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Article

The Effect of Solar Activity on Total Electron Content (TEC) in Low-Latitude Regions: A Case Study of African Stations

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Abstract

The vertical Total Electron Content (TEC) derived from Global Positioning System (GPS) observations for six African stations—Mbarara in western Uganda (30°S, 73°E), Malinda in central Mozambique (40°S, 19.41°E), La Misere in Seychelles (5°S, 48°E), Windhoek in Namibia (17°S, 09°E), Lusaka in Zambia (28°S, 31°E), and Hartebeest Hoek in South Africa (27°S, 04°E)—was used to study the effects of solar activity on TEC for ten solar quiet days in each month during the period 2010–2012. The seasonal effects of solar activity were analysed by grouping each month into four seasons: March Equinox, September Equinox, June Solstice, and December Solstice. The results show that equinoctial TEC values are higher than the solstice values for stations in the Southern Hemisphere. During the equinoctial months, the Sun is directly overhead in the equatorial region, resulting in higher ionization over these regions. Notable differences were observed in the dependence of TEC on F10.7 solar flux, varying with local time and latitude. In the early morning hours, TEC shows a notable divergence from F10.7, with a root mean square error of *r* (0.007). In contrast, from noon to the early afternoon, TEC aligns closely with F10.7, demonstrating a strong correlation of *r* (0.650), especially at lower latitudes.

Keywords: Solar activity, GPS Observation, Ionization, F10.7 Solar Flux, Equinox and Solstice.

1. Introduction

The Total Electron Content (TEC) in the ionosphere, largely influenced by solar activity, is a key factor in causing ionospheric time delays that directly impact the precision and dependability of Global Positioning Systems (GPS). This delay occurs because GPS signals are slowed down as they pass through the ionosphere due to the presence of free electrons. The extent of the time delay is proportional to the number of electrons the signal encounters along its path from the satellite to the ground receiver. Essentially, TEC represents the total number of electrons between two points, typically a GPS satellite and a receiver, and is measured in electrons per square meter, describing how many electrons exist in a column of one square meter along the GPS signal's trajectory, where: [1], [2], [3], [4].

$$10^{16}\, elctrons/m^2 = 1 \text{ TEC unit (TECU).}$$

Variations in TEC, often driven by solar phenomena like solar flares, sunspots, and solar winds, lead to changes in ionospheric conditions, further affecting GPS accuracy. TEC is influenced by several factors [4], [5]: time of the day: electron density usually peaks in the early afternoon and is lowest around midnight, season: higher electron density occurs during winter compared to summer, solar cycle: electron density follows the 11-year solar cycle, peaking during periods of high solar activity, such as the 2014 peak of solar cycle 24, geographic location: electron density varies by location, with the lowest levels in mid-latitude regions, while polar, aurora, and equatorial areas experience more irregular variations [6], [7]. Solar radiation significantly affects TEC, leading to daily and seasonal fluctuations. Daytime sees higher TEC due to stronger solar radiation, particularly around noon, while night-time levels drop as solar influence decreases. Seasonal changes are driven by the Earth's axial tilt, which alters sunlight intensity and duration across different regions [6], [8], [9].

Solar activity, particularly the sunspot cycle, also greatly impacts TEC. Sunspots increase during periods of heightened solar activity, known as solar maximum, which raises TEC levels in the ionosphere. This cycle, lasting around 11 years, influences space weather and the ionosphere [6], [10], [11].

Moreover, solar flares and magnetic storms strongly affect ionospheric behaviour. Solar flares, sudden energy releases from the sun, increase electron density in the lower ionosphere. Magnetic storms, triggered by disturbances in the Earth's magnetosphere from solar wind or coronal mass ejections (CME), heighten ionospheric activity, causing TEC fluctuations that disrupt radio wave propagation, including systems like the Global Navigation Satellite System (GNSS). Magnetic storms from solar bursts can cause significant disturbances in the geo-space environment, increasing electron density and enhancing radio wave absorption [4], [6], [11].

During these disturbances, GNSS positioning errors can be substantial, with deviations of up to 150 meters, particularly during peak solar activity, at midday, and near the horizon. This poses challenges for GNSS-based systems like GPS, which is widely used due to its global reach. However, for high-precision applications, such as in aviation and defence, stand-alone GPS lacks the necessary accuracy, availability, and integrity [12], [13], [14].

Improving GNSS performance requires accurate predictions of ionospheric conditions, especially during solar quiet periods. Research on how TEC affects GPS accuracy in different regions, particularly in equatorial areas like Africa, is essential. Africa, with higher ionospheric activity, offers an ideal setting to study errors caused by time delays due to TEC, especially during solar quiet days. Such research is crucial for enhancing GPS accuracy for both civilian and military purposes.

2. Data and Methodology

2.1 Data Acquisition

The data utilized in this study were collected from six International GNSS Service (IGS) stations located in low-latitude regions across Africa, spanning the years 2010 to 2012. These stations were strategically selected to provide a comprehensive representation of the geomagnetic and ionospheric conditions in the region. The stations included in the study are as follows: **Mbarara** in western Uganda (coordinates: 30° S, 73° E), **Malinda** in central Portugal (coordinates: 40° S, 19.41° E), La Misere in Seychelles (coordinates: 5° S, 48° E), **Windhoek** in Namibia (coordinates: 17° S, 09° E), **Lusaka** in Zambia (coordinates: 28° S, 31° E), and **Hartebeest Hoek** in South Africa (coordinates: 27° S, 04° E).

The classification of these stations was based on their geomagnetic latitude, which is a critical factor in understanding ionospheric behaviour, particularly in low-latitude regions where ionospheric dynamics are highly variable. Figure 1 illustrates the geographical distribution of these stations on a map of Africa, providing a visual representation of their locations.

The GPS observation data were sourced from **UNAVCO**, a leading organization that provides high-precision geodetic data and tools for scientific research. The year 2010 was characterized by low solar activity, with an average annual sunspot number of 16.0. To minimize the potential impact of geomagnetic storms on the data, the analysis focused exclusively on the **ten international quietest**

days (Q-Days) for each month over the three-year period (2010–2012). These Q-Days, which are periods of minimal geomagnetic disturbance, were identified and periodically updated in the **World Data Centre for Geomagnetism**, accessible via the following link: https://wdc.kugi.kyoto-u.ac.jp/qddays/index.html.

