The CORS processor outcomes. Improving the Coastal Ocean SSH & SWH series from the Copernicus altimetry constellation

isardSAT — EUMETSAT — esa European Space Agency

Pablo García[1], Alba Granados[1], Michel Guerra[1], Mònica Roca[1], Bruno Lucas[2], Pierre Féménias[3]

[1] isardSAT, Barcelona, Catalonia (E-mail: pablo.garcia@isardsat.cat), [2] EUMETSAT, Germany, [3] ESRIN / European Space Agency, Italy

ABSTRACT

Coastal zones are known as complex areas for the altimetry studies when retrieving reliable geophysical information of the Ocean surface. This poster describes the Coastal Ocean Retracker for the Sentinels (**CORS**) main characteristics and the outcomes of its validation. The main goal of CORS is to increase the Stability of the L2 data, mainly the SSH and SWH, by discriminating the ocean signal from undesired targets that usually disturb the Coastal Zones echoes. Here below the approach is described in terms of algorithms and strategy, and then, the validation outcomes are described for the three Copernicus altimetry satellites.

The CORS has been optimized over the years, so it is fast, reliable and robust, simplifying the data flow and processing steps, making it a good candidate for an operational Coastal Ocean solution. The Sentinel-3A, Sentinel-3B and Sentinel-6 altimeter data have been used for a global validation of the retrieved SSH and SWH, using different methods: homogeneity tests, Power Spectral Density (PSD) analysis, and an assessment of the stability of the SSH and SWH measurements as a function of the Distance to the Coast. A consistent improvement of the SSH noise over 50% have been observed in different scenarios, as well as a better PSD function in all wavelengths.

COASTAL PROCESSING APPROACH

The first solution of this Coastal Processor was developed within the CP4O project for the CryoSat-2 (CS2) mission, making use of SARin mode, which includes the across-track Angle of Arrival (AoA) data. Low AoA and high Coherence filtering determine a section of the waveform with the expected Nadir Ocean signal, which is then retracked, avoiding interferences from other targets. The CP4O solution is explained in the paper (Garcia et al., 2018. **doi: 10.1016/j.asr.2018.03.015**). But we have a constraint: so far, the CS2 mission is the only altimeter capable to give AoA information. In the near future, the CRISTAL mission will take over.

After that initial idea, the coastal processor has been modified over the years to reach an approach that can be used in any altimeter mission. The strategy of this new approach is to build a solution that is robust and applicable to the highest number of casuistic in the Coastal Regions, not only to a specific area or scenario. Also, we wanted it to be autonomous, fast and simple, so it can be suitable for an operational processing system: no use of external models or ingestion of auxiliary data, more than 10 times faster than the Open Ocean processing, and straight unique results after one round of retracking.

This new approach selects a portion of the waveform that contains the Nadir Ocean signal, based in the Window Delay (WD) and the Mean Sea Surface (MSS) series along the track.

How does it work?

1. In the Open Ocean area, we compute a preliminary Ocean Surface gate reference, considered as an empirical Leading-Edge Point (LEP), as the closest point to 87% of maximum power in the Leading-Edge
2. We align (unbiasing) the MSS values, which represents the reference of the Ocean Surface at Nadir, with respect to the Open Ocean LEP reference
3. For the Coastal Ocean area, we use the unbiased MSS to cut the waveform around it
4. At L2 processing, we use a sub-waveform retracker to estimate the SSH, SWH, and Sigma0, based on (Ray et al., 2014. **doi: 10.1109/TGRS.2014.2330423**), and further developed in the isardSAT Open Ocean retracker (Makhoul et al., 2018. **doi: 10.1016/j.asr.2018.04.004**).

VALIDATION RESULTS

Different exercises have been conducted for the CORS validation. S3A, S3B, and S6 L1B & L2 NTC data series have been used over the last years for this activity. A comparison is done with the official L2 NTC products from the Agencies (ESA or EUMETSAT). Usually, the SSH was the monitored parameter, but lately for S6 both SWH and Sigma0 have been additionally checked.

