Two decades of Significant Wave Height and sigma0 from altimetry record with retracked with WHALES: Towards low noise and coastal efficiency

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Framework: the Sea State CCI

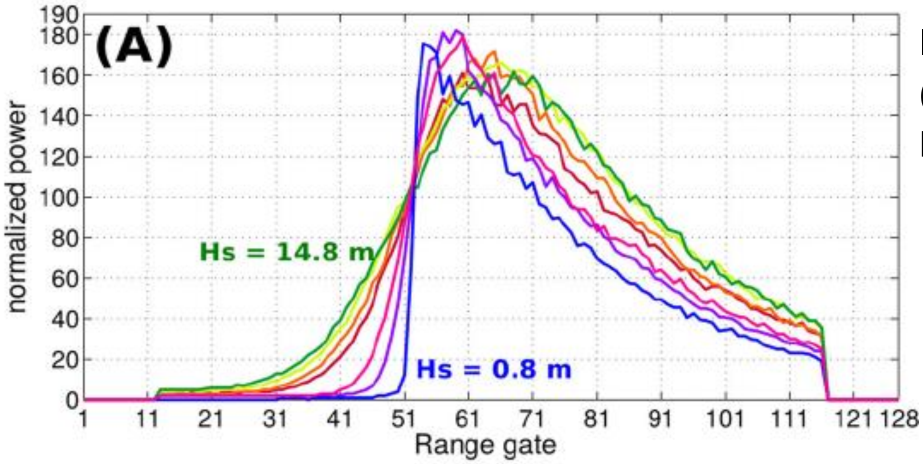
- The main aim of ESA‘s Sea State Climate Change Initiative is the provision consistent time series of significant wave height from satellite altimetry

- TUM is responsible for the coordination of the teams of the Algorithm Development and for setting up a Round Robin exercise

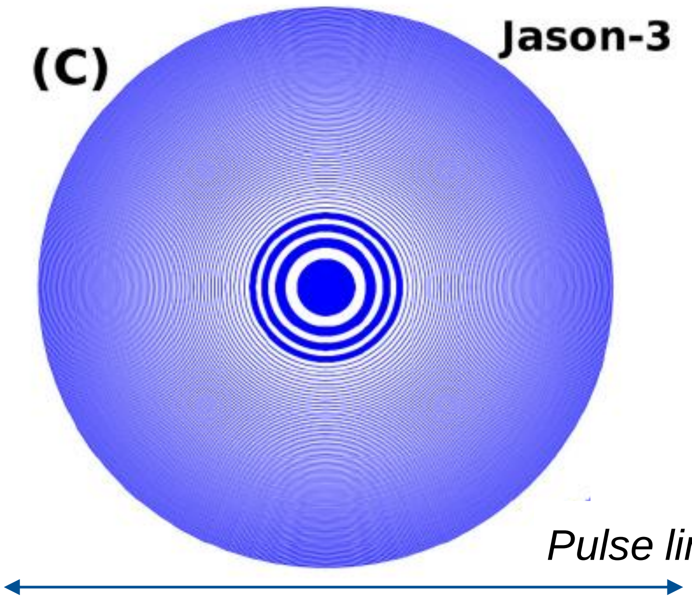
- In the Round Robin, Sea State CCI internal and external partners have been asked to provide a test dataset using their own algorithms. In the next 3 months we are going to evaluate them

- TUM itself is an algorithm developer and takes part to the „competition“ with the WHALES algorithm

SWH in Low Resolution Mode: where are we?



Images from Ardhuin et al. (2019): Observing Sea States, Frontiers in Marine Science



Pulse limited footprint

Areas of improvement:

- Retrieval of SWH is noisy! (even at low sea states can be ~0.50 cm at 20 hz!)
- Poor performances in the last 0-20 km from the coast
- Poor performances for very low and very high sea states

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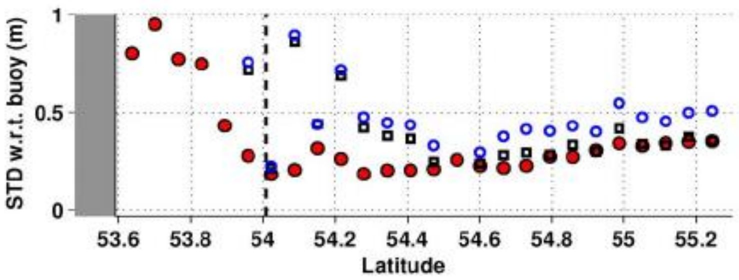
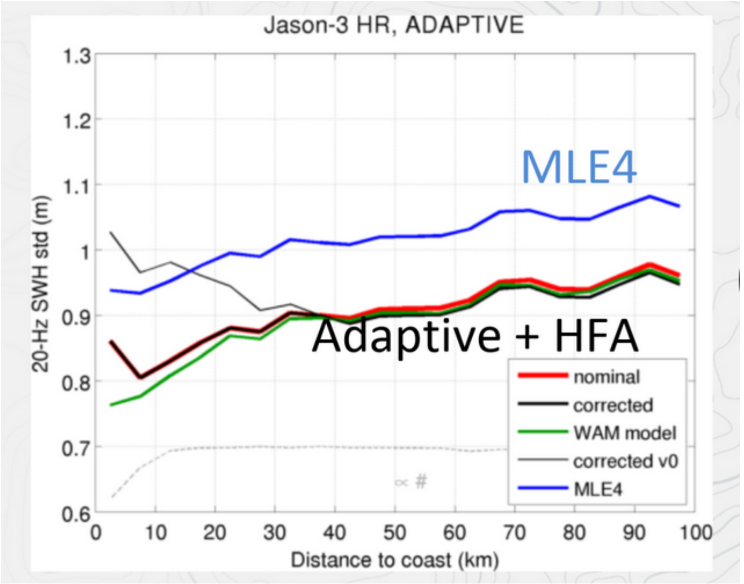


ALES, Conventional, RADS

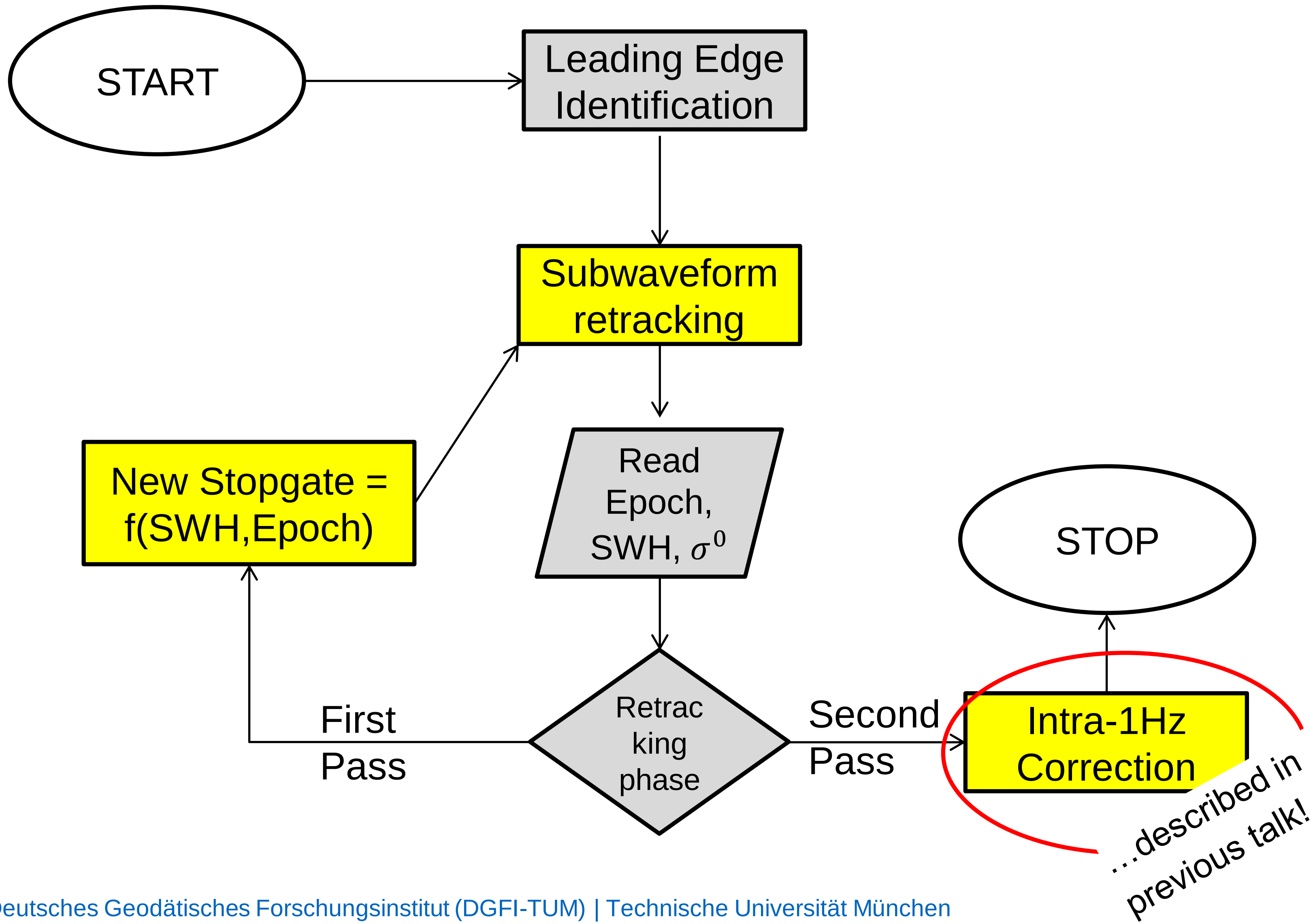
ALES, the adaptive subwaveform retracker, shown significant improvements in detecting wave height (SWH) close to the coast. (Passaro et al., 2015)



