JADE UNIVERSITY OF APPLIED SCIENCES
Wilhelmshaven Oldenburg Elsfleth

Estimation of significant wave heights using GNSS-SNR data from moving ships

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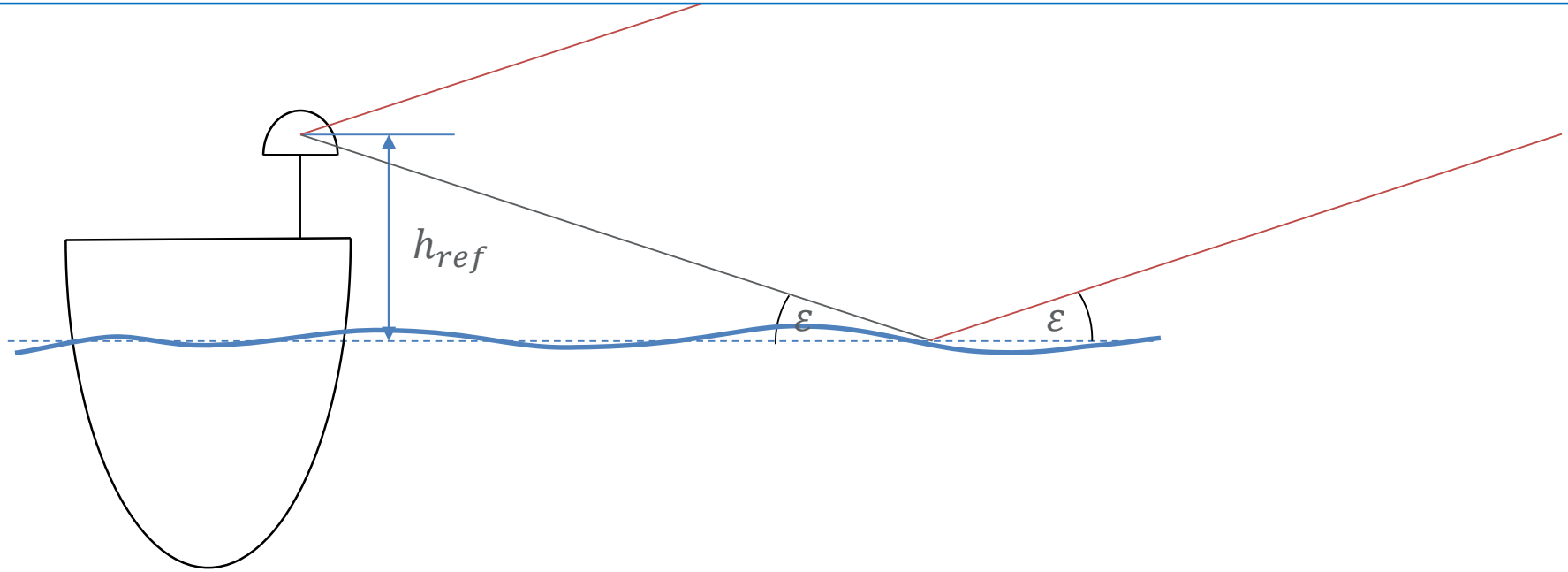
INTRODUCTION

- Jade University close to North Sea coast
- project to combine SSH from altimetry, tide gauges and ships
  - how to get SSH from a ship?
- (possible) solution: GNSS reflectometry
  - accurate model necessary

➢ derive significant wave height (SWH) as a by-product!

GNSS REFLECTOMETRY: SNR FULL MODEL

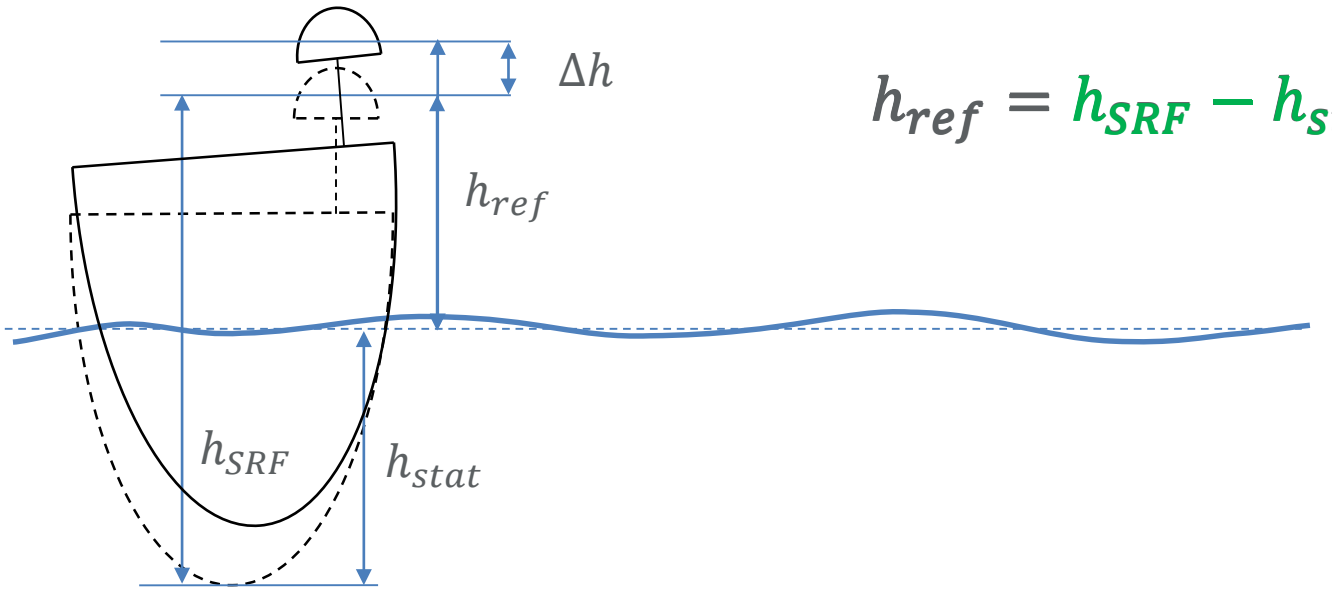


- signal-to-noise ratio (SNR) due to reflected signal
- $SNR = (a_0 + a_1 t + a_2 t^2 \ldots) + \quad e^{-k^2 \delta^2 x^2} \quad \cdot \left(C_1 \sin\left(\frac{4\pi h_{ref}}{\lambda} x\right) + C_2 \cos\left(\frac{4\pi h_{ref}}{\lambda} x\right)\right)$

$$with\ x = \sin\varepsilon$$

- global optimization to determine δ and h_{ref}
- h_{ref} varies due to ship's attitude

