Greenland ice core evidence for spatial and temporal variability of the Atlantic Multi-decadal Oscillation

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ABSTRACT

The Arctic d$^{18}$O ice core record is used as a proxy for Arctic surface air temperatures and to interpret Atlantic Multidecadal Oscillation (AMO) variability. An analysis of d$^{18}$O data from six Arctic ice cores (five from Greenland and one from Canada’s Ellesmere Island) suggests significant AMO spatial and temporal variability within a recent about 660 years. A dominant AMO periodicity near 20 years is clearly observed in the southern (Dye3 site) and the central (GISP2, Crete and Milcent) regions of Greenland. This 20-year variability is, however, significantly reduced in the northern (Camp Century and Agassiz Ice Cap) region. A longer time scale AMO component of 45-65 years is detected only in central Greenland. The absence of the longer time scale in the southern Greenland region suggests the possibility of different origins for the two basic time scales of AMO variability. An analysis of Arctic temperature in three similar regions in a 500-year control simulation of the NOAA GFDL CM2.1 coupled atmosphere-ocean general circulation model agrees qualitatively with the results of the ice core analysis.
Arctic Amplification

$\Delta T(\text{Arctic})/\Delta T(\text{Global})$

variable in time (5, 10, 2.5)

1970-2010 amplification is the lowest 2.5x

1970-2010 Arctic temp trend ~ 1x same as 1900-1940 trend

1970-2010 Global temp trend ~ 2x the 1900-1940 trend

Why is 1970-2010 Arctic warming so slow?
Can we find a 60-70 year AMO cycle in ice core data?

Ice core sites used in this study.

Oxygen isotope $\delta^{18}O$ used as a proxy for temperature as well as for the AMO

Red: 21 year running average of $\delta^{18}O$ ice core composite

Green: AMO index derived from various proxies by Delworth and Mann (2000)

Black: Instrumental era AMO after Parker
Ice core analysis suggests 20 yrs quasi-periodicity instead of expected 60-70 yrs

(a) Five ice core average $\delta^{18}O$ for 1300-1980

(b) An average of FFTs of individual cores: Raw periodogram (gray) and a periodogram smoothed by 11 member Hamming filter (red)

Surprise: Instead of expected 60-70 year periodicity, the only statistically significant periodicity found is that of ~20 years

Chylek et al., GRL, 2011
Wavelet analysis suggests an intermittent ~20 year cycle that was strong during the 19th century.
4000 Years of Dye3 Ice Core Data

20 yr cycle in the last millennium and in 2000 BC-1000 BC

Also seen in the 19th century in the Berkeley Earth Surface Temperature

Thanks to Richard Muller for this figure
Origin of 20 yr Oscillation?

Frankcombe et al., J.Clim., 2010

20 yr
south +
central
Atlantic
Ocean
Meridional
Overturning
Circulation

Frankcombe et al., J.Clim., 2010
De-trended Polar Temperatures

Arctic and Antarctic temperature anomaly after NASA GISS data

De-trended Arctic and Antarctic temperature anomaly and the AMO

The next AMO cycle?

Chylek et al., GRL, 2010
Arctic Temperature Simulations by the GCMs
The latest generation Canadian models reproduce well the late and the early 20th century warming.

The older models (CanCM3 and the NCAR/LANL CCSM3) cannot reproduce the early 20th century warming.
CMIP3 (IPCC 2007) and CMIP5 (IPCC 2013) Models
20th Century Warming Rates
# GCMs Arctic Warming Trends Summary

<table>
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<th>Model</th>
<th>CanCM3 CCCma</th>
<th>CanCM4 CCCma</th>
<th>CanESM2 CCCma</th>
<th>CCSM3 NCAR</th>
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<td></td>
<td>K decade^{-1}</td>
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<td>0.41</td>
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Summary

• Observations suggest that Atlantic Multi-decadal Oscillation (AMO) in the 18th and 19th century was dominated by a 20-year cycle, the 60-80 year cycle was observed in the 20th century

• What will be the length of the next AMO cycle? It will not be a 20-year cycle.

• The current GCMs have difficulty simulating the AMO. For the estimate of the Arctic future we will need a stochastic model to account for the next AMO cycle.