ALES, the multi-mission Adaptive Leading Edge Sub-Waveform Retracker, design and validation

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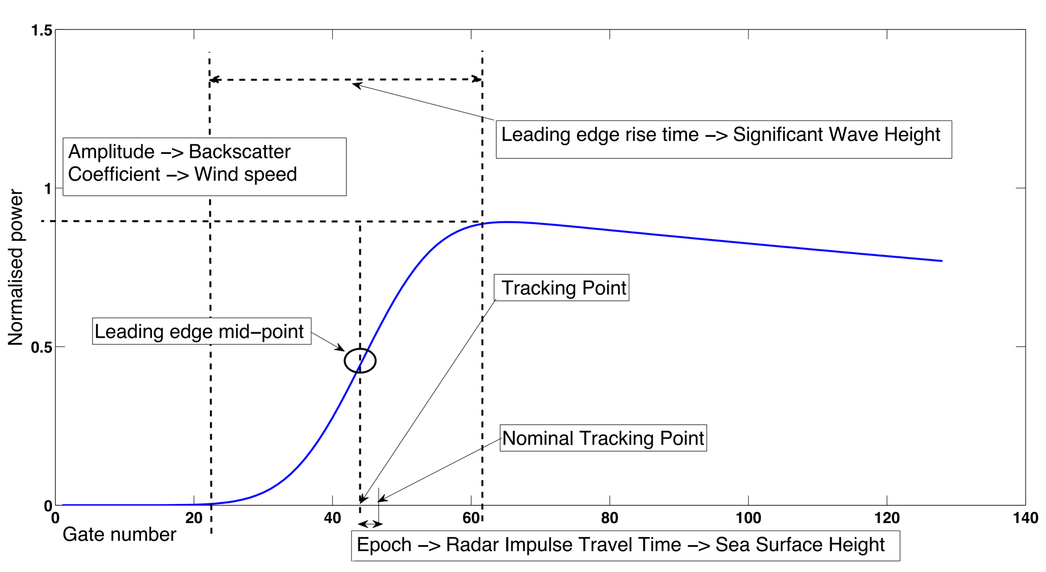
Introduction

Satellite altimetry has revolutionized our understanding of ocean dynamics thanks to precise measurements of sea surface height on a frequent and near-global basis. Nevertheless, coastal data has been flagged as unreliable due to land and calm water interference in the altimeter and radiometer footprint and high frequency tidal and atmospheric forcing.

Our study addresses the first issue, i.e. retracking, the fitting of a waveform model to the observed echoes, the process that allows the estimation of the parameters. To create a coastal-dedicated altimetry dataset we have designed ALES, the Adaptive Leading Edge Subwaveform Retracker.

ALES is potentially applicable to all the pulse-limited altimetry missions and its aim is to retrack with the same precision both open ocean and coastal data with the same algorithm.



Idealized radar altimeter return and parameters of interest that are estimated by retracking

Coastal altimetry: the challenge

From the returned altimeter echo, it is possible to extract information related to Sea Surface Height (Epoch), Significant Wave Height (SWH) and Wind Speed (Backscatter coefficient) as shown in the figure above.

Open-ocean satellite altimeter retracking is based on the Brown physical model [2], which simulates the ocean response by an error function which decays in the trailing edge. This model is less ideal when approaching the coast (depending on altimeter footprint size and sea state), where waveforms are often corrupted by highly reflective features (bright targets) that 'travel' along the trailing edge of the waveform [1].