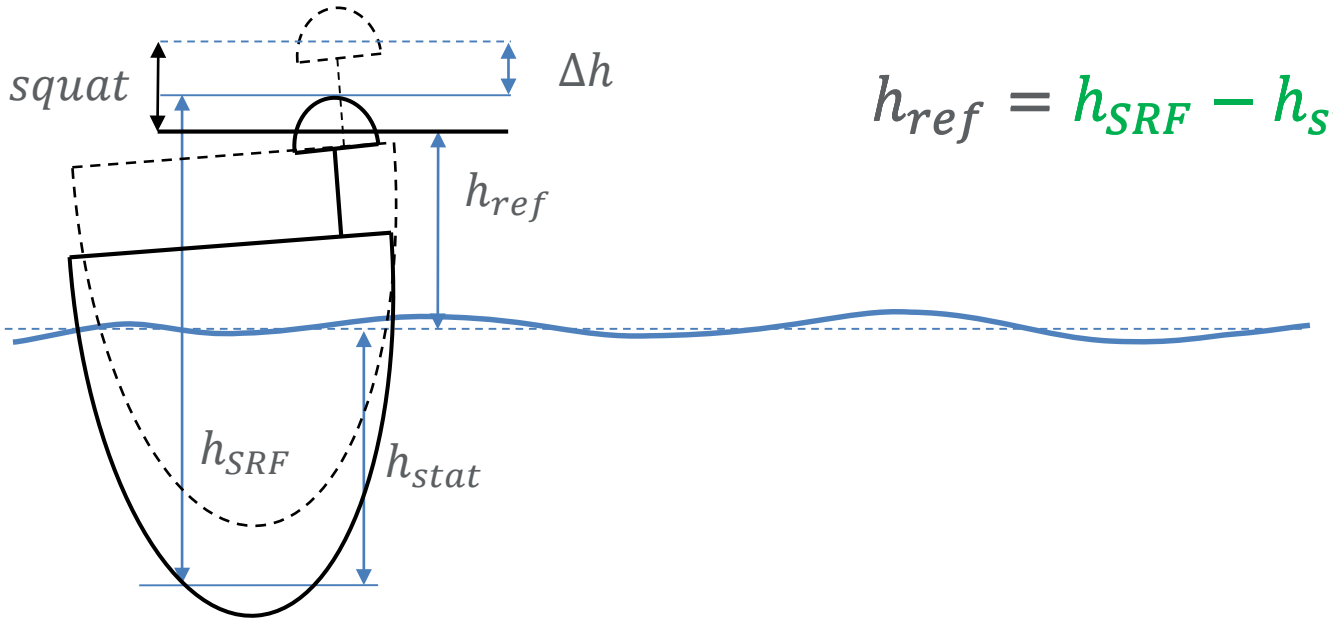
SHIP'S ATTITUDE



$$h_{ref} = h_{SRF} - h_{stat} + \Delta h - squat$$

- h_{SRF}: height in ship's reference frame *constant*
- h_{stat}: static draft *constant*
- Δh: height change due to roll, pitch and heave *correctable*

SHIP'S ATTITUDE



$$h_{ref} = h_{SRF} - h_{stat} + \Delta h - squat$$

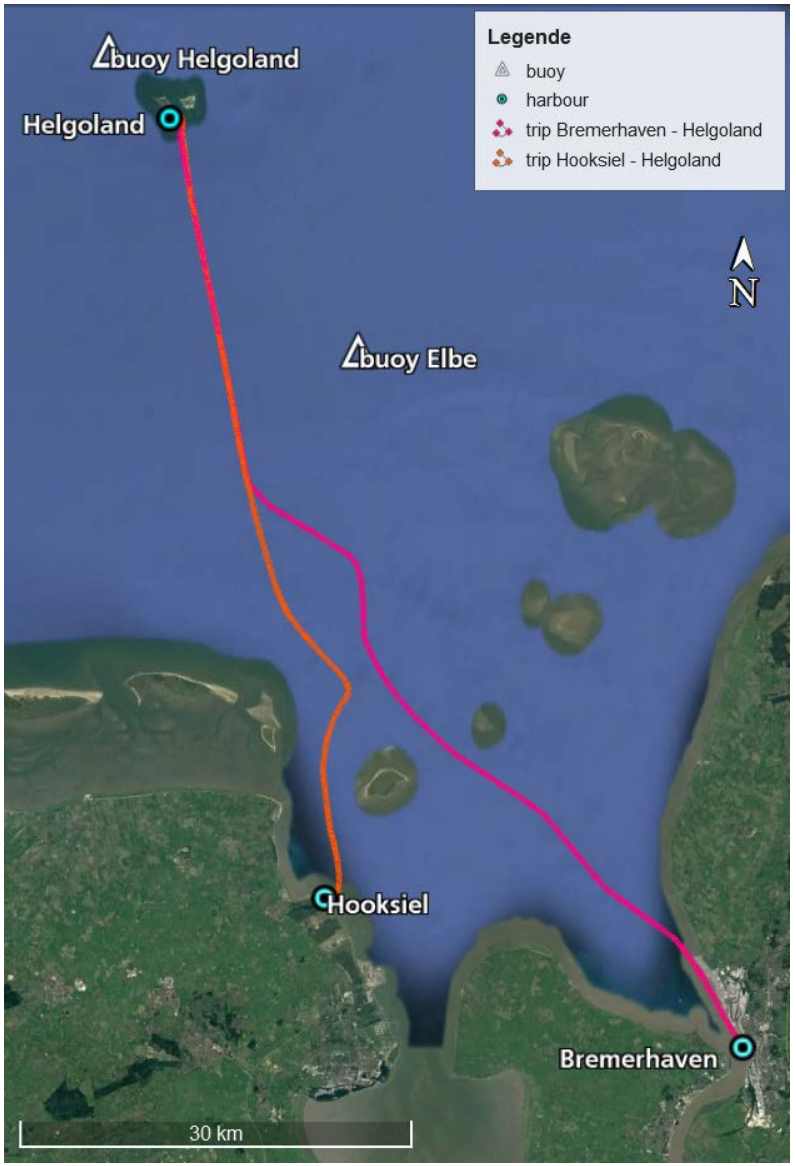
- h_{SRF}: height in ship's reference frame *constant*
- h_{stat}: static draft *constant*
- Δh: height change due to roll, pitch and heave *correctable*
- $squat$: change of sinkage and trim *unknown*
  - function of speed through water and under keel clearance

