Atmospheric effects resolved in airborne GNSS reflectometry by data fusion processing

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Knowledge for Tomorrow

Outline

- Introduction
- Experiment
- Processing
- Results
- Conclusions

Introduction

Motivation: Sea state in coastal areas (surface roughness) and atmospheric sounding from GNSS – Reflectometry.

Objective: Possibility of detecting sea state variations in coastal areas from coherent airborne GNSS-R data using as a metric the Doppler spread and validate Tropospheric effects on reflected signals
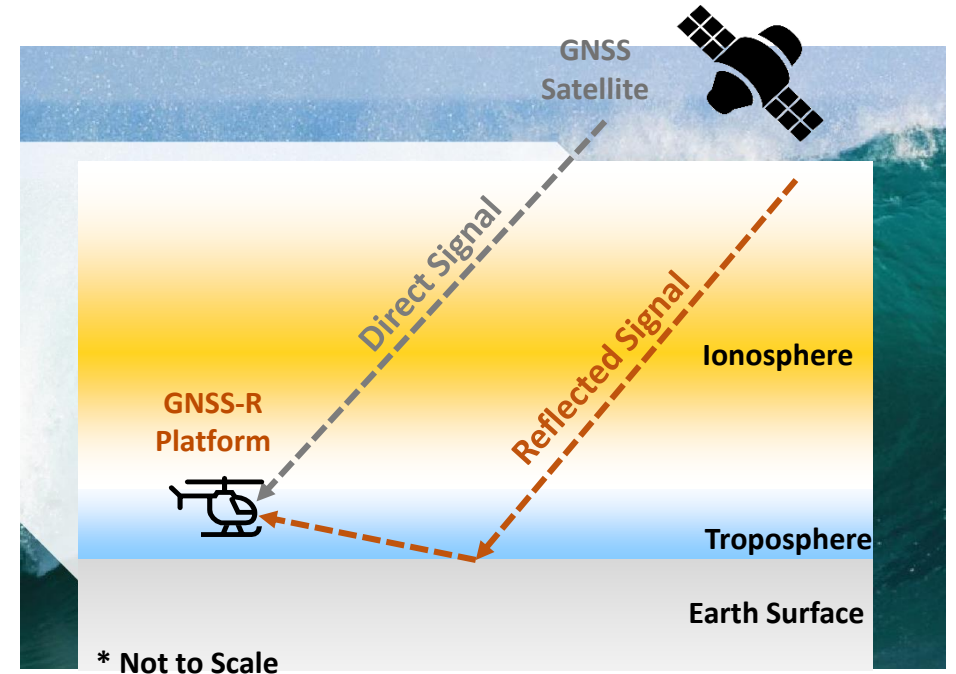

Approach:

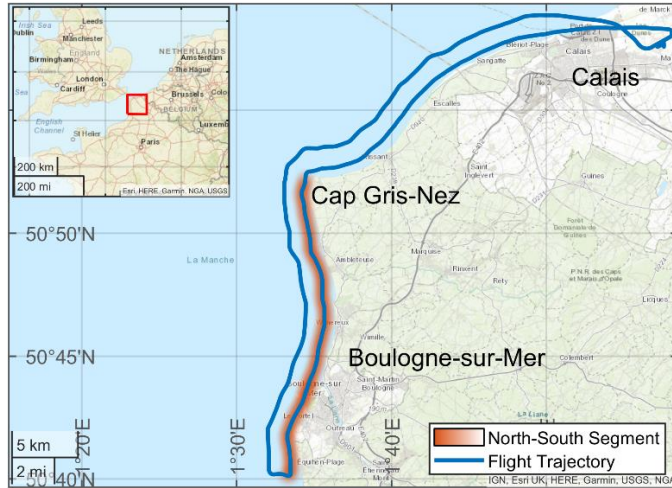| Tracking using a model-aided software receiver	Retracking of the reflected signal	PSD relative Doppler Shift.	Doppler Spread correlate ERA5 Model	Residual phase and Troposphere excess path model comparison

Experiment

Location: North Sea
Calais – Boulogne-sur-
Mer, France
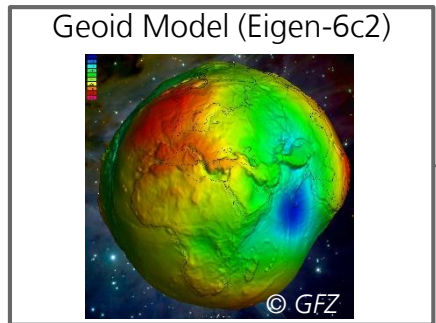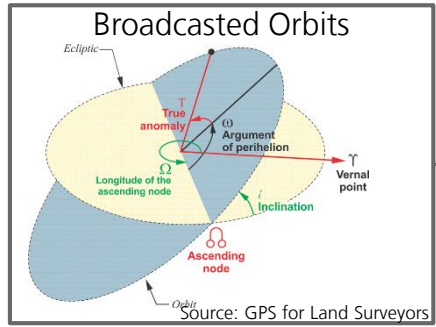**Number of flights:** 4
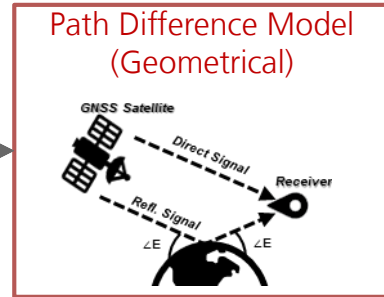**Date:** July 2019

