Building a comprehensive picture of sea surface, troposphere and ionosphere contributions in precise GNSS reflectometry from space

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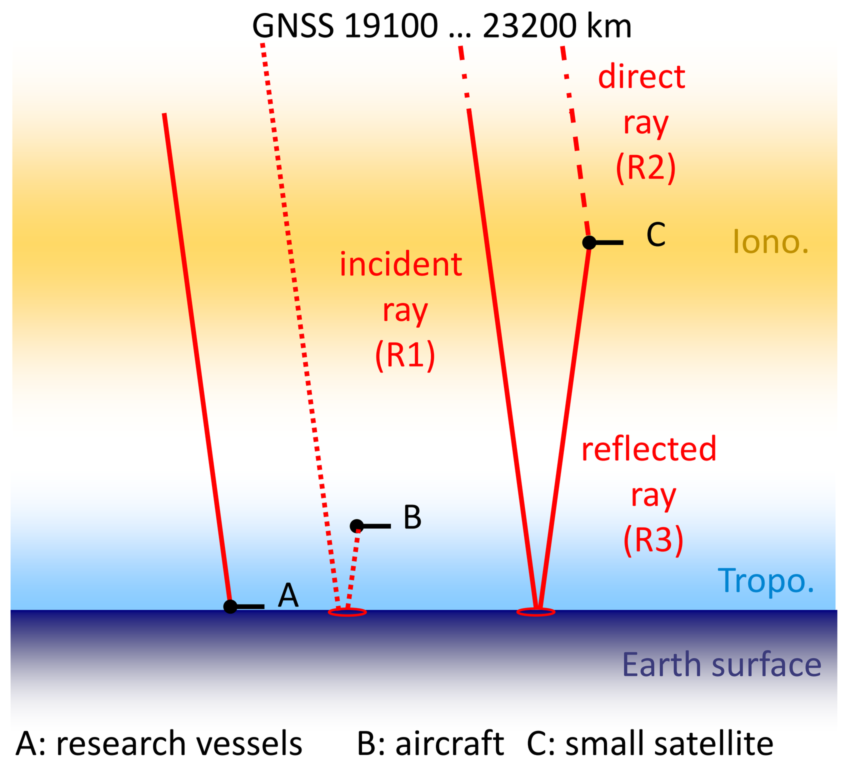


Fig. 1: signals path in GNSS reflectometry scenarios.

(A) Introduction and Goals

Earth-reflected signals of Global Navigation Satellite Systems (GNSS) are an opportunity for different geoscience applications. Corresponding studies contribute to the research field of GNSS reflectometry. In a consortium of science partners and industry, we conduct a reflectometry study on altimetric application of observations from small satellites. Here, we use data of the CyGNSS mission, based on earlier work [1], and we look out to PRETTY mission data [2].

A primary goal is the resolution of sea-surface height anomalies by phase-altimetric analysis. A secondary goal is focused on the detection of tropospheric and ionospheric impact that limit the altimetric performance. Variability in sea surface, troposphere and ionosphere conditions on rather small scales within the reflection track lengths (10 to 100 km) are of main interest.

We demostrate the processing concept (scheme to the right) for a CyGNSS example event in the Caribbean, for implementation see section (B) below.

