A revised sea level budget equation to accurately represent physical processes driving sea level rise

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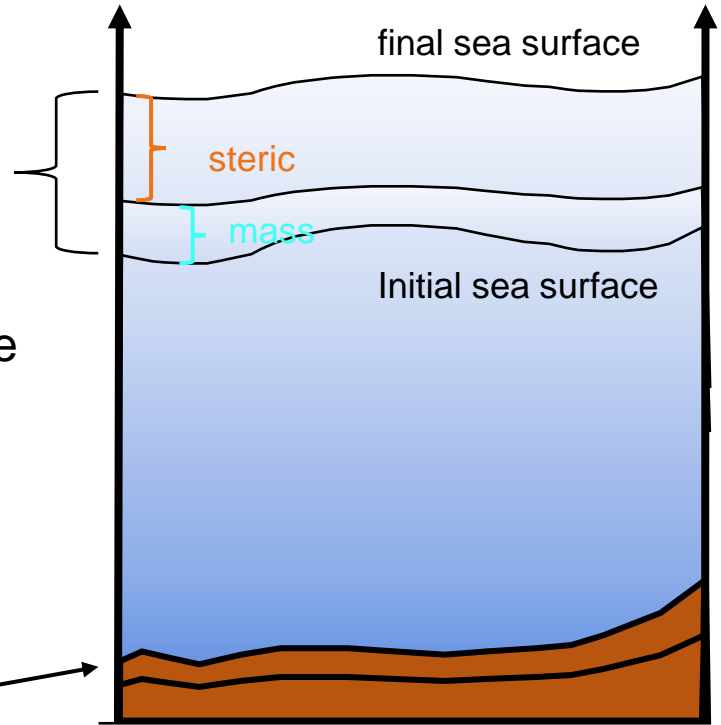
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Attributing global sea level rise to its component parts

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Sea Level Budget (SLB)

- Sea Level Rise (SLR)

- Total SLR = Mass + steric + ocean bottom shape

- Mass : addition of freshwater.

- Steric: temperature and salinity driven.

- Assuming: changes to the ocean bottom considered

final sea surface

steric

mass

Initial sea surface

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Conventional SLB (1990s)

Altimeter

- SLR ≈ steric + mass.

Why?

- Ocean bottom changes → GIA + elastic deformation due to loading

- GIA → modelled and removed.

- Early 2000: mass contribution small.
  Mass → Loading → Solid Earth deformation, hence
  Ocean Bottom Deformation (OBD) negligible.

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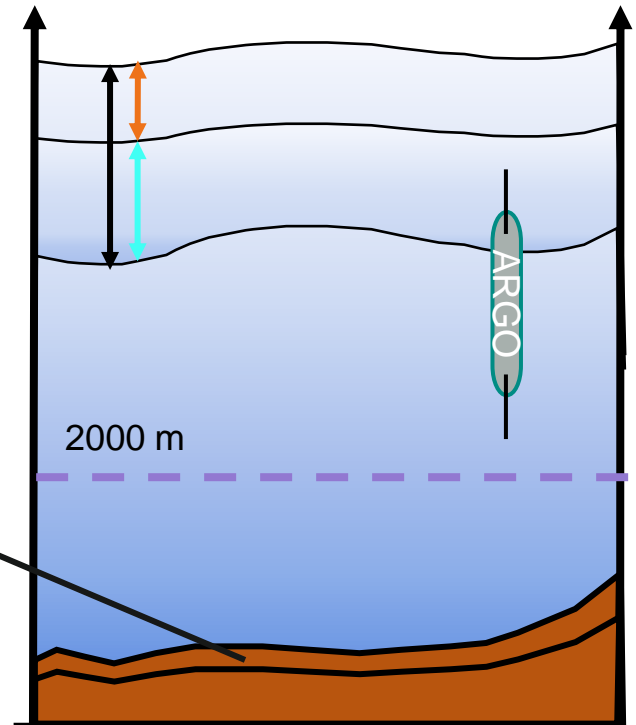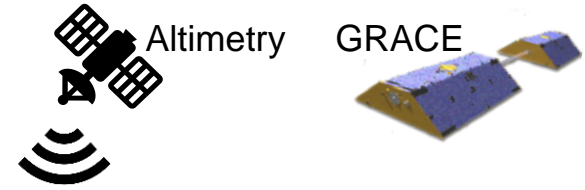
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Contemporary SLR