~780 m

Setup:
Platform: Gyrocopter
1 - Dual-polarized antenna
2 - Front-end receiver (RHCP)
3 - Front-end receiver (LHCP)
Flight control Drone GPS+IMU

Processing

Data Fusion

Broadcasted Orbits

Source: GPS for Land Surveyors

Precise Trajectory

NovAtel
GrafNav Version 8.70

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Geoid Model (Eigen-6c2)

© GFZ

Path Difference Model (Geometrical)

GNSS Satellite
Direct Signal
Receiver
Refl. Signal
∠E ∠E

Signal Processing

Master Branch (Direct Signal)

Acquisition

Tracking

Slave Branch (Reflected Signal)

Model-aided Tracking
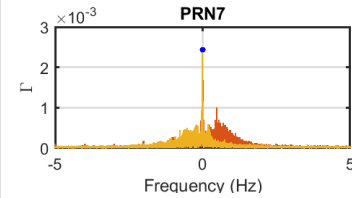
Filtering

Retracking
(Doppler & Phase Correction)

Kucwaj, J.-C., et. al. 2017

Validation

Power Spectral Density

PRN7

Doppler Shift
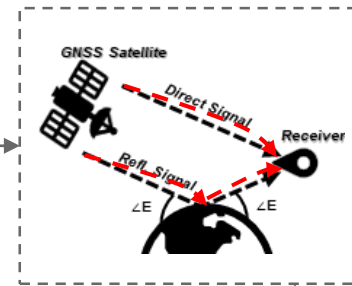
Doppler Spread

Doppler and Sea state

Doppler Spread

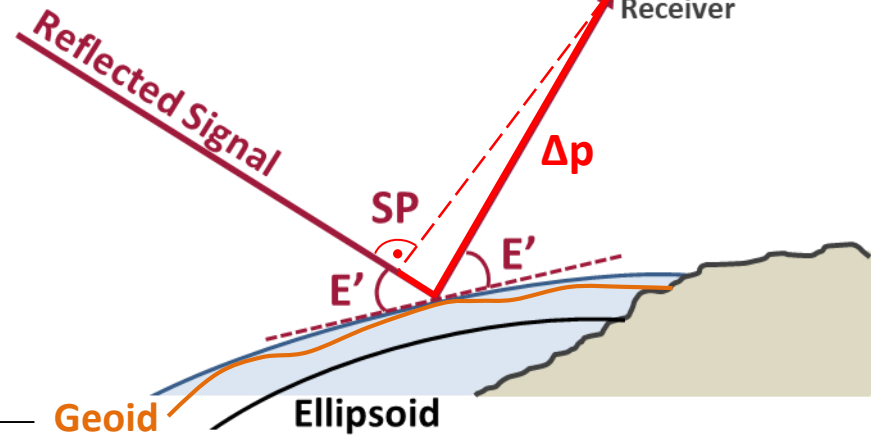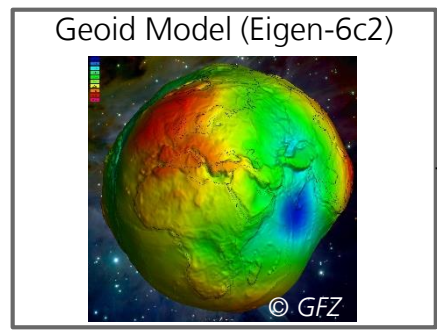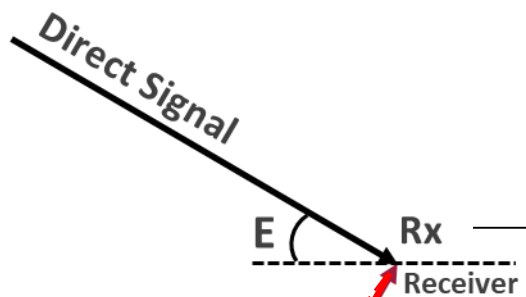Significant Wave Height
Wind Speed

IMPLEMENTED BY
ECMWF

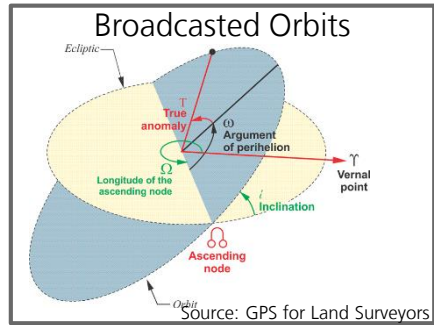Residual phase and Tropospheric residual Model

Residual Phase

GNSS Satellite
Direct Signal
Receiver
Refl. Signal
∠E ∠E

International Standard Atmosphere (ISA)

DLR

Processing > Path Difference Model

Broadcasted Orbits

Source: GPS for Land Surveyors

Precise Trajectory

GrafNav
Version 8.70

Tx

GNSS Satellite

Direct Signal

E

Rx
Receiver

Reflected Signal

Δp

SP

E'   E'

Geoid Model (Eigen-6c2)

