

MTR - SEA LEVEL BUDGET CLOSURE (SLBC) : Cross-ECVs

CLIMATE CHANGE INITIATIVE MID-TERM REVIEW

→ Project Overview

- ◆ First phase of the project (SLBC_cci) : 2017-2020
- ◆ Second phase of the project (SLBC_cci+) : June 2023 - June 2026 (3 years)
 - new consortium (9 partners)
 - continuity of phase 1
 - with new scientific objectives
- ◆ Sciences leaders :
 - **Benoit Meyssignac (CNES/LEGOS)**
 - **Anny Cazenave (LEGOS)**



sea level
budget closure
cci

→ Global Mean Sea Level (GMSL) budget (using Gregory et al., 2021 notations)

$$\Delta\text{GMSL}_{\text{geocentric}} = \Delta\text{GMSL}_{\text{barystatic}} + \Delta\text{GMSL}_{\text{steric}} + \Delta\text{GMSL}_{\text{GRD}}$$

Geocentric sea level
Change



Altimetry
measurements

Change in the mass of the
ocean



Gravimetry measurements:
GRACE/GRACE-FO

Change in the
density of the ocean:
mainly temperature,
salinity neglected.



In-situ T/S profiles
(mainly based on Argo
network)

Gravity Rotation
Deformation: GIA +
Present Day Ice
Melting



Models

→ **Regional** Sea Level (RMSL) budget (using Gregory et al., 2021 notations)

$$\Delta RSL_{\text{geocentric}} = \Delta RSL_{\text{manometric}} + \Delta RSL_{\text{steric}} + \Delta RSL_{\text{GRD}}$$

Geocentric sea level Change

Barystatic + redistribution of water already in the ocean

Change in the atmosphere loading

Change in the density of the ocean : temperature and salinity

Gravity Rotation Deformation: GIA + fingerprint on Present Day Ice Melting

Altimetry measurements

Gravimetry measurements: GRACE / GRACE-FO

Atmosphere reanalyses

In-situ T/S profiles (mainly based on Argo network)

