EGU21-10174

Global sea-level and ocean-mass budgets using advanced data products and uncertainty characterisation

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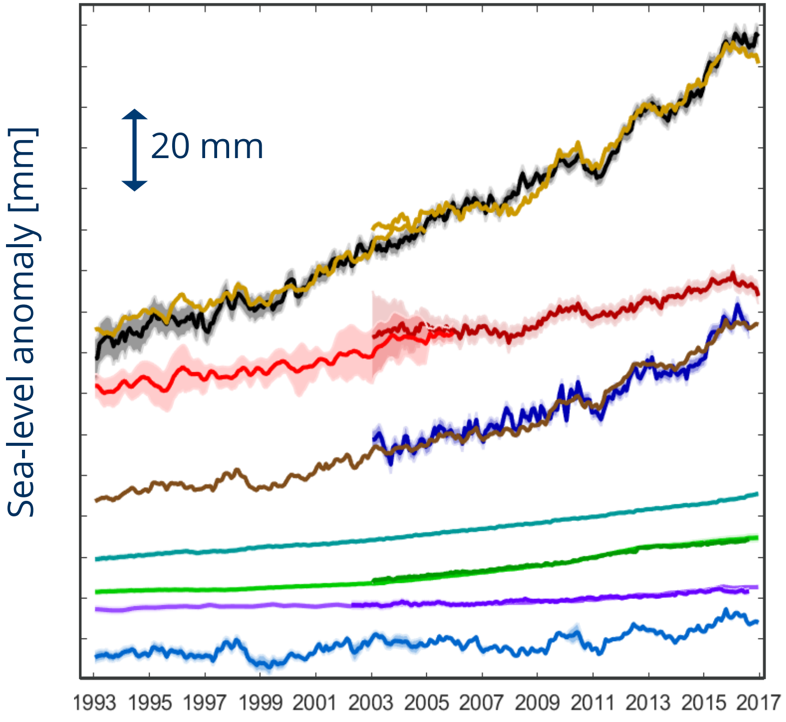
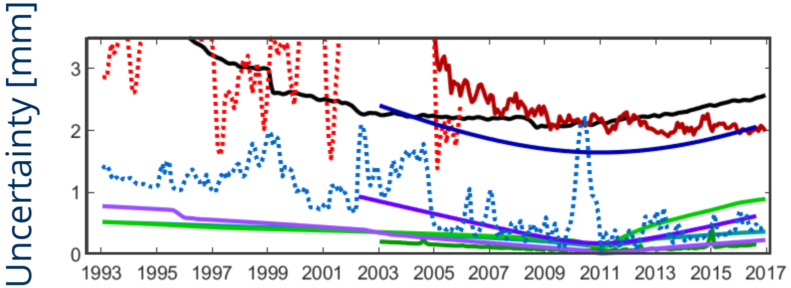
One-slide summary

sea level budget closure cci

1 Datasets developed & advanced within ESA Climate Change Initiative





Global mean sea level
- satellite altimetry (SL_cci)
- sum of steric and mass effects

Steric effect
- Argo profiles and SST (SST_cci)
- ensemble mean steric dataset

Ocean mass effect
- GRACE (SLBC_cci)
- sum of mass contributions

Ocean mass contributions

Glaciers
- Global Glacier Model

Greenland
- satellite altimetry (GrIS_cci)
- GRACE (GrIS_cci)

Antarctica
- satellite altimetry (AIS_cci)
- GRACE (AIS_cci)

Land water storage
- WaterGAP glob. hydrol. model

2 Linear trends: budgets are closed

Trends 2003-2016 [mm/yr]

Total sea level 3.64 ±0.26

Steric 1.19 ±0.17

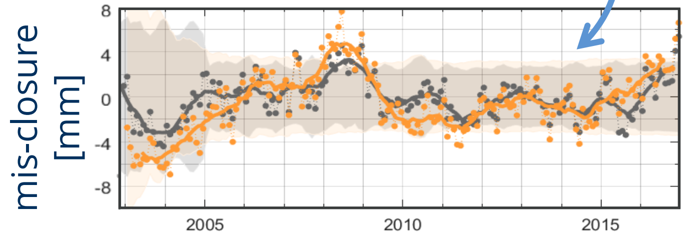
Mass from GRACE 2.19 ±0.22 | from mass contrib. 2.40 ±0.13

mis-closure –0.21 ±0.26

mis-closure

0.27 ±0.40 | 0.05 ±0.34

3 Monthly anomalies: budgets are closed



4 Download time series. Read details in ESSD Discuss.

https://doi.org/10.5285/1562578dd07844f19f01f0db9366106d
https://doi.org/10.5194/essd-2021-137

The SLBC_cci project

ESA's Climate Change Initiative (CCI)

includes several Essential Climate Variables (ECVs) addressing sea level

sea level cci

glaciers cci

sea surface temperature cci

ice sheets greenland cci

antarctic ice sheet cci

Sea Level Budget Closure (SLBC_cci)

was a cross-ECV project that

- utilized the framework and quality of CCI products
- developed additional products in this framework
- investigated the sea level budget and ocean mass budget.

