SYNTHESIS OF ATLANTIC SST PROXY RECORDS DURING THE PAST 2000 YEARS

POTENTIAL LINKS TO AMOC VARIABILITY

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PAGES/Ocean2K working group: over 75 volunteers contributed

PAGES

Ocean 2k metadatabase of marine paleoclimate proxies

- www.pages-igbp.org/workinggroups/ocean2k/metadatabase

- Selection criteria
  - Only marine archives
  - Published in peer-reviewed journals
  - Present in publicly available data repositories
  - Span a portion of the last two millennia
    - 14C date or tephra
    - Undisturbed coretop sediment (multicore or pilot core)
  - Minimum average sample resolution of 1 every 200 years

Goal: Investigate SST variability and uncertainty over the past 2000 years and compare with realistically forced AOGCMs

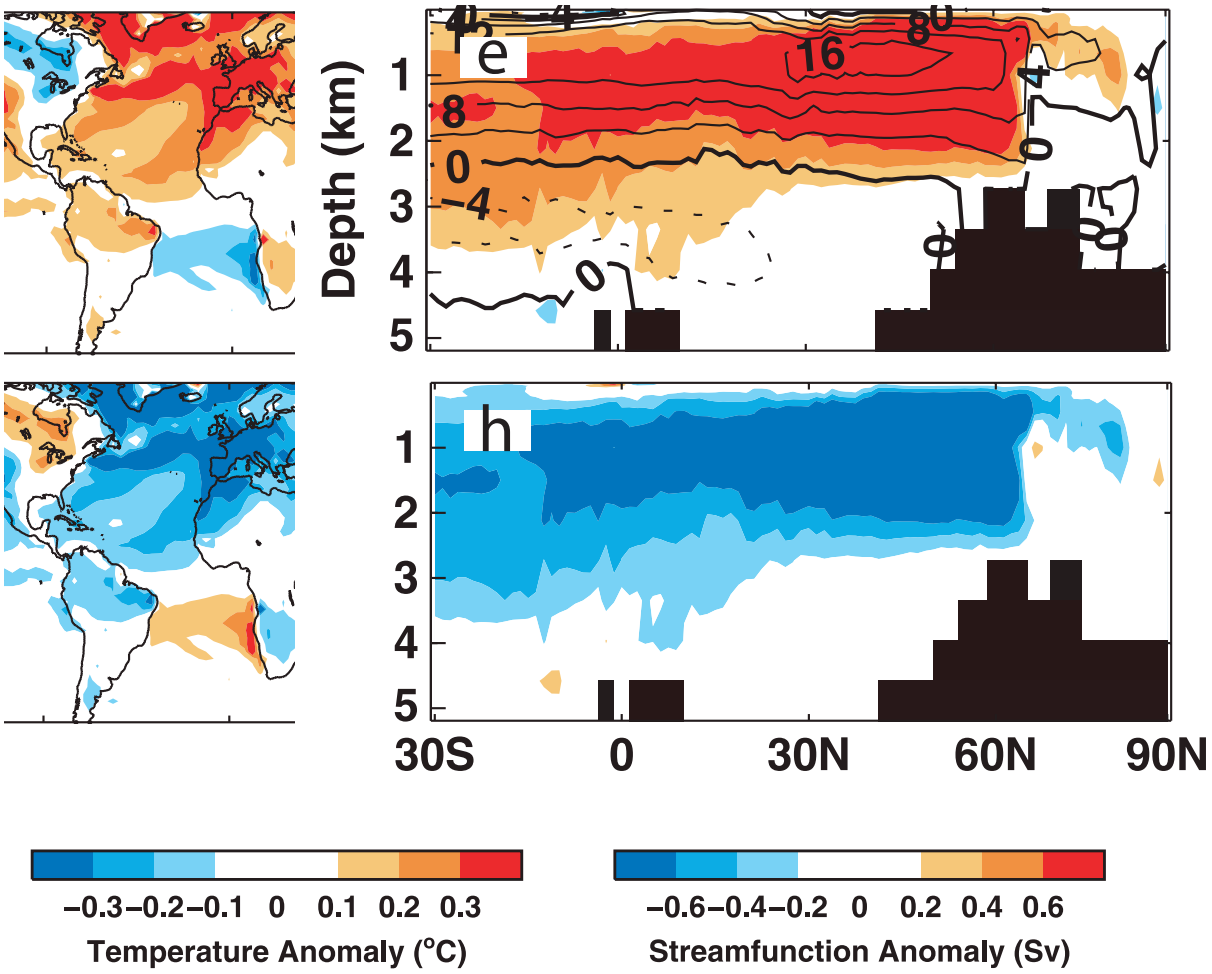
High and low resolution Atlantic proxies

- Low resolution:
  - Decadal-centennial resolution
  - Sedimentary records
    - Primarily Mg/Ca, alkenone Uk37, faunal assemblages
    - N=42 in the Atlantic (North Atlantic n=40; South Atlantic n=2)

- High resolution:
  - Monthly-annual resolution
  - Coral and sclerosponge records
    - Primarily Sr/Ca, $\delta^{18}O$, growth rate
    - N=25 in the Atlantic (primarily Caribbean

High Resolution SST proxies

What is the fingerprint of AMOC variability?



HadCM3 1400 year control run

Strong AMOC:

- Warm N. Atl
- Cool S. Atl

Weak AMOC

- Cool N. Atl
- Warm S. Atl

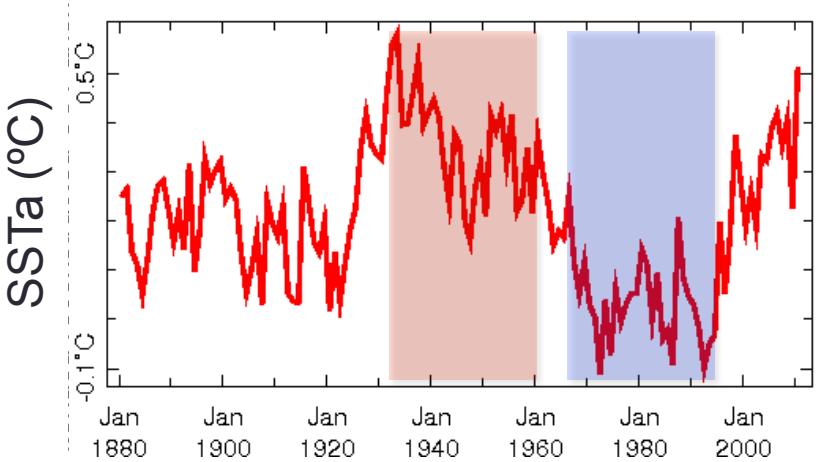
Knight et al. 2005

High Resolution SST proxies

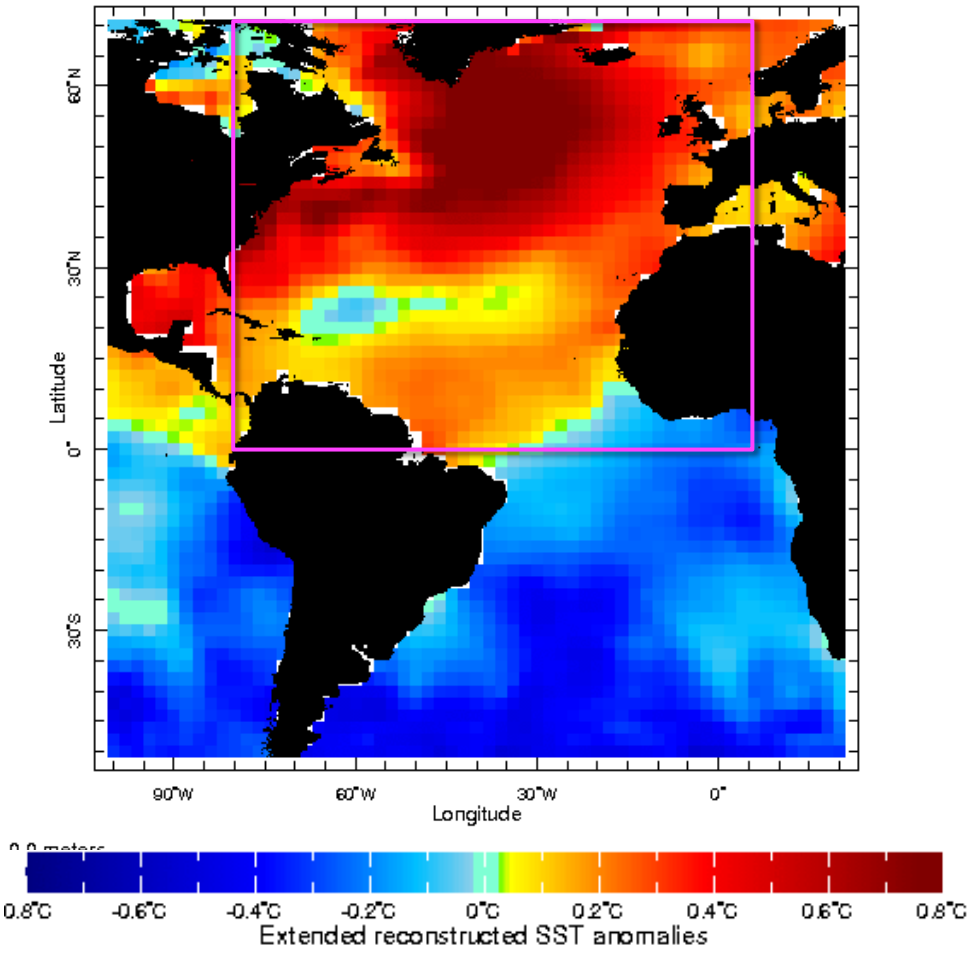
What is the fingerprint of AMOC variability?