© GFZ

Geoid   Ellipsoid

Semmling et. al 2012

Processing > Path Difference Model
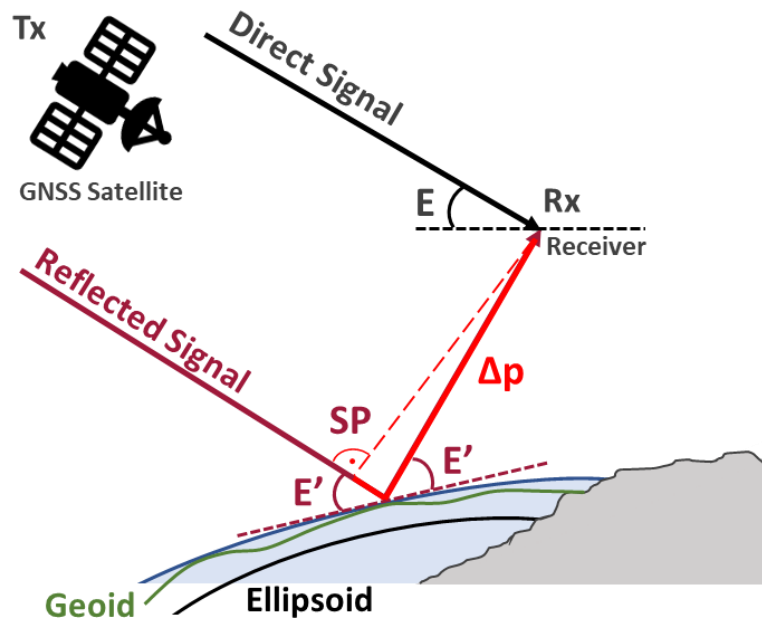
2019/07/17
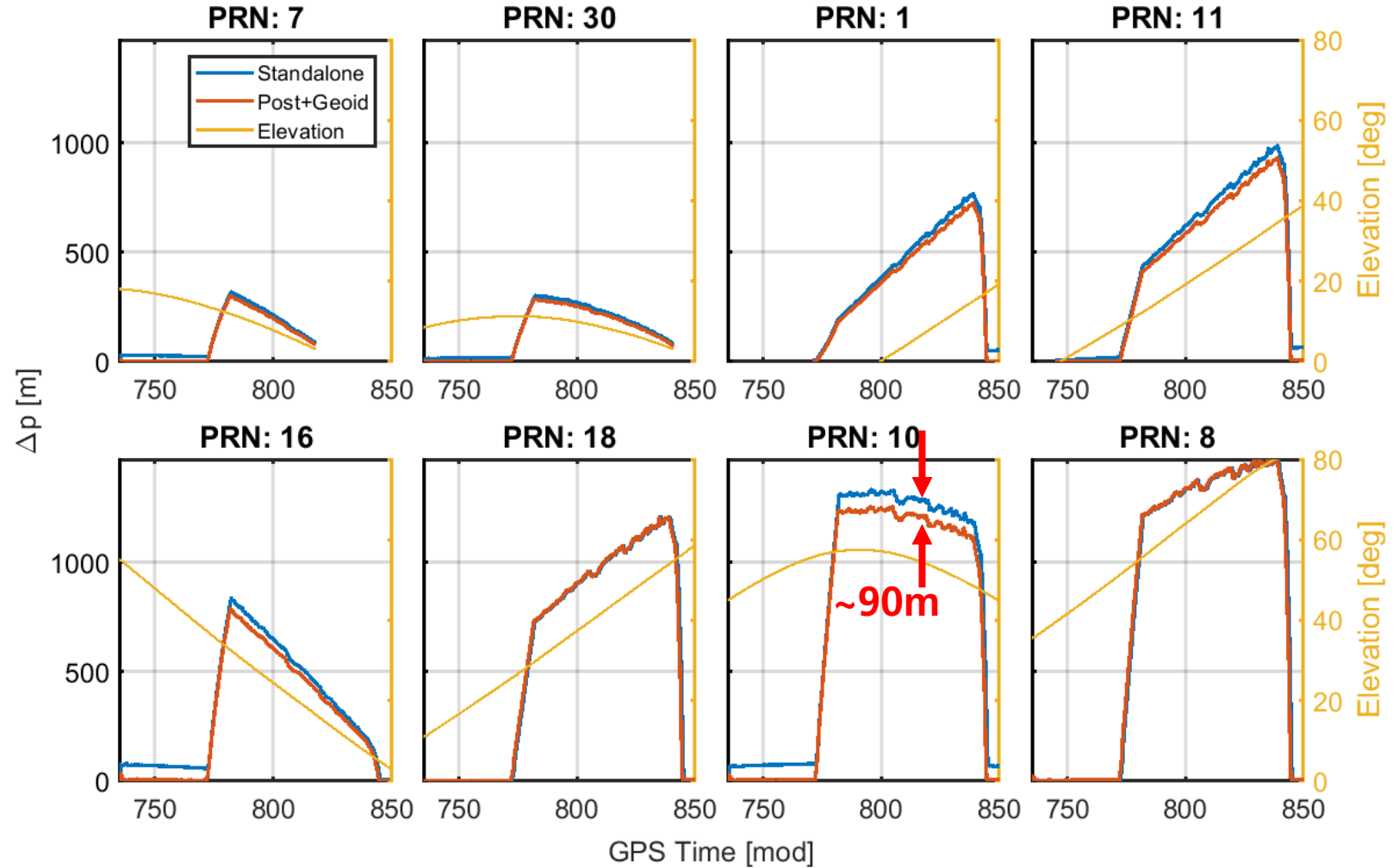
Processing > Retracking

