COPERNICUS
MARINE ENVIRONMENT MONITORING SERVICE

QUALITY INFORMATION DOCUMENT

SYNTHESIS QUALITY OVERVIEW DOCUMENT (SQO)

Associated to extended quality information document (QUID): CMEMS-SL-QUID-008-032-068

QUID Version: 12.0

Associated to Product ID:

SEALEVEL_GLO_PHY_L3_NRT _008_044
SEALEVEL_GLO_PHY_L4_NRT _008_046
SEALEVEL_EUR_PHY_L3_NRT _008_059
SEALEVEL_EUR_PHY_L4_NRT _008_060
SEALEVEL_GLO_PHY_L3_MY_008_062
SEALEVEL_GLO_PHY_L4_MY_008_047
SEALEVEL_EUR_PHY_L3_MY_008_061
SEALEVEL_EUR_PHY_L4_MY_008_068
SEALEVEL_GLO_PHY_NOISE_L4_STATIC_008_033

Issue: 12.0

Contributors to SQO: Maxime ballarotta, Marie-Isabelle PUJOL, SL-TAC Team

SQO approval date by the CMEMS PQ coordination team: 04/12/2024

Change Record

When the quality of the products changes, the QuID is updated and the SQO is updated. A line is added to this table and the version of the SQO document is the same than that of the REFERENCE QUID. The third column specifies which sections or sub-sections have been updated.

Issue	Date	§	Description of Change	Authors	Validated By
1.0	2020/10/31	All	Creation of the document	Taburet G.	Pujol M-I
1.1	2021/01/15	2 4	Update QUID version Add new reference	Pujol M-I	Pujol M-I
2.0	2021/10/01	All	Update with DT-2021 standards	Taburet G.	Pujol M-I
2.1	2021/12/16	0	Change for MY automatic extensions	Pujol M-I	Pujol M-I
3.0	2022/03/01		- Upgrade of constellation status in NRT conditions : add Sentinel-6A	Pujol M-I	Pujol M-I
4.0	2022/03/01		Upgrade of constellation status : - use Jason-3 on new orbit in NRT and MY	Pujol M-I	Pujol M-I
5.0	2022/09/30		Introduction of the L3 5 Hz product.	Pujol M-I	Pujol M-I
9.0	2023/06/15		Introduction of the L3 5Hz product for the global ocean Upgrade SQO version for conformity with QUID	Pujol M-I	Pujol M-I
10.0	2024/04/30		MY interim temporal extension	G Taburet	M-I Pujol
11.0	2024/06/xx		Change of the altimeter standards in NRT Add H2B for L3 5Hz production	M-I Pujol	M-I Pujol
12.0	2024/09/23		Upgrade for CMEMS Nov2024 MY & NRT release - Full reprocessing DT-2024 - Upgrade of NRT processing	M Ballarotta	M-I Pujol

Contents

Executive summary

The quality of the SEALEVEL_[GLO/EUR]_PHY_L[3/4]_[NRT /MY] _008_0* products has been assessed by comparison with independent observations (altimetric measurements and *in-situ* measurements) and in coordination with other projects (Copernicus C3S and CNES SALP).

The error of the following variables for different spatial/temporal scales has been quantified:

- Sea Level Anomaly (noise filtered and unfiltered).
- Absolute Dynamic Topography.
- Geostrophic currents.

The reanalysis products featured in this document cover the period from 1993 to present. The products/datasets are extended in time Four times a year, so that these datasets covers 1993 up to five to nine months before present. These datasets benefit from the highest quality altimeter measurements and geophysical corrections, and are produced with a unique system (no changes in time in the set up, extended in time using the same system) to minimize the risk of quality loss or spurious signals appearing in time.

For additional information regarding the in-depth validation of this product, the calculation of the assessment metrics and other detailed information in quality and noticeable events please refer to:

- The reference QUID document.

Mean Sea Level (MSL):

The mean sea level evolution can be estimated with MY products. On a global scale, the uncertainty of the mean sea level trend has been estimated to +/- 0.4 mm/year on decadal trends (in a confidence interval of 90%). The regional sea level trend uncertainty has an average estimate of 0.83 mm/yr with local values ranging from 0.78 to 1.22 mm/yr depending on the regions. **NRT products should not been used for the analysis of such long-term signals due to frequent constellation/platforms events that can induce jumps or discontinuities and drifts in the time series.**

Mesoscale signal:

Sea level Errors for mesoscales vary between 1 cm² in low variability areas to ~10 cm² in high variability areas. This estimation is based on a 3 to 4-satellite constellation in DT conditions. Errors observed on gridded L4 products are higher (up to +40% error in high variability areas) when only 2 altimeters are available. NRT products quality is reduced due to the unavailability of altimeter measurements in the future**. 4 altimeters are required in NRT conditions to reach the 2-altimeter DT capabilities. On global average, effective resolution with gridded products is nearly 180 km and 33 days at mid latitudes.**

Along-track SLA/ADT fields also include residual noise measurements (uncorrelated) errors that are spatially and temporally variable (correlation with wave heights) and differ from an altimeter to the other and for a measurement sampling to the other. Characteristic mean noise values over the global ocean for the L3 1 Hz measurement vary between ~1.6-3.6 cm RMS for raw measurement and ~0.68-1.53 cm for filtered products. **The presence of this noise measurement limits the observability of the wavelengths shorter than ~65 km (global mean value) with the L3 1 Hz product.** Considering raw L3 5 Hz measurement, the noise level in the North Eastern Atlantic area is estimated around 1.5 cm rms (Sentinel-6A HR) to 3.6 cm rms (Jason-3). **This limits the observability of wavelengths ranging 40 km (Sentinel-6A) to 55 km (Jason-3) with the L3 5 Hz product.**

Geostrophic currents derived from altimeter gridded products are usually underestimated when compared to the in-situ observations. Errors on geostrophic currents have been estimated to range between 9 and 16 cm/s depending on the ocean surface variability. As for SLA field, **NRT products quality is reduced and more sensitive to the constellation changes.**

Important notice:
The contents of this document are an assessment based on the best set of observations available for evaluation at the time the operational system was validated. The validation methodology was defined and agreed within CMEMS, inheriting the long experience of MyOcean and MERSEA series of projects (Hernandez et al., 2018) The results presented in this report and derived estimated accuracy numbers (EAN) are representative of average error levels over large areas of the ocean. These numbers might be used as a mean error in one given point of the area, but in order to refine error estimates locally, the reader is invited to use complementary information from reference QUIDs (error maps for instance, when available).

1. Sea Level Anomaly error description

a. Climatic scales

i. Along-track (L3) & Gridded (L4) products Errors description

In the framework of the ESA SL-cci project, the altimeter measurement errors at climate scales have been estimated using the Topex/Poseidon; Jason-1; Jason-2 missions. Details on the error budget estimation at climate scale can be found in (Ablain et al., 2019; Prandi et al., 2021). Results are summarized in **Table 1** (The errors at climate scales were estimated within the ESA SL_CCI project).

Spatial scales	Temporal scales	Altimetry errors
Global MSL	Long-term evolution (25 years)	< 0.4 mm/yr
	Inter-annual signals (< 5 years)	< 2 mm over 1 year
	Annual signals	< 1 mm
Regional MSL	Long term evolution (> 10 years)	< 1.22 mm/yr

Table 1: Estimated errors at climatic scales observed on sea level DUACS DT products (L3 & L4). (from Ablain et al., 2019; WCRP Global Sea Level Budget Group, 2018; Prandi et al, 2021).

ii. NRT vs REP products

The NRT along track L3 and gridded L4 products are usually less accurate than the DT ones. For these reasons, **we do not recommend using NRT products for climate scale signal studies (e.g. MSL trend).**

iii. CMEMS and C3S products

The CMEMS approach focuses on the mesoscale mapping capacity of the altimeter data together with the stability of the overall dataset whereas the C3S products focus on the stability of the global and regional MSL, even if this implies potential reduction of the spatial sampling of the ocean. **With the best spatial sampling, the all-satellite CMEMS gridded merged products should be preferred for oceanic mesoscale applications and data-assimilation while the C3S two-satellite gridded merged products should be used for climate applications including mean sea level change, variability and oceanic circulation.**

b. Mesoscale

The quality of the global gridded SLA products was estimated by comparison with independent altimeter along-track measurements, with focus on mesoscale signal over the 20180101-20181231 period. The methodology and the results are fully discussed in QUID document (information on the effective spatial and temporal resolution of SLA products also included in the QUID).

i. Mesoscale - Global gridded products (L4)

Error! Reference source not found. presents the variance of the difference between DUACS-DT2024 sea level anomaly gridded product and independent Saral/AltiKa along-track measurements over the period [2018-01-01 to 2018-12-31]. Table 2 gives the variance of the differences for different selection criteria.

