Projecting sea-level change in the Northeast U.S.

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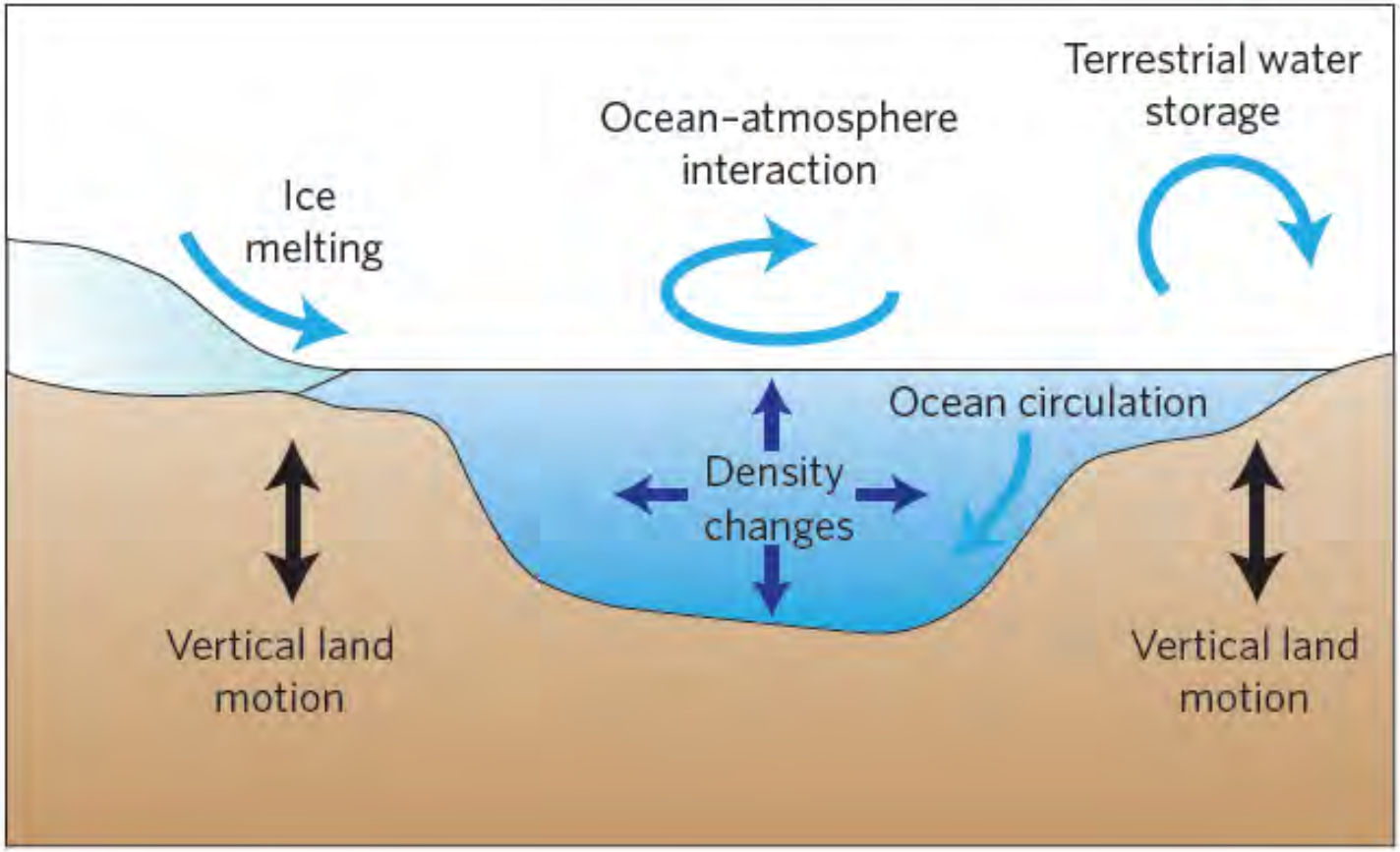
Northeast Coastal Zone Manager's Regional Virtual Meeting

November 18, 2009

Outline

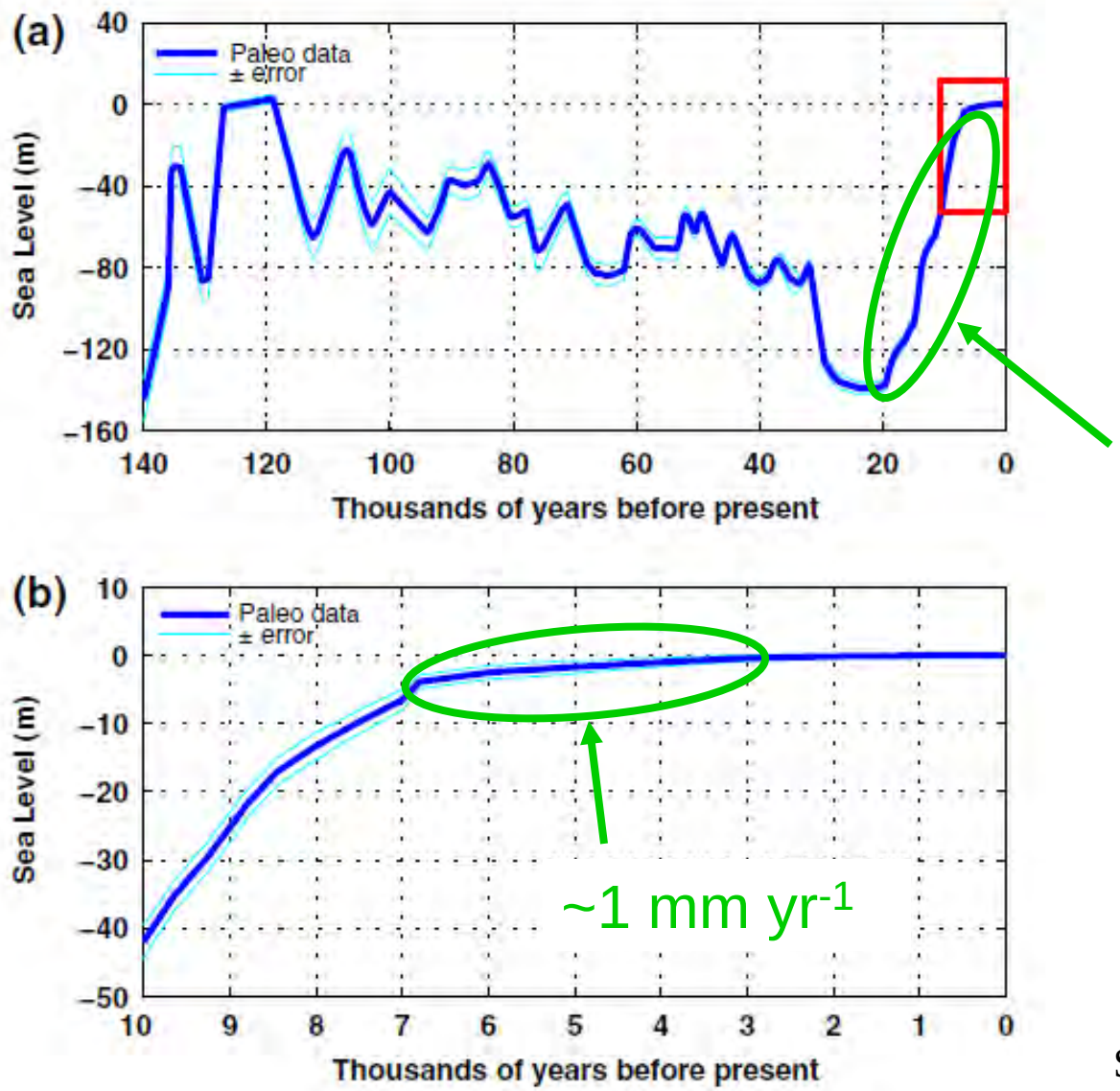
- Change in global-mean sea level (GMSL)
- Regional redistribution of GMSL
- *Relative* sea-level change from land movement
- Changes in the temporal variability of sea level