- Atlantic Multidecal Variability shows similar dipole pattern
- Strongest response in the subpolar gyre

Warm N. Atl proxy SST may reflect enhanced multidecadal AMOC

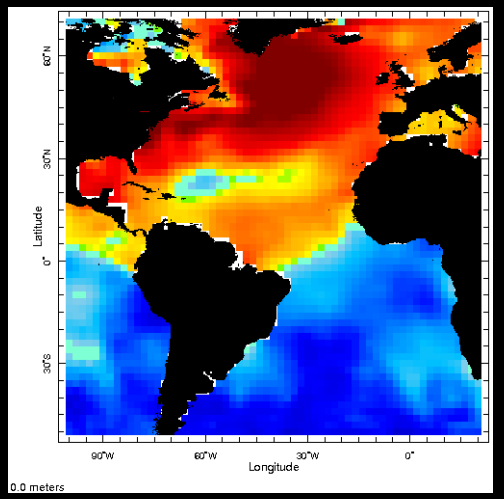


ERSST v3b SSTa AMO+ minus AMO-



Distribution of High Resolution Proxy Records in the Metadatabase

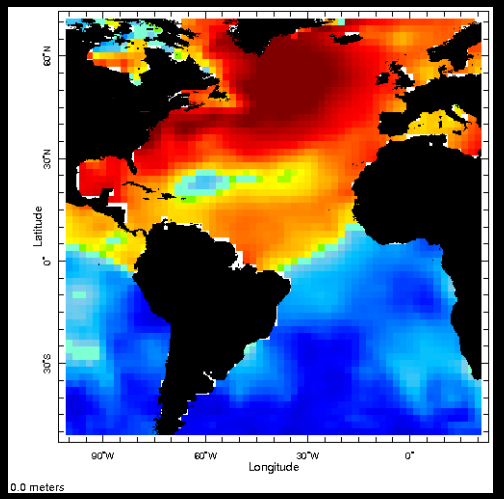
Total n=25
E. Caribbean n =8
W. Caribbean n =2
Florida n =2
Bahamas n=3
Bermuda n =6
East Atlantic n =3
Maine n=1



Challenges:

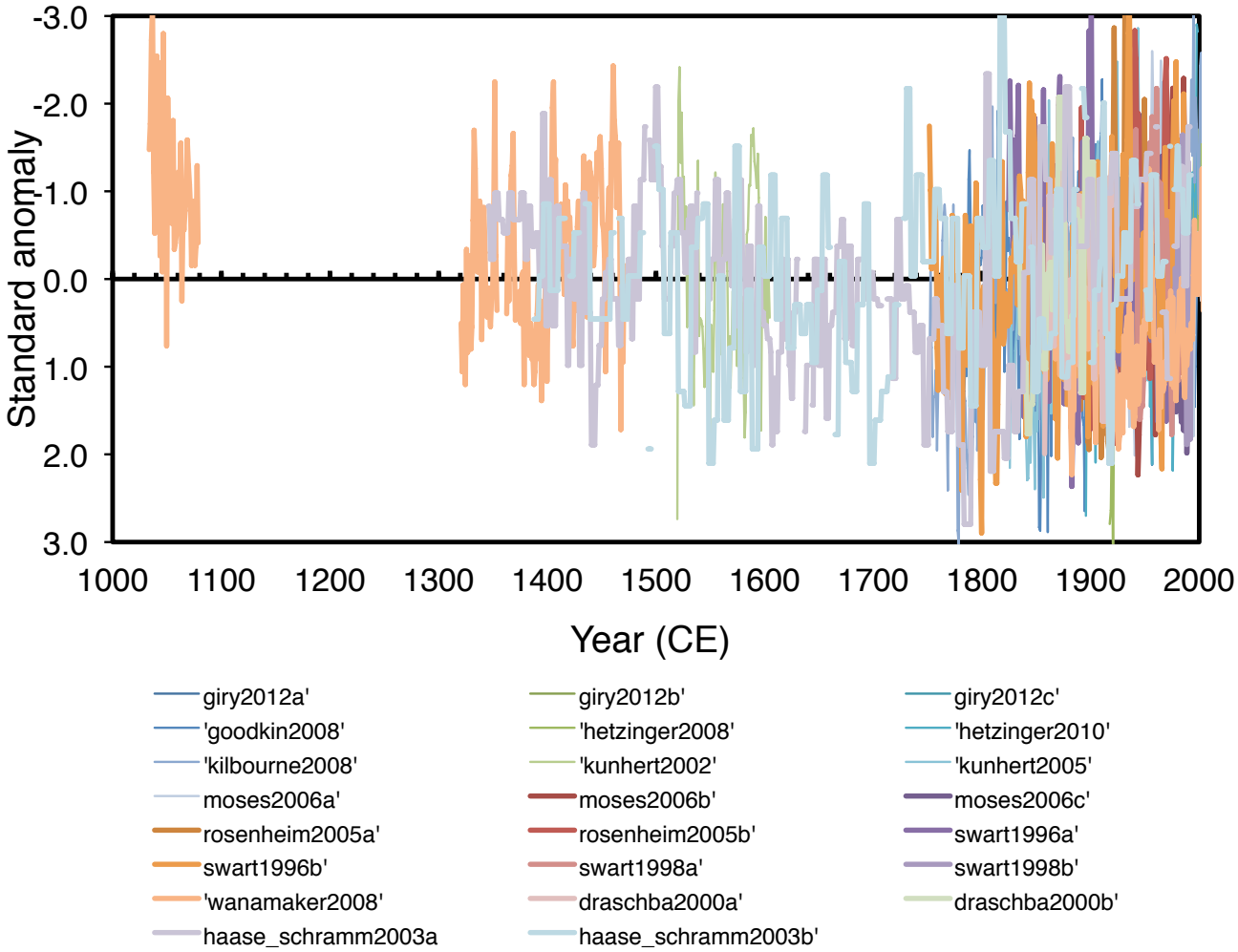
Limited to low latitude
North Atlantic

No Southern Hemisphere
No subpolar gyre



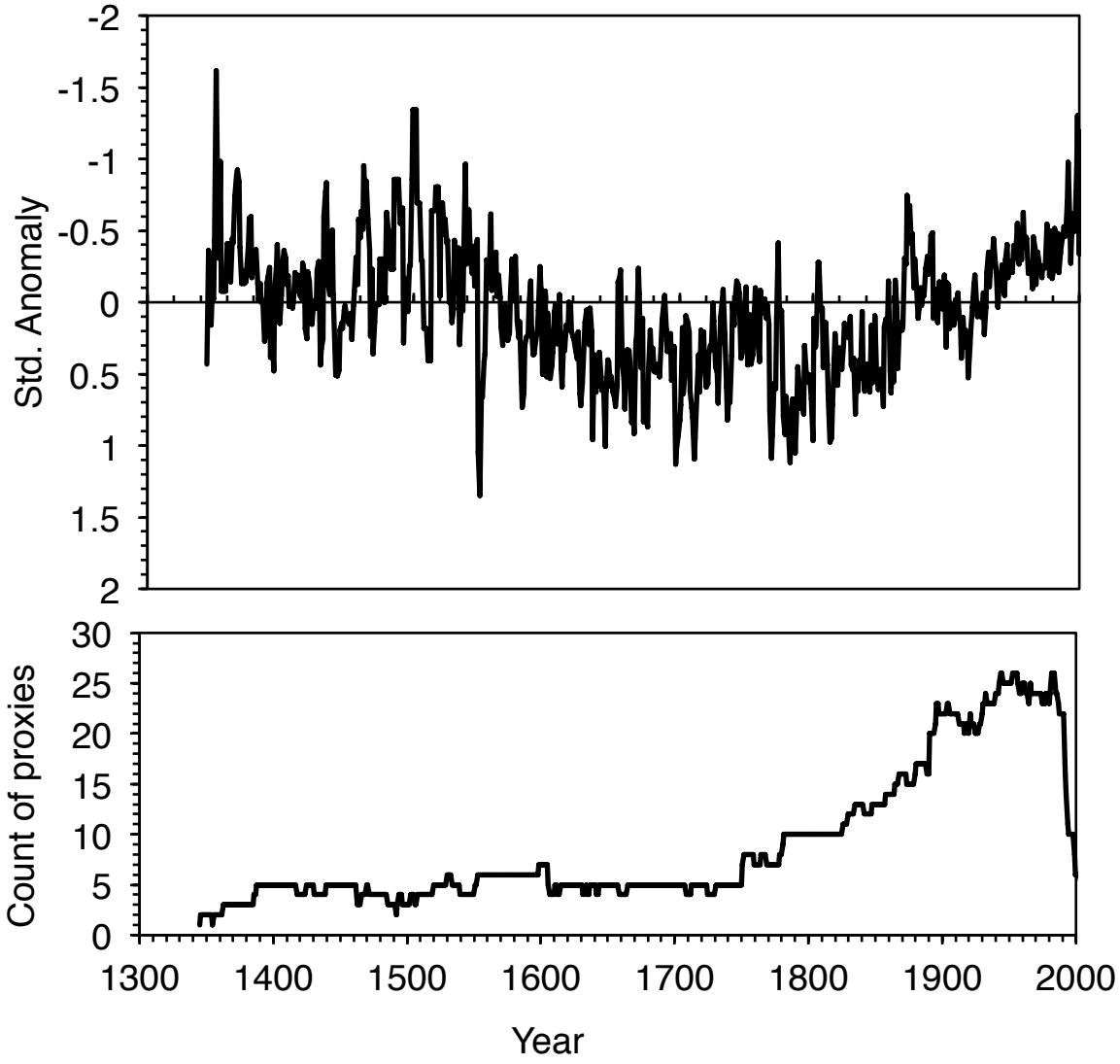
All High Resolution proxy records

Reduce high res data to annual and normalize



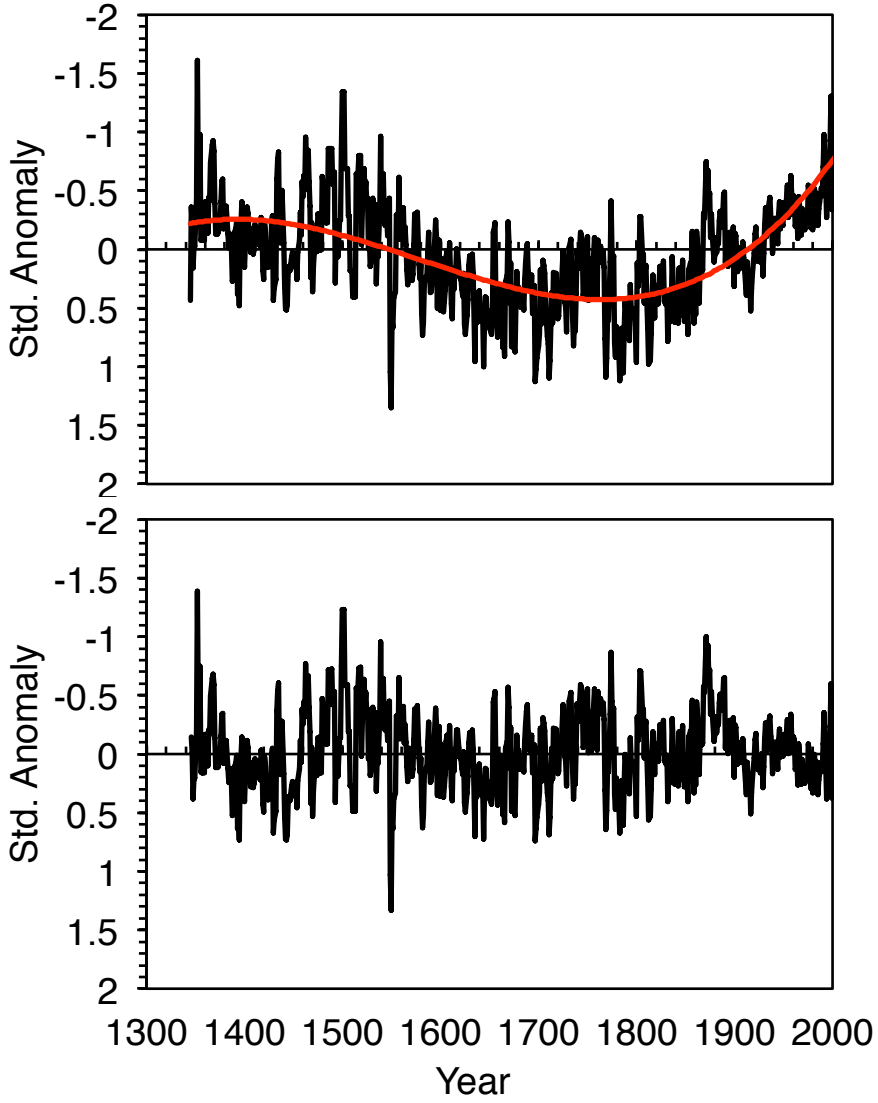
Composite of High Res records

- Compute annual averages of normalized data
- Include only years with at least 2 records
- Coolest SST 1600-1800 C.E.
- Hints of AMO-like variability

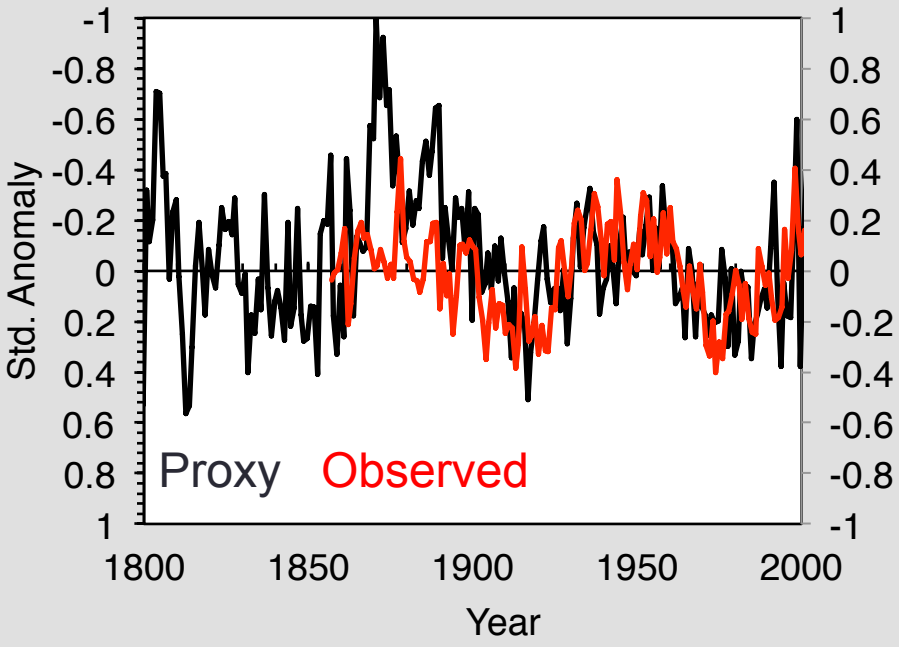


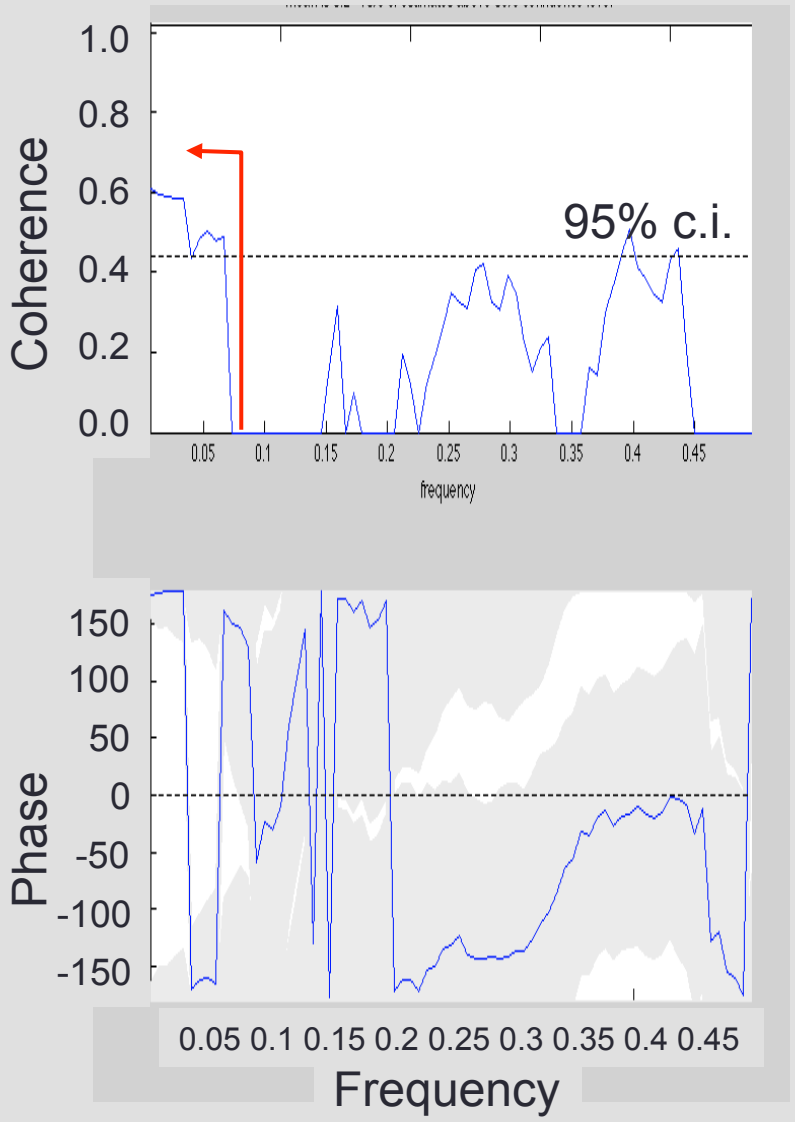
Multidecadal variability in proxies

- Construct proxy-based AMO index
- Assume (for now) that externally-forced SST follows 3rd order polynomial and remove this trend



