Are the Oceans warming? Is sea level rising?

www.cawcr.gov.au

John Church

Centre for Australian Weather and Climate Research

Engineers Australia
Melbourne
October 4, 2012

Australian Government
Bureau of Meteorology

CSIRO

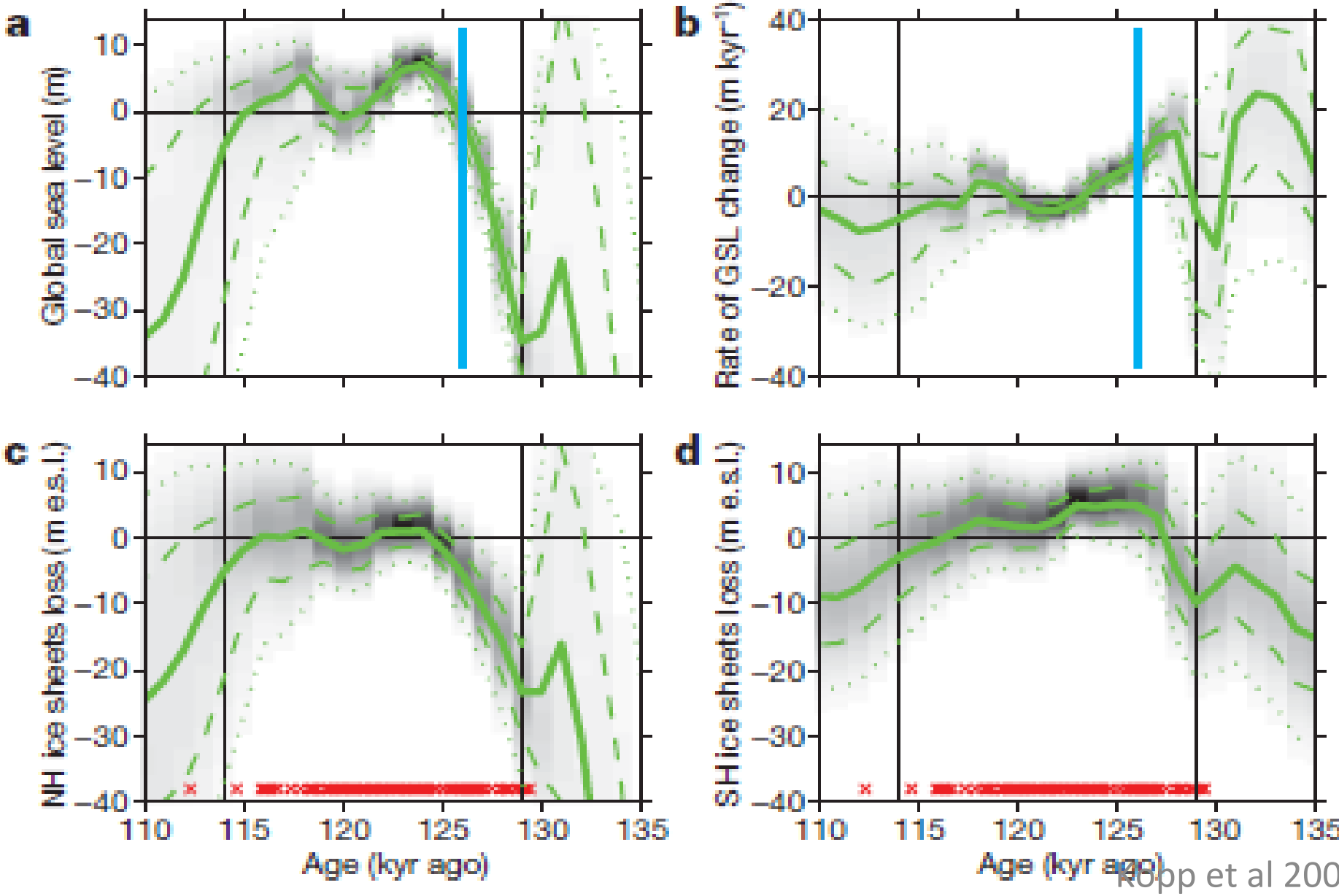
Coastal Development

During the last two thousand years of stable (and in some places falling) relative sea level, our coastal society has developed.

In first meter
150 Million people
1 Trillion Dollars of GDP

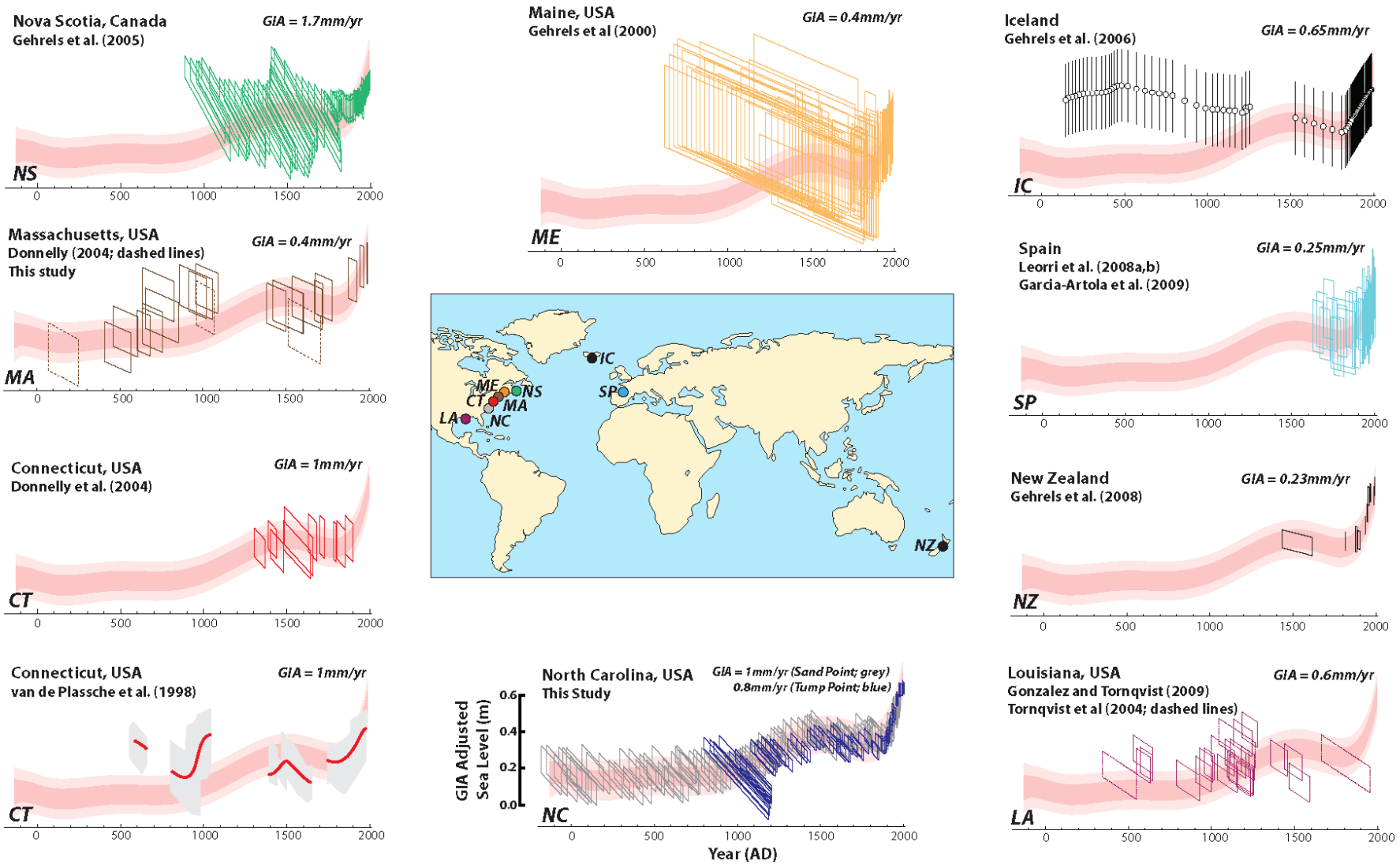
Church *et al.* 2010

The last interglacial may be a useful analogue for the future: Sea level > 6.6 m (95%) above today.



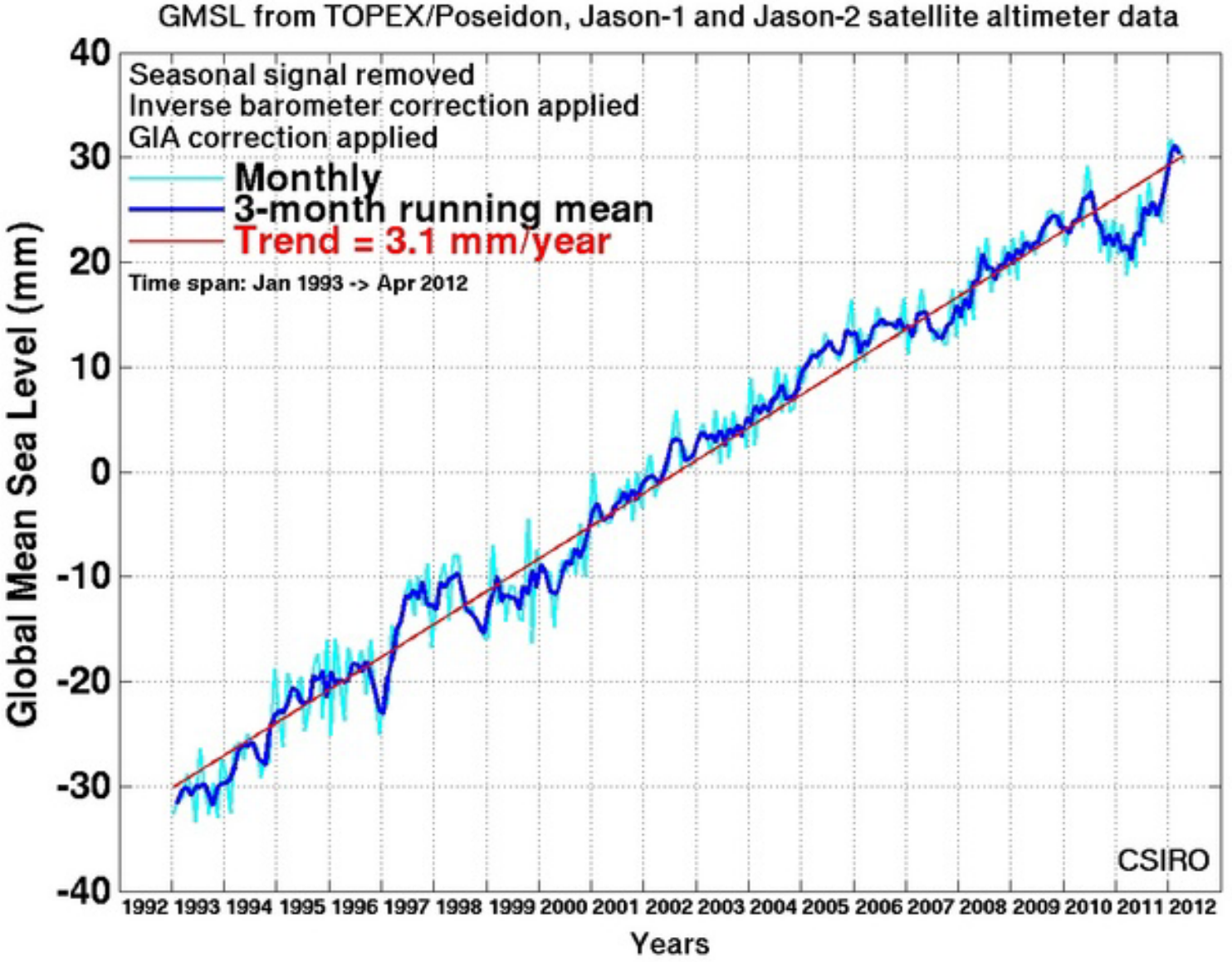
Kopp et al 2009

Salt marsh data indicates a sea-level acceleration. Maybe a small rise over two millenia?

