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Canadian High Arctic Ionospheric Network

Performance of low-cost GNSS receivers for ionospheric studies

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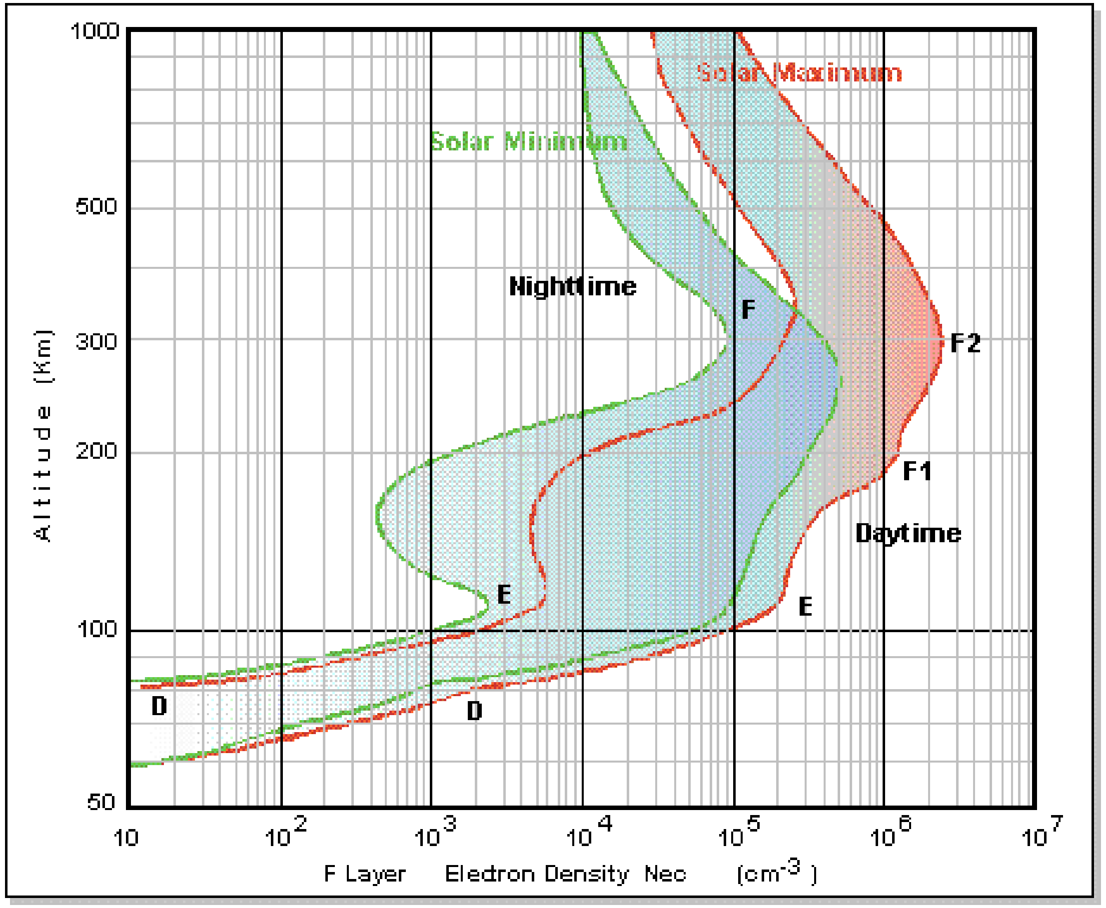
Special thanks to: Elijah Oyeyemi & Busola Olugbon (Nigeria), Olivier Obrou (Cote D'ivoire), Solomon Lomotey (Ghana), Babatunde Rabiu & Aderonke Ekemi (Nigeria), Marco Rainone (Italy)

Outline

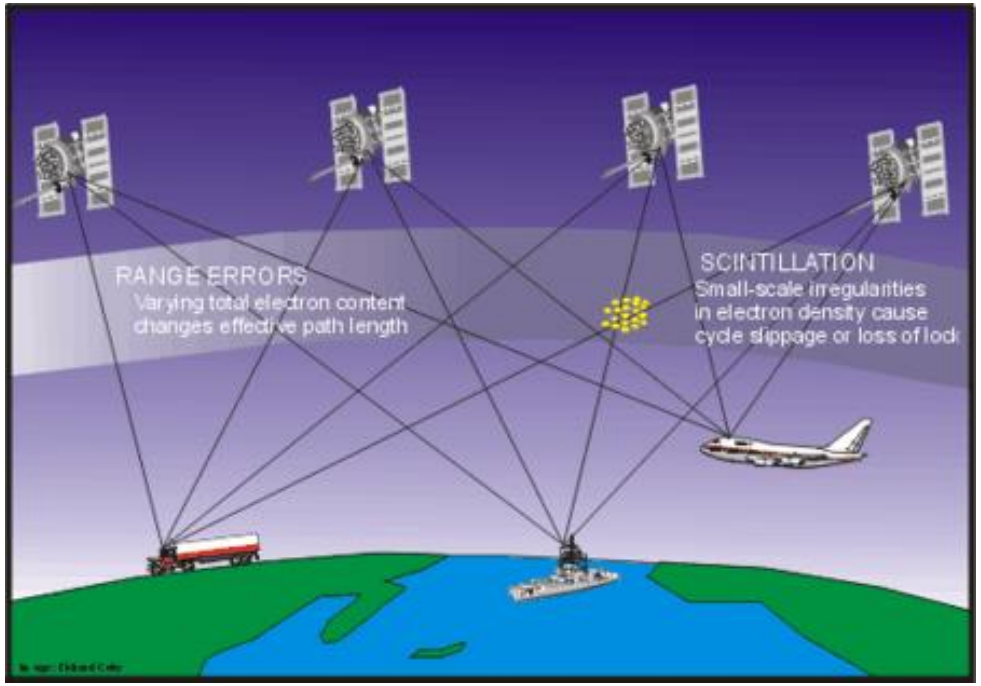
- Intro
  - Ionosphere
  - Ionosphere effects on GNSS
  - How to estimate TEC
  - Research studies: TIDs
  - Solar eclipse
  - Data assimilation
- Devices under test
- Data
  - Map
  - Magnetic activity level
- Results
  - Uncalibrated TEC
  - Cycle slips
  - Calibrated TEC
  - Model validation
- Conclusions

Ionosphere



- Ionized part of the atmosphere from ~60 to a few thousand km above the ground, so-called magnetized cold plasma or weakly ionized gas
- Formed by solar radiation, namely by photochemical absorption processes
- Loss is due to recombination processes
- Due to different ionization production and loss processes the electron density profile with altitude shows a layered structure that changes with time, location and solar activity
- The borders between layers are inflection points in the ED profile
- It is accepted to distinguish D, E and F (F1 and F2) layers
- Structure is highly dynamic and depends on many parameters

