Balancing regional sea level budgets

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Regional sea level

Improving our understanding of regional fluctuations in sea level is critical to both interpreting the current rise and developing accurate projections of future rise.

- "Regional Sea-Level Change and Coastal Impacts" is one of five Grand Challenges of the World Climate Research Programme
- One of four elements of the NASA Sea Level Change Team

What can altimetry, GRACE, and Argo tell us?

The sea level budget may be expressed as height changes from the main components of sea level change:

$$\Delta SSH = \Delta SH + \Delta OM$$

SSH = sea surface height, SH = steric height, *OM* = ocean mass

Argo measures temperature and salinity short of the abyssal ocean (roughly 44 to 75% of Argo profiles are from 2000m).

$$\Delta SH = \Delta SH_{(0–2000m)} + \Delta SH_{(2000m–\infty)}$$

We can estimate a residual from observations:

$$\Delta SL_{residual} = \Delta SSH - \Delta SH_{(0–2000m)} - \Delta OM$$

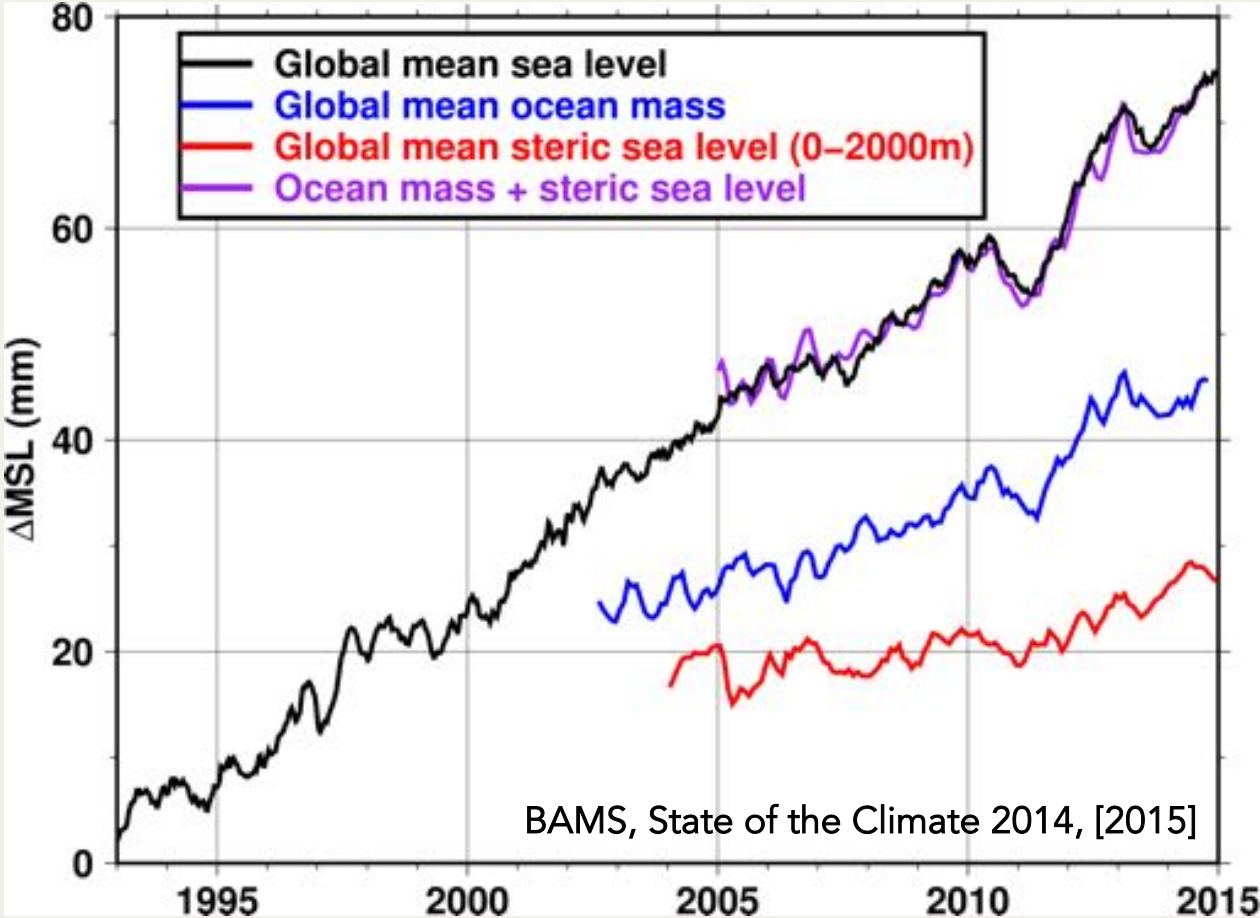
$$\Delta SL_{residual} = \Delta SH_{(2000m–\infty)} + Error$$

Global and regional sea level budgets

Global sea level budgets can be closed within the estimated errors

Bounds size of deep (> 2000 m) ocean warming (e.g. Llovel et al. 2014)

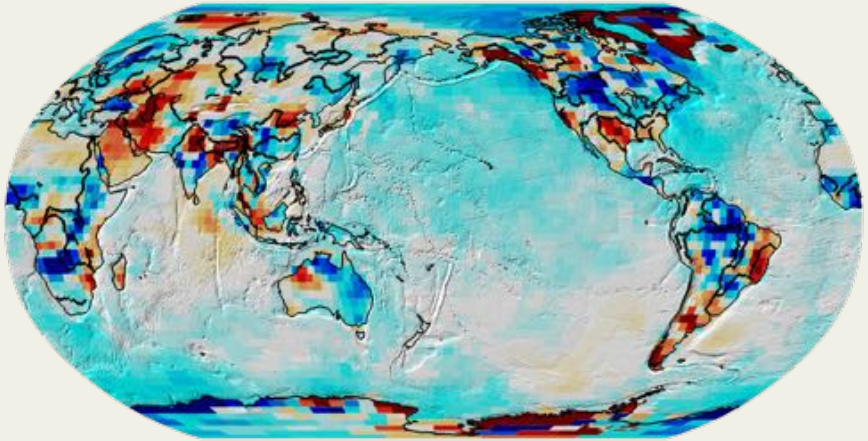
What do regional sea level budgets tell us?