ALES: the solution

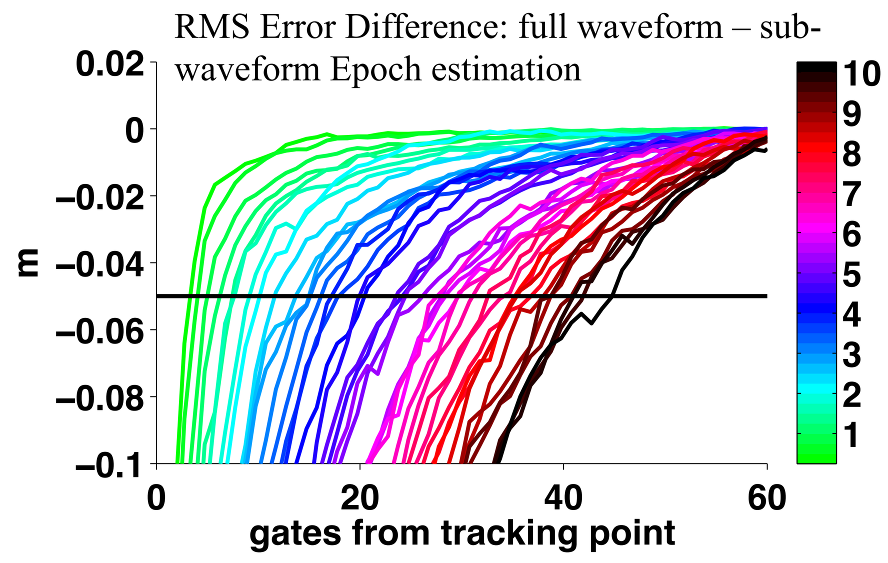
1) MULTI-MISSION: it retracks high-rate averaged Envisat, Jason-1, Jason-2 waveforms (1 measurement every 300-350 metres). Applicable to all pulse-limited altimetry missions

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

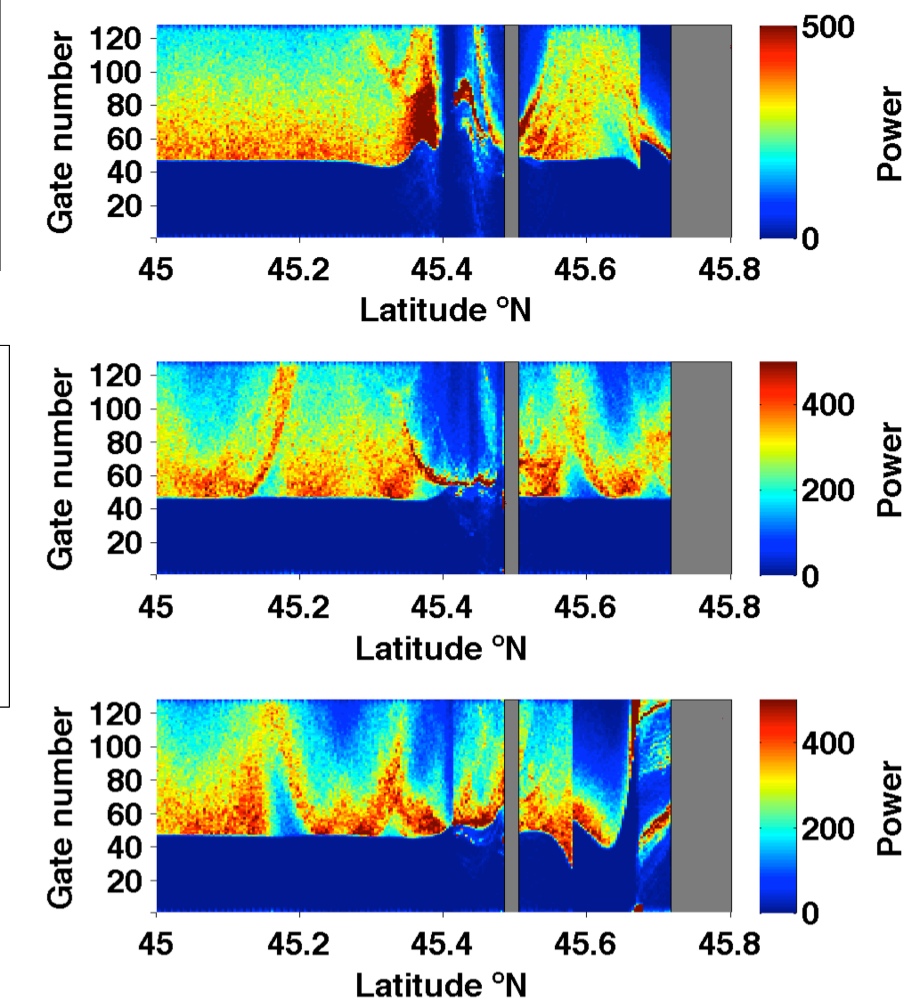
3) UNBIASED: it adapts the width of the subwaveform to the sea-state in order to maintain the same accuracy

4) HOMOGENOUS: it applies the same strategy for both open ocean and coastal waveform. It does not need any waveform classification.

