ALES+: Adapting a homogenous ocean retracker for satellite altimetry to sea ice leads, coastal and inland waters.

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Ocean Surface Topography Science Team

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Summary

- Motivation

- ALES+ concept

- Validation in every domain

- Conclusion

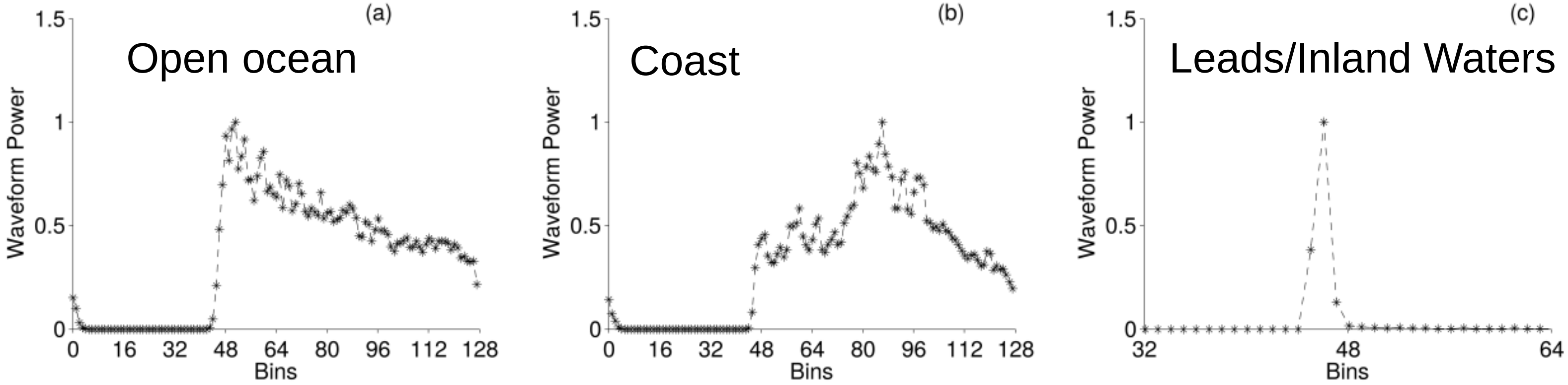
Motivation

- Background from other on-going efforts: see presentations by CLS (ESA Living Planet 2016, OSTST 2016, …)

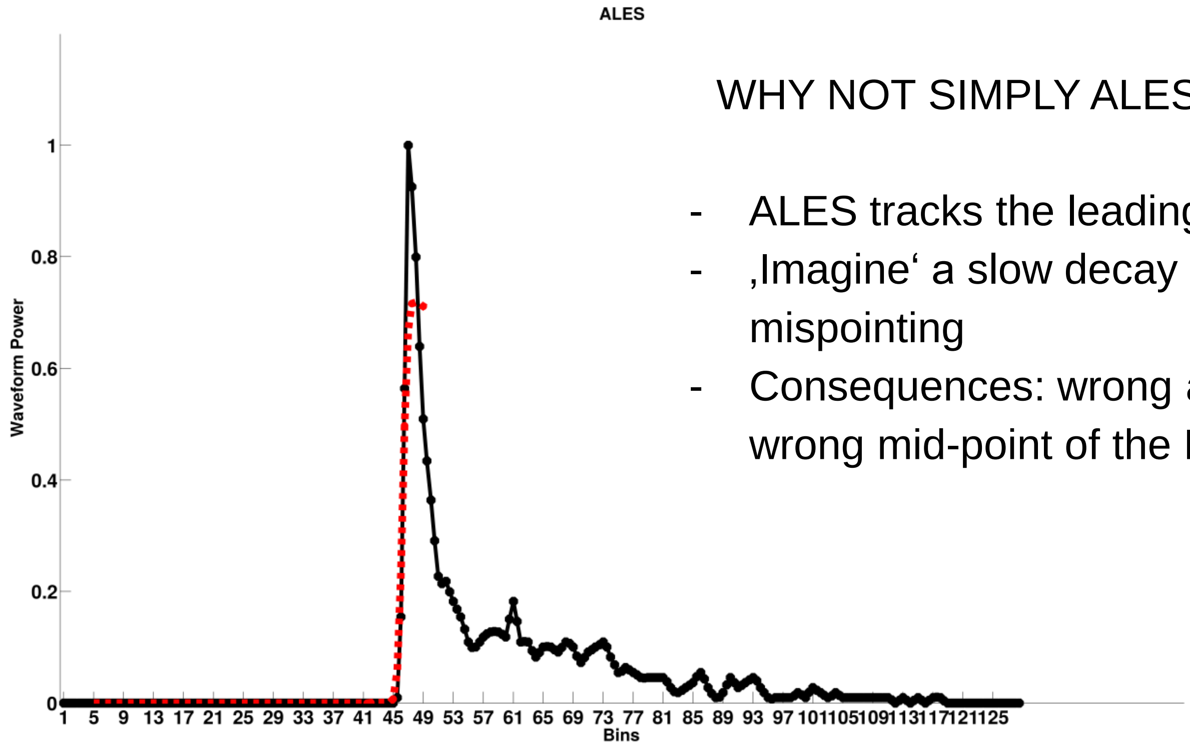
- Different water surfaces = different waveform shapes

- Different retrackers = varying performances and biases within retrackers

- Option work for ESA Sea Level CCI: provide a homogenous solution for the Arctic and Antarctic Ocean (without excluding coastal waters and leads!)



ALES+ concept



WHY NOT SIMPLY ALES?

- ALES tracks the leading edge position
- ‚Imagine' a slow decay varying only with mispointing
- Consequences: wrong amplitude and wrong mid-point of the LE

In general: trailing edge varies also w.r.t. Mean Square Slope (Jackson et al. 1992, Poisson et al. 2015)!

ALES+ concept

$$W(t) = \frac{A}{2}\left\{1 + erf\left[\frac{(t-t_0)}{\sqrt{2}}\sigma\right]\right\} exp\left(-\frac{(t-t_0)}{\tau}\right)$$

Jackson readapted from Jackson et al. 1992

$$W(t) = \frac{P_u}{2}\left\{1 + erf\left[\frac{(t-t_0) - c_\xi \sigma_c^2}{\sqrt{2}}\right]\right\} exp\left(-c_\xi\left[(t-t_0) - \frac{c_\xi \sigma_c^2}{2}\right]\right)$$

Brown-Hayne readapted from Goemmenginger et al. (2011)

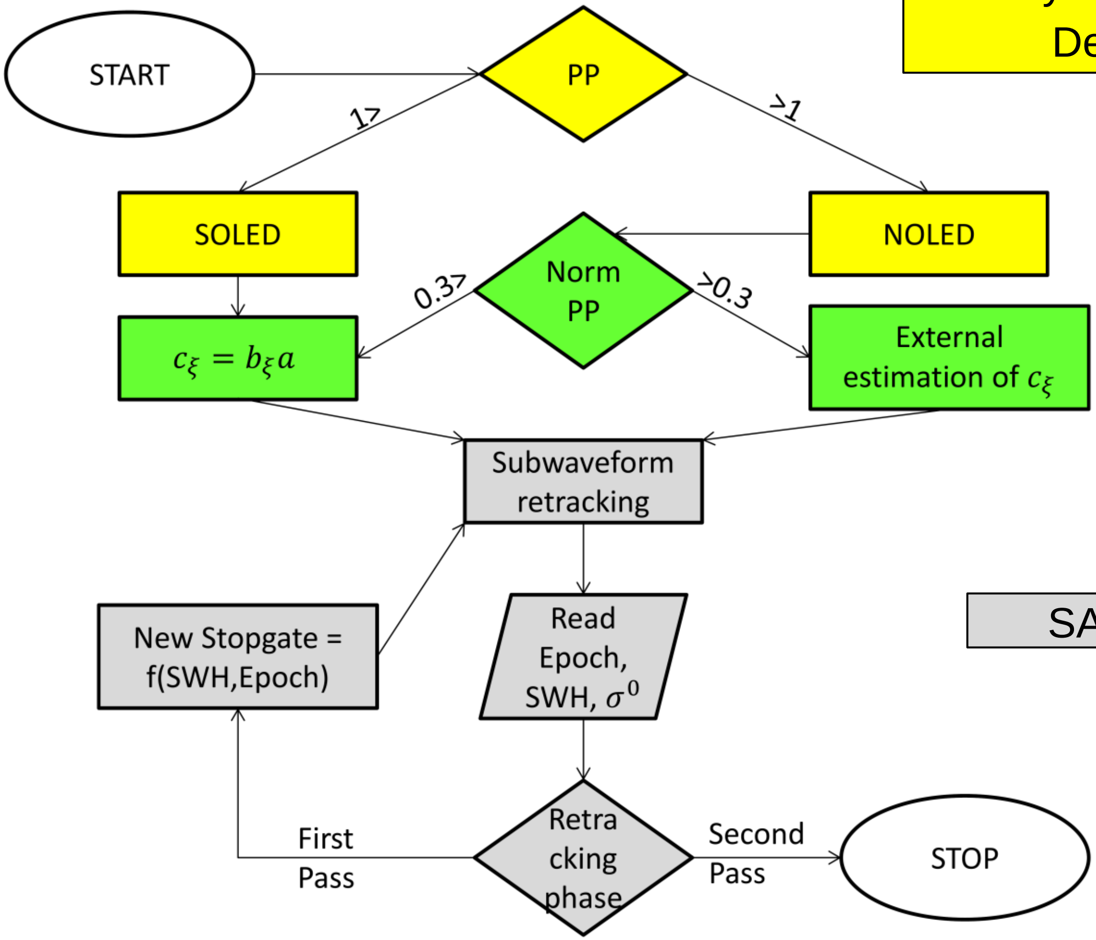
$$\tau = \tau(Mean\ Square\ Slope, Beam\ Width)$$

$$c_\xi = c_\xi(Mispointing, Beam\ Width)$$

CLS et al.: showed how to combine Jackson with Brown-Hayne using MSS as unknown

Our solution: estimate c_ξ from the waveform (if peaky) and give it as a known number to ALES

ALES+ concept



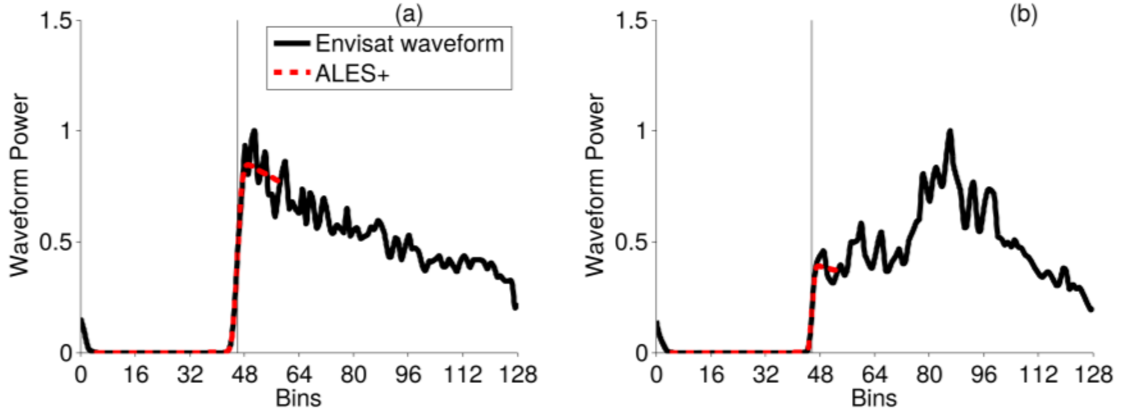
Different Peaky vs Non-Peaky Leading Edge Detection

