Benefit of a second calibration phase to estimate the relative global and regional mean sea level drifts between Jason-3 and Sentinel-6a

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Scientific context

- ➔ Recent studies (Ablain, 2019; Raynal, 2019; etc.) have highlighted a strong 1.3-1.4 mm/yr relative GMSL drift between Sentinel-3 missions (S3A and S3B) and other altimeter missions (Jason-3, Saral-Altika, Jason-2) in SAR mode even after homogenisation of the geophysical corrections between all missions (e.g., use of wet tropospheric correction from a model).
- ➔ The origin of the S3A/S3B drift is still being investigated by altimetry experts, although significant progress has been made very recently.
- ➔ Processing S3A/S3B data using the PLRM mode (Pseudo-LRM, derived from the SAR mode) yields a low GMSL drift, which was estimated by Poisson, 2019 to be approximately 0.3-0.4 mm/yr and due to the PTR (point target response) drifts.
- ➔ This small drift is not statistically detectable over a 3-year period with classical calibration methods (e.g., GMSL differences, comparison with tide gauges).

Scientific context

- ➔ As the S3A and S3B missions are not directly used to build GMSL data records (they are not the reference missions), there is no impact on the accuracy of the GMSL time series. H
- ➔ However, in the event of similar drift on S6A/S6B, which uses similar technology to S3A/S3B, the reliability of the GMSL evolution would be adversely affected.
- ➔ It is then essential to be able to detect such drifts on S6A/S6B missions as soon as possible after their launch to correct them and ensure the accuracy of the long-term evolution of the GMSL time series.

- ➔ **Thus, the main question raised is how accurately a GMSL drift can be detected after the launch of S6A for short periods of up to a few years.**

Objectives

➔ However, the usual calibration methods are not able to detect GMSL drifts of less than 0.6 mm/yr (at 1-sigma) over a 3-year period (Ablain , 2020, Chicago, OSTST).

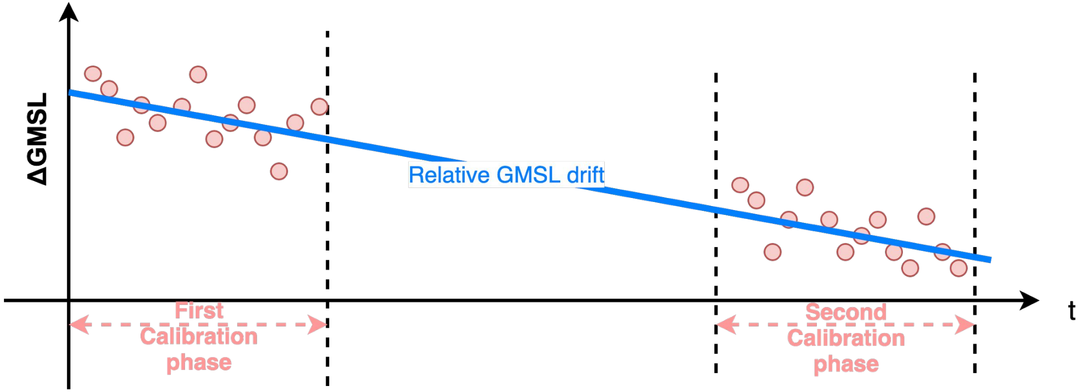
➔ **The objective of this study is to propose a new calibration method based on two calibration phases between Jason-3 and S6A** :

- To date, a first calibration phase of approximately 12 months is planned
- The proposal of a second calibration phase between Jason-3 and S6A after a few years would make it possible to obtain new high accuracy evaluations of the GMSL differences between the 2 missions. T
- The GMSL drift could then be determined with good accuracy, which depends on the duration of this second calibration phase and the time elapsed between the two phases.
- To be able to recommend a scenario, it is important to determine the smallest values for these two parameters that meet the necessary precision requirements to ensure a continued accurate GMSL record.
- The impact of using two calibration phases between Jason-3 and S6A has also been analysed at regional scales

