Effects of Ionospheric Scintillation on GNSS Positioning in the Low Latitude Region of Africa at the close of the 24th Solar Cycle

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Period of Stay in ISEE

I arrived at the ISEE on Friday 12th January 2024 and stayed till 29th March 2024.

Research Summary

Purpose of the Research

The purpose of the research was to investigate the effects of scintillations on GNSS positioning in the low latitude regions of Africa at the tail end of the 24th solar cycle using the RTKLIB positioning applications.

Methodology

The Global Navigation Satellite Systems (GNSS) data (in form of RINEX files) for the work was obtained from the SOPAC website. The locations of the receivers considered were within the dip equatorial region of Africa. The RINEX observation files obtained from the station were unzipped and then processed using the GPS-TEC application software developed at Institute of scientific Research, Boston College, USA. We used the method suggested by Pi et al., (1997) to determine ROTI:

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

ROTI is a good indicator of the existence of ionospheric irregularities and ROTI ≥0.5 indicates the occurrence of irregular ionospheric activities relevant to ionospheric scintillation. The GNSS positioning errors were determined using the RTKLIB application software, (Takasu, 2009).

Preliminary Results

The seasonal variations of scintillations were determined for the two years, 2019 and 2020, at the end of the 24th solar cycle. For contrast, the peak year, 2014, was also analyzed. The plots are given in Figures 1 and 2.

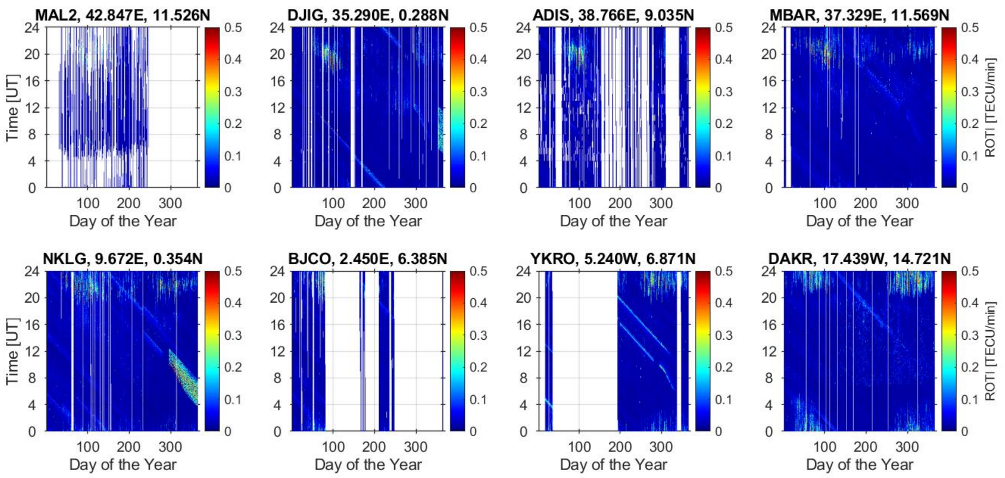


***Figure 1**: The time and seasonal variation of ROTI as observed by eight receivers within the dip equatorial region of Africa in the year 2019.*

The data was observed to have a lot of data outages. The ionospheric irregularities were also observed to be lower at the end of the 24th solar cycle compared to the period of the solar maximum, 2014. 2019 and 2020 represent the period of solar minimum. 2014, in Figure 2 represent the solar maximum for ease of comparison.

