Chesapeake Bay & Rising Sea Level

- Past Rates of Sea Level Rise
- Sea Level Rise Research since 2007 IPCC AR4 report
- Steric Factors & Sea Level (thermal expansion): Josh Willis NASA
  - Ocean Warming
  - Decadal Trends
  - Atlantic Meridional Overturning Circulation (AMOC)
  - 2010 Sea Level Fall
- Glacial Processes (mass changes): Tad Pfeffer University of Colorado
  - Antarctica
  - Greenland
  - Glaciers
  - Sea Level Budget
  - Future Sea Level: Projection Methods and Limits

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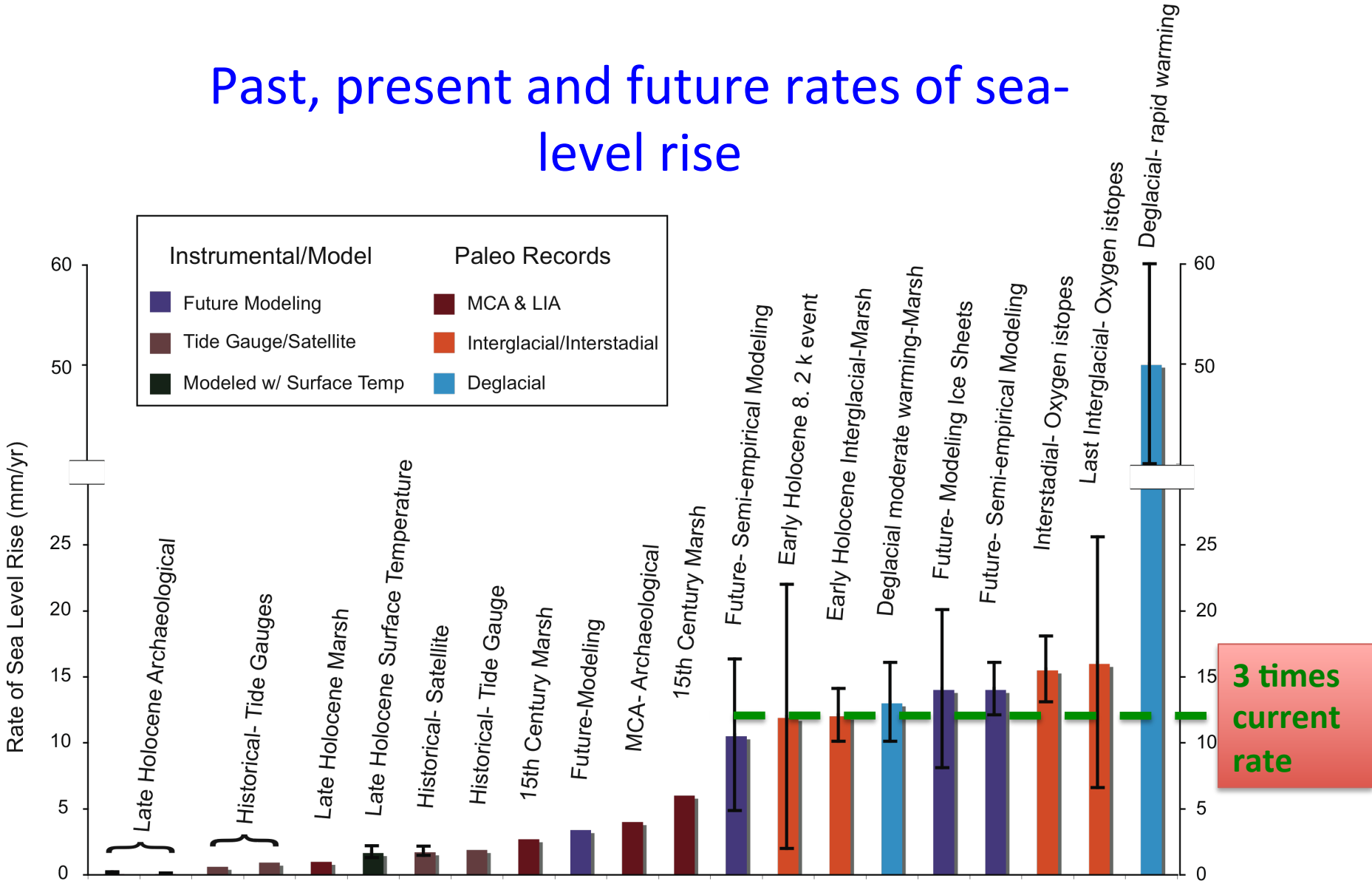
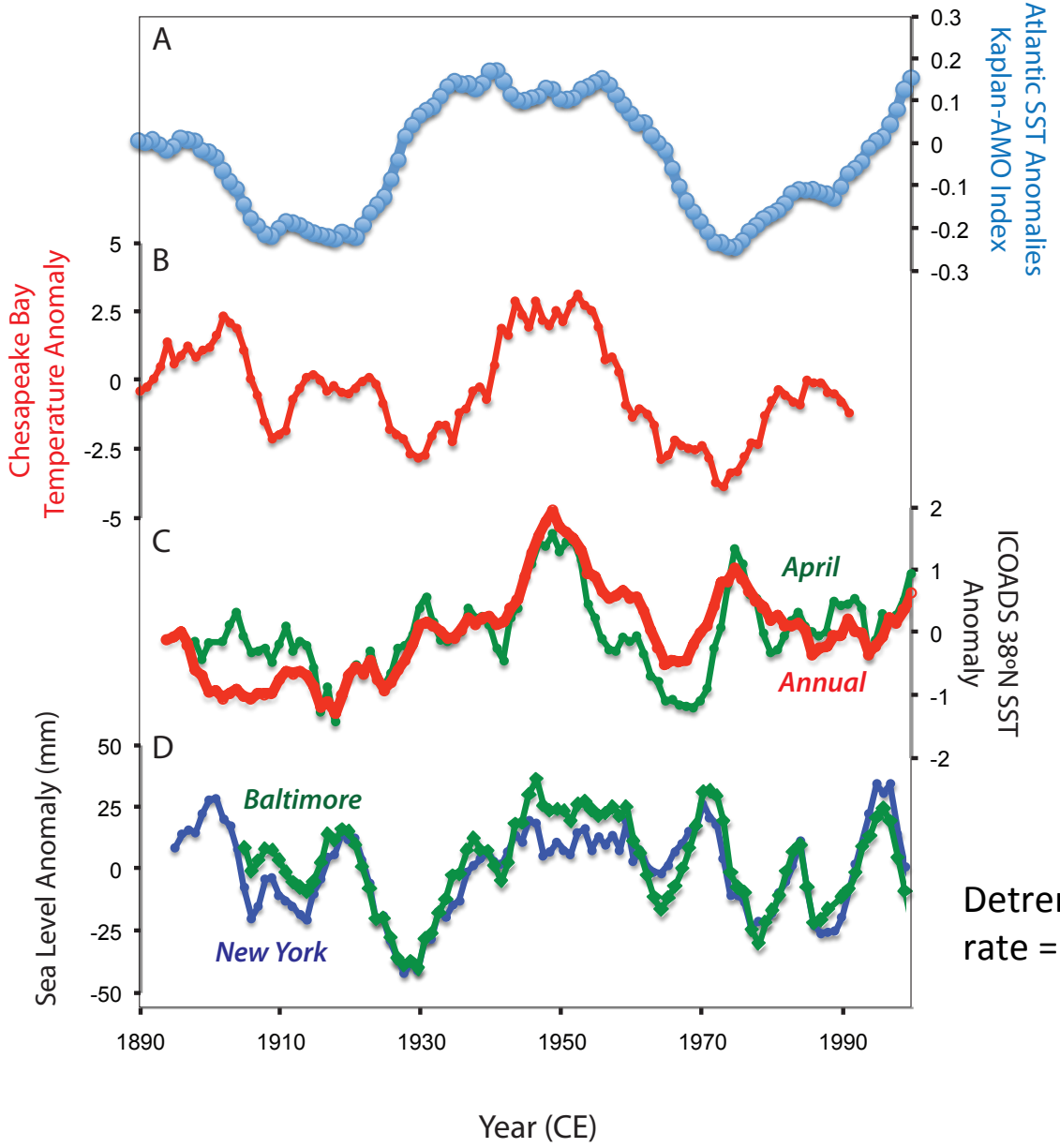
tcronin@usgs.gov