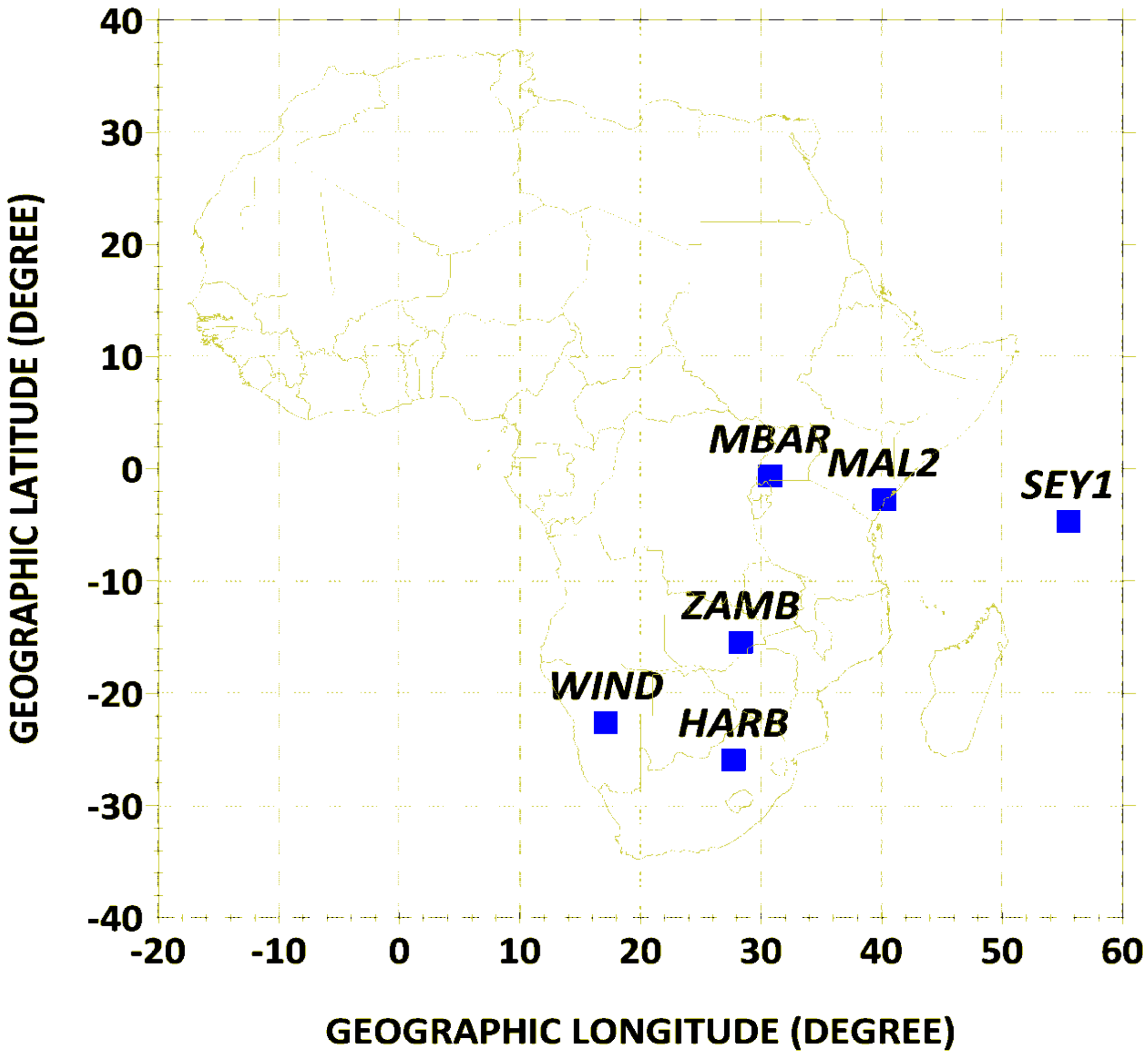


Figure 1. Map of Africa showing the studied location

By concentrating on the Q-Days, the study aimed to isolate the effects of regular ionospheric variations from those caused by geomagnetic disturbances, thereby ensuring a more accurate analysis of the ionospheric behaviour under relatively stable geomagnetic conditions. This approach is particularly important for studies focusing on low-latitude regions, where ionospheric irregularities such as equatorial plasma bubbles and scintillations are more prevalent and can significantly impact GNSS signal propagation.

The selection of these specific stations and time periods was driven by the need to capture a representative dataset that reflects the ionospheric dynamics in low-latitude Africa, a region that has historically been underrepresented in global ionospheric studies. The findings from this study are expected to contribute to a better understanding of ionospheric variability and its implications for GNSS applications in low-latitude regions.

2.2 Data Analysis

The data were processed using the GPS-TEC analysis software (GPS-TECV2.2), which corrects for differential group delays and phase advances on the L1 and L2 frequencies. The slant TEC (STEC) was converted to vertical TEC (VTEC) using geometric parameters. The data were then analysed for diurnal and seasonal variations, and the relationship between TEC and solar radio flux (F10.7) was investigated.

2.3 Methodology

The methodology involved several steps:

1. **Data Extraction and Cleansing**: The raw GPS data were extracted from compressed files and converted to RINEX format. Data cleansing was performed to remove any inconsistencies or errors.
2. **TEC Calculation**: The GPS-TEC software was used to calculate VTEC from the raw GPS data. The software accounts for satellite ephemeris, receiver biases, and ionospheric delays.
3. **Seasonal and Diurnal Analysis**: The data were grouped into seasons (December solstice, March equinox, June solstice, and September equinox) and analysed for diurnal variations.
4. **Solar Activity Correlation**: The relationship between TEC and solar radio flux (F10.7) was analysed using linear regression models. The correlation coefficients were calculated for different local times and seasons.

Linear Fitting and Model:

A piecewise linear fitting approach was applied to model the relationship between TEC and F10.7. The linear model used is:

$$TEC = A1\ F + A2 \qquad 2.1$$

Here, A1 and A2 are coefficients derived from the linear regression analysis. This model helps quantify how TEC changes in response to variations in solar radio flux.

3. Results and Discussion

3.1 Seasonal Variations of TEC

Figures 2, 3, and 4 illustrate the diurnal variations of seasonal average Total Electron Content (TEC) values across all seasons for six stations located in the southern hemisphere: Mbarara in western Uganda (30° S, 73° E), Malinda in central Portugal (40° S, 19.41° E), La Misere in Seychelles (5° S, 48° E), Windhoek in Namibia (17° S, 09° E), Lusaka-Zambia in Zambia (28° S, 31° E), and Hartebeest Hoek in South Africa (27° S, 04° E), for the year 2010-2012. In these Figures, the magenta lines with triangles represent the variations during the June solstice, blue lines with crosses depict the December solstice, cyan lines with circles show the September equinox, and red lines with asterisks indicate the March equinox.

In Figures 2 (a) - (e), it is evident that, across all seasons, daytime TEC values are consistently higher than night-time and pre-sunrise values. The TEC reaches its minimum pre-sunrise range of approximately 3.95–5.2 TECU around 0600 LT, a finding consistent with previous studies by [4], [15], [16]. These studies suggest that TEC sensitivity is weakest during this period. A sharp increase in TEC is observed during sunrise, typically between 0700 and 1500 LT, across all stations and seasons, with the exception of the June solstice at longitudes 55° and 30°, where the rise is more gradual. Daytime TEC peaks occur after local noon, with maximum values typically observed between 1200 and 1600 LT for all stations. The diurnal variation of TEC is asymmetrical around noon, with higher daytime TEC values attributed to increased solar radiation and the upward drift of the ionosphere to higher altitudes, where chemical losses are minimized [16], [17], [18], [19]. Following the post-noon peak, TEC gradually decays, continuing this trend until midnight.

