Extending the climate sea-level data record with Sentinel-6-MF: uncertainty and stability requirements

M. Ablain, A. Barnoud (Magellium),

B. Meyssignac (LEGOS),

A. Guérou (CLS)

Objectives

- ➔ Sea-Level stability requirements for climate-driven studies
- ➔ State of the art on the sea level rise uncertainties derived from altimetry measurements
- ➔ Key issues for extending the climate sea level data record with Sentinel 6-MF

Sea level stability requirements

➔ Sea Level stability requirements stability in GCOS (2011) are :

Variable/ Parameter	Horizontal Resolution	Vertical Resolution	Temporal Resolution	Accuracy	Stability
Global mean sea level	50km	N/A	10 days	2-4mm (global mean); 1 cm over a grid mesh	<0.3mm/yr (global mean)
Regional Sea Level	25km	N/A	Weekly	1cm (over grid mesh of 50-100km)	<1mm/yr (for grid mesh of 50-100km)

➔ More stringent sea level stability requirements endorsed by C3S (Copernicus) :

Description	Spatial resolution	Stability
Global mean sea level	Not applicable	**trend : < 0.1 mm/yr** (over more than a decade) **acceleration : <0.05 mm/yr²**
Regional sea level	50-100km	**trend: < 0.5 mm/yr over more than a decade**

Sea level stability requirements

➔ **Meyssignac et al., OSTST, 2019** : How accurate is accurate enough ?

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

NB: All uncertainties in trends and accelerations are presented in **90% CL**

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Sea level stability requirements

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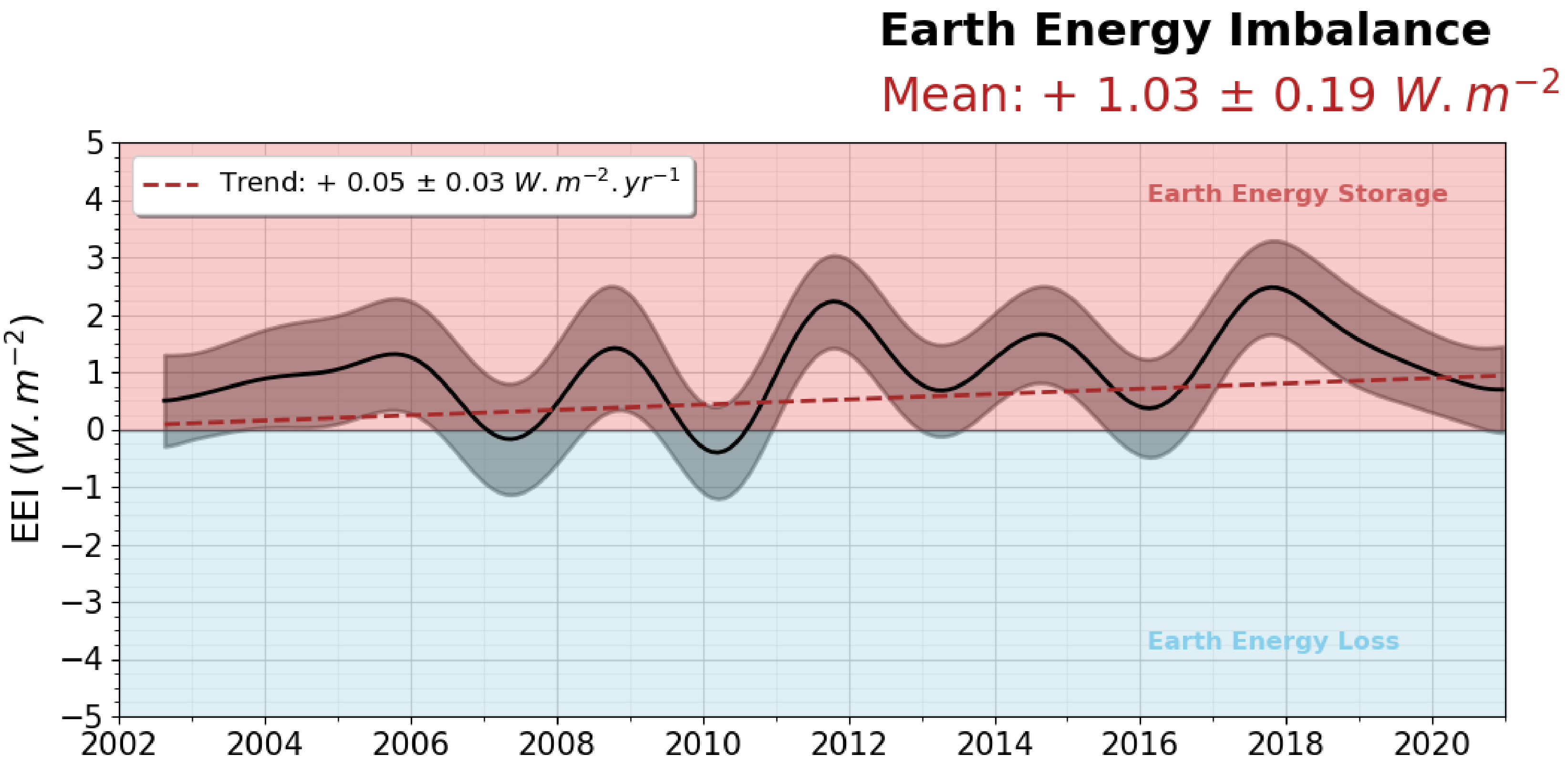
Sea level stability requirements



