Grazing-Angle Ionospheric Delay on GNSS-R: Findings from the ESA PRETTY Mission Observations.

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PRETTY

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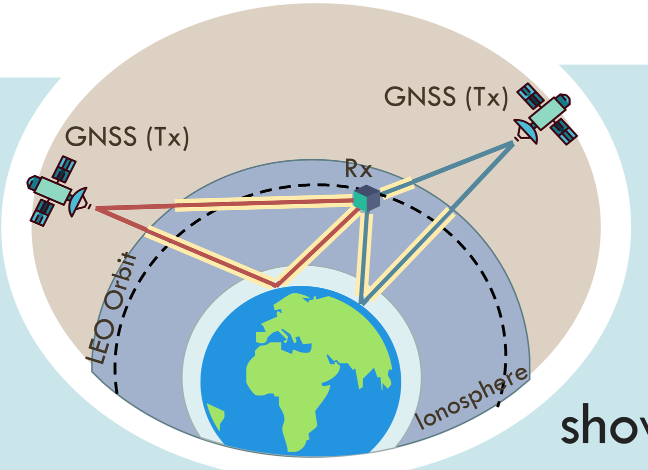
1 Background



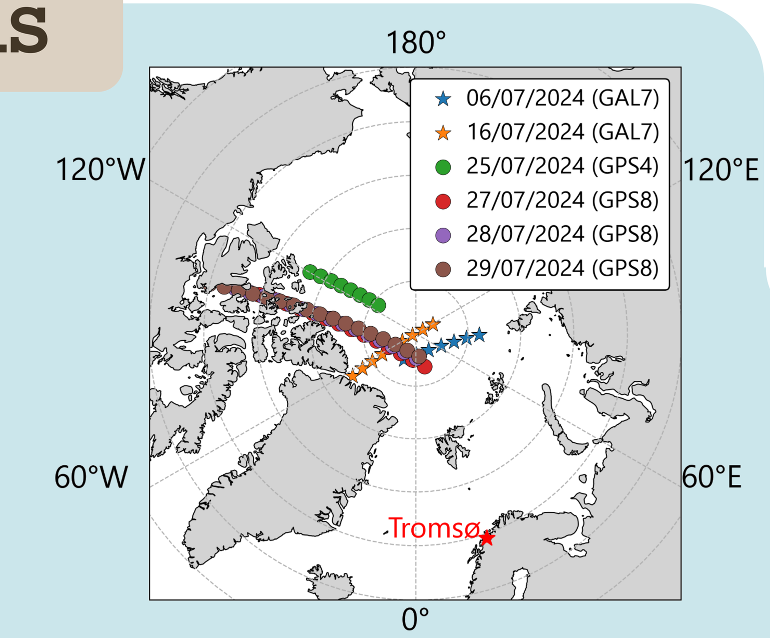
Reflected signals from Global Navigation Satellite Systems (GNSS) that interact with the Earth's surface offer a valuable opportunity for remote sensing of the atmosphere.

The GNSS Reflectometry ESA **"PRETTY"** mission, which has been in orbit since October 2023, focuses on observations of grazing angles up to 15°.

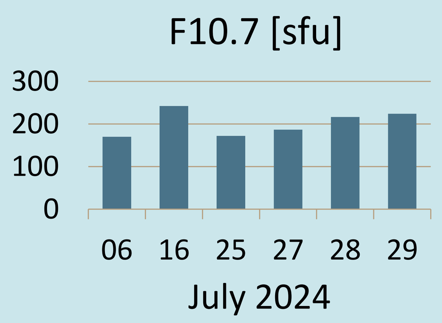
Objective of this study: Investigate the feasibility of using single-frequency GNSS Reflectometry (GNSS-R) code delay observations from the PRETTY mission to estimate the first-order relative ionospheric delay at grazing angles and to assess their potential for retrieving vertical ionospheric structure through Chapman layer model inversion.

2 Data & Methods

DATA:
PRETTY Delay Maps (DM)
Code Delay Observations
GNSS Constellation: Galileo & GPS (E5/L5)
Date: 07.2024



TROPOSPHERE CORRECTION:
ERA 5 (Hersbach et al., 2020)
Ray-tracing
Point-to-point Algorithm (Zus et al., 2012)