Method

➔ The method consists of describing the uncorrelated and correlated errors of a time series. From this error budget, the variance-covariance matrix of the error (Σ) is calculated. Then, the uncertainty of the trend is computed from a general formalism of the distribution of the ordinary least squares (OLS) estimator (β) : see (Abain et al. 2010 for more detail

➔ The relative GMSL drift is calculated from the differences in GMSL measurements during the two phases



Basic principle of the "2-phase calibration" method

Method

➔ The error budget is deduced from the ΔGMSL calibration method :

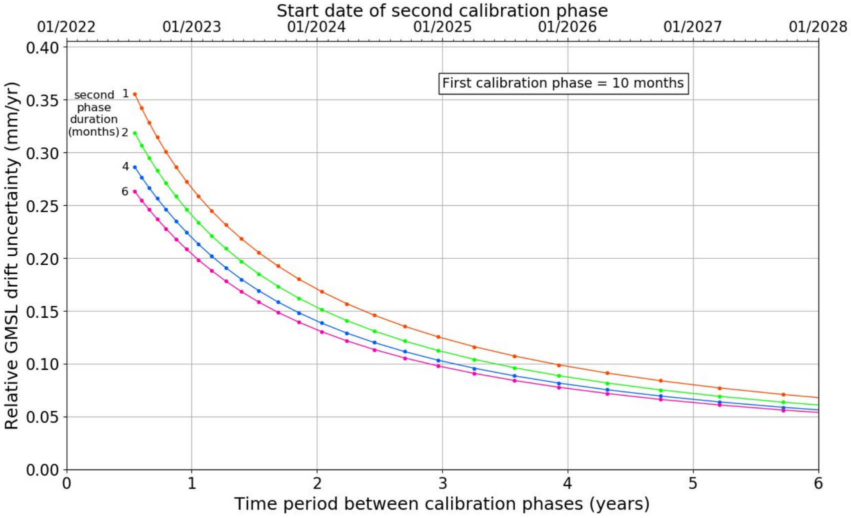
- errors due to large frequency errors and long-term drift errors are assumed to be fully correlated
- The variance in the high-frequency errors has been derived from the Jason-1/Jason-2 and Jason-2/Jason-3 calibration phases.

Source of errors	Error category	GMSL differences without calibration phases uncertainty level (at 1 σ)	GMSL differences with calibration phase Uncertainty level (at 1 σ)
High frequency errors: altimeter noise, geophysical corrections, orbits ...	Correlated errors (λ = 2 months)	σ between 0.6 and 0.8 mm (depending on altimeter missions)	σ = 0.3-0.4 mm
Medium frequency errors: geophysical corrections, orbits ..	Correlated errors (λ = 1 year)	σ between 0.5 and 0.7 mm (depending on altimeter missions)	σ = 0.2-0.3 mm (λ = 6 months)
Large frequency errors: wet tropospheric correction (WTC)	Correlated errors (λ = 5 years)	σ = 0 (model WTC error are cancelled between 2 missions)	σ = 0 (model WTC error are cancelled between 2 missions)
Large frequency errors: orbits (Gravity fields)	Correlated errors (λ = 10 years)	σ = 0.5 mm * sqrt(2)	σ = 0 (error orbit assumed correlated at long scales)
Long-term drift errors: orbit (ITRF) and GIA	Drift error	δ = 0.1 * sqrt(2) (GIA error is removed between 2 missions)	σ = 0 (error orbit assumed correlated at very long scales)

- The level of variance is divided by approximately 2 in comparison with the ΔGMSL calibration method because geophysical errors are fully correlated during the calibration phase.
- For the Jason-3/S6A calibration phase, a similar error budget can be applied, as the errors should probably be very similar.

