Revised uncertainties of the Global Mean Sea Level biases between the TOPEX & Jasons reference missions

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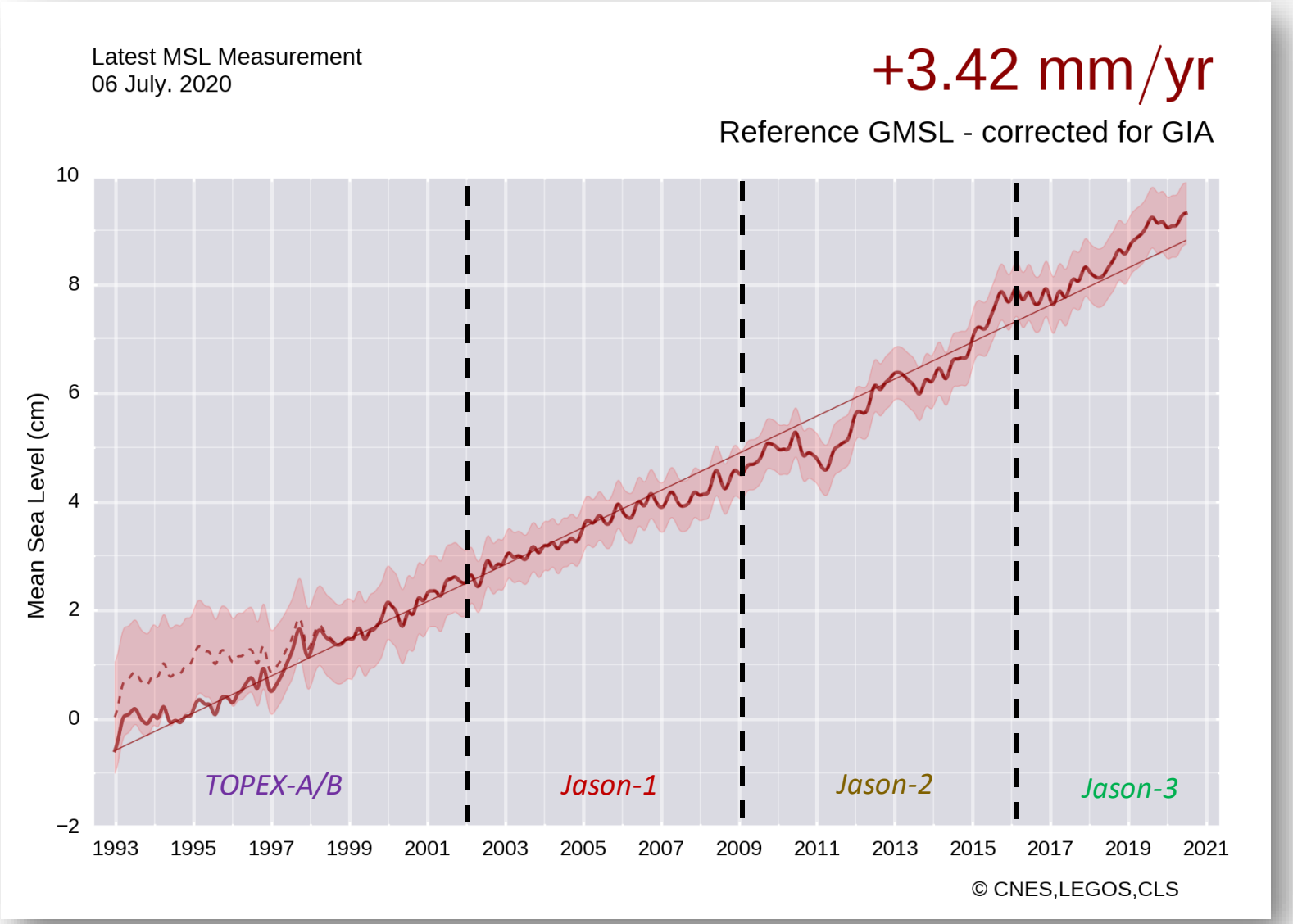
« Global Mean Sea Level » reference record



The reference GMSL record is currently built from 4 different missions: **TOPEX-A/B ; Jason-1 ; Jason-2 and Jason-3**.

