OSTST 2026

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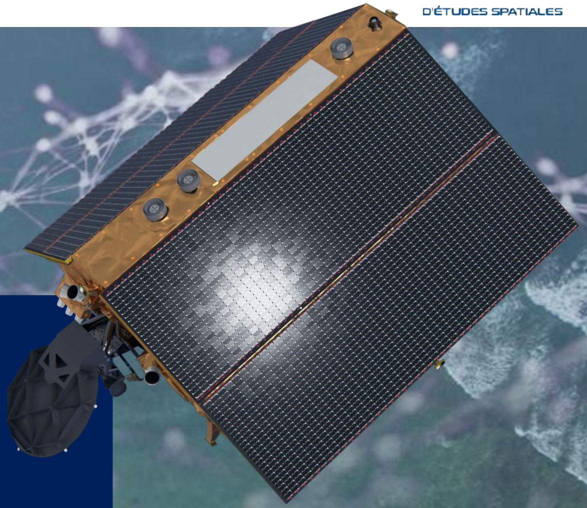

Summary

Workshop on the Sentinel-6 Next Generation’s orbit - Summary

Session chairs:
Alexandre Couhert , CNES, France
Michaël Ablain, Magellium, France

IN PARTNERSHIP WITH NASA NOAA JPL esa

Workshop objectives

- ➔ ESA is considering lowering the S6NG satellite's orbit up to 800 km with a higher inclination :
  - ◆ **Benefits :** Facilitate deorbiting and reduce mission costs , Potentially extending the mission's lifespan from 5 to 7.5 years, Reduces the satellite's exposure to radiation, …Access to the Arctic ocean.
  - ◆ **Challenges :** Impact on the continuity assessment with no tandem phase with the current Sentinel-6 mission, Potential impact on the accuracy and stability of orbit determination, environmental corrections and other unknown effects
- ➔ A **first S6NG orbital workshop** was held in November 2025 (OSTST, Buelton, US), by Benoit Meyssignac and Detlef Stammer :
  - ◆ The objective was to present and improve the work plan to assess the impact of a new S6NG reference orbit on the mean sea level stability uncertainty budget.
- ➔ The aim of this **second workshop** was to present the preliminary results obtained from the ESA ORBITAS study and external studies.

Agenda

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14:00 - 14:20	Preliminary results on the ESA-supported S6NG orbital study (ORBITAS)	Ablain M. et al.
14:20 - 14:40	Selection of alternative orbits for S6NG in the context of ORBITAS study	Carrere L. et al.
14:40 -15:00	Quantifying mean sea level inter-mission offset uncertainties for different S6NG orbit scenarios	Lalau N. et al.
15:00 - 15:20	Investigating differential POD related effects on Jason 3 and Sentinel 3	Quet V. et al.
15:20 - 15:40	Mean sea level stability uncertainties due to environmental corrections in the context of S6NG alternative orbits (ORBITAS)	Marlier G. et al.
15:45 - 16:15	**Coffee break**	
16:20 - 16:40	Quantifying oceanic variability sampling effects in S6NG sea level rise stability uncertainty for various orbit scenarios	Lalau N. et al.
16:40 - 17:00	Arctic contribution to GMSL trends and uncertainties	Mangini F. et al.
17:00 - 17:20	In Situ Verification of the Satellite Radar Altimeter Record: Unified Results from Dedicated Monitoring Sites.	Bonnefond P. et al.
17:20 - 17:40	Assessment of the Sea Level Rise Stability Uncertainty Budget of Non-Reference Altimetry Missions	Kern L. et al.
17:40 - 18:00	Discussions / Adjournment	