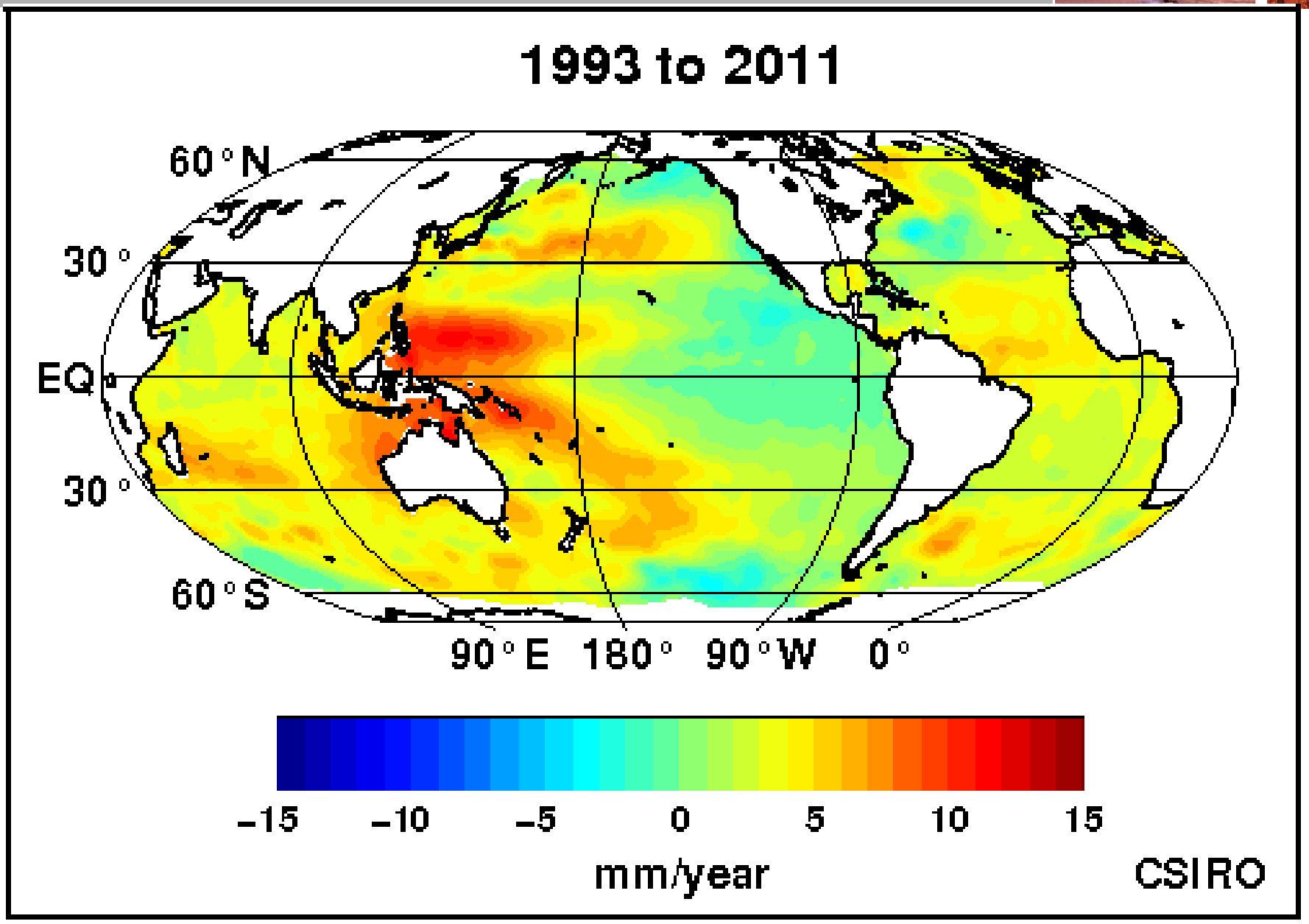


AC Kemp and BP Horton, Pers. Comm., 2010

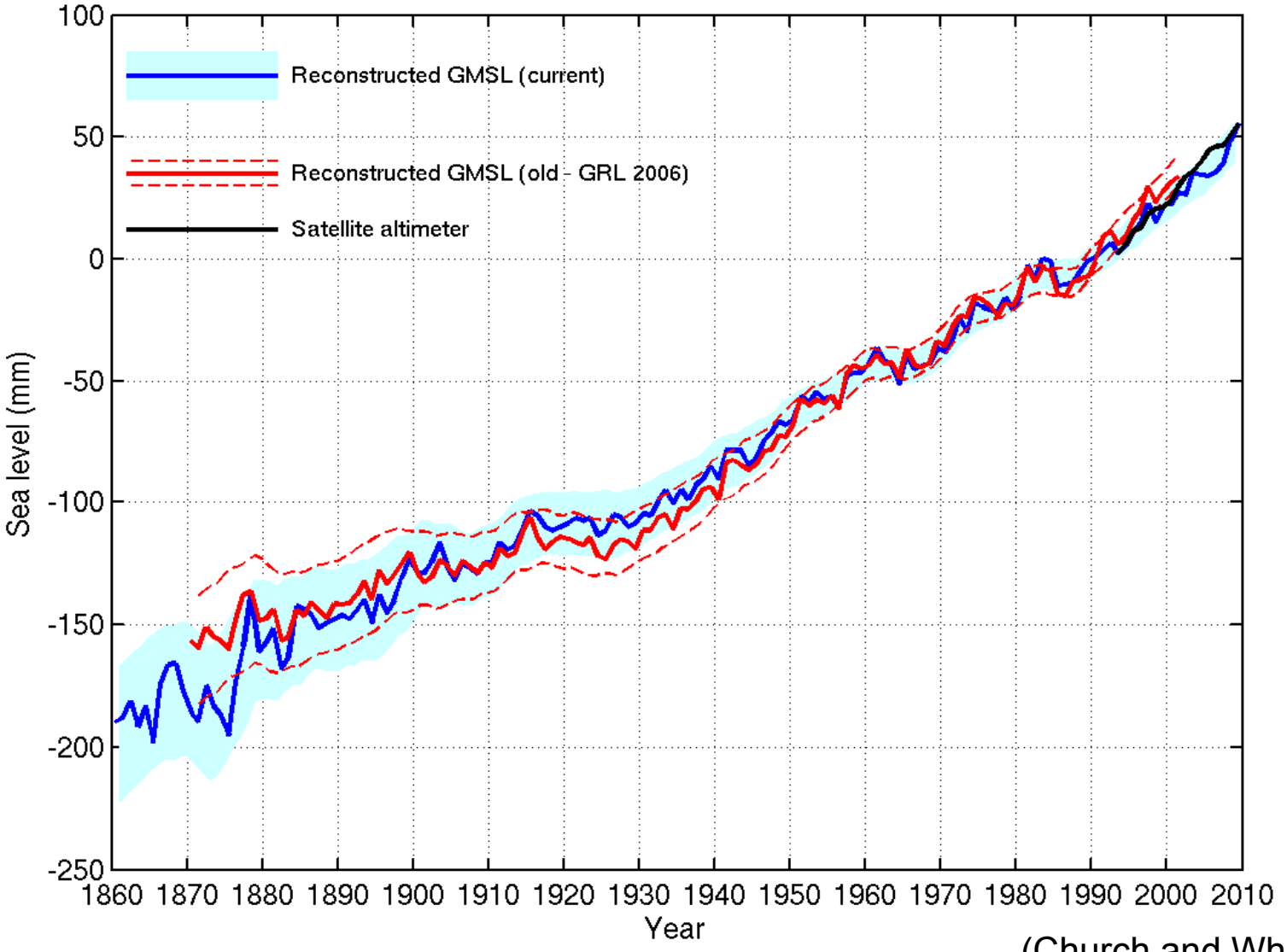
Altimetry-derived global mean sea level



Sea-level rise is not uniform



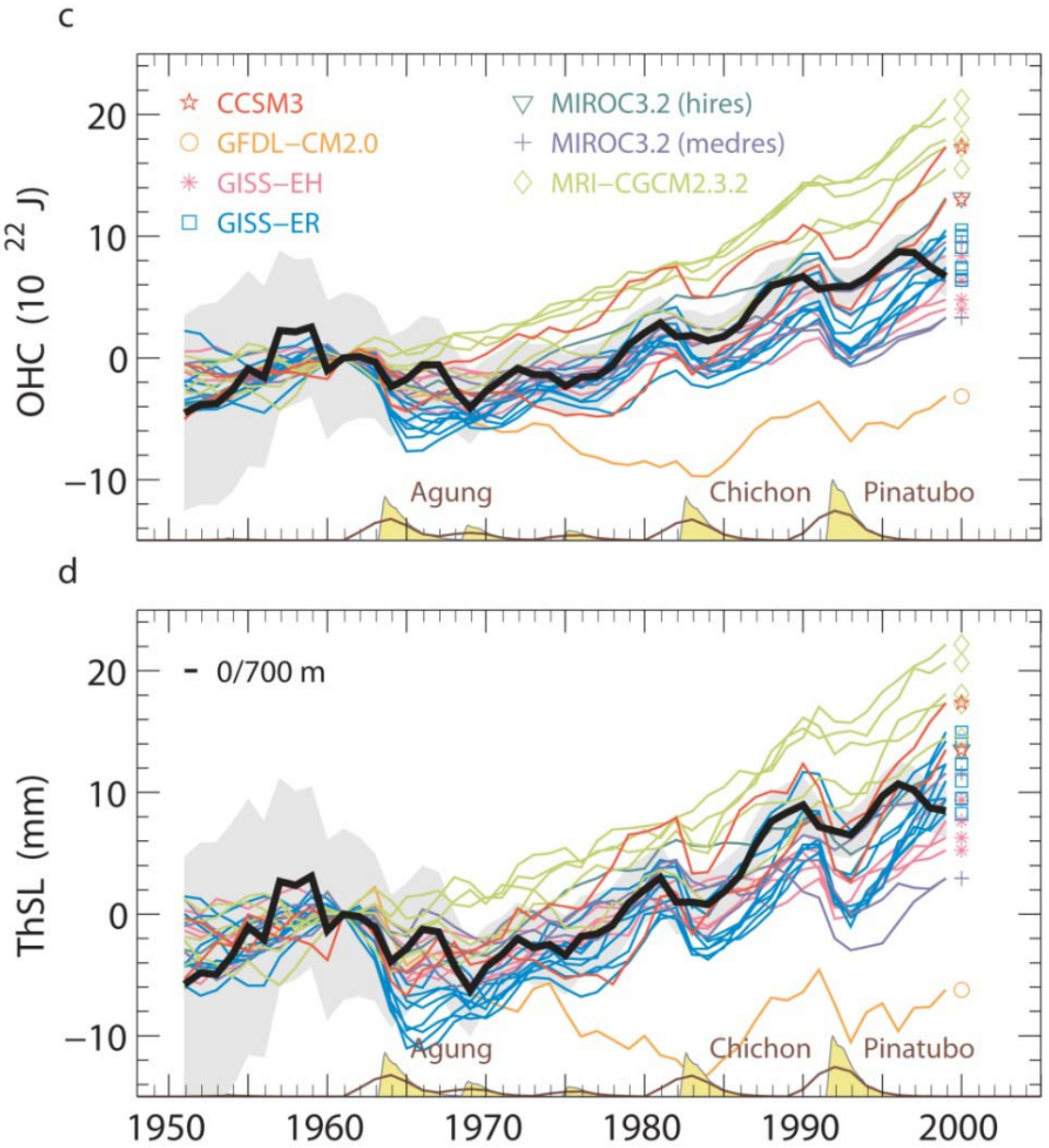
Sea-level rise accelerated during the 20th century – rise is continuing



