Improvements and limitations of recent mean sea surface models: importance for Sentinel-3 and SWOT

M.-I. Pujol[1], G. Dibarboure[2], Y. Faugère[1], P Schaeffer[1], N. Picot[2] P. Femenias[3]

A Mean Sea Surface (MSS) is used to retrieve the Sea Level Anomaly (SLA) for the Sea Surface Height (SSH) measured by the altimeters. This reference is an important component of the error of the SLA. Pujol et al (2018) showed that the MSS errors are significant along uncharted Sentinel-3A tracks for wavelengths from 15 to 100 km.

In this paper we compute an improve MSS reference along the tracks of Sentinel-3A by combining the gridded MSS content with a Sentinel-3A Mean Profile. This work is presented in Dibarboure et Pujol (2018, in prep).

A Hybrid Mean Profile (HMP) was constructed using 17 cycles of Sentinel-3A. The HMP combines the strengths of a classical mean profile with very small errors from 15 to 100 km and of a gridded MSS model for other wavelengths.

Hybrid Mean Profile assessment

The Sentinel-3A (H)MP was assessed using the methodology described in Pujol et al (2018).

- compared to the CNES15 gridded MSS model, **the MP significantly contributes to improve the SLA at wavelengths ranging ~100 to 15km** (Fig1, blue vs red thin line): the mean MP errors is 0,2 cm² i.e. 17% of the estimated noise free SLA variance or 50% of the gridded MSS model error

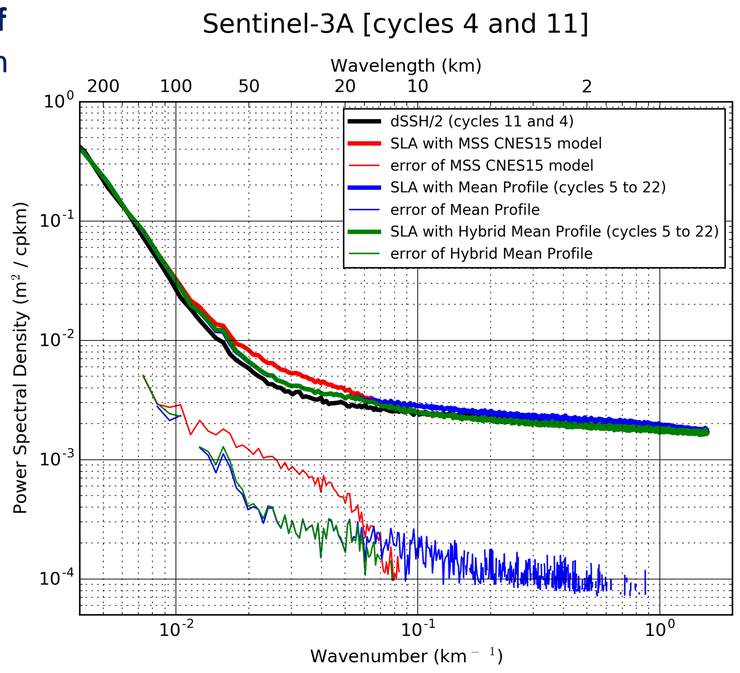

Fig 1: PSD of the SLA free from MSS/MP errors (thick black line); PSD of the SLA computed with the various MSS references (thick colored lines); PSD of the MSS errors (thin colored lines) where statistically significant (95% confidence threshold).

