Improving long term estimates of global mean sea level, global ocean heat content and Earth's energy imbalance using water vapour climate data records

Anne Barnoud[1], Bruno Picard[2], Benoît Meyssignac[3], Florence Marti[1], Michaël Ablain[1], Rémy Roca[3]

[1]Magellium, Ramonville-Saint-Agne, France; [2]Fluctus, Rabastens, France;
[3]LEGOS, Université de Toulouse, CNES, CNRS, UPS, IRD, Toulouse, France

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eo@magellium.fr earthobservation.magellium.com

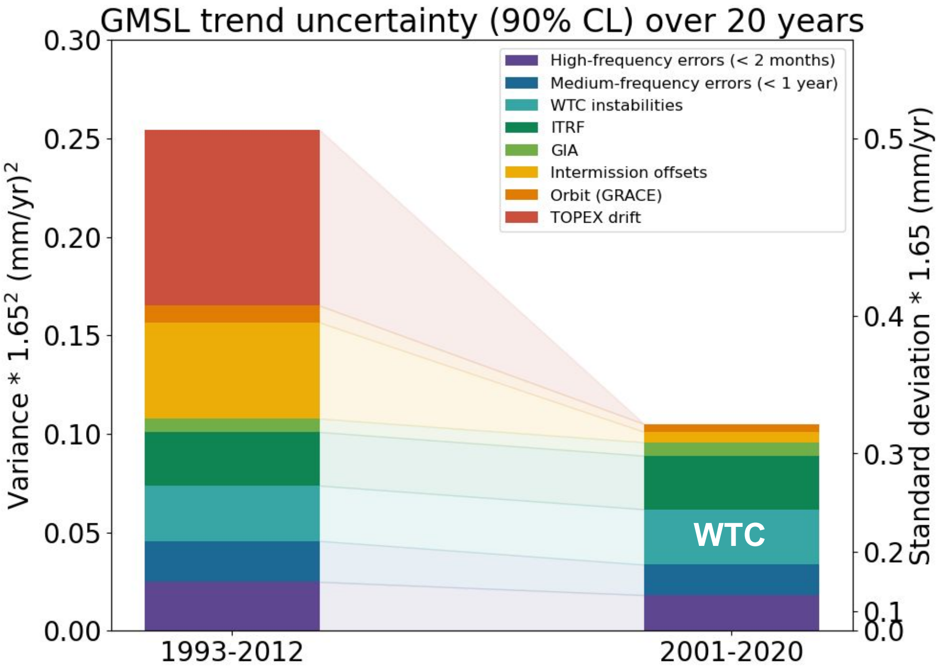
Introduction

- New **stability uncertainty requirements** have been established for **altimetry** to address scientific questions (Meyssignac et al., OSTST 2019, in prep.) such as:
  - closing the sea level budget and identifying the missing contributions;
  - constraining projections of future sea level rise and its contributions;
  - estimating the Earth's energy imbalance and constraining the Earth energy budget.

	Current uncertainty over 20 years (Ablain et al., 2019; Guérou et al., submitted)	Requirements at decadal time scales (endorsed by C3S)
GMSL trend	0.3-0.5 mm/yr	< 0.1 mm/yr
GMSL acceleration	0.07-0.12 mm/yr²	< 0.05 mm/yr²

5-95 % confidence level

Introduction



The **wet tropospheric correction (WTC)** computed from the microwave radiometer (MWR) onboard the altimetry missions is a major source of uncertainty of the GMSL trend. It is modelled by a **standard uncertainty of 0.2 mm/yr** correlated over periods of 5 years in the **GMSL uncertainty budget** (Ablain et al., 2019; Guérou et al., 2022).

Introduction

Total column water vapour (TCWV) climate data records (CDRs):

- are derived from brightness temperature measurements from SSM/I and SSMI/S satellite missions,
- are highly stable in time, as shown by the GEWEX water vapour assessment (Schröder et al., 2016),

CDR dataset	**Total column water vapour trend standard uncertainty (kg/m2/yr)** Schröder et al. (2016)	**Rough conversion to WTC trend standard uncertainty (mm/yr)** following Thao et al. (2014)
HOAPS	0.007	0.049
REMSS	0.006	0.042

- can be easily converted to WTC using a polynomial formula (Keihm et al., 2000; Stum et al., 2011).