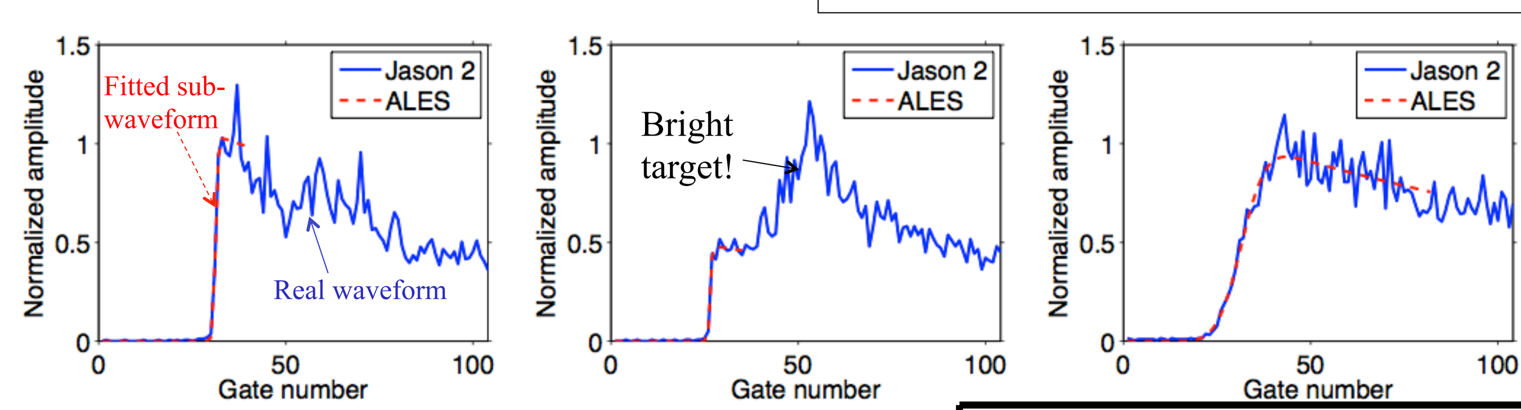
Part I: DESIGN



Bright targets are not constant in time, location or distance from the coast. They are caused by localized areas of very smooth sea. On the right: an example of radargrams of Envisat track 416 over the Adriatic Sea for three different cycles. Can we exclude them in the estimation by selecting a sub-waveform focused on the leading edge?

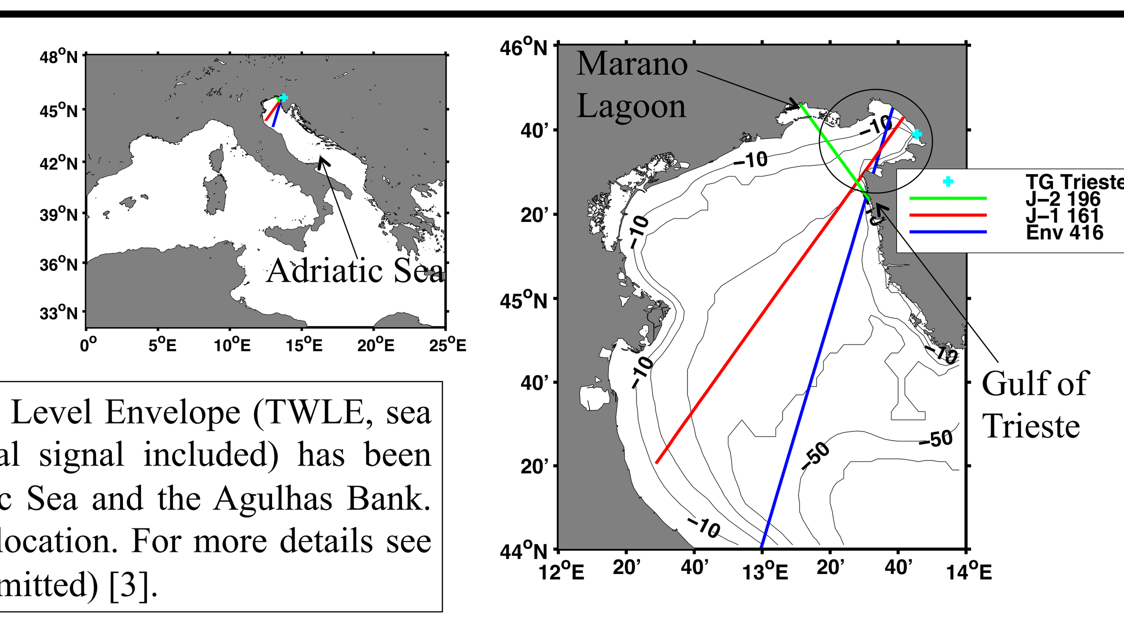


We simulated 500 noisy 'Brown-like' waveforms and compared the Epoch estimation from full-waveform and sub-waveform retracking with a variable number of gates and at different SWH. The plot on the left shows the Root Mean Square (RMS) Error Difference of full-waveform – sub-waveforms. A tolerance of 5 cm (1.3 on 1-Hz data) was set to derive a relationship between sub-waveform width and sea state.