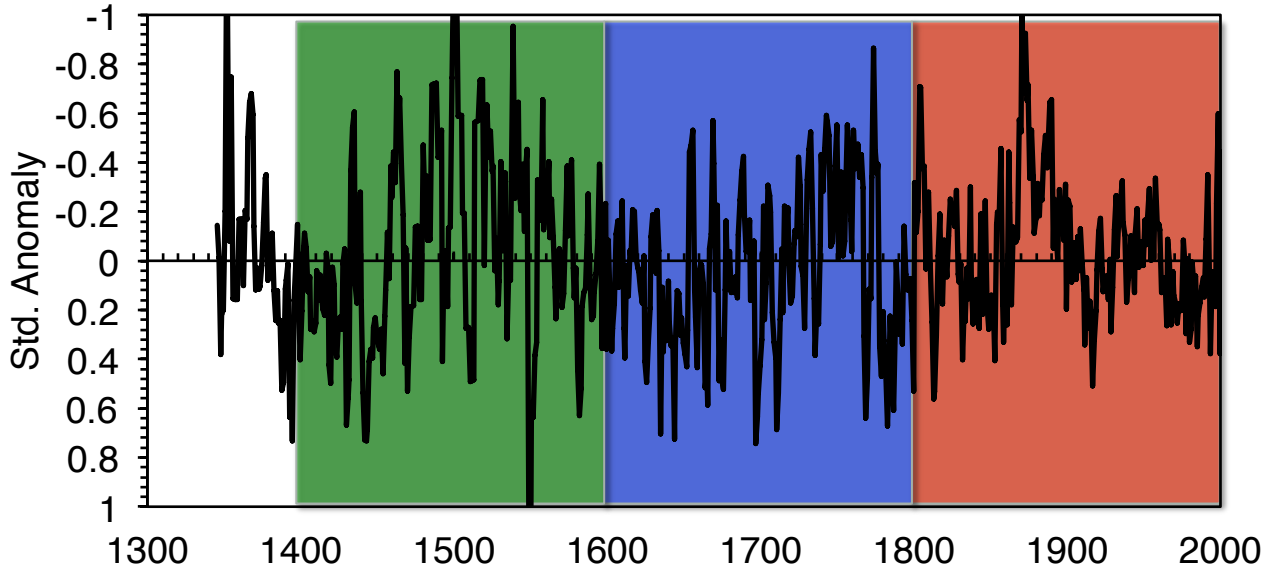
Proxy-based AMO

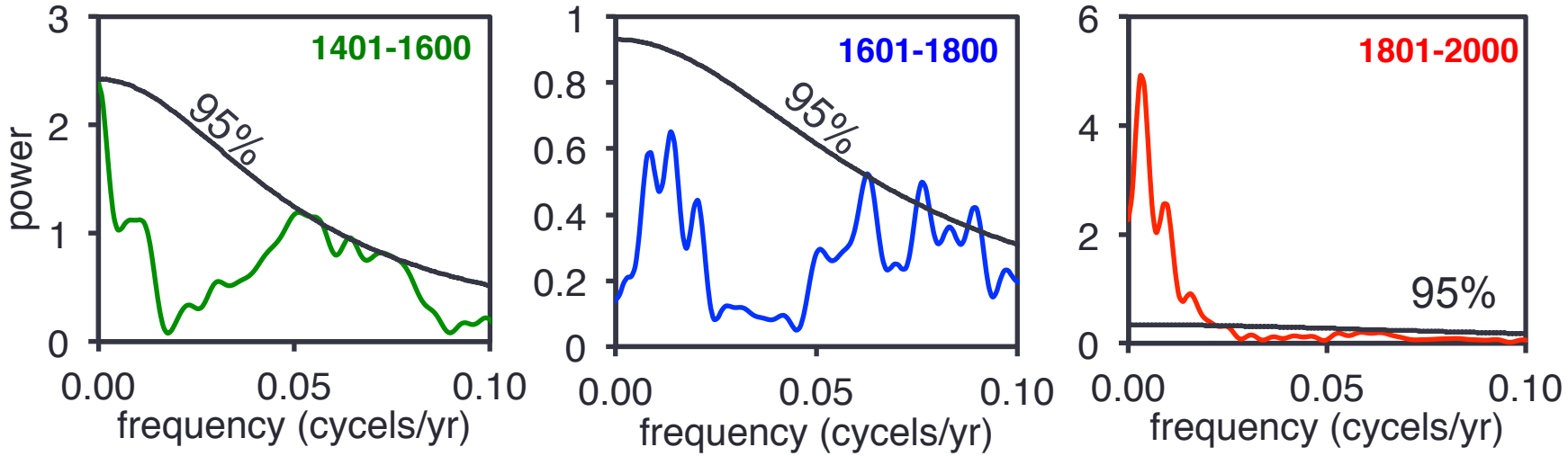




- Significantly coherent and 180º out of phase at periods > ~15 years
- Proxy index may be representative of Atlantic Multidecadal Variability

Spectral analysis





Low Resolution SST proxies

What is the fingerprint of AMOC variability?

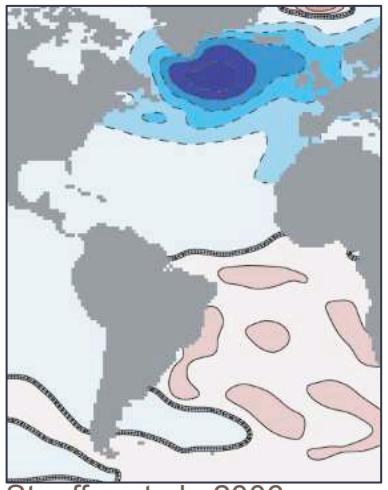
Hosing experiments:

- similar SST responses to AMOC weakening amongst models
  - Hemispheric dipole
  - Strong subpolar gyre response

Caveat:

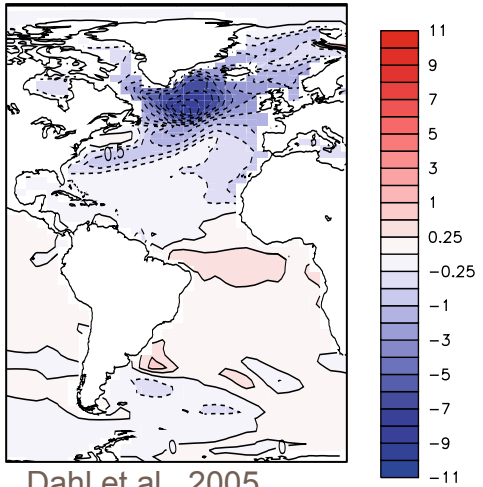
- "Hosing" is unlikely to be the primary forcing of AMOC on the multi-century timescales of proxy records

14 model mean



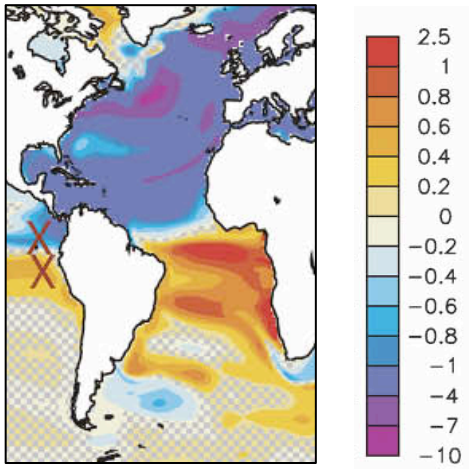
Stouffer et al., 2006

GFDL R30c



Dahl et al., 2005

GFDL CM 2.0

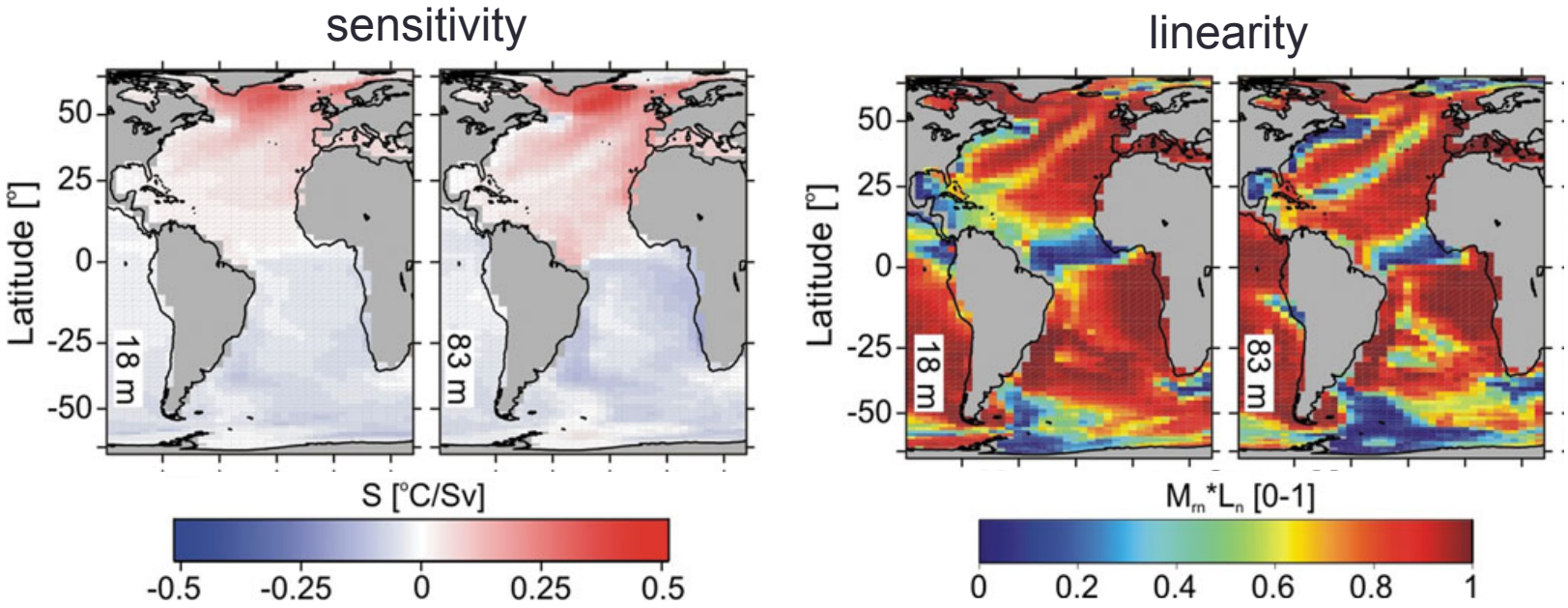


Zhang and Delworth, 2005

SST response to AMOC shutdown

Fingerprinting of the Atlantic meridional overturning circulation in climate models to aid in the design of proxy investigations

