GNSS REMOTE SENSING OF THE PRETTY CUBESAT MISSION: A DEMONSTRATION TO VALIDATE MODELS OF IONOSPHERIC ELECTRON DENSITY

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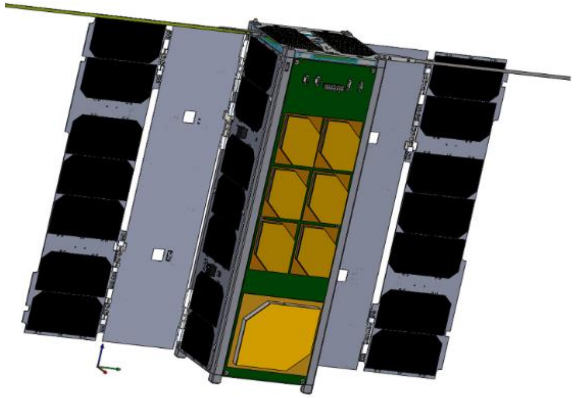

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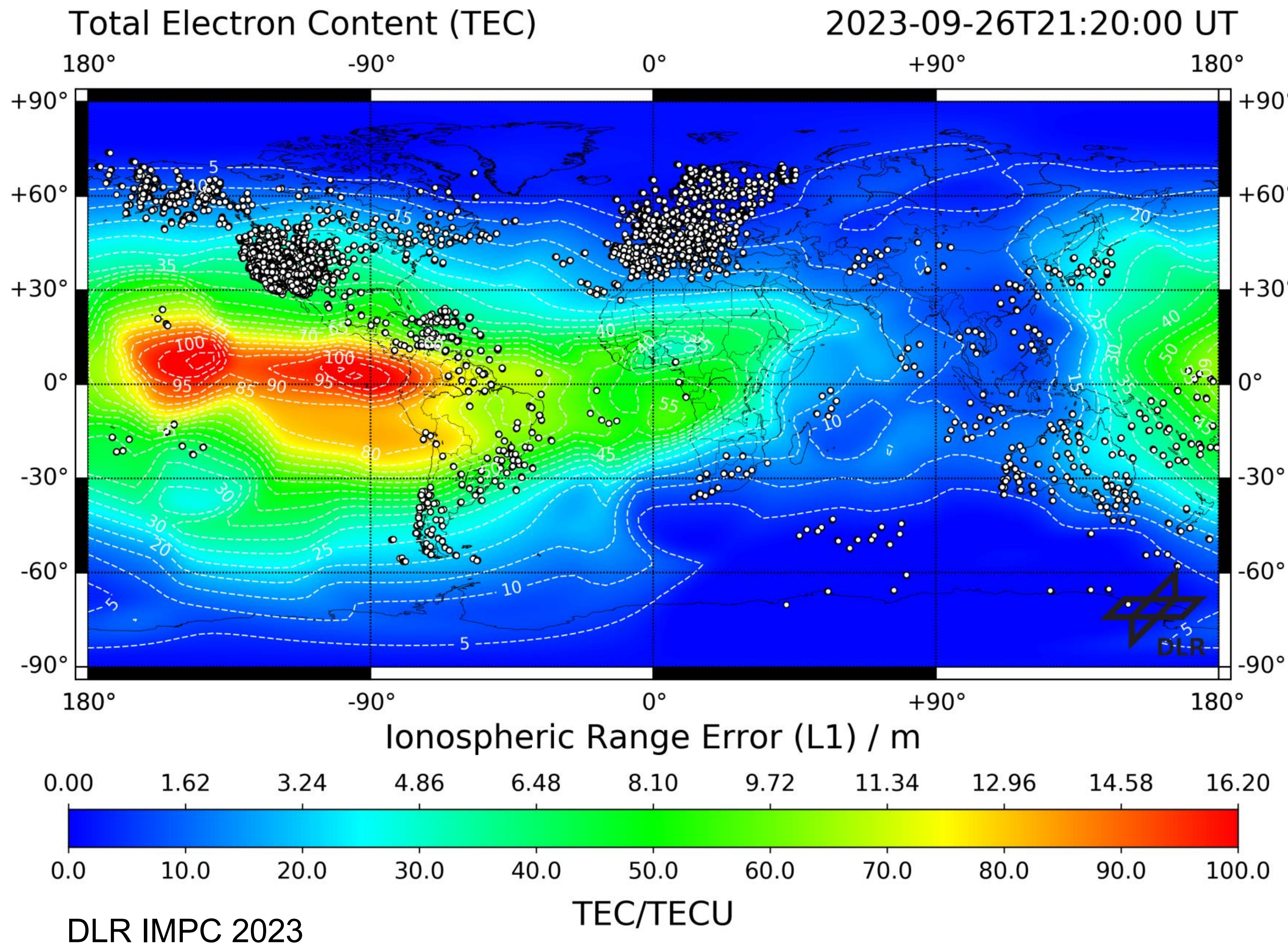
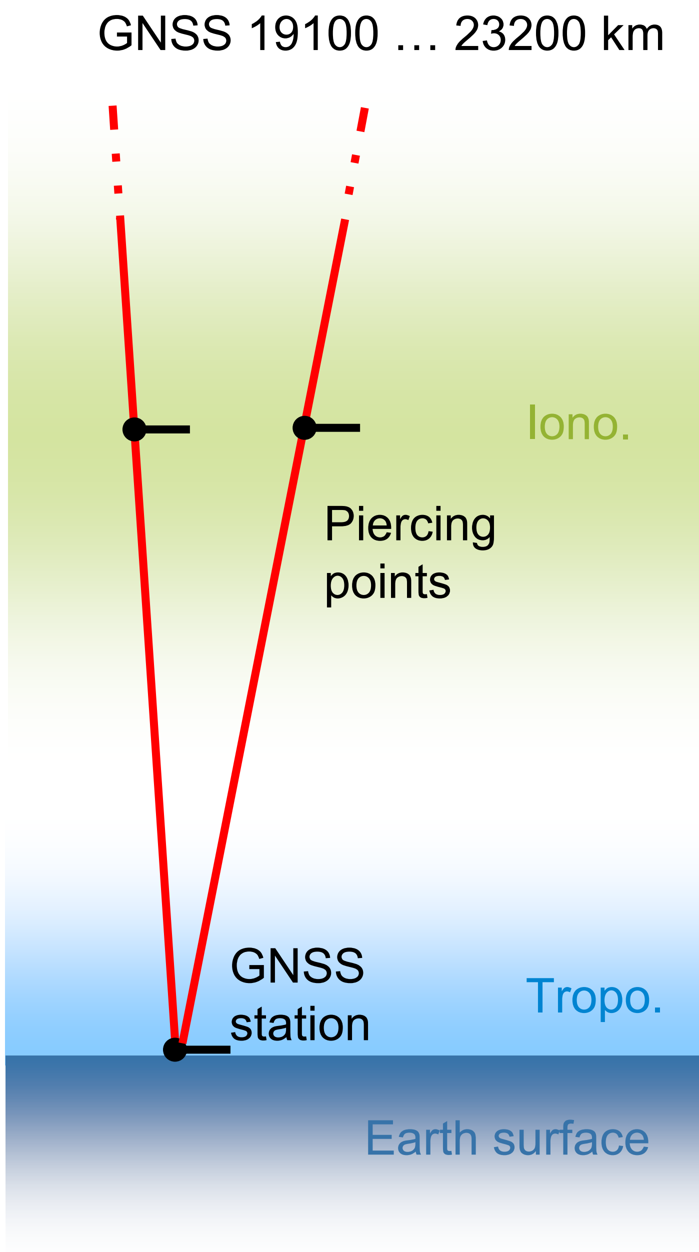
Outline

