

A consistent sea-level reconstruction and its budget on basin and global scales over 1958-2014

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The components of sea-level change



How to increase the water level in Ernie's bath (or the oceans)?

- Add extra water
- Heat the water
- Remove salt from the water

Steric sea-level changes:
density-related sea-level changes

Sea-level budget

Sea-level change = Steric change + Mass change

2002: Munks Enigma

"the historic rise started too early, has too linear a trend, and is too large."

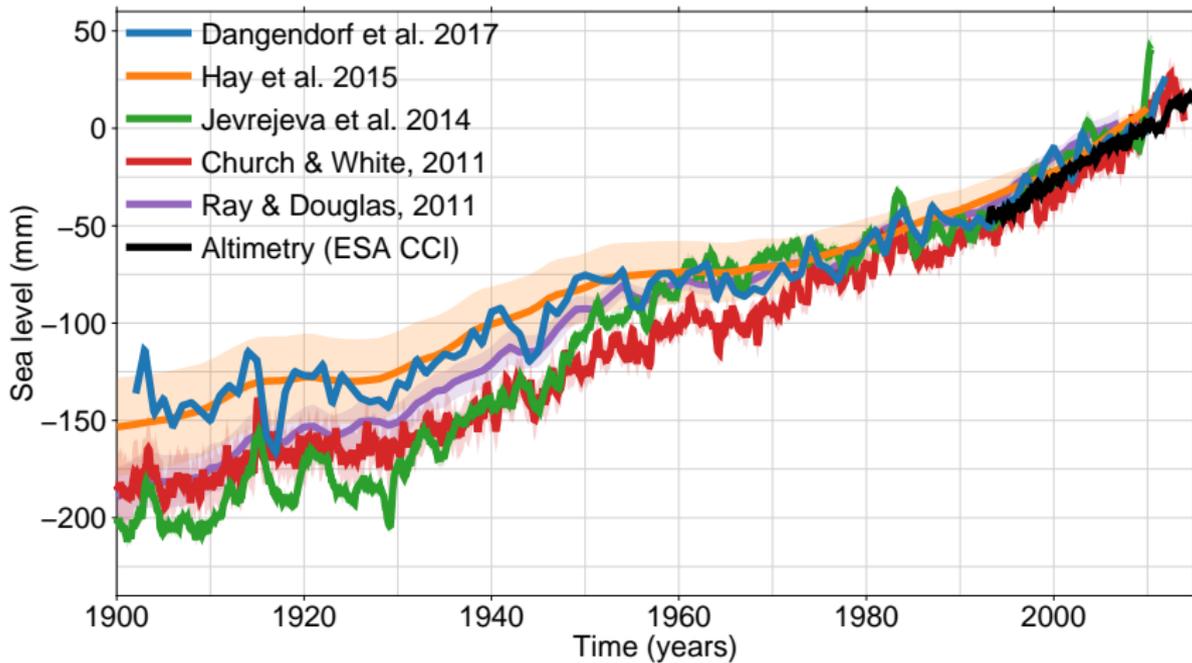
"Among the many possibilities for resolving the enigma, we suggest the following:"

- Traditional estimates of the [...] sea level rise (in the range 1.5 - 2 mm/y) are much too high
- Levitus estimates of [...] steric rise are much too low
- Rotational bounds on the eustatic rise are not valid
- Generous error bars in all these estimates mask the enigma (IPCC)
- all of the above
- none of the above



