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→ 8th COASTAL ALTIMETRY WORKSHOP

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Validation of Significant Wave Height from improved satellite altimetry in the German Bight

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MOTIVATION

THE NEW FRONTIER OF OPERATIONAL OCEANOGRAPHY IS THE COASTAL ZONE, and wave height estimation is at the forefront!

Wave models have a hard time in the coast:

- energy dissipation in shallow areas
- varying wave height with depth (shoaling effect)

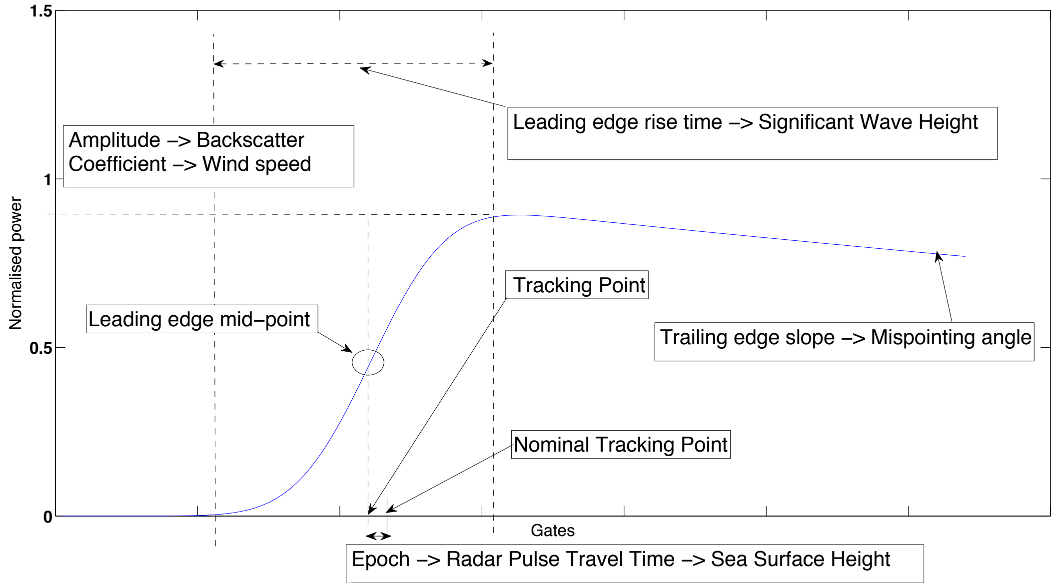
OUR COMMUNITY MUST PROVIDE RELIABLE OBSERVATIONS!

CAN WE IMPROVE THE SIGNIFICANT WAVE HEIGHT RETRIEVAL IN THE COASTAL ZONE?

CAN WE IMPROVE THE CURRENT "OPEN SEA" SIGNIFICANT WAVE HEIGHT ESTIMATES?

Introduction

- Significant Wave Height (SWH) is related to the rising time of a waveform, i.e. the slope of the leading edge



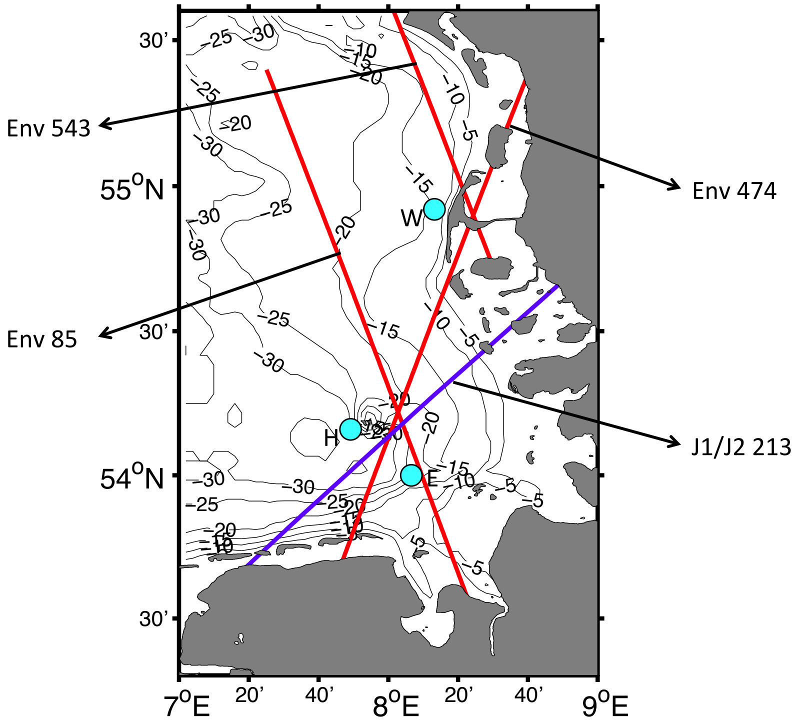
RETRACKING: the on-ground process of fitting a modelled waveform to the real signal in order to estimate the parameters of interest