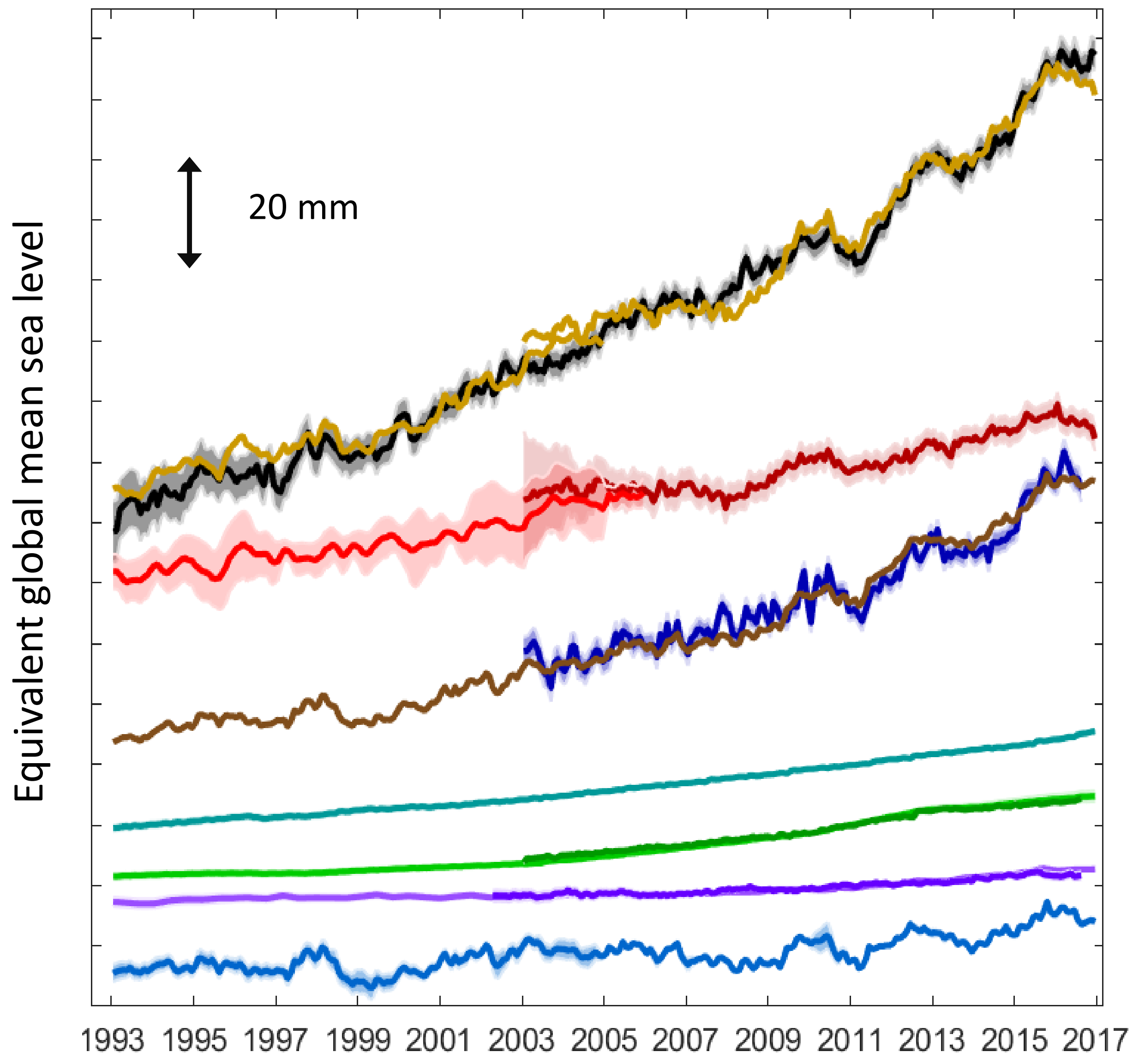
SLBC_cci

- concentrated on products by CCI and by consortium members
- exploited insights into their genesis and uncertainty characteristics
- facilitated a consistent framework of uncertainty characterization and sea level budget analysis.

SLBC_cci

- addressed the global mean sea level budget over
  - 1993-2016 (altimetry era)
  - 2003-2016 (GRACE/Argo era)
- included a regional study for the Arctic.

Budget elements at monthly resolution
(more details given in appendix)



Global mean sea level change
from satellite altimetry (Sea_Level_cci) with comprehensive uncertainty characterisation

Sum of steric effect and ocean mass change

Steric sea level change
from Argo profiles with additional constraints by sea surface temperature (SST_cci)

Ensemble mean of existing steric sea level datasets

Ocean mass change
from GRACE satellite gravimetry (SLBC_cci)

Sum of ocean mass contributions

Glaciers
Global Glacier Model, using Glaciers_cci results for initialisation and validation

Greenland
from improved satellite radar altimetry processing (Greenland_Ice_Sheet_cci), calibrated against satellite laser altimetry,

from GRACE sat. gravimetry (Greenland_Ice_Sheet_cci)

Antarctica
from improved satellite radar altimetry processing (Antarctic_Ice_Sheet_cci) involving a time-evolving ice and snow density mask

from GRACE sat. gravimetry (Antarctic_Ice_Sheet_cci)

Land water storage
WaterGAP global hydrology model with improved representation of reservoir operation

Ocean-mass budget 2003-2016

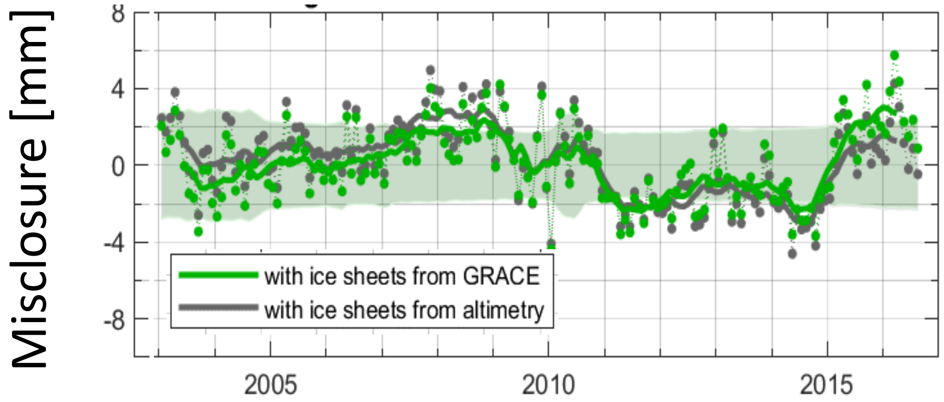
sea level budget closure cci

Linear trends [mm/yr]

Budget element	Method	P2: Jan 2003 –	Aug 2016
Glaciers	GGM	0.77 ± 0.03	0.77 ± 0.03
Greenland	Altimetry	(0.68 ± 0.06)	
	GGM	(0.21 ± 0.03)	
	Altimetry + GGM	0.89 ± 0.07	
	GRACE		0.78 ± 0.02
Antarctica	Radar altimetry	0.34 ± 0.04	
	GRACE		0.27 ± 0.11
Land water storage	WaterGAP	0.40 ± 0.10	0.40 ± 0.10
Sum of mass contributions		2.40 ± 0.13	2.22 ± 0.15
Ocean mass (global)	GRACE	2.19 ± 0.22	2.19 ± 0.22
Misclosure		-0.21 ± 0.26	-0.04 ± 0.27

→ Closure within uncertainties

Monthly anomalies



→ Histograms of monthly misclosure support combined uncertainty assessment of budget elements under a Gaussian assumption

Sea-level budget 1993-2016 and 2003-2016

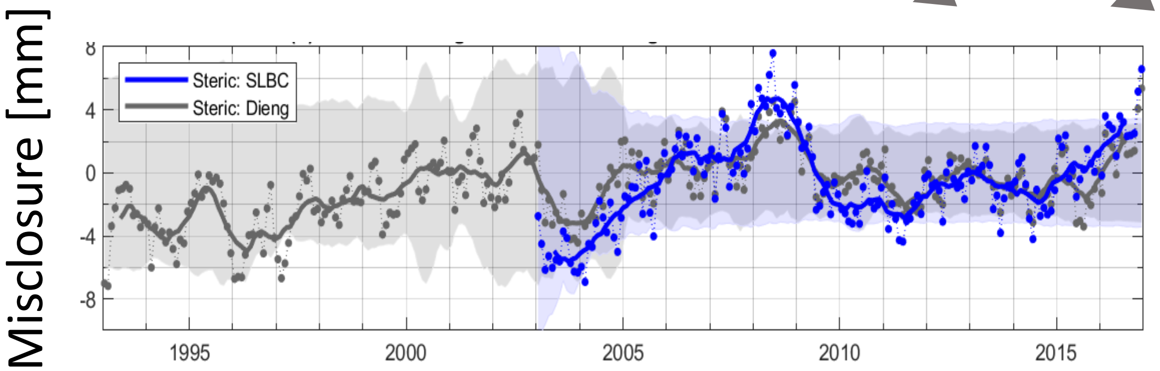
sea level budget closure cci

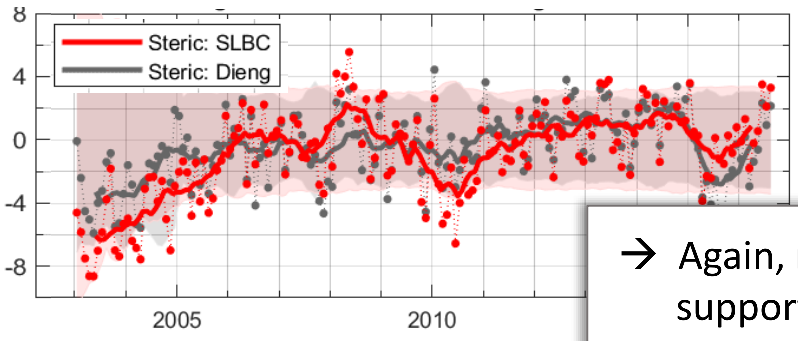
Linear trends [mm/yr]

