Ionospheric Impact on GNSS Reflectometry in the Tropical and Polar Regions: A Simulation Study with NEDM model

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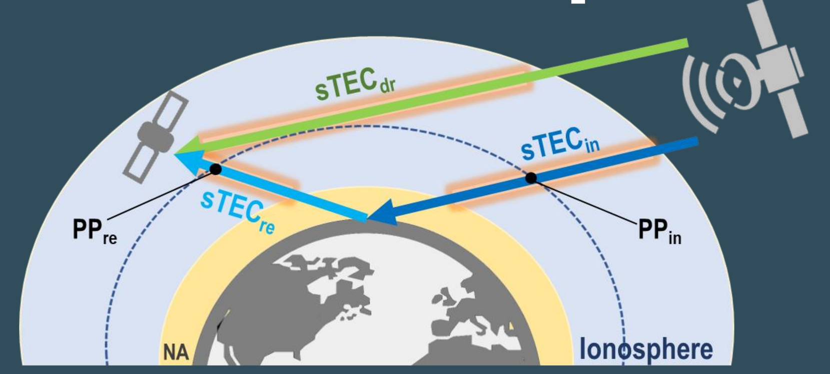
Background

GNSS Reflectometry Satellite mission "PRETTY*":

- Grazing angles observations for global altimetric concept.
- High-precision phase observations are expected at low elevation angles.
- At low elevation angles, the influence of the atmosphere increases due to the longer propagation path.

Objective: Characterize the variable ionospheric delay for PRETTY-like scenario dependent on time and latitude.