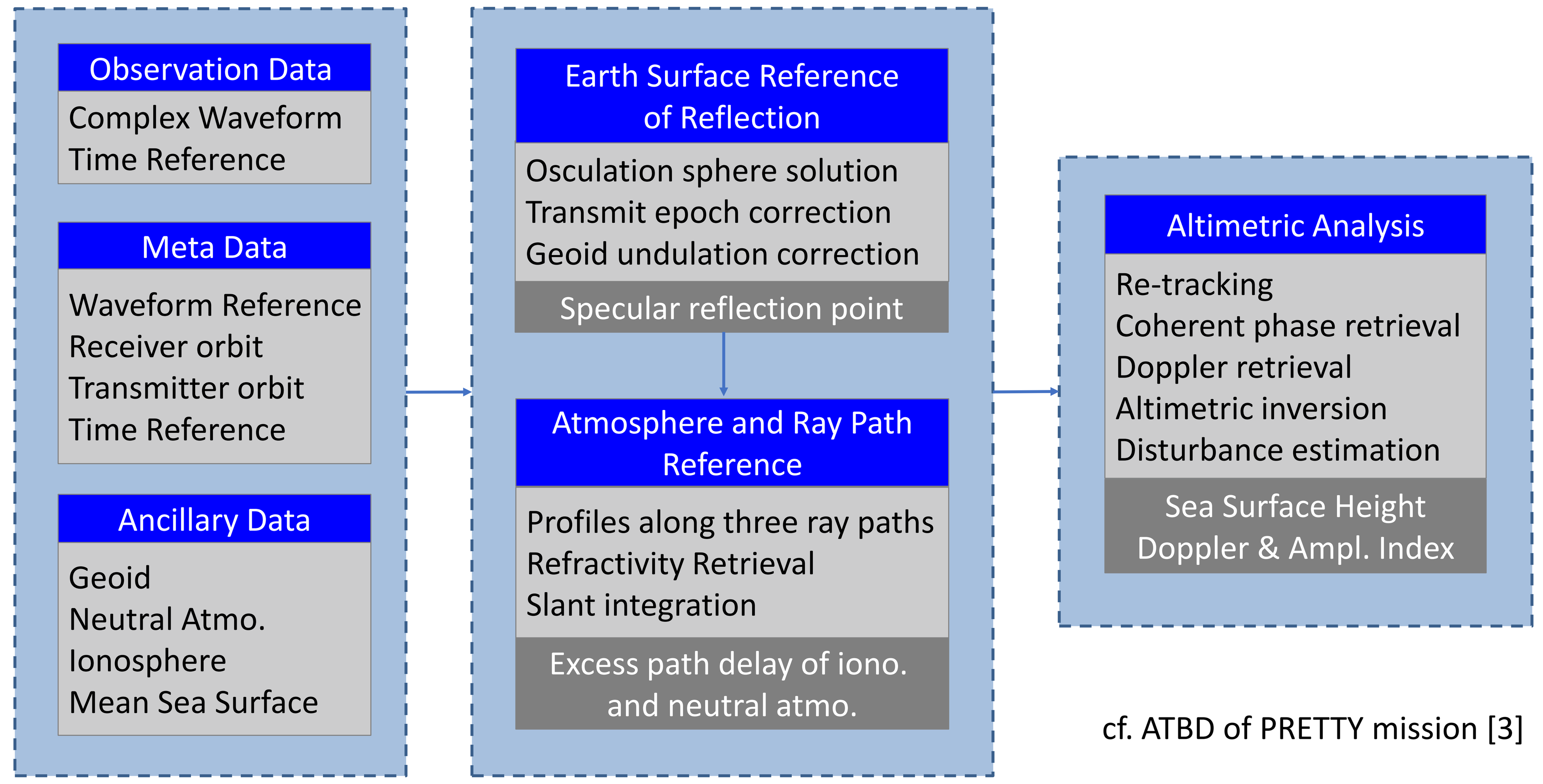


Fig. 2: scheme of altimetric processing based on PRETTY mission baseline document.

(B) Example Implementation

Observation Data

- Delay map of example event (Fig. 3, left)

Earth Surface Reference

- Reflection track of example close to Bahamas (Fig. 3, right)

Altimetric Analysis Results

- Sea surface height retrieval and atmosphere contribution for example event (Fig. 5)
- Detailed phase and Doppler analysis (Fig. 6)

Atmosphere and Ray Path Reference

- Neutral atmo. Refractivity and iono. electron density along the ray paths (Fig. 7)