- Two main issues in SWH estimation:

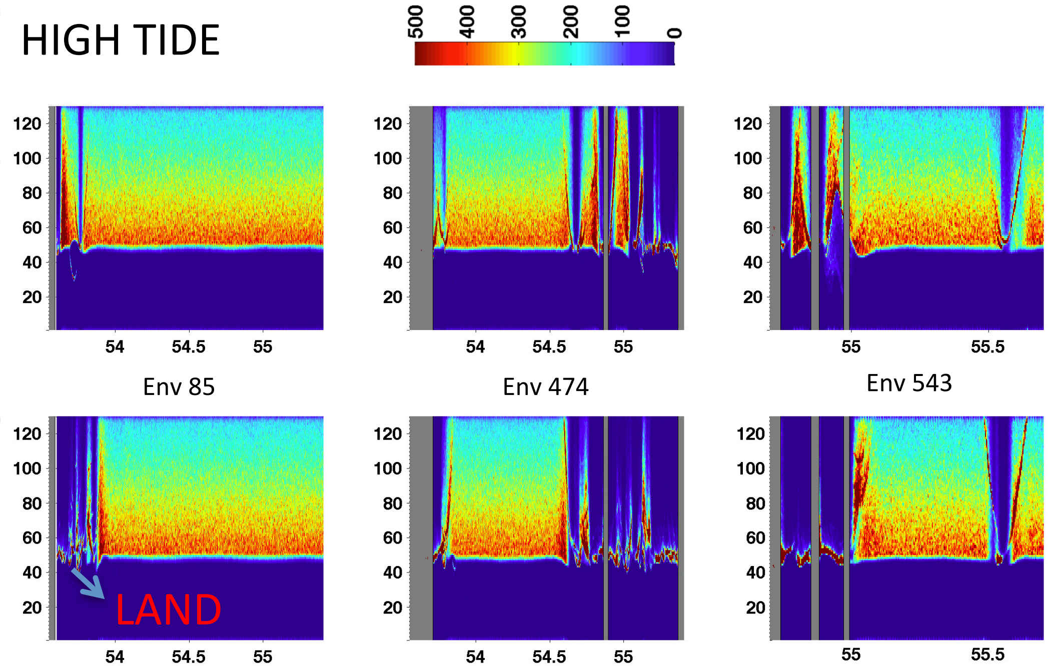
1) COAST: Coastal waveforms are hard to fit due to land and calm water interference in the altimeter footprint

2) LOW SEA STATES: low SWH produces a very sharp leading edge that is therefore poorly sampled

The area of study



HIGH TIDE



LOW TIDE

The German Bight: shallow water + large exposed tidal flats during low tide

3 Envisat Tracks, 1 Jason1/Jason2 track -> validated against 3 buoys (Helgoland, Elbe, Westerland)

Buoy data -> courtesy of German Waterway and Shipping Administration (WSV) and Federal Maritime and Hydrographic Agency (BSH)

