Sentinel-6 MF validation and cross calibration activities

2025 Executive Summary

Reference : CLS-ENVP-RP-26-0101
Issue : 1/ 2
Date : June 18, 2026

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1 Executive Summary

Sentinel-6 MF onboard altimeter (POS4) allows for simultaneous low and high resolution observations due to its innovative design. This is referred as **interleaved mode** in which hence the instrument acquires data at same time in :

- Low Resolution Mode, hereafter "LR", which is the historical mode used by previous altimeters in the Topex/Jason satellites.
- High Resolution Mode, hereafter "HR", commonly called Synthetic Aperture Radar (SAR) or Delay Doppler Altimetry (DDA), and already used on Cryosat-2 and on the Sentinel-3 satellites.

Over the year 2025, POS4 altimeter operated in Range Migration Correction and open loop tracking for most of the globe.

In April 2025, the Sentinel-6 MF processing baseline was upgraded from version F09 to G01, with the new version applied to data from March 14, 2025 onward. G01 major improvements include:

- Upgrade to GDR-G standards for the following models:
  - Ocean and load tides solution 2 (FES): FES14 => FES22 (new barotropic tide model for global ocean).
  - MSS solution 1: Hybrid CNES-CLS2022/Scripps/DTU => Hybrid CNES-CLS2023/Scripps/DTU (more informations on [3]).
  - MSS solution 2: DTU2018 => DTU2021.
  - MDT: CNES-CLS MDT 2018 => CNES-CLS MDT 2022 (new global MDT combining drifters, hydrography profiles and high frequency radar data).
- Addition of C-band Complex Echoes to L1A ALT Products.
- Instrumental Look-Up Tables update for LR MLE retrievals.
- Removal of the MLE3 variables in the Ku-band L2 LR products.
- Vertical Wave Motion correction applied at 20Hz for both HR NR and SAMOSA.
- Wind Speed alignment to model thanks to sigma0 calibration biases update.
- POE-G orbit.

More details about the PB G01 can be found in the dedicated product notice ([1]).

Furthermore, as part of the deployment of the processing baseline G01, the MLE4 range LUT was updated and applied to data starting from April 12, 2025.

A full mission reprocessing was performed in late 2025. See the dedicated assessment report for further details ([2]).

Note also that the second tandem phase between Jason-3 and Sentinel-6 MF took place from January 30 to June 2, 2025. Jason-3 was moved to a different orbit prior to and after this phase, between January 7 and January 30, 2025, and between June 2 and June 18, 2025.

During each cycle, missing measurements were monitored and spurious data were edited . Relevant parameters derived from instrumental measurements and geophysical corrections were also analysed.

Please note that this analysis is done **over ocean** only, no assessment is done over hydrological targets. This summary focuses on the performance over the year 2025.

1/ Data availability

In 2025, data availability over ocean was excellent for both Sentinel-6 MF LR and HR products (figure 1), with respectively 99.84 % and 99.55 % of available data. Over this year, **no important event impacting data availability occurred.**

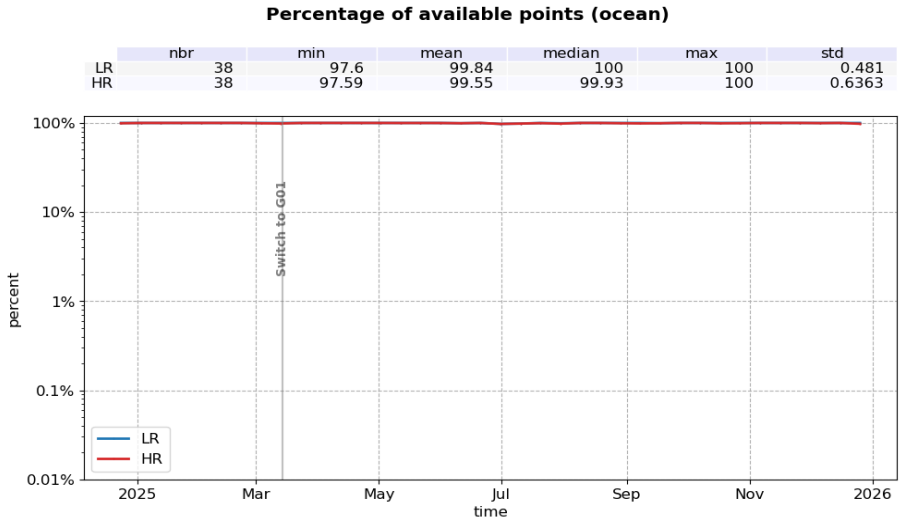

Figure 1: Percentage of available data over ocean for NTC Sentinel-6 MF LR (blue) and HR (red) per cycle over the year 2025.

