Norwegian University of Science and Technology

On the Impact of Sea State on GNSS-R Polarimetric Observations

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Objective

Analysis of the response of polarimetric GNSS-Reflectometry observations to different sea states

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Main Dataset

- Ground-based coastal GNSS-R observations
- Time span of the data: one year, from Jan to Dec 2016
- Sampling interval: 10 second

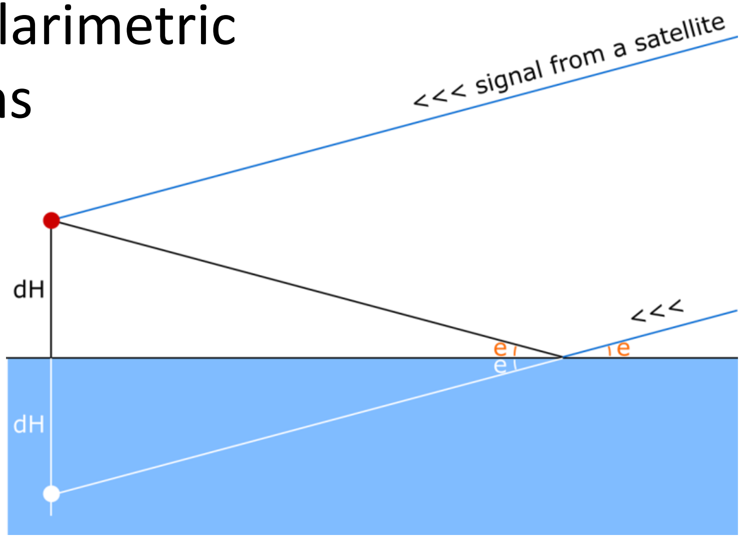
Ancillary Datasets

- Water temperature
- Daily estimate of salinity
- Wind speed

} To be used in a model to estimate permittivity

Experiment setup

- Zenith-looking master antenna for direct signal tracking
- Two side-looking RHCP and LHCP separate antennas to perform polarimetric observations
- About 3 m above sea level



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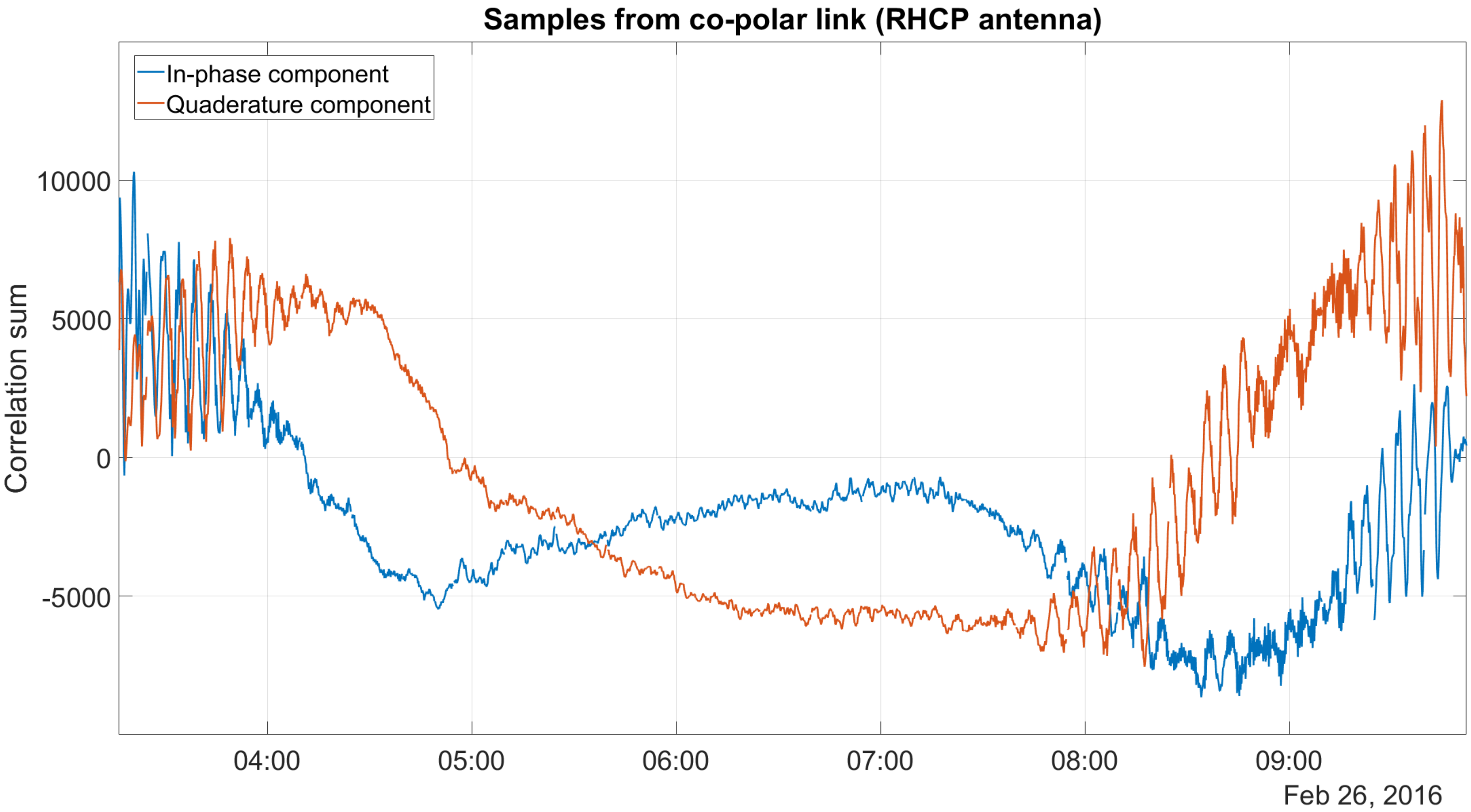
Method

