Estimation and impact of Sentinel-3a GMSL drift on climate-driven studies

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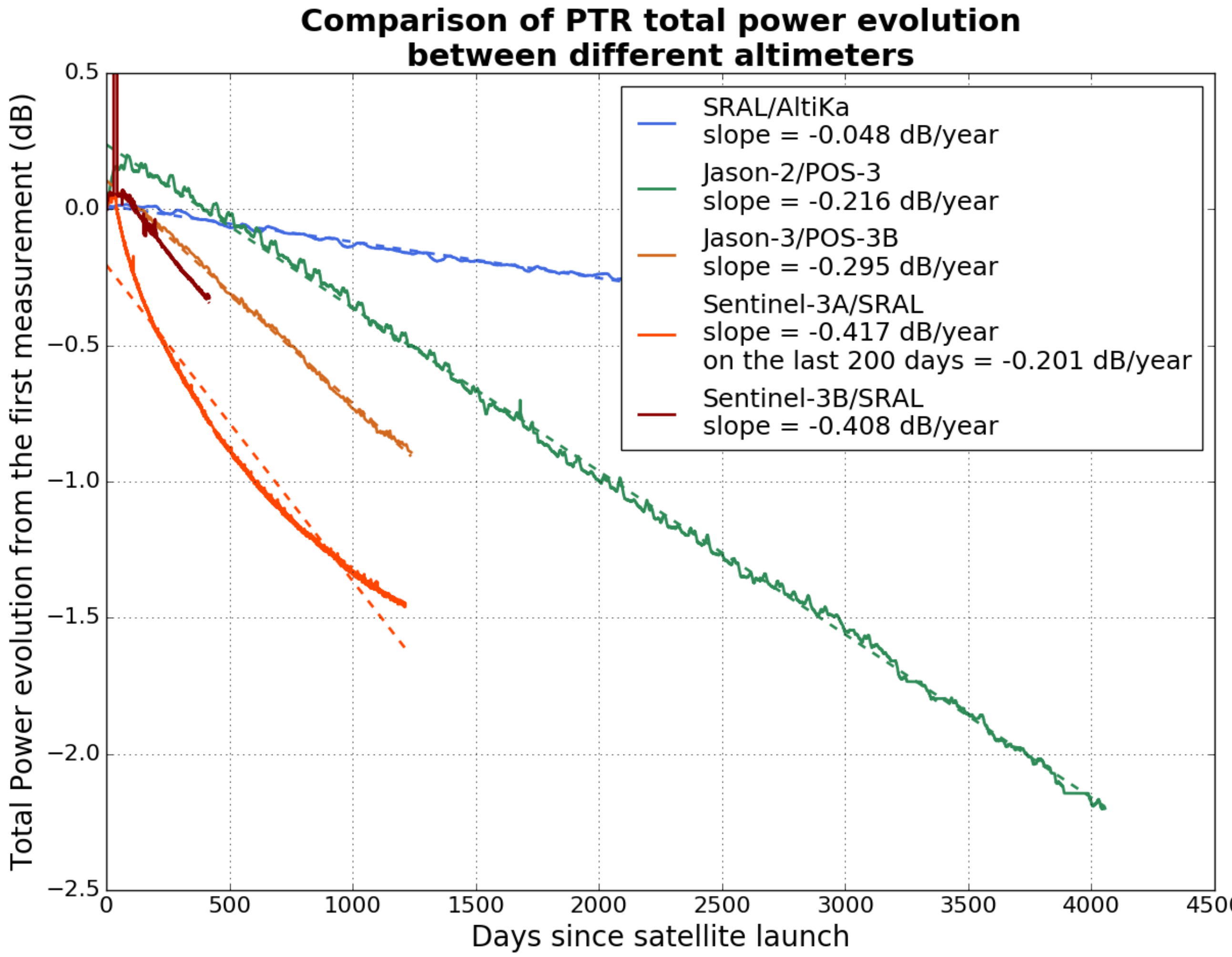
1) Overview

- ➔ PTRF drift detected on Sentinel-3a by altimeter experts

- ➔ Drift is stronger compared to other altimeter missions with a non-linear behavior: likely due to the SAR mode (higher energy, duty cycle)

- ➔ Impact on S3-a GMSL drift would be:
  - ◆ 0.3 mm/yr with SAR mode
  - ◆ 0.4 mm/yr with LRM mode



Courtesy of J.C. Poisson (CLS)

1) Overview

➔ Objective of this study:

- Analyse if the S3-a PTR drift is detectable in the S3-a GMSL timeseries
- Qualify its impact on climate-driven studies

➔ Main principle:

- Estimate the S3-a GMSL drift by comparison with other altimeter missions: Saral/Altika, Jason-3 and Jason-2.