GNSS-R and the Ionosphere

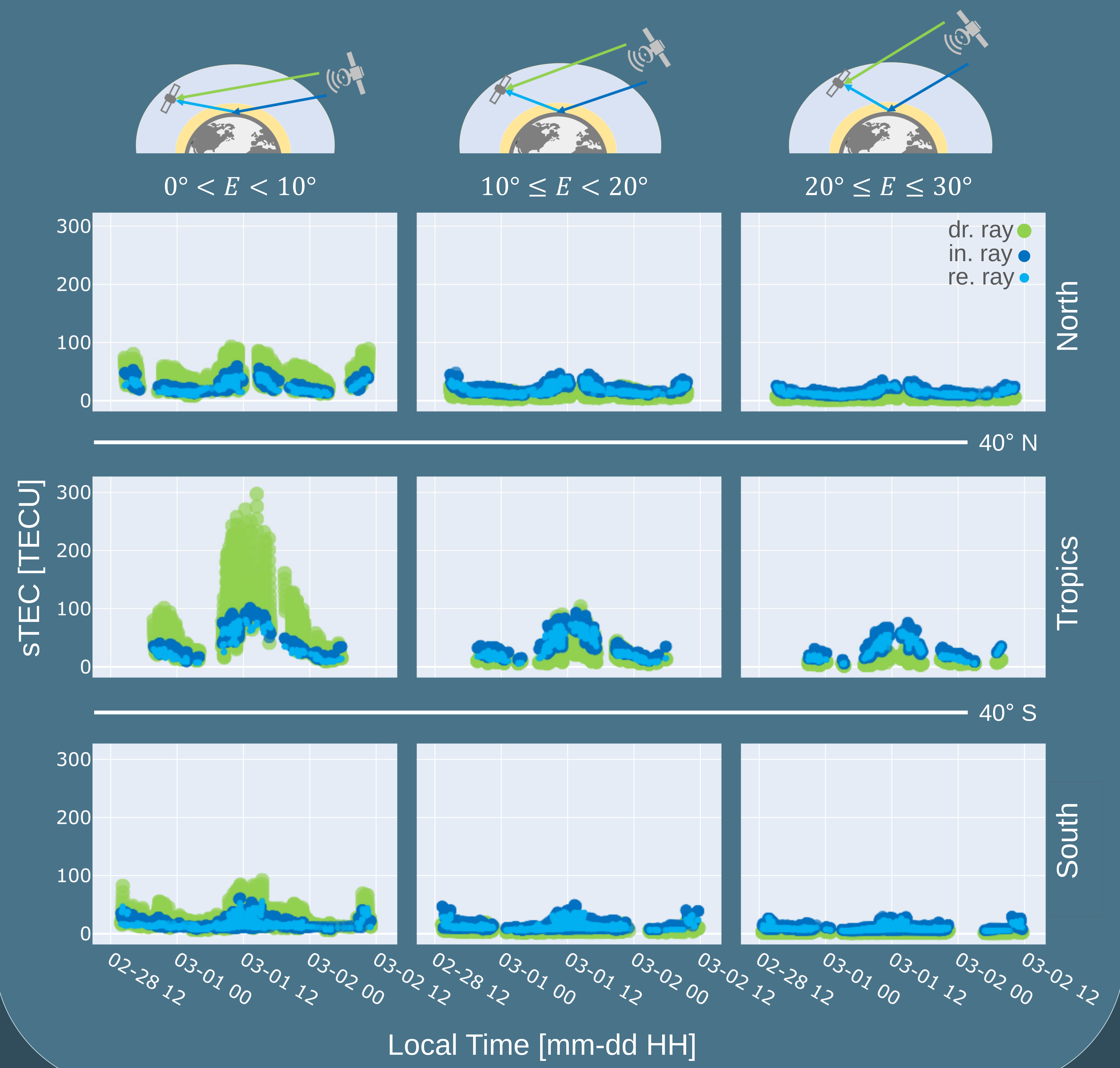


sTEC: Slant Total Electron Content – direct (dr), incident (in) and reflected (re)
PP : Piercing point (electron density peak), NA: Neutral Atmosphere

sTEC Results

Events at different elevation angle ranges and latitudes (North, Tropics, South) have been analyzed.

The lower the elevation, the longer the direct ray travels longer through the ionospheric F-layer. At low elevation angles ($E < 10°$) in the tropics, the direct ray may result in an sTEC of up to 300 TECU. To provide a reference point, 100 TECU equals an ionospheric delay of 16.24 meters for GPS L1 frequency.



Simulation

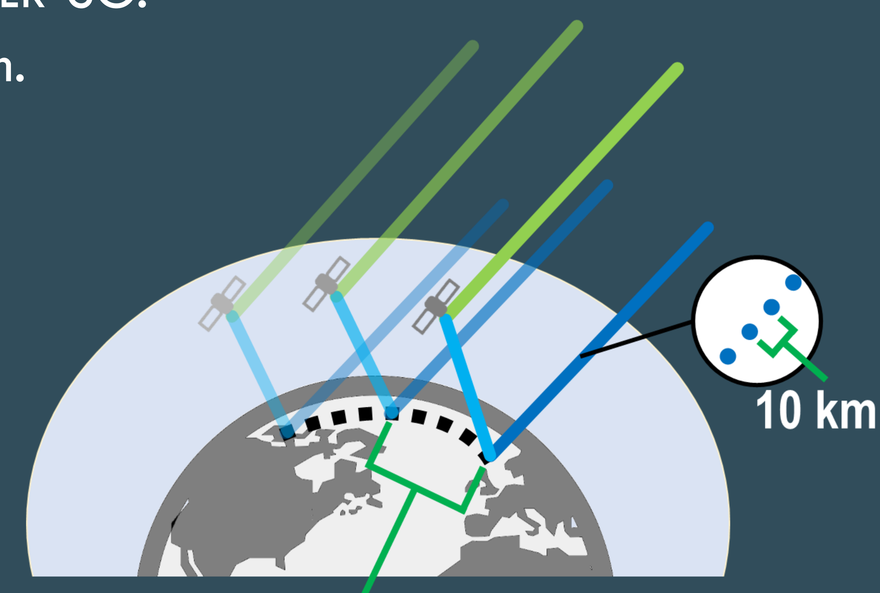
Electron Density Model: Neustrelitz Electron Density Model (NEDM2020)** DLR-SO.

Ray Points: Every 10 km.

