Seal Level Budget Closure CCI+ project (ESA, 2023-2026): from validation of the Earth's observing system to scientific questions

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The sea level budget equation

$$\Delta SL_{total} = \Delta SL_{ocean\ mass} + \Delta SL_{steric}$$

$\Delta SL_{ocean\ mass}$: due to change in the mass of the ocean

ΔSL_{steric}: due to change in the density of the ocean (temperature and salinity*)

Altimetry measurements

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

Gravimetry measurements: GRACE and GRACE-FO = Sum of components: Greenland, Antarctica, glaciers, land water storage, atmosphere water vapor, permafrost + ocean circulation*

Ocean mass budget

*Null or neglected in global mean

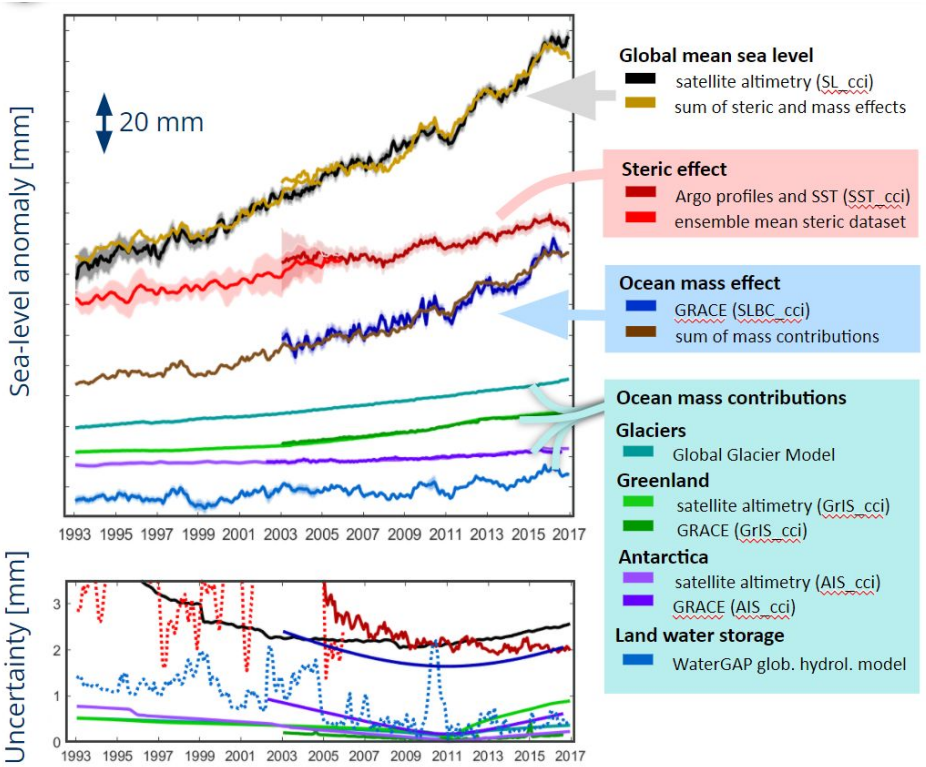
Why do we want to close the sea level budget?

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 in measurements:

- GMSL drift in Topex-A (Dieng et al., 2017), drift in Jason-3 GMSL due WTC (Barnoud et al., 2022)
- drift in T/S profiles from 2016 due to salinity measurements (Barnoud et al., 2021)