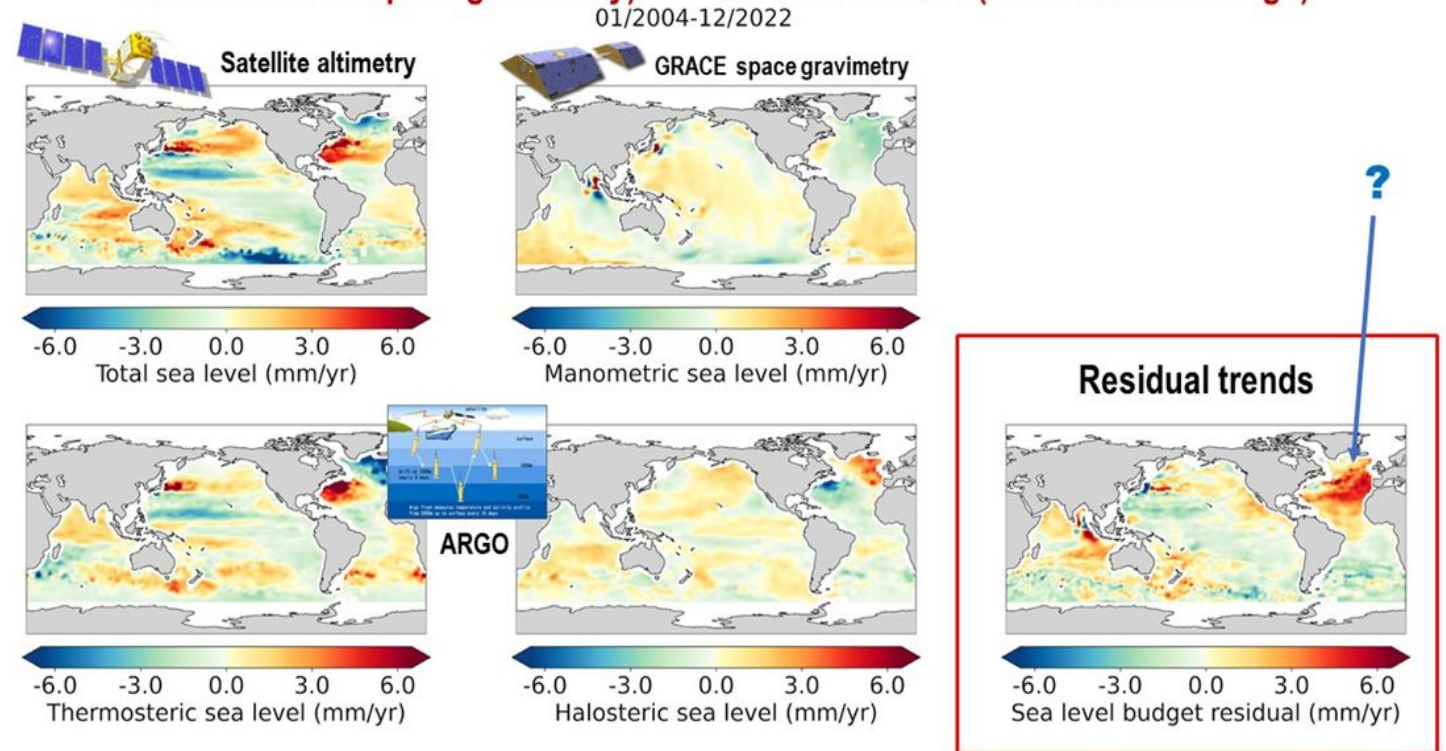
Models

SCIENCE QUESTIONS : Why do we want close the SLB ?

1) Closing the sea level budget as a method to cross-validate worldwide complex observing systems to keep a close watch on their performance

- detection of errors at the regional scales

Regional sea level budget: needs combination of space observations (satellite altimetry + GRACE-based space gravimetry) + in situ observations (T & S data from Argo)

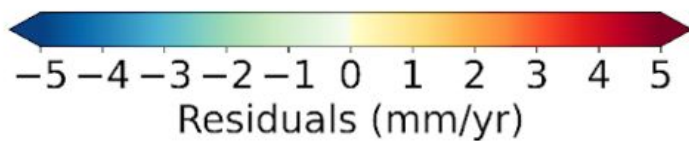
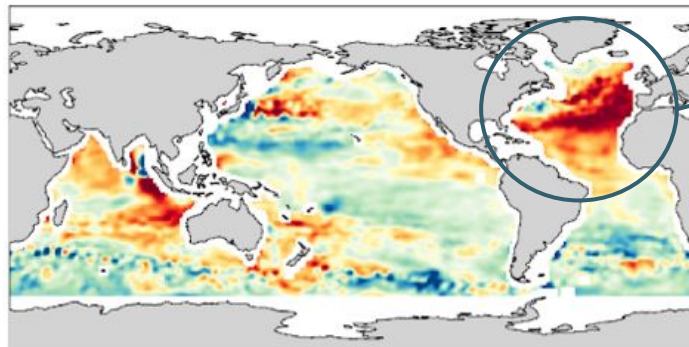


Bouih and Cazenave (in preparation)

SCIENCE QUESTIONS : Why do we want close the SLB ?

