



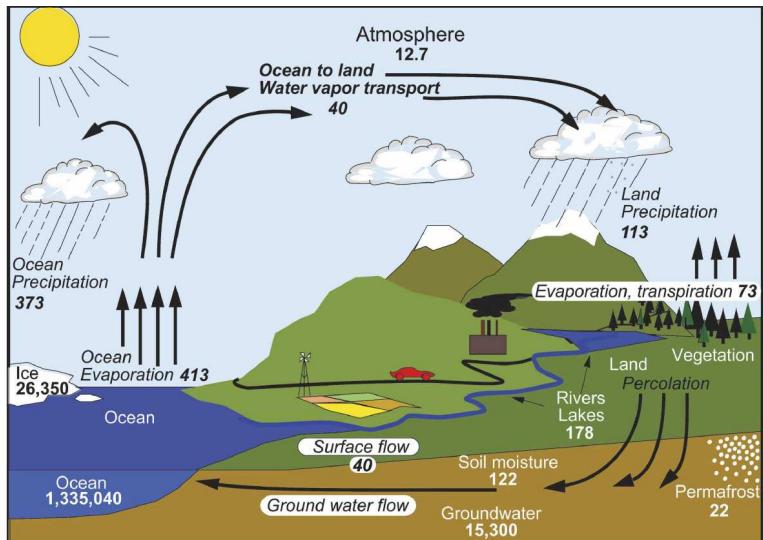
The importance of an accurate geocenter motion in the Earth's water and energy budgets estimated by gravimetry

Alejandro Blazquez & Benoit Meyssignac



Global water budget

Global water budget at annual scale



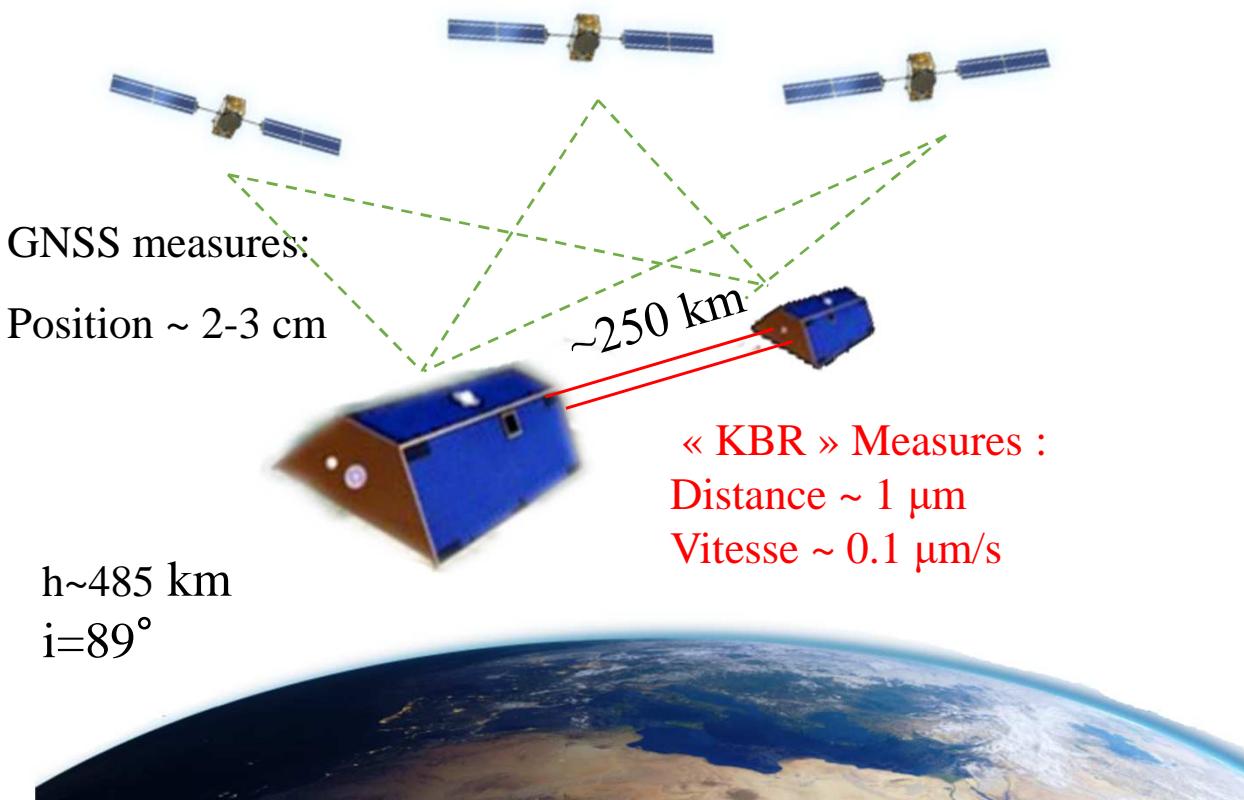
Trenberth et al.(2007)

