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

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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!)

![Waveform Power](a) Open ocean

![Waveform Power](b) Coast

![Waveform Power](c) Leads/Inland Waters
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

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

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)

\[ \tau = \tau(\text{Mean Square Slope, Beam Width}) \]
\[ c_\xi = c_\xi(\text{Mispointing, Beam Width}) \]

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

Our solution: estimate \( c_\xi \) 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

$c_\xi$ 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

Sea ice extent

Fitting Error on the Leading Edge (ERS-2)

- Leads
- Open Ocean SWH < 0.5m

Fitting Error on the Leading Edge (Envisat)

- Leads
- Open Ocean SWH < 0.5m
Validation in the sea ice covered region

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

ALES+ better or equivalent to Improved Threshold Retracker.

RMS( gauge – ALES+) = 0.87

RMS(gauge – Impr.Thres.50%) = 0.81
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

BEGINNING SPARE SLIDES
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**
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
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\[
V_m(t) = P_u \frac{1 + \text{erf}(u(c_\zeta, t, \text{SWH}))}{2} \exp(f(c_\zeta, t, \text{SWH}))
\]
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)

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

1 Hz points generated from raw 20 Hz estimations (same criteria)
**Performance analysis in open waters**

Difference of averaged noise at each 1-Hz point

### Envisat
- 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

### ERS-2
- 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

February 2003
Pulse Peakiness Threshold

September 2003
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

PP normalised waveform: 0.34275

PP normalised waveform: 0.19215
Performance analysis in open waters

Envisat High Correlated Cycles, MIN CORR = 0.95

ERS2 High Correlated Cycles, MIN CORR = 0.95

Marseille TG

ALES
Adaptation of ALES to peaky waveforms (leads)

(Probably said before…)
Adaptation of ALES to peaky waveforms (leads)

(Probably said before…)

Effect of $c_\xi$ on Epoch