

Cal/Val of recent altimeter missions at non-dedicated tide gauge stations in the North Sea

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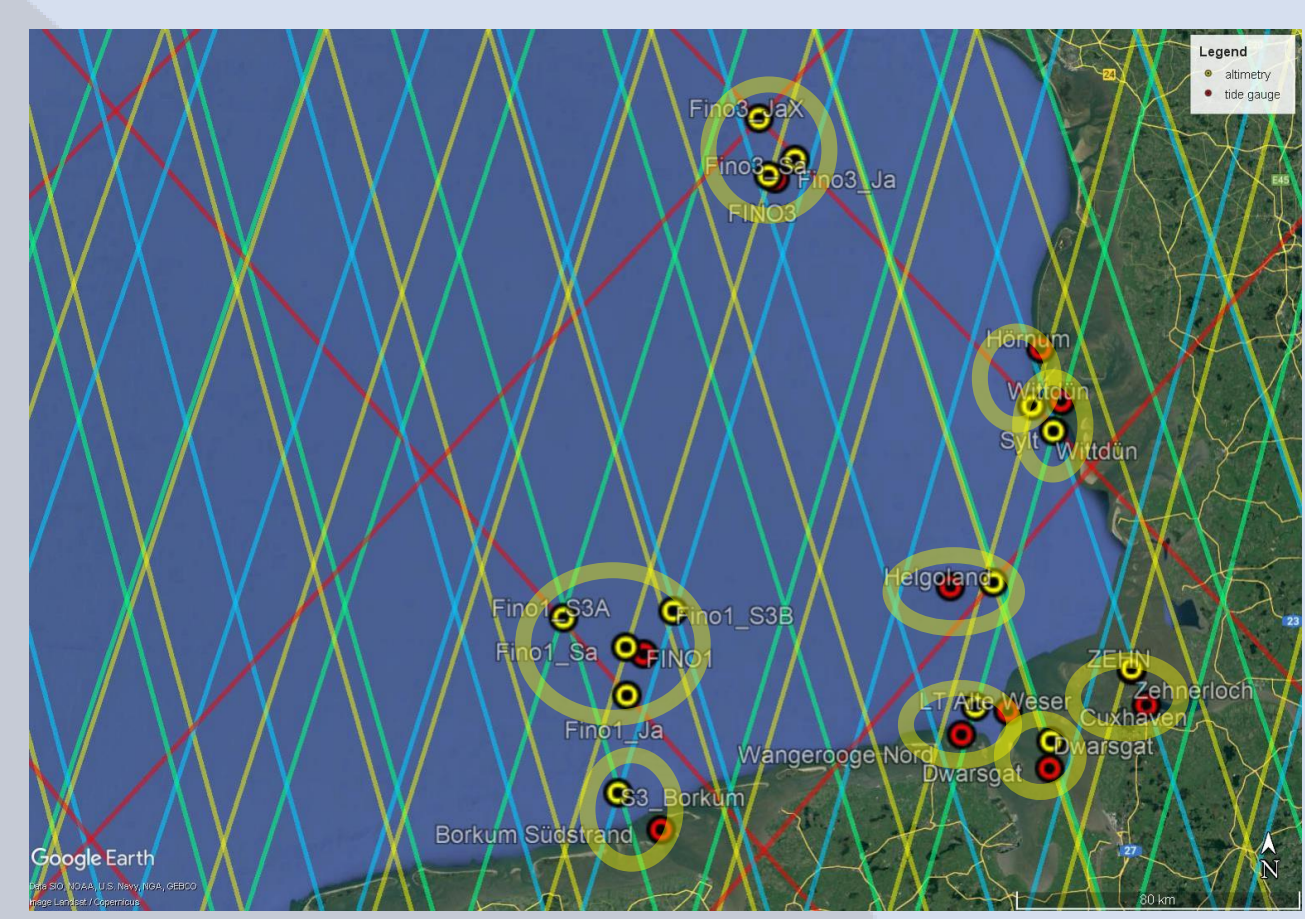
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Objectives

We aim for assessing the precision and accuracy of recent altimeter missions at non-dedicated tide gauge stations in the German Bight (SE North Sea) in the period 2013-2022. The instantaneous SSH/total water envelope from altimetry is compared to high rate tide gauge measurements. The adverse effects of inexact collocation of the measurements are corrected for.

