Contribution of SWOT to the estimation of fine structures of the Mean Sea Surface

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Introduction & Context

The MSS is a huge source of errors for SWOT-KaRIn at short wavelengths. Pujol et al (2023) and Dibarboure et al (2024) clearly underlined the net signature of the CNES_CLS_2015 MSS errors that explain 90% of the KaRIn SSHA energy in the [70, 10km] wavelength range. While up-to-date alternative MSS models are available, Laloue et al (2024) underlined their added value, but also some weakness. A hybrid solution, blending the best part of the CNES_CLS_2022 [Schaeffer et al, 2022], SCRIPPS_CLS2022 [Sandwell et al.] and DTU21 [Andersen et al, 2021] MSS models was proposed (Fig 1). Laloue et al (2024) underlined the improved quality of this hybrid model. The MSS nevertheless remains imperfect at short wavelengths. It still explains ~15% of the SSHA variance in the [100, 15km] wavelength range, and the signature of some geodetic structures remains clearly visible on KaRIn measurements. Now, nearly one cumulated year of KaRIn measurements can be used to improve the MSS estimation at short wavelengths.

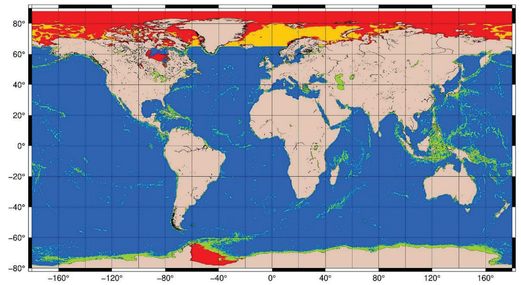


Figure 1: MSS Hybrid2023 hybridation mask.
SCRIPSS_CLS22 used; CNES_CLS_2022 used; CNES_CLS_2022 and DTU21 used with homogenized interannual content

Mean Profile SWOT-KaRIn

The SWOT-KaRIn mean profile for a given phase (calval or science) is given by the equation:

$$PM = \frac{1}{n_{cycles}} \sum_{c=1}^{n_{cycles}} \left(ssha_c - ssha_c^{oi} \right)$$

L3 v1.0 KaRIN data used :

- 102 cycles used for the CalVal phase
- 14 cycles used for the Science phase

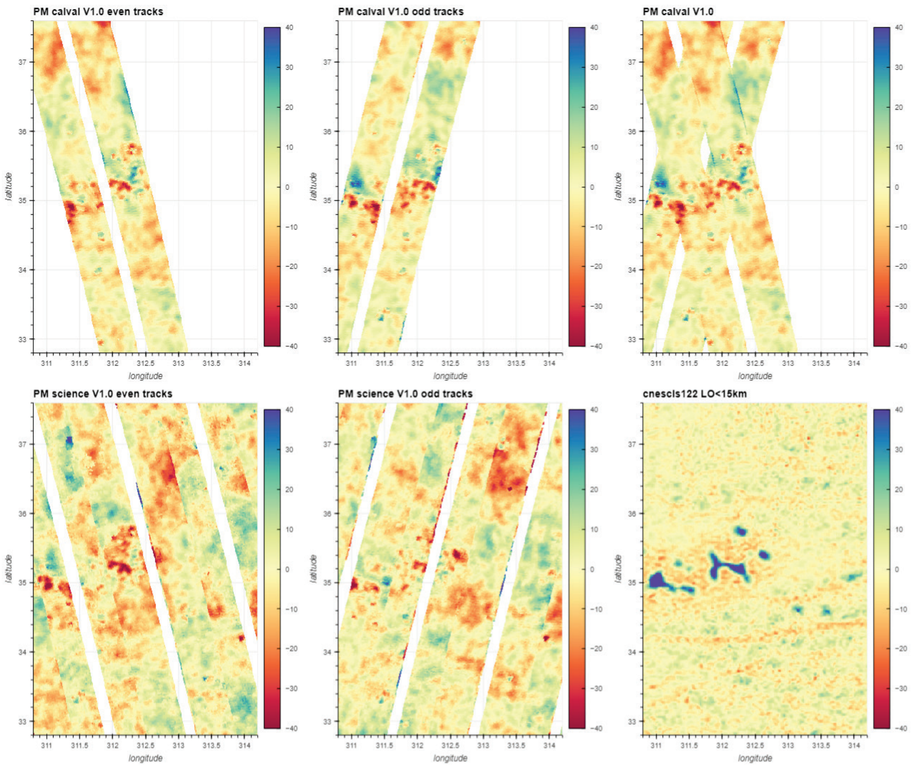


Figure 2: Difference between SWOT-KaRIn mean profile (Top: CalVal; bottom: Science phase) and the MSS CNES CLS 22. The short wavelengths of the MSS are given in the bottom right panel.

- MSS geophysical structures can be retrieved in the MP :
  - enhance our knowledge on these features.
  - contains patterns that could be unknown geophysical structures for the MSS.
- MP are consistent where the swaths overlap.
- But some imperfections remains :
  - Unconsistancy between neigbouring swath induced by commission error (e.g. residual ocean variability; KaRIn residual errors)

On the other hand, the 30 years of available 1Hz nadir measurements can be better leveraged to improve MSS from large to small scales. The use of multi-scale mapping methods, such as the one proposed by (Ubelmann et al., 2021, 2022), shows very promising results (Fig. 3).