➢ *analysis of time intervals with constant squat*

EXPERIMENTAL DATA

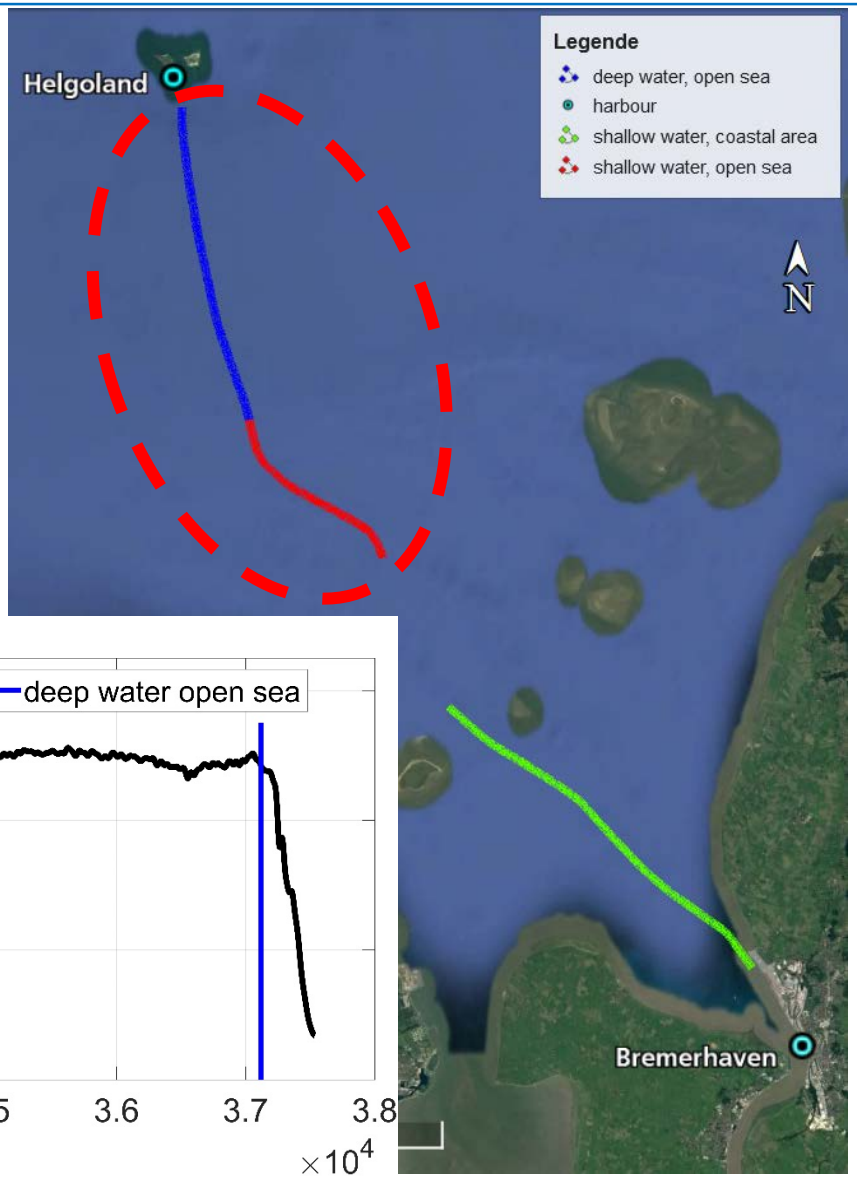
- ferry to island Helgoland
- Hemisphere L1/L2 equipment
  - 1 used for SWH estimation
- 1 Hz recording rate
- 85 days (July - September) with 2 journeys/day

