Validation, cross-calibration and performances of altimetry missions over ocean for mesoscale, coastal and climate applications

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Over the last 3 years, the activities of validation and cross-calibration of altimetry missions over ocean aimed at characterizing their performances for mesoscale, coastal and climate applications.

Two main aspects were addressed over the last few years:

1) **The quantification of improvement brought by new geophysical standards (used to estimate the final Sea Surface Height) and innovative processing algorithms (related to retracking or post processing algorithm).**

The following bar chart illustrates the Jason-1 error reduction (variance reduction of the SSH differences at crossovers) brought by several standard evolutions, for time scales below ten days and spatial scales larger than hundreds of kilometers.

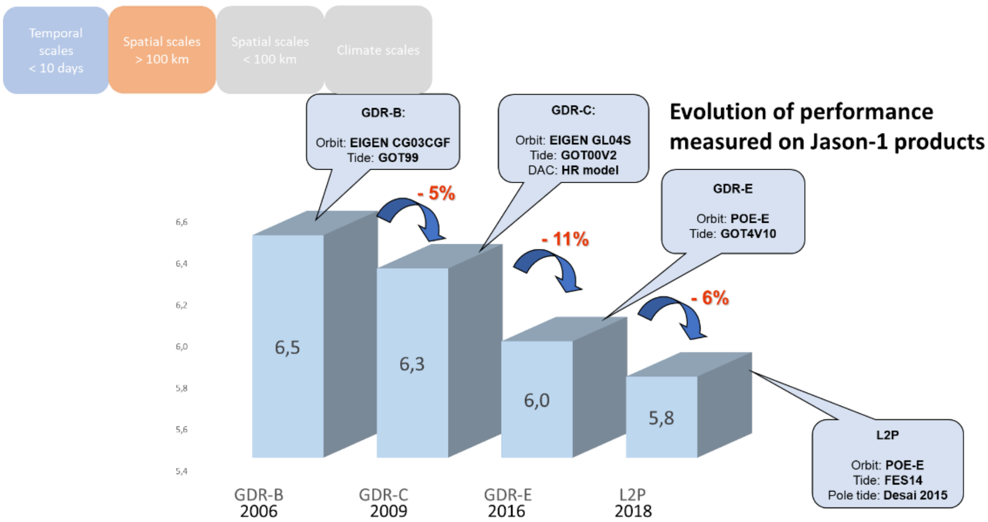

Figure 1: illustration of the SSH error reduction for Jason-1.

The analysis of reprocessed datasets is a crucial activity in order to build an accurate and homogeneous altimetry data record since 1992. In addition to the Jason-1 reprocessing analysis performed in 2016, recent studies have been dedicated to the SARAL/AltiKa GDR-F reprocessing (see G. Jettou et al., OSTST 2019) and Jason-3 GDR-F reprocessing (F. Bignalet et al., OSTST 2020).

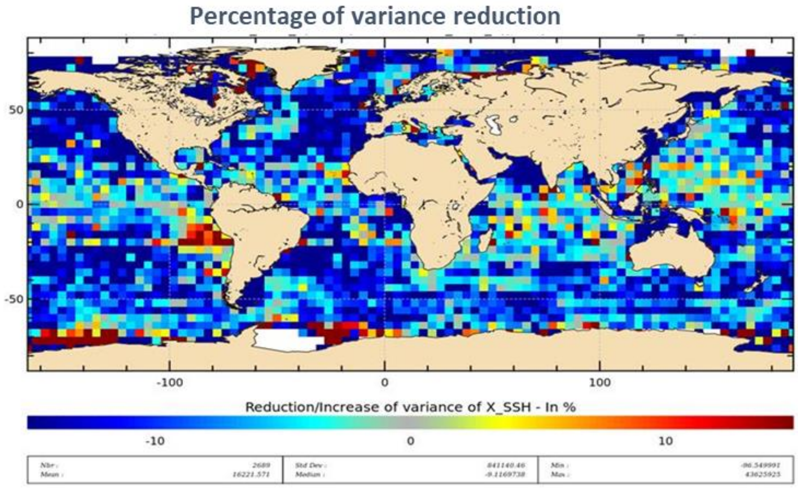

Figure 2: illustration of the variance reduction of the SSH differences at crossovers between SARAL/AltiKa GDR-T dataset and GDR-F reprocessed dataset over the years 2013 to 2015.