David Heslop · André Paul



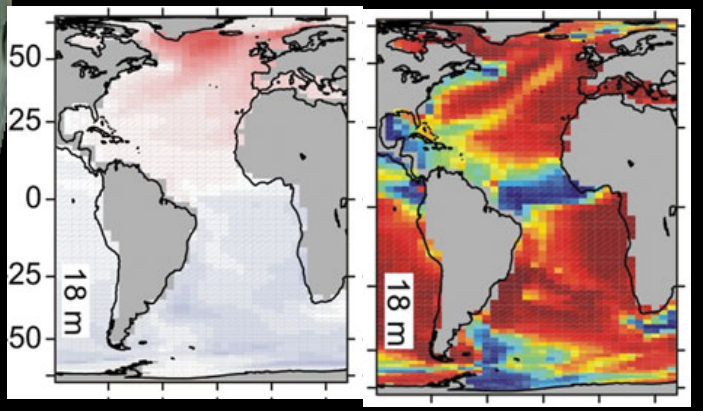
Hemispheric dipole pattern

Sensitive and stable: Subpolar N. Atlantic, Eastern S. Atlantic

Less sensitive and stable: Deep tropics, Caribbean/GOM, Western Boundary

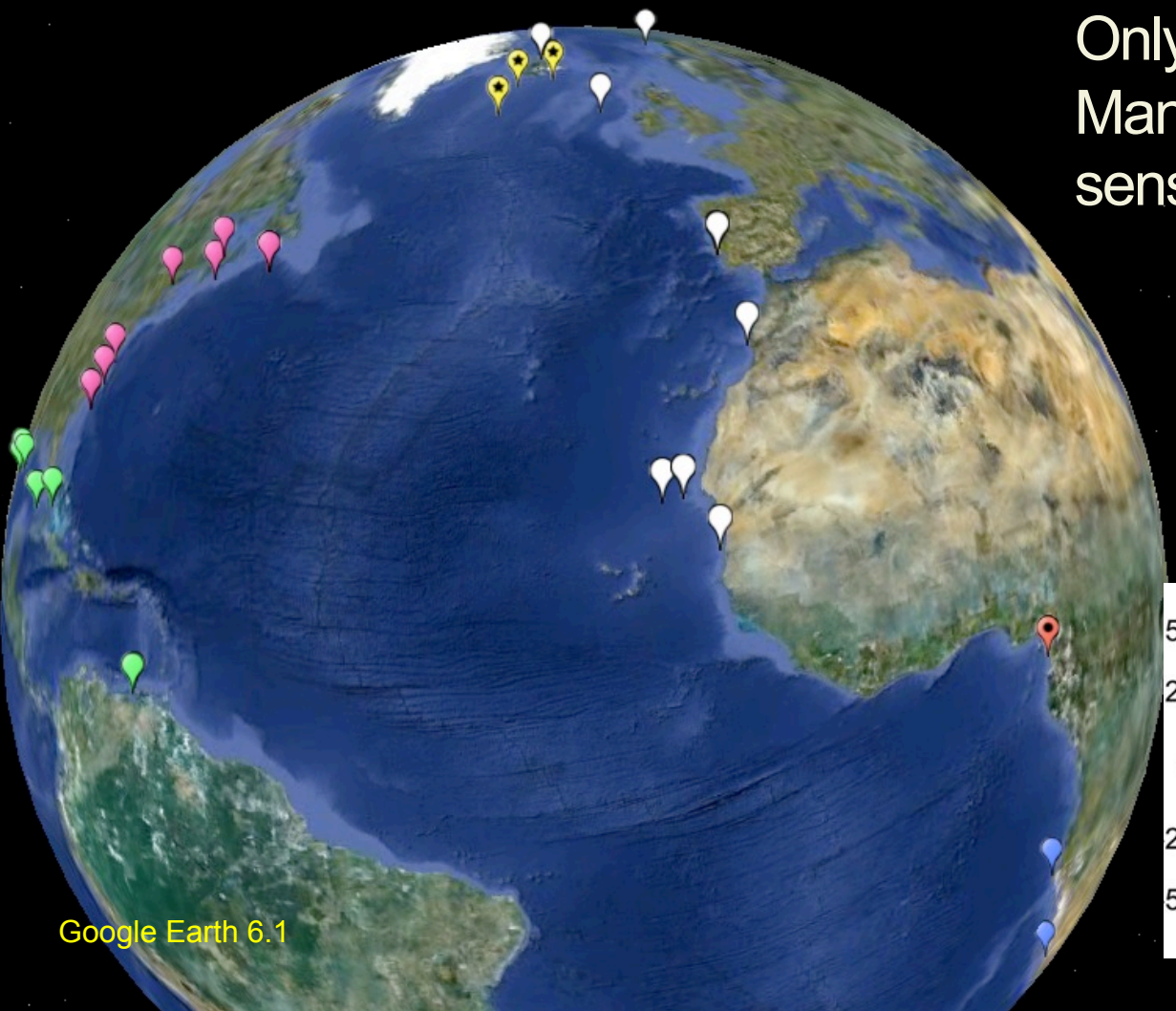
Low resolution proxy records

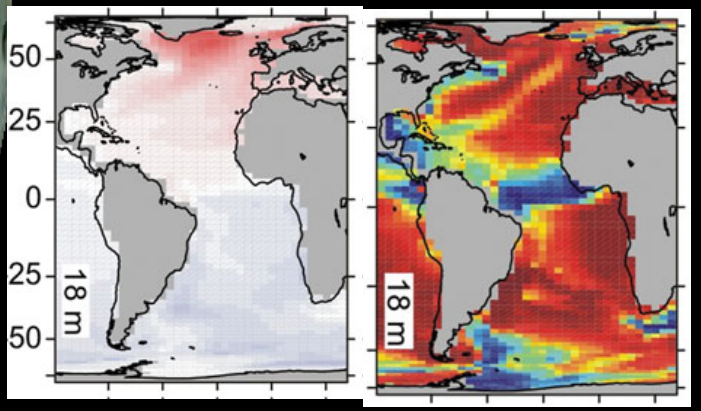
Total n = 42
S. Atl n = 2
Deep tropics n = 2
Carib/GOM n = 9
W. Bndry n = 9
Subpolar gyre n =5



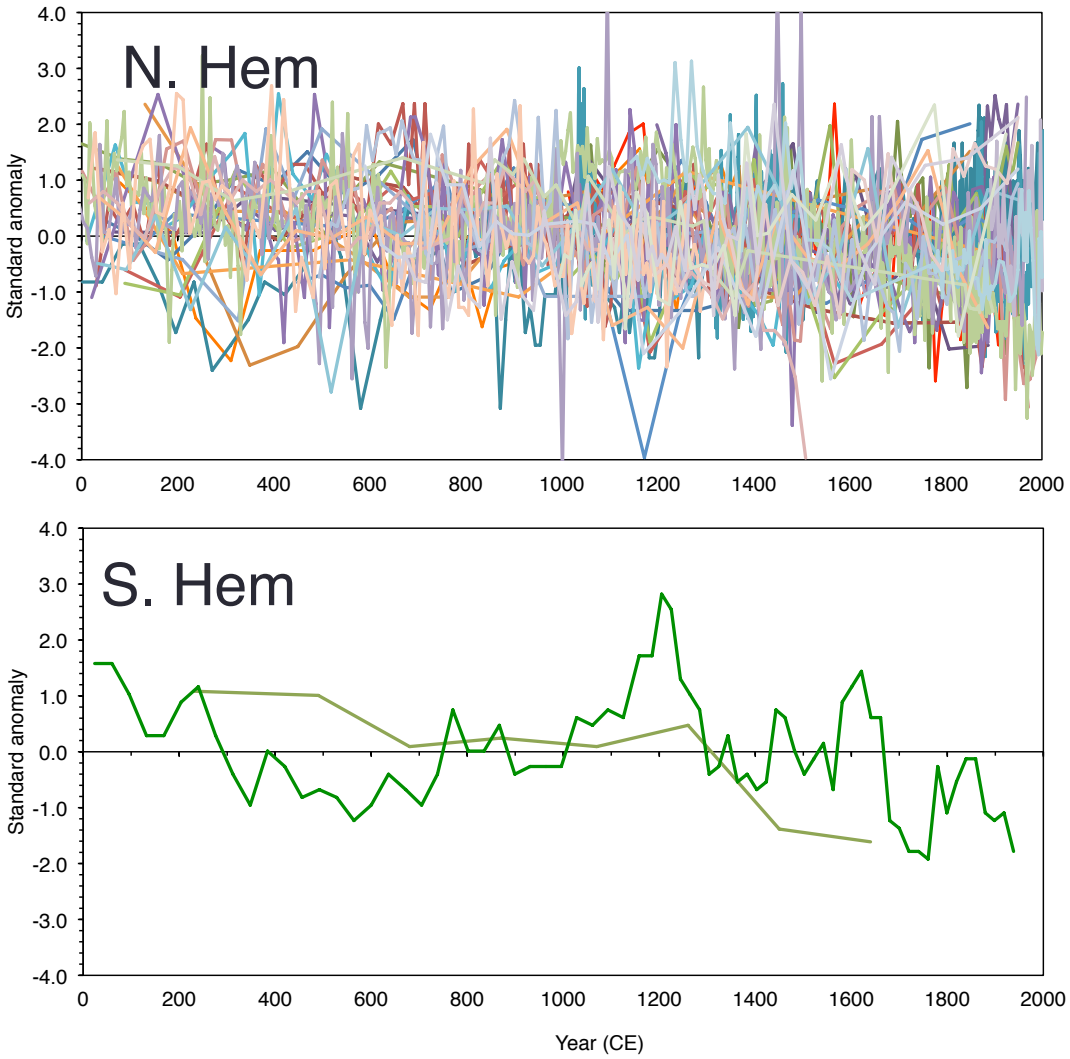
Challenges:

- Coastal bias
- Only 2 S. Hemisphere
- Many records from less sensitive/stable regions





All Low Res. Proxy Records



Dipole pattern in proxy records?

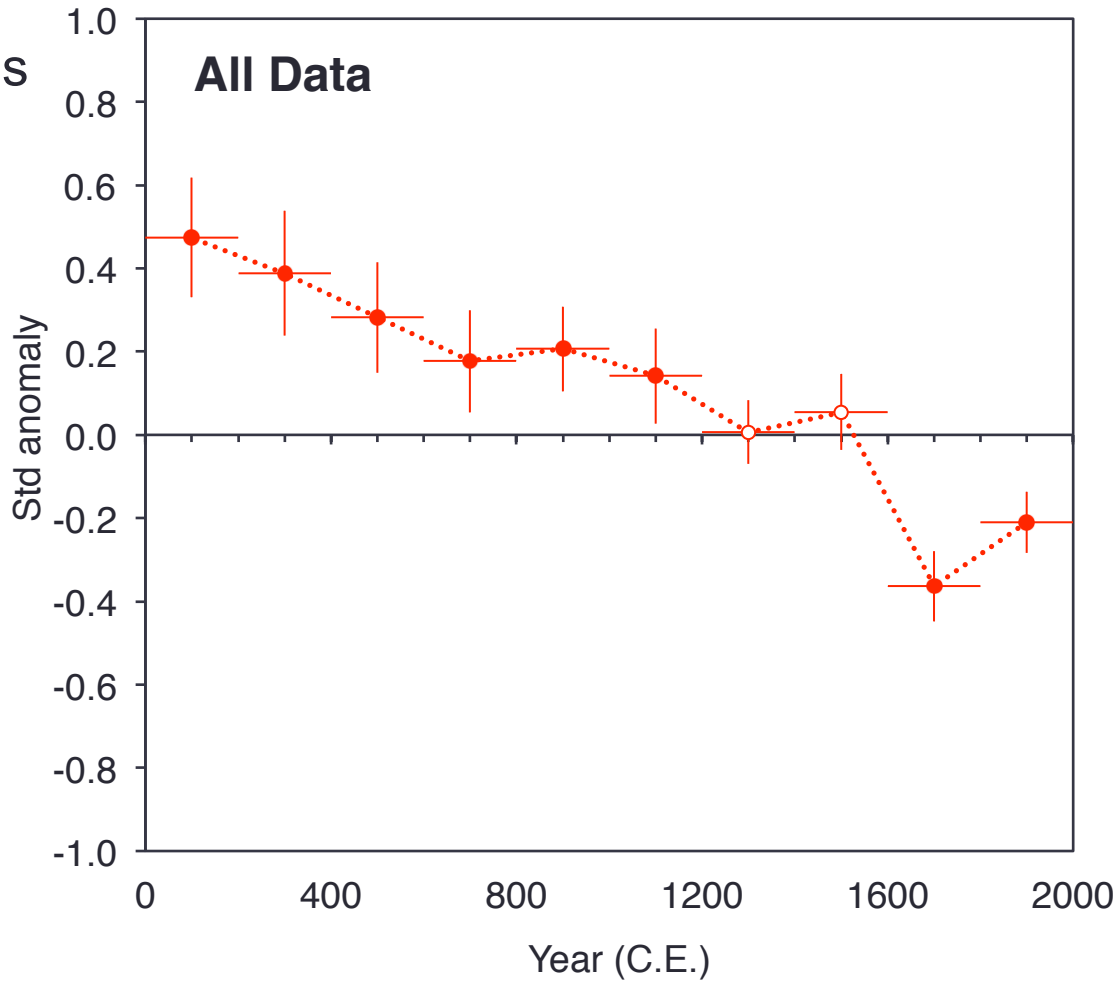
- Dipole index:
  - Normalize proxy records
  - Multiply South Atlantic records by -1
  - Bin every 200 years
  - Evaluate if each bin has mean = 0
  - Error bars are 2 std errors about each bin mean

Dipole pattern in proxy records?

- Dipole index:
  - Normalize proxy records
  - Multiply South Atlantic records by -1
  - Bin every 200 years

42 records, 3632 points

1900: 793
1700: 455
1500: 524
1300: 545
1100: 349
900: 265
700: 215
500: 188
300: 155
100: 143

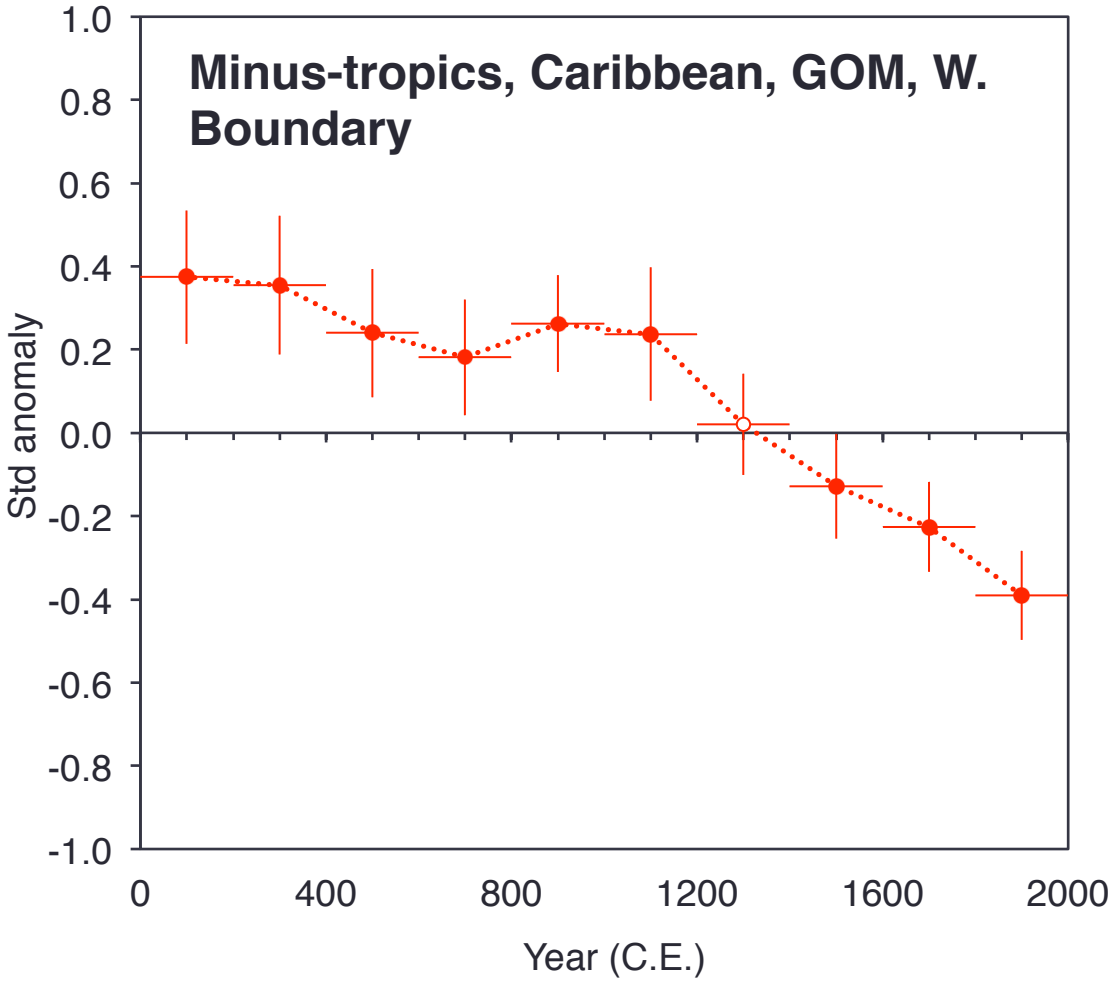


Dipole in most sensitive regions

- Dipole index:
  - Remove deep tropics
  - Remove Carib/GOM
  - Remove Wtrn Bndry