Ionosphere effects on GNSS signals

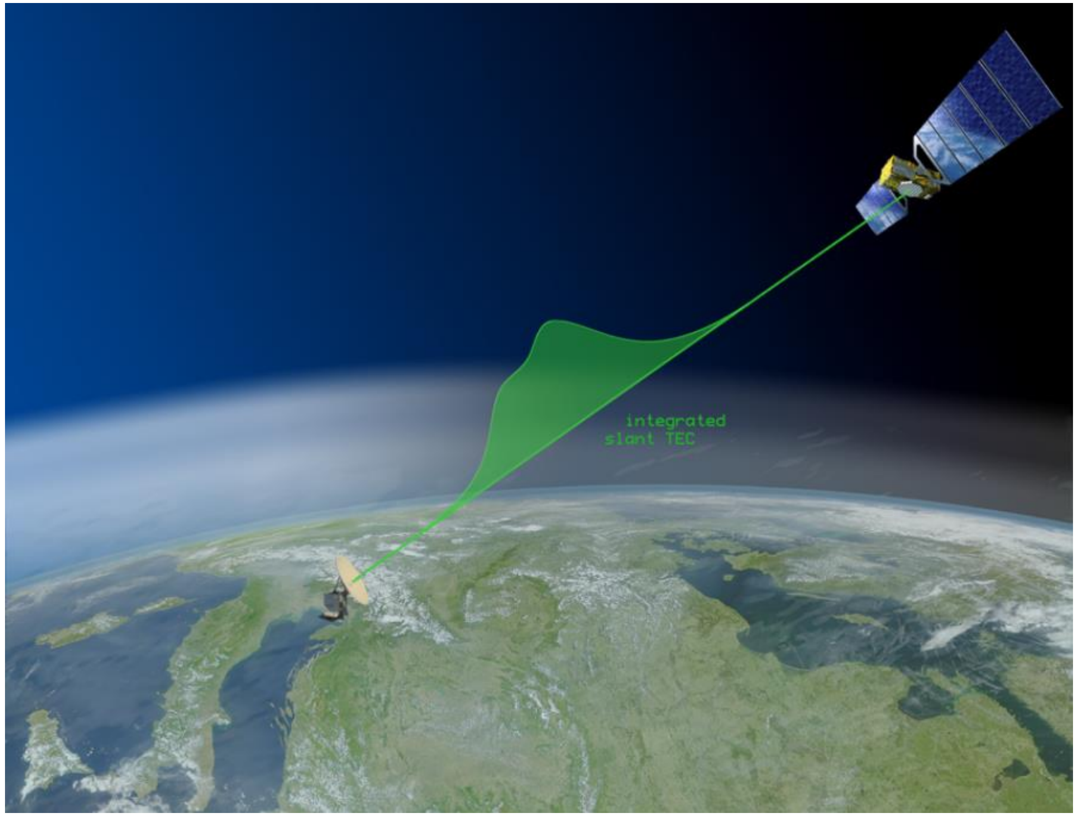


- **Range errors**
  - Group delay
  - Phase advance
  - Depend on the electron density along the ray path

$$d = \frac{40.3}{f^2} \int_{sat}^{rec} n_e \, dl$$

  - Highly variable with time/space
- **Scintillation**
  - Rapid random changes in amplitude and/or phase of the signal
- **Doppler shift**
  - Change in carrier frequency

How to estimate TEC



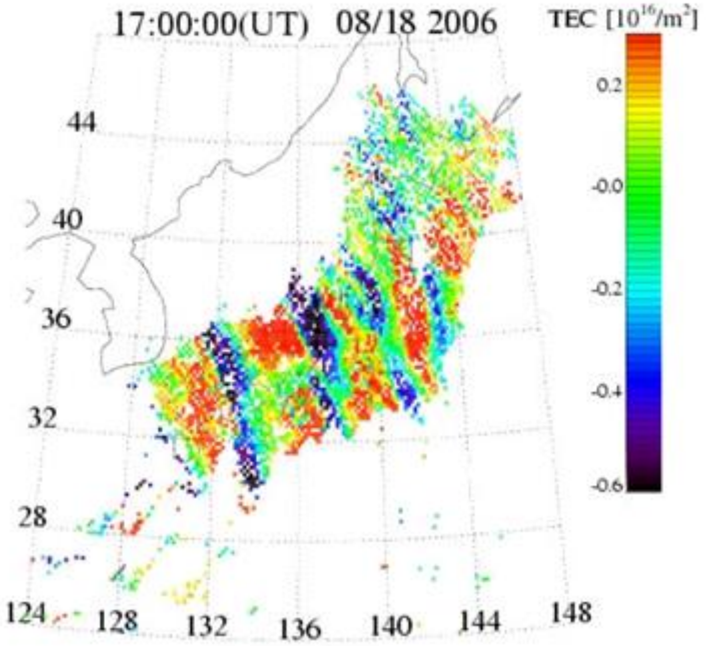
Dual frequency GNSS receivers

$$TEC \sim \frac{1}{40.3}\left(\frac{f_1^2 f_2^2}{f_1^2 - f_2^2}\right)(L_2 - L_1)$$

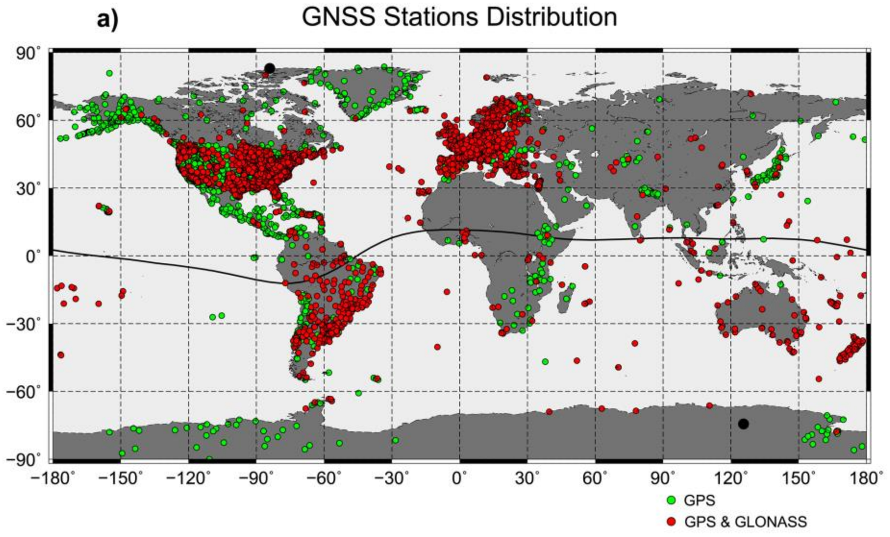
Total electron content (TEC) is the number of electrons in a column with a cross section of one square meter along the signal path