Influences on sea level



Source: Milne et al. (2009)

Global changes—geological past



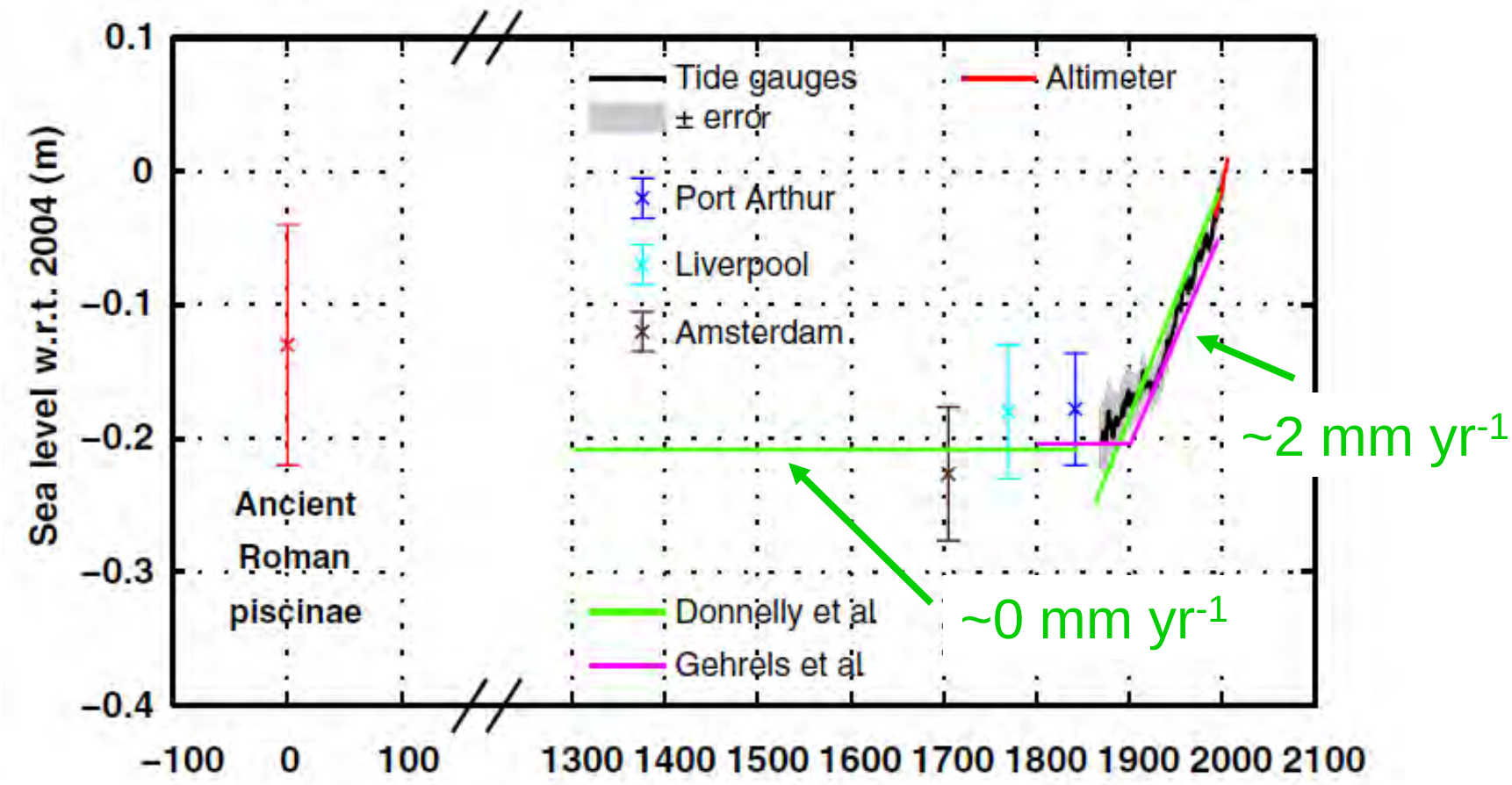
Changes in sea-level due to changes in ice sheet volume

~10 mm yr^{-1}

Rate of sea-level rise decreased over past 10,000 years

Source: Church et al. (2008)

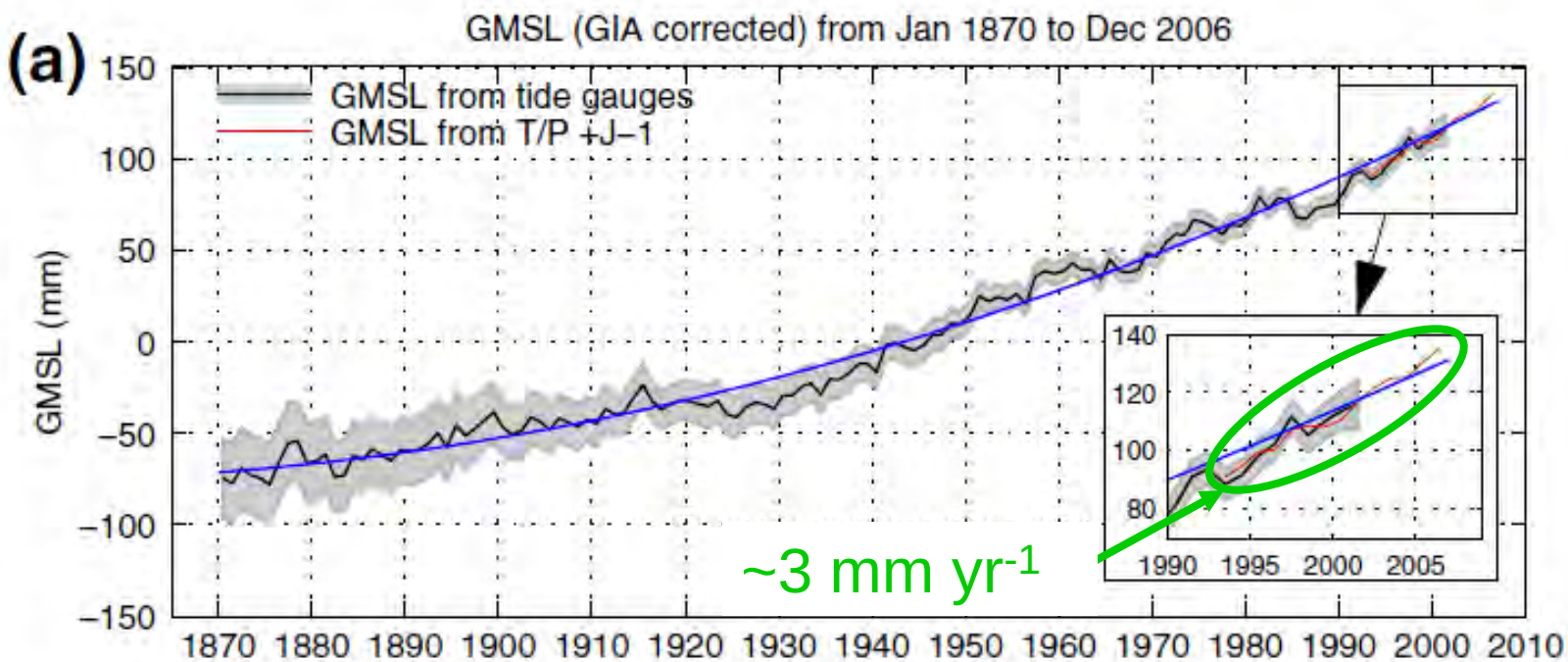
Global changes—last millenium



The rate of sea-level rise abruptly increased about a century ago

Source: Church et al. (2008)

