IONOSPHERIC DELAYS IN PRETTY MISSION DATA: AN OPPORTUNITY TO STUDY IONOSPHERIC F-LAYER STRUCTURE

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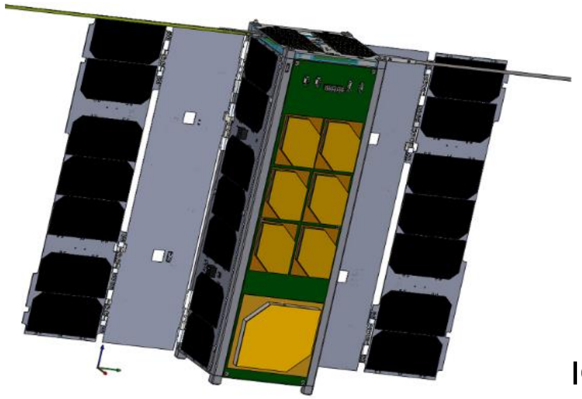

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Outline

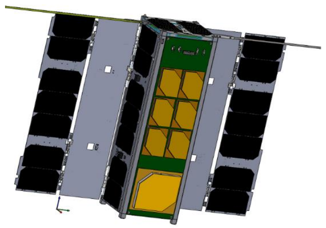
- Why to use GNSS Remote Sensing for Ionosphere Studies?
- PRETTY Mission and its Grazing Geometry
- Preliminary Results of Ionospheric Analysis
- Summary & Outlook

Why and how to use GNSS Reflectometry?

Motivation GNSS Remote Sensing

- A: Low Earth Orbiter

  Wickert et al. 2016
  Semmling et al. 2016
  Cardellach et al. 2020
  Moreno et al. 2023