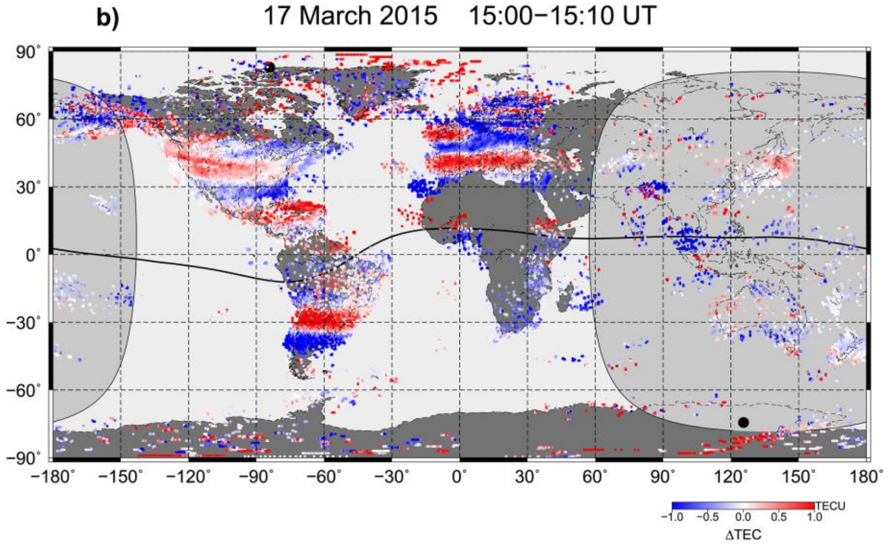
Research studies: TIDs

Japan



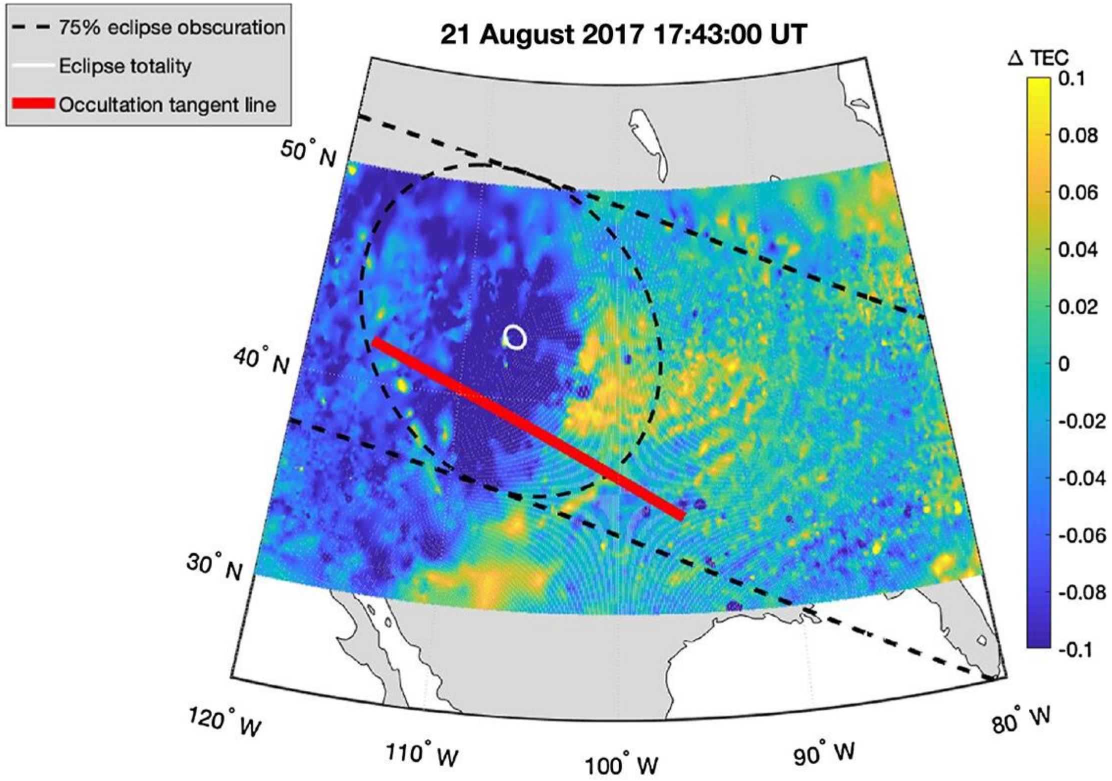
Tsugawa, T., Kotake, N., Otsuka, Y. et al. Medium-scale traveling ionospheric disturbances observed by GPS receiver network in Japan: a short review. GPS Solut 11, 139–144 (2007)

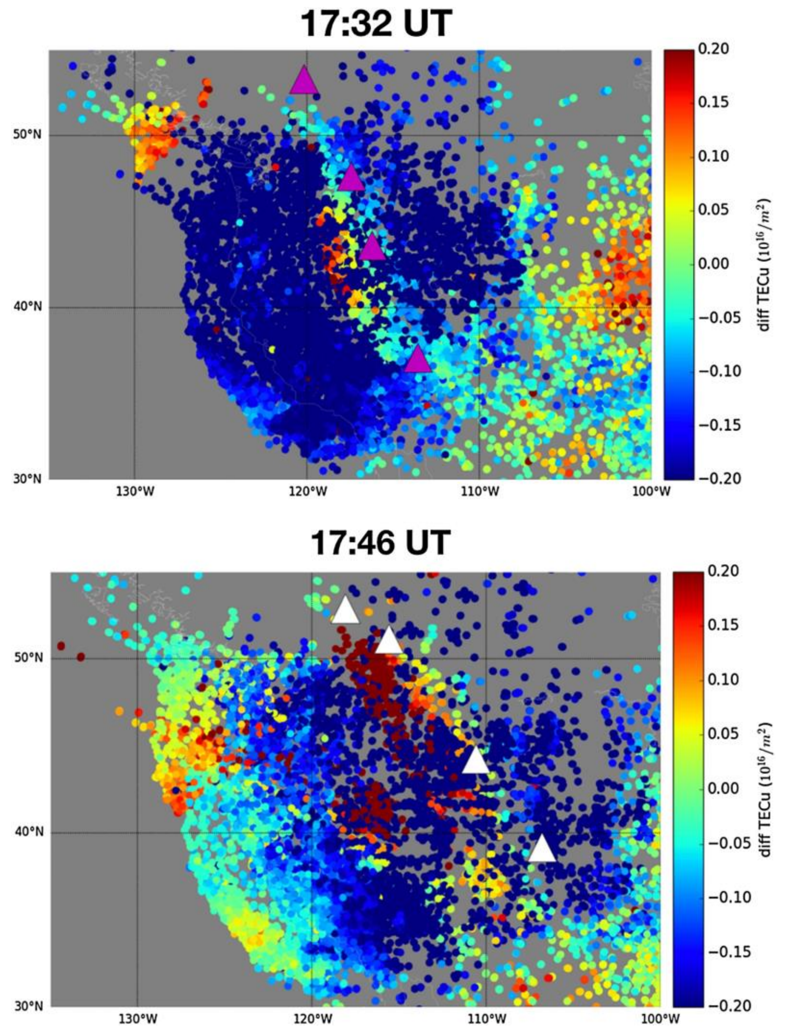




Zakharenkova, I., Astafyeva, E., and Cherniak, I. (2016), GPS and GLONASS observations of large-scale traveling ionospheric disturbances during the 2015 St. Patrick's Day storm, J. Geophys. Res. Space Physics, 121, 12,138– 12,156