From Marti et al. (2021)

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SL trend uncertainties: state of the art

➔ **Maturity of the Sea Level data record**

- Very good stability:
  - GCOS requirements are reached at global and local scales over a period of ~20 years (2000 - 2020)

- Advanced estimate of the associated uncertainty:
  - Error description including time correlation
  - Adapted Mathematical formalism
  - Verified by comparison with independent data (e.g. global tide-gauge network, sea level budget closure)

SL trend uncertainties: state of the art

Source of errors	Type of error	Uncertainty level (at 1-σ)
High frequency errors: altimeter noise, geophysical corrections, orbits ...	Correlated errors (λ = 2 months)	σ = 1.7 mm for TOPEX period / 1.5 mm for Jason-1 period / 1.2 mm for Jason-2/3 period
Medium frequency errors: geophysical corrections, orbits…	Correlated errors (λ = 1 year)	σ = 1.3 mm for TOPEX period / 1.2 mm for Jason-1 period / 1 mm for Jason-2/3 period.
Low frequency errors: wet troposphere correction	Correlated errors (λ = 5 years)	σ = 1.1 mm over all the period (⇔ 0.2 mm/yr for 5 years)
Low frequency errors: orbits (Gravity fields)	Correlated errors (λ = 10 years)	σ = 1.12 mm over TOPEX period and 0.5 mm over Jason period (⇔ 0.05 mm/yr for 10 years)
Altimeter instabilities	Drift error	δ = 0.7 mm/yr on TOPEX-A period δ = 0.1 mm/yr on TOPEX-B period
Long-term drift errors: orbit (ITRF) and GIA	Drift error	δ = 0.12 mm/yr over all the period
GMSL offset errors to link altimetry missions together	Offset error	σ= 2 mm for TP-A/TP-B and 0.5 mm for TP-B/J1, J1/J2, J2/J3.

Sea level rise uncertainty budget at global scale (**Ablain et al., 2019**)