- Background of GNSS Remote Sensing
- Grazing Angle Reflectometry with PRETTY Mission
- Preliminary Results on Ionosphere Validation
- Conclusions & Outlook

Background of GNSS Remote Sensing

Ionospheric TEC Monitoring with GNSS



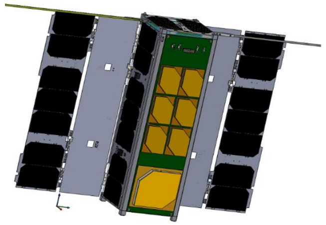


DLR IMPC 2023

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

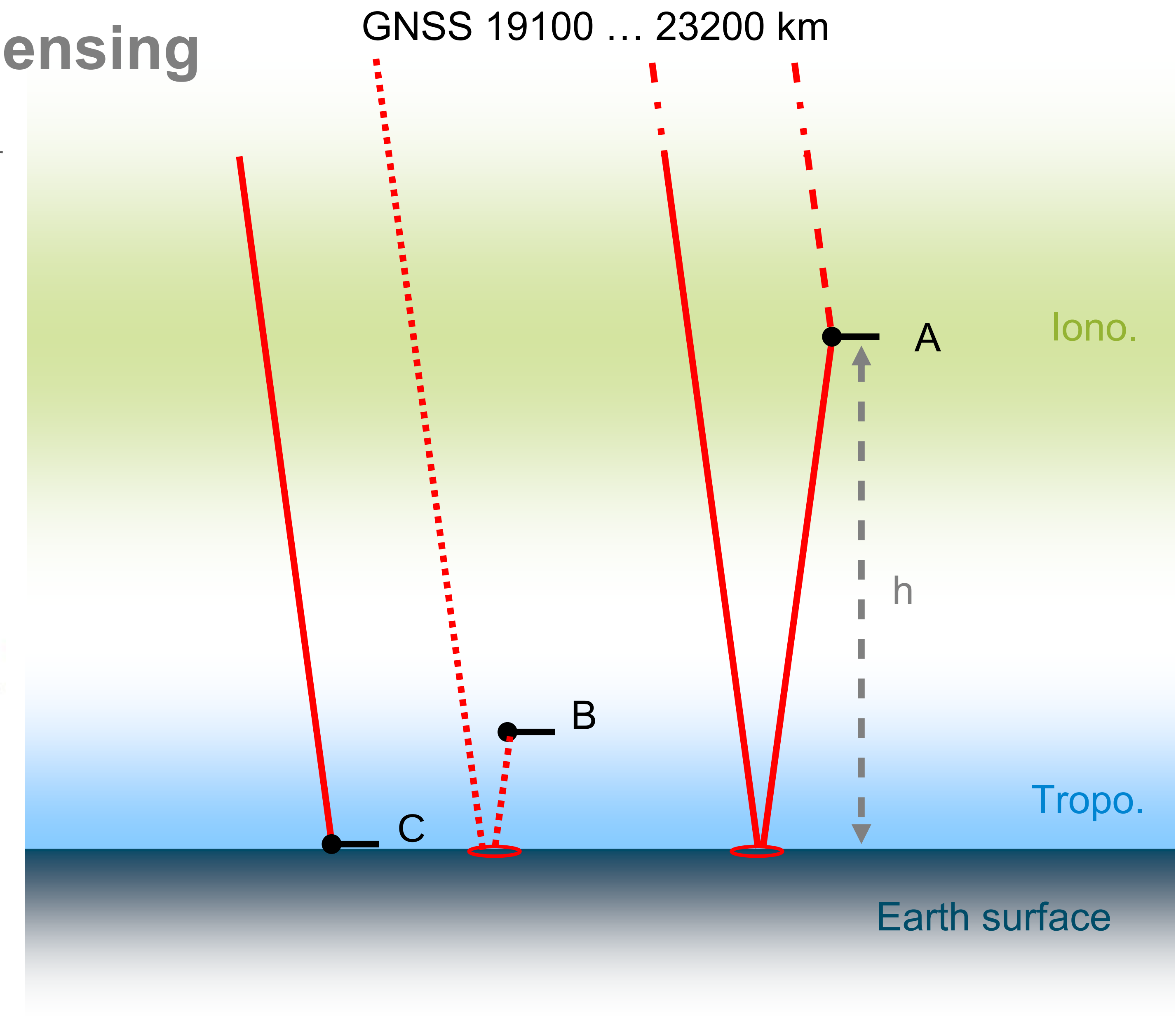
- C: Research Vessels

  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

Considerable Factors Reflectometry

Sea Surface

