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Precise Gnss-R Altimetry With The ESA PRETTY Cubesat: Initial In-Orbit Results

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PRETTY mission

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The PRETTY Mission

Overview

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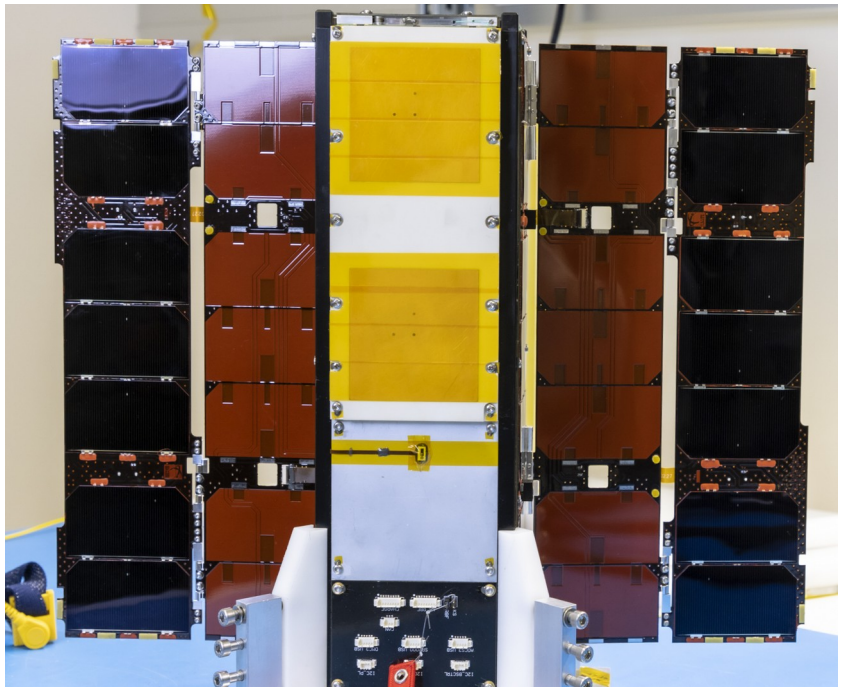
- PRETTY (**P**assive **Re**flectome**t**ry and Dosime**t**r**y**) is an IOD 3U CubeSat funded in "*ESA General Support Technology Programme Fly Elements*" (GSTP Fly) by Austria.
- Launch onboard VEGA VV23 on a 560 km Sun-synchronous polar orbit (with an inclination of 97.66°) on 9 October 2023.
- On 15 February 2024, PRETTY has captured the first ever interferometric GNSS-R measurement using Galileo E5 signals.
- PRETTY has a mass of 4.64 kg
- Available power is 20 W (peak power ~30W)
- 2 Scientific Payloads
  - GNSS reflectometer
  - SATDOS-1 Dosimeter



The PRETTY Mission

Overview: payloads

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GNSS reflectometer

- Altimetric determination of water/ice surface at grazing elevation angles
- Initial focus on **ice/sea ice** areas (polar regions)
- 2 patch array with **6.5dB** gain (Right-Hand Circular Polarization (**RHCP**)) in **L5/E5 band**

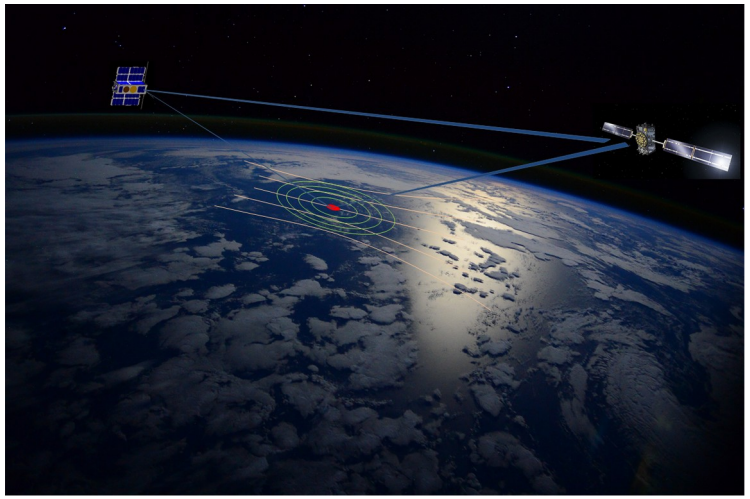

Image: ESA

SATDOS-1 Dosimeter Payload:

- Assessment Total Ionizing Dose (TID) and Single Event Effect (SEE) in orbit
- Shielded and unshielded sensors to assess space radiation environment