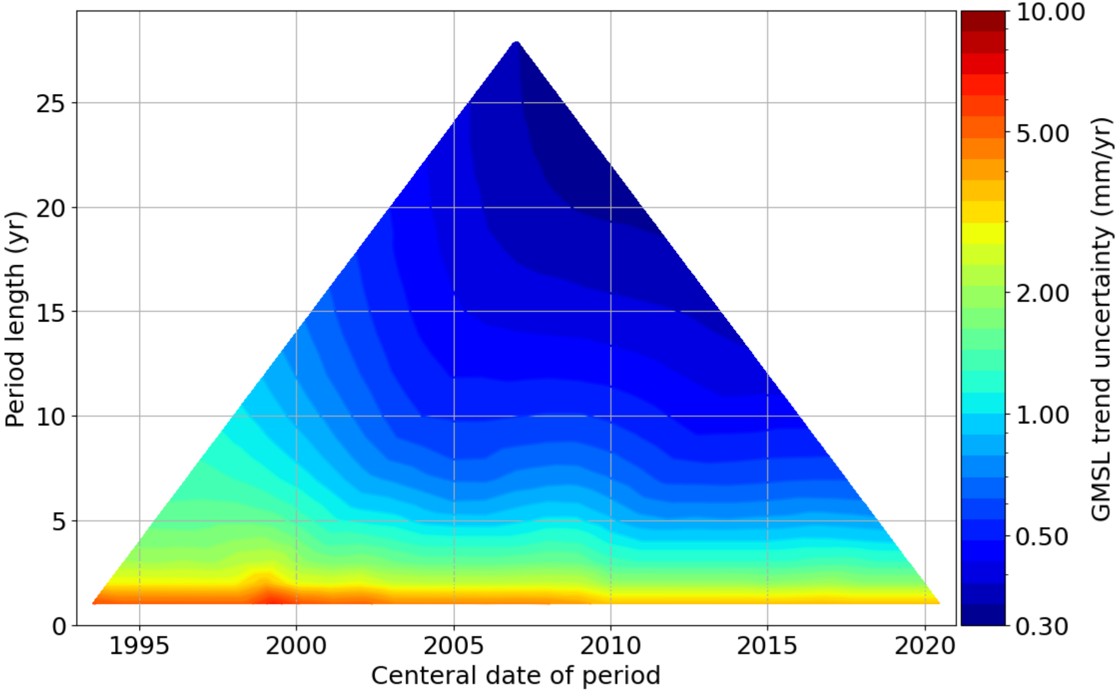
SL trend uncertainties: state of the art

➔ Sea level trend uncertainties

- 10 yr: ≥ 0.45 mm/yr
- 20 yr: ≥ 0.25 mm/yr

➔ Sea level acceleration uncertainties:

- 10 yr: ≥ 0.20 mm/yr²
- 20 yr: ≥ 0.08 mm/yr²



Ablain et al. (2019) updated over 29 years

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SL trend uncertainties: state of the art

Source of errors	Type of error	Uncertainty level (at 1-σ)
High frequency noise from orbit determination	Correlated errors (λ = 1 year)	σ location dependent (8 mm in open ocean)
Low frequency noise from the wet tropospheric correction	Correlated errors (λ = 10 years)	σ location dependent (3 mm in tropical areas)
Orbit determination	Drift error	δ = 0.33 mm/yr
GIA correction	Drift error	δ location dependent (0.3 mm/yr in Hudson Bay)
Inter-mission TP-A/B and TP-B/J1 offset	Offset error	σ = 10 mm
Inter-mission J1/J2 and J2/J3 offset	Offset error	σ = 6 mm

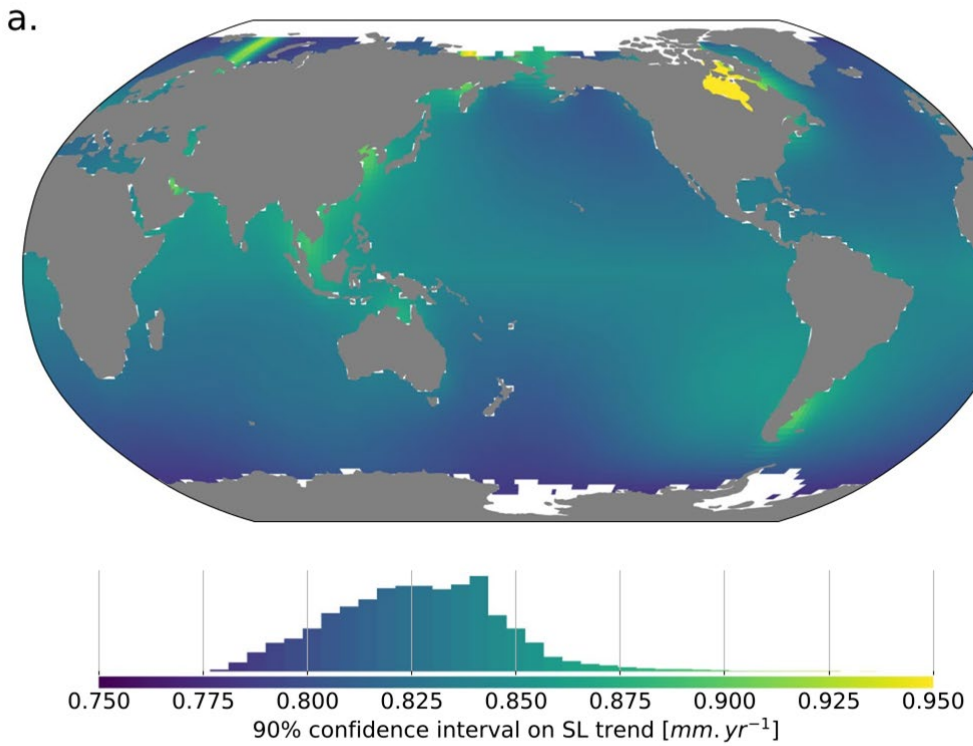
Sea level rise uncertainty budget at local scales (**Prandi et al., 2021**)