The **relative bias calibration** between one mission and its successor is made during **tandem phases** *(Zawadzki et al. 2016)*

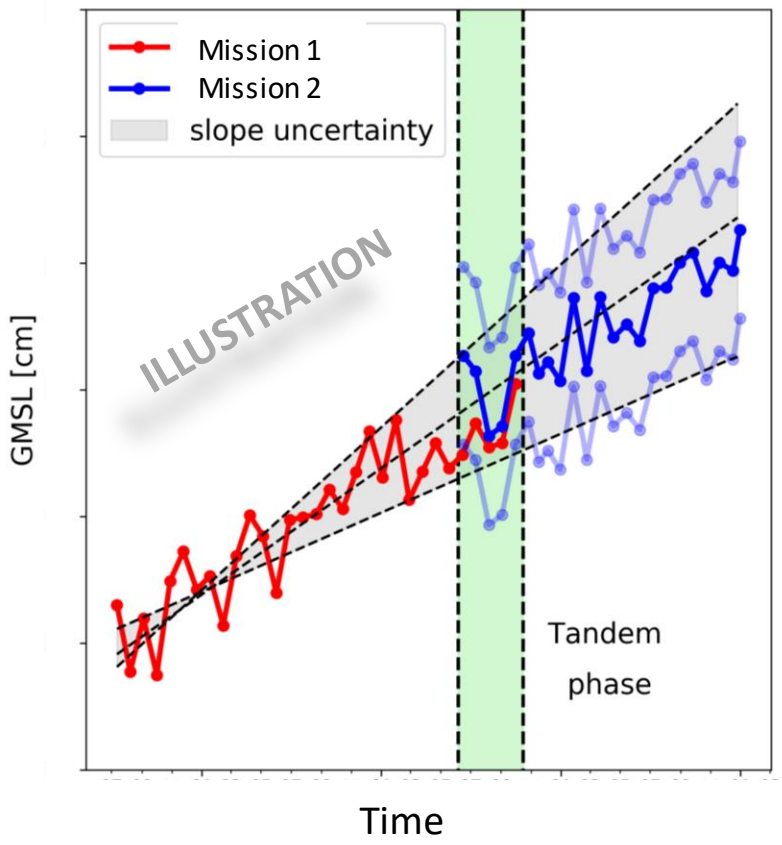
A **continuous GMSL record** is thus obtained and distributed on ww.aviso.altimetry.fr

A new release based on the L2P-2021 altimetry products will be soon available (end of 2020), see **M. Lievin, splinter session «Cal/Val data »** for the presentation of the new L2P-2021 altimetry products

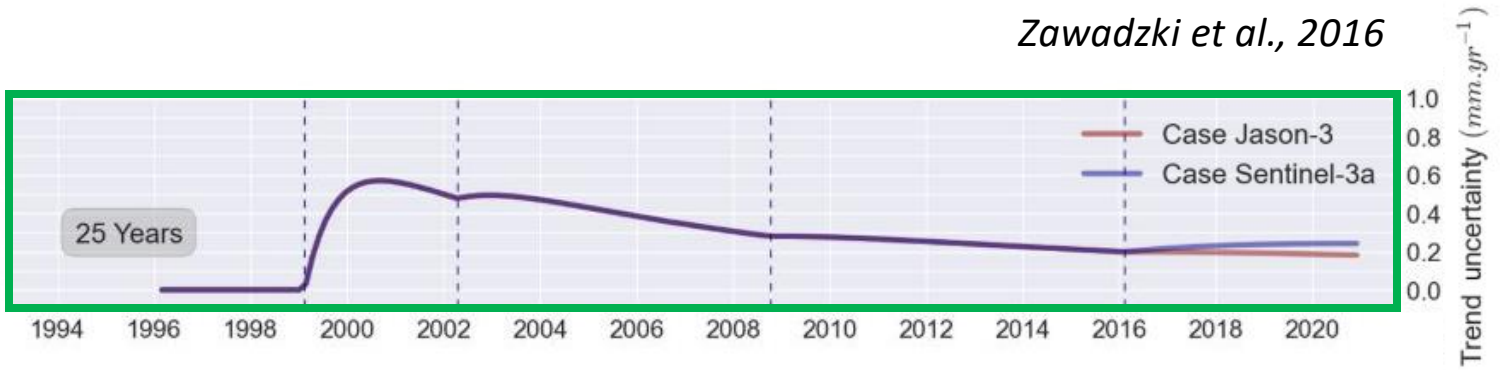
« Global Mean Sea Level » inter-mission biases