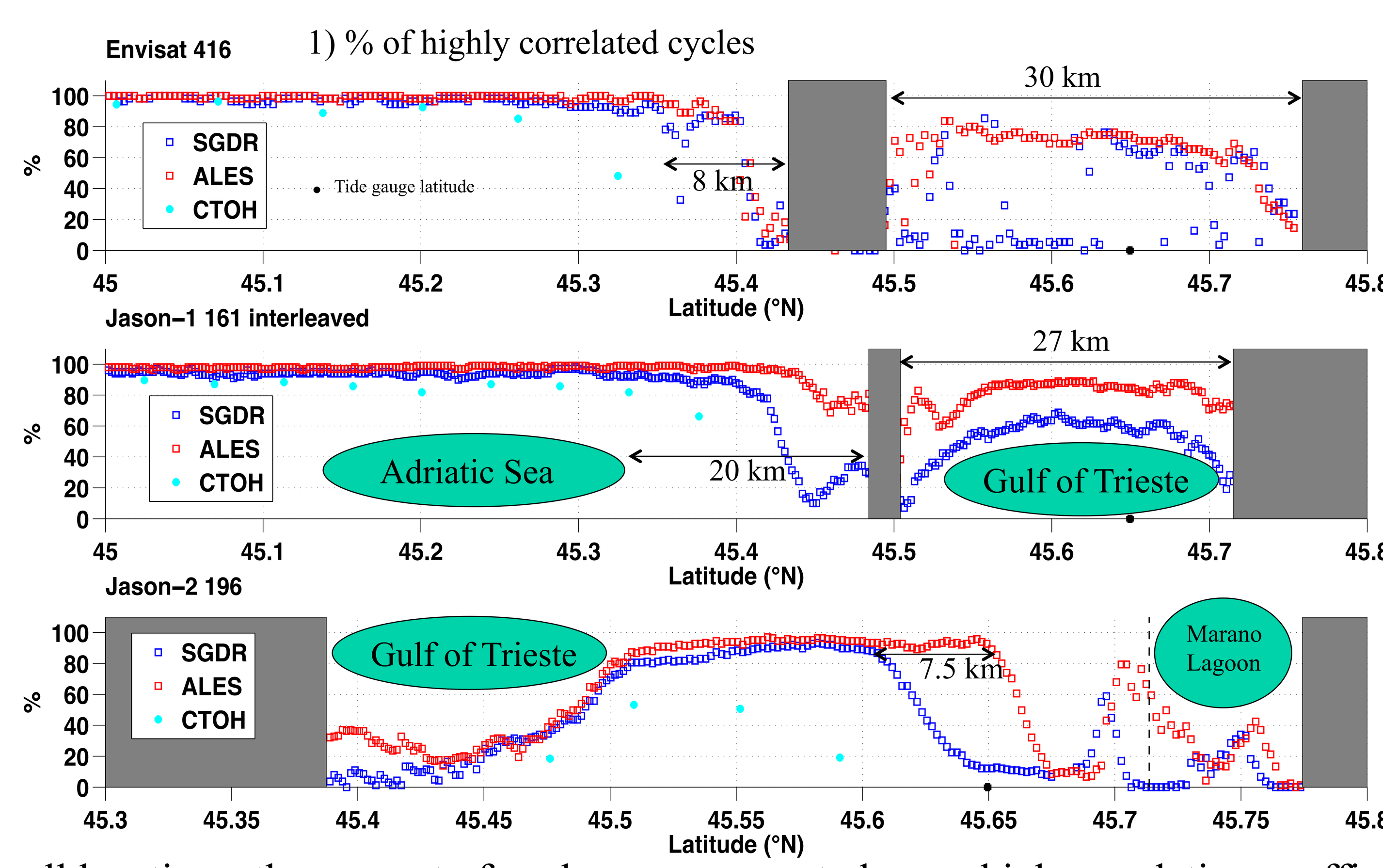
Above are examples of ALES retracking for low SWH (left), coastal waveform (centre) and high SWH (right). For every high-rate waveform, ALES:
1) Finds the leading-edge
2) Computes a first estimate of SWH and Epoch
3) Adapts the width of the sub-waveform depending on SWH
4) Retracks the new sub-waveform for an accurate estimation of Epoch, SWH and Sigma0