Research studies: Solar Eclipse

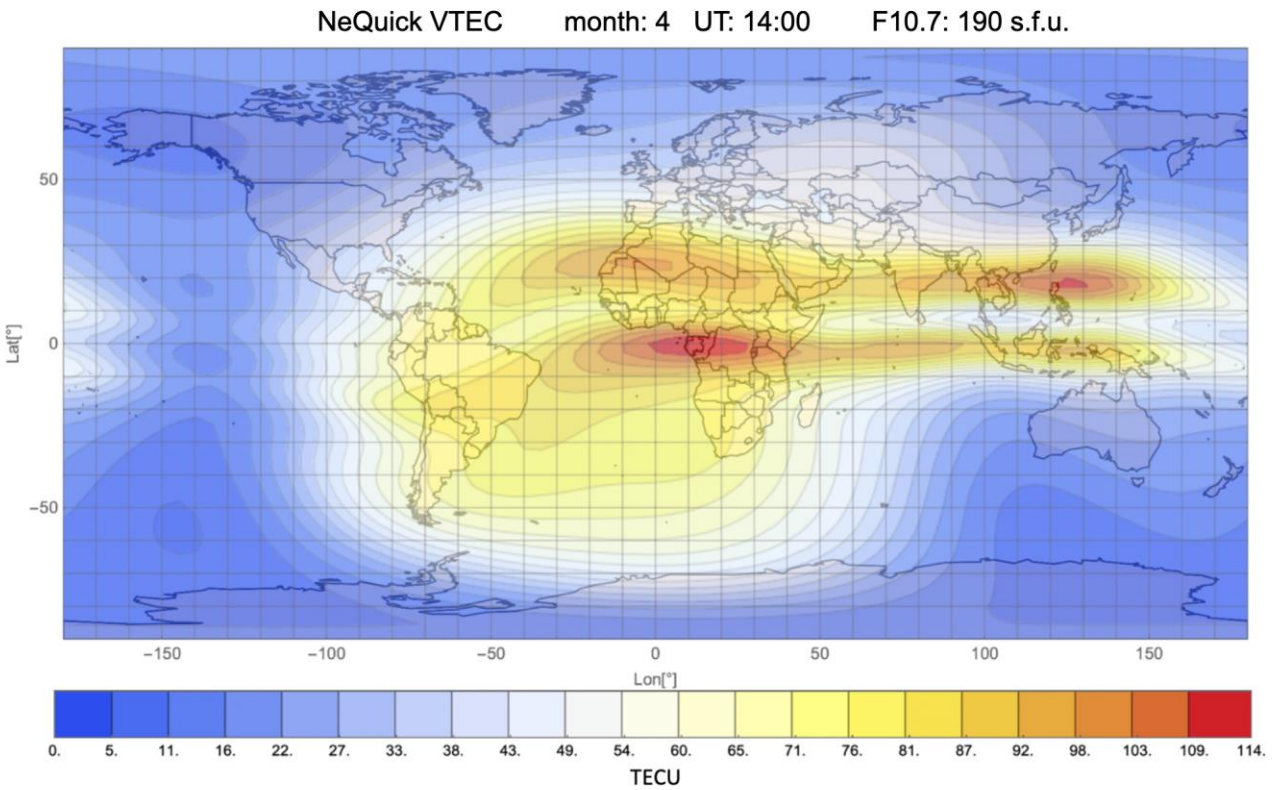


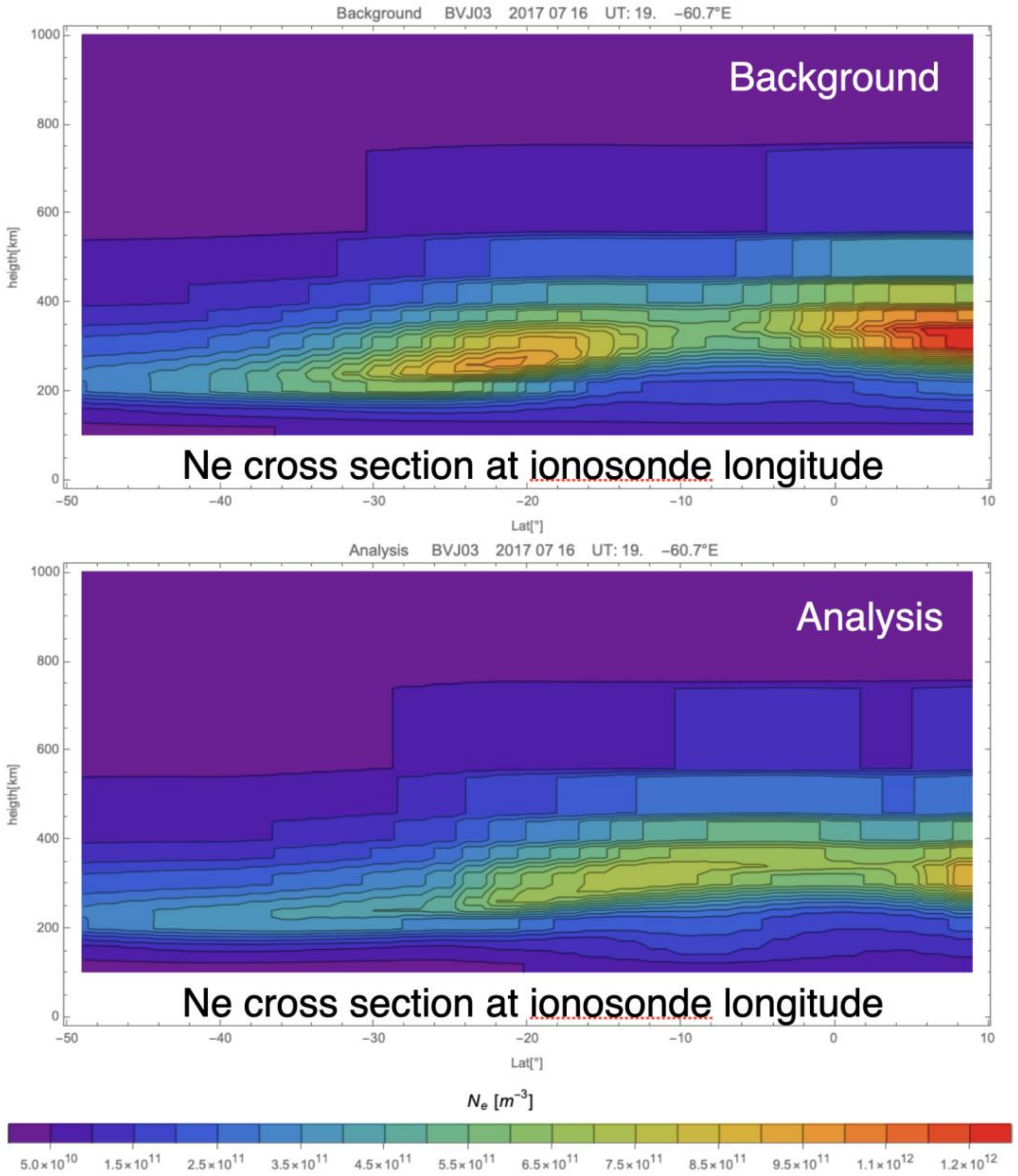


Perry, G. W., Watson, C., Howarth, A. D., Themens, D. R., Foss, V., Langley, R. B., & Yau, A. W. (2019). Topside ionospheric disturbances detected using radio occultation measurements during the August 2017 solar eclipse. Geophysical Research Letters, 46, 7069– 7078

Coster, A. J., Goncharenko, L., Zhang, S.-R., Erickson, P. J., Rideout, W., & Vierinen, J. (2017). GNSS observations of ionospheric variations during the 21 August 2017 solar eclipse. Geophysical Research Letters, 44, 12,041–12,048

Research studies: Data assimilation





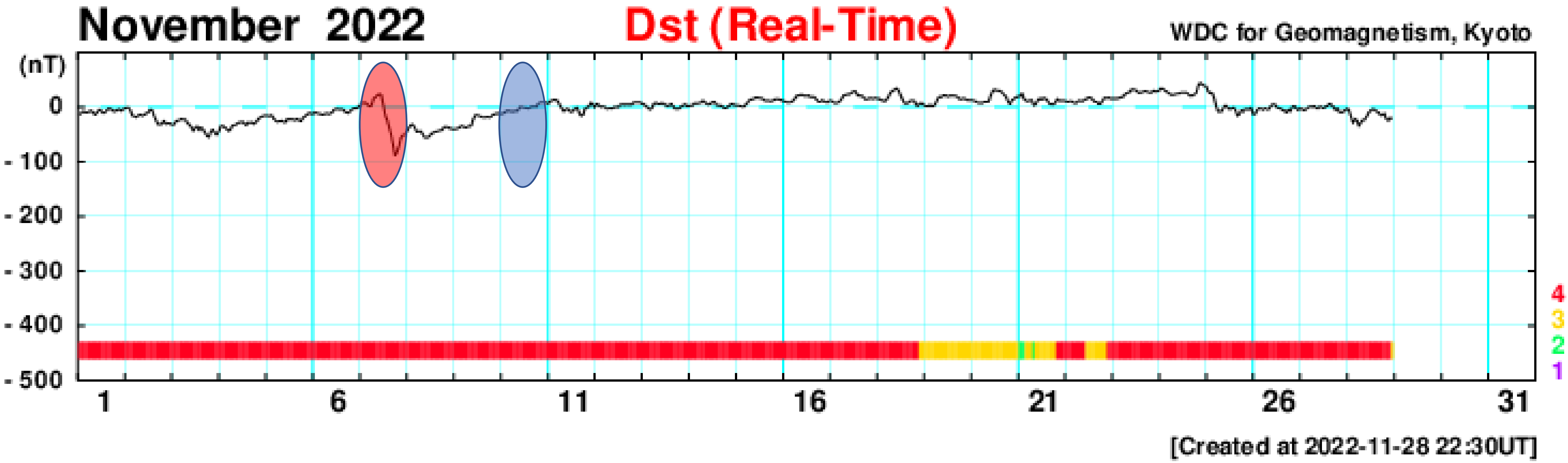
Devices under test (DUT)

- Septentrio PolaRx5S, up to 100Hz, >10k $
- Swift Piksi Multi, up to 20 Hz, 1k $
- U-Blox ZED-F9P, up to 20 Hz , 250 $

Data: map

- High latitudes
  - Qikiqtarjuaq, Canada
- Mid latitudes
  - Fredericton, Canada
- Low latitudes
  - Lagos, Nigeria
  - Abidjan, Côte d'Ivoire
  - Abidjan, Ghana
  - Abuja, Nigeria