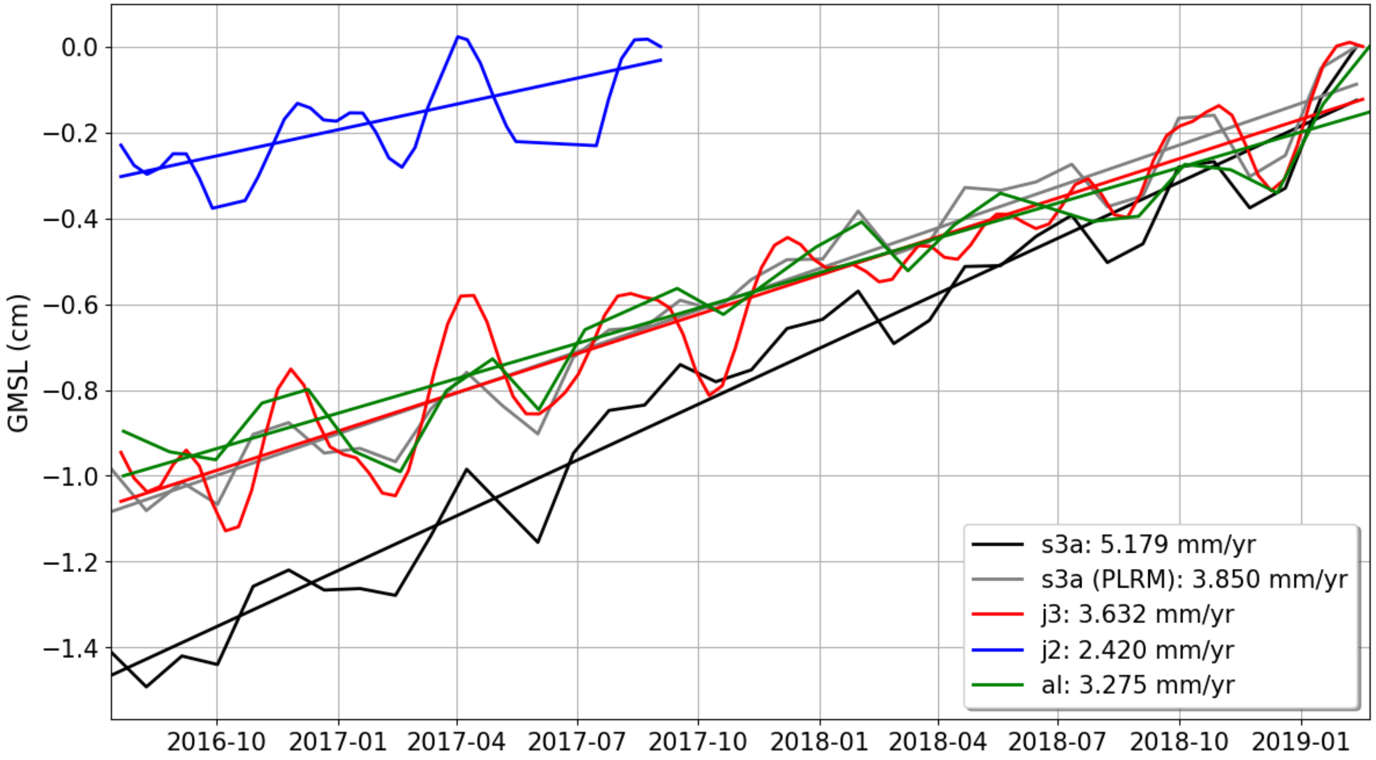
- Accurately calculate the associated uncertainties by a rigorous error budget approach

2) Method : GMSL calculation

- ➔ Relative GMSL drift calculation
  - ◆ GMSL AVISO method (lat <66°)

- ➔ from Marine L2P products (S3A - SAR mode, Saral/altika, Jason-3 and 2) with some updates:
  - ◆ update of S3A with PLRM altimeter parameters (Range, SSB, Iono)
  - ◆ use of model Wet Tropospheric correction for all the missions

- ➔ Comparison of GMSL time series after interpolation on the same time sample



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2) Method: Uncertainties calculation

➔ 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

Source of errors	Error category	Jason-2/3 GMSL uncertainty level (at 1 σ)
High frequency errors: altimeter noise, geophysical corrections, orbits ...	Correlated errors (λ = 2 months)	σ = 1.2 mm
Medium frequency errors: geophysical corrections, orbits ..	Correlated errors (λ = 1 year)	σ = 1 mm
Large frequency errors: wet troposphere correction (WTC)	Correlated errors (λ = 5 years)	σ = 1.1 mm (⟺ to 0.2 mm/yr for 5 years)
Large frequency errors: orbits (Gravity fields)	Correlated errors (λ = 10 years)	σ = 0.5 mm (⟺ to 0.05 mm/yr for 10 years)
Long-term drift errors: orbit (ITRF) and GIA	Drift error	δ = 0.12 mm/yr

GMSL Error budget (Ablain et al., 2019)