- B: Aircraft

  Semmling et al. 2014
  Moreno et al. 2022

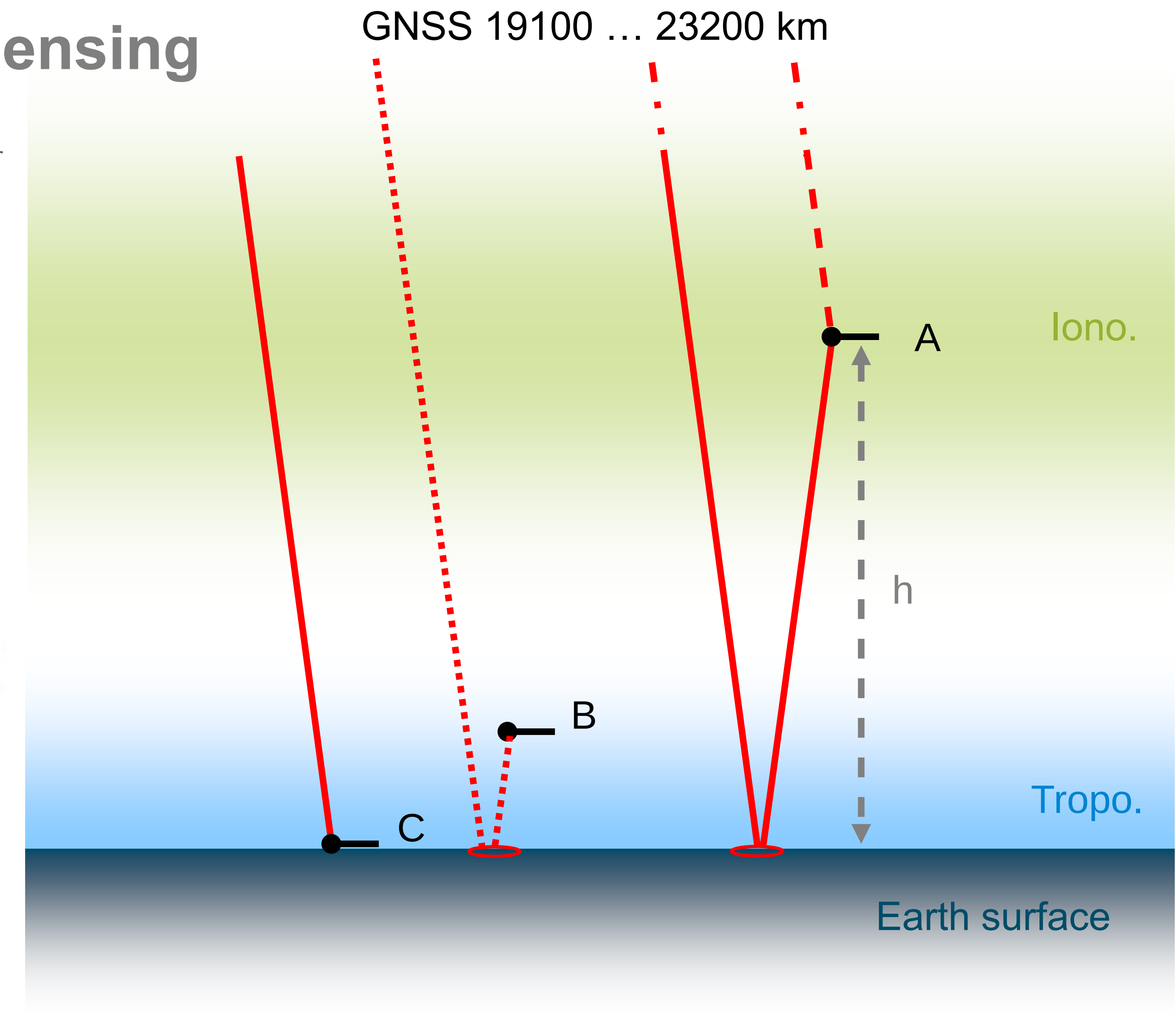
- C: Research Vessels

  Wang et al. 2019
  Semmling et al. 2019, 2022
  Semmling et al. 2023

- Application

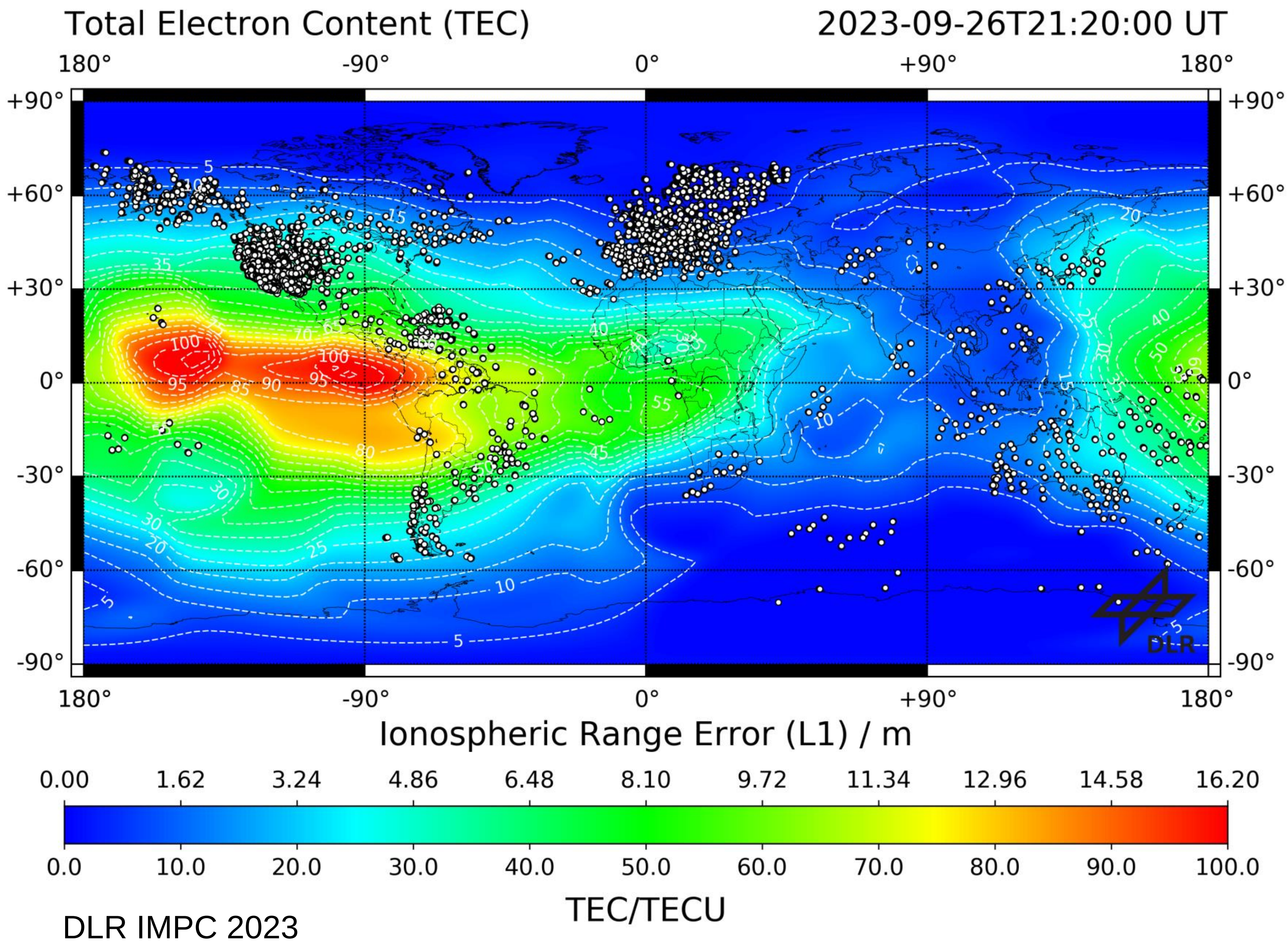
sea surface altimetry
sea state estimation
sea-ice detection

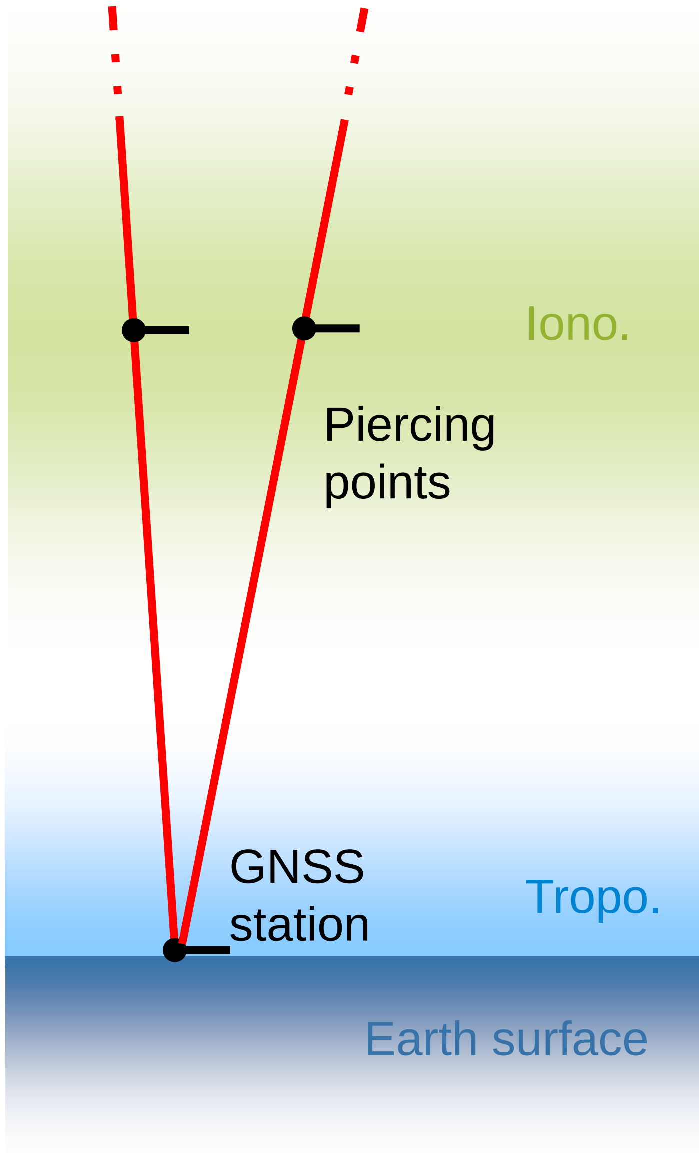
water vapor estimation
ionosphere monitoring