External estimation of trailing edge slope

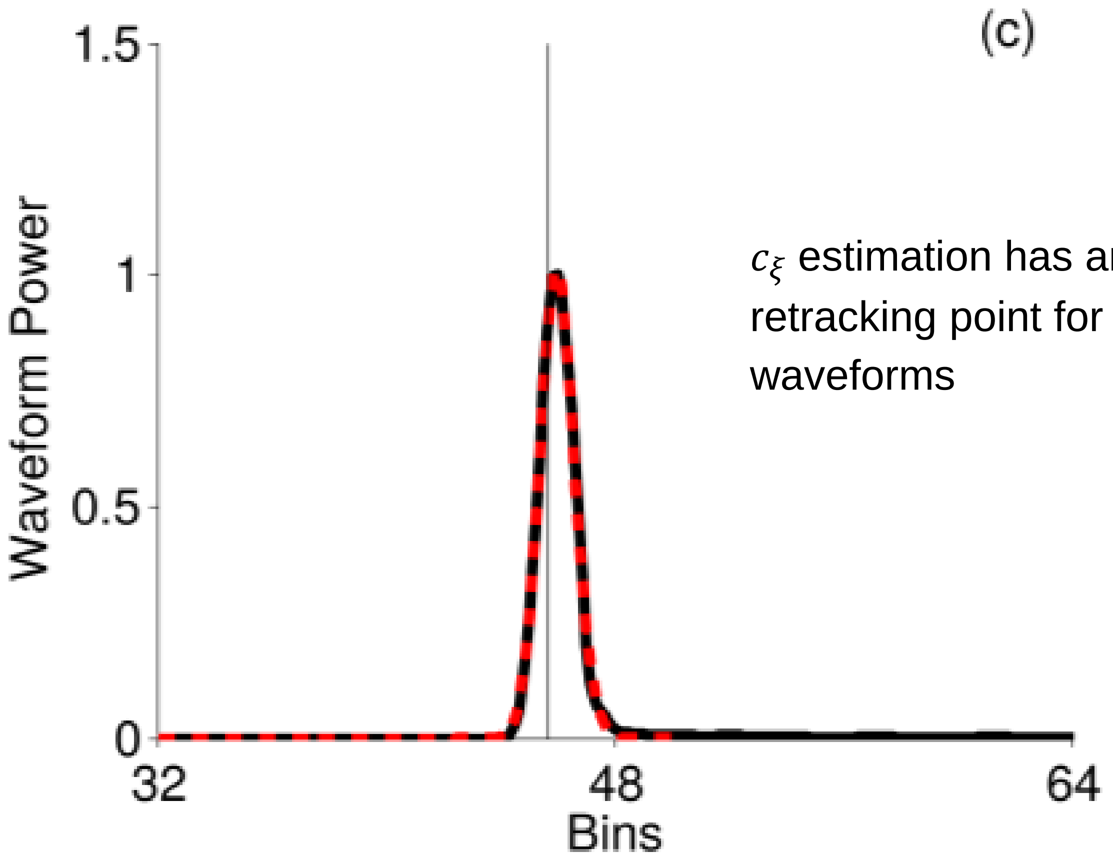
SAME AS ALES!

ALES+ concept

Open ocean | Coast | Leads/Inland Waters

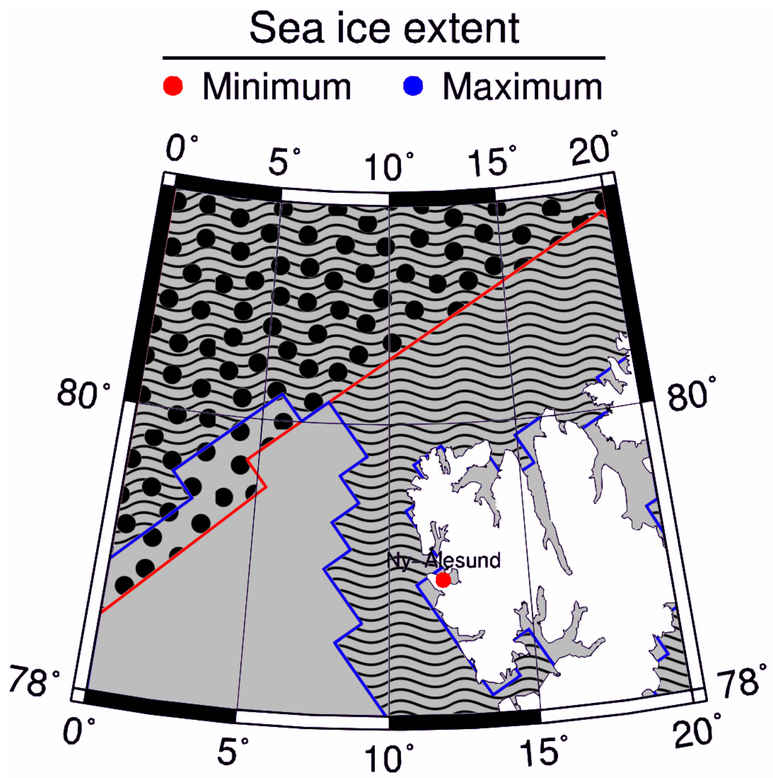


ALES+ concept

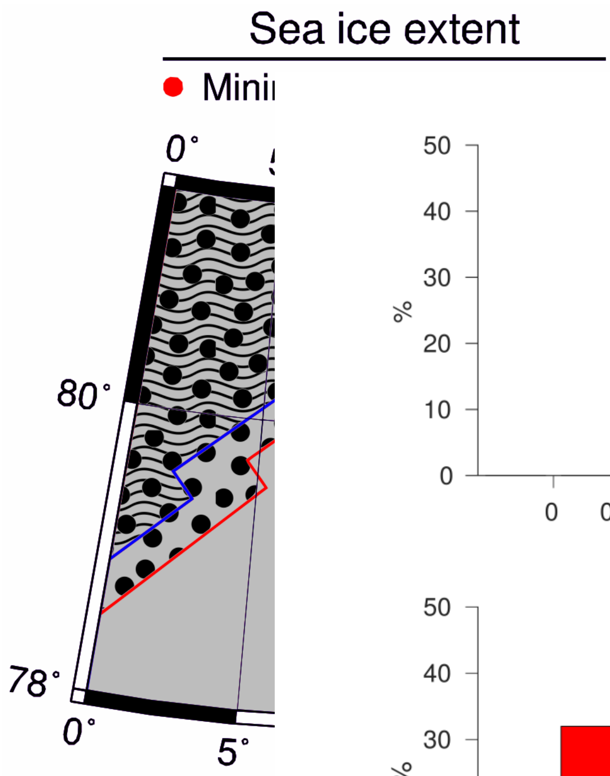


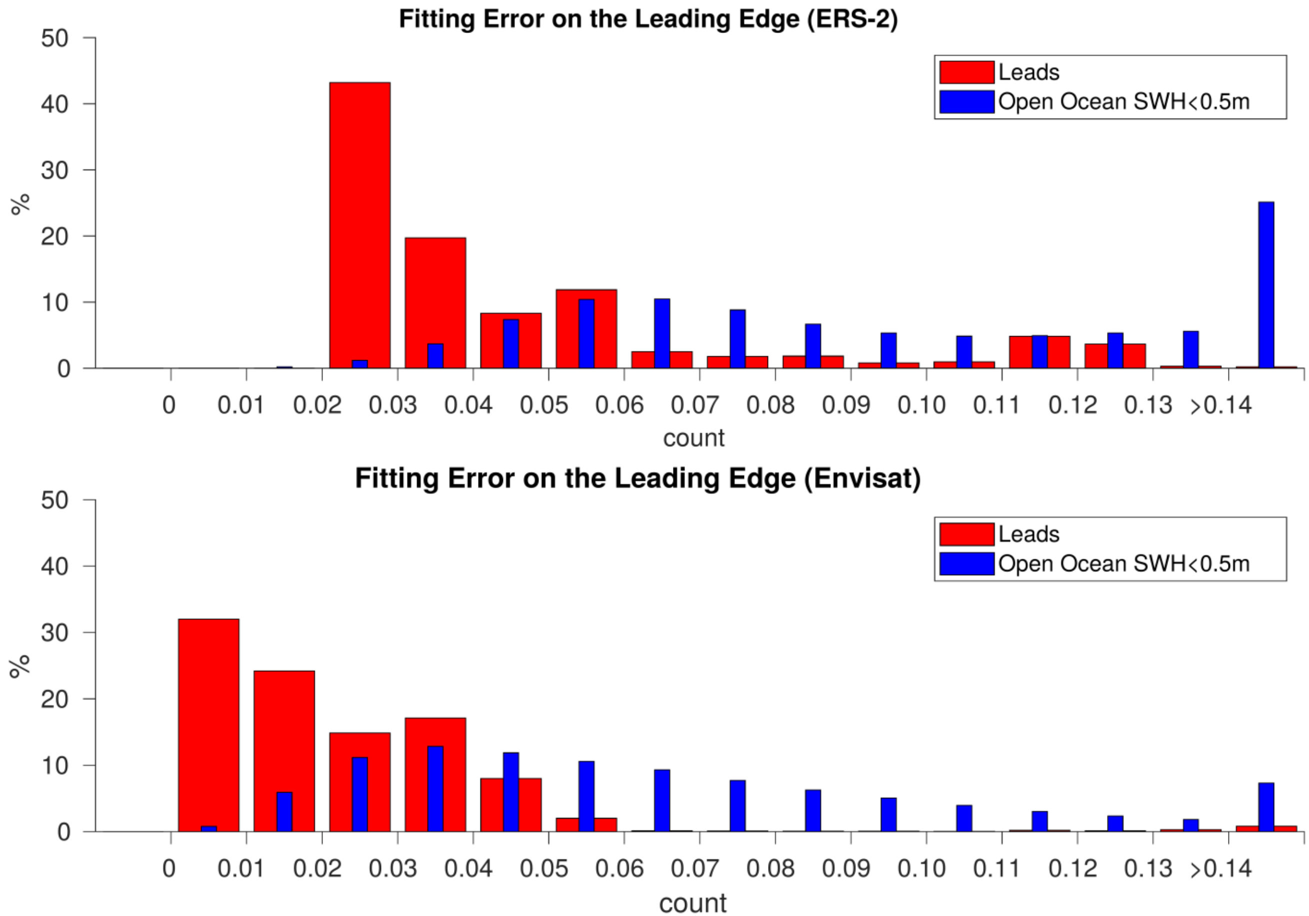
c_ξ estimation has an effect on the retracking point for very peaky waveforms