2) Method: Uncertainties calculation

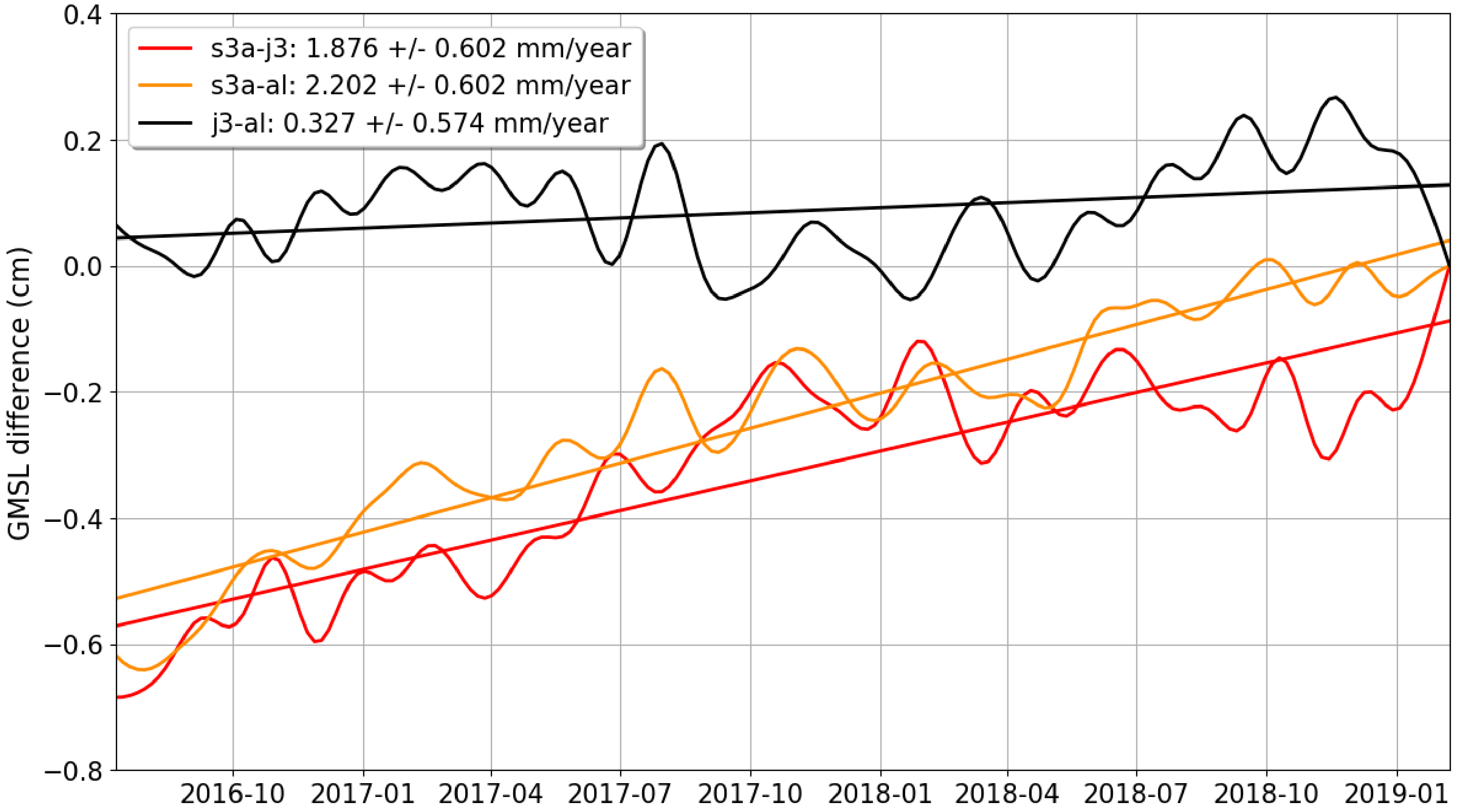
➔ "GMSL differences" error budget is derived from the GMSL one :

- some errors are reduced or cancelled

Source of errors	Error category	Jason-2/3 GMSL uncertainty level (at 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)
Large 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)
Large 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)

3) Analyses: GMSL trend differences : S3A (SAR) / JA3 / AL

- ➔ S3A (SAR) GMSL times series is compared to Jason-3 and SARAL/Altika on the same period :
  - ◆ [July 2016 - February 2019]