Sensitivity of the "2-phase calibration" method

- ➔ The sensitivity of the "2-phase calibration" approach to the length of the second calibration phase was analysed.
- ➔ For a 6-month time span between the 2 calibration phases, the uncertainties range from 0.27 mm/yr for a 6-month second phase duration to 0.36 mm/yr for a 1-month second phase duration. T
- ➔ These values are reduced to approximately 0.10-0.13 mm/yr after 3 years between the 2 calibration phases.
- ➔ These results show that the uncertainty of GMSL drift is weakly sensitive to the duration of the second calibration phase. Thus, there is a very low interest in recommending a second calibration phase longer than 4 months.



Evolution of the relative GMSL drift uncertainties with the time spent between the two calibration phases between Jason-3 and S6A for several different durations of the second calibration phase from 1 month to 6 months.

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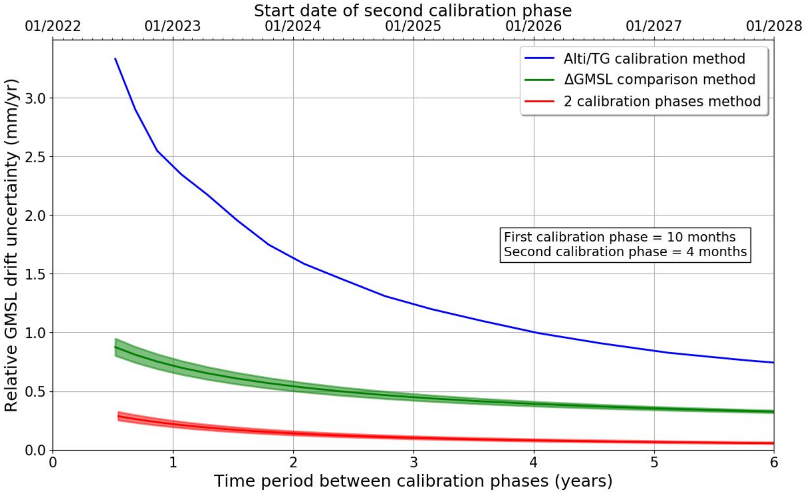
Comparison of the GMSL drift uncertainties

➔ The new “2-phase calibration” method significantly reduces the GMSL drift uncertainties compared to the Alti/TG and ΔGMSL calibration methods, depending on the Time spent between the two Jason-3/S6A calibration phases :

- 1 year : 0.25-0.30 mm/yr (0.8 mm/yr ΔGMSL method)
- 2 years : 0.14-0.16 mm/yr
- 3 years, 0.1 mm/yr whereas it remains close to 0.5 mm/yr with the ΔGMSL method.



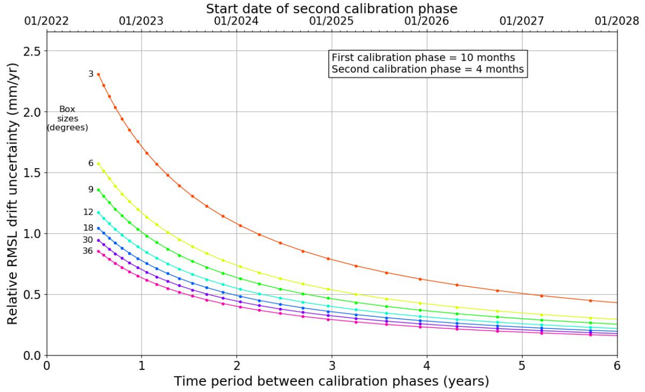
Evolution of the relative GMSL drift uncertainties with the time period between the two calibration phases between Jason-3 and S6A for the different calibration methods - The duration of the second calibration phase was arbitrarily set at 4 months

Such a level of uncertainty with the new “2-phase calibration” method makes it possible to detect a relative drift between Jason-3 and S6A lower than 0.3 mm/yr within a confidence level of 68% for a period of 1 year between the two calibration phases, 95% for 2 years and 99.7% for 3 years.