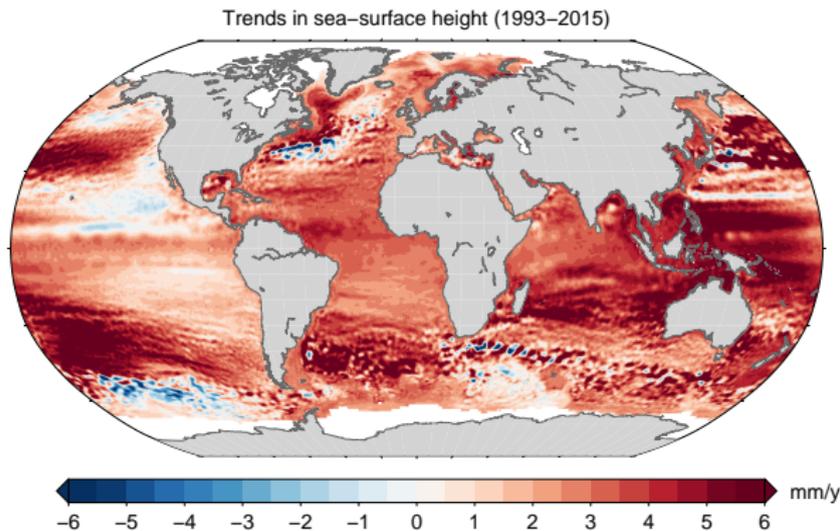
Walter Munk

2017: Sea-level reconstructions are still in disagreement



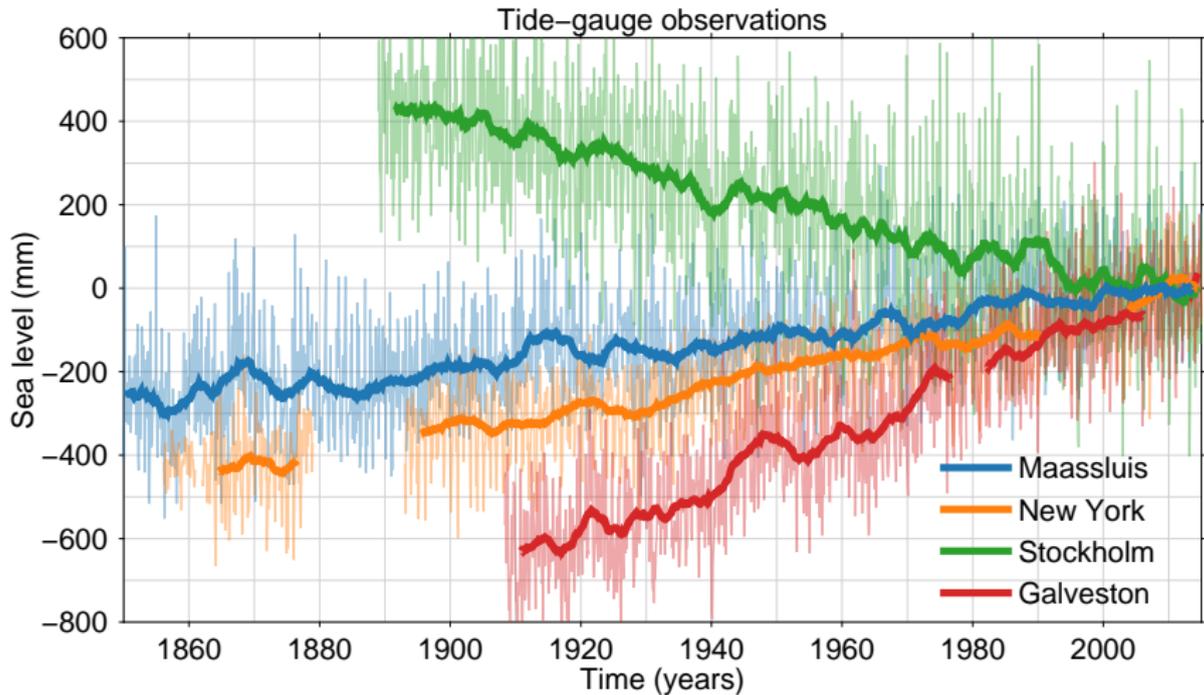
The way forward

- Improved sea-level reconstruction techniques
- Improved knowledge of regional fingerprints from contributing processes
- Towards a sea-level budget on regional scales



