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# Sea State Climate Change Initiative: first steps of the Algorithm Development Team

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## Introduction

The European Space Agency's Sea State Climate Change Initiative (SS_cci) is a European Space Agency (ESA) funded collaboration between fifteen organisations, which started in June 2018. From the Satellite Altimetry perspective, this project provides the opportunity to perform a vast study focused on the estimation, production and exploitation of a consistent dataset of Significant Wave Height (SWH) and Wind Speed. The Algorithm Development Team in SS_cci is composed of different groups who are developing retracking (i.e. estimations based on the fitting of the radar signal) solutions for both Low Resolution Mode (LRM) and SAR Altimetry in a complementary, yet competitive effort. The different solutions proposed will be evaluated in a so-called Round Robin exercise, which will consist of a transparent evaluation of the retracked data provided by the various groups. The testbed will be selected tracks from Jason-3 (J3) and Sentinel-3 (S3) missions. Moreover, research is ongoing to improve the strategies to assemble the so called „multi-looked" SAR waveform (Level-1A to L-1B processing) and to produce a quality-controlled final dataset (post-processing).

## LRM Altimetry

The research on SWH estimation for LRM Altimetry is of great importance for climate monitoring, given the possibility to apply the same retracking methodology for 25 years of data. TUM and PML are working on a Wave-Height-focused Adaptive Leading Edge Subwaveform strategy (WHALES). Besides adapting the width of the subwaveform in order to keep a trade-off between open ocean and coastal retrievals, residuals of the iterative fitting will also be weighted in order to increase the precision of the estimated parameter. Moreover, further gains in precision are expected with a correction to de-correlate SWH from Range estimation. CLS will provide estimations from the Adaptive Numerical Retracker (Thibaut et al., 2017) applied to Jason-3 for evaluation in the Round Robin: the method is using a fully representative physical ocean model including instrumental parameters such as the Point Target Response and an numerical estimation method based on a true Maximum Likelihood criterium.

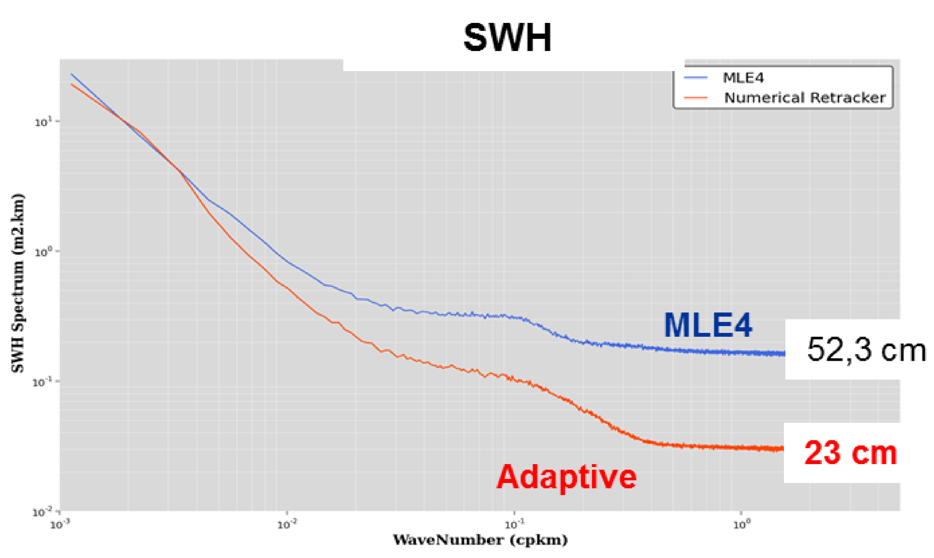


Figure 1: A PSD spectrum of the SWH clearly showing large improvements in the observation of small scales wave height signal using the Adaptive Numerical Retracker

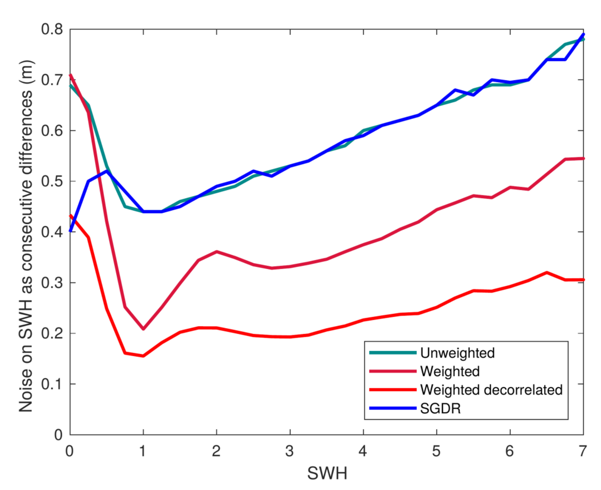


Figure 2: high-frequency noise of WHALES with and without weighting/decorrelation at increasing SWH. Noise from the Sensor Geophysical Data Records (SGDR), i.e. the original data, is also shown

