Closing the global sea level budget by combining multi-mission altimetry and GRACE(-FO) data

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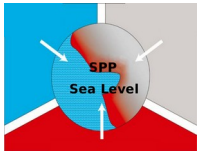


04.05.2020

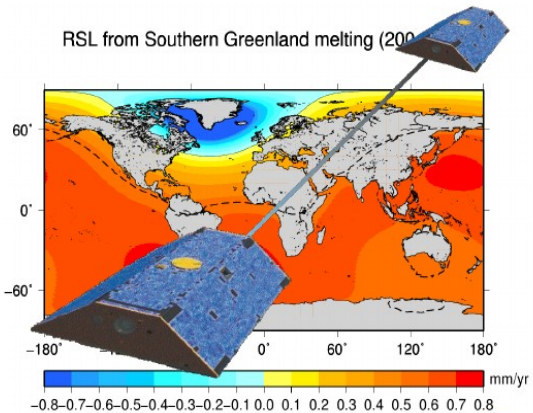
What is investigated?

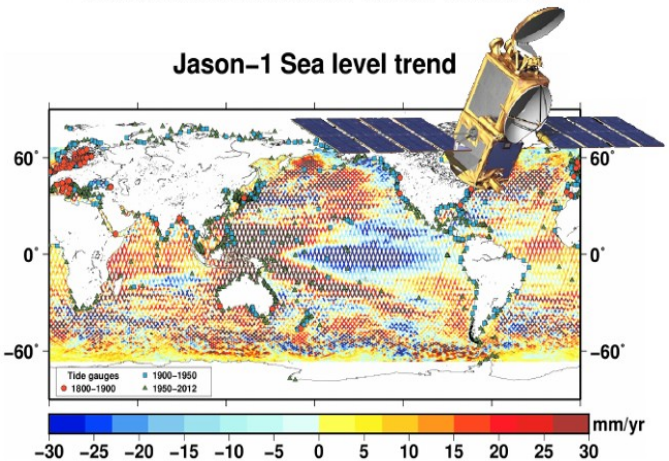
- We present recent enhancements and updates for the global fingerprint joint inversion combining GRACE gravimetry and along-track altimetry data with respect to the inversion used in Uebbing et al. (2019)
  - Use of new RL06 GRACE and GRACE follow-on (GRACE-FO) data
  - Improved representation and modeling of individual contributions of the sea level budget
- Closure of the sea level budget is achieved within 0.1 mm/yr
  - Residual signal mainly includes unmodeled contributions from highly variable ocean current and eddy regions

Inversion: Input Data

Complementary Datasets

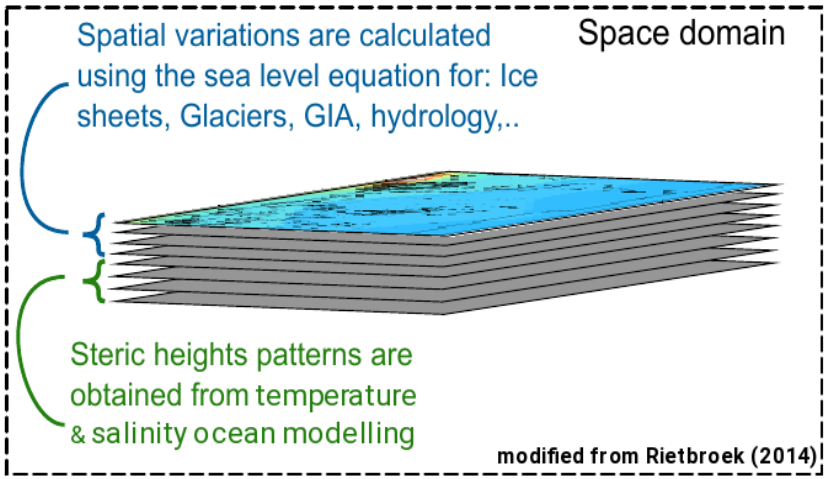
- Altimetry → mass+steric sea level
  - Along-track Jason-1/-2/-3 altimetry data from RADS (Scharroo et al., 2013)
- GRACE(-FO) → ocean mass changes
  - Unsolved, unfiltered monthly GRACE and GRACE-FO normal equations
    - ITSG2018-RL06 normal equations up to degree and order 120 (Kvas et al., 2019)