Global changes—last century



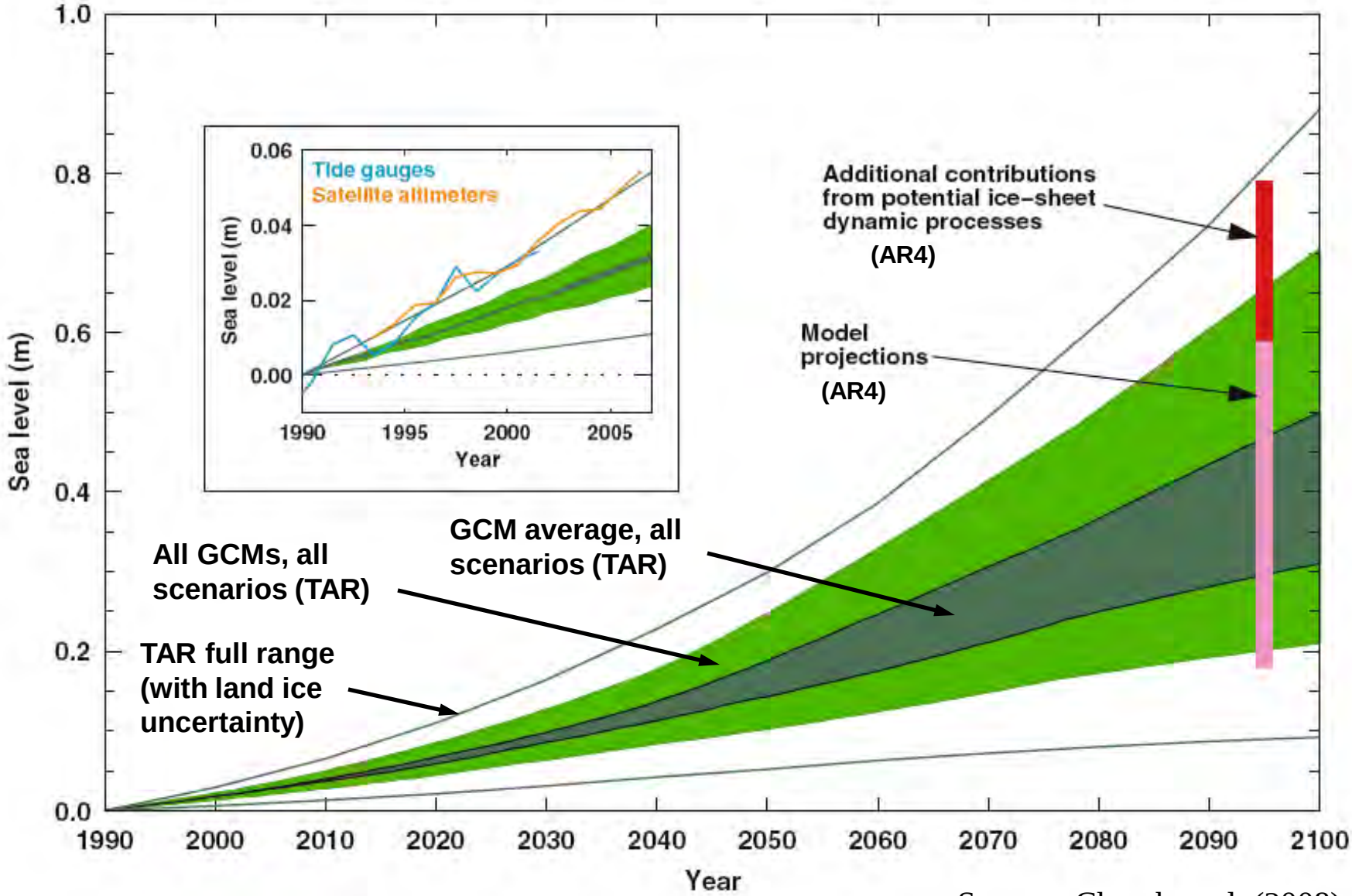
The rate of global mean sea level (GMSL) rise is variable, but overall has increased over the past 140 years. Most recent 20-year trends are ~3 mm yr^{-1}. Closing the sea-level budget is an active area of research.

Source: Church et al. (2008)

Global changes—future

- Global Climate Models, in principle, can be used to project changes in global-mean sea level for a given greenhouse gas emissions scenario.
- Using GCMs, the Intergovernmental Panel on Climate Change (IPCC) Third and Fourth Assessment Reports (TAR and AR4) projected global sea-level increases of 9-88 and 18-79 cm, respectively, over the 21st century (Church et al. 2001, Meehl et al. 2007).
- But representation of ice sheets is poor in GCMs.
- Specifically, there is concern that ice sheet stability has been overestimated in the IPCC AR4. Semi-empirical approaches, tuned to historical observations, give much higher projections, 50-140 cm (Rahmstorf 2007).

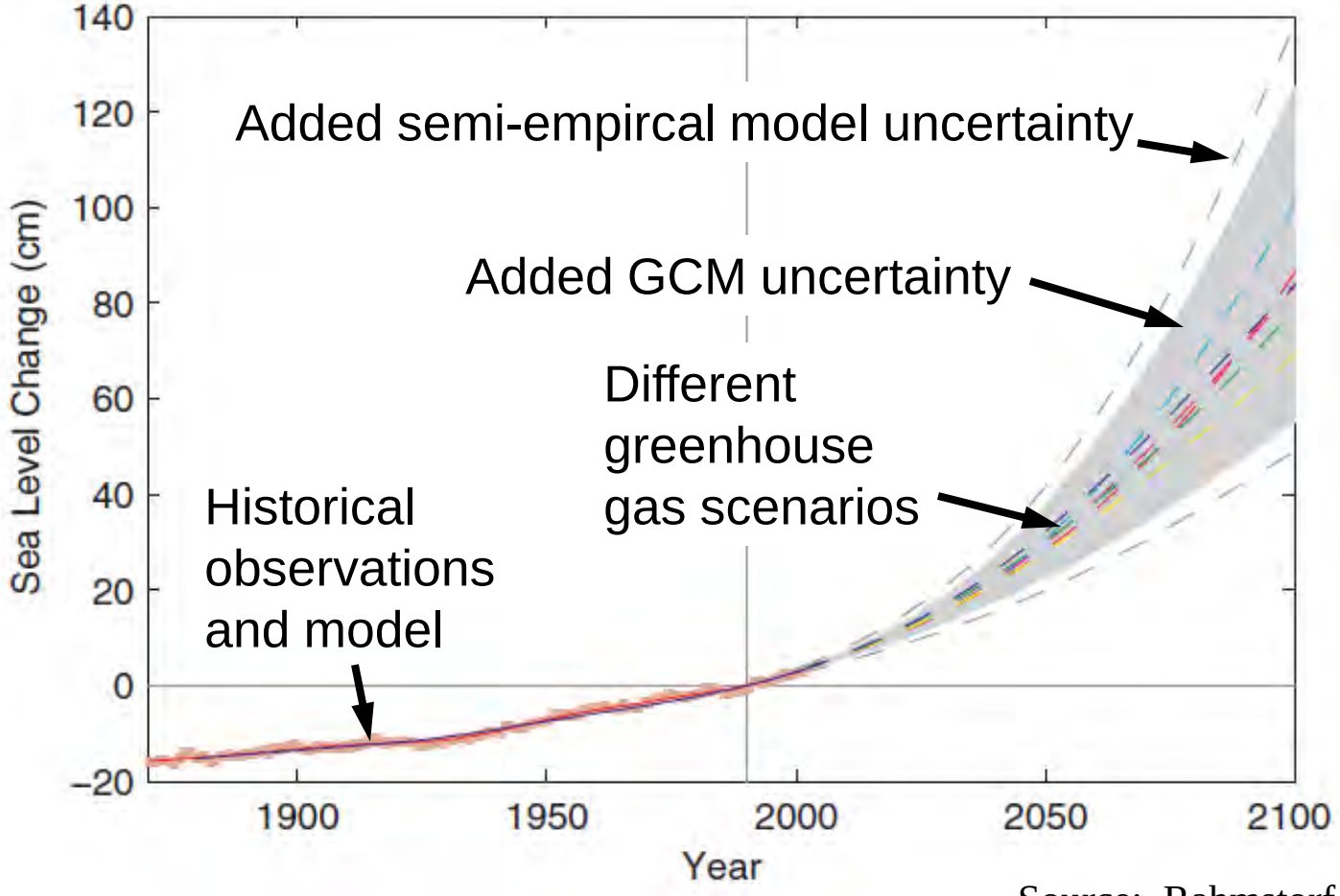
Global changes—future



Source: Church et al. (2008)