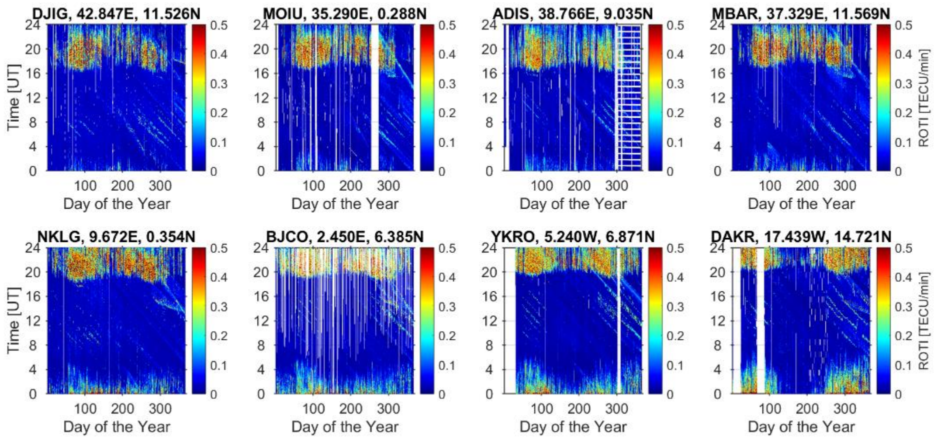
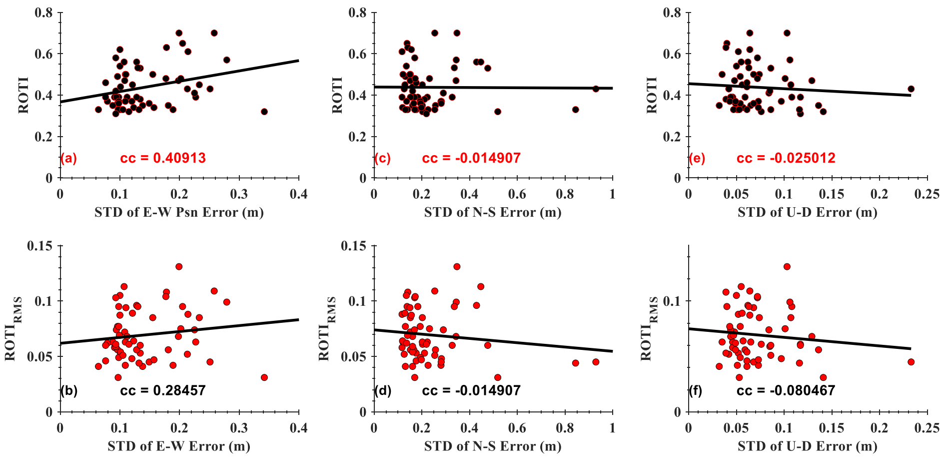


Figure 2: *The time and seasonal variation of occurrences rate of ionospheric scintillation as observed by eight receivers within the dip equatorial region of Africa in the year 2014.*

The ROTI was compared with the GNSS positioning errors. Figures 3 and 4 give summaries.

Figure 3: *The plots showing positioning errors for all the days in 2019 for the receivers with ROTI≥0.25 in all the stations considered. The correlation coefficients are indicated as cc in each subplot.*



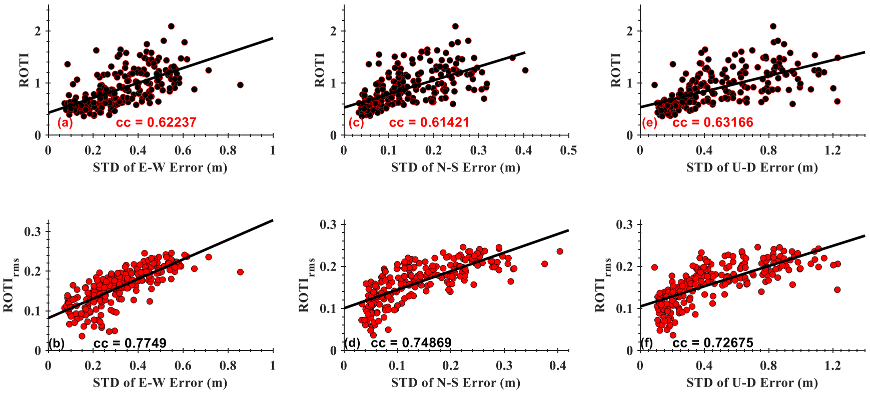


Figure 4: *Positioning errors for all the days with ROTI≥0.25 for Mbar in 2014. The correlation coefficients are indicated.*

Summary

There was observed diurnal and seasonal variations of ionospheric irregularities and seen in Figure 2. During low solar activity period of the 24th solar cycle, 2019 and 2020, the magnitude ionospheric irregularity could not trigger the GNSS positioning errors as opposed to the peak of the solar cycle, 2014. 2019 and 2020 had no plasma bubble while 2014 had plasm bubble. The RTKLIB positioning application was found to be a useful tool for the determination of precise GNSS positioning errors.

The paper is yet to be published.

Reference

Pi, X., Mannucci, A. J., Lindqwister, U. J., & Ho, C. M. (1997). Monitoring of global ionospheric irregularities using the worldwide GPS network. *Geophysical Research Letters*, *24*(18), 2283–2286. https://doi.org/10.1029/97GL02273