What sea-level drifts can be detected at global and regional scales by comparing recent altimetry missions together: S3A, Jason-3 and Saral-Altika?

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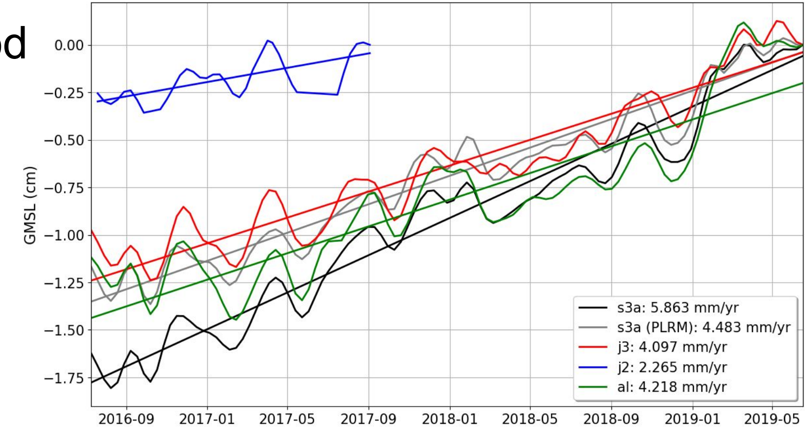
Overview

- GMSL evolution is well monitored with a good description of its error and uncertainties (Ablain et al. , 2019)

- However the description of potential GMSL drift on recent altimeter missions is quite challenging over short period (3-5 years).



Objectif of this study is:

- To provide the global and regional MSL drift detection capability comparing recent altimeters missions (S3A, Jason-3 and Saral/Altika) and analysing the sensitivity of the method :
    - A focus on the detection of S3-A global and regional MSL drift using SAR-mode data is provided

GMSL drift uncertainty

- Method based on (*Ablain et al., 2019*)
  - The estimator of β with the OLS approach is noted $\hat{\beta} \sim (X^t X)^{-1} X^t y$
  - with the following distribution taking into account the error variance-covariance matrix :

$$\hat{\beta} = N(\beta, (X^t X)^{-1} (X^t \Sigma X)(X^t X)^{-1})$$

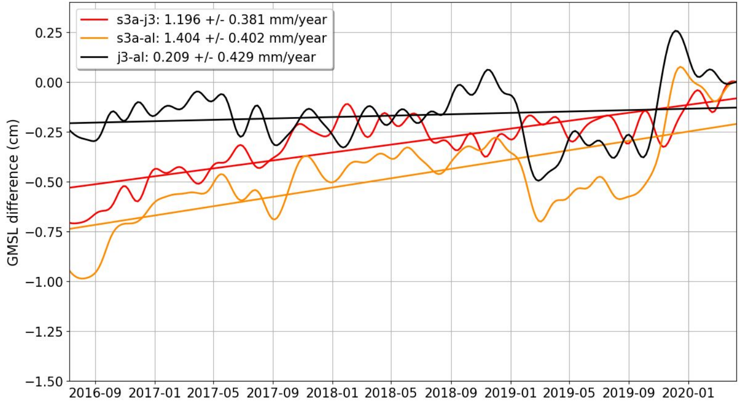
- Σ derived from the error budget description
- HF and MF error variance are computed directly from the GMSL difference signal :
  - GMSL computed with AVISO method from Marine L2P products
  - Comparison of GMSL time series after interpolation on the same time sample (usually using the Topex-Jason mission cycles as reference periods)

Source of errors	Error category	Jason-2/3 GMSL uncertainty level (1 σ)	GMSL differences Uncertainty level (at 1 σ)
High frequency errors: altimeter noise, geophysical corrections, orbits ...	Correlated errors (λ = 2 months)	σ = 1.2 mm	σ between 0.6 and 0.8 mm (depending on altimeter missions)
Medium frequency errors: geophysical corrections, orbits ..	Correlated errors (λ = 1 year)	σ = 1 mm	σ between 0.5 and 0.7 mm (depending on altimeter missions)
Low frequency errors: wet tropospheric correction (WTC)	Correlated errors (λ = 5 years)	σ = 1.1 mm (⇔ to 0.2 mm/yr for 5 years)	σ = 0 (model WTC error are cancelled between 2 missions)
Low frequency errors: orbits (Gravity fields)	Correlated errors (λ = 10 years)	σ = 0.5 mm (⇔ to 0.05 mm/yr for 10 years)	σ = 0.5 mm * sqrt(2)
Long-term drift errors: orbit (ITRF) and GIA	Drift error	δ = 0.12 mm/yr	δ = 0.1 * sqrt(2) (GIA error is removed between 2 missions)