It is important to note that **these results are representative of the quality of the gridded products when 3 to 4 altimeters are available. Degraded results can be observed when only two altimeters are available since they use minimal altimeter sampling. The errors during these periods are estimated up to ~40%higher in high variability areas than those presented in the table. Additionally, these scores correspond to a Delayed-Time (DT) mode processing. This mode incorporates both past and future observations for a specific date to constrain the interpolation process. Degraded results are observed in Near-Real-Time (NRT) products. Which could be 2 times larger than in DT processed products.**

Table 2: Variance of the differences between gridded (L4) DT2024 all-sat-merged products (one altimeter was kept independent for validation) and independent SARAL-DP/AltiKa along-track measurements for different geographic selections (unit = cm²). Statistics are presented for wavelengths ranging between 65-500 km and after latitude selection (|LAT| < 60°).

Selection criteria	AL [2018]
Reference area*	1.0
Low variability (<200 cm²) & offshore (distance coast >200 km) areas	2.2
High variability (>200 cm²) & offshore (distance coast >200 km) areas	10.2
Coastal areas (distance coast < 200 km)	4.9

**The reference area is defined by [330, 360°E]; [-22, -8°N] and corresponds to a very low-variability area in the South Atlantic subtropical gyre where the observed errors are small.*

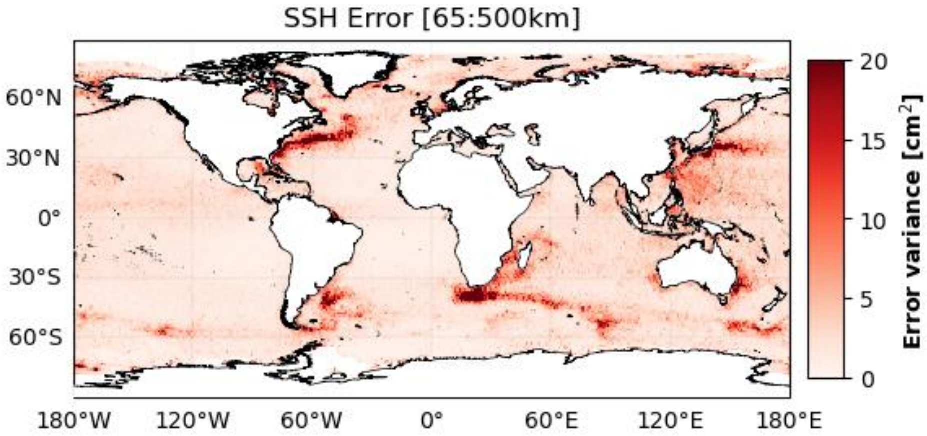

Figure 1: Variance of the difference between global gridded DUACS DT-2024 sea level anomaly and independent SARAL/AltiKa along-track measurements over the period [20180101-20181231] (units: cm).

ii. Mesoscale - Regional gridded products (L4)

Same methodology as previously was used for validation of the regional products over Europe area, including Mediterranean and Black Sea. Saral-DP/AltiKa along-track measurements over the period [2016, 2019] were used as independent measurements. The Table 3 presents the SLA gridded product errors for the total signal for the different basins that compose the Europe product.

Selection criteria	ALG [2018] unfiltered
Mediterranean Sea	14.8
Black Sea	18.1
Atlantic	18.2

Table 3: Variance of the differences between gridded (L4) DT2024 regional Europe all-sat-merged products (one altimeter was kept independent for validation) and independent SARAL-DP/Altika along-track measurements over the period [2018-01-01, 2018-12-31]] (unit = cm²).

2. MDT/ADT error description

The quality of the ADT field is directly depending on the quality of the SLA and MDT fields (see QUID document). The SLA error budget is described in the previous chapter. The quality of the MDT field is fully described in associated QUID and SQO documents:

MDT products are:

- SEALEVEL_GLO_PHY_MDT_008_063: used for Global ocean processing, expect for Mediterranean and Black Sea.
- SEALEVEL_MED_PHY_MDT_L4_STATIC_008_066: used over Mediterranean Sea.
- SEALEVEL_BLK_PHY_MDT_L4_STATIC_008_067: Used over Black Sea.

3. Geostrophic velocity error description

a. Along-track products (L3)

The geostrophic currents in the across-track direction are computed using the principle of geostrophic flow from along-track SLA/ADT fields. The analysis of the spectral content of the kinetic energy gives an indication of the quality of the current estimated. The PDS shows that the kinetic energy bellow ~100 km (depends on the mission and geographical area considered) is

- higher than expected, probably due to residual noises on SLA
- a/o drastically fall at wavelengths corresponding to the cut-off frequency used for low pass filtering applied on SLA.

