G4.1: Satellite Gravimetry: Data Analysis, Results and Future Mission Concepts

CAN SWARM AND SLR CONTRIBUTE TO CLOSING THE GLOBAL SEA LEVEL BUDGET?

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Closing the Sea Level Budget

Global mean sea level change can be expressed as the sum of mass-related and steric contributions (WCRP, 2018)

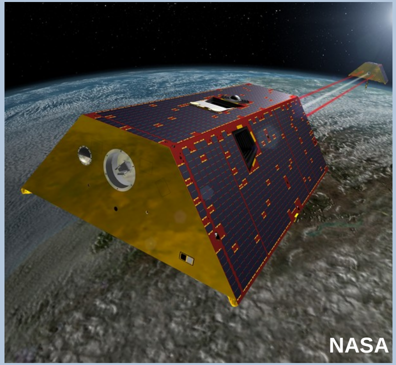
Total = **Mass** + **Steric**

Total

Altimetry

=

Mass



GRACE(-FO)

+

Steric

Argo

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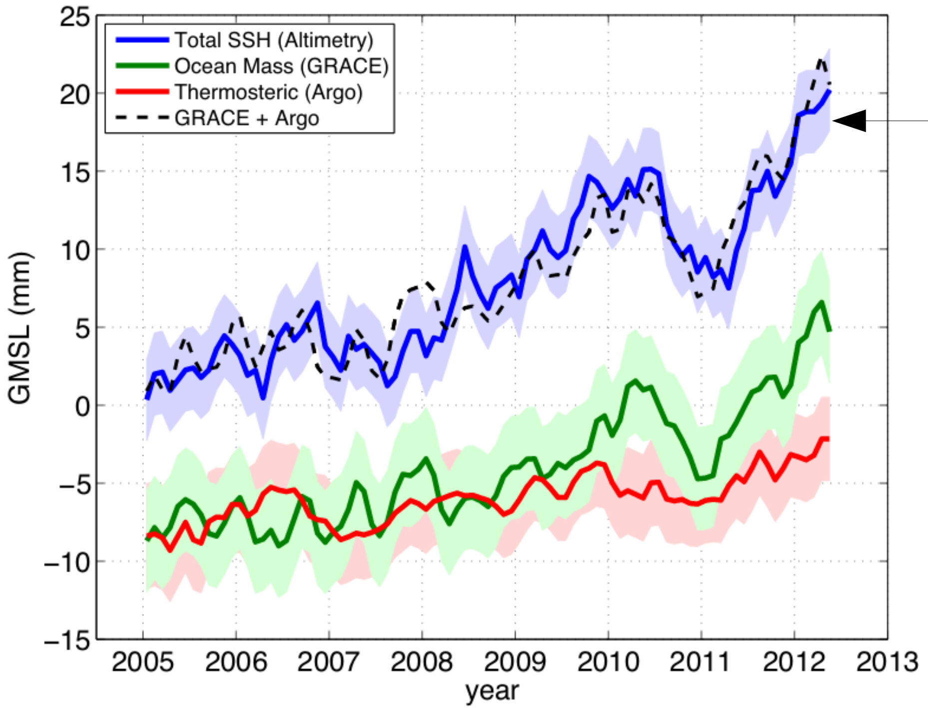
IPCC: Sea Level Budget



IPCC AR5 (2013)

Altimetry = GRACE+Argo?

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Let's focus on Ocean Mass

There are three ways to derive ocean mass change (Uebbing et al., 2019):

1)	2)	3)
Mass = Total (altimetry) - Steric (Argo)	Derive mass change directly from GRACE(-FO)	Combine GRACE and altimetry in a joint inversion

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Let's focus on Ocean Mass

There are three ways to derive ocean mass change (Uebbing et al., 2019):

not considered in this presentation

Mass
=
Total (altimetry)
-
Steric (Argo)

2)

Derive mass changes directly from GRACE(-FO)

3)

Combine GRACE and altimetry in a joint inversion

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Derive Ocean Mass Change directly

There are three ways to derive ocean mass change (Uebbing et al., 2019):

1)	2)	3)
Mass = Total (altimetry) - Steric (Argo)	Derive mass changes directly from GRACE(-FO)	Combine GRACE and altimetry in a joint inversion