Validation in the sea ice covered region



Validation in the sea ice covered region





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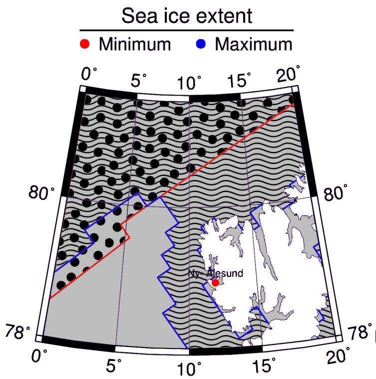
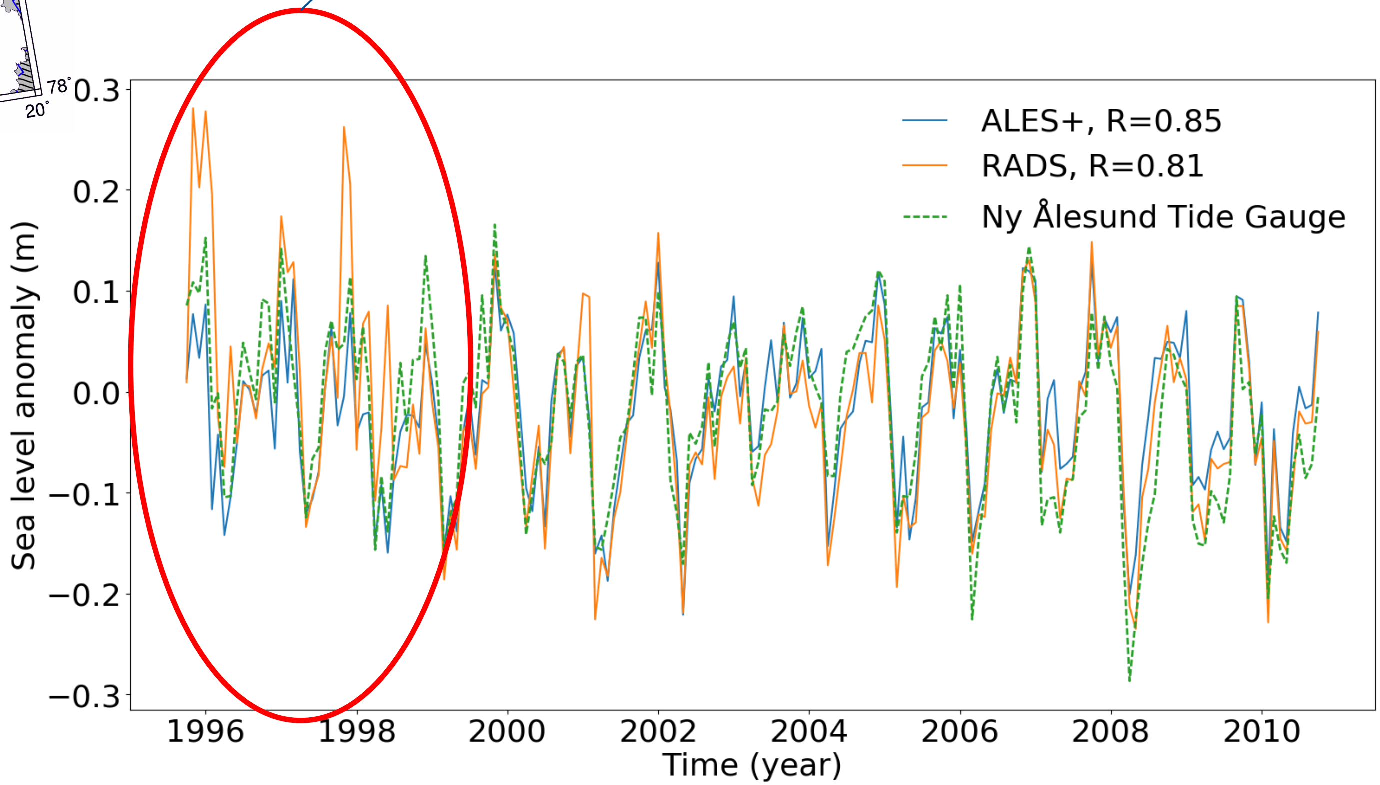
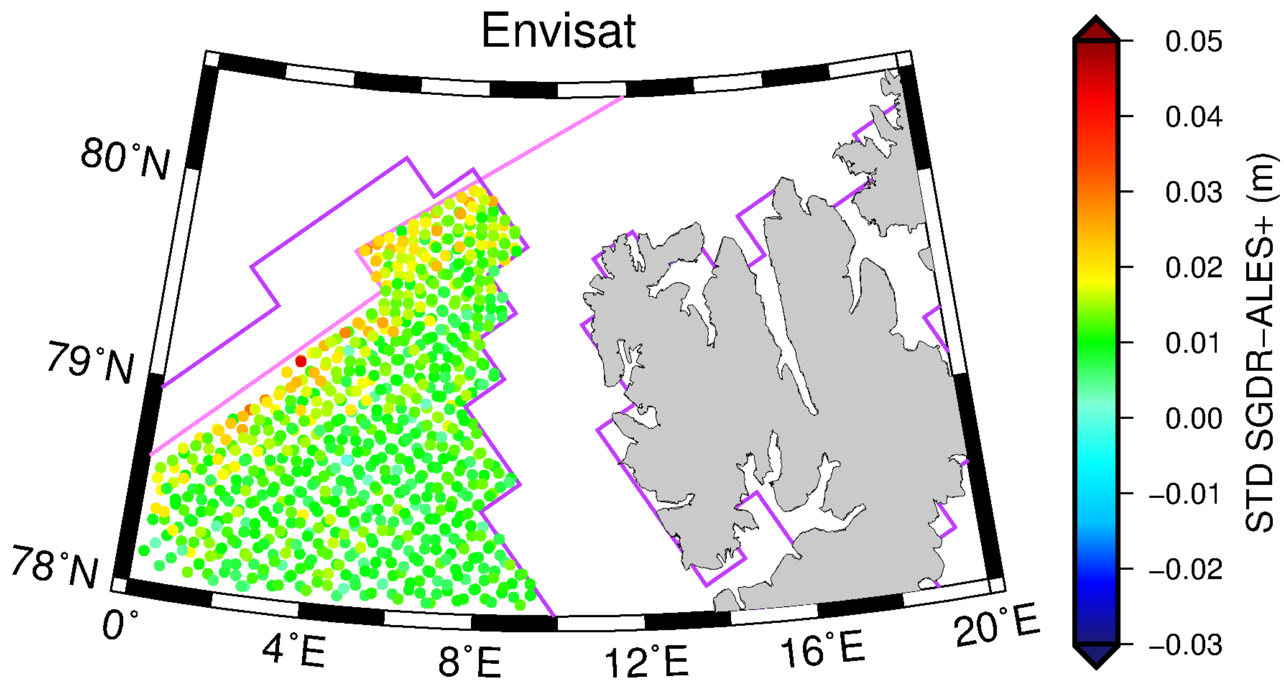


Best improvement during winter months with sea ice!

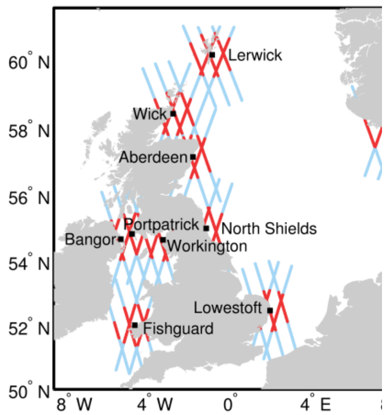


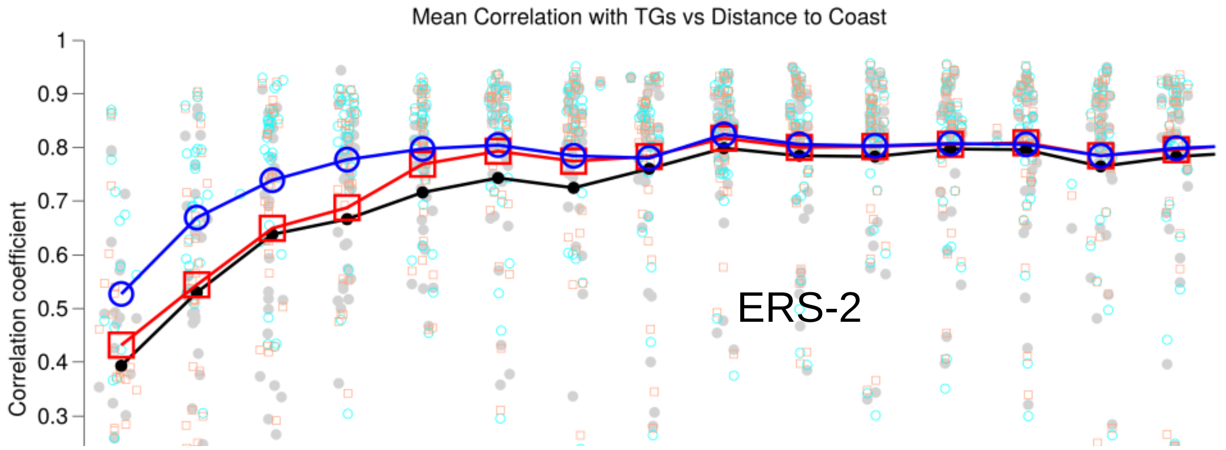
Performances in the open ocean

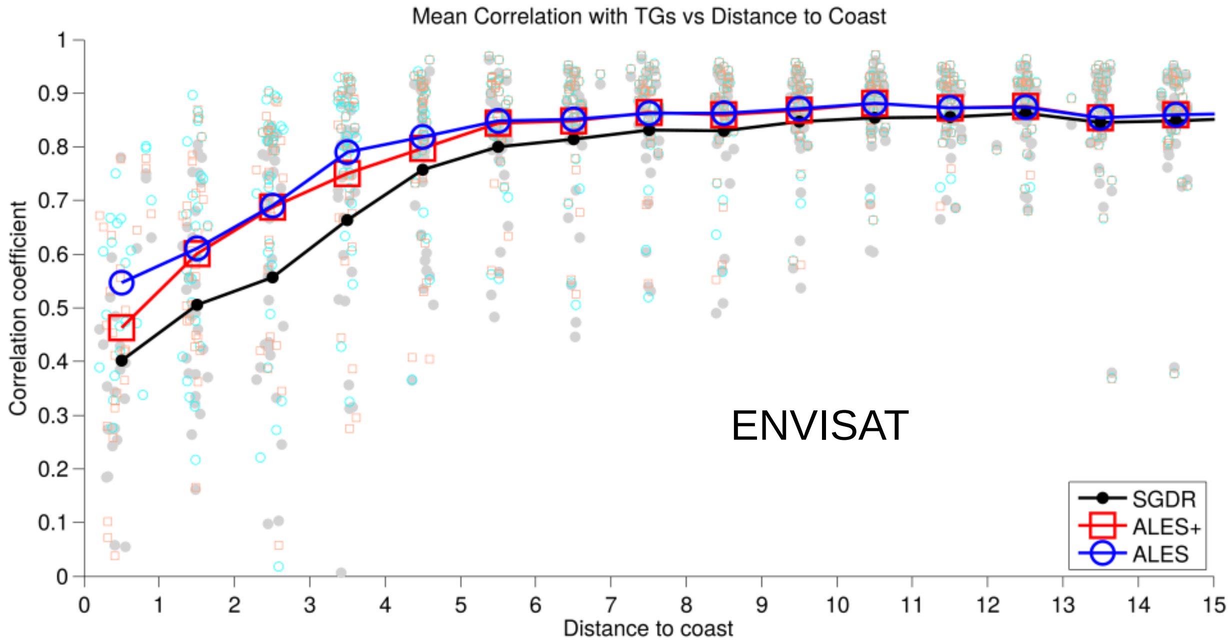


ALES+ constantly more precise than current SGDR standards thanks to recomputed Sea State Bias (see ALES global validation talk in Cal/Val Session)