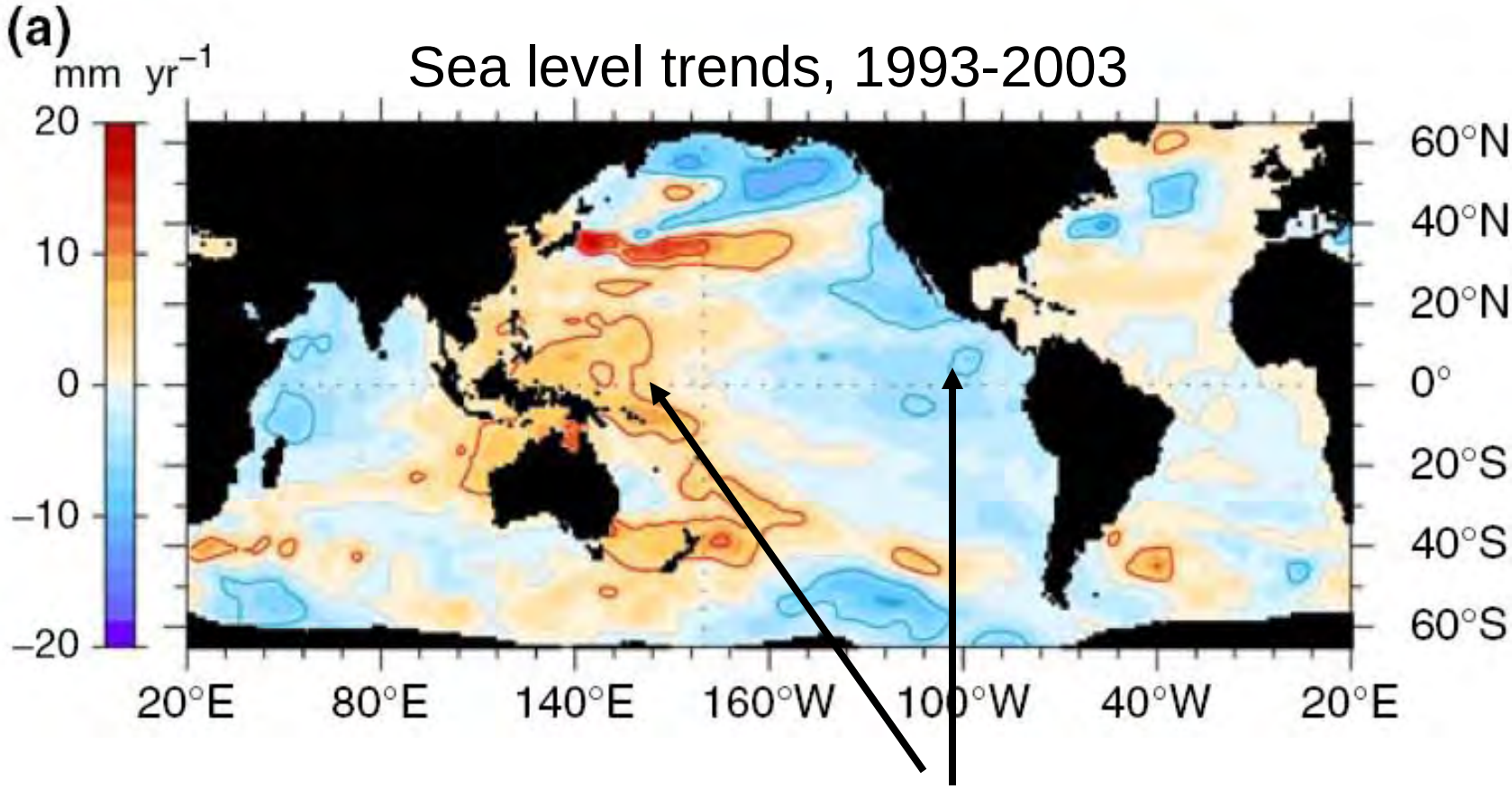
Global changes—future

Semi-empirical model of global-mean sea level based on global-mean surface air temperature



Source: Rahmstorf (2007)

Regional changes—present



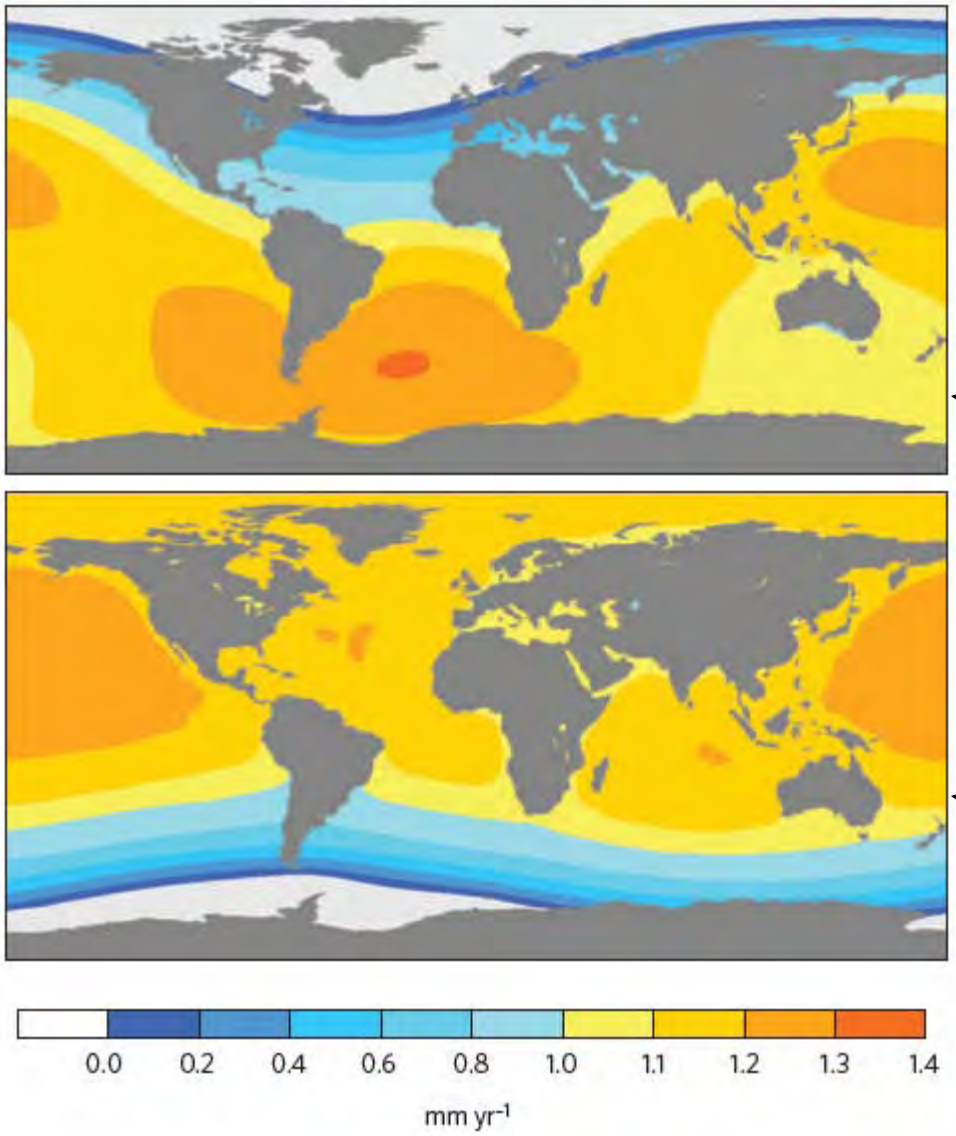
Signal of El Niño to La Niña transition

Source: Church et al. (2008)