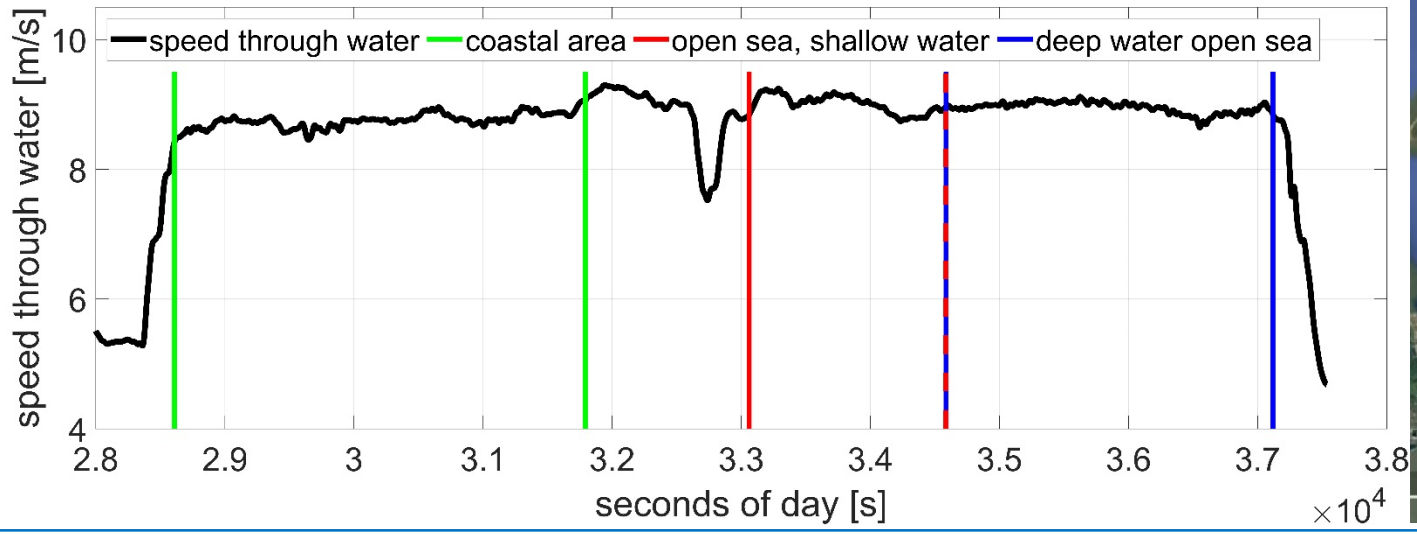
- buoy data as ground truth for evaluation
  - resolution of only 0.1 m



EXPERIMENTAL DATA

- constant speed through water
- separate by 25 m UKC
  - 322 intervals
- damping and squat for each interval
- problems with dry areas in the Wadden Sea
  - usage of open sea intervals (145)





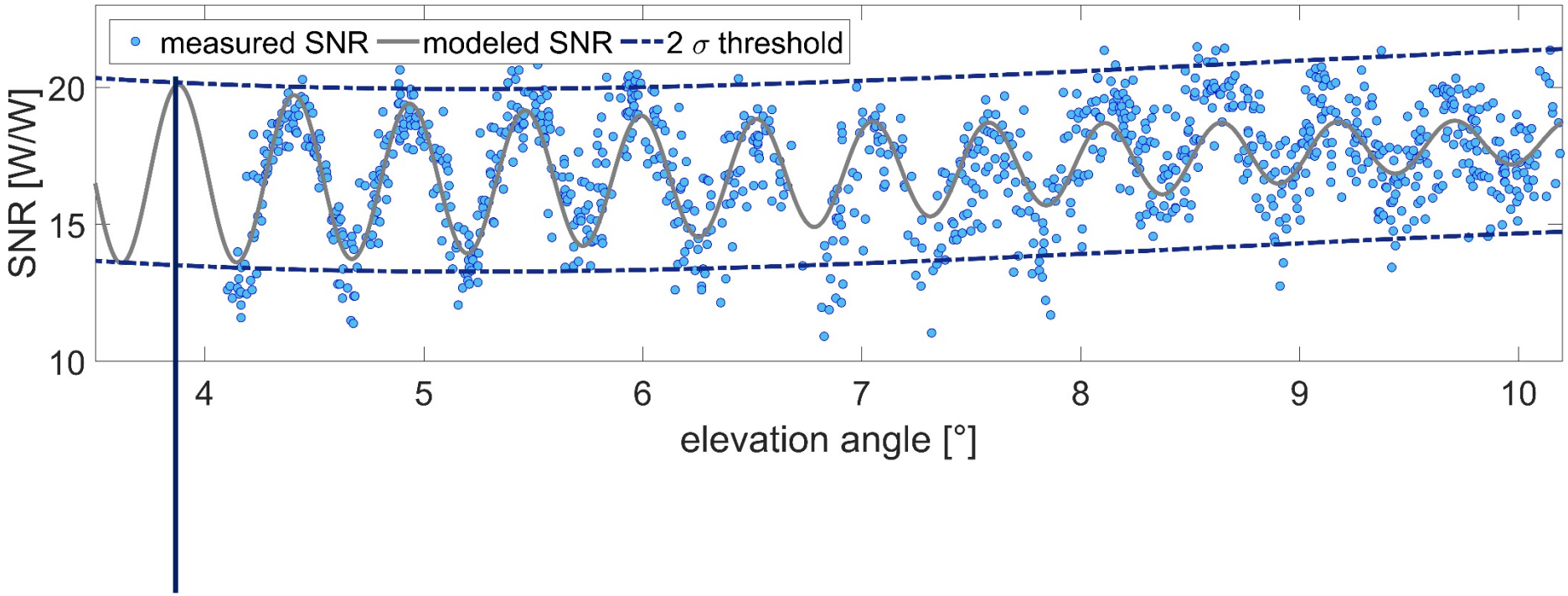
IMPACT OF LEVEL OF SIGNIFICANCE

- empirical model to derive SWH from elevation angle where coherence is lost [Alonso-Arroyo et al. (2015)]

$$e_0 = 55.44 \cdot e^{-3.3 \cdot SWH}$$

- e_0: elevation angle where modeled amplitude gets insignificant
  - consideration of damping necessary