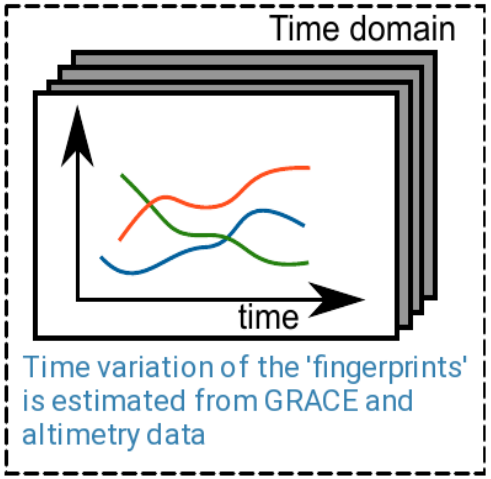




Global Inversion Method

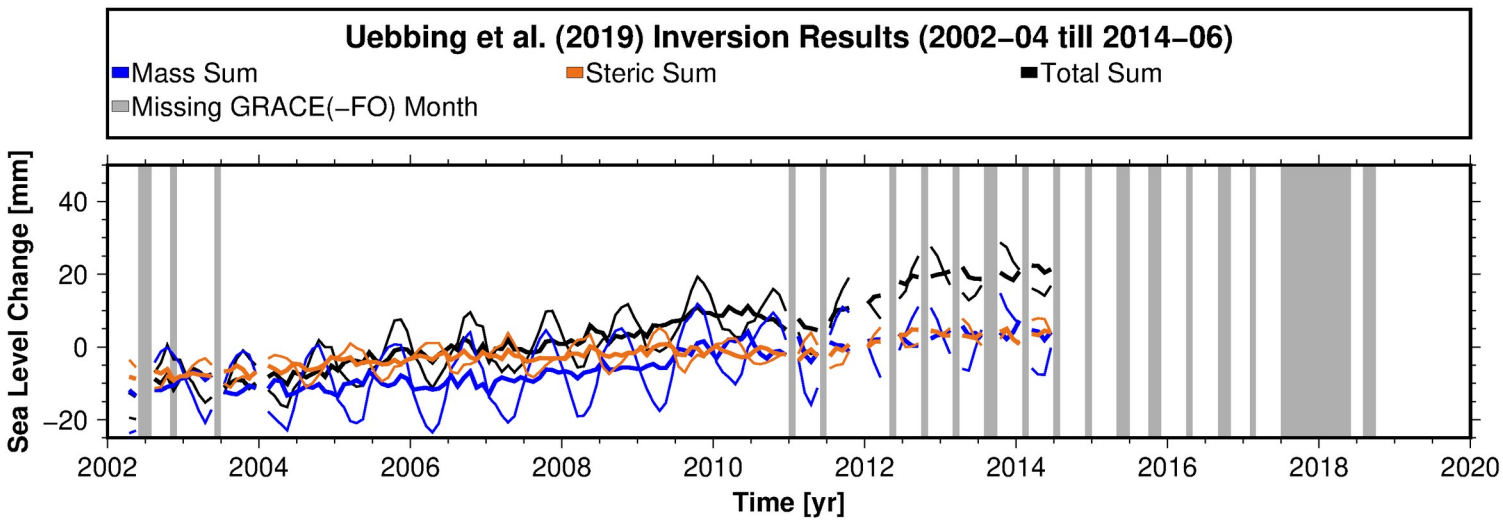
- Idea of the global fingerprint inversion (Rietbroek et al., 2016)
  - Forward modeling of gravitationally-elastic rotationally consistent sea level patterns → **fingerprints**
  - Consistent treatment of reference frames
  - Time-variable amplitudes are fitted to time-invariant fingerprints