SEA LEVEL
Measuring Sea Level
Is *not* this easy

Past, present and future rates of sea-level rise

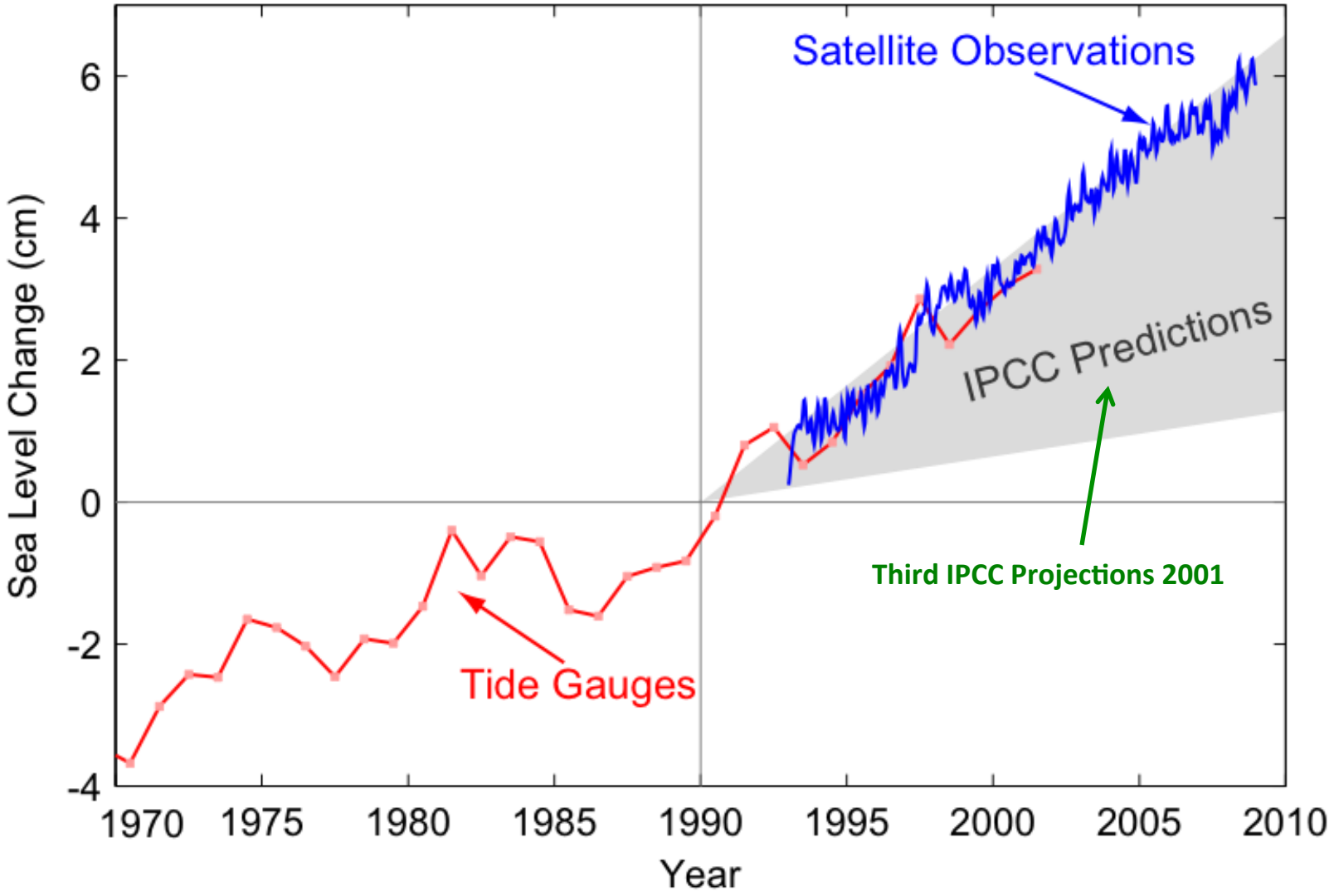


Chesapeake Bay Temperature, Tide Gauge Sea Level & Climate Variability

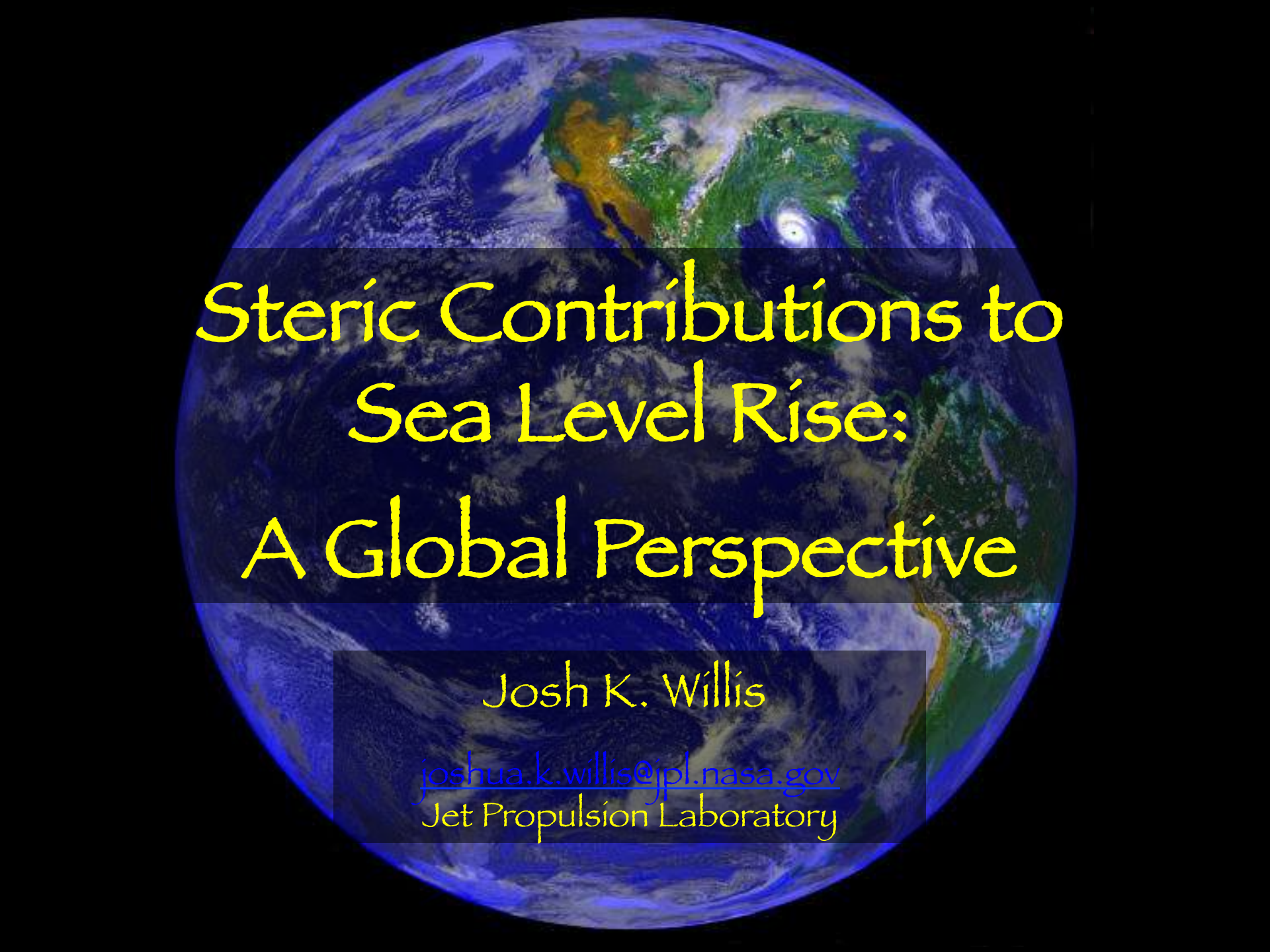


Detrended, from
rate = 2.9 mm/yr

Sea-level change 1970-2010
Models underestimated rate of SL Rise



Copenhagen Diagnosis 2010:



Steric Contributions to Sea Level Rise: A Global Perspective

Josh K. Willis

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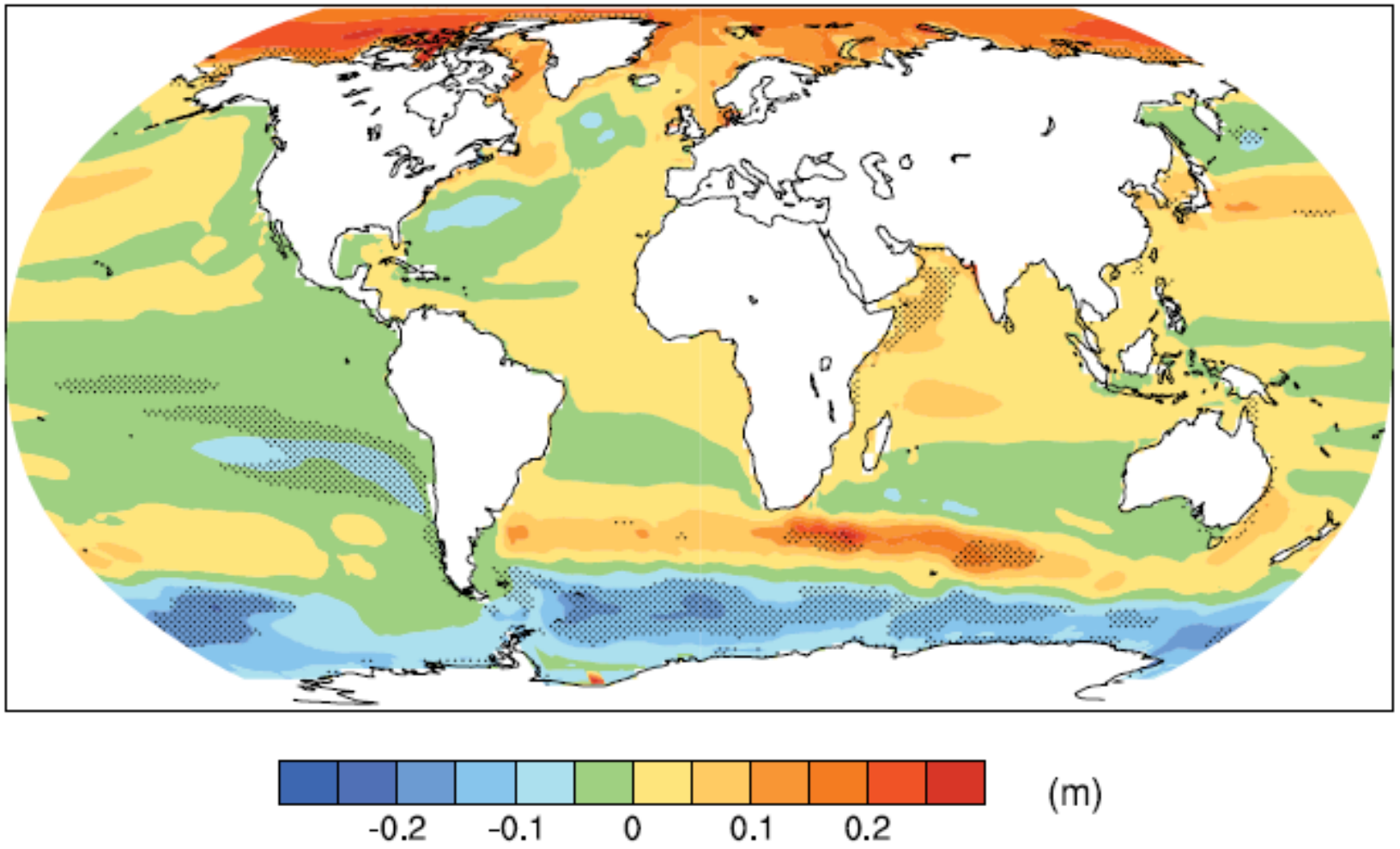
Jet Propulsion Laboratory