ORBITAS summary : approach

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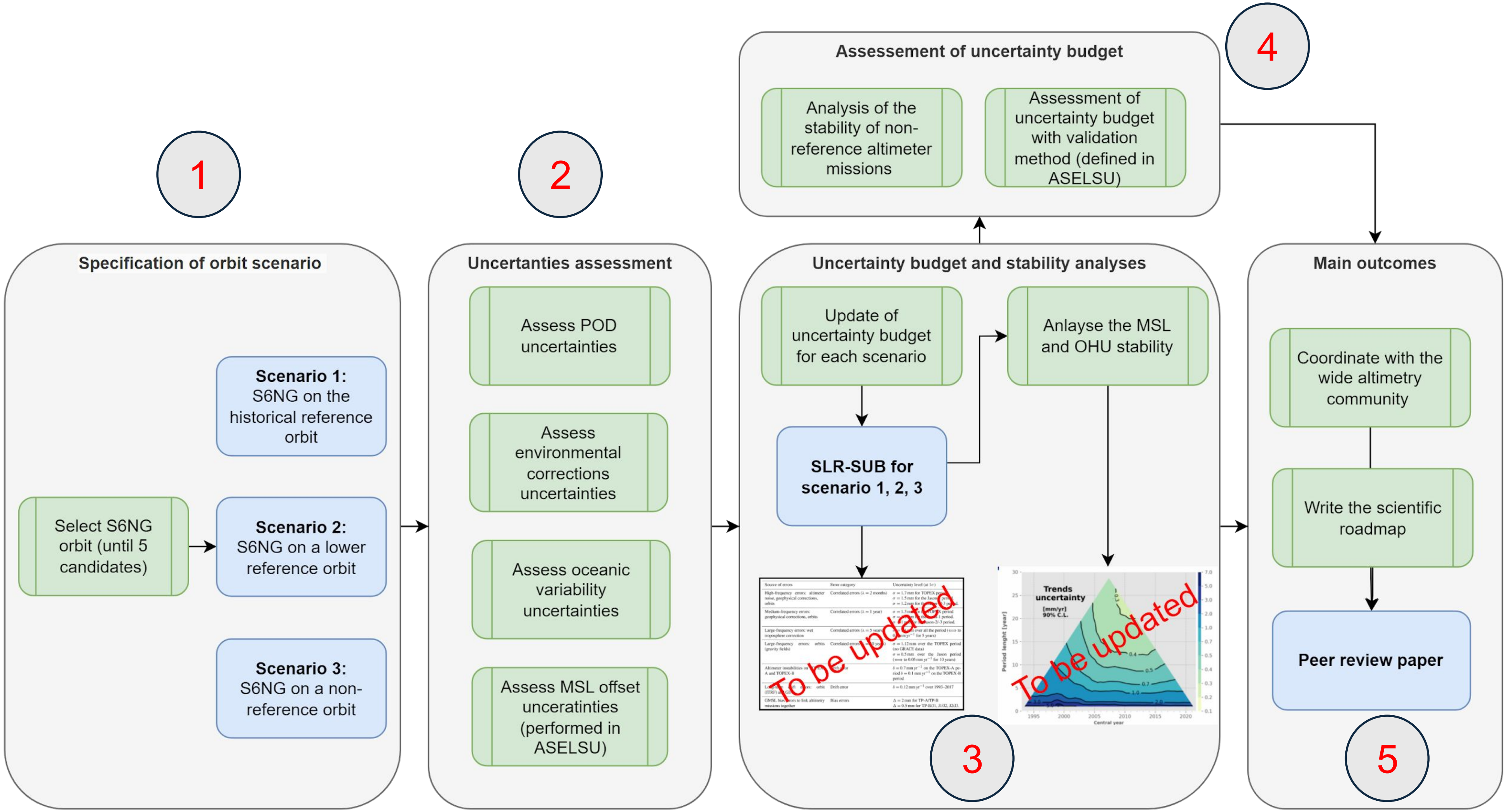
➔ **Primary objective** of the S6NG orbital study (so-called ORBITAS): evaluate how a new reference orbit for S6NG will impact the **mean sea level uncertainty budget** and ensure the mission still meets the scientific requirements for stability.



ORBITAS summary : S6NG orbit selection

1

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➔ **5 alternative S6NG orbits are selected** :

- on tidal aliasing and geometric criteria
- ensuring a diverse mix of orbital parameters and performances
- 1 year of ground track has been produced on 2023
- phased on the same ascending longitude (99.9242°) at the Equator as S6A.
- Ground tracks for S6NG orbits' candidates are available for downloading for any independent analyses.

	Altitude (km)	Inc (deg)	Exact repeat (days)	Sub-cycle (days)	Criteria
A878_i66_c10	878.781	66	9.90203376669	1	Similar to S6A
A1150_i72_c11	1150.363	72	10.91793059818	5	Higher altitude
A801_i71_c22	801.813	71	21.810664645814	7	Lower altitude
A1104_i76_c16	1104.847	76	15.895743501366	3	Higher inclination
A926_i67_c13	926.487	67	12.878227217757	4	Best score
S6A	1336.299	66	9.9156470	3	

See Loren Carrere's slides for more information

ORBITAS summary : assess continuity

2

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➔ **Main preliminary results :** Without a tandem phase between S6B and S6NG, MSL offset uncertainties are mainly increased at regional scales (see table below) :

- Ocean variability differences between two altimetry missions on different orbits is the primary cause
- Uncertainties are reduced extending the MSL offset calculation over a longer time period (feasible outside a tandem phase)
- Similar results for the all the alternative S6NG orbits

➔ **Future work :** to consolidate uncertainty assumptions (POD, oceanic variability…)

Orbit configuration	GMSL offset uncertainty at 1-σ	
	over a 1-year period	over a 5-year period
S6NG / Ref (no tandem phase)	0.74 to 0.95 mm	0.62 to 0.71 mm
Ref / Ref (tandem phase)	0.20 mm	-