The December solstice generally exhibits higher TEC values compared to the March and September equinoxes, with the exception of Hartebeest Hoek , where the September equinox values exceed those of the December solstice. The June solstice shows minimal TEC values for most stations in the southern hemisphere, except for Sey1 and Lusaka-Zambia. Overall, the TEC measurements indicate that equinoctial values are higher than solstice values for stations in the southern hemisphere. This is due to the Sun being directly overhead the equatorial region during equinoctial months, leading to increased ionization and higher TEC levels [19], [20].

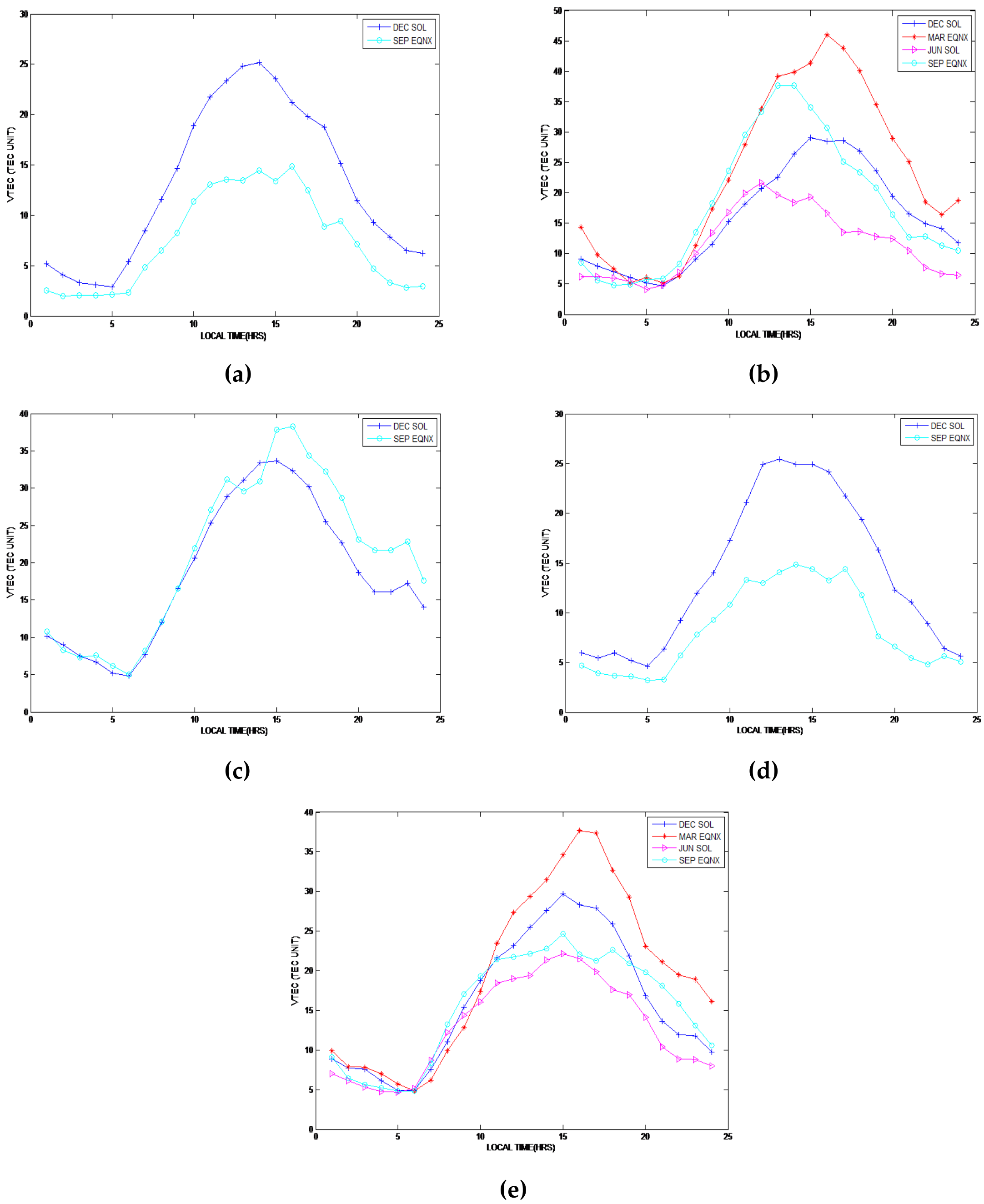


Figure 2: Seasonal variation of vertical Total Electron Content for the five stations in the year 2010 (a) Wind, (b) Seyi, (c) Harb, (d) Mal2, and (e) Mbar.

Figure 3 (a) - (e) illustrates the diurnal hourly monthly median variation of Total Electron Content (TEC) across five stations in the Southern Hemisphere during the year 2011. These stations include Mbarara in western Uganda (30°S, 73°E), Malinda in central Portugal (40°S, 19.41°E), La Misere in Seychelles (5°S, 48°E), Windhoek in Namibia (17°S, 09°E), and Hartebeest Hoek in South Africa (27°S, 04°E). The analysis reveals distinct seasonal and diurnal trends in TEC variations, with notable differences across the stations. For all five stations, TEC values reach their minimum around 07:00 LT, except for Windhoek, where the lowest value occurs earlier, at approximately 05:00 LT. During the March equinox, TEC reaches its peak in the post-noon hours, around 16:00 LT, for most stations. However, Mbarara exhibits a deviation from this pattern, attaining its highest TEC values at noon (12:00 LT). Following these peaks, TEC declines progressively, forming a distinctive saw tooth pattern around midnight. Interestingly, in the post-midnight hours, there is a noticeable secondary rise in TEC before it eventually declines again. The December solstice exhibits generally lower TEC values across all stations for the year 2011. Peak TEC values are observed in the post-noon period, around 15:00 LT, except for Windhoek, which demonstrates a plateau-like behaviour during this time rather than a distinct peak. The September equinox shows the highest TEC peak at La Misere compared to the other stations, indicating stronger ionospheric activity over Seychelles during this period. These findings highlight the complex interplay between seasonal variations and local ionospheric dynamics, reinforcing the need for further studies to refine TEC predictive models for different geophysical conditions.