Part II: VALIDATION



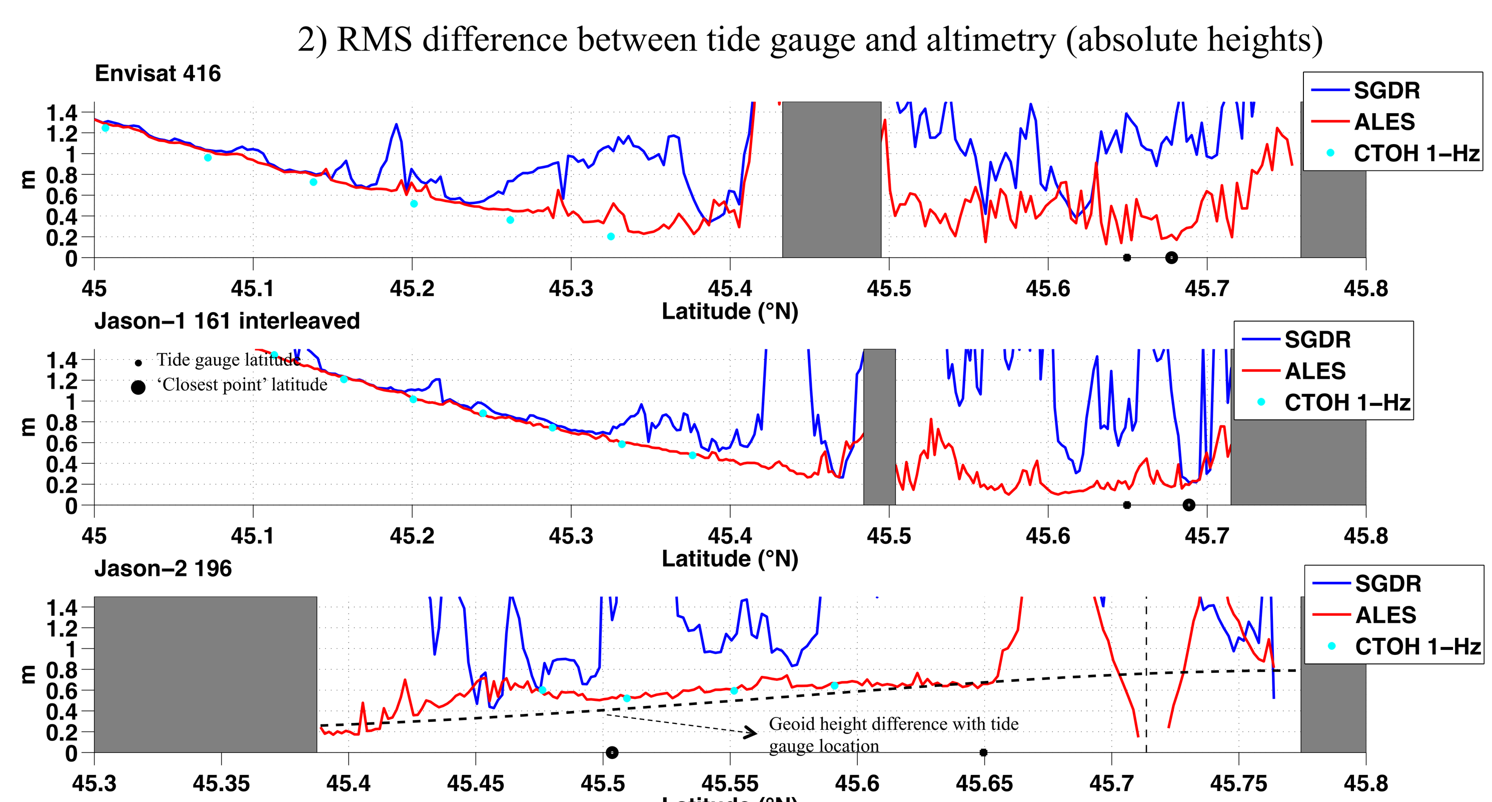
Retrieval of Total Water Level Envelope (TWLE, sea surface height with tidal signal included) has been validated on the Adriatic Sea and the Agulhas Bank. Here we show the first location. For more details see Passaro et al. (2013, submitted) [3].