(B.1) Observation Data and Earth Surface Reference

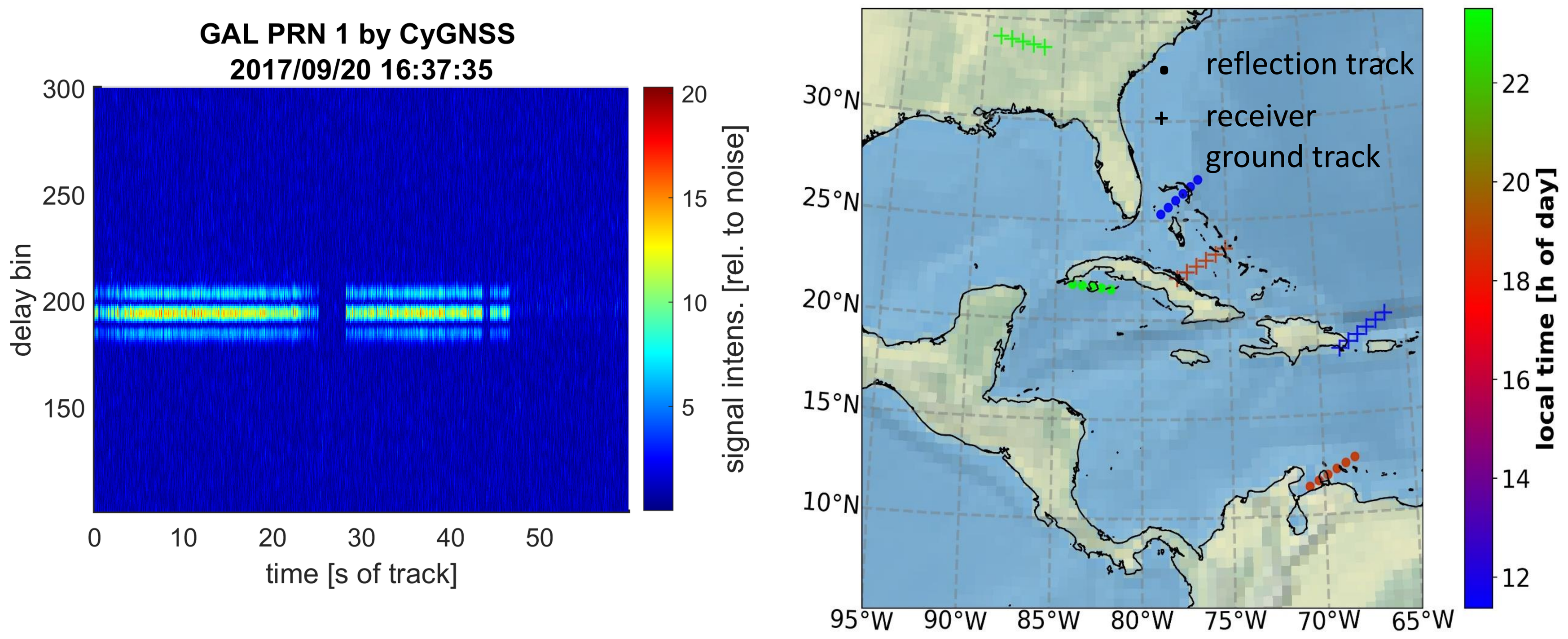


Fig. 3, left: delay map of CyGNSS example event close to Bahamas. Right: geodetic reference of three CyGNSS reflection events over the Caribbean (the Bahamas event in blue).