GRACE JPL-Mascons

GRCTellus JPL-Mascons

- "Monthly" global mass grids
- Fit tracking data to 4,551 equal-area 3°x3° spherical caps
- Includes crustal loading
- Two solutions
  - With and without a Coastline Resolution Improvement (CRI) filter
  - Previous GRACE studies of ocean mass needed masks/filters near the coast, forward modeling of land hydrology, or other "mascon" solutions



10.5067/TEMSC-OCL05 Watkins et al. (2015)

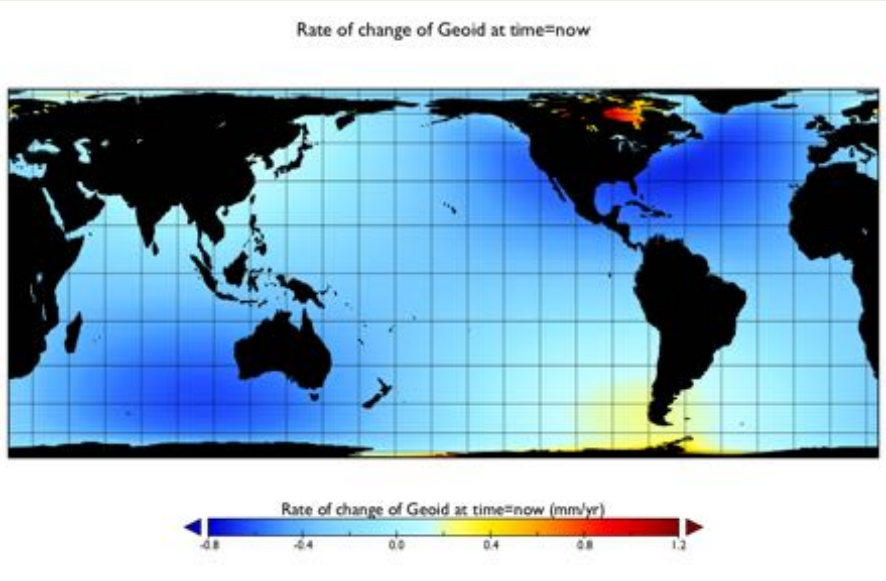
Modifications

- Mean atmosphere
- Pole tide (Wahr 2015)

Altimetry

For total sea level we use Jason-1 and Jason-2 data from RADS

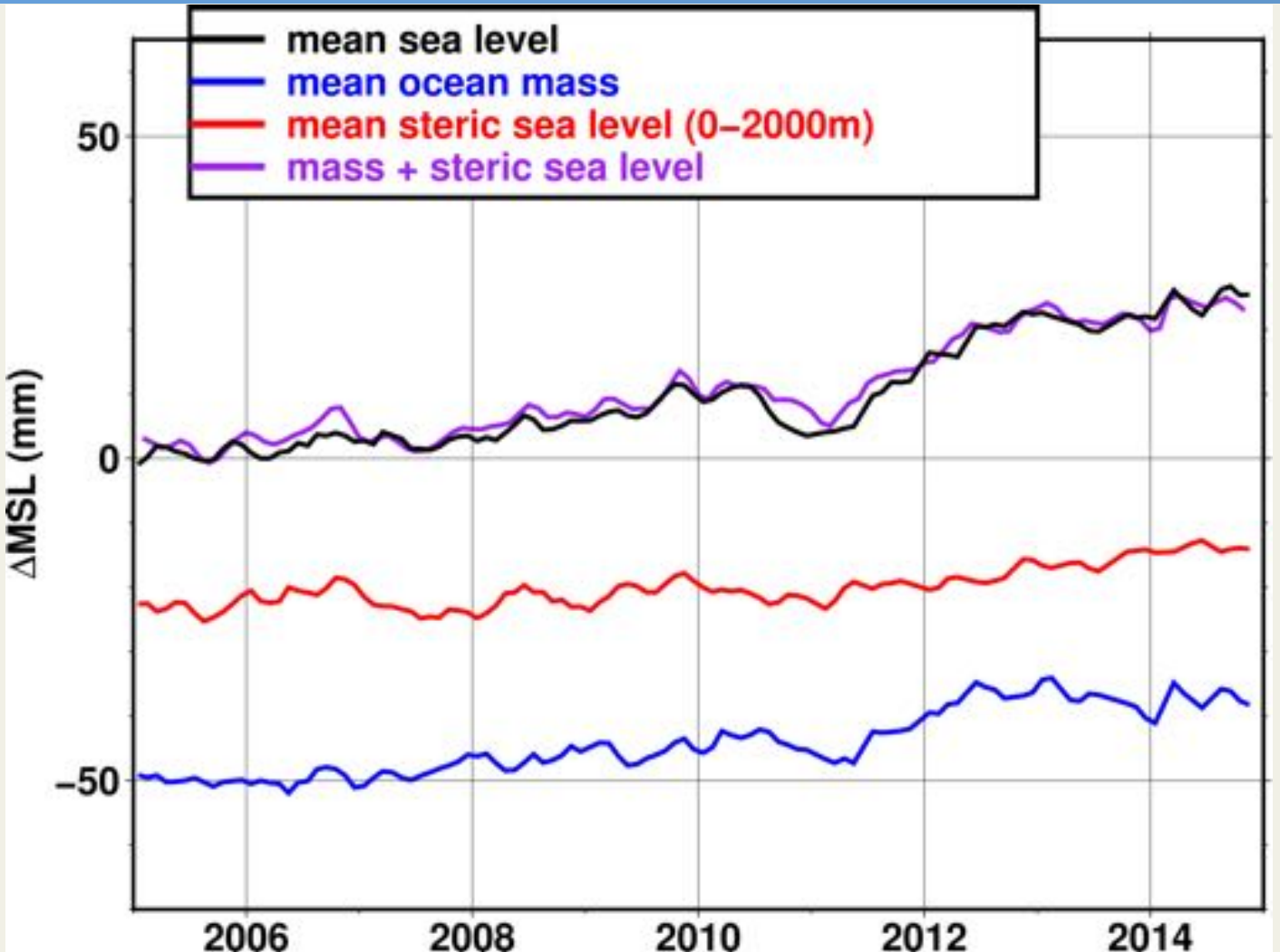
- GOT4.10 tide model; Desai [2015] pole tide
- GIA radial geoid rates Peltier ICE5Gv1.3 [2012].
  - Average correction increases SLR by +0.25 mm/year.



