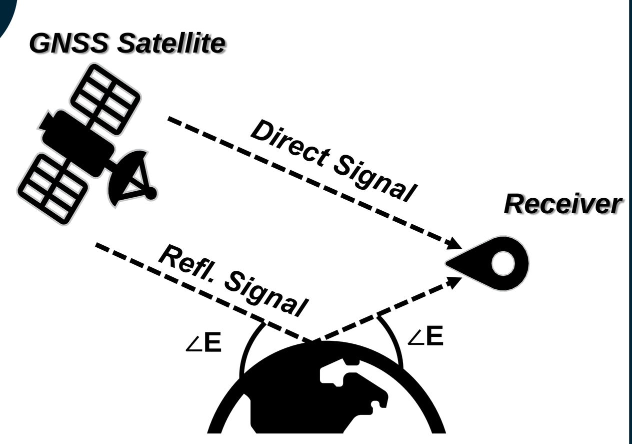
living planet symposium | BONN 2022

Sea state dependent Doppler spread as a limit of coherent GNSS reflectometry from an airborne platform.

M. Moreno[1], M. Semmling[1], G. Stienne[2], W. Dalil[2], M. Hoque[1], J. Wickert[3,4], S. Reboul[2].

[1]Institute for Solar-terrestrial Physics (DLR-SO), DE, [2]Université Littoral Côte d'Opale (ULCO), FR, [3]German Research Centre for Geosciences (GFZ), DE, [4]Technische Universität Berlin, DE.

Introduction

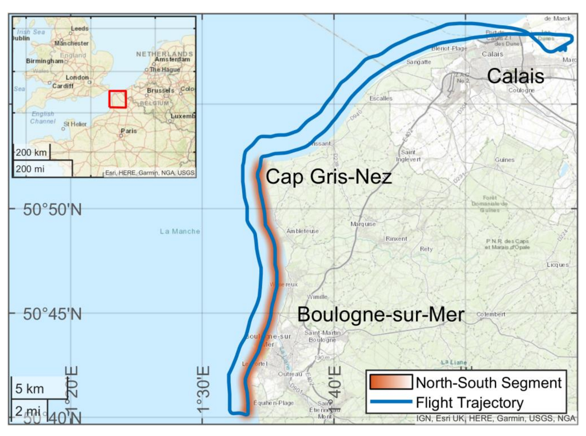


Technique: GNSS Reflectometry
GNSS – R. Bistatic system that allows to retrieve Earth surface properties from the analysis of the Direct and Reflected signals.

Question: Possibility of detecting sea state variations in coastal areas from coherent airborne GNSS-R data using as a metric the Doppler spread.

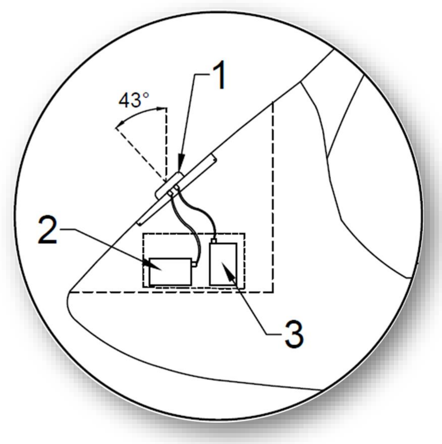
Approach: Tracking and retracking of the reflected signal by means of a model-aided software receiver. Reflected signal in Power Spectral Density (PSD) representation to retrieve power and relative Doppler shift (f). Estimation of Doppler Spread (σ_f) to correlate with sea state parameters from ancillary data (ECMWF | ERA 5). Residual phase and σ_f limit as indicator of GNSS-R observations coherence.

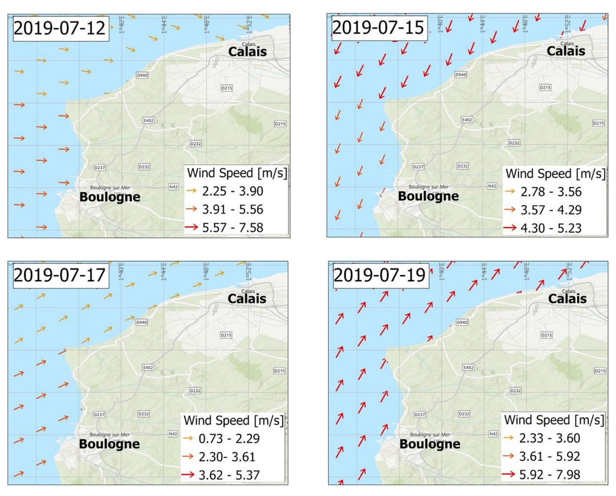
Experiment and Processing



Location: North Sea
Calais – Boulogne-sur-Mer, France
Flight height: ~750m
Number of flights: 4
Date: July 2019