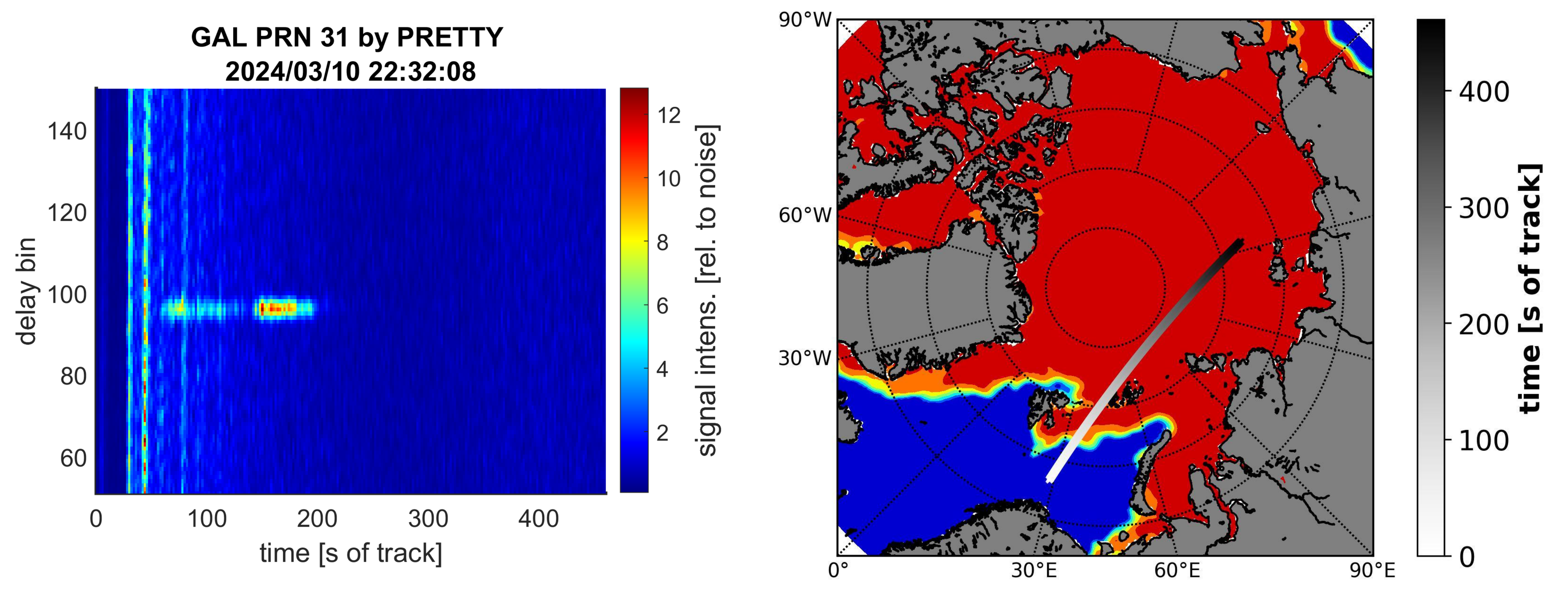


Fig. 4, left: delay map of PRETTY example event over the Arctic. Right: geodetic reference of the reflection track, starting over the open ocean (blue), within the first 100s the track reaches compact sea ice (red). First part over ice shows strong reflected signal intensity.

(C) Conclusion and Outlook

Sea Surface contributions

- Calm ocean areas, see Fig. 3, or sea-ice cover, see Fig. 4, are favourable for phase altimetry
- Altimetric analysis allows to resolve surface height anomelies, for example, due to geoid undulation, see Fig. 5

Atmospheric contributions

- Modeled delays of neutral atmo. and iono. are large, however rather constant, see Fig. 5
- Phase altimetric results are more sensitive to variations within the track
- Focus on disturbed atmosphere to come

(B.2) Altimetric Analysis and Atmosphere Reference

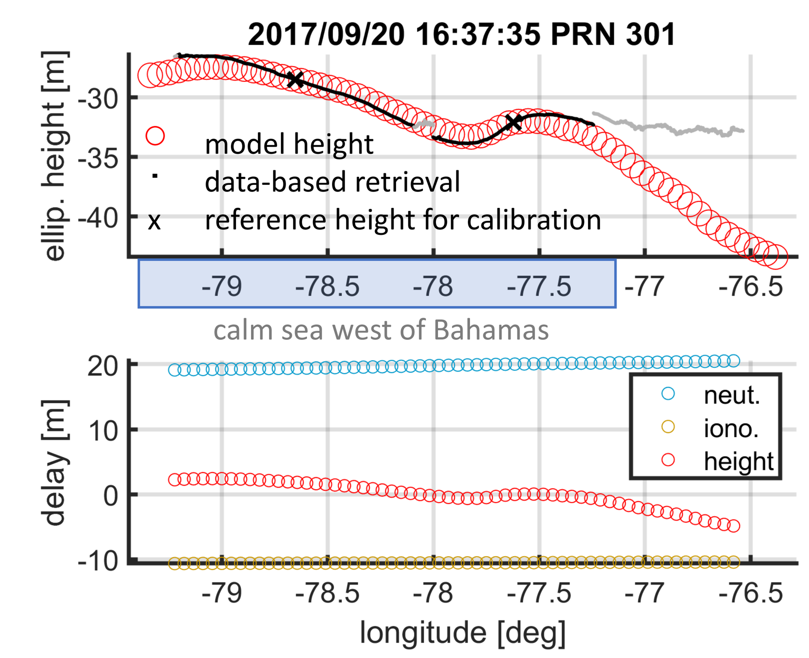


Fig. 5: phase altimetric results (upper panel); model-based contribution of neutral atmosphere, ionosphere and sea surface height (lower panel).