Source: AVISO

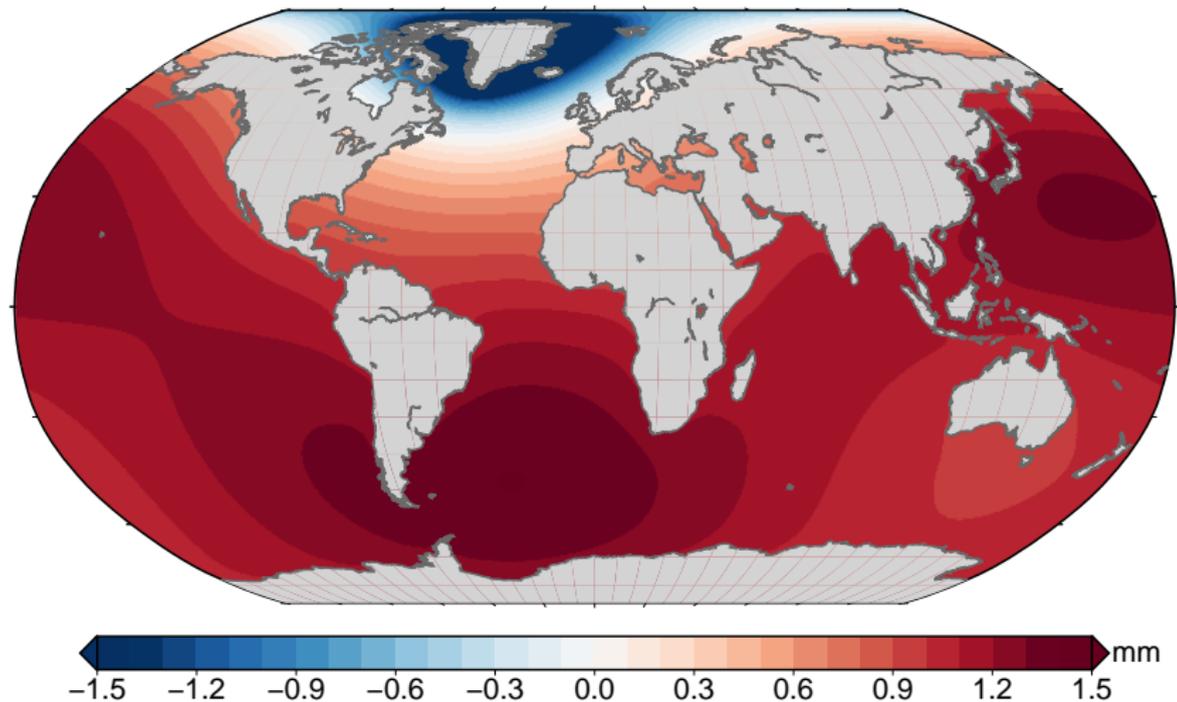
Regional variations often persistent



Source: PSMSL

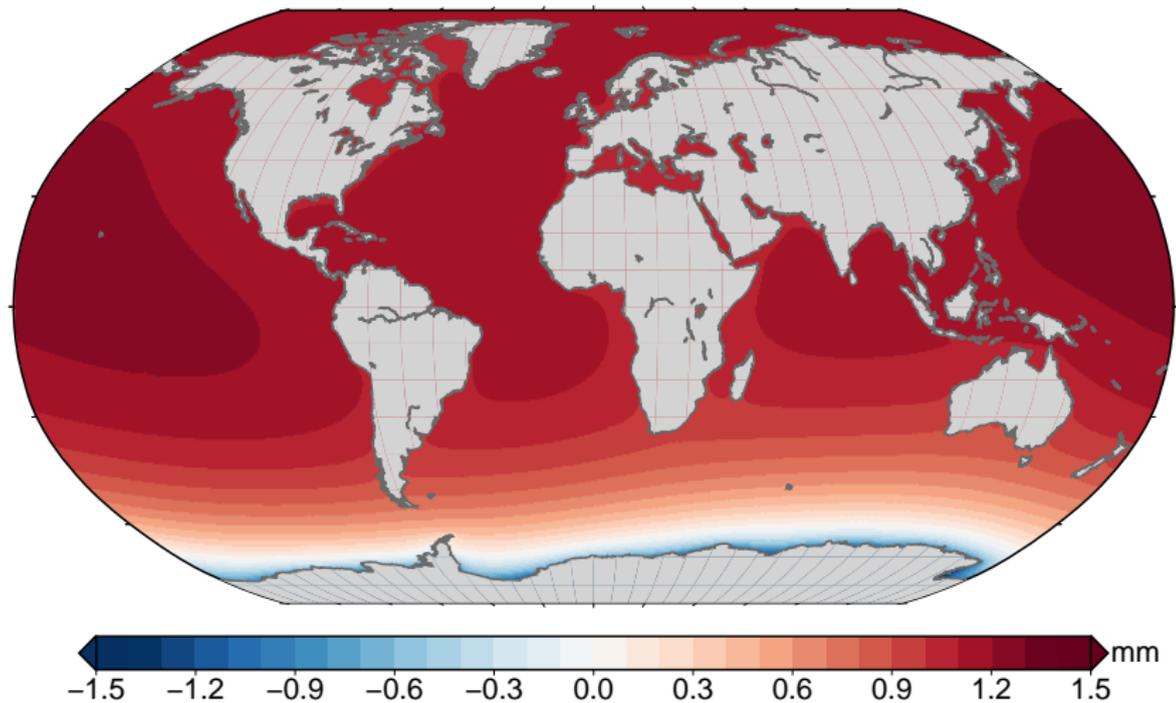
Greenland mass loss and sea level

Sea level changes when Greenland loses 362 Gigatons of ice



