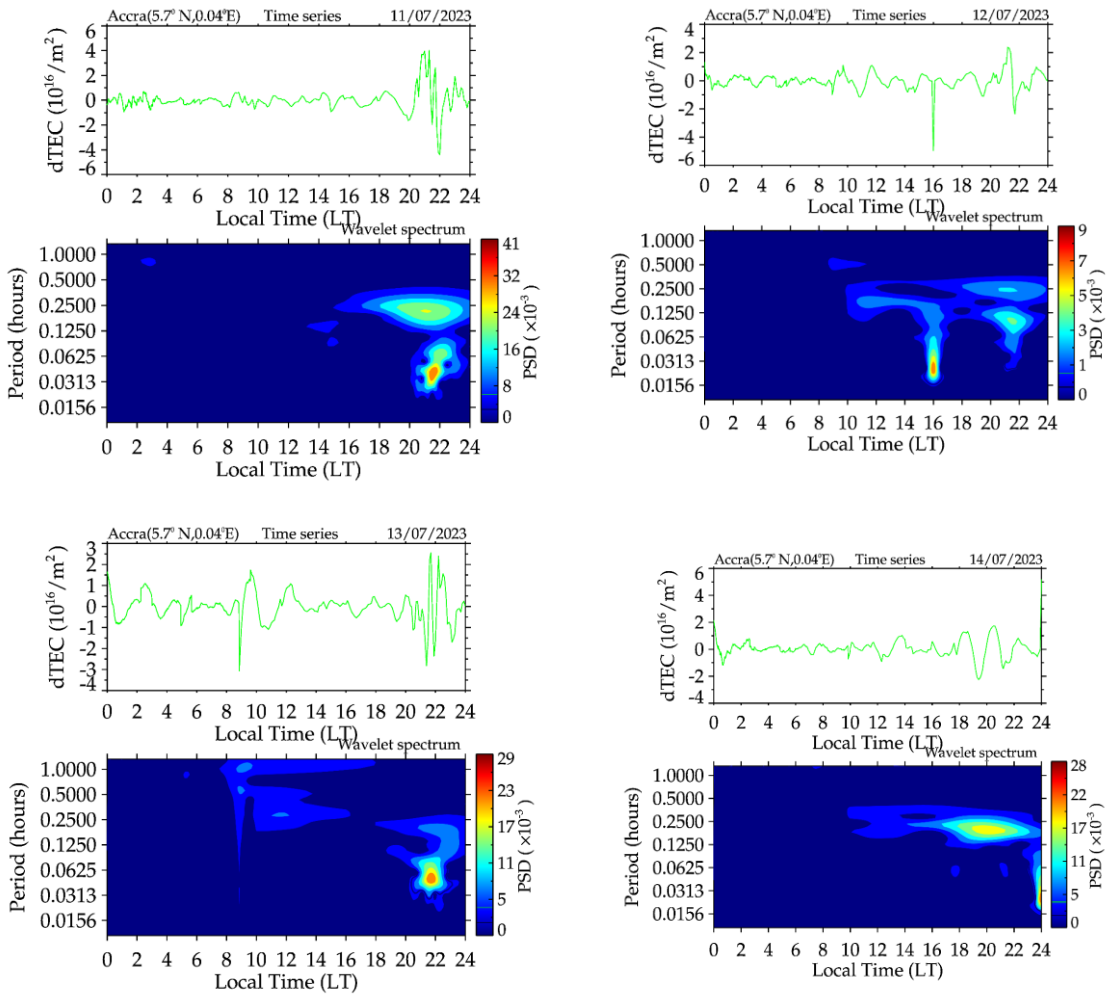


Figure 5.0 Times series of DTEC (top panel) in green and the Wavelet transform spectrum (bottom) on the 11th -14th July 2023 Accra Accra (5.7°N, 0.04°E) .