2/ Sea Level Anomalies

In 2025 Sentinel-6 MF and Jason-3 SSHA followed identical seasonal cycles and variations (figure 2), with mean values of 5.3 cm for Sentinel-6 MF LR MLE4, 5.3 cm for LR NR, 3.9 cm for HR SAMOSA, 5.5 cm for HR NR and 5.3 cm for Jason-3. Excluding the Caspian Sea, Sentinel-6 MF SSHA daily standard deviation shows to be similar between all datasets.

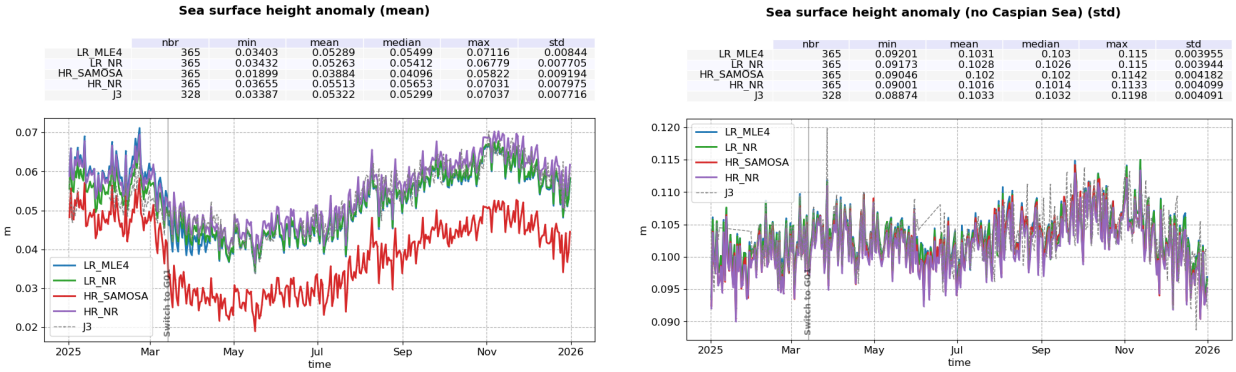

Figure 2: Mean (left) and standard deviation (right) SSHA by day for LR MLE4 (blue), LR NR (green), HR SAMOSA (red), HR NR (purple) and Jason-3 (black). Computed over the year 2025. The discontinuities in Jason-3 monitoring are due to orbit changes during its tandem phase with Sentinel-6 MF.

The comparison between LR MLE4 and LR NR SSHA, as shown in figure 3, shows that LR MLE4 is now fully consistent with LR NR thanks to the MLE4 LUT update. HR NR SSHA comparison to HR SAMOSA highlights a strong correlation to sea state, and initial investigations indicate that it is mostly due to the absence of skewness parameter in SAMOSA. This is under investigation.