- Coherent in-phase and quadrature (I,Q) correlation sums are provided by the receiver - **data level 0**

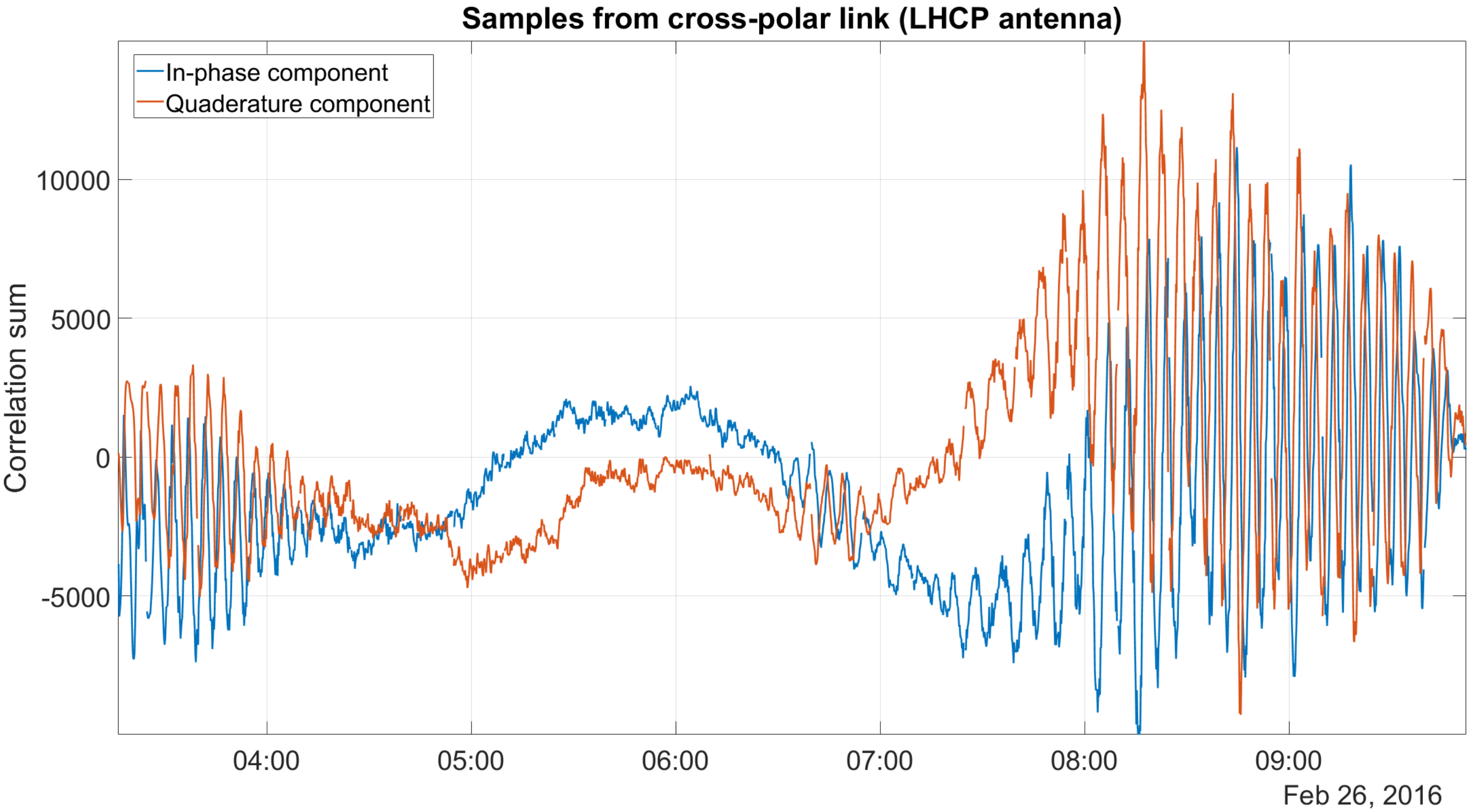
- Reflected and direct signal powers from RHCP and LHCP samples are combined in three power ratios - **data level 1**

