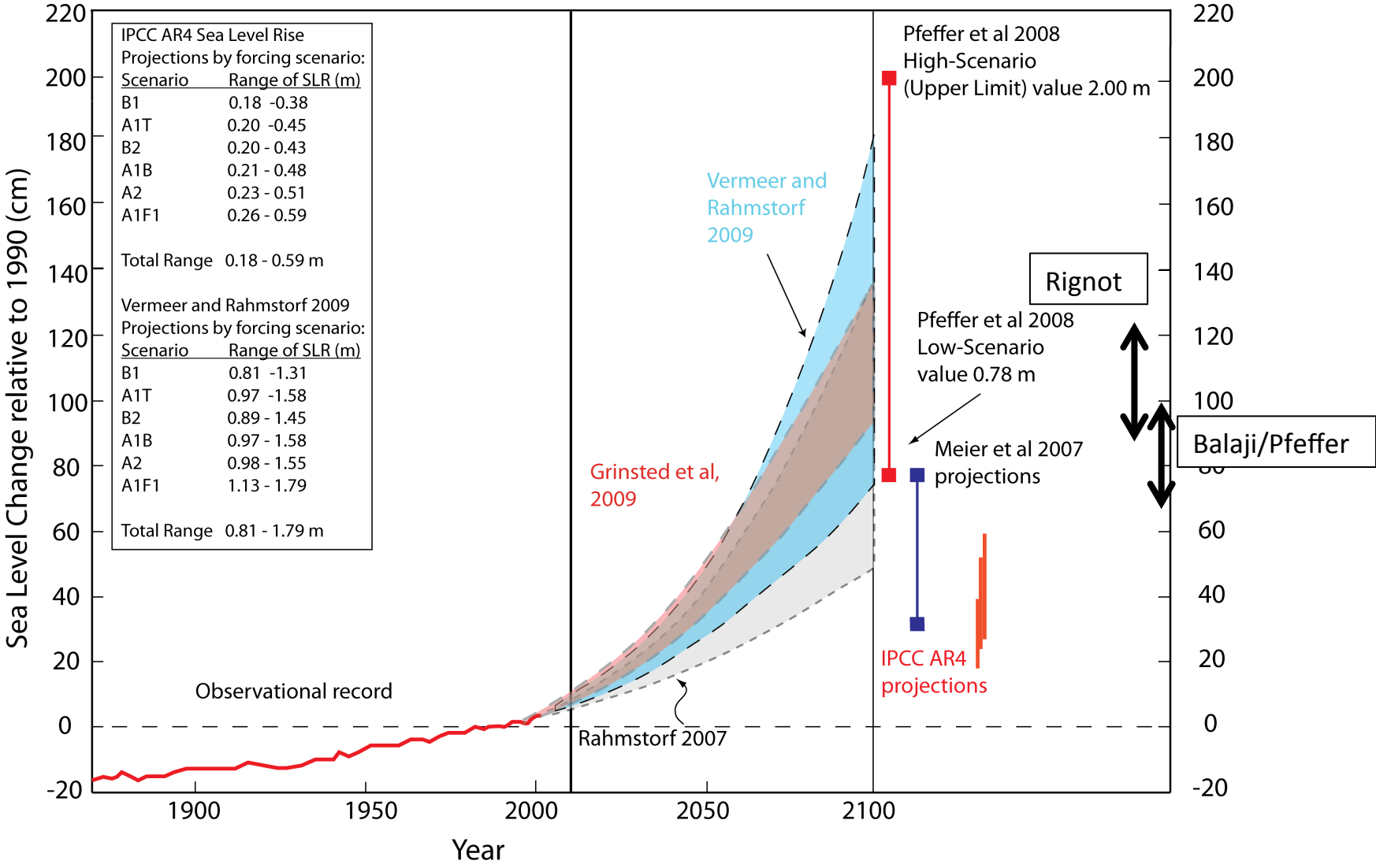
Projecting Future Sea Level Rise: Updated



Balaji/Pfeffer and Rignot land ice projections with AR4 steric added

New Projection Methods, Headed for AR5

Process-based numerical models:

Climatic Surface Mass Balance (Temperature index, Degree Day, Energy Balance) *[Radic and Hock, 2011, Greve et all, 2011]*

Flow Dynamics (Distributed parameter Navier-Stokes) *[Price et al, 2011, Lipscomb et al, 2009, Pattyn et al, 2008]*

Semi-Empirical models:

Temperature – Sea Level correlation *[Rahmstorf, 2007, Jevrejeva et al, 2010]*

Extrapolation:

Integrate observed rates/trends *[Meier et al, 2007, Rignot et al, 2011]*

Accumulation Area Ratio Equilibrium:

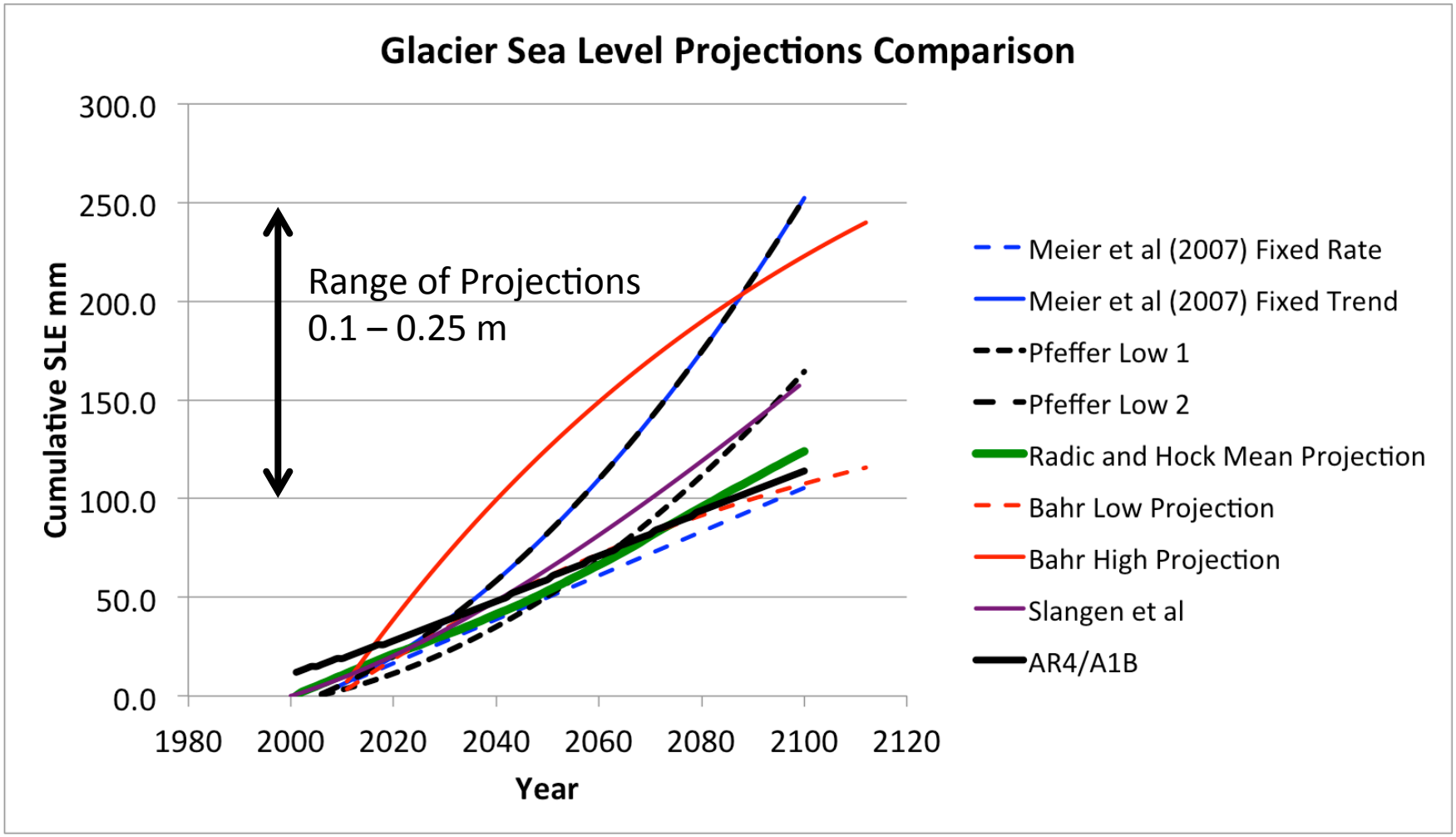
Return to steady-state mass balance geometry *[Bahr et al, 2009]*

Limit Seeking:

Exclude unrealistic/implausible outcomes *[Pfeffer et el, 2008]*

Model Type		Principal Flaws
Climatic Surface Mass Balance		Boundary conditions, Processes not understood (infiltration and refreezing), does not include marine dynamics.
Flow Dynamics		Major processes not understood (calving, basal sliding), boundary conditions.
Semi-Empirical		All SLR processes lumped, time scale dependence lost.
Extrapolation		Stationarity assumed.
AAR Equilibration		Theoretical equilibrium state proposed, does not include marine dynamics.
Limit Seeking		Not a “best-estimate” tool; designed to exclude bad values more than include good values.

Comparison of projections: **Glaciers only**



Eight new glacier projection schemes compared, along with the AR4 projection (2007, scenario A1B). BUT NOTE: Inventory still incomplete, terrestrial interception not accounted for.

Comparison of projections: **Greenland Ice Sheet, Surface Mass Balance only**

Source	Period	Projected SLR at 2100 (m)
AR4 (Meehl, 2007), scenario A1B	1990 to 2090-2099	0.01 – 0.08
Feitweis et al (2008)	1970-1999 to 2090-2099	0.03 – 0.05
Mernild et al (2010)	1990-1999 to 2070-2080	0.12
Graversen et al (2011)	2000 to 2100	0.02 – 0.08
Yoshimori and Abe-Ouchi (in press)	1980-1999 to 2100	0.02 – 0.13
Range of Projections		**0.01 to 0.08**

5 projection schemes: Greenland Ice Sheet, Surface Mass Balance only

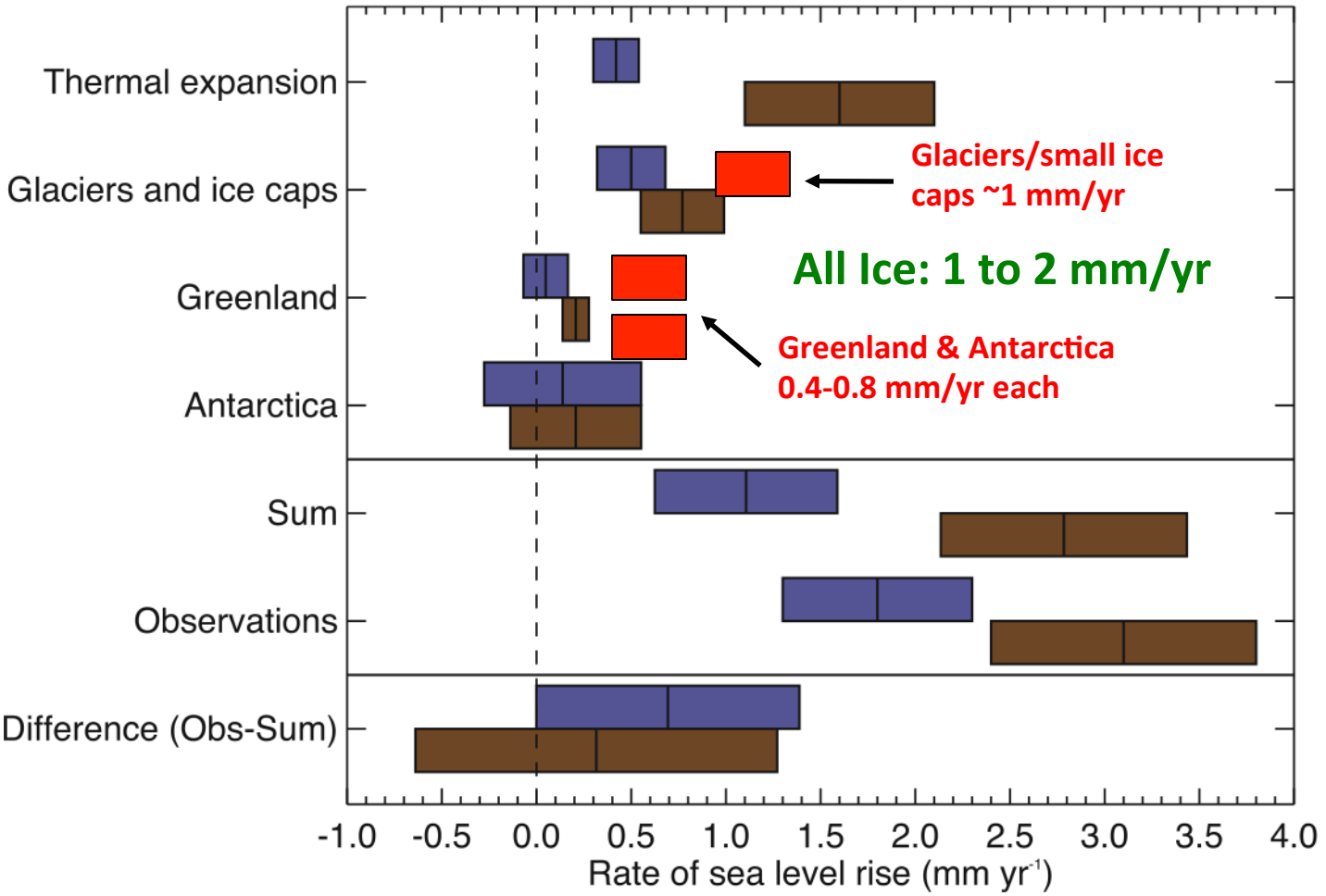
Sea Level Budget:

IPCC: 1961 to 2003 (blue)

IPCC: 1993 to 2003 (brown)

New estimates published 2007-2010 (red)

Ice is Melting Faster



IPCC, 2007, Updated

Chesapeake Bay & Rising Sea Level

- **21st century rate of SL Rise may reach or exceed 10 mm/yr = 3 times the rate since 1993 and 5 times the rate since 1960.**
- **Multiple Causes**
- **Regional Rates in Chesapeake Bay may be higher**
- **Process-based models don't provide regional SL patterns**
- **Semi-empirical models: Physical basis lacking; calibration does not cover climate-system behavior for the 21st century [elevated CO_2, ice loss from ice sheets].**
- **Questions: *What is future land ice mass balance? What regional processes influence east coast sea level?***

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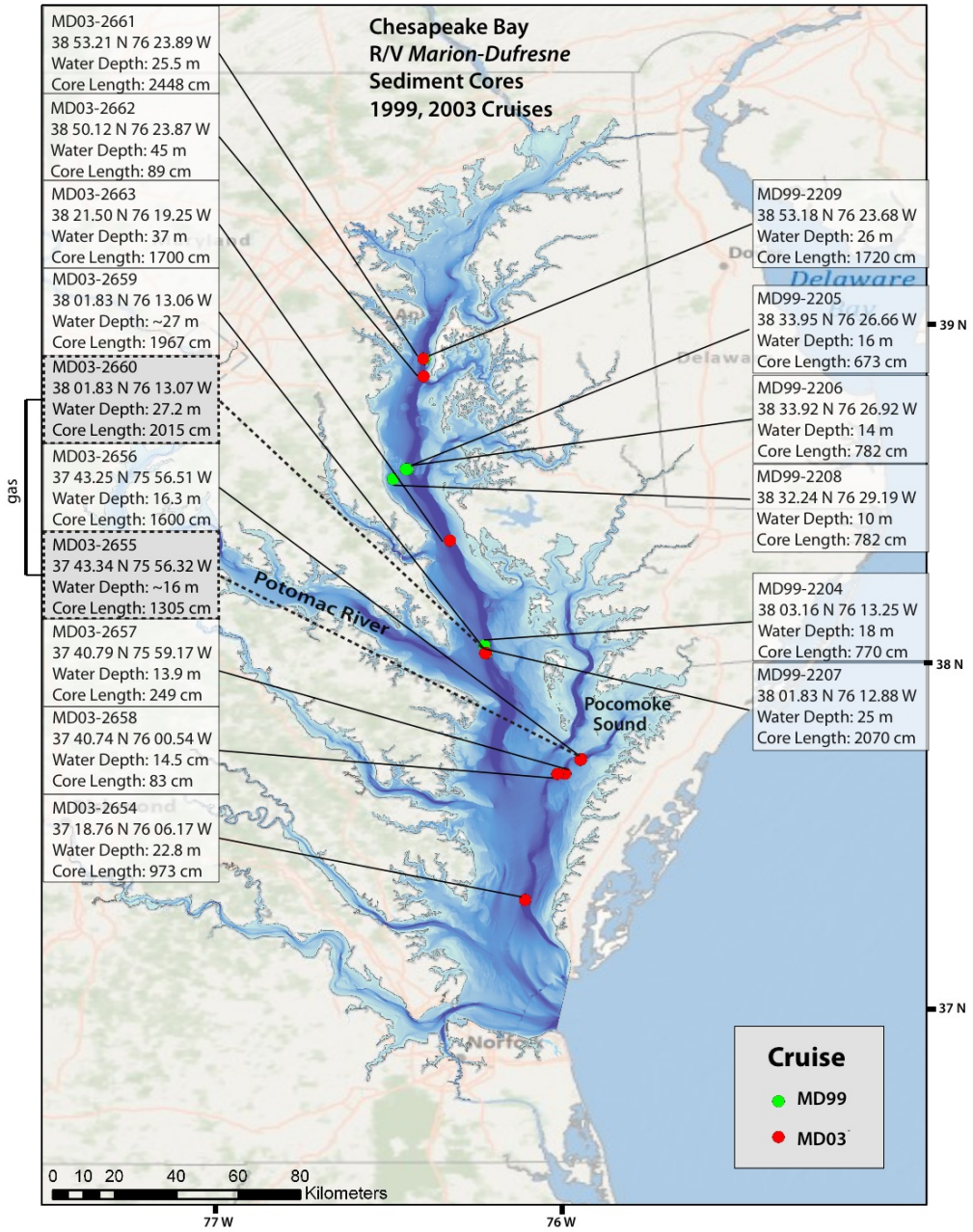
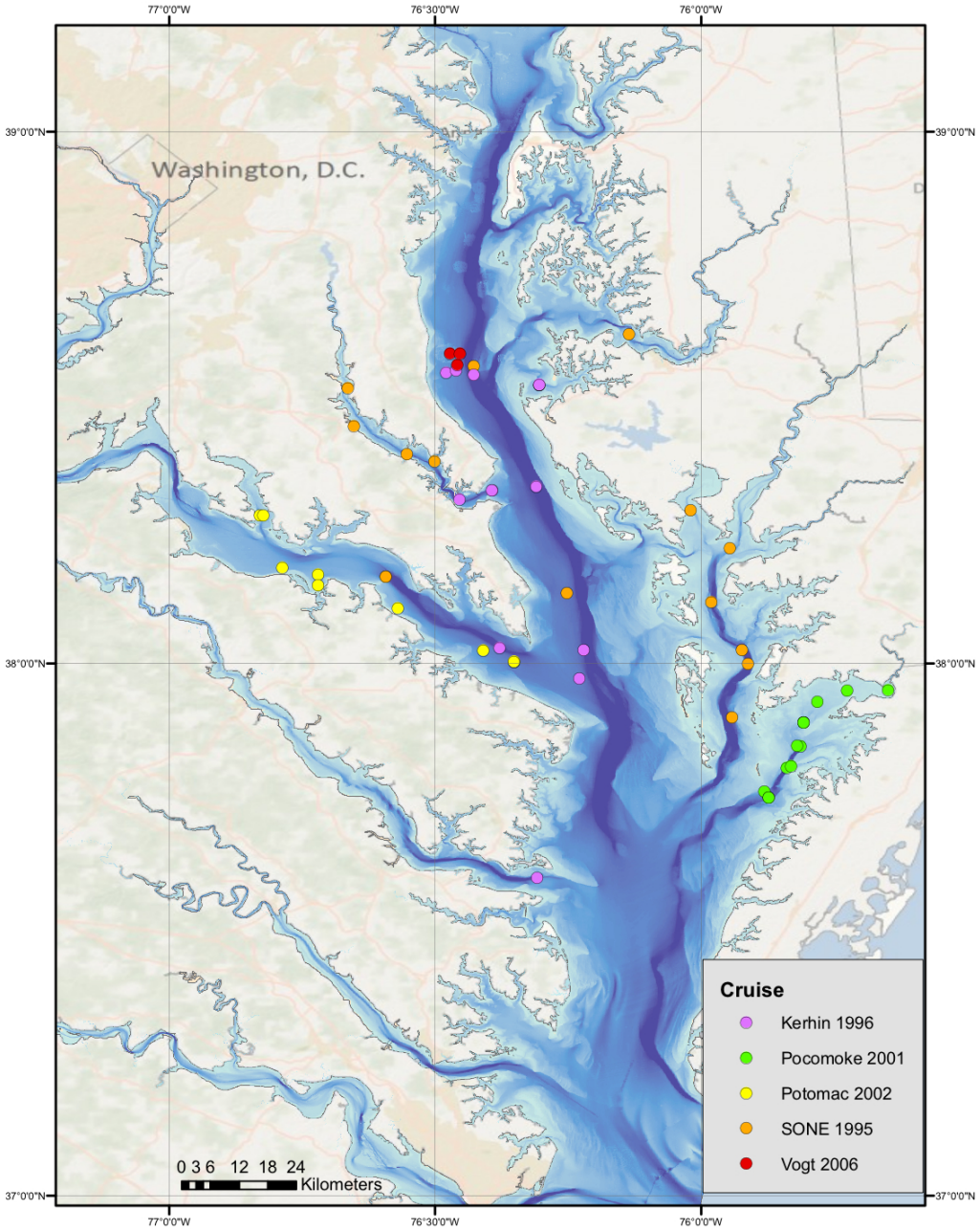
Sea Ice- does not contribute to SL Rise