Global water budget at longer scales

$$\Delta M_{\text{Land}} \sim 760 \pm 100 \text{ Gt/yr} + \Delta M_{\text{Ocean}} \sim 760 \pm 100 \text{ Gt/yr} + \Delta M_{\text{Atm}} \sim 10 \text{ Gt/yr} = \Delta M_{\text{loss TOA}} \sim 10^{-3} \text{ Gt/yr}$$

(Red arrow points to the last term)

GRACE & GRACE FO missions



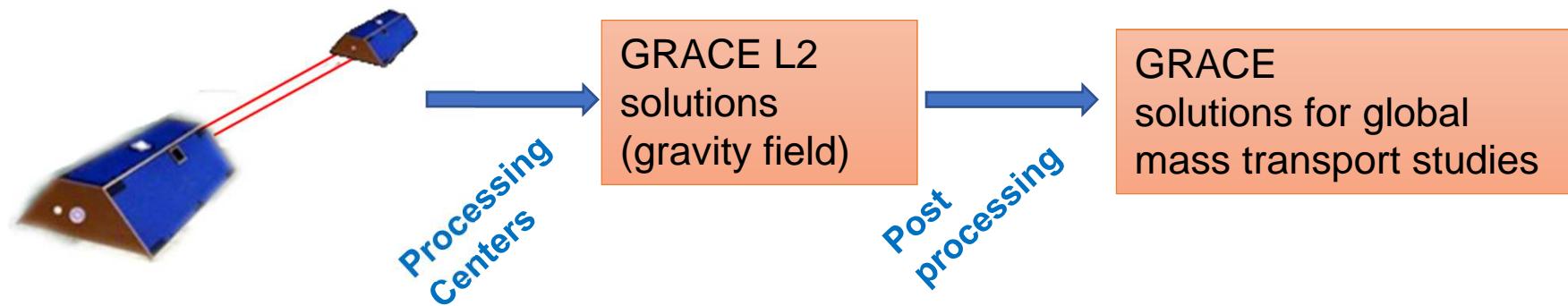
L1 data from satellites
KBR, GNSS measures,
accelerometers, star tracker

Ancillary data from models
Atmospheric, ocean, hydrological
dealiasing

Inversion
Processing
Centers

GRACE L2 Solutions
(Gravity field)