- Ratio estimates are inverted to sea surface roughness based on the permittivity of water calculated using ancillary data - **data level 2**

Examples of the data level 0 from the receiver



Examples of the data level 0 from the receiver



Processing Flow:

0.1 Hz In-phase and quadrature samples from RHCP and LHCP links

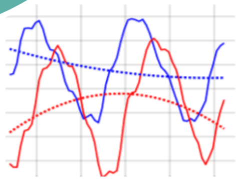
Power ratios from the estimates of the direct and reflected signals' power

Roughness estimates using a polarization-independent model

Direct (P1) $I_{slv} + iQ_{slv} = (I_{drc} + iQ_{drc})$
$+$
Reflected $(I_{rfl} + iQ_{rfl})$

P2: cross-polar link - LHCP,
P3: co-polar link - RHCP

Power estimates using:



Polynomial fit $P_1 = G_d^{right} P_0$

Lomb-Scargle Periodogram
$$\begin{cases} P_2 = G_d^{left} \left|R^x\right|^2 W_s^2 S_2^2 P_0 \\ P_3 = G_d^{right} \left|R^c\right|^2 W_s^2 S_3^2 P_0 \end{cases}$$

G: gain, R: Fresnel reflection coeff., W: power loss due to insufficient tracking of reflected signals, S: roughness, P0: incoming reference power

$$\left.\begin{aligned} P_{21} &= \left|R^x\right|^2 \left|S_2\right|^2 \\ P_{31} &= \left|R^c\right|^2 \left|S_3\right|^2 \\ P_{23} &= \frac{\left|R^x\right|^2}{\left|R^c\right|^2} \left|S_{23}\right|^2 \end{aligned}\right\}$$