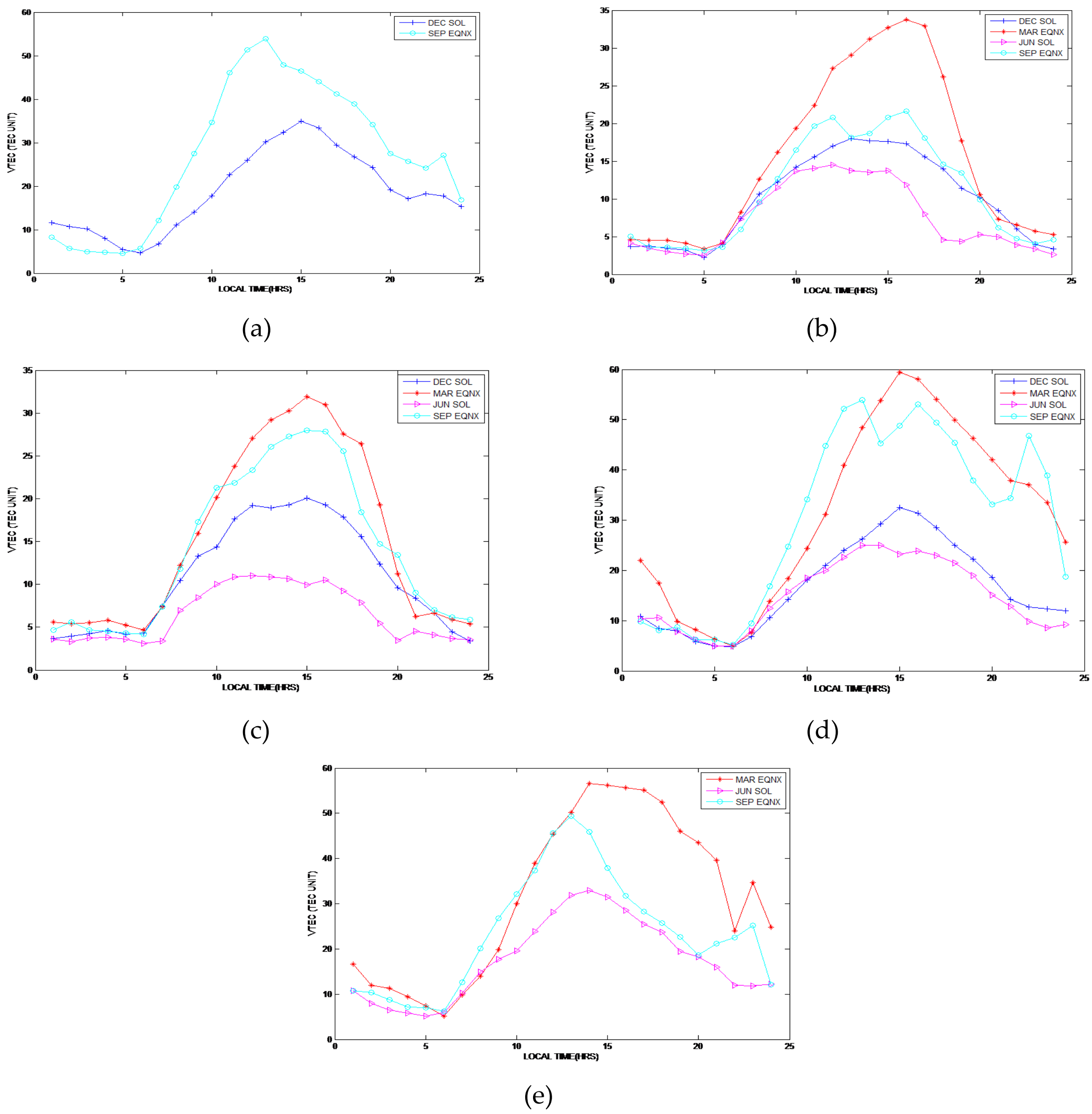


Figure 3: Seasonal variation of vertical Total Electron Content for the five stations in the year 2011 (a) Sey1, (b) Wind (c) Harb, (d) Mal2, and (e) Mbar.

In Figure 4 (a) - (e), the diurnal seasonal variation depicts highest value of in September equinox at 1600 LT except for Harb which has its maximum at March equinox at 1100LT, followed by December solstices at 1400LT. December solstice is higher than June solstice. The diurnal seasonal variation also shows a semi-annual pattern, maxima in equinoctials months and minima in solstice's months. The forenoon rate of production and afternoon decay of ionization is faster in the December solstice compared to that in the June solstice. December solstice value is therefore greater than June solstice. The VTEC minimum value of 3.20 – 20.21 TECU was observed at 0600 LT, regardless of the season except for December solstice in Harb that was around 0300LT.

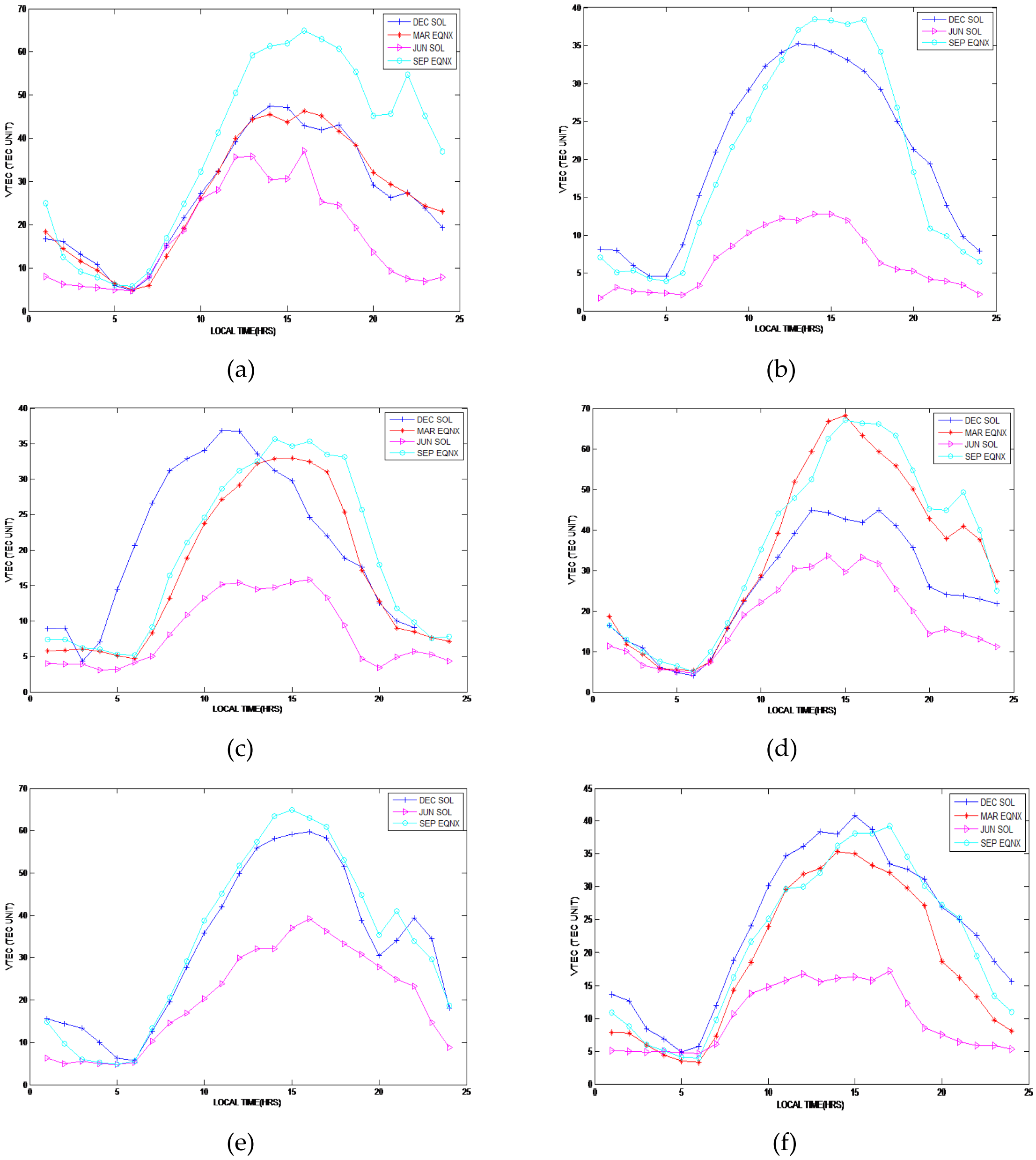


Figure 4: Seasonal variation of vertical Total Electron Content for the six stations in the year 2012 (a) Sey1, (b) Wind (c) Harb, (d) Mal2, (e) Mbar and (f) Zamb.