Regional changes—future

- “One of the few statements that can be made with certainty is that future sea-level change will not be the same everywhere” (Milne et al. 2009)
- Regionality in sea-level rise is due to changes in gravity, ocean currents, and ocean density

Future regionality due to gravity changes



Sea-level change due to 1-mm yr^{-1} sea-level rise equivalent resulting from melting of:

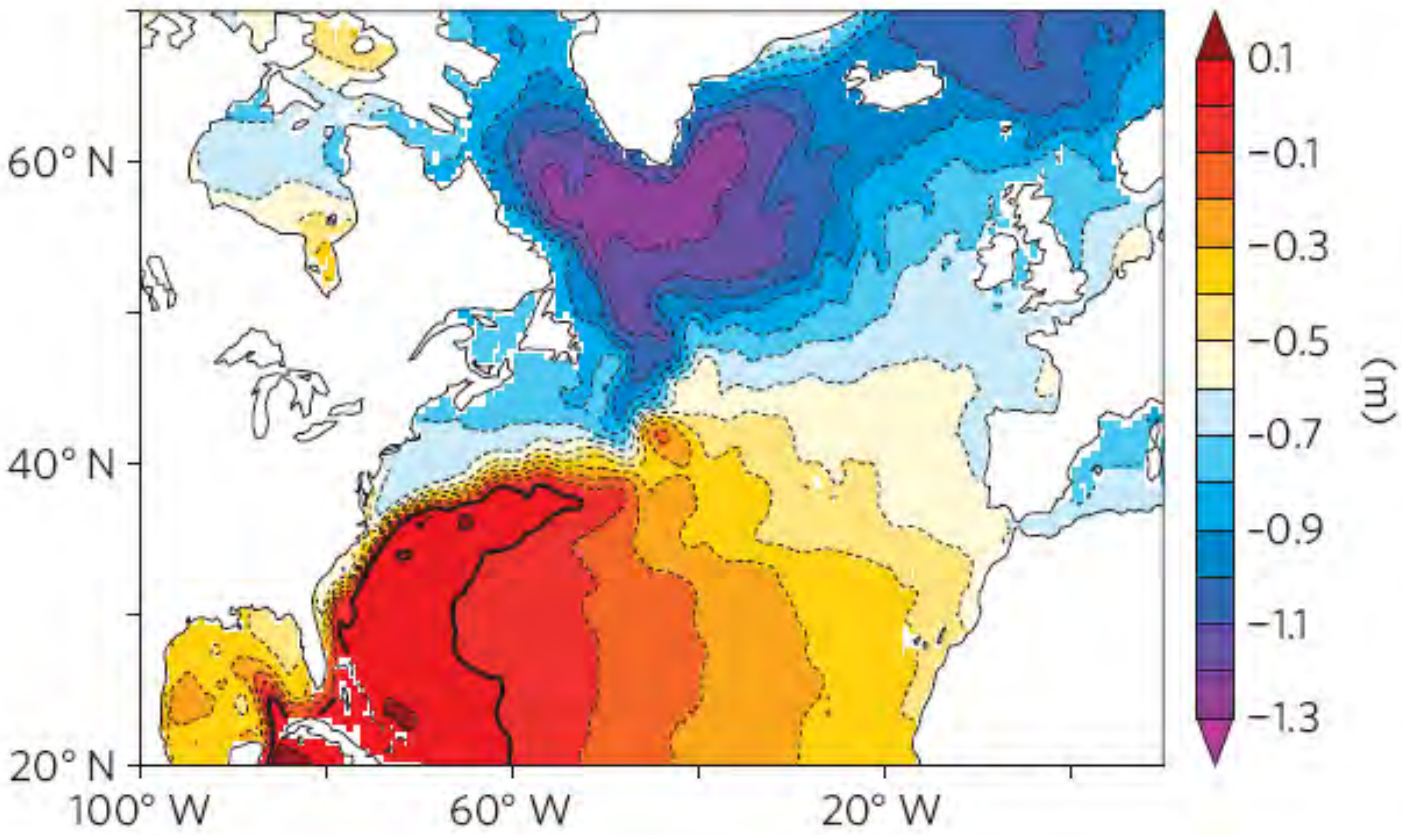
the Greenland Ice Sheet

the W. Antarctic Ice Sheet

Source: Milne et al. (2009)

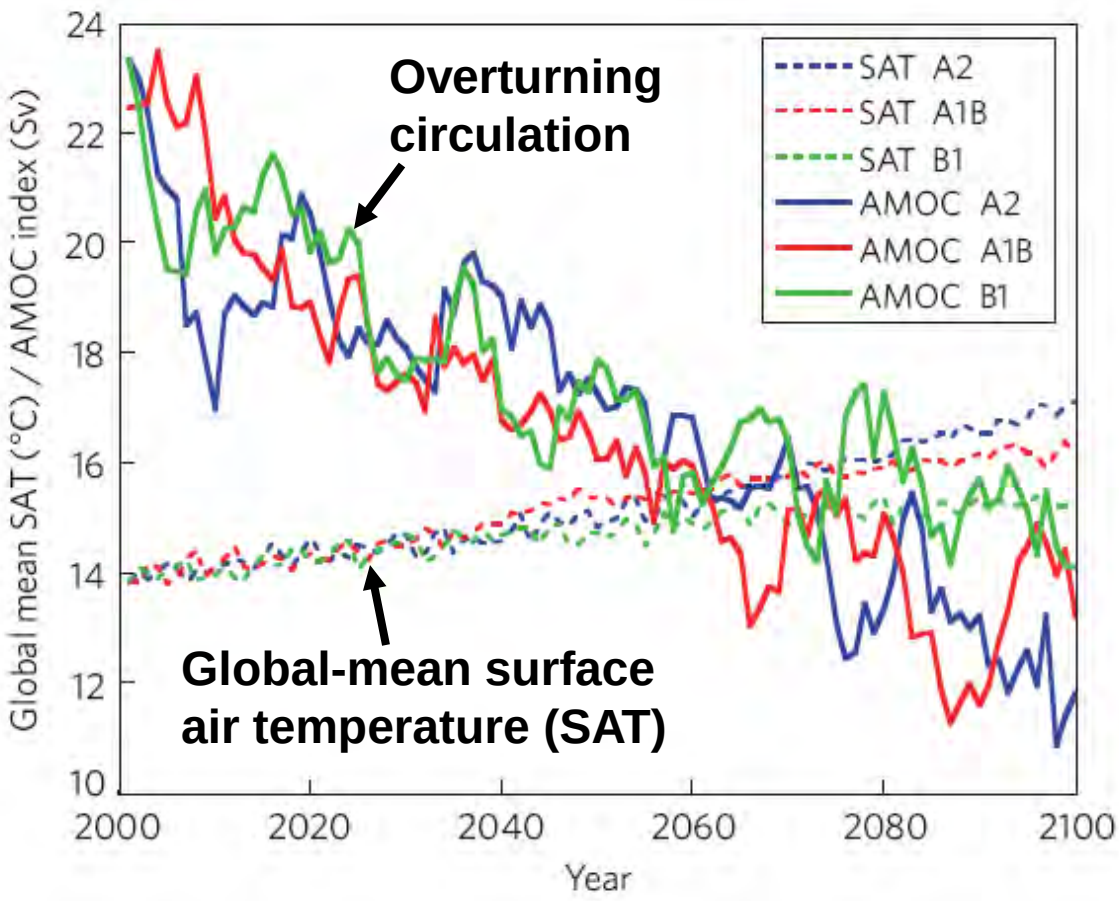
Regional sea-level variation due to ocean currents