Budget element	Method	P1: Jan 1993 – Dec 2016	P2: Jan 2003 – Aug 2016		
Total sea-level	altimetry	3.05 ± 0.24	3.64 ± 0.26	3.64 ± 0.26	3.64 ± 0.26
Steric component	Dieng	1.15 ± 0.12			
	SLBC_cci + deep steric estimate		1.19 ± 0.17	1.19 ± 0.17	1.19 ± 0.17
Glaciers	GGM	0.64 ± 0.03	0.77 ± 0.03	0.77 ± 0.03	
Greenland	(altimetry)	(0.43 ± 0.04)	(0.68 ± 0.06)		
	(GGM)	(0.17 ± 0.02)	(0.21 ± 0.03)		
	Altimetry + GGM	0.60 ± 0.04	0.89 ± 0.07		
	GRACE			0.78 ± 0.02	
Antarctica	altimetry	0.19 ± 0.04	0.34 ± 0.04		
	GRACE			0.27 ± 0.11	
Land water storage	WaterGAP	0.32 ± 0.10	0.40 ± 0.10	0.40 ± 0.10	
Sum of mass contributions		1.75 ± 0.12	2.40 ± 0.13	2.22 ± 0.15	
Ocean mass (65°N-65°S)	GRACE				2.18 ± 0.25
Sum of contributions		2.90 ± 0.17	3.59 ± 0.22	3.41 ± 0.23	3.37 ± 0.30
Misclosure		0.15 ± 0.29	0.05 ± 0.34	0.23 ± 0.35	0.27 ± 0.40

