Recent developments in multi-mission altimeter sea state products: the ESA CCI dataset v2

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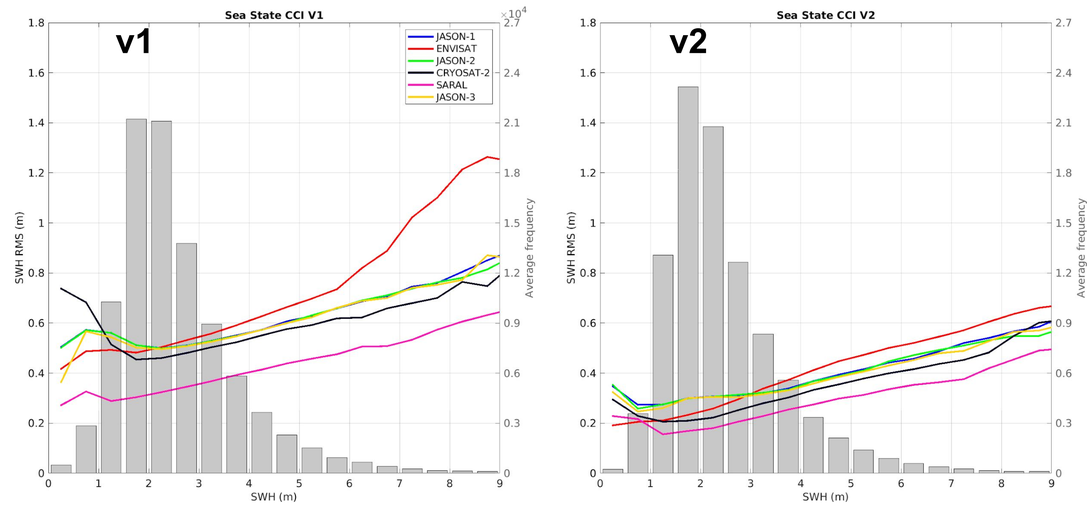
In 2018, the European Space Agency (ESA) launched the Sea State Climate Change Initiative (CCI) project in the context of the CCI+ program. The objective of this 3-year initial phase is to reprocess and analyze sea state records from satellite altimeters (all ESA missions and the Jason series since 2002) and radar imagery (all wave modes from Sentinel 1), complemented and validated with in situ data, in order to provide the first sea state Climate Data Record needed for climate research. A primary concern of the project is the accuracy and stability of the multi-mission data sets. Algorithm developments are therefore carried out to ensure the best possible quality of wave products with a particular focus on consistency. These developments include the reprocessing of conventional and Delay-Doppler altimeter missions with new waveform retracking algorithms, data editing and filtering methods for removing outliers and increasing the signal-to-noise ratio, mission calibration against quality-controlled in-situ measurements and mission inter-calibration at mission crossovers needed to ensure long-term consistency.

Overview of v2 dataset

Mission	Instrument	Band	Covered period	Source Product
JASON-1	Poseidon-2	Ku	2002-2012	SGDR version E [Aviso]
ENVISAT	RA-2	Ku	2002-2012	SGDR v3 [ESA]
JASON-2	Poseidon-3	Ku	2008-2017	SGDR version D [Aviso]
CRYOSAT-2	SIRAL	Ku	2010-2020	SIR LRM L1B version D [ESA]
SARAL	AltiKa	Ka	2013-2019	SGDR version T [Aviso]
JASON-3	Poseidon-3B	Ku	2016-2019	SGDR version D [Aviso]

- L2P: Along-track products separated per satellite and pass
- L3 : Merged daily products retaining only valid measurements
- L4 : Monthly gridded products (1°x1°)

Noise characteristics



This figure shows the RMS of the 20-Hz SWH records as a function of SWH for each altimeter mission (colored lines) as produced by conventional retrackers (CCI v1, left panel) and by the WHALES retracker (CCI v2, right panel). In both case, we see that the RMS noise increases almost linearly with the sea state conditions (except at low sea state due to inadequate sampling of the steep leading edge). An important difference is the strong reduction of the noise in the V2 dataset, a consequence of the subwaveform fitting approach of the WHALES retracker.