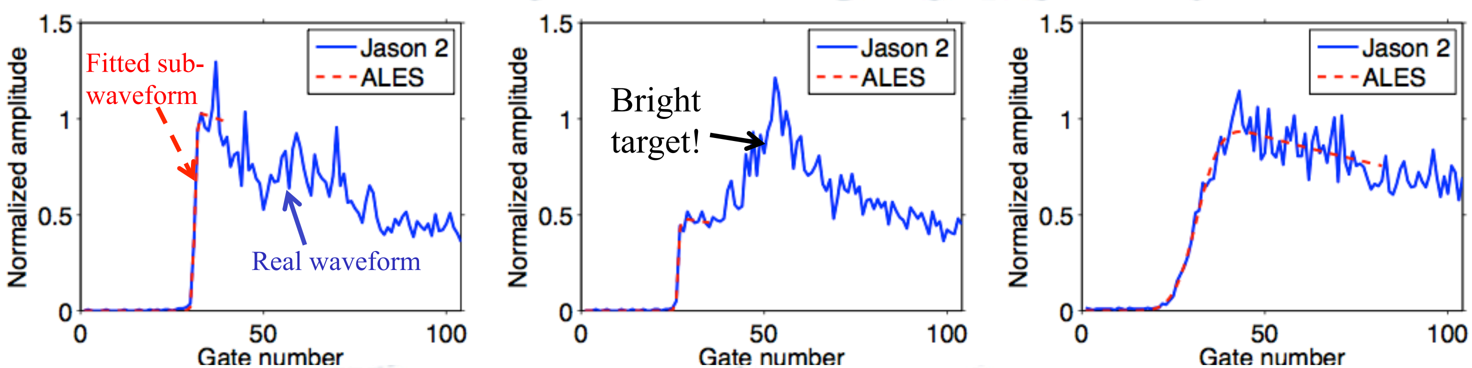
Altimetry data: ALES retracker

- COASTAL-DEDICATED: by extracting a sub-waveform, it avoids contamination from bright targets in the tail

- ADAPTIVE: it adapts the width of the subwaveform to the sea-state in order to maintain the same level of accuracy

- HOMOGENOUS: it applies the same strategy for both open ocean and coastal waveform

ALGORITHM DESCRIPTION AND SEA LEVEL RETRIEVAL VALIDATION IN Passaro et al. (2014)!



Envisat retracking: technical issues

1

Rising time of the leading edge (estimated by retracking)

$$\sigma_c^2 = \sigma_p^2 + \sigma_s^2 \qquad \sigma_s = SWH/2c$$

Width of point-target response function

- 0.53 * 3.125 ns ("old" SGDR)
- 0.66 * 3.125 ns ("new" SGDR)

Which value gives the best results?

2

ENVISAT SGDR provide 2 additional gates to describe the leading edge:

"DFT" gates -> generated by applying a discrete Fourier transform at 2 intermediate frequencies starting from the individual echo

Does the DFT-gates insertion improve the retracking?

Warning: no negative SWH

$$\sigma_c^2 = \sigma_p^2 + \sigma_s^2 \qquad \sigma_s = SWH/2c$$

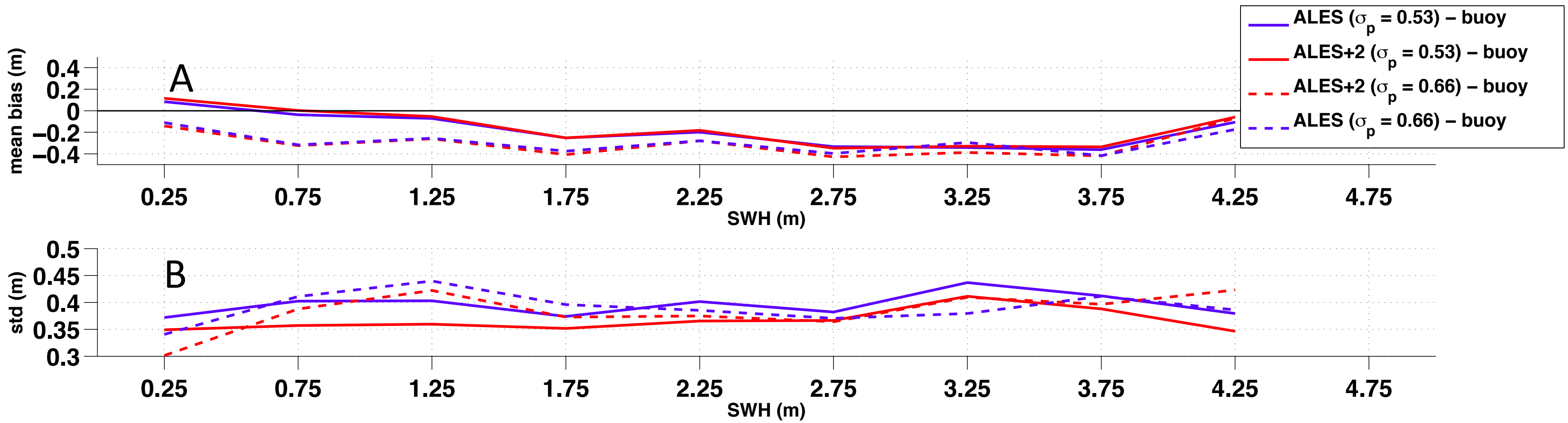
For low sea states, the SWH can be related to a negative square root if $\sigma_p^2 > \sigma_c^2$