➔ Can we use these highly stable **water vapour climate data records** to compute a **CDR-derived WTC** and reduce the WTC **low frequency uncertainty?**

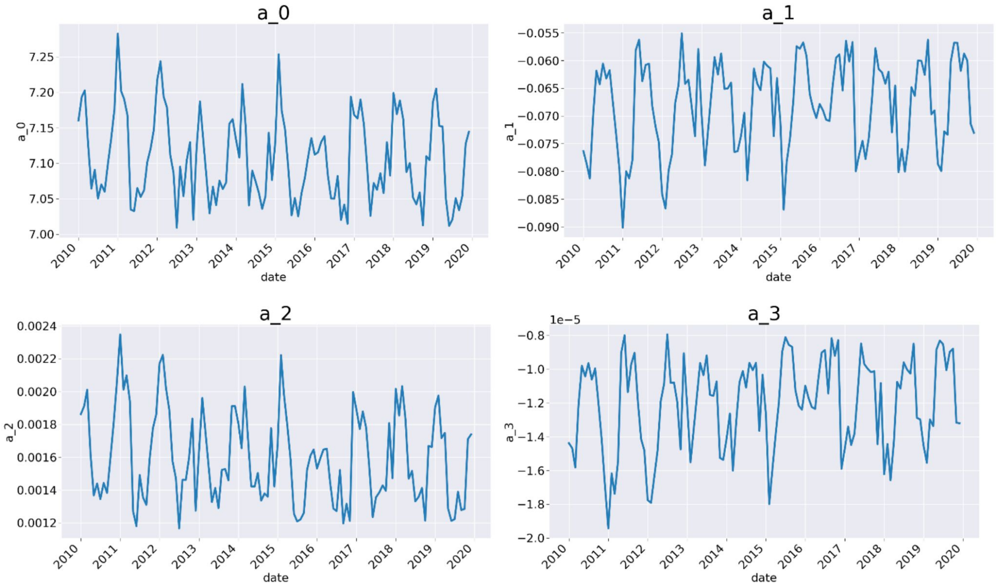
From water vapour to wet tropospheric correction

Polynomial formula (Keihm et al., 2000; Stum et al., 2011)