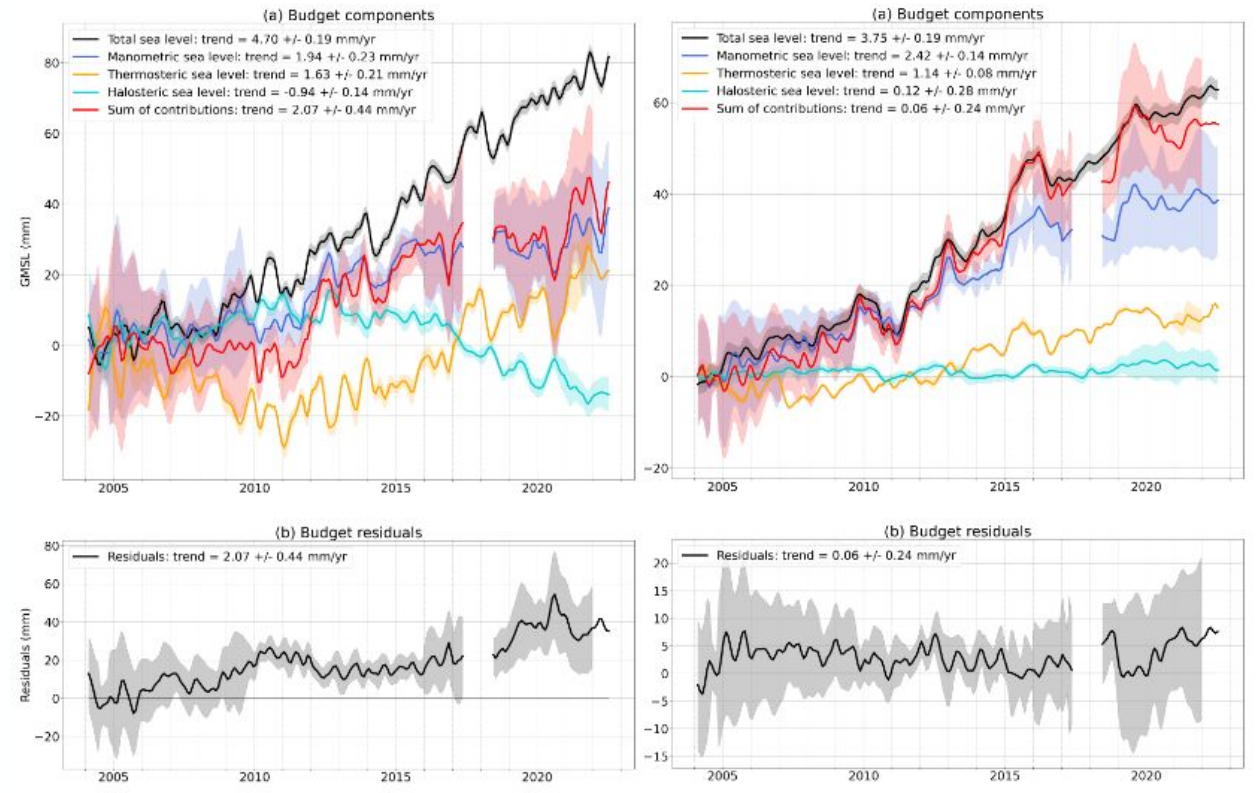
1) Closing the sea level budget as a method to cross-validate worldwide complex observing systems to keep a close watch on their performance

- detection of errors at the regional scales
- detection of errors at the global mean
- uncertainties must be estimated to assess the system performances