New retracker algorithm were also proposed by the altimetry community and assessed in the frame of CalVal activities. The adaptive retracker proposed by P. Thibaut et al during OSTST 2017 presents improved performances in term of noise reduction and a reduce spectral bump error for altimetry missions in LRM mode. All this R&D activities supported by CNES have resulted in the inclusion of this innovative and robust retracking algorithm in the GDR-F version of the Jason-3 L2 GDR products. Post processing filtering applied directly on the Sea Level Anomaly variable such as the High Frequency Adjustement (HFA) proposed by Zaron et al. OSTST 2016 and by N. Tran et al., 2019 also largely improved data quality at 20 Hz.

The CalVal activities aims at quantifying the improvements brough by such algorithms at short wavelengths and measure the increased observability of oceanic sub mesoscale processes.

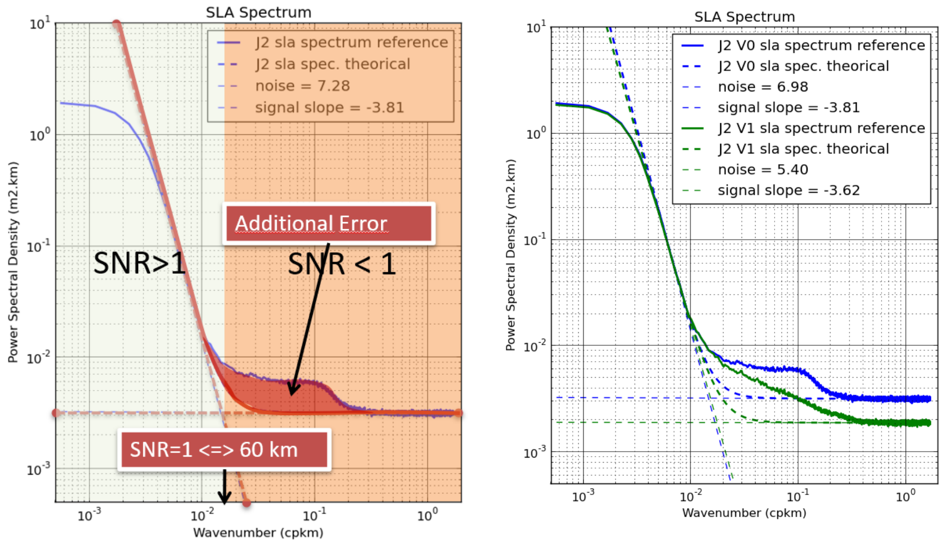

Figure 3: illustration of Jason-2 SLA spectrum and quantification of residual errors at short wavelengths (left panel). Illustration of the variance reduction when denoising method is applied (right panel)

Each algorithm evolution may have an impact on the GMSL trend uncertainties estimation. An important part of the CalVal activity is the refinement of the altimetry error budget and assessment of their impact on the Global Mean Sea Level evolution.

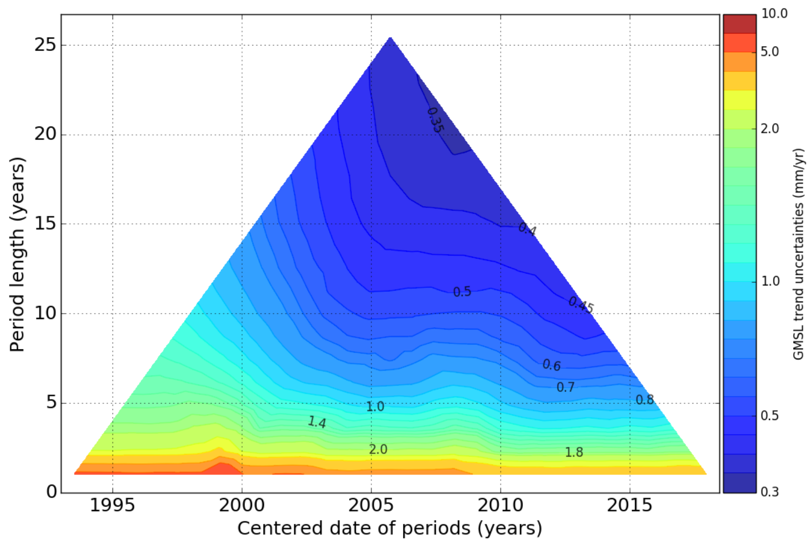

Figure 4: evolution of the GMSL trend uncertainties for different time spans over the 25-years period (CI = 90%)

2) The performances of recently launched altimetry missions and missions onboarding new sensor technology.