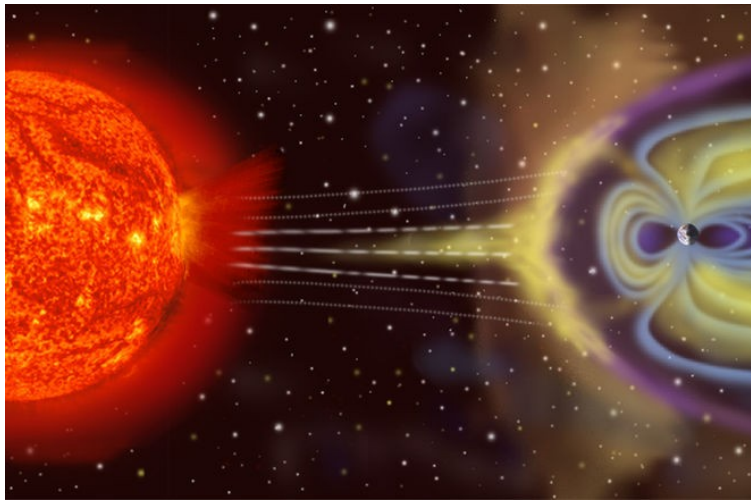

Image: NASA

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Overview: GNSS-R payload

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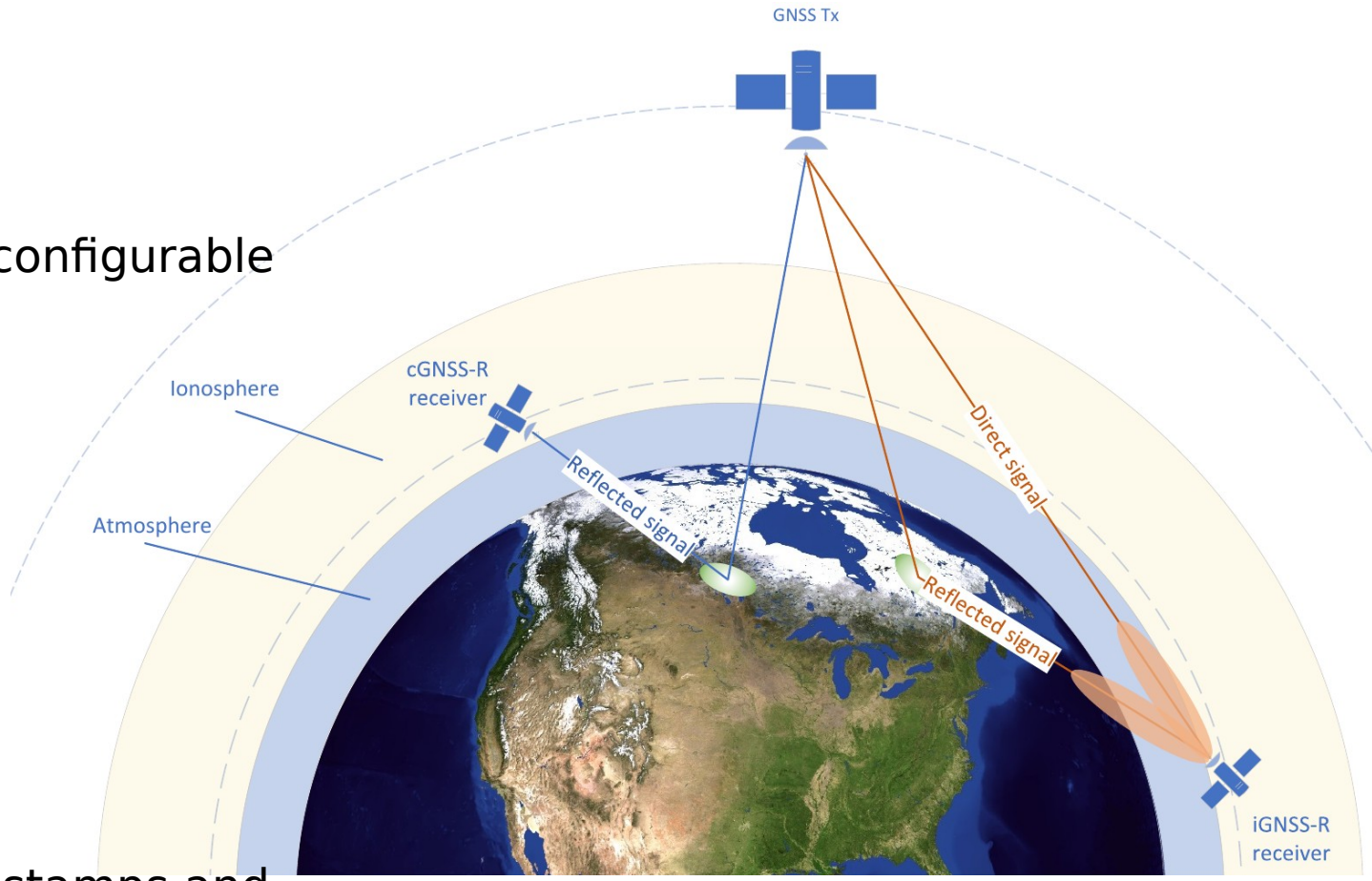
- On PRETTY we have the possibility for
  - Interferometric **iGNSS-R**
  - Clean Replica **cGNSS-R**
- Most steps in the signal processing chain configurable via software
  - Integration time (coherent and incoherent)
  - Doppler frequency for DDM
  - Delay resolution for DDM
  - Power and/or complex waveform
- RAW data acquisition possible
- Data generated in space
- Format is netCDF (easier post-processing)
- Includes all settings from processing, timestamps and metadata



Note: angles and distances not in scale

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Overview: GNSS-R payload

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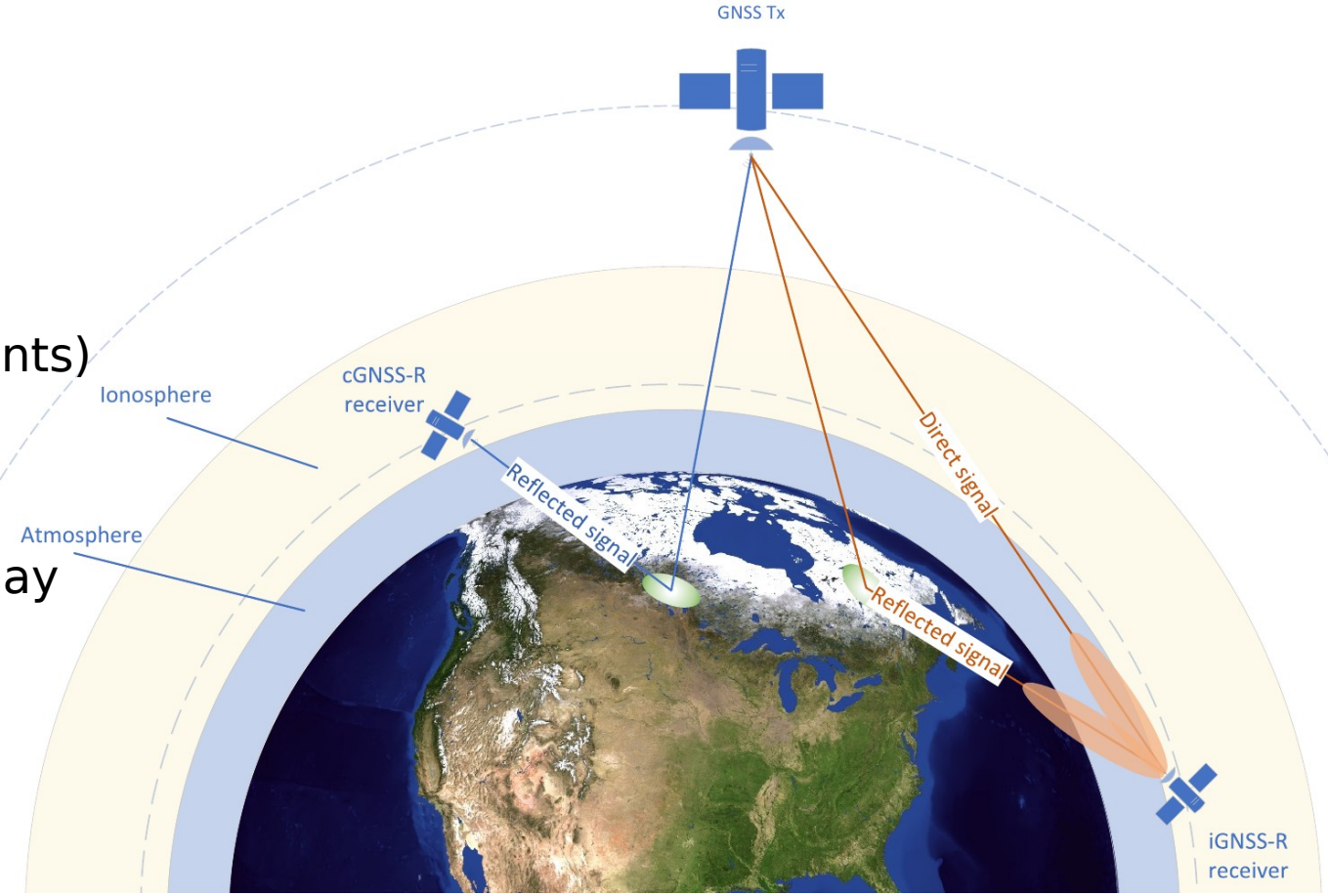
Limitations