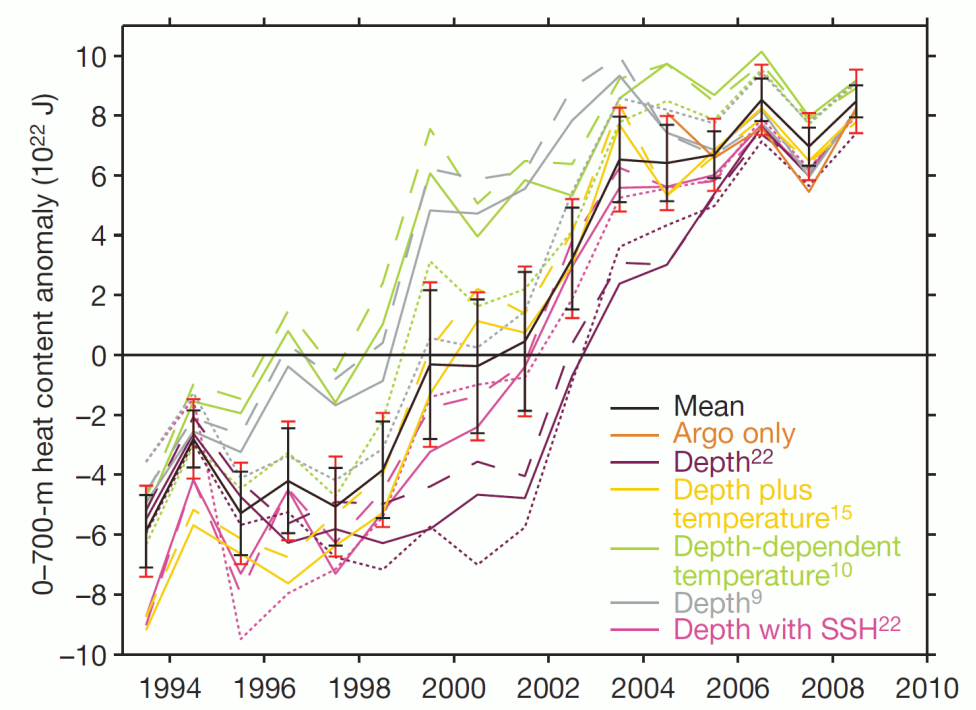
Sea Level in 2100



From IPCC, 2007

Stippled areas are statistically significant

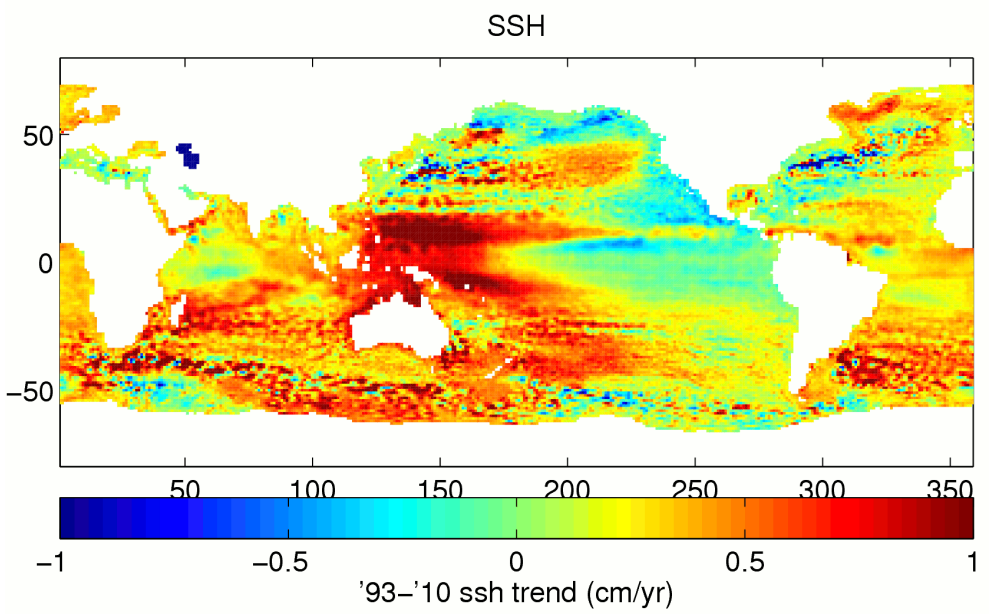
Global Sea Level Budget
Ocean Warming

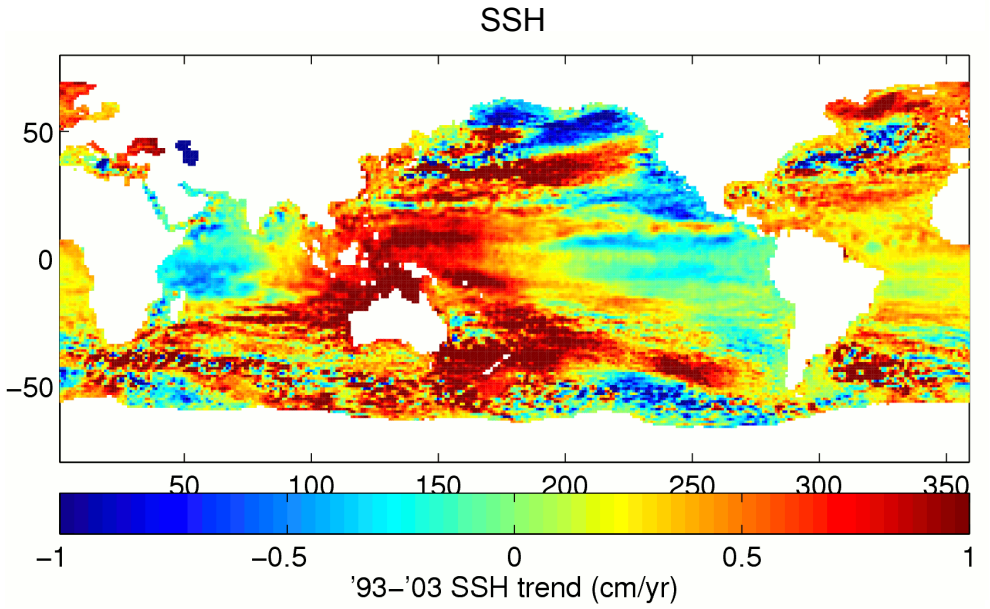


Different approaches to correcting Expendable Bathythermograph (XBT) biases yield different results

Warming over 15 years is robust, but interannual fluctuations are not

From Lyman et al., *Nature*, 2010





Decadal Trends Sea-Surface Height

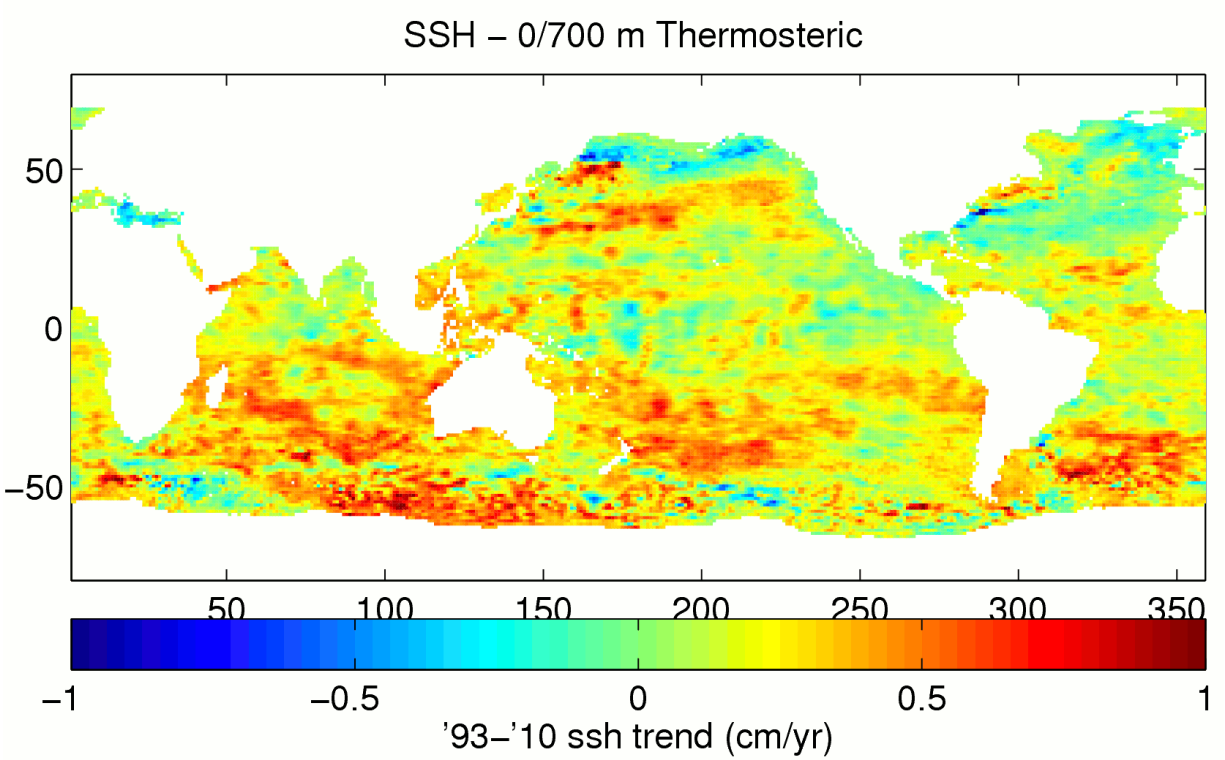
Even in 17-year trend, upper-ocean thermal changes (presumably circulation) account for much of the regional variations.