Courtesy of P.Thibaut, CLS

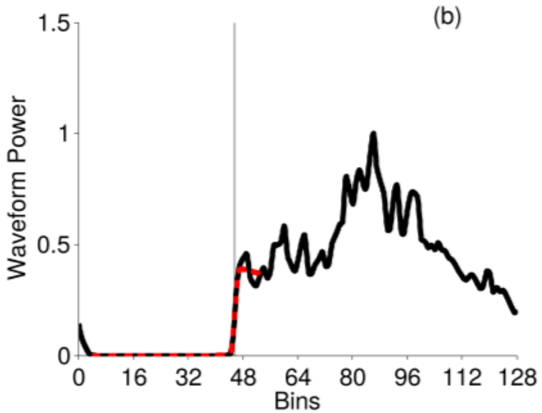
CLS („Nelder-Mead“ or „Adaptive“ retracker) recently showed strong advantages for wave height (SWH) when using a numerical and weighted solution. Can the ALES concept take advantage from that?

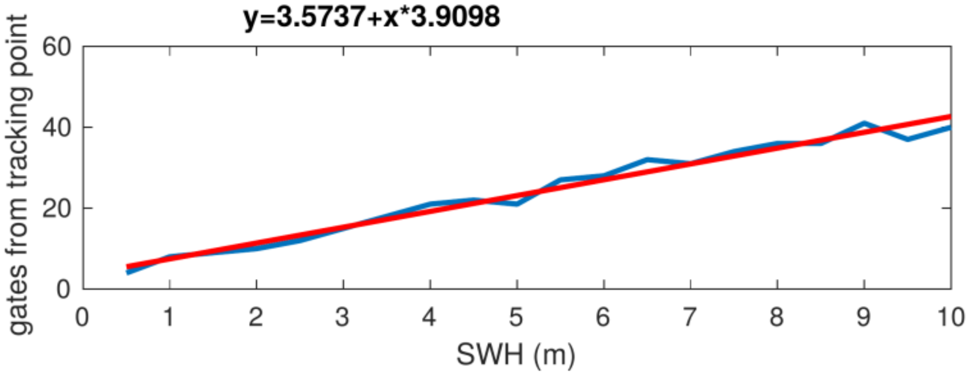
WHALES: the structure



WHALES: Adaptive Subwaveform

- WHALES is based on a linear relationship between SIGNIFICANT WAVE HEIGHT and width of the subwaveform





New linear relationship linking first estimation of SWH and width of the subwaveform in the second pass

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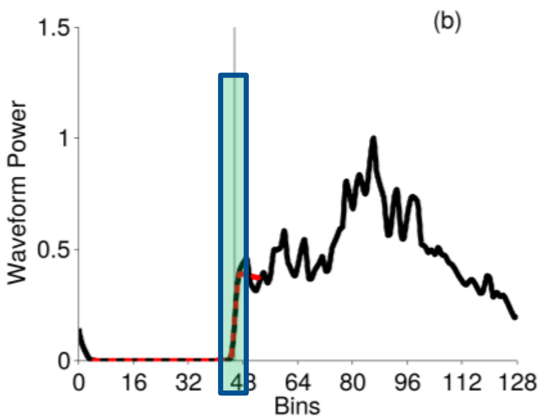

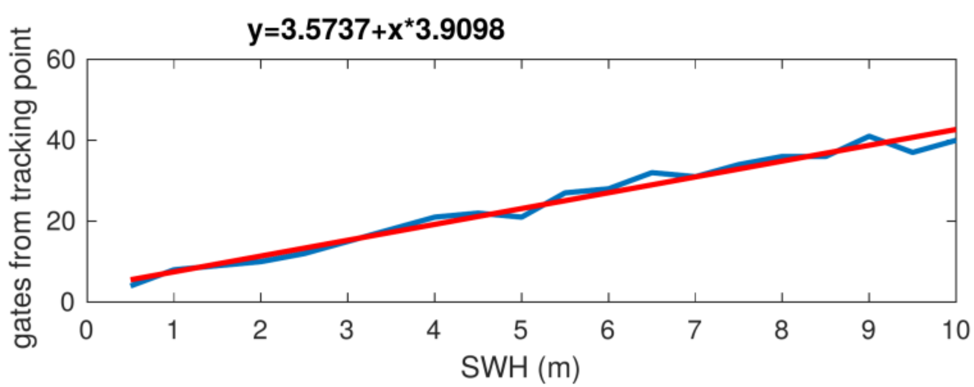

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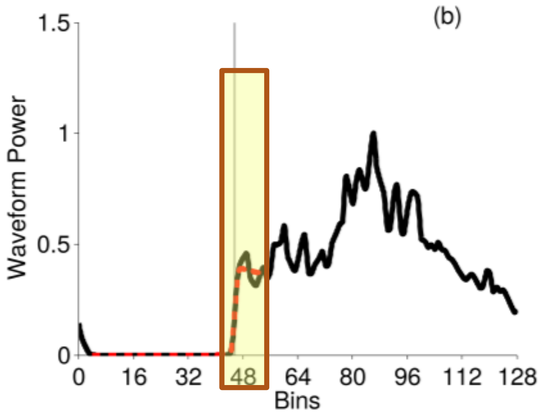