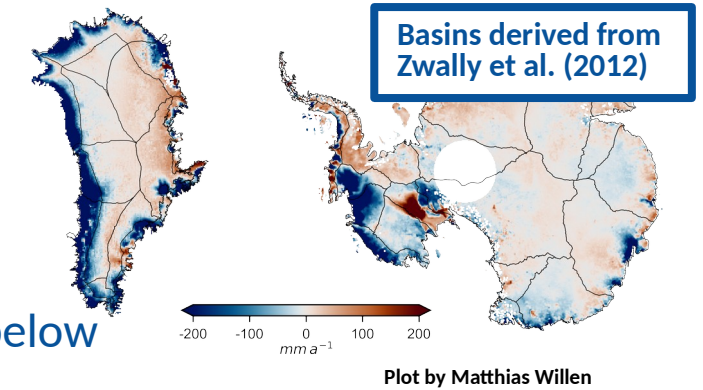
Uebbing et al. (2019) Inversion

- While the inversion in Uebbing et al. (2019) provided good quality agreement of summed global ocean mass change (OMC) in comparison with other OMC estimates
- Deficiencies with respect to
  - Data availability
  - Modeling of individual mass and steric contributions
  - Relatively large residual component (0.3 mm/yr)



Improved Fingerprint Representation

- Mass components
  - Glaciers: 68 fingerprints (updated based on Randolph Glacier Inventory v6.0, RGIv6)
  - Hydrology: 25 leading EOFs explaining >90% of the variance based on WGHMv2.0 (Müller Schmied et al., 2014)
  - Ice sheet fingerprints from Greenland (16) and Antarctica (27) augmented by trend patterns extracted from Ice Altimetry
    - for more on this see display D1692
  - Internal Mass Variations (IMV): 200 EOFs based on RL06 AOD1B-GAB product
- Steric components
  - 200 fingerprints for upper 700m and 50 for deep ocean below 700m based on ORA-S5 reanalysis data