However, **uncertainties on the GMSL inter-mission biases remain**

It creates direct **uncertainties on the GMSL values and the estimation of its slope** (and acceleration)
The impact can be large, **as much as 0.2 mm/yr** of uncertainty on the GMSL slope over 25 years *(Zawadzki et al., 2016)*



Zawadzki et al., 2016



The figure above shows the GMSL trend uncertainty due to, **only**, the inter-mission GMSL bias uncertainties. One concludes that after 25 years of data acquired with 4 different missions, the inter-mission bias uncertainties create an uncertainty of 0.2 mm/yr on the GMSL trend estimation (red curve).

« Global Mean Sea Level » error budget

The inter-missions bias uncertainties **are only one source** among other potential errors.

Ablain et al. (2019) gives a description of **the error budget** as we currently know it, including the **inter-mission biases**

Table 1. Altimetry GMSL error budget given at 1σ.

Source of errors	Error category	Uncertainty level (at 1σ)	References
High-frequency errors: altimeter noise, geophysical corrections, orbits	Correlated errors ($\lambda = 2$ months)	$\sigma = 1.7$ mm for TOPEX period $\sigma = 1.5$ mm for the Jason-1 period. $\sigma = 1.2$ mm for the Jason-2/-3 period.	Calculation explained in this paper
Medium-frequency errors: geophysical corrections, orbits	Correlated errors ($\lambda = 1$ year)	$\sigma = 1.3$ mm for the TOPEX period $\sigma = 1.2$ mm for the Jason-1 period. $\sigma = 1$ mm for the Jason-2/-3 period.	Calculation explained in this paper
Large-frequency errors: wet troposphere correction	Correlated errors ($\lambda = 5$ years)	$\sigma = 1.1$ mm over all the period ($\Longleftrightarrow$ to 0.2 mm yr^{-1} for 5 years)	Legeais et al. (2014), Thao et al. (2014)
Large-frequency errors: orbits (gravity fields)	Correlated errors ($\lambda = 10$ years)	$\sigma = 1.12$ mm over the TOPEX period (no GRACE data) $\sigma = 0.5$ mm over the Jason period ($\Longleftrightarrow$ to 0.05 mm yr^{-1} for 10 years)	Couhert et al. (2015), Rudenko et al. (2017)
Altimeter instabilities on TOPEX-A and TOPEX-B	Drift error	$\delta = 0.7$ mm yr^{-1} on the TOPEX-A period $\delta = 0.1$ mm yr^{-1} on the TOPEX-B period	Ablain (2017), Beckley et al. (2017), Watson et al. (2015)
Long-term drift errors: orbit (ITRF) and GIA	Drift error	$\delta = 0.12$ mm yr^{-1} over 1993–2017	Couhert et al. (2015), Spada (2017)
GMSL bias errors to link altimetry missions together	Bias errors	$\Delta = 2$ mm for TP-A/TP-B $\Delta = 0.5$ mm for TP-B/J1, J1/J2, J2/J3.	Zawadzki et al. (2018)

Uncertainties of the inter-missions biases

The **inter-mission biases uncertainties** given in *Ablain et al. (2019)* are based on the work of ***Zawadzki et al. (2016).***

Table 1. Altimetry GMSL error budget given at 1σ.