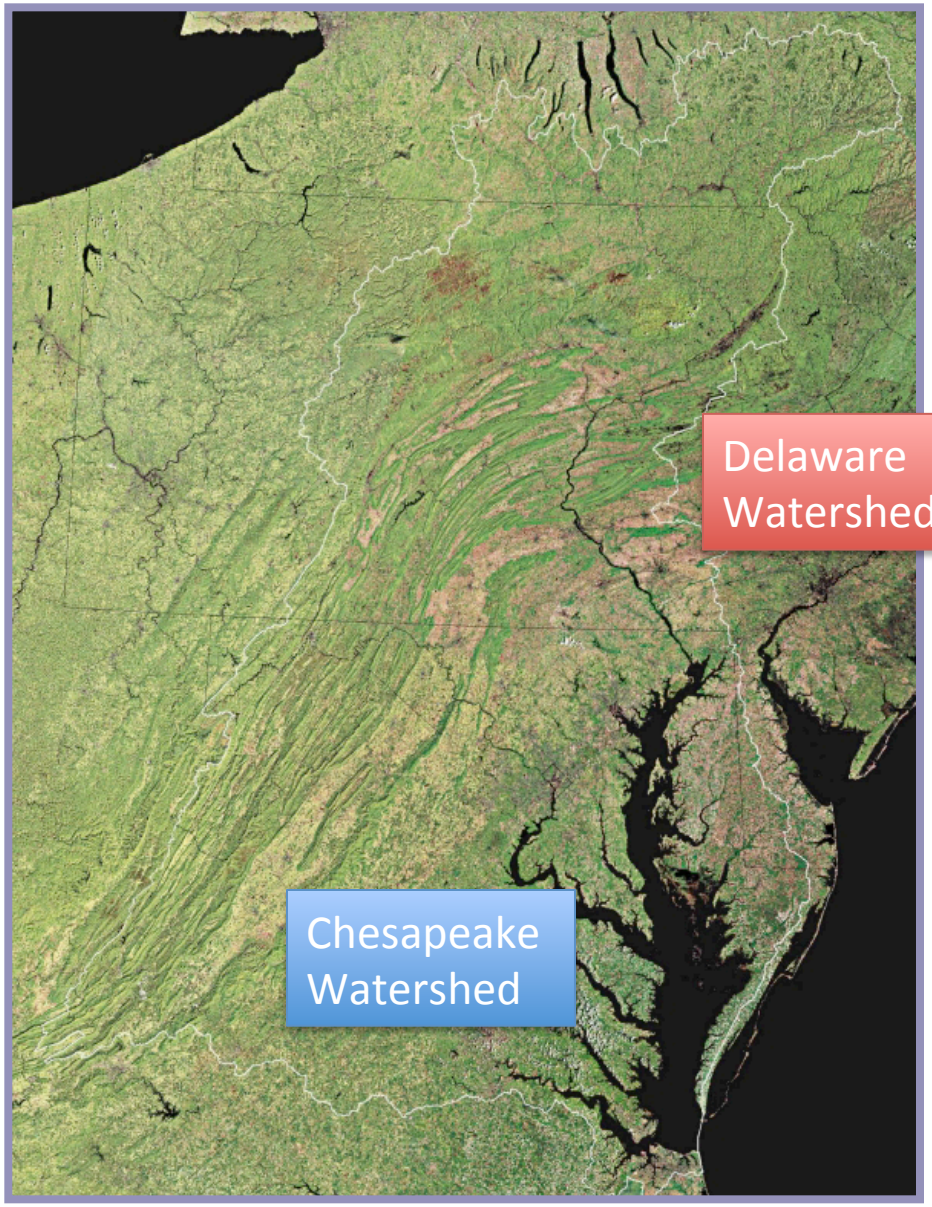
2000 years of Hydrologic Variability in the Eastern US

