Climate response to a multidecadal warming/cooling of the North Atlantic Ocean

NERC Centres for Atmospheric Science
NATURAL ENVIRONMENT RESEARCH COUNCIL

Dan Hodson and Rowan Sutton

The University of Reading

Introduction

During the past two centuries there have been distinct multidecadal variations in the summertime climate of both North America and western Europe. In particular, over the US there have been significant variations in rainfall and drought frequency. It has been suggested[1,2] that changes in the Atlantic Ocean, associated with a pattern of Sea Surface Temperature (SST) variation known at the Atlantic Multidecadal Oscillation[3,4] (AMO) may have been partly responsible for these variations. To date, most of the evidence for a link between the Atlantic ocean and climate over the US and Europe comes from correlation between observed variables. These, whilst hinting at a role for the ocean, do not prove causality. Here we present an analysis that seeks to demonstrate this causal link between the AMO and continental climate variations.

Atlantic Multidecadal Oscillation

Figure 1A shows an index of the Atlantic Multidecadal Oscillation during the period 1871-2003. **Figure 1B** shows the SST pattern associated with this index. There have been both warm and cool phases of the AMO between 1871 and 2003. This study attempts to understand the impacts these warmings and coolings had on global and regional climate.

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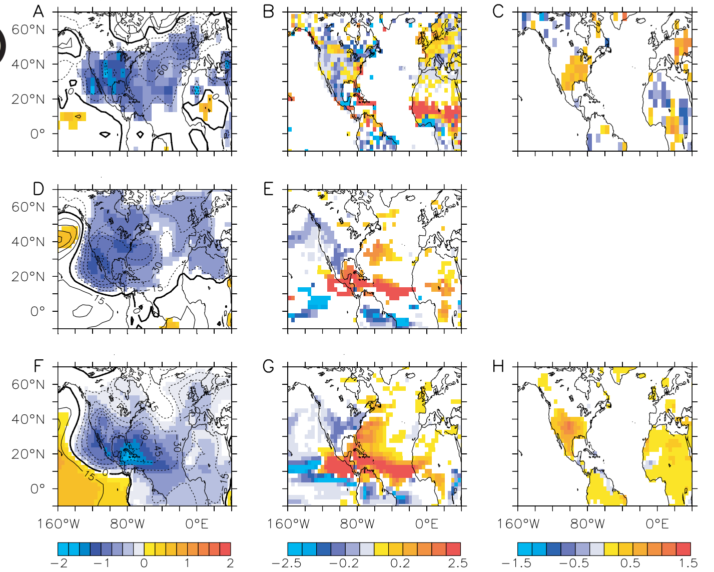

Figure 2: AMO impacts on northern summer (June-July-August, JJA) climate.
A-C Composite difference (1931:1960-1961:1990) of observed mean JJA conditions in :
A)mean sea level pressure (contours interval 30Pa, shading is signal-to-noise ratio)
B) land precipitation (mm/day), NB, *nonlinear* precipitation scale; central range:(-0.5, 0.5). Values between (0.5,2.5) and (-2.5,-0.5) are each shaded with a single colour.
C) land surface air temperature (°C).
D, E) As for A,B but HadAM3 atmosphere model forced with observed SST data. In D the contour interval is 15Pa.
F-H) As A-C but HadAM3 forced with AMO SST pattern (Fig 1B). In F the contour interval is 15Pa.
In A and C-H regions where anomalies are not significant at the 90% level are shaded white. In E and G precipitation values are shown over the sea as well as the land.