$$WTC = (a_0 + a_1 TCWV + a_2 TCWV^2 + a_3 TCWV^3) TCWV$$

Determination of a_i coefficients

Polynomial fit using ERA5 data

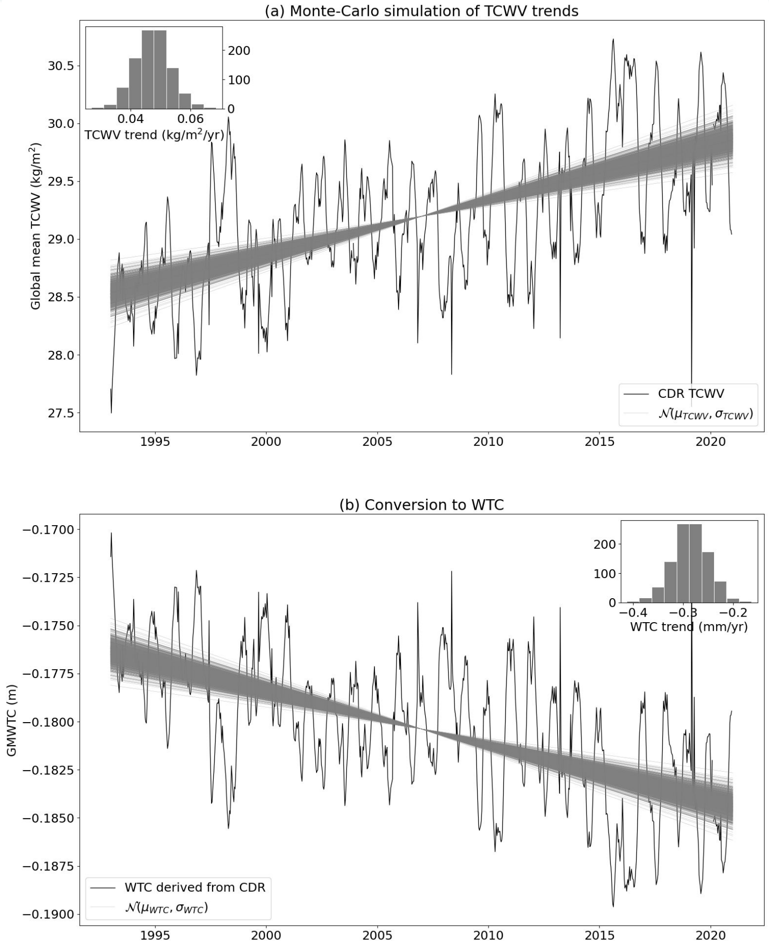


temporal average = a_i
standard deviation = σ_{ai}

Main assumptions

- the relationship is stable with time,
- the temperature has a negligible role.

Uncertainty propagation from TCWV to WTC



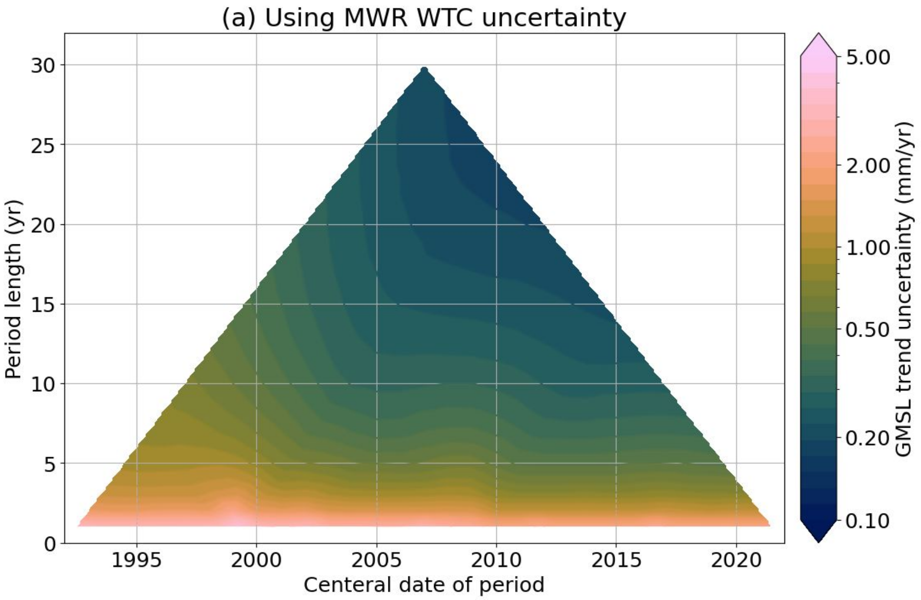
- Empirical uncertainty propagation using a Monte-Carlo approach of:
  - TCWV trend uncertainty (from Schröder et al., 2016)
  - TCWV bias uncertainty (from Schröder et al., 2013)
  - a_i polynomial coefficient uncertainties estimated in this study