Two possible interpretations:
1) Derive a negative SWH

2) Set the SWH = 0

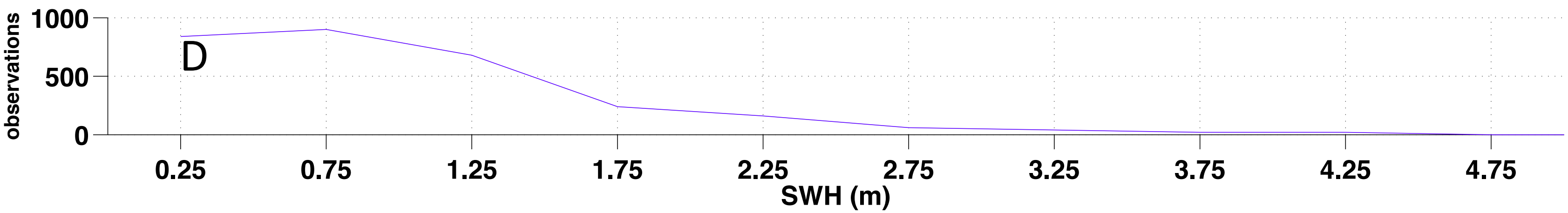
Here we chose 2) because:
- for the sake of comparison, because this has been done in the Jason SGDR
- a negative SWH is not plausible and therefore SWH=0 would be the closest guess to the truth in the comparison with a buoy

DEBATABLE CHOICE -> “bad” consequences in next slide

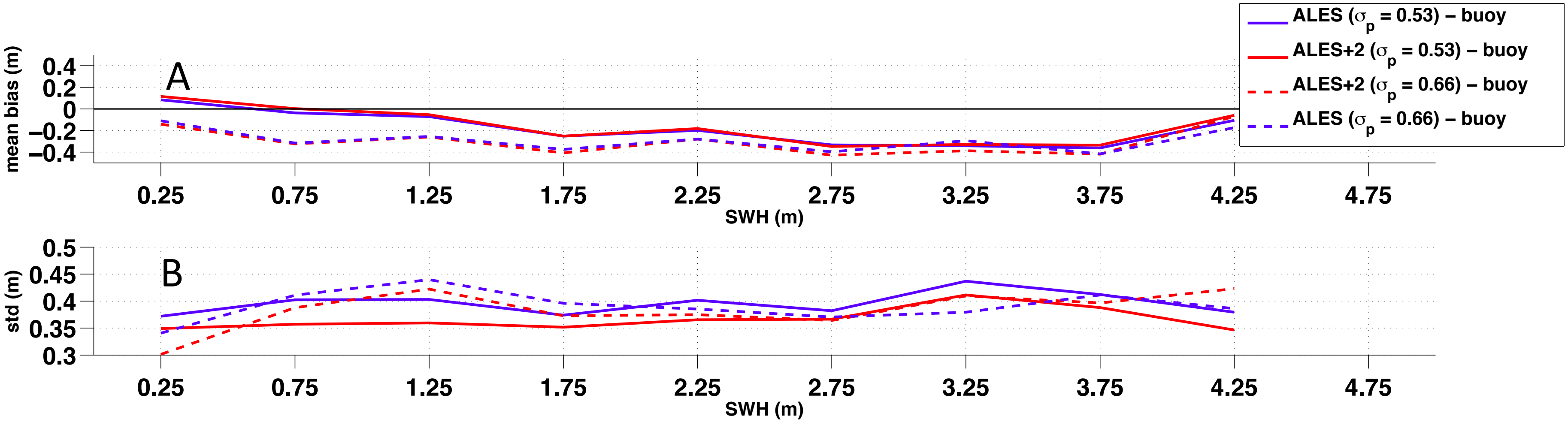


HOW TO GET AN ANSWER:

- consider the 20 high-rate points closest to each buoy for all the tracks
- check the bias and standard deviation of the difference Altimetry – Buoy



N.B.: Conclusions are restricted to low SHW (<2.5 m)

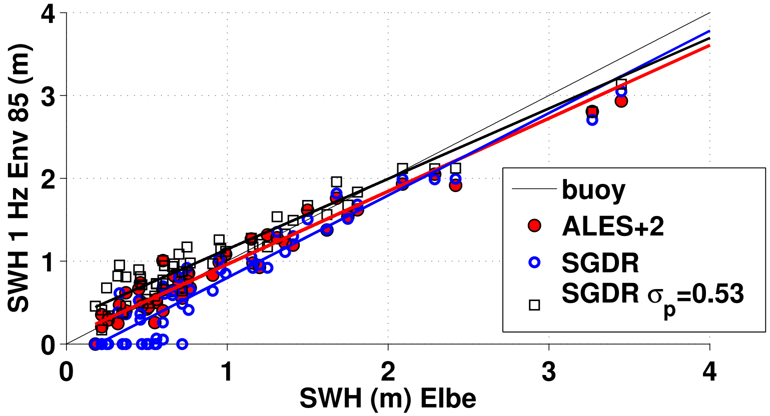


1) The use of the new PTR value (0.66*gate resolution) is responsible for an evident underestimation (~20 cm at low sea-state) [strategy of choice for ALES -> σ_p=0.53r_t]

2) The addition of the DFT gates ('ALES+2') lowers the noise! [strategy of choice for the following slides]

3) The 'anomalous' low std at SWH=0.25 m for σ_p=0.66r_t is caused by the points where SWH assumes null values.

Validation: Closest point - Envisat



Distance from buoy: 3.2 Km
Distance from coast: 17.3 Km

		Correlation	Slope	Bias (m)	StD (m)
Env 85 (Helgoland)	SGDR	0.56 (0.52)	0.71 (0.57)	-0.23 (0.12)	0.69 (0.69)
	ALES	0.89	0.63	0.09	0.27
Env 85 (Elbe)	SGDR	0.97 (0.97)	0.99 (0.85)	-0.22 (0.13)	0.18 (0.15)
	ALES	0.97	0.88	-0.01	0.13
Env 474 (Helgoland)	SGDR	0.63 (0.60)	0.76 (0.63)	-0.31 (0.05)	0.56 (0.58)
	ALES	0.93	0.65	0.00	0.20
Env 474 (Elbe)	SGDR	0.91 (0.90)	1.06 (0.90)	-0.05 (0.23)	0.21 (0.22)
	ALES	0.97	0.97	0.09	0.08
Env 543 (Westerland)	SGDR	0.20 (0.15)	0.42 (0.63)	-0.48 (0.16)	0.67 (0.58)
	ALES	0.55	0.55	-0.01	0.41

ALES scores best for correlation and std!

ALES median bias < 10 cm!

* SGDR ‘corrected’ with the ‘old’ σ_p overestimates low SWH. ALES doesn’t, despite using the same value.

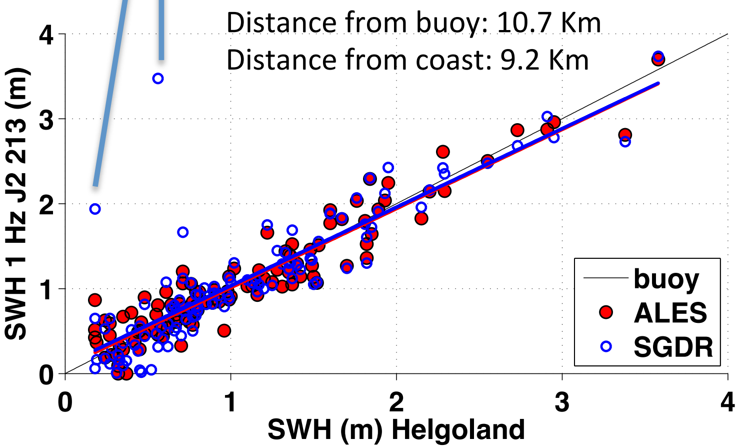
Possible reason -> the noisy trailing edge tends to increase the estimated rising time of the leading edge.