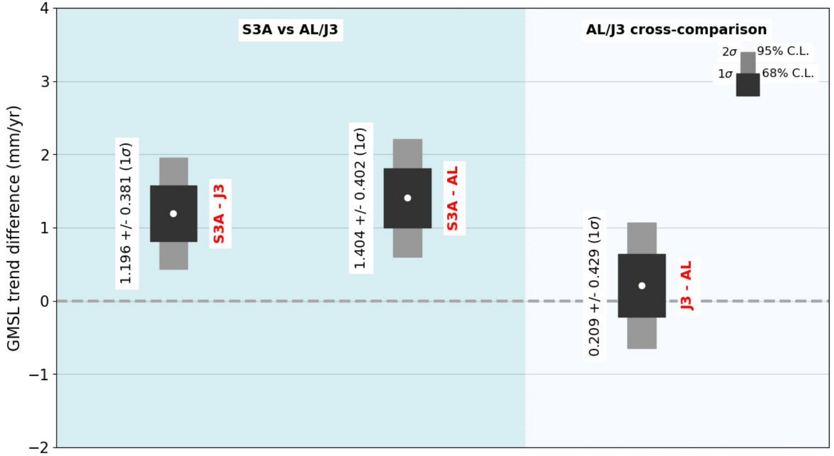
From Ablain et al. 2019

GMSL drift uncertainty

- Drifts and uncertainties on S3A compared to J3 and AL (period 07/2016 to 04/2020) :
  - No significative J3 vs AL drift makes for a strong basis for comparison with S3A
  - S3 vs J3 and AL both find approx **1.3 +/- 0.4 mm/yr drift (68% C.L.)**
- Data updated from *Ablain, OSTST, Chicago, Oct. 2019* :
  - + 1 year period
  - reprocessing with more homogeneous data
- The origin of this drift has been explained by altimetry experts (see J.Aublanc, OSTST 2020)



S3A GMSL trend differences vs AL/J3 using model WTC
Period: 07/2016 to 04/2020



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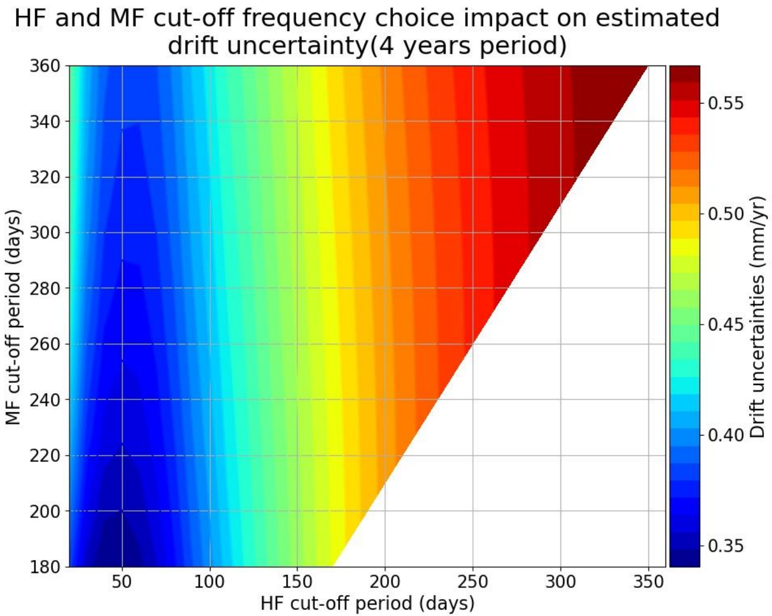
GMSL drift uncertainty

- The sensibility of error budget has been studied for high frequency errors
-
- Uncertainties are computed for different HF and MF cut-off frequencies :
  - Low impact from the variation of the MF frequency.
  - Variations of the HF period has a high impact on the computed uncertainties for short time periods : up to 25%.
  - The currently chosen periods HF = 2 months and MF = 1 year correspond to a minimum in estimated uncertainties.