→ Closure within uncertainties

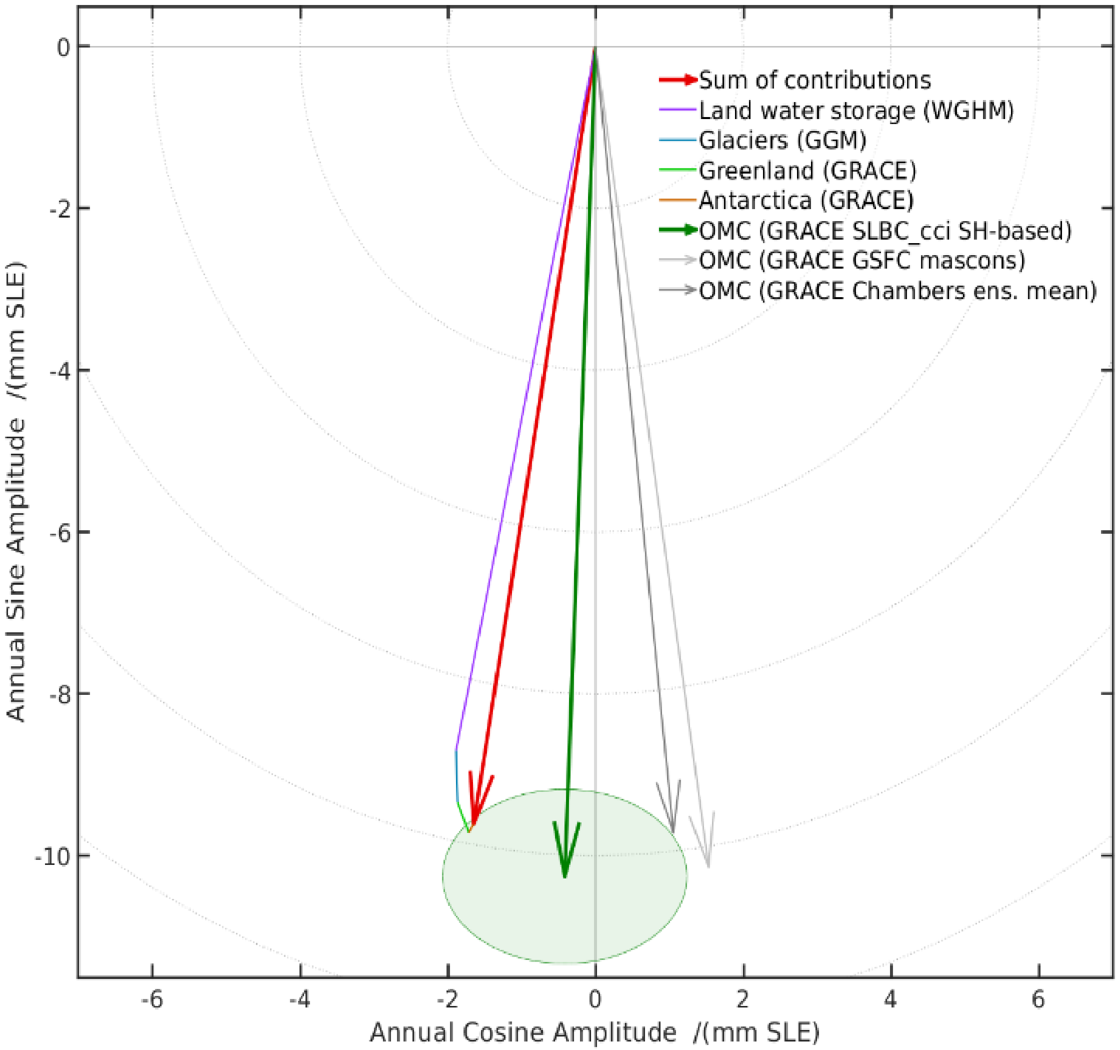
Monthly anomalies





→ Again, monthly misclosure supports combined uncertainty assessment

Mass budget of annual harmonic signal

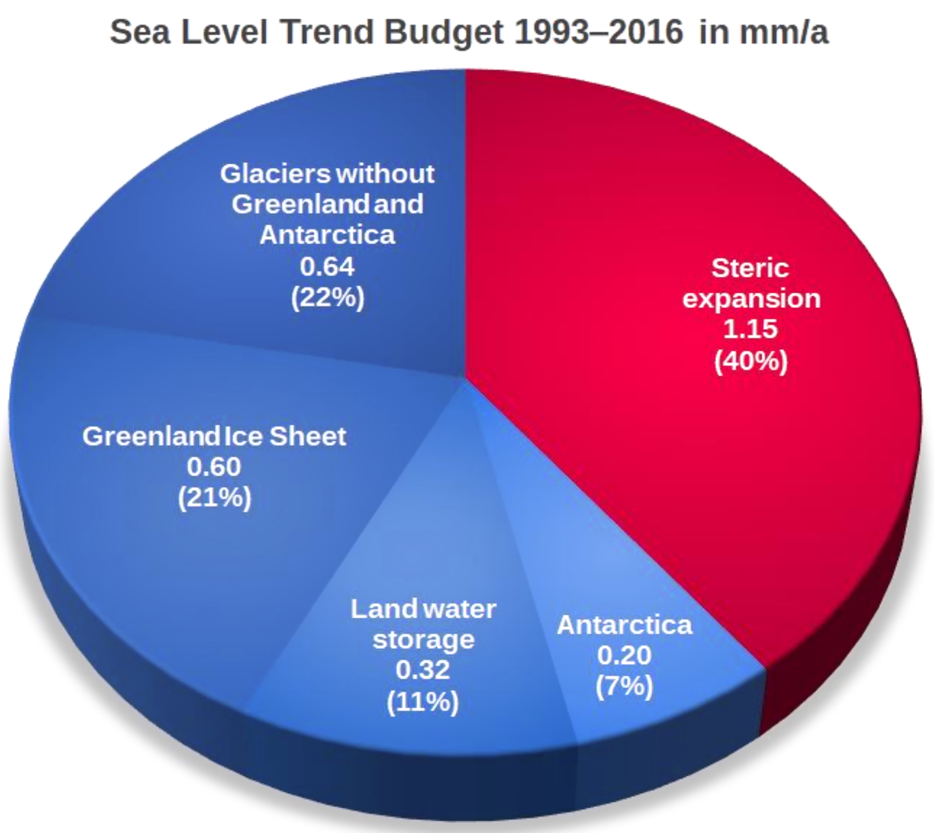


→ The phase of GRACE ocean mass change is ~7 days later than the phase of the sum of components.

→ Still within uncertainties.

Conclusions and perspectives

- Global sea level budget and ocean mass **budget** (for multi-year linear trends and monthly anomalies) are **closed** within uncertainties.
- **Uncertainties** are large: 0.2 - 0.3 mm/yr (1-sigma) for the trend of several budget elements.
- Trend uncertainties are an obstacle against estimating missing components or using budget assessments to decide on the “best” dataset for a single component. (Resist to temptations to do so!)
- Improving the **uncertainty characterization** and making it consistent across datasets (und cultures) remains a major task, as important as reducing the uncertainties themselves.
- We have made progress towards both goals.
- In doubt, choose the dataset for which you understand the uncertainty characterization.
- While we have focused on the largest-possible scale (global mean sea level), **regional and local assessments** will bring us closer to process understanding. (And will add more challenges.)



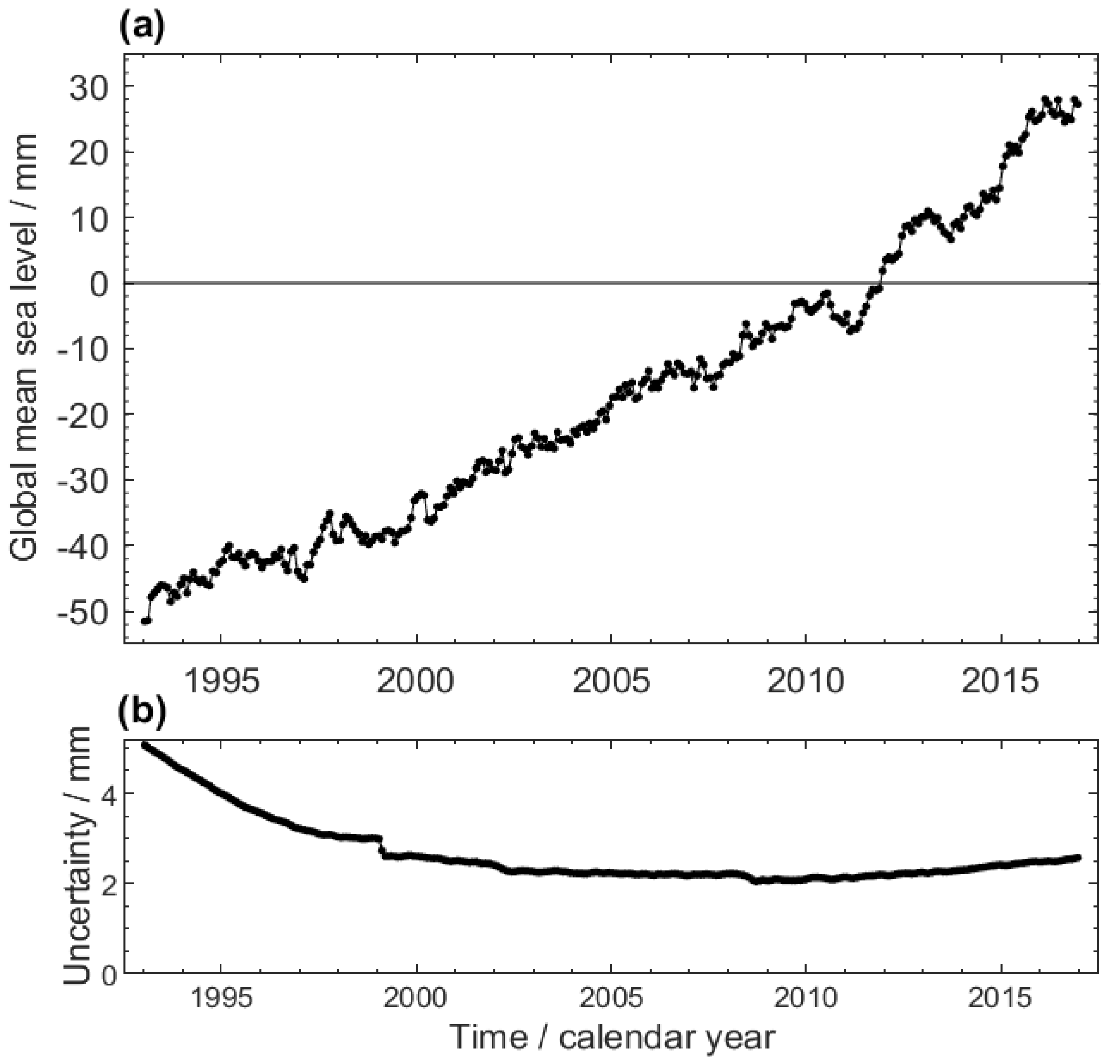
- Download timeseries from https://doi.org/10.5285/1562578dd07844f19f01f0db9366106d
  Read ESSD Discussion paper https://doi.org/10.5194/essd-2021-137

Appendix: some details on data products

Global Mean Sea Level from altimetry

- Sea Level CCI product until 2015
- AVISO/CMEMS for 2016
- TOPEX A drift correction from Ablain et al.
- New uncertainty characterisation based on Ablain et al. (2017)

✓ GMSL data and underlying global grids of sea level changes are available from the CCI Sea Level project (www.esa-sealevel-cci.org).