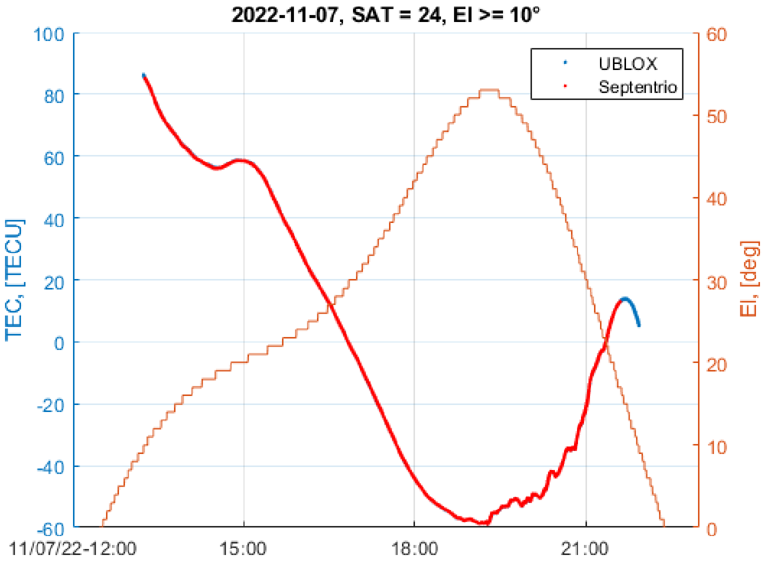
Data: geomagnetic activity level

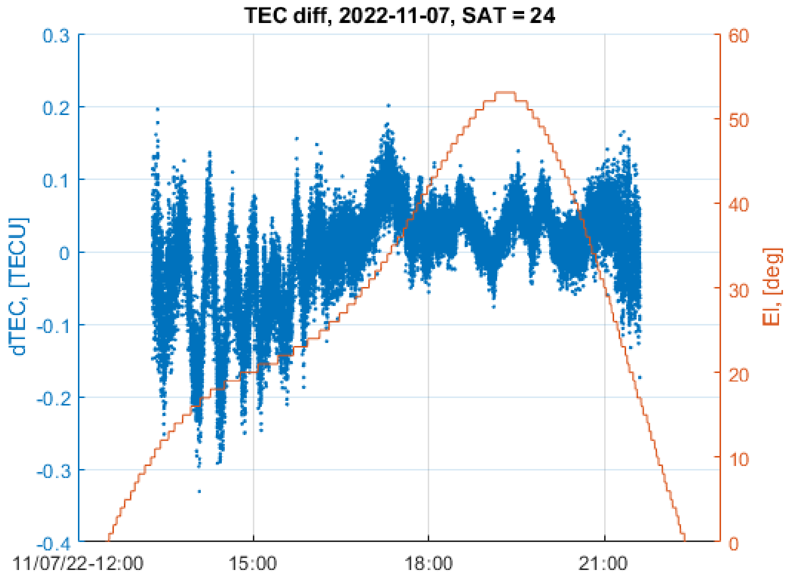


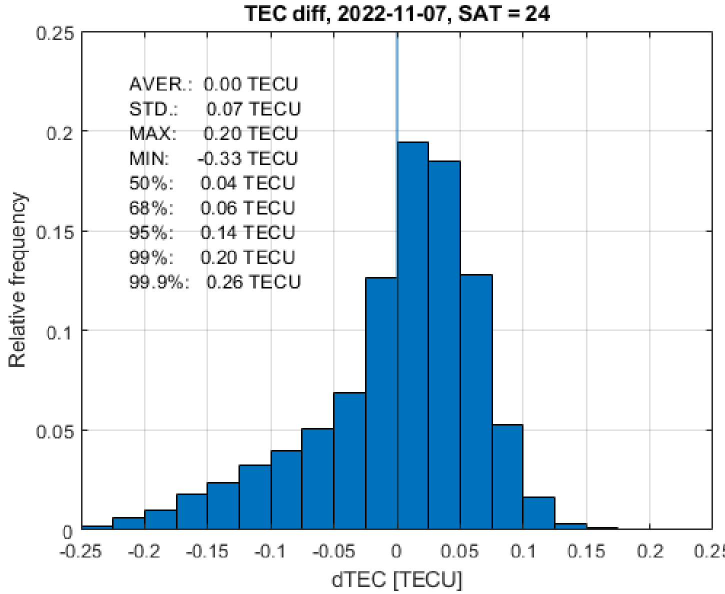
Results: uncalibrated TEC

Nigeria, Abuja, 9.1° N, 7.4° E

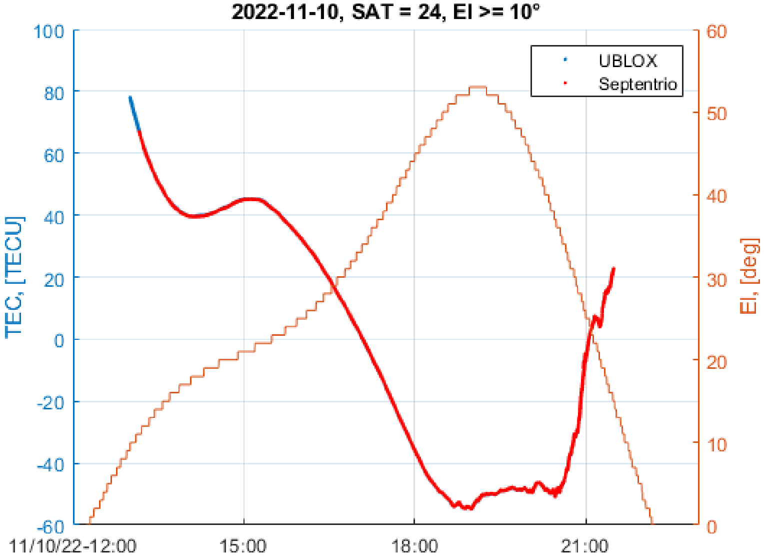