$$\gamma^R = \gamma^{filt}\,\gamma^{\Delta p^*}$$
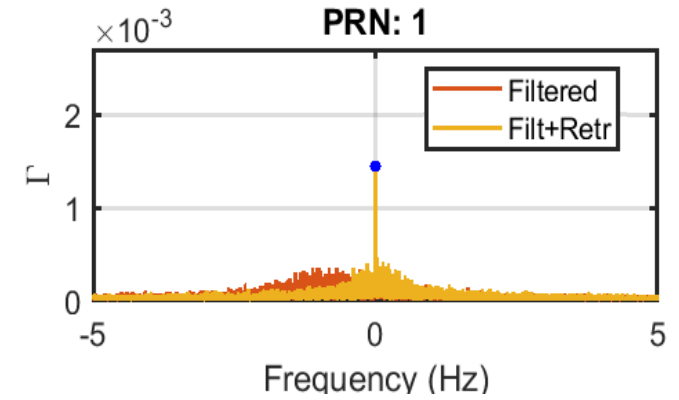
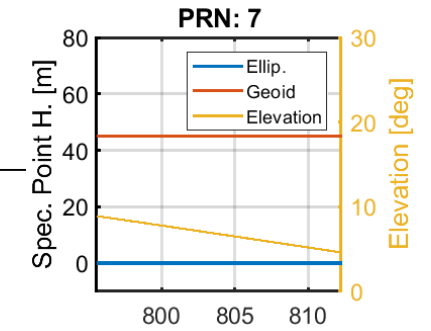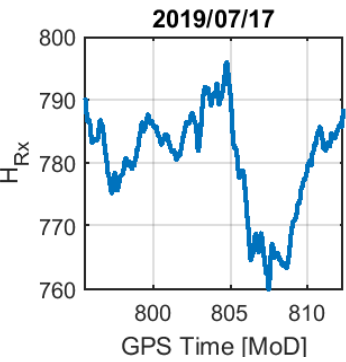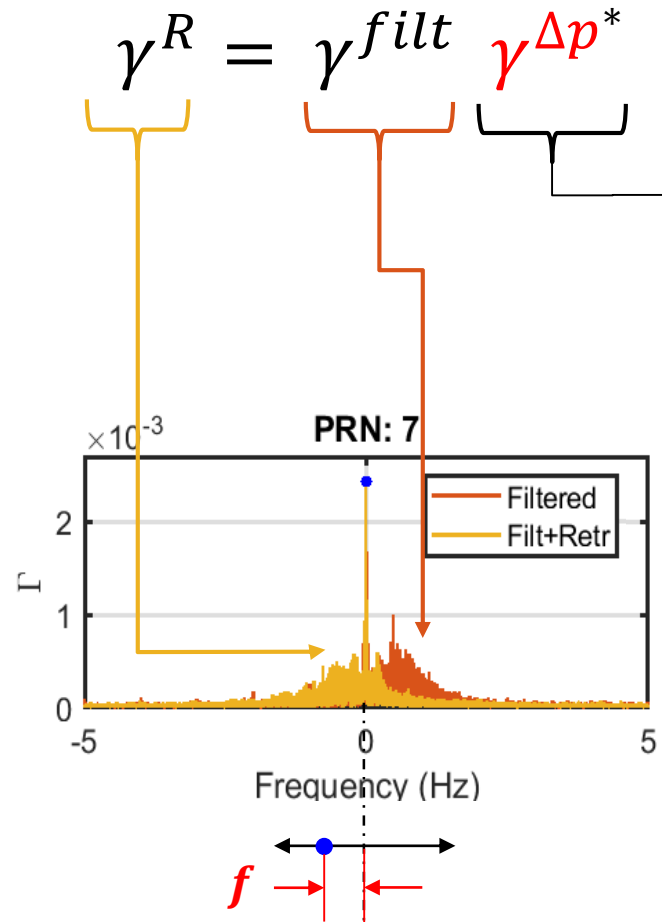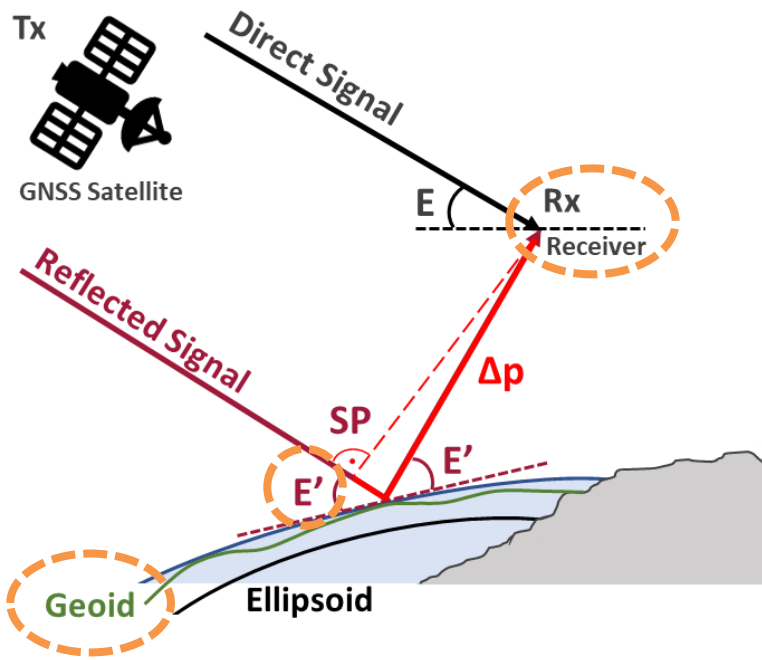# Results
Residual Doppler Spread