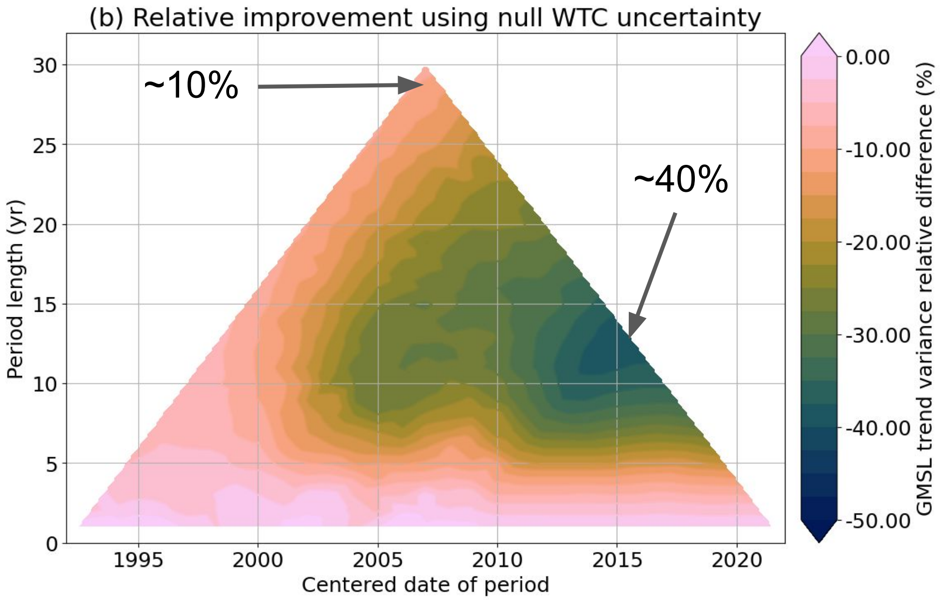
➔ CDR-derived WTC trend uncertainty of **0.05 mm/yr** (68 % confidence level) whatever the period and CDR dataset used, to be compared with the MWR WTC uncertainty of 0.2 mm/yr correlated over periods of 5 years (Legeais et al., 2014; Ablain et al., 2019).

WTC contribution to GMSL trend uncertainties

GMSL trend uncertainty

Maximal GMSL trend variance reduction with perfectly stable WTC

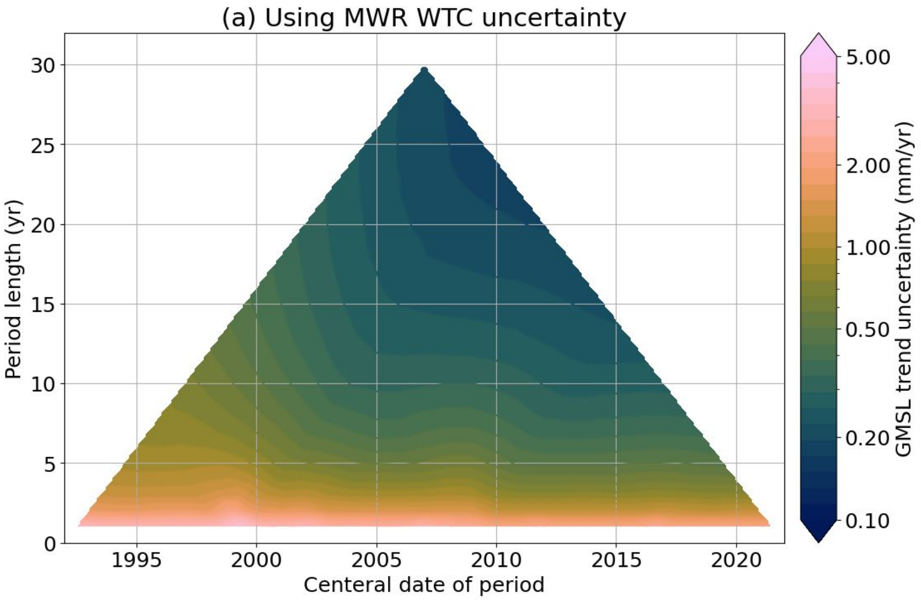




68 % confidence level (1σ)