Source of errors	Error category	Uncertainty level (at 1σ)	References
GMSL bias errors to link altimetry missions together	Bias errors	$\Delta = 2$ mm for TP-A/TP-B $\Delta = 0.5$ mm for TP-B/J1, J1/J2, J2/J3.	Zawadzki et al. (2018)*

*Typo in Ablain et al (2019), this is indeed 2016

In this former work, only the inter-mission bias between Jason-2 and Jason-3 has been derived, with simulated data of Jason-3 (real data not being available at that time).

In 2019, no other studies than *Zawadzki et al. (2016)* were available, therefore, ***Ablain et al. (2019) assumed*** **the value of 0.5 mm (@1-sigma) to be valid for all inter-mission bias uncertainties** (except TOPEX-A/-B which is a special case).

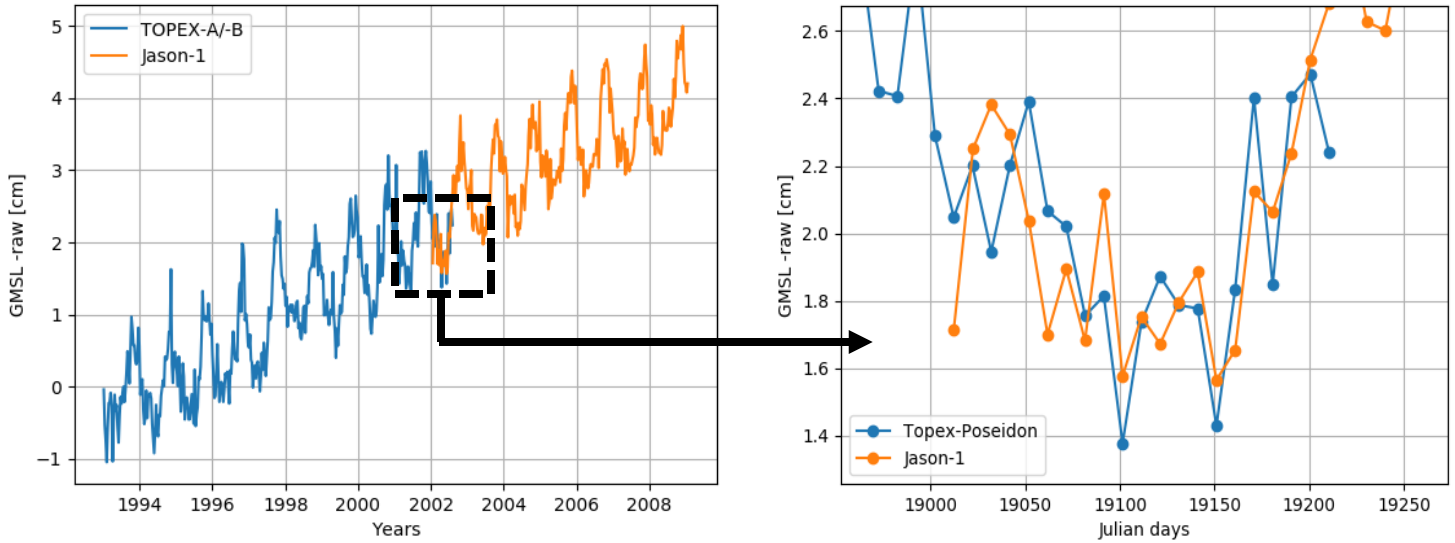
In this study, we **revisited the method to estimate the inter-mission bias uncertainties** and estimate it for each reference missions *(except for TOPEX-A/-B).* We also **estimated the GMSL uncertainties with the partially revisited error budget** and **quantified its sensitivity** to the inter-mission biases uncertainties.

New method to estimate the GMSL bias uncertainties

GMSL estimates from two different missions: X, Y

- Inter-mission bias estimates is the **mean(X-Y)** over the tandem phase
- Associated uncertainty can be estimated as:

sigma(X-Y) = sqrt[**sigma(X)**^2 + **sigma(Y)**^2 – 2 . **corr(X, Y)** . **sigma(X)** . **sigma(Y)**] / sqrt(**N obs. Indep**)