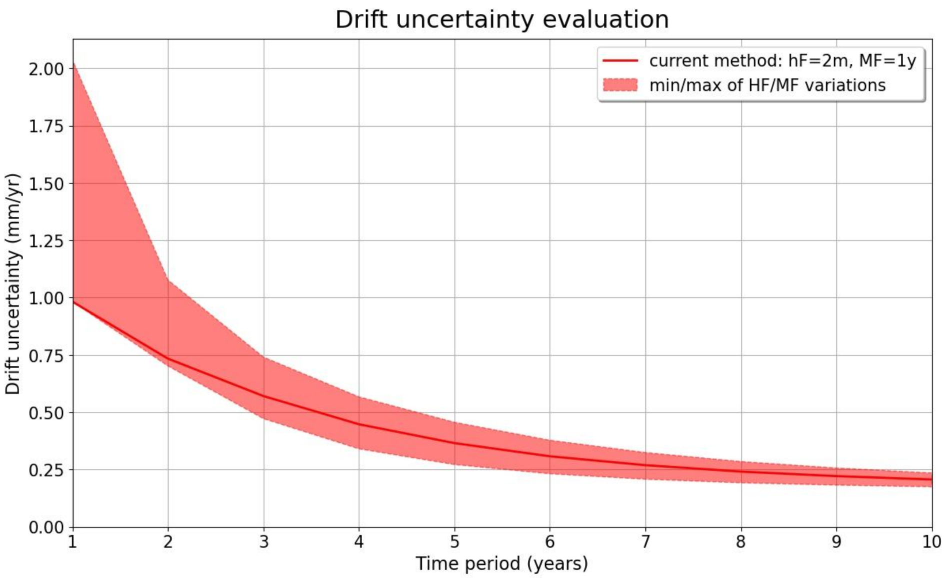


Uncertainties computed for a time period of 4 years, for different HF and MF cut-off frequencies.

HF variance is computed as the variance of the residue from a low-pass Lanczos filter at the HF frequency. MF variance is computed as the variance of the difference of the residue from a low-pass Lanczos filter at the MF freq. and the signal filtered at the HF freq.

GMSL drift uncertainty

- Uncertainties evaluated for :
  - current method with frequencies HF=2m and MF=1y
  - all combinations of frequencies HF in [2m, 1y] and MF in [6m, 1y]
- For time periods < 3y :
  - current method (HF=2m, MF=1y) is the least conservative i.e. yields lower uncertainties than other combinations
- At 3y, drift unc. between [0.5, 0.75] mm/yr
- At 5y, drift unc. between [0.25, 0.4] mm/yr
- At 10y, drift unc. < 0.25 mm/yr
- A more robust approach must be devised for short time periods



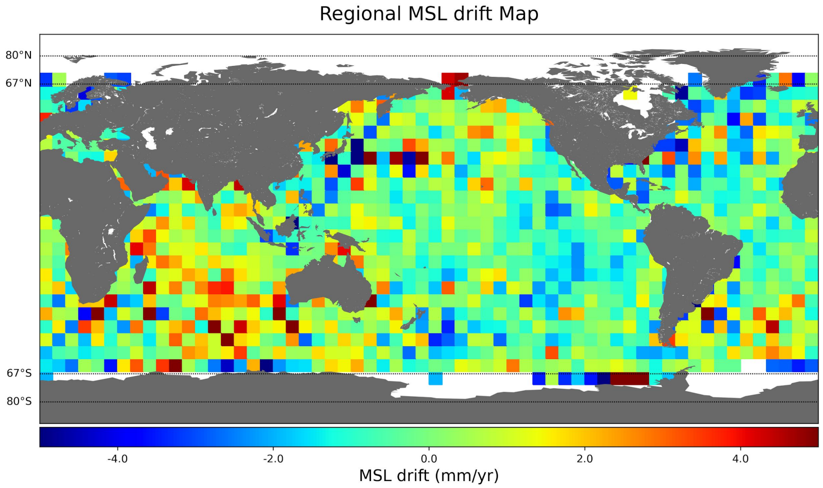
Min/max of uncertainties computed for all HF variations between 2 months and 1 year and all MF variations between 6 months and 1 year, for different time periods.

Regional MSL drift uncertainty

- Regional MSL drift and associated uncertainties have been analyzed at regional scales
- From experience, regional drifts in altimetry are very difficult to detect by such a direct approach because of the ocean variability that is not observed in the same way

- Such an approach is especially effective between the tandem phase

- **However, our intention is to quantify precisely the level of uncertainty reached as a function of the period duration and also of the size of the regional area analysed by the direct method.**



Regional MSL trend differences between S3A and J3: are there significant ?