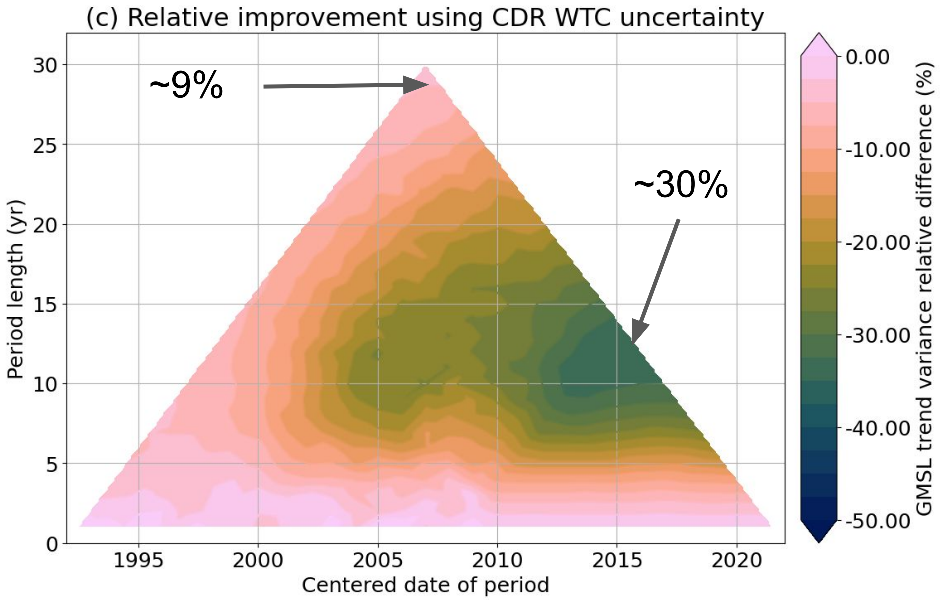
Improvement of the GMSL trend uncertainty using CDRs

GMSL trend uncertainty



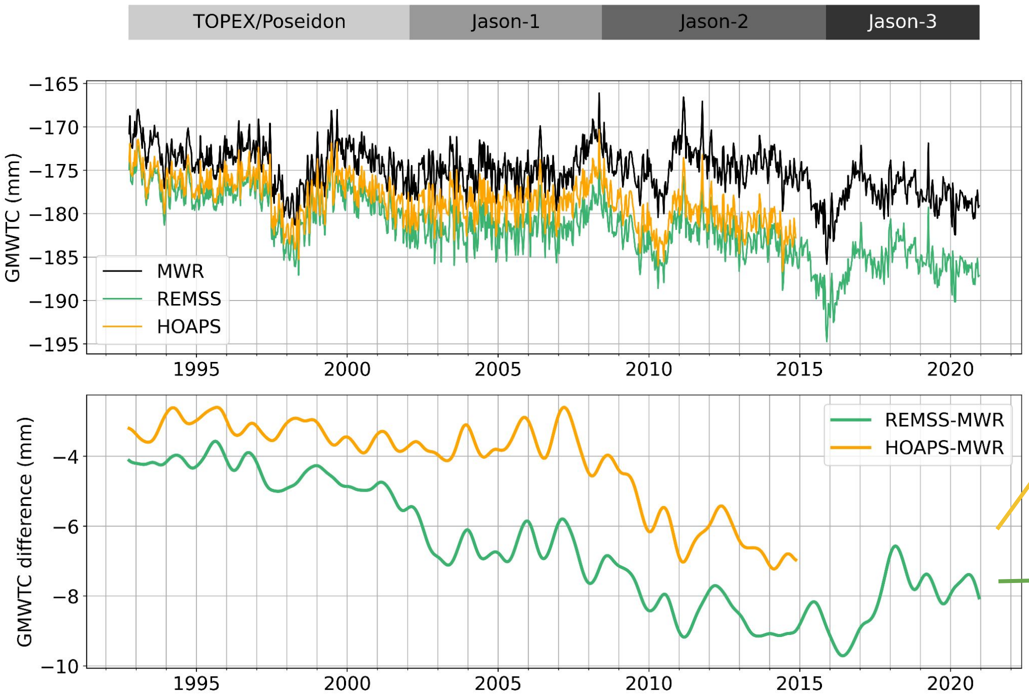
68 % confidence level (1σ)