- Power budget
  - 20W available
  - GNSS-R payload (during measurements) ~10W
- Data downlink budget
  - Single Groundstation, ~100MB per day
  - 3mins are ~30MB data generated
  - This limits measurement duration to ~20min per day



- Note: angles and distances not in scale

PRETTY mission

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Launch and Commissioning

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- 9th October, 03:36 CEST VEGA VV23 launched with PRETTY on-board

https://www.esa.int/ESA_Multimedia/Videos/2023/10/Vega_VV23_liftoff

- First contact achieved 9th October 21:27

- Commissioning started in October, but lasted until April
- VHF band which is assigned for PRETTY already occupied by ORBCOMM constellation
- ADCS tuning way harder than expected
- PRETTY in Sun-synchronous orbit
  - Initial 570km altitude, 97.7 deg inclination
  - Currently 555km (Sunstorm in May reduced altitude by ~200m!)

Status
Acquisitions

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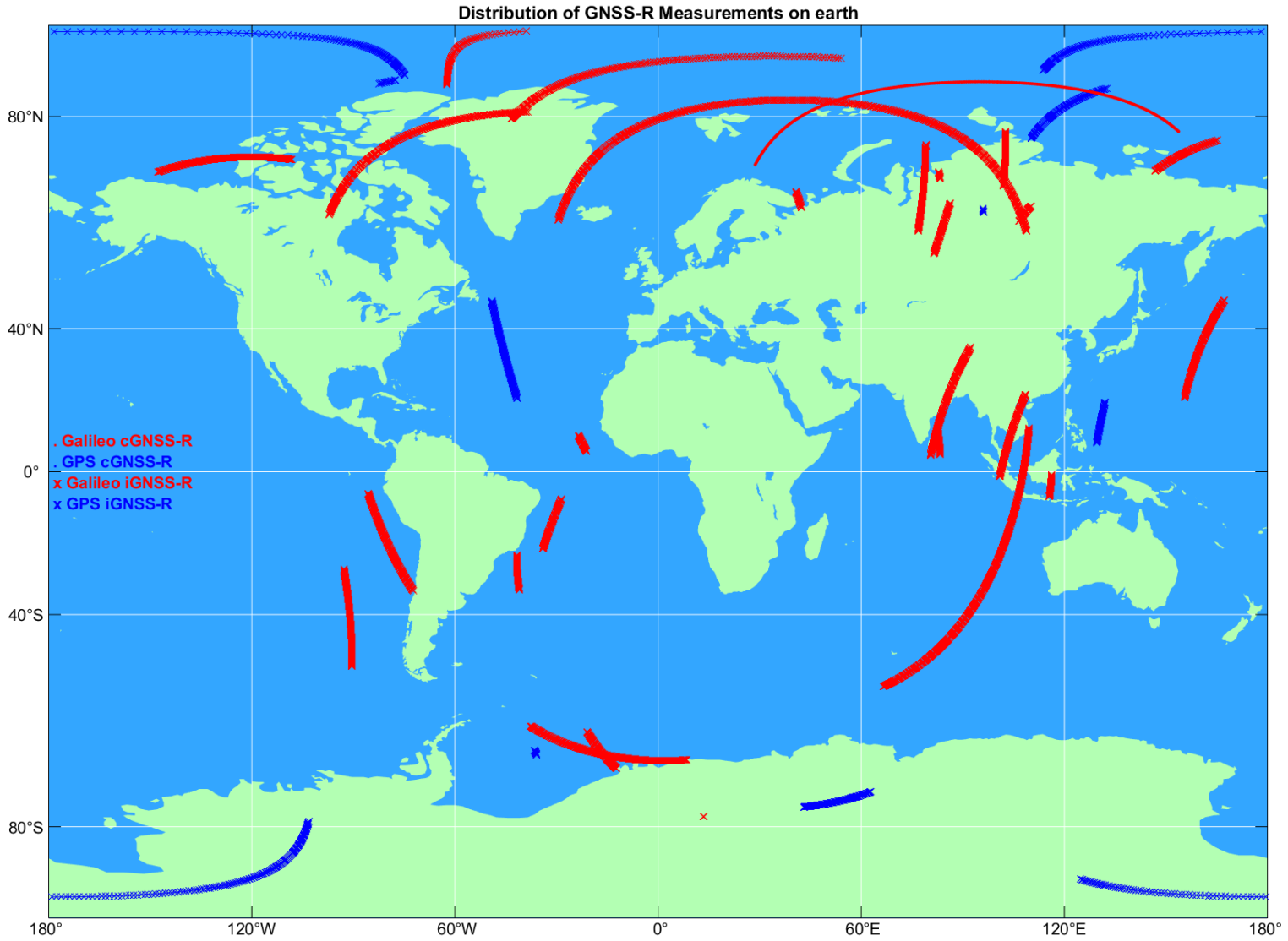
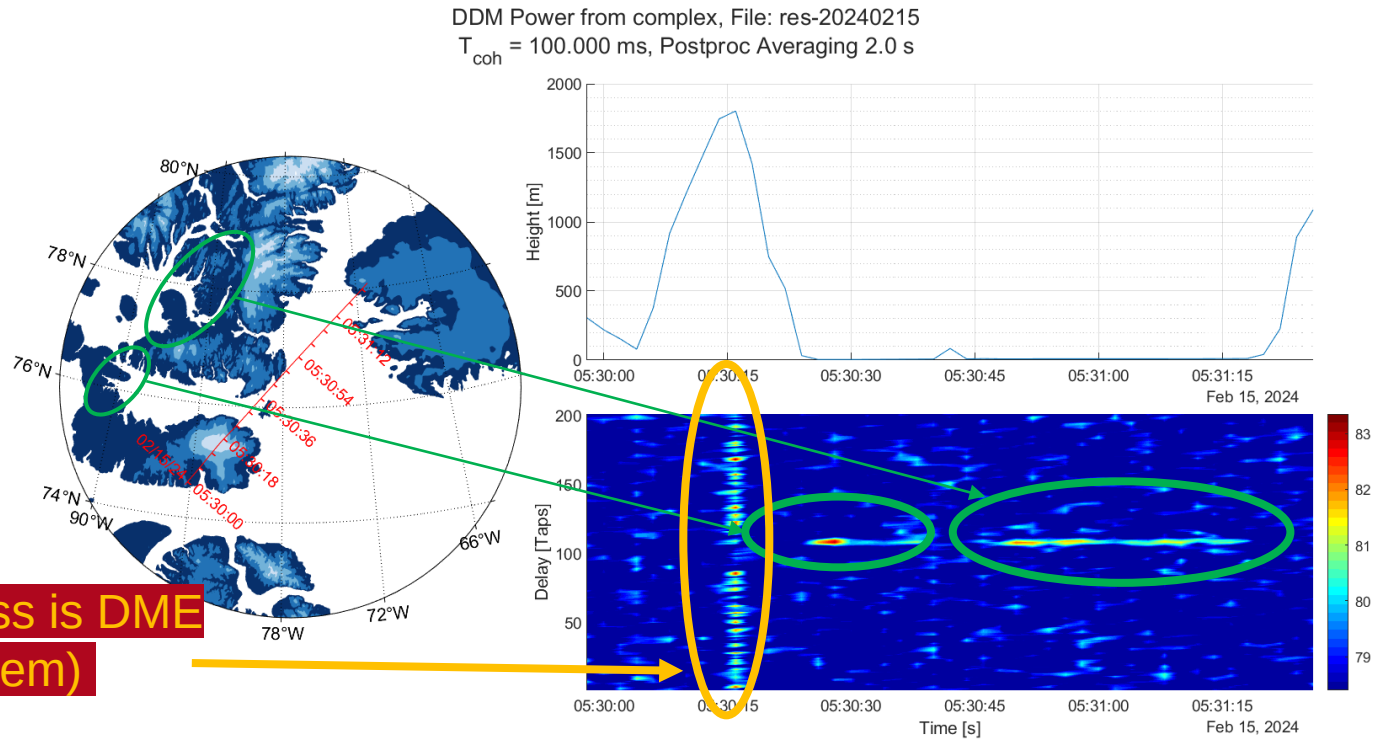
- Status 06.06.2024
  - 56 measurements done
  - Only 4 not successful
  - 14 RAW measurements
  - 37 interferometric
  - 1 conventional measurement
- Most of observations are Galileo
  - 27 GAL
  - 11 GPS