Post processing parameters



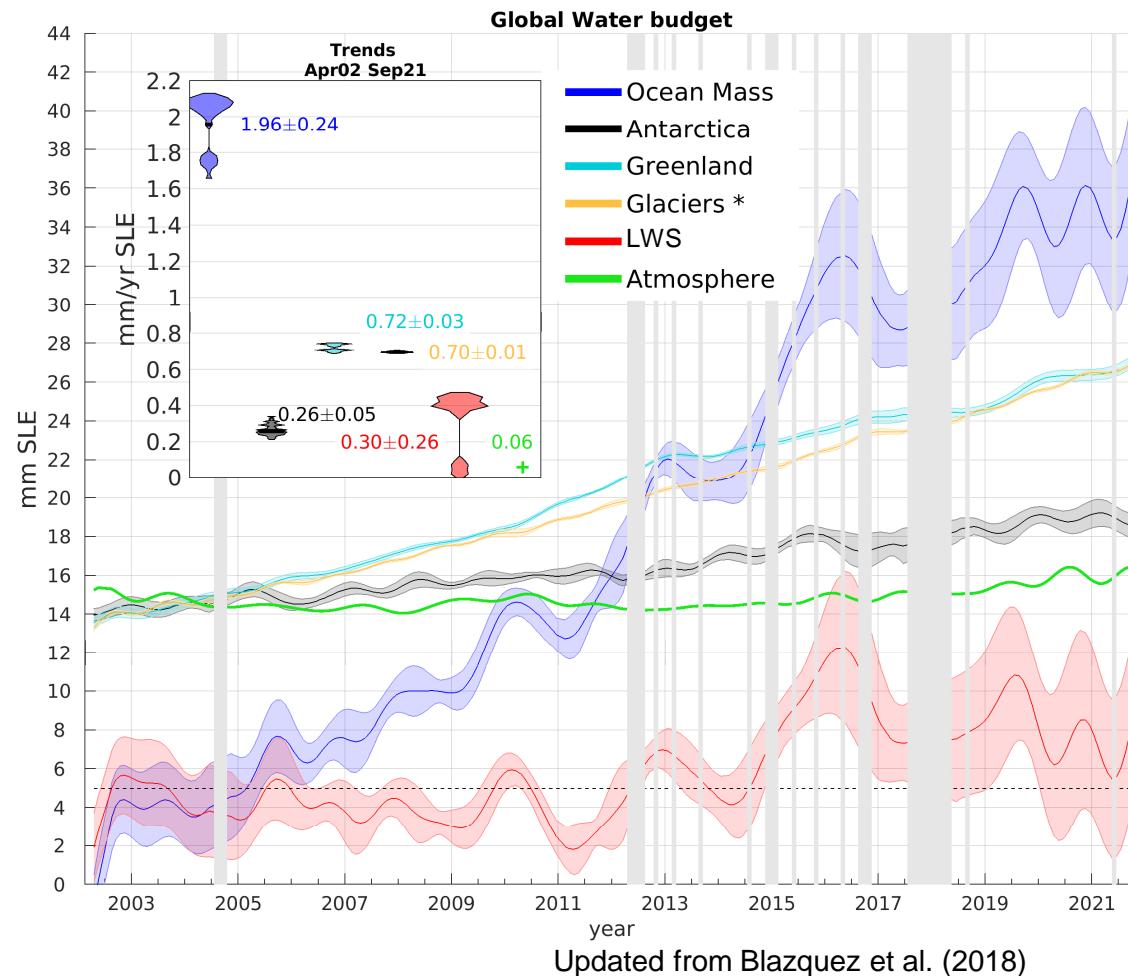
➤ L2 Limitations

- Geocenter motion
- Earth oblateness
- Anisotropic noise
- Leakage and Gibbs effect

➤ Solid-Earth Changes

- GIA correction
- Pole tide correction
- Earthquakes
- ...

GRACE-based global water budget



$$\Delta M_{\text{Land}} + \Delta M_{\text{Ocean}} + \Delta M_{\text{Atm}} = 0$$