North Atlantic ocean

All oceans except North Atlantic

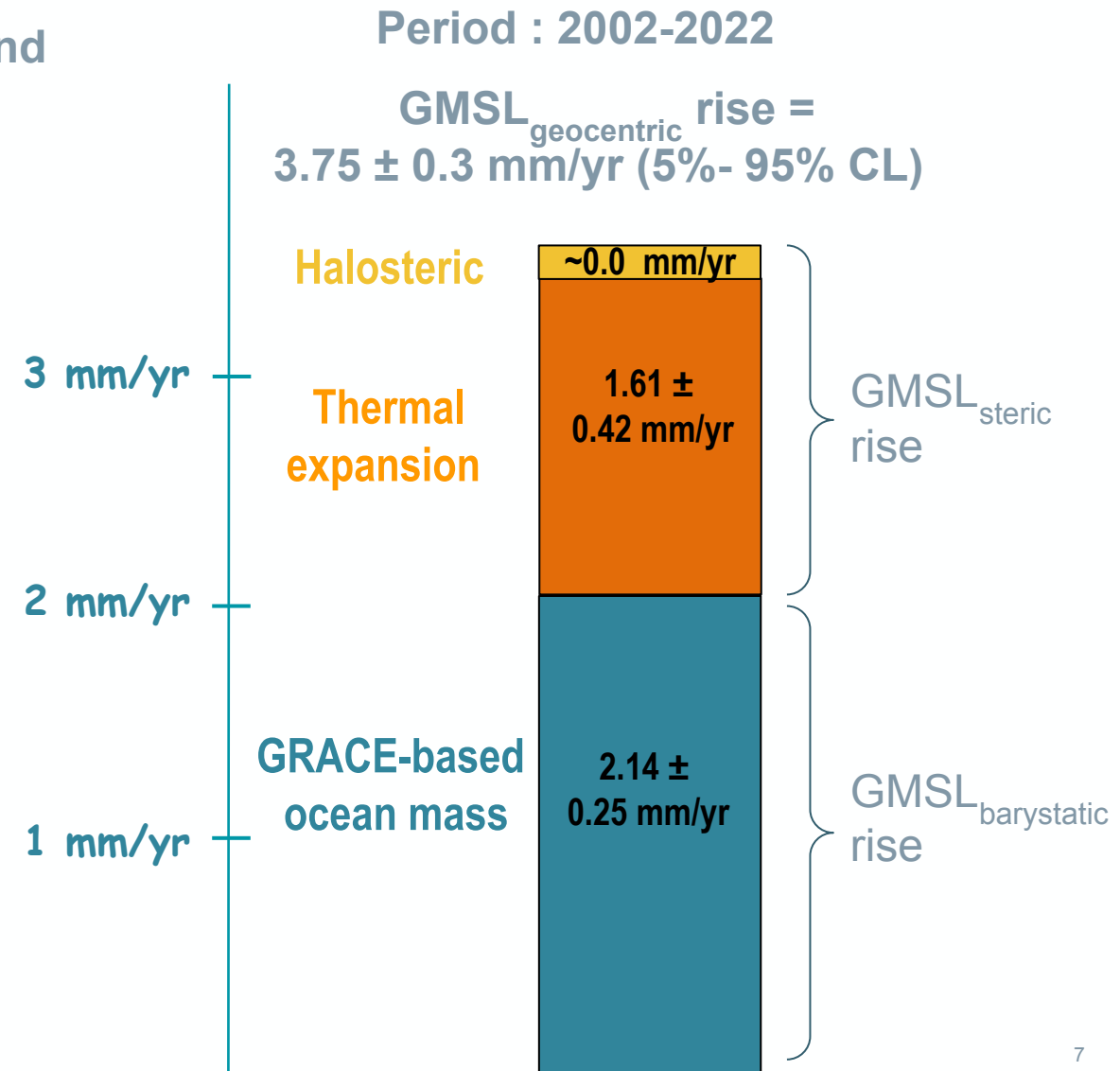


Bouih and Cazenave (in preparation)

SCIENCE QUESTIONS : Why do we want close the SLB ?

2) Closing the sea level budget as a method to understand causes of current sea level rise

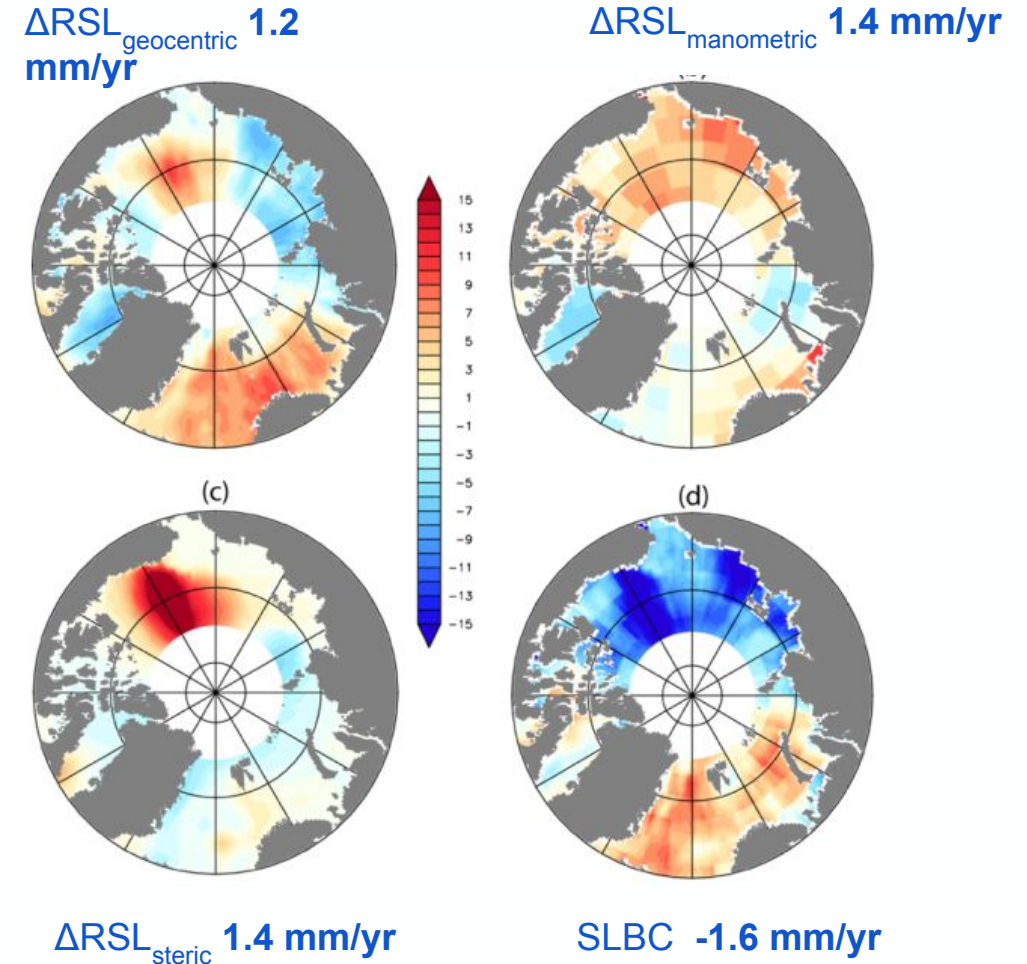
- Are the GIA and GRD fingerprint signals already detectable?
- Is the regional sea level accelerating? Where?
- Are regional trend patterns still dominated by internal climate variability? or is the anthropogenic forced signal emerging? If so, where?
- How much is the regional sea level affected by the interannual variability ?
- What is the contribution of terrestrial water storage, including permafrost melt?
- Is there an acceleration of melting in the Arctic and Antarctic?
-