1992-2002 average of dynamic sea level



Source: Yin et al. (2009)

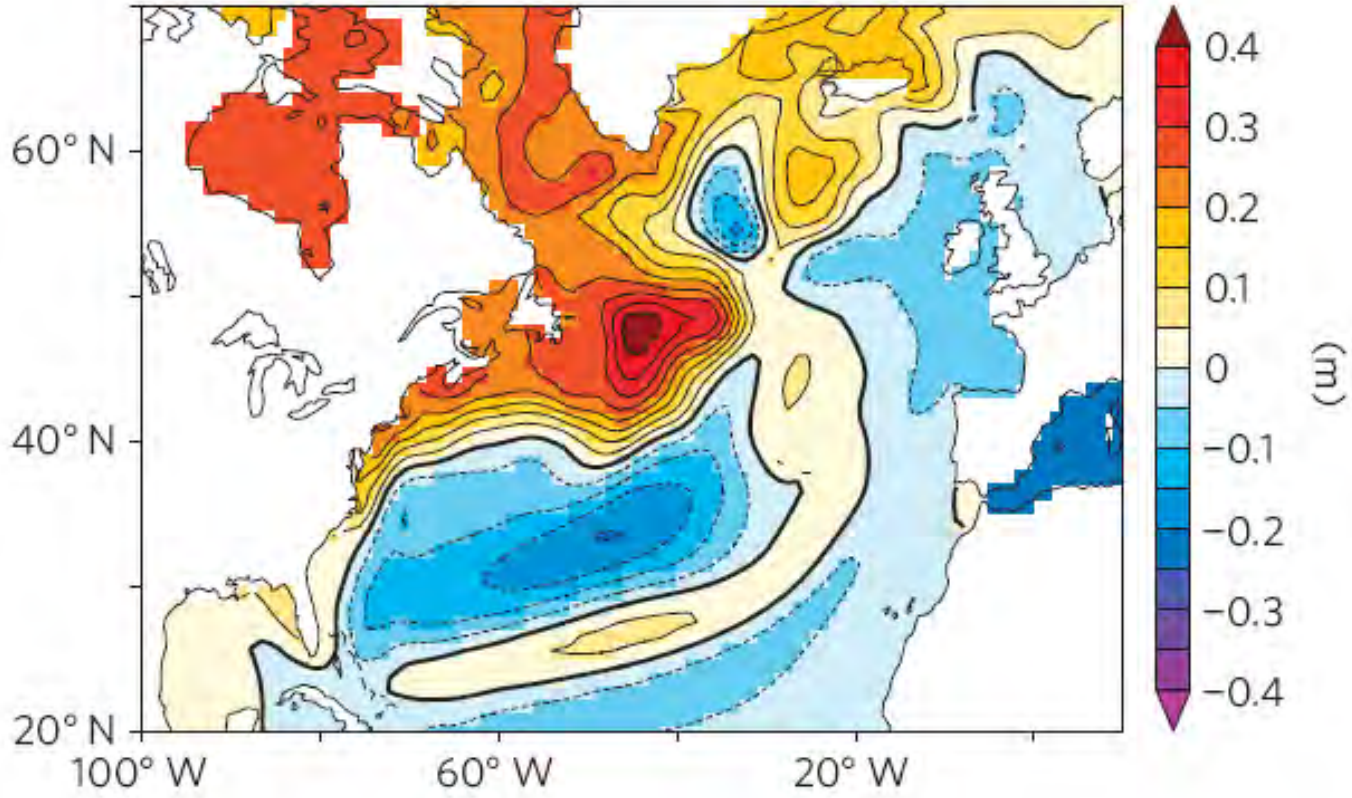
Projected changes in North Atlantic Meridional Overturning Circulation (AMOC)



Source: Yin et al. (2009)

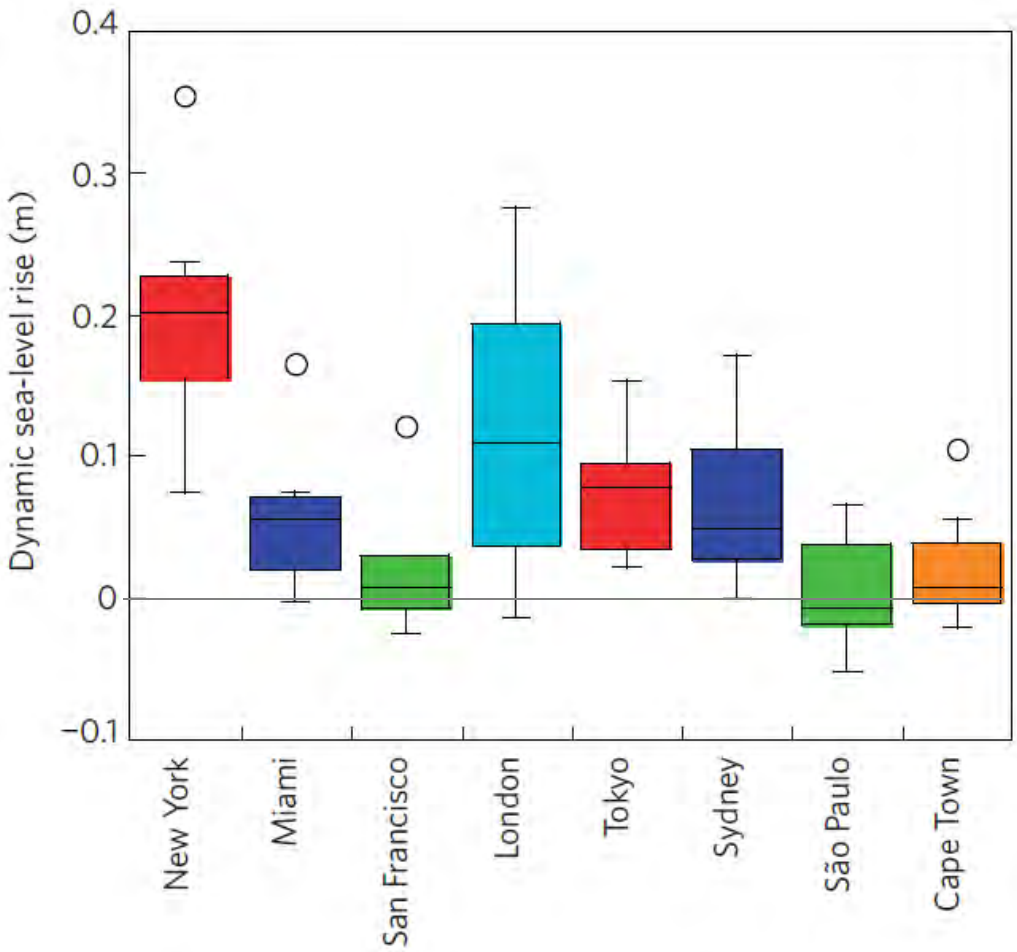
Future regionality due to changing ocean currents

Projected 21st century change in dynamic sea level from the GFDL CM2.1 model (A2 scenario)



Source: Yin et al. (2009)