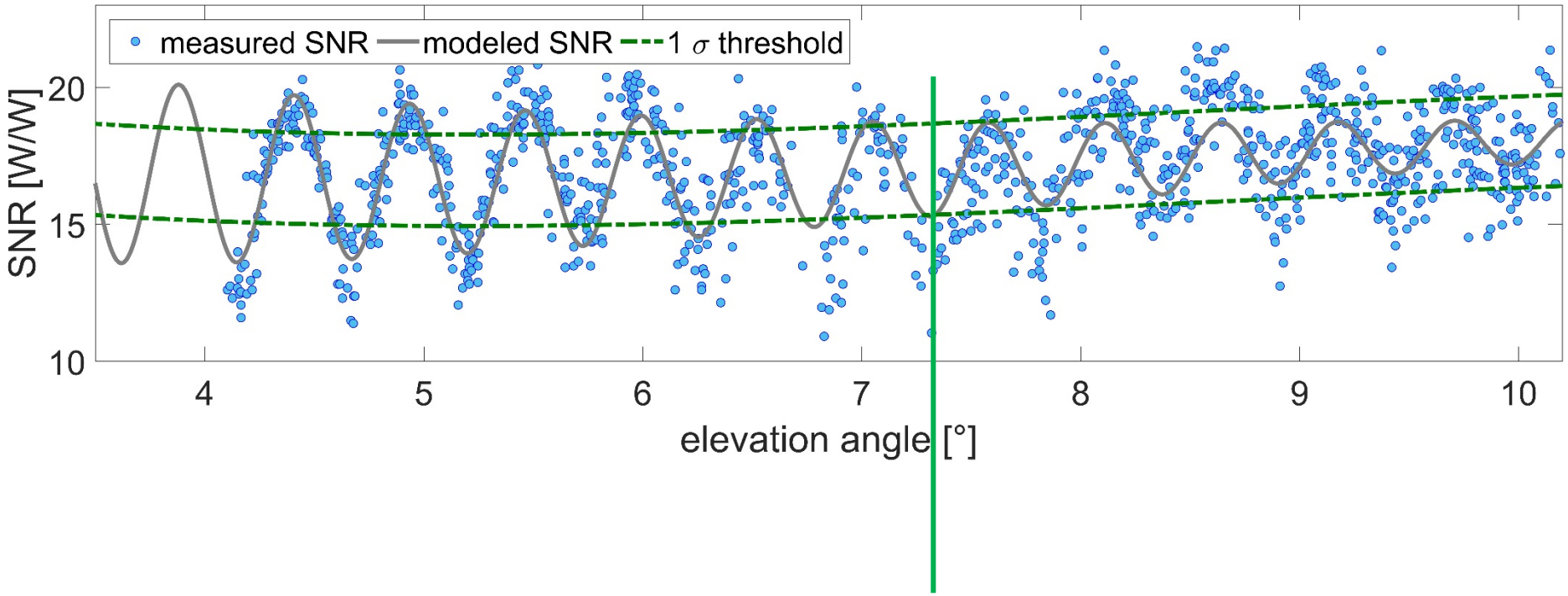
IMPACT OF LEVEL OF SIGNIFICANCE



2σ SWH: 0.82 m

- which level of significance?

IMPACT OF LEVEL OF SIGNIFICANCE

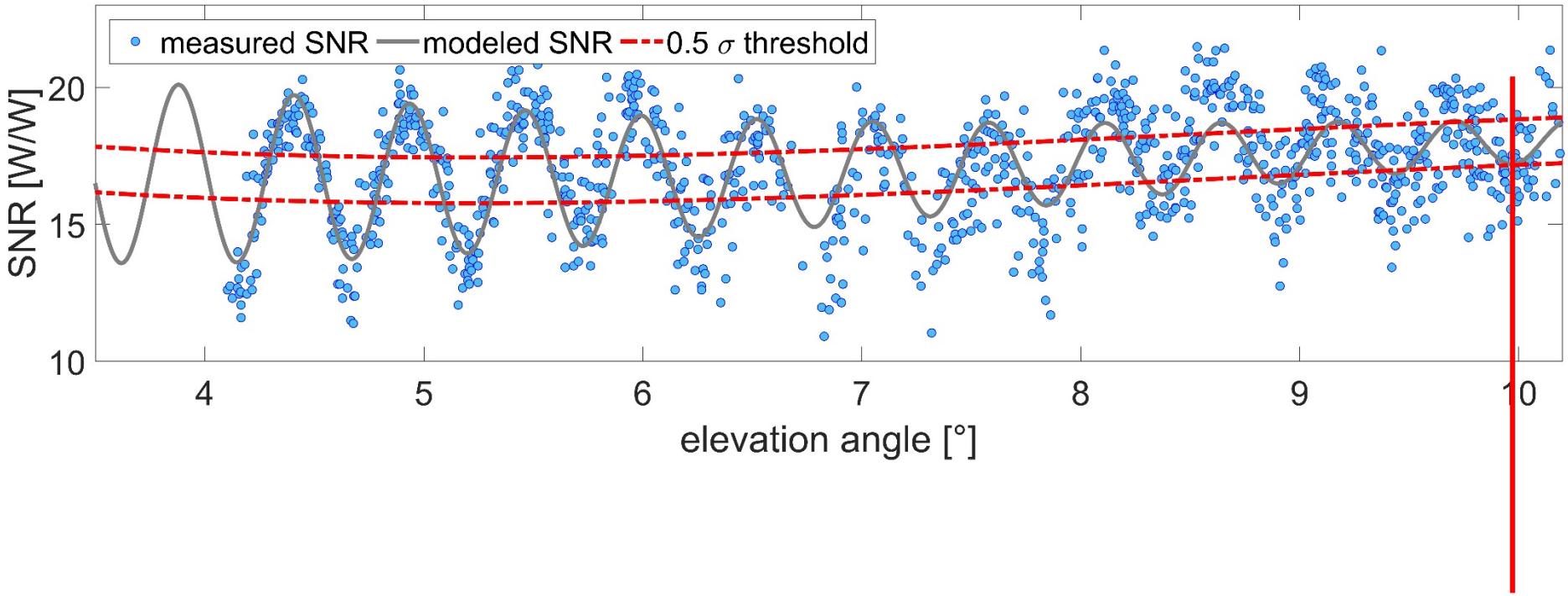


2σ SWH: 0.82 m

1σ SWH: 0.61 m

- which level of significance?