Orbit configuration	Regional MSL offset uncertainty at 1-σ over 100x300 km (median $[P_{16}, P_{84}]$)	
	over a 1-year period	over a 5-year period
S6NG / Ref (no tandem phase)	18.0 to 20.5 mm [9.9, 39.7]	12.2 to 13.7 mm [6.7, 27.3]
Ref / Ref (tandem phase)	1.8 mm [1.3 ; 2.1]	-

See Noémie Lalau's slides for more information

ORBITAS summary : POD effects 2

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➔ **Main results :** Analyzed of POD effects due to the orbit change by comparing Jason-3 and Sentinel-3A for three components: ITRF realisation (antenna positions), gravity model and geocentre movement model.

- Negligible differences of uncertainties amplitudes between JA-3 and S3A orbits regarding ITRF and geocenter motion model at global scale
- More important impacts locally (~100x300 km² scale) essentially from the gravity field with a lower altitude.

➔ **Future work :** Absolute validation of regional GNSS-based orbit accuracy using independent SLR/DORIS observations

POD Uncertainty budget at global mean

Source of uncertainties		Temporal structure of errors	Uncertainties (1-sigma)	
			Ja3	Sent3
POD	Reference frame orientation & scale (ITRF)	short-term time-correlated effects at 1 yr	u_σ = 0.2 mm	u_σ = 0.2 mm
		Linear time-correlated effects	u_σ = 0.03 mm/yr	u_σ = 0.04 mm/yr
	Reference frame origin (Geocenter motion)	short-term time-correlated effects at 1 yr	u_σ = 0.1 mm	u_σ = 0.1 mm
		Linear time-correlated effects	u_σ = 0.01 mm/yr	u_σ = 0.01 mm/yr
	Gravity field model	short-term time-correlated effects at 1 yr	u_σ = 0.03 mm	u_σ = 0.07 mm
		Linear time-correlated effects	u_σ = 0.01 mm/yr	u_σ = 0.01 mm/yr

POD Uncertainty budget at regional scales

Source of uncertainties		Temporal structure of errors	Uncertainties (1-sigma)	
			Ja3	Sent3
POD	Reference frame orientation & scale	Linear time-correlated effects	u_σ = 0.2 mm/yr Up to ~1.5 mm/yr locally (99%)	u_σ = 0.2 mm/yr Up to ~2.5 mm/yr locally (99%)
	Reference frame origin (geocenter motion)	Linear time-correlated effects	u_σ = 0.1 mm/yr Up to ~1 mm/yr locally (99%)	u_σ = 0.1 mm/yr Up to ~2 mm/yr locally (99%)
	Gravity field model	Linear time-correlated effects	u_σ = 0.07 mm/yr Up to ~1 mm/yr locally (99%)	u_σ = 0.12 mm/yr Up to ±2 mm/yr locally (99%)

See Victor Quet's slides for more information

ORBITAS summary : environmental effects 2

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➔ Impact of changing the S6NG orbit on MSL stability due to environmental corrections is small based

➔ MSL trend uncertainties over 10 years (1-sigma) at local scales due to :

- **Ocean tide effects** are small and very similar for the alternative S6NG orbit between ranging 0.07 and 0.18 mm/yr
- **DAC effects** are slightly higher, very still very similar most of the alternative S6NG orbit between ranging 0.45 and 0.63 mm/yr, excepted for the S6NG orbit - A801_i71_c2 with lower uncertainties : 0.28 mm/yr (to be consolidated)
- **DT effects** are very small and also very similar for the alternative S6NG orbit ranging from 0.05 to 0.07 mm/yr

➔ Future work : to propagate uncertainties from input data for ocean tide and DT corrections.

Orbits		A878_i66_c10	A1150_i72_c11	A801_i71_c22	A1104_i76_c16	A926_i67_c13	Ref. S6
Uncertainty (mm/yr) at 1- sigma over 10 years	due to ocean tide effects	0.10	0.07	0.18	0.07	0.05	0.14
	due to DAC effects	0.43	0.50	0.28	0.63	0.59	0.51
	due to DT effects	0.05	0.05	0.06	0.06	0.07	0.06