(Church and White 2011)

Ocean heat content and steric sea-level

- Models without volcanic forcing warm too much
- Need to compare variability and trends in observations and models, with various forcing.
- Not just upper ocean but also deep and abyssal ocean and horizontal distribution
- Require multiple models and ensembles



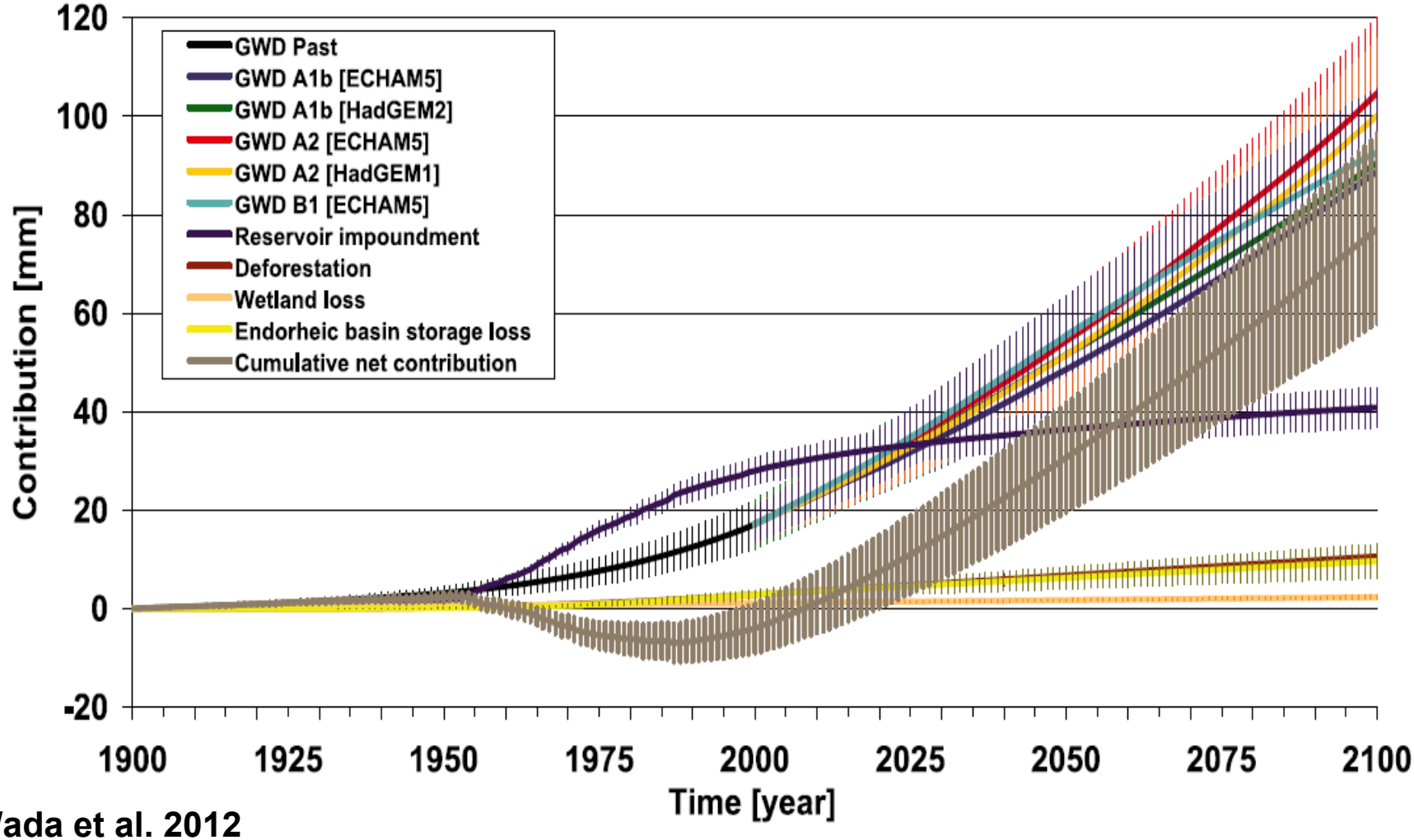
Domingues et al. 2008

Worldwide, glaciers are melting
The Rhone Glacier 1900 and 2000

Church et al. 2010

Depleting aquifers – Storing water in reservoirs

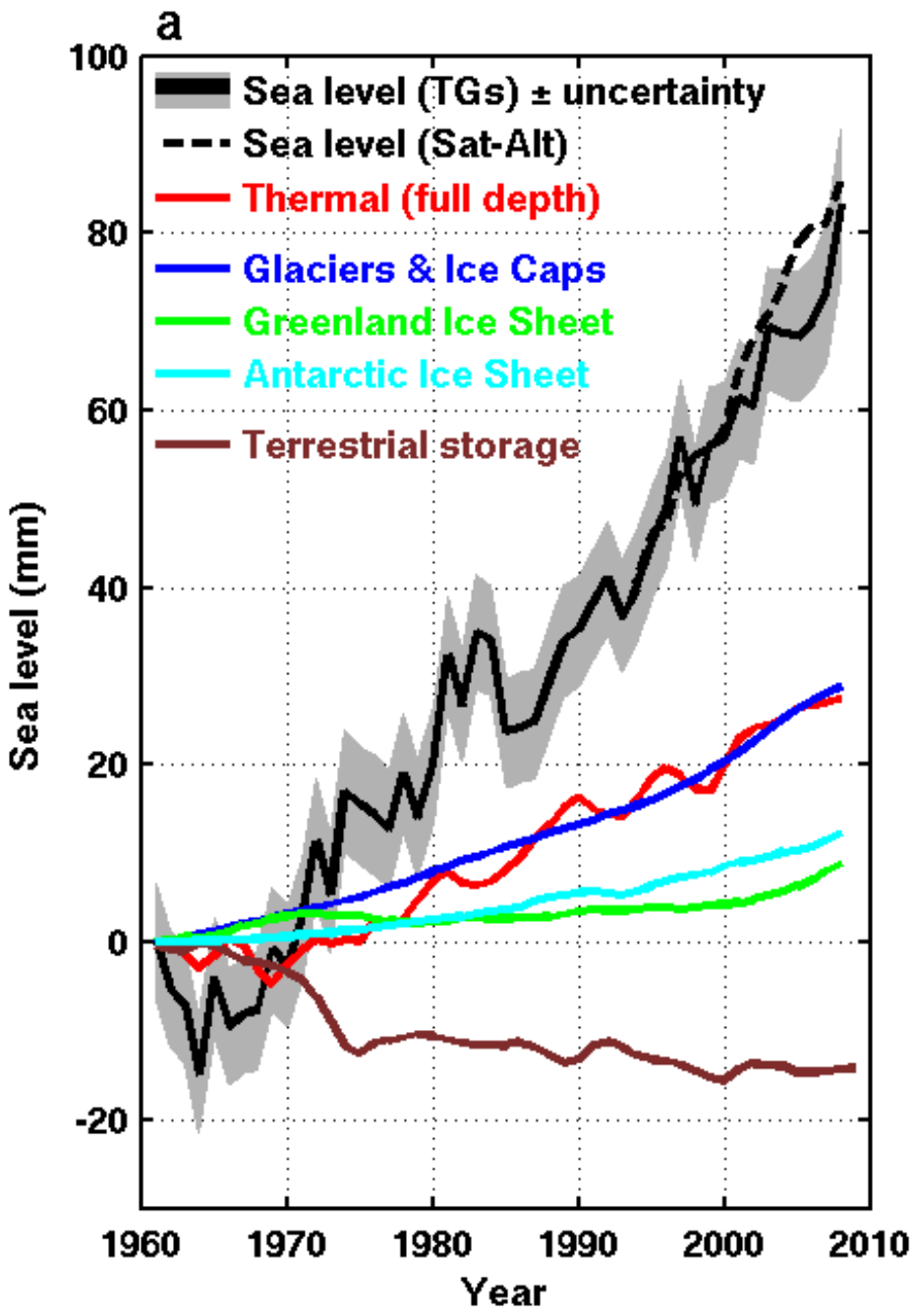
(b)