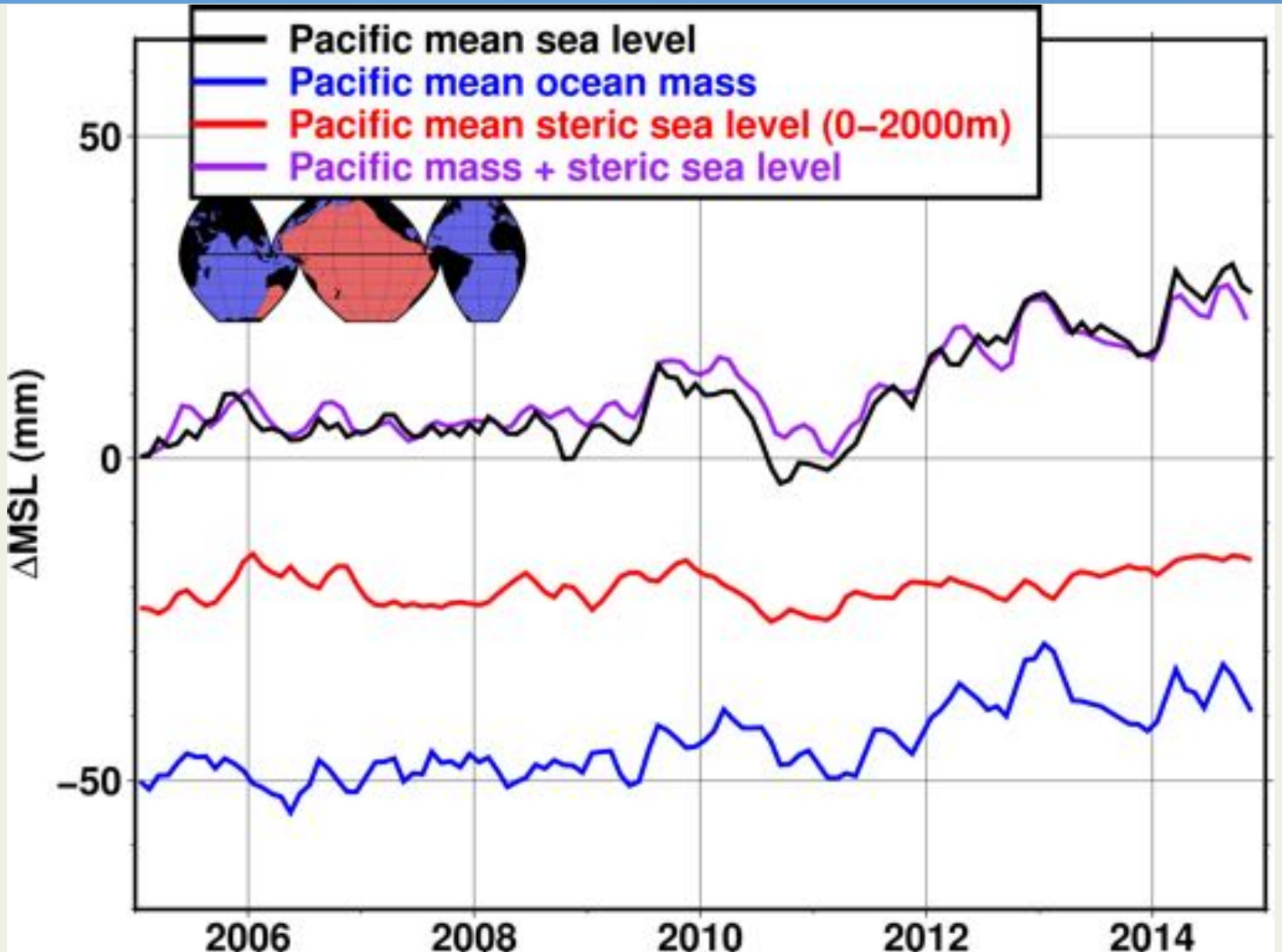
For Argo, we use gridded temperature and salinity fields from:

- IPRC: UH International Pacific Research Center
- JAMSTEC: Japan Agency for Marine-Earth Science and Technology
- SIO: Roemmich-Gilson