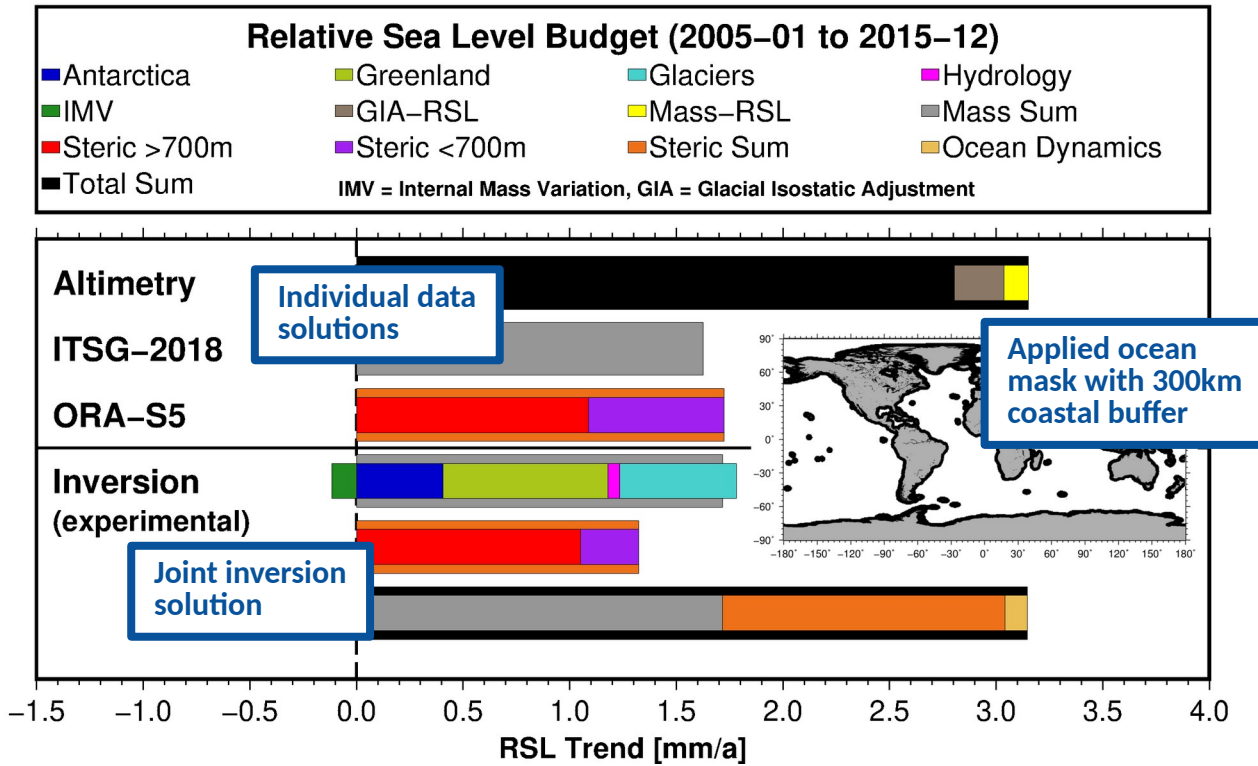


Overview of Inversion Updates

	Uebbing et al. (2019)	Updated Inversion (this study)
Gravity Data	GFZ RL05 GRACE	ITSG-2018 (RL06) GRACE(-FO)
Altimetry Data	Jason-1/-2	Jason-1/-2/-3
Hydrology	60 EOFs from WGHMv1	25 EOFs from WGHMv2
Antarctic Ice Sheet	27 basins (uniform melting)	27 basins (non-uniform melting)
Greenland Ice Sheet	16 basins (uniform melting)	16 basins (non-uniform melting)
Land Glaciers	16 basins (only major glaciers)	68 basins (RGIv6)
Steric	200 ORA-P5 (full depth only)	250 ORA-S5 (>700m and <700m)
Intern. Mass Var.	10 EOFs (RL05 AOD1B-GAD)	200 EOFs (RL06 AOD1B-GAB)
Residual / “other”	100 EOFs from residuals	directly computed after 1st iteration

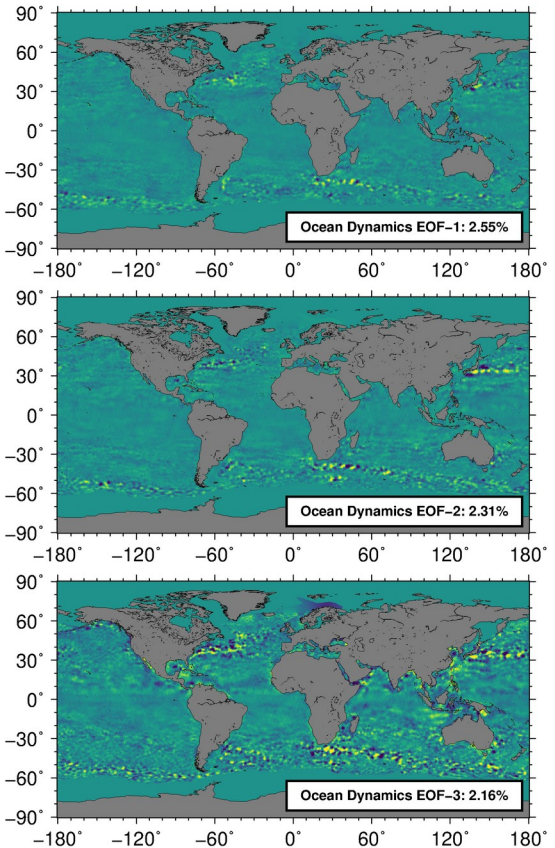
Global Sea Level Budget

- New and extended inversion provides better understanding of individual sea level drivers
- Closed budget
  - Residual (= ocean dynamics) in the order of 0.1 mm/yr