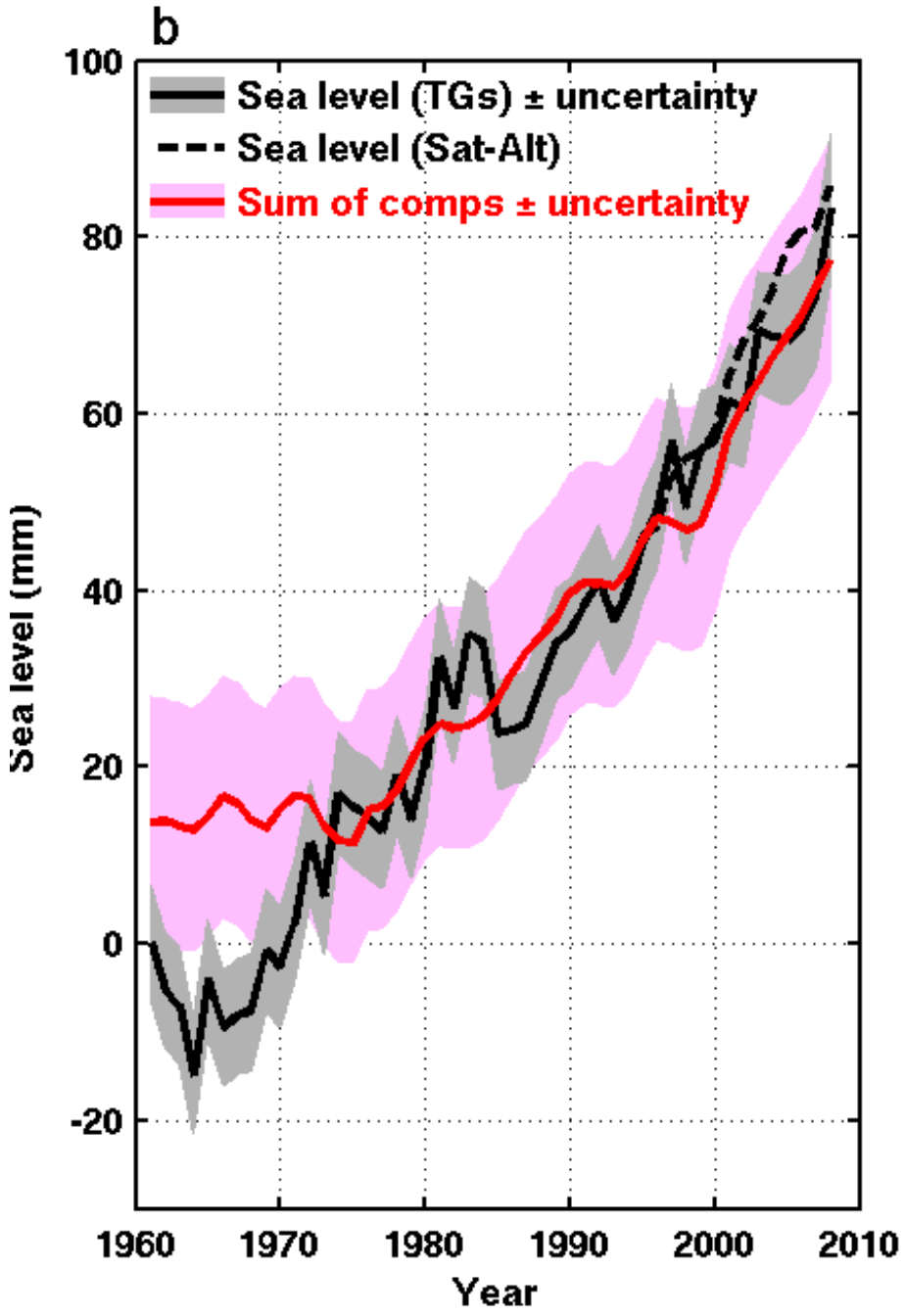
Wada et al. 2012

Observed sea level and the contributions

Glaciers and thermal expansion the largest contributions



Church *et al.* 2011



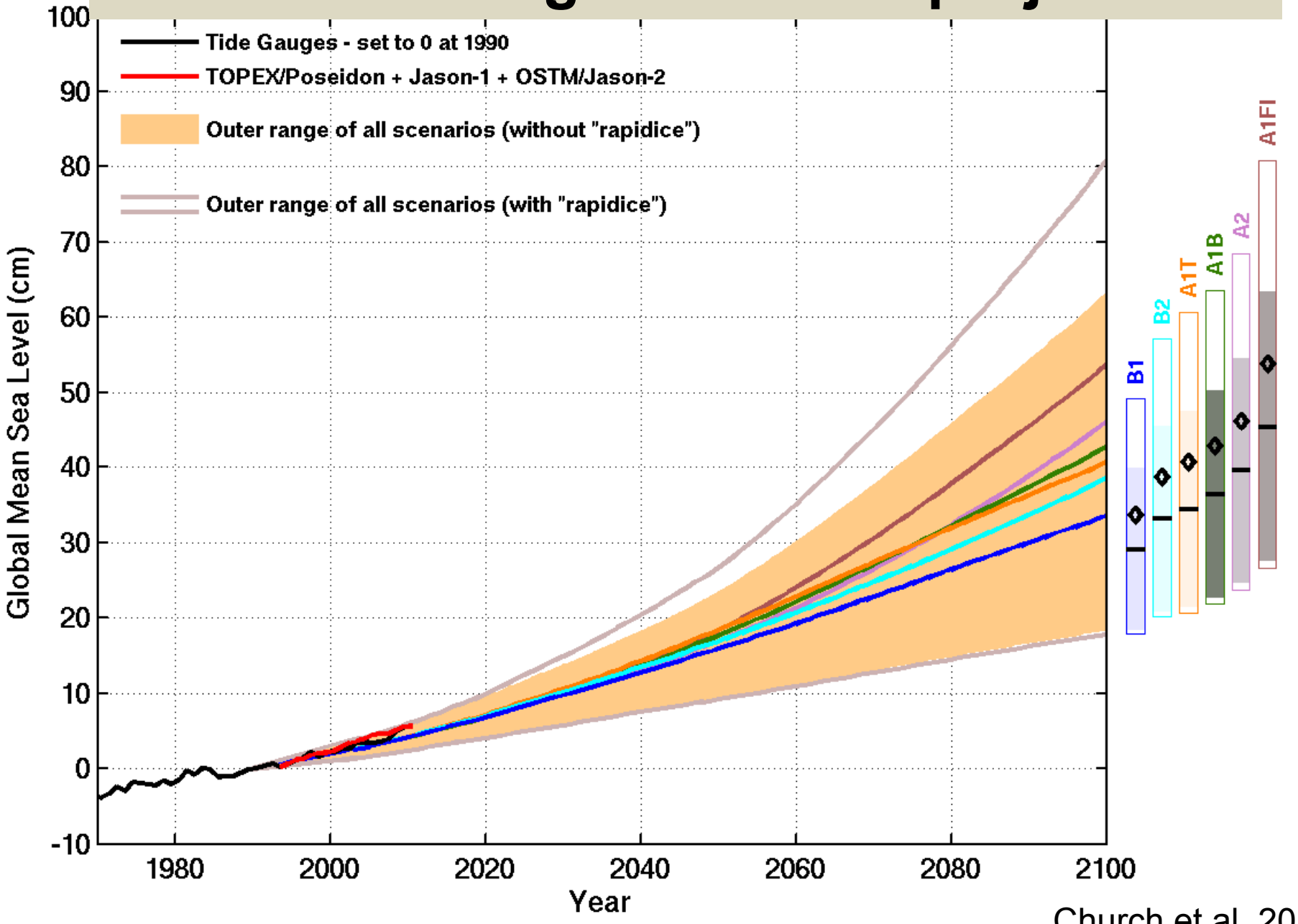
Observed sea level and the contributions are almost equal since the early 1970s.

The observed sea level and the sum of contribution has accelerated.

Opens door for using observations to constrain projections.

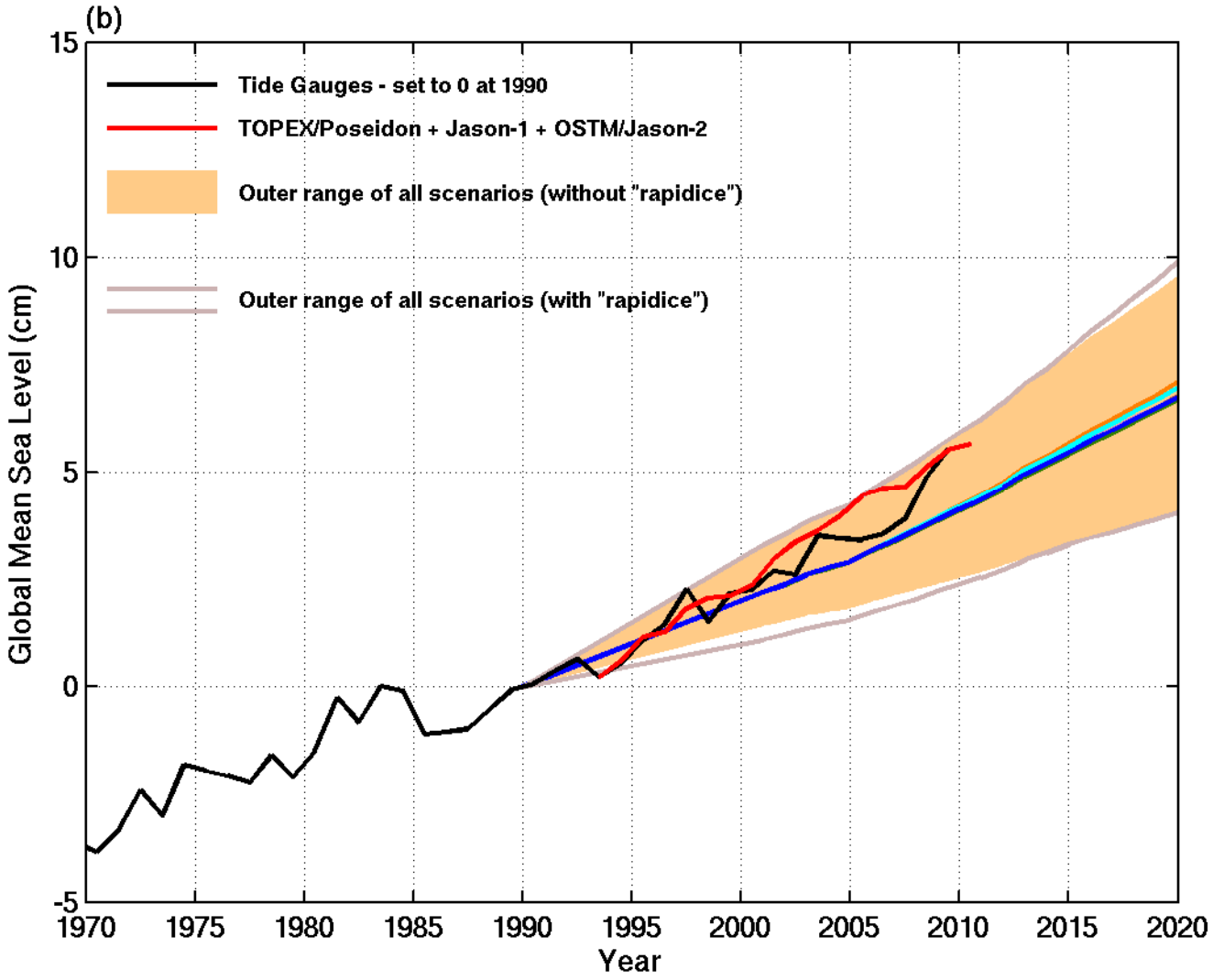
Church *et al.* 2011

Central challenge to narrow projections



Church et al. 2011

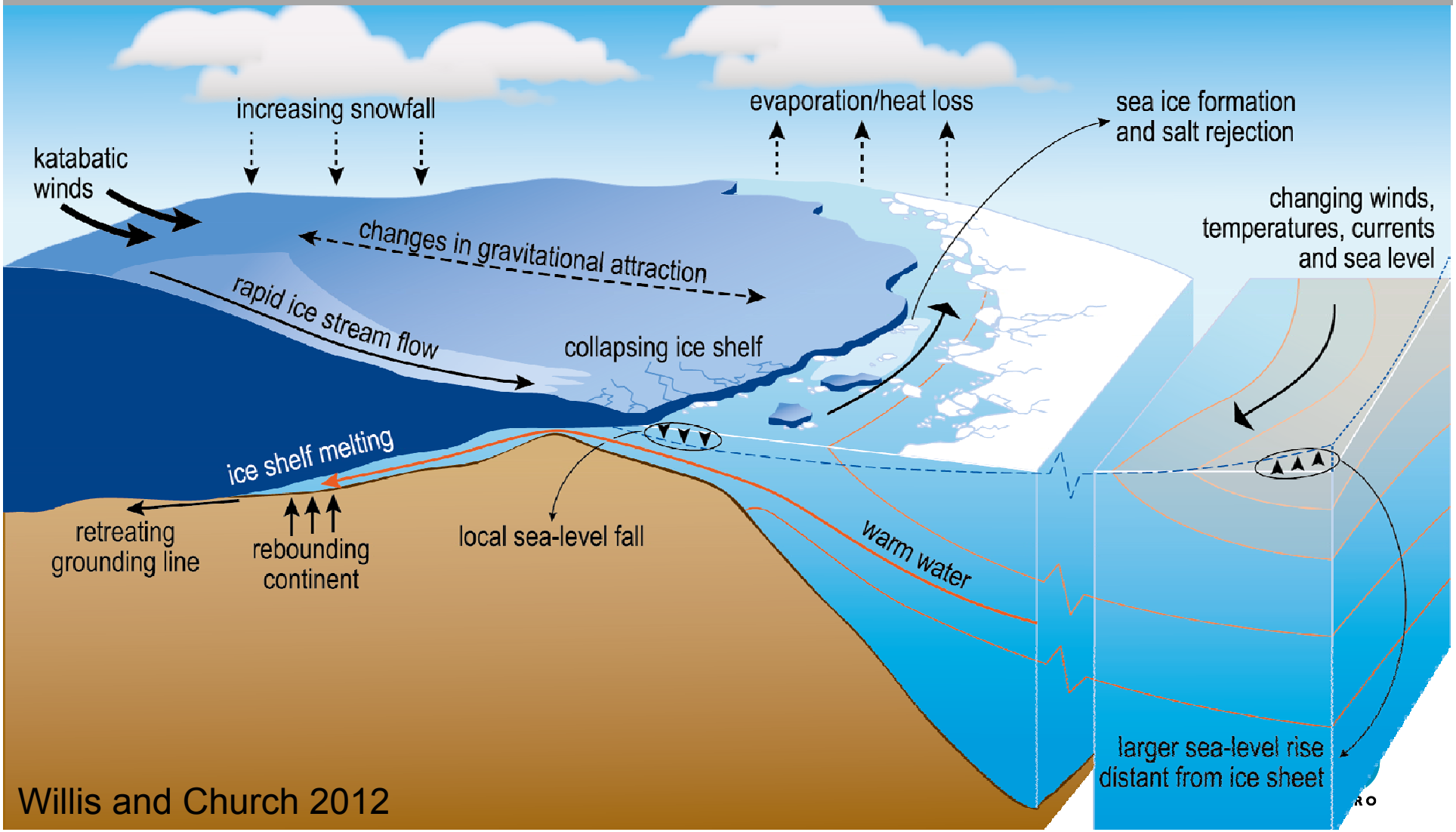
Observed sea level consistent with projections but tracking towards upper end