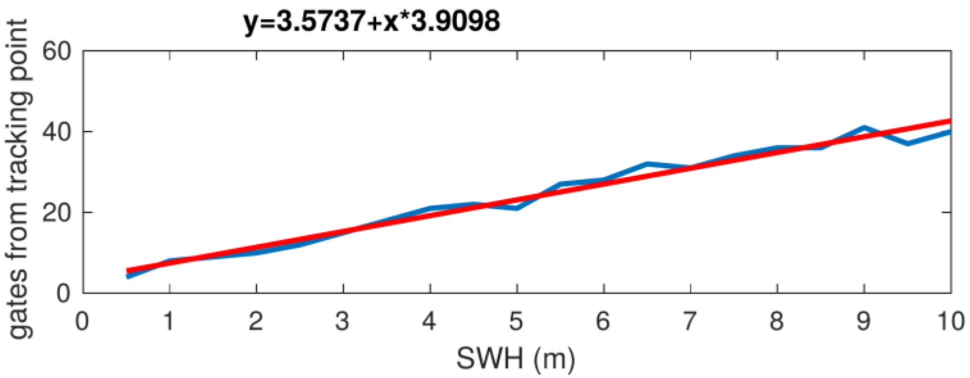

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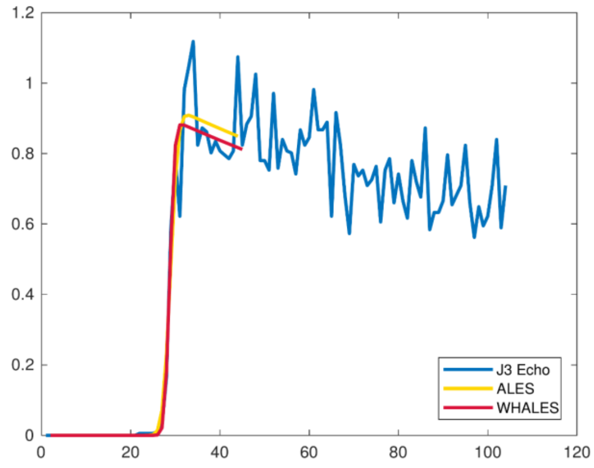
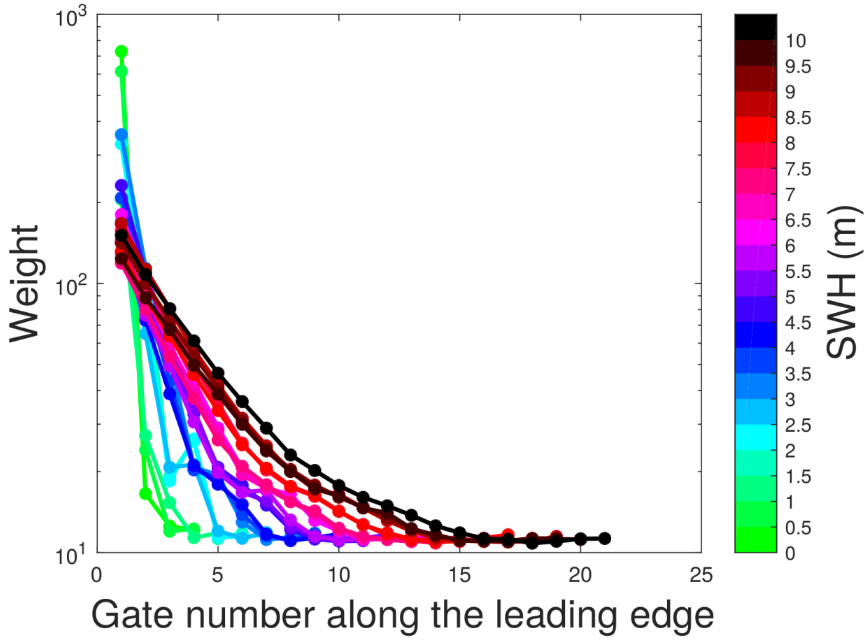
WHALES: Adaptive Weights (and correlated errors)



$$C = \sum W * R^2$$



Statistical weighting: 1/uncertainty
The higher the confidence in our fitting, the higher the weight

WHALES: Adaptive Weights (and correlated errors)

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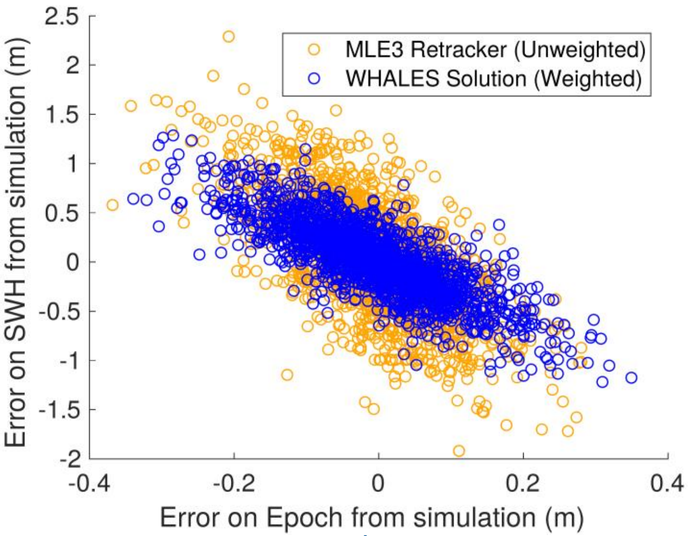
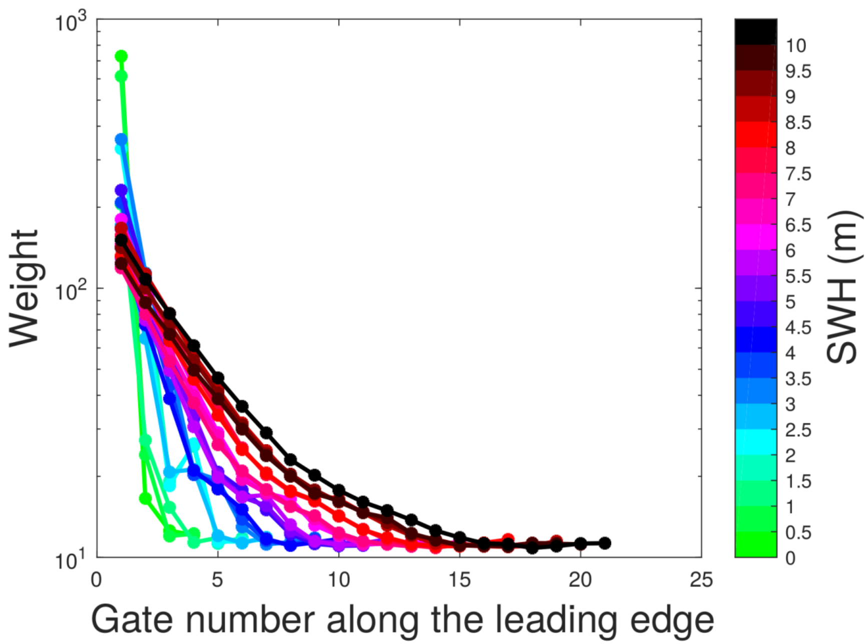


Note: correlation of errors can be reduced by intra-1Hz corrections (Sandwell &Smith 2005, Quartly et al. 2019, previous talk by Quartly et al.)