## SAR Altimetry

isardSAT will contribute to the evaluation of optimized L1B processing baselines of SAR altimetric data using L1A from Sentinel-3. The innovative Amplitude Compensation and Dilation Compensation (ACDC) algorithm will be adapted to Sentinel-3 within the L1B processing chain, providing improved performance in retracked parameters (SWH). Effects of the ACDC on the noise of the estimates are visible in Figure 3. The impact of the swell when retracking SAR ocean data will be studied, by incorporating a model of the sea surface height with swell in the SAR ocean backscattering model. TUM and PML have built a simulator for SAMOSA (the current functional form used in S-3 retracking) SAR waveforms to study the possible adaptation of a subwaveform retracker similar to ALES+ (Passaro et al., 2018) to the SAR case. The challenge is to understand how the leading edge of the SAR waveform varies with changing SWH, without considering the changes that the wave heights causes in the trailing edge decay. The objective is to maximise coastal retrievals while decreasing the noise in SWH.

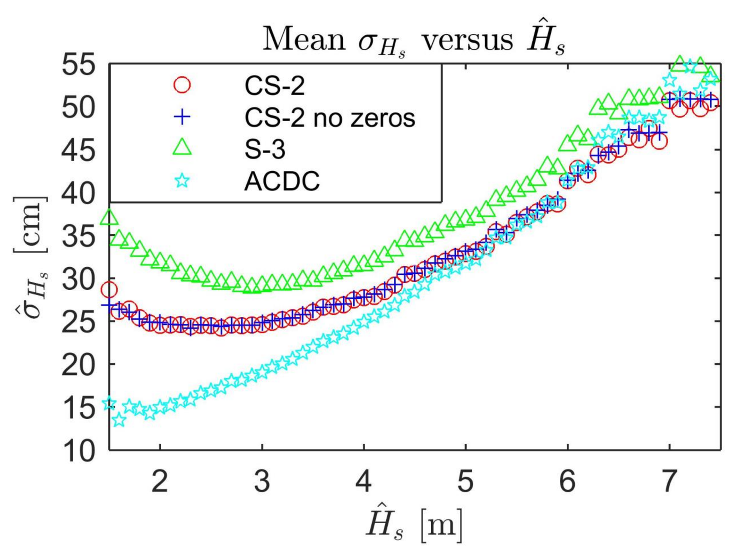


Figure 3: Noise performance of SWH for different processing baselines using CryoSat-2 FBR over Agulhas area

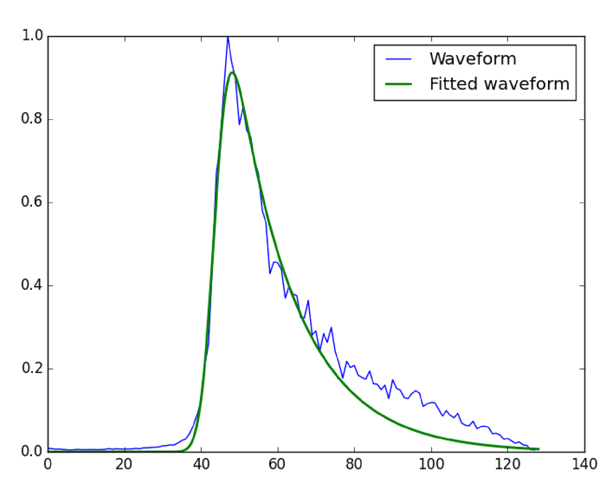


Figure 4: First attempt of retrieving the leading edge slope in a SAR waveform using an ALES+ like solution.

## Round Robin

In the initial phase of the Sea State CCI project, a number of candidate SWH algorithms will be assessed through an open Round Robin process to see which are the most appropriate to take forward for full data production and evaluation. One aspect of this will be to consider the along-track spectra of SWH values produced by the various algorithms. At large wavelengths (>100 km), the algorithms may be expected to converge, representing the true spatial scales of variation of SWH. At very short wavelengths the spectra simply indicate the noise in the estimates induced by the random speckle noise in the waveforms. However, different retracking algorithms can give rise to different spectra at intermediate scales. Figure 5 shows the marked divergence between spectra derived using the MLE-3 or MLE-4 algorithms. Another aspect involves comparison with in-situ data. Figure 6 shows the comparison between SWH measured at the West Bay harbour and Sentinel-3 observations at various distance along the two closest tracks (265 in blue is evaluated in the scatter plot). In SAR mode, the correlation between in-situ and satellite observations improves with decreasing distance from the buoy/coast.