On the past 4 years, several altimetry missions were launched: Jason-3 and Sentinel-3A in 2016, Hy-2B and Sentinel-3B in 2018, HY-2C in 2020. An important part of the CalVal activities is to assess the performances of these new missions and the consistency of their measurements with in-flight satellites.

The tandem phase between Jason-3 and Jason-2 has been carefully analyzed and showed the very good agreement between the two missions with differences ranged between +/- 1 mm only (Picot et al., OSTST 2016; H. Roinard et al., 2017).

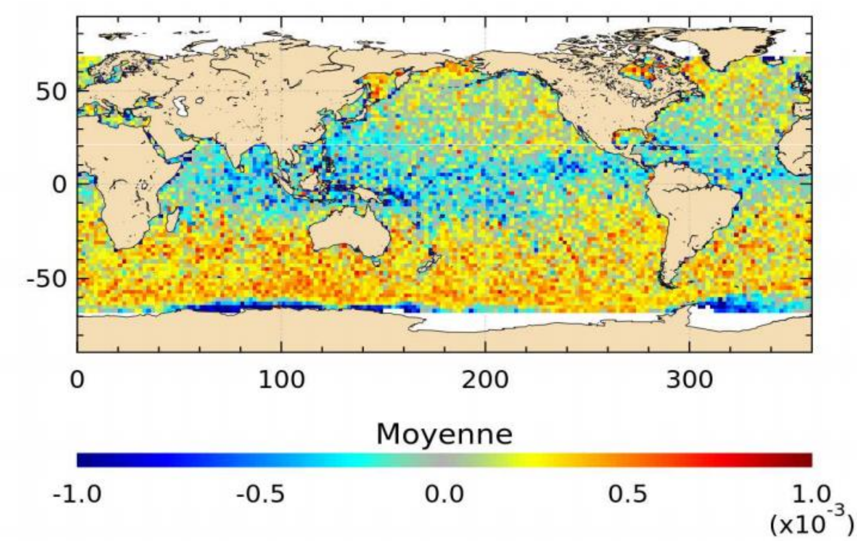

Figure 5: SSH residue between Jason-3 and Jason-2 during the tandem phase (mm)

Hy-2B dataset over ocean has been also analyzed. The CalVal analyses (M. Raynal et al., OSTST 2019) demonstrated the good performances of the altimeter and the improvement brought on L4 products when integrating this new altimeter in the Multi-Missions SSALTO/DUACS system.

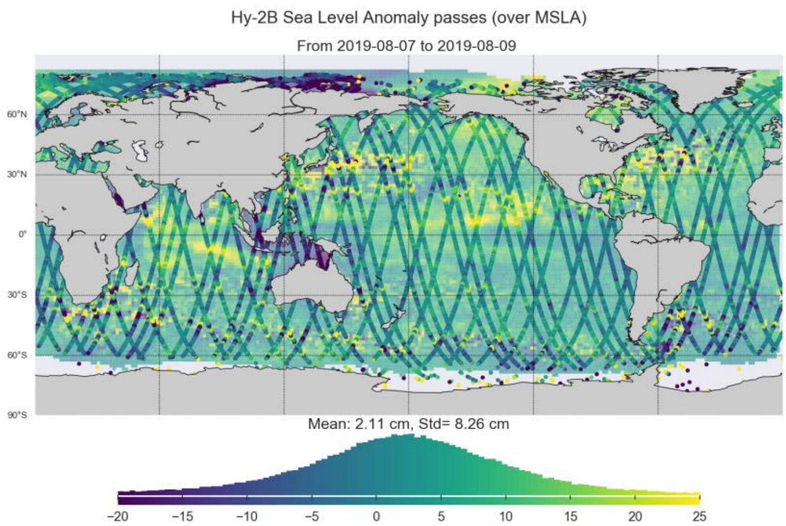

Figure 6: Hy-2B Sea Level Anomaly over Mean Sea Level Anomaly grid derived from aviso L4 products.

Specific studies have been carried on for Sentinel-3A and Sentinel-3B onboarding a Synthetic Aperture Radar (SAR) altimeter (as for Cryosat-2 altimeter). A lot of studies have been carried out to understand the quality and performances of the SAR mode observations compared to conventional altimetry.

The Global Sea Surface Height acquisitions in SAR mode (global compared to Cryosat-2 SARM that was limited to specific geographical areas) allow to significantly reduce the level of white noise of sea level observations (lower by ~50% with respect to conventional altimetry) and provide improved along-track resolution (~300 m in along-track direction). These improvements contribute to enhance the observation of small, short oceanic features.