Time step: 10 seconds.

$$sTEC_x = \int_{alongray} N_e dl$$

N_e: Electron density



Specular point change (10 s)

Relative sTEC

$$\frac{sTEC_{in} + sTEC_{re} - sTEC_{dr}}{\Delta sTEC}$$

Relative Ionospheric Delay (GPS L1)

$$\Delta^{iono} = \frac{40.3}{f^2} \Delta sTEC$$

Data

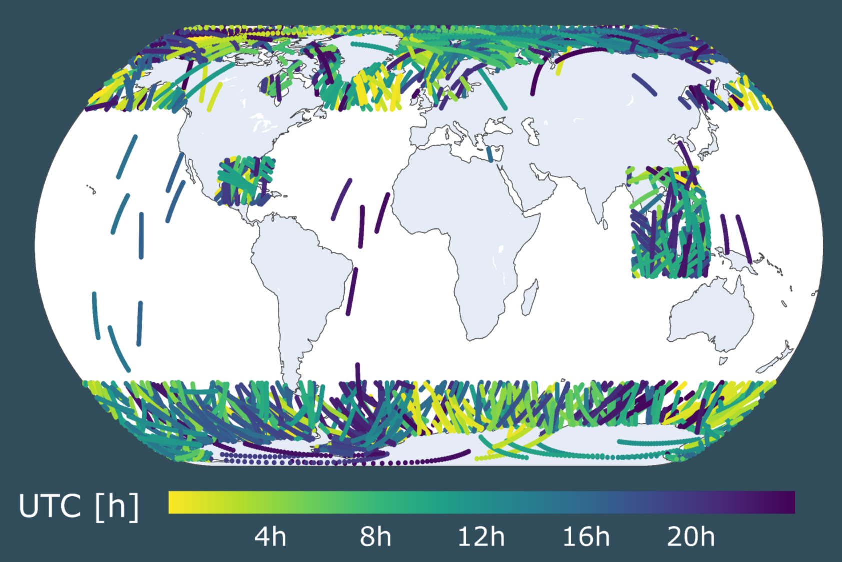
GNSS Constellation: GPS.

LEO Orbit data: Spire Global CubeSat LEMUR-2.

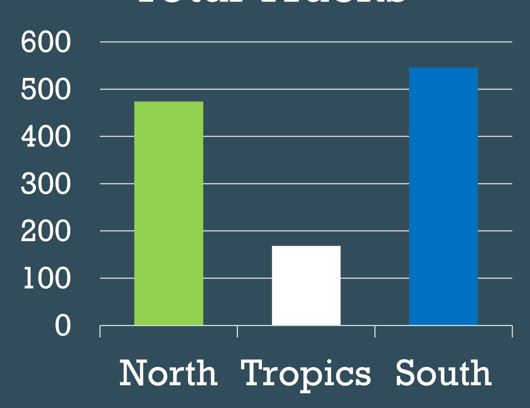
Earth Model: Osculation sphere.

Date: 01.03.2021

Specular Point Tracks



Total Tracks



Conclusions

- The relative ionospheric delay varies depending on the elevation angle, latitude, and local time. Specifically, for elevation angles <10° and latitudes between 40°S and 40°N, the Δ^{iono} could vary up to ±20 meters.
- In altimetry applications, minimizing the presence of ionospheric delay is advantageous. Consequently, the most favorable conditions entail nighttime observations at elevations ranging from 10° to 30°.
- On the other hand, observations during daytime at elevation angles below 10° may be valuable for deriving ionospheric parameters through GNSS Reflectometry.

* Dielacher, H. Fragner, and O. Koudelka, "PRETTY – passive GNSS-Reflectometry for CubeSats," Elektrotech. Inftech., vol. 139, no. 1, pp. 25–32, Feb. 2022, doi: 10.1007/s00502-022-00993-7.

** M. M. Hoque, N. Jakowski, and F. S. Prol, "A new climatological electron density model for supporting space weather services," J. Space Weather Space Clim., vol. 12, p. 1, 2022, doi: 10.1051/swsc/2021044.

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