- RMS differences (RMS-D) is upper bound of precision
- Estimation of mean regional mission bias, σ of bias is upper bound of accuracy

Observations in the German Bight



Satellite tracks and gauges in the German Bight

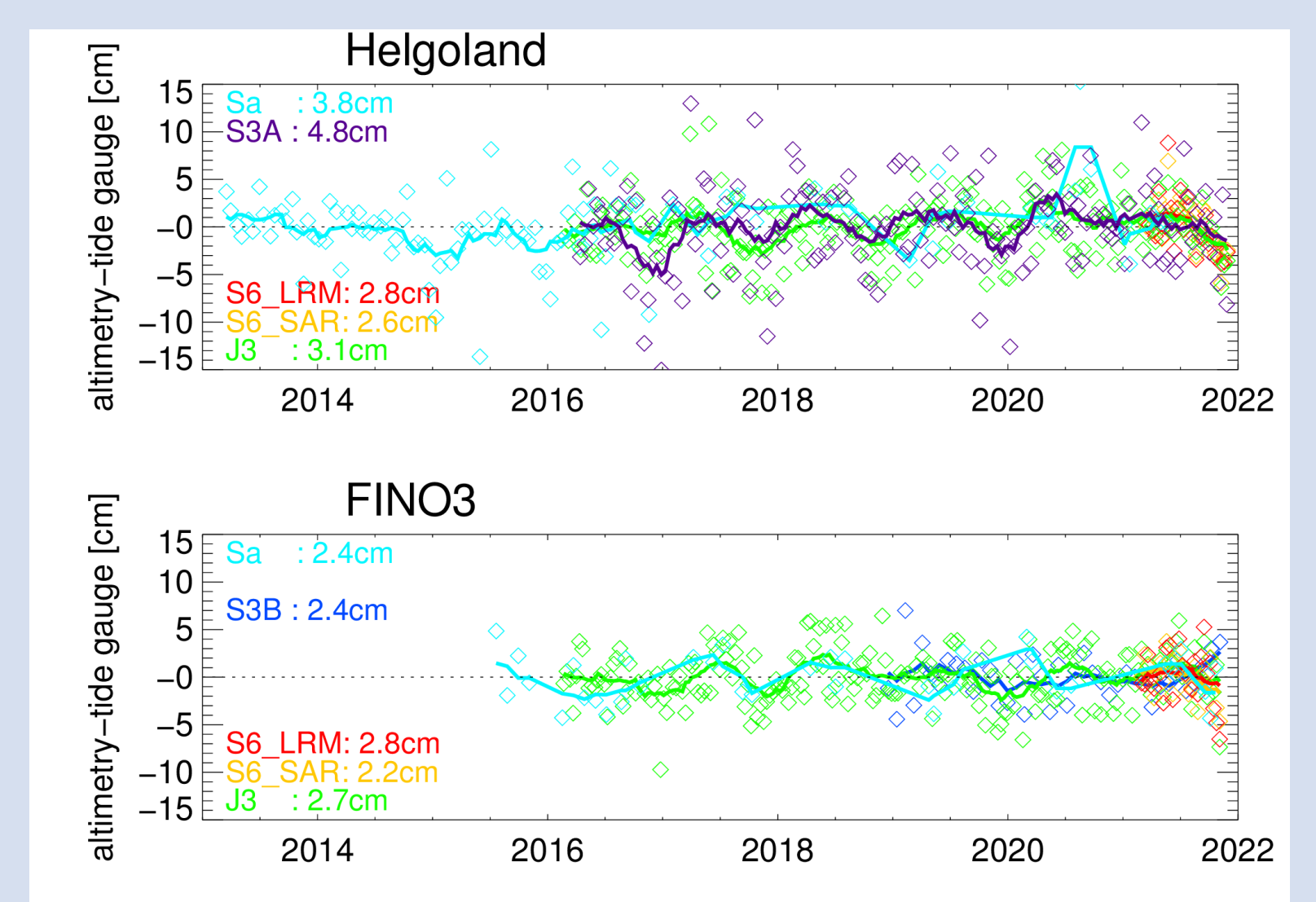
Altimetry:

- Jason-3, Sentinel-6 Saral, Sentinel-3A, Sentinel-3B
- HF data
- GDR-retrackers
- coastal processing

Tide gauges:

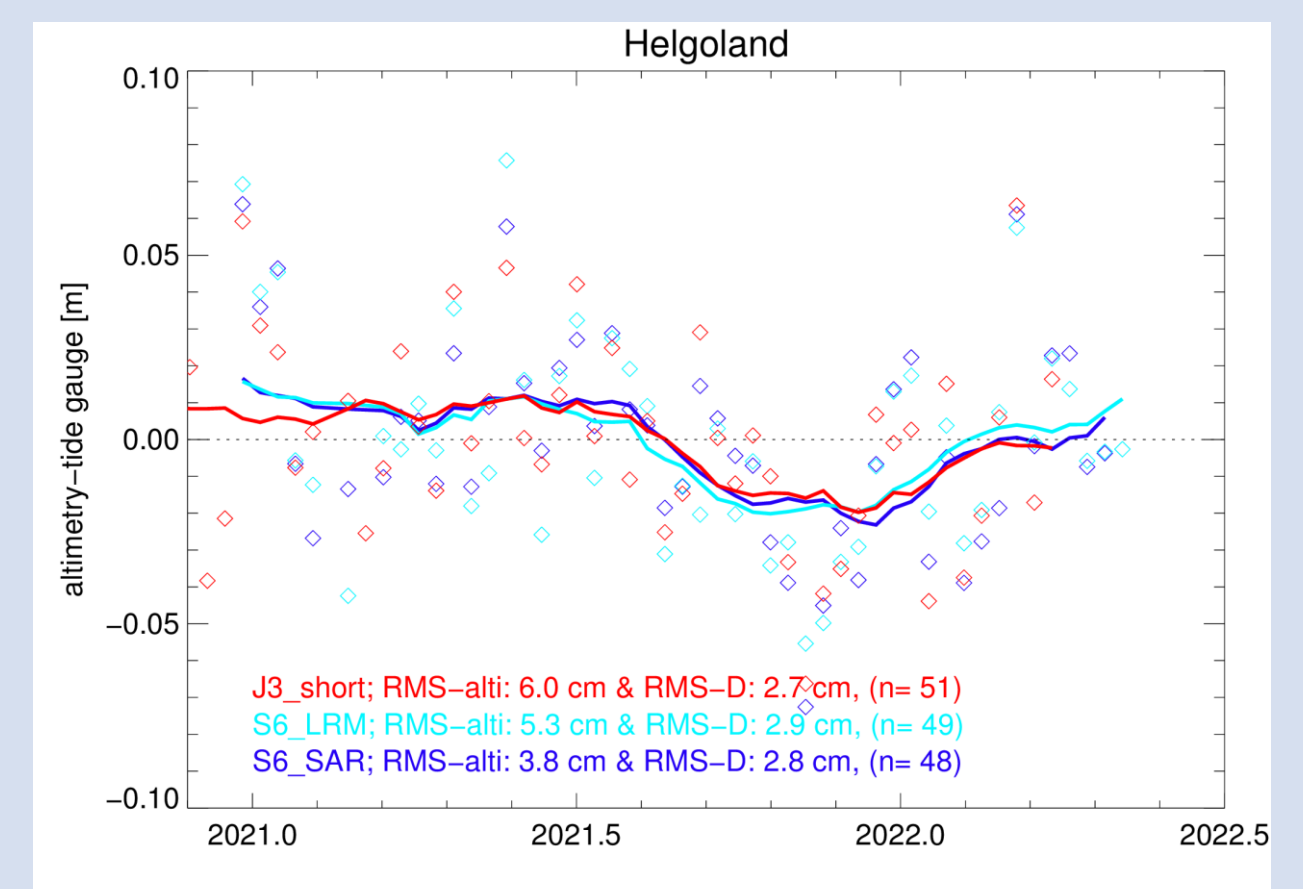
- 3 open water gauges, 8 coastal gauges
- 1 minute data
- georeferenced by GPS