Altimetry   GRACE
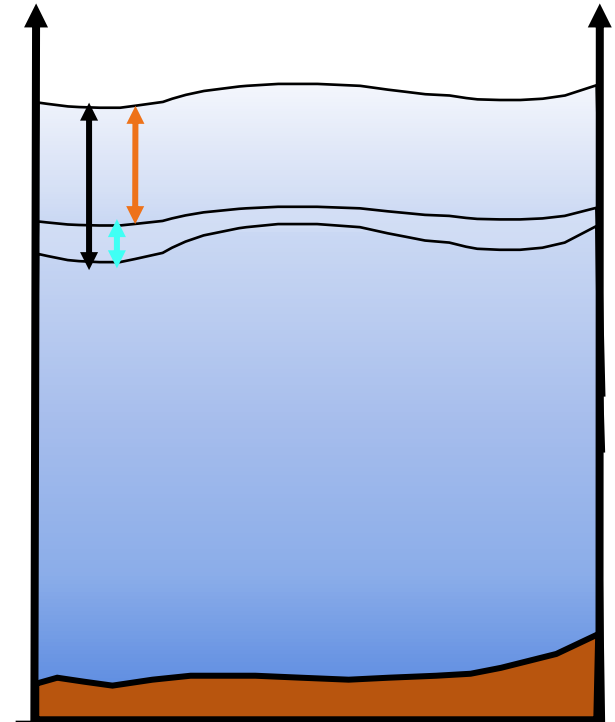
- Mass change has accelerated, and
  Mass → Loading → Solid Earth deformation,

- hence solid Earth deformation not negligible.

- OBD as large as deep-steric

- Acknowledged in the community, but a
  mathematical derivation was missing!
  (Kuo et al., 2008; Ray et al.,2013;Frederikse et al., 2017)
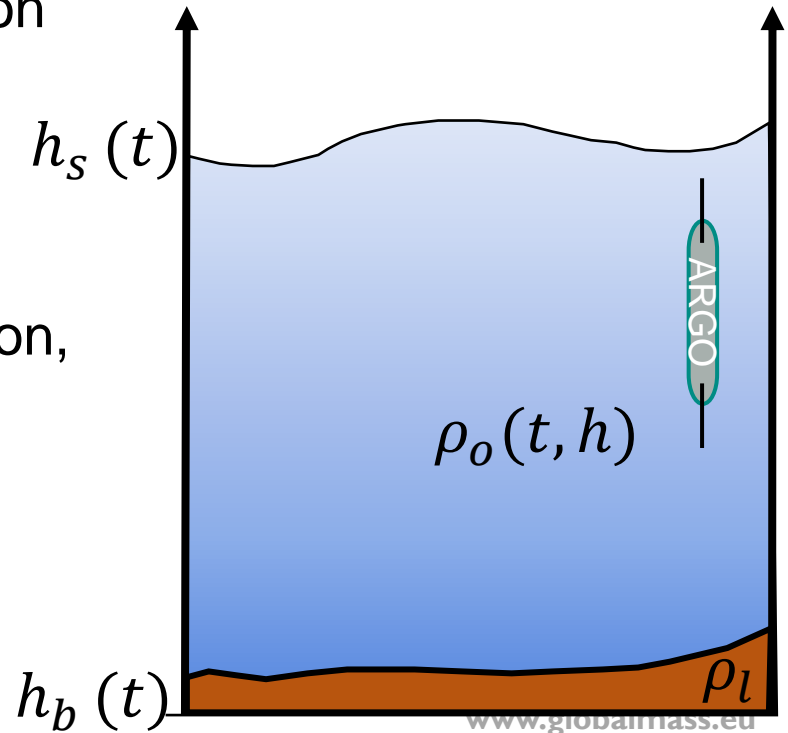
ARGO

2000 m

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OBD term in the budget

- We derive the sea level budget equation

- show:

OBD should be a part of the SLB,

which assumption can lead to its omission,

a consistent SLB equation:

$$\frac{dm}{dt} = f\{SSH, \ steric, \ OBD\}.$$

$h_s(t)$

ARGO

$\rho_o(t,h)$

ρ_l

$h_b(t)$

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We updated the SLB

- Dedicated OBD term in the SLB:

  SLR = mass + steric + OBD.