- Eastern US climate exhibits centennial and multi-decadal variability
- Medieval climate 600-1200: warmer, drier
- Little Ice Age 1400-1850 was cool, wet
- 20th century: more variable precipitation
- Future hydrologic extremes expected to affect Chesapeake Watershed and Bay

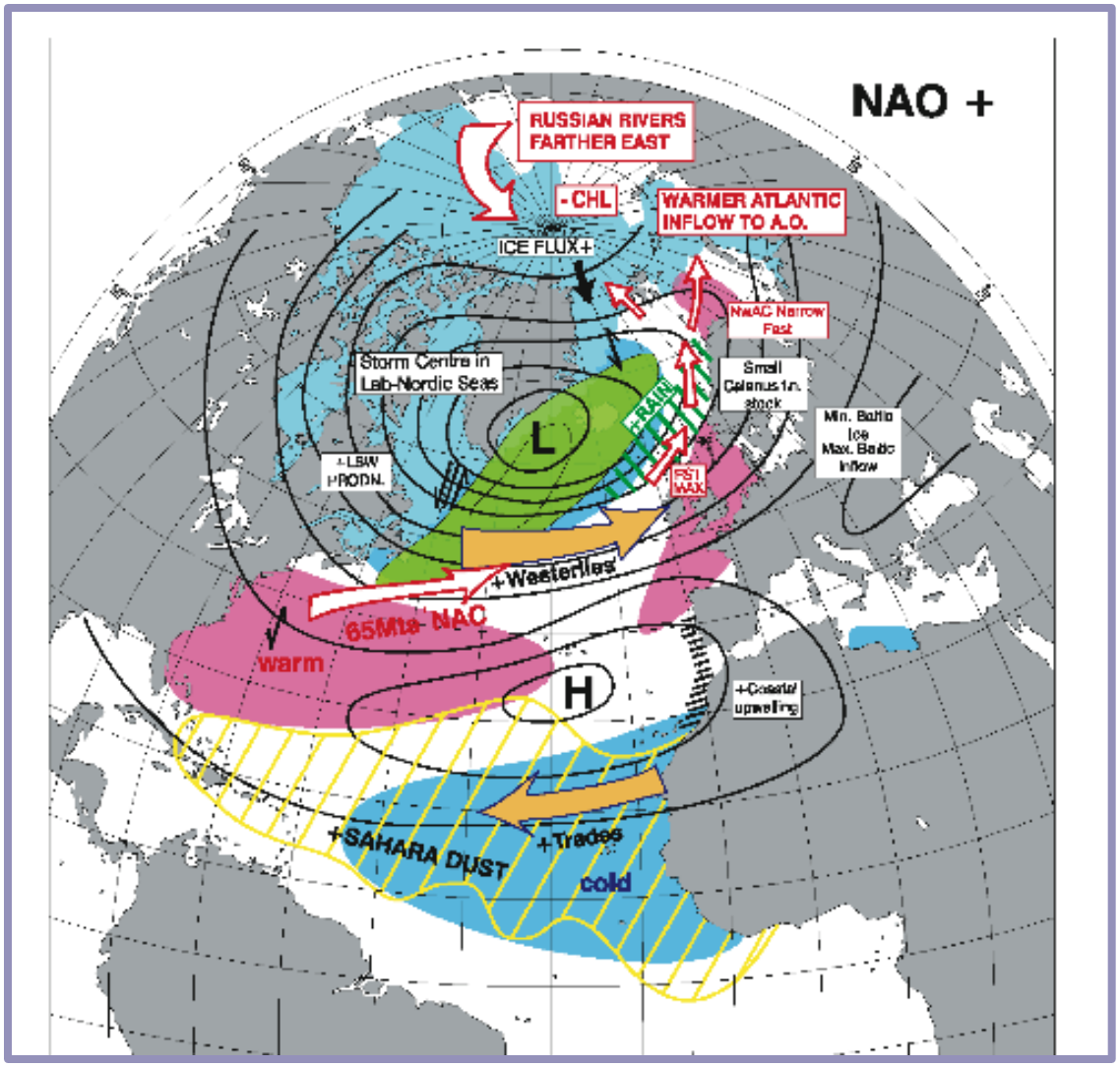
1999 & 2003 Long Sediment Coring on *Marion-Dufresne*




77°0'0"W
76°30'0"W
76°0'0"W
39°0'0"N
38°0'0"N
37°0'0"N
Washington, D.C.
0 3 6 12 18 24
Kilometers
Cruise
Kerhin 1996
Pocomoke 2001
Potomac 2002
SONE 1995
Vogt 2006