Status

First acquisitions

- Received First Light on 15. February 2024
  - Second time the GNSS-R payload was operated
  - Data post-processed (increased coherent integration time)

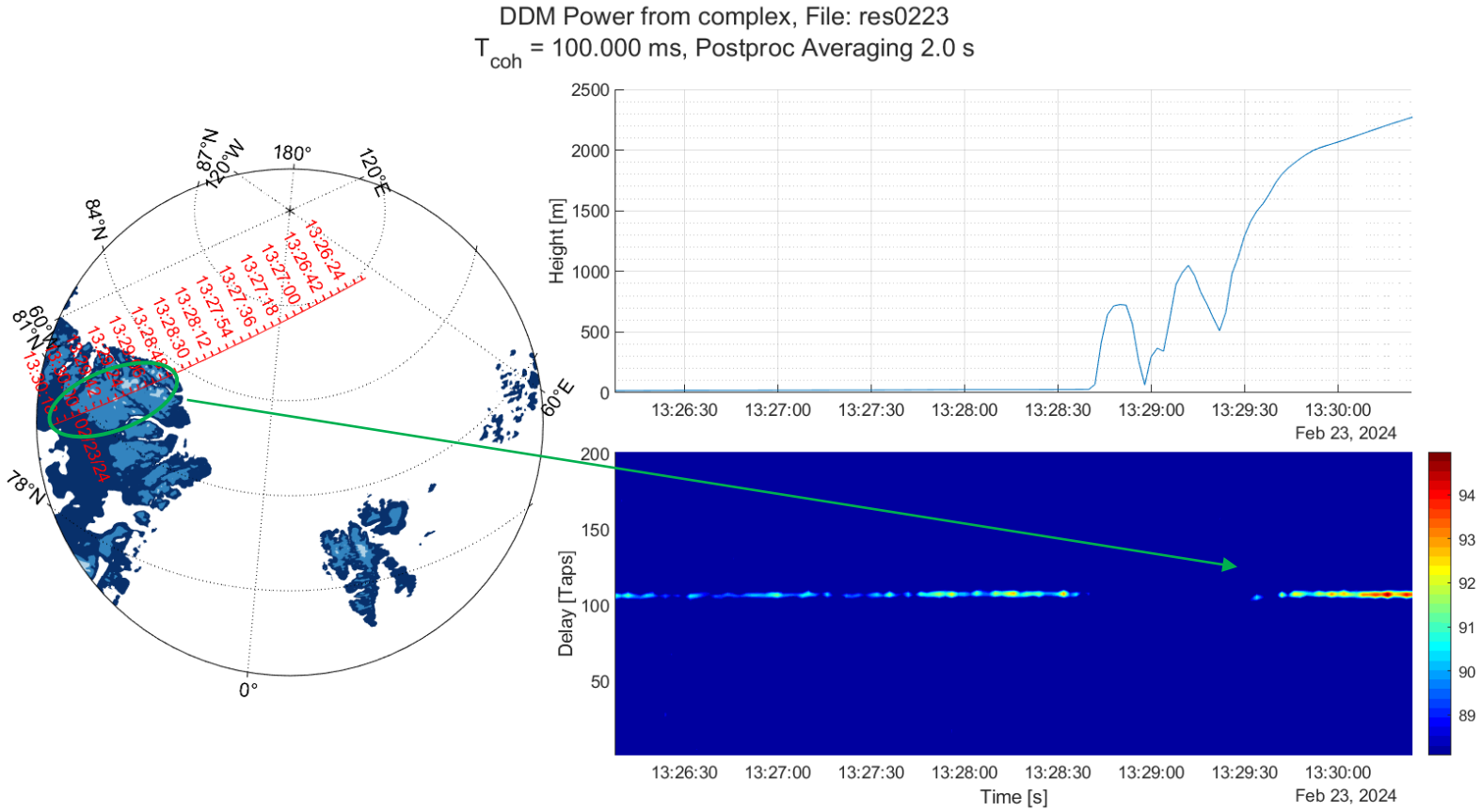


Interference, first guess is DME (aviation nav system)

Status

First acquisitions

- Successful acquisition over topographic features (23 February 2024)