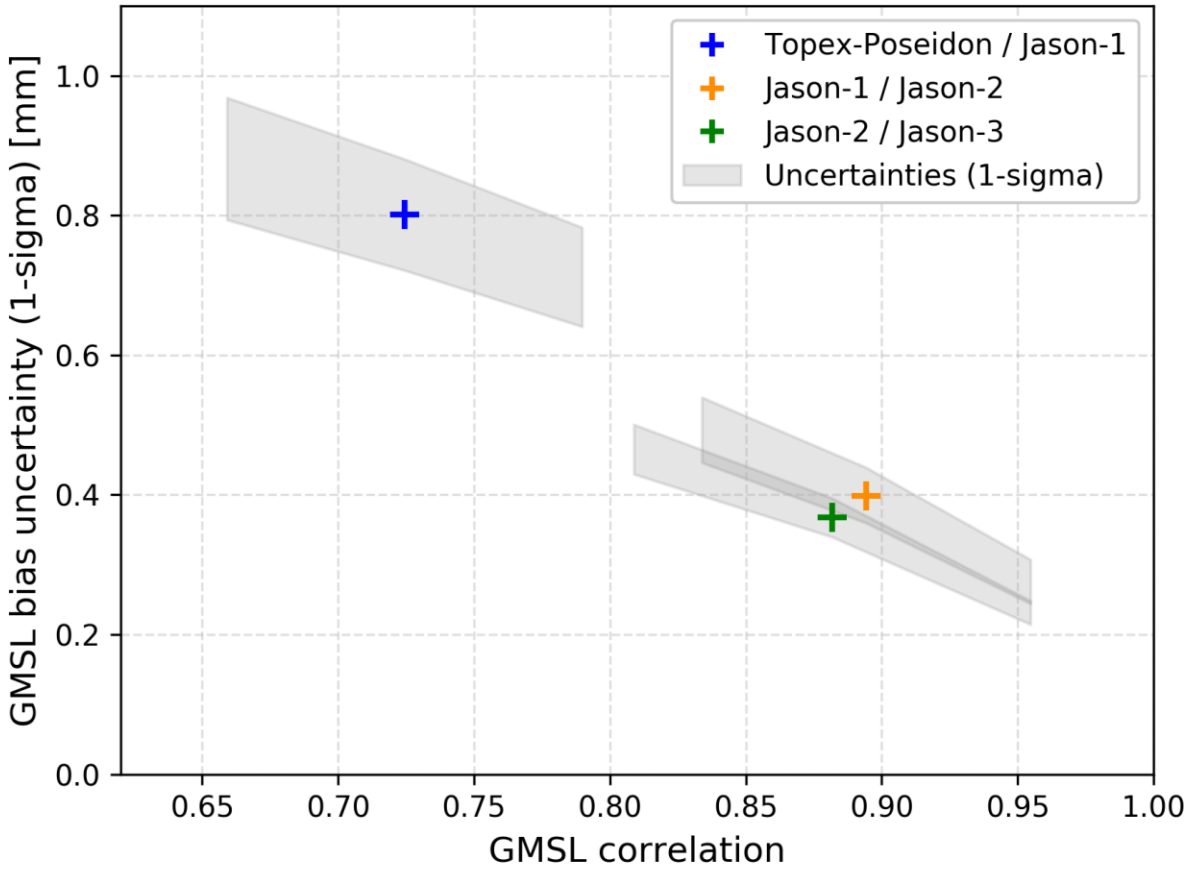
<u>One needs to estimate:</u>

- The noise level for each mission
- The inter-correlation of the GMSL records
- The number of independent measurements for each GMSL record within the tandem phase

<u>We did:</u>

- Direct measurement on the GMSL records *(2-months low-pass filter)*
- Direct measurement on the GMSL records over the tandem phase
- Assume same hypothesis *as Zawadzki et al. (2016):* *Auto-correlation of the GMSL record at 1-month (i.e., Nobs. indep=3)*

New estimation of the GMSL bias uncertainties



We obtain **new estimations of the GMSL inter-mission bias uncertainties** for the four reference missions.

We **found lower uncertainties values** than the one suggested by *Ablain et al. (2019)* (i.e., 0.5 mm) **for J1/J2 and J2/J3**, and **higher for TOPEX/J1**.

