Modelled and observed multi-decadal variability in the North Atlantic jet stream and its connection to Sea Surface Temperatures

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Previous studies have argued that Global Climate Models underestimate multi-decadal variability in the North Atlantic jet stream, as viewed through the wintertime North Atlantic Oscillation (NAO)

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The focus of this study: to dig further into the details of this discrepancy with a view to understanding it.
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- Calculate the 20 year running mean
- Calculate its standard deviation
20 year running means

ERA20C, DJFM

ERA20C reanalysis

DJFM
1920-2010
20 year running means

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LENSE hist, DJFM

CESM LENS

DJFM
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U700 standard deviation (m/s)
20 year running means

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DJFM
1920-2010

Grey = ERA20C lies within the distribution of individual LENS members.
20 year running means
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Progressively more variability over the North Atlantic ocean toward the late winter
20 year running means

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Can have confidence in this because it looks the same in different reanalyses and can also see associated variability in in-situ measurements of precip in March.
20 year running means

ERA20C, DJFM
ERA20C, DEC
ERA20C, JAN
ERA20C, FEB
ERA20C, MAR

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ERA20C - LENs, DJFM

U700 standard deviation (m/s)
20 year running means
Large discrepancies in the low frequency variability in U700 over the North Atlantic in late winter. March, and to a lesser extent February.
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- True of virtually all CMIP5 models
- True for timescales beyond about a 10 year running mean
What gives rise to the multi-decadal variability seen in the North Atlantic jet stream in the reanalysis in late winter?
Possibility 1:

The variability arises as a result of the chance sampling of higher frequency (interannual) variability, with no need to invoke an underlying low frequency forcing.
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What are the chances of obtaining the multi-decadal variability observed through the chance sampling of white noise with a standard deviation equal to that of the interannual variability?

Compare with synthetic white noise time series of equivalent length to the observational record.

(Similar conclusions hold if red noise time series are considered)
20 year running means
20 year running means

[Images of maps showing temperature variations across different months and years.]

= not significantly different from white noise at the 95% level
(accounting for spatial correlation by the method of Wilks (2016))

(Similar picture if you assume a red noise time series since the lagged autocorrelation from one year to the next is typically less than 0.2)
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- **Internal coupled ocean-atmosphere processes (SSTs)**
- **External forcings**

(and the models must not be responding in the same way to this forcing)
Variability in this box in the North Atlantic (U700NA)
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March, U700NA

- raw

20thC reanalysis + ERA-Interim
Variability in this box in the North Atlantic (U700NA)

March, U700NA

- **raw**
- **20y means**

20thC reanalysis + ERA-Interim
Variability in this box in the North Atlantic (U700NA)

Correlation between U700NA and ERSSTv5 SST’s (20y running means)

Stippling – significant at the 95% level
Variability in this box in the North Atlantic (U700NA) raw 20y means 20thC reanalysis + ERA-Interim Correlation between U700NA and ERSSTv5 SST’s (20y running means) Stippling – significant at the 95% level

Looks like the pattern of SST variability associated with Atlantic Multi-decadal Variability (AMV/AMO) on these timescales

Correlation between U700NA and ERSSTv5 SST’s (20y running means) Stippling – significant at the 95% level
Correlation between Trenberth and Shea (2006) AMV index and U700NA (Blue – significant at 95% level after accounting for reduced degrees of freedom)
We know that atmospheric circulation variability plays an important role in driving the AMV (e.g., Yeager and Danabasoglu 2014, Delworth and Zeng 2016)
CESM Initialized decadal prediction large ensemble (Yeager 2018)

Initialized with observation based ocean and sea ice states every November from 1954-2015
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Decadal prediction (10 year lead time), SST

- CESM decadal predictions (individual)
- CESM decadal predictions (mean)
- OBS (ERSSTv5/ ERA20C+ERA-Interim)

Prediction of March SSTs in the sub-polar gyre region at 10 year lead time
CESM Initialized decadal prediction large ensemble (Yeager 2018)

Initialized with observation based ocean and sea ice states every November from 1954-2015

Prediction of March U700NA at 5 year lead time
March Winds

AMV
March Winds

AMV
March Winds

X

AMV


March Winds

AMV
In observations, there’s evidence for AMV driving multi-decadal variability in the March winds. The model doesn’t seem to capture this connection.
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Conclusions

- Modelled multi-decadal variability in the North Atlantic jet stream is entirely consistent with the sampling of white noise year-to-year variability.

- Reanalyses, on the other hand, show greatly enhanced multi-decadal variability in the late winter (March in particular).

- This March variability is strongly connected to SST anomalies that resemble Atlantic Multidecadal Variability/Oscillation (AMV/AMO).

- Various lines of reasoning can be used to argue that this connection represents a driving of the winds by the SSTs. In particular, CESM decadal predictions can predict the relevant SSTs at 10 year lead time, without predicting the March winds → their instantaneous connection does not represent a driving of the SSTs by the winds.

- In the late winter, models do not appear to respond to AMV SST variability in the same way that the real world does.

- Mechanisms remain to be understood.
(e) March time series, unfiltered

Cor(AMV,U700NA) = -0.24, 95% significant

(f) March time series, 20y running means

Cor(AMV,U700NA) = -0.86, 95% significant