IMPACT OF LEVEL OF SIGNIFICANCE



2σ SWH: 0.82 m

1σ SWH: 0.61 m

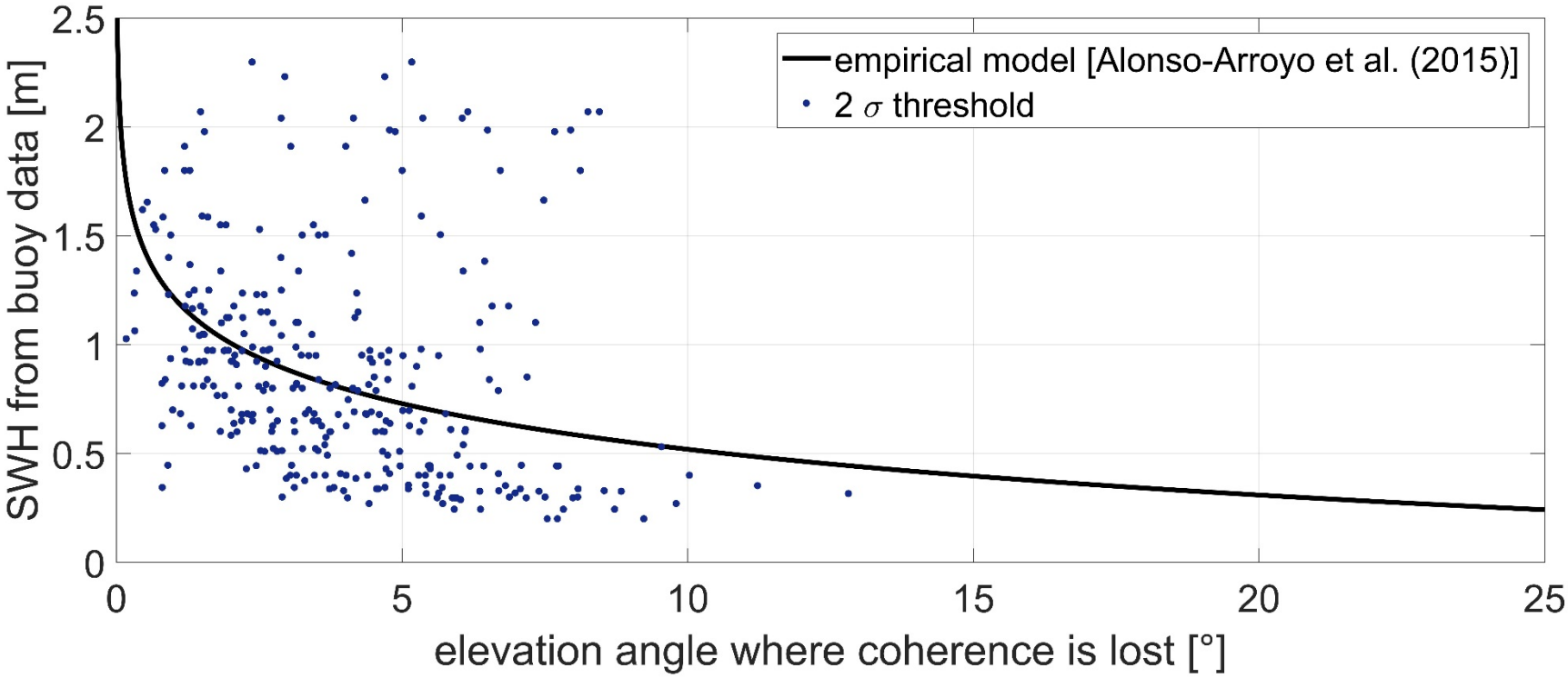
0.5σ SWH: 0.52 m

- which level of significance?

buoy SWH: 0.40 m

FUNCTIONAL MODEL

- data differs to model of Alonso-Arroyo et al. (2015)
- horizontal shift with variation of threshold
- less scattering at lower thresholds



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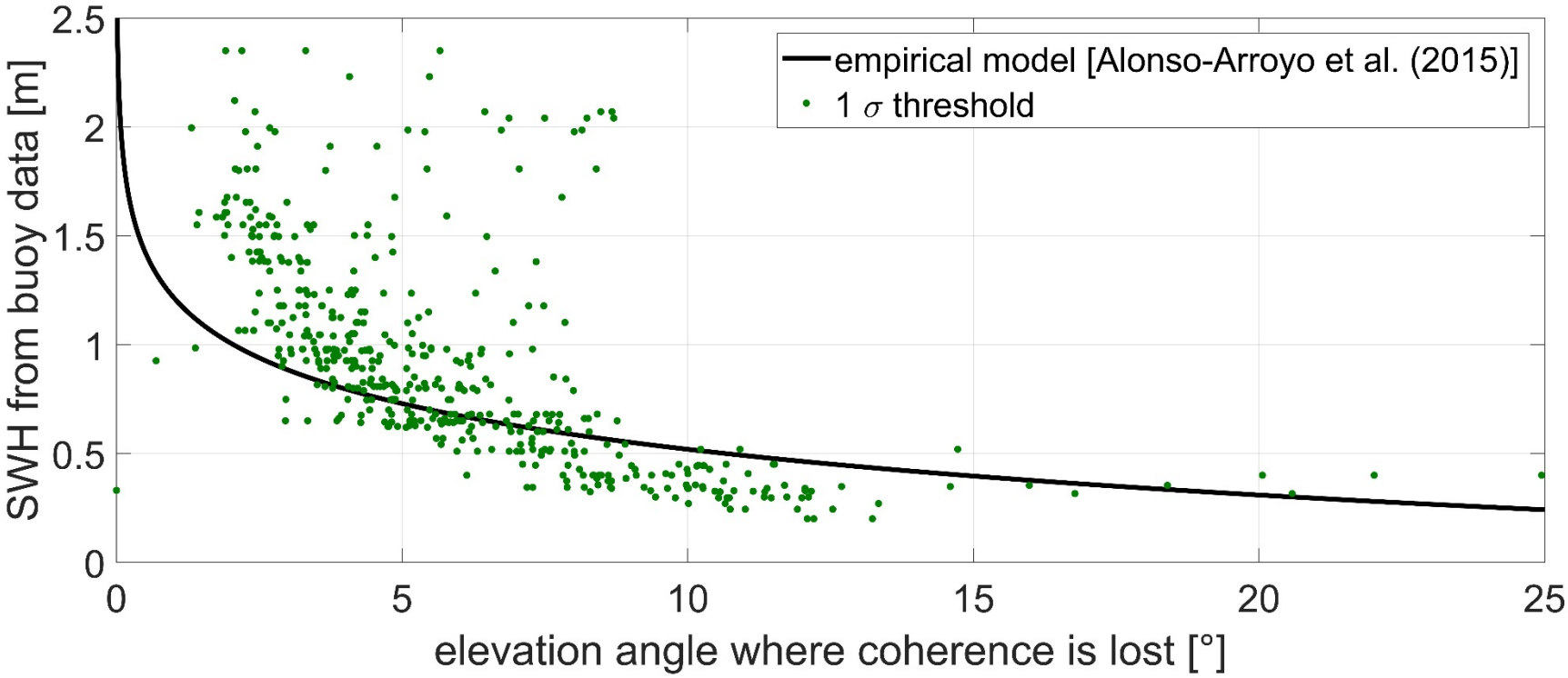