Statistical weighting: 1/uncertainty

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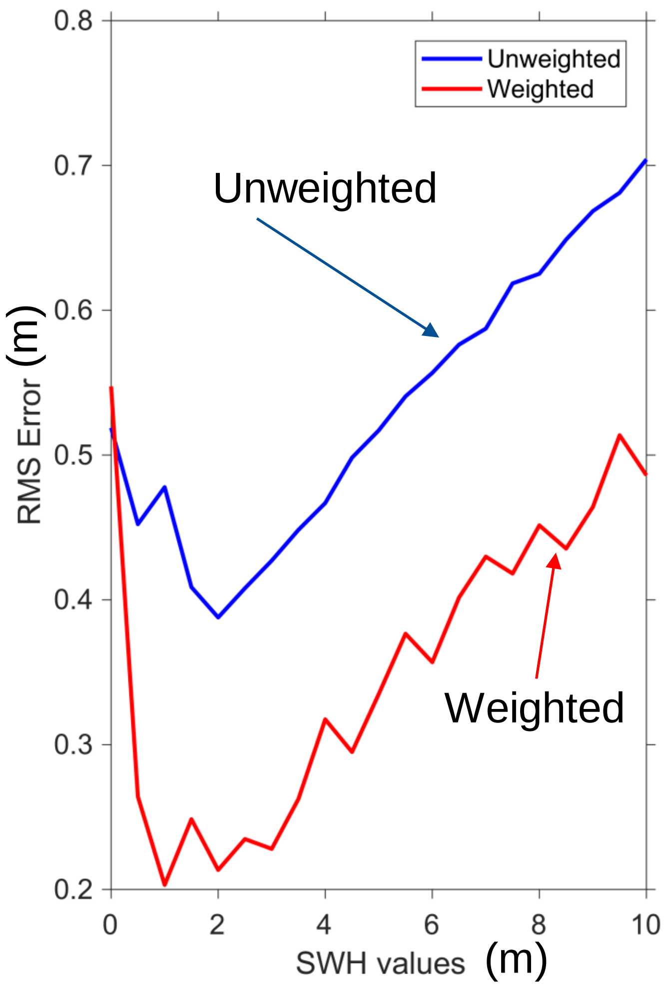
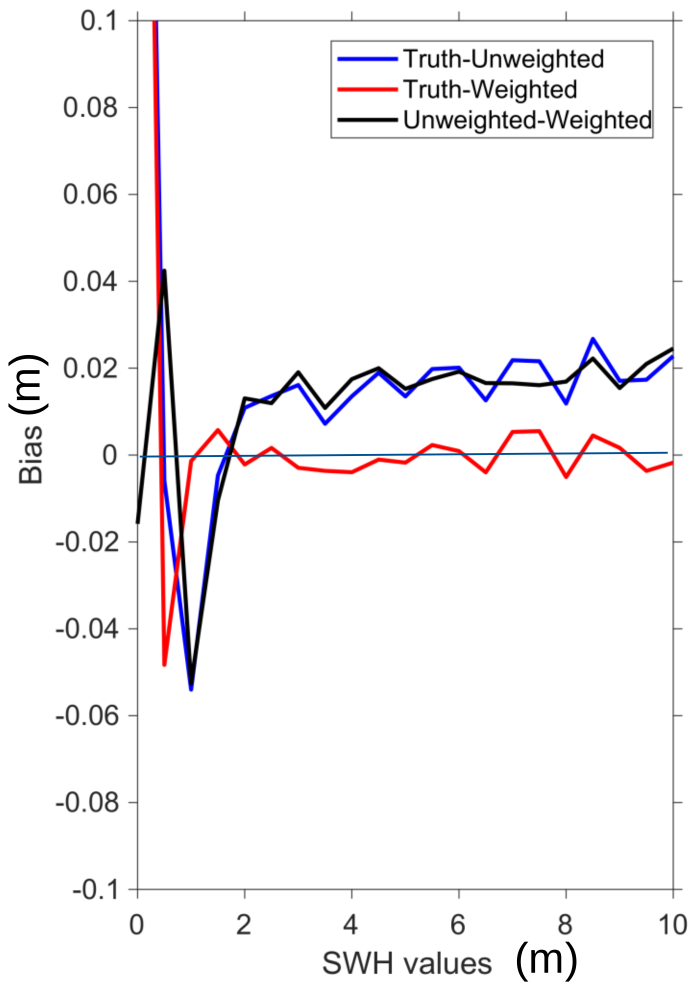
WHALES: expected improvements

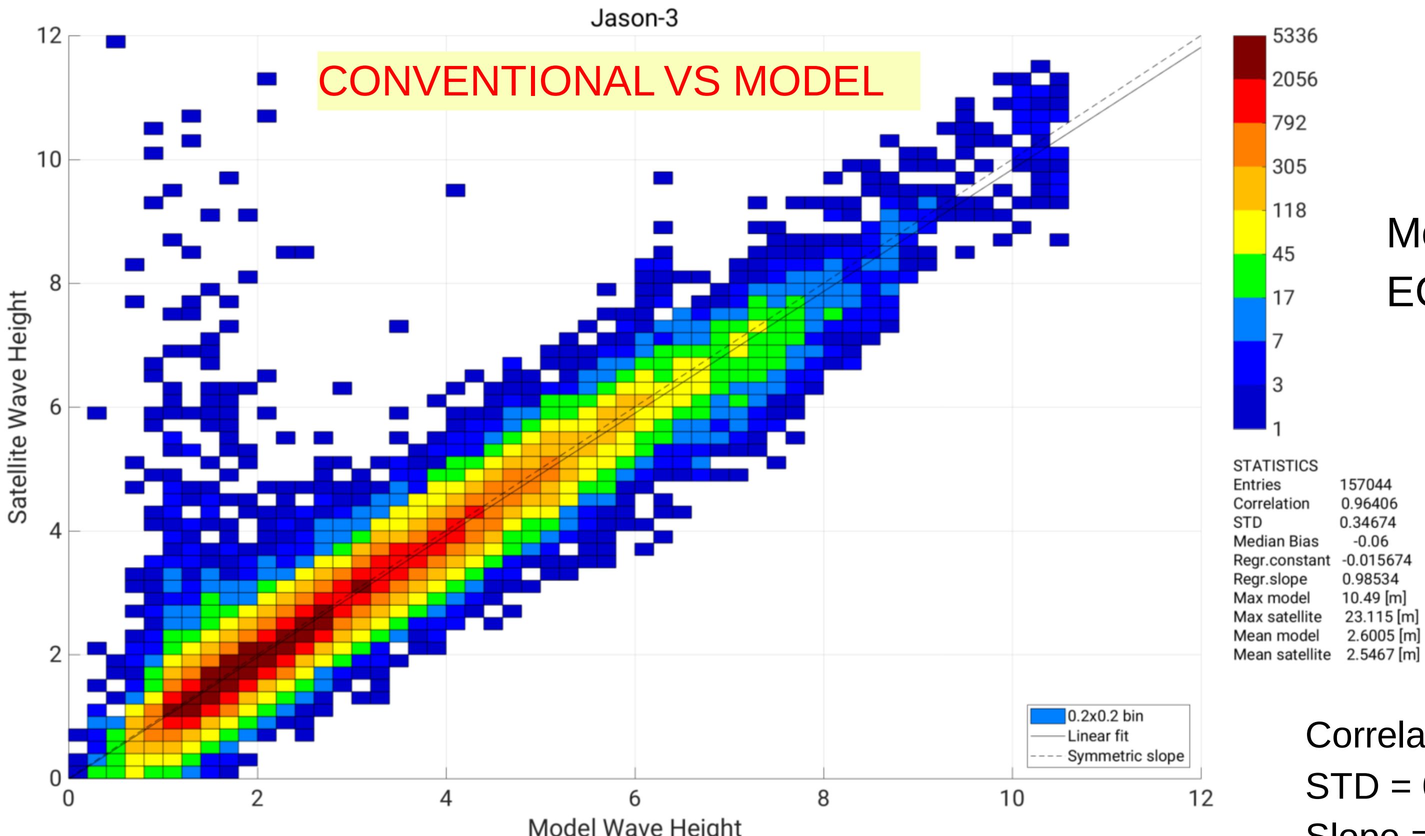
From Montecarlo experiment using simulated waveforms:





WHALES: Validation snapshots Open Ocean

Comparison with model (despite J3 assimilated in the model): better correlation, better treatment of very low sea states, better standard deviation