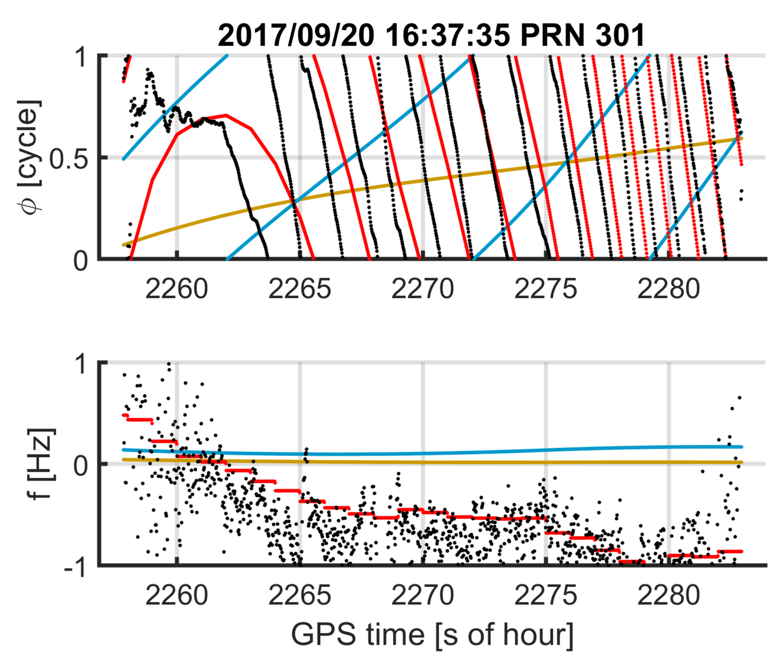


Fig. 6: zoom into coherent phase residual (upper panel) and derived Doppler (lower panel); observation (black) and model color-code as in Fig. 5.

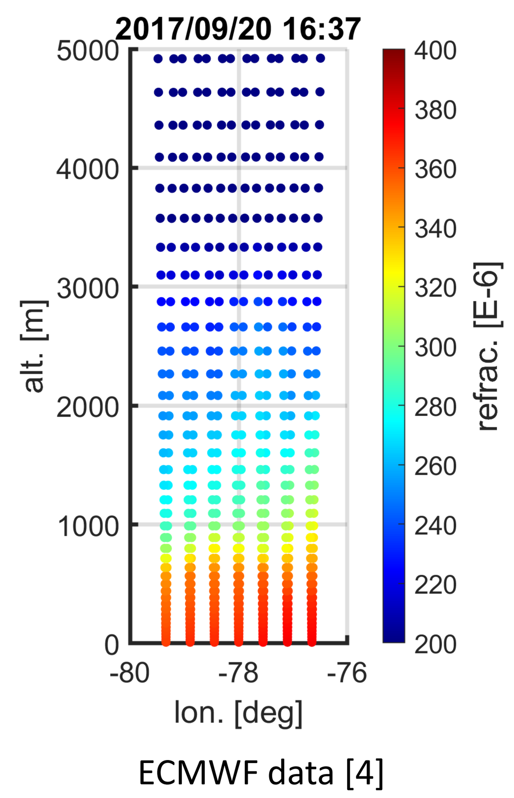
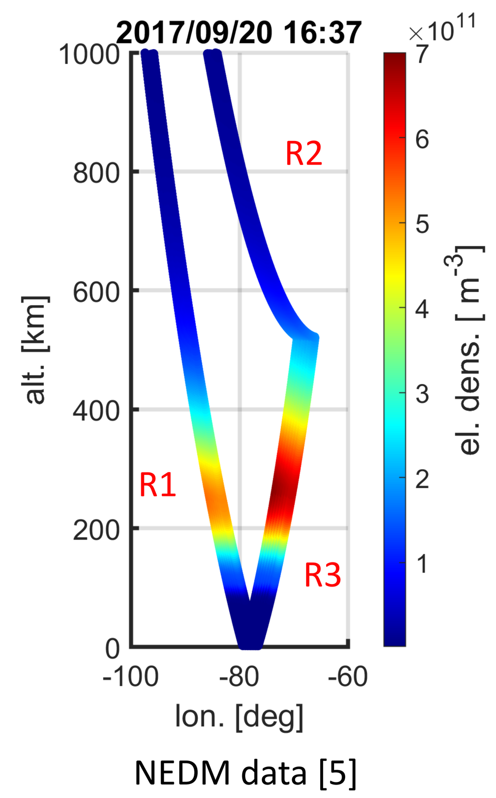


Fig. 7: projection of refractivity along ray paths for neutral atmosphere reference (to the left), electron density for ionosphere reference (to the right). Both panels show ray paths every 10s for the 60s event. The left panel comprises altitudes of highest refractivities in the lower troposphere (from reflection height to 5km). The right panel has altitudes up to 1000 km to cover high electron densities.



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