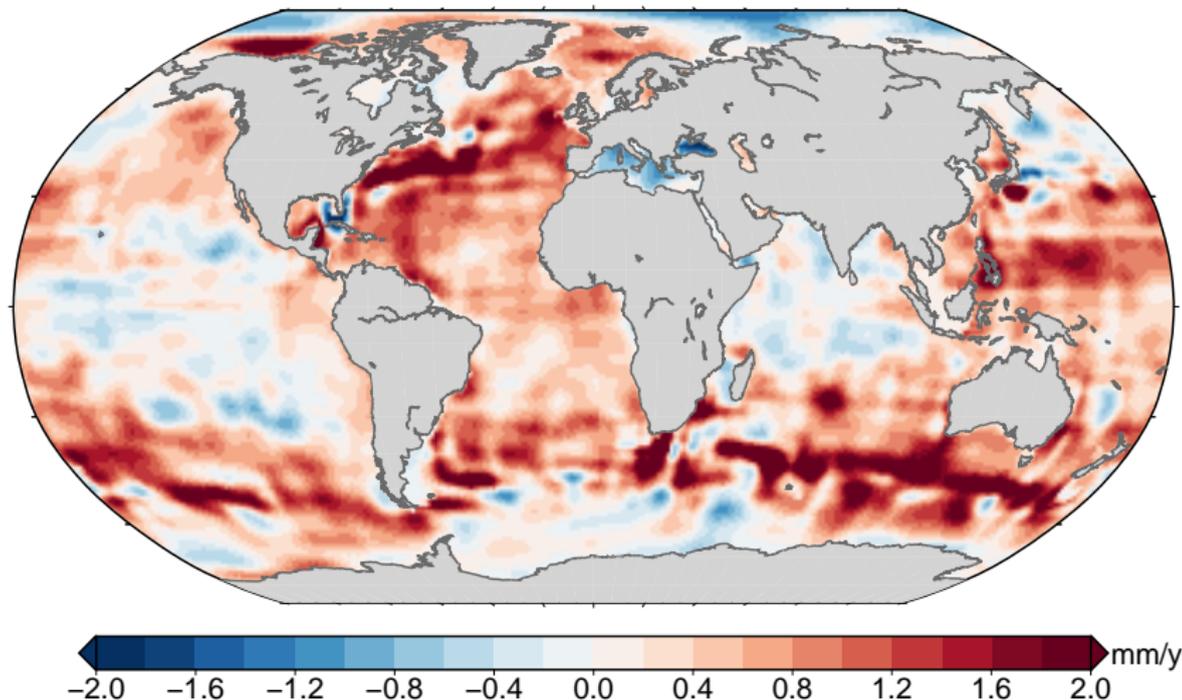
Antarctica

Sea level changes when Antarctica loses 362 Gigatons of ice



Density changes not uniform

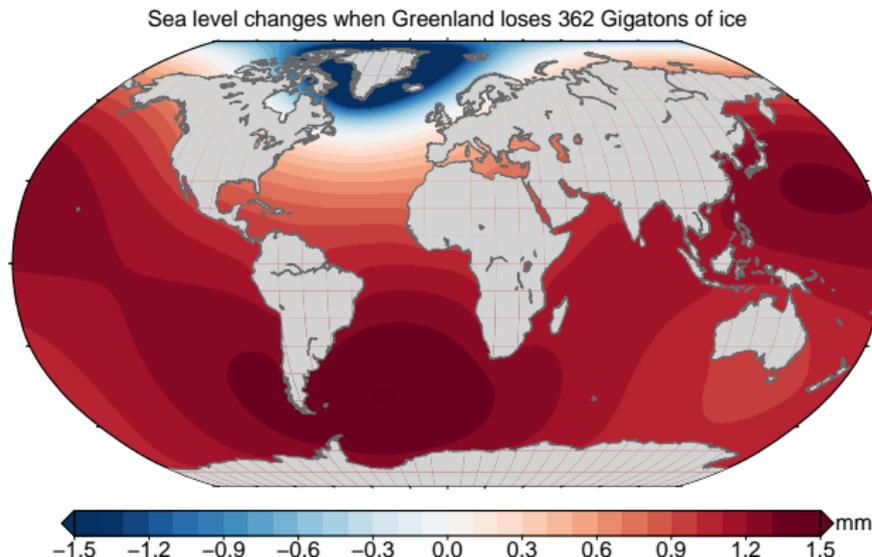
Steric sea level changes 1958–2014