Status

First acquisitions

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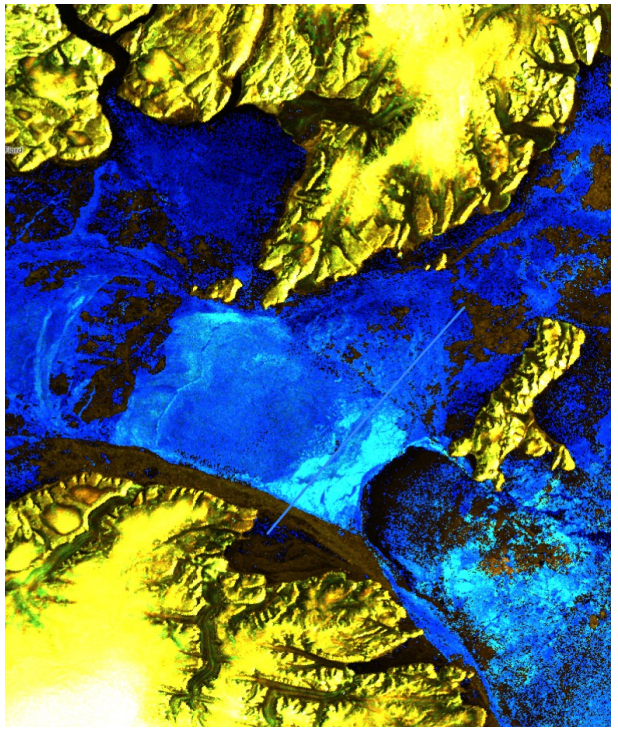
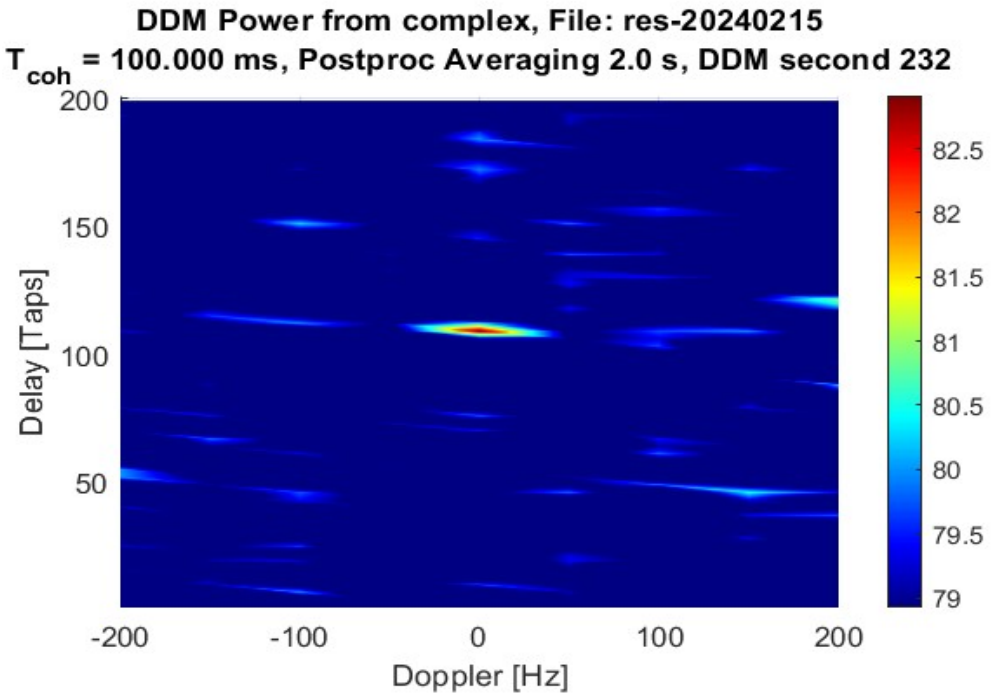
- Received First Light on 15. February 2024
  - Also DDM was generated during first light (data just after the plateu in the first light)





Status: RFI!!

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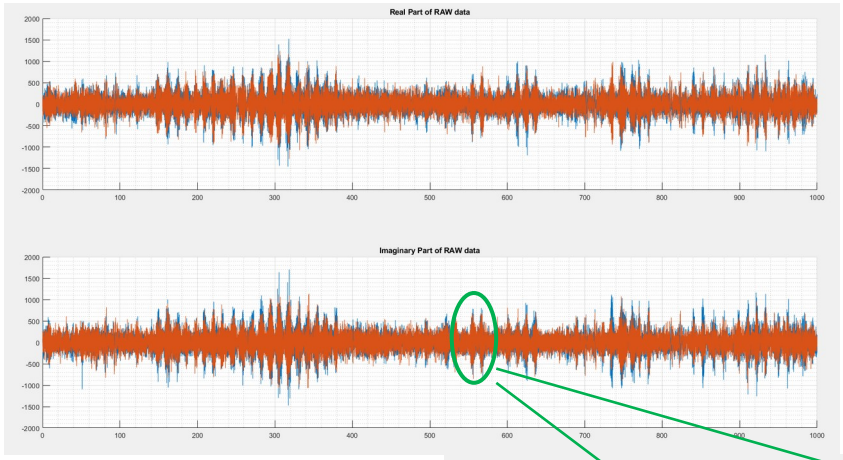
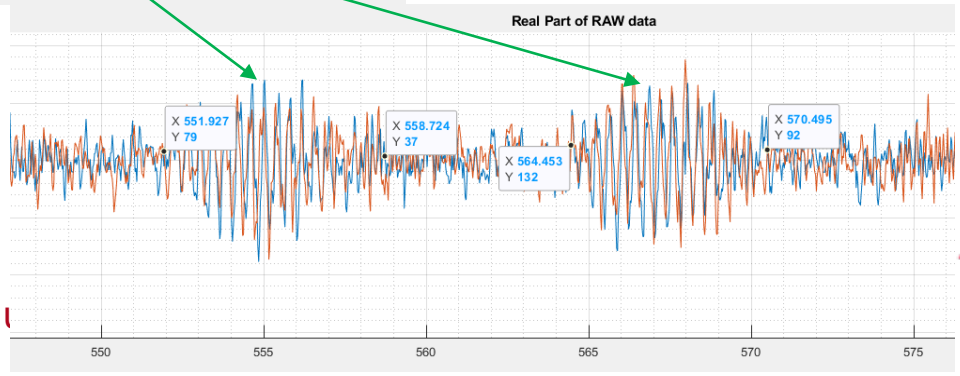
- Received RAW data on 23. February 2024
  - Lots of interference
  - Shape of pulses corresponds to DME
  - PRETTY location during RAW measurement in high density area of DME stations



Pulseblanking technique already implemented during ground testing. Need to tune threshold (SW parameter)



From “Fig. 4: DMA station’s location” taken from “DME/TACAN Impact Analysis on GNSS Reflectometry” DOI: 10.1109/JSTARS.2016.2556745

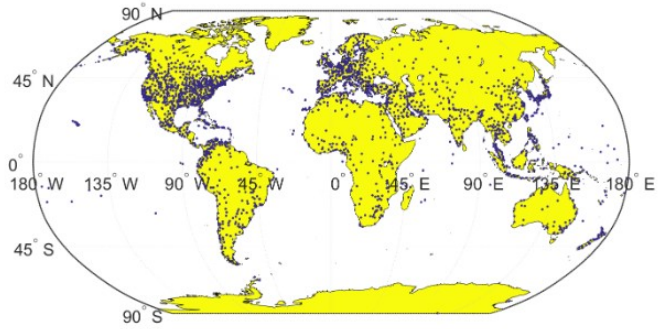


Fig. 4: DME station’s locations [14].

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Towards altimetry

Coherent segments?