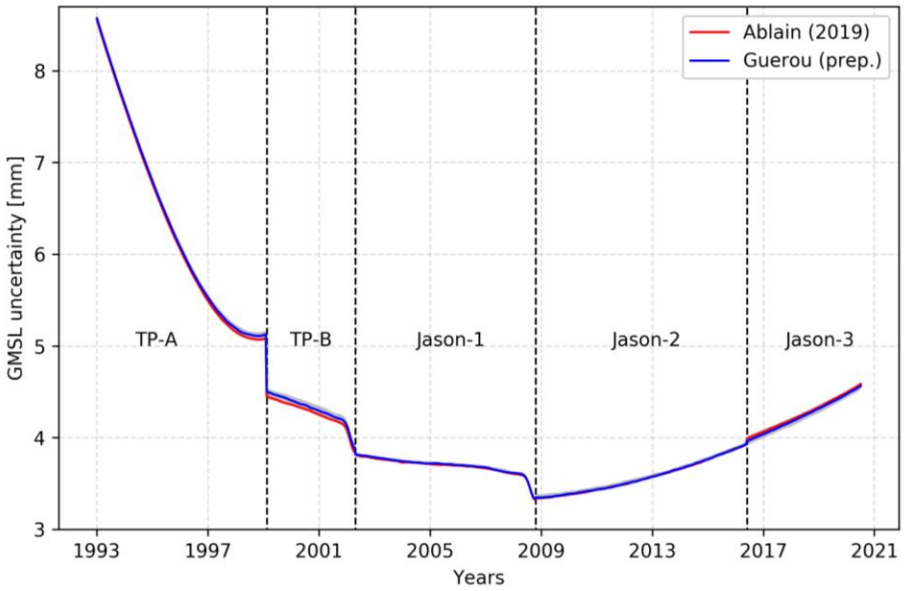
@ 1-sigma	TOPEX-A/B Jason-1	Jason-1 Jason-2	Jason-2 Jason-3
GMSL bias uncertainties [mm]	**0.8** *[0.65/0.97]**	**0.40** *[0.25/055]**	**0.37** *[0.2/0.5]**

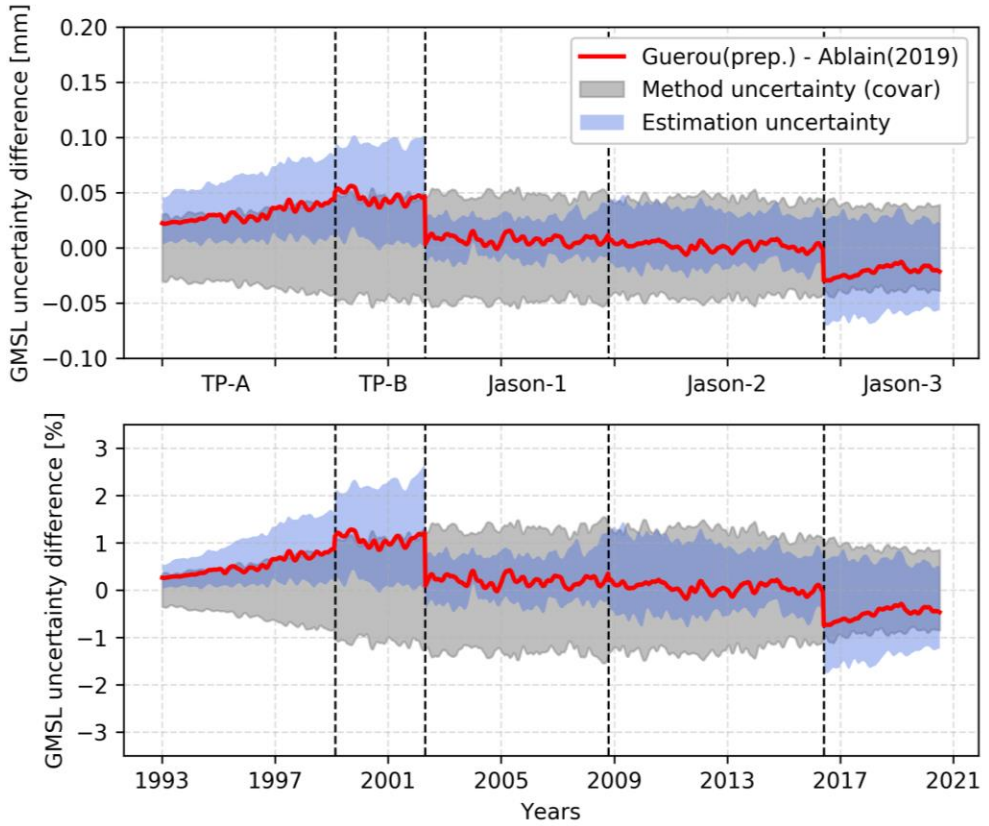
** The uncertainties of the derived values (i.e., shaded areas on the plot) are obtained by varying the GMSL noise levels and the GMSL inter-correlation with respect to our measurement method parameters*