Validation: Closest point - Jason

* Jason SGDR include high rate (20 Hz) SWH (unlike for Envisat)

		Correlation	Slope	Bias (m)	StD (m)
J2 213 - 1 Hz (Helgoland)	SGDR	0.85	0.93	- 0.04	0.34
	ALES	0.95	0.90	-0.01	0.15
J2 213 - 20 Hz (Helgoland)	SGDR	0.80	0.83	0.07	0.67
	ALES	0.85	0.87	0.01	0.57
J1 213 - 1 Hz (Helgoland)	SGDR	0.81	0.95	0.03	0.52
	ALES	0.93	0.98	0.11	0.23
J1 213 - 20 Hz (Helgoland)	SGDR	0.86	1.04	-0.02	0.55
	ALES	0.87	1.06	-0.01	0.33

SGDR wrong estimations (influence of Helgoland island in the footprint)



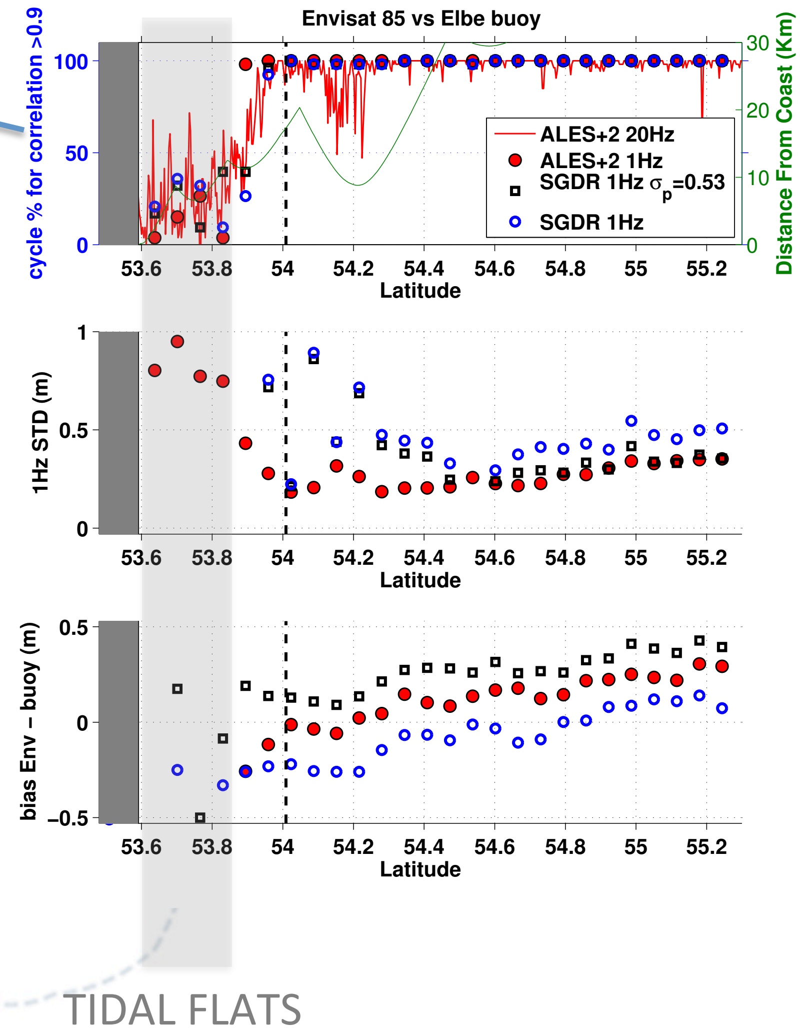
No systematic bias issues in Jason

Std(altimetry – buoy)

ALES brings a variance reduction by a factor of 5 at 1 Hz!