- Roughness (Sea State)
- Penetration (e.g. Sea Ice)
- …

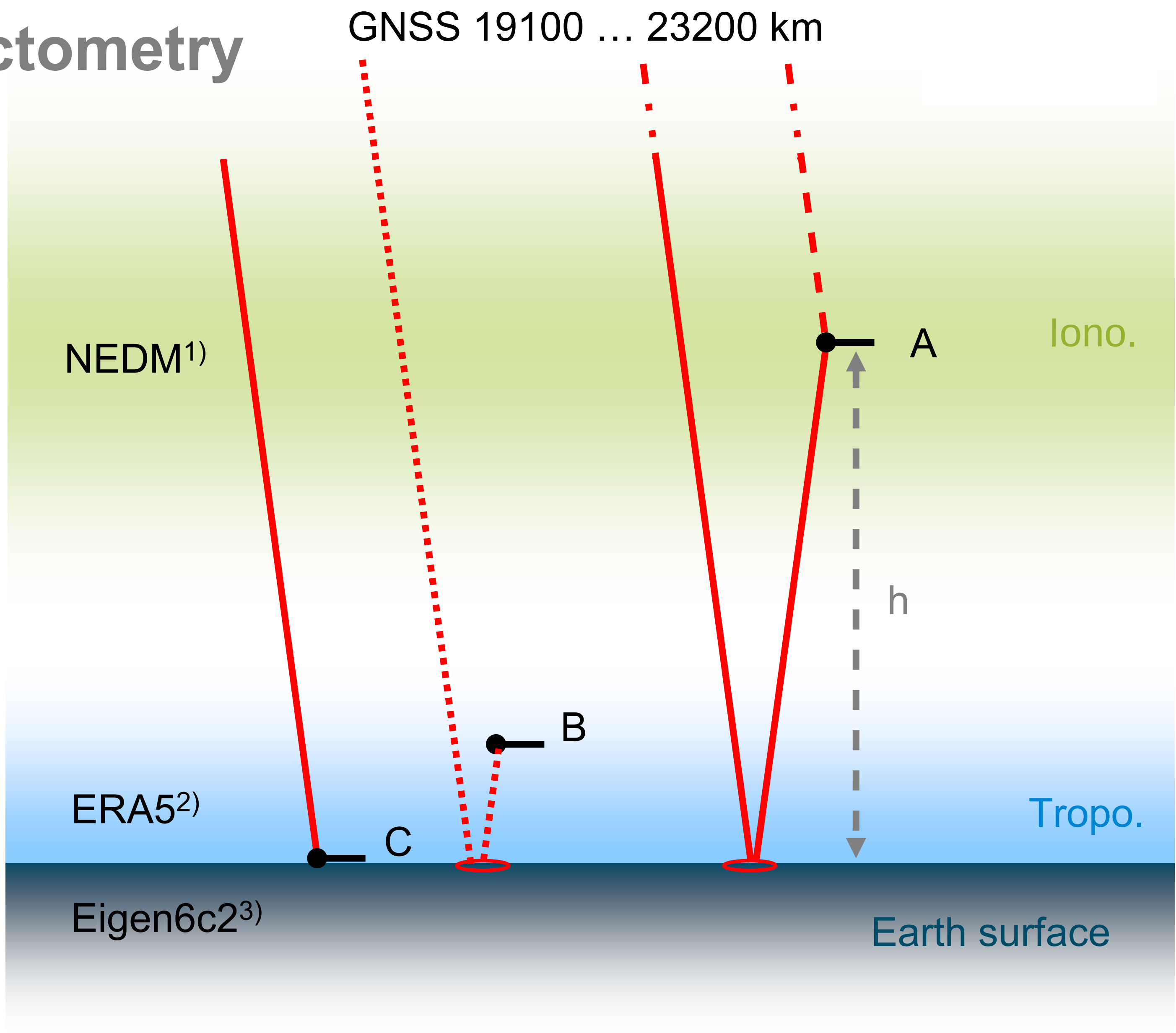
Atmosphere

- Refraction
  (neutral gas and ionosphere)
- Scintillation
  (Plasma Depletion, Space Weather)
- …

Receiver & Transmitter

- Position & Attitude uncertainty
  (of vessel, aircraft or satellite)
- Antenna & Instrumental parameter
  (e.g. gain pattern)
- …

degree of disturbance



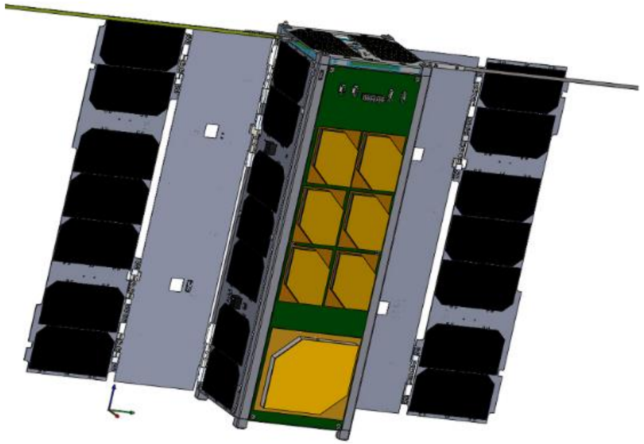
1) Hoque et al. 2022 ; 2) Hersbach et al. 2020 ; 3) Förste et al. 2013