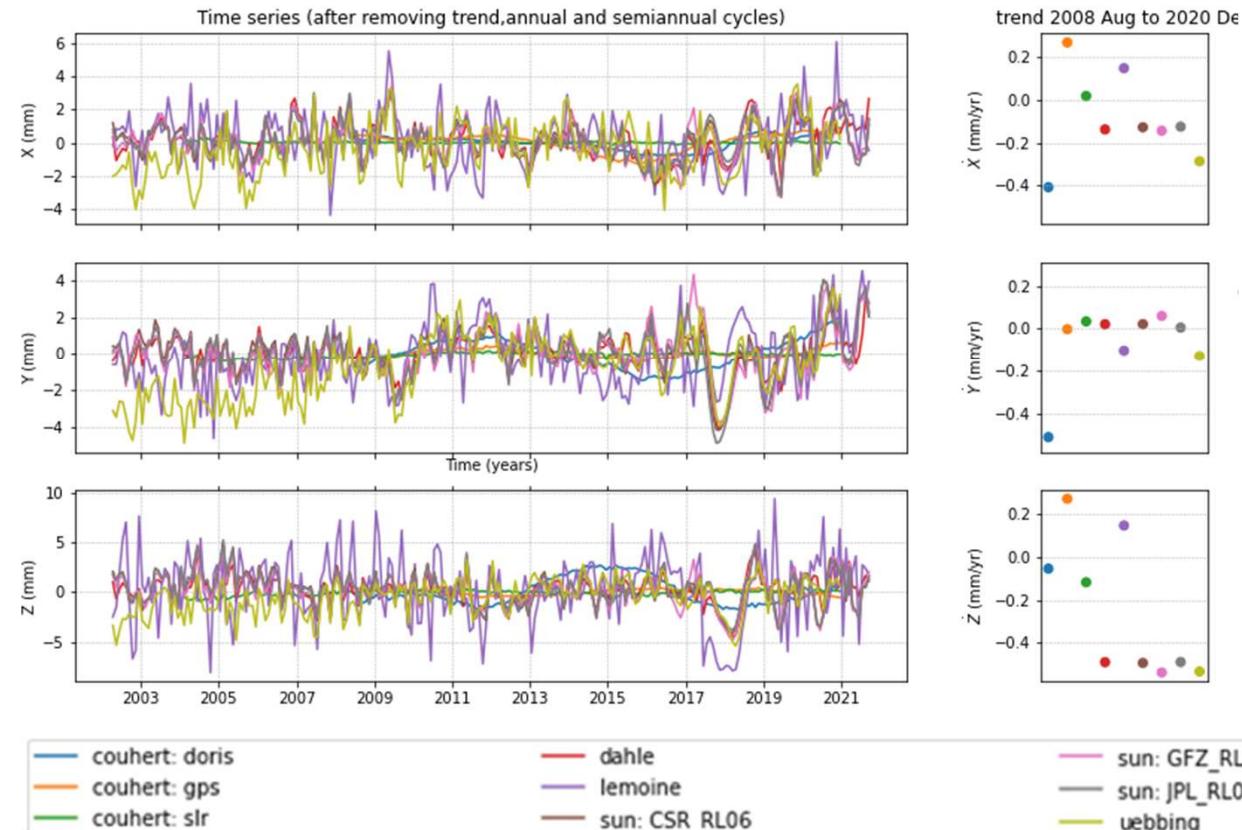
Greenland, Antarctica, Glaciers, LWS

Source of the uncertainties in the trends

mmSLE/yr	Ocean mass	Greenland	Antarctica	LWS
geocenter	0.19	<0.01	0.03	0.22
Center	0.06	0.01	0.05	0.06
GIA	0.03	0.03	0.01	0.04
C20	0.01	<0.01	<0.01	0.02
filter	0.01	<0.01	0.02	0.01
TOTAL	0.24	0.03	0.05	0.26