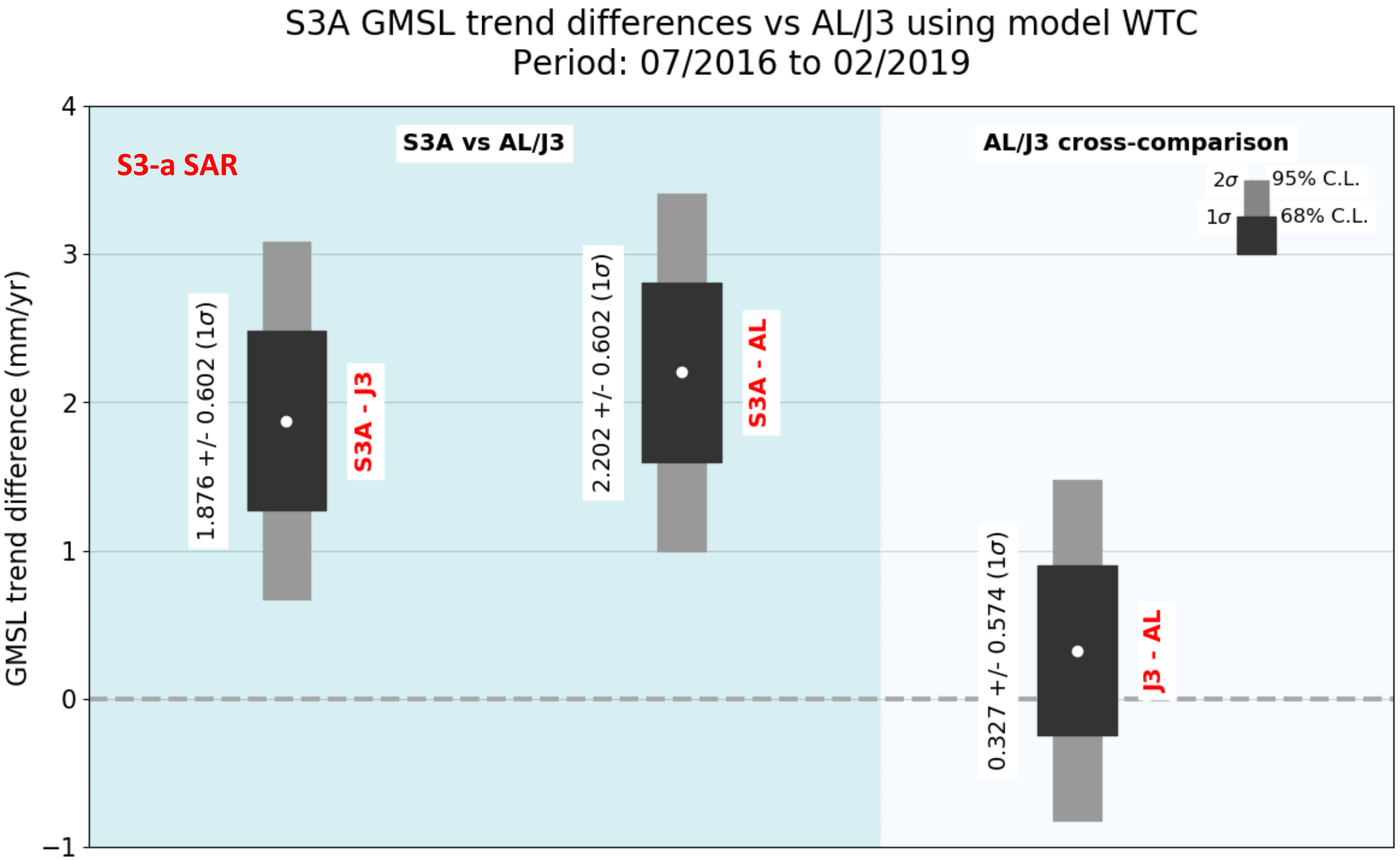


3) Analyses: GMSL trend differences: S3A (SAR) / JA3 / AL

- ➔ Significant relative drift detected on S3-a GMSL (SAR) within 95% confidence interval (CL) :
  - ◆ S3A- JA3= 1.9 ±1.2 mm/yr
  - ◆ S3A -AL = 2.2 ±1.2 mm/yr

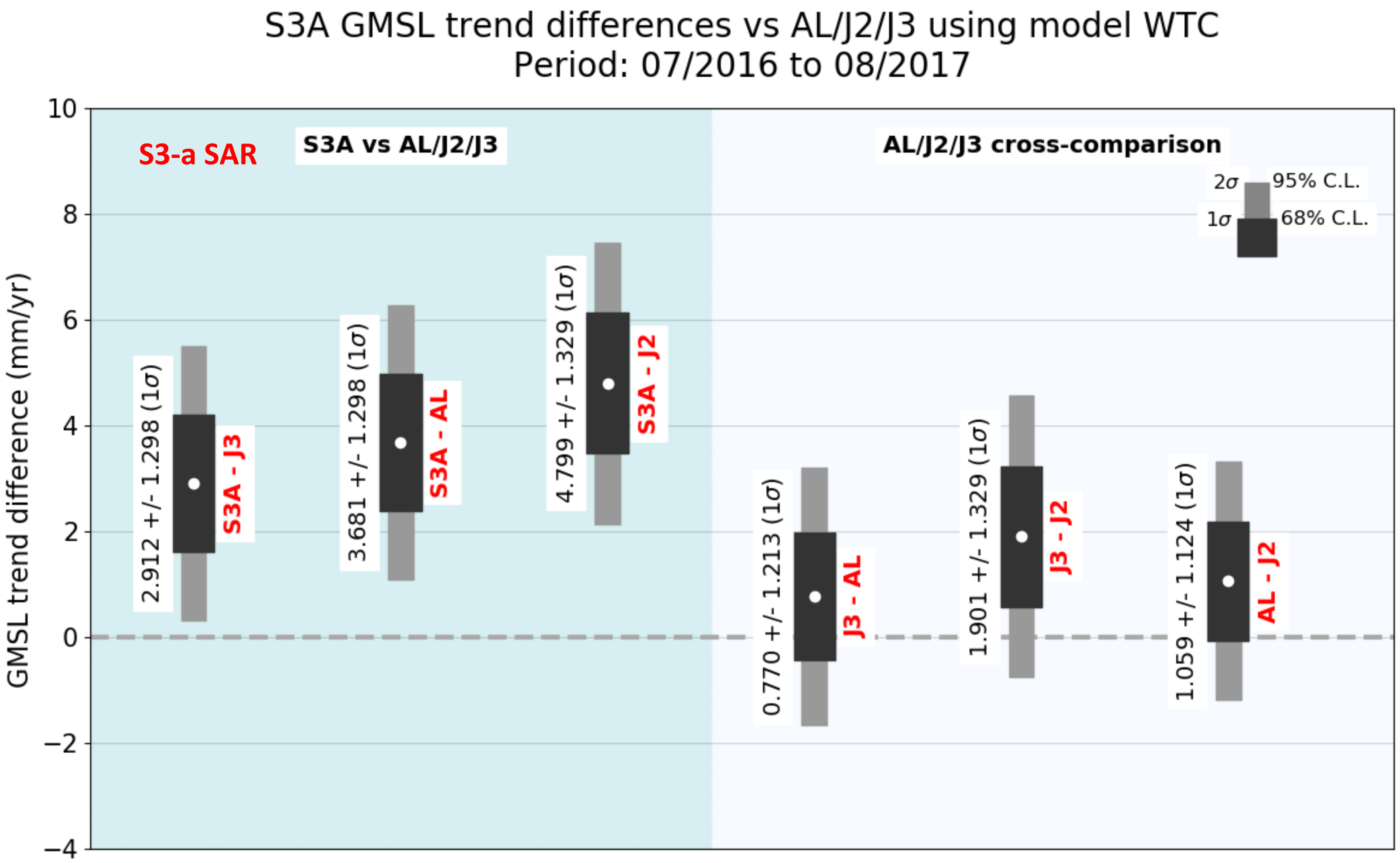
- ➔ No significant drift detected with JA3 and AL :
  - ◆ 0.3 mm/yr ± 0.6 mm/yr [68%]
  - ◆ 0.3 mm/yr ± 1.2 mm/yr [95%]