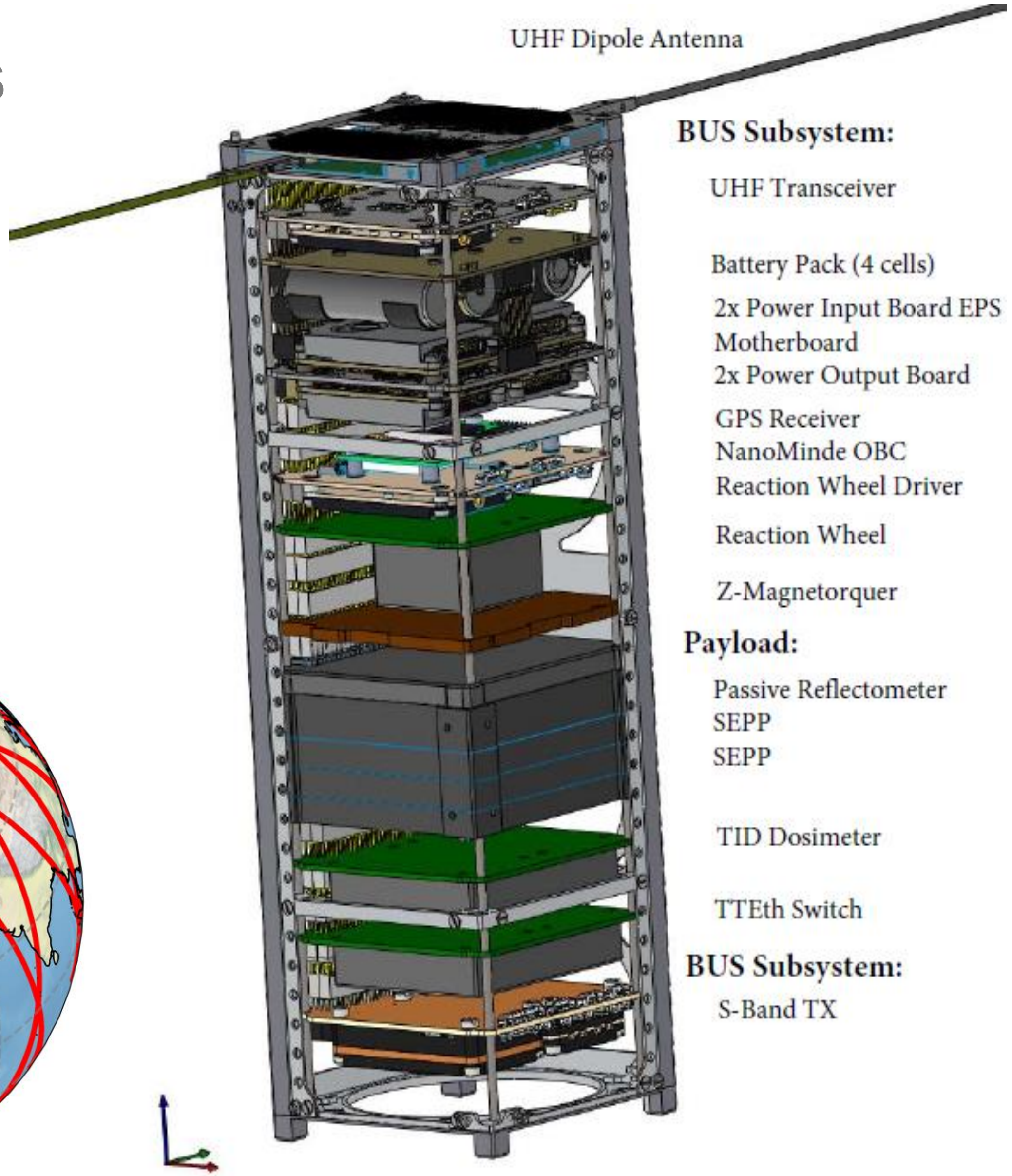
Grazing Angle Reflectometry with PRETTY Mission

PRETTY Satellite Mission Parameters

Passive **RE**flec**T**ometry and dosime**T**r**Y**

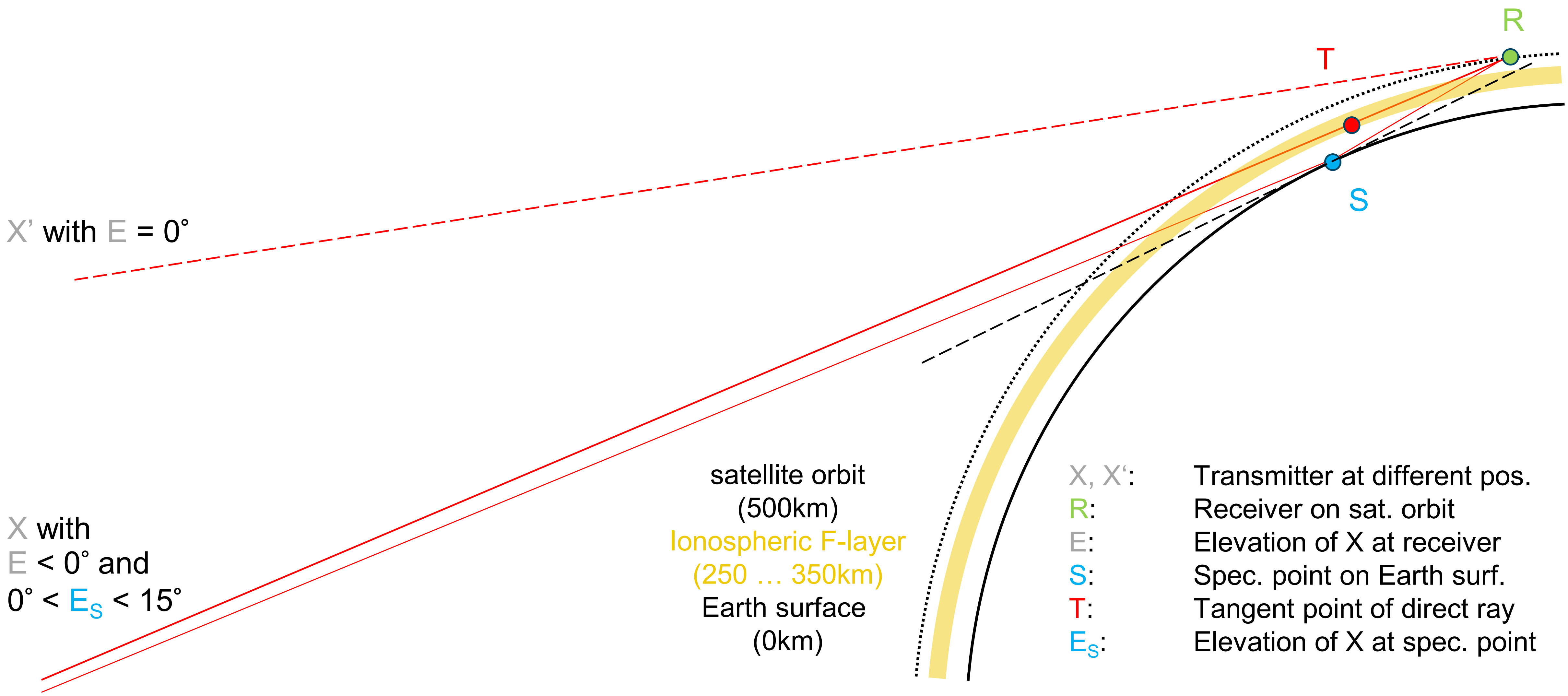
- ESA CubeSat mission, developed by an Austrian consortium led by Beyond Gravity Austria
- Size: 30 x 10 x 10 cm³
- Orbit: polar SSO, altitude 560 km
- GNSS-R antenna: RHCP, limb pointing
- GNSS-R grazing elevations: 0° to 15°
- GNSS-R signal carrier: L5