Storm

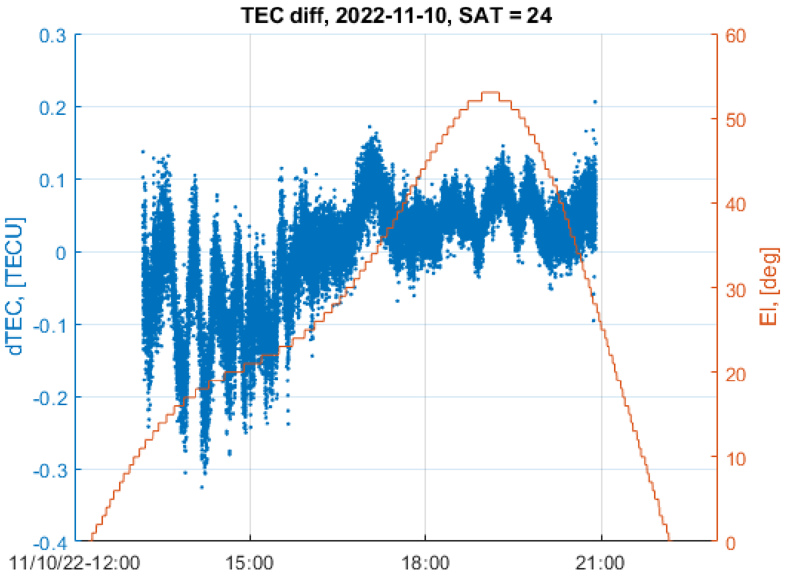


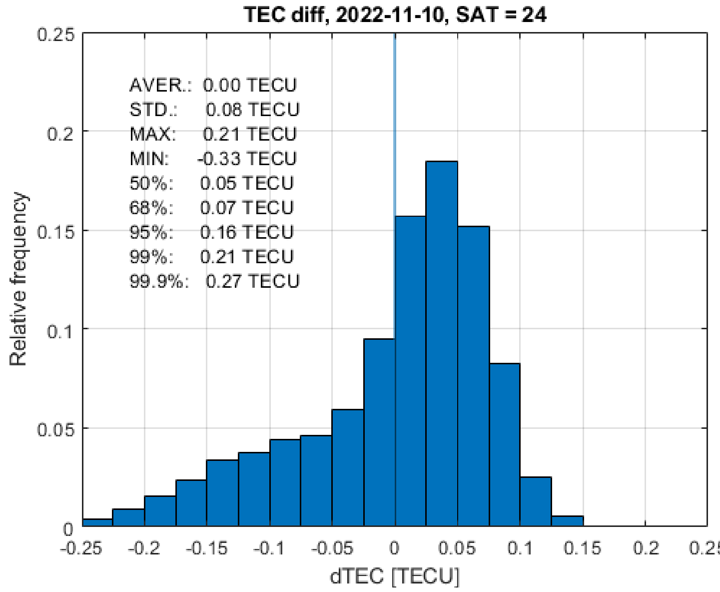




Quiet



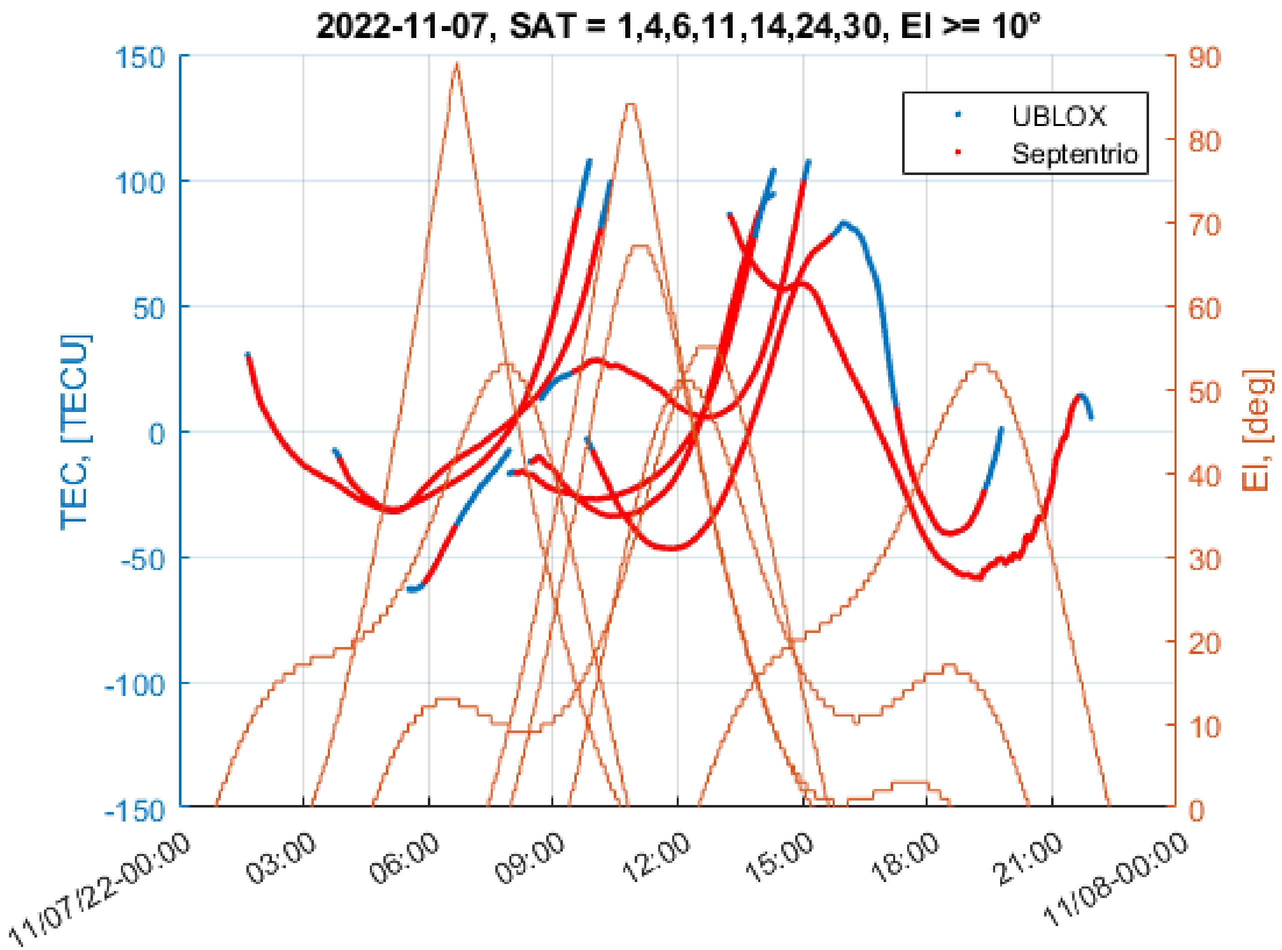


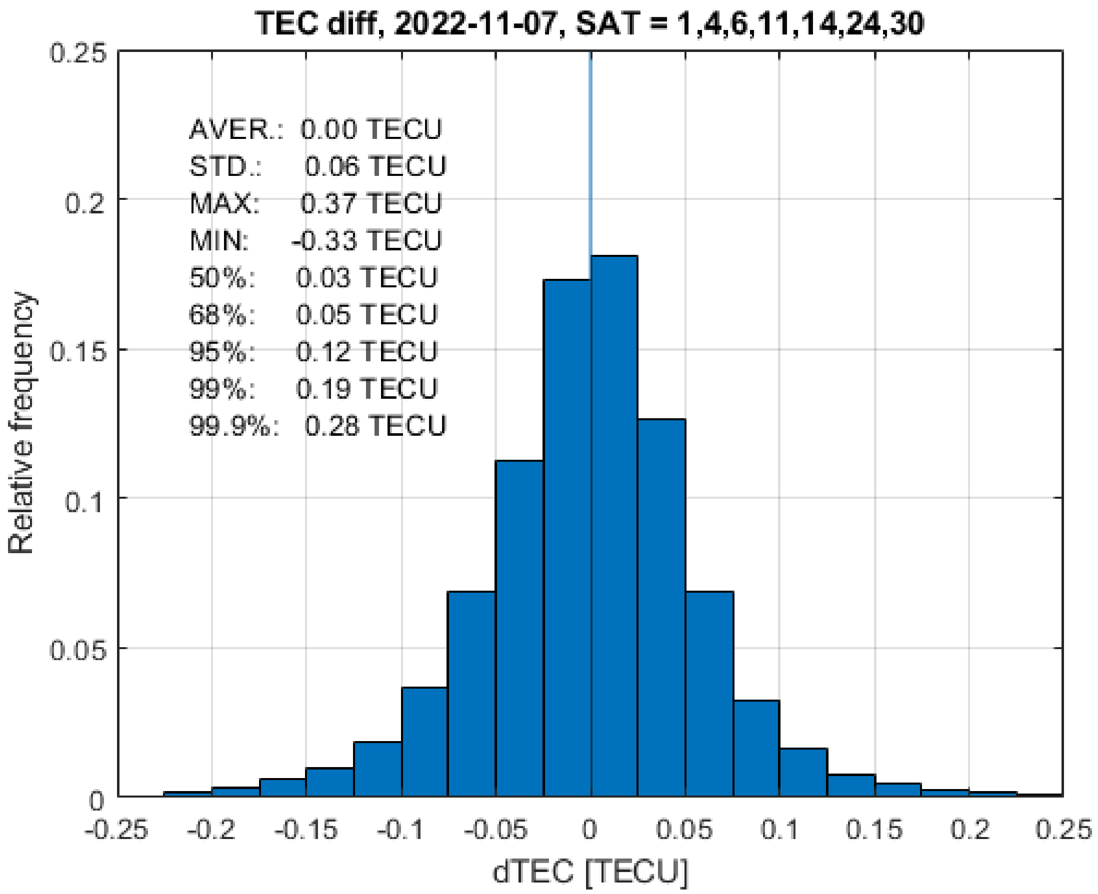


Credits: Elijah Oyeyemi, Busola Olugbon

Results: uncalibrated TEC