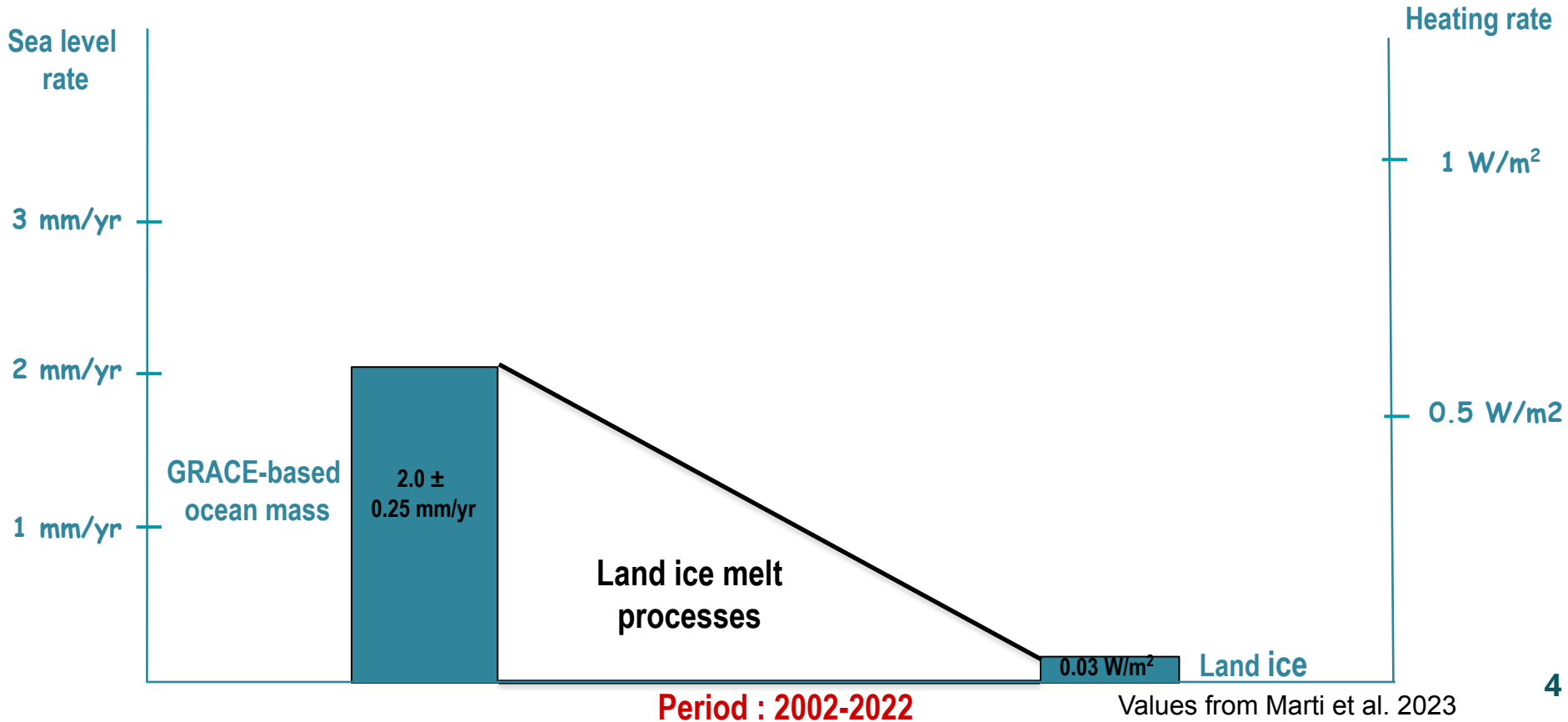
➔ uncertainties must be estimated to assess the system performances



from Horwath et al. 2022

Why do we want to close the sea level budget?