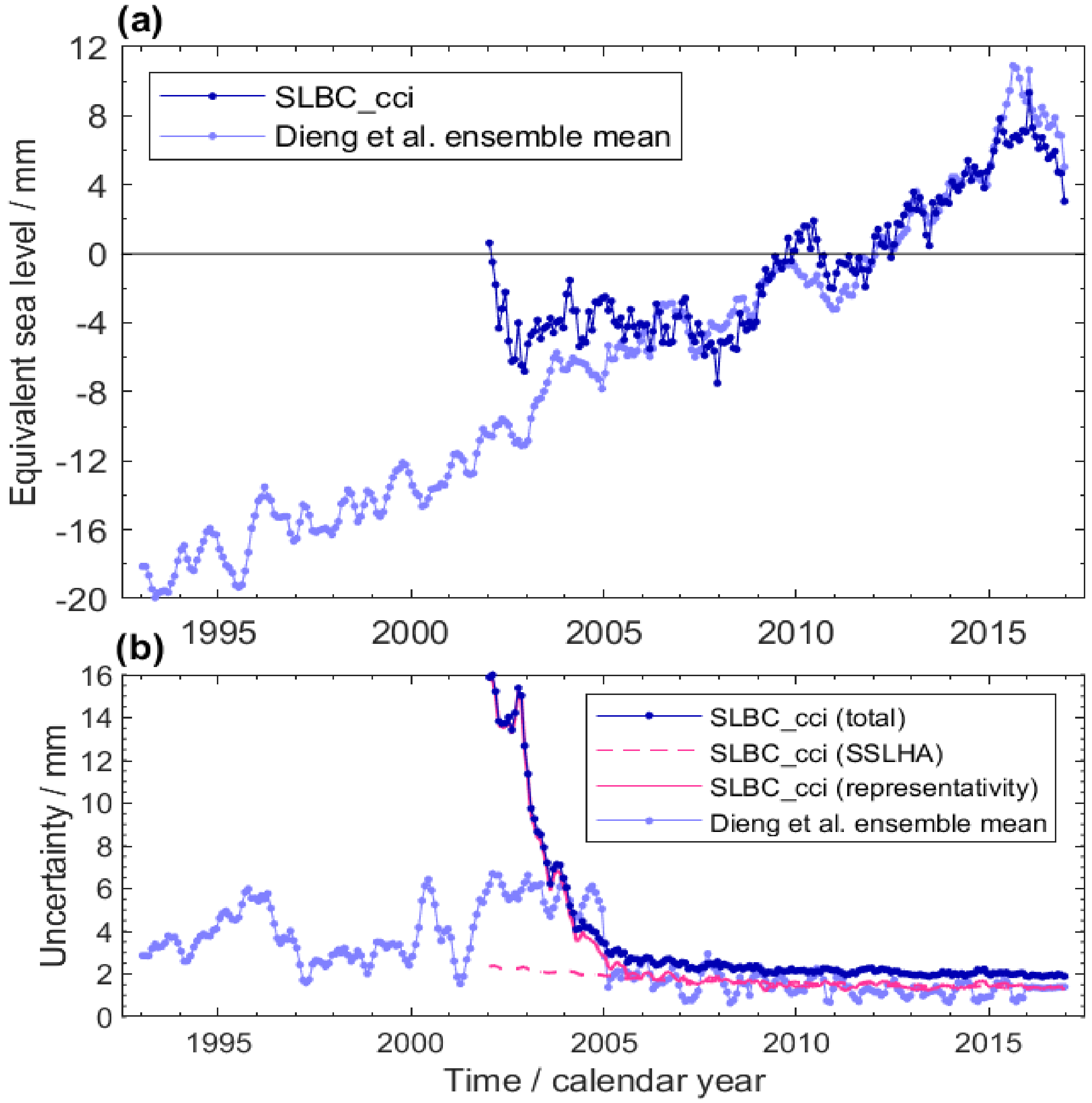


Steric component

Development within SLBC project

- Based on Argo profiles
- Incorporate Sea Surface Temperature (via conditional climatology method)
- Advanced uncertainty characterisation

✓ Gridded SLBC_cci steric sea level height anomaly product at 5°x5° spatial resolution and monthly temporal resolution, from January 2002 to December 2017, as well as the spatial average over the latitude range from 65°N to 65°S.

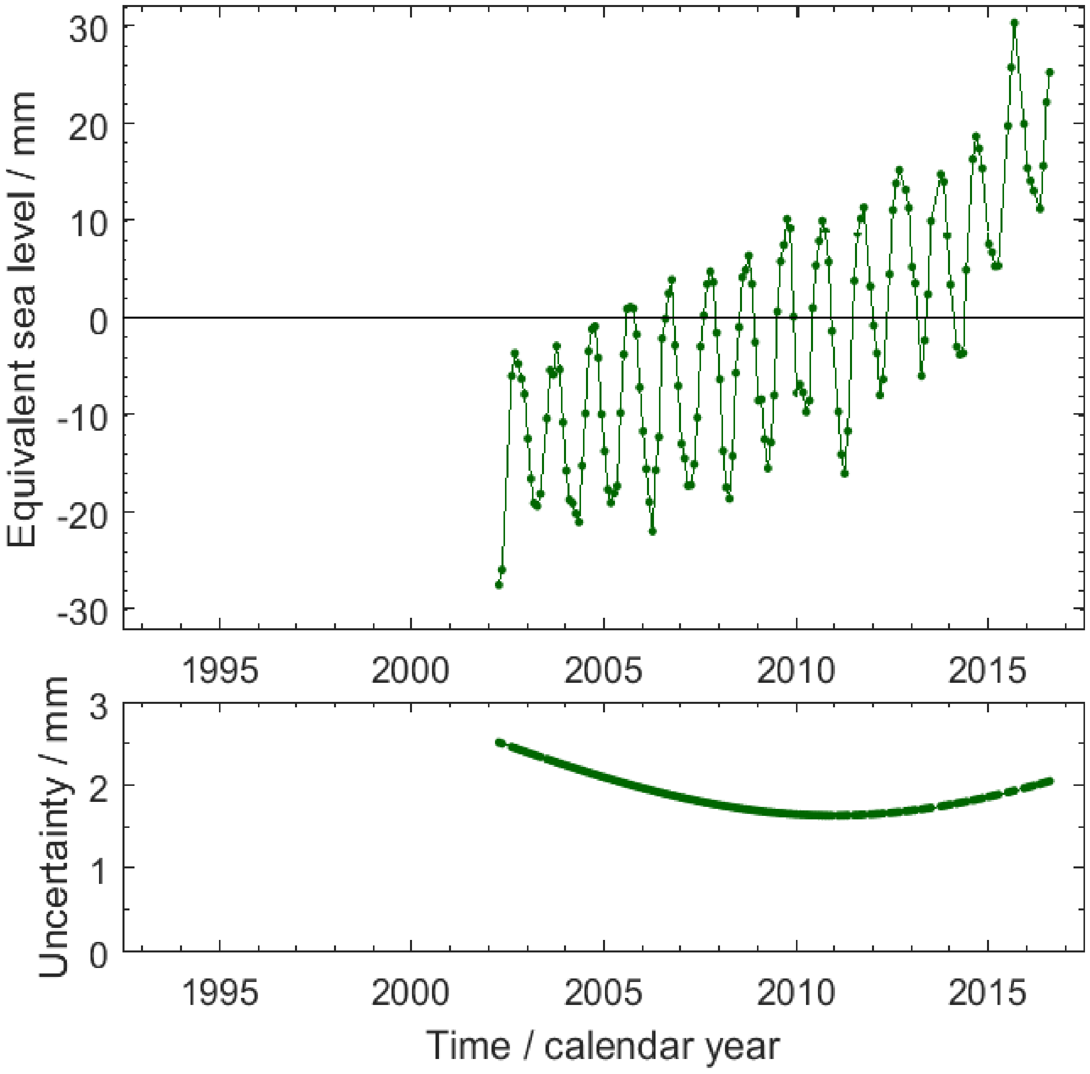


Global Ocean mass change from GRACE

sea level budget closure cci

- GRACE monthly spherical harmonic solutions: ITSG-Grace2018.
- Integration over buffered ocean kernel
- Handling of “AOD” background models based on recent methodological insights (cf. Uebbing et al. 2019)