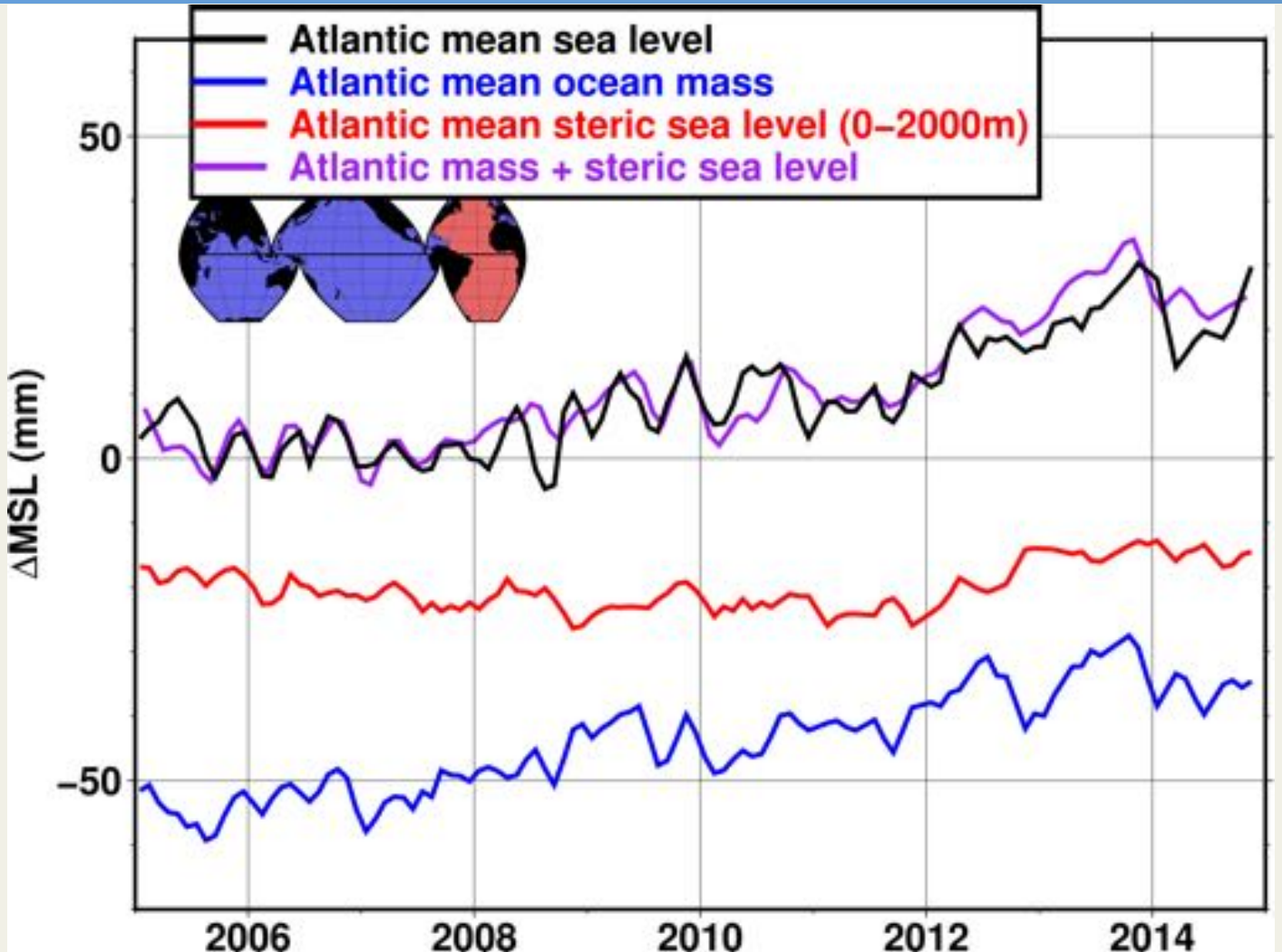
Global mean sea level budget



Pacific Ocean sea level budget



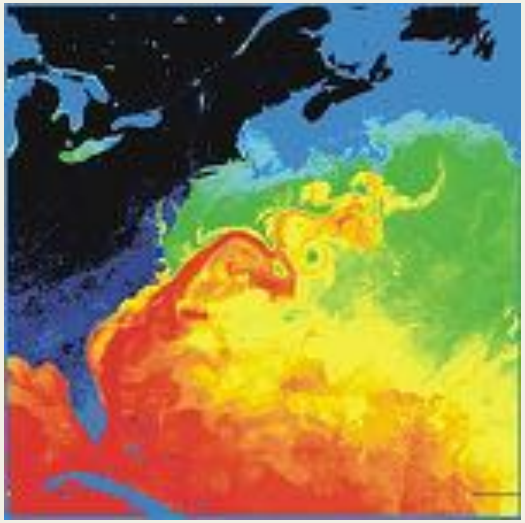
Atlantic Ocean sea level budget

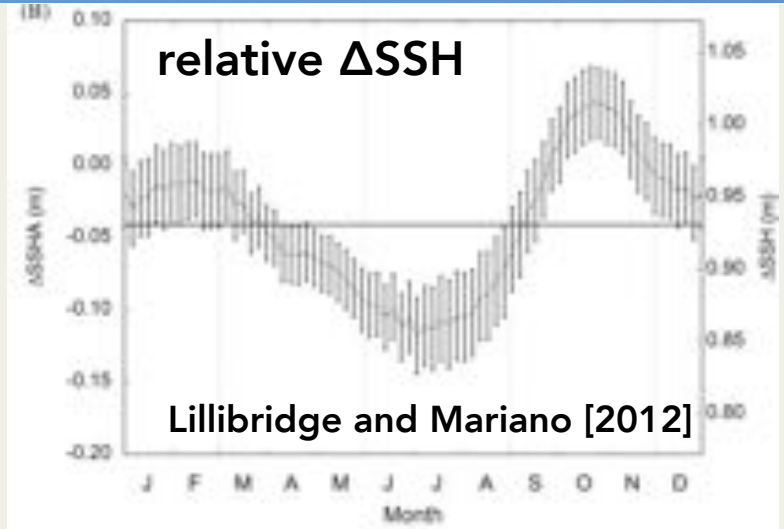


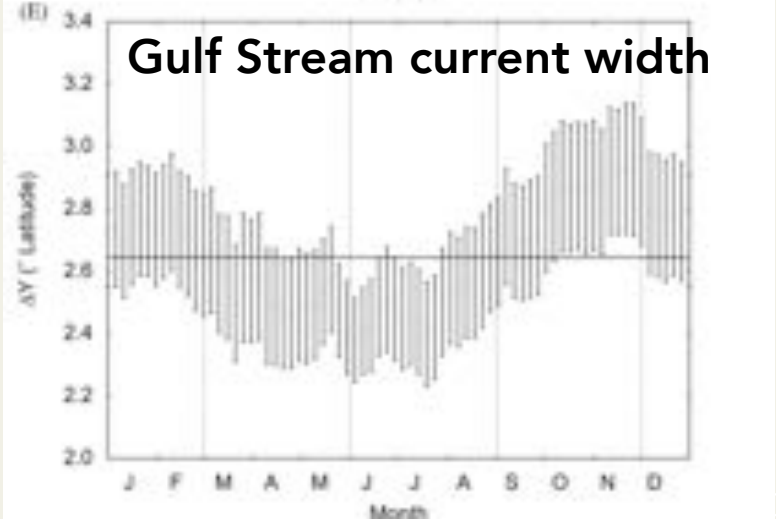
Gulf Stream variability

Relative sea level and current width in the Gulf Stream peaks in September/October.

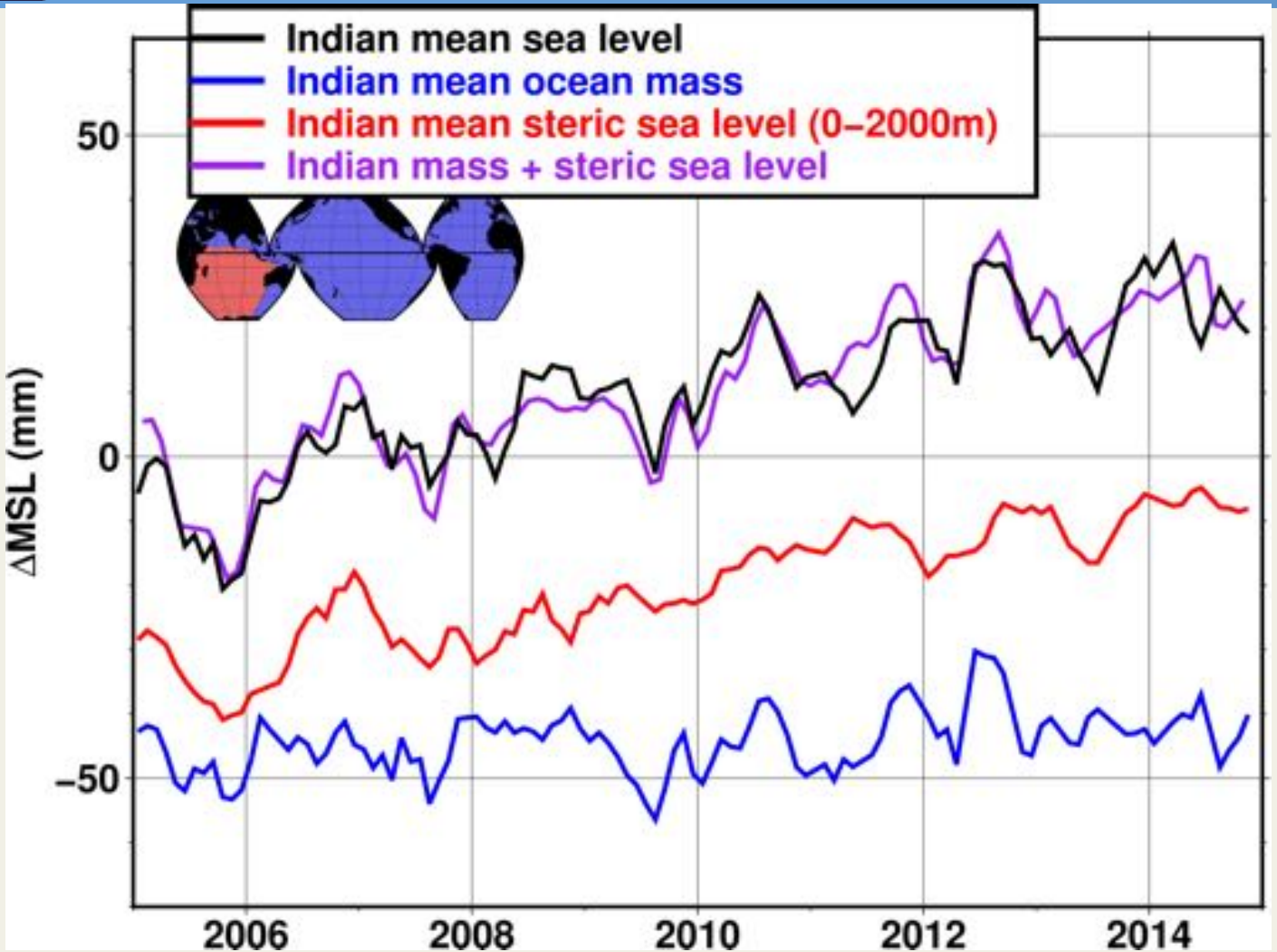
Prior to 2010 Argo coverage in the North Atlantic was not dense enough to sample the Sep/Oct peak.