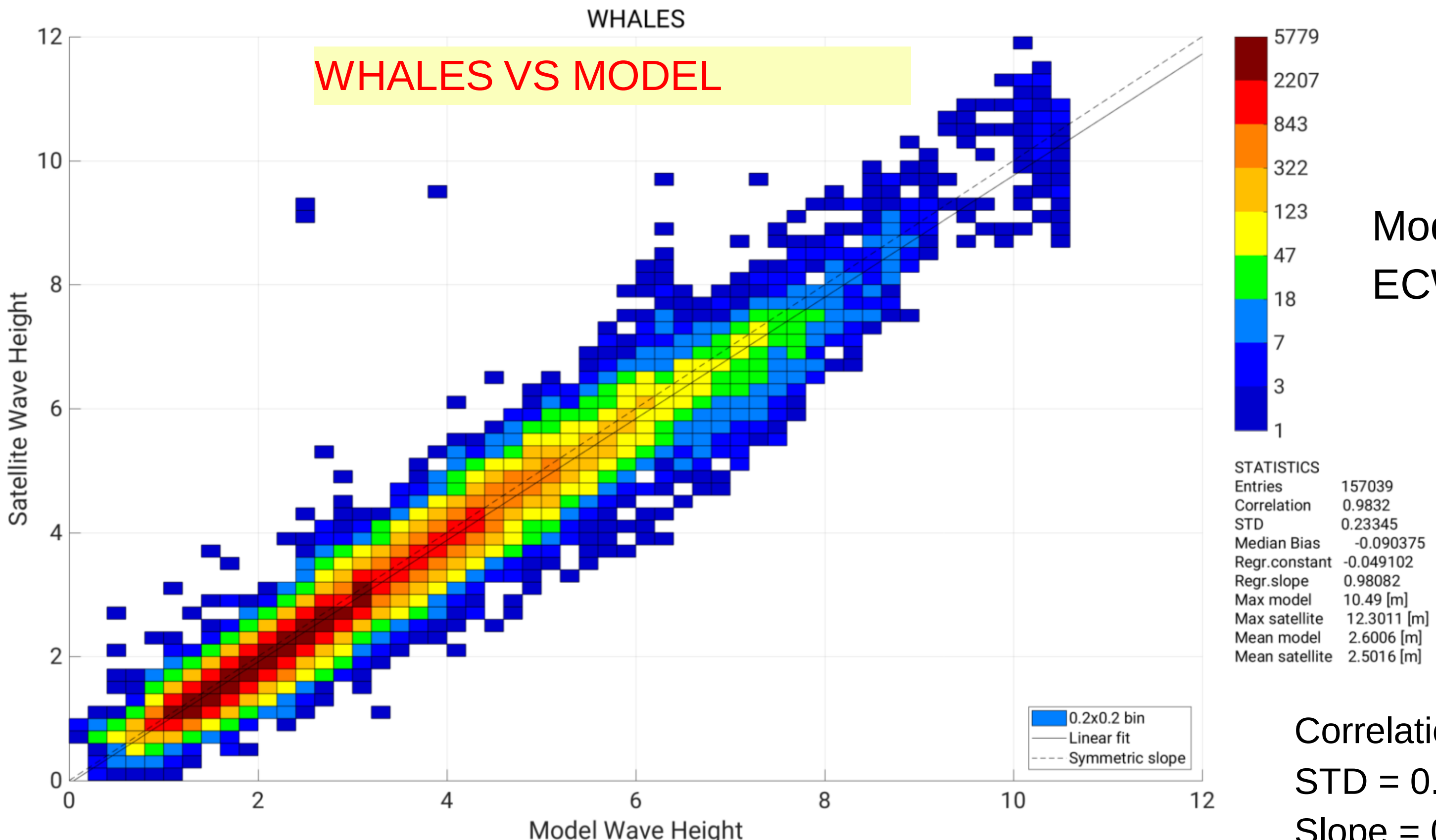


Model used:
ECWAM

Correlation = 0.96
STD = 0.35
Slope = 0.98
Bias = -0.06
Entries = 157044

WHALES: Validation snapshots Open Ocean

Comparison with model (despite J3 assimilated in the model): better correlation, better treatment of very low sea states, better standard deviation

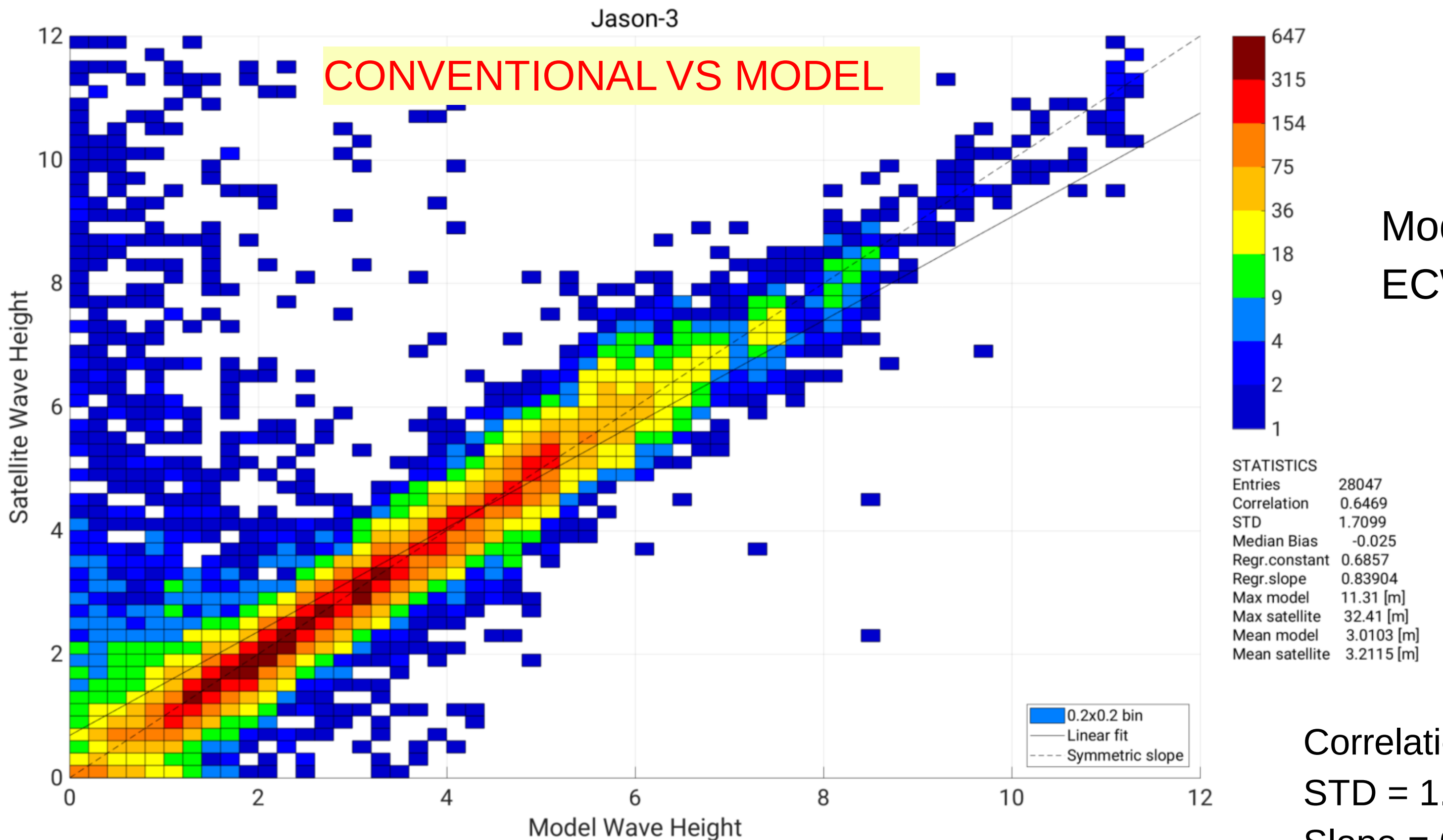


Model used: ECWAM

Correlation = 0.98
STD = 0.23
Slope = 0.98
Bias = -0.09
Entries = 157039

WHALES: Validation snapshots Coast

Comparison with model (despite J3 assimilated in the model): better correlation, better treatment of very low sea states, better standard deviation