Source: MetOffice EN4 v4.1.1

Combine prior knowledge with observations

Prior knowledge on regional sea-level rise patterns



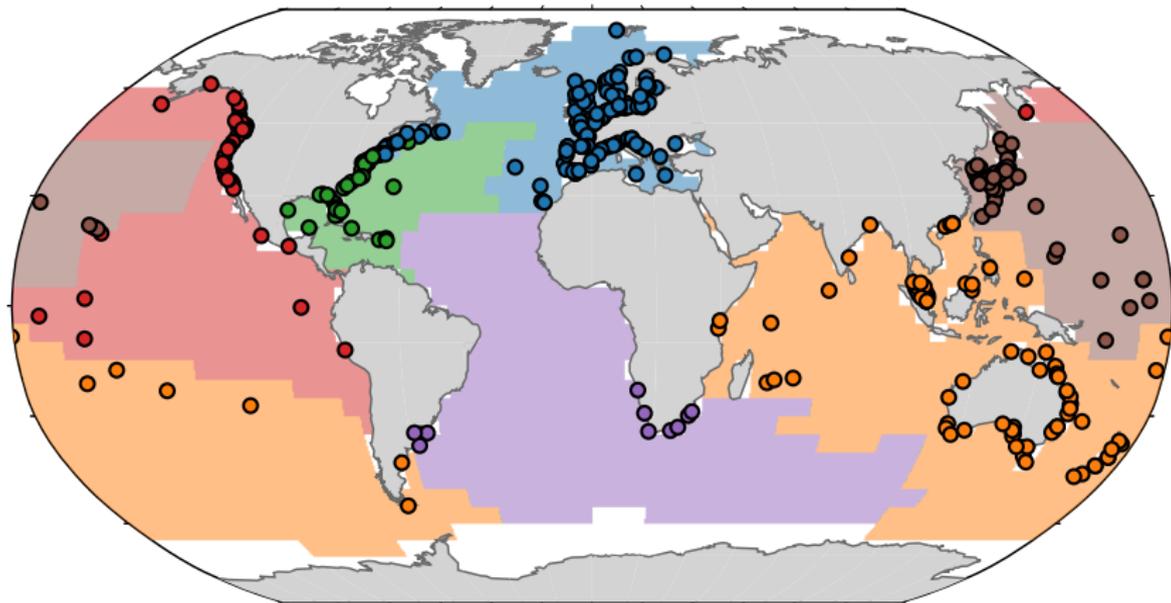
Observations of land motion



IJmuiden Tide Gauge