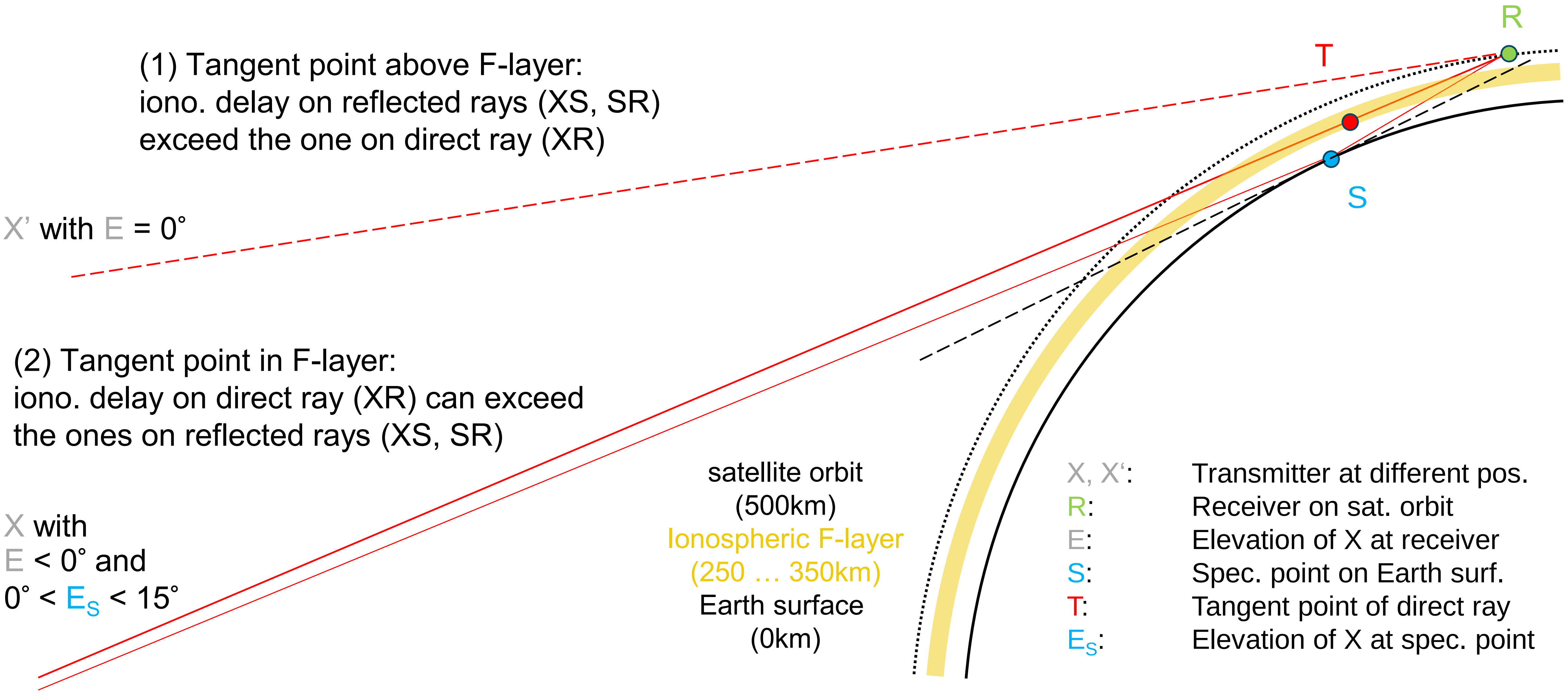


Fragner et al. 2020

Ray Geometry at Grazing Angles



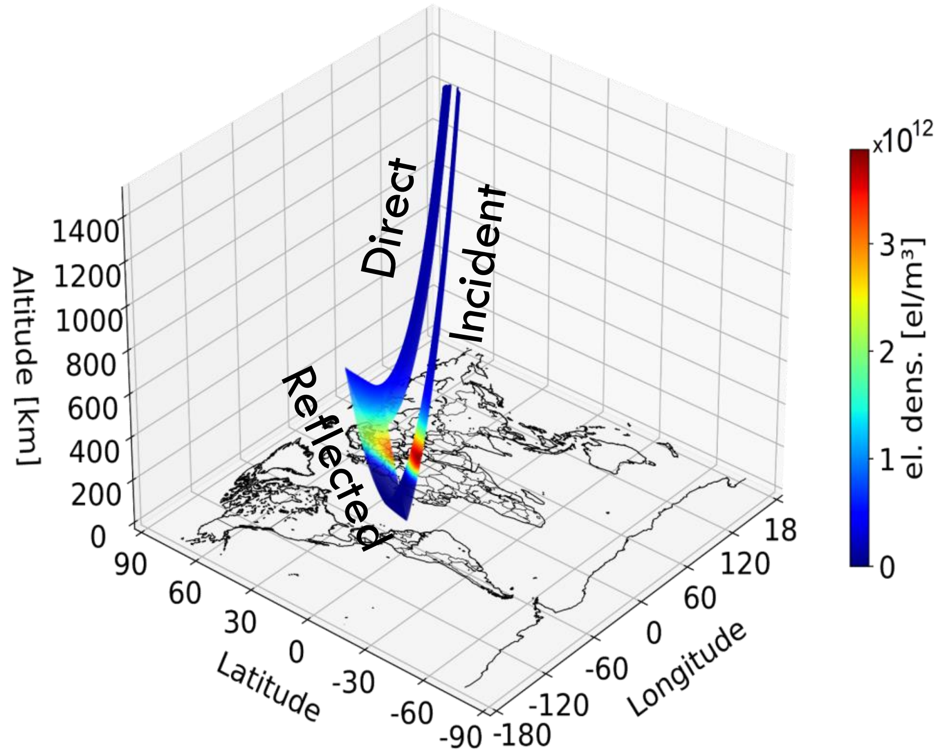
Scenarios of Ionospheric Delay



Preliminary Results on Ionosphere Validation

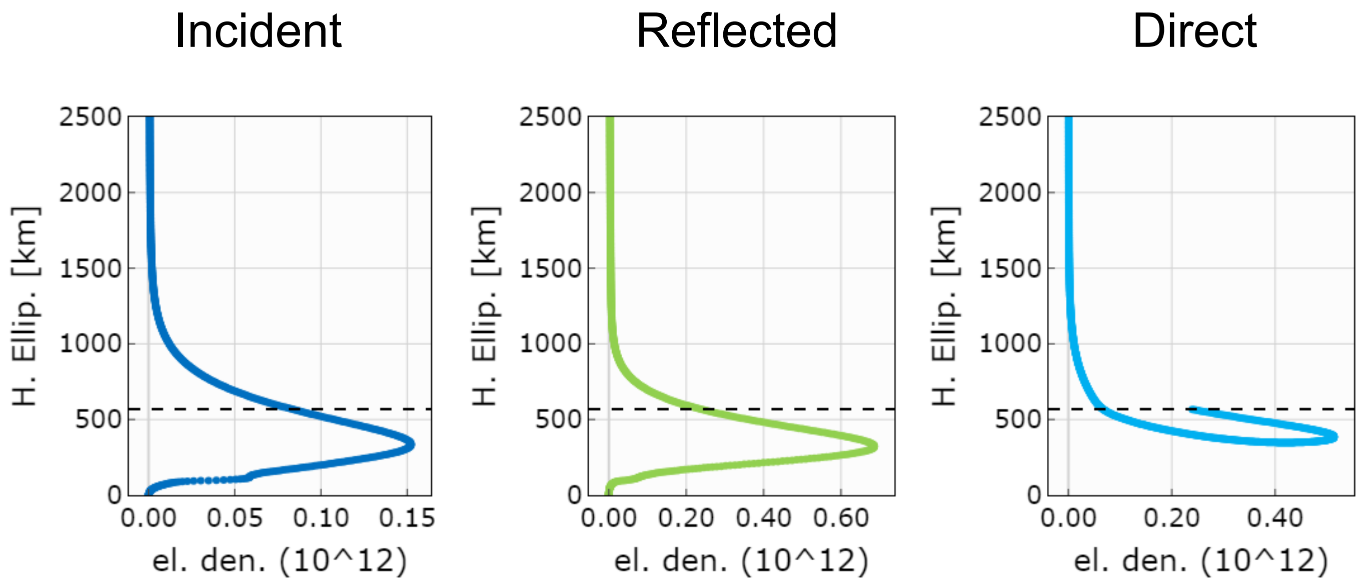
Modelling Ionospheric Electron Content

- Ray points every 10 km along ray paths (Direct, Incident, Reflected)
- Retrieve electron density from NEDM 2020 Model