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



Values from Marti et al. 2023

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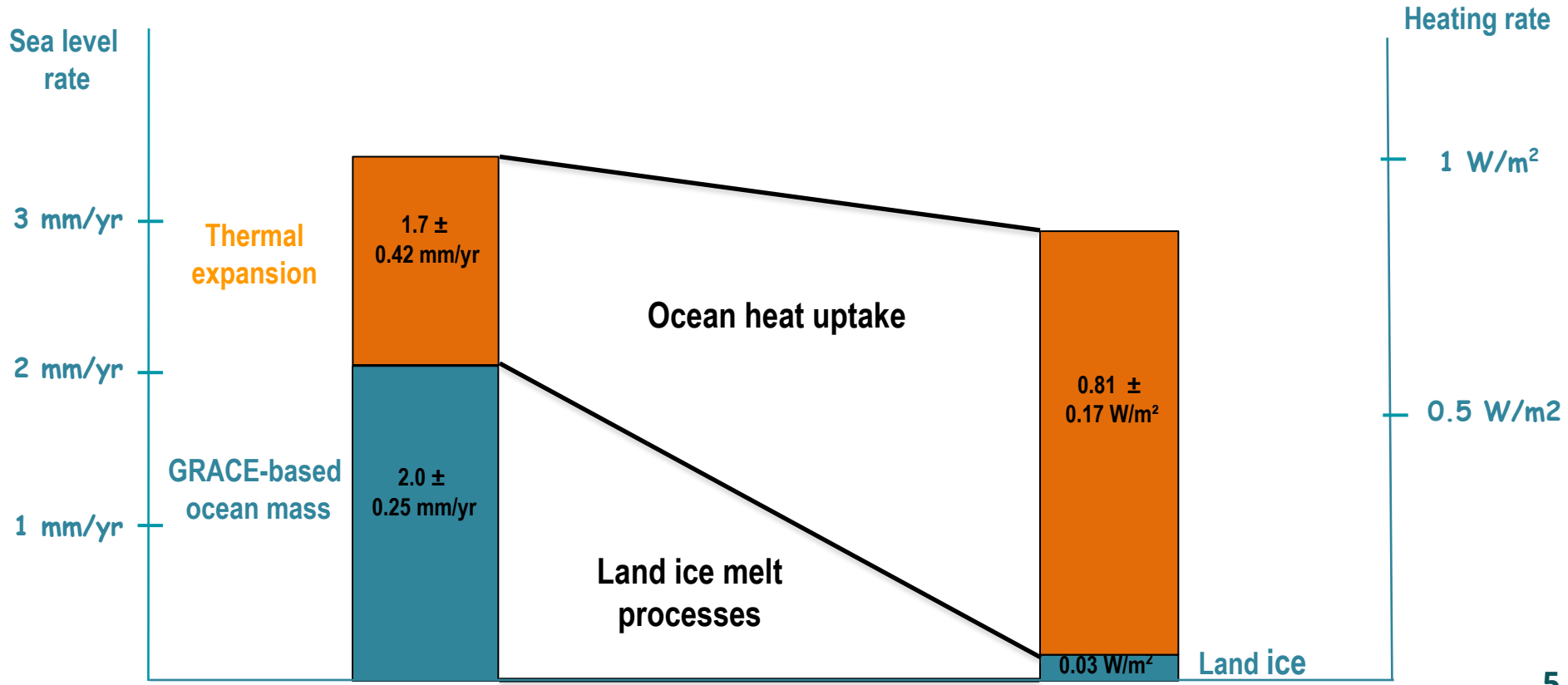