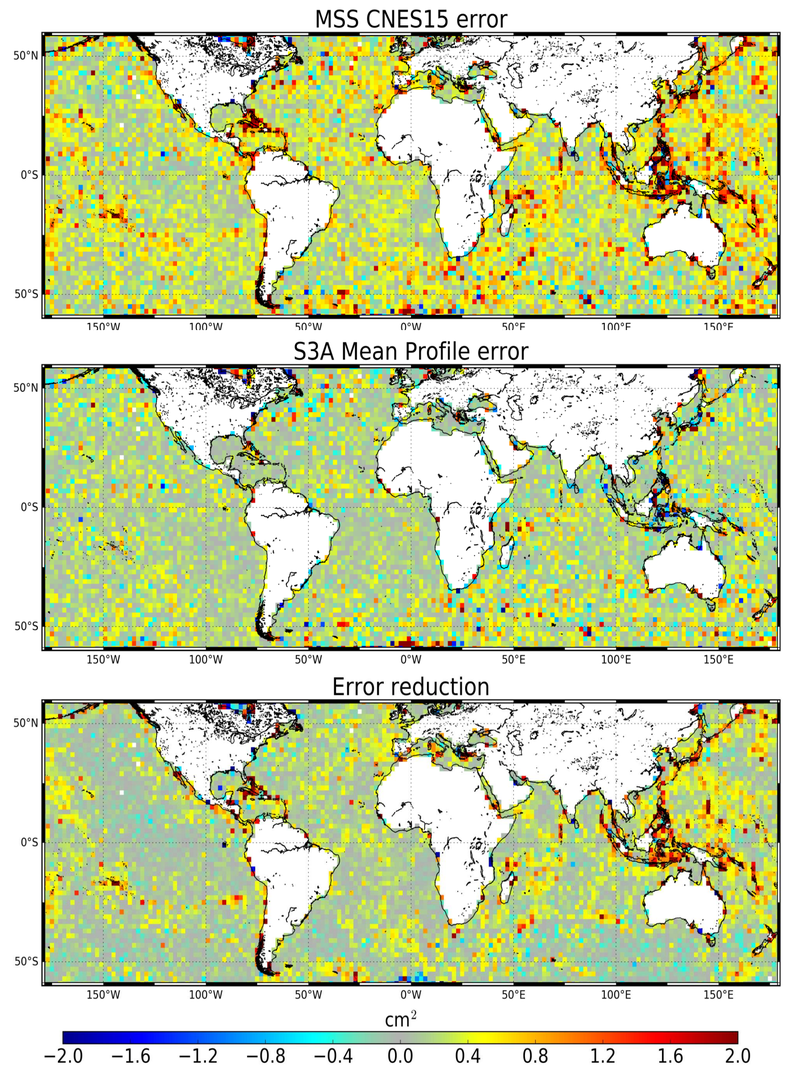

Fig 2: top: CNES15 MSS model error variance for wavelengths ranging 15 to 100km. Middle: same for Sentinel-3A Mean Profile. Bottom: MSS error reduction from CNES15 to the Sentinel-3A mean profile (i.e. difference between top and middle panels)

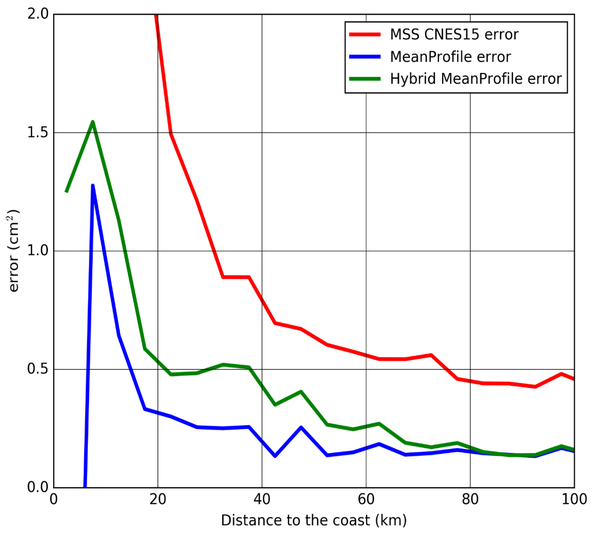

Fig 3: Error in cm² of the MSS references as a function of the distance to the nearest coast.