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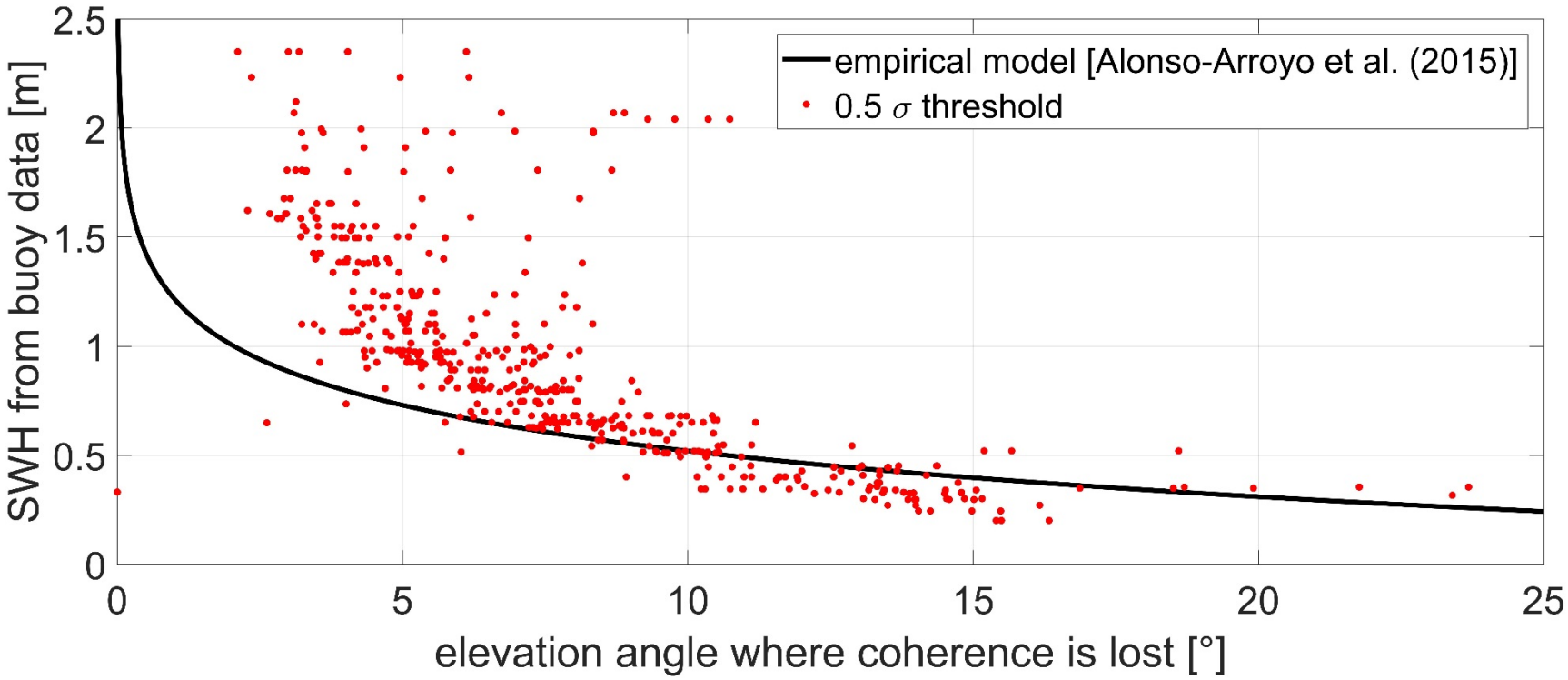


FUNCTIONAL MODEL

- data differs to model of Alonso-Arroyo et al. (2015)
- horizontal shift with variation of threshold
- less scattering at lower thresholds
- functional model → extension