2019/07/12	2019/07/15	2019/07/17	2019/07/19
Sea state from ECMWF | ERA5 Model			
SWH: 0.30 m - WS: 5.49 m/s	SWH: 0.58 m - WS: 4.29 m/s	SWH: 0.26 m - WS: 2.92 m/s	SWH: 0.55 m - WS: 6.50 m/s
Power vs. Doppler shift (f) Spectrum (10s)			
Mapped Doppler Spread (σ_{fv}) (120s)			
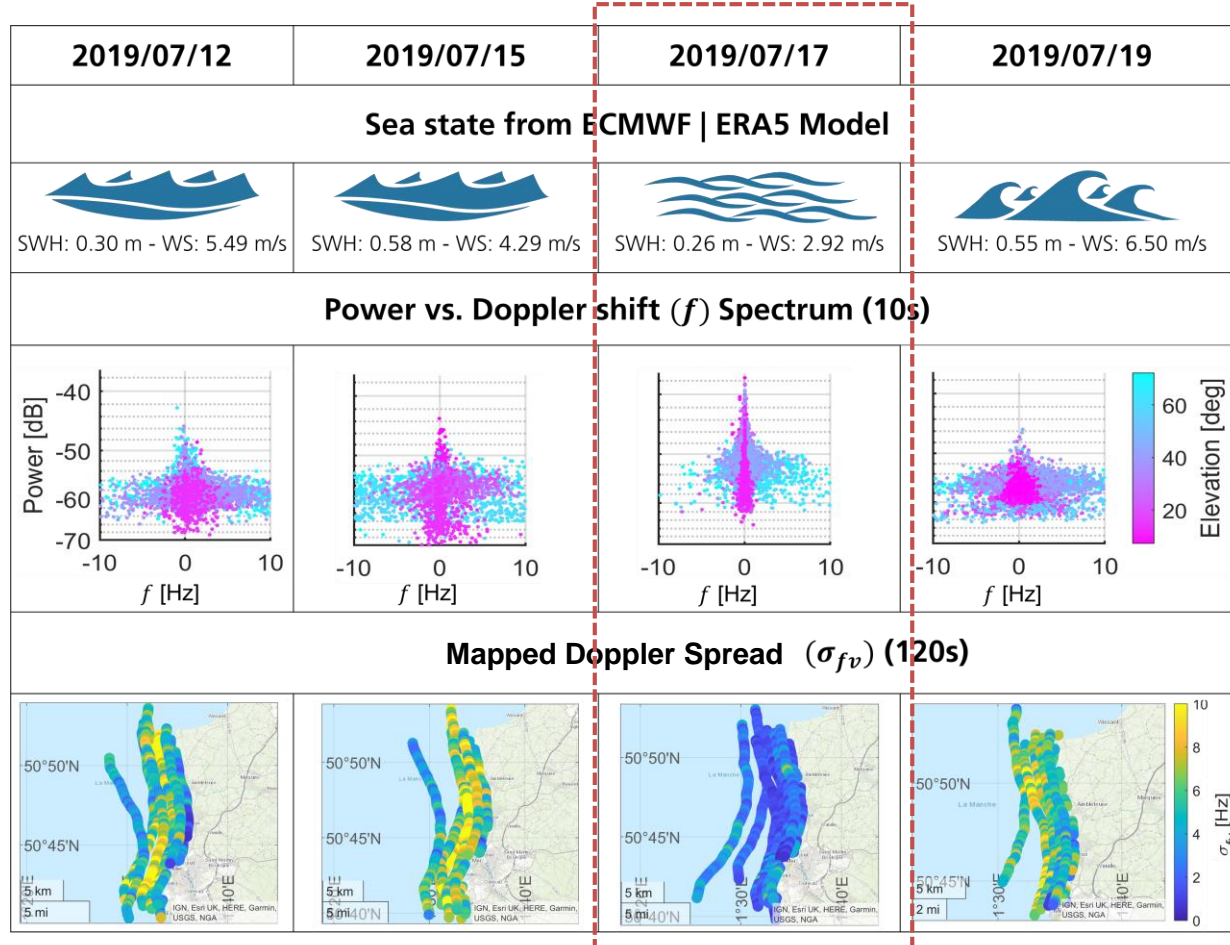
Correlation between Sea State and Mapped Doppler Spread σ_{fv}	
Wind Speed	0.88
SWH	0.75