- **The error reduction has a geographical distribution correlated with geodetic structures** (Fig2): this is a reduction of the omission errors of gridded MSS.
- The MP **error is smaller by a factor of 2 to 10 in coastal regions** even if the filtering processing applied for the HMP construction slightly increase the errors near the coast (Fig 3). This is a reduction of both commission and omission errors of the MSS model: it is explained by the better coastal quality of SARM data in the MP, compared to historical LRM data used for the gridded MSS model

Commission error signatures

Commission errors correspond to the leakage of non-MSS content (e.g. altimeter noise, ocean variability) in the MSS/MP field. Commission error can affect the SLA signal differently according to the period considered :

$$V(\widehat{sla_j}) = V(sla) + V(\varepsilon_{\widehat{ssh}}) + V(\boldsymbol{\varepsilon_{\widehat{mss}}}) - 2\,.\,\mathbf{C}(\boldsymbol{\widehat{sla_j}, \varepsilon_{\widehat{mss}}})$$

Covariance/commission error

Variance of Estimated SLA	Variance of the true SLA	Variance of measurement errors	Variance of the MSS errors

- $C(\widehat{sla_j}, \varepsilon_{\widehat{mss}}) = \frac{V(sla) + V(\varepsilon_{\widehat{ssh}})}{n}$ if cycle j is in the MSS
- $C(\widehat{sla_j}, \varepsilon_{\widehat{mss}}) = 0$ if cycle j is independent from the MSS

- if the SLA is computed over a period that is independent from the MSS model, the MSS model error increases the SLA variance → **the HMP error has to be smaller than the gridded model error**
- if the SLA is computed over a period that was used for the MSS model, the commission error artificially reduces the SLA variance (covariance term in the equation above) → To be useful, the HMP error reduction must compensate this covariance term, i.e. **HMP errors must be at least 50% smaller than the gridded MSS error**

The commission error of the HMP is measured comparing the results of cycle 11 (independent) and 12 (not independent) (Fig 4 and 5) where the covariance term generates artificial variance reduction. The commission error is 0,15 cm² for wavelengths ranging 100 to 15km → **it explains 75% of the errors of our Sentinel-3A HMP**

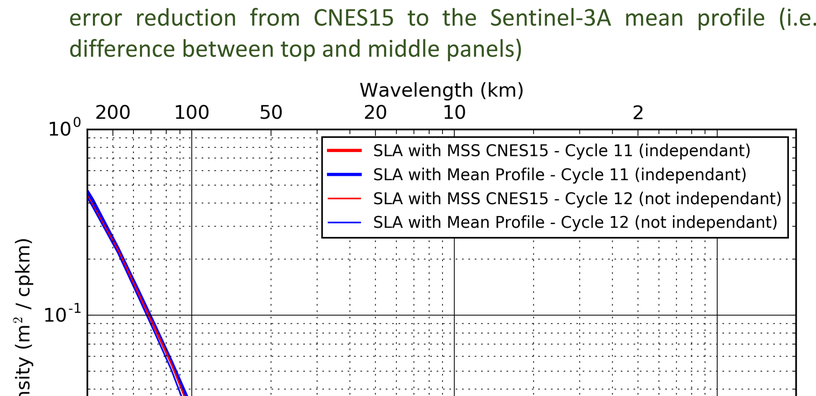

Fig 4: PSD of the sea-level anomaly computed with the various MSS references (coloured lines). Thick lines are for SLA over cycle 11 of Sentinel-3A (SSH data is independent from the Mean Profile). Thin lines are for cycle 12 (not independent, SSH data used in the Mean Profile).