SL trend uncertainties: state of the art

➔ Sea level trend uncertainties over 26 years :
  - 0.8 mm/yr (average)
  - until 1.2 mm/yr locally

➔ Sea level acceleration uncertainties over 26 years :
  - 0.06 mm/yr² (average)
  - until 0.12 mm/yr² locally

period : 1993-2019



Prandi et al. (2021)

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Extending sea level data record with S6-MF

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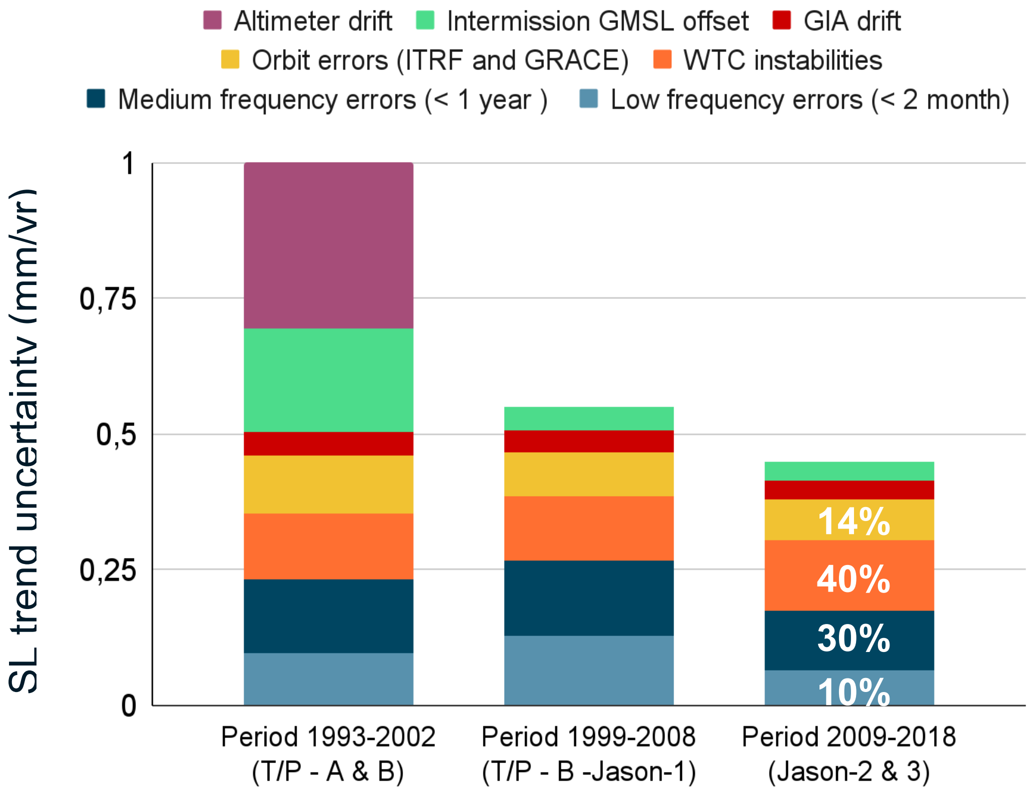
- ➔ SL climate data record to be extended with **S6-MF** (Jason-3 moved on 7th of April)
- ➔ Main objective: assess and verify the SL trend uncertainties with **S6-MF**

Contribution of each source of errors to the total GMSL trend uncertainty

From Guérou et al., 2022 (in prep.)