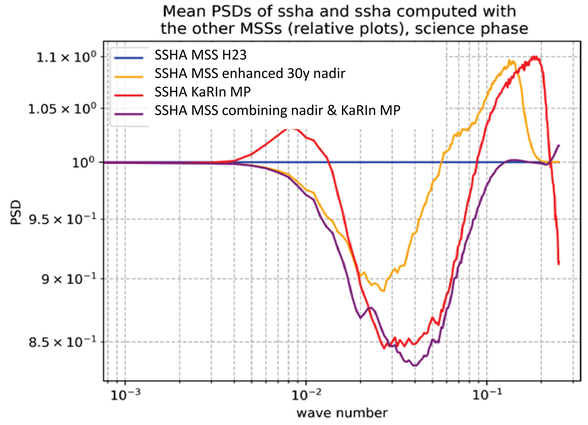
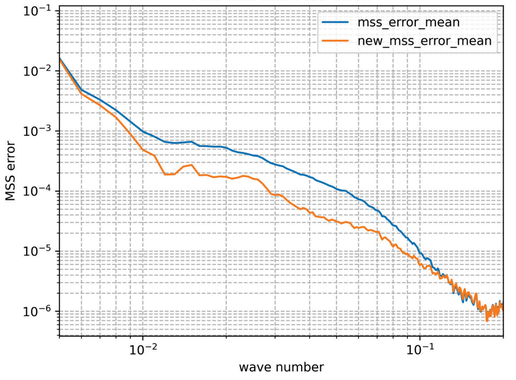


Fig 3: Relative mean SSHA PSDs (cycles independent of the PM and latitude ∈ [-60°; 60°]) obtained with different MSSs. MSS Hybrid2023 used as reference.

Analyze of the SSHA SPD for independent KaRIn measurements shows that :

- Enhanced use of 30 years of nadir measurement reduces mean SSHA PSD for wavelength ∈ [17km; 100km]: up to 10% (yellow line)
- The KaRIn MP reduces mean SSHA PSD for wavelength ∈ [13km; 50km]: up to 15% (red line)
- But KaRIn MP remains less performant than the MSS innovation on WL > 50km.
- An optimal combination of the enhanced MSS and KaRIn MP (here in its preliminary version) leads to improved results at WL ∈ [100, 15km]. But MSS estimation will remains limited at short WL (<10km). (purple line)

Figure 4: Hybrid MSS (blue line) and optimized KaRIn MP (orange line; preliminary version) spectral error estimation. Estimation done using the Laloue et al (2024) methodology, using two independent SWOT-KaRIn cycles measurements



- The combination of bandpass-filtered MP and enhanced MSS using 30 years of nadir measurement allows for an **error reduction on [10km; 100km]** (Fig 4) : reduction of **65% integrated error reduction** compared to the MSS Hybrid 2023 (preliminary results)

Toward a future MSS

Much work remains to be done to improve the obtained results and use KaRIn data to calculate a new generation of MSS better resolved at short wavelengths:

- Optimization of the MSS inversion technique for enhanced static signal extraction at long & short wavelengths with nadir measurements
- Improvement of the ocean variability reduction for the KaRIn mean profile computation : use additional cycles for the Science phase; Use up to date DUACS gridded products for ocean variability mitigation
- Use the optimal KaRIn MP for the future MSS computation

In parallel with the CNES_CLS work, other groups are also improving their MSS model. Validation and comparison of these future MSS are expected. As done in 2023, a future MSS combining the best of each individual MSS could be envisioned by 2025.

Andersen, O. B. (2022). DTU21 Mean Sea Surface [Data set]. Technical University of Denmark. https://doi.org/10.11583/DTU.19383221.v1
Dibarboure, G., Pujol, M.I.: Improving the quality of sentinel-3a data with a hybrid mean sea surface model, and implications for sentinel-3b and swot. Advances in Space Research 68(2), 1116–1139 (2021)
Laloue et al : Merging recent Mean Sea Surface into a 2023 Hybrid model (from Scripps, DTU, CLS and CNES), in prep
Pujol et al : MSS errors & SWOT KaRIn measurements. SWOT-ST 2023. https://swotst.aviso.altimetry.fr/fileadmin/user_upload/SWOTST2023/20230921_ocean_2_mss/10h00-3-PUJOL_MSS_errors.pdf
Sandwell, D. T. (2024). Adding Mean Sea Surface (MSS) as an Altimetry Product. UC San Diego: Scripps Institution of Oceanography. http://dx.doi.org/10.21221/S26P4H Retrieved from https://escholarship.org/uc/item/08z6v9wq
Schaeffer et al: The CNES CLS 2022 Mean Sea Surface: Short Wavelength Improvements from CryoSat-2 and SARAL/AltiKa High-Sampled Altimeter Data. *Remote Sensing*, *15*(11), 2910.(2023). https://doi.org/10.3390/rs15112910
Ubelmann et al : Reconstructing ocean surface current combining altimetry and future spaceborne Doppler data. Journal of Geophysical Research: Oceans, 126, e2020JC016560. https://doi.org/10.1029/2020JC016560 , 2021