Performances in the coastal zone

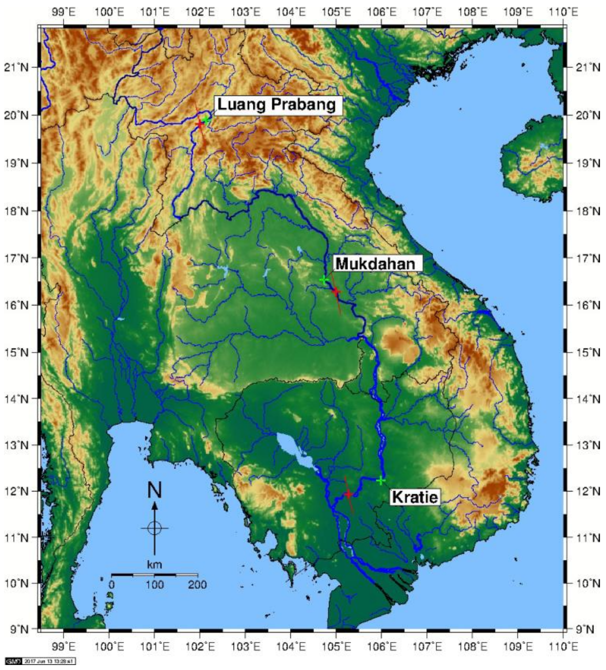






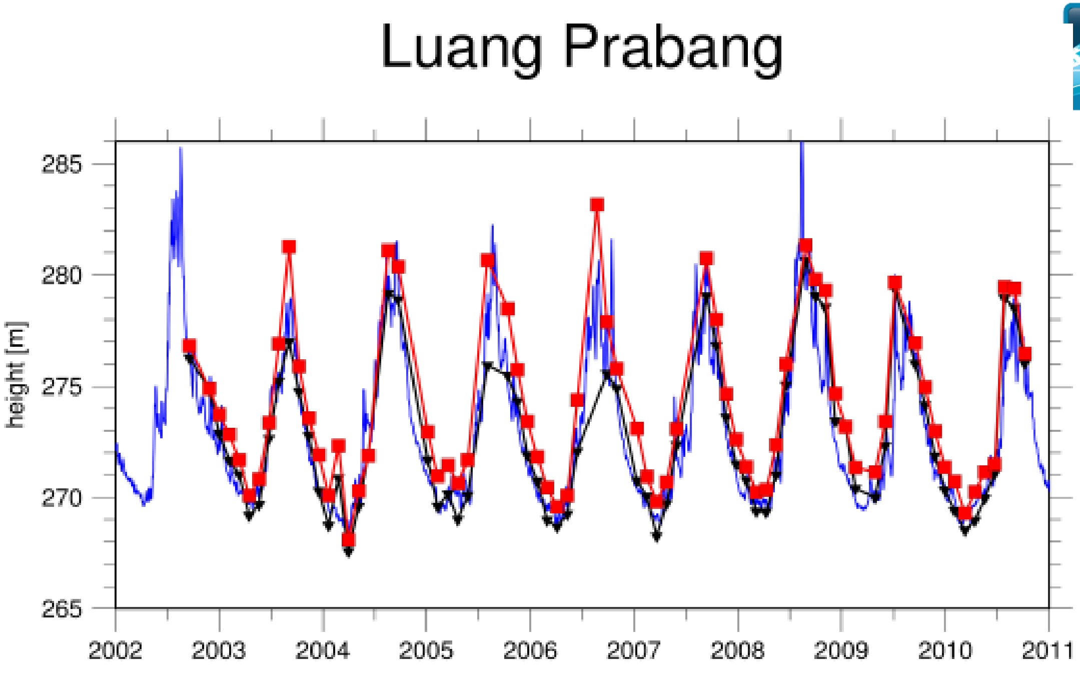
ALES+ improves SGDR standards, but for coastal zone ALES is still better

Performances in inland waters



RMS(gauge – ALES+) = 0.87

RMS(gauge – Impr.Thres.50%) = 0.81



ALES+ better or equivalent to Improved Threshold Retracker.

Conclusions

- ALES+ is a quick, non-computational demanding and effective way of retracking altimetry echoes from open ocean, leads, inland waters and coast.

- ALES+ improves the current standards of ERS-2 and Envisat in all the domains

- First applications: A DTU/TUM gridded Artic and Antarctic SSH product is available from Sea Level CCI

- No secrets: A full description AND validation of ALES+ is under review

BEGINNING SPARE SLIDES

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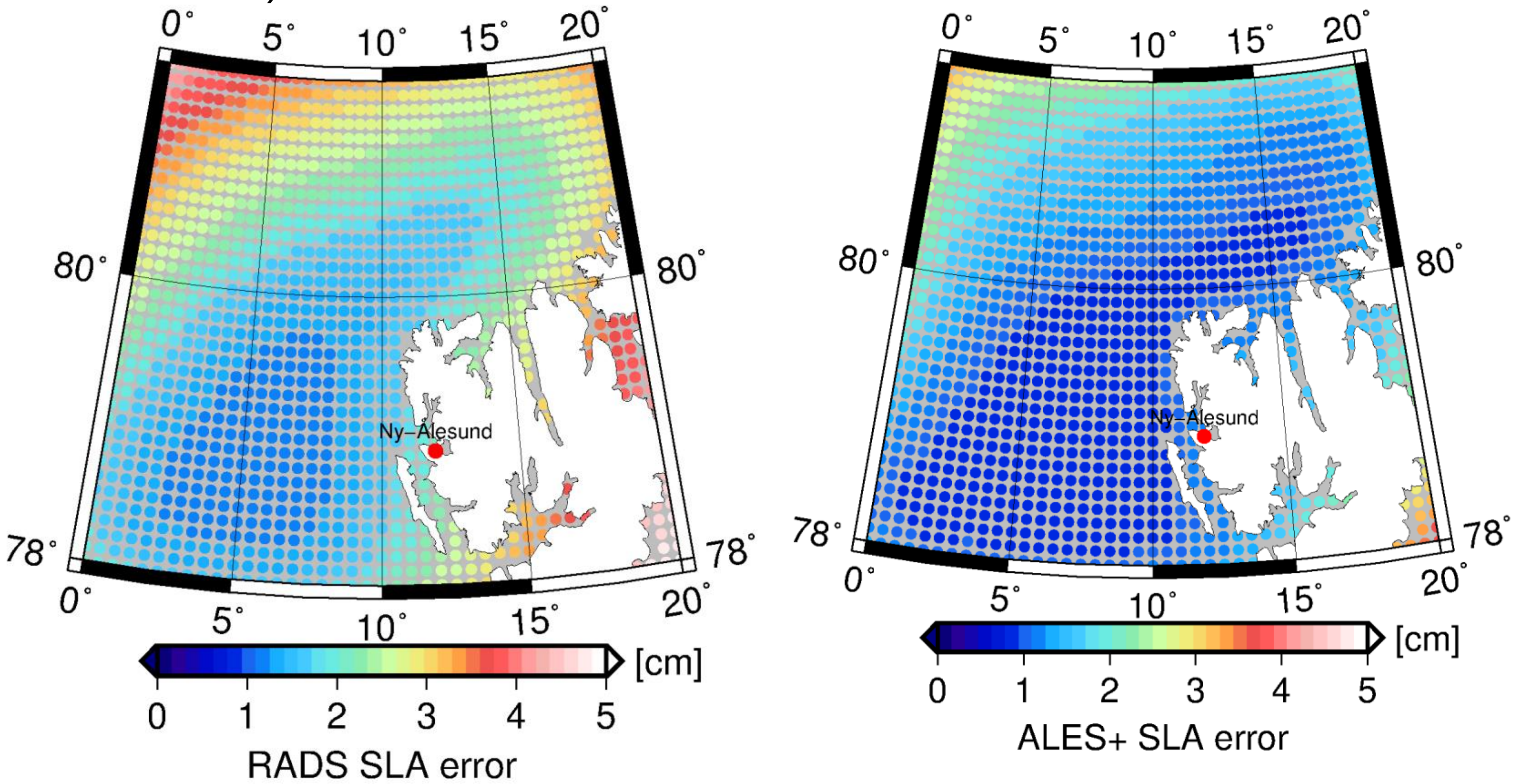
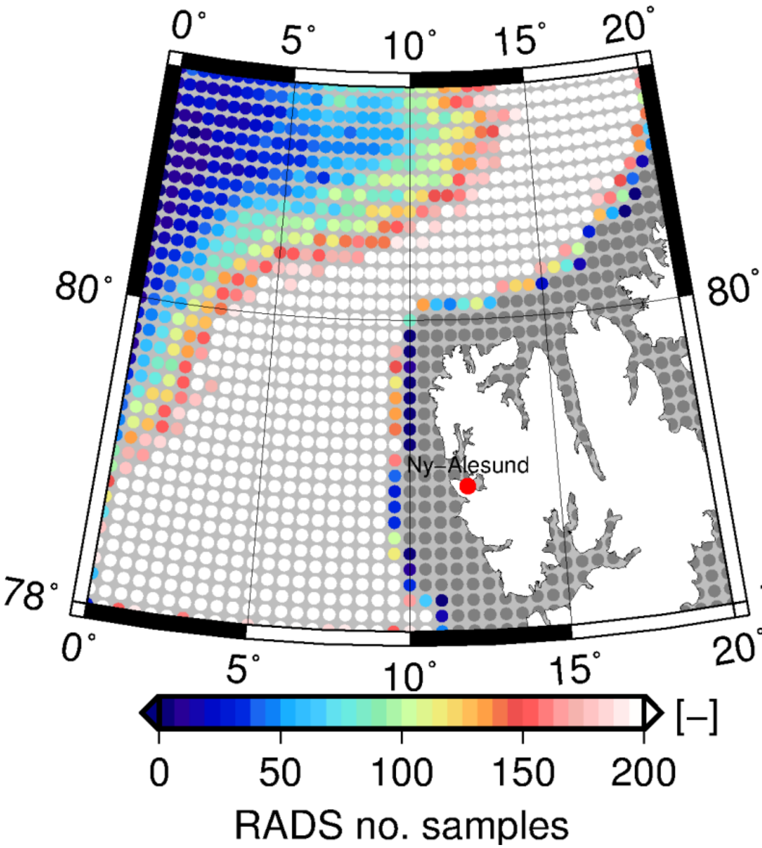
Prediction error in the gridded dataset

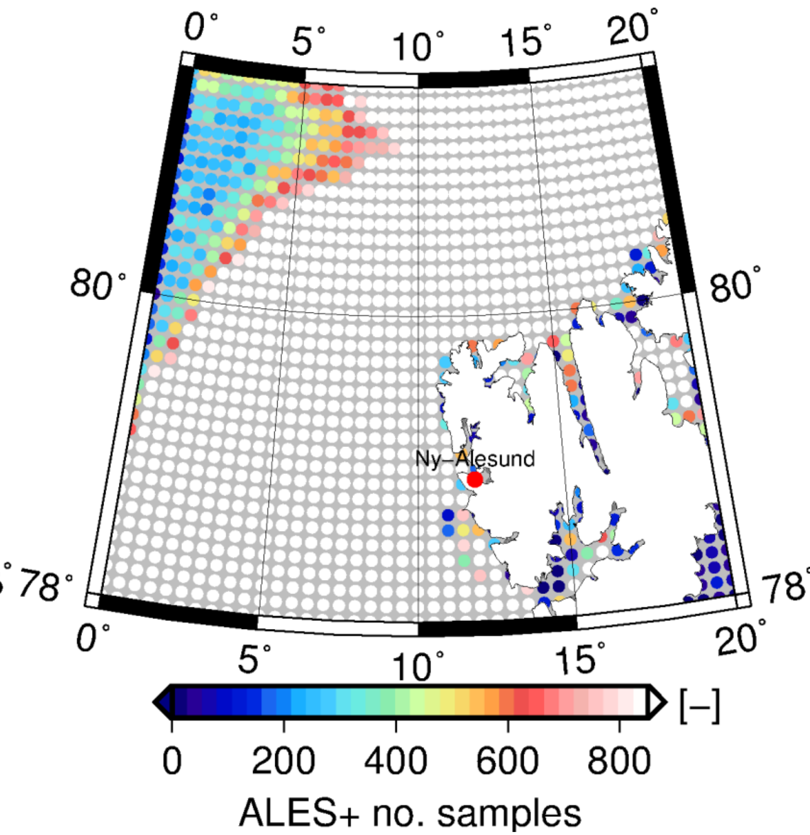
Depends on the „quality of data“ (variance) and on the „quantity“ (num of measurements)



Gridding by least square collocation method. Correlation scale: 500 km.