See Garance Marlier’s slides for more information

ORBITAS summary : sampling effects

2

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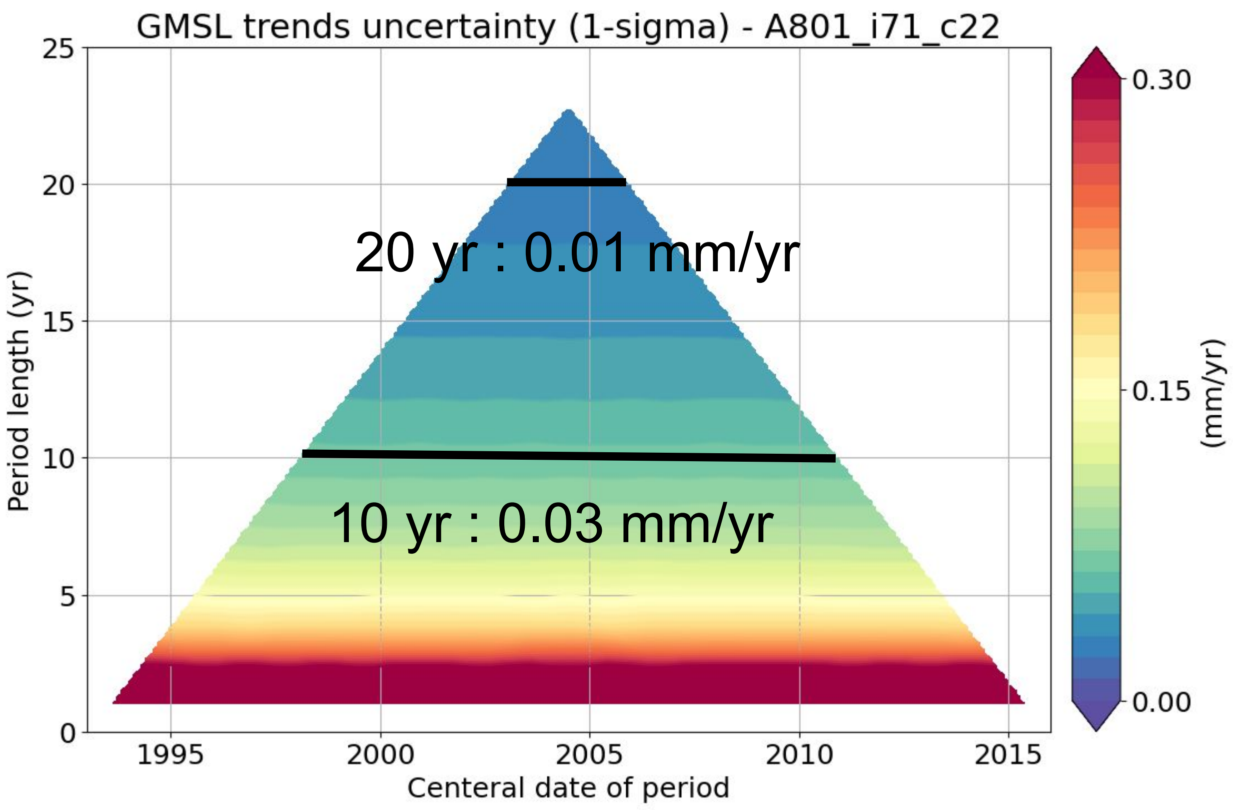
➔ The spatio-temporal sampling of ocean variability has a low impact on GMSL stability :

- **0.03 mm/yr at 1-σ over 10 years** and **does not depend on the alternative S6NG orbits**.
- Detection of a systematic error signal of ± 1 mm correlated at around 5 years due to the GMSL method applied in this study : investigate whether this error stems from the GMSL weighted averaging method itself, or from relying on a single reference mission rather than a multi-mission baseline ?