- ➔ The S3A (SAR) GMSL drift detected is much higher than the PTR drift sought: 0.3 mm/yr



3) Analyses: GMSL trend differences: S3A (SAR) / JA3 / AL /J2

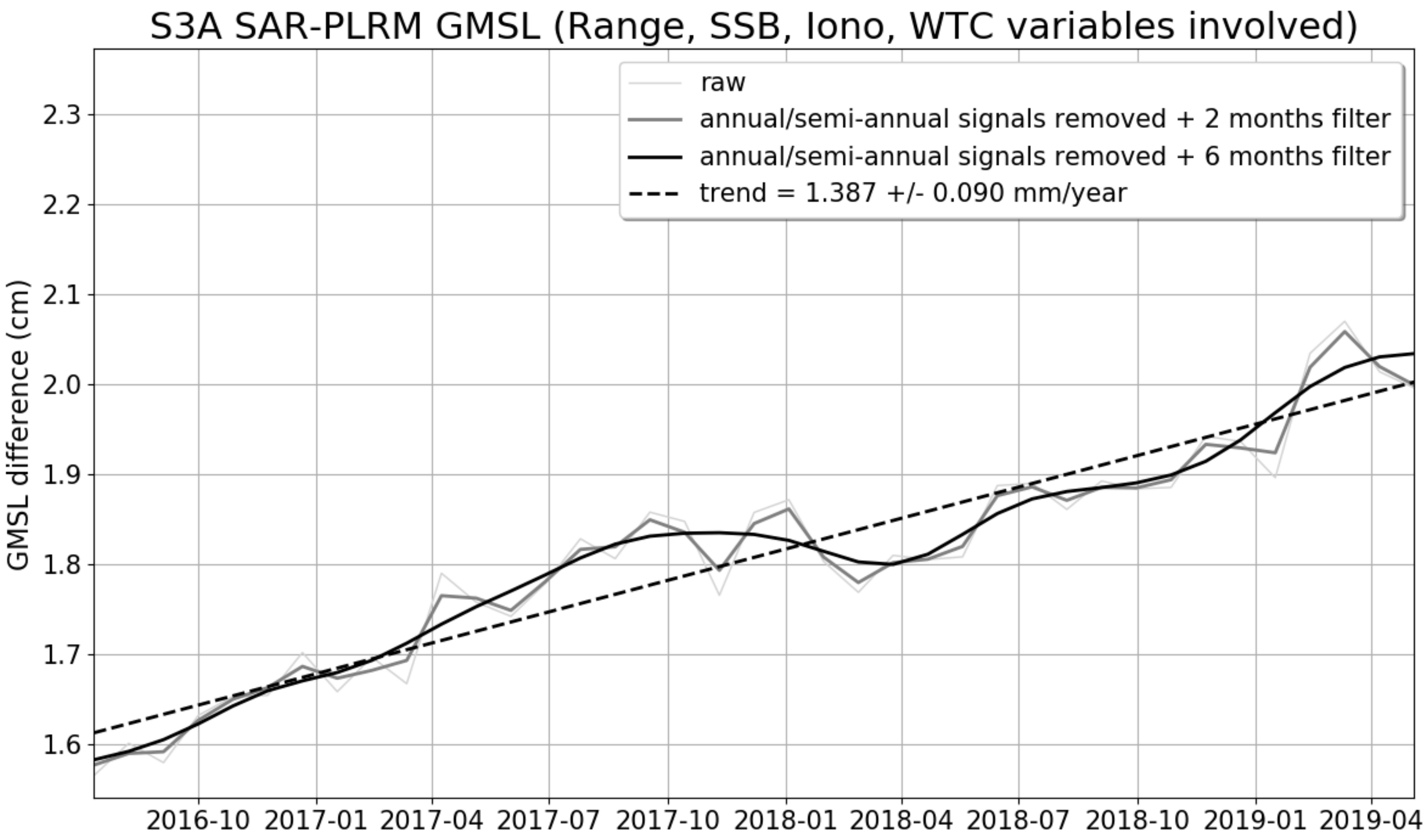
- ➔ Same analysis has been performed on S3A ∩ JA2 period :
  - ◆ [July 2016, August 2017]
- ➔ Significant relative drift is also detected on S3-a GMSL (SAR)
  - ◆ Uncertainties are higher (2.6 mm/yr, 95% CL) but S3-a drift is stronger and is still significant.
- ➔ No significant drift detected between JA3, JA2 and AL within a 90-95% confidence interval