Nigeria, Abuja, 9.1° N, 7.4° E





Results: cycle slips

Nigeria, Abuja, 9.1° N, 7.4° E

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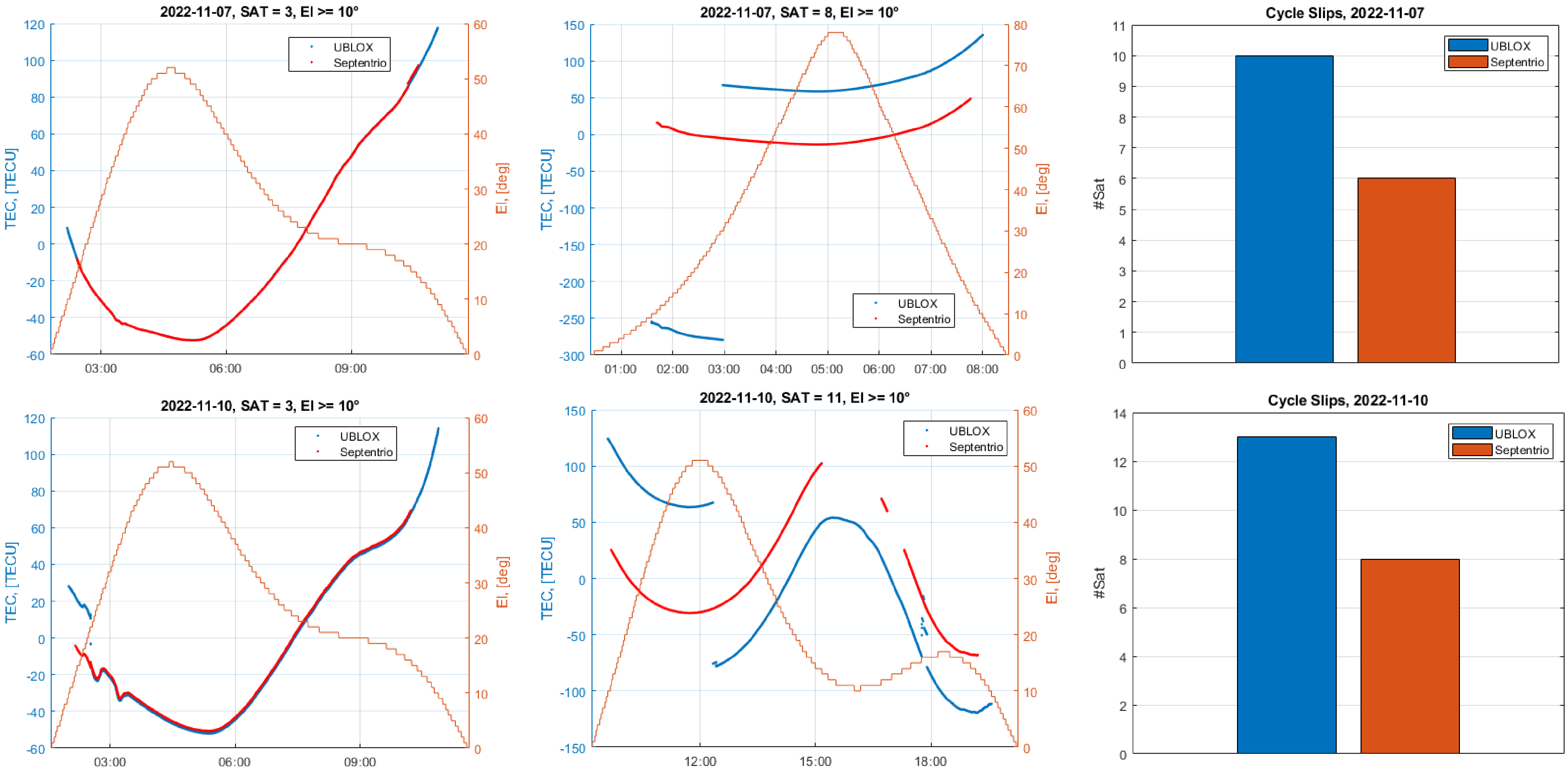
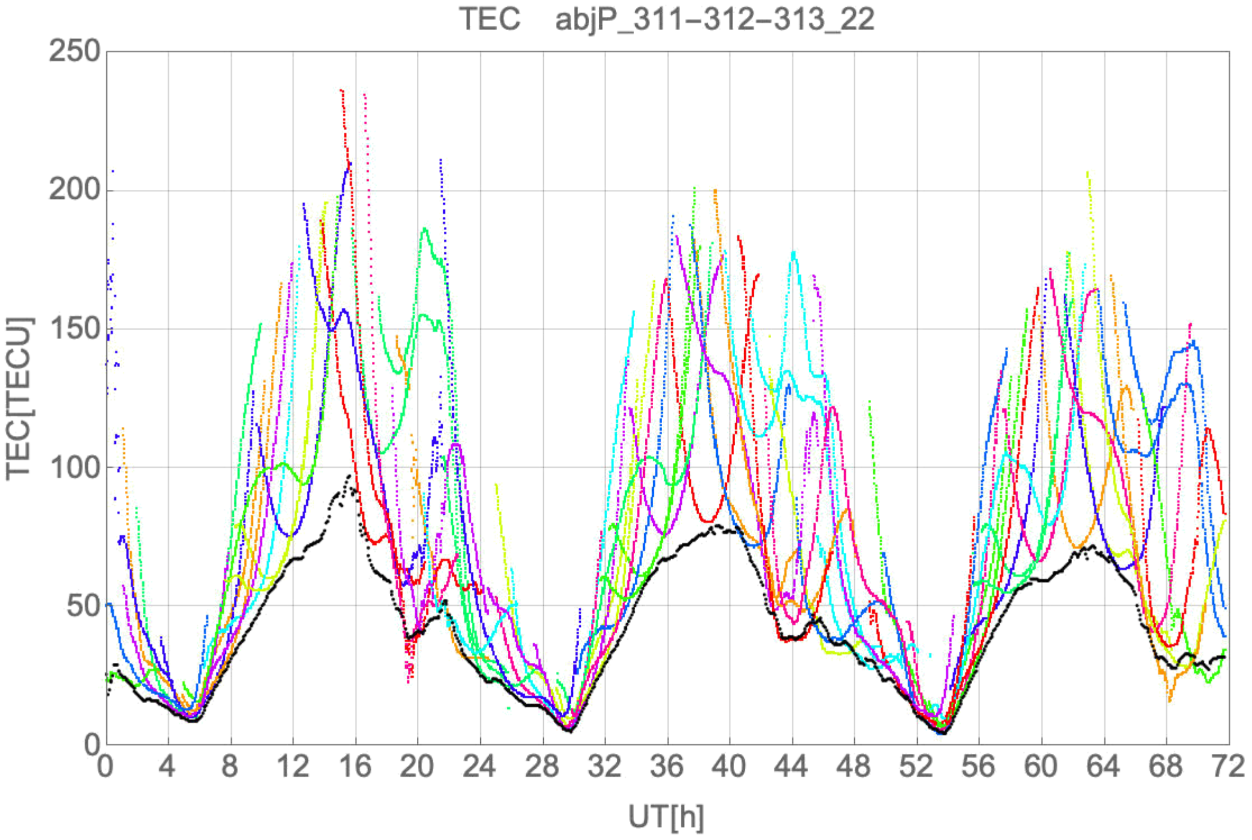
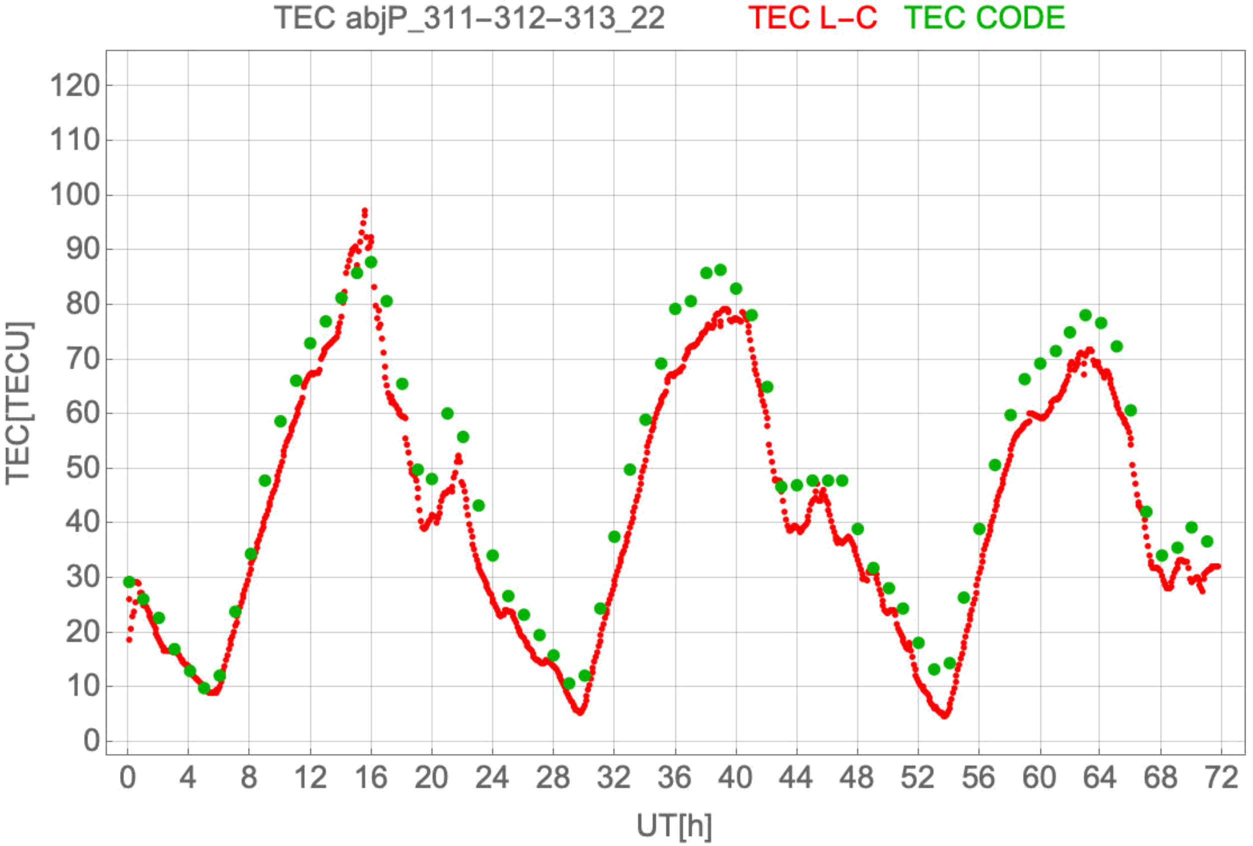