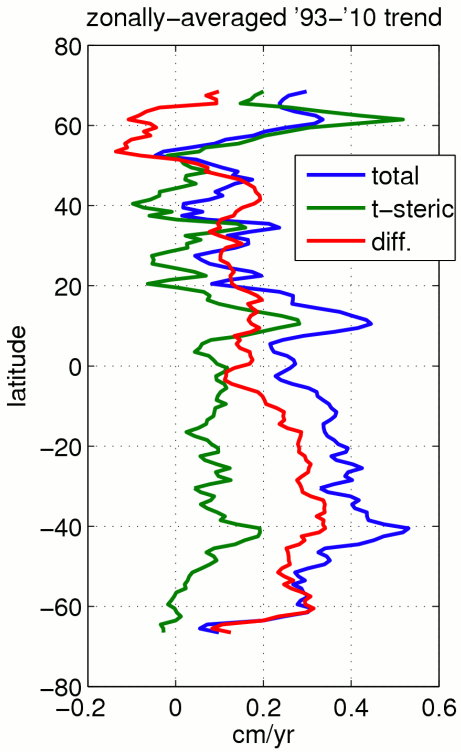
However, this is somewhat smoother than 10-year trend

Decadal Trends

Difference between Total and Thermosteric

Zonal Averages

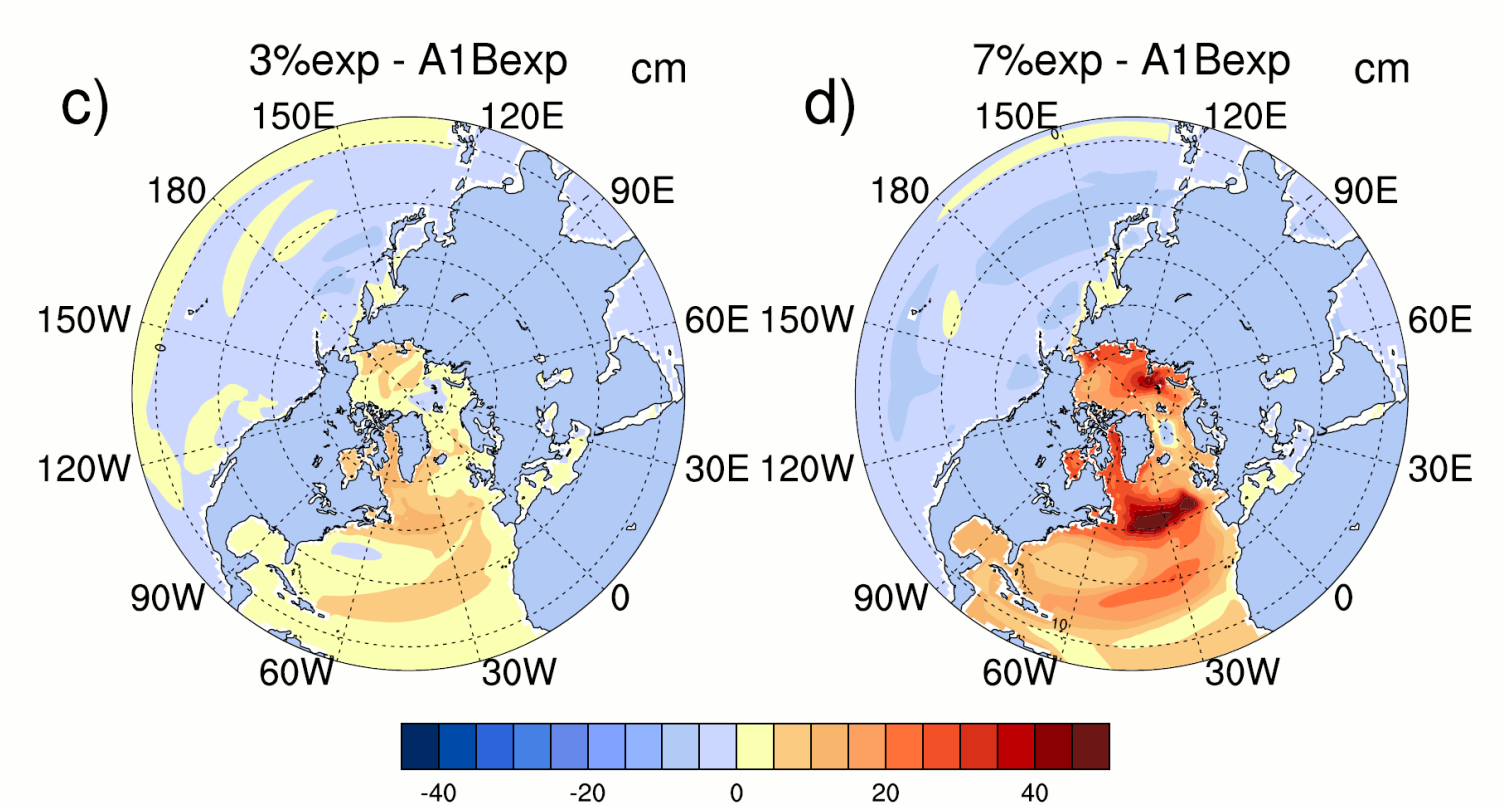




Difference is much more uniform suggesting much of this is due to ocean mass. However, zonal average suggests deep changes (and/or salinity) are important at high latitude

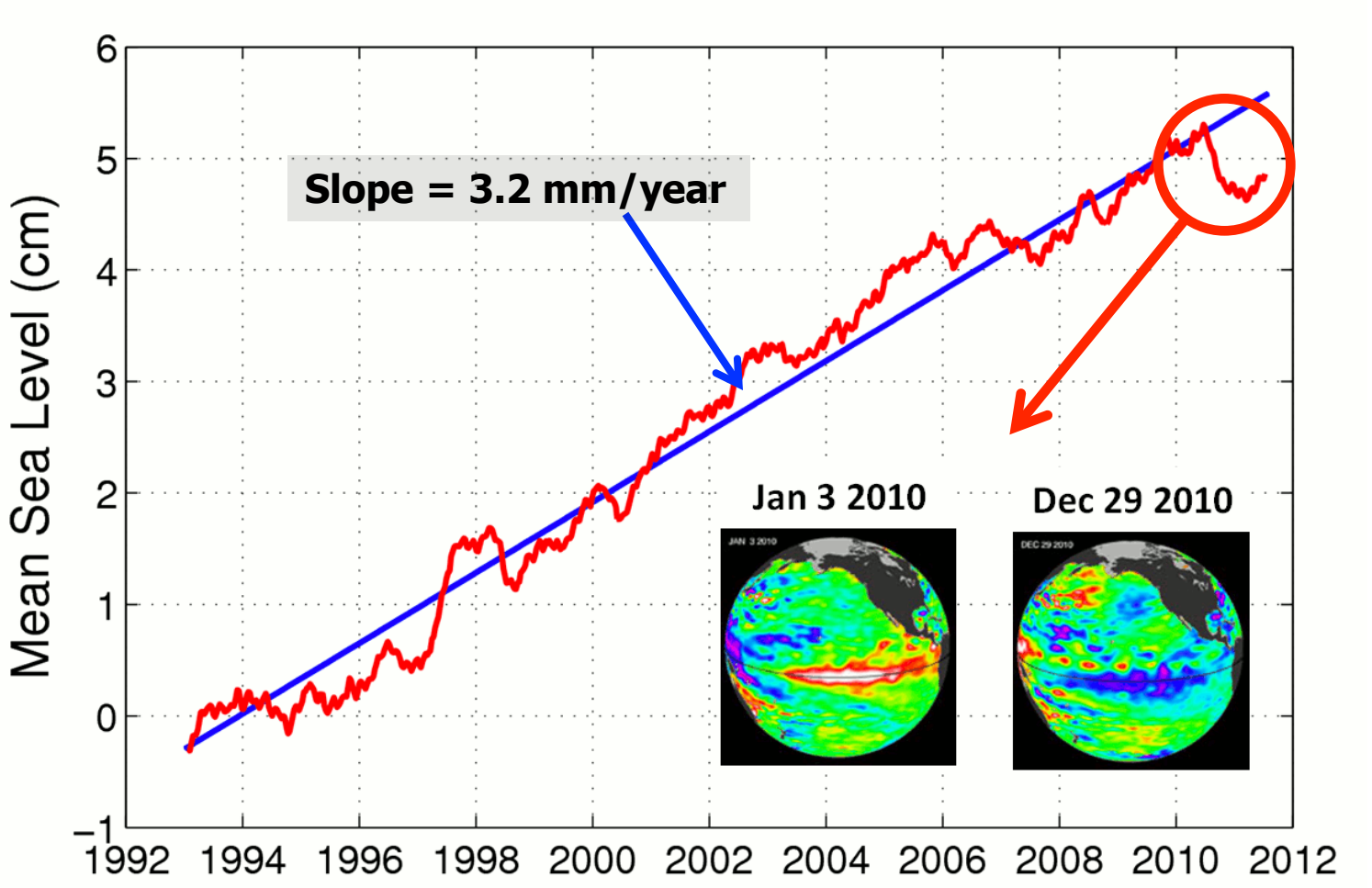
Regional sea level change And Atlantic Meridional Overturning Circulation