Doppler Spread Distribution

0.5 Hz
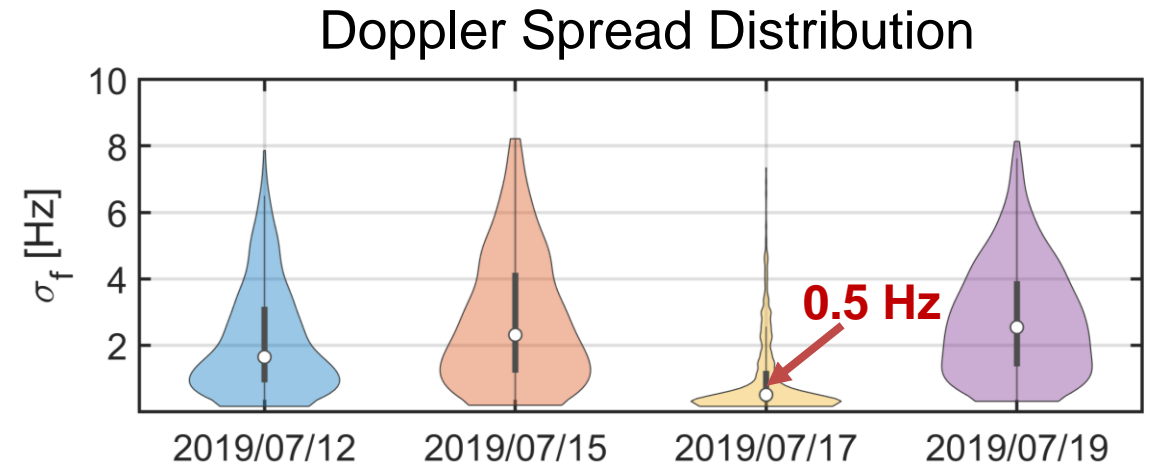
Results
Residual Carrier phase
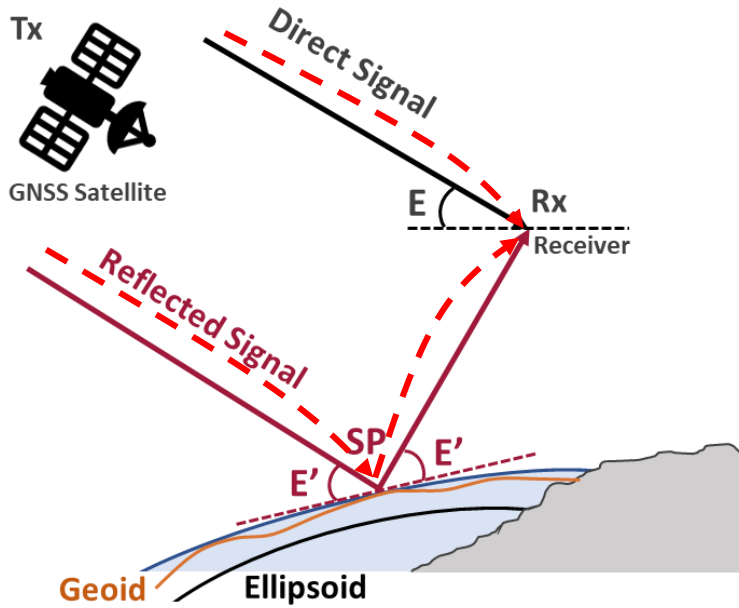
2019/07/17

SWH: 0.26 m - WS: 2.92 m/s

$$\Delta_{tro} = \Delta p_{tro} - \Delta p$$

International Standard Atmosphere (ISA)