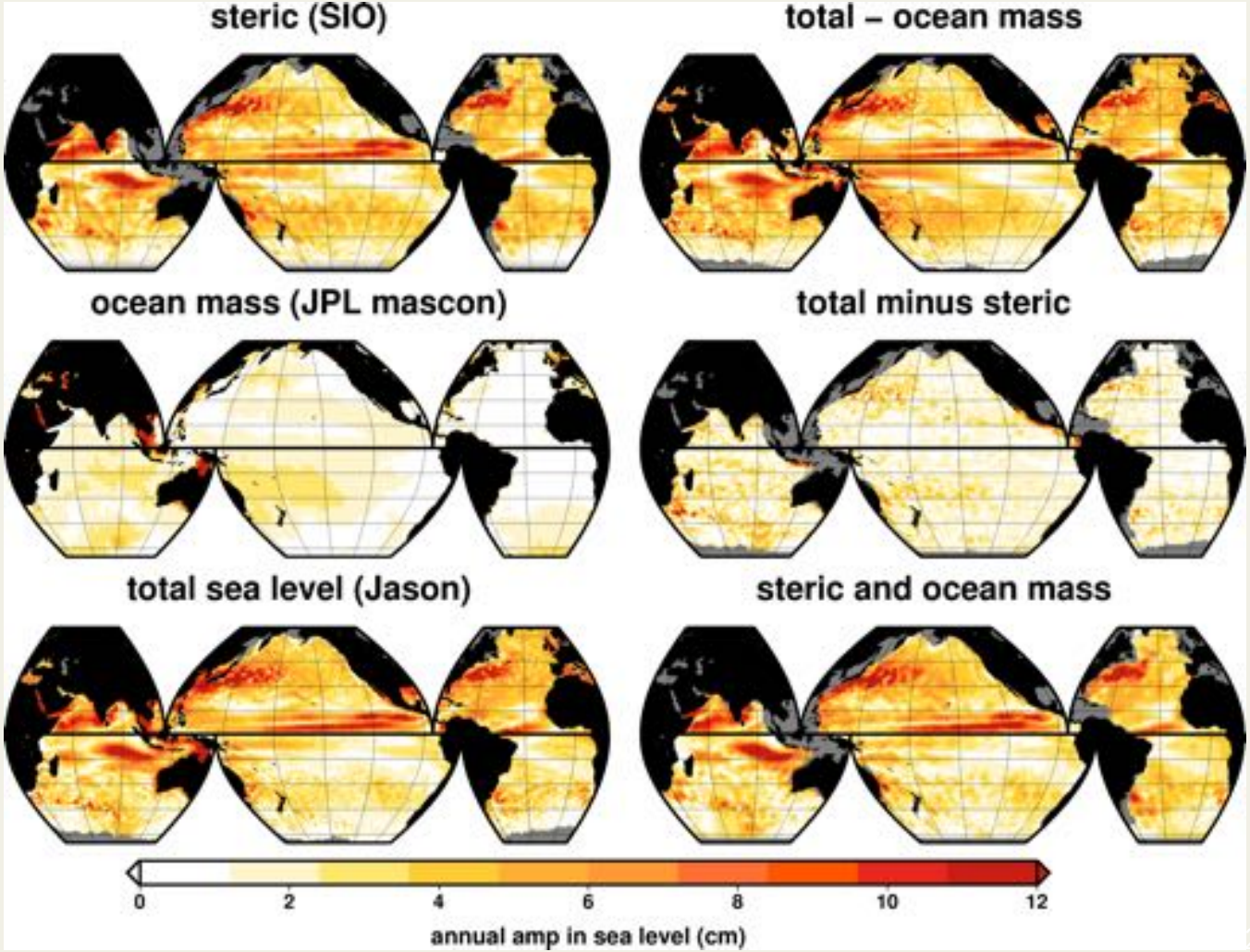


Indian Ocean sea level budget



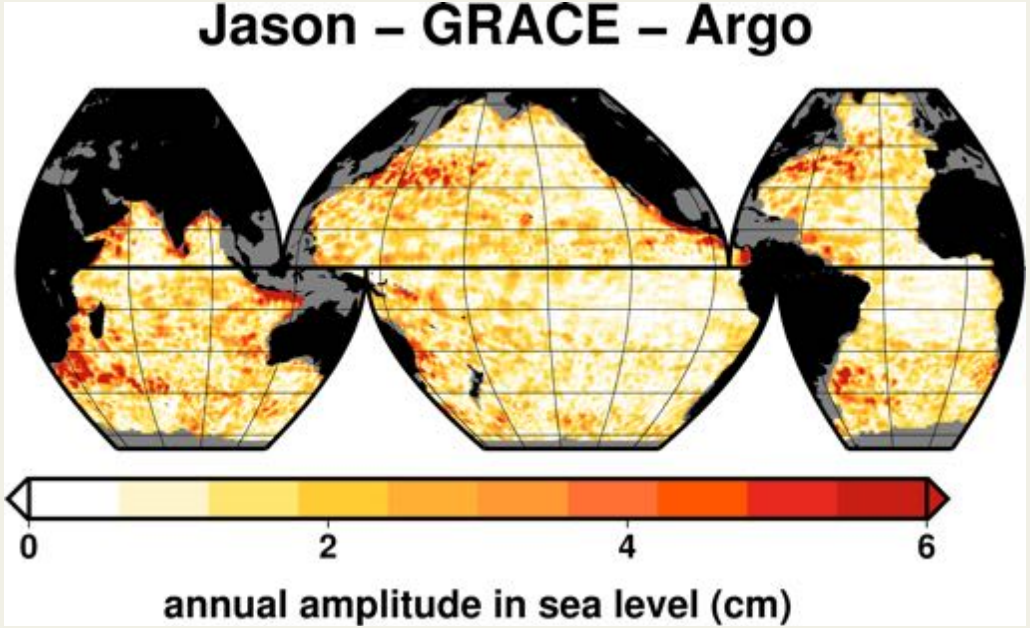
Annual amplitude of sea level components