Conclusions

- In the 20th century the Atlantic Multidecadal Oscillation (AMO) had a clear impact on northern summer climate.
- The high AMO between 1930-1960 may have lead to a warmer, drier U.S. summer climate.
- The atmosphere responds most strongly to the tropical part of the AMO.
- Future trends in North Atlantic climate may be the result of a nonlinear competition between the AMO and direct anthropogenic warming effects.
- There are implications for the interpretation of instrumental and proxy climate records

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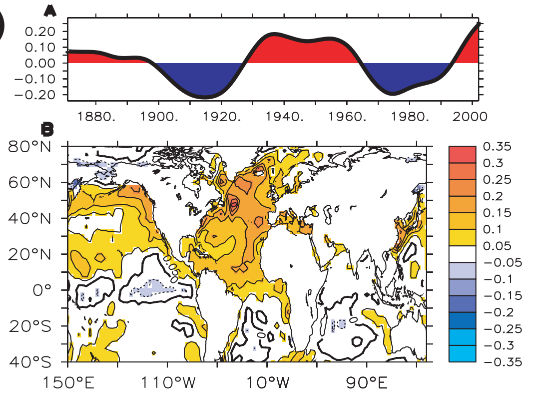

Figure 1: AMO Index
A) Index of the Atlantic Multidecadal Oscillation (AMO) 1871-2003 (°C). (Average annual mean sea surface temperature (SST) observations over 0-60N, 75-7.5W. Smoothed, detrended) . This index explains 53% of the variance in the detrended unfiltered index.
B)The spatial pattern of the AMO (°C per standard deviation) .

Observations

First, we examined the variations in observed climate that were associated with the AMO. **Figure 2** shows composites (1931:1960-1961:1990) of summertime (JJA) observed **A)** mean sea-level pressure (MSLP), **B)** precipitation and **C)** surface temperature. **Figures 2A-2C** link changes in climate with the changes in North Atlantic SSTs through the AMO index.

Are these changes a response to changes in the oceans? To find out we must turn to a global atmospheric circulation model.

Model Studies

We forced an atmospheric general circulation model (HadAM3) with the observed SSTs for 1871-1999. The results are shown in **Figure 2D,E**.

Both composites of MSLP (**Figure 2D**) and precipitation (**Figure 2E**) show good agreement with observations (**Figure 2A,2B**). Therefore observed climate variations linked to the AMO can be reproduced in a model forced with only observed SSTs; implying the observed variations were forced by variations in the SSTs.

Finally, *which* part of the ocean forced these climate variations? We forced HadAM3 with the North Atlantic part (0-60N) of the AMO SST pattern (**Figure 1B**). **Figures 2 F,G,H** shows the linear response to this forcing. Over the Caribbean, central America, and the US there is good agreement with both the previous simulations (**Fig. 2D,E**) and observations (**Fig. 2A,B,C**).

Figure 3 shows results from two similar experiments where we use only the extratropical (30:60N) or tropical (0:30N) part of the AMO SST pattern. These show that tropical Atlantic SSTs affected the US and Mexico whilst the extratropical Atlantic SSTs affected western Europe.

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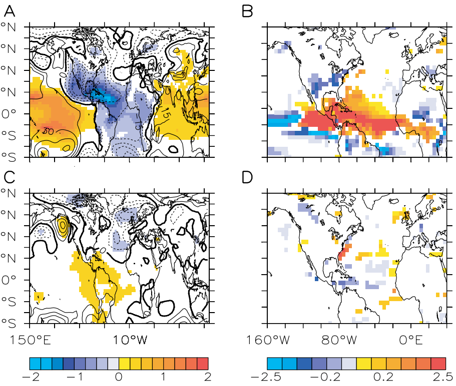

Figure 3: Response of HadAM3 to southern and northern parts of the AMO SST pattern.
A, B) HadAM3 forced by southern (tropical) part of the AMO pattern (Fig1B).
A) Mean sea level pressure (contours interval 15Pa, shading is signal-to-noise ratio).
B) Precipitation (mm/day); scale is nonlinear (see Fig 2.)
C, D) As A,B but HadAM3 forced by northern (extratropical) part of the AMO pattern.
Regions where anomalies are not significant at the 90% level are shaded white.

References

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www.met.rdg.ac.uk/~dan/ *d.l.r.hodson@reading.ac.uk*