Model used: ECWAM

Correlation = 0.64

STD = 1.70 m

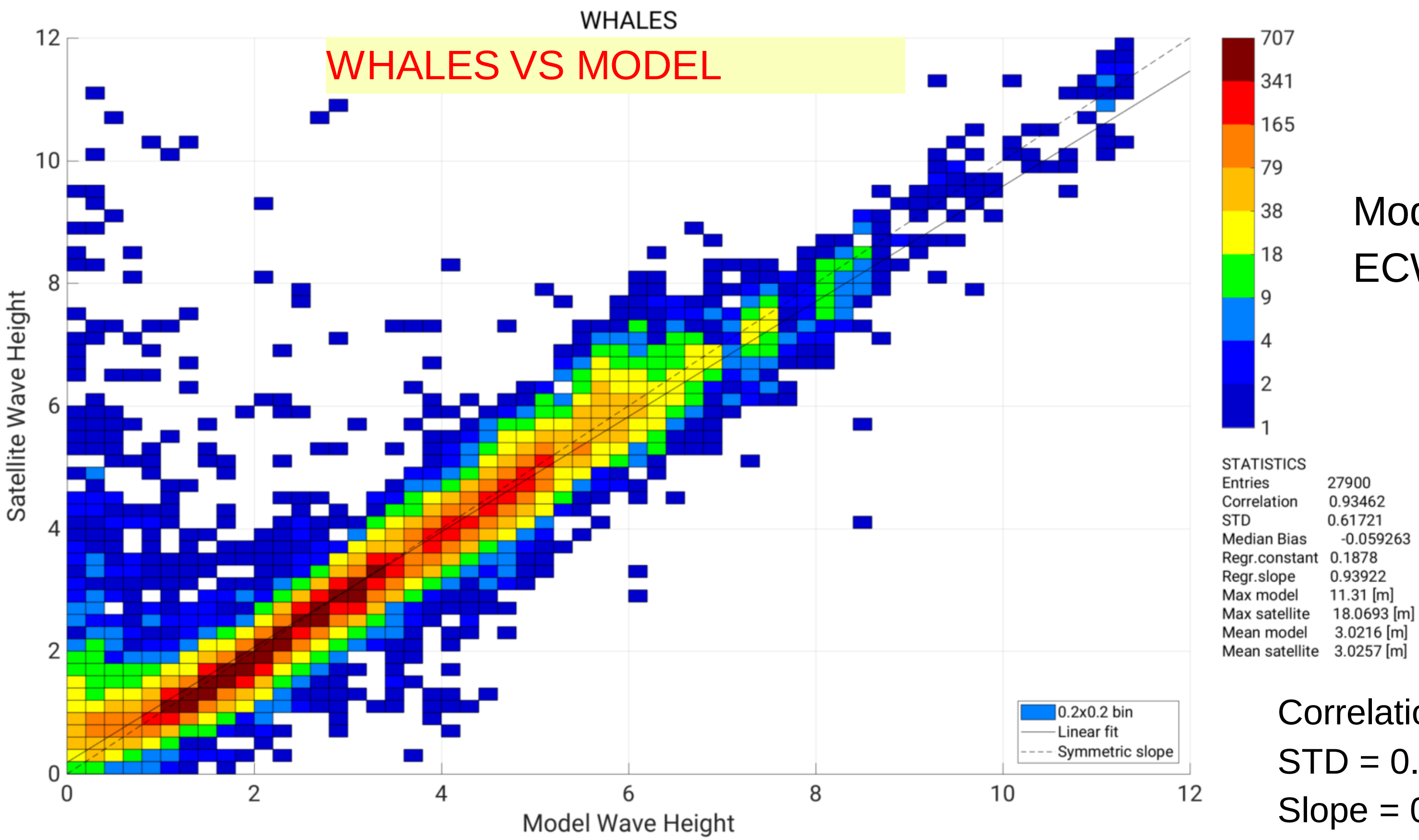
Slope = 0.83

Bias = -0.03

Entries = 28047

WHALES: Validation snapshots Coast

Comparison with model (despite J3 assimilated in the model): better correlation, better treatment of very low sea states, better standard deviation