Delaware
Watershed
Chesapeake
Watershed

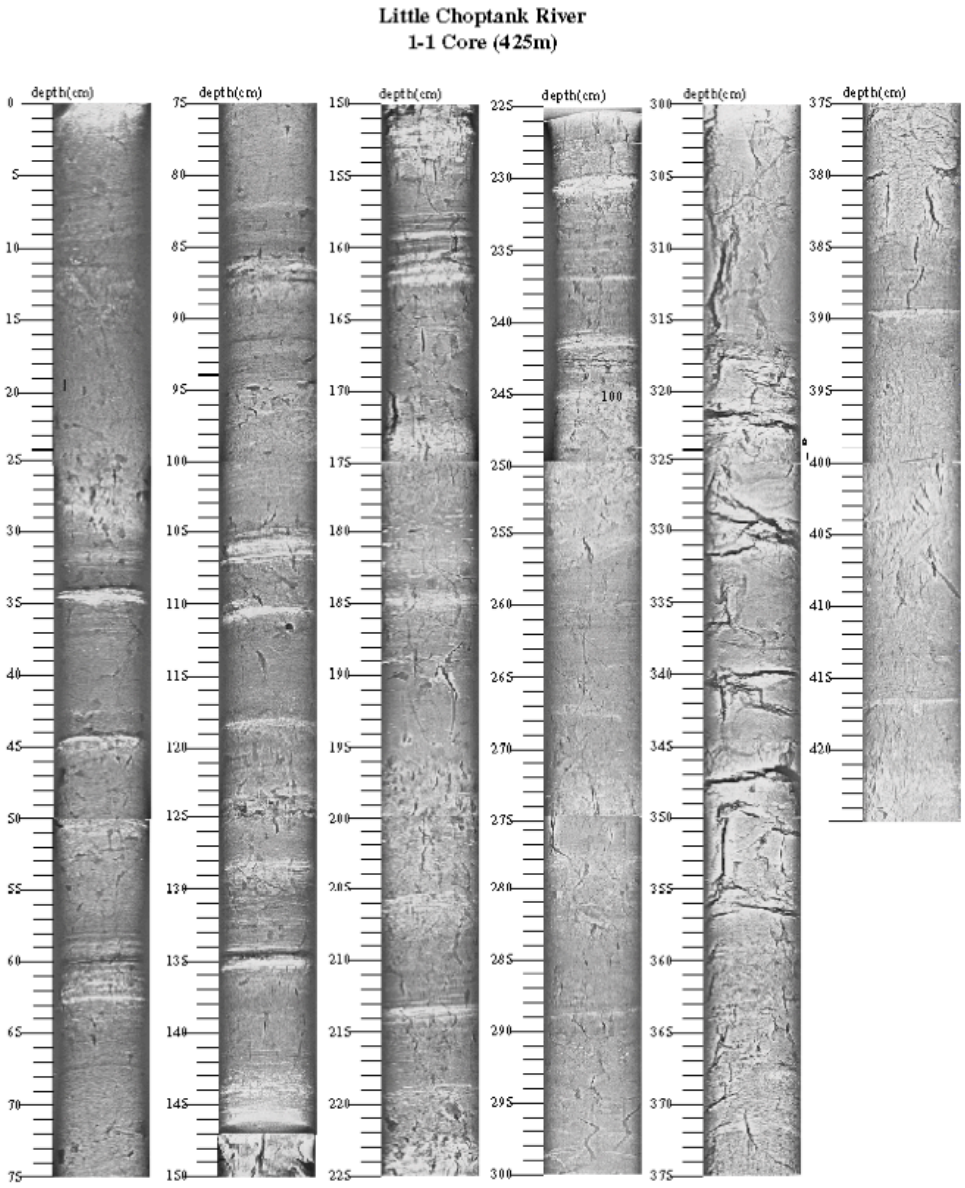
North Atlantic Oscillation Affects East Coast Precipitation



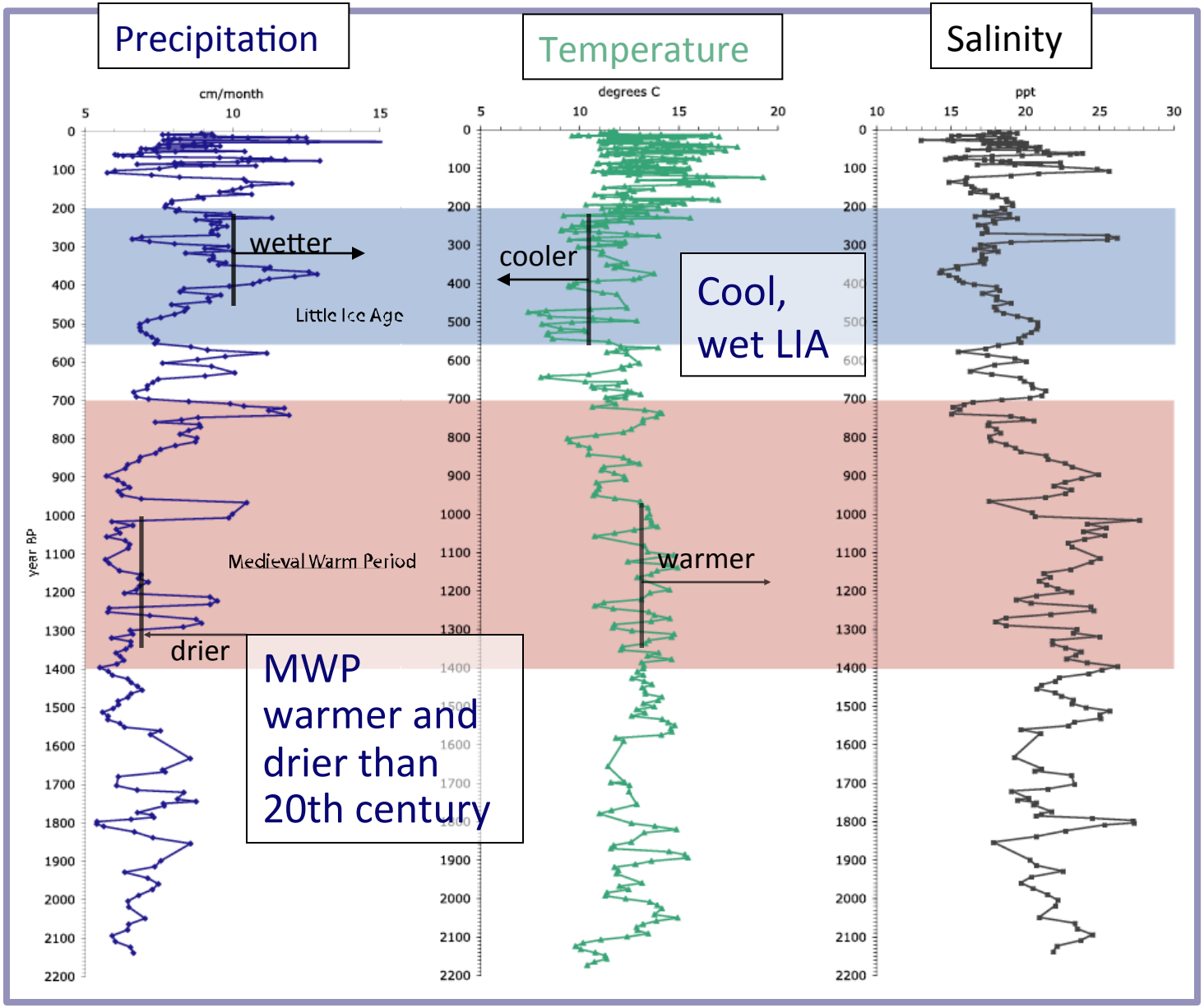
Hurrell and Dickson, 2003

- Strengthened westerlies across the Atlantic
- Positive temperature anomalies over western subtropical Atlantic
- Northeastward shifted storm center