See Noémie Lalau's slides for more information

ORBITAS summary : coverage effects

2

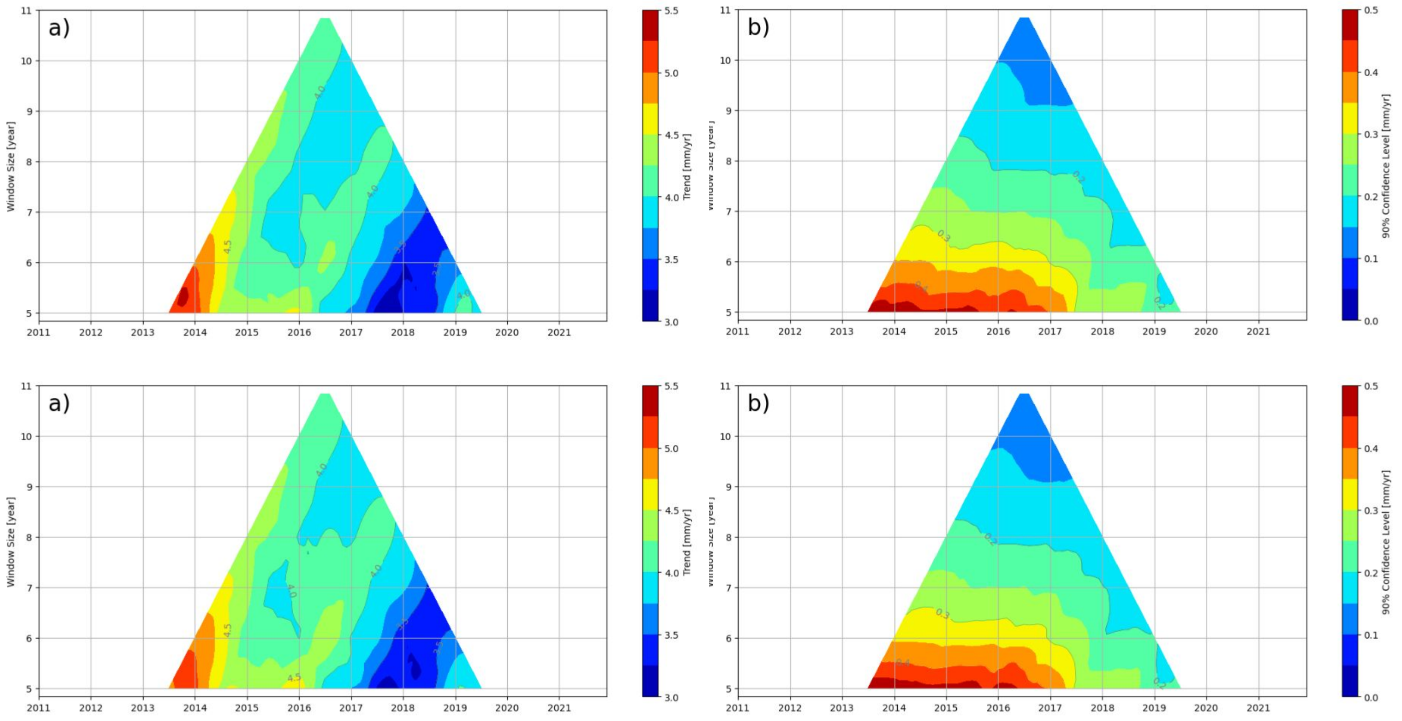
GMSL sea-level trends and uncertainties: including the Arctic ocean (lower) or not (upper) : very similar results

➔ Including the Arctic Ocean in the GMSL has a low or negligible impact on GMSL stability over the 10-year period :

- Arctic sea-level trend comparable with GMSL trend over the 10-year period
- GMSL between -66 and +66 degrees is a very good proxy of the GMSL measurand : GMSL including the Arctic Ocean.