The seasonal sea level budget is closed in most regions.



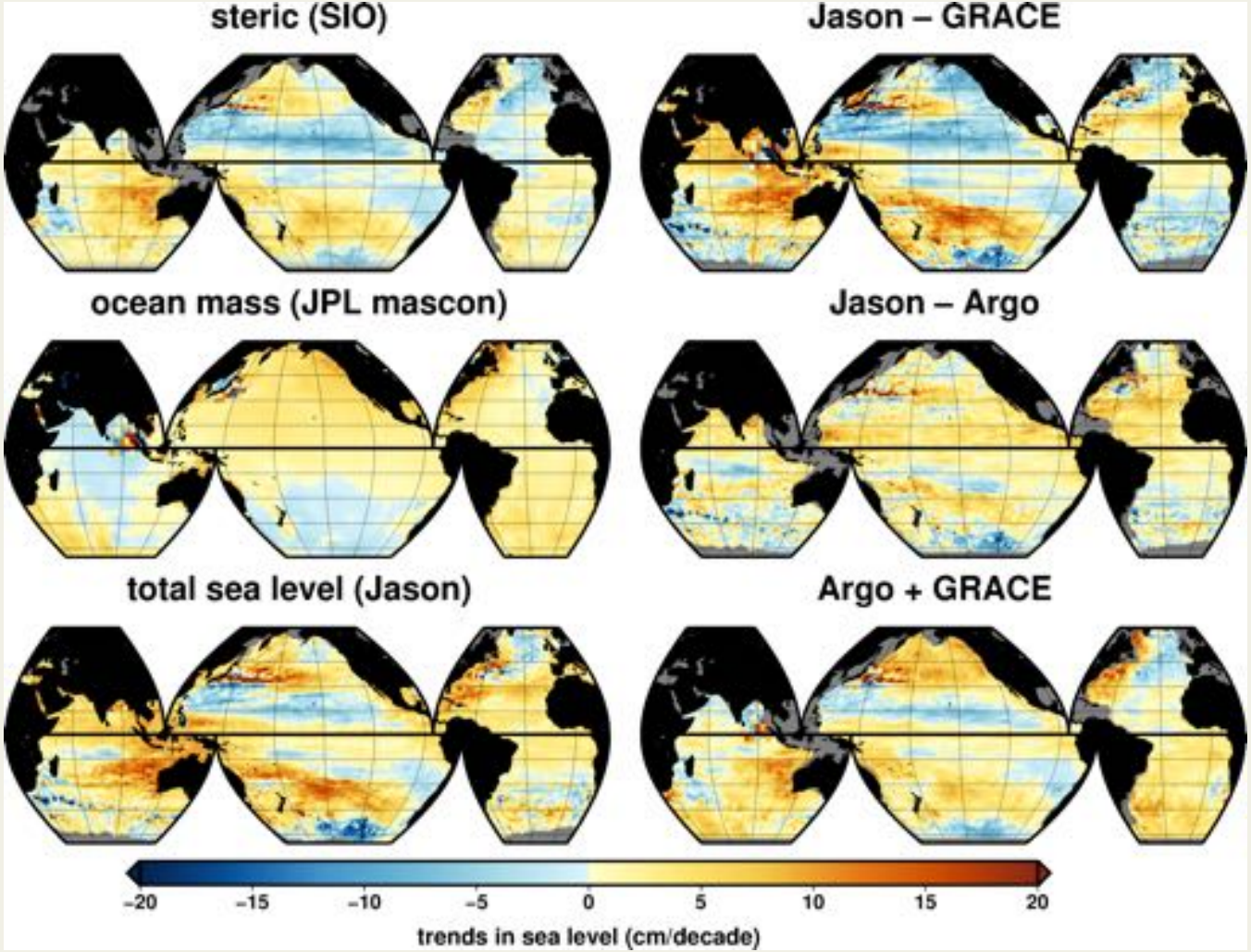
Residual seasonal signal

The residual annual signal is significant mainly in mesoscale regions.