In medium latitudes and for wavelengths larger than ~100 km, the kinetic energy spectral slope corresponds to the SQG theory (Held et al., 1995).

b. Gridded product (L4)

The absolute surface currents in the product are computed using the principle of geostrophic flow from gridded SLA/ADT fields. The comparison with drifter measurements gives an indication of the errors on geostrophic current products. The methodology used for this comparison is described in (Pujol et al., 2016).

The Figure 2 shows the zonal and meridional RMS differences in 5°x5° boxes between AOML drifters and absolute geostrophic current products over the period [1993, 2021]. The equatorial band was excluded from the analysis since the geostrophic approximation do not lead to an accurate estimation of the currents in this area. Elsewhere, the RMS of the differences is around 11.4 (10.5) cm/s for zonal (meridional) component. Locally, the RMS of the differences is higher. It reaches more than 15 cm/s over high variability areas. Table 4 gives the RMS of the differences for different selection criteria.

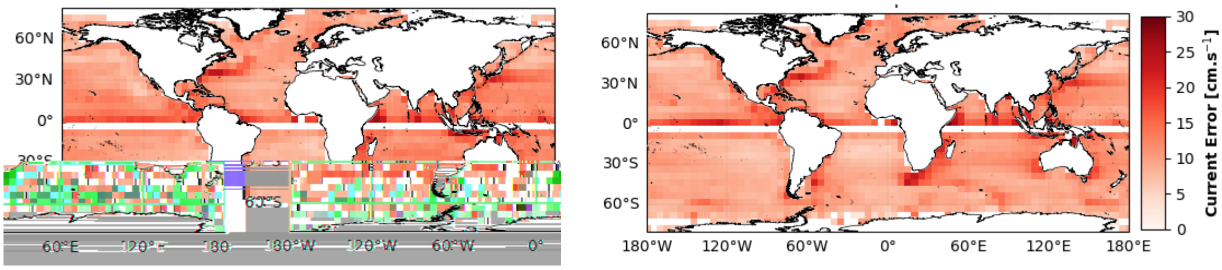

Figure 1: Zonal (left) and meridional (right) RMS of the difference between global gridded DUACS DT-2024 geostrophic current and drifter's measurements over the period [1993-2021] (units: cm/s).

Table 4: RMS of the differences between global gridded DUACS DT-2024 geostrophic currents and independent drifter measurements (unit = cm/s). Statistics are presented for latitude selection (5°N<|LAT| < 60°N).

Selection criteria	Zonal	Meridional
Reference area*	57.8	36.7
Dist coast > 200 km & variance < 200 cm²	10.8	9.9
Dist coast > 200 km & variance > 200 cm²	16.2	15.7224.9
Dist coast < 200 km	11.4	10.5

**The reference area is defined by [330, 360°E]; [-22, -8°N] and corresponds to a very low-variability area in the South Atlantic subtropical gyre where the observed errors are small.*

4. References

Ablain, M., Meyssignac, B., Zawadzki, L., Jugier, R., Ribes, A., Spada, G., Benveniste, J., Cazenave, A., Picot, N., 2019. Uncertainty in satellite estimates of global mean sea-level changes, trend and acceleration. Earth Syst. Sci. Data 11, 1189–1202. https://doi.org/10.5194/essd-11-1189-2019

Held, I.M., Pierrehumbert, R.T., Garner, S.T., Swanson, K.L., 1995. Surface quasi-geostrophic dynamics. J. Fluid Mech. 282, 1–20. https://doi.org/10.1017/S0022112095000012

Hernandez, F., Smith, G., Baetens, K., Cossarini, G., Garcia-Hermosa, I., Drévillon, M., Maksymczuk, J., Melet, A., Régnier, C., Von Schuckmann, K., 2018. Measuring Performances, Skill and Accuracy in Operational Oceanography: New Challenges and Approaches, in: Chassignet, E.P., Pascual, A., Tintoré, J., Verron, J. (Eds.), New Frontiers in Operational Oceanography. GODAE OceanView. https://doi.org/10.17125/gov2018.ch29

Prandi, P., Meyssignac, B., Ablain, M., Spada, G., Ribes, A., Benveniste, J., 2021. Local sea level trends, accelerations and uncertainties over 1993–2019. Sci. Data 8, 1. https://doi.org/10.1038/s41597-020-00786-7

Pujol, M.-I., Faugère, Y., Taburet, G., Dupuy, S., Pelloquin, C., Ablain, M., Picot, N., 2016. DUACS DT2014: the new multi-mission altimeter data set reprocessed over 20years. Ocean Sci. 12, 1067–1090. https://doi.org/10.5194/os-12-1067-2016