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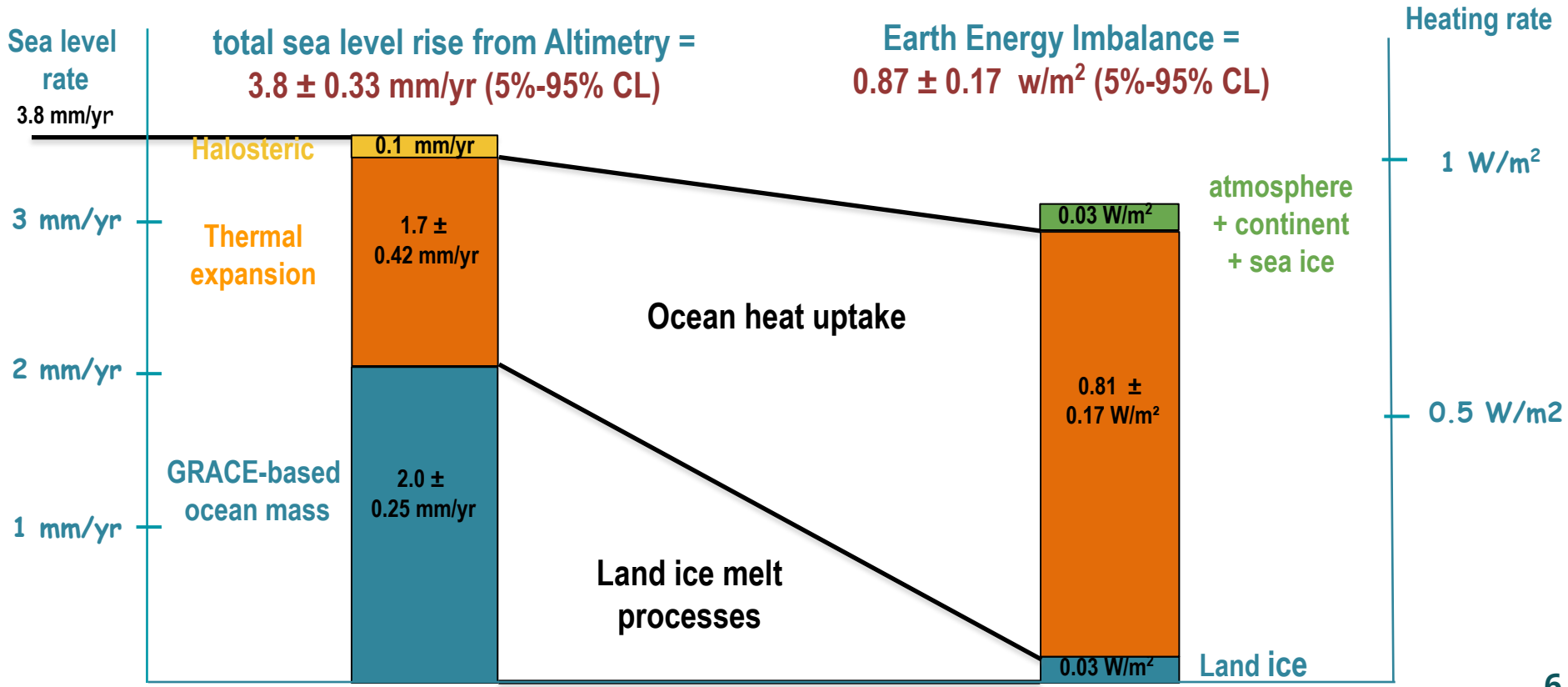

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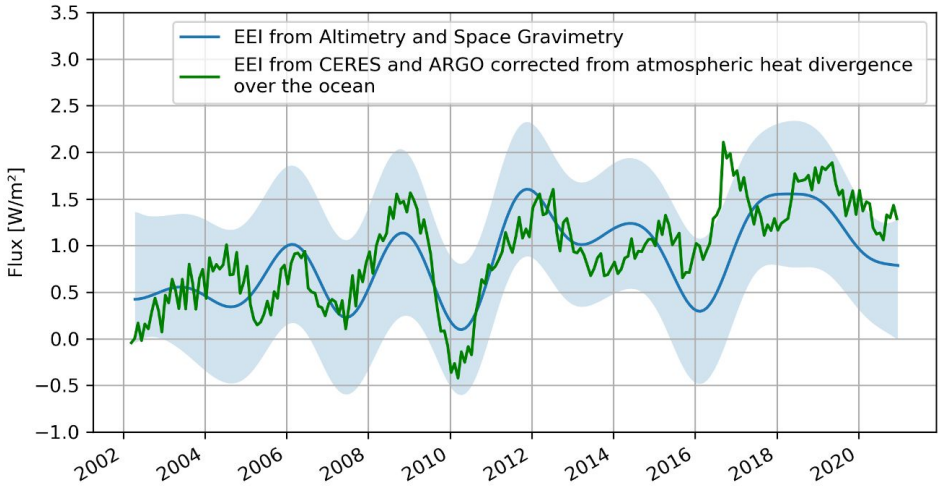
Why do we want to close the sea level budget?

3) Closing the sea level budget as an efficient approach to test the consistency of different observed integrals of the climate system including sea level, ocean temperature and ocean mass, with regard to conservation laws including those of mass, energy and freshwater.