Sediment Records Provide High-Resolution Records of Hydrological Variability and Sea level



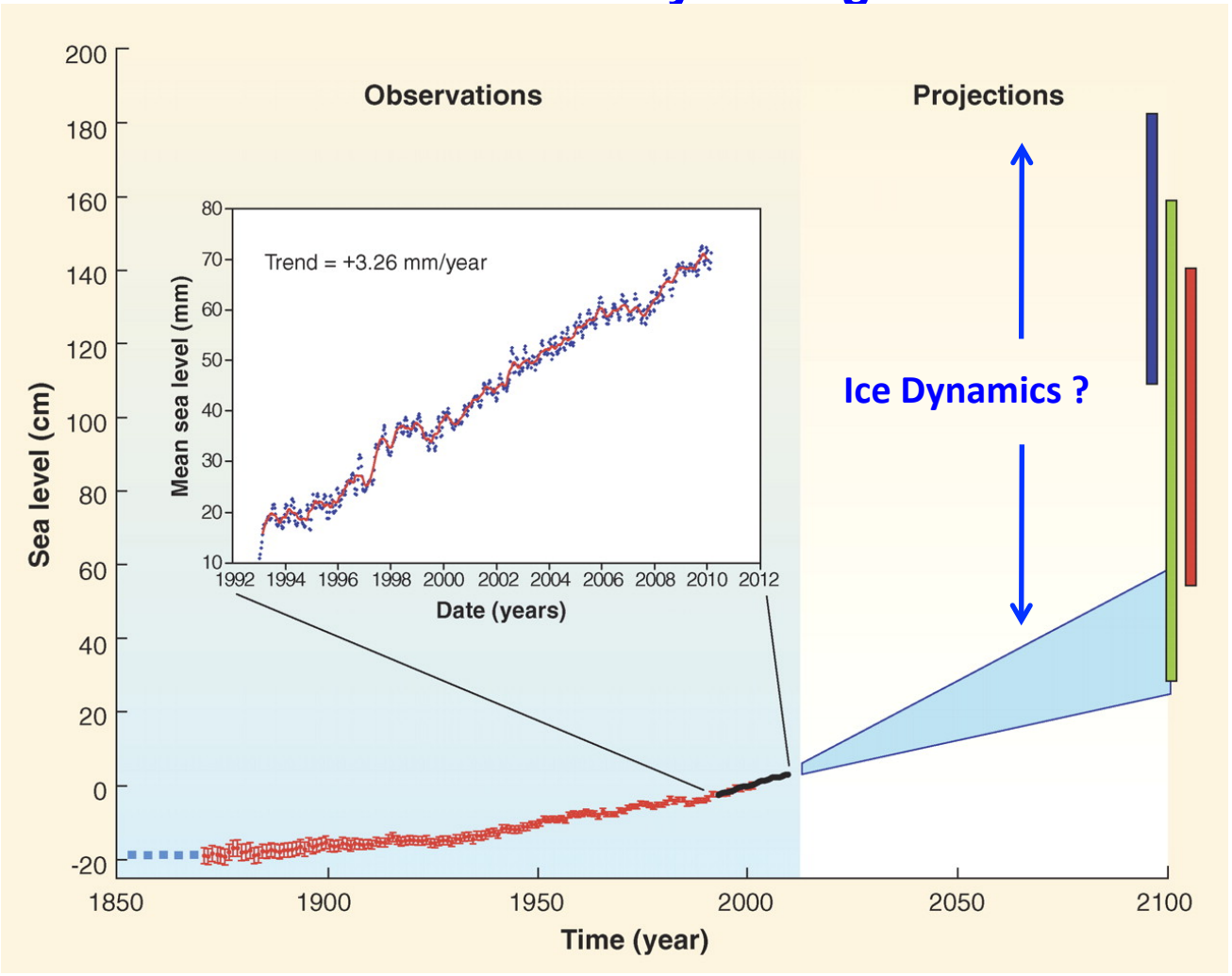
2000-Year Rainfall and Temperature Records,Eastern US



Multi-decadal variability-Droughts

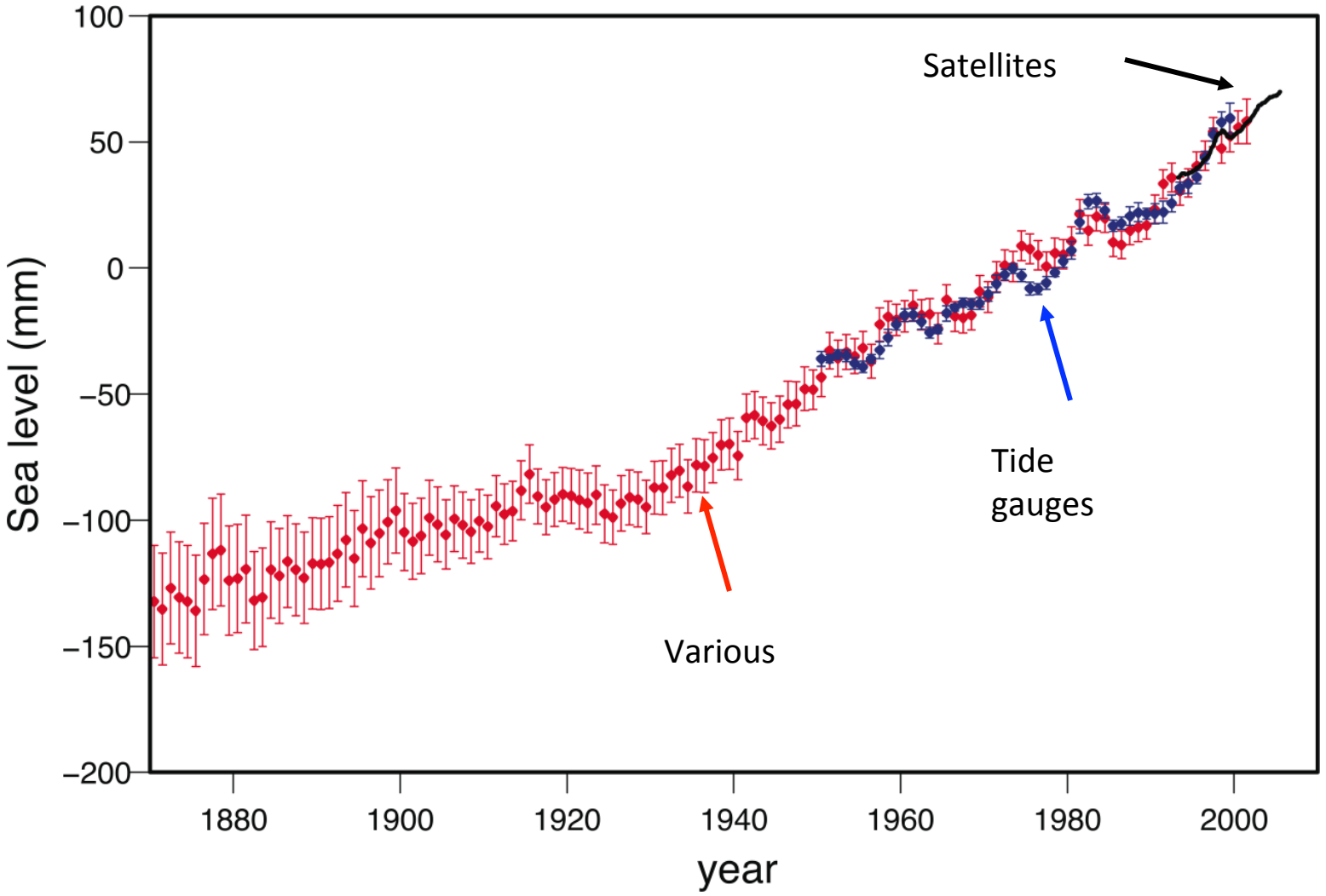
Cronin et al. 2003, 2006, 2010; Saenger et al. 2006, 2008