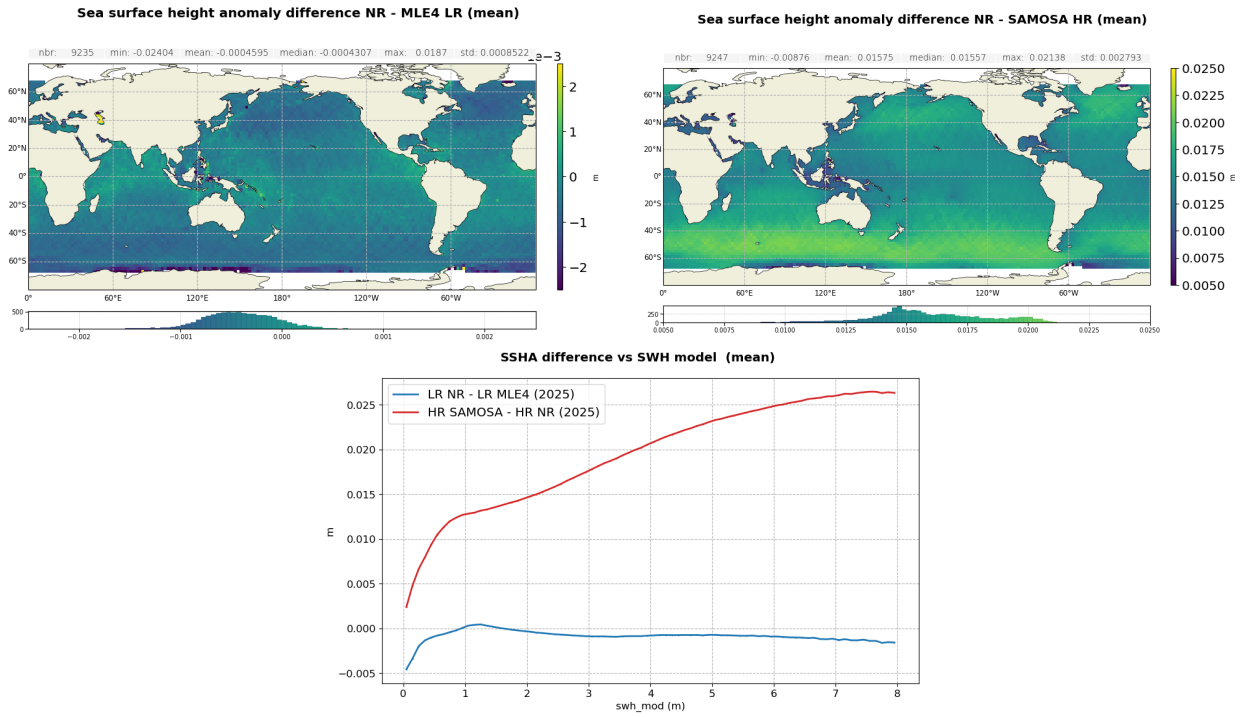

Figure 3: Maps of Sentinel-6 MF SSHA difference for LR NR - LR MLE4 (top left) and HR NR - HR SAMOSA (top right), and the corresponding mean as a function of ERA 5 model SWH (bottom).

3/ Performance at crossover points

Looking at SSH difference at mono-mission crossovers, mean values are well centered around 0 for all modes and retrackers (figure 4 left panel).
Concerning the SSH error at mono-mission crossovers ($STD\ /\ \sqrt{2}$), Sentinel-6 MF shows very good and stable performance with an error of 3.3 cm in LR and 3.2 cm in HR, which is similar to Jason-3 error (figure 4 right panel).
The degraded Jason-3 values observed around January and June 2025 are due to the orbit changes performed before and after the tandem phase with Sentinel-6 MF.

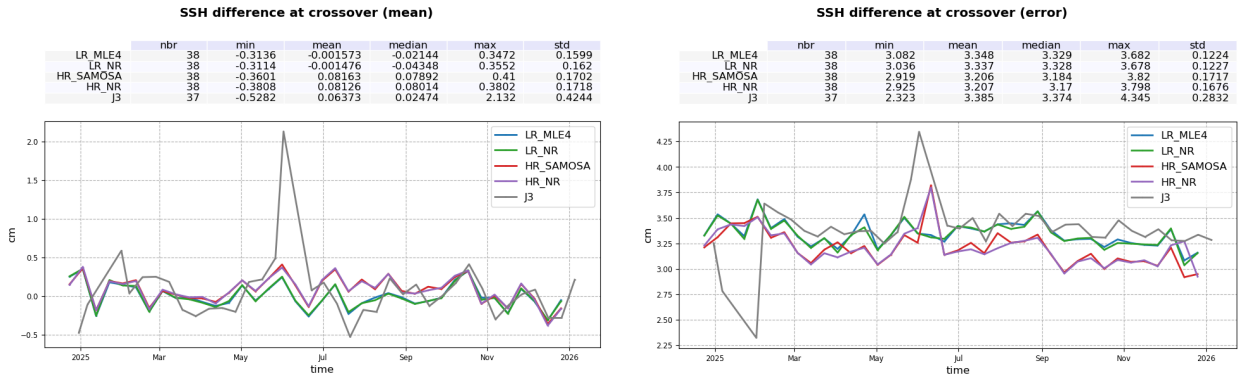

Figure 4: Monitoring of SSH difference at mono-mission crossover for Sentinel-6 MF LR MLE4 (blue), LR NR (green), HR SAMOSA (red), HR NR (purple) and Jason-3 (black). Mean (left) and error (right) per cycle are computed over the year 2025. Only data with |latitude| < 50 °, bathymetry < -1000 m and low oceanic variability were selected.