✓ Time series from GRACE for 4 series of SH GRACE solutions, 3 GIA corrections (and the option of no GIA correction), and 3 different integration domains.



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Global glaciers mass change

sea level budget closure cci

Global Glacier Model uses:

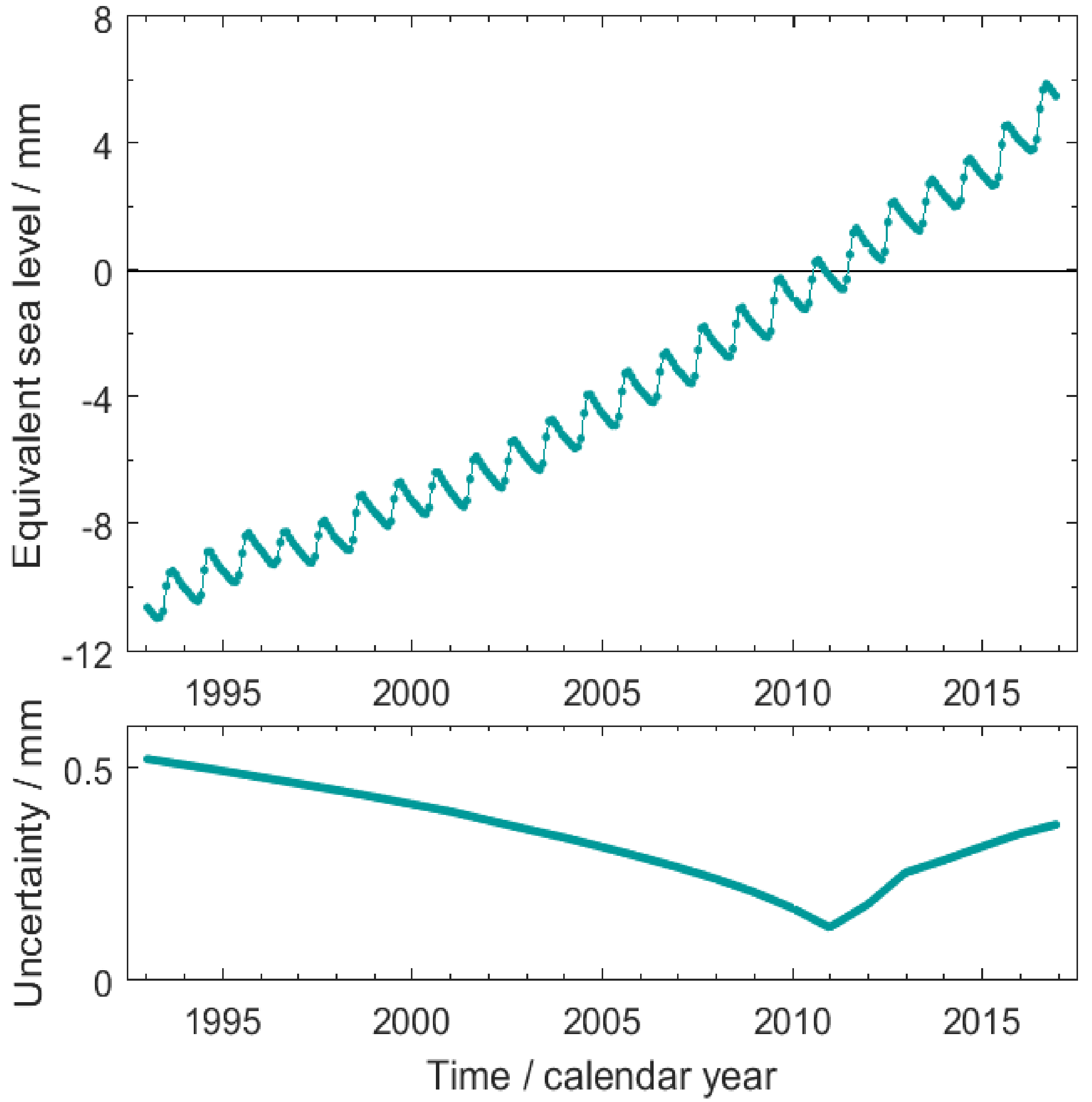
- global glacier outlines (RGI 6.0)
- atmospheric boundary conditions: 7 different global reanalysis products and observational data sets
- measured mass balances for calibration and validation

✓ Global grids of glacier mass change as well as glacier mass change rates at annual resolution and monthly resolution

glaciers cci

Universität Bremen

Universität Zürich[UZH]