- Show that updated SLB = conventional SLB

  (for constant ocean bottom $h_b(t)$)

- Updated equation represents physical processes better.

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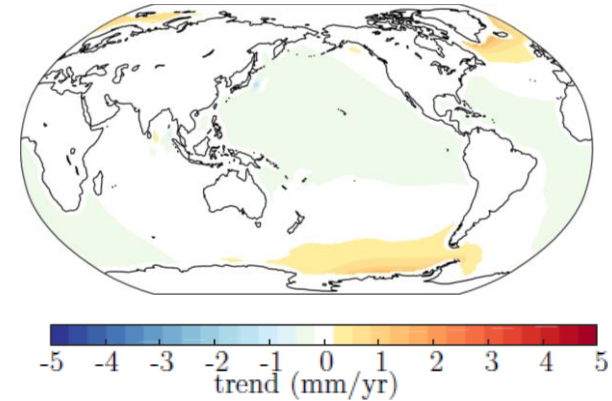MASS

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Computing OBD

▪ Get Mass redistribution from GRACE

▪ Already corrected for GIA (using ICE-6G)

▪ Using mass redistribution and Love load numbers, we estimate elastic deformation of solid Earth
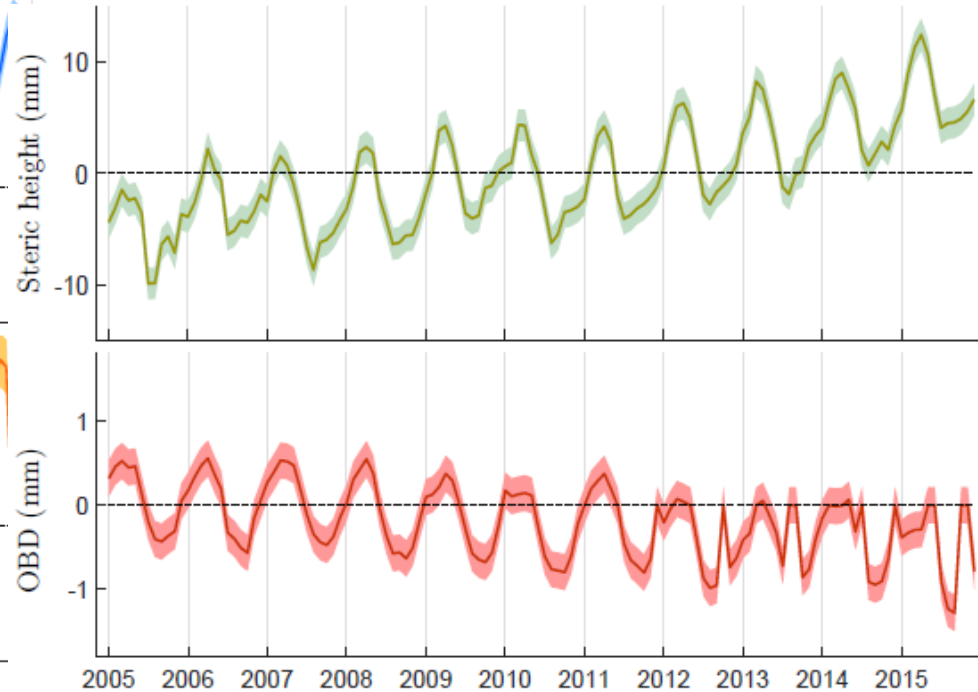

trend (mm/yr)