SCIENCE QUESTIONS : Why do we want close the SLB ?

3) Closing the sea level budget as a method for assessing the sea level change in Arctic Ocean

- the warming of the Arctic has been four times faster than the rest of the globe
- the Arctic observing network is lacking the capability to provide a full picture of the changing Arctic Ocean.
- Understanding the disclosure of sea-level budget in the Arctic region
- Validating of the sea level budget components with independent estimates of the relevant physical processes
- Identifying the largest source of uncertainties affecting the sea level budget closure in the Nordic Seas and Arctic Ocean



from Horvath et al., 2021

→ Better accuracy needed in sea level estimates

Climate Science Question	Accuracy in GMSL rates in mm/yr	Accuracy in GMSL acceleration in mm/yr per decade	Accuracy in regional sea level rates in mm/yr on 20-yr trends
Closing the sea level budget	Detection ^{1a} : ±0.1mm/yr - Quantification ^{1a} : ±0.02mm/yr		Detection ² : ±0.3 mm/yr Quantification ² : ±0.07mm/yr
Detecting and attributing the signal in sea level that is forced by GHG emissions	Detection ^{3a} : ±1.5mm/yr - Quantification ^{3a} : ±0.7mm/yr		Detection: ±0.5 mm/yr Quantification: ±0.1mm/yr
Estimating the EEI	Detection ^{4b} : ±0.1mm/yr Quantification ^{4b} : ±0.03mm/yr	Detection ^{5b} : ±0.5mm/yr per decade Quantification ^{5b} : ±0.1mm/yr per decade	

From Meyssignac et al. ,2023
[How accurate is accurate enough for measuring sea-level rise and variability | Nature Climate Change](#)