Number of points in the gridded dataset





Use 1-Hz averages

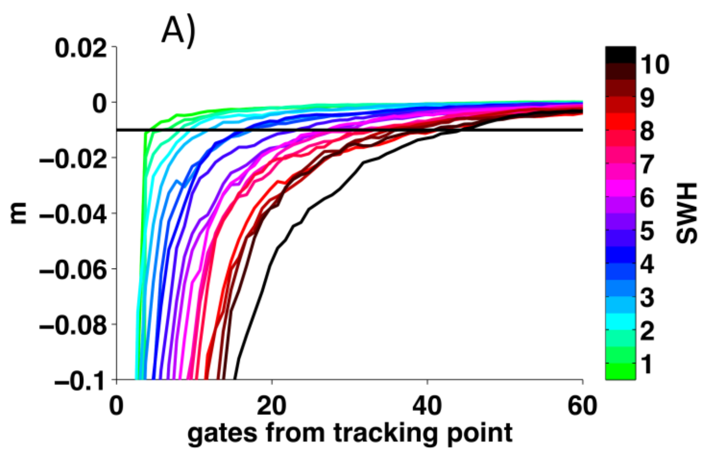
Use high-rate data independently

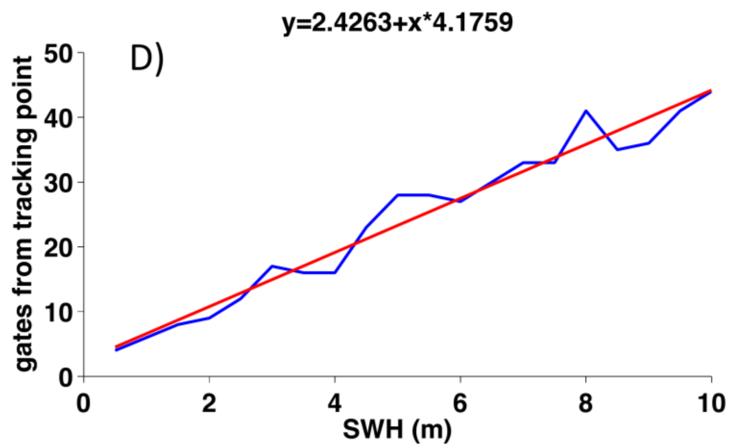
Extension of ALES retracking strategy to ERS-2

Remember ALES?

- Adaptive Subwaveform Retracker: key step -> Subwaveform Width proportional to Sea State
- Objectives: avoid perturbations of the signal, do not degrade precision/accuracy from open ocean to coast
- Birth of ALES concept: Montecarlo Simulation

RMS Difference of Full Waveform Range Error – Subwaveform Range Error





Extension of ALES retracking strategy to ERS-2

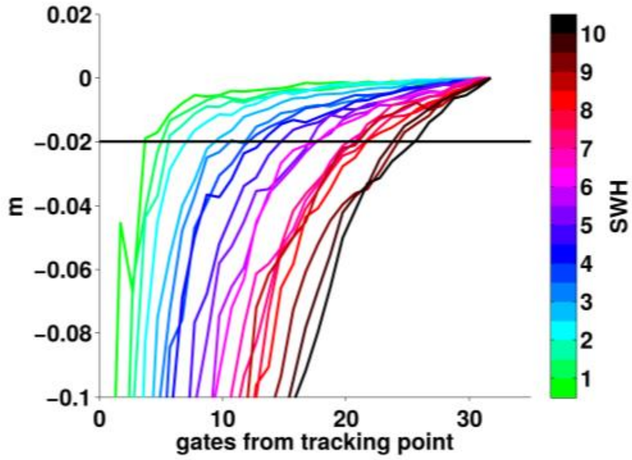
Problem:

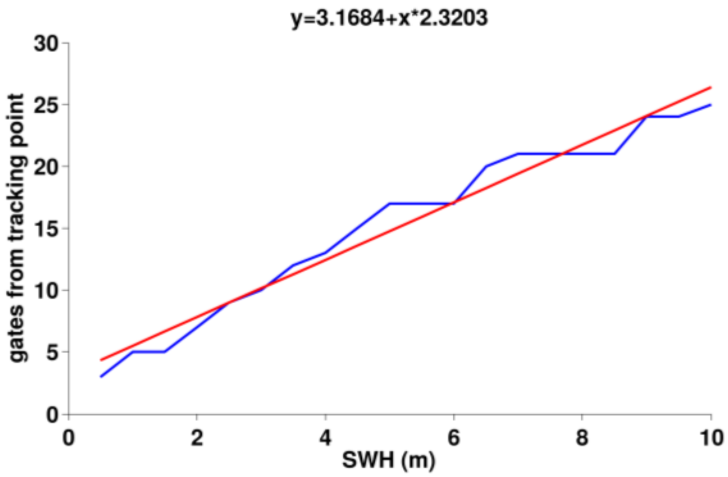
Envisat PRF =1800 Hz →18-Hz waveforms from 100 IE

ERS2   PRF = 1050 Hz →20-Hz waveforms from 50 IE

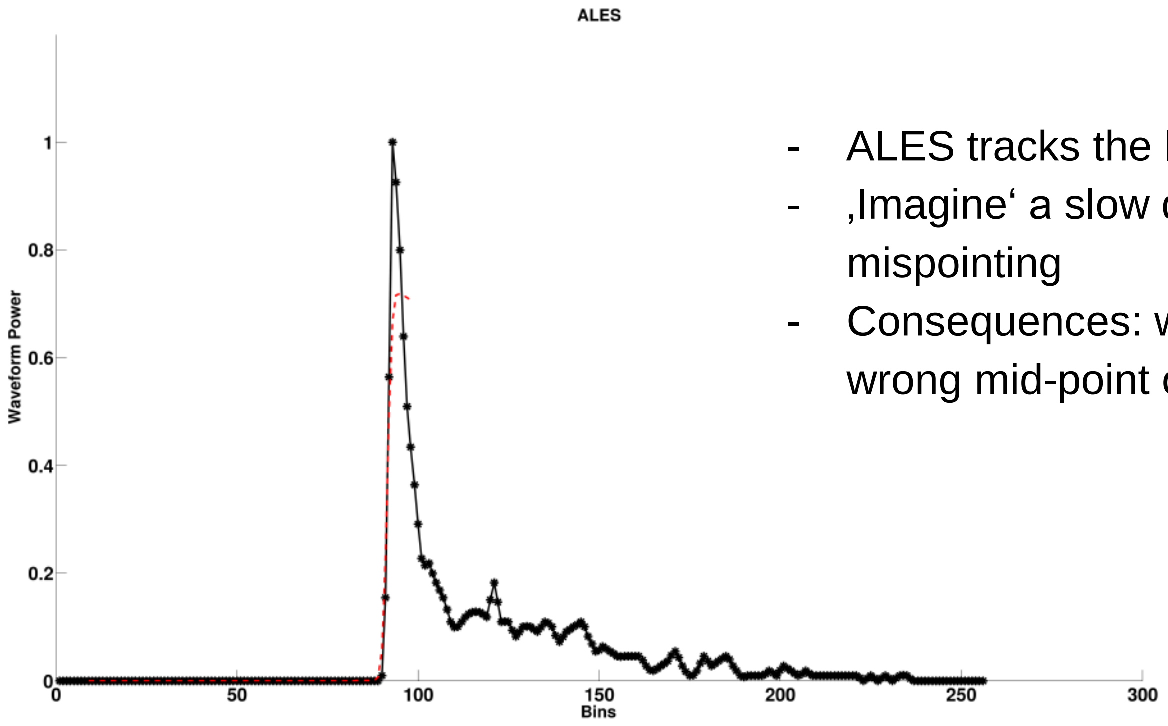
Compromise: tolerance bar set at 2 cm at 20 Hz, i.e. 0.45 cm at 1 Hz

RMS Difference of Full Waveform Range Error – Subwaveform Range Error





Adaptation of ALES to peaky waveforms (leads)



- ALES tracks the leading edge position
- ‚Imagine' a slow decay varying only with mispointing
- Consequences: wrong amplitude and wrong mid-point of the LE

In general: trailing edge varies also w.r.t. Mean Square Slope (Jackson et al. 1992, Poisson et al. 2015)!

From ALES to ALES+

Pulse Peakiness threshold: PP>1 -> peaky

ALES+ (non-peaky waveforms):

1. Leading Edge Detection

2. First retracking (leading edge only)
3. Subwaveform extension
4. Second retracking of the extended subwaveform

ALES+ (peaky waveforms):

1. Leading Edge Detection

1a: External estimation of trailing edge slope*

2. First retracking (leading edge only)
3. Subwaveform extension
4. Second retracking of the extended subwaveform

*1a: Brown-Hayne simplified model with trailing edge slope as 4th unknown
(follows CLS solution proposed in CCI and adapts it to ALES)

From ALES to ALES+

ALES (non-peaky waveforms):

1. Leading Edge Detection

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ALES (peaky waveforms):

1. Leading Edge Detection

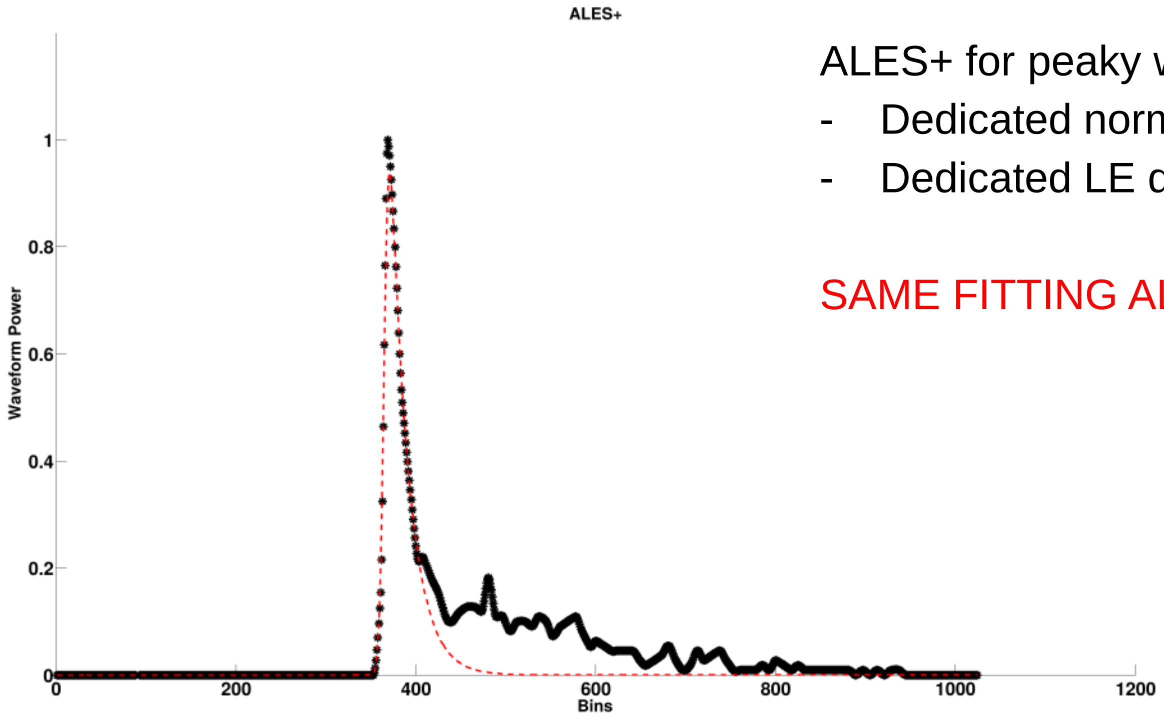
1a: External estimation of trailing edge slope*