Uncertainty due to the geocenter motion

Geocenter motion



Spread among these solutions about 0.3 to 0.5 mm/yr depending on the axis

Z Axis Uncertainty up to $\pm 0.54\text{mm/yr}$
(Riddell et al. 2017)

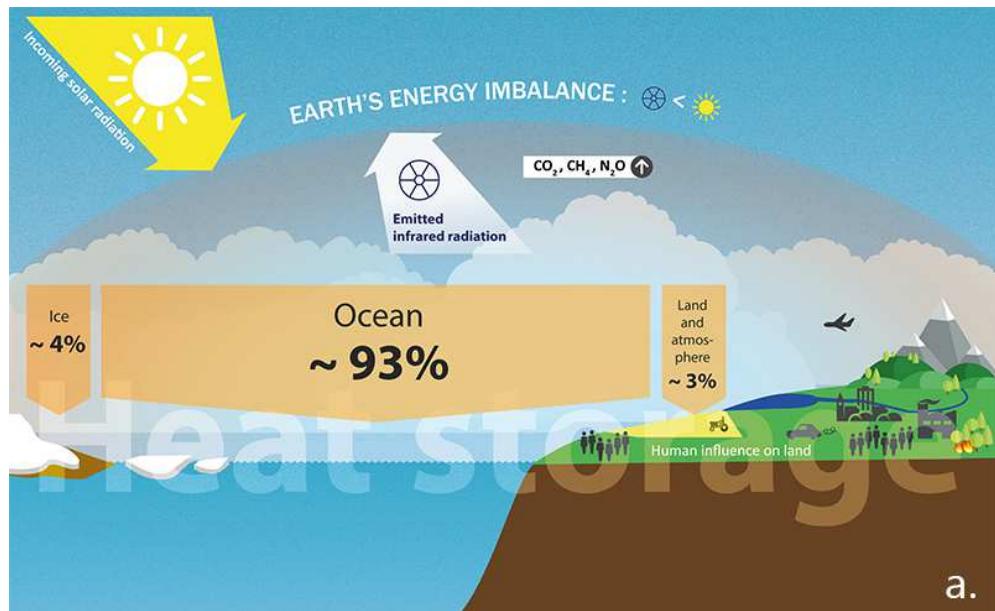
Source of the uncertainties in the trends

mmSLE/yr	Ocean mass	Greenland	Antarctica	LWS	
geocenter	0.19	<0.01	0.03	0.22	
	Ocean	Greenland	Antarctica	Arctic Islands	LWS
X	-0.50	<0.01	<0.01	<0.01	0.49
Y	-0.28	<0.01	0.02	<0.01	0.27
Z	-0.60	0.03	-0.19	0.02	0.73

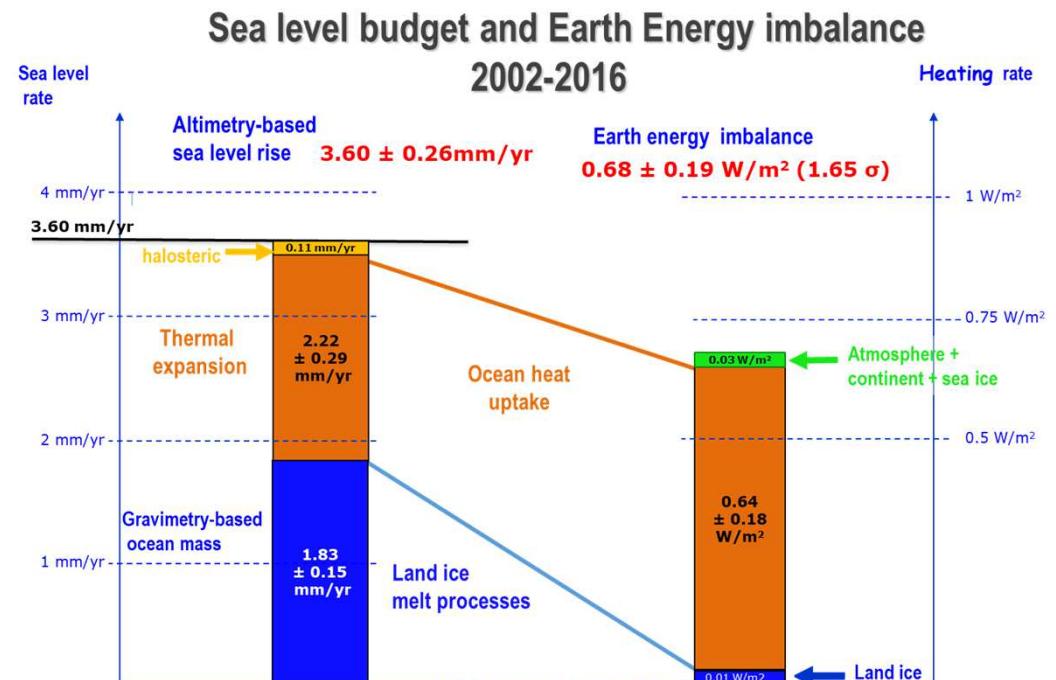
Table S2: Unitary effect of each axis of the geocenter motion on the components of the global water budget.