➔ That is particularly relevant when we use the sea level budget to constrain the water & energy cycle:

- ◆ Sea level budget need to be consistent with the global energy budget



Marti et al. 2023

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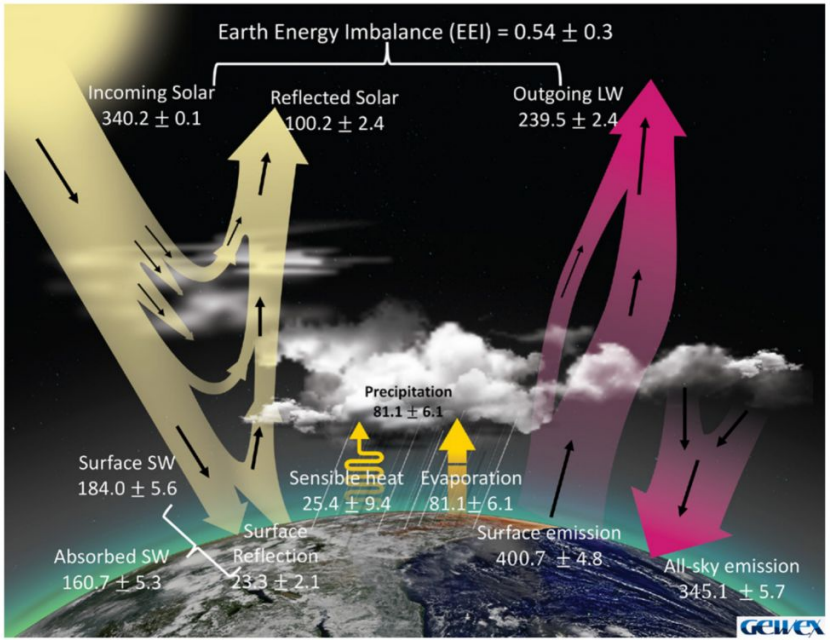
➔ That is particularly relevant when we use the sea level budget to constrain the water & energy cycle:

- Sea level budget need to be consistent with the global energy budget
- The different contributions in the global energy budget can be constrained with the earth energy imbalance derived from altimetry and gravimetry measurements (Hakuba et al., 2021, Marti et al., 2023)



from Stephens et al. 2023

Scientific objectives of SLBC_cci+

- SLBC_cci+ project:
  - cross-ECV project in the framework of the Climate Change Initiative (CCI) supported by ESA
  - Phase 1 of the project (SLBC_cci) from 2017 to 2021
  - Phase 2 of the project (SLBC_cci+) started in May 2023 for a period of 3 years
    - new consortium (9 partners)
    - continuity of phase 1
    - with new scientific objectives