3) Analyses: GMSL S3A SAR vs. PLRM

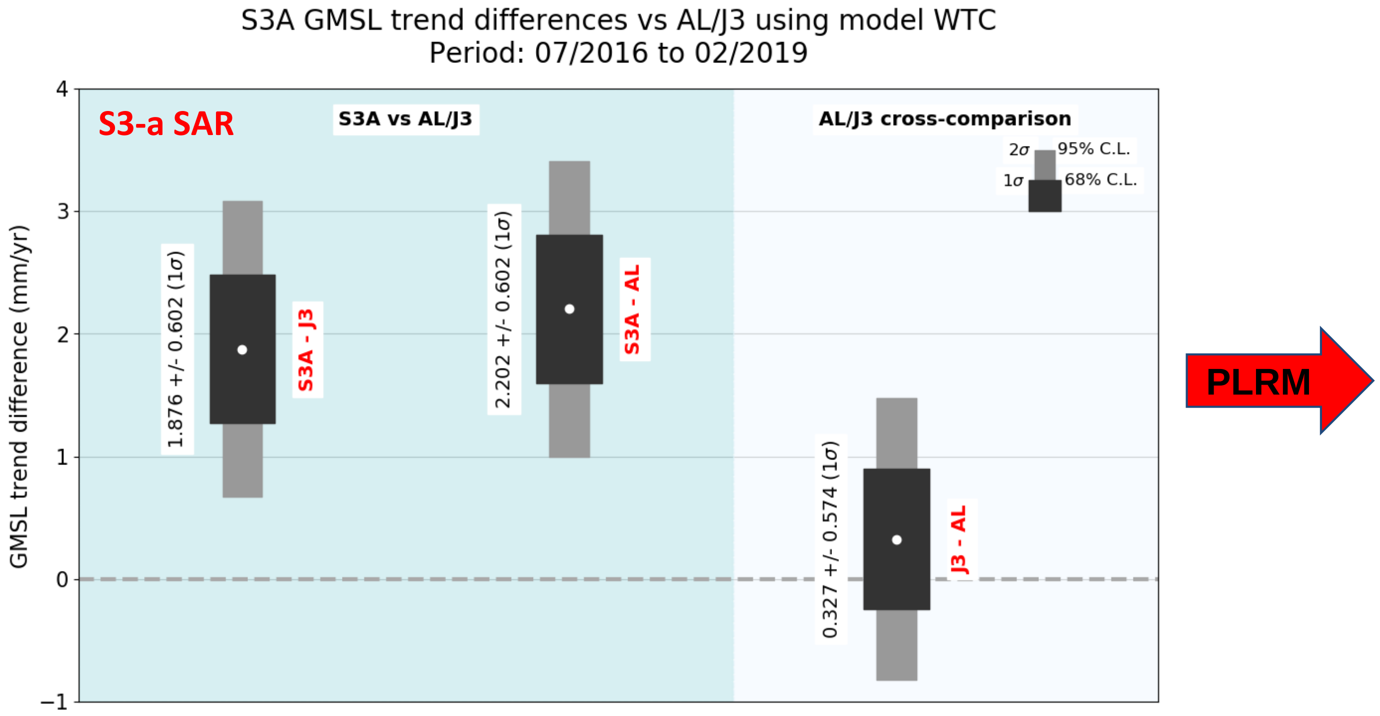
- ➔ Impact of using S3A PLRM altimeter parameters have been analyzed

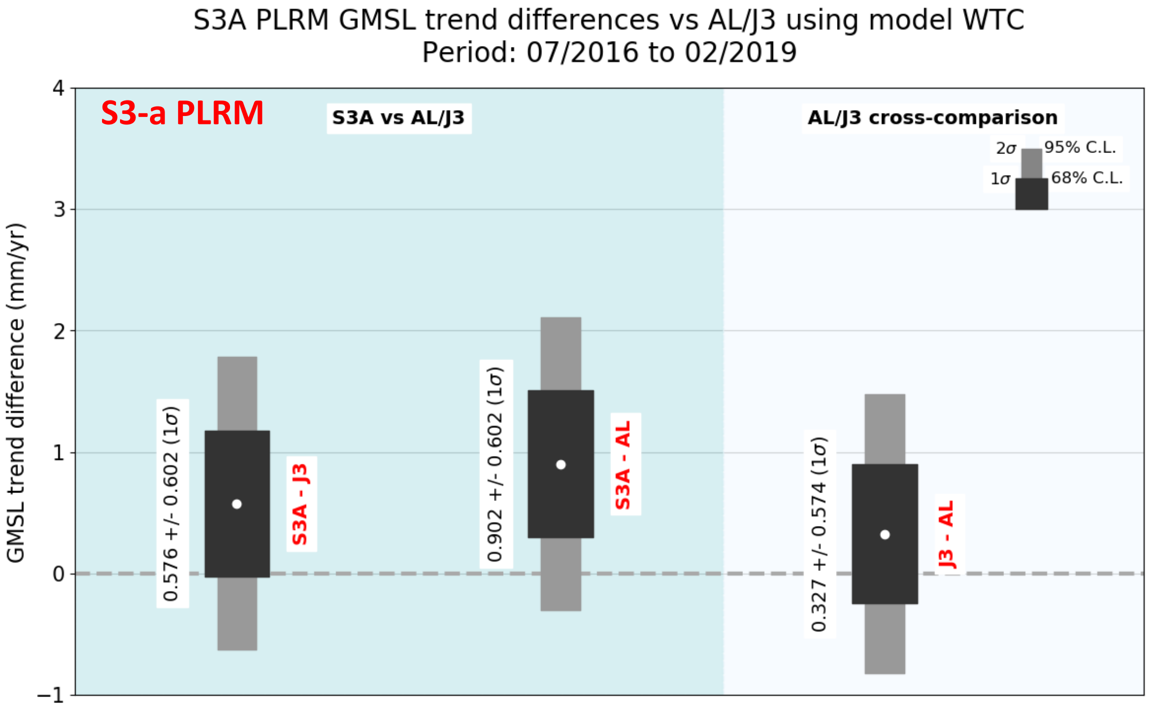
- ➔ Strong drift detected between GMSL in SAR and PLRM mode:
  - ◆ 1.4 mm/yr over all the S3-a period