S3 SSH noise extensive validation

For both S3 satellites, an extensive study of the SSH noise has been done during the extension of the S3MPC contract. Several study cases were selected considering various scenarios: Philippines and Cuba presents complex coastal topographies with reefs, islands, many coastal fronts, shallow waters, bays, coastal lowlands and cliffs; Baltic Sea and White Sea are covered by ice (sea ice) part of the year; Svalbard presents a rough sea state; the Mediterranean Sea covers a huge amount of different coastal cases and a well studied area; and the South West Pacific Ocean represents a vast area of 30 million square meters of coastal scenarios with longitudes from Malaysia to Salomon Islands and latitudes from Australia to Thailand.

In the table below we can read the different ratios of SSH noise improvement in the different AoI's. In the last 10 km we consistently see values around 50% for most of the cases. The noise is calculated as an average of differences between consecutive records along track. This gives similar results as the usually adopted standard deviation of detrended 20 Hz data packets. The presence of sea ice (Baltic or White Sea in winter) is not a problem for maintaining the improvement ratio, but the rough sea states (Svalbard) are a handicap.

Area of Interest	Mediterranean Sea	Cuba	Philippines	Baltic Sea	White Sea Sum / Win	Svalbard	Pacific Ocean
Improvement ratio of SSH noise	50% 48%	46% 56%	66% 56%	56% 55%	38% / 49% 45% / 44%	23% 32%	52% 58%

Homogeneity Study over Open Ocean

It is important to test the compatibility of the CORS processor with respect to the equivalent Open Ocean processor for having a seamless transition between both outcomes. For doing so, we have tested a 20 x 20 degrees in the Central Pacific Ocean, knowing that such transitions are done still far from the coast, and given that near the coast we would lose precision in the statistics.

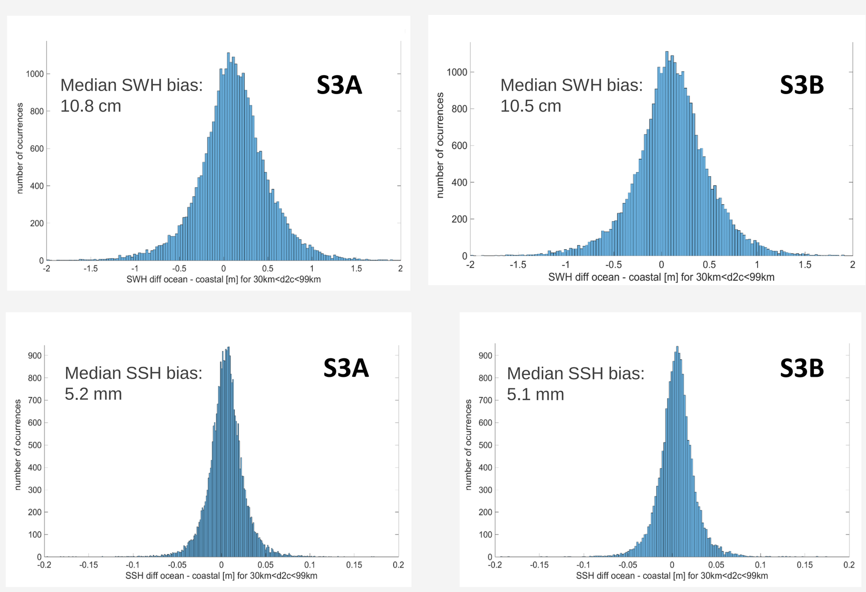
In the histograms on the right, it is represented the distribution of the differences in SSH and SWH between the isardSAT Open Ocean and CORS retrackers.

We see for both two Sentinel-3 satellites similar values and a regular distribution, which gives us confidence in the results.

The SSH bias is around 5 mm.

The SWH bias is around 10 cm.

These differences could be partially related to the different Sea State Bias corresponding to both approaches.

