Continuity of global and regional mean sea level data record

S6NG Orbit Workshop | Buelton,USA

OSTST, 16 November 2025

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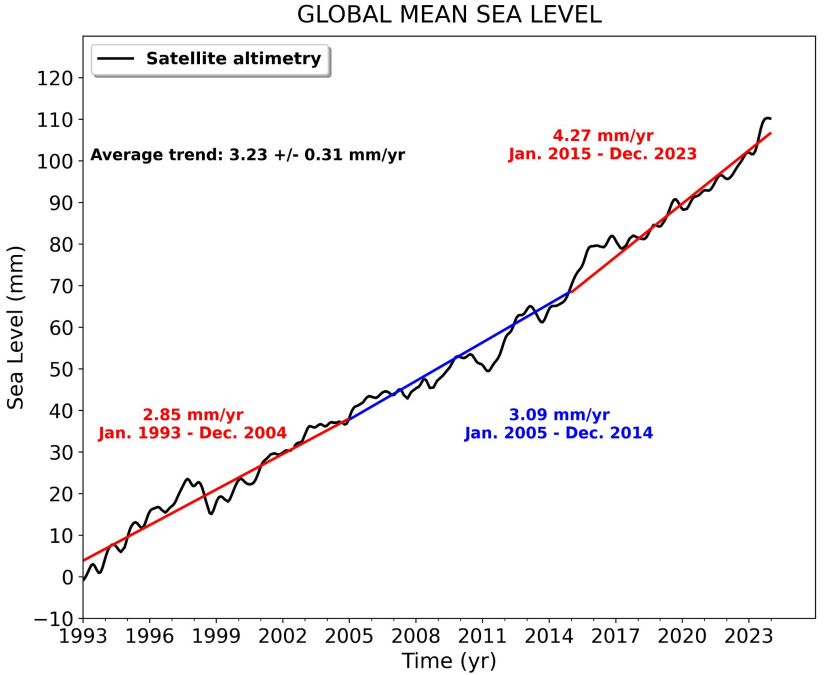
Overview

- **Altimetry missions** provide more than 30 years of precise, accurate, and continuous measurements thanks to the reference missions **in the same orbit:**
  - TOPEX/Poseidon, Jasons (1,2,3) and Sentinel-6 MF
- In the future, Sentinel-6B and Sentinel-6C will maintain this record into the next decade, followed by S6NG

- **Over the 01/1993 - 12/2023 period:**
  - GMSL trend is : +3.23 mm/yr ±0.31 mm/yr
  - GMSL acceleration is : +0.6 mm/yr/decade ±0.5 mm/yr/decade
  - Within a **[5%,95%] confidence interval**

