Representing the North Atlantic Oscillation in a seasonal prediction model
- Predictability and Uncertainties -

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NAO seasonal forecasts

Why focus on the NAO?

- Main mode of variability at a seasonal time scale over the North Atlantic mid-latitudes
- Controls jet stream position: impact on temperature and precipitation over Europe and North America
  - Positive NAO in winter: wetter and milder conditions over Northern Europe; colder and drier conditions over northeast Canada and Greenland
  - Negative NAO: more meridional position of the jet stream
- First step towards seasonal forecasts of use to end-users: storminess, frost days, etc.
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*Dec-Jan-Feb precipitation and temperature anomaly correlation with January NAO index: 1950-2000*
*Source: NOAA/CPC*
NAO seasonal forecasts

**Which level of skill in seasonal forecasts?**

- Seasonal forecasts of the NAO generally show limited skill (Doblas-Reyes et al. 2003; Kim et al. 2012)
- Need for a proper representation of NAO links to Atlantic Ocean variability, Quasi-Biennial Oscillation or ENSO

**Prospects for improvement**

- MetOffice: higher resolution coupled ocean-atmosphere seasonal re-forecasts show high correlation skill (Scaife et al. 2014)
- EC-Earth: potential improvements with high resolution and improvements in sea-ice initialization (Batté et al. 2014)
- Recent study (Eade et al. 2014) suggests predictability over the North Atlantic is under-estimated by models?
Presentation outline

1. How does CNRM-CM predict the winter NAO in seasonal re-forecasts?

2. Dealing with uncertainties: ensemble size and re-forecast length
Coupled model seasonal re-forecasts with CNRM-CM

ARPEGE v6
- Prognostic physics scheme
- 91 vertical levels
- QBO and ozone parameterization

Seasonal re-forecasts
Ensemble predictions initialized each November

(Voldoire et al. 2013)
Coupled model seasonal re-forecasts with CNRM-CM

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Seasonal re-forecasts
Months 2-4 of each ensemble member are selected
Coupled model seasonal re-forecasts with CNRM-CM

**ARPEGE v6**
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**Seasonal re-forecasts**
DJF mean calculated for each member: compared to reference data

(Voldoire et al. 2013)
Coupled model NAO re-forecasts

Experiments

- REF: reference coupled model experiment
- "Stochastic dynamics" experiments: in-run perturbations of model dynamics (Batté and Déqué 2012)
  - SDM: random monthly mean corrections of ARPEGE tendency errors applied to each member
  - S5J: random sequences of five consecutive days of error corrections applied to each member
- 30-member ensembles; 1979/80–2012/13 re-forecast period (34 years)

Initialization

- Atmosphere: ERA-Interim reanalysis (Dee et al., 2011)
- Ocean: NEMOVAR reanalysis

North Atlantic Oscillation index

- Based on ERA-Interim PC1 of 500 hPa geopotential height DJF anomalies over the 1979/80–2012/13 re-forecast period
- Observed index calculated in cross-validation mode
- Projection of model anomalies on ERA-Interim EOF pattern
Seasonal re-forecast DJF Z500 bias

Mean bias for Z500 DJF 1979–2012 re-forecasts with respect to ERA-Interim (m)

- Z500 bias in CNRM-CM seasonal re-forecast very similar to the NAO pattern
- SD perturbations reduce this bias and the gradient over the North Atlantic
NAO index correlation

Boxplot of NAO index for coupled seasonal re-forecasts of DJF 1979/80–2012/13. Black lines show the NAO index for ERA-Interim reference data, boxes show the inter-quartile range of ensemble members, and dots the ensemble mean index.

**NAO correlation skill**
- Significant correlation skill for ensemble mean NAO re-forecasts over the time period
- High spread with 30 members: most events are inside the spread of the ensemble (except 2009/10)
- Some improvement with the SD5J experiment: significance?
Uncertainties in NAO skill

Due to ensemble size
- How many ensemble members to adequately represent variability?
- Estimates by grouping together 4 sets of 30-member re-forecast ensembles
- Confidence intervals estimated by random selection of ensemble members are very large
- Still the case when using 60-member ensembles

Due to re-forecast period
- Over-estimation of NAO predictability in recent decades?
- Need for longer re-forecast lengths (Shi et al. 2015)
Forced model seasonal predictions with ARPEGE

Experiment description

- Atmosphere-only run with ARPEGE
  - T127 horizontal resolution
  - 31 vertical levels
  - Diagnostic physics
- SST forcing from 20CR reanalysis (Compo et al. 2011)
- Atmospheric initial conditions: ARPEGE run nudged towards 20CR reanalysis data
- 15-member ensemble
- 121 startdates: November 1890 to 2010
- 4-month re-forecast length: focus on DJF season

NAO index: area-averaged SLP

- Based on area-averaged sea-level pressure differences between two boxes (Stephenson et al. 2006)
  - North box: 90W-60E; 55N-90N
  - South box: 90W-60E; 20N-55N
NAO index correlation

Correlation & Hindcast length
- Correlation with 20CR
- 21, 31, 41-year sliding window
- Multi-decadal variations in prediction skill

Sensitivity to hindcast length
- Year-to-year changes in correlation skill (just by shifting the hindcast period)
- Ex: winter 2009/10 is not well represented by the forced model in this experiment
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Estimation of correlation skill

- Correlation with 20CR
- Random draws of 30 years (with repetition)
- Histogram of computed correlation score:
  - Most correlation values are positive
  - A majority are non-significant
Probabilistic skill

1980-2010

NAO index > 2nd tercile

Probabilistic formulation
- Probability: ratio of ensemble members predicting the event
- Calibration based on other years of the hindcast

Brier Score and decomposition
- Reliability diagram for NAO index > 2nd tercile and < 1st tercile
- Forecast probability against observed frequency for both events
- Sensitivity of results to hindcast period
- Low skill over both periods
- Size of dots: frequency of forecasts; suggests the model often sticks to climatology (underconfident)
Probabilistic skill

**1960-2010**

**NAO index > 2nd tercile**

- BS = 0.195
- Rel = 0.015
- Res = 0.044

**NAO index < 1st tercile**

- BS = 0.218
- Rel = 0.048
- Res = 0.052

**Probabilistic formulation**

- Probability: ratio of ensemble members predicting the event
- Calibration based on other years of the hindcast

**Brier Score and decomposition**

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- Forecast probability against observed frequency for both events
- Sensitivity of results to hindcast period
- Low skill over both periods
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Conclusions

Model NAO prediction skill

Coupled seasonal re-forecasts with CNRM-CM
- show some skill in predicting the NAO index for DJF 1979–2012
- are improved in terms of Z500 mean climate with the introduction of stochastic dynamics perturbations

But results are subject to high levels of uncertainties w.r.t. ensemble size, re-forecast period.

Prospects

- Larger ensembles and longer re-forecast times could reduce uncertainties... but results with 20CR forced runs suggest these will remain for mid-latitudes : stick to the Tropics ?
- Results shown here are with low-resolution runs : improvements with higher resolution ocean and atmosphere components ?
- Typical skill scores used in seasonal prediction should be completed with additional analyses (representation of teleconnections, number and duration of weather regimes...)

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Thanks for your attention!