Geometrical

Semmling et. al 2012

Results
Residual Carrier phase

2019/07/15

SWH: 0.58 m - WS: 4.29 m/s

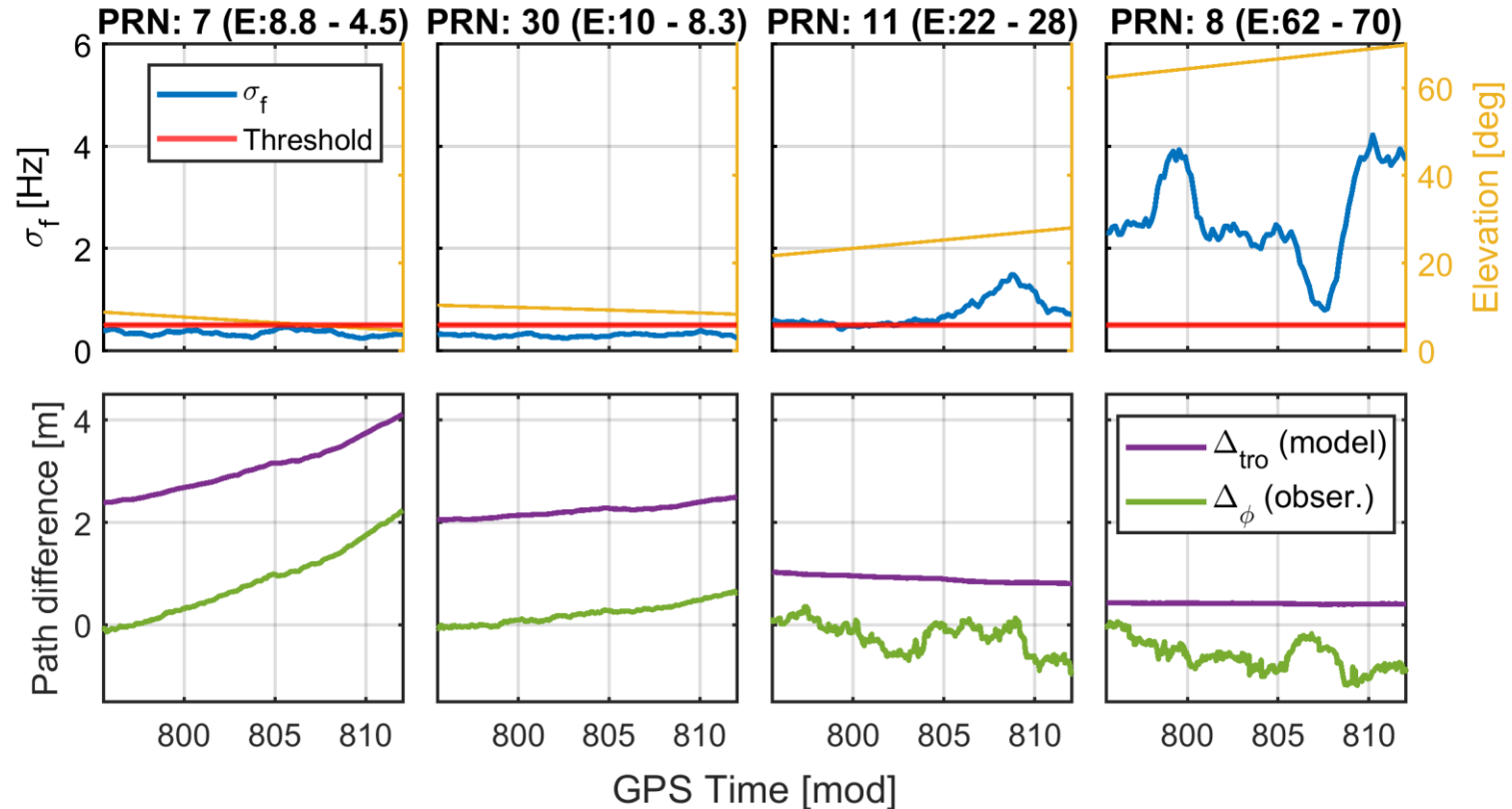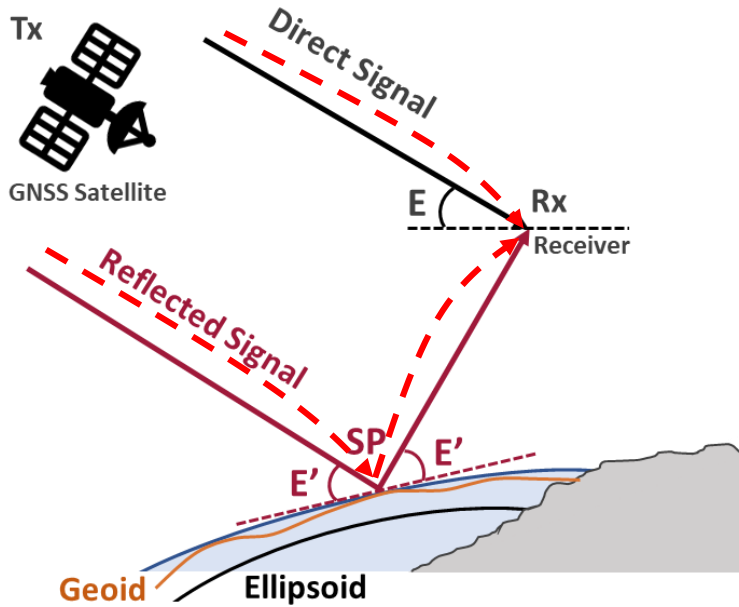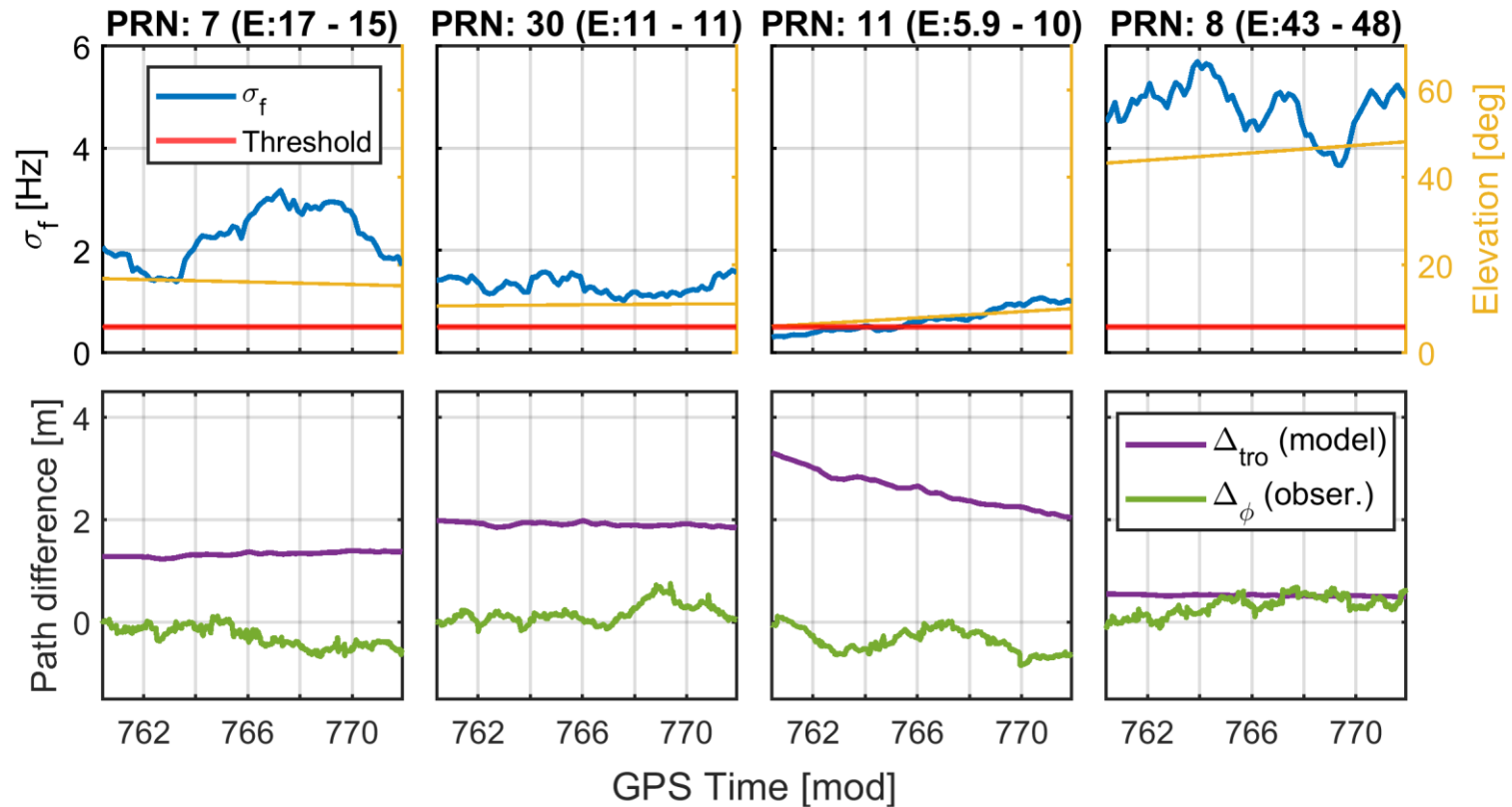$$\Delta_{tro} = \Delta p_{tro} - \Delta p$$