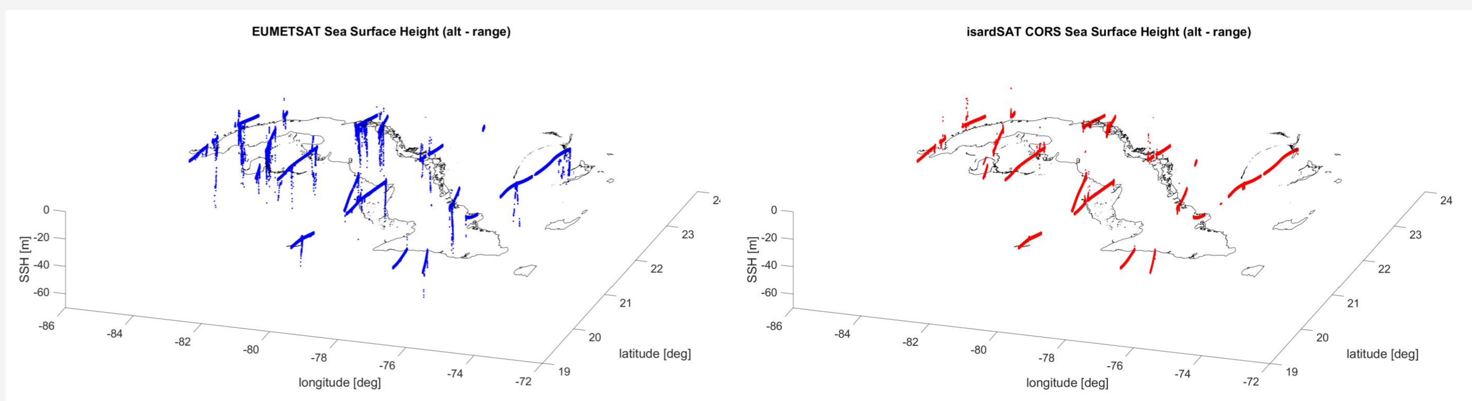


Validation of Sentinel-6 reprocessed F06 products

Recently this year, EUMETSAT released the whole S6 mission reprocessed dataset from the F06 Processing Baseline, making it possible to analyse a full mission homogeneous and improved PDAP dataset.

From this whole mission data series (L1B and L2 NTC products), we have validated and compared both the PDAP and the CORS outputs over the Cuba archipelago.

For having a straight idea of the level of improvement of the SSH estimations around Cuba, we can observe the below figure. The 3D SSH misrepresentation on the left blue PDAP case contrasts with the improved CORS SSH mapping on the right red plot. We can see how CORS better resolve underestimations (trailing edge peaks).



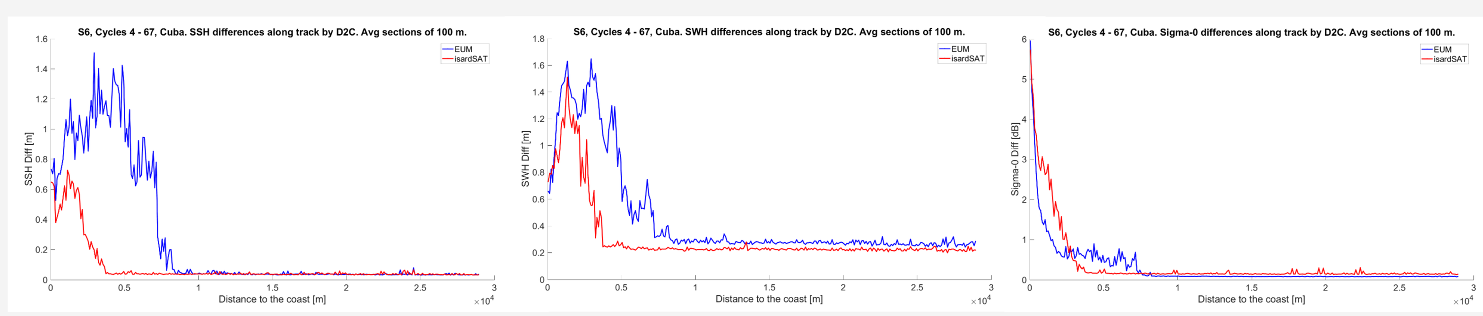
The SSH noise improvement ratio in the last 10 km to the coast is of 76.07%.

The SWH noise improvement ratio in the last 10 km to the coast is of 42.73%.