Results: calibrated TEC

Côte d'Ivoire, Abidjan, 5.34° N, 3.99° W

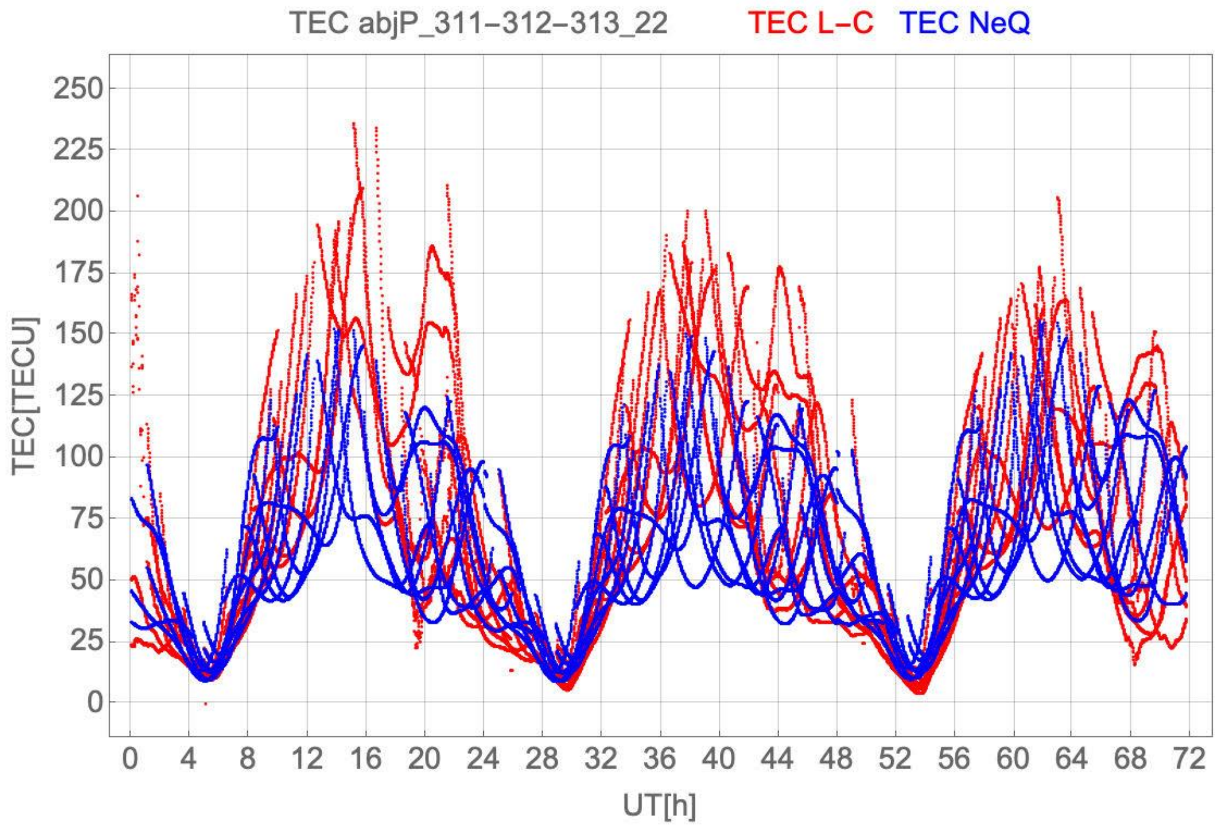




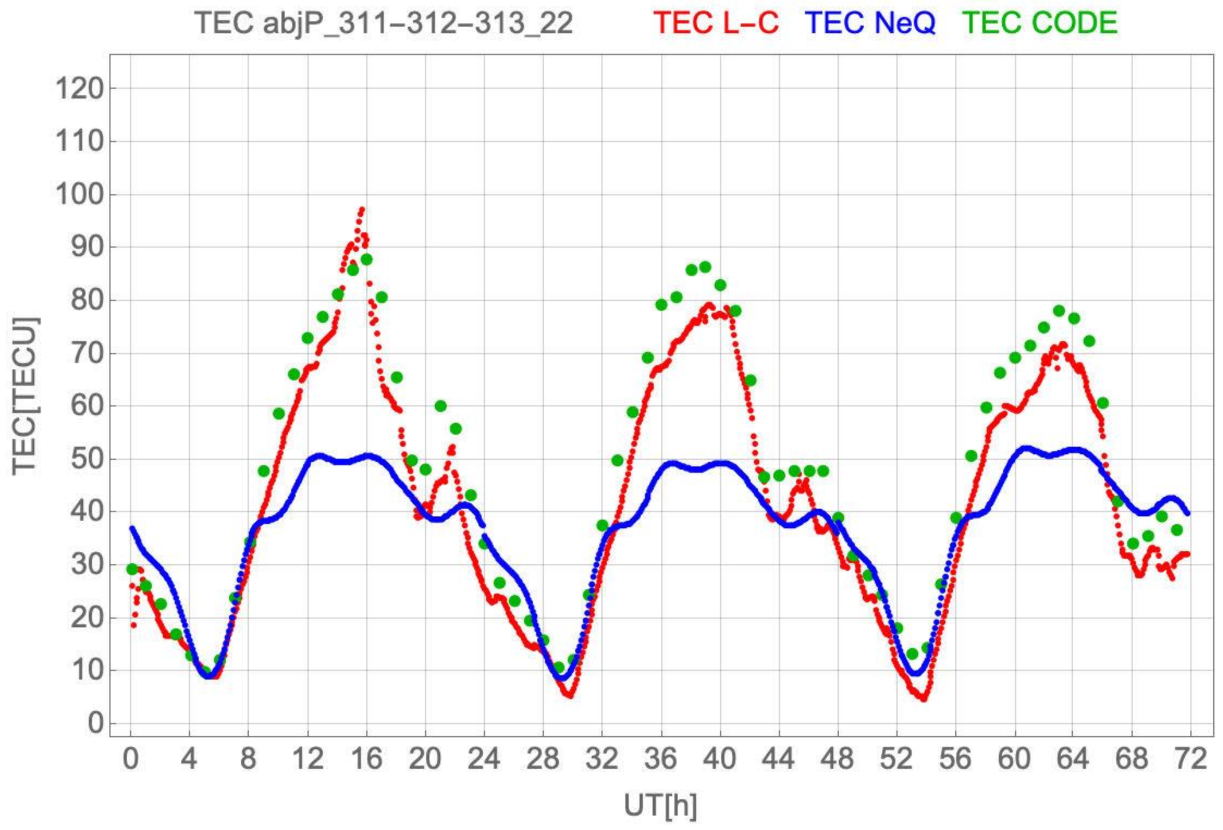
Credits: Olivier Obrou

Results: model validation Côte d'Ivoire, Abidjan, 5.34° N, 3.99° W

STEC



VTEC



United Nations International Meeting on the Applications of Global Navigation Satellite Systems, Vienna, 5 - 9 December 2022

Conclusions

- Low-cost dual frequency GNSS receivers are a great alternative to geodetic/scientific grade receivers to estimate TEC values

- Their performance is comparable across different latitudes: low, middle, and high

- More investigations must be done in order to understand whether they can be used for scintillation monitoring

Proposed setup

- ArduSimple U-BLOX F9P evaluation board - $235 USD

https://www.digikey.com/en/products/detail/ardusimple/AS-RTK2B-F9P-L1L2-NH-02/14309736

- TOPGNSS AN-105L antenna - $65 USD

https://www.aliexpress.us/item/3256802908957760.html

- LMR-240 cable 15m - $80 USD

https://www.digikey.com/en/products/detail/amphenol-times-microwave-systems/LMR-240/9644146

- Raspberry Pi 4B, 4GB, 32 GB - ~$100 USD (pre-covid times)

any other single board computer with one USB port, Ethernet/WiFi and Linux/Windows OS will work