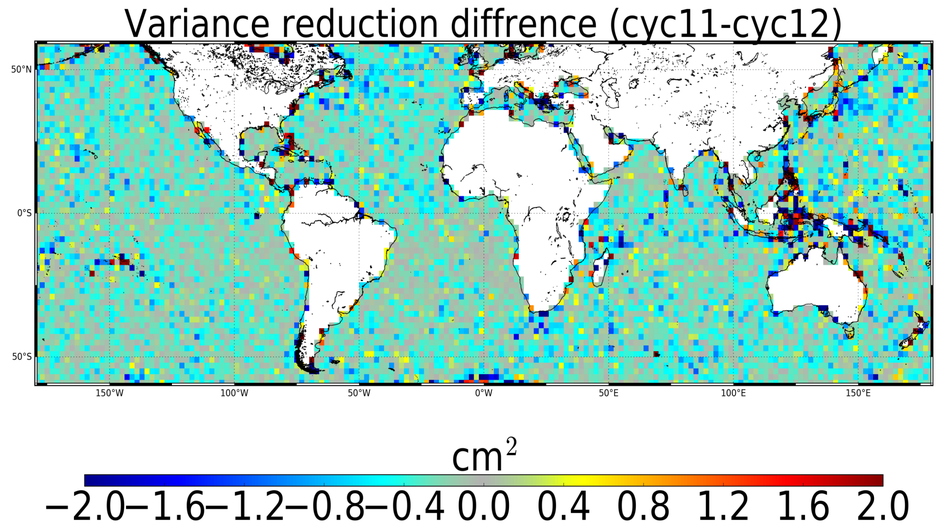

Fig 5: Delta between cycle 11 and cycle 12 of the SLA variance reduction when the Sentinel-3 mean profile replaces the CNES15 MSS model. Wavelengths [15, 100 Km] are considered.

MSS errors for Sentinel-3B and SWOT

A model was developed to predict the HMP errors as a function of the number of cycle available. It takes into account the specificities of the different missions considered (Sentinel-3 and SWOT), i.e. the cycle duration and the instrumental noise.

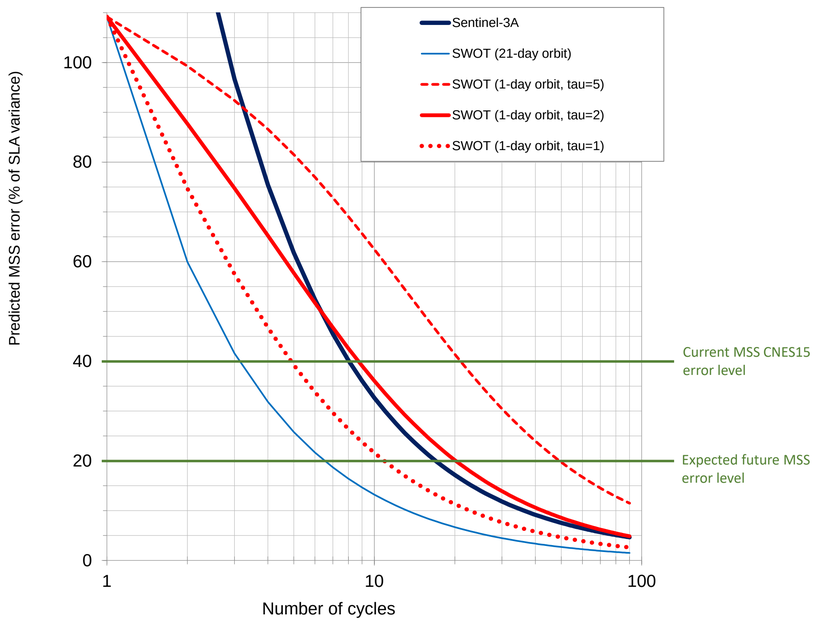

Fig 6: Prediction of he HMP error (noise, oceanic variability, omission) for Sentinel-3 and SWOT. For the 1-day orbit, three scenarios are given.

If the next generation of MSS model has an error 50% smaller than the CNES15 (or DTU13) models:

- **the first HMP Sentinel-3B should be considered after 17 cycles (interleaved orbit) i.e. in Spring 2020 for a NRT production** (i.e. over independent cycles); **after 2,5 year, i.e. Spring 2021 for a production DT production** (i.e. over non independent cycles)
- SWOT during the 21-day cycle should contribute to estimate a HMP at shorter wavelengths with an error level reaching 20% of the signal variance after only ~7 cycles; less than 2% after the 3-year nominal duration of the mission. **Approximately 10 months of 21-day phase are needed to reach the breakthrough MSS error level.**

References:

- Dibarboure G., M.-I. Pujol. (2018). Improving the quality of Sentinel-3A with a hybrid mean sea surface model, and implications for Sentinel-3B and SWOT. In prep.
- Pujol, M.-I., Schaeffer, P., Faugère, Y., Raynal, M., Dibarboure, G., & Picot, N. (2018). Gauging the improvement of recent mean sea surface models: A new approach for identifying and quantifying their errors. Journal of Geophysical Research: Oceans, 123. https://doi.org/10.1029/2017JC013503