➔ S3A GMSL drift with PLMR parameters is significantly reduced compared to the other missions :

- ◆ No significant drift detected for JA3 (95% CL) and ALTIKA (85% CL)

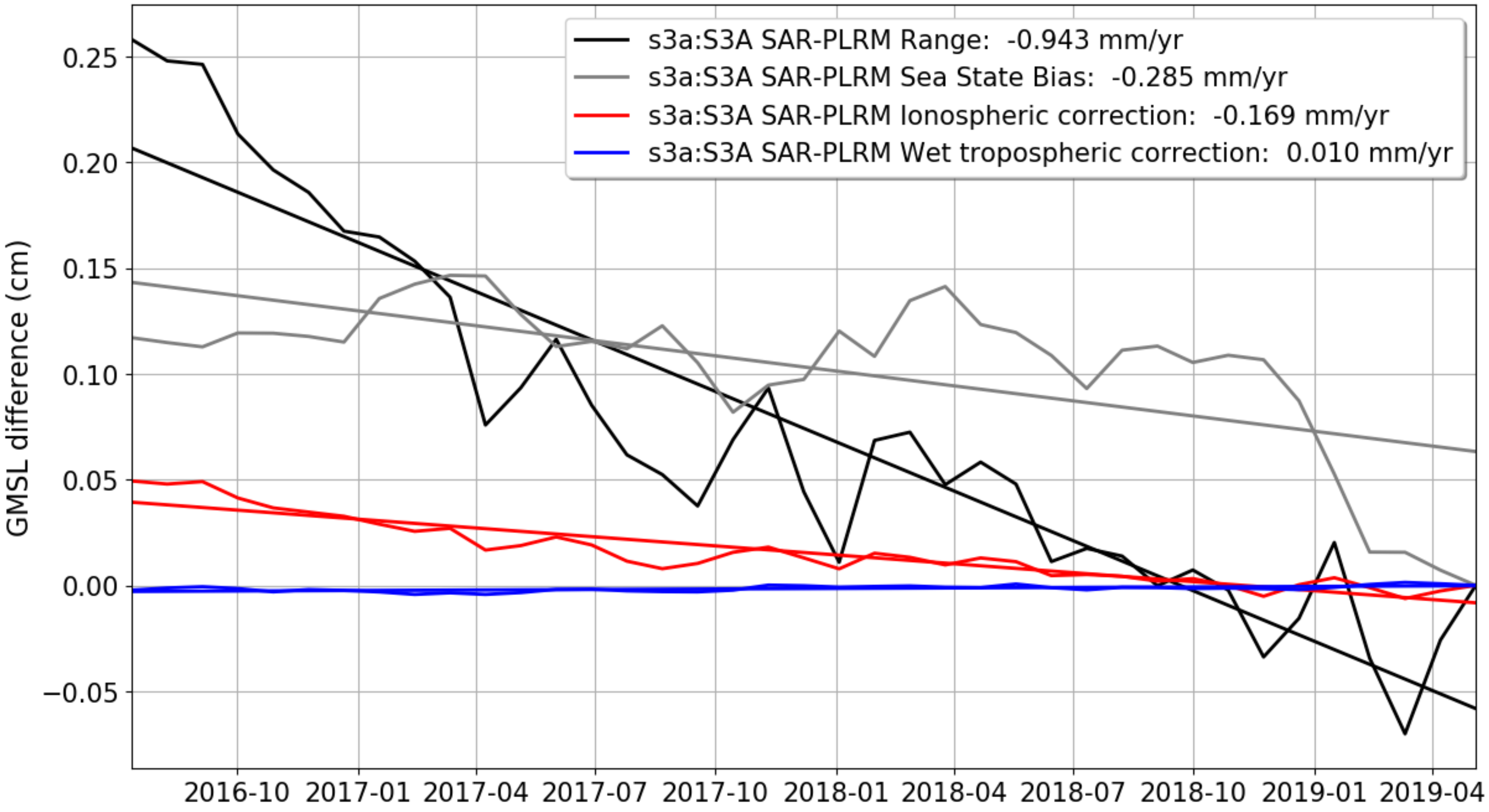




3) Analyses: GMSL S3A SAR vs. PLRM

- ➔ Impact of each PLRM parameter has been analyzed:
  - ◆ Range: -0.94 mm/yr
  - ◆ SSB: -0.28 mm/yr
  - ◆ Iono: -0.17 mm/yr
  - ◆ WTC: ~ 0.00 mm/yr