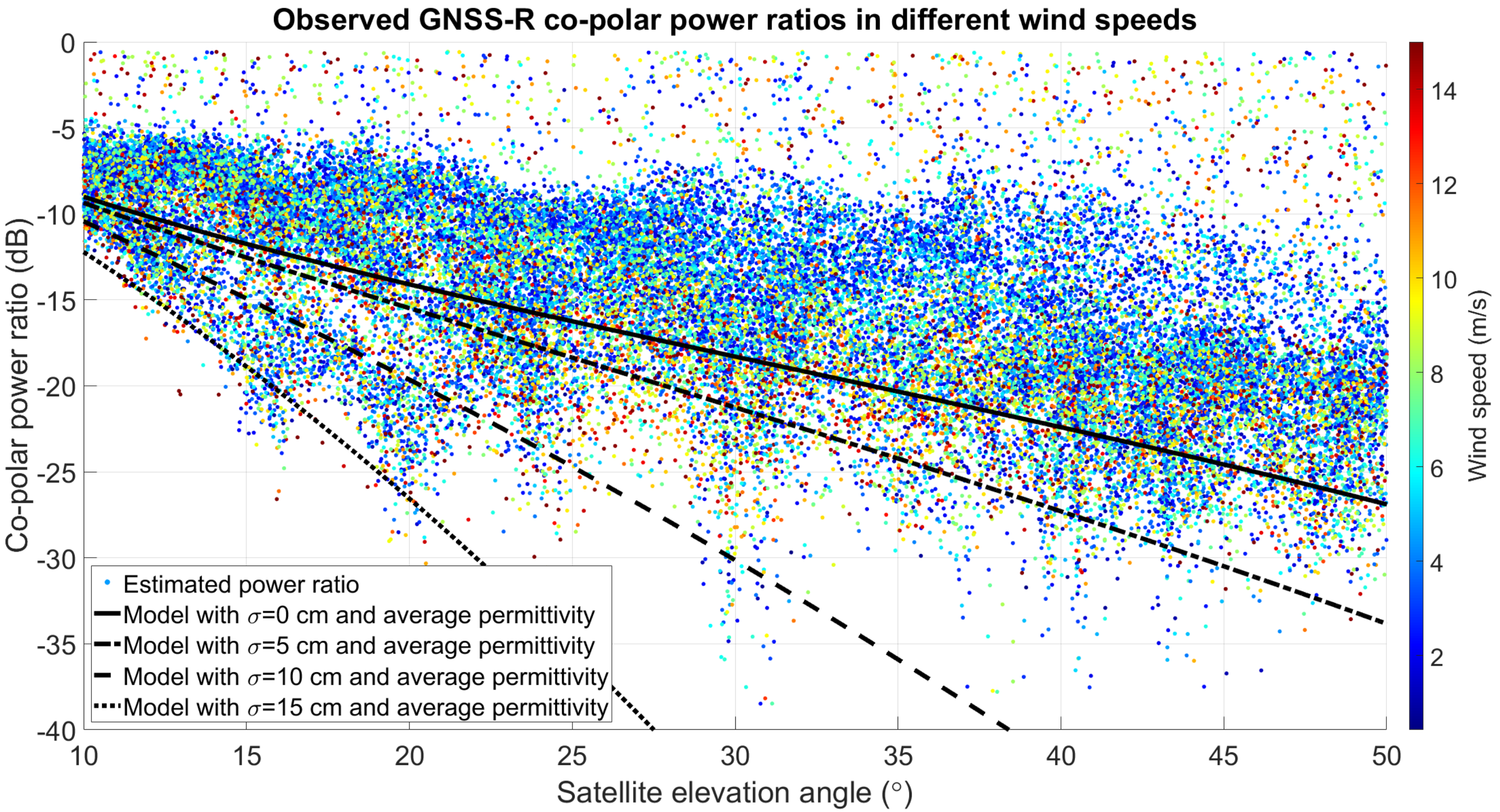
$$S(\sigma) = e^{-\frac{1}{2}\frac{(2\pi)^2}{\lambda^2}\sigma^2 \sin^2\theta}$$