Regional MSL drift uncertainty

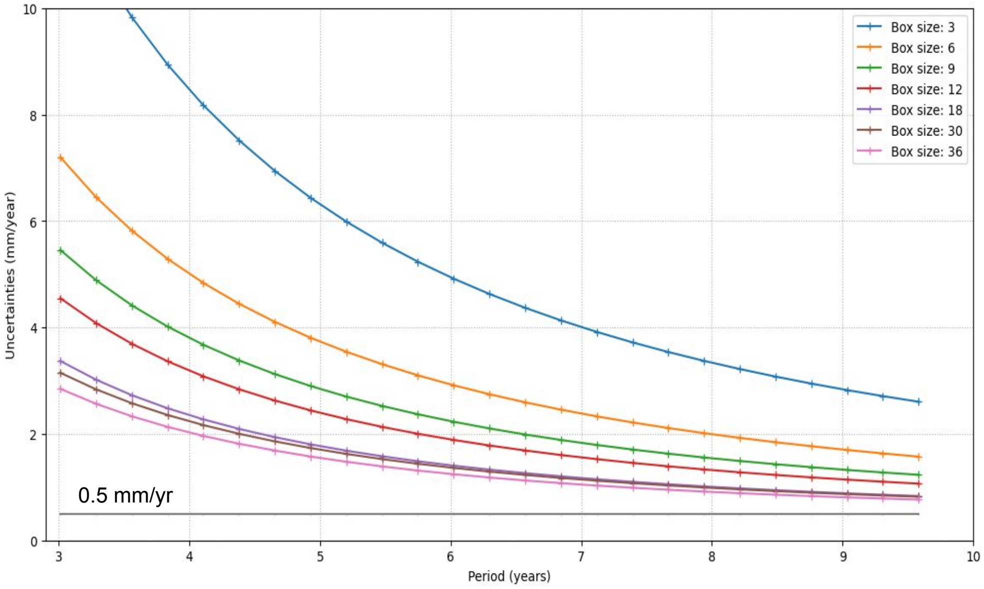
- Same method than the one used at global scale, based on (*Ablain et al., 2019*)
- HF and MF errors computed directly from regional MSL signals
- Low frequency (WTC) and long-term drift errors (orbit, GIA) values taken from *Prandi et al. 2020*

Source of errors	Error category	Jason-2/3 GMSL uncertainty level (1 σ)	GMSL differences Uncertainty level (at 1 σ)
High frequency errors: altimeter noise, geophysical corrections, orbits ...	Correlated errors (λ = 2 months)	location dependent	location dependent
Medium frequency errors: geophysical corrections, orbits ..	Correlated errors (λ = 1 year)	location dependent	location dependent
Low frequency errors: wet tropospheric correction (WTC)	Correlated errors (λ = 5 years)	location dependent	σ = 0 (model WTC error are cancelled between 2 missions)
Long-term drift errors: orbit	Drift error	δ = 0.33 mm/yr	δ = 0.33 * sqrt(2) mm/yr
GIA	Drift error	location dependent	δ = 0 mm/yr (GIA error is removed between 2 missions)

From Prandi et al. 2020 (submitted)

Regional MSL drift uncertainty

- Uncertainties evaluated for different box sizes and different time periods
- HF and MF variance is computed from S3/J3 but results for other missions are very similar
- Regional drifts under 2 mm/yr can be detected for time periods of over :
    - 4.5 years for box sizes >= 18°
    - 6 years for box sizes >= 12°
    - 8 years for box sizes >= 6°
- Regional drifts under 1 mm/yr can be detected for time periods of over 8 years for box sizes >= 18°
- The C3S requirement of detecting 0.5 mm/yr drifts at regional scale is not achievable using this method over a mission's life cycle.

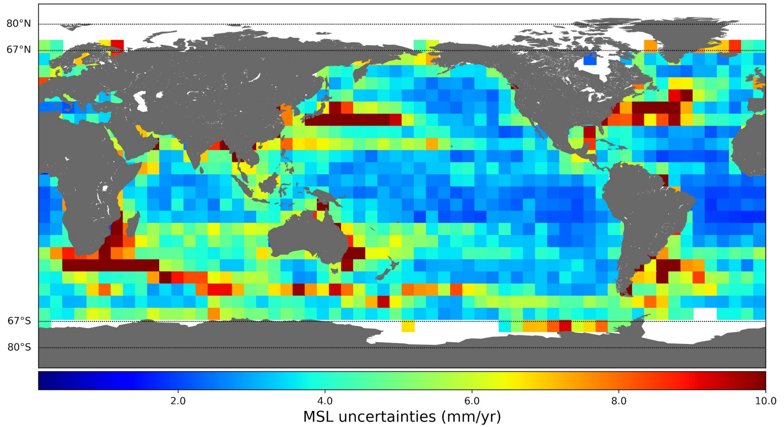


Evolution of uncertainties depending on the mission period for different box sizes (from 3°x3° to 36°x36°).