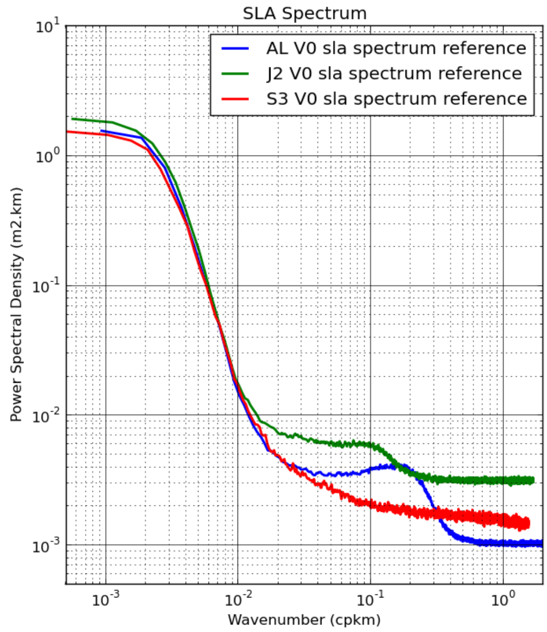

Figure 7: SLA anomaly spectra from Jason-2, SARAL/AltiKa and Sentinel-3 SARM datasets.

Small residual weaknesses have also been detected thanks to CalVal analyses. The short wavelengths below ~10 kilometers, present a linear increase of energy and not a white noise plateau as it is the case for conventional altimetry. It has been showed (Raynal et al., OSTST and more recently P. Rieu et al., 2020 https://doi.org/10.1016/j.asr.2020.09.037), these wavelengths are sensitive to the swell period and direction. SWH and range estimated parameters are impacted.

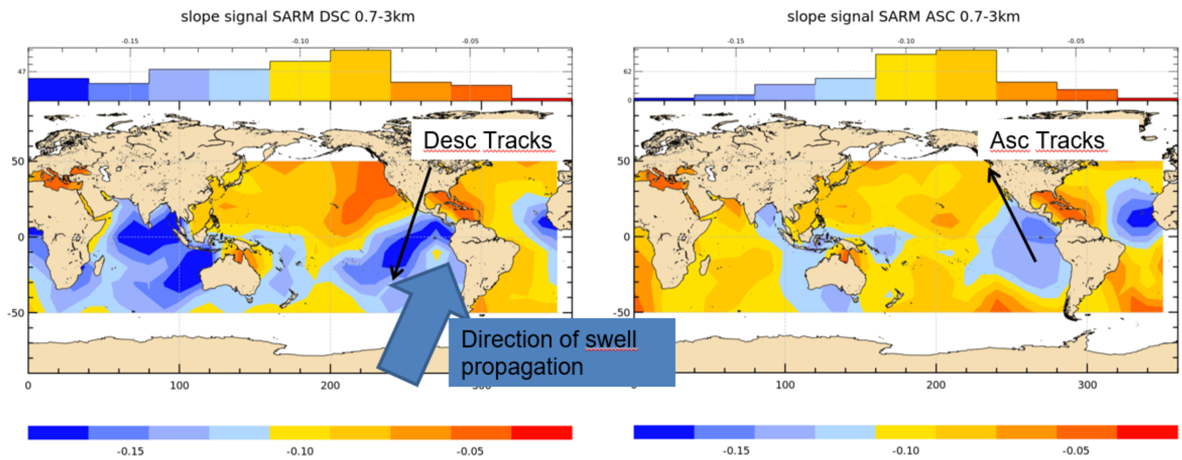

Figure 8: Map of the S3A SLA spectrum slope measured for wavelengths ranged between 700 m and 3 km for ascending and descending passes

Thanks to the success of Tandem phases already exercised for the Jason missions, ESA decided to experiment the same configuration between Sentinel-3B and Sentinel-3A satellites. The complete analyses of the Sentinel-3 tandem showed an excellent agreement between the two -A and -B missions with differences ranged between +/- 2.5 mm only.