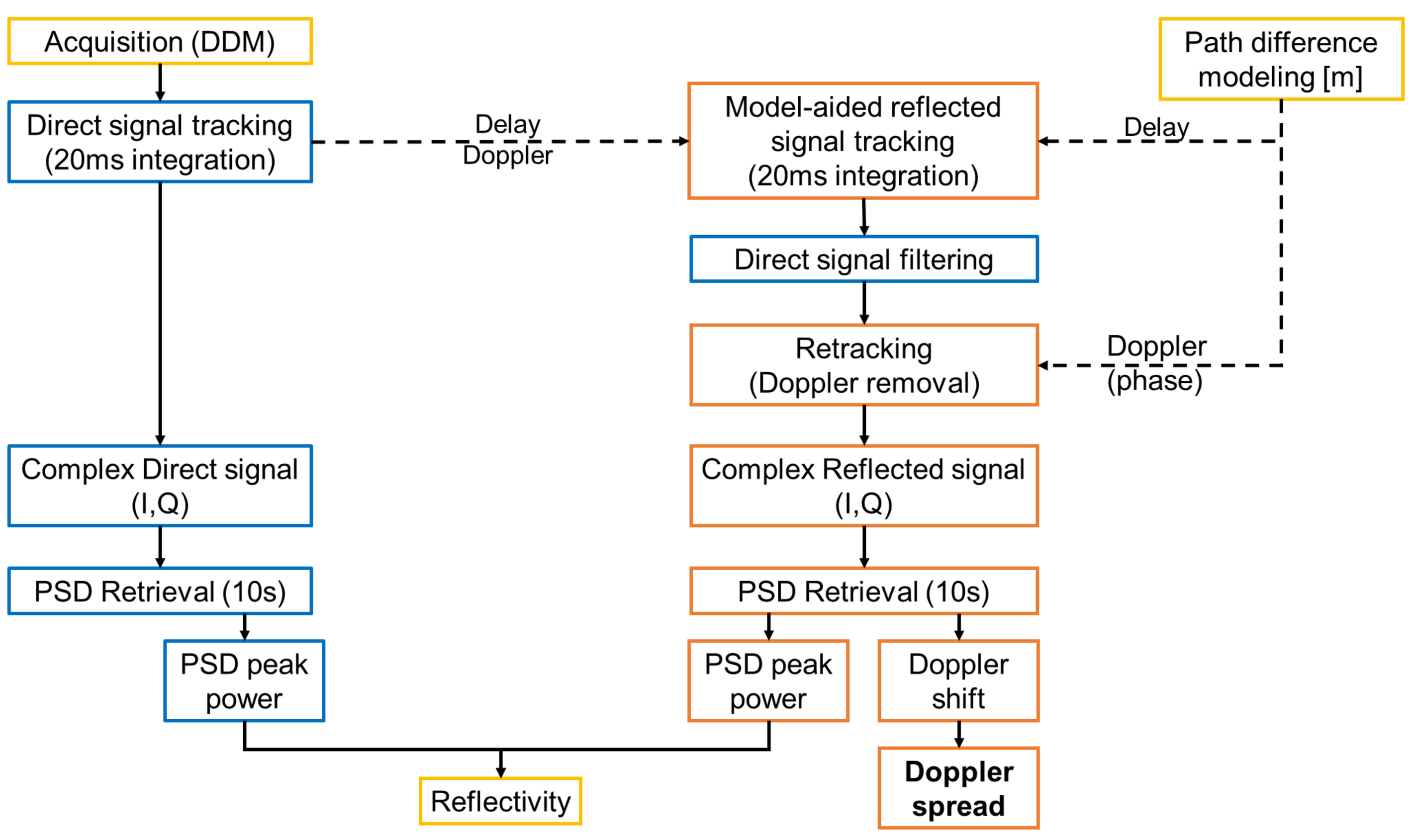
Setup:
Platform: Gyrocopter
1 - Dual-polarized antenna
2 - Front-end receiver (RHCP)
3 - Front-end receiver (LHCP)
Flight control Drone GPS+IMU