As in Garnaut update: Based on IPCC 2007 and Church and White 2011

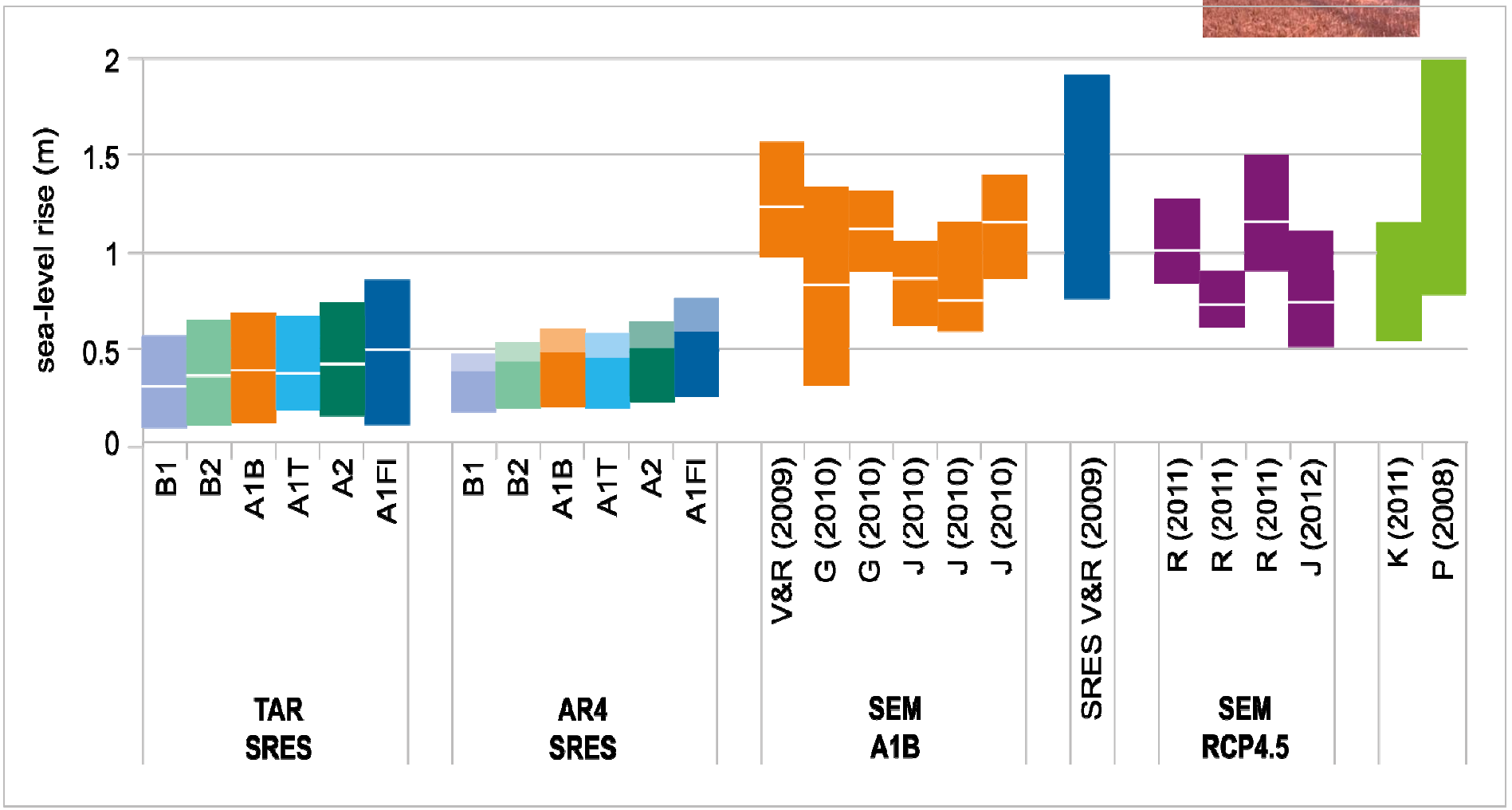
How will the dynamical flow of ice/land evolve?

Is surface mass balance changing?



Willis and Church 2012

Should we have confidence in projections of larger rises from semi-empirical models?

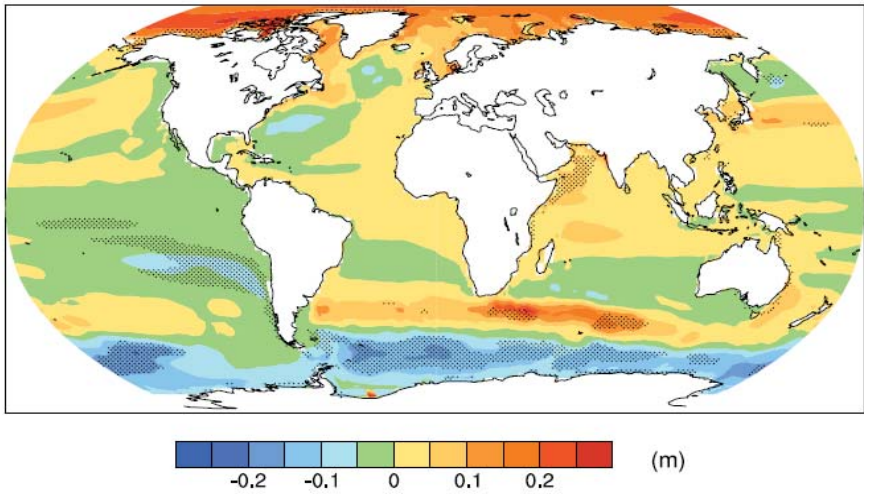


Australian Government
Bureau of Meteorology

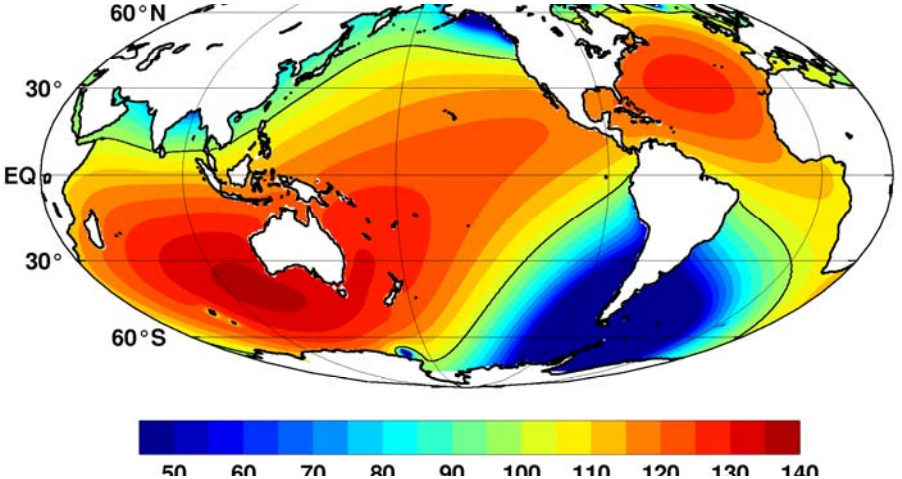
The Centre for Australian Weather and Climate Researc
A partnership between CSIRO and the Bureau of Meteorolc

Willis and Church, 2012

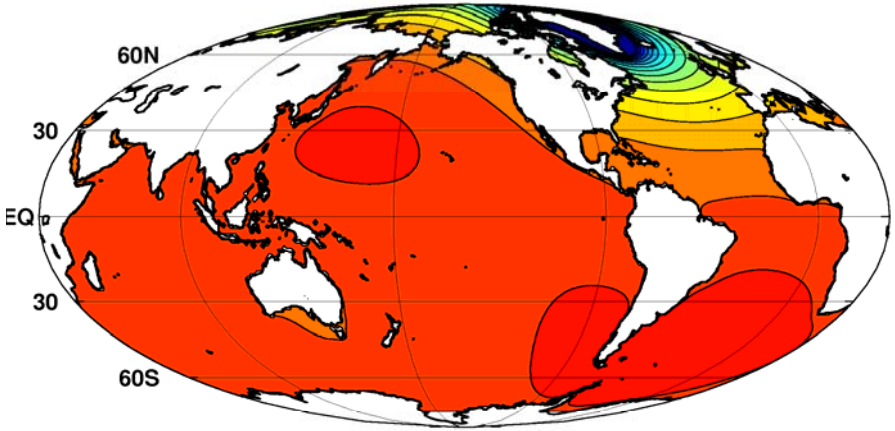
Sea-level rise will not be uniform because of ocean changes and gravitational changes