1) % of highly correlated cycles

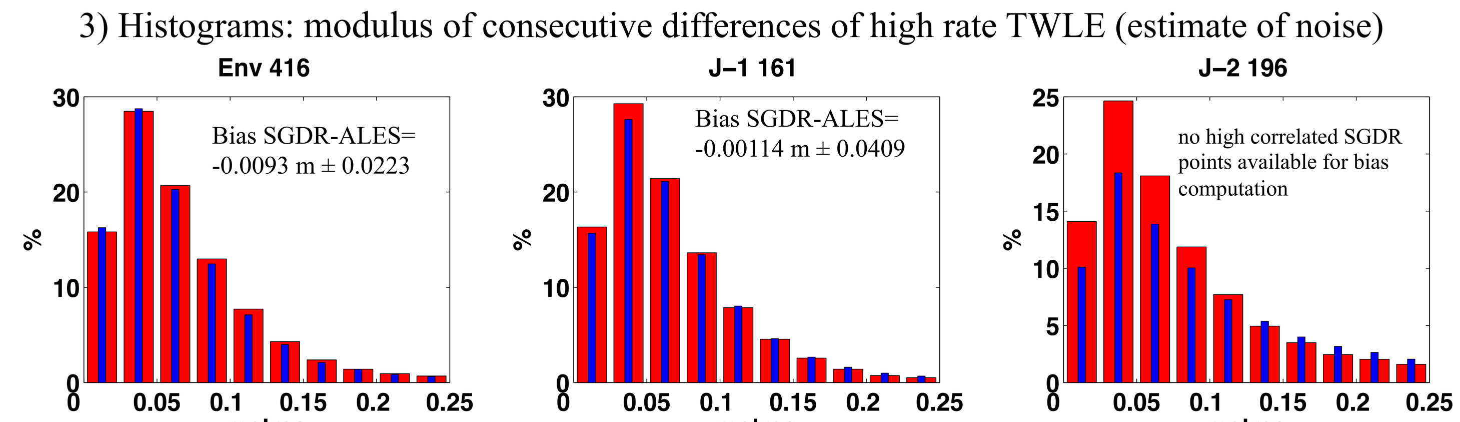


* For all locations, the amount of cycles we can use to have a high correlation coefficient is equivalent or higher using ALES
* Approaching the coast and in the entire Gulf of Trieste, the improvement is particularly striking
* High-rate retracking can provide reliable data even in areas where analysis is currently prevented by standard coastal altimetry data

2) RMS difference between tide gauge and altimetry (absolute heights)



3) Histograms: modulus of consecutive differences of high rate TWLE (estimate of noise)



TWLE retrievals are validated against tide gauge values from Trieste, using all the available cycles for each satellite track. Raw high-rate data from ALES and standard product (SGDR) are compared with CTOH post-processed 1-Hz coastal altimetry product.

In 1) the percentage of highly correlated cycles is shown for each along-track location is shown. For each location they are defined as the number of cycles that guarantee a correlation coefficient of at least 0.9.

In 2) RMS difference between absolute sea level (referred to ellipsoid) from tide gauges and ALES is shown. For the analysis, outliers from ALES have been detected and excluded. RMS difference using SGDR estimations at the same points is shown for comparison.

In 3) histograms of the modulus of consecutive TWLE differences are shown. Consecutive differences are considered a first approximation of noise.
Biases between SGDR and ALES for each track are computed. Only points with correlation coefficient higher than 0.9 are taken into consideration for this computation.

Conclusions

Sea Level estimation from ALES improves the amount of high-rate valid data in the coastal zone, whilst it does not degrade the open-ocean performance either in terms of accuracy or in terms of noise.

The bias with standard SGDR product is below 1 cm and comparability with ground truth is increased. It is possible to retrieve Sea Level in areas where no 1-Hz post-processed products are available

For more info: COASTALT: http://www.coastalt.eu/ eSurge: http://www.storm-surge.info

TEST DATA ARE AVAILABLE!!!

We are searching for collaboration regarding data assimilation, coastal circulation and synergy with other sensors. Drop us an e-mail!

References

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