Validation against in-situ platforms

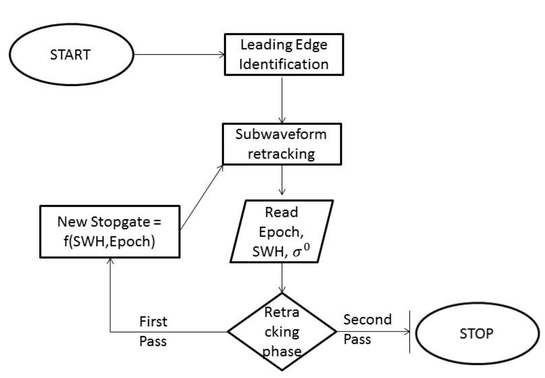
Mission	#values	Bias (m)		NRMSE (%)	
		Before correction	After correction	Before correction	After correction
JASON-1	10184	-0.08	-0.01	10.14	9.72
ENVISAT	12503	-0.02	-0.02	9.02	9.03
JASON-2	14837	-0.1	0	9.84	8.99
CRYOSAT-2	830	-0.06	0.02	8.54	7.79
SARAL	10732	0.24	0.04	13.88	9.49
JASON-3	6232	-0.06	0.01	9.15	8.84
AVERAGE	**9220**	**0.09**	**0.02**	**10.1**	**8.98**

Finally, an independent verification of the inter-calibration procedure is carried out by comparing the statistical errors between altimeter and in situ matchup pairs before and after calibration. Table 2 shows that the asbolute bias is reduced, on average, from 9 cm to 2 cm and the normalized RMSE (NRMSE) from 10.1% to 8.98%.

The ESA Sea State CCI dataset v2.0 includes 6 altimeter missions launched after 2002. The high resolution radar waveforms retrieved from the SGDR source product, were all reprocessed with the WHALES waveform retracker algorithm in order to derive significant wave height (SWH) and sigma0 parameters. A data editing methodology was consistently applied to all missions' 1Hz data in order to remove outliers. The rejections flags include tests on land and sea ice masks, thresholds on Hs and Hs RMS, number of valid waveforms and statistical outlier detection.

WHALES retracker

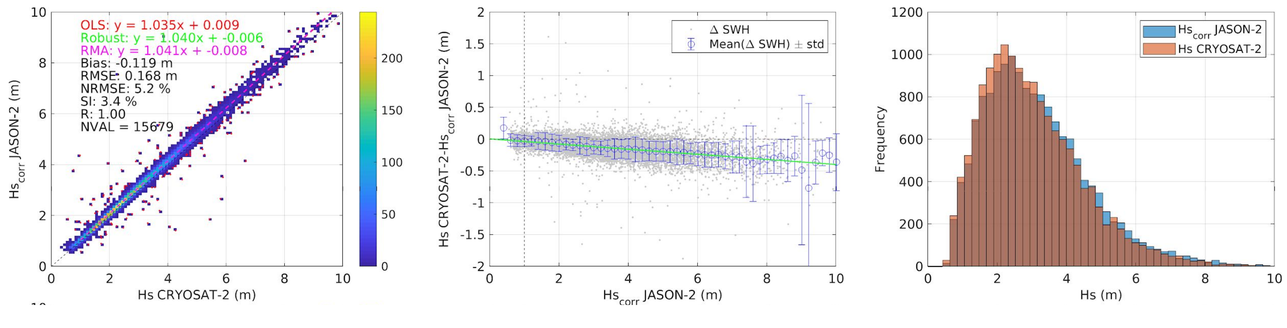
The Low Resolution Mode (LRM) waveforms are characterised by a rising leading edge that becomes less steep as the SWH increases, and a slowly decreasing trailing edge. The standard retracking methods are still affected by a suboptimal distribution of the residuals in the fitting process, which results in high level of noise in the estimations. WHALES is designed as a unified way to solve these problems and is based on two principles:



1) The application of a weighted fitting solution, whose weights are adapted to the SWH in order to guarantee a more uniform distribution of the residuals during the iterative fitting. This guarantees significantly more precise estimations.

2) A subwaveform strategy to focus the retracking on the portion of the signal of interest, avoiding heterogeneous backscattering in the trailing edge (partially inherited from the ALES retracker, Passaro et al., 2014). This guarantees efficiency in the coastal zone and a better representation of the oceanic scales of variability.

Multi-mission inter-calibration



SWH estimated from radar altimeter records requires calibration in order to match the ground truth as closely as possible and ensure multi-mission consistency. Following the methodology used for v1 dataset (Dodet et al., 2020), we used in situ matchups to perform an absolute calibration of the JASON-2 reference mission. In a second step, the remaining missions were compared against the calibrated JASON-2 data at crossover locations in order to perform inter-calibration. Robust linear regressions were fitted through SWH records > 1m because of the different error characteristics at low sea states. Linear corrections were then applied to the whole SWH range so as to avoid discontinuities in the distribution.

What's next ?

The next version of the Sea State CCI dataset is under preparation. Among the new features, there will be:

- Sentinel-3A Delay Doppler Hs reprocessed with LR-RMC retracker
- Sentinel-1A/B SAR total Hs from deep learning approaches
- other improvements based on your needs: please complete this survey to let us know what you would like to see in future versions
  https://esa-survey.limequery.org/997962?lang=en

Sea State CCI 2nd User Consultation Meeting - March 23-25 2021