Validation: Along track- Envisat

The maximum percentage of cycles of data that could be retained whilst guaranteeing a correlation with the buoy time series of at least 0.9.



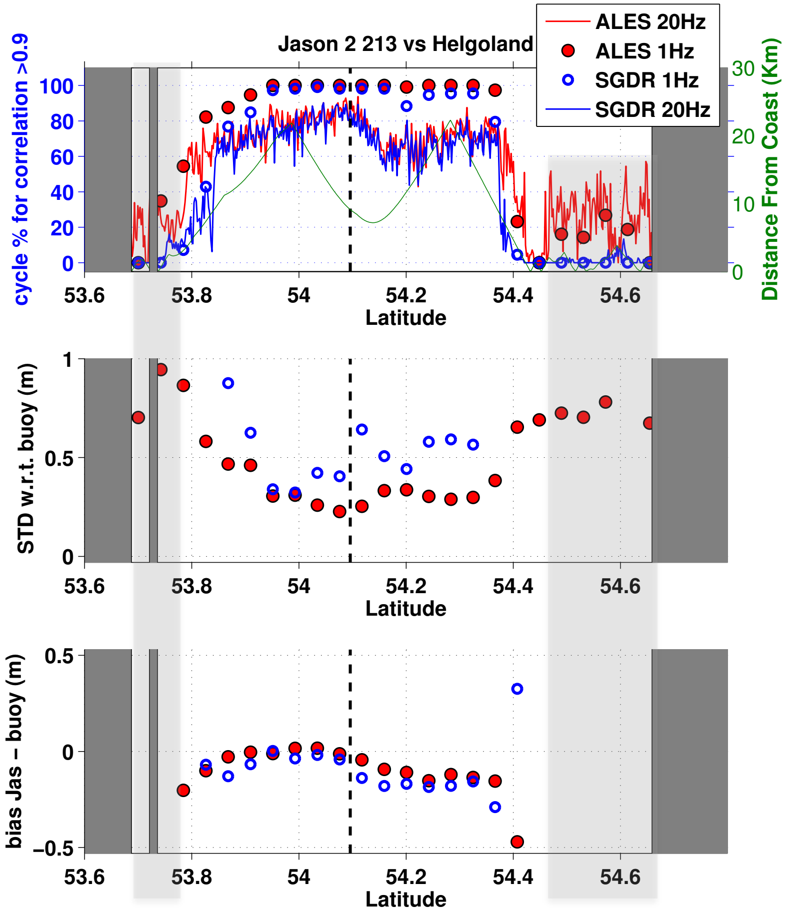
- ALES improves the amount of correct estimations getting close to the coast

- Systematic bias of SGDR, ALES has the minimum bias at the point closest to the buoy

- In the tidal flats, high-rate data better than 1 Hz averages -> need of a dedicated data screening and outlier detection

- ALES noise performances do not degrade close to the coast (std w.r.t. buoy value)

Validation: Along track- Jason



TIDAL FLATS

TIDAL FLATS

- ALES brings very significant improvements in terms of correlation and std all along the track

- Retrieval of SWH in the tidal flats at high tide, where SGDR does not provide any value

Conclusions

For Envisat mission, the addition of the 2 DFT gates and the use of σ_p=0.53r_t brings improvements respectively in terms of noise and bias

ALES is able to extend the quality and the quantity of SWH retrievals towards the coast, for about 7 to 22 km in terms of spatial improvement.

ALES bias with buoy values is within 10 cm. The comparability with the ground truth is increased.

ALES 1-Hz estimations have a constantly lower standard deviation compared to the original SGDR product.

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REFERENCES

[1] Passaro, M., Cipollini, P., Vignudelli, S., Quartly, G., Snaith, H. (2014). ALES: a multi-mission adaptive sub-waveform retracker for coastal and open ocean altimetry, Remote Sensing of Environment, *145*, 173-179.
[2] Passaro, M., Fenoglio-Marc, L., Cipollini, P. (2014). Validation of Significant Wave Height From Improved Satellite Altimetry in the German Bight, IEEE Transactions on Geoscience and Remote Sensing (ACCEPTED)