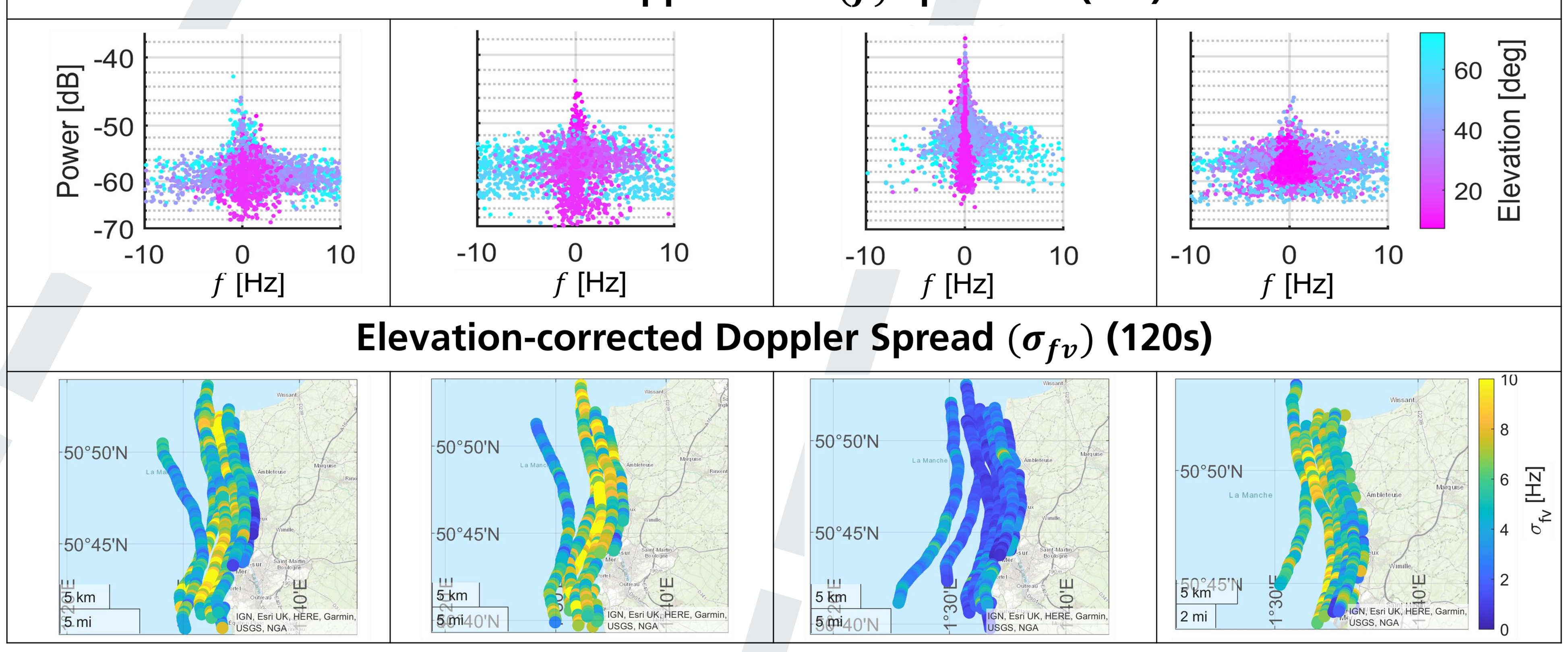
Ancillary data:
ECMWF | ERA 5 Reanalysis.
- Significant Wave Height (SWH)
  Spatial resolution: 50 km
- Wind Speed (WS)
  Spatial resolution: 25 km

Processing Flowchart:



Results

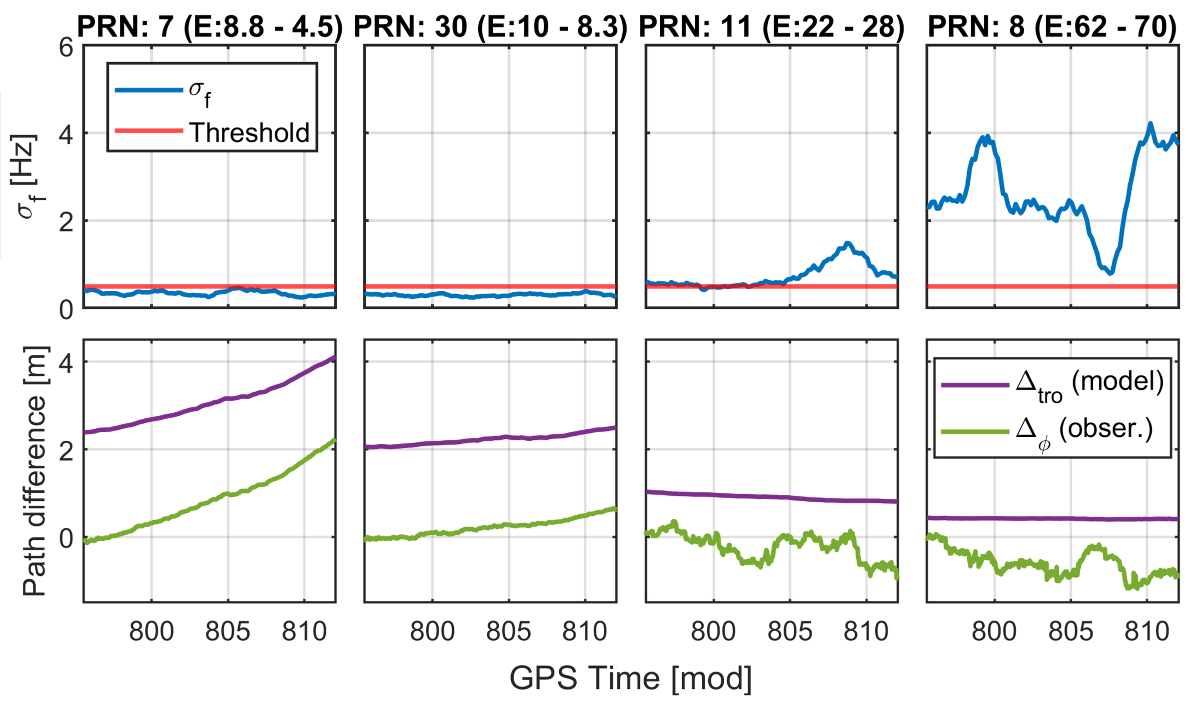
2019/07/12	2019/07/15	2019/07/17	2019/07/19
Sea state from ECMWF | ERA5 Model			
SWH: 0.30 m - WS: 5.49 m/s	SWH: 0.58 m - WS: 4.29 m/s	SWH: 0.26 m - WS: 2.92 m/s	SWH: 0.55 m - WS: 6.50 m/s



Correlation between Sea State and Doppler Spread			
Parameter ERA5	$E \leq 10°$	$10 < E \leq 30°$	$E > 30°$
Wind Speed	0.88	0.66	0.58
Significant Wave Height	0.75	0.58	0.56

Doppler spread over time at the lowest sea state (2019/07/17). A threshold of 0.5 Hz is found in the σ_f at satellites with low elevation angles ($E \leq 10°$).

Observations below the σ_f threshold, are accompanied by coherent residual phase Δ_ϕ. The latter agrees with the tropospheric residual model Δ_{tro}, computed from ray-tracing approach.



Conclusions

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 followed by 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. Alternative antenna(s) setup e.g. zenith- and nadir-looking array may contribute capture the direct and reflected signals improving the final results.

The comparison of phase residuals 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.

Literature
- Kucwaj, J.-C.; Reboul, S.; Stienne, G.; Choquel, J.-B.; Benjelloun, M. Circular Regression Applied to GNSS-R Phase Altimetry. Remote Sensing 2017, 9, doi:10.3390/rs9070651.
- Semmling, A.M.; Wickert, J.; Schön, S.; Stosius, R.; Markgraf, M.; Gerber, T.; Ge, M.; Beyerle, G. A Zeppelin Experiment to Study Airborne Altimetry Using Specular Global Navigation Satellite System Reflections. Radio Science 2013, 48, 427–440, doi:10.1002/rds.20049.
- Semmling, A.M.; Beckheinrich, J.; Wickert, J.; Beyerle, G.; Schön, S.; Fabra, F.; Pflug, H.; He, K.; Schwabe, J.; Scheinert, M. Sea Surface Topography Retrieved from GNSS Reflectometry Phase Data of the GEOHALO Flight Mission. Geophysical Research Letters 2014, 41, 954–960, doi:10.1002/2013GL058725

Contact email: mario.moreno@dlr.de

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