SWOT MSS Removal
Frequently Asked Questions

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Background:

The mean sea surface (MSS) is equal to the marine geoid height (time invariant) plus the mean dynamic topography. Over the past 5 years we have worked to assemble the best MSS to be used to isolate the sea surface height anomaly. This document will assist the users of the L2_expert or L3_expert SWOT products on best practices for removing the MSS from the SWOT data.

FAQ:

1. **What versions of the MSS are currently available on each product and which are best for removing the MSS to create sea surface height anomaly?**

There are five versions of the MSS that can be used on SWOT products:

CNES_CLS15 – (*mean_sea_surface_cnescls*) – not recommended [1] This is an older version that is available on the L2_LR products but lacks short wavelength resolution.

DTU18 (*mean_sea_surface_dtu*) [2] – not recommended. This is also an older version that is available on the L2_LR products but lacks some short wavelength resolution, it is most accurate in the Arctic areas. Also **not recommended**.

CNES_CLS22 – [3] – recommended. This version is available on the L2_LR products in November 2023 and is a major improvement over CLS15.

MDT-CNES-CLS22 [4] – optional - The Mean Dynamic Topography MDT-CNES-CLS22 is an estimate of the mean over the 1993-2012 period of the sea surface height above geoid. The geoid is GOCO06S geoid model (based on the complete GOCE mission fully reprocessed and 14 years of GRACE data) and 30 years of altimetry and in-situ data (hydrologic, drifters and High Frequency radar on a limited area)

SIO_V32 – [5] - recommended. This is one of the components used in the Hybrid 23 model. It is freely available as described below.

Hybrid23 – [6] – recommended but grid not yet available. This is the most recent version of the MSS developed by CLS/Scripps/CNES/DTU. It is available on the L3_LR products. The Hybrid23 is still under evaluation so not yet available.

Below we describe how to replace the MSS on any of the SWOT products with the freely available CNES_CLS22 and SIO_V32 grid.

2. **How can a user apply their own custom MSS correction model?**

Suppose the user has a grid of their own favorite MSS model and they would like to replace the MSS available on the SWOT_L2_LR_SSH_Expert*.nc or SWOT_L3_LR_SSH_Expert*.nc product with that version. We have developed python code to replace the MSS with either the CNES_CLS22 and SIO_V32 grids. The code and sample file are available at the following site. This code will also download the global **CNES_CLS22 and SIO_V32** MSS files.
https://topex.ucsd.edu/pub/MSS_replace/replace_mss.tar

3. **Given that the resolution of the SWOT data is better than the resolution of the best MSS grids. How can one remove the small-scale residual MSS signal using a stack of SWOT data?**

The full wavelength resolution of the best MSS grids (Hybrid 23 or SIO V32) is about 20 km and SWOT can resolve large amplitude geoid signals of 10 km wavelength. These residual geoid signals such as small seamounts will appear as persistent dots on large stacks of SWOT repeat data. One approach to the removal of this residual geoid signal is to first remove the best available MSS, remove the large scale and mesoscale dynamic structure (can be done for instance by using the grided SSHA maps computed using measurements from other altimeters) and then average as many SWOT repeats as are available. That average will be a mix of residual geoid signal and true ocean dynamic topography averaged over that interval. An experimental approach would be to high-pass filter the mean of the stack at 20 km wavelength and remove only that component. That short-wavelength residual could be used to update the MSS grid.

If the stack average is not high-pass filtered then the global analysis by Pujol et al [8], based on a MSS error prediction model proposed by Dibarboure and Pujol [8], shows that about 90 cycles of SWOT averaging can significantly reduce the MSS omission error. After 9 cycles the error is expected to be reduced to 18%, 18 cycles 9%, 90 cycles 5%, and 130 cycles 2%.

References:

[1] - https://www.aviso.altimetry.fr/en/data/products/auxiliary-products/mss/mss-cnes-cls15-description.html
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[3] - Schaeffer, P.; Pujol, M.-I.; Veillard, P.; Faugere, Y.; Dagneaux, Q.; Dibarboure, G.; Picot, N. The CNES CLS 2022 Mean Sea Surface: Short Wavelength Improvements from CryoSat-2 and SARAL/AltiKa High-Sampled Altimeter Data. Remote Sens. 2023, 15, 2910. https://doi.org/10.3390/rs15112910 https://www.aviso.altimetry.fr/en/data/products/auxiliary-products/mss/mss-cnes-cls2022-description.html
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[5] – Sandwell, D. T., Adding Mean Sea Surface (MSS) as an Altimetry Product, SIO Technical Report, August, 2022. https://topex.ucsd.edu/pub/MSS_replace/MSS_construction_10.pdf
[6] - Schaeffer et al., 2023: Hybrid MSS CLS/Scripps/CNES/DTU v2023. http:// . . . (Phil, please add link to the Hybrid23).
[7] – Pujol et al., 2023: MSS errors & SWOT KaRIn measurements
[8] - Dibarboure G., M.-I. Pujol. (2019). Improving the quality of Sentinel-3A with a hybrid mean sea surface model, and implications for Sentinel-3B and SWOT. Advance in Space Res. https://doi.org/10.1016/j.asr.2019.06.018