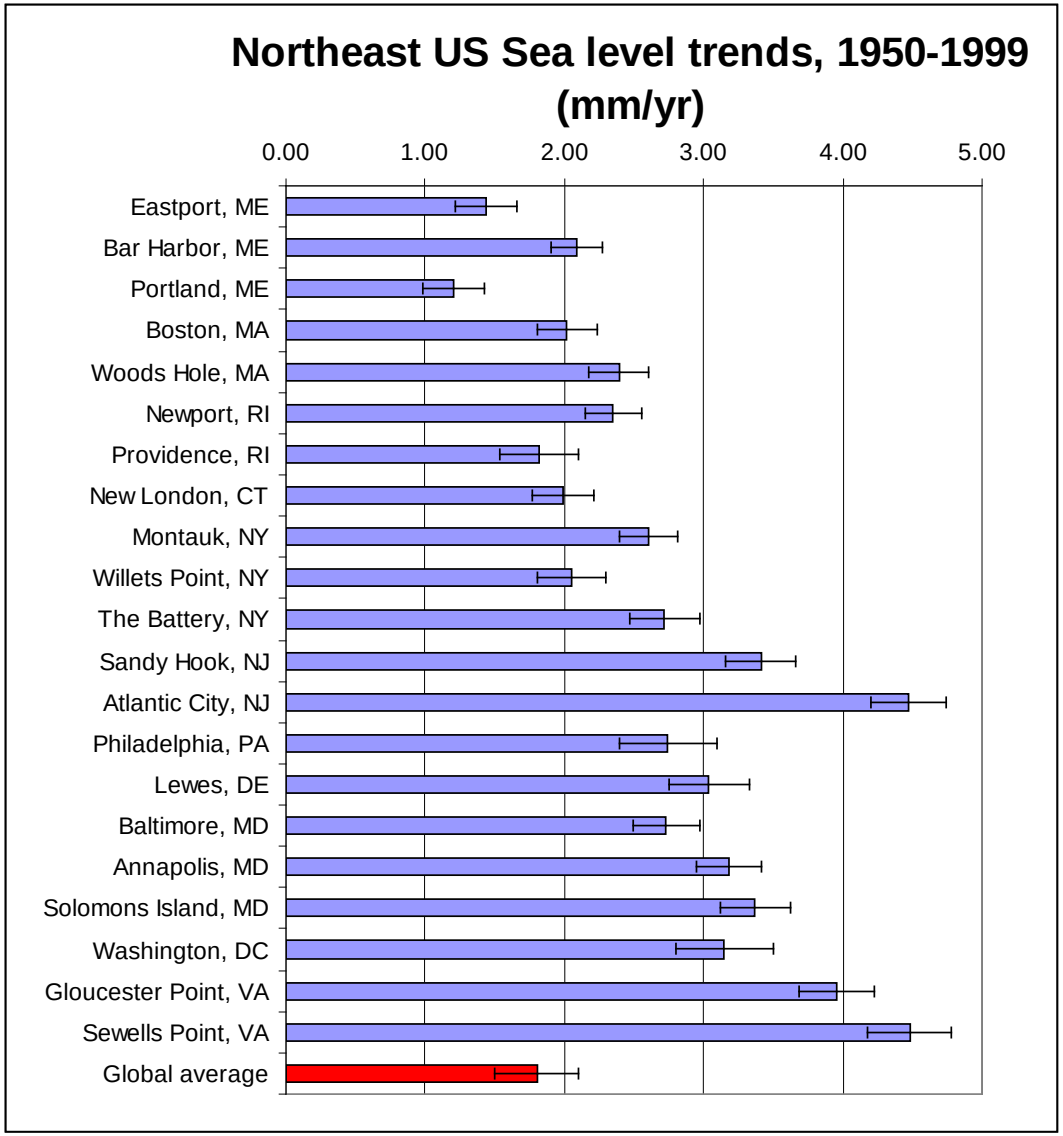
Future regionality due to changing ocean currents



Dynamic sea level changes over 21st Century from 10 AR4 models under the A1B scenario.

Source: Yin et al. (2009)

Regional changes—Northeast U.S.



In the Northeast U.S., sea level is rising much faster than the global average, most likely due to local land subsidence.

Inferred subsidence rates are -0.6 to 2.7 mm yr^{-1}.

Over the 21st Century, this is an additional sea-level rise of -6 to 27 cm.

Sources: Zervas (2001), Church et al. (2004)

Changes in temporal variability

- Storminess changes
- Tidal range changes

Storminess change

- Extreme high sea levels have increased, but no more than expected from increase in mean sea level (Church et al. 2008).
- Uncertainty is large in projections of tropical cyclone changes.
- Extratropical cyclones are expected to become less frequent but more intense, though regional distribution of changes is poorly known (Lambert and Fyfe, 2006).

Tidal range change

- Tides: 15-20% range increase at Baltimore for 1-m sea-level rise (Zhong et al., 2008)

Summary

- Best bet for GMSL is probably Rahmstorf (2007).
- For regional component, add in local subsidence inferred from difference between changes in local sea level and GMSL.
- Potential for large regional differences in sea level is large but very uncertain. Same applies to changes in temporal variability.

References

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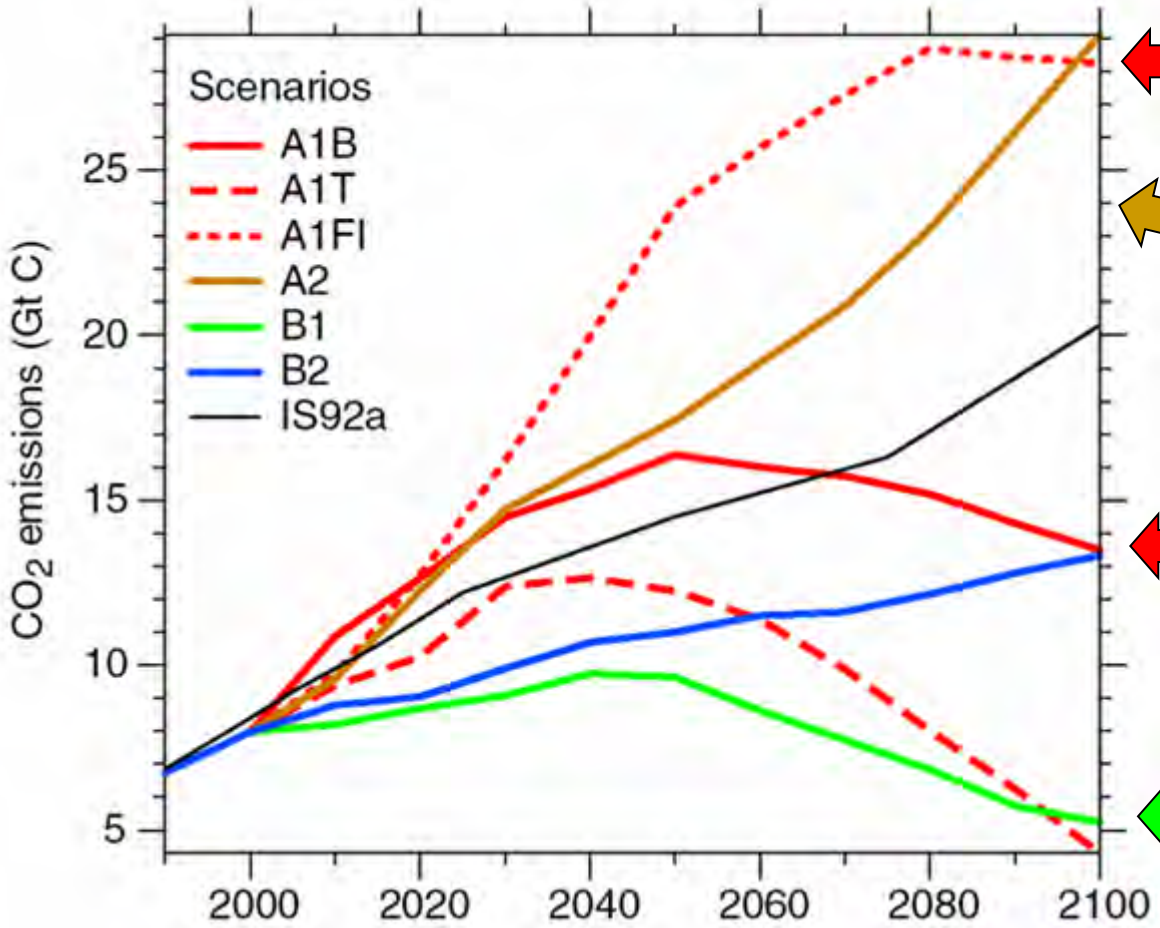
Thank you—questions?