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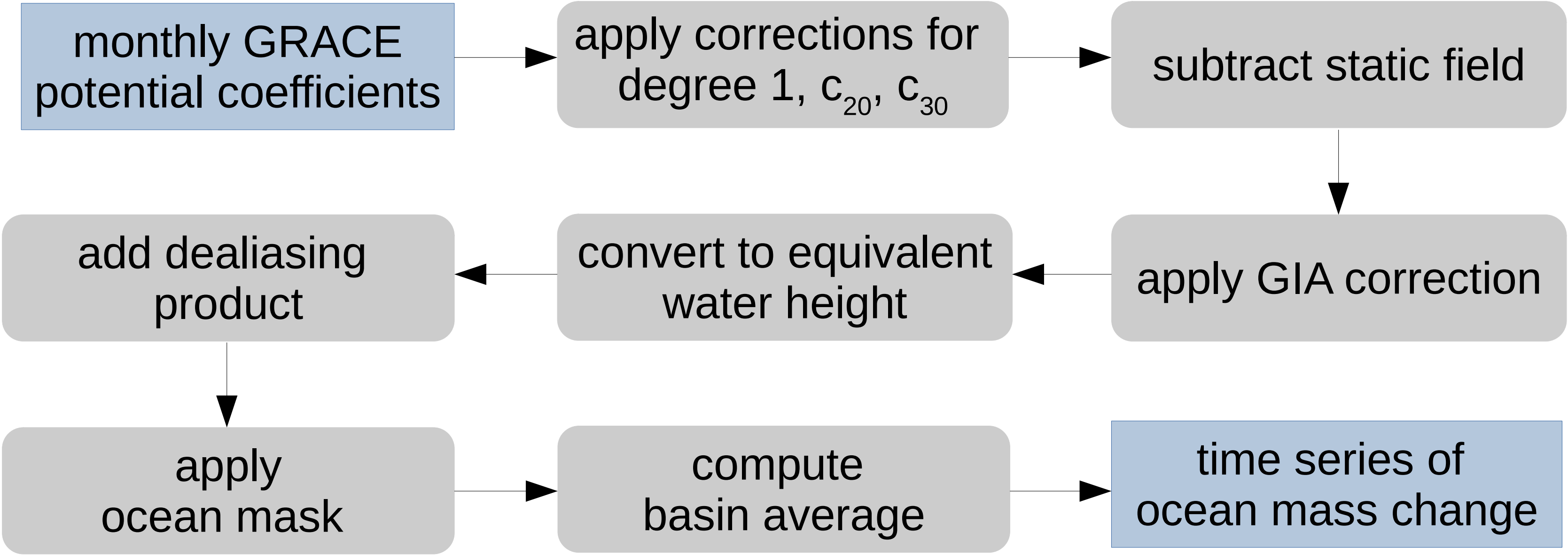
Ocean Mass from GRACE How-to



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Ocean Mass from GRACE How-to

monthly GRACE potential coefficients
ITSG-Grace2018

→ apply corrections for degree 1, c_{20}, c_{30}
degree 1: GCN_RL06 from CSR
C_{20} & c_{30}: from TN14

→ subtract static field
static part of GOCO06s

→ apply GIA correction
A et al. (2013)

→ convert to equivalent water height

→ add dealiasing product
AOD1B RL06: GAB product

→ apply ocean mask
300km ocean mask

→ compute basin average

→ time series of ocean mass change

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Remember...

There are three ways to derive ocean mass change (Uebbing et al., 2019):

1)	2)	3)
Mass = Total (altimetry) - Steric (Argo)	Derive mass changes directly from GRACE(-FO)	Combine GRACE and altimetry in a joint inversion

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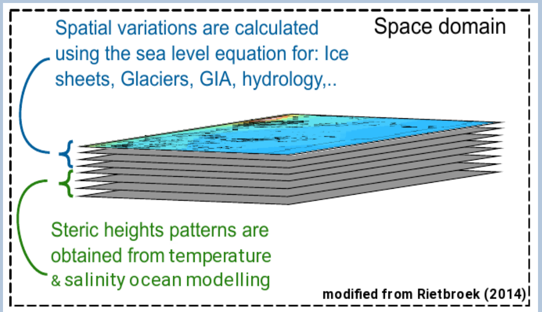
Joint Inversion – The Idea

The fingerprint inversion combines altimetric and gravimetric data to split total sea level change into different components (Rietbroek et al., 2016)

Base functions (predefined)

- Each contribution is parameterized by predefined spatial patterns (‘fingerprints’)
- Fingerprints are either mass-related (glaciers, Antarctica, Greenland, hydrology, internal mass variation) or steric (FESOM)