As shown in figure 5, the mean differences in sea surface height (SSH) at Sentinel-6 MF and Jason-3 crossover points exhibit consistent behavior across all four Sentinel-6 MF retrieval types throughout 2025. There is no evidence of drift or recurring patterns over the year. The observed mean SSH differences are

minimal: -0.1 cm for LR MLE4, -0.1 cm for LR NR, 1.3 cm for HR SAMOSA, and -0.4 cm for HR NR. The PB G01 update is associated with a jump in SSH differences for all retrackers, with larger increases for LR MLE4 and HR SAMOSA (+1 cm relative to Jason-3) than for the NR retrackers (+0.5 cm).

The HR SAMOSA map (middle left panel) also highlights the absence of skewness parameter in the HR SAMOSA processing, leading to correlation with sea state conditions in the comparison with Jason-3. Thanks to the addition of this parameter to the HR NR processing, such patterns are not visible on the HR NR SSH comparison to Jason-3.

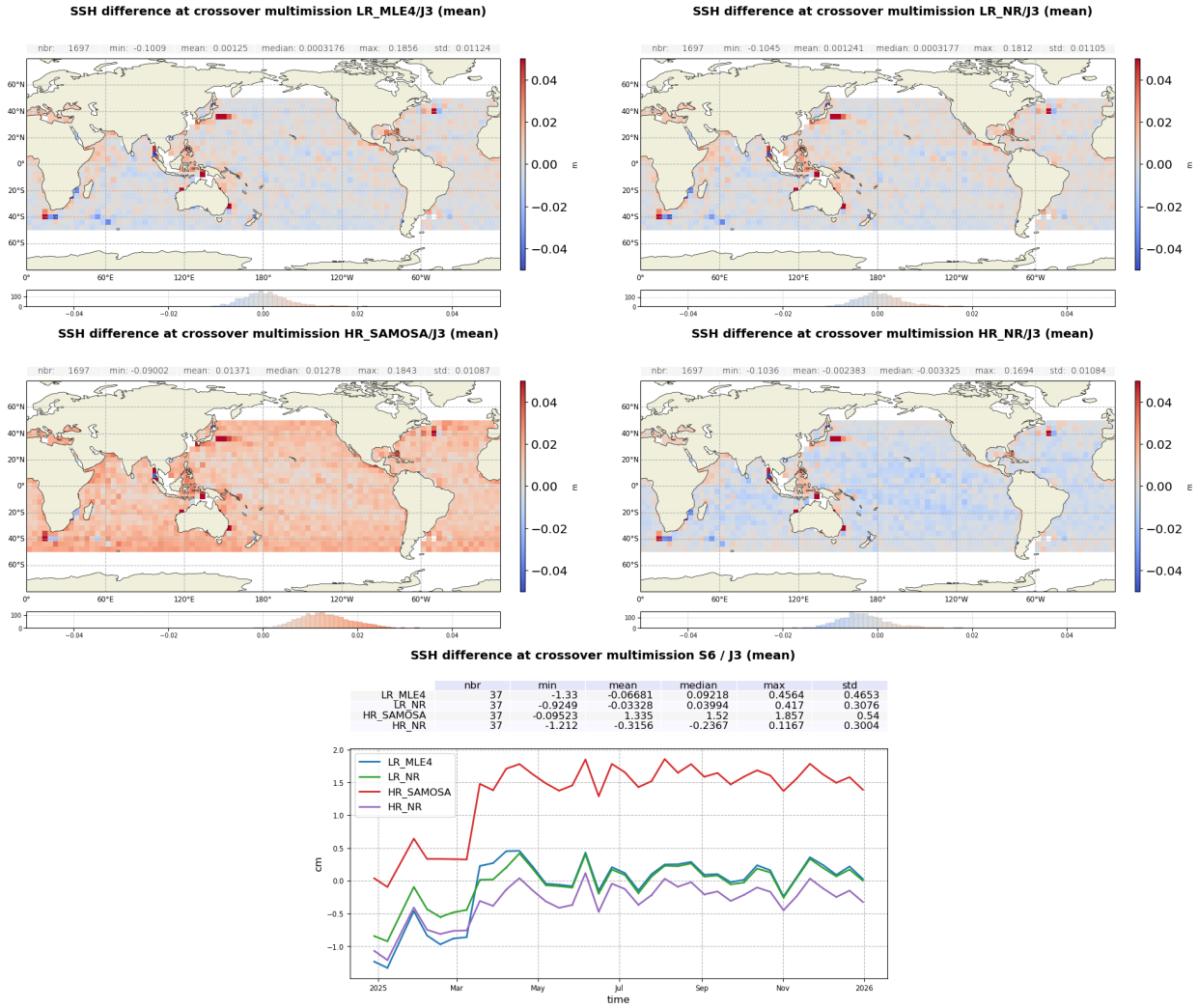

Figure 5: Sentinel-6 MF - Jason-3 SSH difference at crossover: maps over year 2025 for LR MLE4 (top left), LR NR (top right), HR SAMOSA (middle left) and HR NR (middle right), and corresponding cyclic monitoring (bottom). Only data with |latitude| < 50 °, bathymetry < -1000 m and low oceanic variability were selected.

4/ Contribution to Global Mean Sea Level

Regional and global biases between missions have to be precisely estimated in order to ensure the quality of the reference GMSL series as seen in Figure 6. For more details, see the dedicated section on AVISO+ website[1].