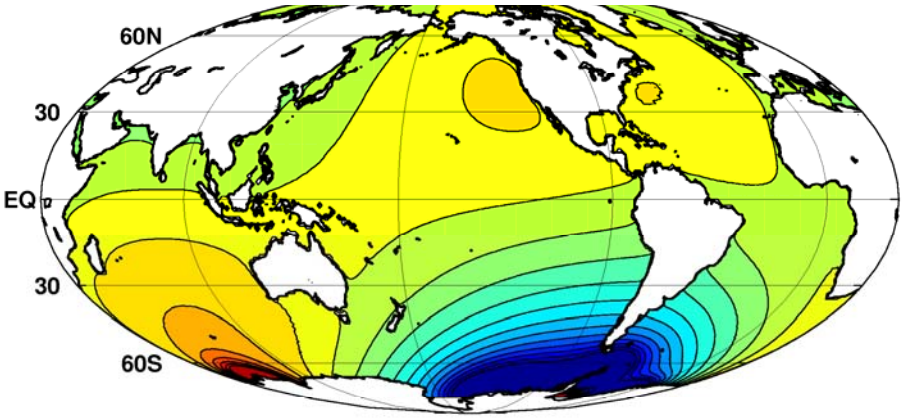
Glacier and ice cap Fingerprint



Greenland Fingerprint

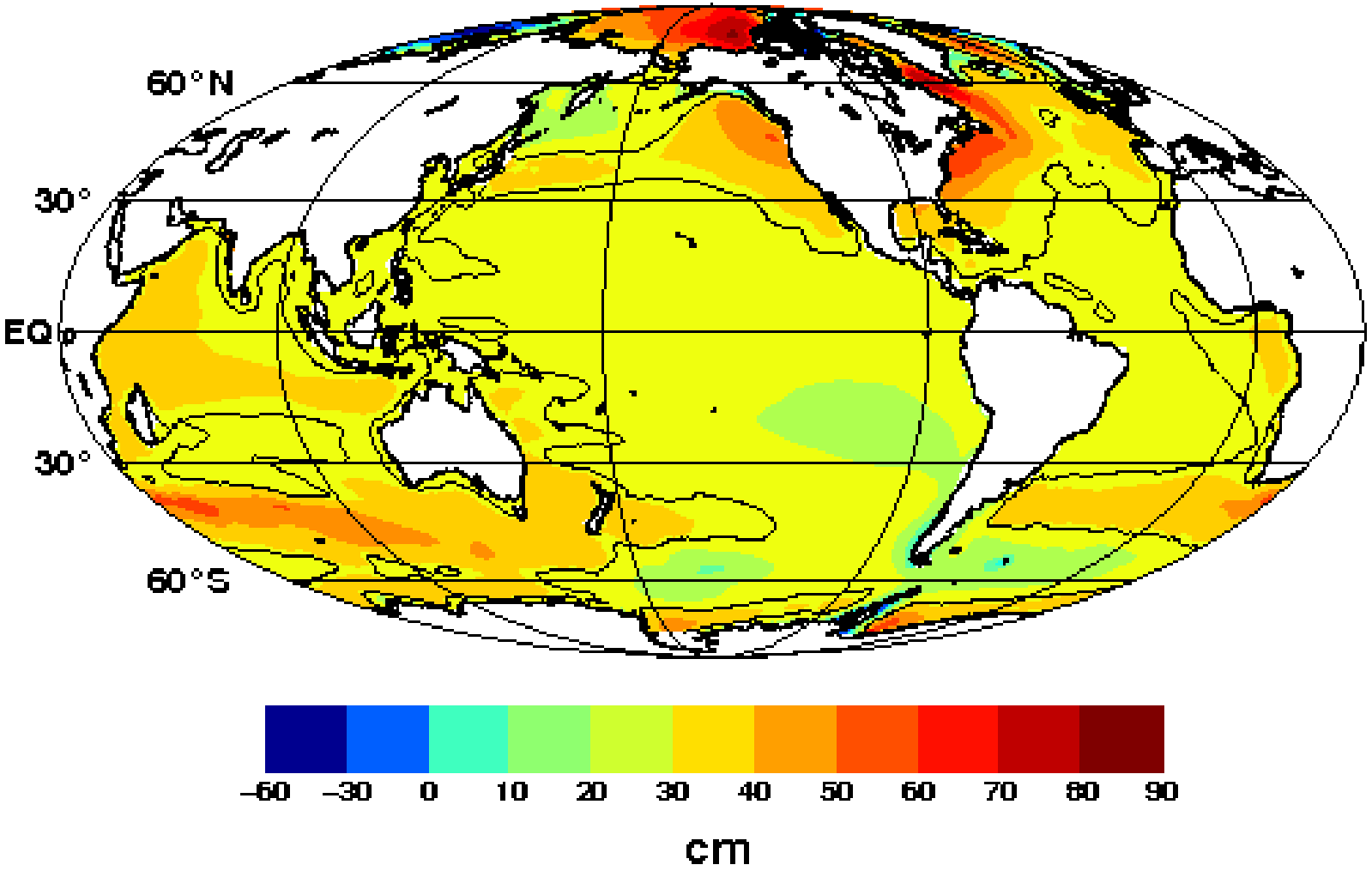


Antarctic Fingerprint



Gomez et al. 2011

Updated regional projections for the A1B Scenario



Church *et al.* 2011

Beyond 2100

How close are we to a commitment to melting of the Greenland Ice Sheet?

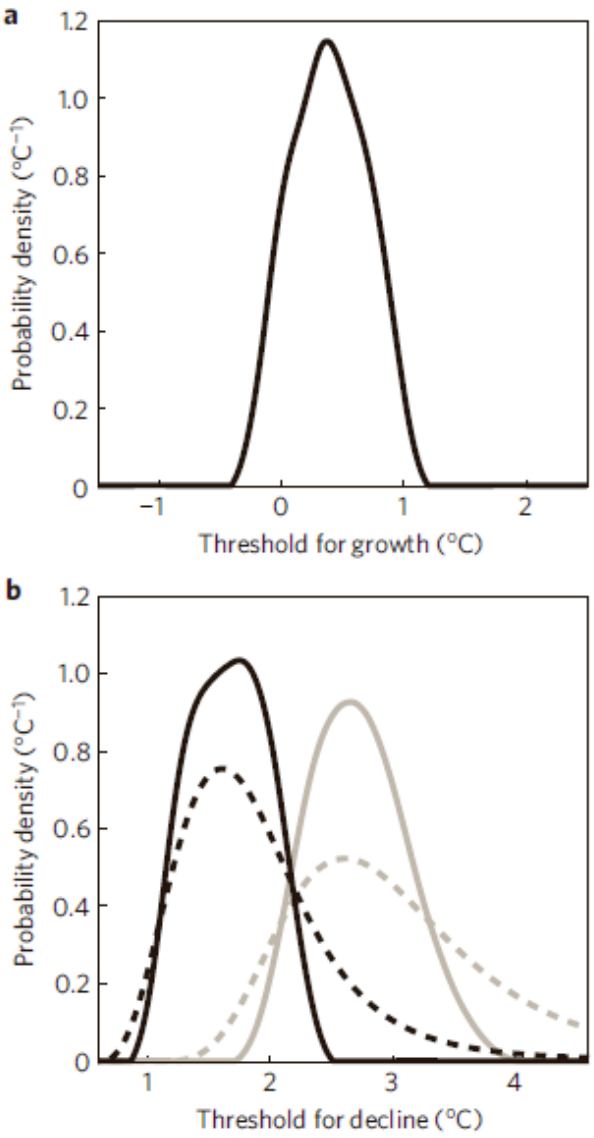
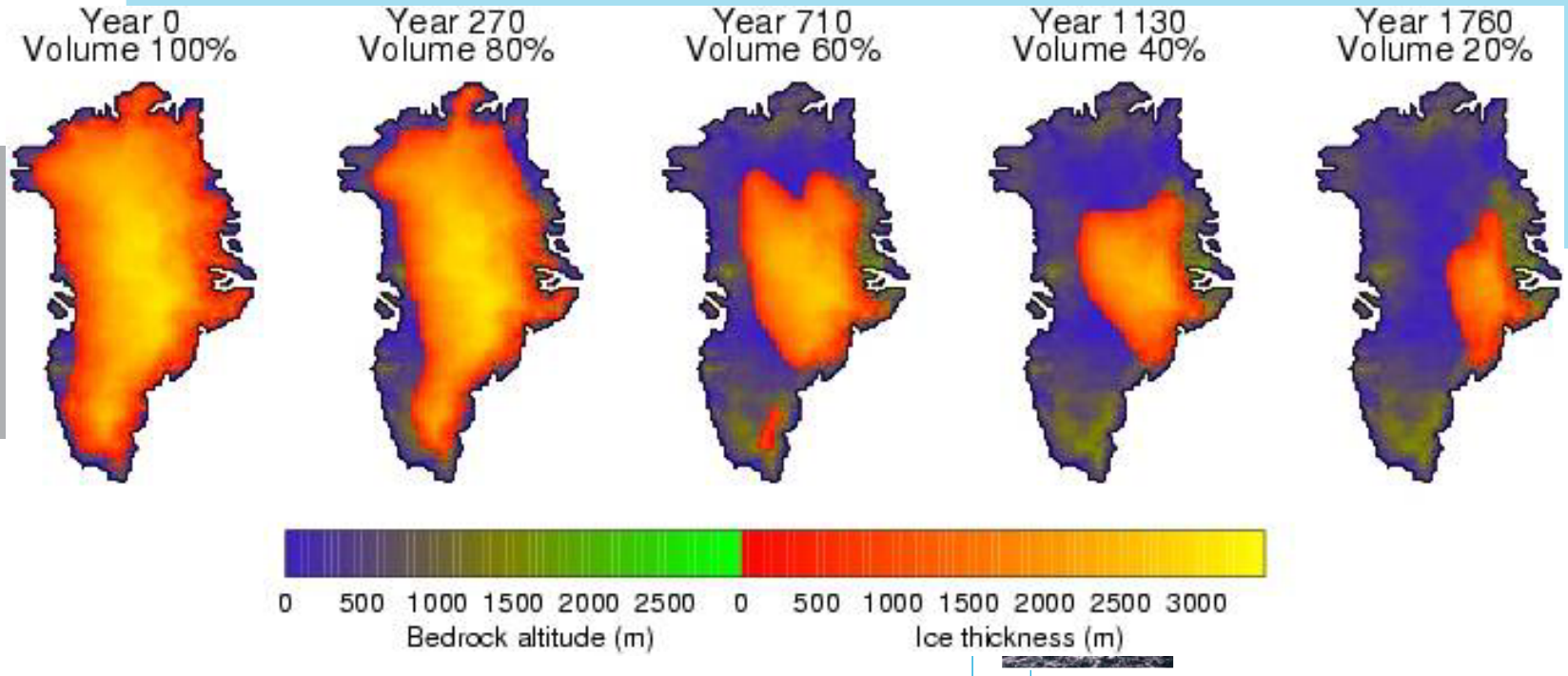


Figure 2 | Threshold estimates. Probability distributions of the regional summer temperature threshold for **a**, growth and **b**, decline of the GIS using the fully coupled climate–ice-sheet model (black solid lines) and the negative SMB criterion (grey solid line). The dashed black and grey lines show the distributions of the gobal mean temperature threshold for decline of the GIS using each method, respectively.

Robinson et al. 2012

Approaching a threshold for Greenland melting

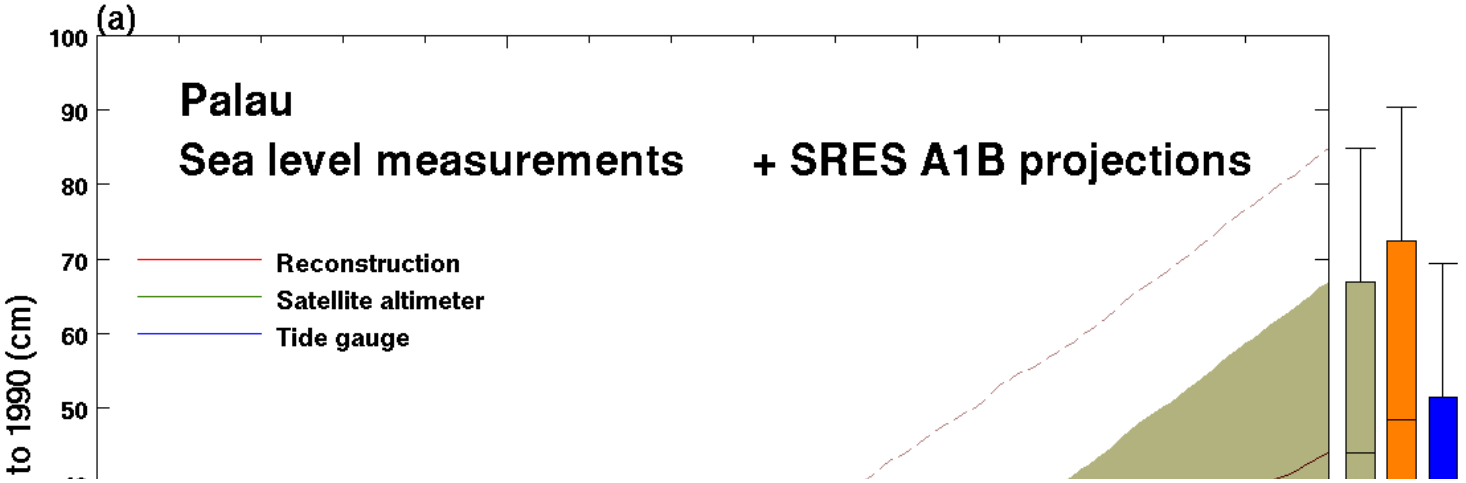
Greenland ice sheet evolution under $4\times CO_2$