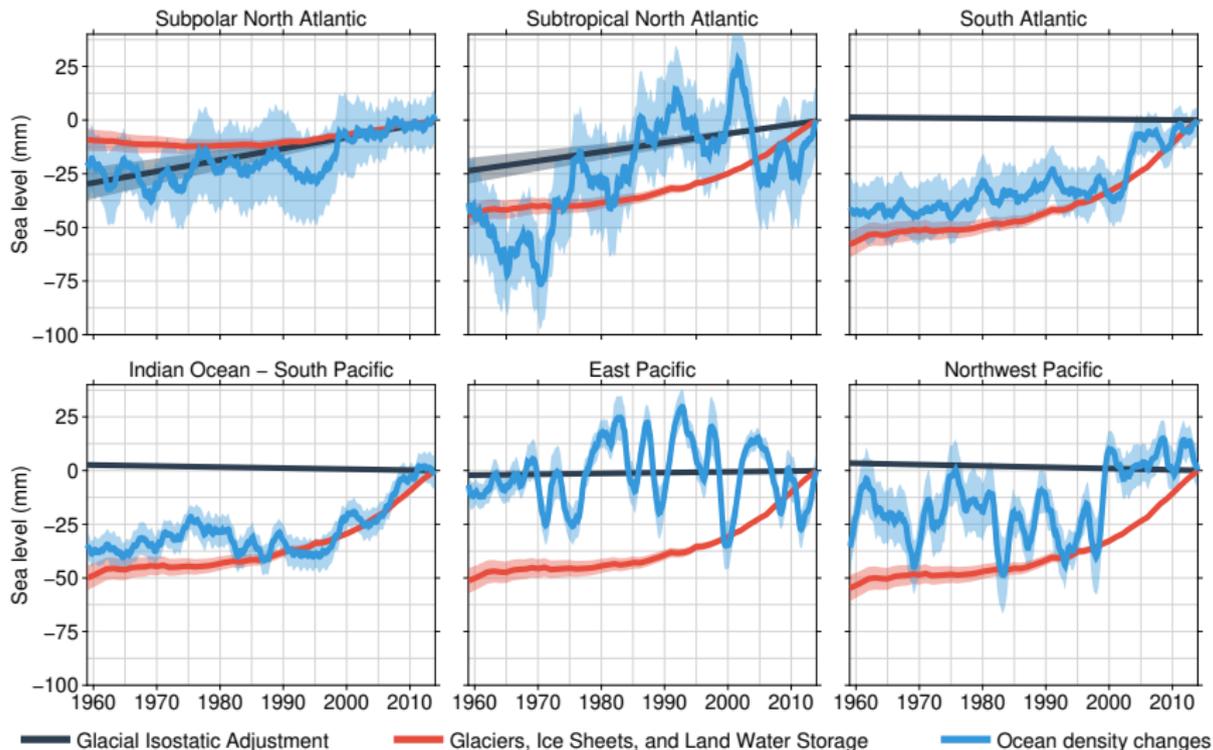
The sea-level budget on a basin scale

Tide-gauge locations and ocean basins



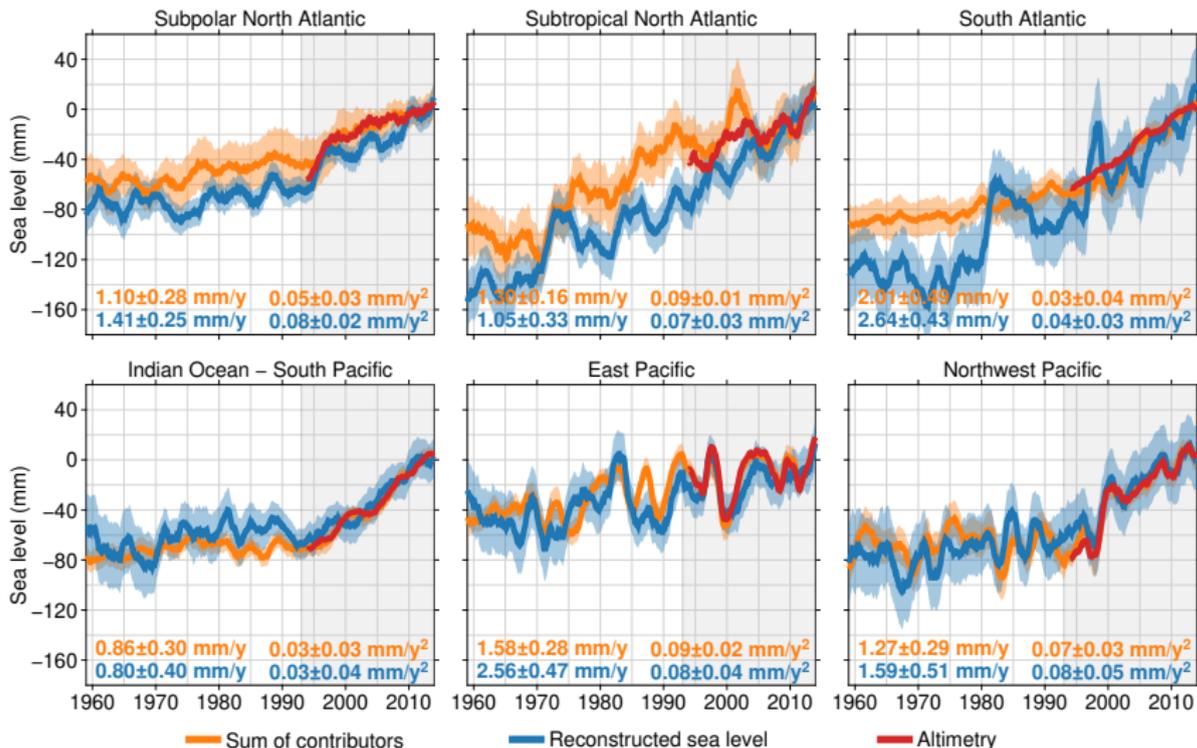
Source: PSMSL, Nevada Geodetic Laboratory, Wöppelmann and Marcos [2015]