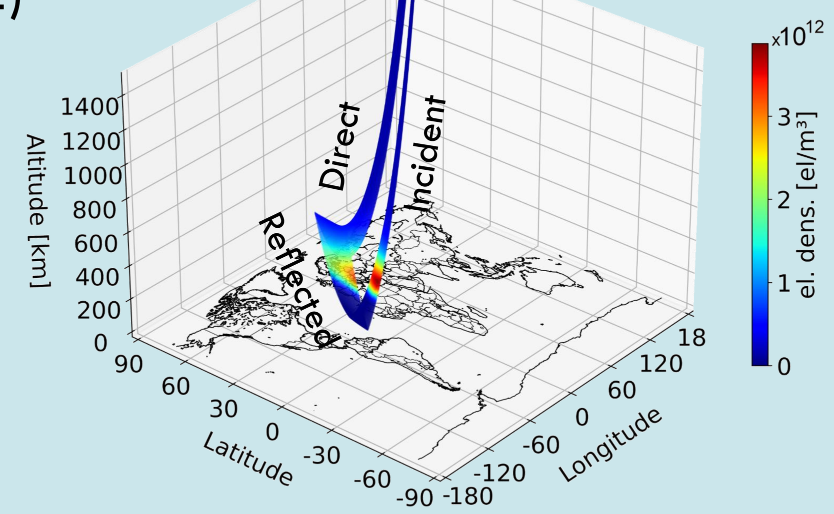


IONOSPHERE MODELS:
NEDM2020 (Hoque et al., 2022)
NeQuick 2 (Nava et al., 2008)
IRI Model (Bilitza et al., 2022)

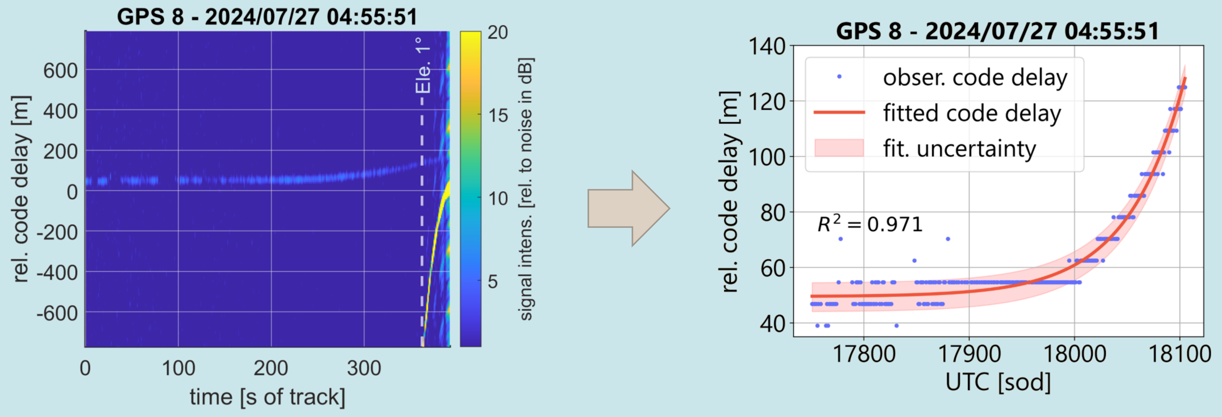
Model Rel. ionospheric Delay:

$$\Delta_{iono}^{model} = \frac{40.3 * 10^{16}}{f^2} \Delta sTEC$$

$$\Delta sTEC = sTEC_{in} + sTEC_{re} - sTEC_{di}$$



PRETTY DELAY MAP → Obs_{fit}



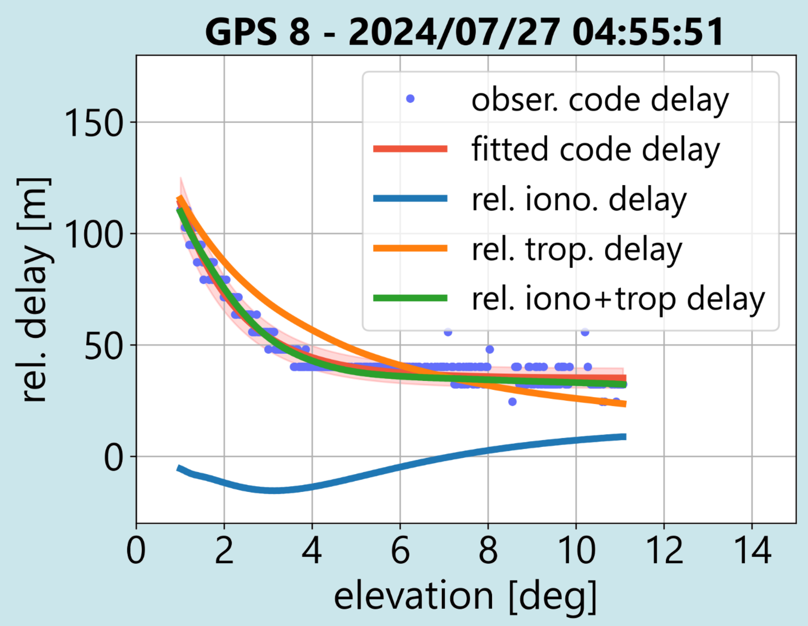
RELATIVE IONOSPHERIC DELAY ESTIMATION

$$\Delta_{iono}^{est} = Obs_{fit} - (\Delta_{geom.} + \Delta_{tropo.} + Inst.)$$

$\Delta_{geom.}$: Geometric delay (surface)
$\Delta_{tropo.}$: Tropospheric delay
$Inst.$: Instrumental errors

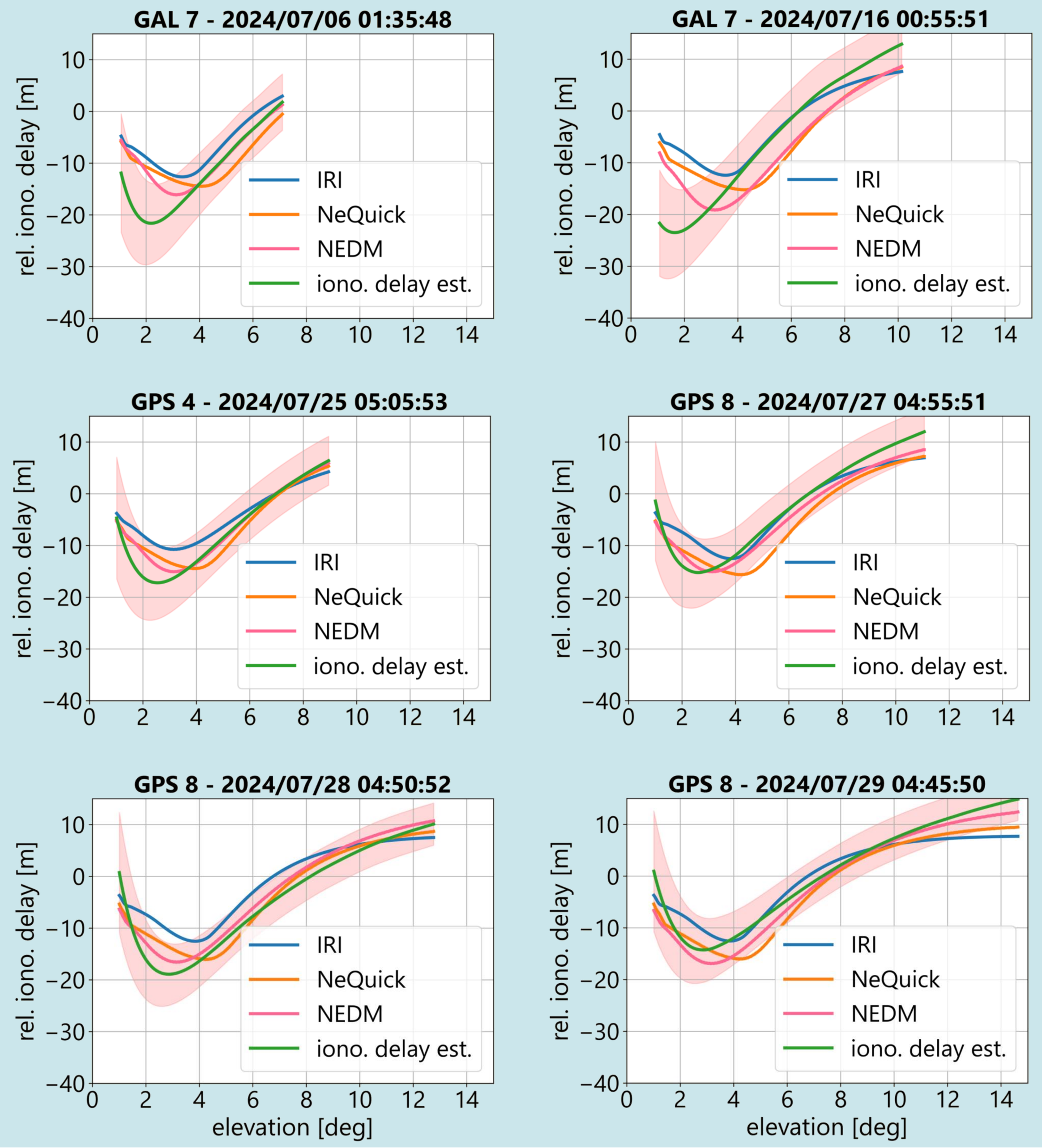
3 Results

Combined tropospheric and ionospheric delays show good agreement with PRETTY code delay observations!