Dynamic Sea Level Change in 2100 with Greenland ice loss



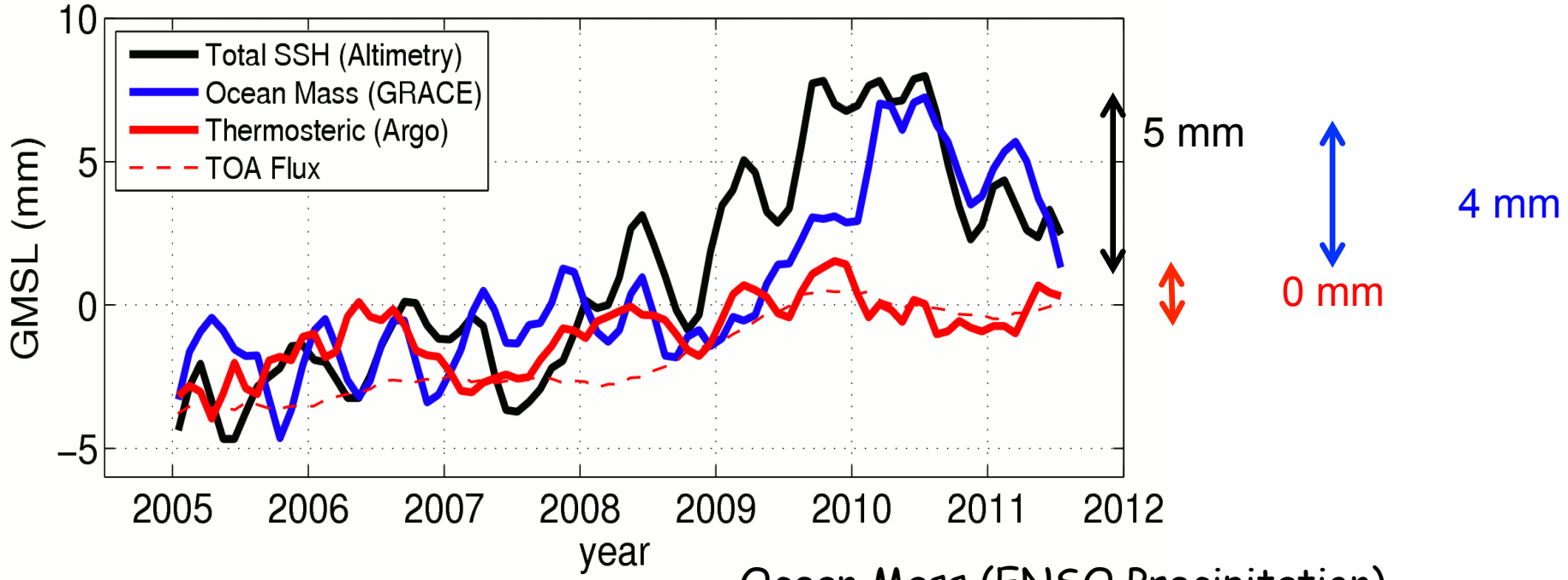
From Hu et al., *GRL*, 2009

Global Sea Level Drops 5 mm in 2010



Boening et al., *Science*, submitted

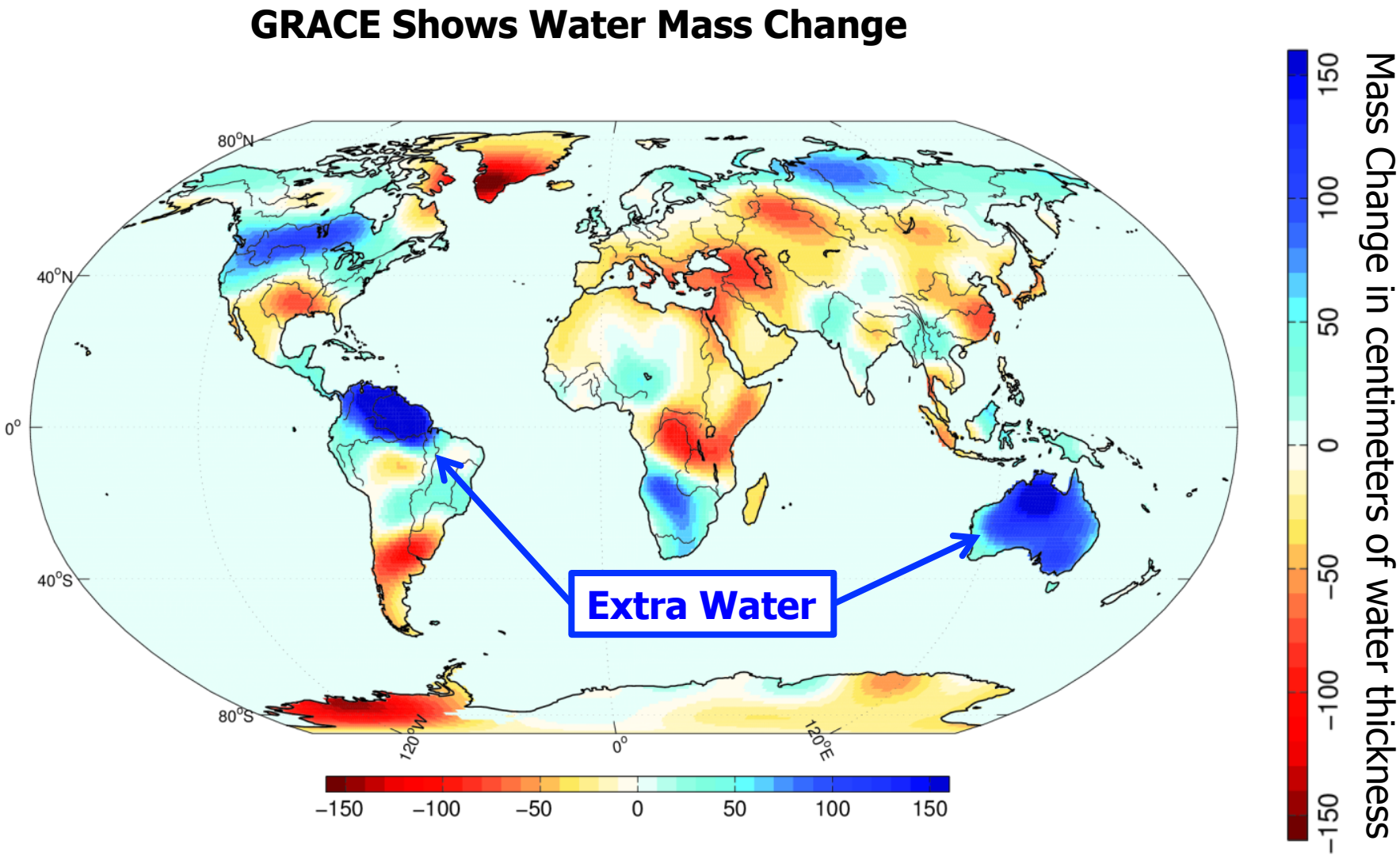
Sea Level budget during 2010 Sea-Level drop



Ocean Mass (ENSO Precipitation) decrease was biggest contributor to drop

Boening et al., *Science*, submitted

Were did the water go?



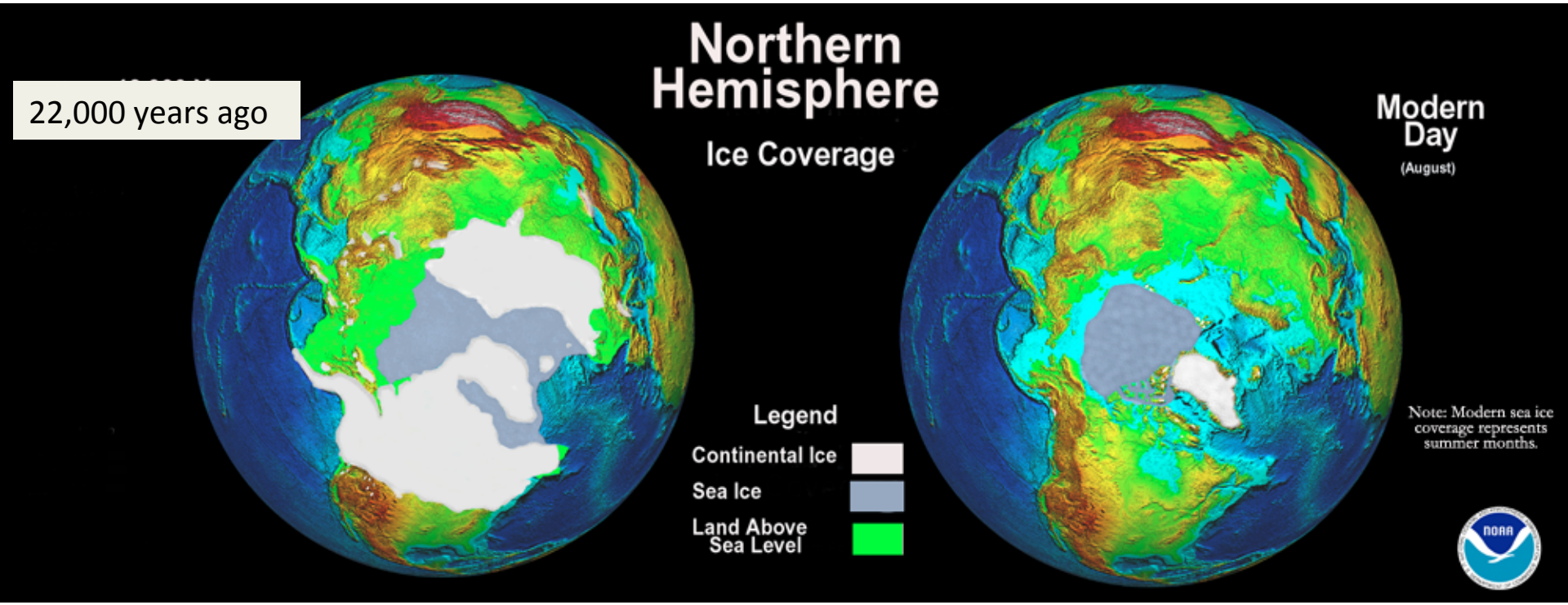
Boening et al., *Science*, submitted

Steric Conclusions

- Thermal expansion accounts for 1/2 to 1/3 of global mean sea level rise (~ 1 mm/yr)
- Regional variations on interannual to decadal time scales *dominated* by steric (order 10 – 20 cm)
- Projections remain highly uncertain
- Global observing systems provide new insights: 5 mm drop in GMSL due mostly to precip. & ocean mass change