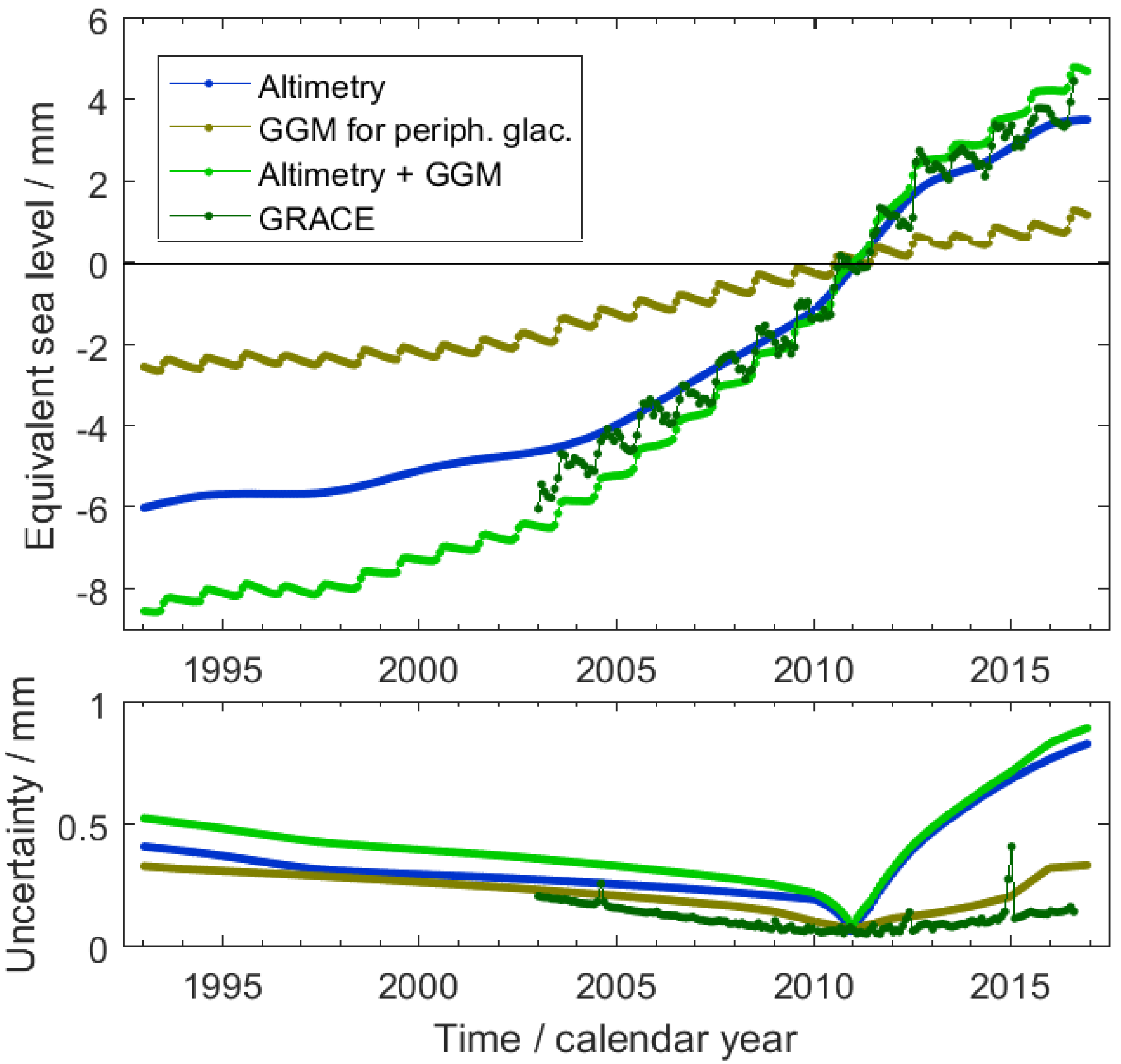


Greenland

- GRACE mass balance based on CSR-RL06, including peripheral glaciers and ice caps
- **Sum of:** Radar altimetry, calibrated to ICESat laser altimetry 2003-2009, over ice sheet, and Peripheral glacier mass change

✓ Monthly GRACE-based mass change estimates (grids and basin time series) from CCI Greenland Ice Sheet (http://esa-icesheets-greenland-cci.org/).

✓ Altimetry-based rates of change as monthly grids in a 100x100km² resolution from 1992-2017

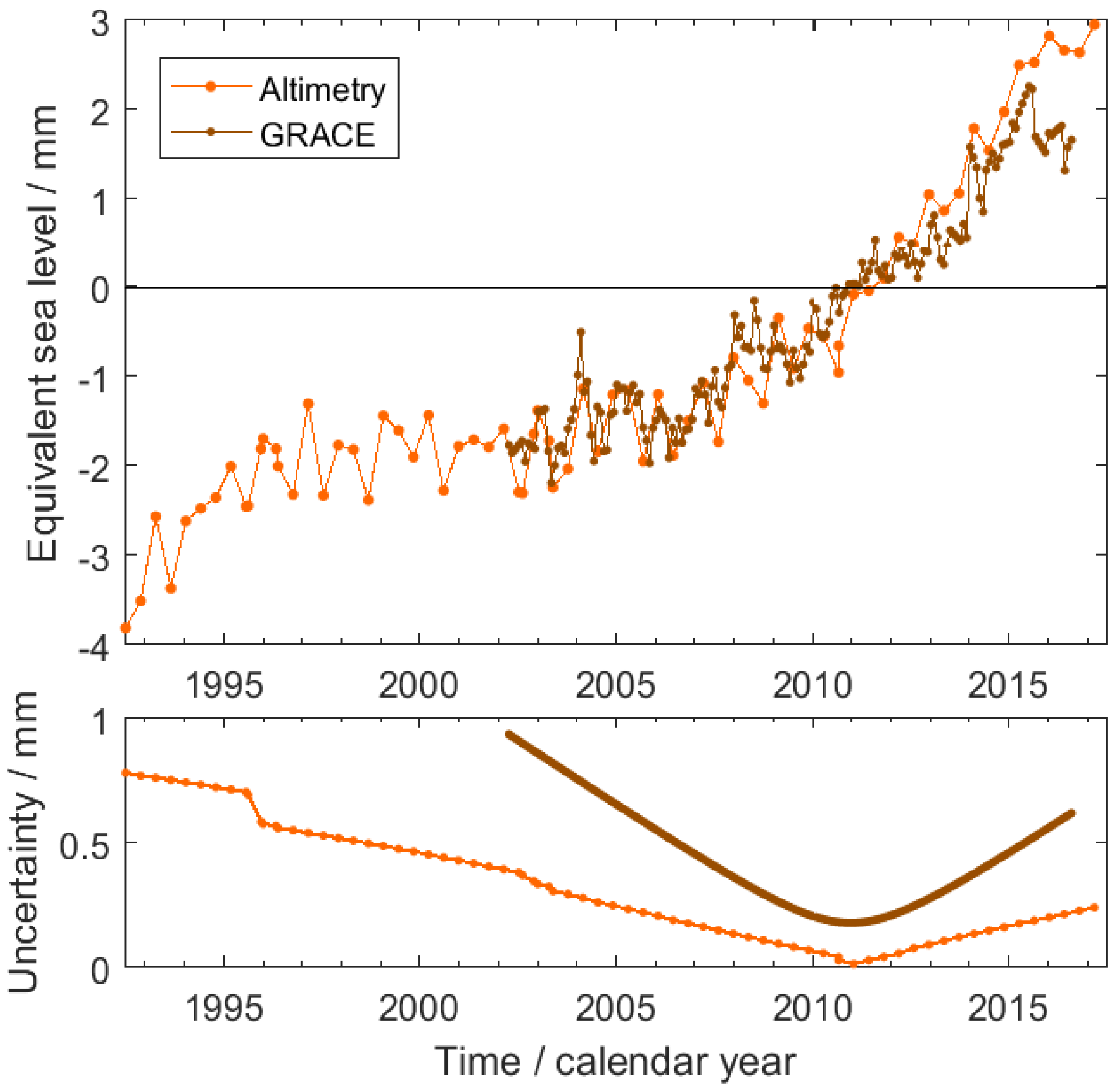


Antarctica

- GRACE mass balance using ITSG-Grace2016
- Radar altimetry using a time-evolving ice density mask

✓ Monthly GRACE-based mass change estimates (grids and basin time series) from CCI Antarctic Ice Sheet (http://esa-icesheets-antarctica-cci.org/).