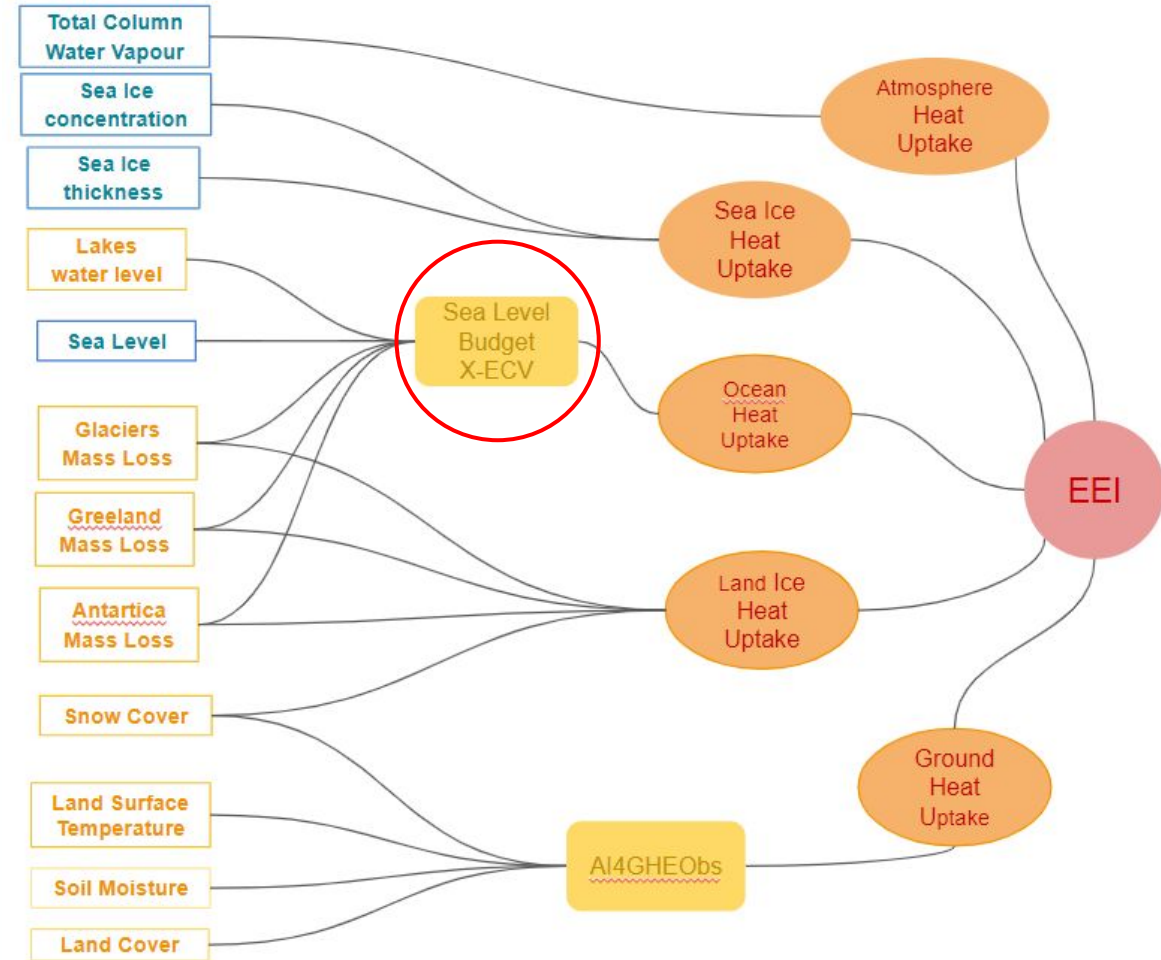
supported by
 ESA in ASELSU
 project (S6-NG)

- $\Delta SL_{\text{geocentric}}$ **Geocentric/Absolute sea level change :**
 - ◆ To guarantee the CONTINUITY of future altimetry missions (e.g. Sentinel-6 next generation)
 - ◆ To improve the ACCURACY and STABILITY of measurements

