Forced and Unforced North Atlantic Oscillations

Dan Hodson and Rowan Sutton,Department of Meteorology, University of Reading. dan@met.rdg.ac.uk

Introduction

The North Atlantic Oscillation (NAO) is a dominant pattern of variability of the northern winter flow. The fundamental origins of the NAO are processes internal to the atmosphere. The NAO index for the last century, however, exhibits prominent decadal-timescale fluctuations, the origins of which have yet to be fully explained.

Efforts to account for low frequency NAO variability tend to assume that the spatial structure of the NAO is well defined, and that external forcings will modify only its temporal behaviour, for example by reddening the spectrum.

In reality, however, the response to external forcings may be characterised by spatial patterns that differ, perhaps markedly, from the internal NAO pattern.

This study aims to elucidate the similarities and difference between the NAO pattern that arises from processes internal to the atmosphere, and the patterns of variability that arise in response to external forcing by the oceans.

Method

- To separate internal atmospheric variability from variability that arises in response to changes in the oceans we use an ensemble of integrations with an atmosphere model.
- We use six simulations with the HadAM3 AGCM of the period 1871-1999.
- All members share a common sea surface temperature (SST) forcing field, but have different initial atmospheric conditions.
- The internal variability is estimated from the differences between individual ensemble members and the ensemble mean.
- SST-forced variability is estimated using an optimal detection algorithm that extracts the variability that is common to all members of the ensemble.
- We separate the SST forced variability into high frequency and low frequency components using, as a filter, a 7 year running mean.
- Our analysis yields dominant patterns (EOFs) of internal and SST-forced variability, together with associated timeseries (principal components).
- For the forced patterns we determine the pattern of SST forcing by regressing the SST at each grid point on the appropriate principal component.
- Fig 1 shows leading EOFs of internal and SST-forced variability.
- Fig 2 shows the time series and SST patterns associated with the SST-forced variability.

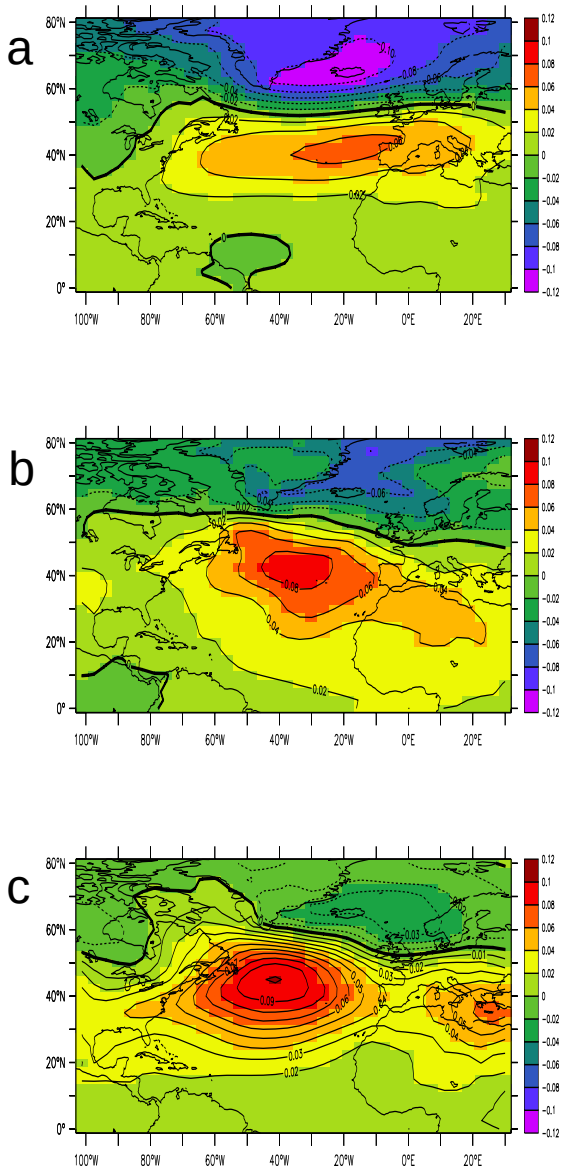

Figure 1

a) The 1st EOF of the internal variability in djf
b) First EOF of the forced response of MSLP after Low Pass filtering the data (djf).
c) as (b) but using a High Pass filter instead (djf).

Results

- NAO-like patterns are found in the SST-forced response as well as in the internal variability.
- At first glance the three patterns in Fig 1 look very similar, however there are at least two clear differences:
  - The ratio of the maxima to minima; in the unforced pattern the Iceland Low dominates, whilst in the forced patterns the Azores High dominates (high frequency pattern) or both centres have comparable weight (low frequency pattern).
  - The orientation of the dipole; the unforced pattern is approximately North-pointing, whereas the two forced dipoles point more North-East.
- The high frequency and low frequency forced components are responses to different aspects of oceanic forcing. The former is correlated with SST in the equatorial pacific and the North Atlantic tripole pattern, whilst the latter is primarily correlated with the North Atlantic region.

Conclusions and Implications

- There is no unique NAO pattern that accurately characterises both the internal variability and the SST-forced response.
- It is important to understand the differences between forced and unforced NAO patterns to accurately assess the predictability of climate in the North Atlantic region.
- An accurate distinction between the character of forced and unforced NAO variability may also be important for climate change detection.

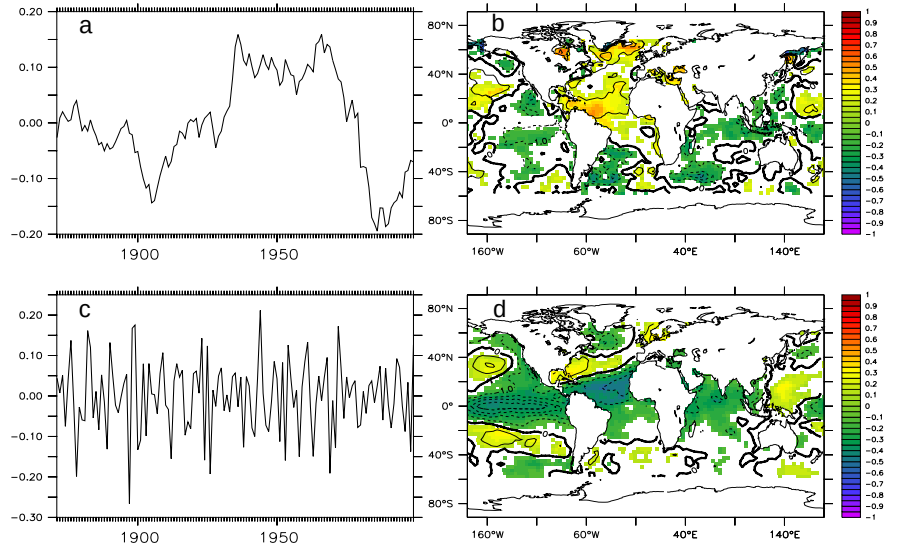

Figure 2

a) Time series associated with Fig 1b. b) SST forcing field (djf) regressed onto (a)
c) Time series associated with Fig 1c. d) SST forcing field (djf) regressed onto (c)