A: e.g. PRETTY, h ~ 560 km
B: e.g. HALO, h ~ 3500 m
C: e.g. Polarstern, h ~ 25 m

Ionospheric TEC Monitoring with GNSS





DLR IMPC 2023

More Detailed Model View …

F-layer

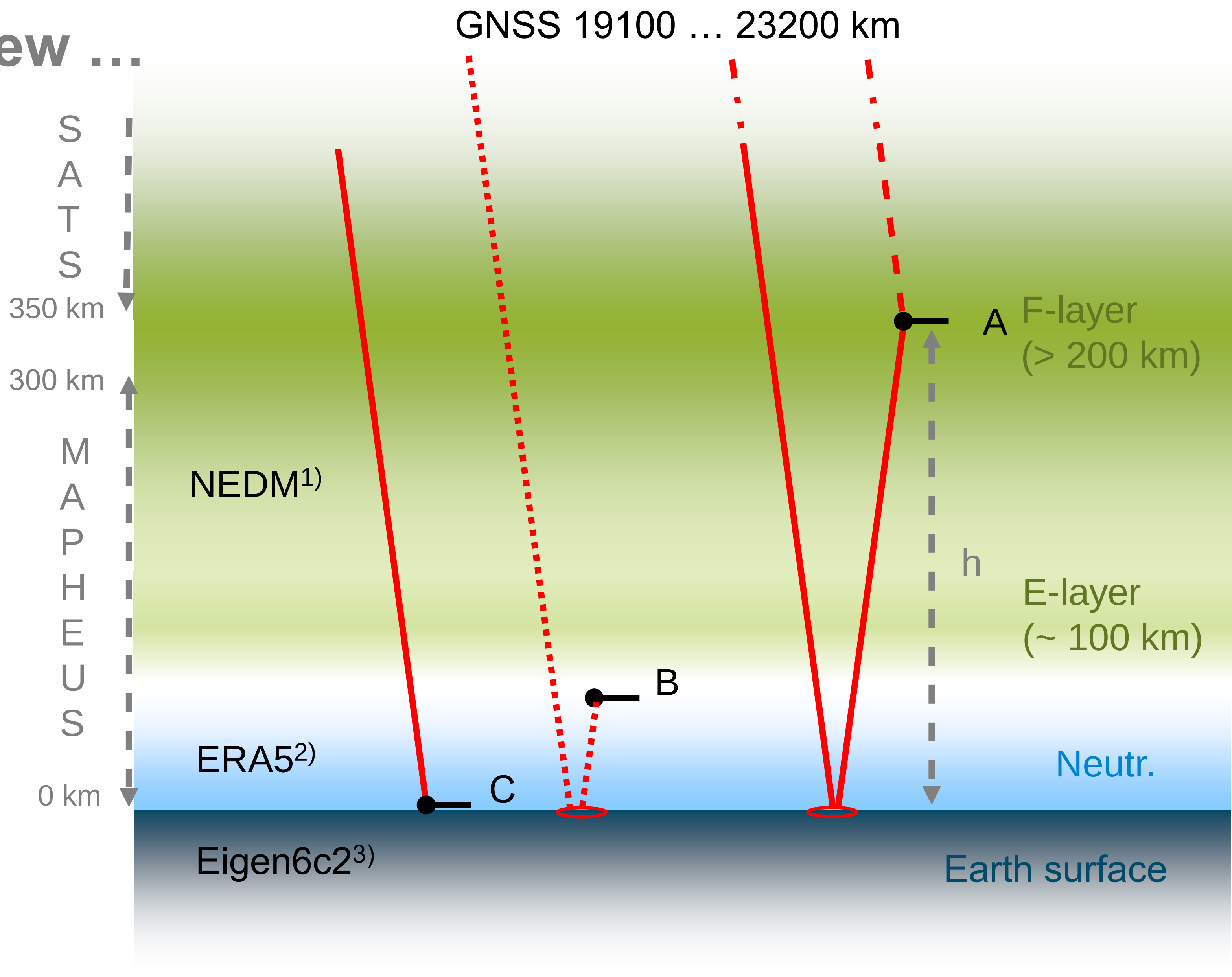
- permanent, usually highest density
- max. elec. density at 250 … 400 km
- regular daily cycle
- dependent on sun incidence

E-layer

- usually weaker, sporadic peaks
- max. elec. density at 110 … 130 km
- less predictable
- important for radio communication