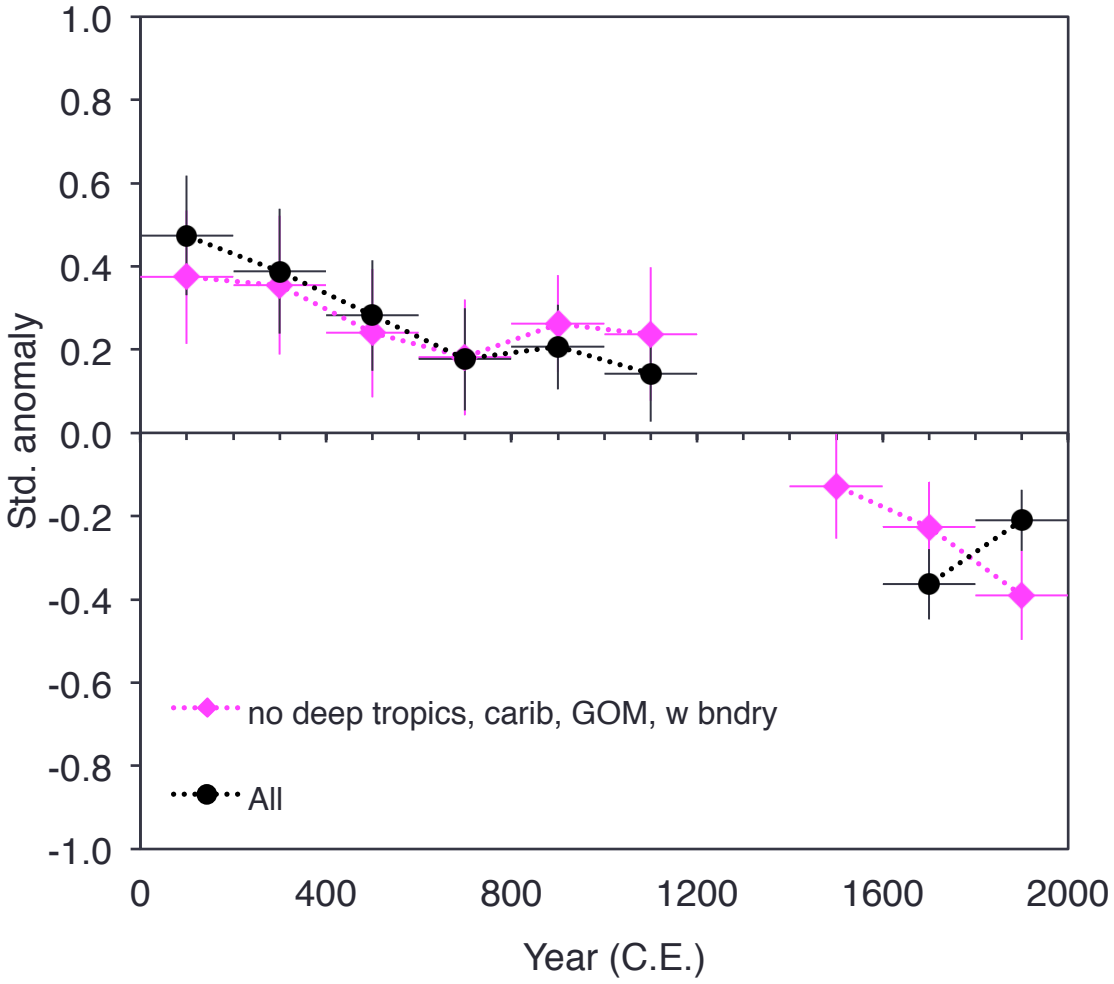
22 records, 2048 points

1900: 400
1700: 248
1500: 254
1300: 249
1100: 199
900: 186
700: 141
500: 136
300: 124
100: 111



Summary of low resolution SST

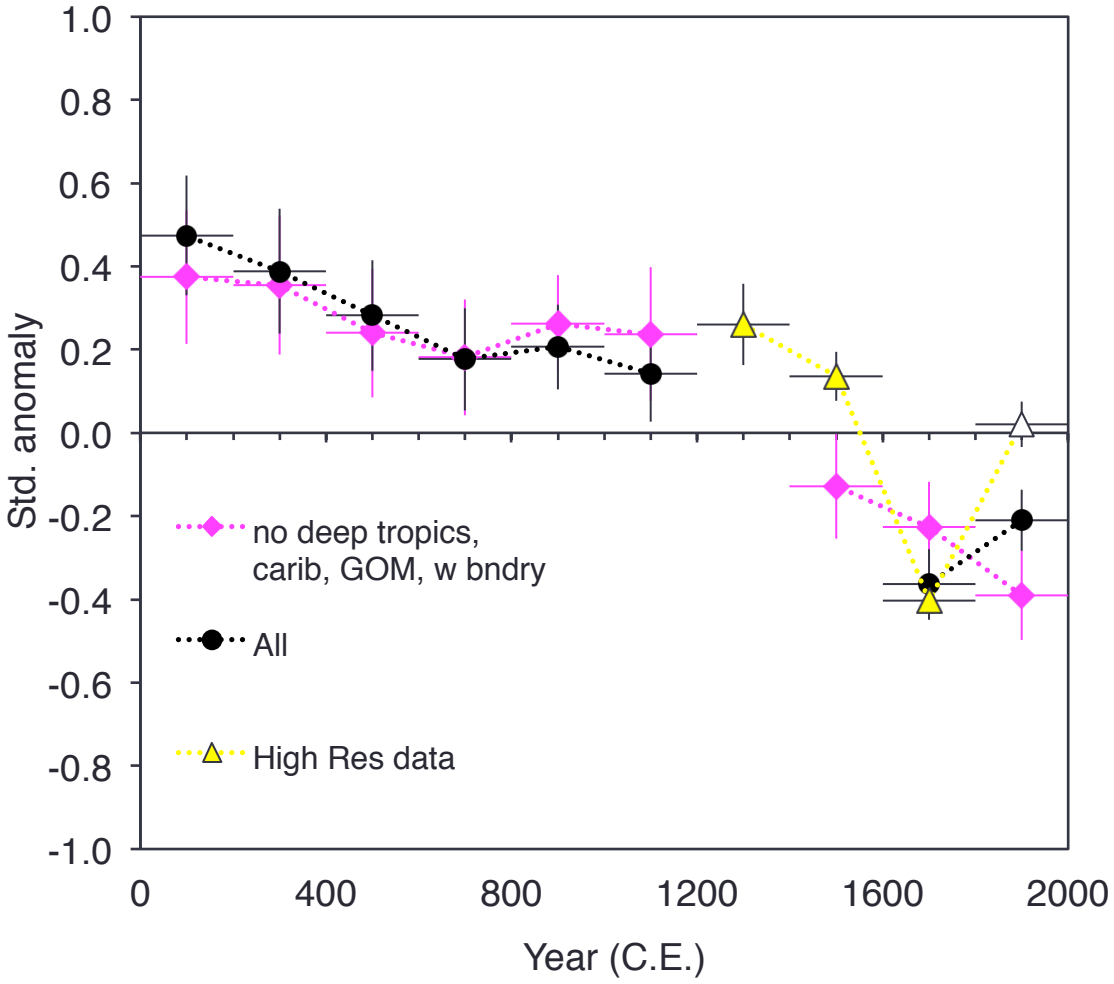
- SST proxies show cooling through much of the past 2k
- Interpreted only in terms of AMOC, circulation may have been weakest in recent centuries
- More well dated records needed 1200-1600 CE