2. First retracking (leading edge only)
3. Subwaveform extension
4. Second retracking of the extended subwaveform

c_ξ

$$V_m(t) = P_u \frac{|1 + \mathrm{erf}(u(c_\xi, t, SWH))|}{2} \exp(f(c_\xi, t, SWH))$$

From ALES to ALES+



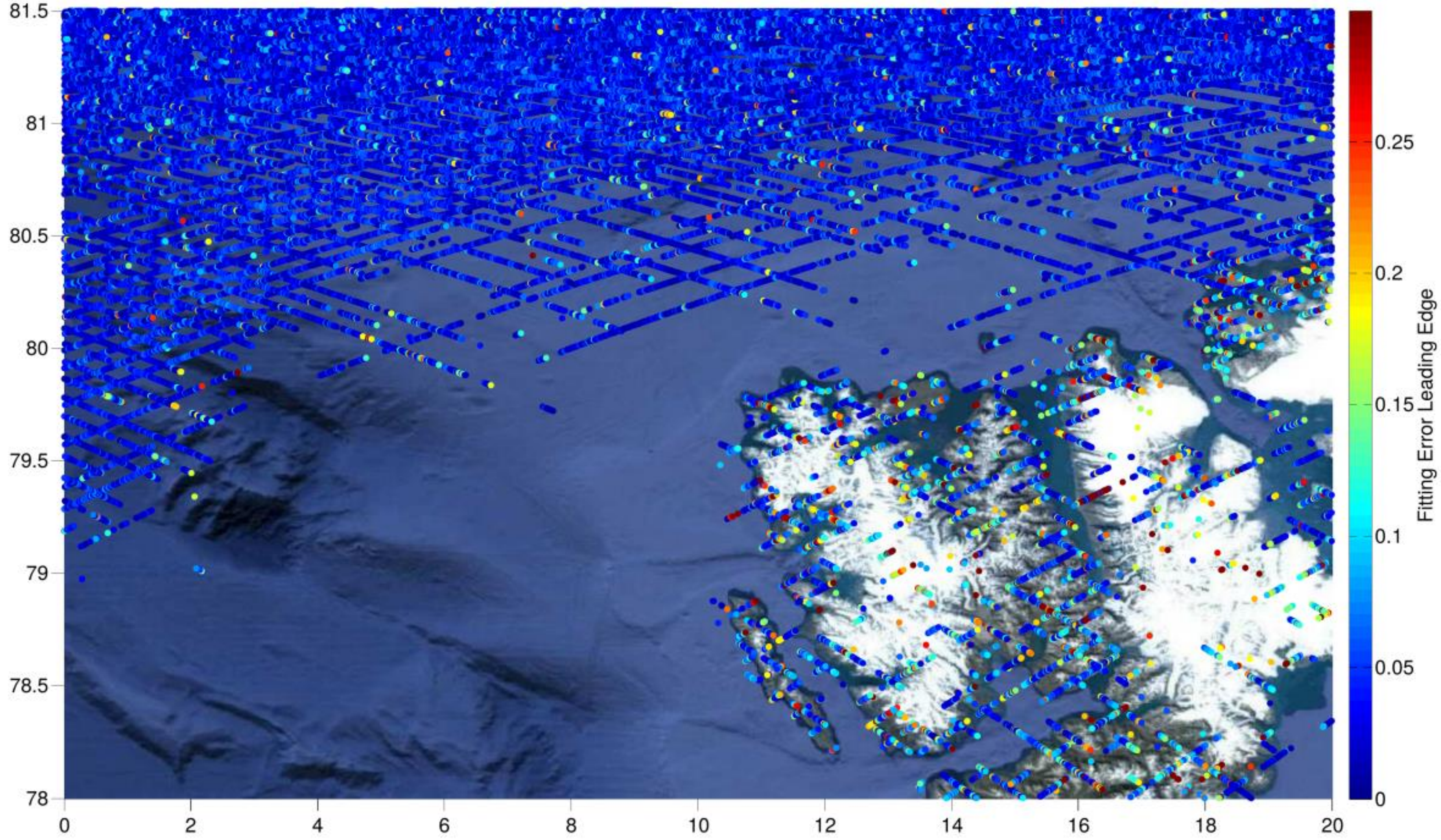
ALES+ for peaky waveforms
- Dedicated normalisation
- Dedicated LE determination

SAME FITTING ALGORITHM

Performance analysis in the open ocean

Fitting quality on the leading edge (in normalised units)

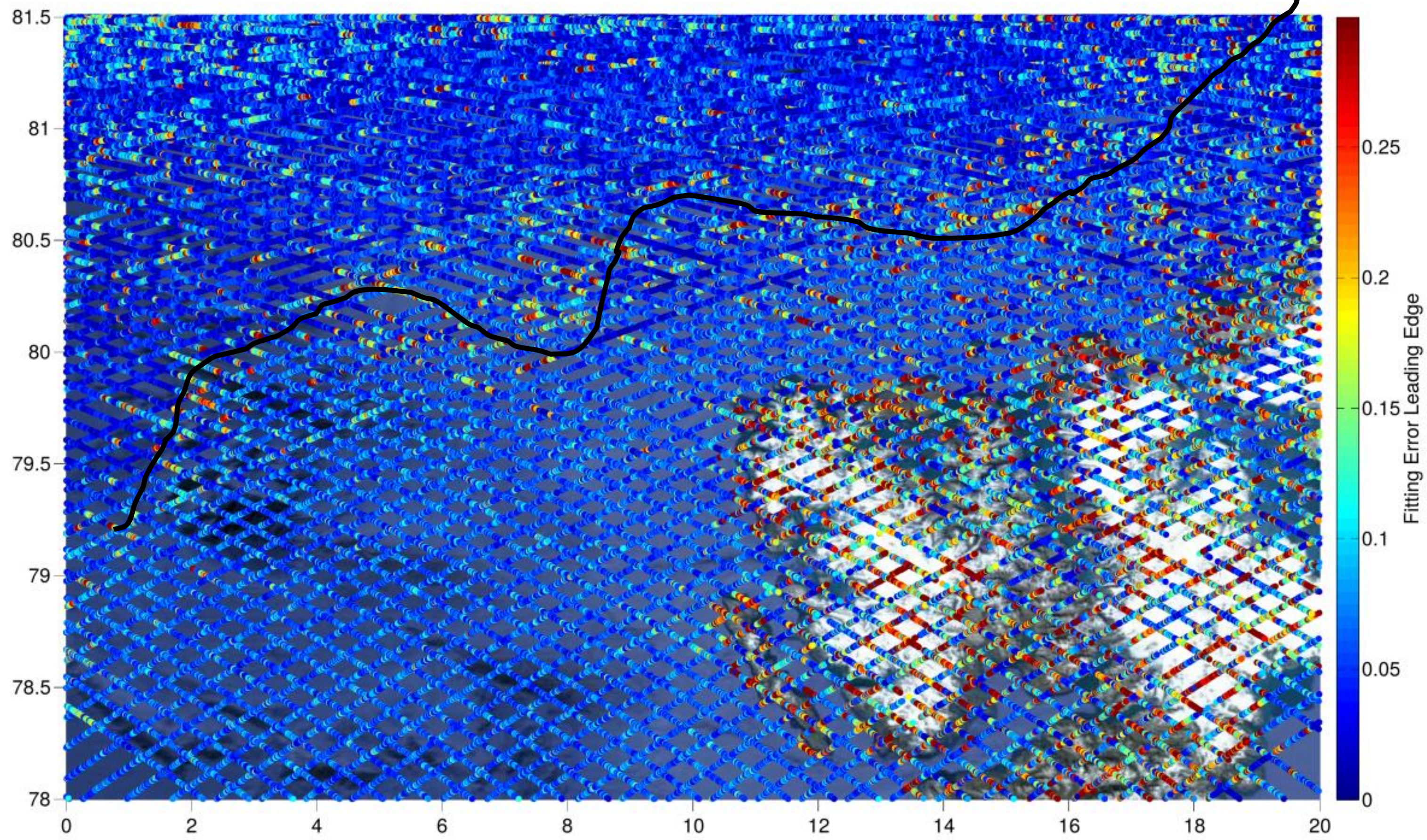
Only PP>1



Performance analysis in the open ocean

Fitting quality on the leading edge (in normalised units)

Sea-Ice/Open Water Border…breaking ice?

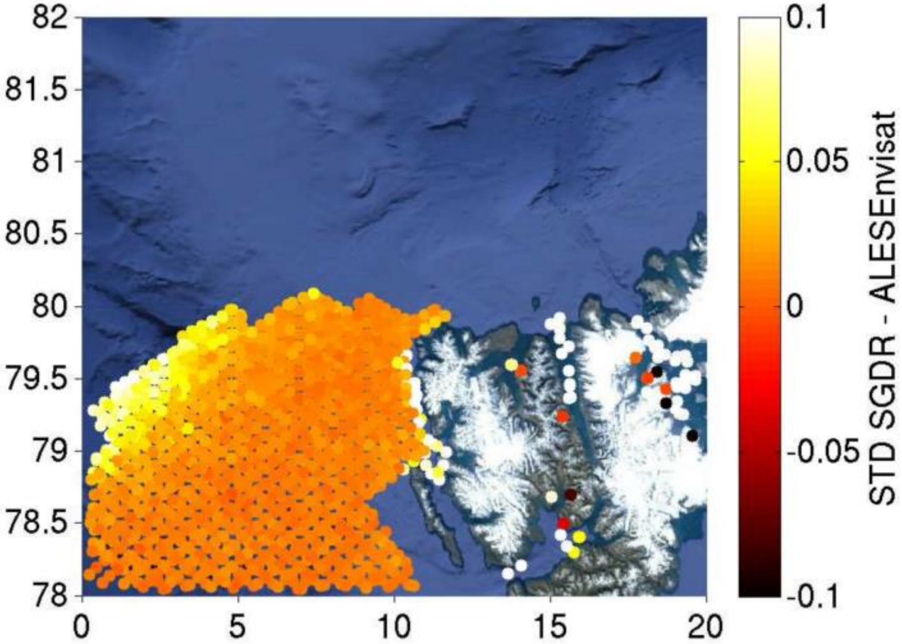


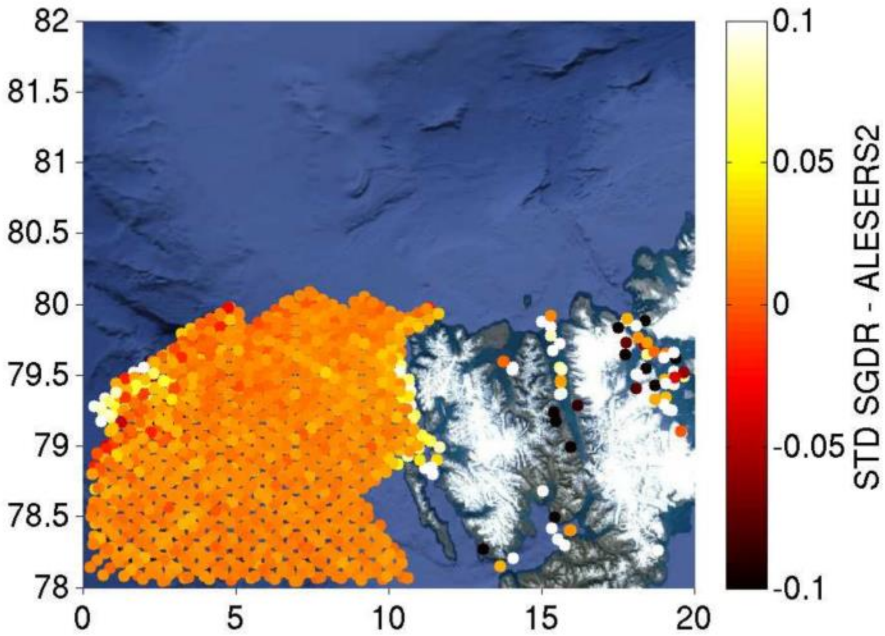
Performance analysis in open waters

Difference of Noise Statistics (std within 1-Hz block)