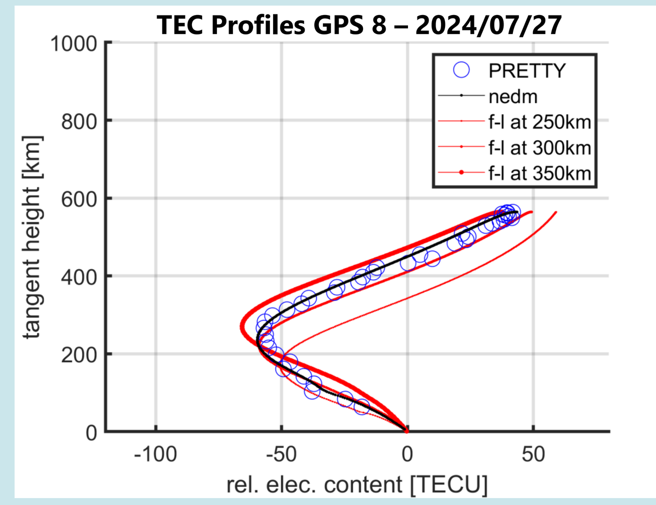


Feasible to isolate ionospheric delay!

GNSS-R Estimated Relative Ionospheric Delay



What can GNSS-R tell us about the ionosphere's vertical structure?



GNSS-R estimates → Chapman Parameters h_m, N_0, H

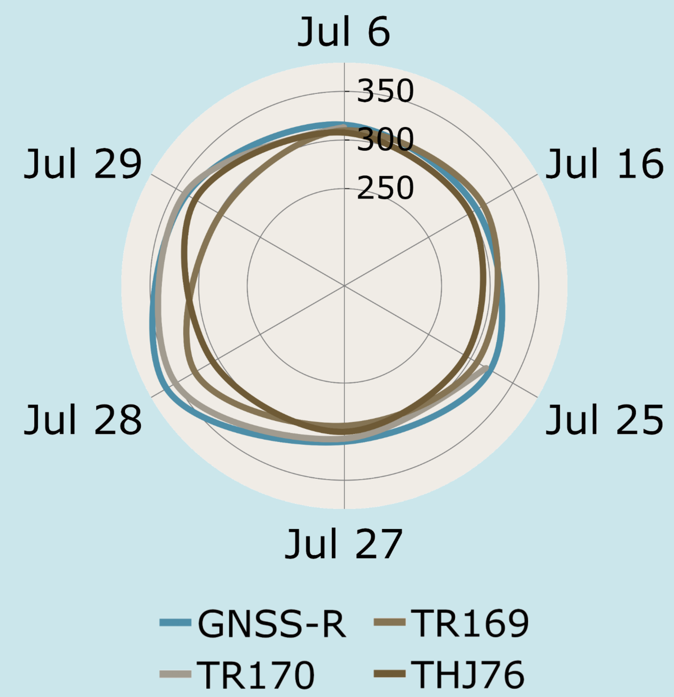
Retrieved Chapman layer parameters

Date	PRN	UTC	h_m [km]	N_0 [el/m³]	H [km]
07/06	GAL – 7	01:35:48	315.71	5.35e11	123.48
07/16	GAL – 7	00:55:51	307.35	6.34e11	120.81
07/25	GPS – 4	05:05:53	323.26	4.33e11	115.22
07/27	GPS – 8	04:55:51	310.34	3.64e11	100.81
07/28	GPS – 8	04:50:52	361.29	4.09e11	111.61
07/29	GPS – 8	04:45:50	337.49	3.80e11	126.18

4 Conclusions

- After tropospheric correction, GNSS-R code delay observations from PRETTY allow reliable estimation of first-order ionospheric delay at grazing angles.
- **PRETTY** observations down to 1° reveal a peak with a negative relative ionospheric delay (~20 m) near 3°, where the direct signal contributes ~60% of the total delay. This proportion shifts to ~40% at 10°, highlighting elevation-dependent ray contributions.

h_m Comparison GNSS-R vs. Ionosonde/EISCAT



- Chapman-based inversion of GNSS-R code delay observations yields F-layer peak heights ranging from 307 to 367 km, consistent with high-latitude values under high solar activity (F10.7 = 150–250). The mean RMSE is ~1.2 m (~4 TECU), showing strong agreement with modeled profiles. Comparison with EISCAT and ionosonde stations shows differences within ±15 km, with the closest match observed for EISCAT TROMSØ (TR170).

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