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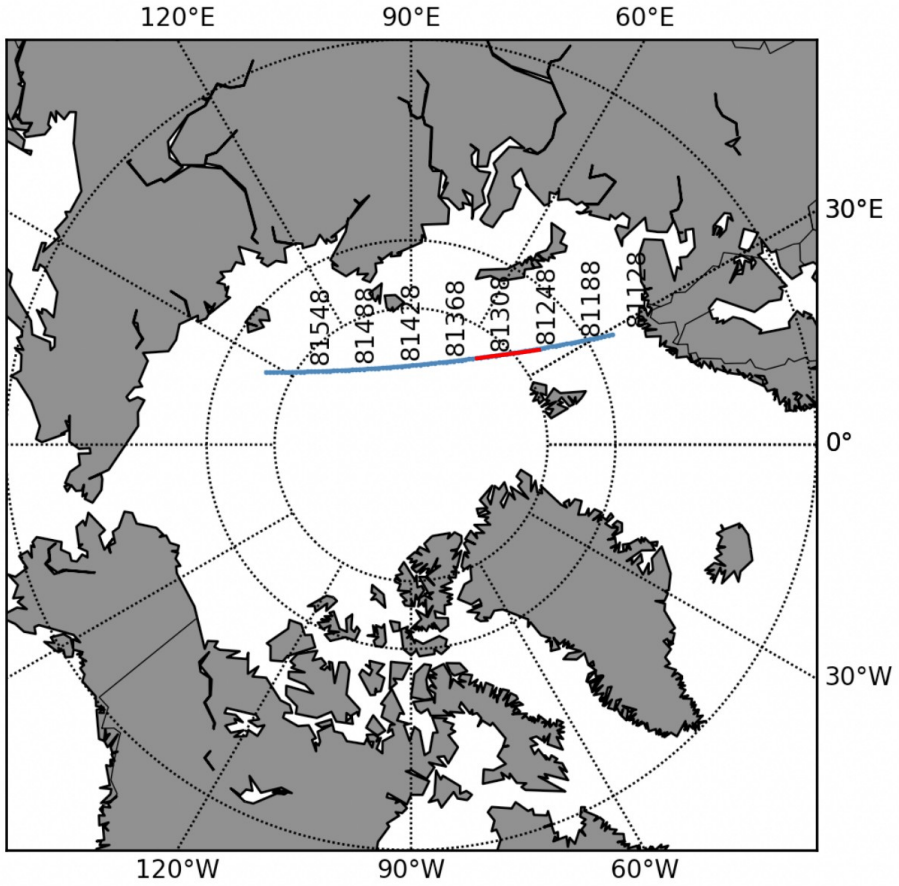
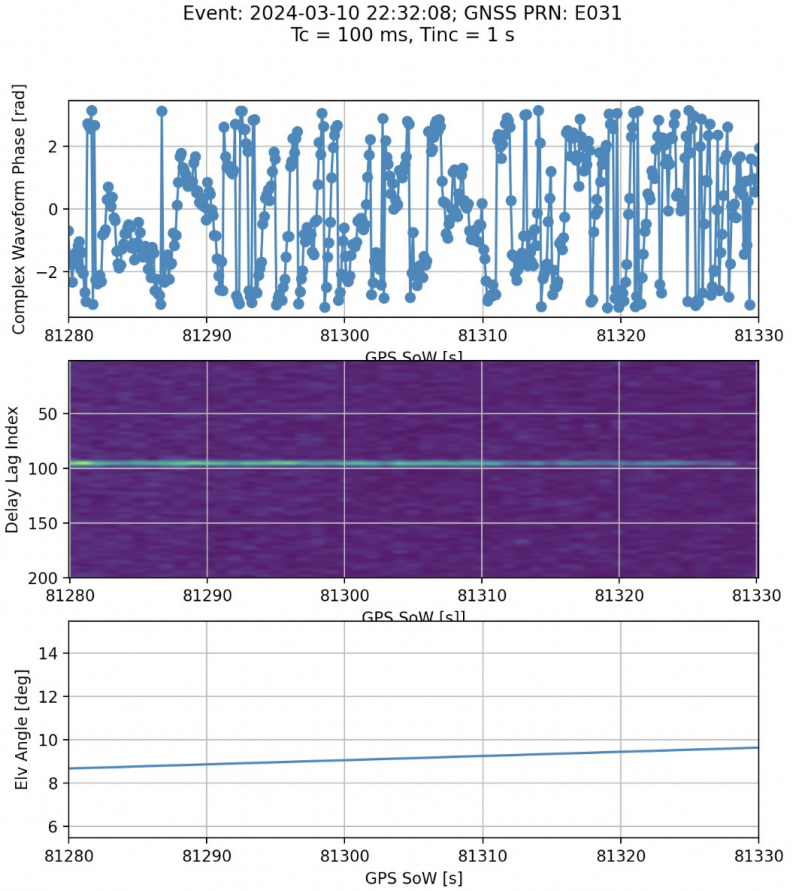
- 19 tracks analyzed: 18 iGNSS-R + **1 cGNSS-R**





Towards altimetry

Coherent segments?