3.2 Comparative analysis of TEC and Solar flux (F10.7)

Figures 5 to 14 present the results of correlation analysis between TEC and F10.7, depicting the relationship between monthly median Total Electron Content (TEC), measured in TEC units (TECU), and solar radio flux (F10.7), expressed in solar flux units (sfu; 1 sfu = 10^{-22} $W{\cdot}m^{-2}{\cdot}Hz^{-1}$). The data are from the year 2012 and are analysed at five specific local times: 06.00 LT, 10:00 LT, 12:00 LT, 18:00 LT, and 24:00 LT. These figures illustrate how TEC varies with solar activity across different times of the day and seasons.

3.2.1 Solar Activity Modulations

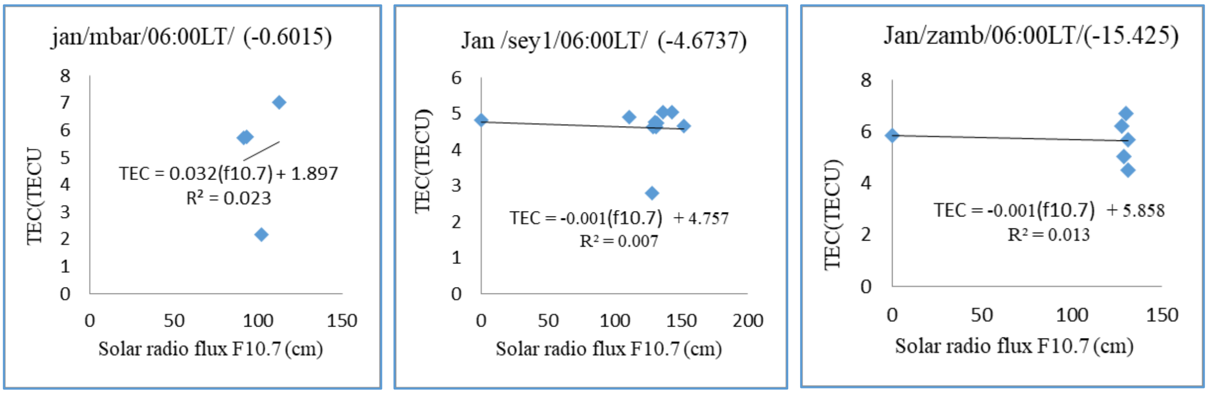
The results indicate that TEC is strongly influenced by solar activity, with evident seasonal and local time variations. Notably, saturation effects are observed in daytime TEC at low latitudes, whereas amplification occurs during the post-noon period, particularly in the Southern Hemisphere during the June solstice and March equinox. This pattern is consistent with previous findings in TEC [21], foF2 [16],

[16], and NmF2 [22], [23]. The distribution of linear coefficients in low-latitude regions aligns along the dip equator, forming a double peak structure. The double-peak structure observed in low-latitude TEC aligns with the geomagnetic configuration of the dip equator, which is indicative of geomagnetic configuration effects [16]. This structure is a result of the equatorial ionization anomaly (EIA), which creates two peaks in electron density on either side of the magnetic equator [16], [24].

3.2.2 Latitude and Local Time Dependence

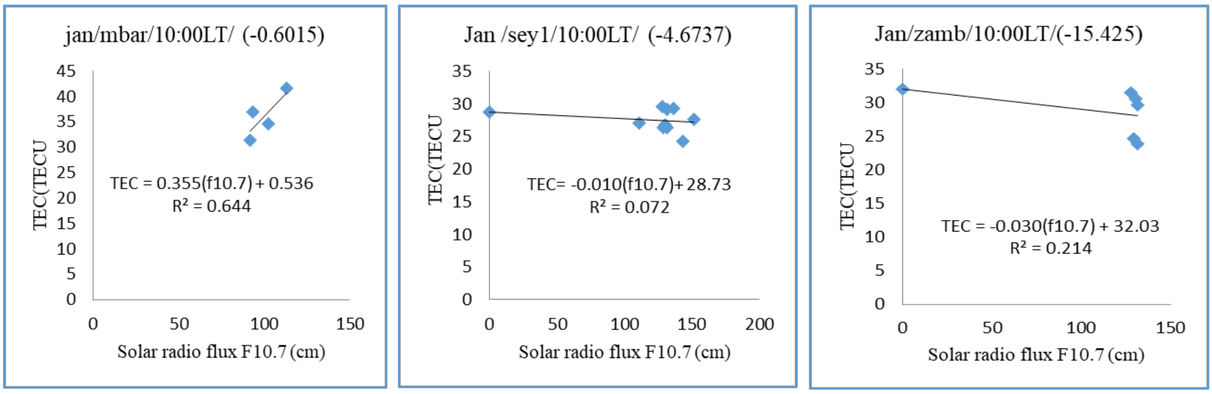
Across multiple latitudes, TEC exhibits a generally linear relationship with F10.7, with scatter diminishing as latitude decreases. The linear correlation coefficient, *r* (TEC, F10.7), was calculated for different latitudes (-0.6015, -4.6737, -15.4255) as a function of local time and geographic position during two seasons, the December solstice and the September equinox. The correlation coefficients remain relatively high, reaching approximately 0.6 during daytime (around 12:00 LT). However, the correlation weakens at night-time, particularly during early morning hours (24:00 LT, 06:00 LT, and 10:00 LT), as latitude decreases.

This pattern suggests that GPS signal errors are minimal during morning hours compared to the daytime period around 12:00 LT and 18:00 LT, where higher TEC levels lead to increased ionospheric signal delays. These findings emphasize the importance of local time and seasonal considerations in TEC modelling, particularly for improving GPS-based navigation and communication systems.