Difference Gauge/Altimetry



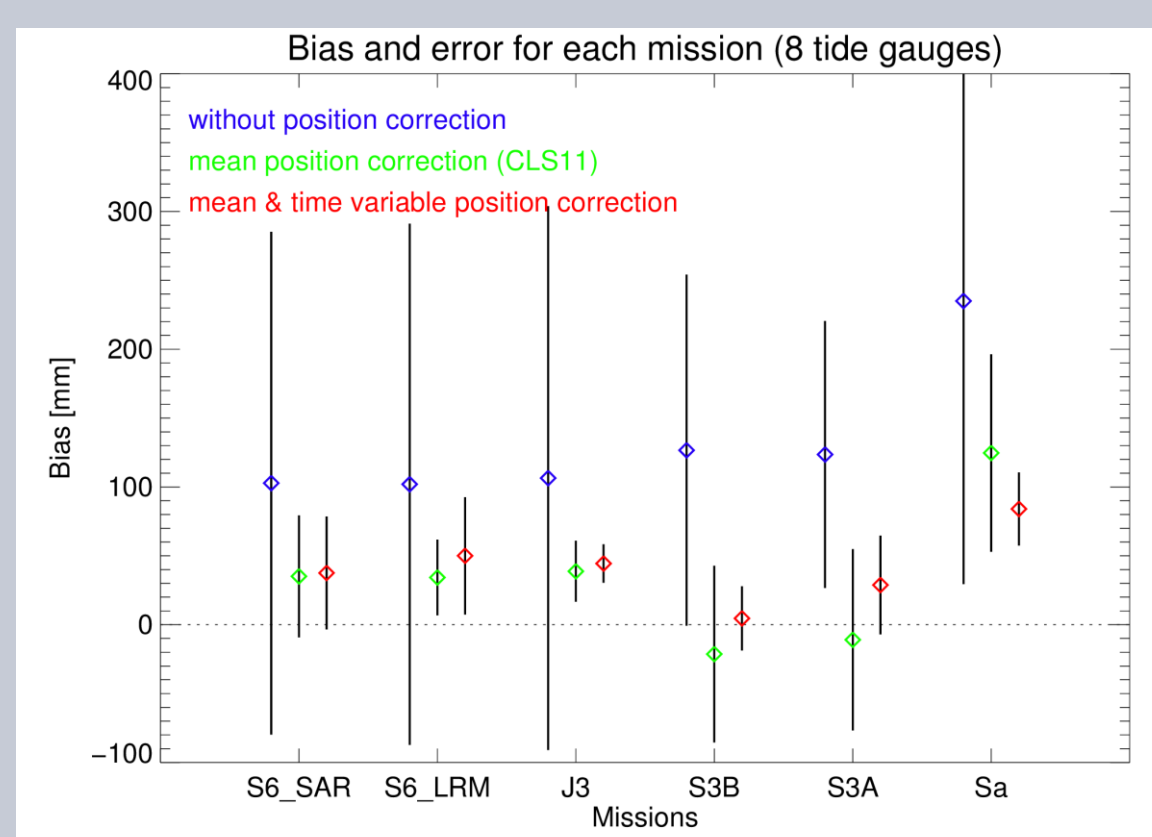
Solid line: 3-months boxcar, numbers: RMS-difference