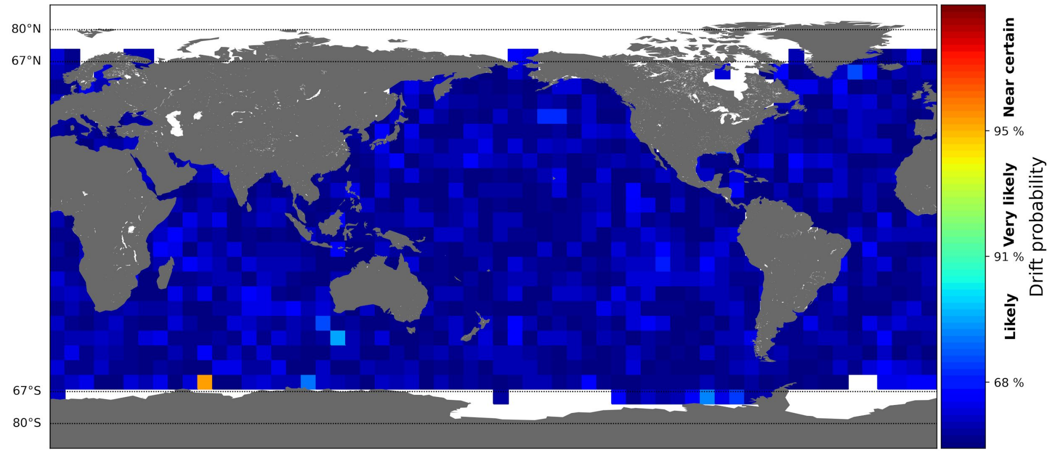
Regional MSL drift uncertainty

- Regional MSL drift and uncertainties, and drift probability are evaluated on S3A/J3, for box sizes of 6°, represented as deviation from the mean GMSL S3A/J3 drift.
- Zones with high computed drifts also have high drift uncertainties : simply a reflexion of high ocean variability in those zones.
- Method accuracy insufficient to detect regional drifts on S3A/J3.

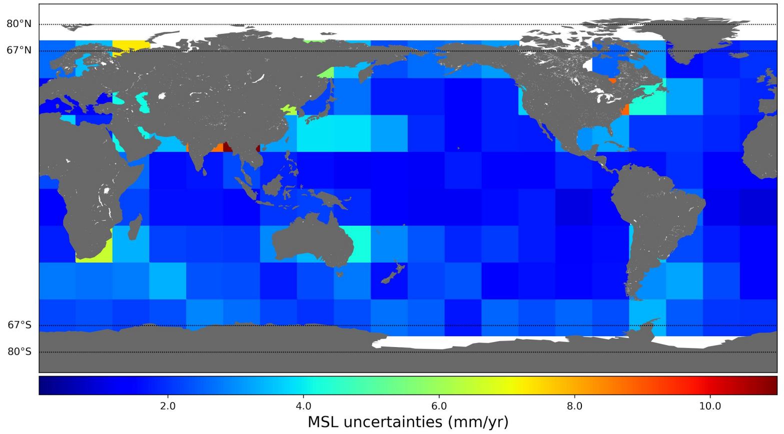
Regional MSL uncertainties Map: 6° boxes



Drift probabilities on s3a/j3 with 6° boxes



Regional MSL uncertainties Map: 18° boxes



Conclusion

➔ The GMSL comparison between recent altimeter missions highlights a significant S3A GMSL (based on SAR mode) drift from 07/2016 to 04/2020 compared to SARAL/Altika and Jason-3:

- +1.3 mm/yr with an uncertainty of 0.4 mm/yr (68% confidence level)
- no significant drift detected between Jason-3 and SARAL/Altika
- Cross-comparisons with S3B GMSL have also been performed but results must be consolidated.

➔ Our uncertainty estimation is sensitive to the error budget allocated especially at high frequencies and for short period lower than 3 years:

- An improved and more robust approach is contemplated in order to better estimate uncertainties over short periods of time and thus help detect drifts quicker.

➔ Regional scales :

- Regional drifts <= 1 mm/yr can be detected for time periods of over 8 years at 2000 km spatial scale
- Detection of drift lower than 0.5 mm/yr as expressed by C3S requirements is impossible at regional scale : **new calibration method must be foreseen to be able to verify this level of requirement (see Ablain presentation, error session or** https://www.essoar.org/doi/10.1002/essoar.10502856.1 **)**

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