Last Ice Age

Modern



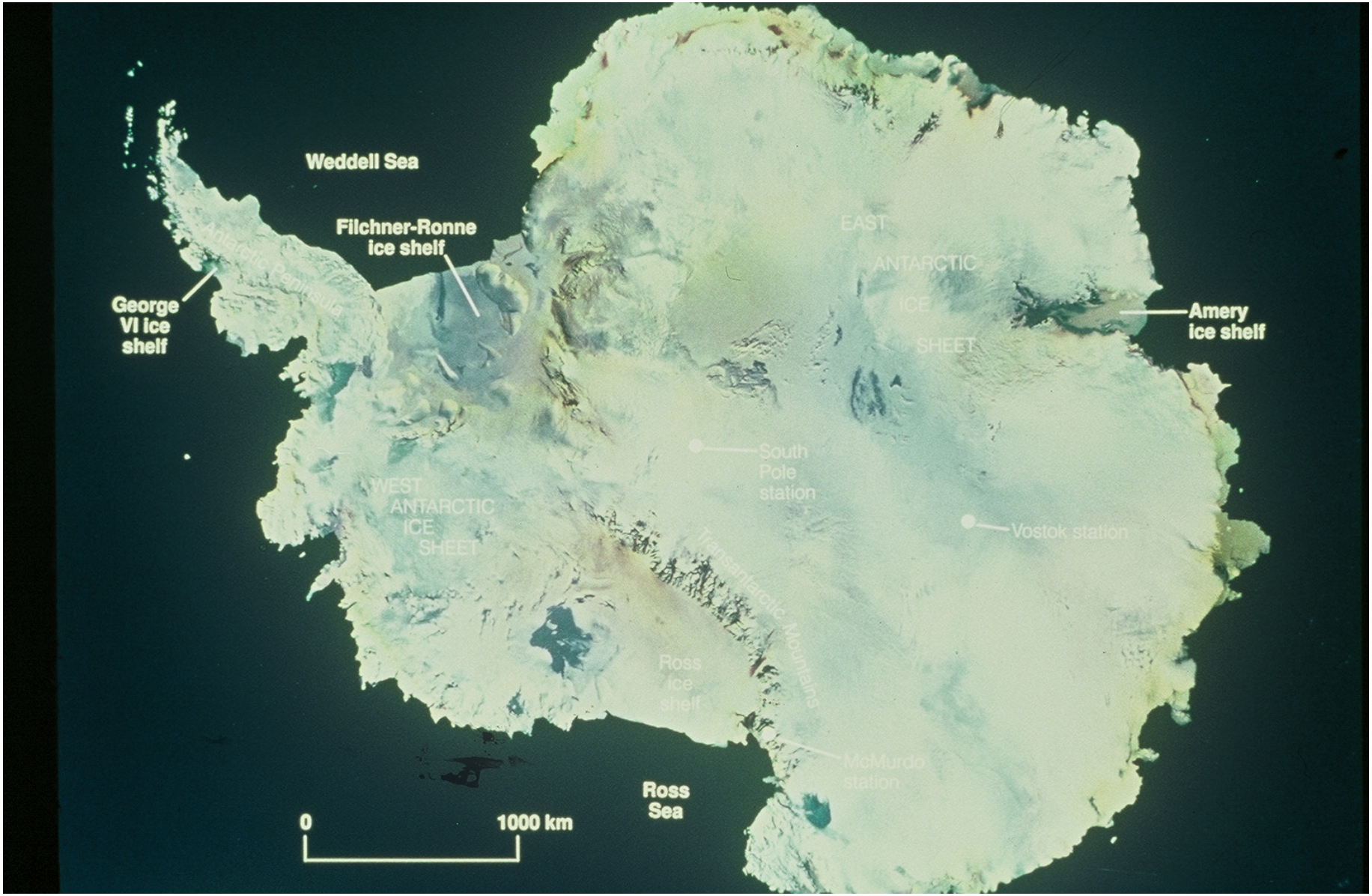
A review of glacier and ice sheet contributions to sea level rise in the 21st century

W. T. Pfeffer

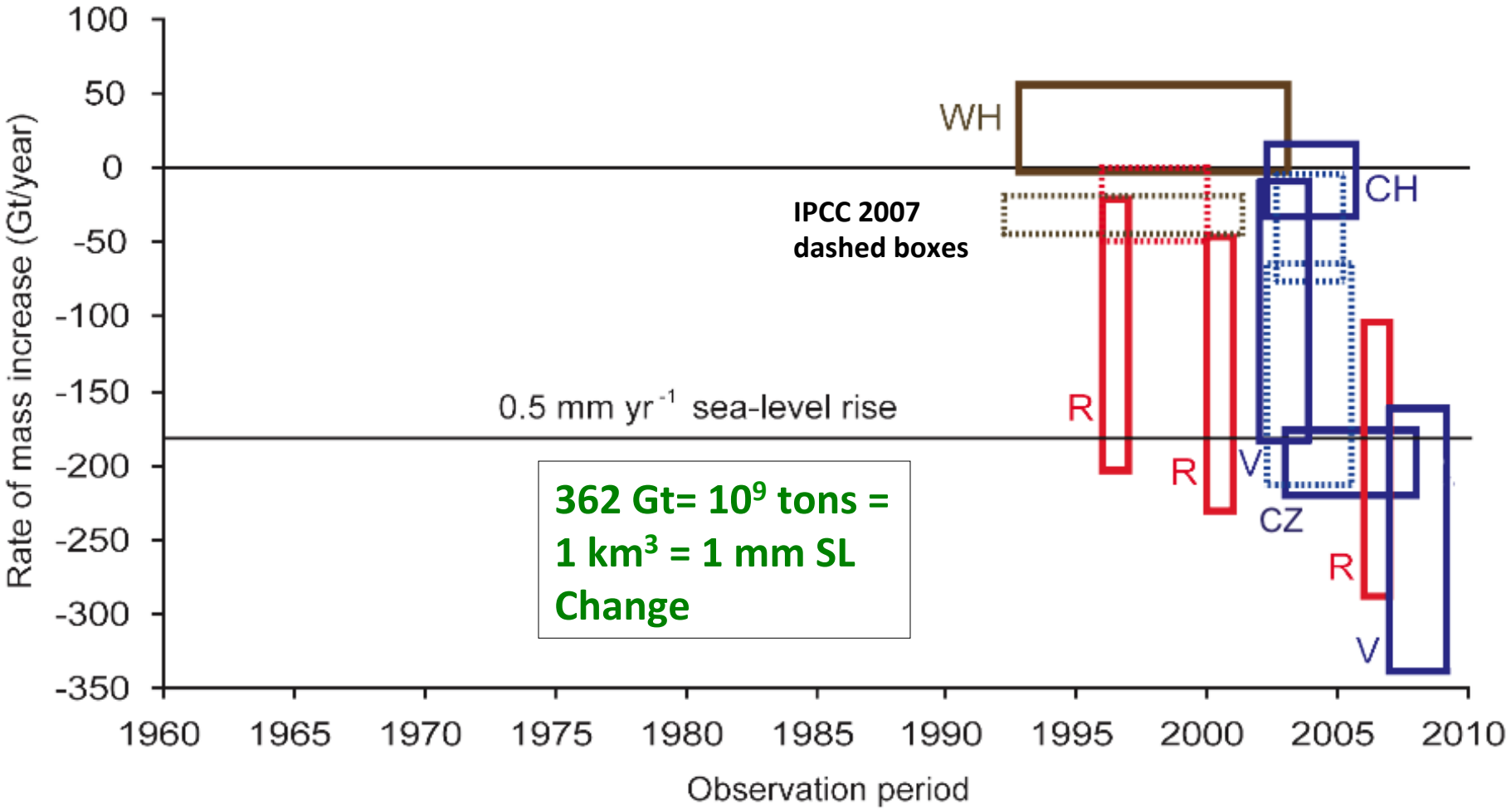
W.T. Pfeffer
INSTAAR and
Civil, Environmental, and Architectural Engineering,
University of Colorado