Required Model Data

1) empirical model for iono. electron dens. distribution (NEDM)
2) numerical weather model for neutral gas based on data reanalysis (ERA5)
3) geoid model for Ocean surface heights (Eigen6c2)



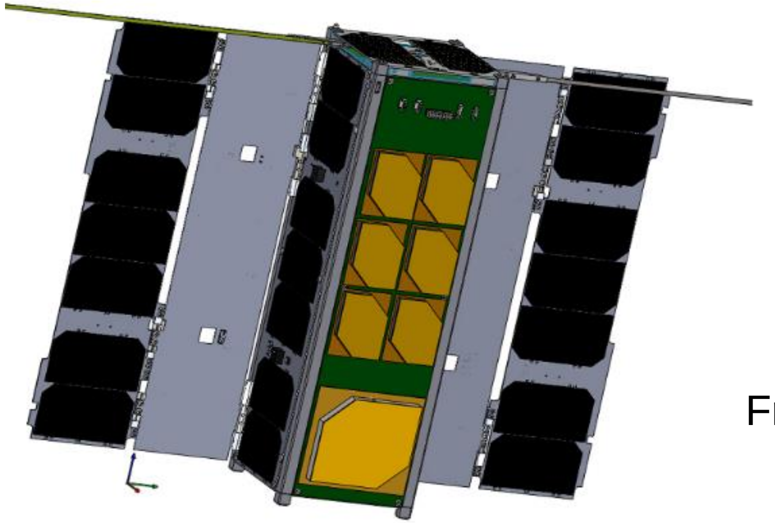
1) Hoque et al. 2022 ; 2) Hersbach et al. 2020 ; 3) Förste et al. 2013

PRETTY Mission and its Grazing Geometry

Satellite Mission Parameters

PRETTY (**P**assive **RE**flec**T**ometry and dosime**T**r**Y**)

- ESA CubeSat mission, developed by an Austrian consortium led by Beyond Gravity Austria
- Size: 30 x 10 x 10 cm³
- Orbit: polar SSO, altitude 560 km
- GNSS-R antenna: RHCP, limb pointing
- GNSS-R grazing elevations: 0° to 15°
- GNSS-R signal carrier: L5

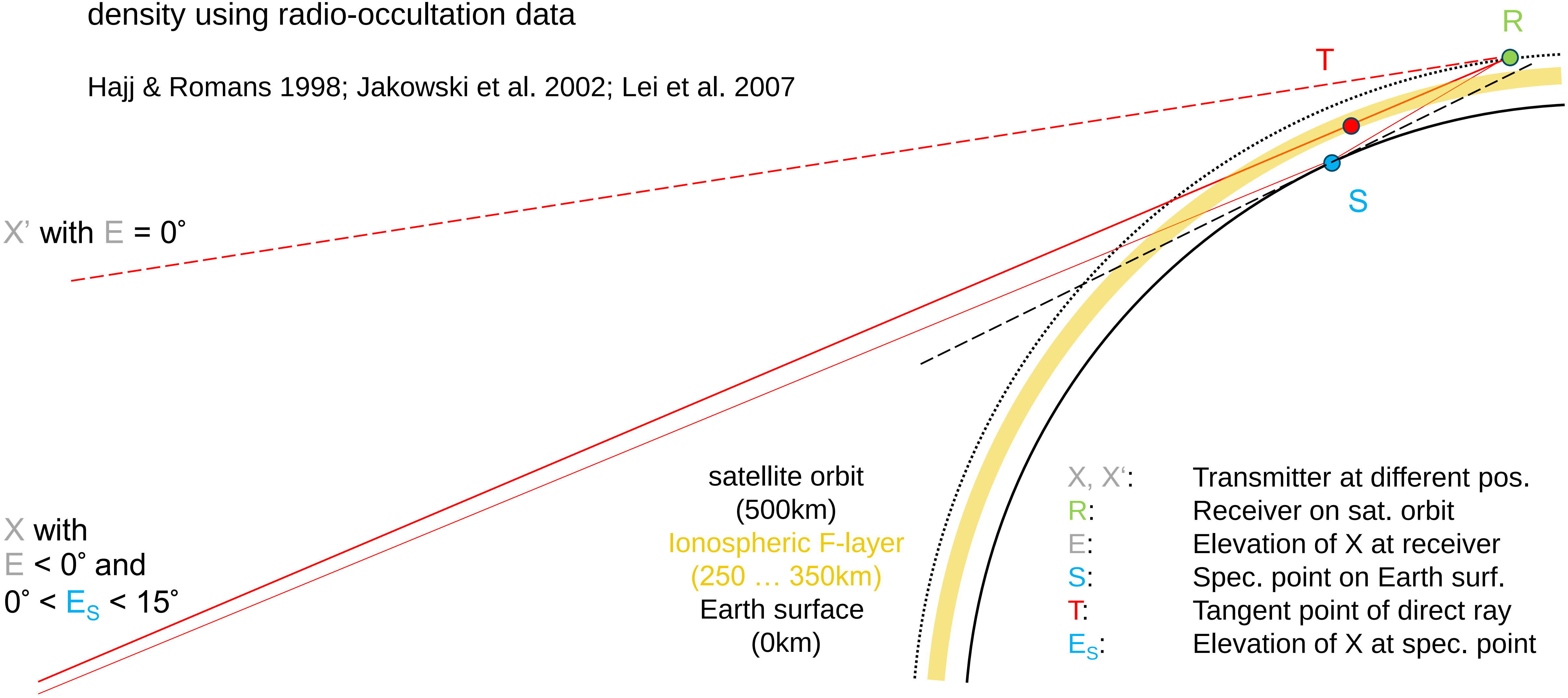


Fragner et al. 2020

Grazing Angles and Occultation Geometry

Previous studies revealed inversion of iono. electron density using radio-occultation data