International Standard Atmosphere (ISA)

Geometrical

Semmling et. al 2012

Conclusions and Outlook

- The results show that **loss of coherence** in phase observations is accompanied by a **Doppler spread of more than 0.5 Hz**. The results also indicate a **major influence of sea state** in this respect depending on the elevation angle.

- **Only 15%** of the estimates correspond to **coherent observations**. Therefore, even under coastal conditions, the **coherent measurements from airborne platform are limited**.

- The comparison of residual phase and excess path model (**tropospheric contribution**) shows agreement. Future studies may use this **sensitivity of coherent reflectometry observations** to troposphere contribution for the retrieval of related parameters, like **water vapor.**

- Satellite mission **PRETTY** is currently prepared to extend this study to possibilities of **coherent reflectometry for altimetric** and **atmosphere sounding from space** purposes.
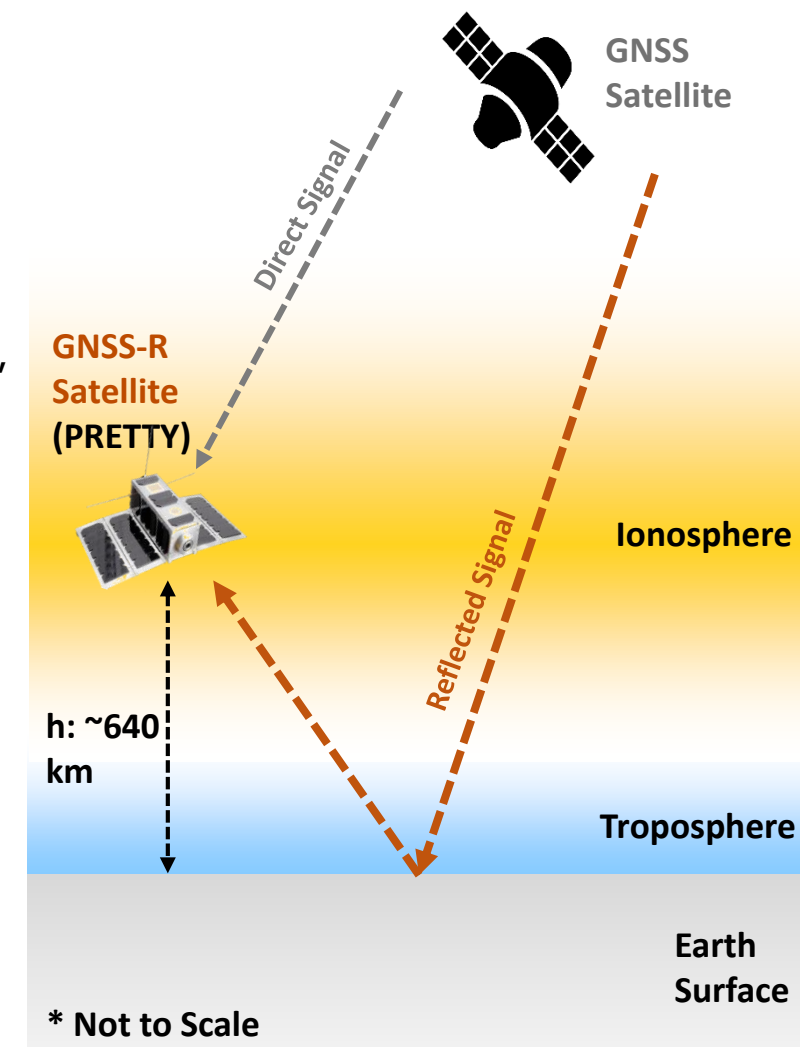
Thank you!

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