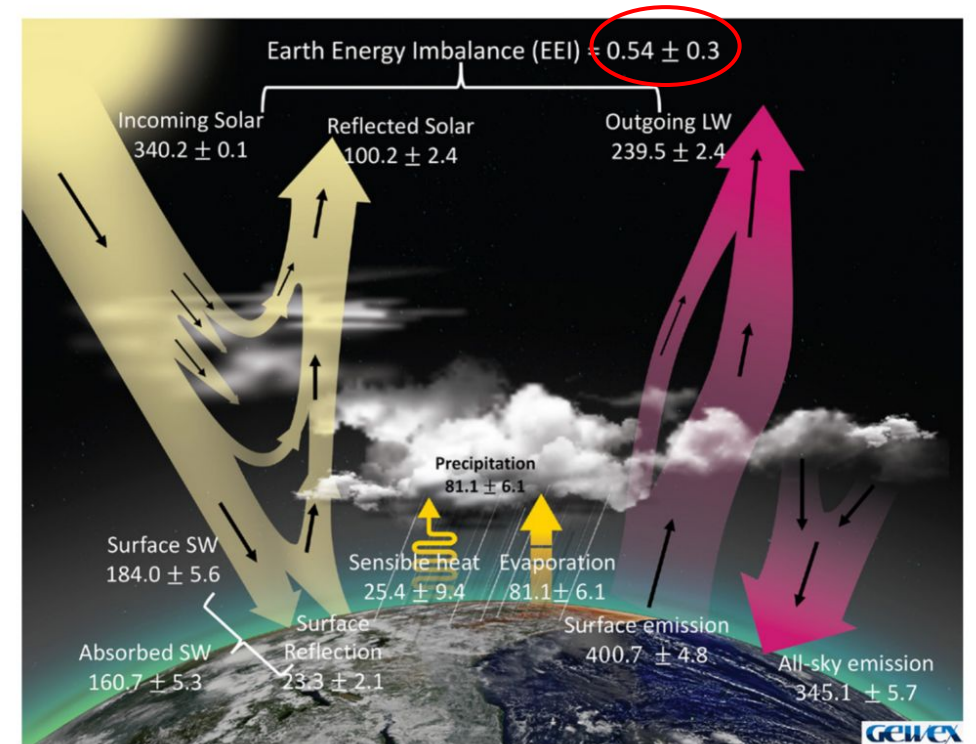
- $\Delta SL_{\text{ocean mass}}$ **Ocean mass change (Barystatic/Manometric) :**
 - ◆ to improve the OBSERVABILITY with future gravimetry missions (e.g. NGGM / MAGIC)
 - ◆ to improve the ACCURACY of measurements

- $\Delta SL_{\text{steric}}$ **Steric sea level change :**
 - ◆ to improve the OBSERVABILITY of Argo network (e.g. deep Argo)
 - ◆ to improve the STABILITY of measurements (e.g. halosteric drift from 2016)

- Use the sea level budget to constrain the water-energy cycle: e.g. IPCC, GEWEX EEI, MOTECUSOMA cross-ECV project and others
 - ◆ set the ground for the estimate of the Ocean heat uptake from the sea level budget. Use the ocean heat uptake in a heat inventory of the Earth to estimate the EEI
 - ◆ Use the EEI to derive the fluxes of the energy cycle
 - ◆ combine with TAS to estimate the climate feedback and the climate sensitivity
- Use sea level budget to explain regional and coastal sea level and constrain projections of future sea level e.g. IPCC projections