✓ Altimetry-based mass changes for the West Antarctic Ice Sheet, the East Antarctic Ice Sheet and the Antarctic Peninsula at a 140-day resolution from 1992 to 2016



antarctic ice sheet cci

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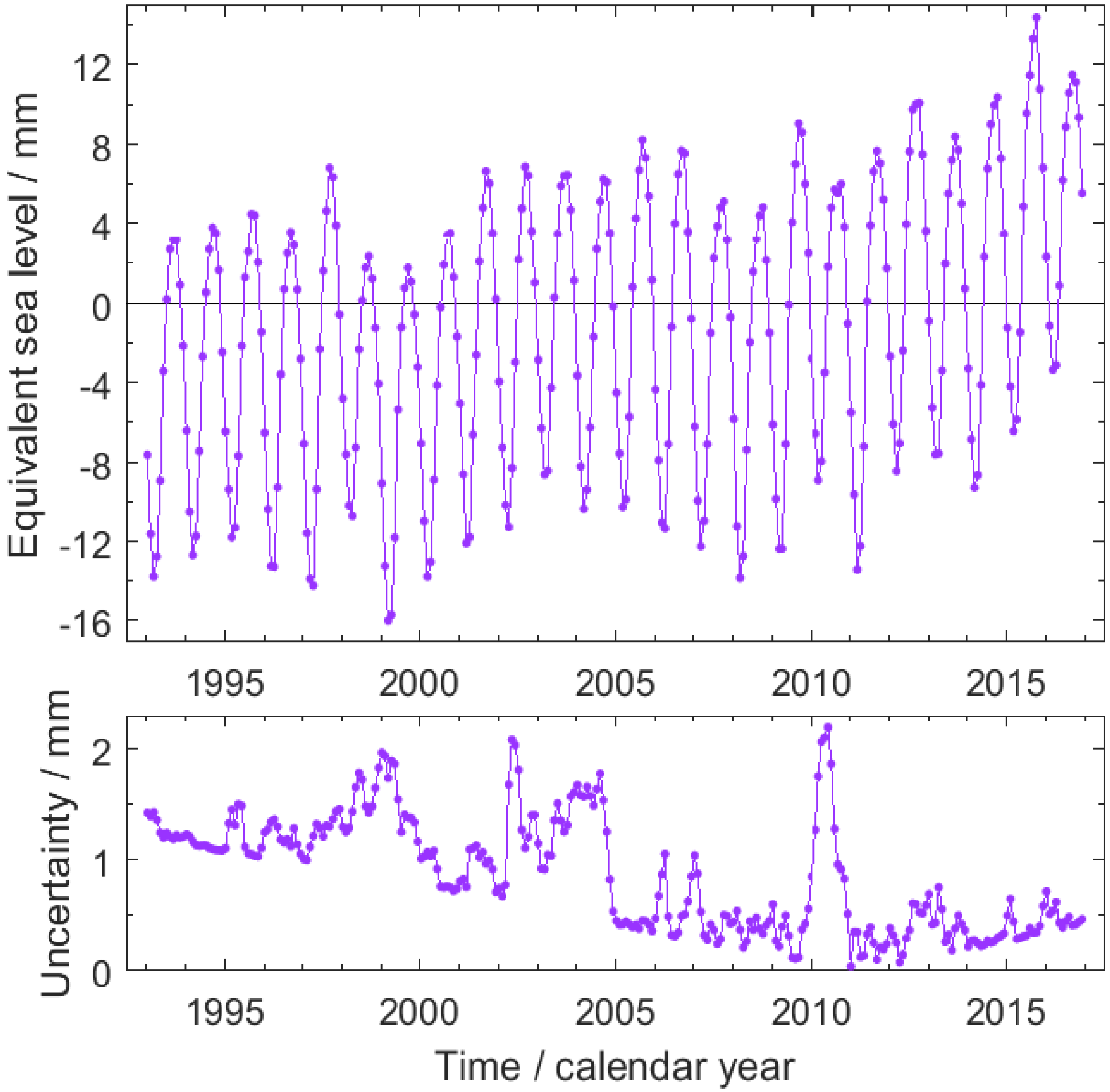
Land water storage (incl. snow cover)

sea level budget closure cci

- Global hydrological model WaterGAP2.2d
- Two irrigation scenarios:
  - 70% deficit irrigation
  - optimal irrigation
- Two climate forcings
- Use ensemble mean and spread

✓ Results from 8 runs of the WaterGAP2.2d global hydrology model as monthly grids from 1992 to 2016. Two versions (wg22d_std and wg22d_gl) were run with two irrigation variants (70% deficit irrigation and optimal irrigation) and two state-of-the-art climate forcings.



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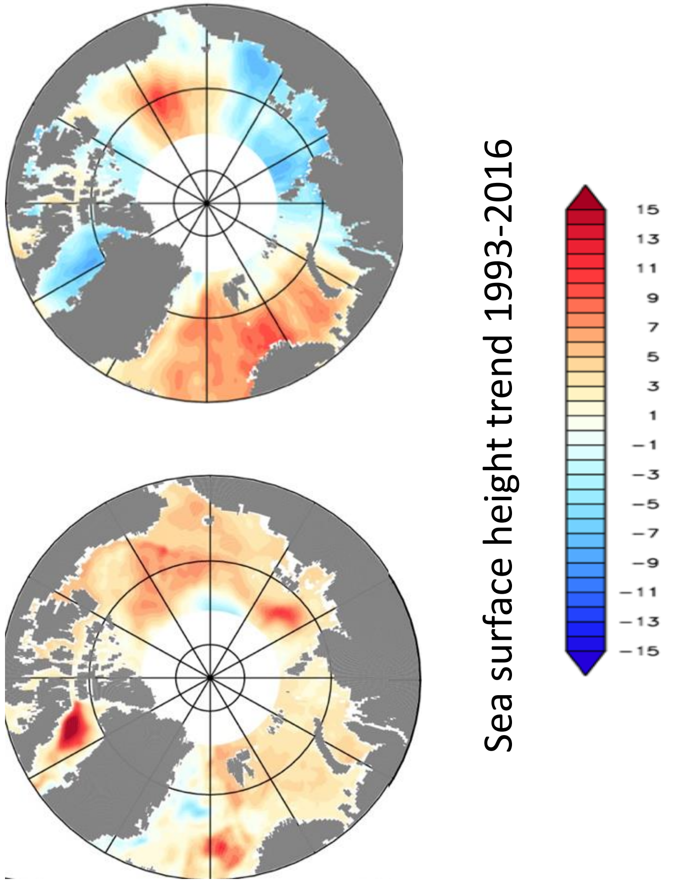
Arctic Ocean (ocean north of 65°N)

sea level budget closure cci

- ✓ *DTU Arctic Altimetric Sea Level Record:* The SLA data cover the region from 65°N-81.5°N and 180°W-180°E with a resolution of 0.25° in latitudinal and 0.5° in longitude, respectively. Data are given in monthly intervals between January 1996 and October 2018.

- ✓ *NERSC TOPAZ4:*The TOPAZ4 (“Towards an Operational Prediction system for the North Atlantic European coastal Zones”) covers the Nordic Seas and entire Arctic Oceans bounded by 65°N-90°N and 180°W to 180°E with a spatial resolution of 0.25°. The temporal coverage is from 2003-2017 at a monthly resolution.

- ✓ Raj et al. (2020) https://doi.org/10.3390/rs12172837



DTU

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