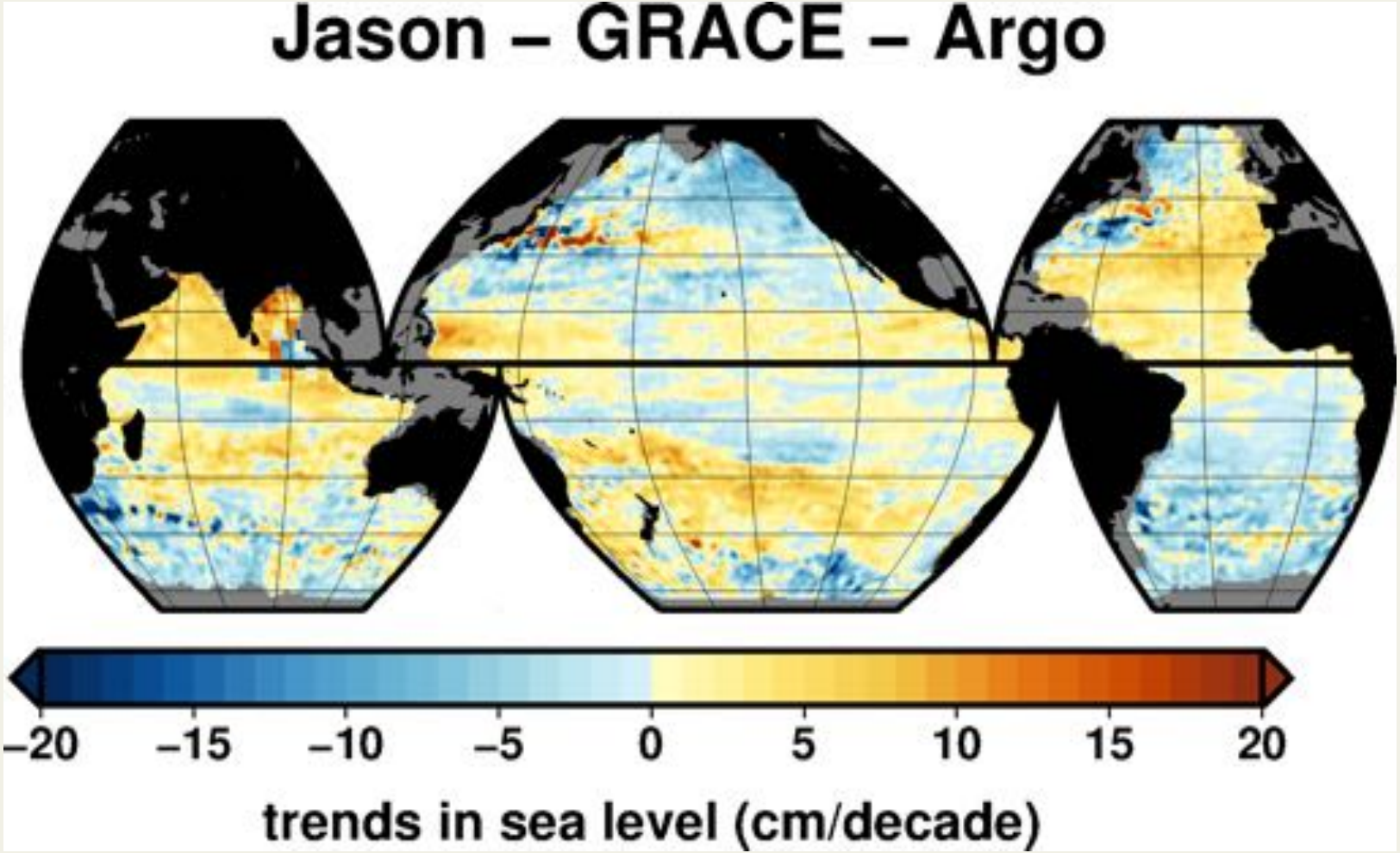


[Note change in scale.]

Local sea level budget trends



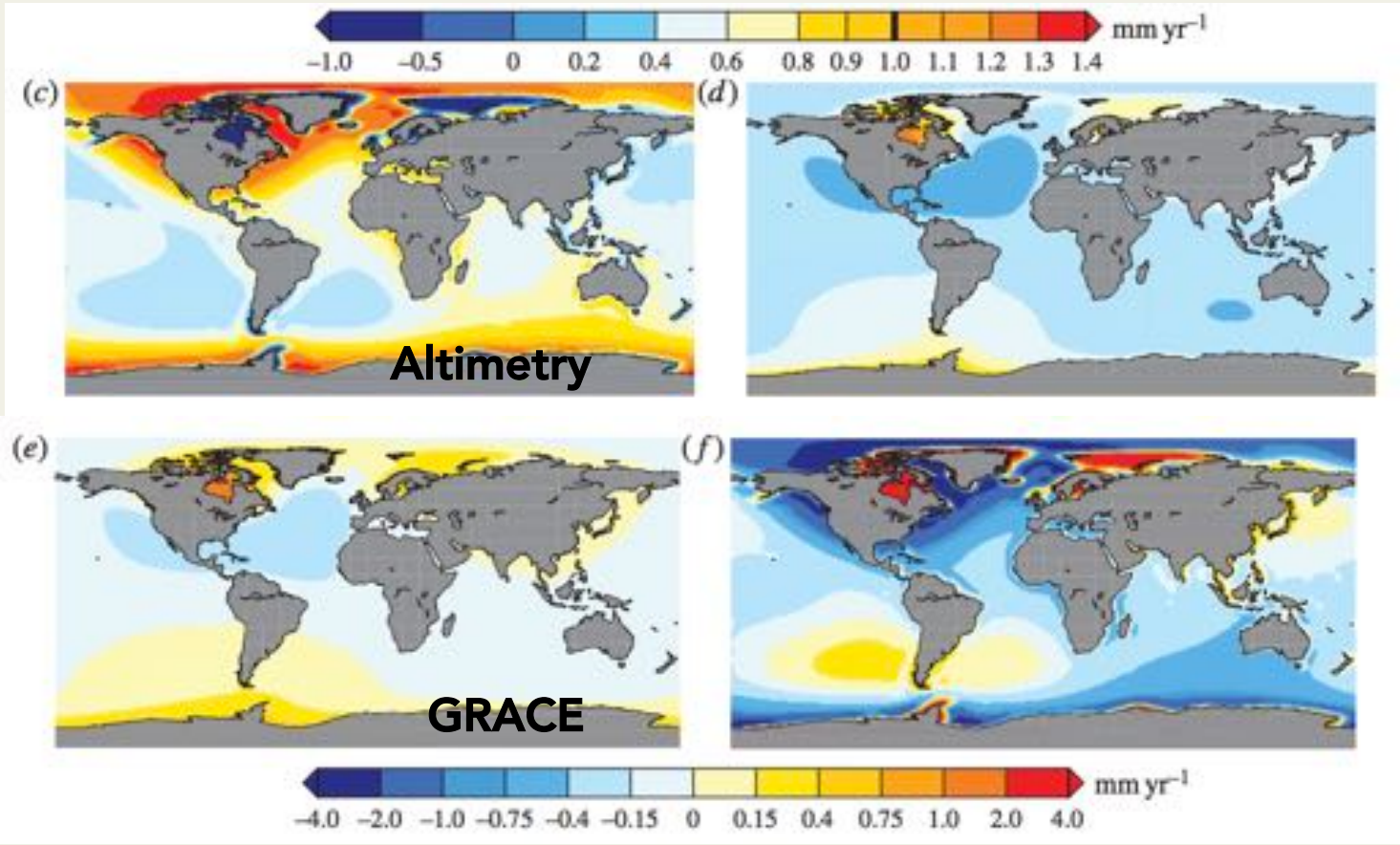
Residual trends



Sea level fingerprints?

Predicted spatial patterns of relative sea level change caused by a mass loss equivalent to a 1 mm/yr globally averaged SLR.