Uncertainties at regional scales

- ➔ Similar work performed at regional scales
- ➔ Error budget has been updated to take into account regional altimetry errors
- ➔ The detection of a relative regional sea-level drift lower than 0.5 mm/yr is possible at large basin scales as early as 2 years between the two Jason-3/S6A calibration phases. After 3 years, the uncertainties become less than 0.5 mm/yr for spatial scales up to approximately 1000 km

Such a level of uncertainty would allow the detection of large-scale errors of approximately 0.5-1.0 mm/yr with a good confidence interval (at least 90%). This situation would also allow the detection of long-term orbit errors between Jason-3 and S6A and would provide a way to measure the improvement of orbit solutions in the future.



Evolution of the relative averaged regional MSL drift uncertainties with the time period between the two calibration phases between Jason-3 and S6A for different box sizes from 3x3 degrees (corresponding to ~330 km spatial scale) to 36x36 degrees (corresponding to ~4000 km spatial scales).

Conclusions (1/3)

➔ The benefits of a second calibration phase between Jason-3 and S6A for climate studies are clearly demonstrated in this study:

- The uncertainty levels on the GMSL drift estimate would be low enough to detect any drift detrimental to the stability of the current GMSL record.
- It would indeed be possible to check the stability between two satellites with an accuracy at least 3 times better at the global scale than with the most accurate method to date (ΔGMSL calibration method) for any period of time.
- The same is true for the regional scale for which the ΔGMSL calibration method and Alti-TG calibration method are far from accurate enough to provide statistically significant results on regional MSL drift and where the "2-phase calibration" method would provide RMSL drift estimates with very good precision.
- For instance, the "2-phase calibration" method is more accurate on 6x6 degrees RMSL drift estimates than the ΔGMSL calibration method on the global scale GMSL drift estimate.

Conclusions (2/3)

➔ This study also shows that the time spent between the two calibration phases is significantly more sensitive than the length of the second calibration phase for the reduction in uncertainties:

- ◆ A second short calibration phase (a few months) will have no significant impact on the uncertainty level and will therefore allow Jason-3 to return quickly to an orbit that will allow it to contribute again to independent observations.

➔ Therefore, assuming that it would be technically feasible to move Jason-3 to its initial orbit in a few years, an optimal scenario can be recommended :

- ◆ To carry-out the second calibration phase approximately 1.5-2 years after the first and for a duration of 3-4 months.
- ◆ This situation would allow the detection of a relative GMSL drift with an accuracy of approximately 0.15 mm/yr and 0.4-0.5 mm/yr at oceanic basin scales (2000-4000 km).
- ◆ With such a scenario, the currently unobservable 0.3-0.4 mm/yr instrumental GMSL drift present on S3A and S3B due to the PTR evolution would be detectable on S6A (if it is present) within a confidence level of 95%.

Conclusions (3/3)

- ➔ A third calibration phase between Jason-3 and S6A could be imagine in the ideal case Jason-3 is still operational :
  - ◆ assuming such a scenario is feasible 1 year after the end of the second calibration phase, the relative GMSL drift uncertainties would be lower than 0.1 mm/yr.
  - ◆ This level of stability has never been reached before.
  - ◆ With such a stability a whole series of new unprecedented scientific perspectives could be tackled with the sea level data.
  - ◆ These perspectives range from the detection of the deep ocean contribution and the permafrost contribution to GMSL rise, the closure of the regional sea level rise, the detection and attribution of regional sea level changes in response to anthropogenic emissions or the monitoring of the Earth energy imbalance in response to climate natural variability.
- ➔ **We argue that the scientific added value would be such that the option of a multiple calibration phases (with 2 or 3 phases) between Jason 3 and S6A should be considered.**

➔ The details of the study are available in this note :

https://www.essoar.org/doi/10.1002/essoar.10502856.1

Thank you for you attention !

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