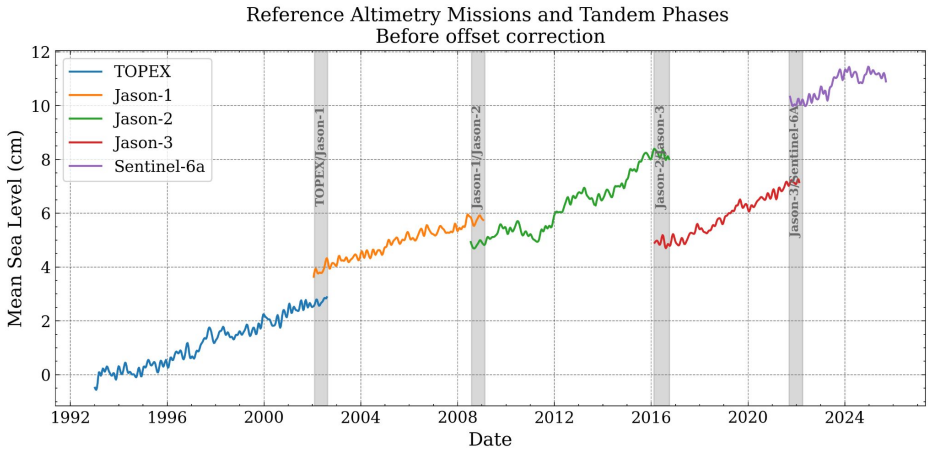


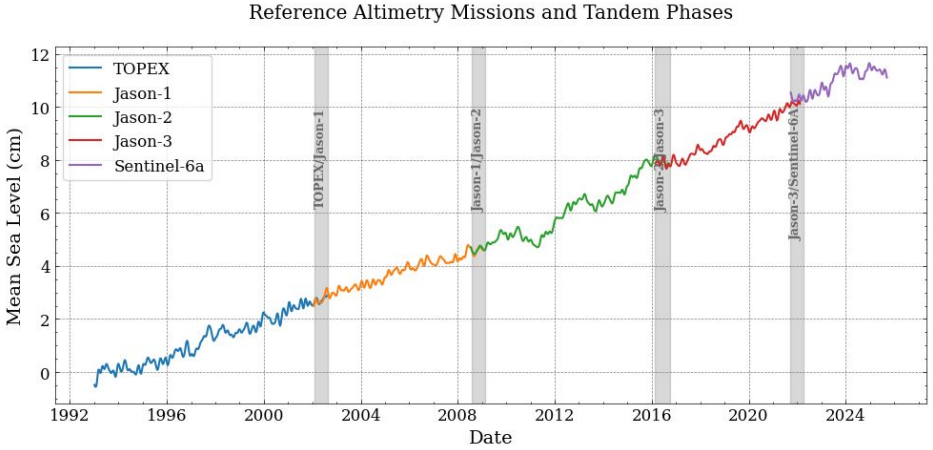
*From C3S sea level gridded products (**vDT2024**)*

Update from Cazenave et al., 2023

How to ensure continuity?

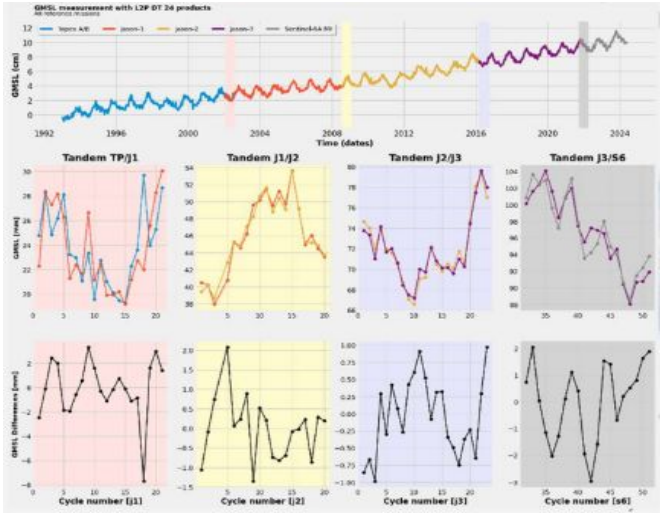
- ➔ Continuity between successive missions is essential to maintain the stability of the mean sea level record
- ➔ **Tandem flight phase** is the most effective method to ensure cross-calibration
- ➔ During a tandem phase, two reference satellites fly less than one minute apart on identical ground tracks, allowing precise detection of any systematic instrumental errors
- ➔ Tandem phases have been implemented for all reference mission (TP/J1, J1/J2, J2/J3, J3/S6MF)





Global mean

➔ GMSL offsets uncertainties : Global offset uncertainty: **0.2 – 0.6 mm** (1-σ)



Quet V., Cal/Val Workshop in Crête, 2025, Sea Level Stability Uncertainty Budget: Latest improvements and impacts on the GMSL

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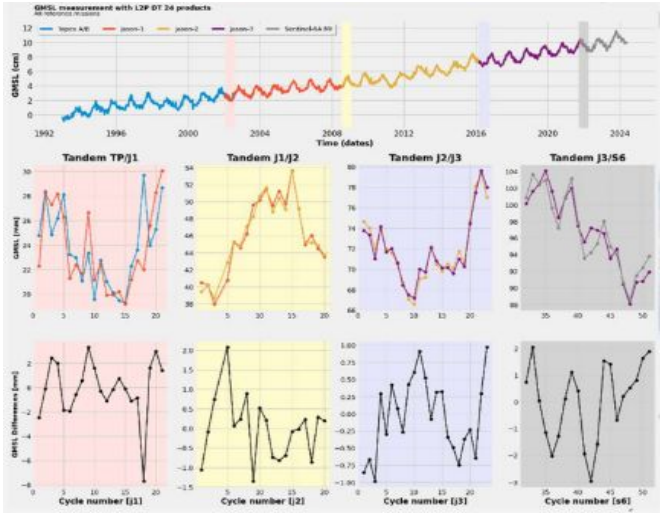


$$\overline{X} = \overline{x} \pm t_{1-\alpha/2}^{n-1} \frac{s}{\sqrt{n}}$$

with *s* the standard deviation of the sample ; *n* the number of independent measurements of the sample ; *t* the Student coefficient for n − 1° of freedom and a confidence level of α