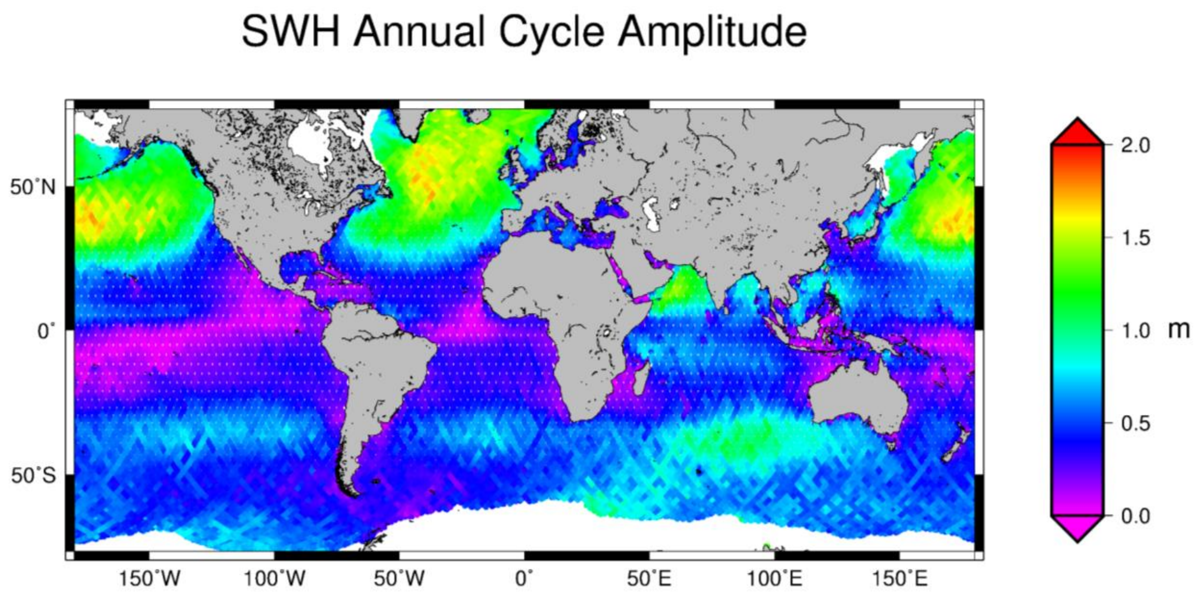


Model used:
ECWAM

Correlation = 0.93
STD = 0.61 m
Slope = 0.93
Bias = -0.06
Entries = 27900

Conclusions and Perspectives

Improving the quality of along-track data, applicable to all the LRM era…

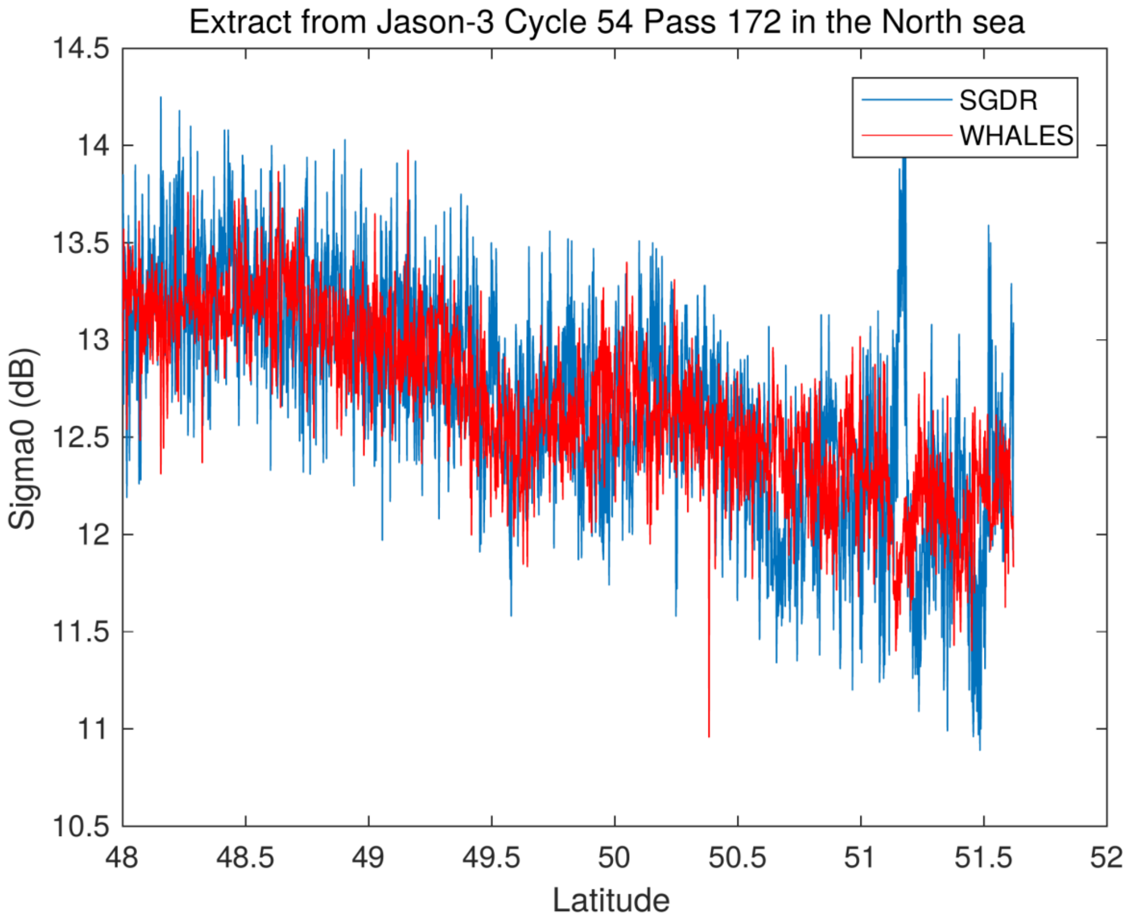


…TUM aims at using WHALES time series to study trends, periodicities and extremes, with special focus in the coastal ocean

SPARE SLIDES

Sigma0

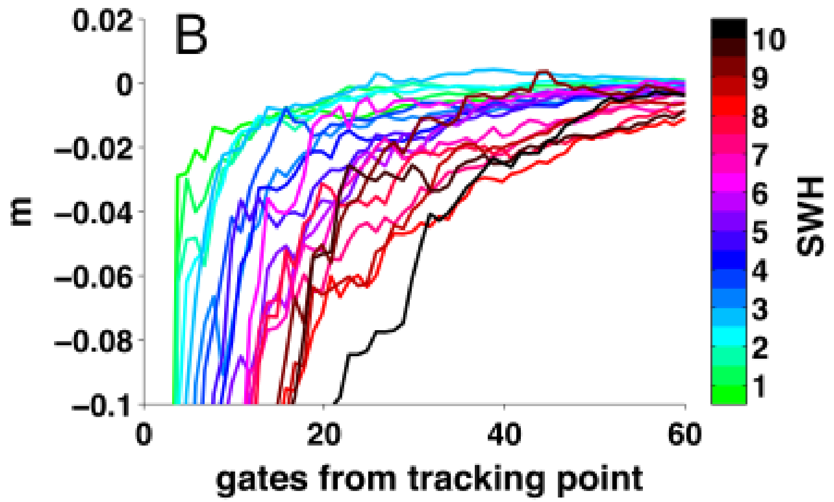
Sigma0 is there…and much less noisy too



WHALES: Subwaveform tuned for SWH estimation

- ALES is based on a linear relationship between theoretical precision ON SEA LEVEL HEIGHT and width of the subwaveform

Theoretical precision difference „Full waveform – Subwaveform“



Subwaveform width

Not yet adapted for SWH, despite good results!

WHALES: Subwaveform tuned for SWH estimation

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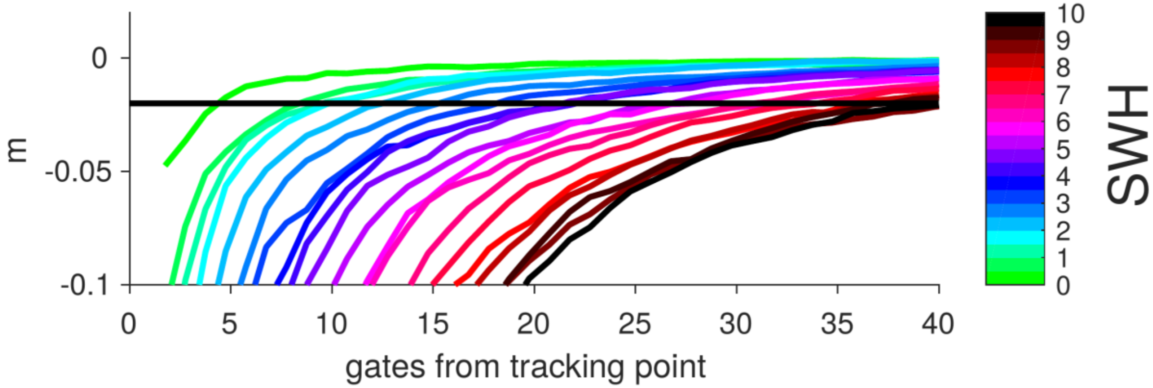
Theoretical precision difference „Full waveform – Subwaveform“

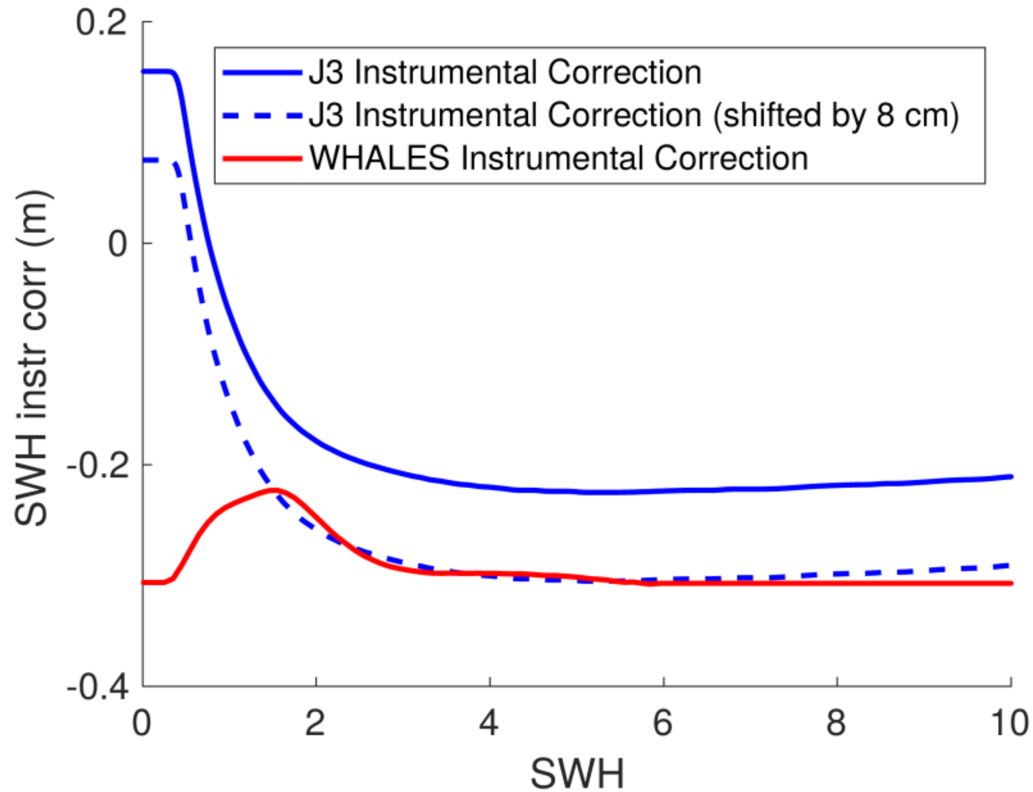


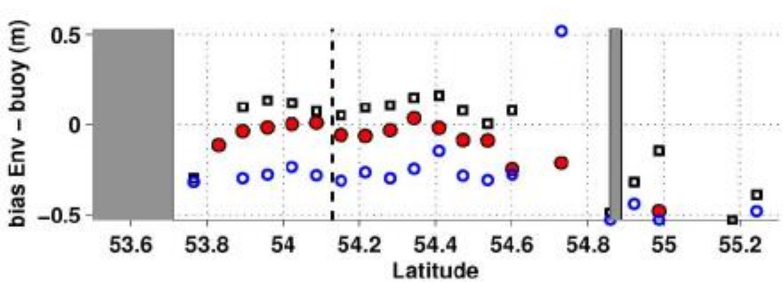
Subwaveform width

Treatment of Point Target Response

Dedicated instrumental correction (PTR Gaussian hypotheses) -> waiting for PML input

Current solution: empirical instrumental correction derivation by comparison with Jason-3 official product





…note that missing specific PTR correction was not a problem in ALES…(providing PTR is stable)

WHALES: Subwaveform tuned for SWH estimation

- Why is an adaptive subwaveform scheme convenient for SWH estimation?