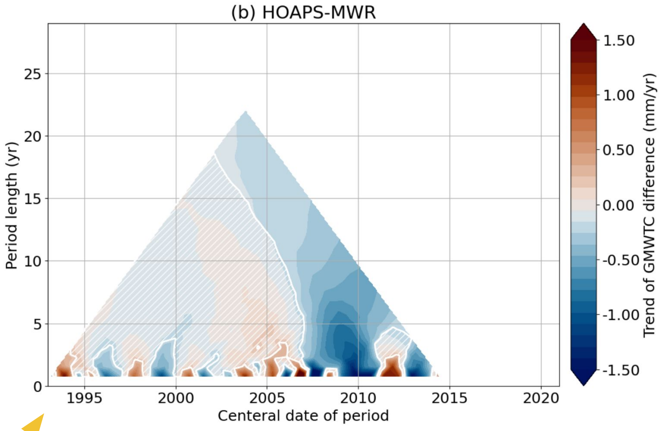
GMSL trend variance reduction using a CDR-derived WTC

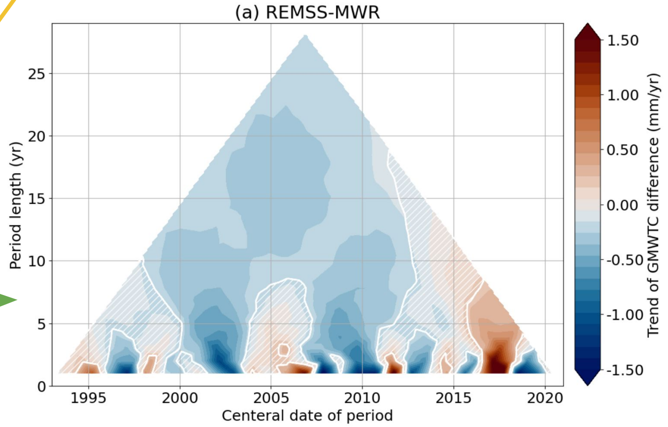


Global mean wet tropospheric correction

Combination of MWR high frequencies (< 1 yr) with CDR low frequencies (> 1 yr).