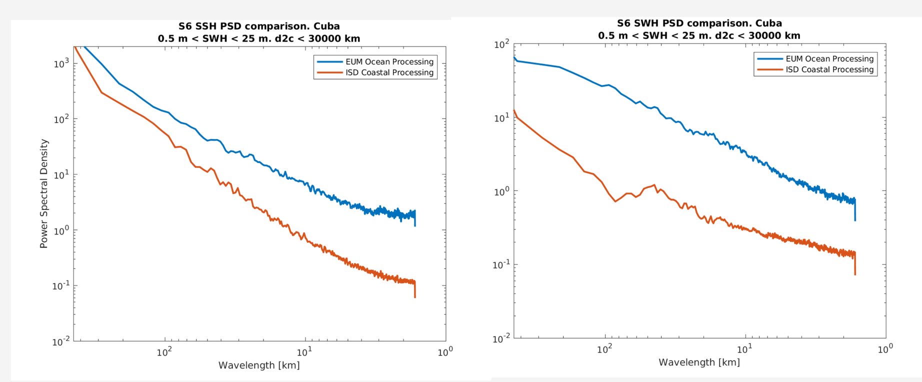
The Sigma0 noise worsening ratio in the last 10 km to the coast is of 10.67%.

In the figures below we represent the noise of the 3 parameters versus the distance to the coast (d2c).

It is clear the SSH and SWH improvement at all distances, and especially how CORS approaches the coast without worsening the stability up to 3-4 km from the coast, while PDAP does so around 8 km from the coast.



Finally, we can also represent the Power Spectral Density (PSD) of the SSH and SWH parameters, which explain the performances along the different spatial wavelengths. In both SSH and SWH PSD analysis, we see a notably better performance of the CORS processor when compared to the PDAP NTC products, filtering up to 30 km to the coastline and for SWH between 0.5 and 25 m. The mesoscale zone is specially improved.



SUMMARY

Algorithm development

- The CORS processor is developed from the initial idea for the CryoSat-2 mission (Garcia et al., 2018. **doi: 10.1016/j.asr.2018.03.015**) in the CP4O project.
- The current design relies in a discrimination of the maximum amount of contamination from undesired targets, to isolate the ocean nadir signal. The MSS, unbiased from Open Ocean empirical LEP, is used for this purpose.
- A refinement of the algorithms have been done over the last years focusing the effort in having a solution that covers most of the varied coastal scenarios, that is robust and reliable.
- In addition, the CORS approach is a fast solution (more than 10 times faster than the equivalent Open Ocean solution) and is autonomous (no need of external models or auxiliary data than the one available for L2 processing).

Sentinel-3 assessment

- An extensive validation over various AoIs has been performed for the S3 mission over the time. All coastal topographies, angles of attack to the coastline, sea states, sea ice conditions, etc. have been considered.
- For this Sentinel-3 validation exercise we observe an improvement of around 50% in ocean surface height stability with respect to the Agency NTC L2 products. The results are very homogeneous for both satellites.
- A study of the homogeneity between CORS and its equivalent Open Ocean processor gives values of 5 mm in SSH and 10 cm for SWH, both consistent between both satellites. This is considered as not negligible, but we have to state that the Sea State Bias of the CORS retracker may differ from the Open Ocean one.

Sentinel-6 assessment

- Recently EUMETSAT delivered a full mission reprocessed dataset: processing baseline F06. This dataset has been used for a comparison versus the CORS outputs. L1B and L2 NTC products are considered for the exercise.
- The results are even better than for S3 regarding the SSH stability: the ratio of improvement is of 76%. For the SWH, it is of 43%. For Sigma0 it is worsened by 11% due to the section 0-3 km; in section 3-8 km CORS outperforms PDAP.
- From the PSD figures we read a CORS better behaviour for both SSH and SWH, especially in the mesoscale area. We have to note that this study includes all distances from 30 km up to the coastline.

Future work

- Several modifications are envisaged for the code evolution, e.g. a more dynamic approach is being designed. Additional validation exercises are to be performed to reinforce the current performance evaluation of the CORS processor.