1) If you use a fixed subwaveform, say for example a leading-edge retracker, your noise performances are much more dependent on the sea state
2) You have the best compromise between data quantity at the coast and preservation of data quality in the open ocean
3) You avoid inhomogeneities in the footprint which are related to the „spectral hump“

WHALES: Weighted residuals in Nelder-Mead

From Passaro et al. 2014: „ALES adopts an unweighted least-square estimator whose convergence is sought through the Nelder-Mead (NM) algorithm"

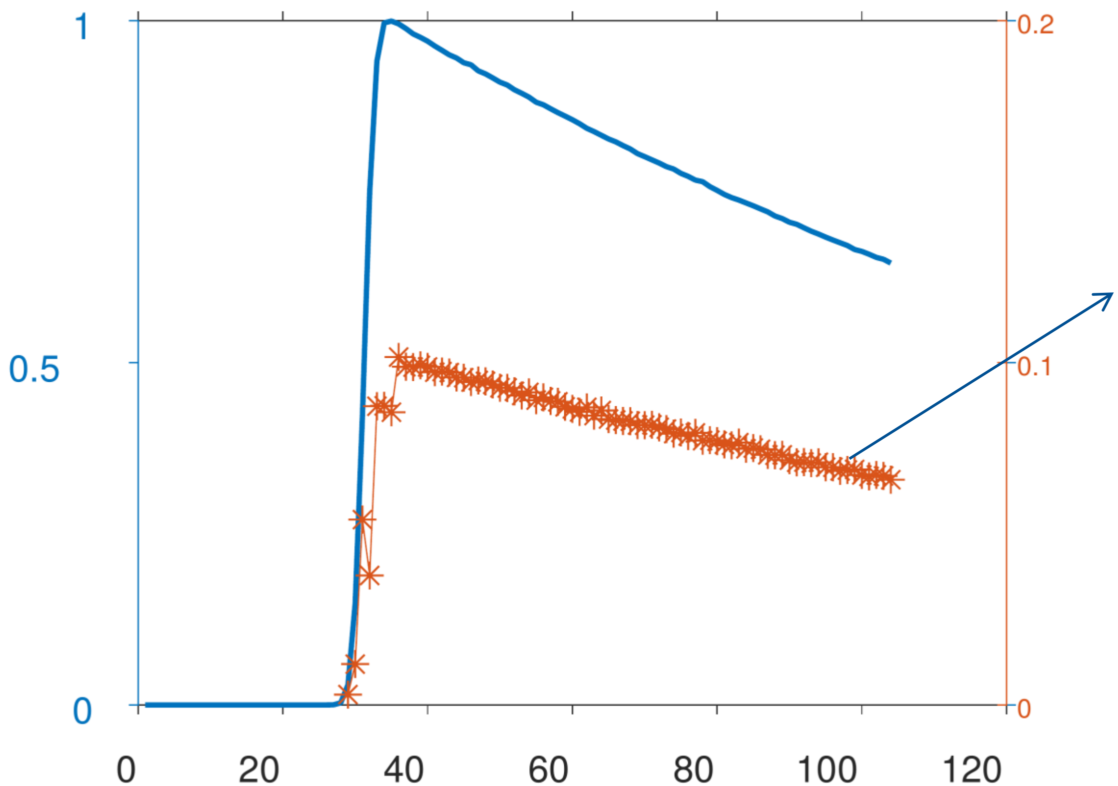
NM does not require the computation of the derivatives. „Downhill method": it finds a minimum of the cost function in a multi-dimensional space. Iterations: the next point of NM is a combination of parameters that gives a smaller cost function than the previous iteration.

Who uses a weighted estimator in the latest retracking solutions? At least: Deng&Featherstone (2006), CLS („Nelder-Mead" or „Adaptive" retracker), Peng&Deng

Peng&Deng downweighted peaks in the trailing edge for coastal altimetry purposes

Sandwell&Smith 2005 warned against using a specific weighted estimator (Maus et al., 1998, downweight of gates with higher noise) due to increase in sea level – SWH correlation. Need to keep this „under control", we will also add a step to de-correlate sea level and SWH!

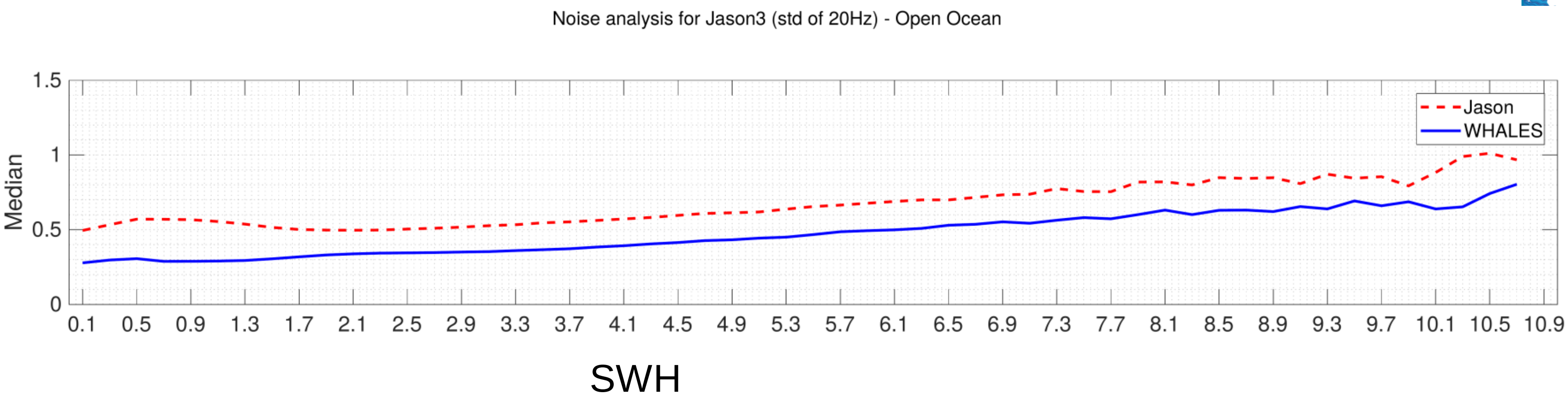
WHALES: Weighted residuals in Nelder-Mead



STD of Residuals from a minimization through Nelder Mead…not healthy, ideally the std of the residual should be constant…at least for the part of the wavevorm we need!

WHALES Retracker – Noise Performances (real data)

High-rate noise: Decrease of ~60% in terms of variance (median values of the std in the 1Hz records are shown) [more if we do intra-1hz corrections]



Testbed area: West Coast of North America (Latitude 30 to 60, Longitude -160 to 120)

Draft of the Round Robin Agreement

The main concepts:

- A definite number of statistics
- Separate open ocean and coast
- External data (buoys) to be provided „ready to use“
- Code of the validation functions to be freely available
- Weights or criteria of final decision to be collegially decided by the consortium