Future Rates of SL Rise Far exceeds Estimates of 5 years ago



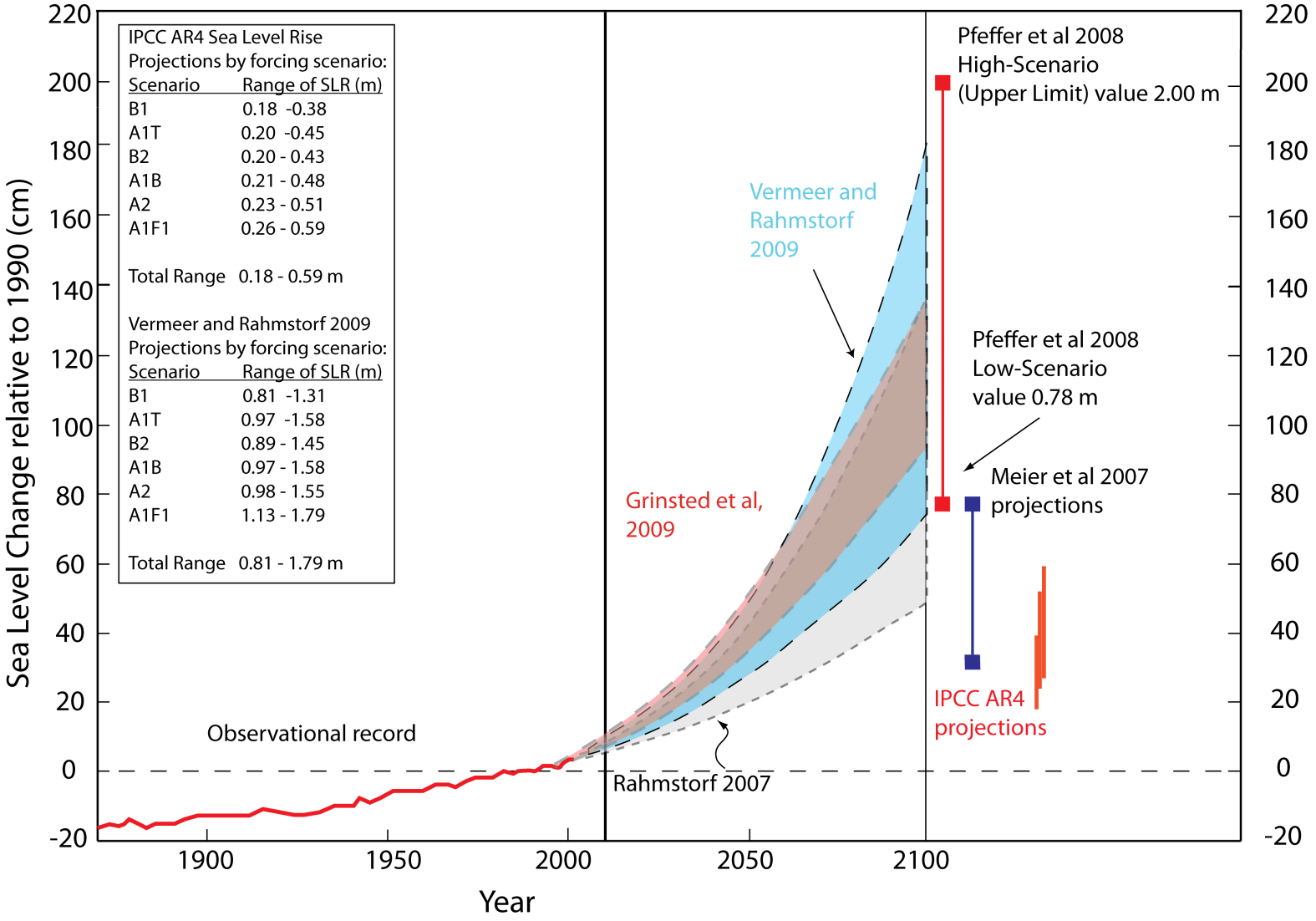
Science
AAAS

R J Nicholls, A Cazenave Science 2010;328:1517-1520



IPCC: Figure 5.13. *Annual averages of the global mean sea level (mm). Red curve shows reconstructed sea level fields since 1870 (from Church and White, 2006); blue curve shows coastal tide gauge measurements since 1950 (from Holgate and Woodworth, 2004) and black curve based on satellite altimetry (Leuliette et al., 2004). Red and blue curves are deviations from averages for 1961 to 1990, and black curve is deviation from average of the red curve for the period 1993 to 2001. Error bars = 90% confidence intervals.*

Projecting Future Sea Level Rise: Post-AR4, Pre-AR5



Various projections: SLR to 2100, as of ca. 2009