Blazquez et al. (2018)

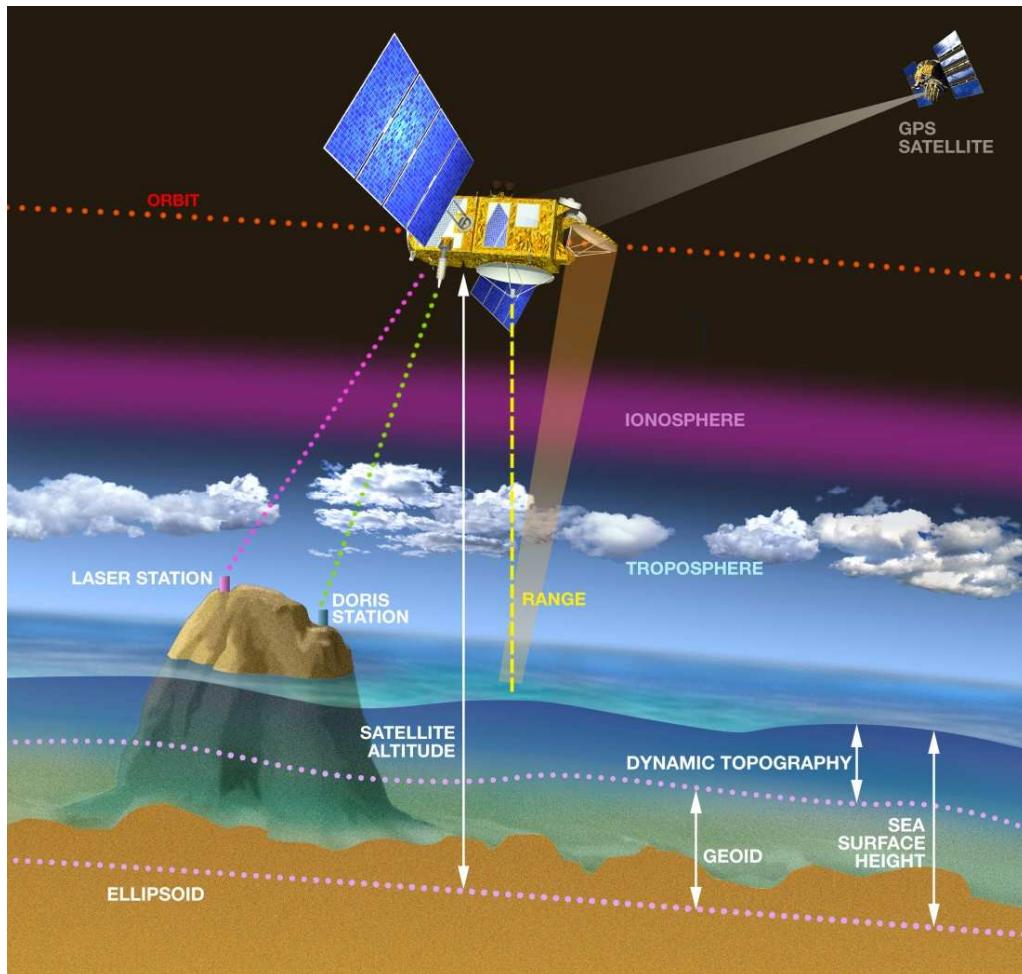
Earth Energy Imbalance



Von Schuckmann et al 2016



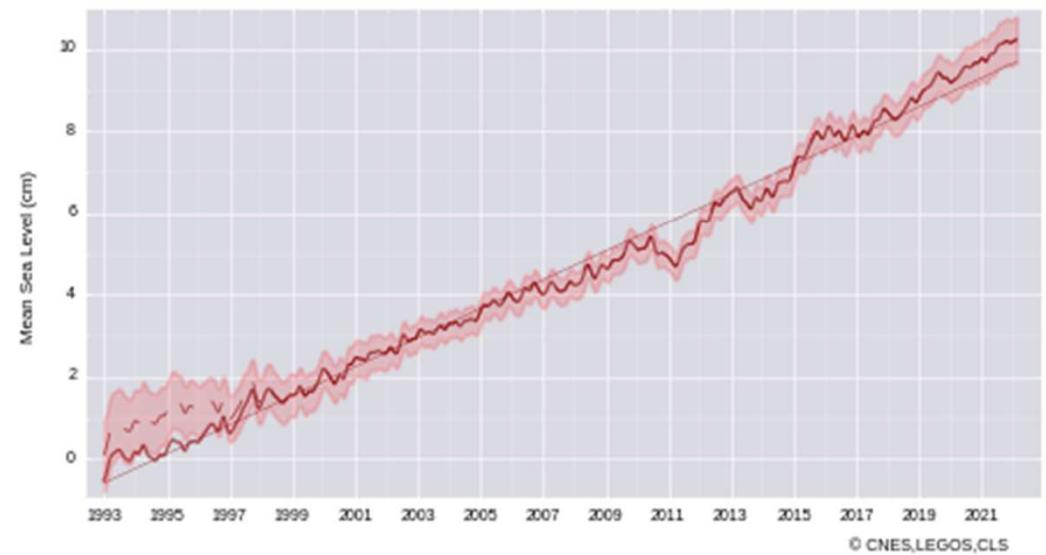
Altimetry-based sea-level



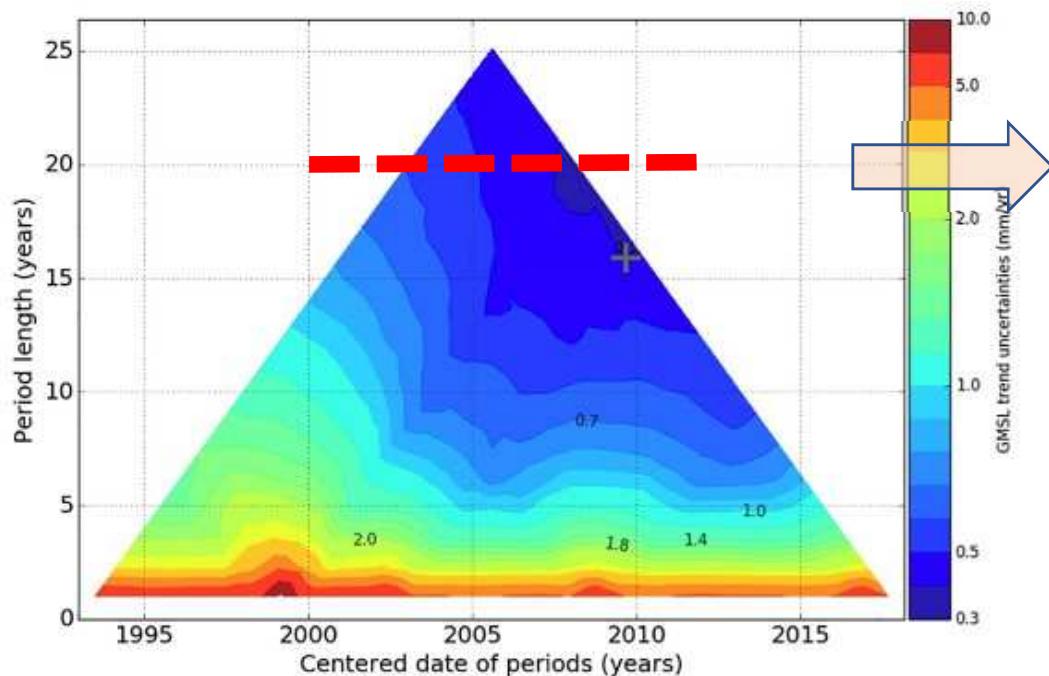
Latest MSL Measurement
21 February. 2022