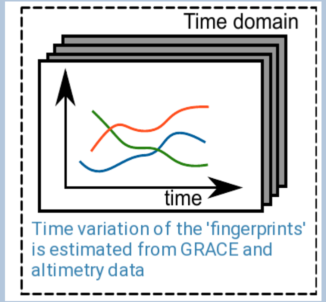


least squares adjustment

For more information on the joint inversion approach, see display **D3787**

Time variation (estimated)

- The temporal evolution for each fingerprint is estimated in a least squares adjustment
- In other words: we now know which effect (melting of glaciers & ice sheets, hydrology, steric,...) contributes how much to sea level change



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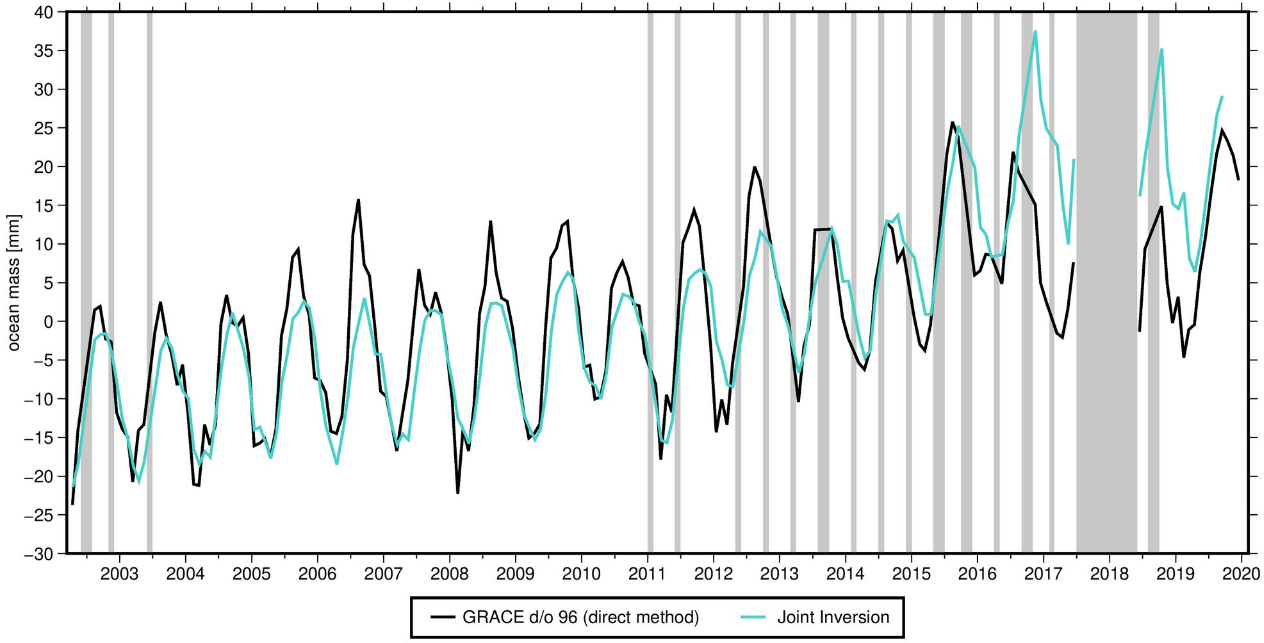
Ocean Mass from GRACE & Joint Inversion - Results



- In this figure, we show two time series of ocean mass change:
  - We use GRACE data in the direct approach
  - We use GRACE & altimetry in a joint inversion to derive ocean mass change
- Both solutions show a similar development of ocean mass change
- In 08-2016, the direct method & the joint inversion start to diverge, which might be due to the lower quality of GRACE data, but still needs to be further investigated