Moreno et al. 2023

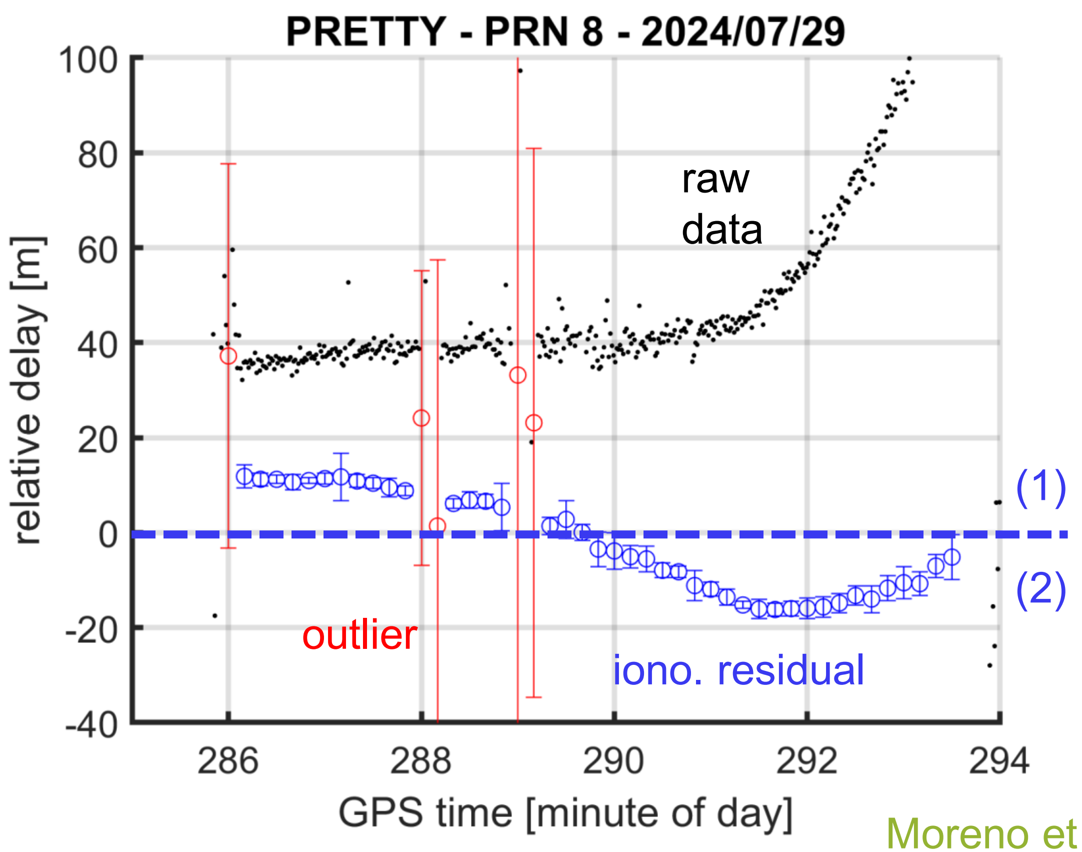
PRN 303 - 2024.02.23 @ 13:30:26



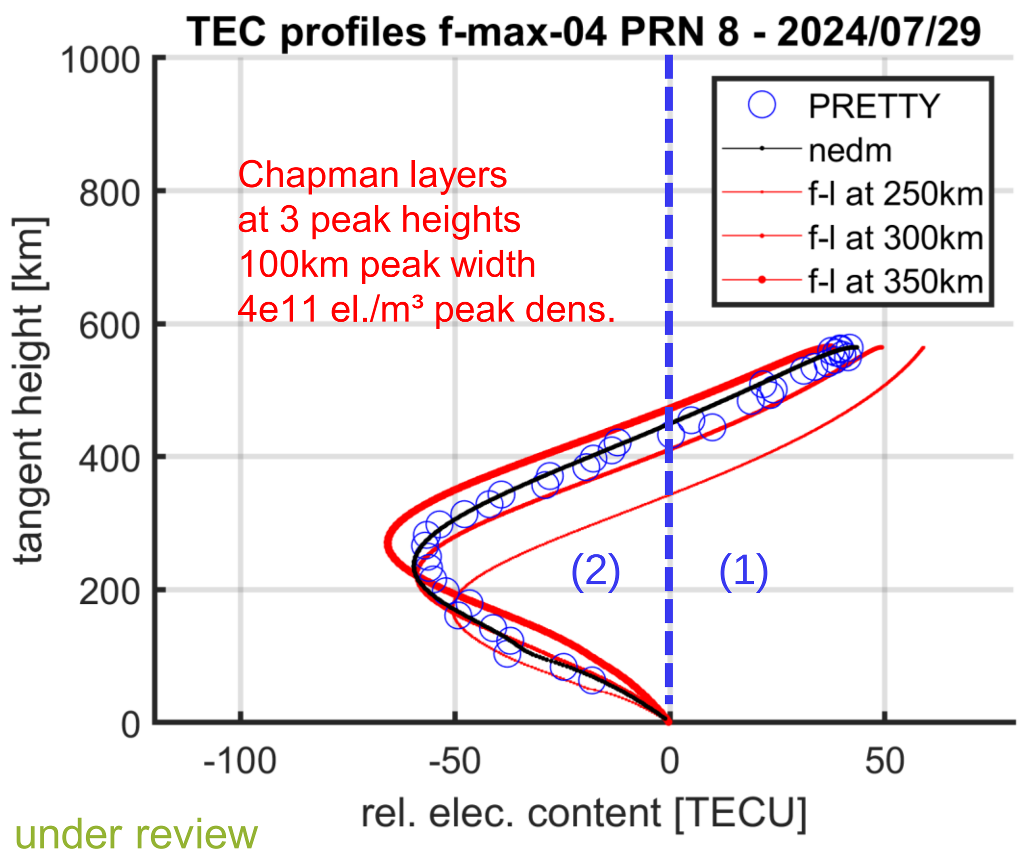
elec. dens. → integrated to → elec. content