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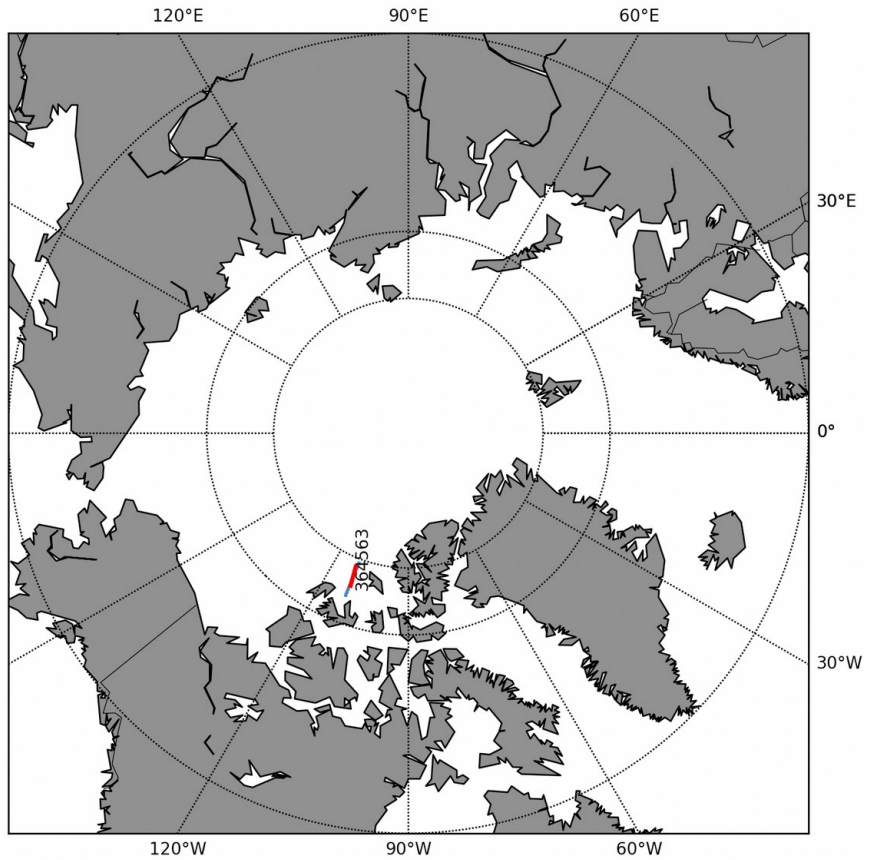
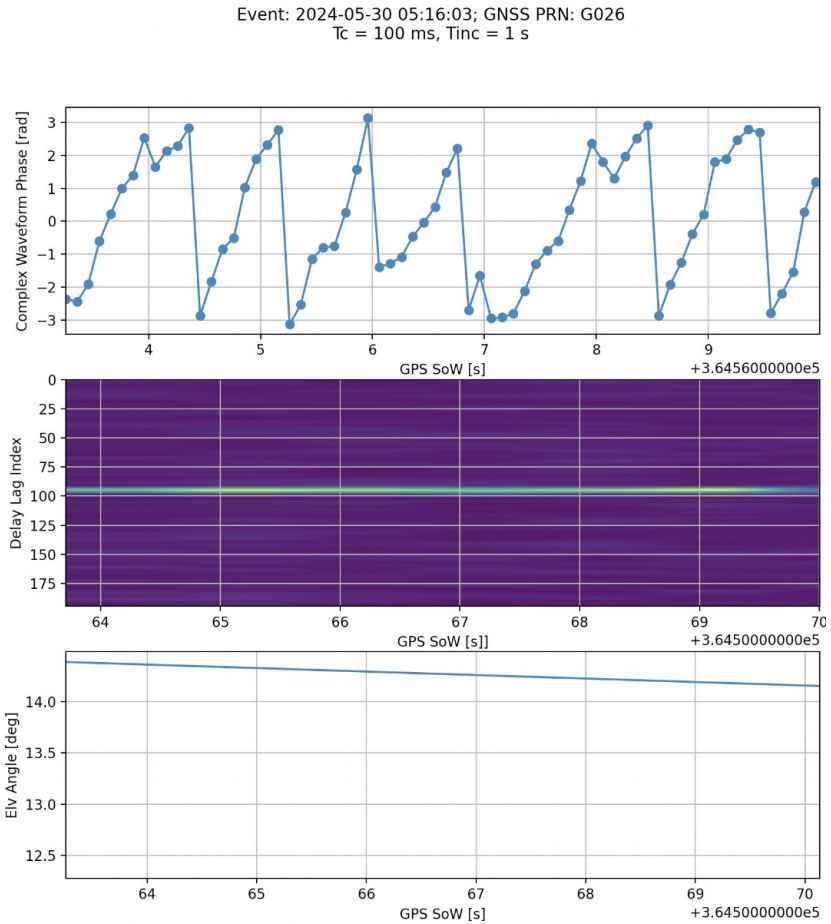
- 19 tracks analyzed: 18 **iGNSS-R** + 1 cGNSS-R





Towards altimetry

Atmospheric corrections

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- Two variants for the tropospheric correction are available:
  - V1) ray-tracing utilizing the atmospheric reanalysis ERA5 (no assumption on the structure of the troposphere).
  - V2) utilizing Mapping Functions (MFs) and zenith delays (ZDs) from the GFZ-VMF1 which is based on ERA5. The contribution from the direct link neglected.
- Uncertainty of tropospheric correction is estimated to be 0.4% (Zus et al, 2012 Radio Sci.).
- PRETTY is single frequency → ionospheric correction through IRI model

Towards altimetry

Atmospheric corrections

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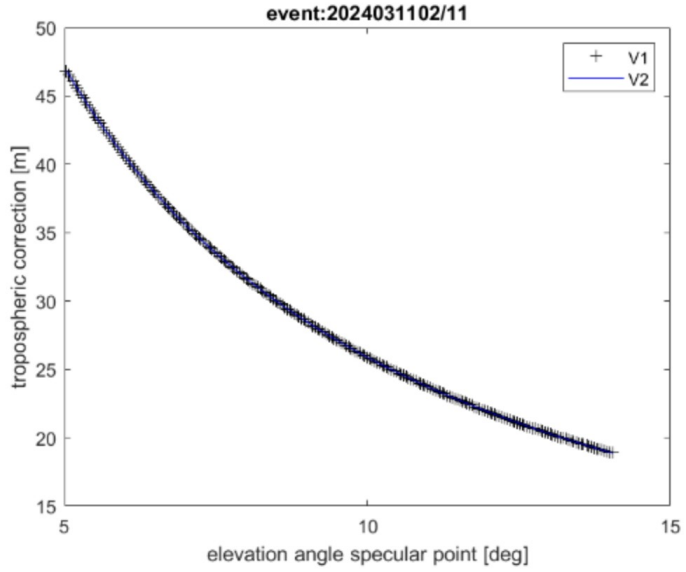
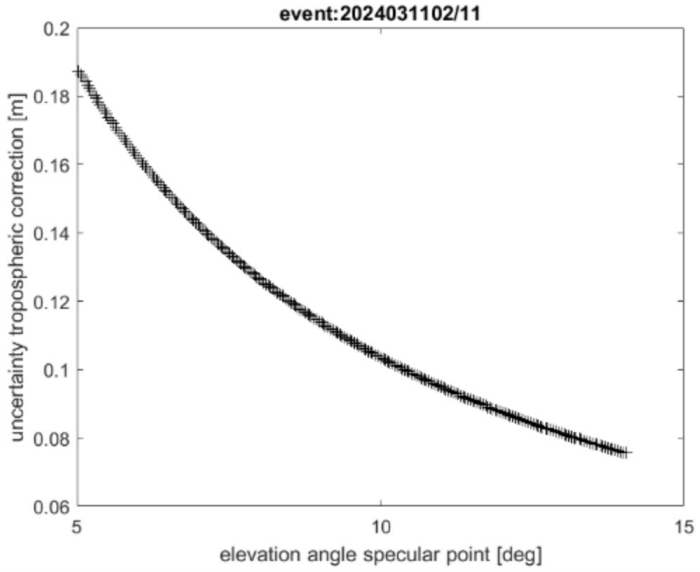
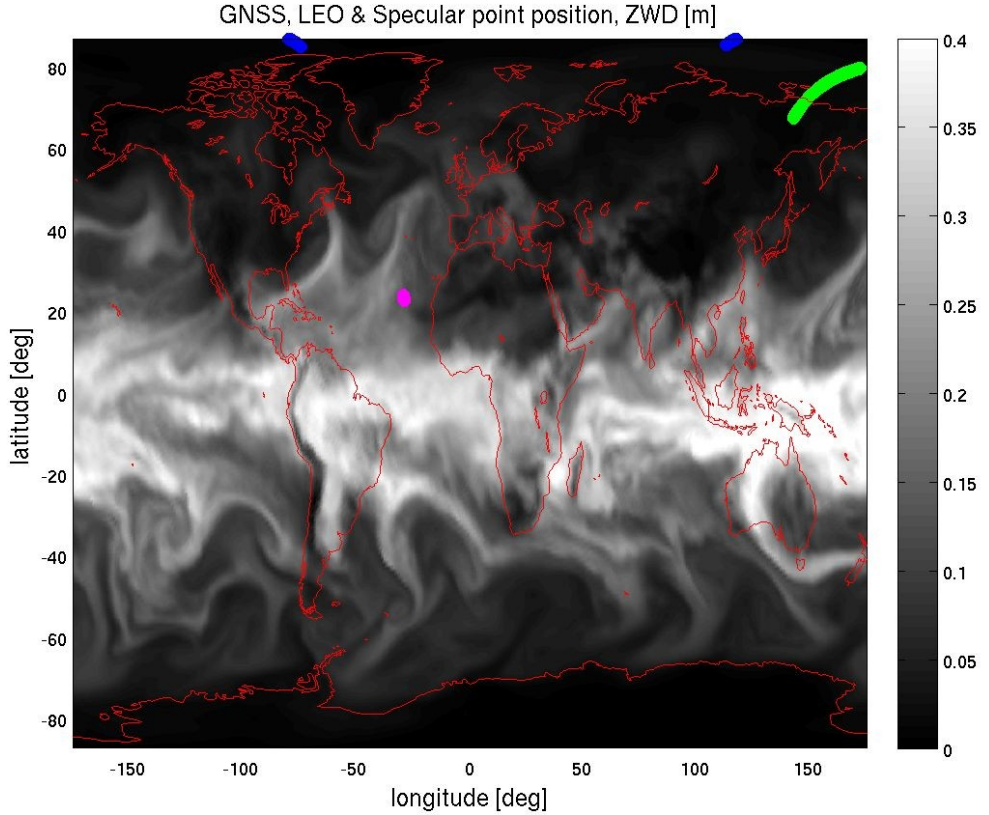
Example for PRETTY event on 11.3.2024 around 2UTC:

- The map shows ZWD from ERA5 and location of GNSS, LEO and specular point.







Towards altimetry
Atmospheric corrections

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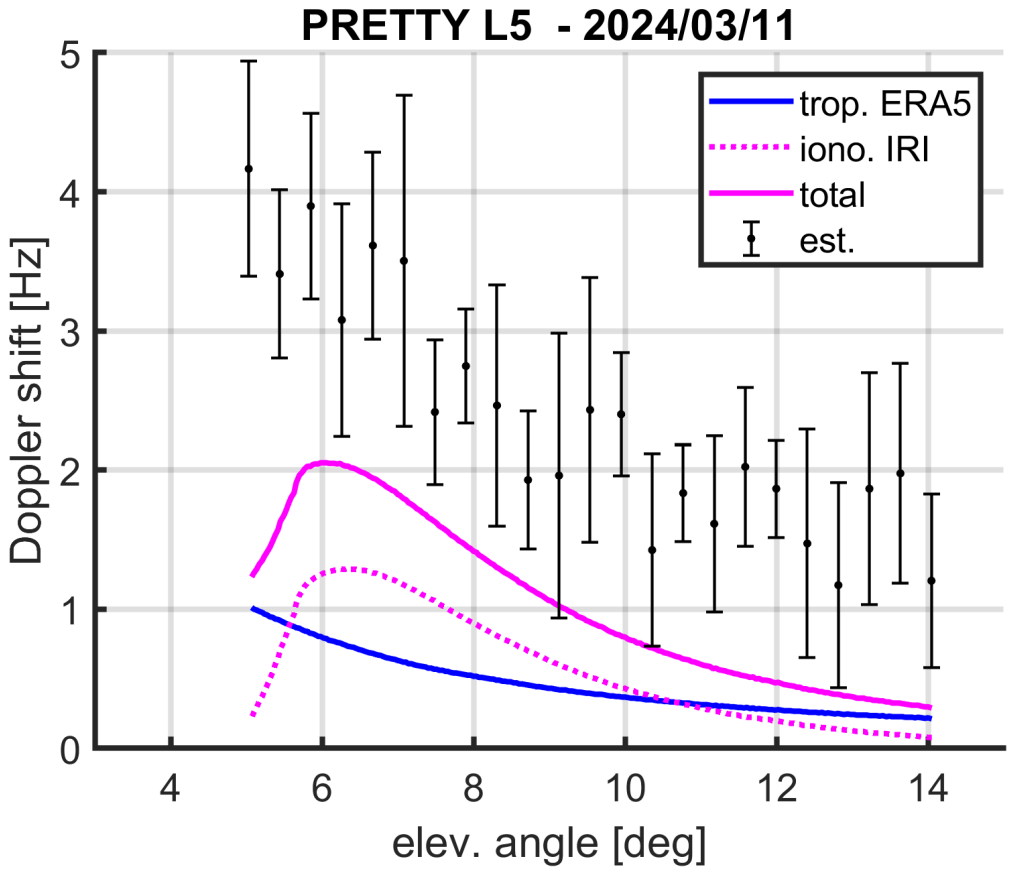
Example for PRETTY event on 11.3.2024 around 2UTC:

- Comparison between modelled atmospheric effects and actual PRETTY data



Towards altimetry

Conclusions and Future Steps

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- Coherent phase observations found in some of the tracks
- The carrier phase observations are still too noisy for phase unwrapping
  - To acquire more cGNSS-R tracks to improve the SNR
  - To optimize the onboard OL model
  - To make lower elevation angle measurements (e.g. down to 2 deg elevation angle)
  -
- Atmospheric corrections being implemented following 2 methods, 0.4% uncertainty

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Towards scatterometry

Status

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- PRETTY design focused on altimetric applications
- Current data/metadata still incomplete for proper power calibration (e.g., antenna gain pattern)
- BGA working towards producing complete metadata for scatterometry
- Once ready:
  - **Wind speed products**: Geophysical (NTNU) and Deep Learning (GFZ) approaches implemented
  - **Soil Moisture products**: Geophysical (NTNU) approach implemented

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Summary

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- GNSS-R payload first light shows very good results, **first ever L5/E5 iGNSS-R acquistions from space**
- Digital Elevation Map (DEM) allows for **measurements over land**
- Interference in E5/L5 are clearly visible, but countermeasures are already in place
- Payload proved capable to acquire **both iGNSS-R and cGNSS-R data**
- Segments of coherent carrier phase identified
- Still too noisy for altimetric retrievals --> Receiver configuration being adjusted (cGNSS-R, elevation range, OL model parameters)
- Atmospheric corrections in place

Thank you!

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