Mask: Maximum Sea Ice extension (March 1992)

1 Hz points generated from raw 20 Hz estimations (same criteria)

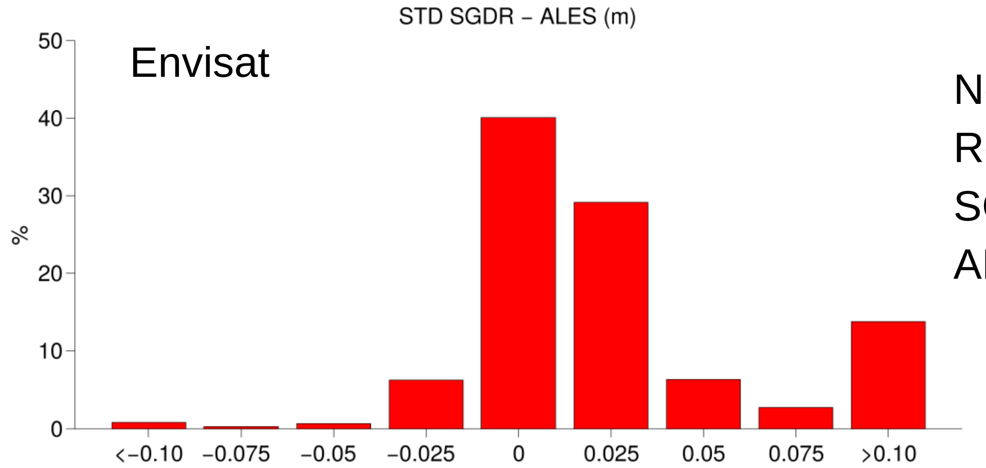




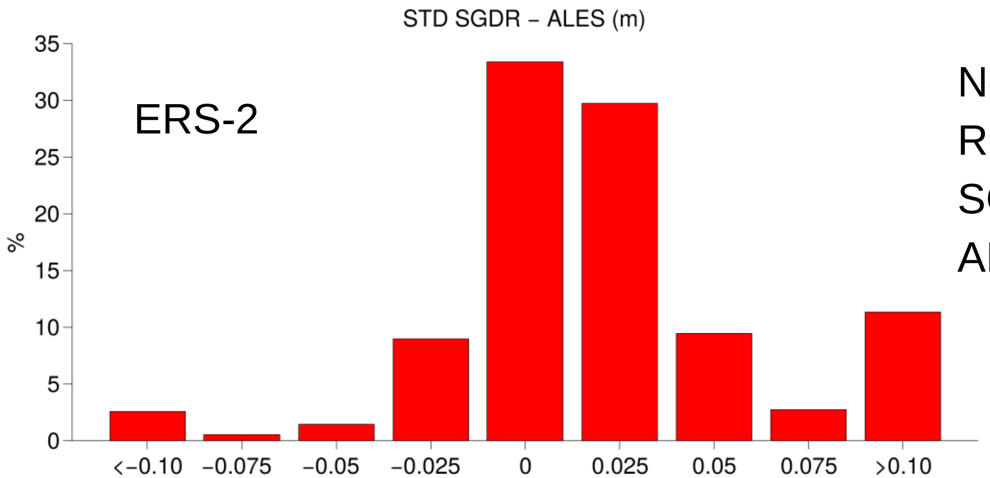
Almost costant improvement in the open ocean
Large improvements in coastal areas and in sea ice proximity

Performance analysis in open waters

Difference of averaged noise at each 1-Hz point



Noise reduction in the 76% of points
Reduction of over 3 cm in 27% of points
SGDR Median Noise = 6.74 cm
ALES Median Noise = 5.26 cm



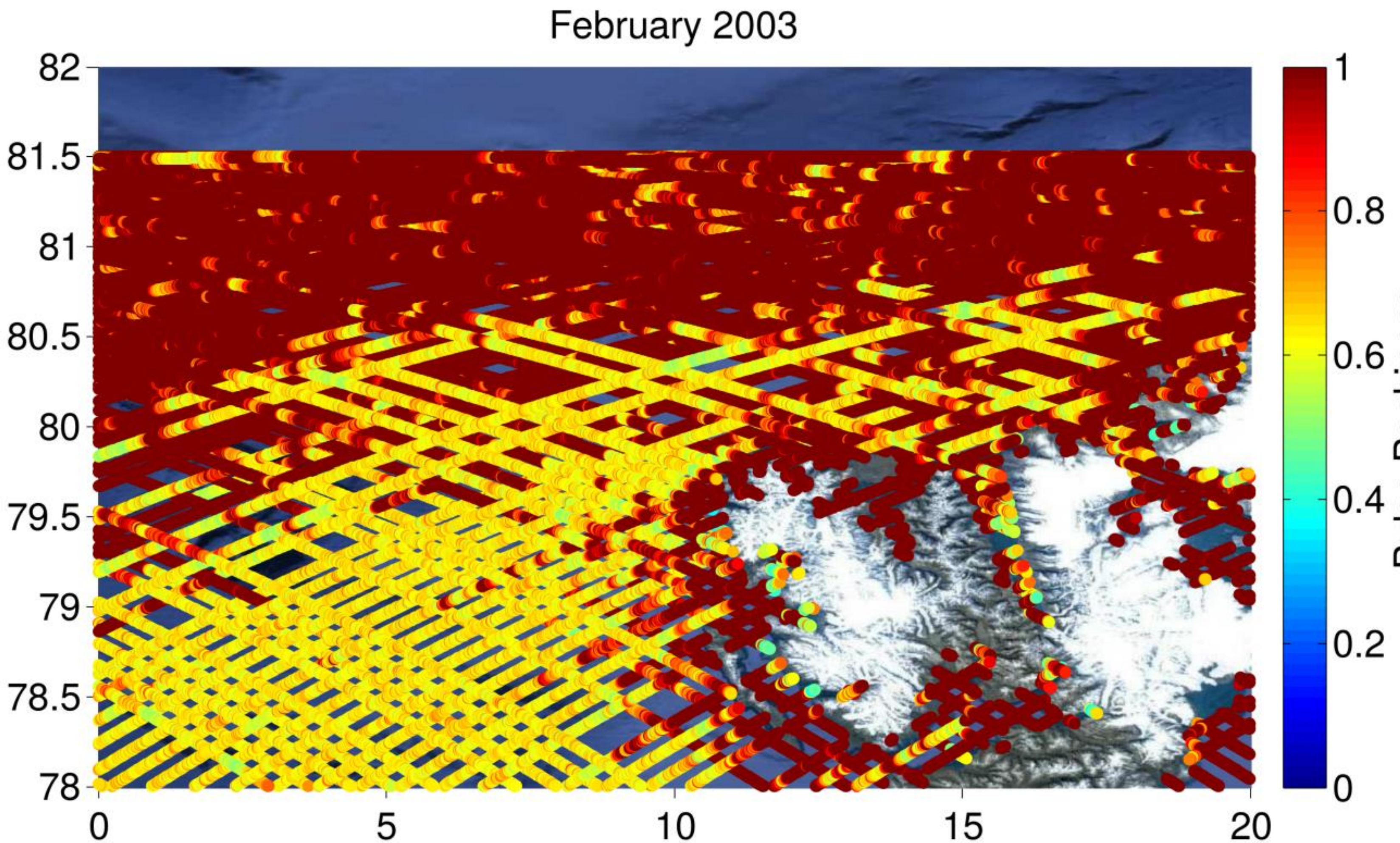
Noise reduction in the 72% of points
Reduction of over 3 cm in 30% of points
SGDR Median Noise = 9.72 cm
ALES Median Noise = 8.49 cm

Pulse Peakiness Threshold

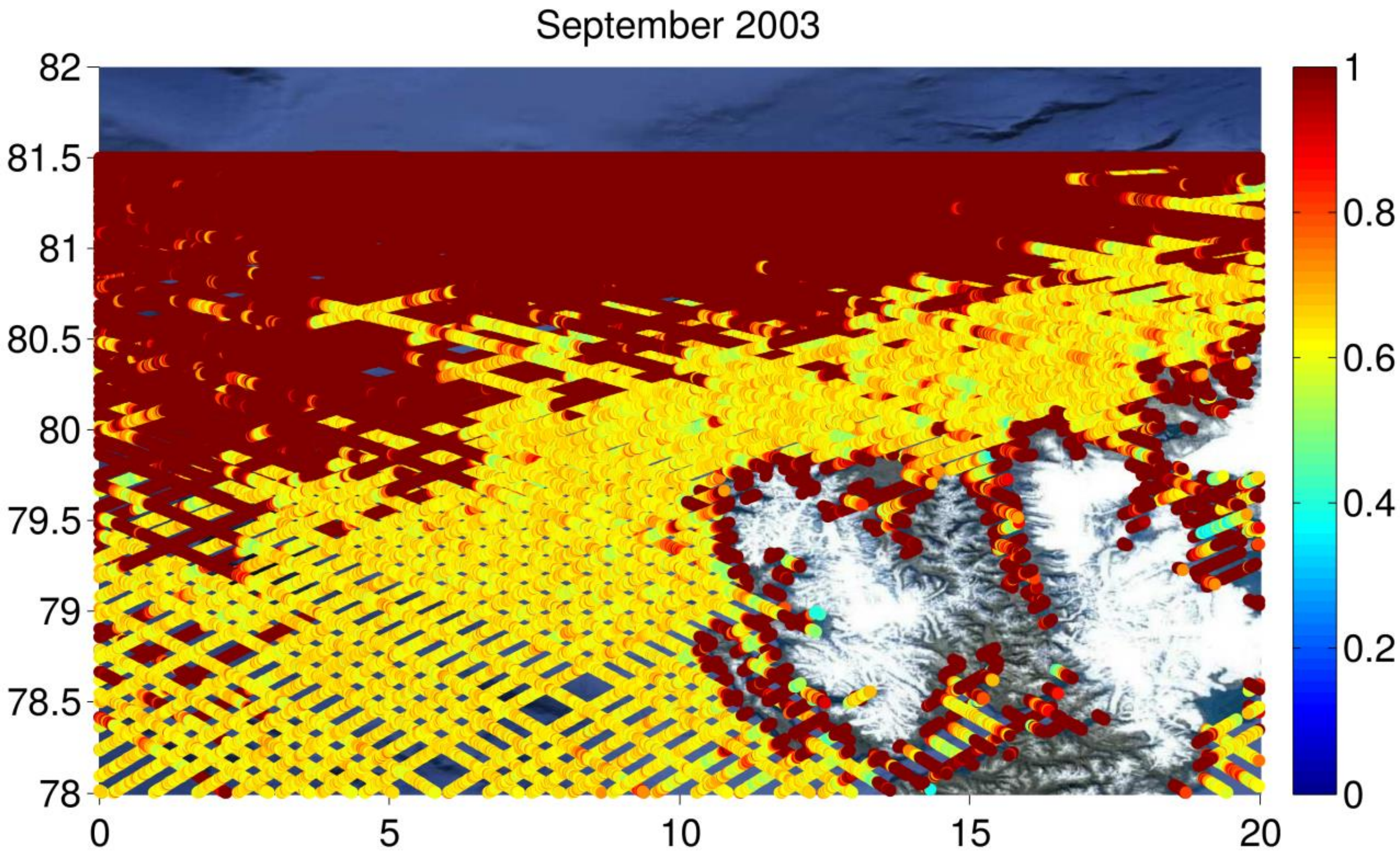
Why using PP=1 as Threshold? (In literature, leads if PP>1.7)