Hajj & Romans 1998; Jakowski et al. 2002; Lei et al. 2007

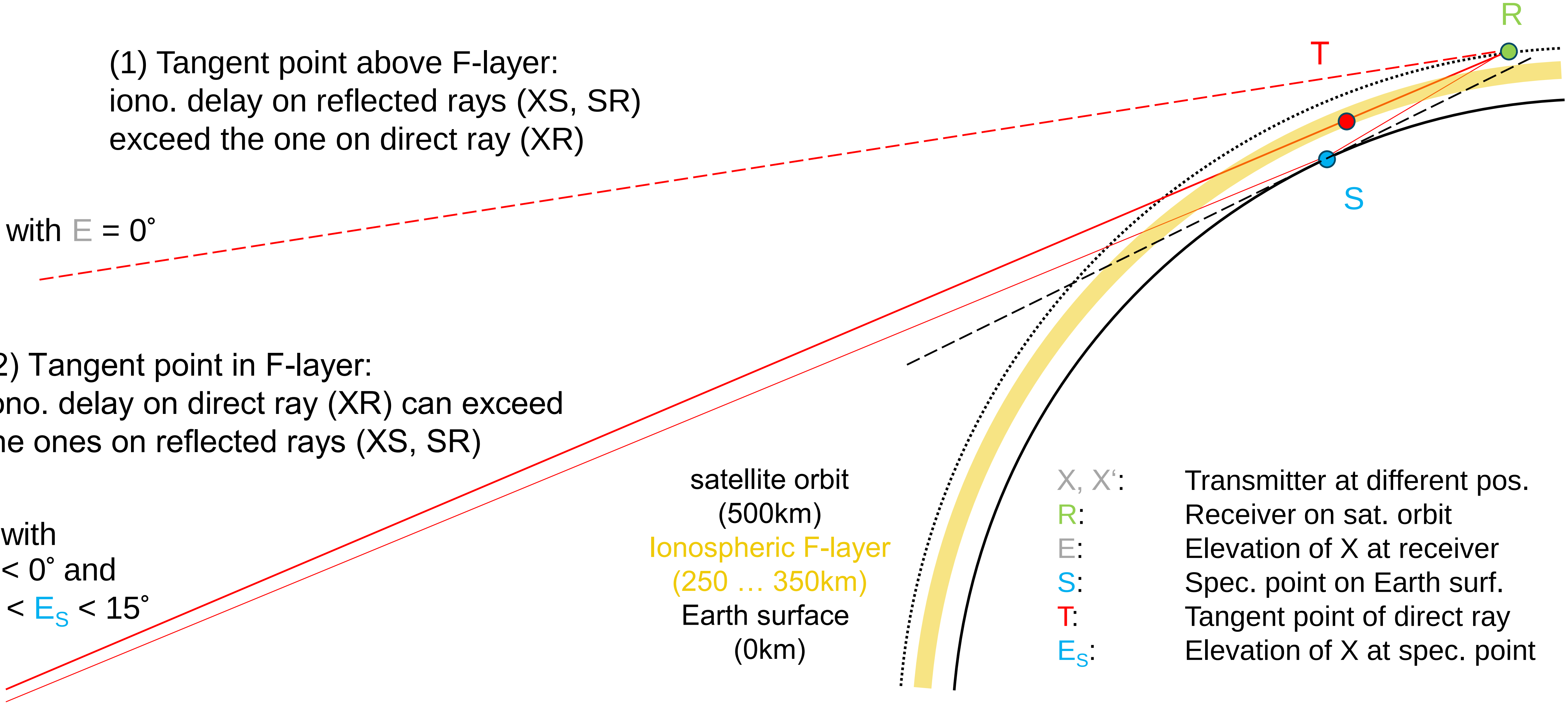


X, X‘:	Transmitter at different pos.
R:	Receiver on sat. orbit
E:	Elevation of X at receiver
S:	Spec. point on Earth surf.
T:	Tangent point of direct ray
E_S:	Elevation of X at spec. point

Scenarios of Ionospheric Delay

(1) Tangent point above F-layer:
iono. delay on reflected rays (XS, SR) exceed the one on direct ray (XR)

(2) Tangent point in F-layer:
iono. delay on direct ray (XR) can exceed the ones on reflected rays (XS, SR)