Impact on the GMSL uncertainties

We used the **variance/co-variance matrix approach** as described in *Ablain et al. (2019)* to **estimate the GMSL record uncertainties**.

We used the **same error budget** as in *Ablain et al. (2019)* **but the inter-missions biases uncertainties, that we updated** with our new estimations.



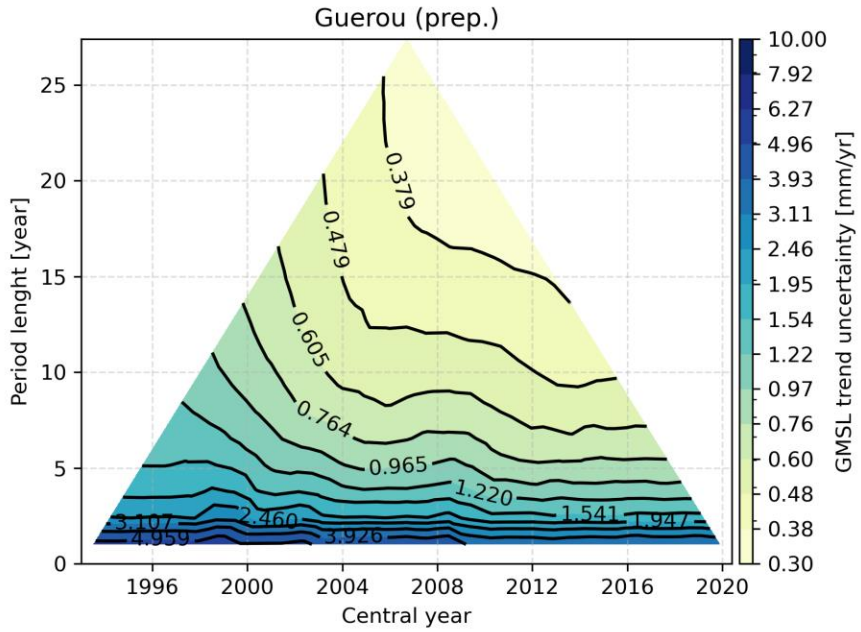


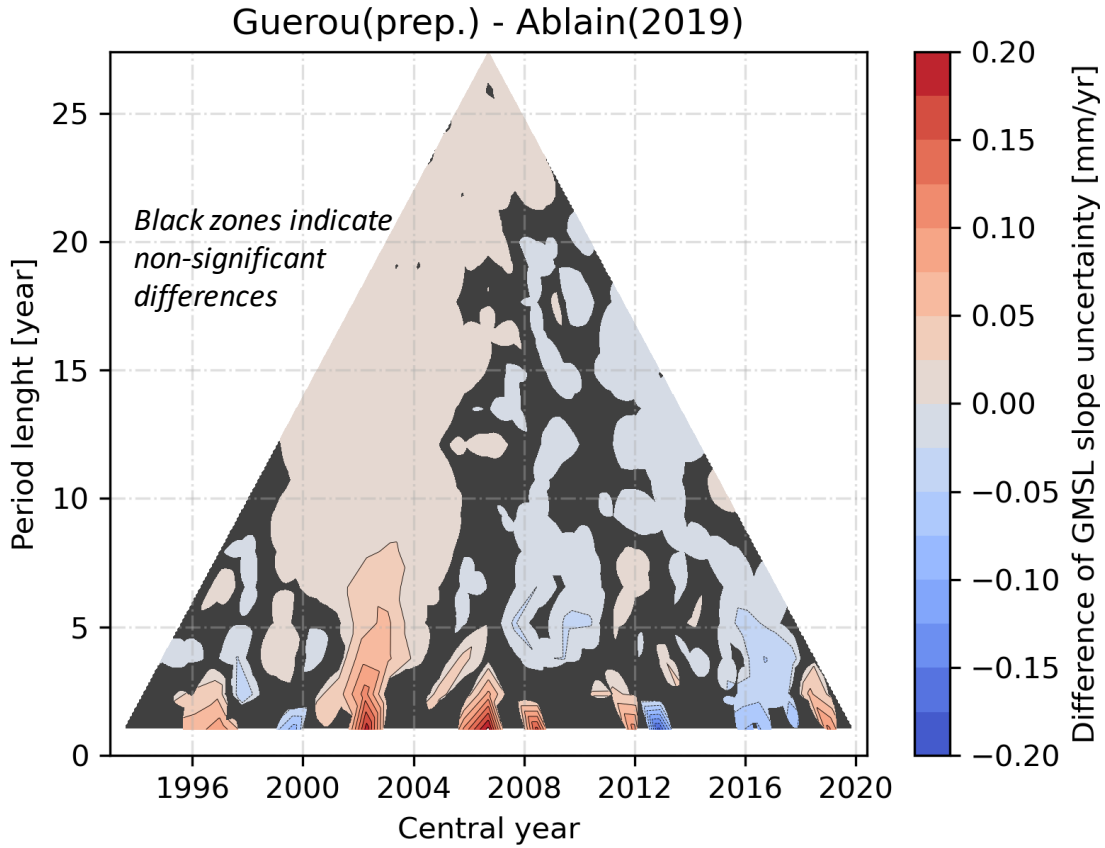
The new values of **the inter-mission bias uncertainties have a low impact on the GMSL record total uncertainties**.
The differences of uncertainties (as compared to Ablain et al. 2019) **are smaller than +/- 0.05 mm,** we find **higher uncertainties during the TOPEX** period and **lower ones during the Jason-3 period.** This is however within the uncertainties of the comparison method (grey shades). **Still, the uncertainties we obtain are more accurate** since the revisited error budget with the new inter-mission bias is more representative of the GMSL record uncertainties.

Impact on the GMSL slope uncertainties

We used the **variance/co-variance matrix approach** as described in *Ablain et al. (2019)* to **estimate the GMSL slope uncertainties**.

We used the **same error budget** as in *Ablain et al. (2019)* **but the inter-missions biases uncertainties, that we updated** with our new estimations.





The **GMSL slope uncertainties**, as compare to Ablain et al. (2019), **are not significantly changed for periods longer than 5 years** (i.e., less than 0.025 mm/yr of uncertainties differences).
Differences larger than +/- 0.1 mm/yr for period of ~2 years are however observed around the switches from TOPEX-B to Jason-1, and Jason-2 to Jason-3, respectively.

Conclusion

Outputs

- New estimation of the inter-mission GMSL bias uncertainties of the four reference missions :
  0.8 mm for TOPEX-B/Jason-1 ; 0.4 mm for Jason-1/Jason-2 and Jason-2/Jason-3 (Guerou et al., in prep.)
- Characterization of the GMSL uncertainties (values & slope) due to the update of the bias uncertainties,
  as compare to Ablain et al. (2019).

Knowledge acquired

- Better understanding of the sensitivity of the GMSL error budget to the inter-mission biases uncertainties

Take-home messages

- Long-term (climate) GMSL uncertainties are not significantly changed with the update of the GMSL bias uncertainties
- This is holding as long as the tandem phases between missions are of high-quality, allowing to keep the inter-mission bias uncertainties as low as possible.