trends

uncertainties



See Antonio Bonaduce's slides for more information

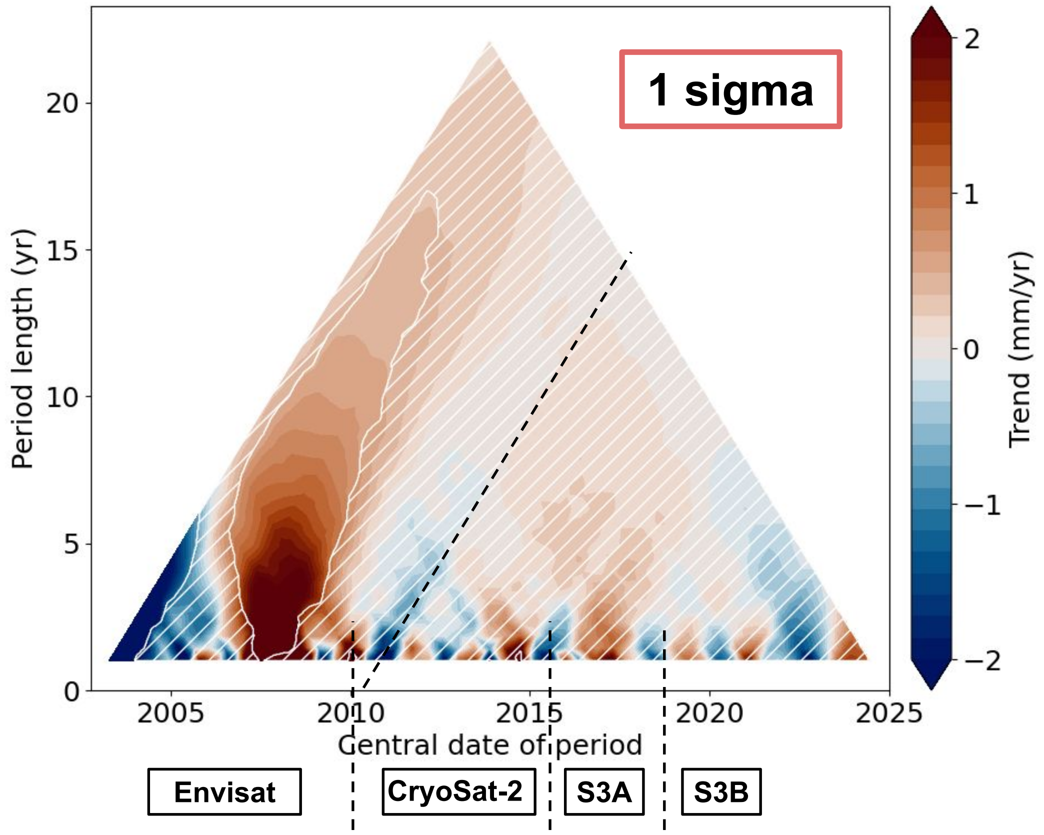
ORBITAS summary : assessment

- ➔ Over the recent period, the reference missions (Cryosat, S3A and S3D) show similar trends to the uncertainty budget with respect to the global mean: **0.09 mm/yr over 10 years.**
- ➔ Same level as the scientific stability goal **of 0.1 mm/yr over 10 years (confidence level of 90%)** from Meyssignac et al., 2023.
- ➔ However a ***likely*** drift in the GMSL difference between 2002 and 2011 over the *envisat period* is detected, and not yet explained

Future work (on going) :

- Same analyses at regional scales
- Sea level and energy budget analyses

GMSL trend differences between the reference and non-reference altimetry missions, with a 1-sigma uncertainty estimate

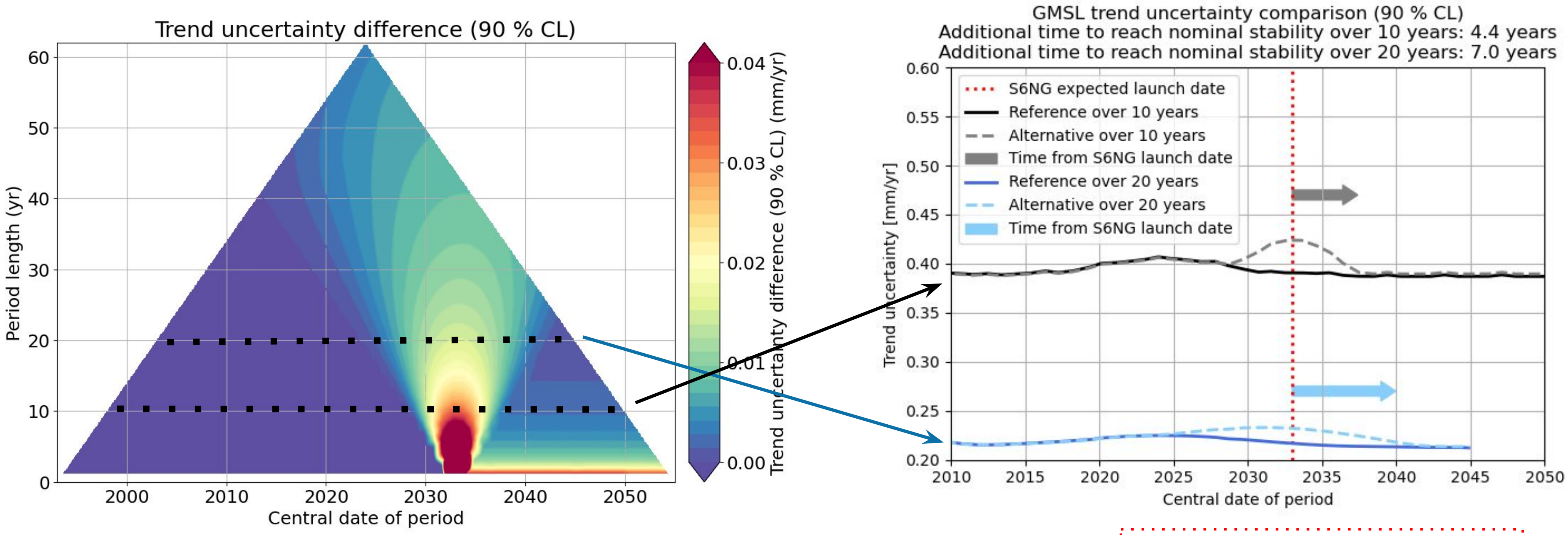


See Louis Kern's slides for more information

ORBITAS summary : preliminary conclusions

➔ Preliminary assessment (with caution) of the total impact on sea level uncertainty stability :

- **low/negligible at global mean (**CL of 90%**)** :
  - +0.04 mm/yr over 10 yr
  - +0.02 mm/yr over 20 yr