Greenland **West Antarctica**



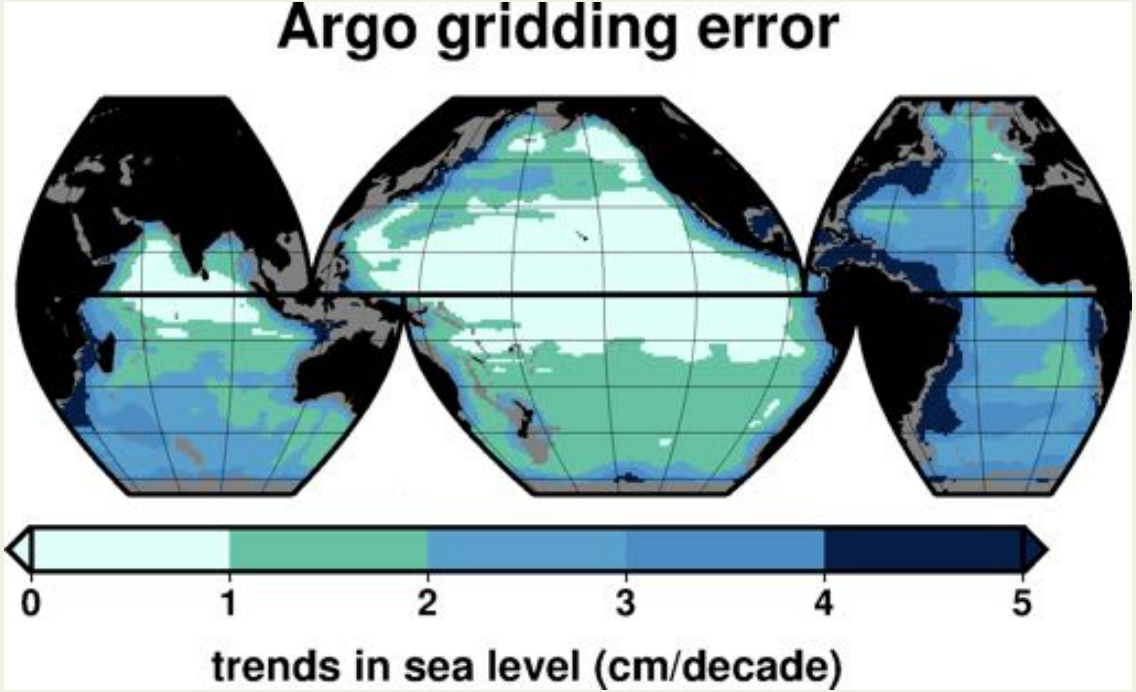
Tamisiea and Mitrovica [2011]

Residual trends and Argo errors

We use the estimated gridding errors from the JAMSTEC monthly grids of Argo temperature and salinity to infer the error in the Argo trends.

We assume errors in depth are correlated.

Errors are generally higher in the Atlantic and the Southern Ocean.



95% significance

Spectrum of residual trends

We transformed the residual trends into weighted spherical harmonics to find the degree variances.

The sea level budget closes:

At basin scales:

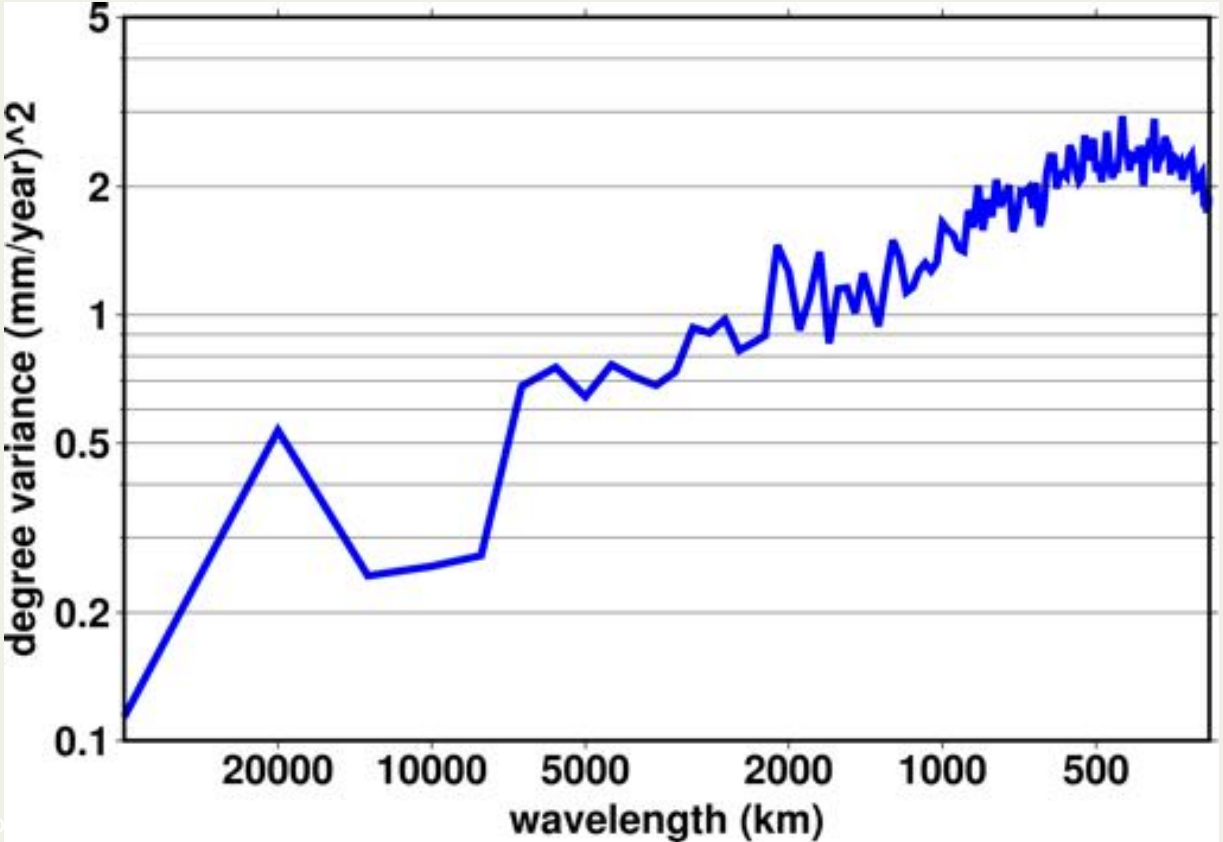
<0.5 $(mm/year)^2$

For scales 2000km:

~1 $(mm/year)^2$

For scales <1000km:

1–3 $(mm/year)^2$



Conclusions

- The seasonal level budget and the sea level rise budget both close globally and on basin scales.
- With the current observing system, we can expect budgets to close < 1 mm/year at scales > 2000 km.
- Budget closure should improve as the observing system expands:
  - Altimetry
    - 2016 and beyond: five or more active altimeters, SWOT
  - GRACE Follow-on (2017)
    - Consistent monthly ocean mass measurements
  - Argo
    - ~4000 active floats and Deep Argo