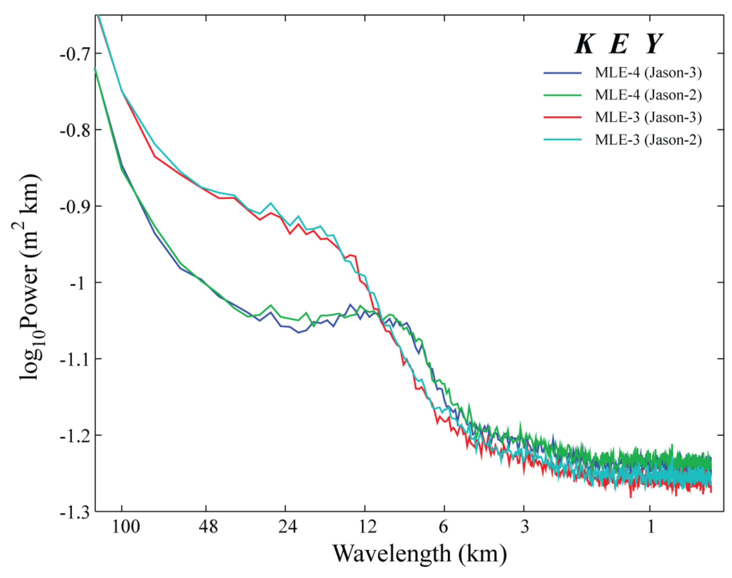


Figure 5: Along-track spectra of wave height from different altimeters and different retrackers. The lines show average spectra over 10 days from cycle 015 of Jason-3 and cycle 295 of Jason-2. This is during the tandem phase, when they observed the same location ~70 seconds apart.

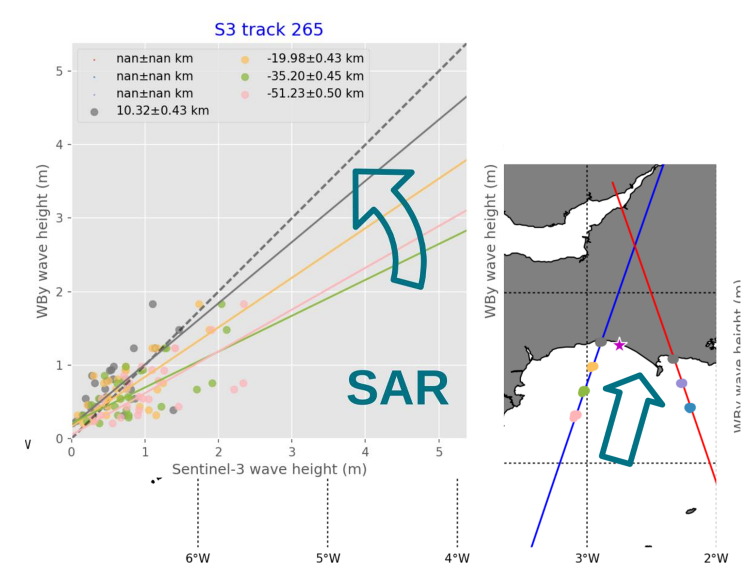


Figure 6: Comparison between significant wave height measured at the West Bay harbour in Dorset, UK, and Sentinel-3 observations at various distance along the two closest tracks (track 265 in blue). Further details in the Nencioli et al. talk on Friday at 11:45.

## Post-Processing

Analysis of fine-scale ocean dynamics requires preliminary noise filtering that often results in loss of geophysical information and artifacts in the sea state spectrum. We propose a data post-processing approach to separate at best fine scale geophysical information and noise. The chosen approach is inspired by wavelet shrinkage de-noising principles, but with the Empirical Mode Decomposition as key part. EMD is a method to decompose signals into a finite and often small number of scale-dependent components, called intrinsic mode functions (IMF), each being modulated in amplitude and frequency. Since the decomposition is based on the local characteristic sampling scale of the data, it is applicable to non-linear and non-stationary processes. Being fully data-driven and owing to the AM/FM nature of IMFs, EMD is particularly relevant for altimeter data denoising. Some exemplified results are shown in a companion poster and in related articles (Quilfen et al., 2018).

## Call to participate

The Algorithm Development Team of the SS_cci welcomes input from the whole OSTST Community. For this reason, we are issuing an open call for all scientists who wish to participate in the Round Robin using their own algorithms. The Round Robin will be a blind test (i.e. all participants will be provided with the same L1 data and expected to provide their L2 retrievals) and will verify output against a reference data set that is not available to the participants until all participation results have been formally announced. The assessment activity will be performed internally and results will be published anonymously. Details on how to participate will follow in the coming weeks (Autumn 2018).

## Resources

For more information on the ESA Climate Change Initiative, visit cci.esa.int .

## References

Passaro, M., Rose, S.K., Andersen, O.B., Boergens, E., Calafat, F.M., Dettmering, D. and Benveniste, J., 2018. ALES+: Adapting a homogenous ocean retracker for satellite altimetry to sea ice leads, coastal and inland waters. Remote Sensing of Environment, 211, pp.456-471.

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