The Atlantic Multidecadal Oscillation – A paleo perspective

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The Atlantic Multidecadal Oscillation

1. Detrended, 10yr running mean of N. Atlantic SST
2. 65-70 yr period suggested by observations (~ 2 cycles)
3. Temporarily dampens or enhances rate of warming
4. Strong climate connections (Atlantic hurricanes, regional rainfall anomalies)

Enfield et al. 2001
Questions that Paleo archives can help address:

1. Is Atlantic multidecadal variability persistent?

2. Has the amplitude and frequency of AMV varied?  
   Due to human activity?  
   In relationship with background climate?

3. Does the evidence of pre-industrial AMV present a coherent picture of that variability?

4. Is AMV associated with AMOC variability?
AMO Reconstructions

- Tree ring records screened for correlations to N. Atlantic SST
- (12 records $r>|0.25|$)

$\text{North Atlantic SSTA} = -0.0607 - 0.0566 \text{PC1} + 0.0703 \text{PC2}$
$+ 0.0528 \text{PC4} - 0.0679 \text{PC5}$  \hspace{1cm} (1)

$r=0.64$
$r=0.81$ (10-yr smoothed)

Assumes persistent connection between N. Atl. SST & tree ring response
Two Atlantic (marine) records passed screening criteria – 100m sclerosponge Sr/Ca, Chesapeake Bay salinity reconstruction (SST from same site did not pass)

Assumes persistent links between N. Atlantic SST and environmental response
Advantages of corals:
Occur throughout tropics and in some subtropical locations.
Usually annually banded
Long-lived
Fossil corals
**Coral growth rate** and geochemistry sensitive to environment
Instrumental SST variability correlated to AMO at Yucatan coral site

![Graph showing correlation between SST anomaly and AMO anomaly with r=0.68]

- SST anomaly (°C)
- AMO anomaly
- ERSSTA

Year:
1840 1880 1920 1960 2000
Coral growth quantified from CAT scans

Figure 7. Quantification of annual coral growth by 3D CT scanning. (A) 3D CT scan reconstruction of the skeleton. (B) A slice cut subparallel to the upward growth axis (C) A slice cut parallel to the upward growth axis, reveals clear annual growth bands. [adapted from Cantin et al., 2010]
Three corals have similar growth histories – longest to 1773 C.E.


Correlation:

- Calibration period 1900-1960: \( r = -0.77 \) (p<0.05)
- Verification periods: \( r = -0.56 \) and \( -0.55 \) (p<0.01)
Coral record extends SST record ~ 80 years

Spectral peak – 45-70 years

\[ r = 0.66 \quad p < 0.01 \quad \text{(annual)} \]
\[ r = 0.56 \quad p < 0.01 \quad \text{(annual)} \]
\[ r = 0.7 \quad p < 0.05 \quad \text{(decadal)} \]
General similarities but important differences between AMO reconstructions

![Graph showing SST (°C) over time (Year C.E.) for Mann09 AMO, AMO, Yucatan SST, and Gray AMO.]
Corals from reef 2m above modern sea level 2 of 3 coral cores have growth rate variability similar to modern coral (spectral peak 50-70yrs) 3rd coral has >50 years with little variability

Implies tropical AMV is natural
Variations in amplitude and period are natural

Ph. D Thesis L. Vasquez-Bedoya (et al., in prep.)
U/Th Dates – W. Thompson
Coral growth in eastern Caribbean is weakly positively correlated to SST
Digging Deeper Into Coral Growth SST Connection

Well-nourished corals have fat tissue layers

A. Cohen

Barkley, Cohen, de Putron unpub.
Coral growth correlated to chlorophyll-a

Field data
WEq & CEq Pac, Red Sea

Cohen et al.
Different seasonality of chlorophyll peaks at USVI and Yucatan ...

... may explain different relationships between coral growth and SST.
Evidence of different long-term behavior in E and W Caribbean

Martinez et al. 2009 (link Atlantic trends to AMO influence on stratification)
Conclusions:

1. Atlantic Multidecadal Variability is **Natural**
2. Variations in frequency and amplitude are **Natural**
3. Many outstanding questions

Ongoing and Future Work:
Continuing reconstructions where SST and nutrients are inversely correlated on seasonal basis – using reanalysis products and models to evaluate longer-term link
Extracting other paleo-oceanographic information from regions where controls on coral growth rates are more complicated