Observation Example GPS PRN 8 – 2024/07/29

Satellite Obs. Data



Comparison with model profiles



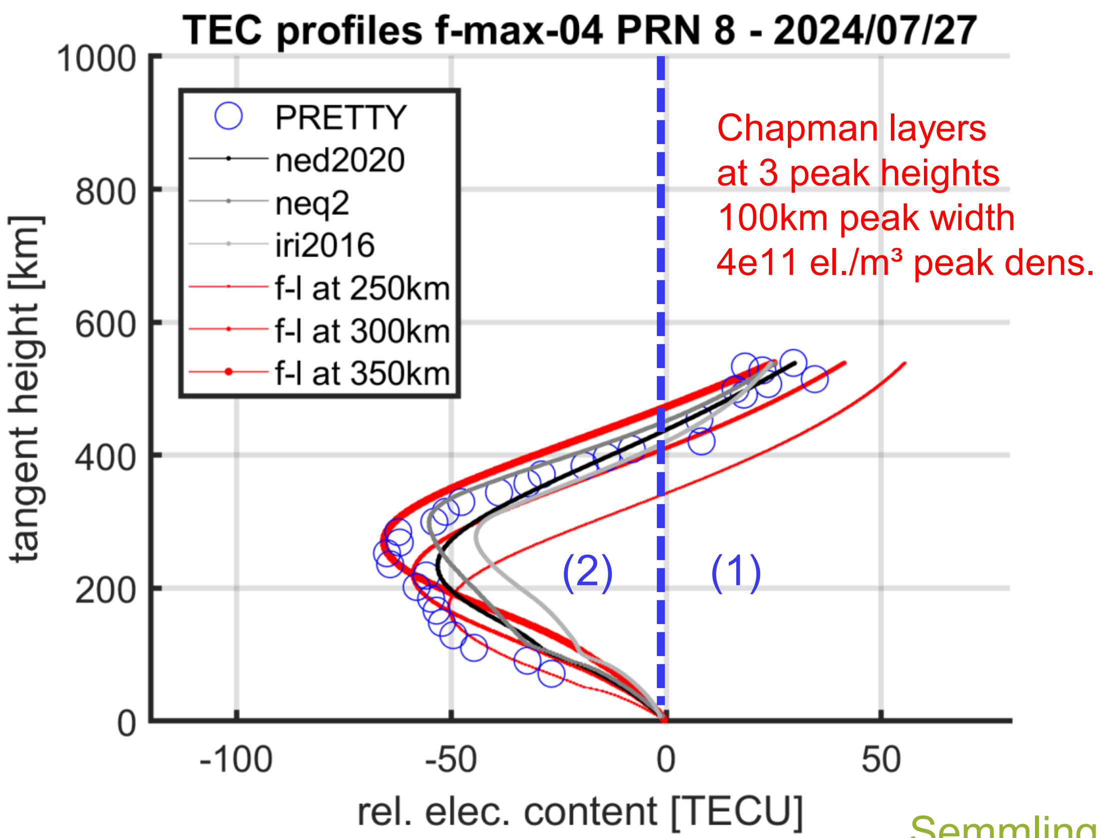
Moreno et al. under review

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

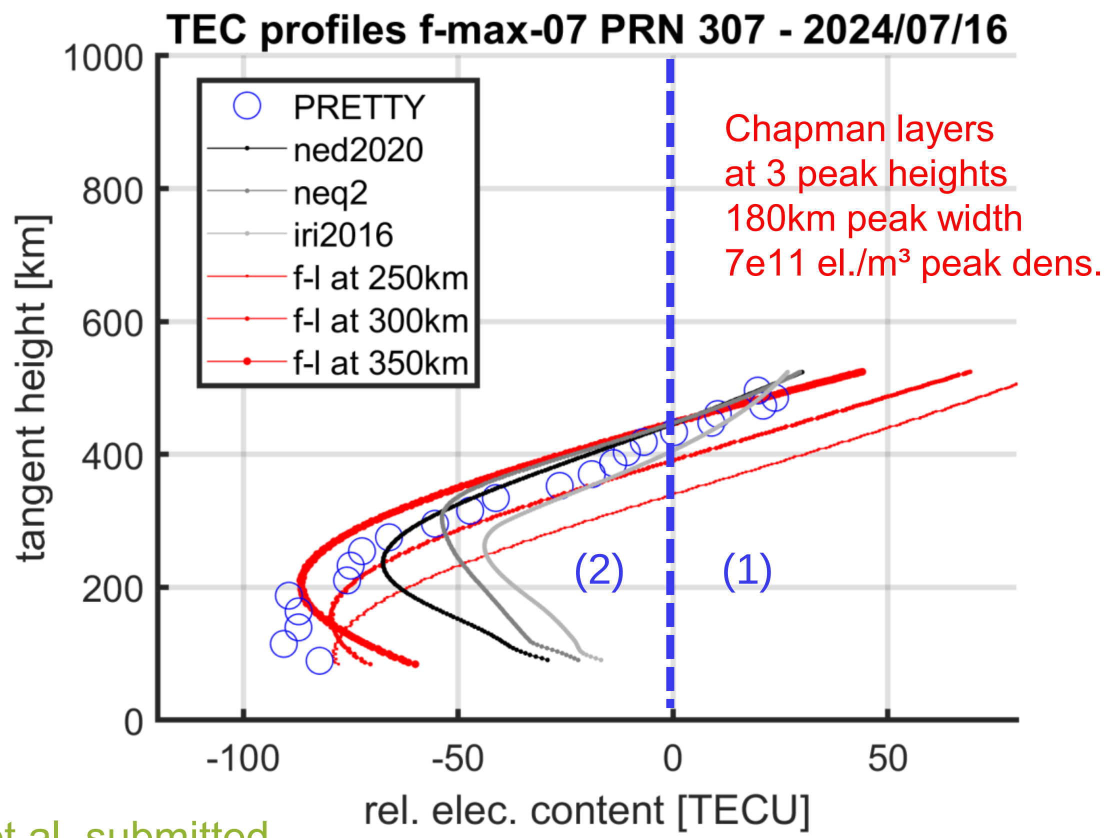
More Examples for GPS and Galileo

Comparison with model profiles



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

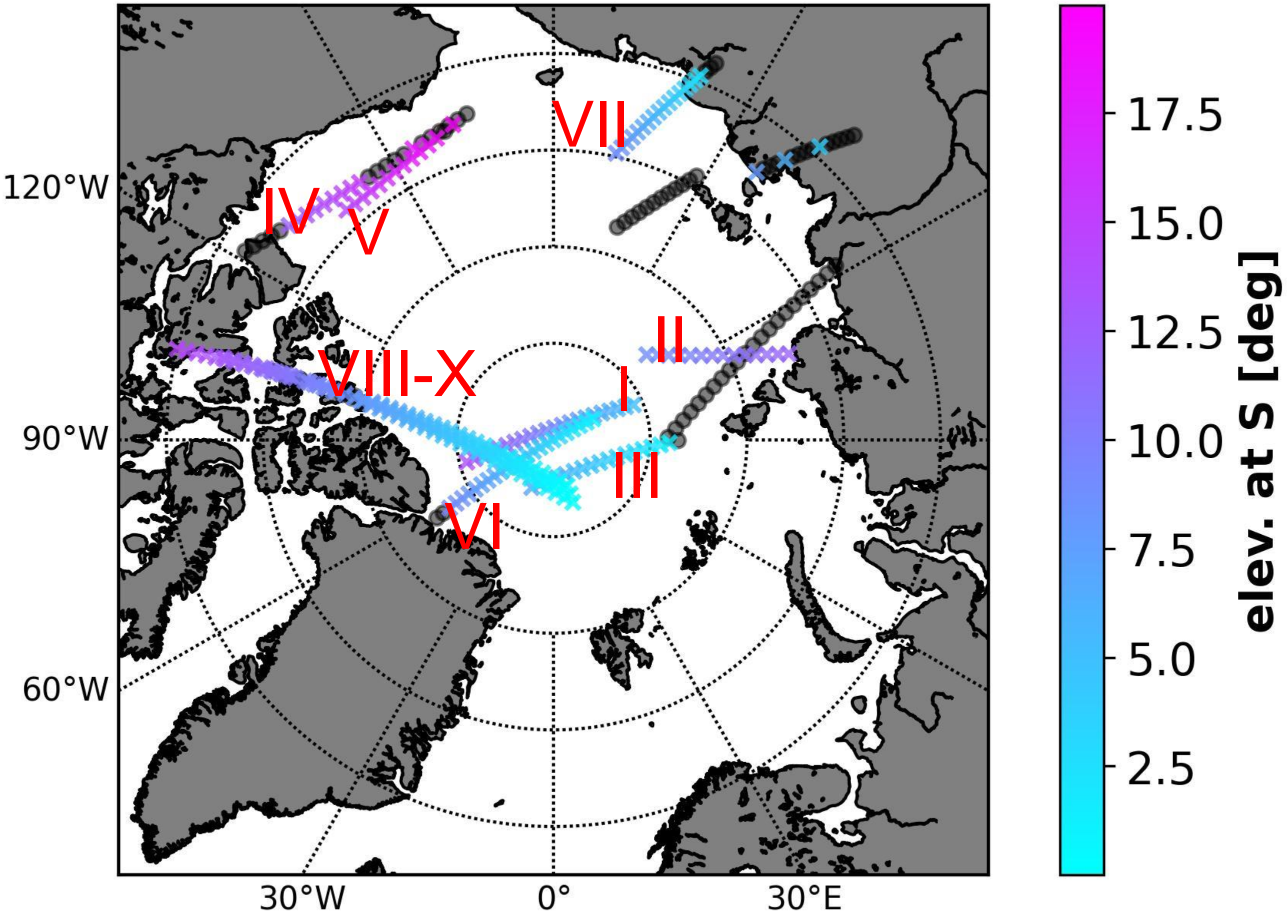
Comparison with model profiles



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 *

* Ray geometry down to $E_S = 3°$

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

Conclusions & Outlook

- **PRETTY** cubesat mission provides **grazing-angle reflectometry data**
- Reflection with **sufficient SNR over smooth Earth surface** e.g. Arctic sea ice
- **Elec. content profiles** modelled and retrieved from PRETTY observation
- Some retrievals give **excellent validation of model computation** (NEDM)
- Local minimum of profiles when **sensitive to F-layer structure**
- Fitted layer allow **to estimate ionospheric peak- and scale height**
- **Open uncertainties** (especially orbit and bending) to be determined

https://www.hydrognss.org/

Acknowledgements

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Thank you for your attention

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  (submitted)