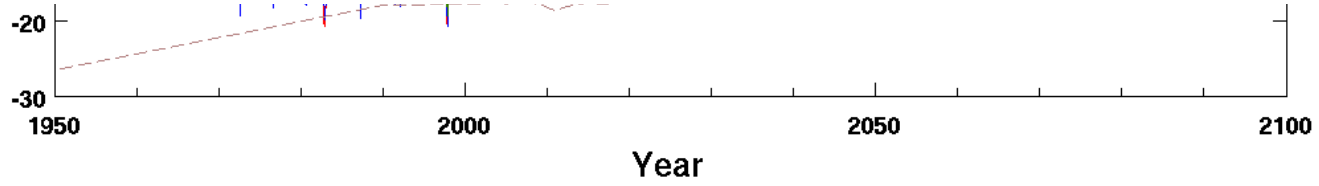
Simulated using the HadCM3 AOGCM coupled to the ice sheet model of Huybrechts and De Wolde (Ridley et al., 2005)

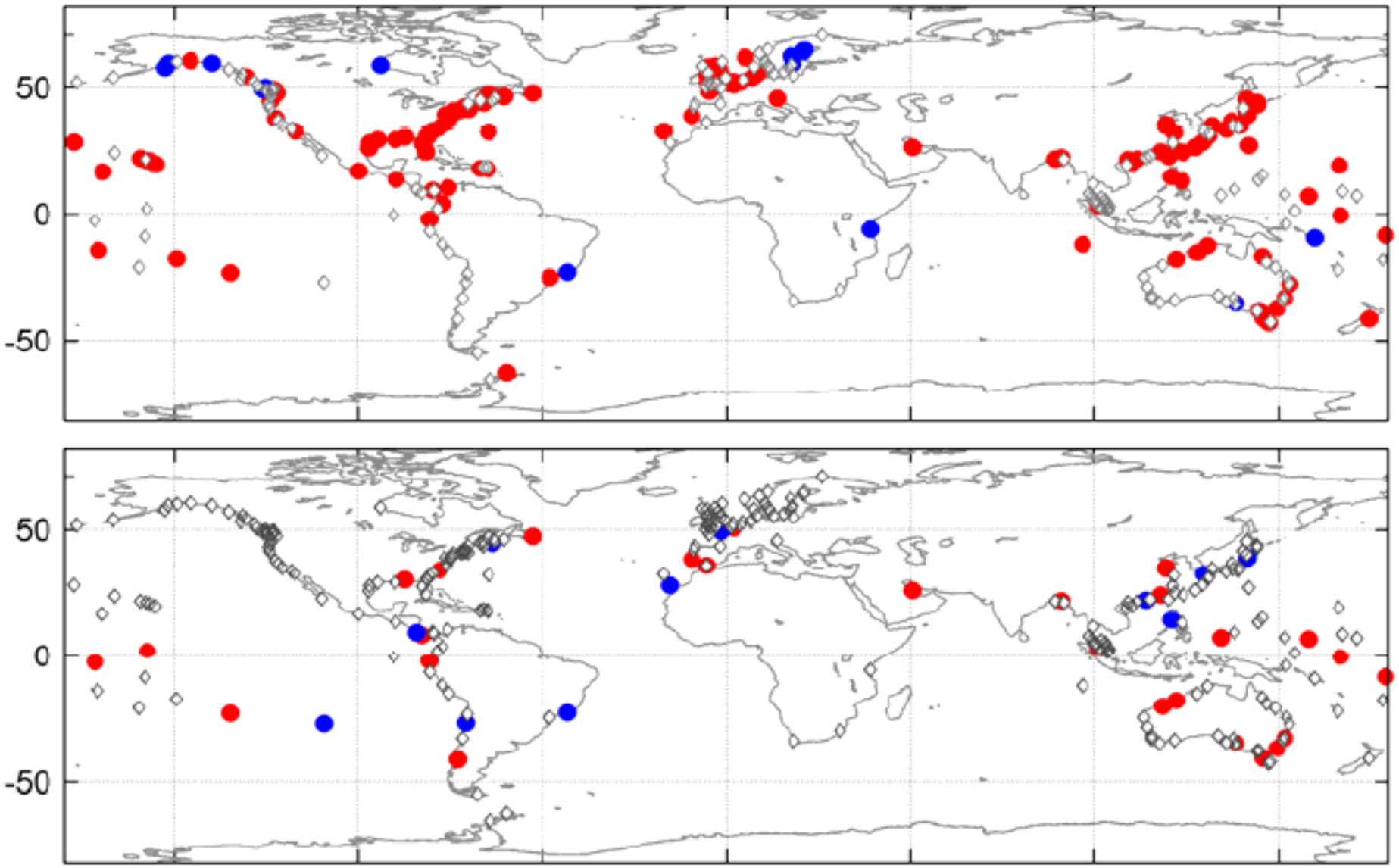
The last interglacial may be a useful analogue for the future: Sea level > 6.6 m (95%) above today.

Need regional distributions of sea-level rise projections



Large scale patterns implies potential for seasonal to interannual sea level predictions – suggestions of significant skill

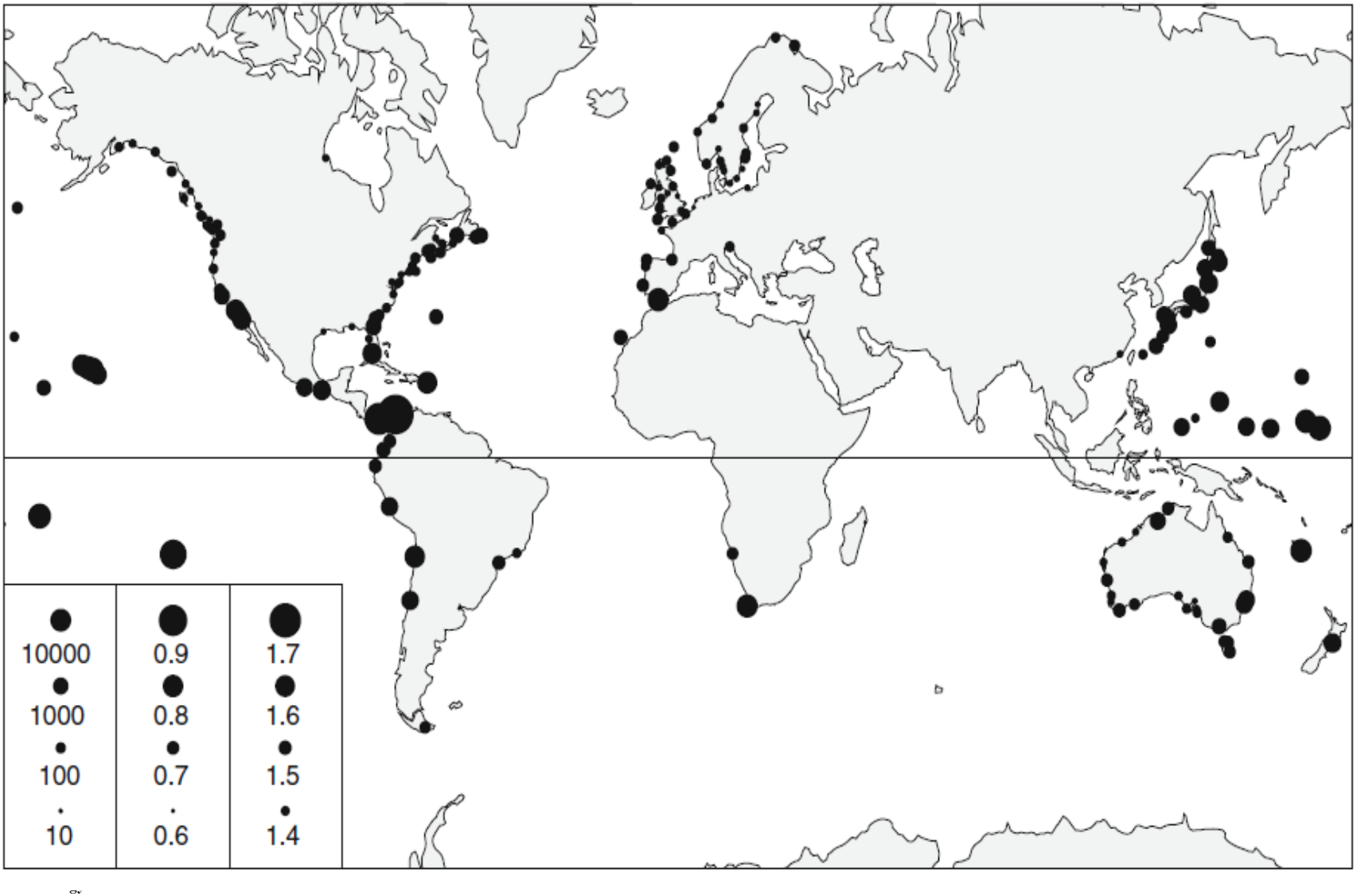




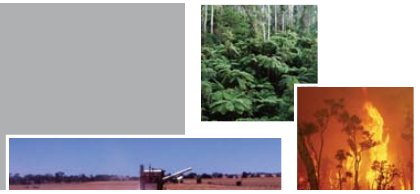
Statistically significant trends in annual 99 percentile observed sea levels and sea levels reduced to their annual medians

Menendez and Woodworth, 2010

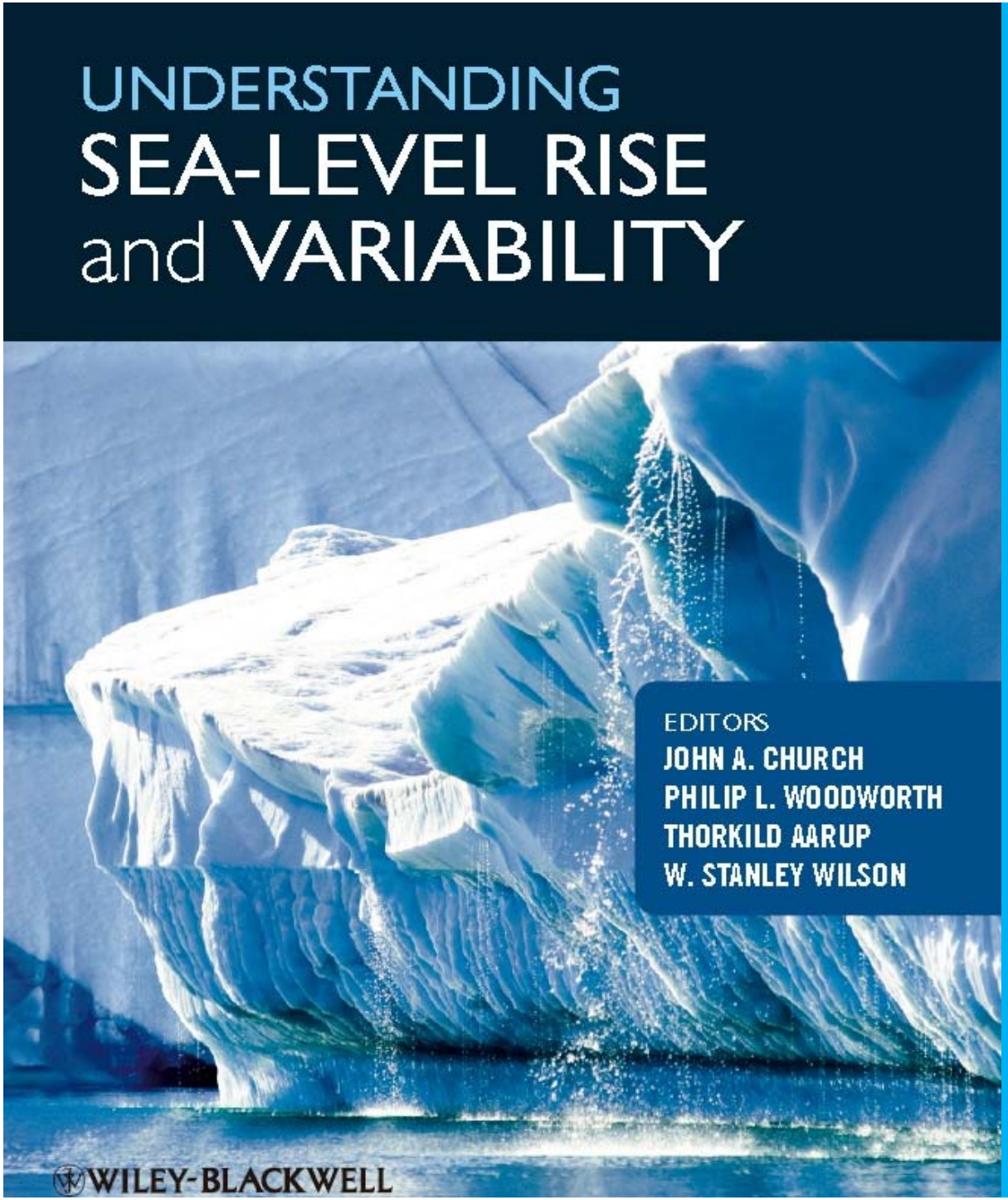
To maintain current flooding risk, need an allowance larger than GMSL rise