Extending sea level data record with S6-MF

➔ Target for S6-MF to verify the Jason-2/Jason-3 SL rise uncertainty budget

S6-MF errors to be verified by order of their global contribution (in %)		Jason-2/Jason-3 sea level rise uncertainty budget	
		Global scale	Local scale
(~40 %)	Wet troposphere correction stability	δ < 0.2 mm/yr over 5 years	Location dependent
(~30 %)	Medium frequency errors (altimeter, geophysical corrections, orbits …)	$\sigma \leq$ 1 mm for timescales between 2 months and 1 year	Location dependent
(~14 %)	Long-term orbit error (ITRF and Gravity fields)	≤ 0.1 mm/year	Location dependent (max ≤1.0 mm/yr over 10 years)
(~10 %)	Low frequency errors(altimeter, geophysical corrections, orbits …)	$\sigma \leq$ 1 mm for timescales lower than 2 months	Location dependent
(< 3 %)	GMSL offset - J3A and S6-MF	$\sigma \leq$ 0.5 mm	$\sigma \leq$ 6 mm
(≅ 0%)	Long -term stability of altimeter parameters	$\delta \cong 0$	$\delta \cong 0$

Extending sea level data record with S6-MF

➔ What is needed to bring S6-MF SL rise uncertainty closer to the scientific sea level stability requirements ?

1 - Better knowledge of the errors and their uncertainties	

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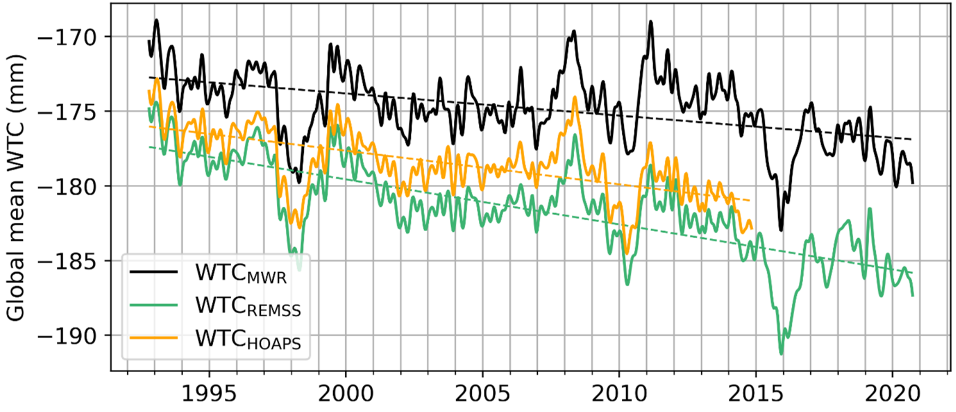


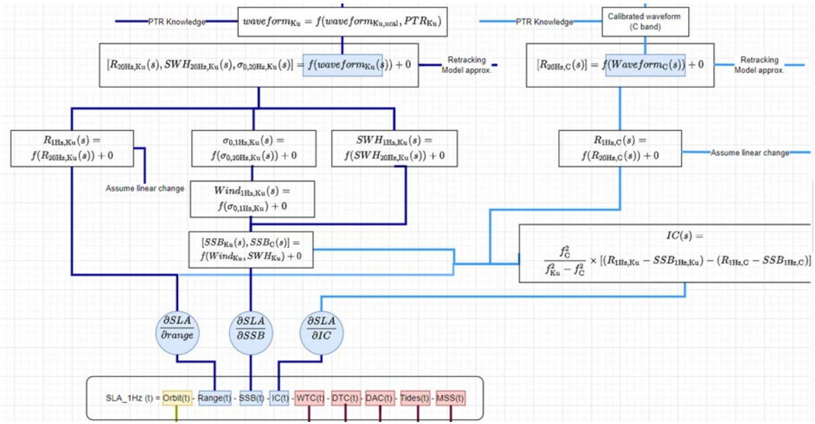
Use of water vapor CDR to reduce WTC stability uncertainties (Barnoud et al., in prep., SALP):

➔ WTC drift uncertainty is reduced from 0.2 mm/yr to 0.05 mm/yr over a 5-year period

Extending sea level data record with S6-MF

➔ What is needed to bring S6-MF SL rise uncertainty closer to the scientific sea level stability requirements ?