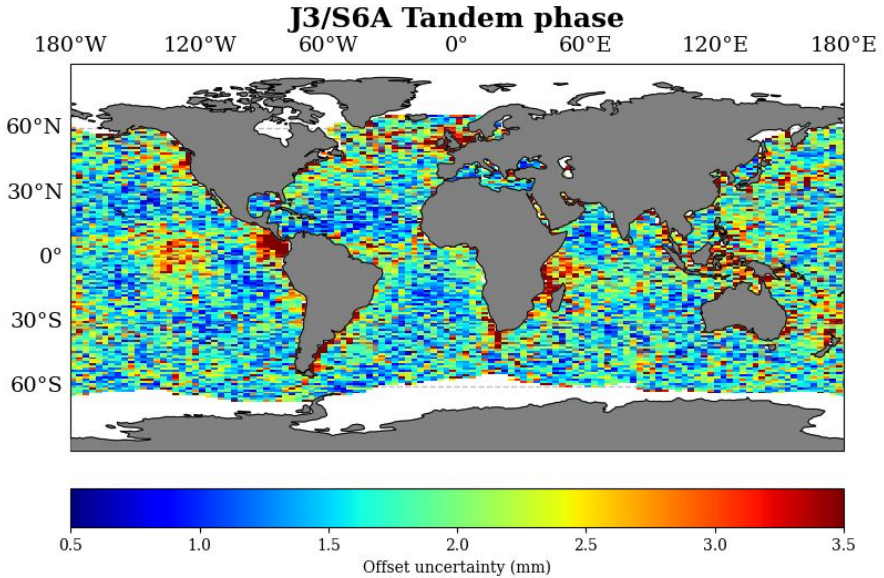
Missions	Offset (mm)	Uncertainty (mm) at 1σ
TP / Jason-1	11.6	0.6
Jason-1 / Jason-2	2.3	0.2
Jason-2 / Jason-3	-29.7	0.3
S6A / Jason-3	-2.1	0.4

Quet V., Cal/Val Workshop in Crete, 2025, Sea Level Stability Uncertainty Budget: Latest improvements and impacts on the GMSL

Lalau et al. 2025, outcomes from the ESA-supported ASELSU project (www.aselsu.org)

Regional scales

➔ Regional (a few hundred km) MSL offsets uncertainties : 2 mm (1-σ), $CI_{95\%}$=[0.7 - 4.3]



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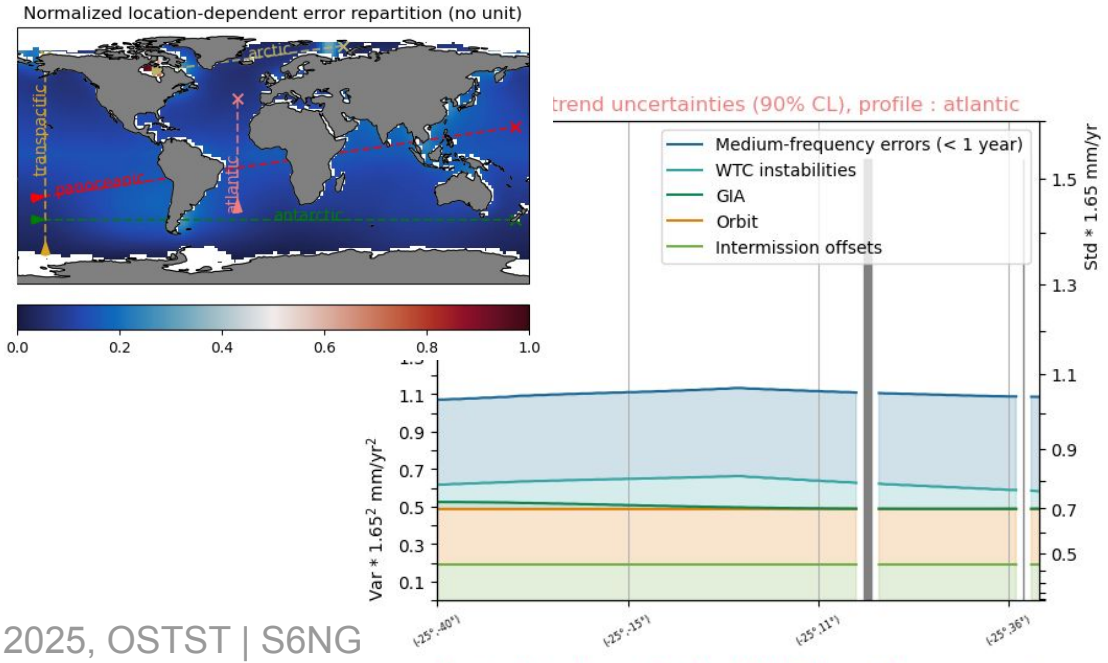
Contribution to GMSL & RMSL trend uncertainty

Impact of MSL offset uncertainties on MSL trend uncertainties with tandem phases:

- ➔ Global MSL (GMSL) trend uncertainty: **< 0.03 mm/yr** over 10 years (90 % CL)
- ➔ Regional MSL (RMSL) trend uncertainty: **< 0.5 mm/yr** over 20 years (90 % CL)



- ➔ Requirements:
  - 0.1 mm yr^{-1} over 10 years on the GMSL trend
  - 0.3 mm yr^{-1} over 20 years on the RMSL trend

Orbit change impact

- The S6NG orbit may change, making a classical tandem phase impossible
- This raises concerns about continuity of the global and regional sea level record

Missions	Along-track offset uncertainty (mm)			
	Spatial		Global	
	Tandem	Outside a tandem	Tandem	Outside a tandem
TP / Jason-1	**3** [1.12; 7.04]	**23** [2.79; 78.78]	**0.6**	**0.8**
Jason-1 / Jason-2	**2.7** [0.94; 7.09]	**23** [3.51; 85.73]	**0.2**	**0.4**
Jason-2 / Jason-3	**2** [0.77; 4.72]	**23** [3.01; 92.76]	**0.3**	**0.3**
Jason-3 / Sentinel-6A	**2.2** [0.88; 4.73]	**25** [2.93; 88.01]	**0.4**	**0.4**

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S3A / S6A	**-**	**13** [3.36; 36.91]	**-**	**0.6**

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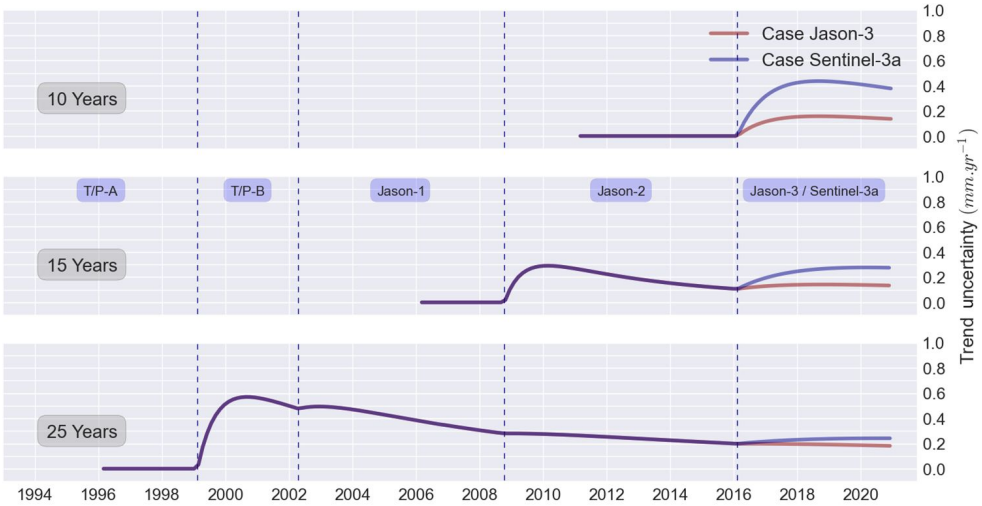

Zawadzki & Ablain, 2016
https://doi.org/10.5194/os-12-9-2016

Example study of tandem phase impact using synthetic Jason-3 and Sentinel-3A data:

- ➔ Offset uncertainty impact on GMSL trend over a 10-year period
- ➔ 0.15 mm/yr with tandem phase
- ➔ **0.4 mm/yr** without tandem phase
- ➔ Requirements: **0.1 mm yr^{-1}** over 10 years on the global MSL trend

Conclusion

- ➔ We have built and maintained a uniquely stable global sea level record for over 30 years
- ➔ With the tandem phases, we have ensure precise continuity with reduced impact on MSL trend uncertainties:
  - ◆ Global offset uncertainty: **0.2 – 0.6 mm** (1-σ)
  - ◆ Regional (a few hundred km) MSL offsets uncertainties : **2 mm** (1-σ), $CI_{95\%}$=[0.7 - 4.3]
  - ◆ Impact on GMSL trend uncertainty: < 0.03 mm/yr over 10 years (90 % CL)
  - ◆ Impact on RMSL trend uncertainty: < 0.5 mm/yr over 20 years (90 % CL)
- ➔ The potential Sentinel-6 Next Generation orbit change challenges the way we ensure this continuity
- ➔ ESA-supported **ORBITAS study** aims to assess the impact of the S6-NG orbit change, including on the continuity of global and regional sea level measurements
- ➔ Objectives:
  - ◆ Quantify the potential continuity loss under several S6NG orbit scenarios
  - ◆ Evaluate alternative calibration strategies, to mitigate the impact of orbit change