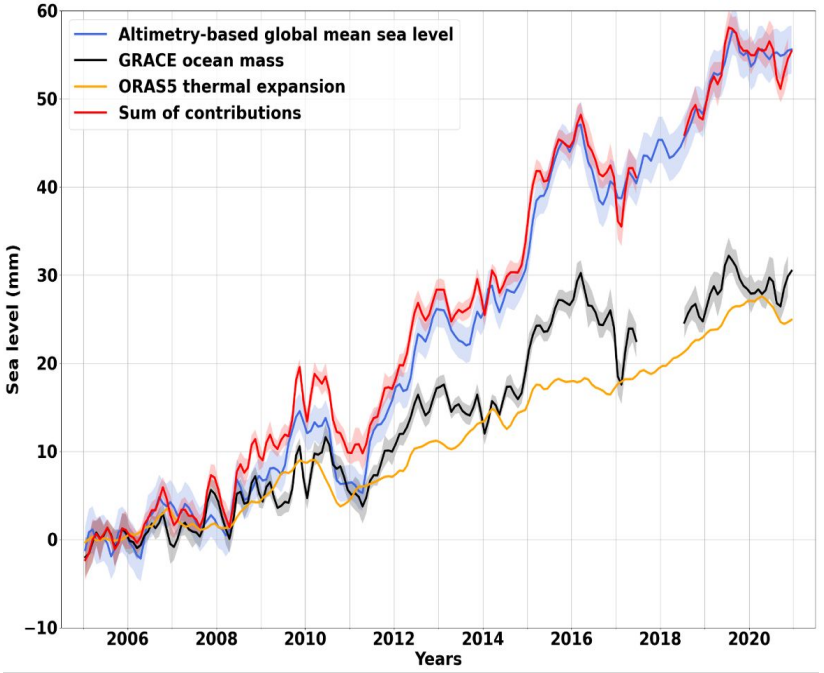
sea level budget closure cci

Scientific objectives of SLBC_cci+

1) Revisit the sea level budget and ocean mass budget

➔ In the continuity of phase 1
- ◆ extend the global mean components to 2024
- ◆ extend the uncertainty estimates

➔ with new features
- ◆ link to CCI ECVs (e.g. snow cover)



from Barnoud et al. 2023

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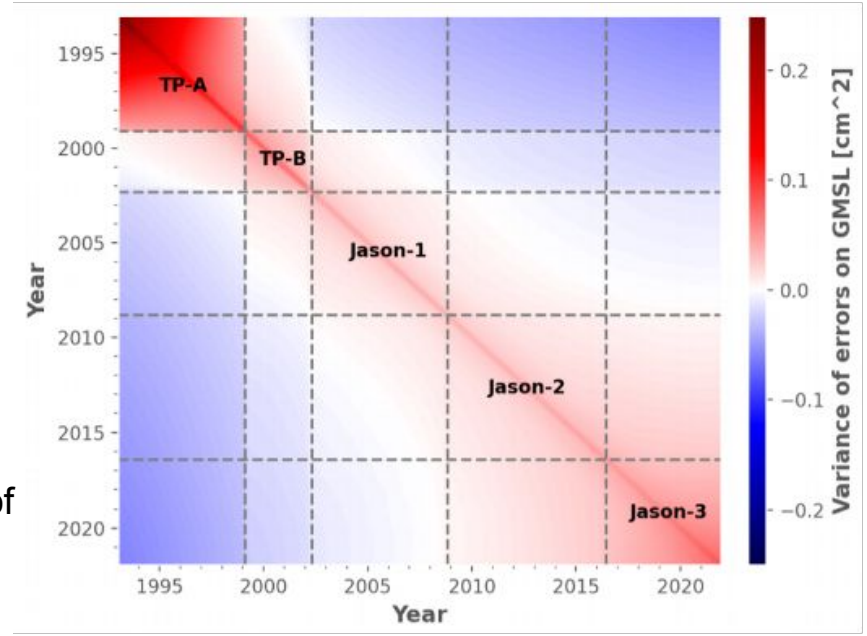
  - ◆ improve uncertainty estimates
    - include time correlations from error measurements
    - estimate errors linked to the observability of the system (i.e. due to the spatio-temporal resolution of each component)



from Ablain et al. 2019, Guerou et al. 2022

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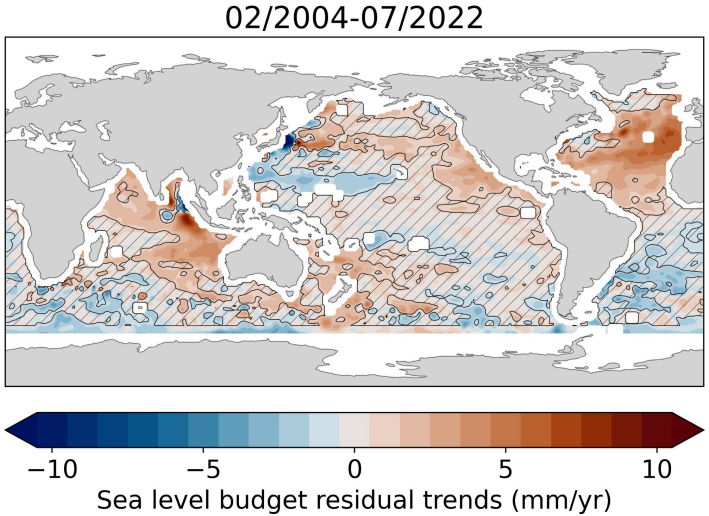
  - ◆ assess the sea level budget at regional scales

Sea level budget residual using C3SvDT2021, JPL, CSR and GSFC mascons ensemble mean, steric from SIO down to 2000 m depth and ORAS5 steric between 2000 and 6000 m depth.