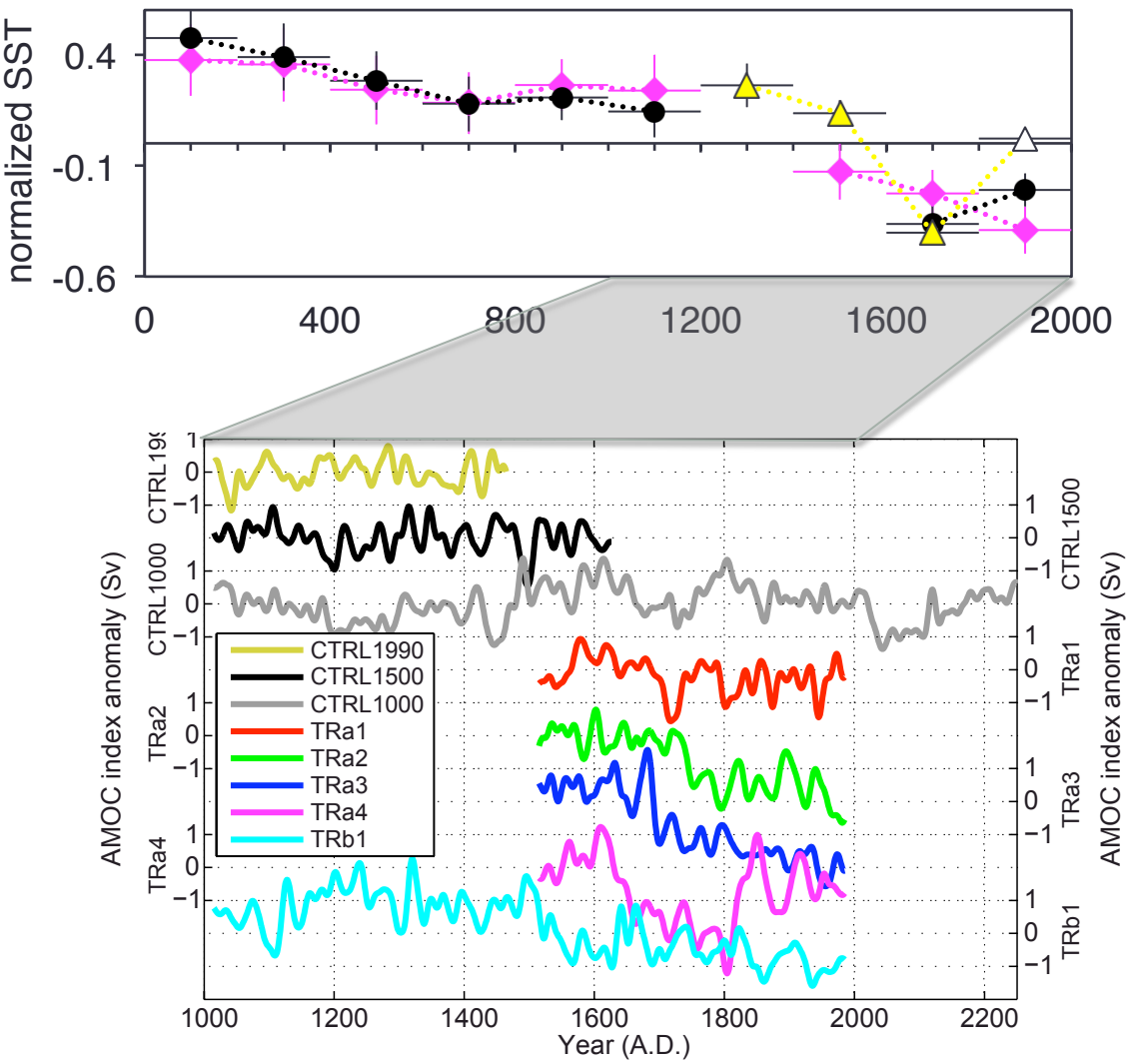
Add High Resolution Data

- Normalized high res data
- Multiply all by -1 (Sr/Ca and $\delta^{18}O$ are inversely related to SST)
- Bin in the same way as low resolution data

- Supports weakening AMOC during past 2 millennia, particularly since the LIA

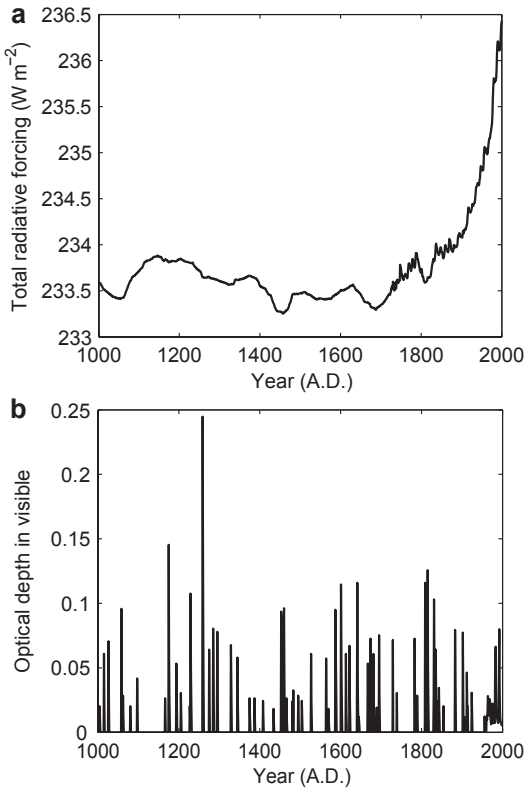


Comparison with transient simulations



CCSM3 forced with solar, GHG, volcanic

Long term weakening not discussed



Hofer et al. 2011

Summary and Conclusions

- Proxy records in the Ocean2k metadatabase show SST variability that may reflect AMOC changes

- High Resolution (annual) proxy records
  - Strong AMO-like variability during the 20th century
  - No significant 50-80 year cycles earlier in the record
  - 10-20 year periods appear more persistent

- Low Resolution (decadal-centennial) proxy records
  - Cooling throughout the past 2 millennia
  - Dipole index can be interpreted as AMOC weakening
  - Not sensitive to location of proxy records
  - Similar trends observed in transient simulations

Future work

- Proxy bias (e.g. seasonal SST)
- Coastal bias
- Model bias
  - Comparison with a full suite of AOGCMs
- Age model uncertainty in low resolution records
- Proxies other than paleotemperature
  - $\delta^{18}O$ as a density proxy to reconstruct transport
  - Hydrologic proxies sensitive to ITCZ migrations

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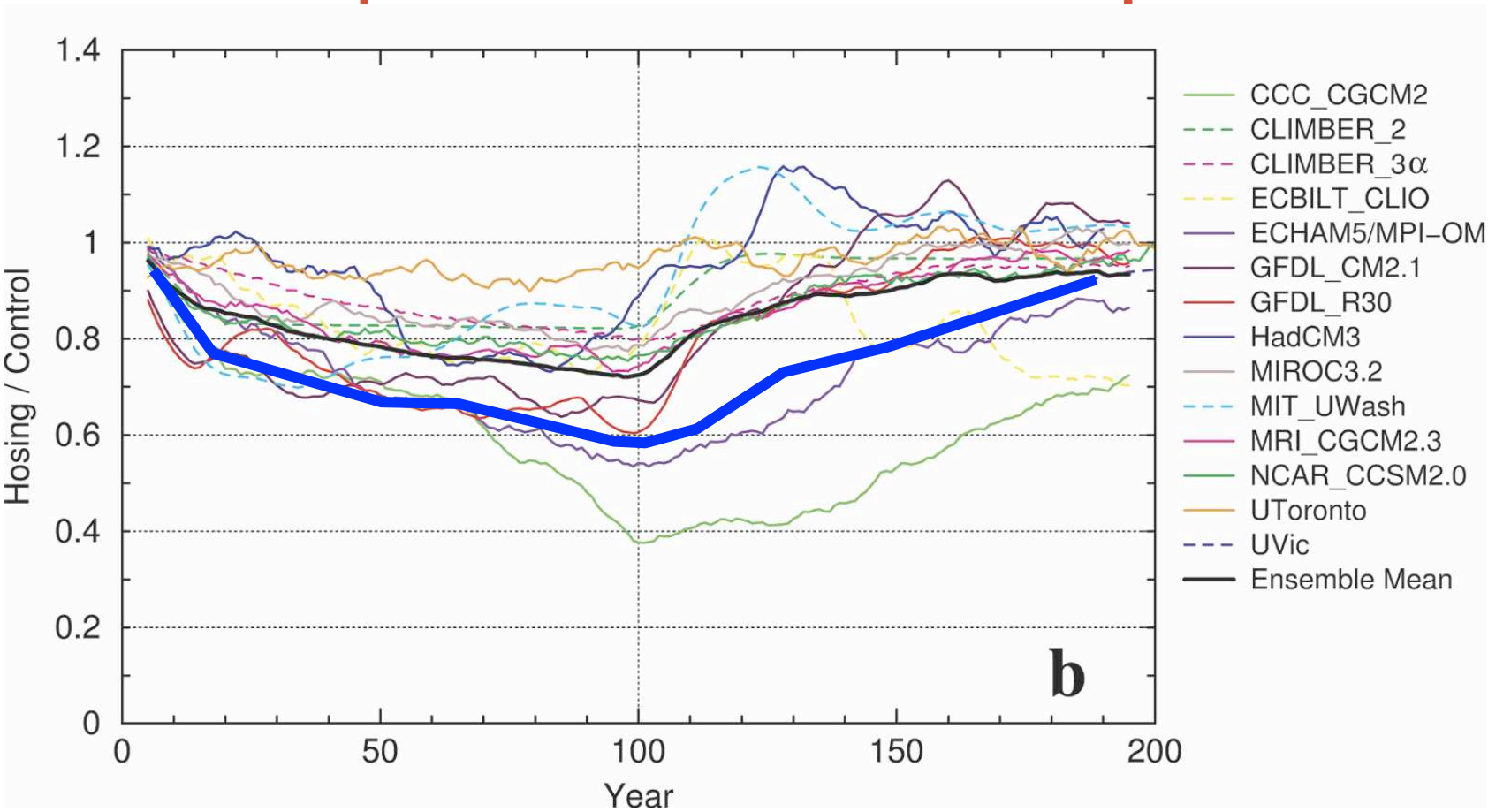
Model dependent AMOC response



Uvic model may more sensitive than average to hosing

Stouffer et al., 2006

Dipole pattern in proxy records?

- Dipole index:
  - Only “bullseye” and South Atlantic records
  - More data necessary

7 records, 646 points

1900: 123
1700: 70
1500: 66
1300: 75
1100: 63
900: 66
700: 46
500: 48
300: 48
100: 41