1 - Better knowledge of the errors and their uncertainties	Wet Troposphere Correction
	Altimeter parameters and derived corrections

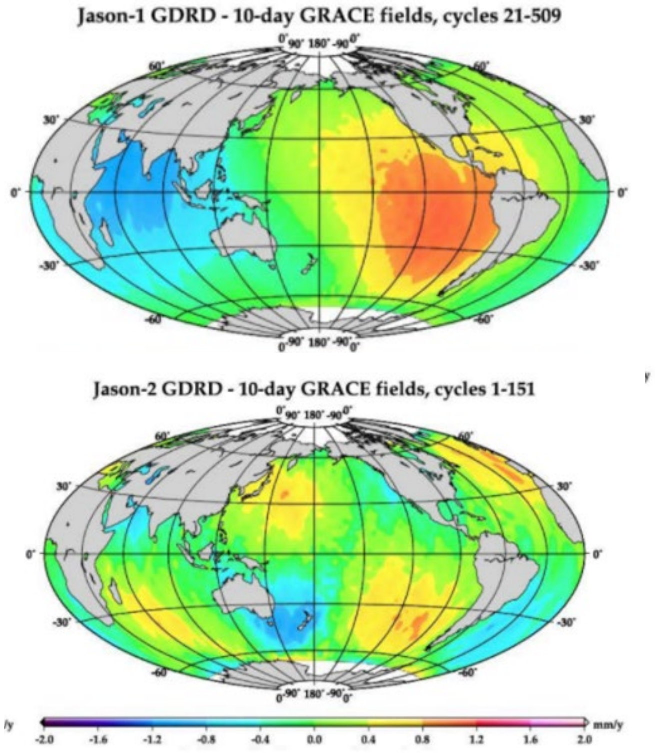


Main objective of ESA ASELSU project: Improve our knowledge of time-correlated altimeter errors by propagating them from altimeter LEVEL 0 to SL ECV

Extending sea level data record with S6-MF

➔ What is needed to bring S6-MF SL rise uncertainty closer to the scientific sea level stability requirements ?

1 - Better knowledge of the errors and their uncertainties	Wet Troposphere Correction
	Altimeter parameters and derived corrections
	Orbit calculation



Couhert et al. (2015)

Extending sea level data record with S6-MF

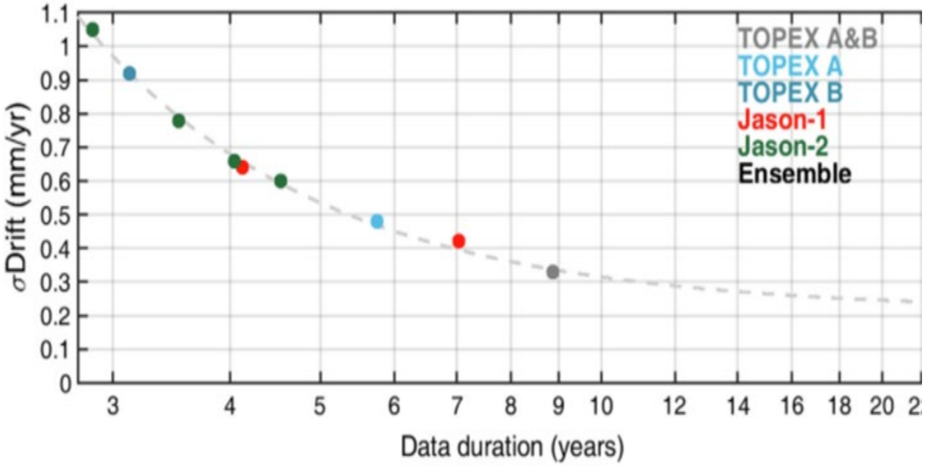
➔ What is needed to bring S6-MF SL rise uncertainty closer to the scientific sea level stability requirements ?