Scientific objectives of SLBC_cci+

2) Perform sciences studies with the revisited sea level budget and ocean mass budget

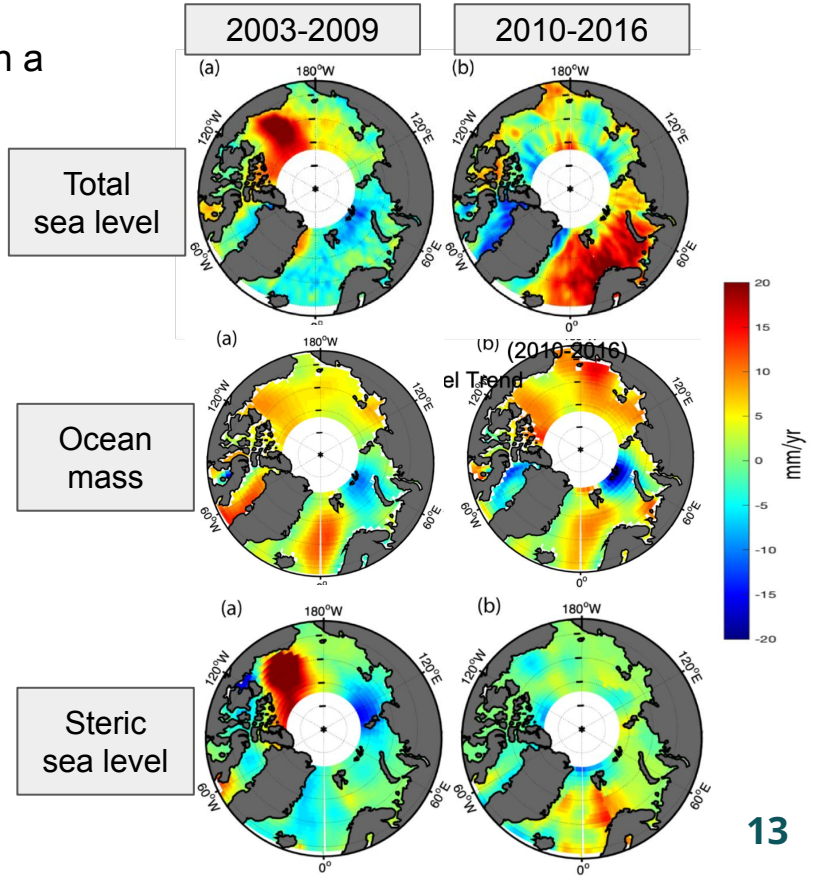
➔ assess another objective closure of the sea level budget with a bayesian approach

➔ assess the closure of the sea level budget in the Arctic to evaluate the role of the different contributions in this rapidly changing area

➔ compare the sea level budget with reanalysis and climate models to understand the main Earth system physical processes leading to the temporal evolution of sea level and its contributions and address budget misclosure if any

➔ detect and attribute the forced signal in the different contributions to sea level