Sentinel-6 MF GMSL may be impacted by two known effects:

- The instrumental aging consisting of the evolution of the PTR shape in range direction. It impacts both range and SWH estimates in the analytical models as is the case of LR MLE4 and HR SAMOSA. Note that numerical models account for the in-flight instrument aging and hence are not affected by these impacts.
- In HR mode, the evolution of the PTR shape in azimuth direction has an impact on the range variations within a burst. It is corrected by the range walk correction introduced in PB F09.

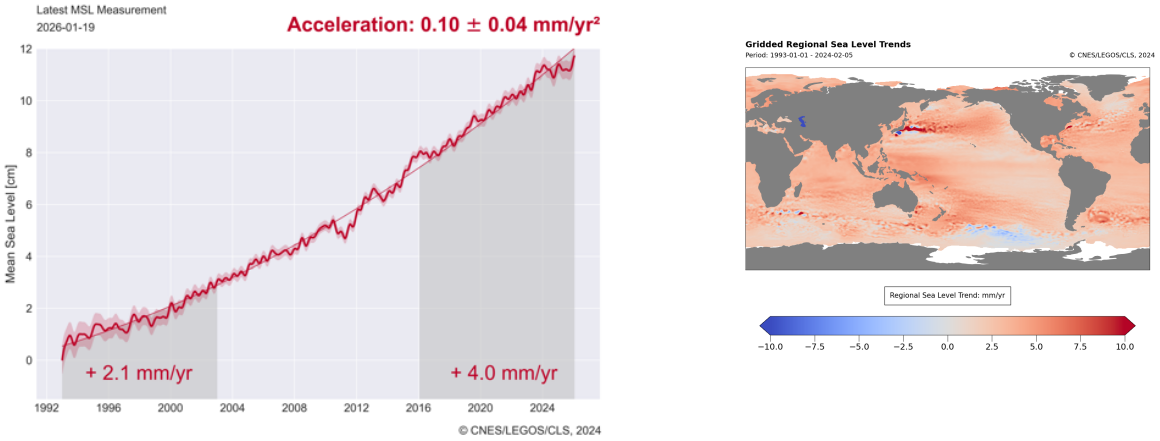

Figure 6: Global (left) and regional (right) MSL trends from 1993 onwards.

[1] https://www.aviso.altimetry.fr/en/data/products/ocean-indicators-products/mean-sea-level.html

2 References

References

[1] Product notice for Sentinel-6 MF Processing Baseline G01 available at : https://user.eumetsat.int/s3/eup-strapi-media/Copernicus_Sentinel_6_Michael_Freilich_Product_Notice_Altimetry_v10_B_68a7c5ecb4.pdf

[2] Sentinel-6 MF G01 Reprocessing Calval Assessment available at : https://user.eumetsat.int/s3/ope-eup-strapi-media/Sentinel_6_MF_G01_Reprocessing_Calval_Assessment_7e75a56d93.pdf

[3] Laloue, A., Schaeffer, P., Pujol, M.-I., Veillard, P., Andersen, O., Sandwell, D., Delepoulle, A., Dibarboure, G and Faugère, Y.: Merging Recent Mean Sea Surface Into a 2023 Hybrid Model (From Scripps, DTU, CLS, and CNES), https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2024EA003836, 2025.