Extra slides

IPCC emissions scenarios



HIGHEST

A1FI (940 ppm)

A2 (830 ppm)

A1B (700 ppm)

LOWEST

B1 (550 ppm)

Source: IPCC 2001

Jim Hansen: <350 ppm

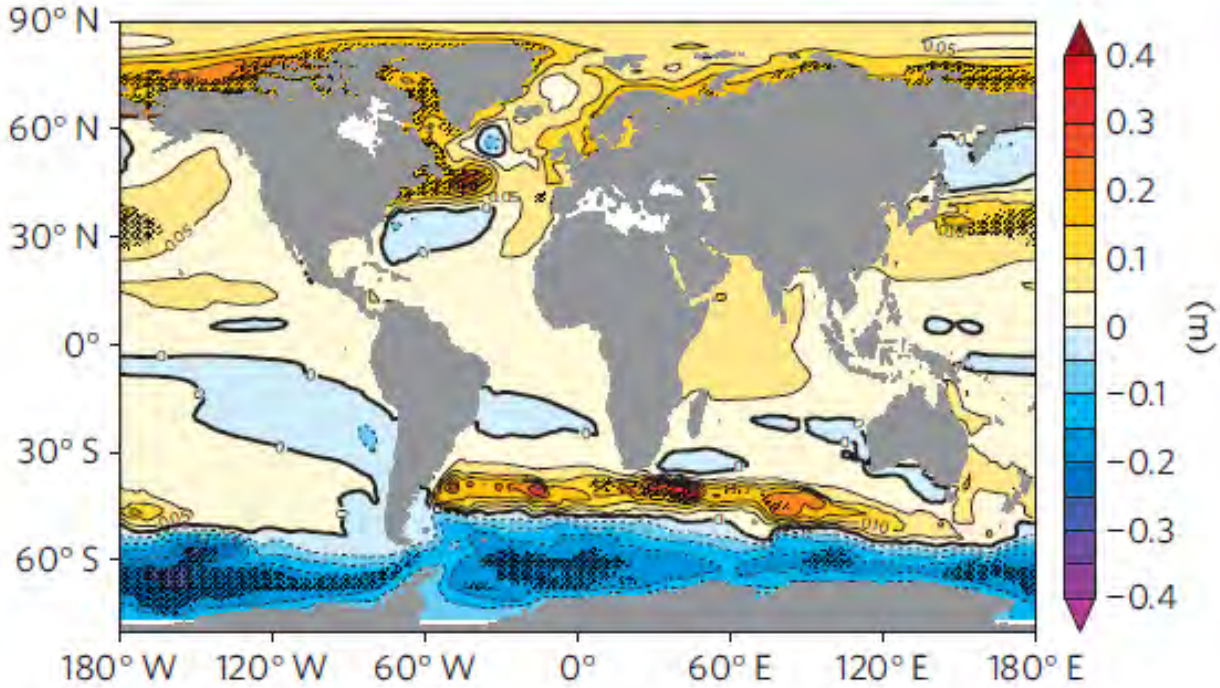
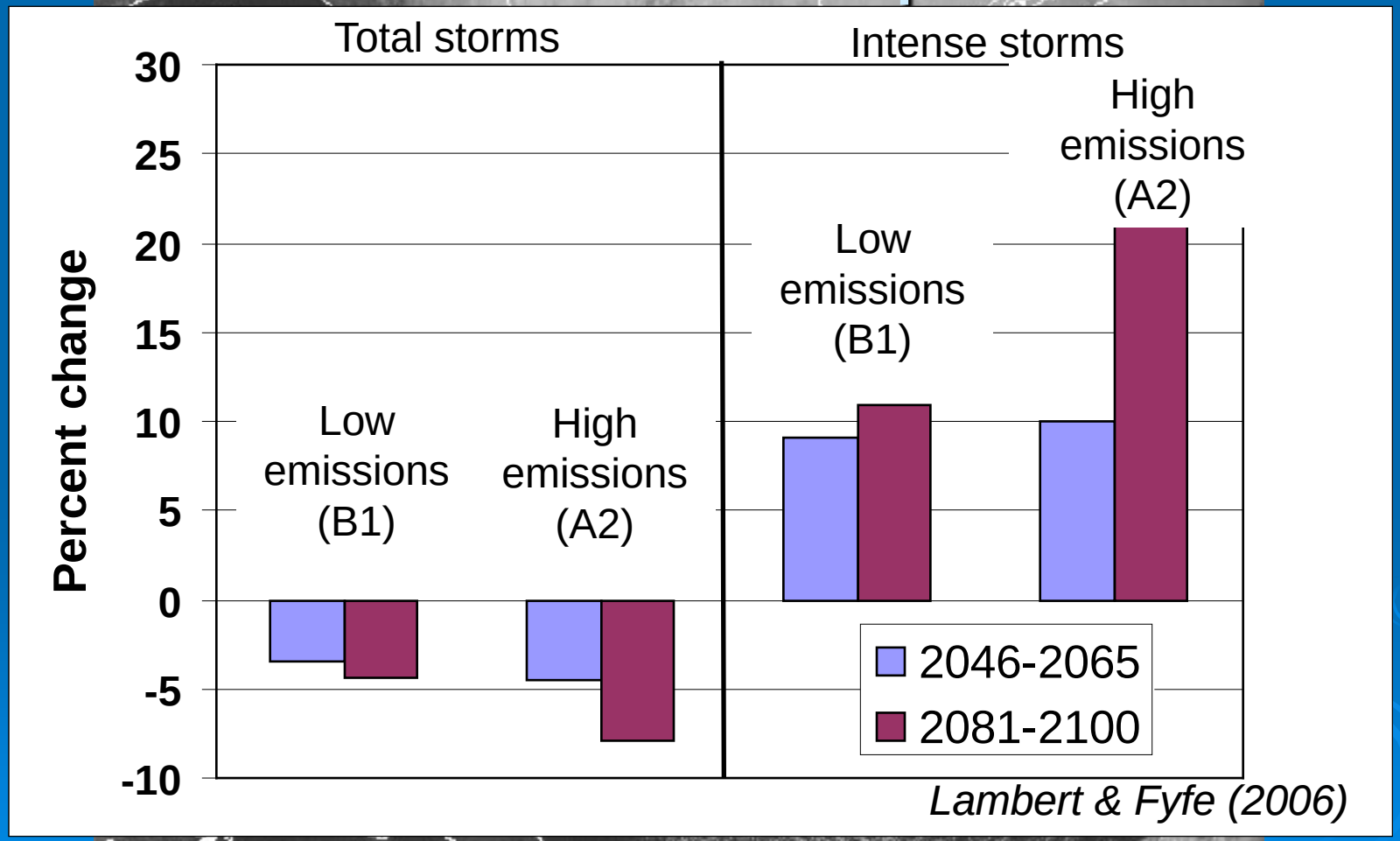


Figure 1 | Multi-model ensemble mean projection of the dynamic sea level. The values show the mean change (2091–2100 relative to 1981–2000) projected by ten AR4 climate models under the A1B scenario. Stippling indicates the regions where the ensemble mean divided by the ensemble standard deviation is greater than two. See Supplementary Fig. S1 for the models used in the calculation of the ensemble mean and their projections.

Changes in extratropical winter storms in the Northern Hemisphere



Lambert & Fyfe (2006)