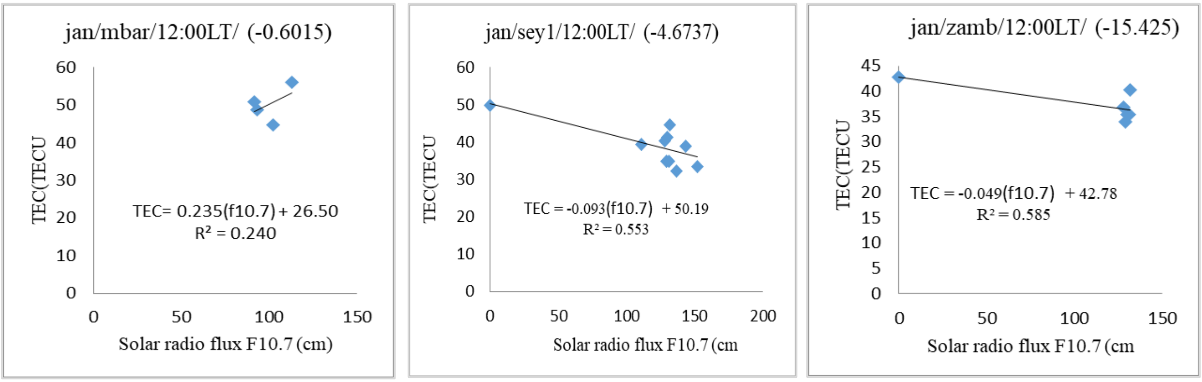
(a) (b) (c)

Figure 5. Plots of monthly median Total Electron Content (TECU) at 0600 LT versus F10.7 (solar flux unit, 1 sfu = 10^{-22} W.m^{-2}.Hz^{-1}), January for 2012 (a) Mbar , (b) Sey1 , and (c) Zamb.



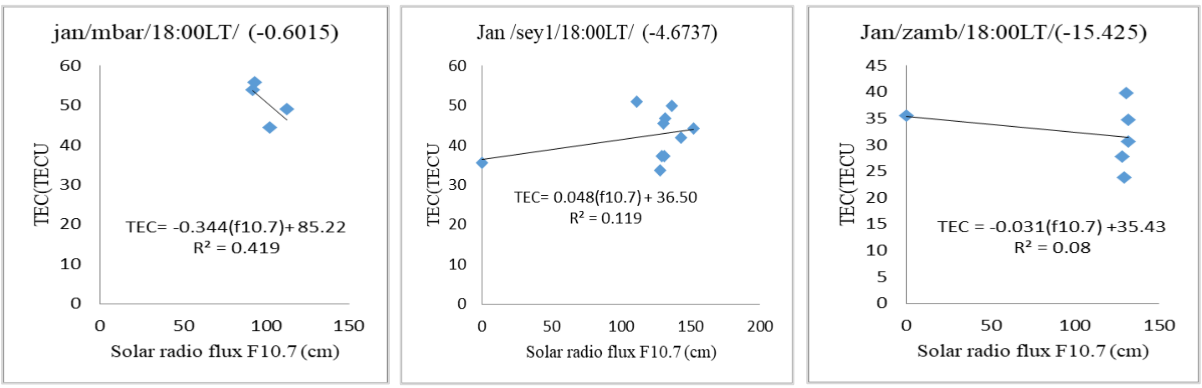
(a) (b) (c)

Figure 6. Plots of monthly median of Total Electron Content (TECU) at 1000 LT versus F10.7 (solar flux unit, 1 sfu = 10^{-22} W.m^{-2}.Hz^{-1}),January for 2012 (a) Mbar , (b) Sey1 , and (c) Zamb



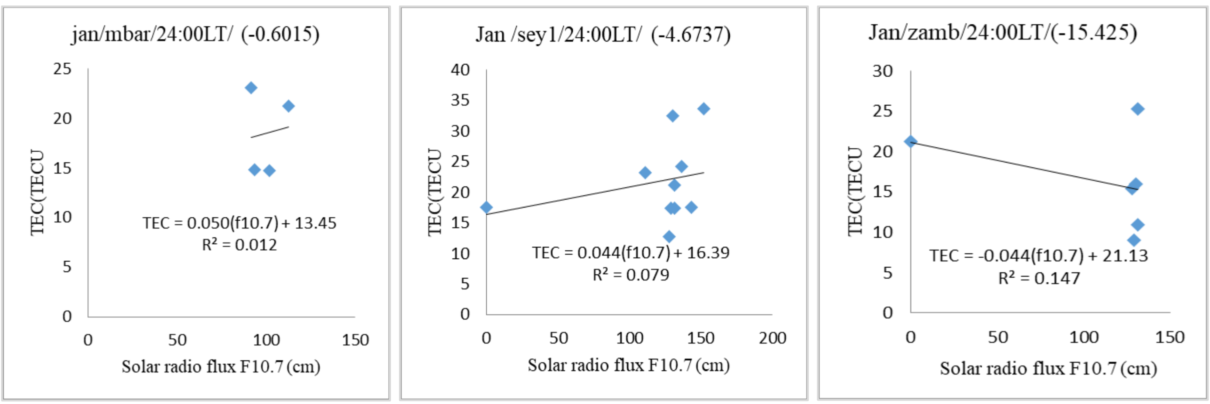
(a) (b) (c)

Figure 7. Plots of monthly median of Total Electron Content (TECU) at 1200 LT versus F10.7 (solar flux unit, 1 sfu = 10^{-22} W.m^{-2}.Hz^{-1}), January for 2012 (a) Mbar , (b) Sey1 , and (c) Zamb



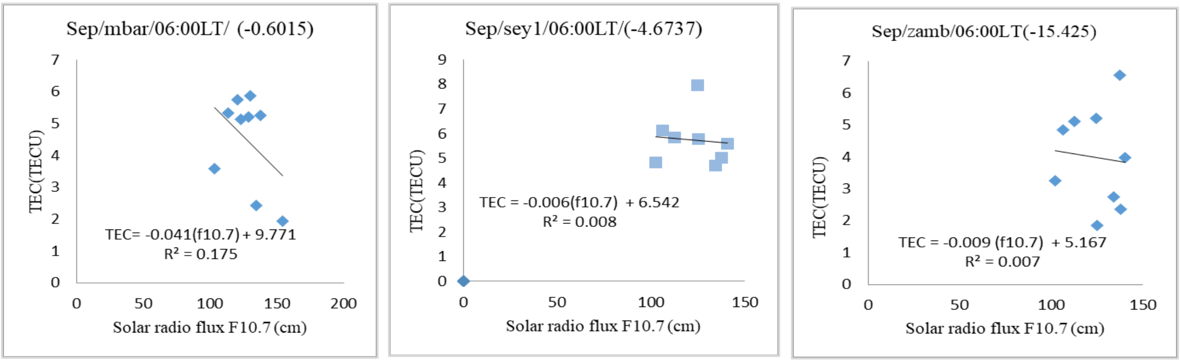
(a) (b) (c)

Figure 8. Plots of monthly median Total Electron Content (TECU) at 1800 LT versus F10.7 (solar flux unit, 1 sfu = 10^{-22} W.m^{-2}.Hz^{-1}),January for 2012 (a) Mbar , (b) Sey1 , and (c) Zamb