+3.53 mm/yr

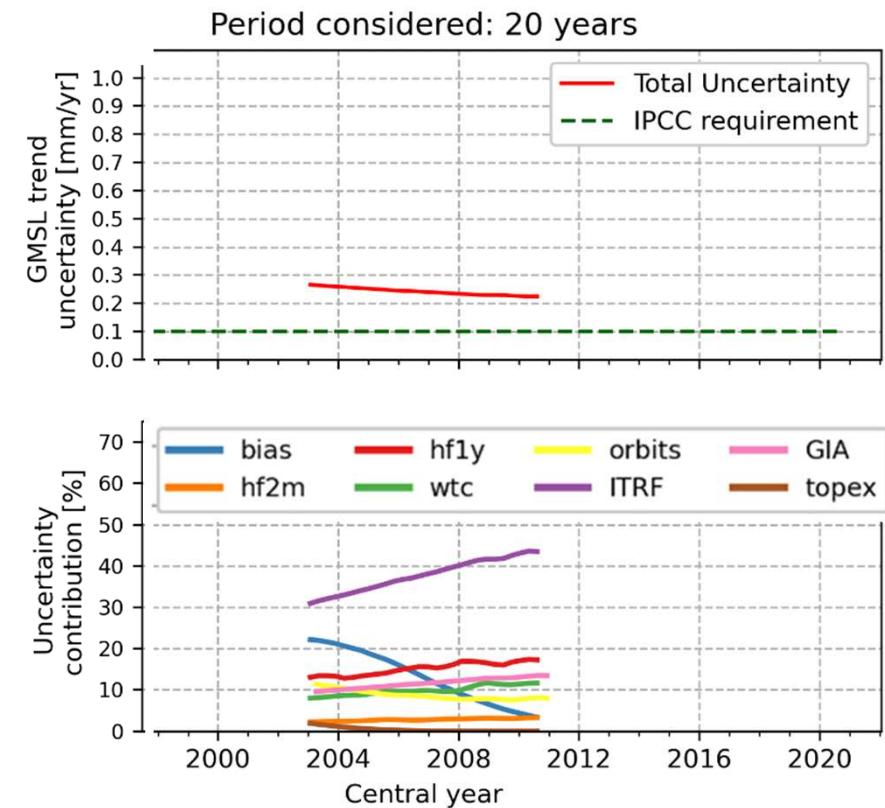
Reference GMSL - corrected for GIA



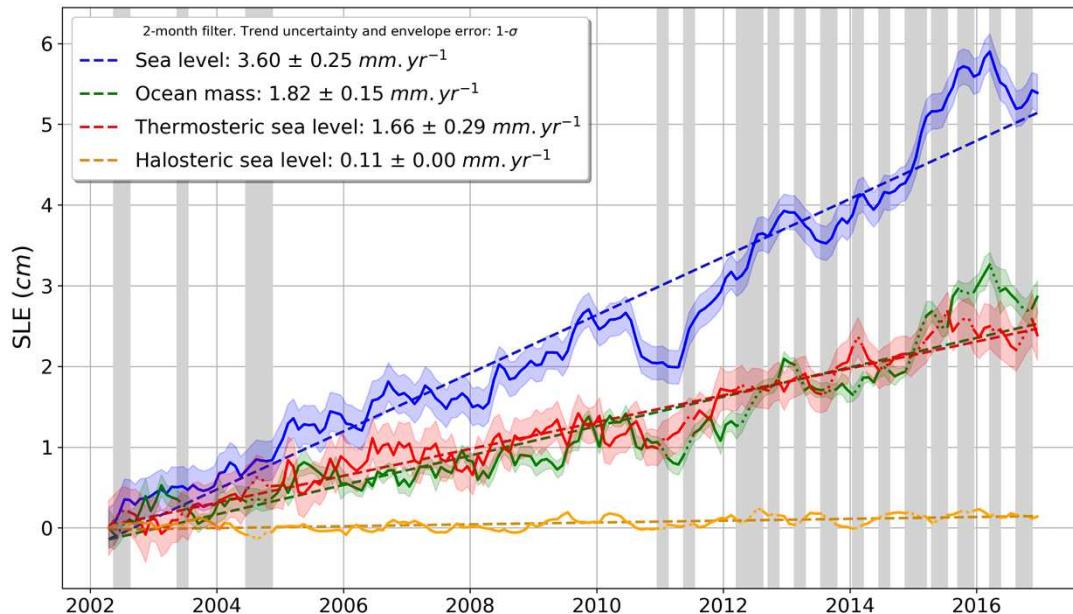
Uncertainty in the global-mean sea-level



Updated from Ablain et al. (2019)

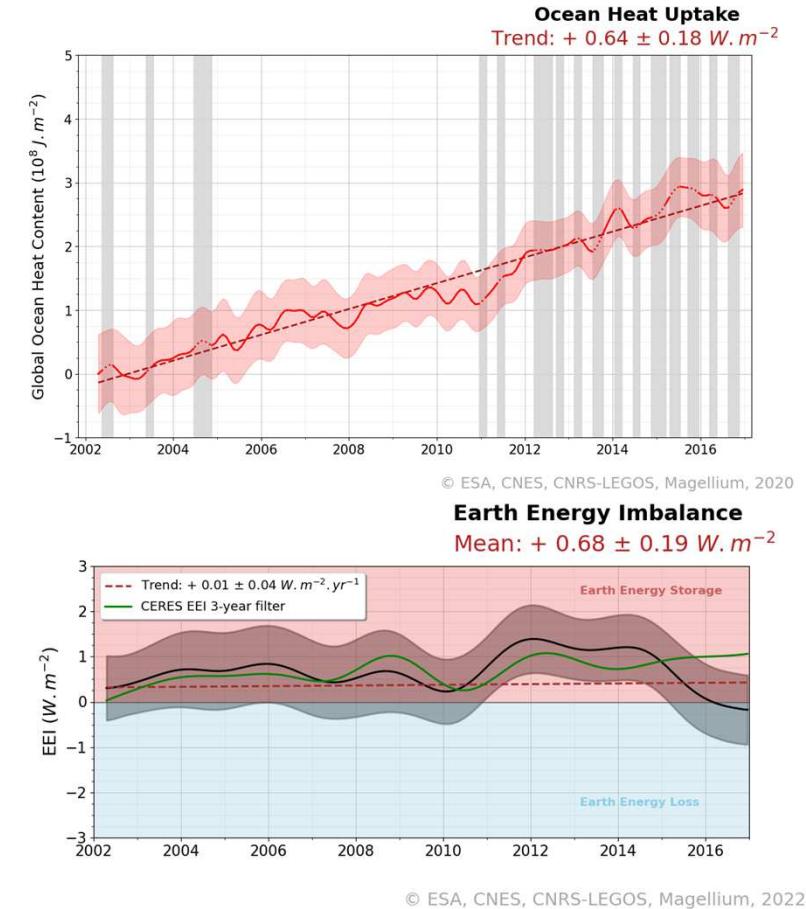


Earth Energy Imbalance



Uncertainties in mmSLE/yr over 15 yr

Gravimetry ocean mass (Blazquez et al., 2018)	$\pm 0.15 \text{ mmSLE/yr}$
Altimetry Sea-level (Ablain et al., 2019)	$\pm 0.26 \text{ mmSLE/yr}$
EEI (Marti et al., 2022)	$\pm 0.19 \text{ W/m}^2$