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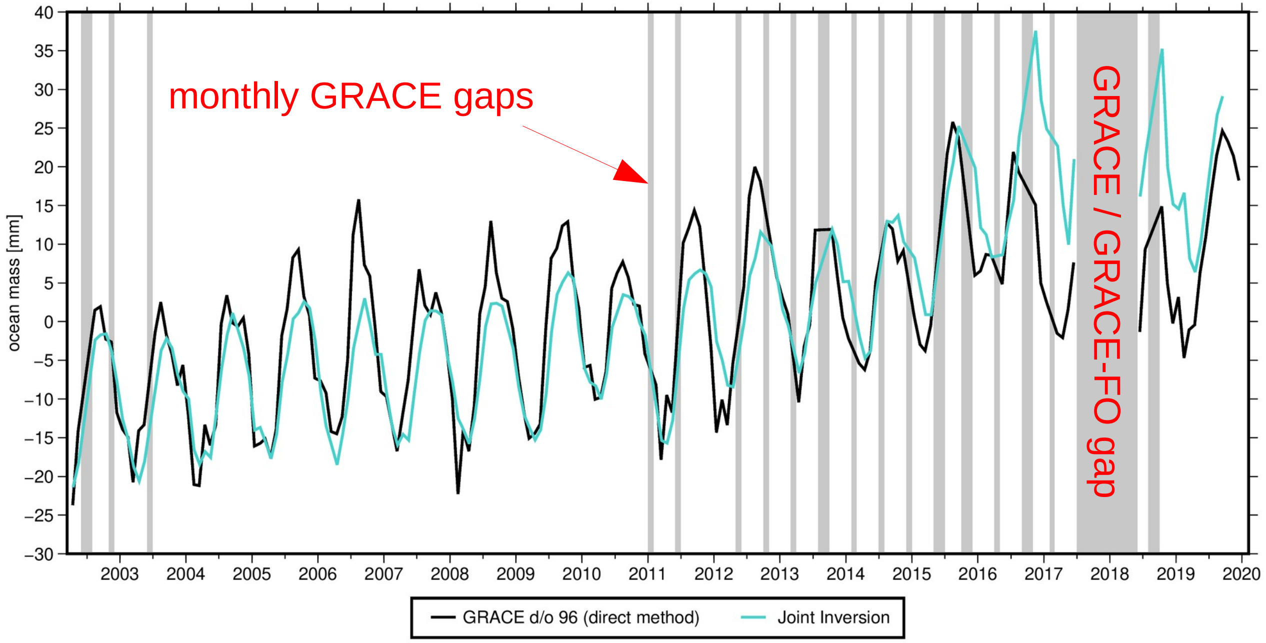
Ocean Mass from GRACE & Joint Inversion - Results



- Both methods only work when gravimetric data is available
- It makes sense to include additional data to
  - get results in the GRACE gaps
  - support the separation of sea level components in combination with GRACE

→ let's have a look at Swarm & satellite laser ranging

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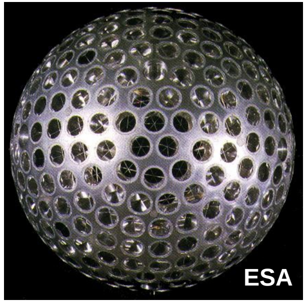
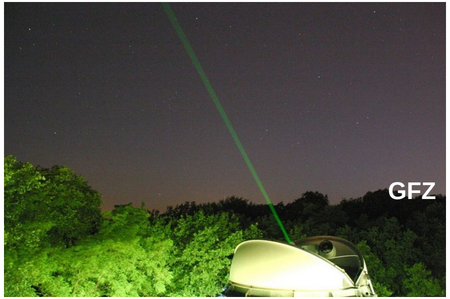
Ocean Mass from Swarm & SLR

- We derive monthly time-variable gravity fields from kinematic orbits (AIUB, Bern) of Swarm with the integral equation approach (Mayer-Gürr, 2006)
- These gravity fields inevitably have a lower spatial resolution (~ d/o 12), but capture the main mass changes within the Earth's system well
- In Lück et al. (2018), we showed that ocean mass from Swarm (12-2013 to 12-2016) has an RMSE of 4.0 mm w.r.t. GRACE

- We furthermore derive monthly time-variable gravity fields from satellite laser ranging (SLR) up to d/o 5 using dynamical orbit determination
- 5 SLR satellites are used:
  Lageos 1/2, Ajisai, Starlette, Stella
- We also use these gravity fields to derive ocean mass change





→ This will help to close the GRACE(-FO) gaps and can possibly improve existing GRACE(-FO) solutions