1 - Better knowledge of the errors and their uncertainties	Wet Troposphere Correction
	Altimeter parameters and derived corrections
	Orbit calculation
2 - Better knowledge of the accuracy of the methods	

Extending sea level data record with S6-MF

→ What is needed to bring S6-MF SL rise uncertainty closer to the scientific sea level stability requirements ?

1 - Better knowledge of the errors and their uncertainties	Wet Troposphere Correction
	Altimeter parameters and derived corrections
	Orbit calculation
2 - Better knowledge of the accuracy of the methods	From conventional methods



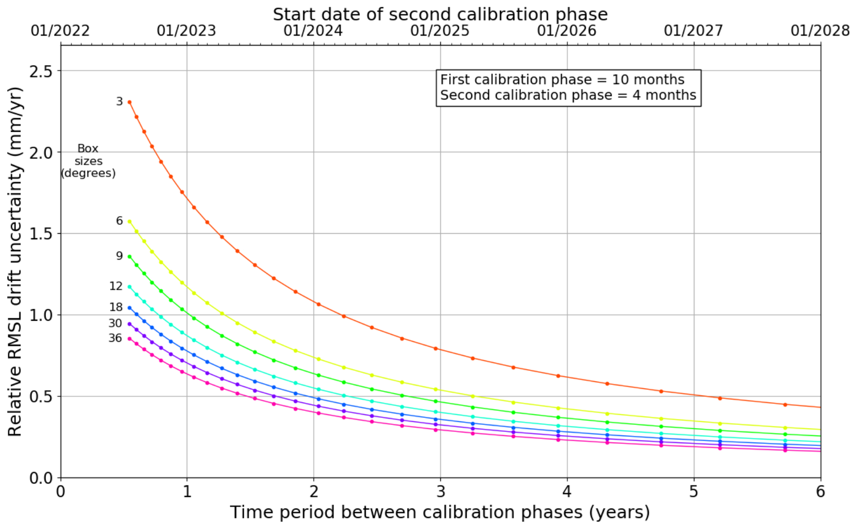
Drift uncertainty between Altimetry and Tide gauge comparison from **C. Watson et al., 2021**:

- **0.5 mm/yr at 10 years (90% CL)**

Extending sea level data record with S6-MF

➔ What is needed to bring S6-MF SL rise uncertainty closer to the scientific sea level stability requirements ?

1 - Better knowledge of the errors and their uncertainties	Wet Troposphere Correction
	Altimeter parameters and derived corrections
	Orbit calculation
2 - Better knowledge of the accuracy of the methods	From conventional methods
	From new approaches



Benefit of a second calibration phase from **Ablain et al., (2021)** :

- **global < 0.2 mm/yr at 5 years (90% CL)**
- **regional < 0.5 mm/yr at 5 years (90% CL)**

Conclusions

➔ **Assessing and verifying the Jason-2/Jason-3 SL uncertainty budget with S6-MF:**
- During the tandem phase with Jason-3 : objective of the Virtual OSTST
- Continuously after the tandem phase by comparison with other altimeter missions and in-situ data

➔ **Improving the current the SL trend uncertainties with S6-MF is possible !**
- Thanks to a better knowledge of the errors and their uncertainties
- Thanks to a better knowledge of the accuracy of the methods

➔ **Work is already on-going…**
- Update of the current SL rise uncertainty budget is coming: SALP project (CNES)
- Use of Wet-Vapor CDR to reduce WTC stability uncertainties: SALP project (CNES)
- Improving knowledge of altimeter errors and method uncertainties: ASELSU and S6-JTEX projects (ESA), SALP project (CNES)

➔ **…very helpful to prepare requirements of future altimetry missions (S6-NG)**

Thank you for your attention

contact : michael.ablain@magellium.fr

1, rue Ariane 31520 Ramonville Saint-Agne
05 62 24 70 00
info@magellium.fr
https://www.magellium.com
https://www.linkedin.com/company/magellium