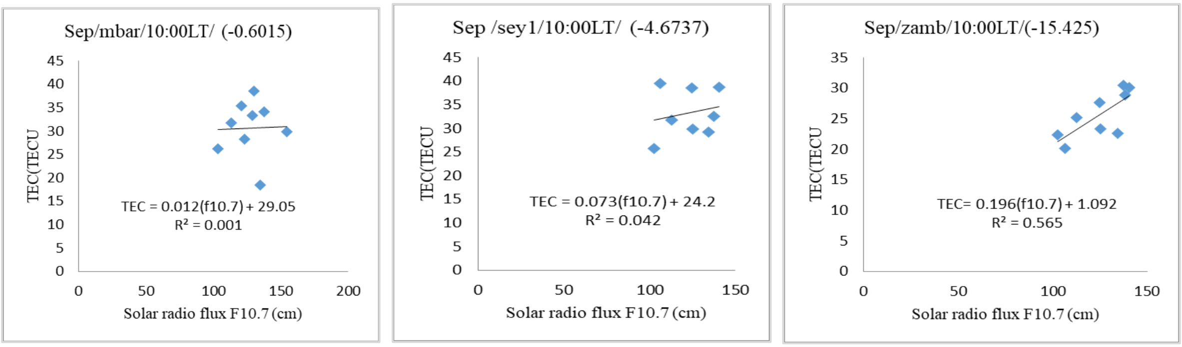
(a) (b) (c)

Figure 9. Plots of monthly median Total Electron Content (TECU) at 2400 LT versus F10.7 (solar flux unit, 1 sfu = 10^{-22} W.m^{-2}.Hz^{-1}), January for 2012 (a) Mbar , (b) Sey1 , and (c) Zamb



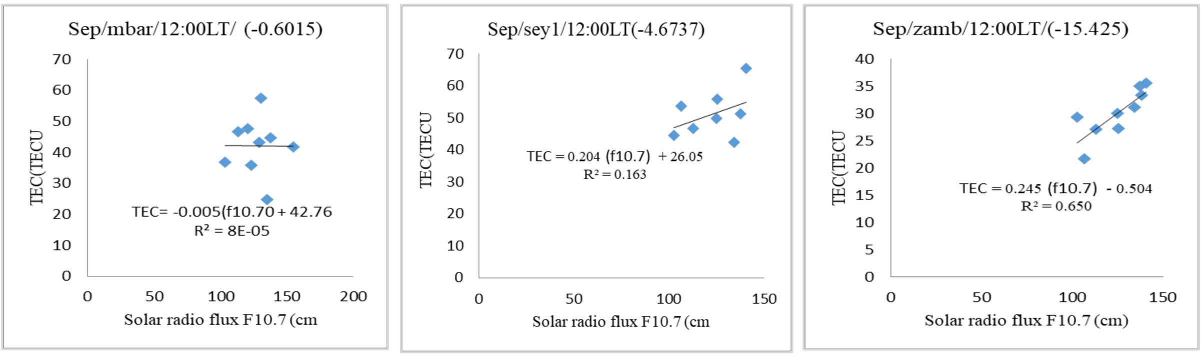
(a) (b) (c)

Figure 10. Plots of monthly median Total Electron Content (TECU) at 0600 LT versus F10.7 (solar flux unit, 1 sfu = 10^{-22} W.m^{-2}.Hz^{-1}), September for 2012 (a) Mbar , (b) Sey1 , and (c) Zamb



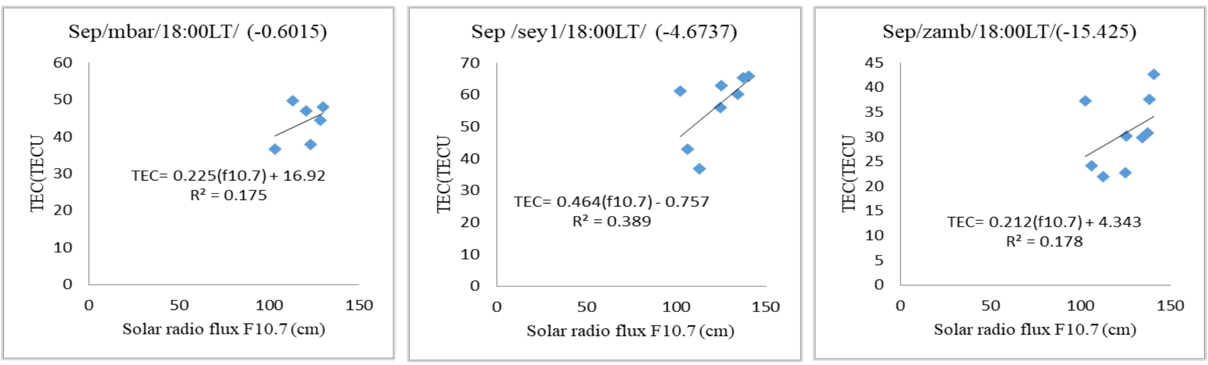
(a) (b) (c)

Figure 11. Plots of monthly median Total Electron Content (TECU) at 1000 LT versus F10.7 (solar flux unit, 1 sfu = 10^{-22} W.m^{-2}.Hz^{-1}), September for 2012 (a) Mbar , (b) Sey1 , and (c)Zamb



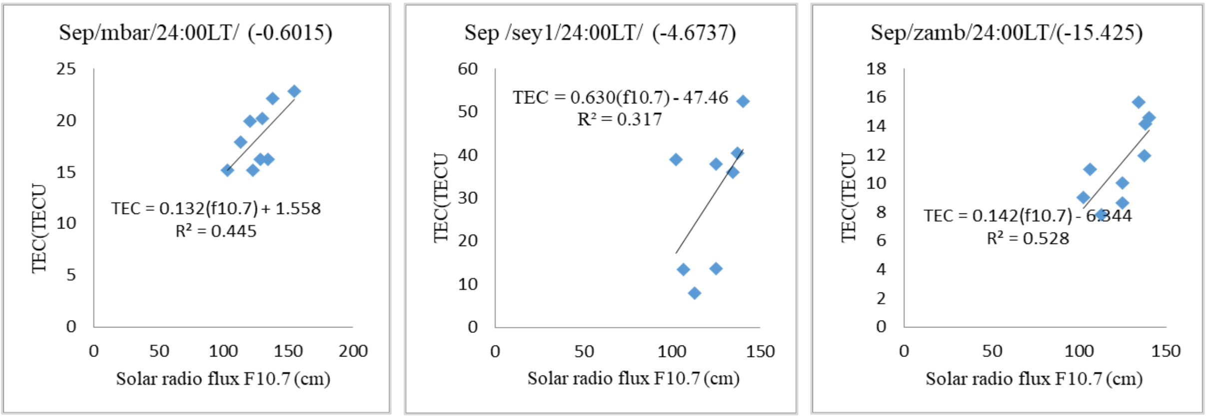
(a) (b) (c)

Figure 12. Plots of monthly median Total Electron Content (TECU) at 1200 LT versus F10.7 (solar flux unit, 1 sfu = 10^{-22} W.m^{-2}.Hz^{-1}), September for 2012 (a) Mbar , (b) Sey1 , and (c) Zamb



(a) (b) (c)

Figure 13. Plots of monthly median Total Electron Content (TECU) at 1800 LT versus F10.7 (solar flux unit, 1 sfu = 10^{-22} W.m^{-2}.Hz^{-1}), September for 2012 (a) Mbar , (b) Sey1 , and (c) Zamb



(a) (b) (c)

Figure 14 Plots of monthly median Total Electron Content (TECU) at 2400 LT versus F10.7 (solar flux unit, 1 sfu = 10^{-22} W.m^{-2}.Hz^{-1}), September for 2012 (a) Mbar , (b) Sey1 , and (c) Zamb.