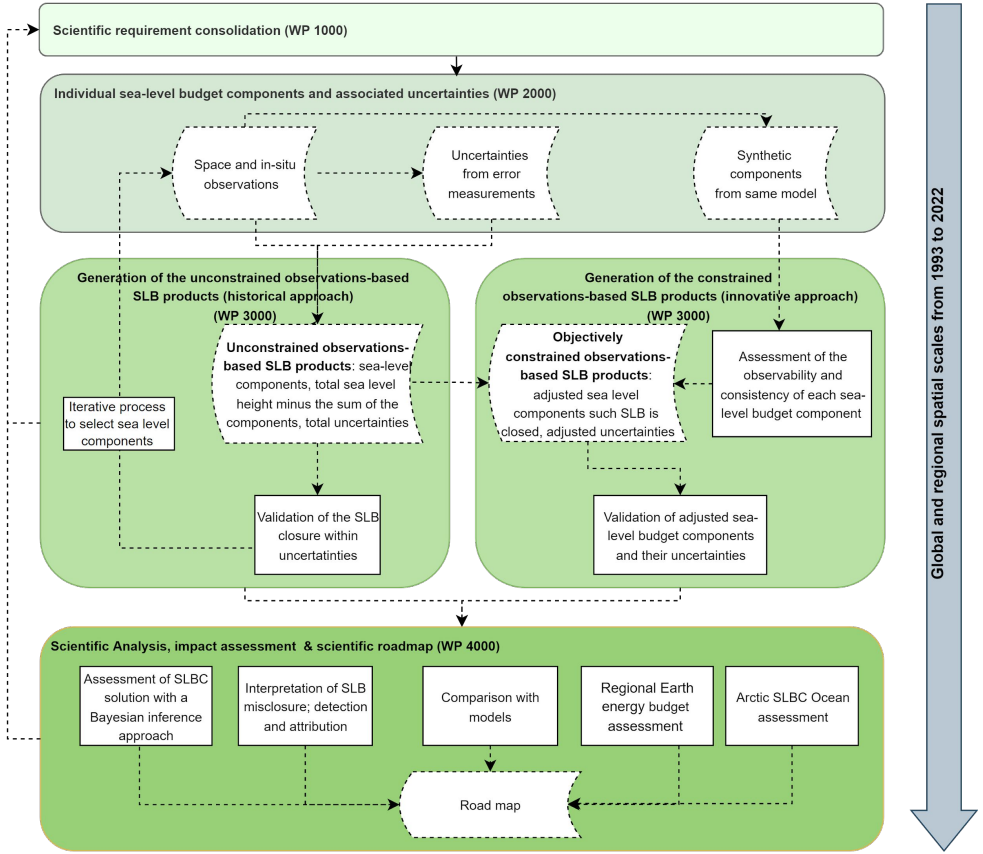
➔ evaluate the consistency of the sea level budget with the global energy budget and with regional energy budget over the North Atlantic



Conclusion / summary

Main outcomes expected in SLBC_cci+ (2023-2026) are:

- ➔ to understand the causes of sea level rise:
  - ◆ at global
  - ◆ at regional scales
- ➔ to assess the robustness of the observing system:
  - ◆ detection of errors
  - ◆ characterisation of uncertainties
- ➔ to ensure the consistency between observed variables of the climate system:
  - ◆ determining at which spatial and time scales the SLB can be closed
  - ◆ providing recommendation to improve the future observing systems



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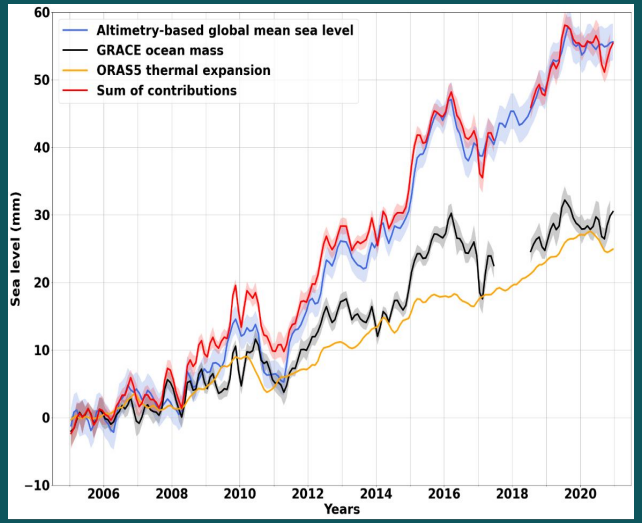

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