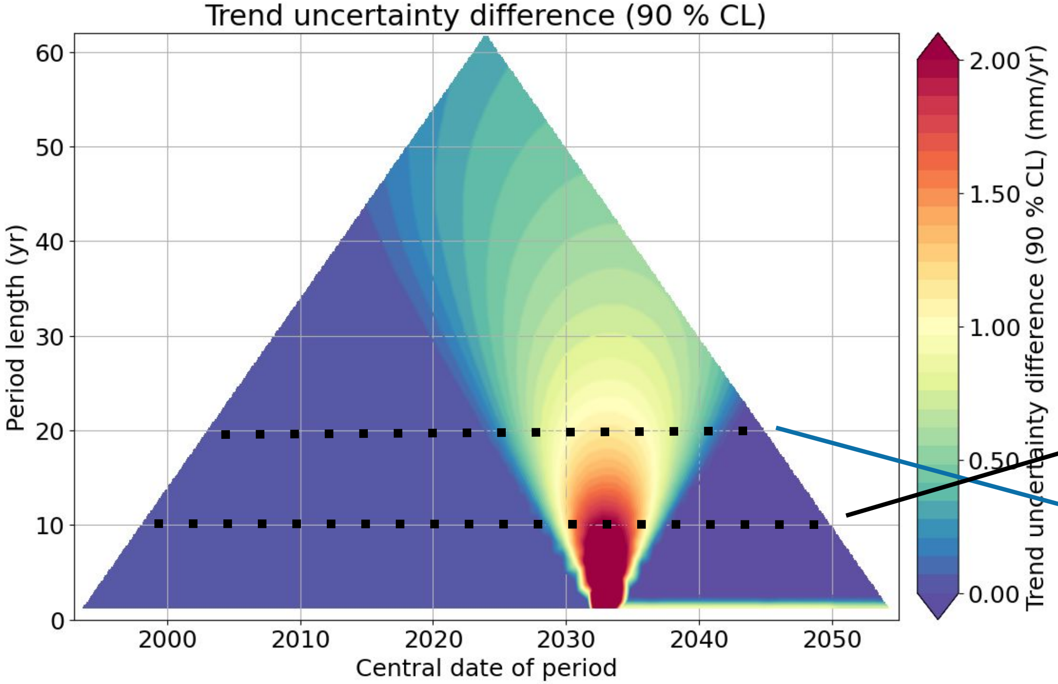
Courtesy of Thomas Vaujour

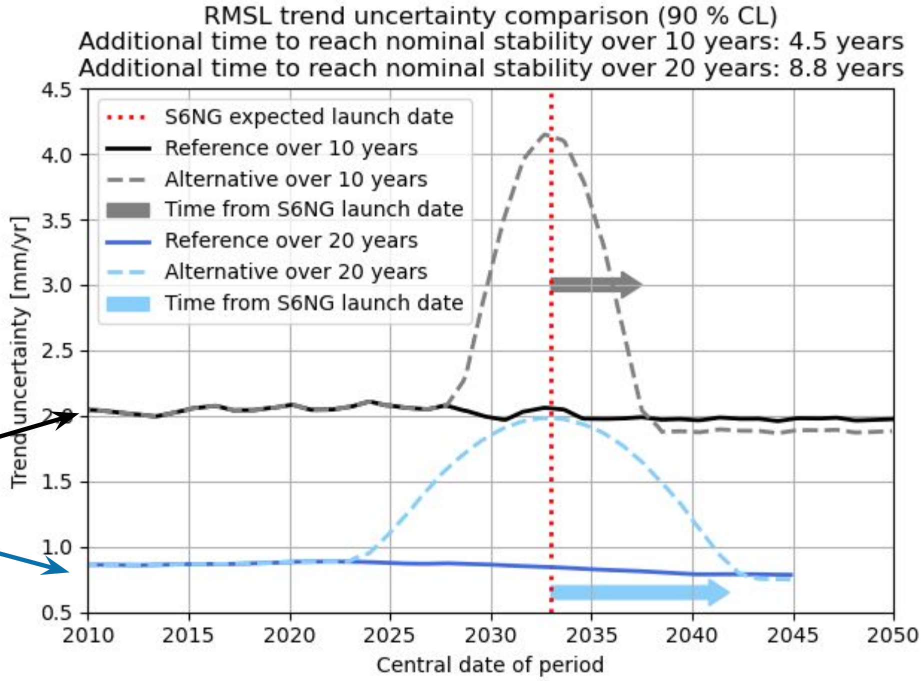
S6NG expected launch date

ORBITAS summary : preliminary conclusions

➔ Preliminary assessment (with caution) of the total impact on sea level uncertainty stability :

- **Strong at regional scales (**CL of 90%**)** :
  - +2.2 mm/yr over 10 yr
  - +1.2 mm/yr over 20 yr