σ : Standard deviation of sea surface height

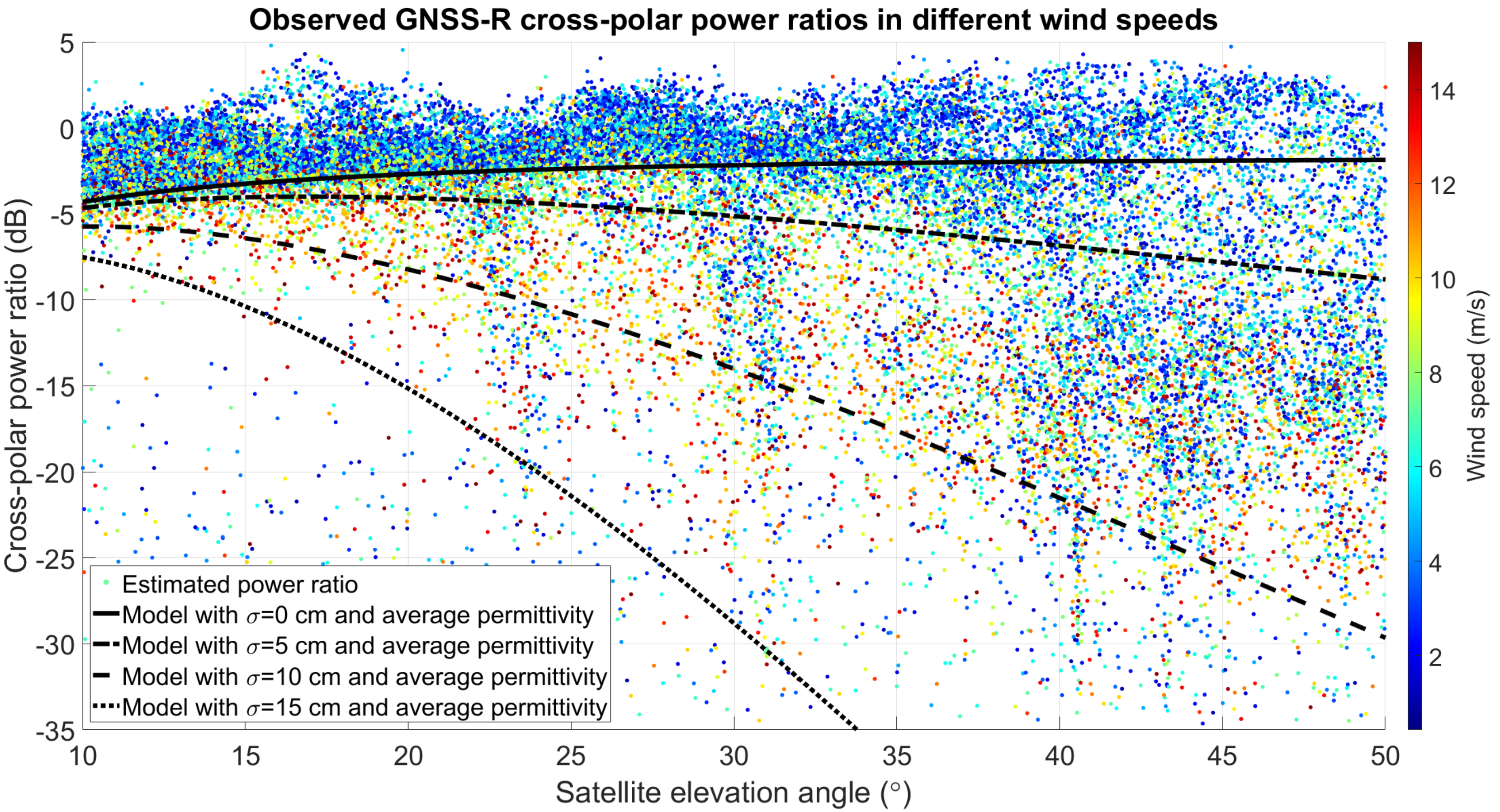
P_{21}: Cross-polar power ratio, P_{31}: co-polar power ratio, P_{23}: cross to co polar power ratio