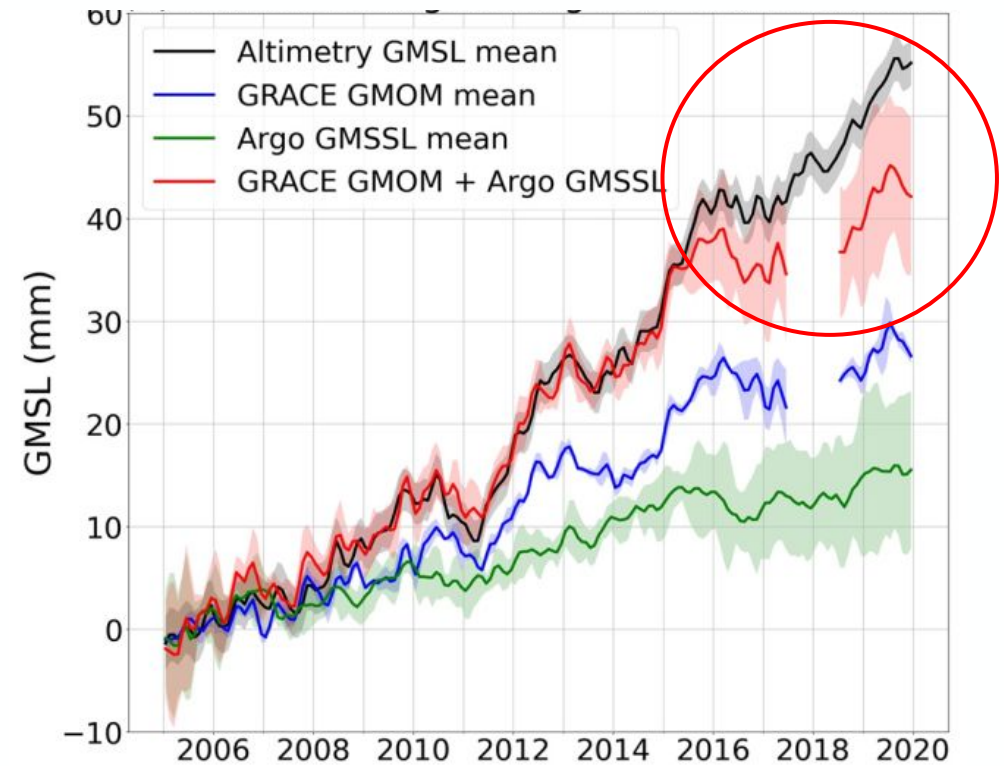


- 1) Closure of the sea level budget with **robust and reliable uncertainties** including the temporal and spatial correlation of errors because uncertainties are essential to a) detect errors in the observing system b) to constrain the fluxes of the Energy cycle and c) to test theories about the climate energy budget variability



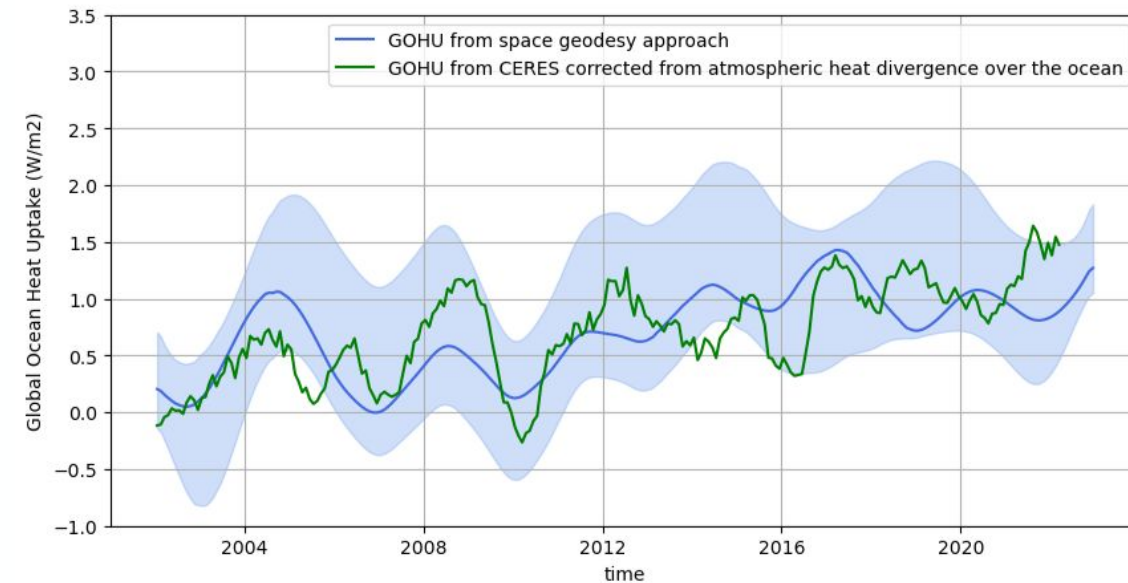
Stephens et al., 2023

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- 2) Correct the records of the sea level budget contributions **for errors identified** with the non-closure of the sea level budget (e.g. salinity drift in Argo profiles)



Barnoud et al. (2021)

- 1) Closure of the sea level budget with **robust and reliable uncertainties** including the temporal and spatial correlation of errors because uncertainties are essential to a) detect errors in the observing system b) to constrain the fluxes of the Energy cycle and c) to test theories about the climate energy budget variability
- 2) Correct the records of the sea level budget contributions **for errors identified** with the non-closure of the sea level budget (e.g. salinity drift in Argo profiles)
- 3) **Improve the closure at high frequency (monthly) and regionally (extra tropics)** to enable improvement in the EEI record, the energy fluxes and test the closure of the energy budget at monthly time scales



Update from Marti et al., 2023