Summary



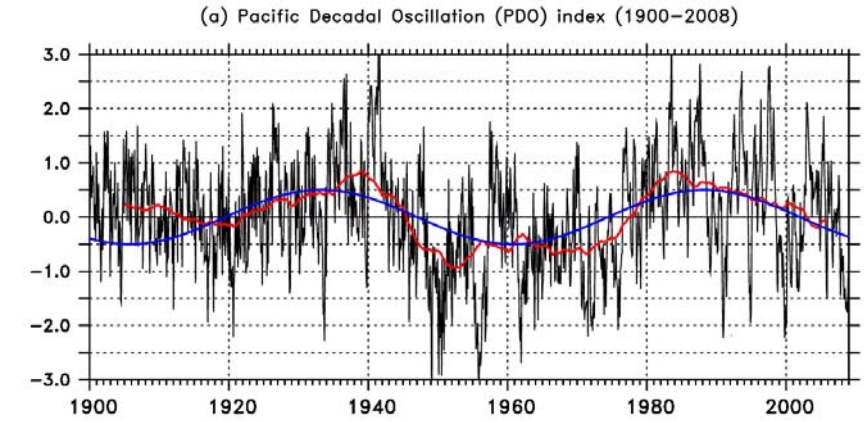
- Sea level was higher in a warmer world and is rising now. The rate of rise has increased.
- Ocean thermal expansion and mass changes (glaciers, ice sheets and terrestrial reservoirs) explain sea-level change.
- Sea level will continue to rise during the 21st century. We will need to adapt (extreme events).
- The amount of adaptation is dependent on future emissions.
- The regional distribution is inadequately understood.
- There are long-term commitments.
- There is potential for a larger rise.
- To minimise costs monitoring and understanding is essential. Need to manage risk.
- Need to strengthen science/government/business/community partnerships.

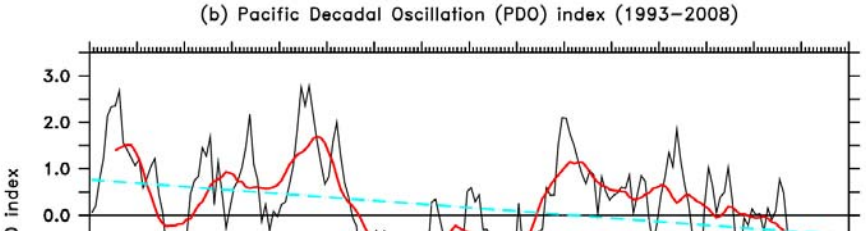


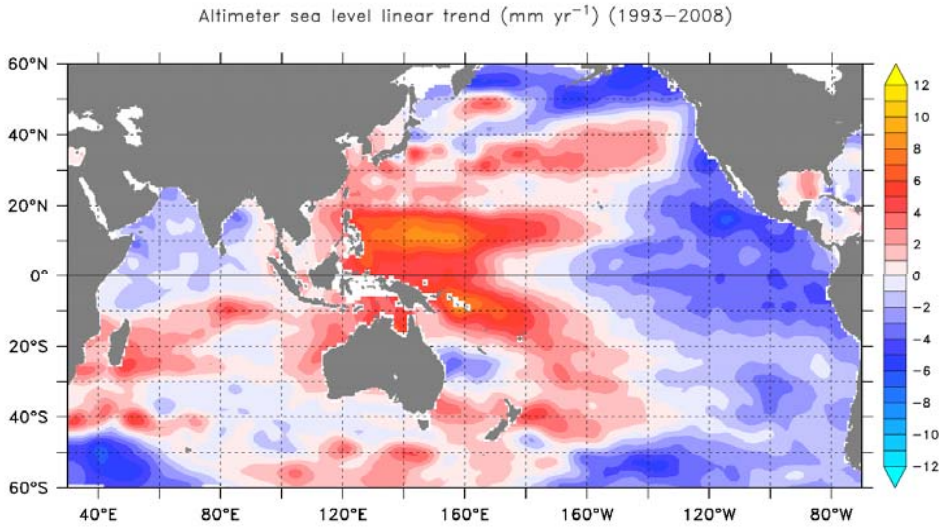
Current status of Understanding, impacts, research recommendations and monitoring requirements

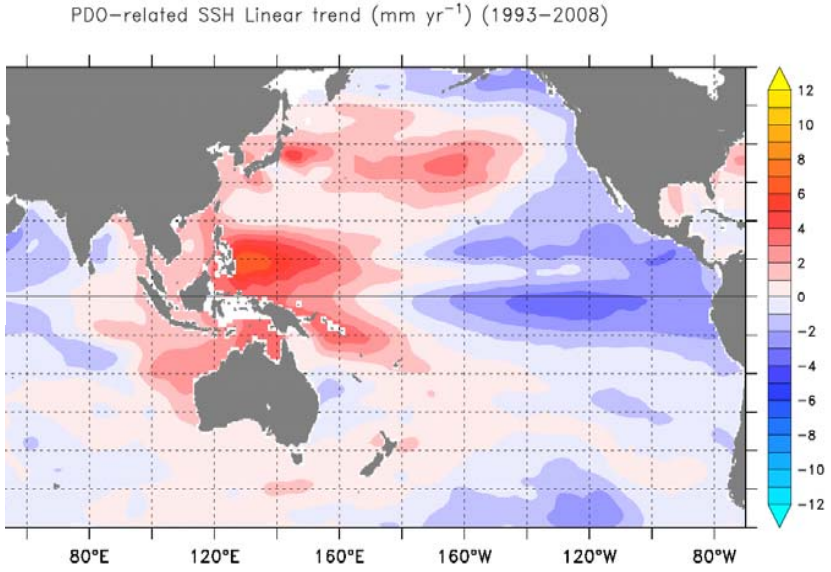
Wiley-Blackwell 2010

Decadal variability is consistent with much of the trend since 1993

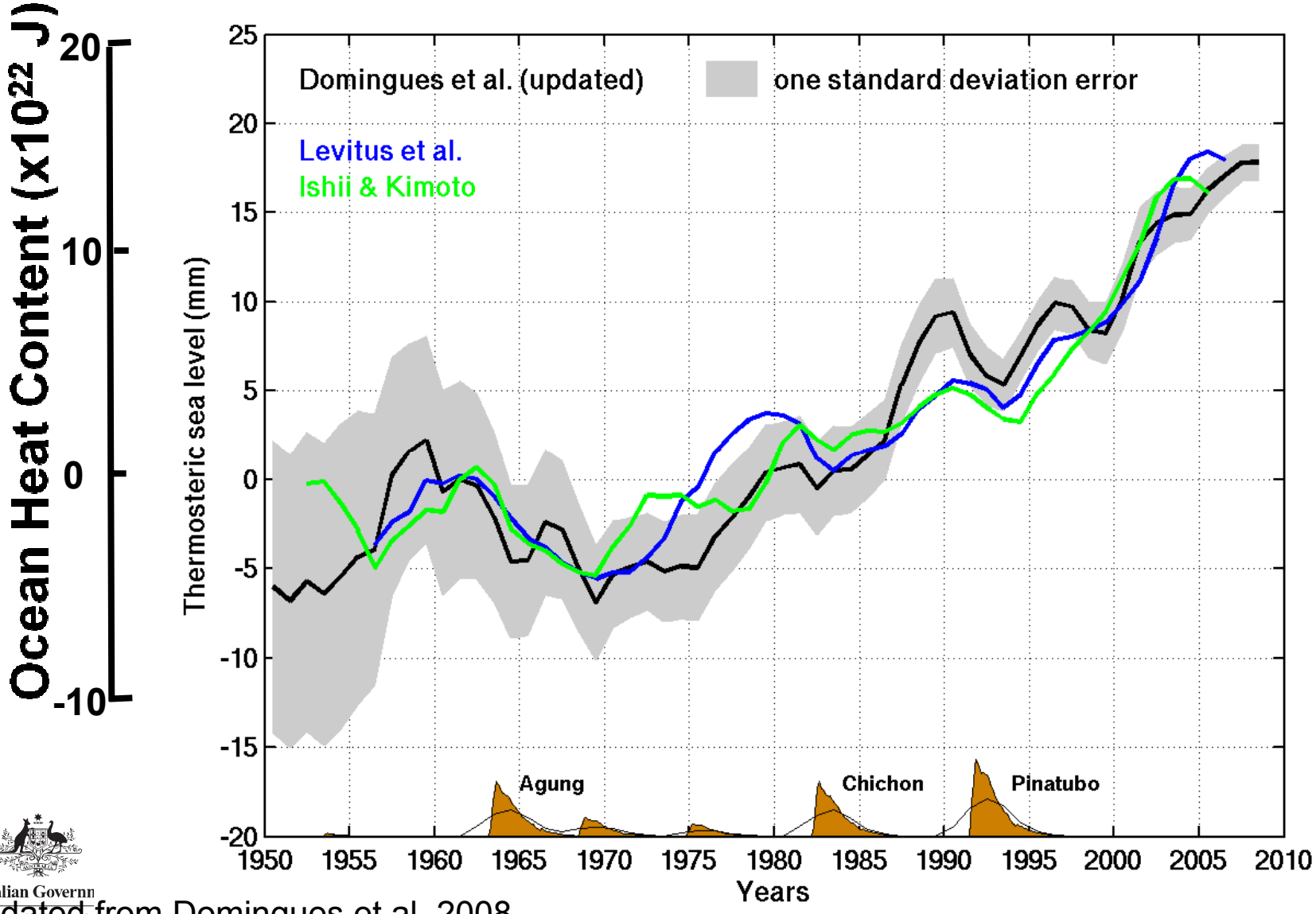








The Ocean is continuing to warm and expand



Australian Government
Bureau of Meteorology

Updated from Domingues et al. 2008