Earth Energy Imbalance Uncertainty

Nowadays:

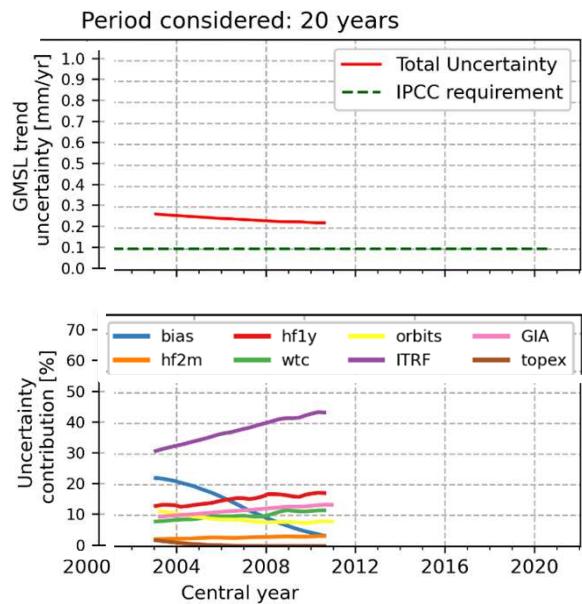
$\pm 0.17 \text{ W.m}^{-2}$ in 18-yr mean EEI

Goal:

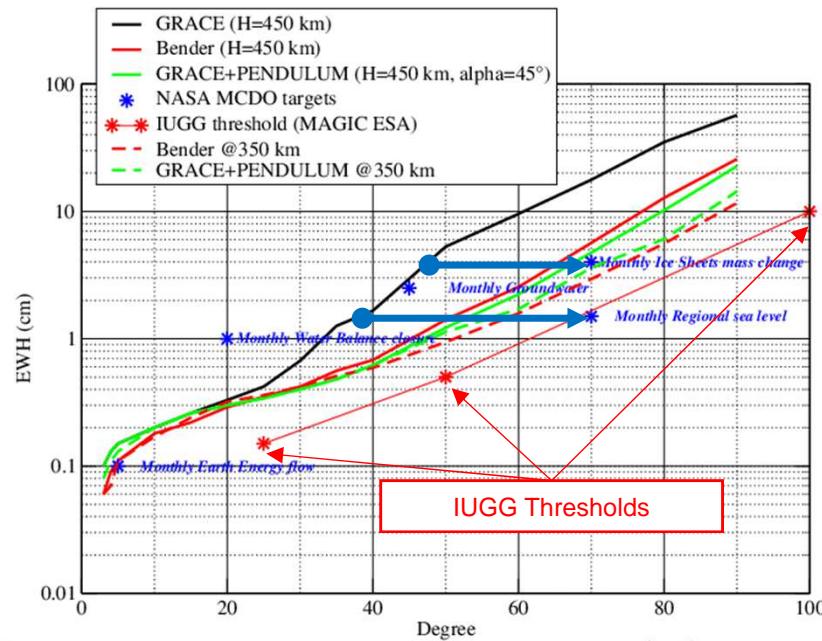
$\pm 0.10 \text{ W.m}^{-2}$ in 20-year mean EEI & trends in EEI

Monitor & understand EEI variations due to:
Hiatus, Volcanoes... the effect of CO₂ policies

Objective: Altimetry $\pm 0.2\text{mm/yr}$ over 20 years



Gravimetry: Ocean mass at $\pm 0.2\text{mm/yr}$ over 20 years



Conclusions

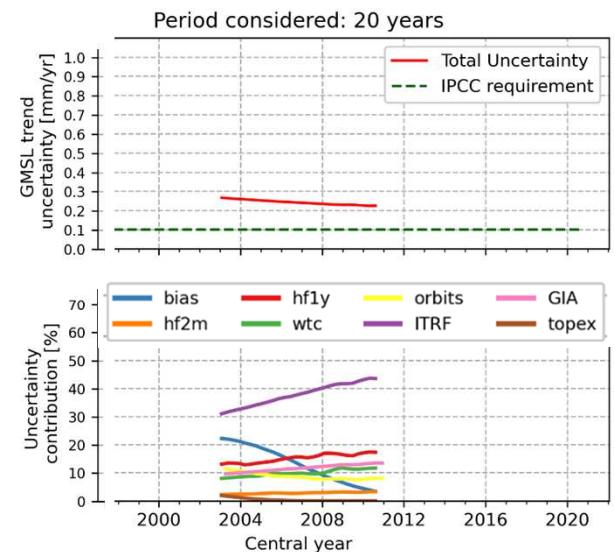
The uncertainty in geocenter dominates:

- The uncertainty in the gravimetry-based **ocean mass trend** and the Earth global water budget.
- The uncertainty in the 20 yr trend of altimetry-based **global-mean sea-level**.
- The uncertainty in the geodetic-based **EEI**

In order to fulfil IPCC requirements, we need an accuracy in the **geocenter motion trend of 1mm/yr in all axis**

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