X, X':	Transmitter at different pos.
R:	Receiver on sat. orbit
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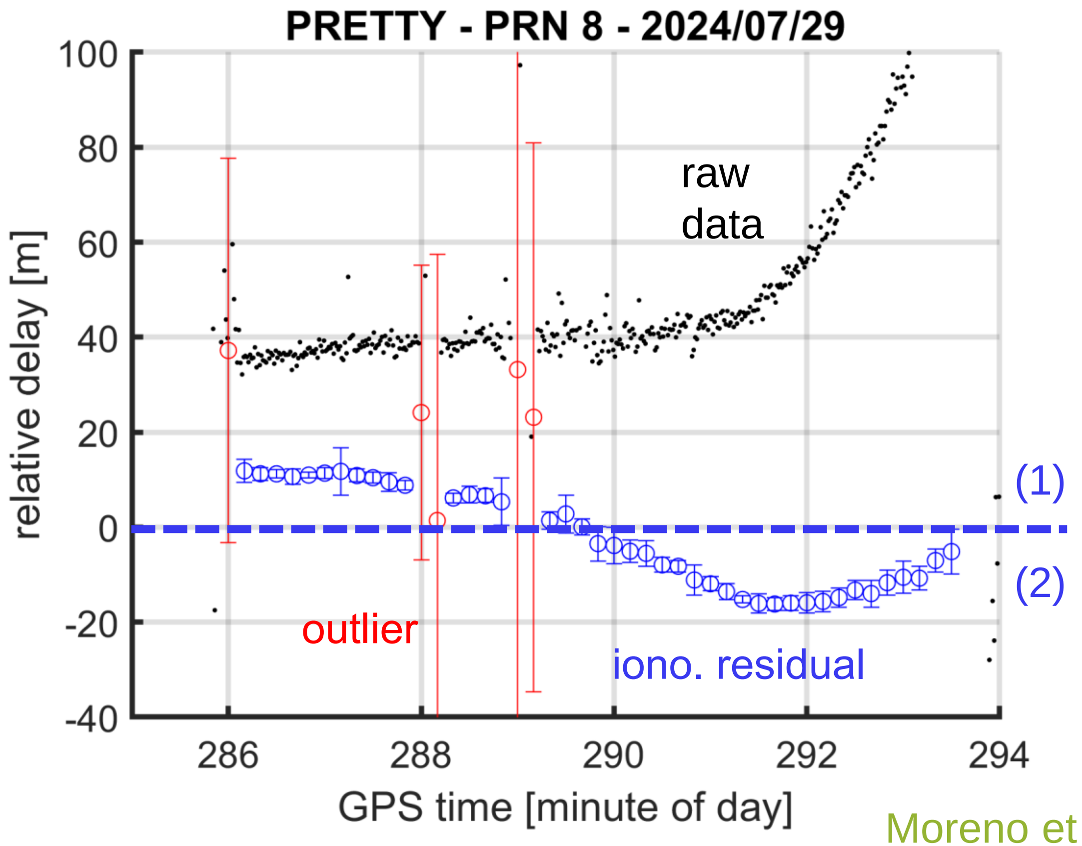
E_S:	Elevation of X at spec. point

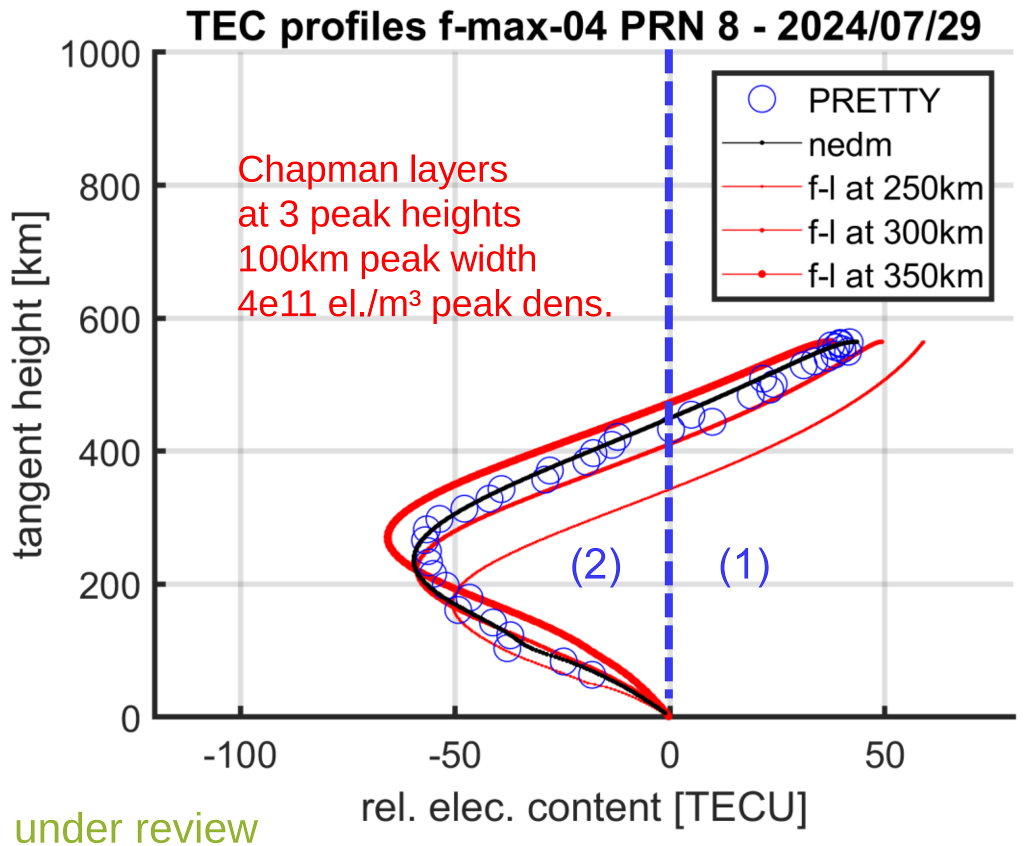
Preliminary Results of Ionospheric Analysis