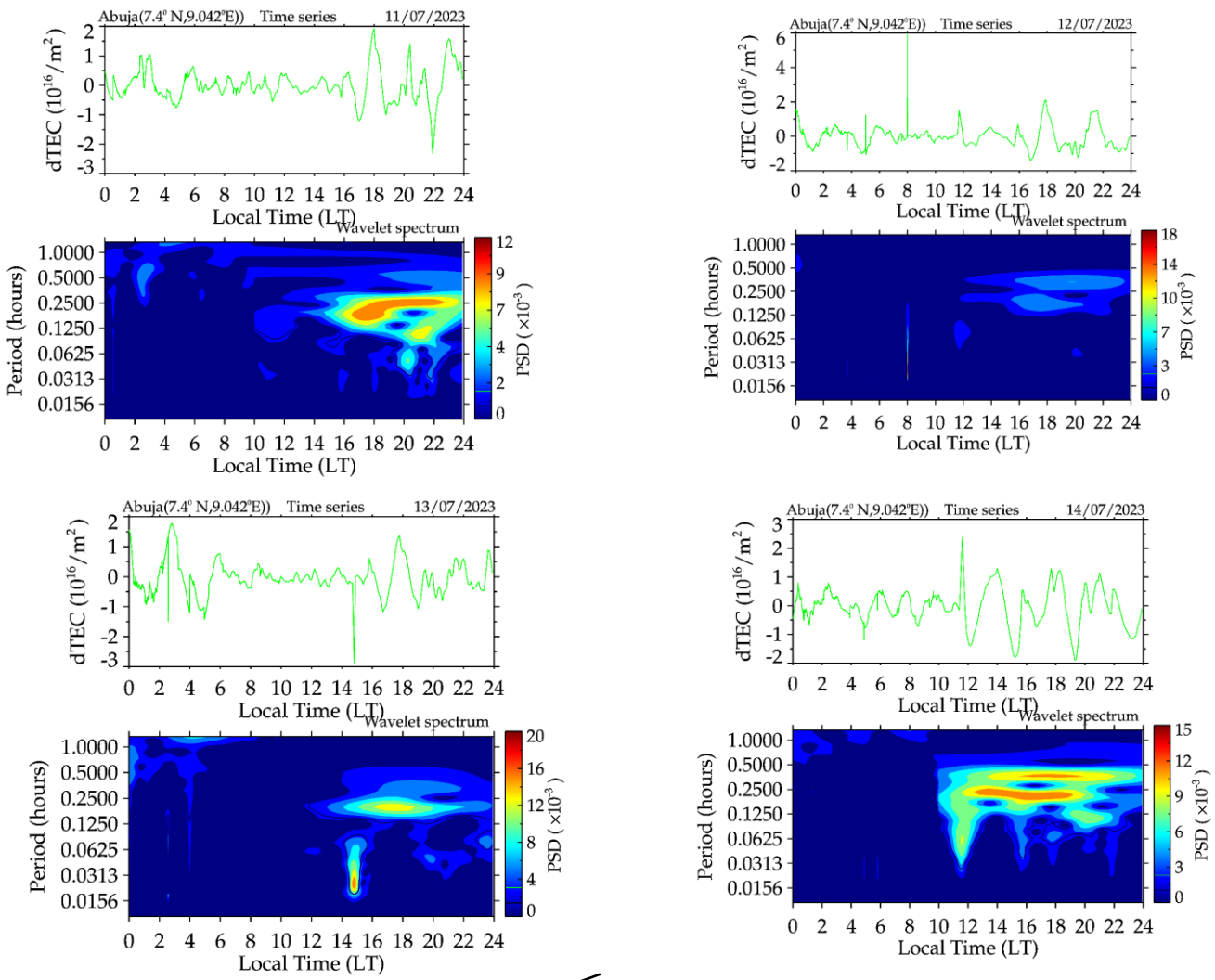


Figure 6.0Times series of DTEC (top panel) in green and the Wavelet transform spectrum (bottom) on the 11th -14th July 2023 Accra Abuja (7.4°N, 09.04°E) .

Are these observed period detected from the DTEC at both Accra and Nigeria stations evidence of Small scale travelling Ionospheric Disturbances (SSTIDs)?

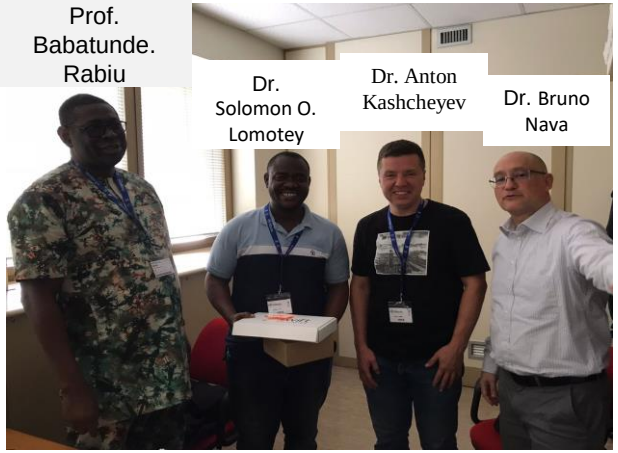
~15 Min, ~30 mim and 3.75 min

SUMMARY/ WAY FORWARD & ACKNOWLEDGMENTS

Our investigation revealed the following:

- **A distinct daily variation in VTEC was noted, with a notable peak in VTEC during the post-sunset hours of 20:00 to 24:00**
- **Sudden enhancement of EXB drift is typically linked to the post-sunset VTEC peaks (Pre-reversal-enhancement, PRE).**
- **On July 13, 2024, the geomagnetism Dst index values indicate the presence of a moderate storm (-43 nT).**
- **Investigation is necessary into a number of possible explanations of the periodic variation, including trans-equatorial winds, equatorial electrodynamics, and equatorial atmospheric waves.**
- **In order to understand the electrodynamic processes responsible for this result in the equatorial ionosphere, more ground-based instruments such as radars, GNSS networks, magnetometers, Fabry-Perot interferometers, and optical imagers are needed. However, a single GNSS station located at the equatorial ionization anomaly (EIA) south crest region cannot justify these observations identified.**

Thanks to the efforts of Prof. Rabiu Babatunde (Executive Director of UN-ARCSSTE-E), Dr. Bruno Nava, and Dr. Anton Kashcheyev from the United Nations African Regional Centre for Space Science and Technology Education-English (UN-ARCSSTE-E), Nigeria, The Abdus Salam International Centre for Theoretical Physics (ICTP), Trieste, Italy, and University of New Brunswick, Fredericton, Canada, respectively, we were able to obtain Low-Cost dual frequency Global Navigation Satellite Systems (GNSS) for scientific and research studies under collaboration of ICTP on October 12, 2022.



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MENTORS: Prof. Babatunde Rabiu (Executive Director, ARCSSTE-E) and Prof Christine Amory-Mazaudier (Senior Scientist Sorbonne Universites)

THANK YOU ALL FOR YOUR ATTENTION!!!!!