4. Conclusion

This study analysed TEC data from ten quiet days obtained from UNAVCO between 2010 and 2012 to examine the impact of solar activity on TEC. Significant variations exist in the relationship between TEC and F10.7, depending on local time and latitude (location). During the early hours, TEC deviates substantially from F10.7 as latitude decreases, as indicated by the root mean square error. However, from noon to the post-noon period, TEC shows a strong correlation with F10.7 as latitude decreases. TEC exhibits strong solar activity modulation with distinct seasonal and local time variations. Saturation occurs in daytime TEC at low latitudes, while amplification is observed in the post-noon period in the Southern Hemisphere during the June solstice and the March equinox. For practical applications, the dependence of TEC on solar activity can be effectively represented using linear regression, as higher-order regressions do not significantly enhance the fitting accuracy

References

1. Abe, O., Rabiu, A. and Adeniyi, J. (2013). Variability of foE in the equatorial ionosphere with solar activity. *Adv. Space Res.* **51**, 69–75.
2. Kumar, S., Tan, E. L. and Murti, D. S. (2015). Impacts of solar activity on performance of the IRI-2012 model predictions from low to mid latitudes. *Earth Planets Space* **67**, 42.
3. Panda, S. K., Gedam, S. S. and Rajaram, G. (2015). Study of Ionospheric TEC from GPS observations and comparisons with IRI and SPIM model predictions in the low latitude anomaly Indian subcontinental region. *Adv. Space Res.* **55**, 1948–1964.
4. Rabiu, A., Groves, K., Abdulrahim, R., Fayose, R., Adeniyi, J., Ariyibi, E., Oyeyemi, E., and Okere, B. (2011). *TEC derived from some GPS stations in Nigeria and comparison with the IRI*. 12–16.
5. Bolaji, O. S., Adeniyi, J. O., Radicella, S. M. and Doherty, P. H. (2012). Variability of total electron content over an equatorial West African station during low solar activity. *Radio Sci.* **47**, 1–9.
6. Hargreaves, J. K. (1992) *The Solar-Terrestrial Environment: An Introduction to Geospace-the Science of the Terrestrial Upper Atmosphere, Ionosphere, and Magnetosphere*. (Cambridge university press).
7. Akala, A. O., Seemala, G. K., Doherty, P. H., Valladares, C. E., Carrano, C. S., Espinoza, J., and Oluyo, S. (2013). Comparison of equatorial GPS-TEC observations over an African station and an American station during the minimum and ascending phases of solar cycle 24. *Annales Geophysicae*, *31*(11), 2085–2096. https://doi.org/10.5194/angeo-31-2085-2013
8. Mendillo, M. (2006) Storms in the ionosphere: Patterns and processes for total electron content. *Rev. Geophys.* **44**.
9. Kelley, M. C. (2009) *The Earth's Ionosphere: Plasma Physics and Electrodynamics*. vol. 96 (Academic press).
10. Davies, K. (1990) *Ionospheric Radio*. (Iet,).
11. Schunk, R. W. and Nagy, A. F. (2000) *Ionospheres: Physics, Plasma Physics, and Chemistry*. (Cambridge university press).
12. Spilker Jr, J. J., Axelrad, P., Parkinson, B. W. and Enge, P. (1996) *Global Positioning System: Theory and Applications, Volume I*. (American Institute of Aeronautics and Astronautics).
13. Skone, S., Knudsen, K. and De Jong, M. (2001) Limitations in GPS receiver tracking performance under ionospheric scintillation conditions. *Phys. Chem. Earth Part Solid Earth Geod.* **26**, 613–621.
14. Kintner, P., Humphreys, T. and Hinks, J. (2009) GNSS and ionospheric scintillation. *GNSS* **4**, 22–30.
15. Rama Rao, P., Gopi Krishna, S., Niranjan, K. and Prasad, D. (2006) Temporal and spatial variations in TEC using simultaneous measurements from the Indian GPS network of receivers during the low solar activity period of 2004–2005. in vol. 24 3279–3292 (Copernicus Publications Göttingen, Germany).
16. Liu, L. and Chen, Y. (2009) Statistical analysis of solar activity variations of total electron content derived at Jet Propulsion Laboratory from GPS observations. *J. Geophys. Res. Space Phys.* **114**.
17. Skinner, N. (1966) Measurements of total electron content near the magnetic equator. *Planet. Space Sci.* **14**, 1123–1129.

18. Lee, C.-C. and Reinisch, B. (2007) Quiet-condition variations in the scale height at F2-layer peak at Jicamarca during solar minimum and maximum. in vol. 25 2541–2550 (Copernicus Publications Göttingen, Germany).
19. Adewale, A., Oyeyemi, E., Adeniyi, J., Adeloye, A. and Oladipo, O. (2011) Comparison of total electron content predicted using the IRI-2007 model with GPS observations over Lagos, Nigeria. *9420 Dt 9420 Cf.*
20. Karia, S. P., Pathak, K. N., Yadav, K. S., Chaudhary, N. P. and Jana, N. C. P. R. (2014) Modification in atmospheric refractivity and GPS based TEC as earthquake precursors. *Positioning* **5**, 46–52.
21. Balan, N. and Bailey, G. (1995) Equatorial plasma fountain and its effects: Possibility of an additional layer. *J. Geophys. Res. Space Phys.* **100**, 21421–21432.
22. Liu, L., Wan, W., Zhang, M.-L. and Zhao, B. (2008) Case study on total electron content enhancements at low latitudes during low geomagnetic activities before the storms. in vol. 26 893–903 (Copernicus GmbH).
23. Odeyemi, O. O., Adeniyi, J. O., Oyeyemi, E. O., Panda, S. K., Jamjareegulgarn, P., Olugbon, B., Oluwadare, E. J., Akala, A. O., Olawepo, A. O., and Adewale, A. A. (2022). Morphologies of ionospheric-equivalent slab-thickness and scale height over equatorial latitude in Africa. *Advances in Space Research*, *69*(1), 236–253. https://doi.org/10.1016/j.asr.2021.10.030
24. Olawepo, A. O., Adeniyi, J. O. and Oluwadare, E. J. (2017) TEC variations and IRI-2012 performance at equatorial latitudes over Africa during low solar activity. *Adv. Space Res.* **59**, 1800–1809.

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All the authors (EJO, PCA and KAO) conceptualized and designed the study. EJO and KAO were involved in data collection/acquisition. EJO, PCA and KAO were involved in the analysis. All the authors were involved in the writing and revising the manuscript for intellectual content.

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