Observation Example GPS PRN 8 – 2024/07/29

Satellite Obs. Data



Comparison with model profiles



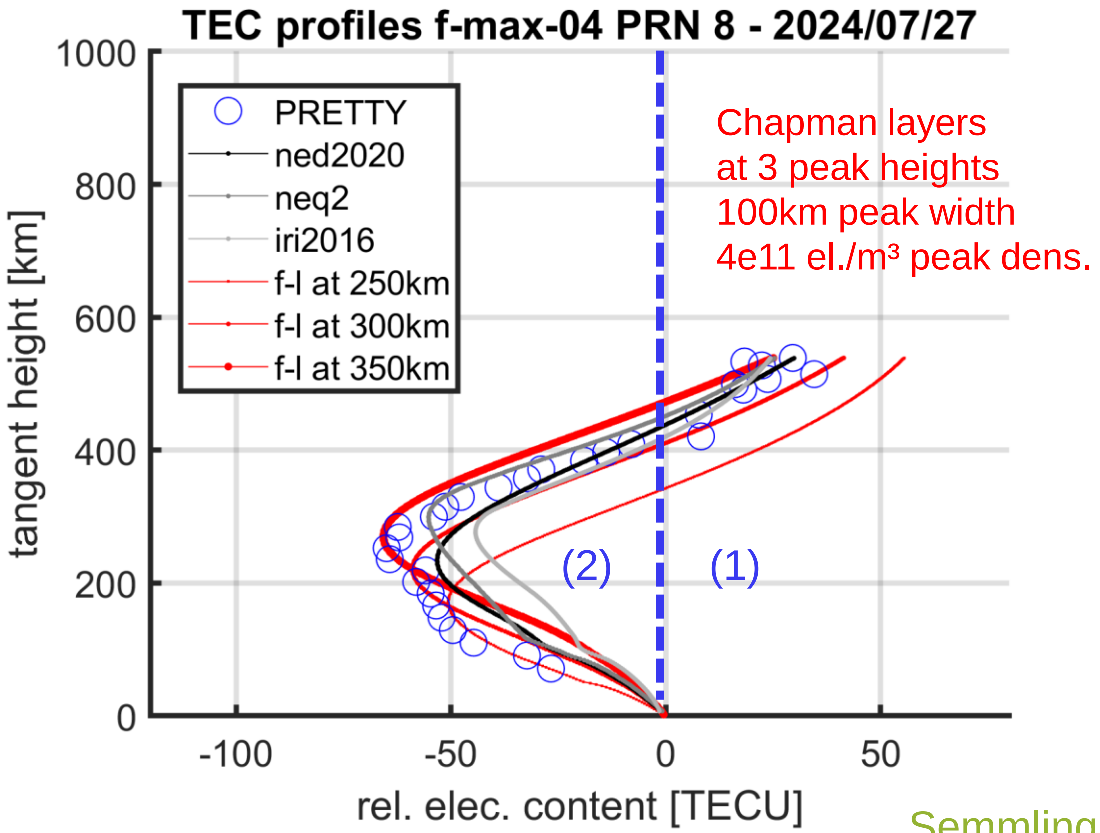
Moreno et al. under review

Ionospheric residual is retrieved after correction of tropospheric delay. Residual below zero belong to scenario (2), tangent point in F-layer

Iono. Residual is converted to relative electron content and compared to predictions with NEDM and chapman layers