Coastal and Estuarine Research Foundation
7 November 2011

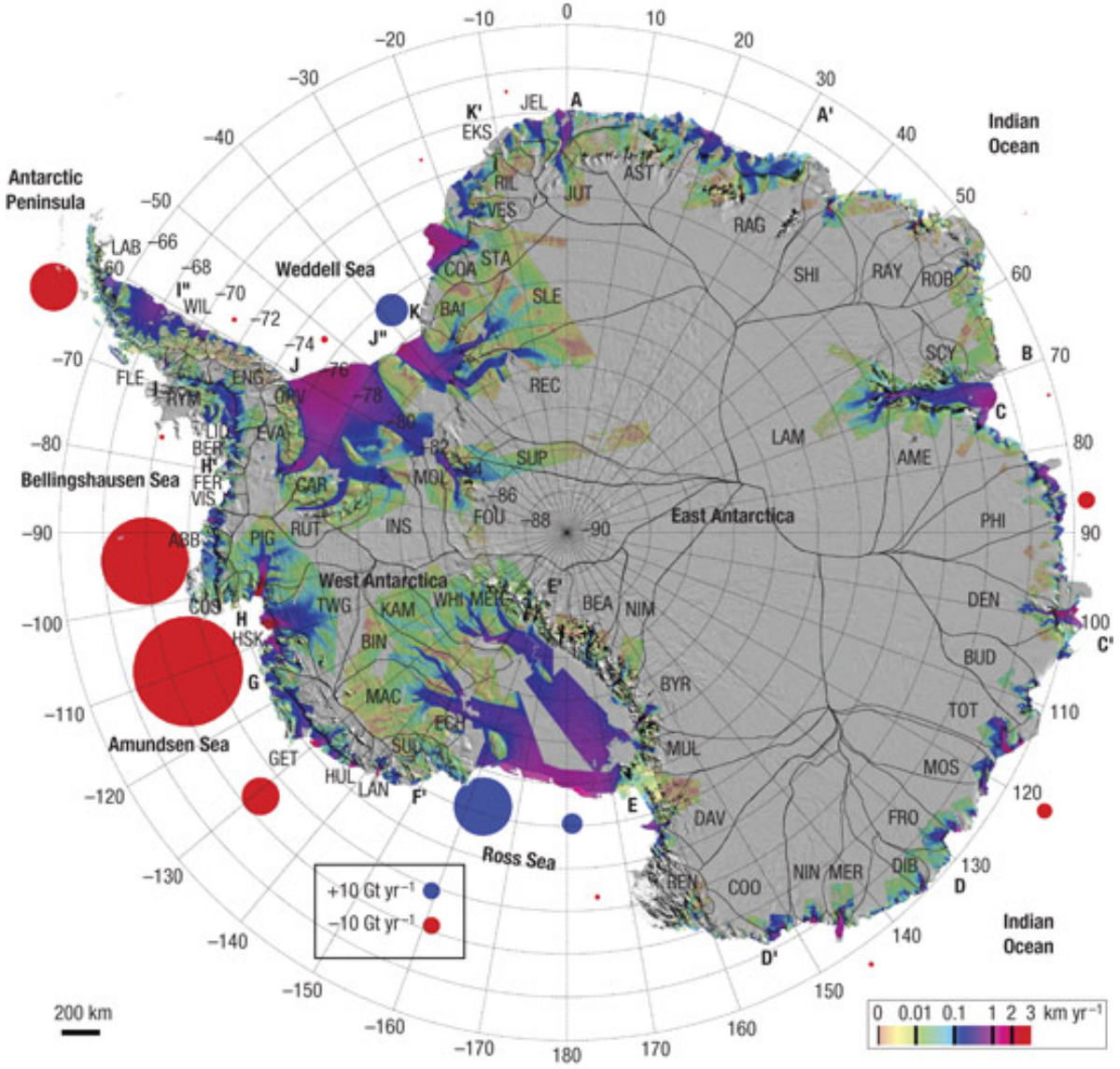
with thanks to
Balaji Rajagopalan
Civil, Environmental, and Architectural Engineering, University of Colorado


Weddell Sea
Filchner-Ronne ice shelf
Antarctic Peninsula
George VI ice shelf
EAST ANTARCTIC ICE SHEET
Amery ice shelf
South Pole station
WEST ANTARCTIC ICE SHEET
Vostok station
Transantarctic Mountains
Ross ice shelf
McMurdo station
Ross Sea
0
1000 km