Co-polar vs cross-polar power ratios

In different wind speeds

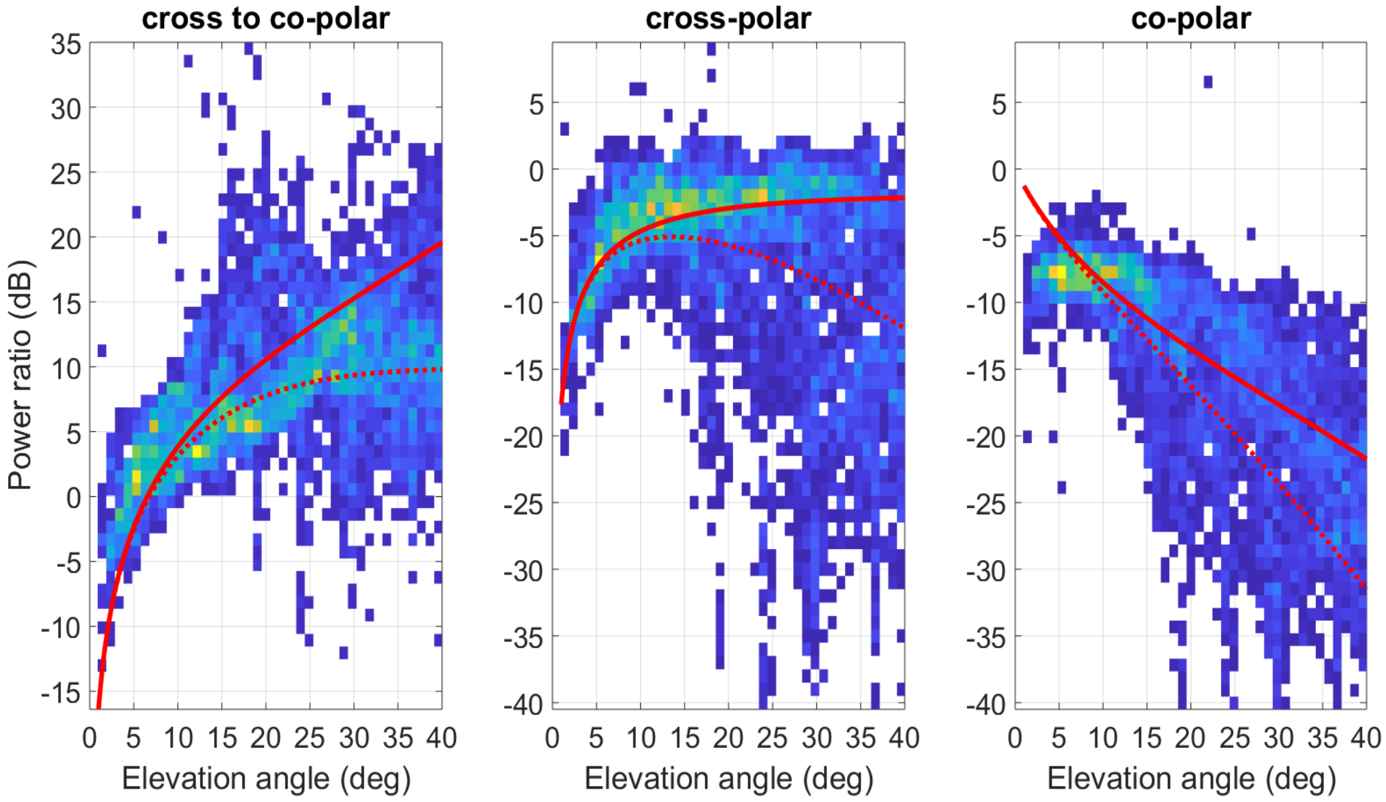


Observed GNSS-R co-polar power ratios in different wind speeds
Co-polar power ratio (dB)
0
-5
-10
-15
-20
-25
-30
-35
-40
10
15
20
25
30
35
40
45
50
Satellite elevation angle (°)
Estimated power ratio
Model with σ=0 cm and average permittivity
Model with σ=5 cm and average permittivity
Model with σ=10 cm and average permittivity
Model with σ=15 cm and average permittivity
Wind speed (m/s)
2
4
6
8
10
12
14