- ➔ Interannual variations observed on SSB



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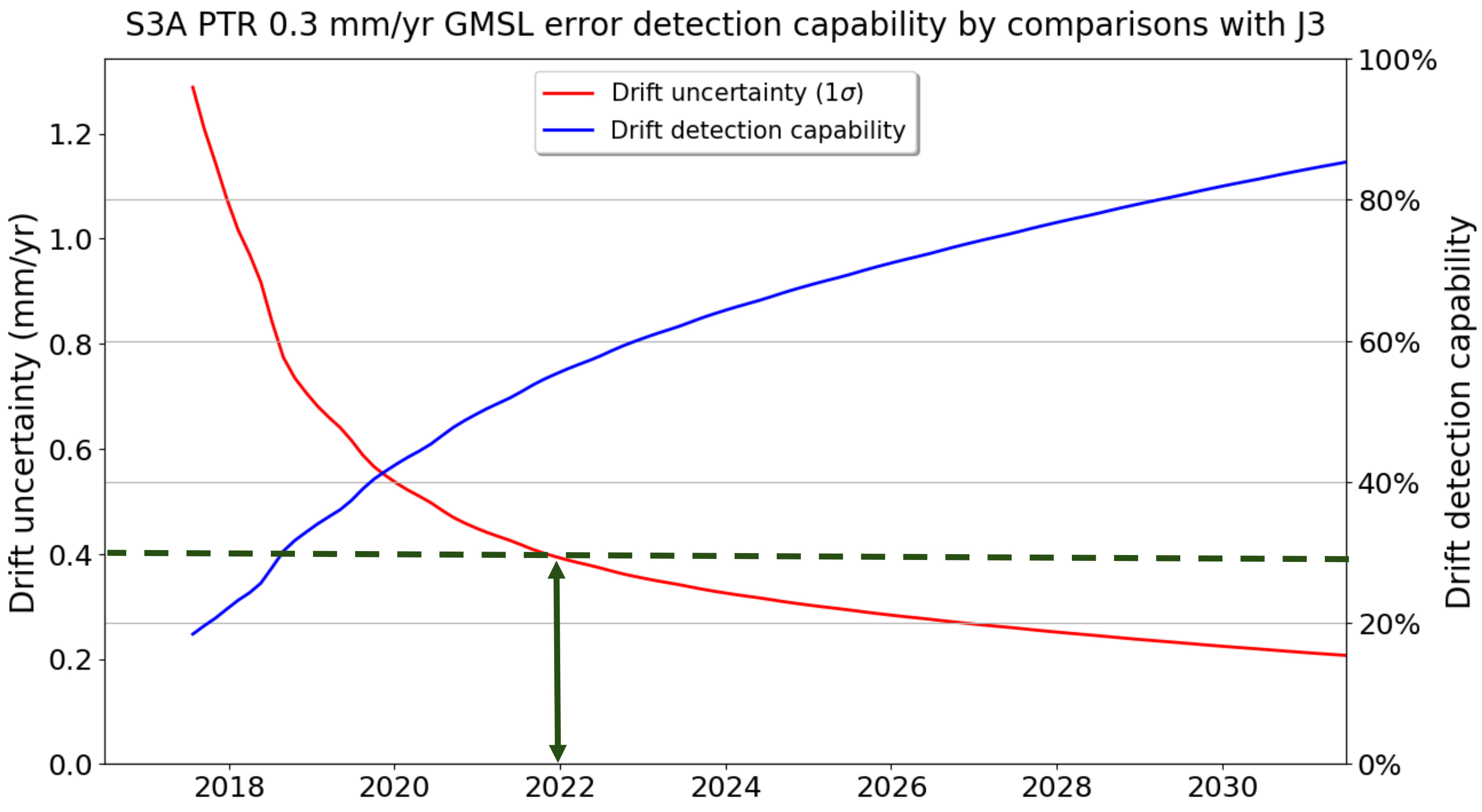
Conclusions (1/3)

1. The 0.3-0.4 mm/yr (PTR drift) sought on S3-a is not statistically detectable on a 3-year period.

➔ Uncertainties close to 0.6 mm/yr (1-σ) over a 3-year period (S3A)

➔ ~5 years (t ≥ 2022) is the minimum time required to detect such a drift



Conclusions (2/3)

2. A strong and significant drift of 1.9 - 2.2 mm/yr +/- 1.2 mm/yr within a 95% CL is detected on S3A **SAR** GMSL. No drift above 0.4-0.6 mm/yr detected using **PLRM** data.

➔ Some known limitations on PDGS S3A products data to date:

- PLRM is not strictly equivalent to LRM (pulse correlation), no SSB applicable to SAR or PLRM mode, wind dependency observed on SAR data, centering sensibility…

➔ GMSL S3A (SAR) drift is also detected with tide-gauges:

- Altit/TG = 2.4 mm/yr (A. Guerou, CLS)
- Uncertainty = +/- 2.0 mm/yr within a 68% CL (Ablain et., 2018)
- No relevant statistical drift detected with other altimeter missions

Conclusions (3/3)

➔ What would be the impact of such errors for climate-driven studies ?

Climate-driven studies	Uncertainties	
	Global scale	Regional scale
Closing the sea level budget and identifying the missing contributions	<±0.3 to ±0.1 mm/yr	<±1mm/yr
Constraining projections of future sea level rise and its contributions	<±0.2mm/yr	<±0.5mm/yr
Estimating the Earth energy imbalance and constraint the energy budget of the Earth	<±0.1mm/yr	<±0.5mm/yr

Ref : B. Meyssignac's talk, Plenary session

3. Impact of SAR and PTR errors on climate driven studies:
- 2 mm/yr GMSL drift error makes any climate-driven studies unfeasible
- 0.3-0.4 GMSL drift error makes some climate-driven studies difficult with significant degraded results that prevent relevant scientific analyses

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Thank you for attention

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OSTST recommendation : to be discussed

(1) Given the strong drift observed on S3A data in SAR mode, which is currently misunderstood:

(a) PLRM data must be used for S3A and S3B for any climate-oriented studies

(b) data for the future Sentinel-6 mission (2020) shall be provided with the LRM mode after careful validation, calibration and homogenization with the other missions at least for the delayed time (e.g. MARINE-L2P-DT product) in order to build an accurate climate data-record

(2) The correction of the PTR drift detected on the S3A data must be corrected by alternative methods to be defined (e.g. numerical retracking), in view of the Sentinel-6 mission launch if such a problem would also be detected.