- After application of the time variable position correction very good agreement between tide gauge and altimeter observations
- Some systematic differences on annual scales remain
- Jason-3, Sentinel-6 (LRM & SAR) show very close results (bottom figure)



Solid line: 3-months boxcar

Regional Mission Bias



- Regional mission biases differ by up to 20 cm between gauges
- Alignment after correction for inexact collocation (position corrections)

Mission	Bias CLS11 [cm]	Bias DTU21 [cm]	No. Gauges
S6 SAR	2.8±4.2	4.5±2.0	5
S6 LRM	3.2±2.9	5.1±1.4	5
Jason-3	4.5±1.3	6.2±1.9	5
S3B	0.2±2.3	0.0±3.4	6
S3A	2.6±3.6	1.2±5.2	7
Saral	8.1±2.7	7.0±5.4	9

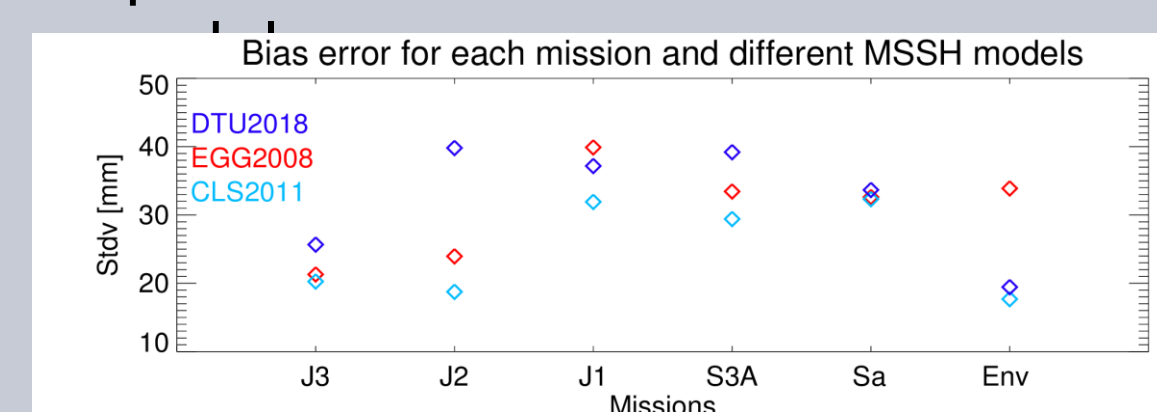
Position corrections mean (Δ MSSH) and time variable (Δ SLA)

Measurements are not exactly collocated in space

$$\Delta\text{SSH}_{\text{obs}} = \text{Bias}_{\text{regional}} + \Delta\text{MSSH} + \Delta\text{SLA} + \epsilon$$