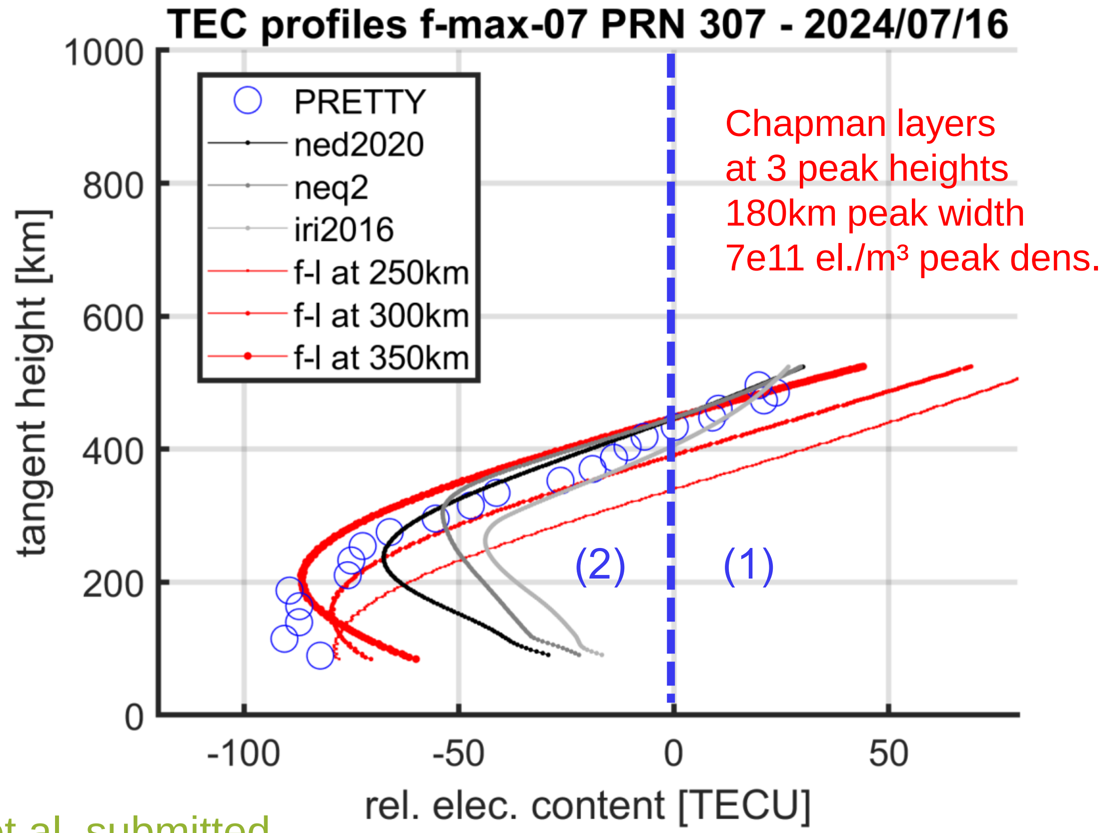
More Examples for GPS and Galileo

Comparison with model profiles



Very similiar to previous example,
two days earlier same ground track

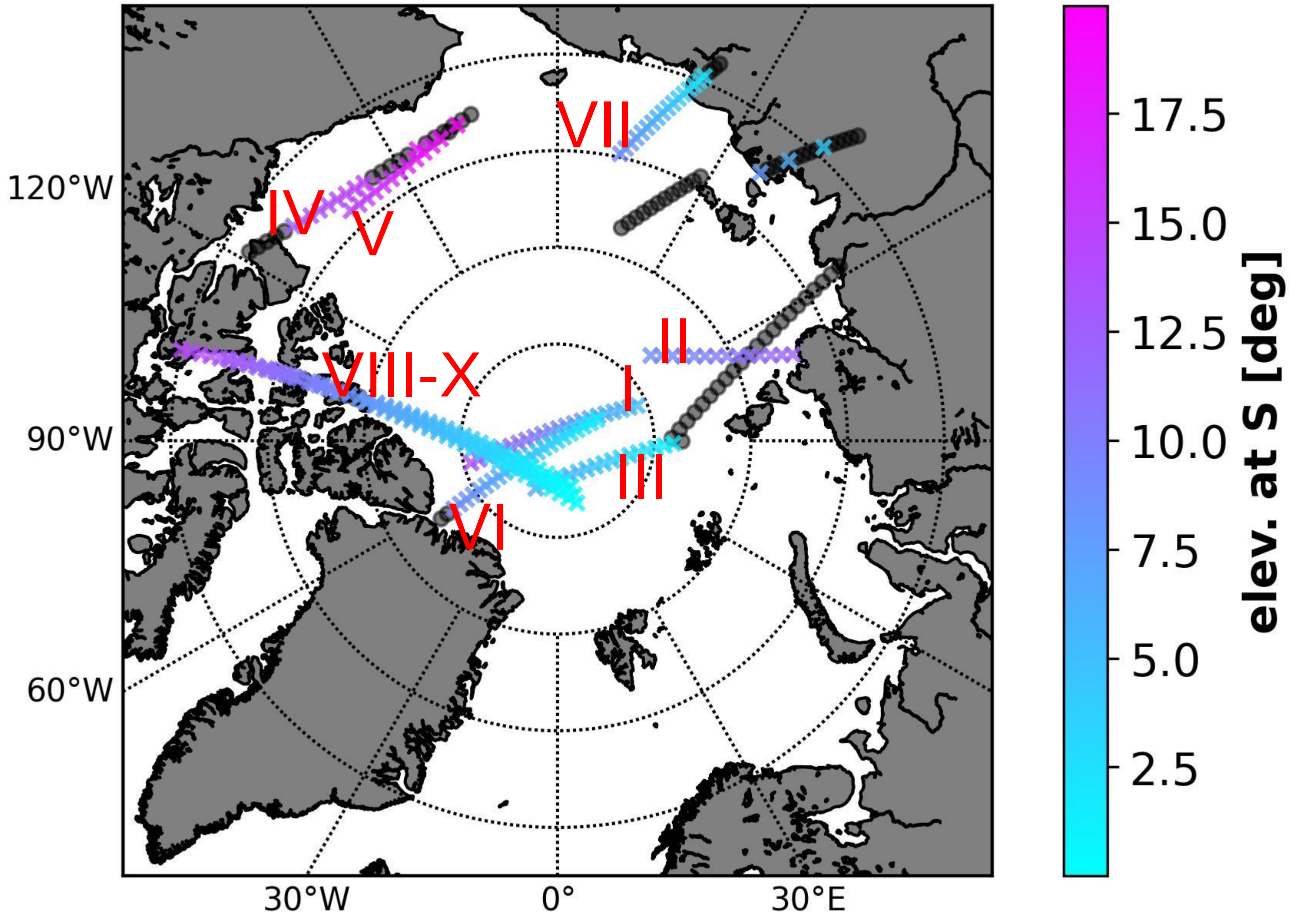
Comparison with model profiles



Semmling et al. submitted

Significantly different example,
about 2 weeks earlier, different track
larger peak width and peak density

Geo-Reference and Uncertainties



I	GPS PRN 11	2024/03/11
II	GPS PRN 25	2024/05/15
III	GAL PRN 7	2024/07/06
IV	GPS PRN 4	2024/07/08
V	GPS PRN 4	2024/07/15
VI	GAL PRN 7	2024/07/16
VII	GAL PRN 8	2024/07/20
VIII	GPS PRN 8	2024/07/27
IX	GPS PRN 8	2024/07/28
X	GPS PRN 8	2024/07/29

Tropo. Unc.: ~60cm (2 TECU) *
Surface Unc.: ~10cm (< 1 TECU) *
Bending Effect: ~10% of tang. Height *

* Ray geometry at E_S = 3°

Conclusions & Outlook

- **PRETTY** mission gathered code delay obs. in **grazing-angle reflectometry**
- **Ionospheric delay profiles** retrieved after tropo. and surface correction
- **Rel. Electron Content** reaches **min.** when **tangent point crosses F-layer**
- Some retrieved profiles show **excellent agreement with model** (NEDM)
- Others indicate **persisting biases**
- **Chapman layers fitted** to estimate peak height and scale height
- Expected **delay uncertainties** (troposphere, surface) are **not significant**
- **Bending has an effect** (on tangent height) to be considered in future

Acknowledgements

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Thank you for your attention

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