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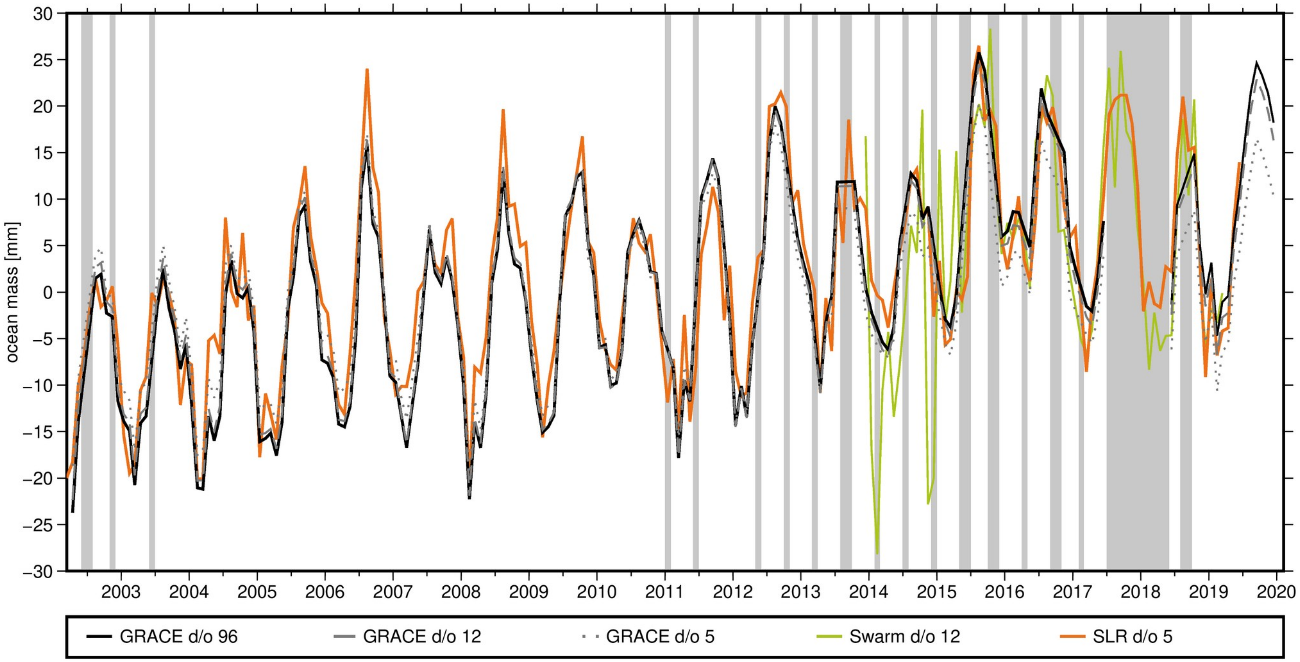
Ocean Mass from GRACE, Swarm & SLR - Results



- The figure shows time series of ocean mass change derived from the direct method
- Ocean mass change from Swarm & SLR follows the GRACE(-FO) time series well, but is overall noisier
- Swarm results until mid-2015 are of lower quality due to ionospheric disturbances in the GPS observations (Schreiter et al., 2018)

→ in a next step, we want to include Swarm & SLR in the joint inversion

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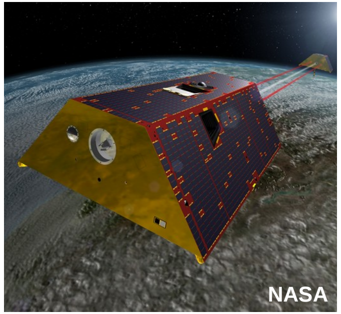
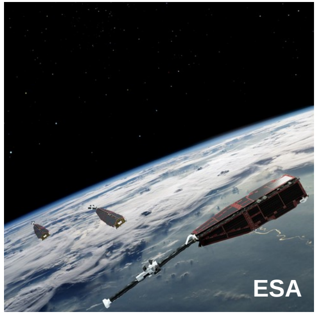
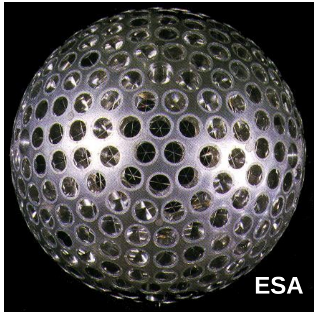
Conclusions & Outlook

- Ocean mass change is usually derived from GRACE(-FO) data
- Swarm & satellite laser ranging can be used to fill the gaps
- In a joint inversion approach, we combine altimetric & gravimetric data to get more reliable results and to split sea level change into its individual components
- Here, we presented a joint inversion result from altimetry & GRACE(-FO)
- We are currently working on including Swarm & satellite laser ranging in the joint inversion to close the gaps and to aid in separating the sea level components in combination with GRACE(-FO)







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