Adjust for MSSH differences

- Estimates of Δ MSSH differ by up to 10cm between MSSH

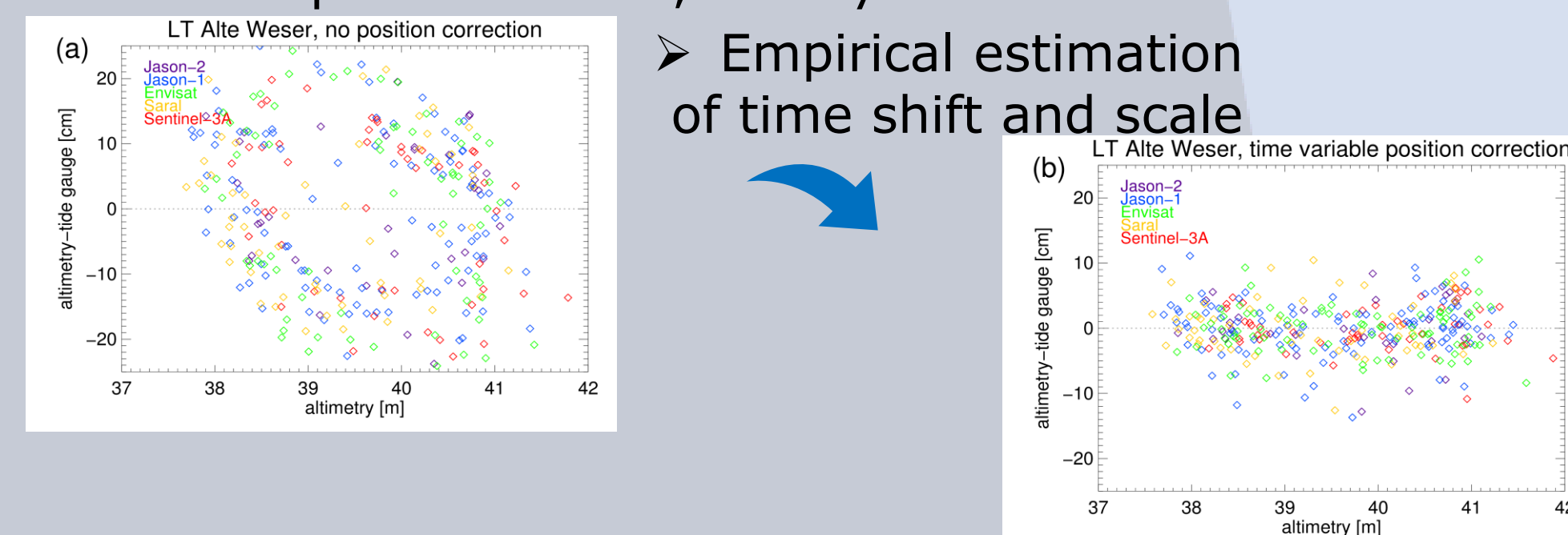


- Check mission bias consistency at gauges
- Regional mission biases match best for MSSHs CLS2011 and DTU2021