Copenhagen Diagnosis 2010: Antarctic ice loss since 1960



Antarctic Ice Sheet Velocity and Mass Balance: 1992-2006

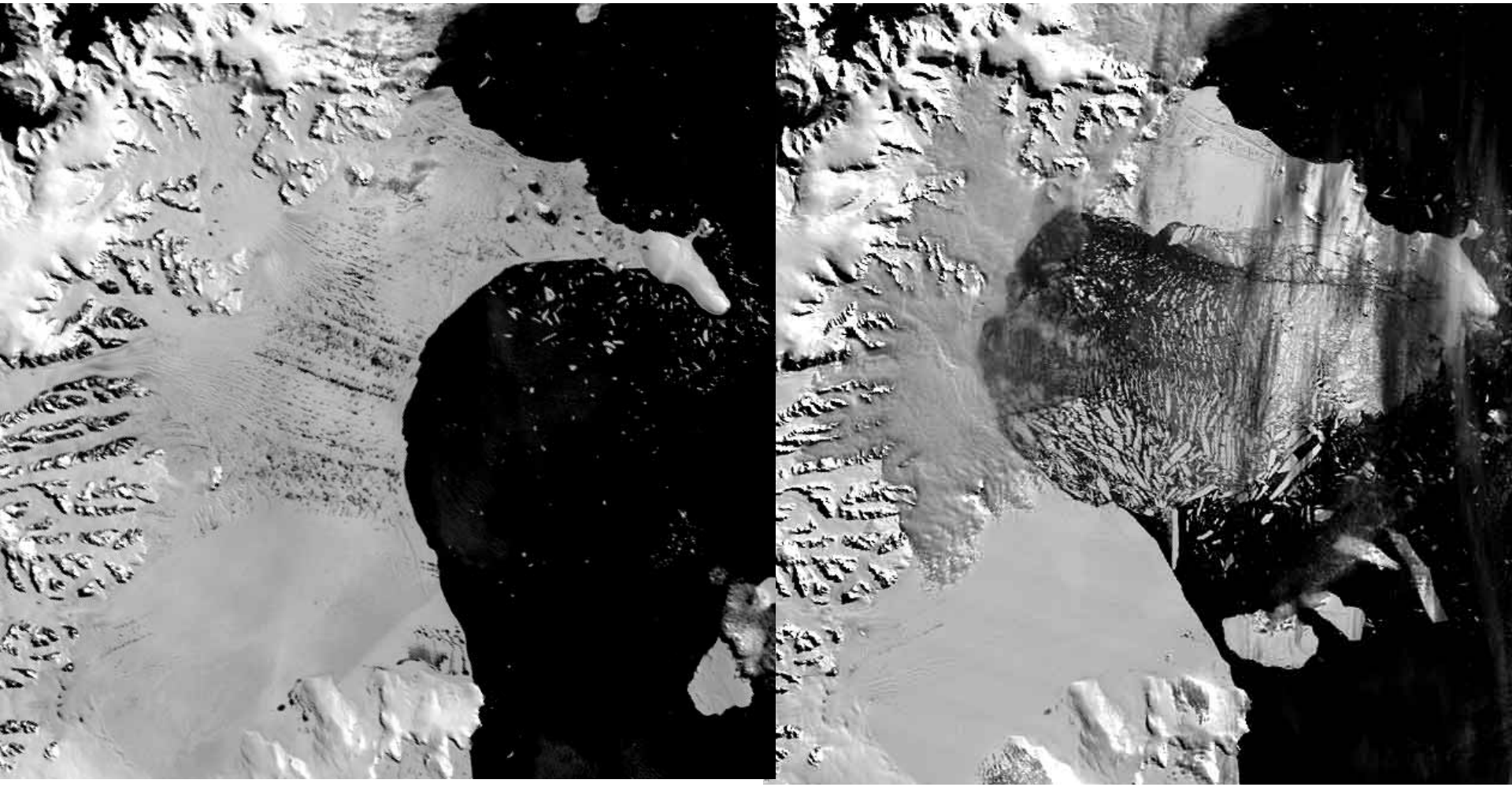


Rignot et al. 2008 Nature

Larsen Ice Shelf Break-up Antarctic Peninsula 2002

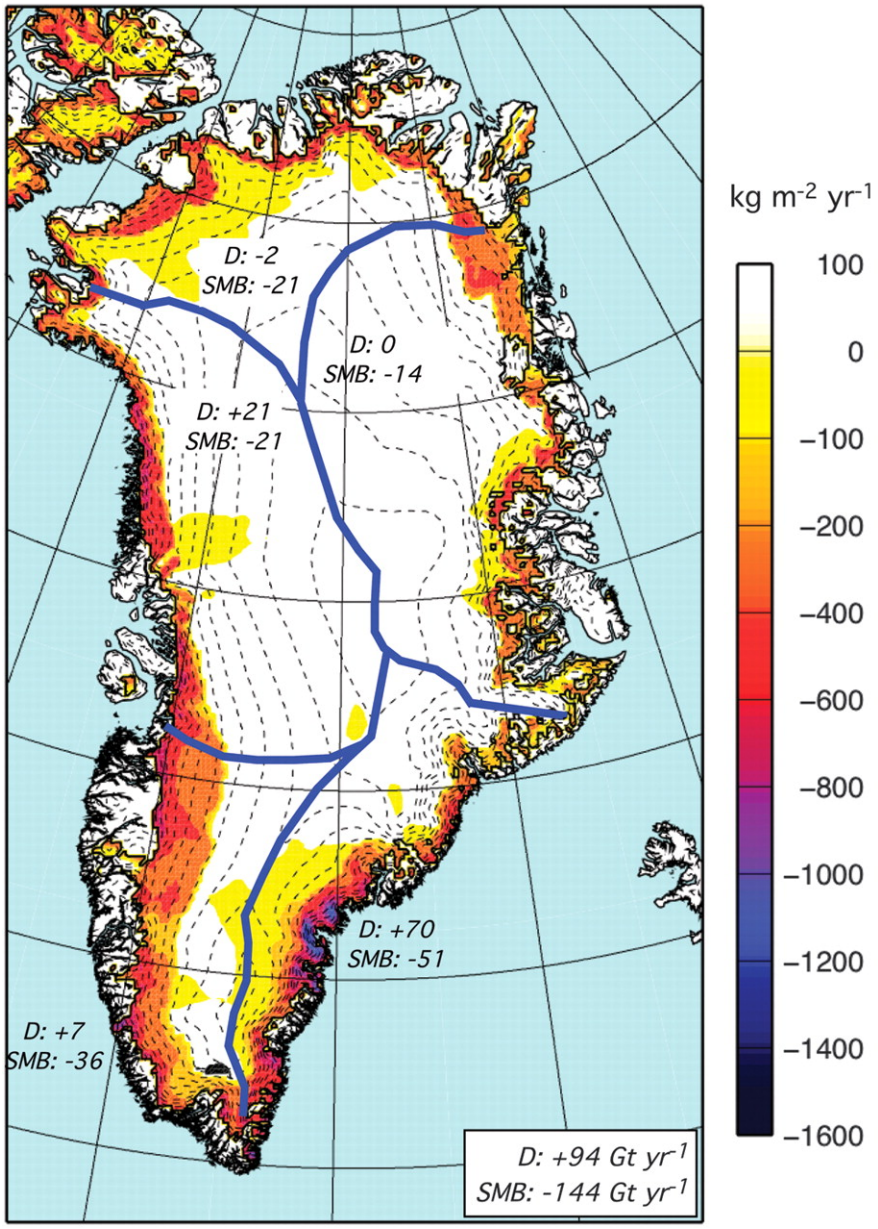
January 2002

March 2002



NASA

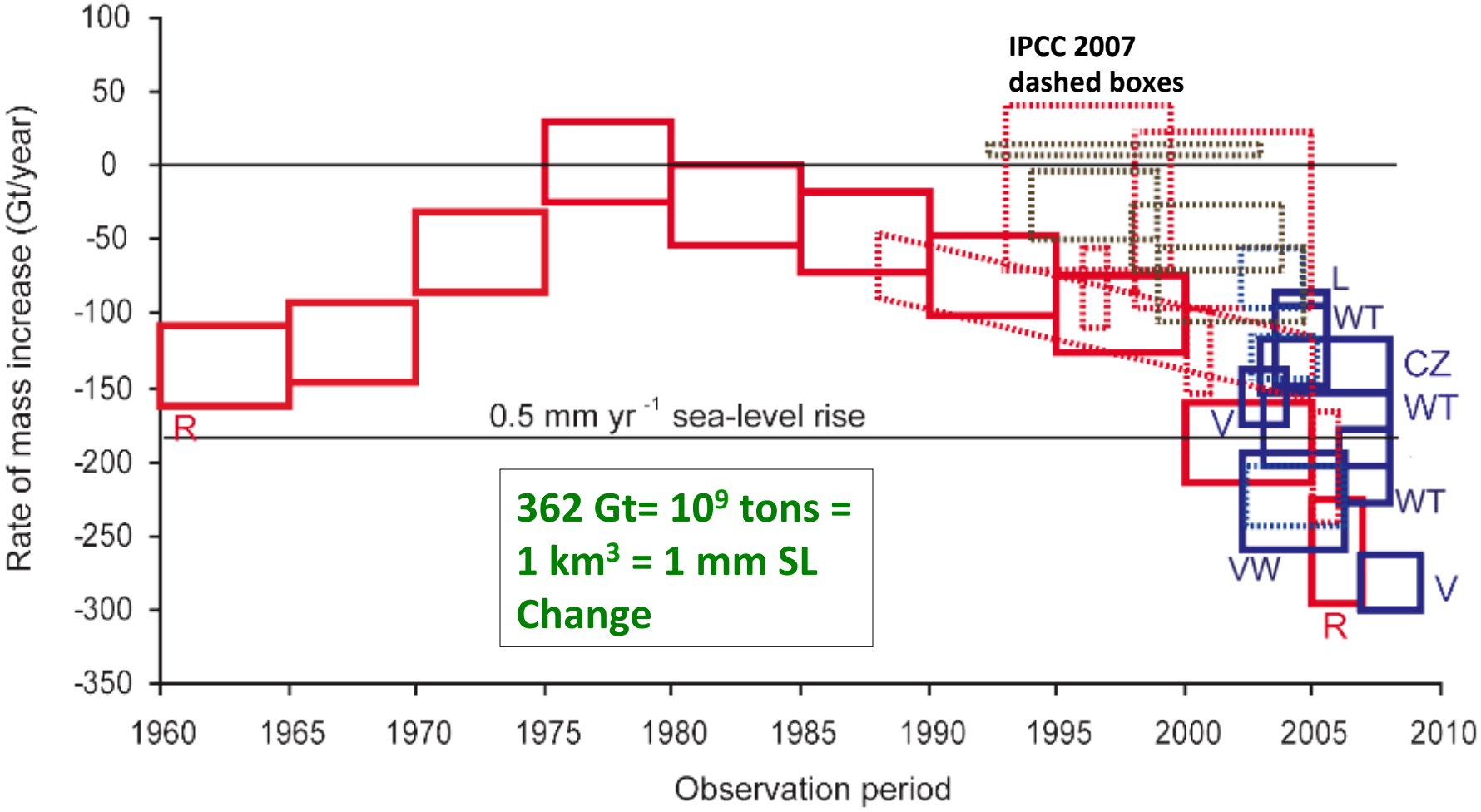
Greenland ice sheet loss from Surface Mass Balance (SMB) and Ice Discharge (D): 2003–2008

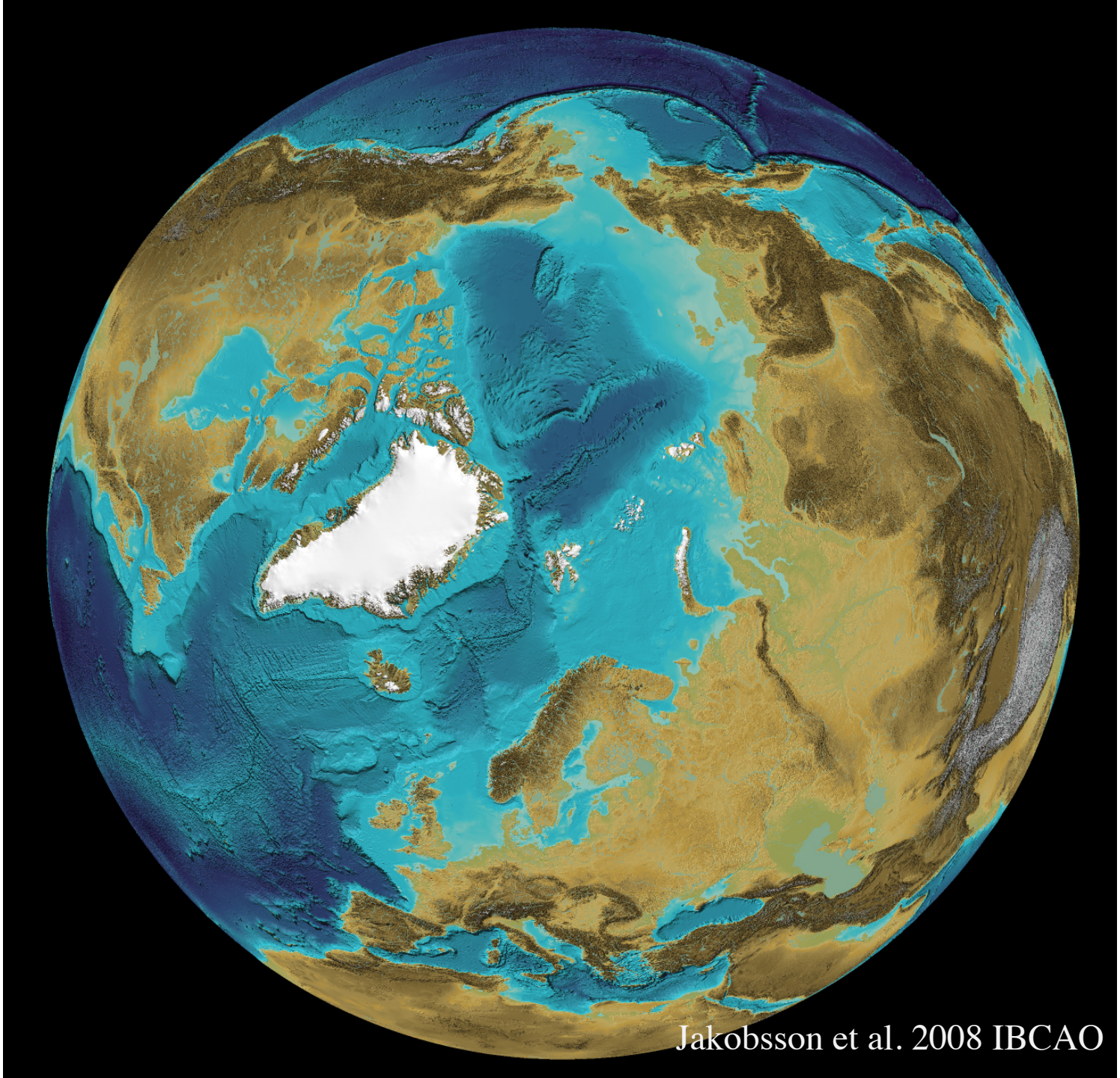


Science
AAAS

M van den Broeke et al.
Science 2009;326:984-986

Copenhagen Diagnosis 2010: Greenland ice loss since 1960




Jakobsson et al. 2008 IBCAO