Causes of basin-mean sea-level changes



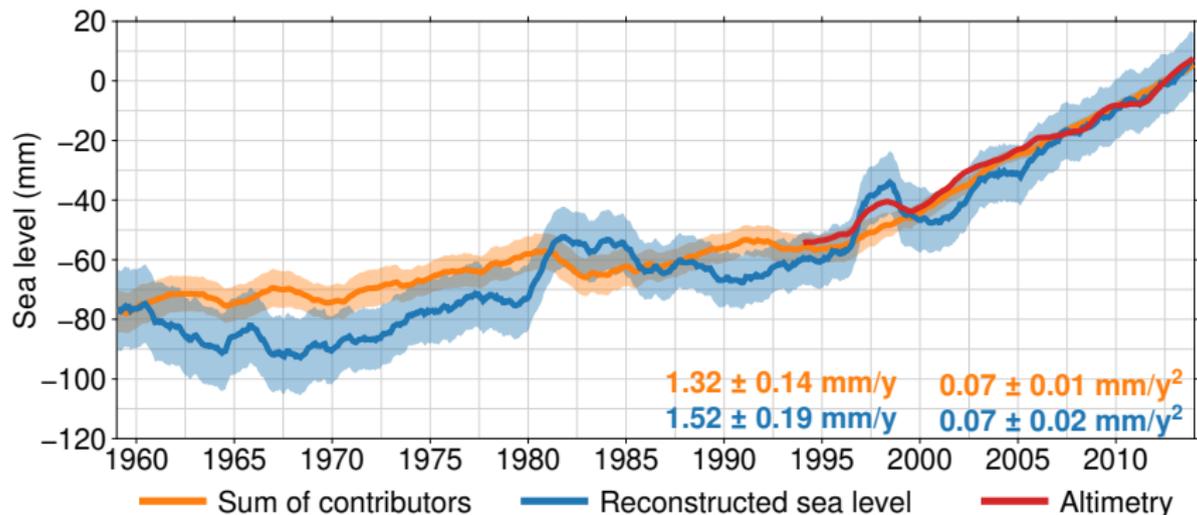
Sources: GIA: Peltier et al [2015], Glaciers: Marzeion et al [2017], Ice Sheets: RACMO2.3 [Van den Broeke et al. 2016], LWS: Wada et al. [2010,2014]. Density: EN4, Good et al [2013]

A regional sea-level budget



Sources: Altimetry data: AVISO, Tide-gauge data: PSMSL, VLM data: Nevada Geodetic Laboratory, Wöppelmann and Marcos [2015]

Closure of the global budget



Sources: Altimetry data: AVISO, Tide-gauge data: PSMSL, VLM data: Nevada Geodetic Laboratory, Wöppelmann and Marcos [2015]

Conclusions

- Reconstructing sea-level rise requires thorough knowledge of underlying physics
- Regional variations in sea-level rise are often persistent
- Sea-level changes are caused by mass and density changes
- Regional and global sea-level budget can be reasonably closed, Atlantic Ocean exception