Relating winter NAO skill to jet variability across timescales

Tim Woollings

Dept. of Physics, University of Oxford

Tess Parker, Antje Weisheimer, Laura Baker, Len Shaffrey, Chris O’Reilly, Elizabeth Barnes, Brian Hoskins, Young-Oh Kwon, Robert Lee, Camille Li, Erica Madonna, Marie McGraw, Regina Rodrigues, Clemens Spensberger, Keith Williams, Hugh Baker and Cheikh Mbengue
**Motivation**

- Several recent extremes due to jet variability
- Is variability increasing?

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**Figure 1.** Seasonal NAO values from 1899 to winter 2014, plotted both annually (thin lines) and with a 5-year running mean applied (thick lines). NAO index data are from Hurrell (2014).

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**Table 1 and 2** summarize changes in the mean and variance of the NAO for the seasons and calendar months, respectively, for several standard normal climatological time periods and the whole NAO index period. They confirm large decreases in NAO in summer and annually for the latest (since 1981) time periods. This summer decline is sustained (significant for both the 1981–2010 and 1991–2013 periods), which contributes to the 1981–2010 annual NAO being significantly negative (Table 1). Significant positive trends are seen in the extended winter (DJFM) and spring seasons/months for sub-periods between 1951 and 1990 (the extended winter series is only significant for 1961–1990) (Tables 1 and 2). The last few decades' significant summer decline in the NAO is not seen for the AO (Figure 2).

Also apparent is a remarkable increase in variability in winter NAO in the latter half of the record, shown in the running standard deviation plots in Figure 3. Figure 3 confirms that the enhanced variability is restricted to winter, when NAO winter (DJF) variability has almost doubled over the whole record. The standard deviation of winter (DJF) NAO for successive and overlapping 30-year climatological normal periods has increased steadily and significantly from 0.67 in 1901–1930 to 1.16 in 1981–2010 ($P = 0.004$), while other seasons' trends are less dramatic (Table 1). Inspection of the monthly NAO index time series (Figure 4) shows that this enhanced variability is strongest and most significant in December ($P = 0.01$). The standard deviation of December NAO was 1.27 for the overall 1900–2013 period but increased systematically...
Decadal jet speed variability

- Decadal NAO is mostly variations in jet speed
- Interannual NAO is mostly variations in jet latitude
- Suggests distinct mechanism (and predictability?) on decadal timescale

Woollings et al (2015, CD)
Jet latitude and speed have different sensitivities

Jet latitude sensitive to heating either side of jet

Jet speed sensitive to heating within jet and in tropics

Based on idealized dry dynamical core simulations; Baker et al (2017, JClim)
Ocean influence on decadal timescale?

Ocean-atmosphere coupling in the model:
Decrease in ocean heat flux convergence
-> Colder subpolar gyre
-> Stronger atmospheric jet

Woollings et al (2015, CD)
Linking timescales: Weaker jets are more variable

Dry dynamical core

Woollings et al (2018, J Clim)
Mechanism

Jet speed affects vorticity gradient and hence wave propagation

$K^* = \cos \phi \left( \frac{\beta^*}{[u] - c} \right)^{1/2}$

- Poleward turning latitude remote from jet
- Lots of cyclonic wave breaking
- Very variable jet latitude

- Poleward turning latitude close to jet
- Little cyclonic wave breaking
- Waves turned instead
- Increased anticyclonic wave breaking
- Less variable jet latitude

*Woollings et al (2018, J Clim).*
Slow decadal variability modulates the faster timescales

In order to directly compare the ASF-20C experimental hindcasts with the SEAS5 forecasts, the correlation skill for each is recalculated over the 29-year common forecast period of DJF 1981-2009. ASF-20C is correlated with ERA-20C, as before, and SEAS5 with ERAI. The correlation skill of the ASF-20C ensemble mean jet latitude has increased for this shorter period and is statistically significant, while for jet speed the correlation has disappeared. Correlation skill of the SEAS5 ensemble mean jet latitude with ERAI over the common forecast period remains unchanged, while the correlation for jet speed has decreased and is no longer statistically significant.

An 11-year running mean of the jet latitude and speed can be used to represent that part of the time series that varies on approximately decadal timescales (“slow” component). Subtracting this from the time series of jet latitude and speed over the 110-year period—5– Jet latitude; \( r = 0.25 \)  Jet speed; \( r = 0.21 \)

- Skill in jet latitude and speed both very small but significant
- Both contribute to skill in NAO
- Dominant source of skill is interannual jet latitude

**20th Century Atmospheric Seasonal Hindcast**

ECMWF model, atmosphere-only, forced with observed SST and sea ice.
20th Century Atmospheric Seasonal Hindcast

- Model jet is too strong
- Also not enough variability in jet position
- This is consistent with the general relationship between mean jet speed and variability of jet latitude
Conclusions

- Interannual winter NAO is mostly affected by jet latitude
- Decadal winter NAO is more related to jet speed – suggests potentially distinct source of skill for S2D timescales
- NAO skill in the Atmospheric Seasonal Hindcast largely comes from interannual jet latitude
- Decadal variations in the jet speed modulate the amount of interannual shifting
- In weak-jet decades we might expect more variability on S2S timescales
- Mean biases in jet speed can affect the strength of model’s shifting variability