Courtesy of Thomas Vaujour

S6NG expected launch date

IN SITU VERIFICATION OF THE SATELLITE RADAR ALTIMETER RECORD: UNIFIED RESULTS FROM DEDICATED MONITORING SITES

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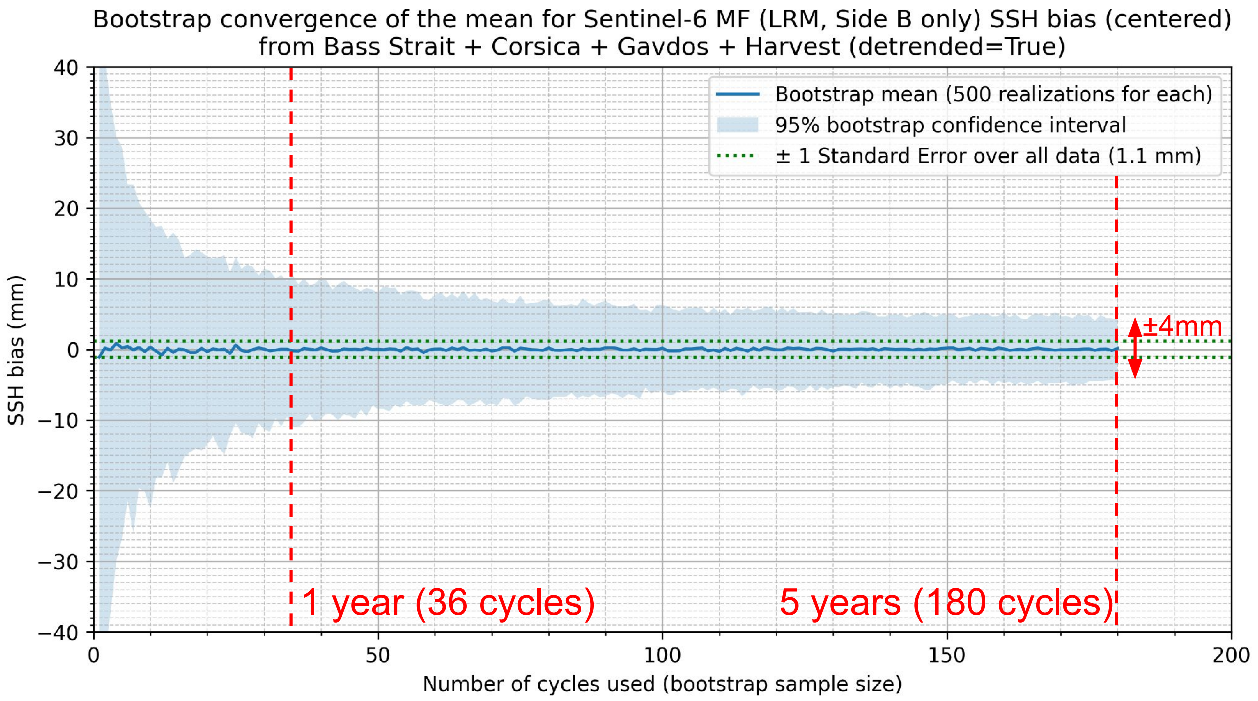
➔ **Main question addressed in this study: Can in situ Calibration Sites help in case of lack of tandem phase?**

- **No:** in situ sites fulfill a different aim, they **can't replace tandem phases with equivalent precision** nor provide complete insight into regional patterns in SSH differences.
- **But:** they can help as a "spare tire" but only after several years of SSH bias monitoring

➔ **In the event of an S6NG orbit change, only one or two calibration sites could be maintained.**

- Loss of historical information and expertise acquired over several decades
- Absolute calibration is complementary to the assessment of the relative SSH bias during a tandem phase: it is an important metrological exercise at an instrumental level :
  - Absolute biases for recent missions are likely insignificantly different from zero



Over a full mission duration (5 years) the uncertainty falls to 4 mm : In situ sites (as a whole) can not reach the climate data record requirement stability of less than 1 mm over 1 year - these data suggest **it takes 5 years**.

For more information : see Pascal Bonnefond' slides

Collaborative Paper

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- ➔ Paper on preparation
- ➔ Objective: draft by early 2027
- ➔ We welcome any external contributions. If you would like to contribute your work, please contact us.

Evaluating the Mean Sea Level Stability Uncertainties for Sentinel-6 Next Generation: Implications of Reference Orbit Changes

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Contents

Discussions

- Are there any orbit change effects missing from the ORBITAS study that could impact sea-level stability uncertainty?
- Which effects studied in ORBITAS require further analysis to be fully understood ?
  - S6NG ORBIT Selection
  - POD effects
  - Environmental corrections
  - Oceanic variability observability
  - Continuity / offset
- How to better assess uncertainties ?
  - e.g for POD : Absolute validation of regional GNSS-based orbit accuracy using independent SLR/DORIS observations