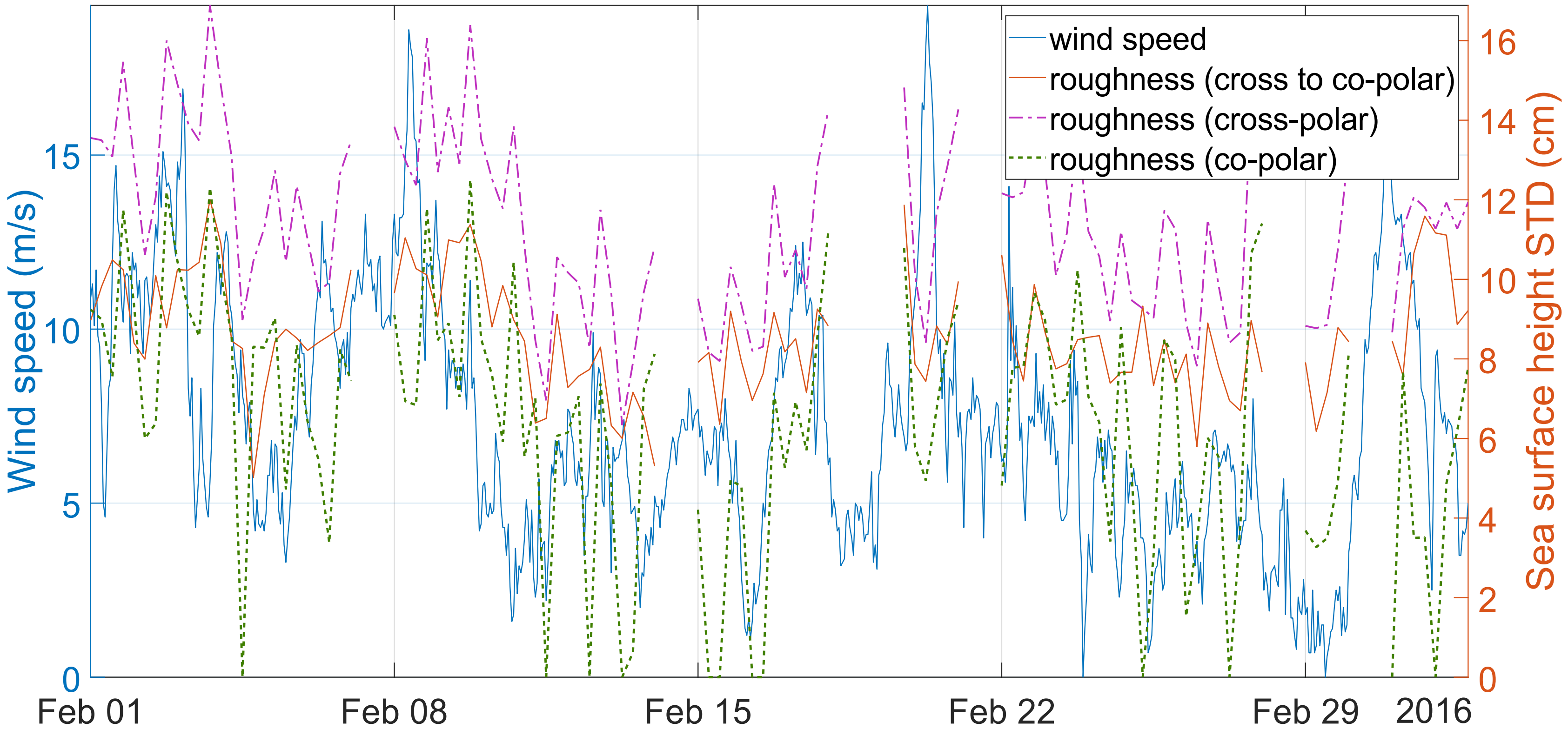


Observed GNSS-R cross-polar power ratios in different wind speeds
Cross-polar power ratio (dB)
Satellite elevation angle (°)
Wind speed (m/s)
5
0
-5
-10
-15
-20
-25
-30
-35
10
15
20
25
30
35
40
45
50
2
4
6
8
10
12
14
Estimated power ratio
Model with σ=0 cm and average permittivity
Model with σ=5 cm and average permittivity
Model with σ=10 cm and average permittivity
Model with σ=15 cm and average permittivity

Distribution of power ratios



Roughness estimates vs wind speed



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Summary

- The effect of different wind speeds as an indicator of sea states on polarimetric observations has been demonstrated using a dataset from a ground-based setup
- Higher sensitivity to the surface roughness is observed for the cross-polar power ratios compared to the co-polar measurements
- The cross-polar power ratios exhibit a pattern in which low wind speeds show higher ratios and high wind speeds show lower ratios
- The model needs enhancement to better describe roughness effect particularly for the co-polar ratios in low elevation angles

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Acknowledgement

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Thank you

References

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