$$e_0 = a \cdot e^{b \cdot SWH} + c$$

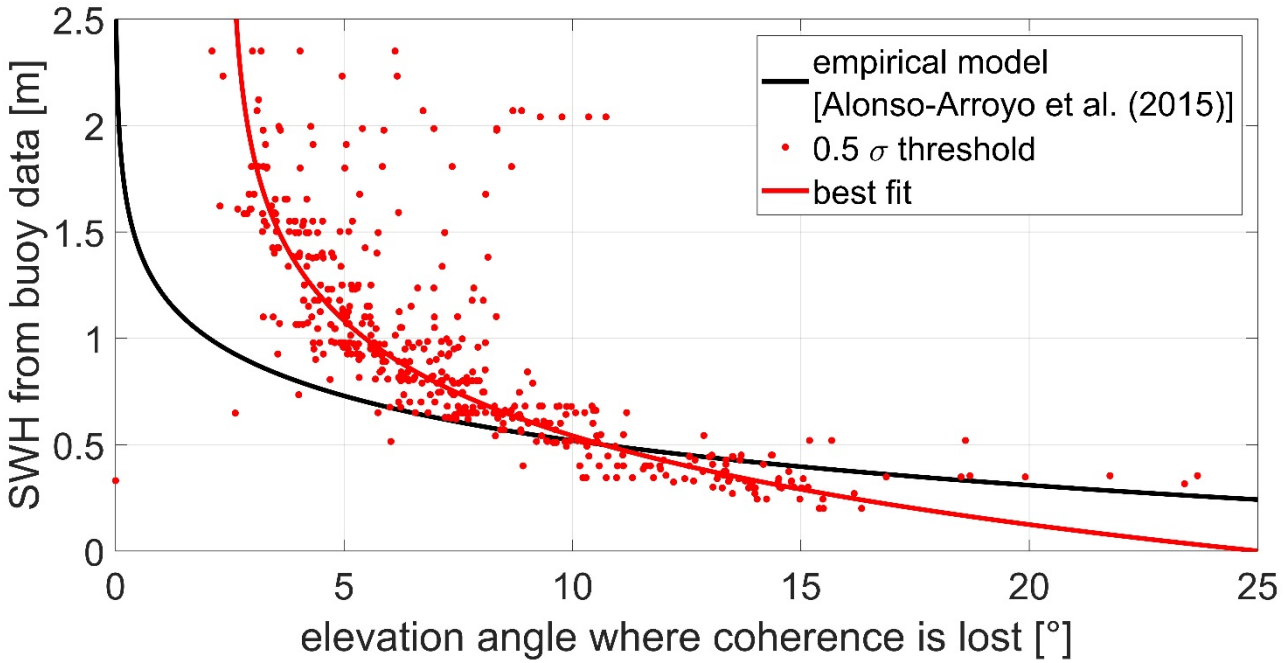
$$a + c = 25°$$

- best fit to experimental data

NEW FUNCTIONAL MODEL

$$e_0 = 22.50 \cdot e^{-2.02 \cdot SWH} + 2.50$$

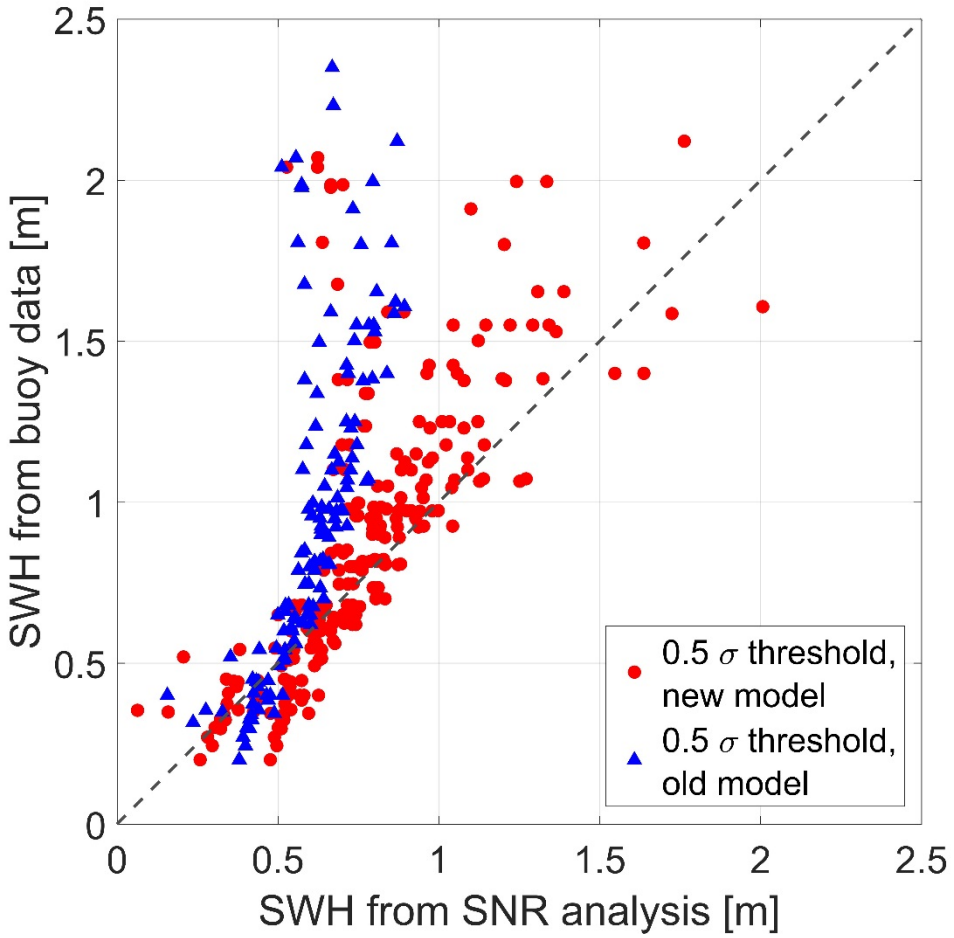
- best result with threshold of 0.5σ

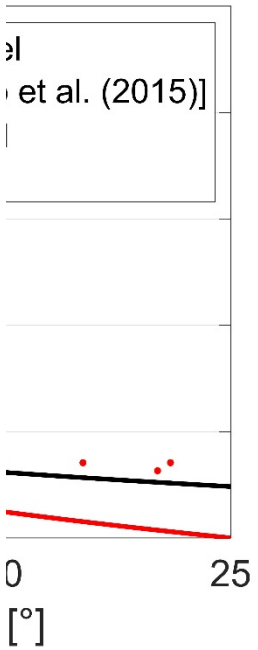


NEW FUNCTIONAL MODEL

$$e_0 = 22.50 \cdot e^{-2.02 \cdot SWH} + 2.50$$

- best result with threshold of 0.5σ
- estimated SWH with new model fits better to SWH from buoys





CONCLUSION AND OUTLOOK

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- estimation of SWH with GNSS-SNR on moving ships possible!
  - knowledge of ships attitude necessary
  - constant speed and under keel clearance (squat)
- influence of level of significance
- better ground truth data for SWH necessary
- extend or use other functional model?

- our approach:
- ➢ SWH < 1.3 m observable in open sea

Thank you for your attention!