-5 -4 -3 -2 -1 0 1 2 3 4 5
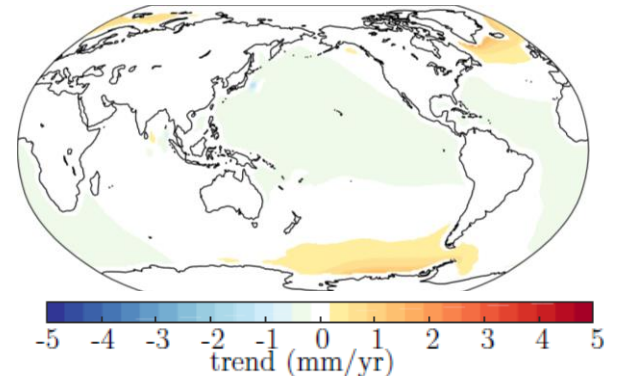
Results: global mean OBD

- Using JPL GRACE data: -0.11 ± 0.01 mm/yr.

- Frederikse et al., 2017: -0.13 ± 0.01 mm/yr.

- Deep-steric: 0.11 mm/yr.

- OBD has implications for regional SLB.

  (regional signal nearly 10 time higher than global mean)

- Including OBD increases the gap in SLB.

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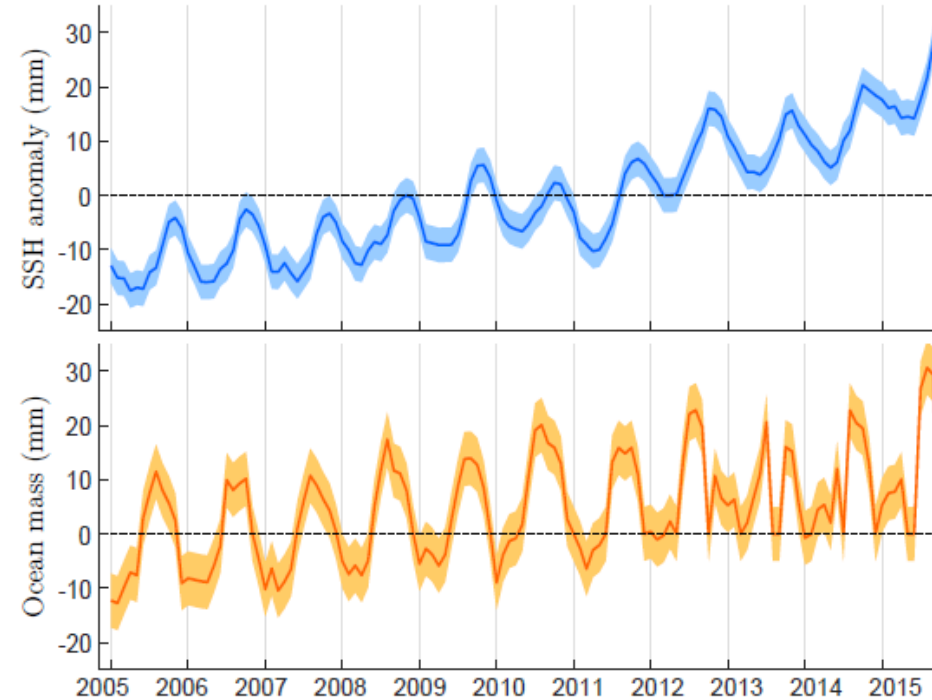
Conclusions

▪ Physical processes in SLB: mass, steric, and elastic OBD

▪ Conventional equation does not represents all the processes

▪ We derived and updated the SLB using volume-mass relation

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Thank you

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Key Points:
- The conventional sea level budget equation does not include elastic ocean bottom deformation, implicitly assuming it is negligible
- Recent increases in ocean mass yield global-mean ocean bottom deformation of similar magnitude to the deep steric sea level contribution
- We use a mass-volume approach to derive and update the sea level

Sea Level Budgets Should Account for Ocean Bottom Deformation

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Abstract   The conventional sea level budget (SLB) equates changes in sea surface height with the sum of ocean mass and steric change, where solid-Earth movements are included as corrections but limited to the impact of glacial isostatic adjustment. However, changes in ocean mass load also deform the ocean

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