1) Remember the objective: it's NOT a classification, it's a search for potentially high trailing edge slopes [i.e. NON OCEANIC]

Pulse Peakiness Threshold



Pulse Peakiness Threshold



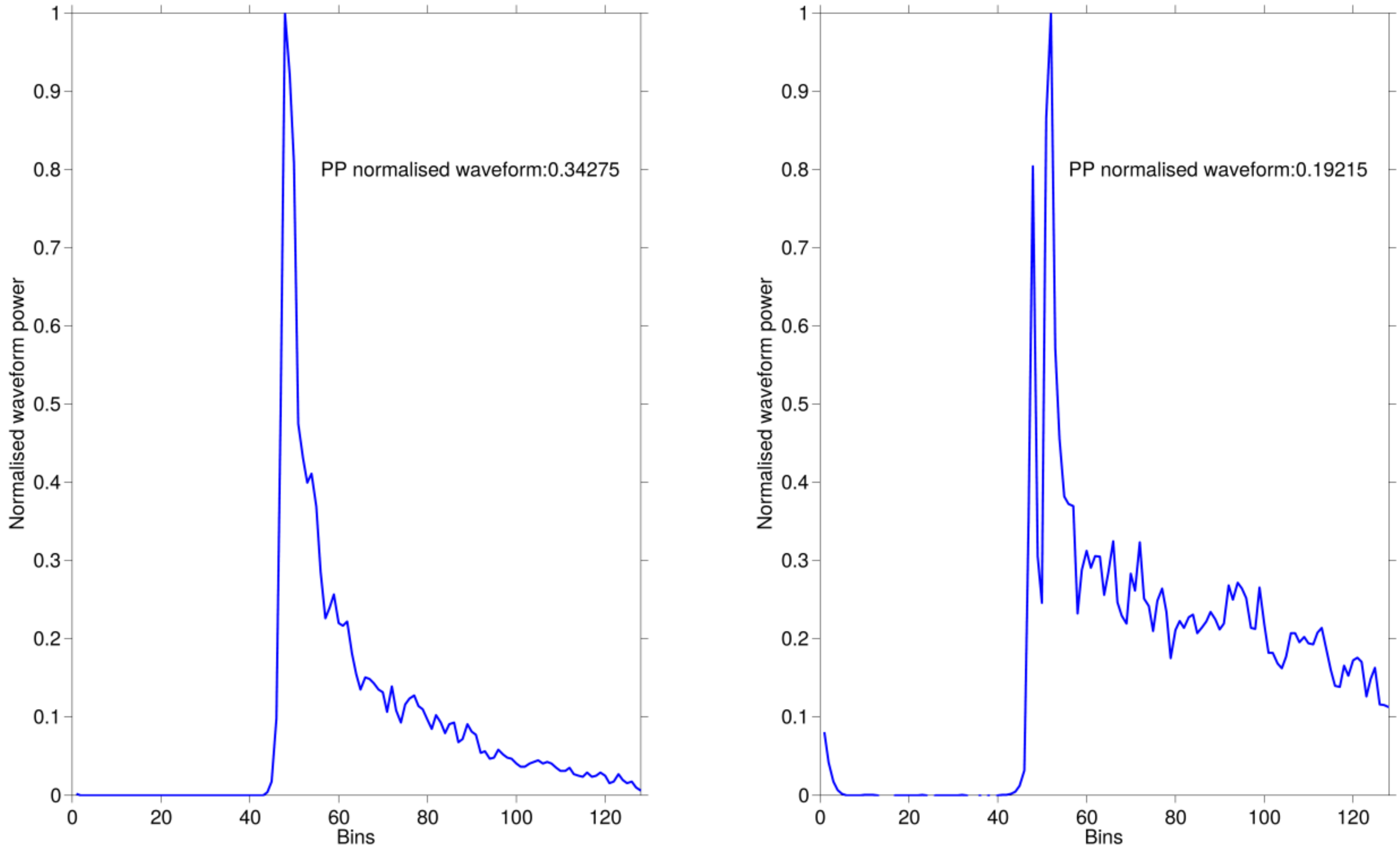
Pulse Peakiness Threshold

Why using PP=1 as Threshold? (In literature, leads if PP>1.7)

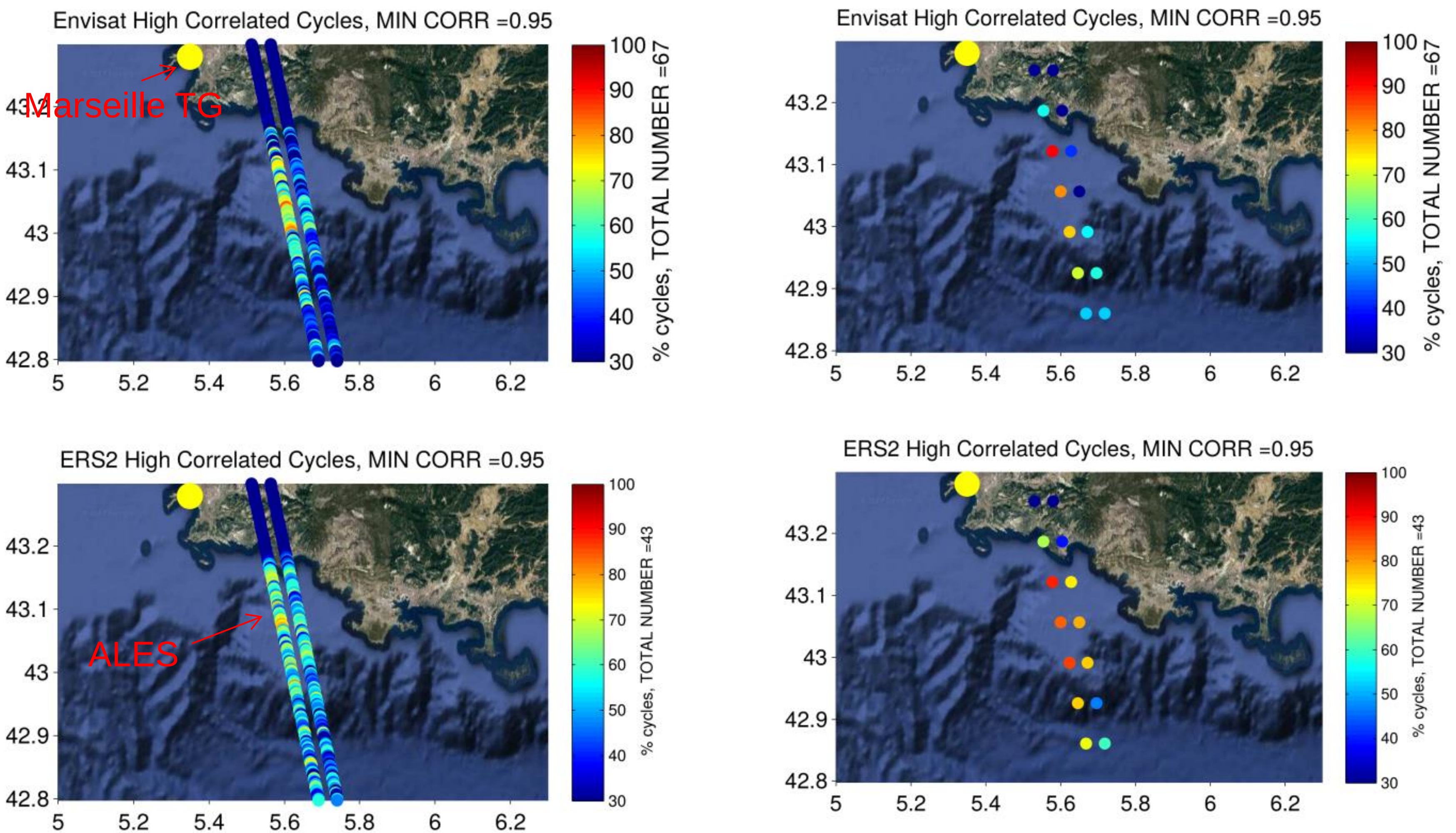
1) Remember the objective: it‘s NOT a classification, it‘s a search for potentially high trailing edge slopes [i.e. NON OCEANIC]

2) Further check on the PP of the NORMALISED waveform, to exclude double peaks (PPnorm > 0.3)

Pulse Peakiness Threshold

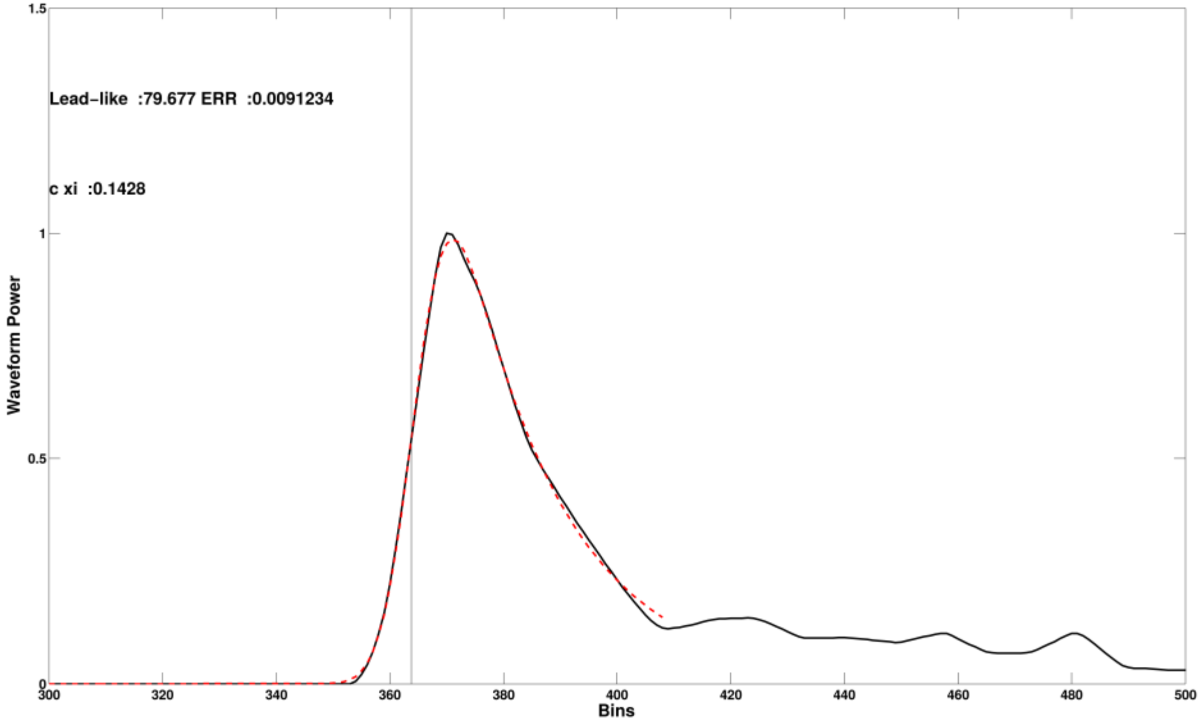


Performance analysis in open waters



Adaptation of ALES to peaky waveforms (leads)

(Probably said before…)



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