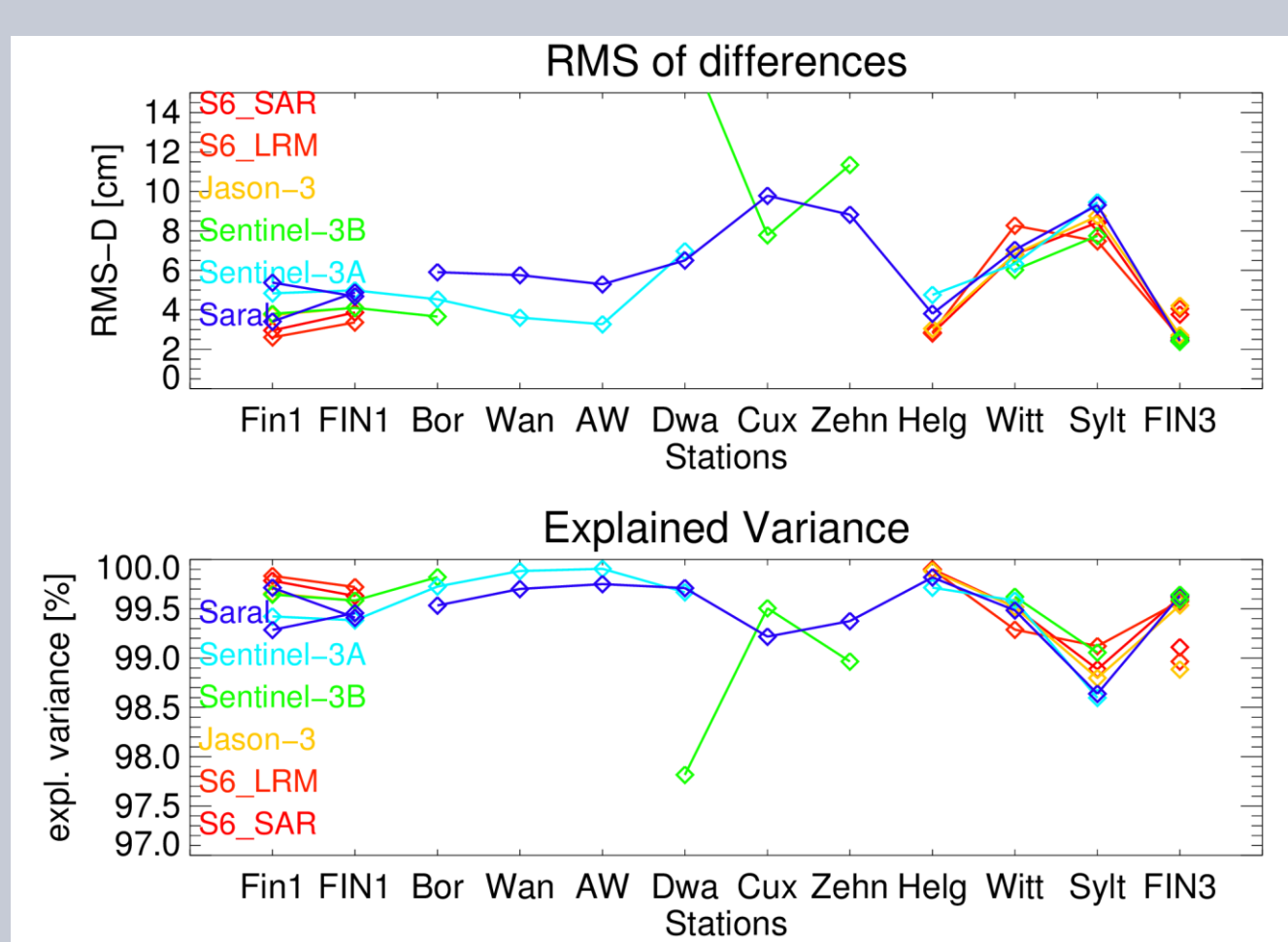
Adjust amplitude and arrival time

- Δ SLA depends on SSH, mainly tides

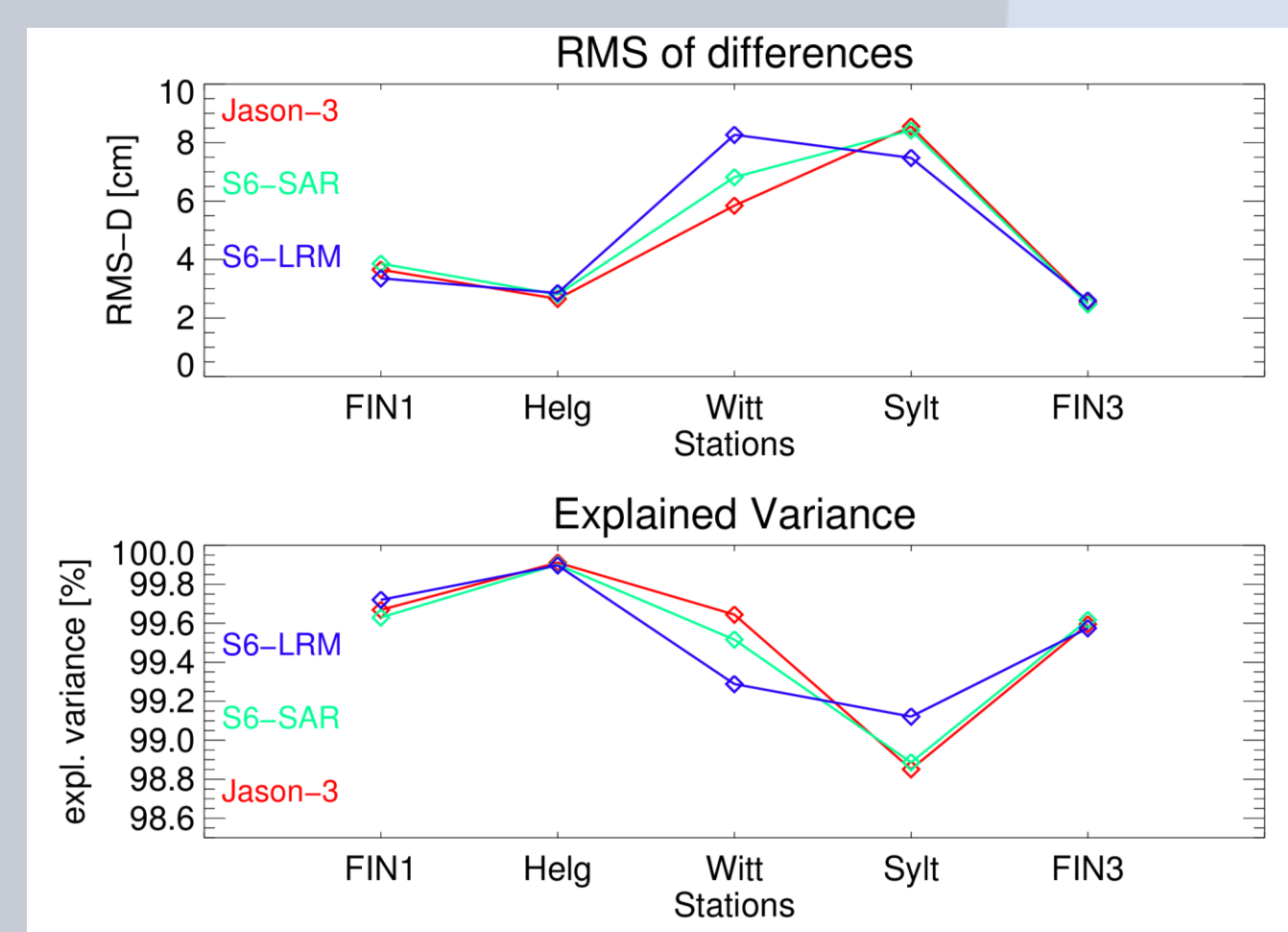
- Empirical estimation of time shift and scale



RMS difference and explained variance (counter-clockwise along coast)



- RMS difference open water: 2-3 cm
- RMS difference coast: 3-10 cm
- RMS difference combined precision of tide gauge, altimeter and position correction
- Estimated altimeter precision: 1.5-2.7 cm



Best fitting stations - Lowest RMS differences

Tide gauge	Mission	RMS diff [cm]	Expl. Var. [%]	Distance [km]	Collocated values
FINO3	Sentinel-6 SAR	2.5	100	2	31
FINO3	Sentinel-6 LRM	2.6	100	2	31
FINO3	Jason-3	2.7	99	2	203
FINO3	Sentinel-3B	2.5	99	7	78
LT Alte Weser	Sentinel-3A	3.3	100	9	78
Fino1	Saral	3.4	100	2	57

Conclusions

- Assessment of accuracy & precision for 5 altimeter missions (2013-2022) relative to 11 tide gauges in the German Bight
- Regional mission bias: uncertainty 1.5-3 cm, longer and more time series necessary, limited by MSS uncertainty
- Lowest RMS differences: 2.2-3.4 cm (~1.5-2.7 cm precision), higher RMS-D at the coast (up to 10 cm)
- Sentinel-3: at some locations excellent agreement very close to the coast (LT Alte Weser and Wittdün)
- operational GNSS-controlled tide gauges, e.g. by WSV and BfG might complement the calibration and monitoring activities at dedicated Cal/Val stations.

Esselborn et al., Remote Sens. 2022, <https://doi.org/10.3390/rs14010236>

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