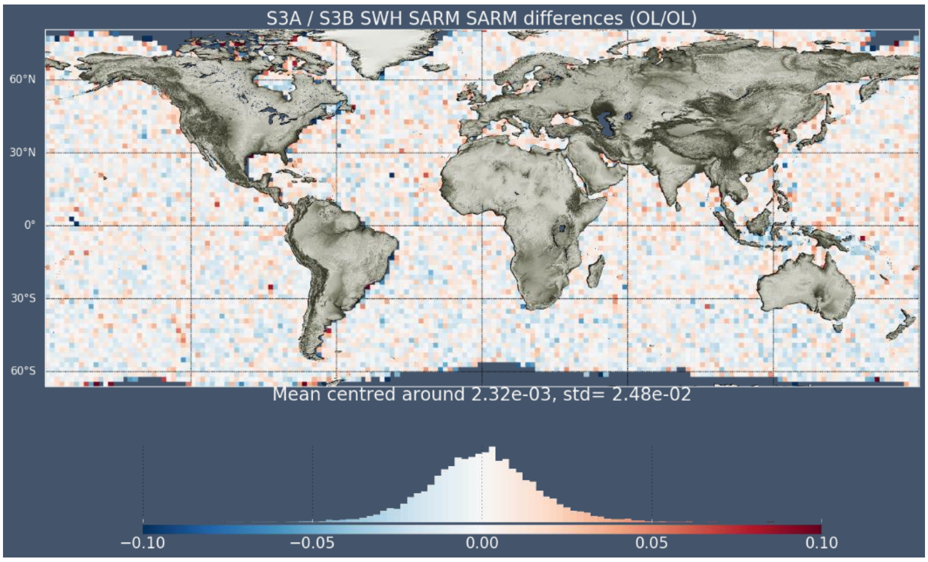

Figure 9: SSH (alt - range – mss) differences between Sentinel-3A and Sentinel-3B in Open-Loop mode during the tandem phase.

The CalVal analyses also allowed to point out small residual errors, weakness of the SARM processing, allowing a deeper understanding of the current limitations of the SARM and opening perspectives for its improvement.

For the wavelengths above hundred of kilometers, it has been demonstrated in Raynal et al. OSTST 2019 that the SARM SWH and range estimate present a small sensitivity (few millimeters on range and few centimeters on SWH) to the waveform centering. Recent studies from Dinardo et al. show that the use of a dynamic SARM masking allows to better capture the vertical variations of the SARM stack correct this effect.

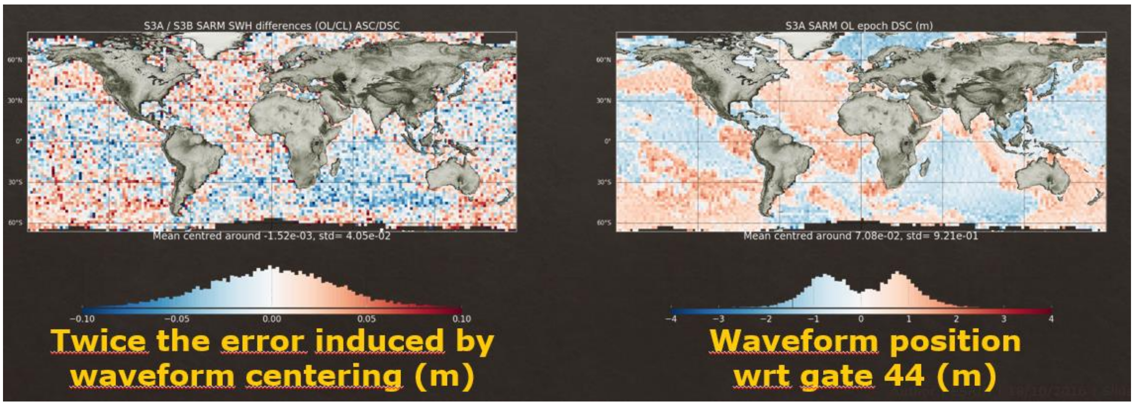

Figure 10: SSH (alt - range – mss) differences between Sentinel-3A in Open Loop and Sentinel-3B in Close-Loop mode during the tandem phase. (left panel), waveform position in the tracking window illustrated by the epoch value given with respect to the gate 44 (right panel). Plot from Raynal et al, ESA LPS 2019.

On the long term period it has been identified a drift on the SARM range parameter, of 1.7 mm/year with an uncertainty of 1.2 mm/yr (Ablain et al., 2019). Recent investigations (see J. Aublanc et al., OSTST 2020, S. Dinardo et al., OSTST 2019, J. Poisson et al., OSTST 2019, A. Guérou et al., OSTST 2020) allowed to identify the source of such a drift.