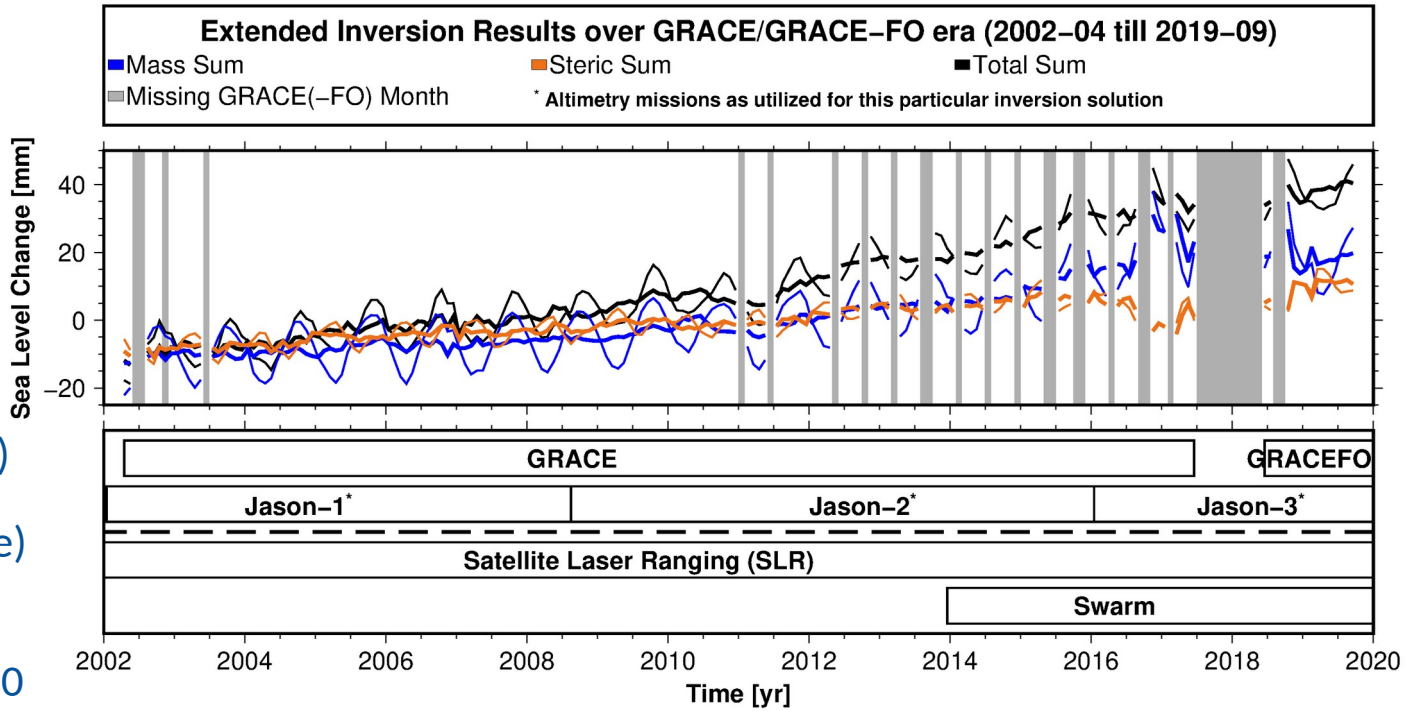
Inversion Residual Signal Content

- The residual component of the updated inversion with respect to altimetry (denoted here as “ocean dynamics”) mainly includes variations of the major current systems and eddy regions
  - Not modeled by any of the fingerprints so far
- All significant signals are captured within the inversion
  - The percentage of explained variance is low and similar for individual EOFs



Extending the Inversion Period

- Currently the inversion results are limited to the availability of GRACE(-FO) data
  - Missing months and an 11 month gap
- First experiments using time-variable gravity (TVG) derived from SLR are promising (not shown here)
  - Also add Swarm TVG
    - See display D1550



- Further extensions with respect to additional altimetry missions and inclusion of Argo profile data for better separating steric and mass contributions

Conclusions and Outlook

- The updated and extended inversion allows to close the sea level budget within about 0.1 mm/yr
  - Results fit with individually processed data products
  - Significant over estimation of the deep ocean steric contribution by ORA-S5?
    - Requires further investigation
    - Introduce additional Argo profile data to better separate the steric contribution (see display D2806)
- Residual signals are mainly due to ocean dynamics contributions from dominant major current and eddy regions
  - Examine possibilities to better model these effects in the future
- Significant amount of missing results due to missing monthly GRACE solutions and gap between GRACE and GRACE-FO
  - Incorporate Swarm and SLR data in order to estimate solutions for these months

Literature

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