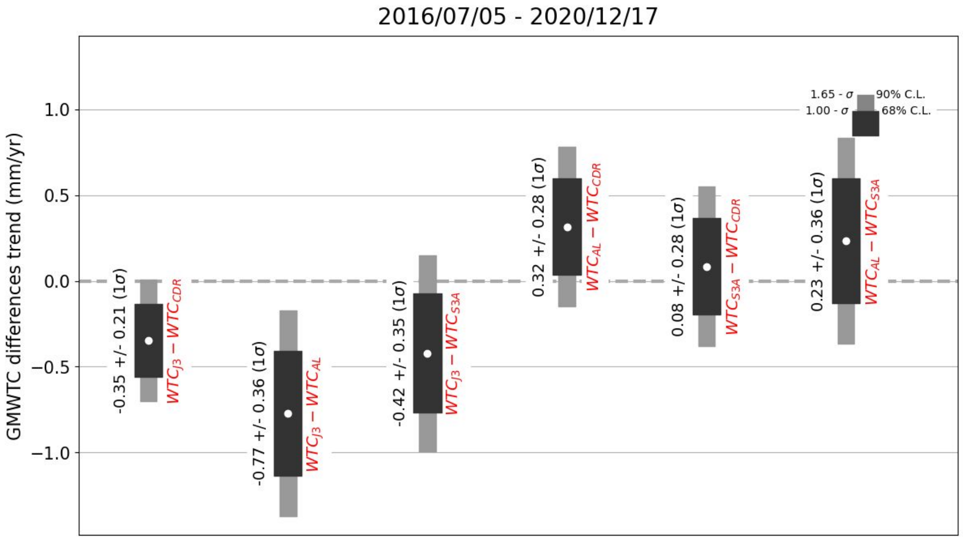


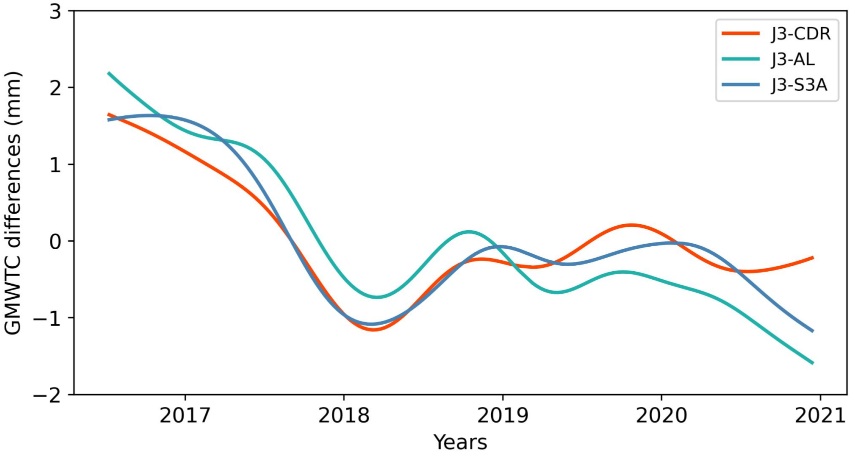




Assessment over Jason-3 period

- Comparison between CDRs, Jason-3 MWR, SARAL/AltiKa MWR and Sentinel-3A MWR WTC
  - CDRs are consistent with SARAL/AltiKa and Sentinel-3A MWR WTC.
  - We detect a likely drift of Jason-3 radiometer of the order of -0.5 mm/yr.





Impact on the Earth's energy imbalance estimate

- The **Earth's energy imbalance** (EEI) quantifies the excess of energy stored in the Earth's system.

- **Uncertainty of EEI from geodetic data**

    - Standard uncertainty of 0.13-0.15 W/m^2
      (Meyssignac et al., 2019; Hakuba et al., 2021; Marti et al., 2022)

    - WTC is responsible for ~15 % of the EEI uncertainty variance over 2002-2016

    - Using the **CDR-derived WTC reduces the EEI variance by ~12 %** over 2002-2016.

Earth's energy imbalance from satellite altimetry and gravimetry:
see posters Ablain, Marti et al. **SC1_004** and **SC1_005**

Conclusions

- The **WTC** is responsible for **10-40 % of the GMSL trend uncertainty variance**.
- The use of **water vapour climate data records** allow to **reduce the GMSL trend uncertainty** (variance reduced **by 9-30 %**) and consequently allow to reduce the uncertainty on the global ocean heat content and Earth's energy imbalance derived from geodetic data.
- We detect a likely **drift of Jason-3 radiometer** of the order of **-0.5 mm/yr**, consistent with the global mean sea level budget. Correcting for this drift is important for climate change studies.

Outlook

- Further improvements involve investigating the impact of the spatio-temporal variations of the relationship between water vapour and WTC on the CDR-derived WTC estimate and uncertainty.
- A full description of water vapour uncertainties (variance-covariance matrix) would allow a more comprehensive propagation of uncertainties.

CDR-derived WTC soon available on AVISO+/ODATIS portal for independent assessment

Thank you for your attention.

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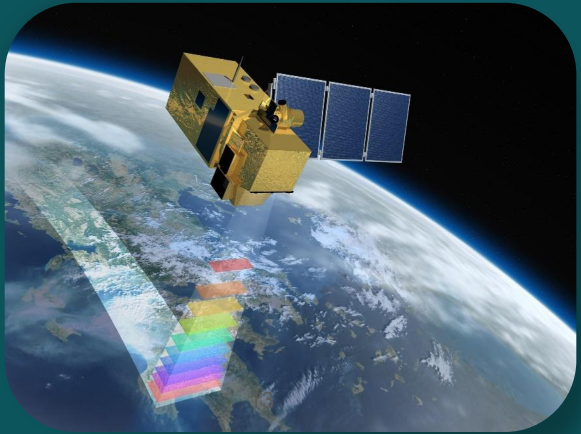

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