NAO predictability from external forcing in the late 20th century

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Introduction

The North Atlantic Oscillation (NAO) is predictable on near-decadal timescales. Smith et al. (2020) demonstrate that predictive skill for the NAO only emerges in multi-model ensembles that are large enough to overcome to the "signal-to-noise paradox" (Scaife and Smith 2018). The reported skill is derived from two components in yet unknown proportions: ocean initialization and external forcing.

Methods and data

Using a 269-member uninitialized multi-model large ensemble, we show that external forcing is the larger component of this NAO predictability. To compare with Smith et al. (2020)'s large initialized ensemble, we consider the years 1962 – 2015.

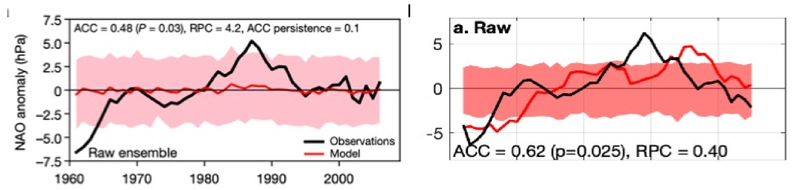
Institution	Model	Start year	Horizontal Resolution	Number of members
National Center for Atmospheric Research (NCAR)	Community Earth System Model 1 (CESM)	1920	~1.3°x0.9°/nominal 1.0°	39
Geophysical Fluid Dynamics Laboratory (GFDL)	Climate Model version 3 (CM3)	1920	~2.0°x2.5°/~1.0°x0.9°	20
Geophysical Fluid Dynamics Laboratory (GFDL)	Earth System Model 2M (ESM2M)	1950	~2.0°x2.5°/~1.0°x0.9°	30
Canadian Center for Climate Modelling and Analysis (CCCma)	Canadian Earth System Model version 2 (canESM2)	1950	~2.8°x2.8°/~1.4°x0.9°	50
Commonwealth Scientific and Industrial Organisation (CSIRO)	Mark 3.0 (Mk3)	1850	~1.9°x1.9°/~1.9°x1.0°	30
Max Planck Institute for Meteorology (MPI)	Earth System Model – Low Resolution (ESM-LR)	1850	~1.9°x1.9°/nominal 1.5°	100

All model output is publicly available as part of the Multi-model Large Ensemble Archive: http://www.cesm.ucar.edu/projects/community-projects/MMLEA

We compare model output to observations. For gridded sea-level pressure we compare to NCEP/NCAR reanalysis. For the NAO index we use HadSLP2. For SST, we use HadISST and ERSSTv5 (not shown here).

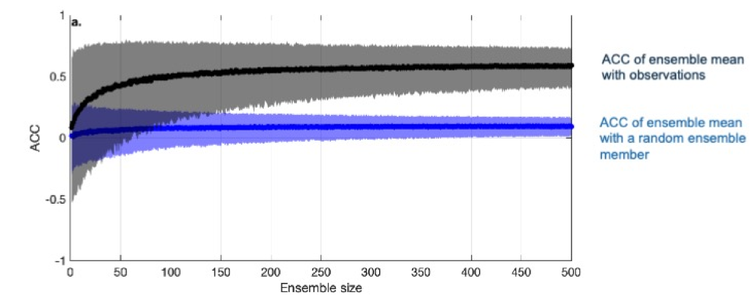
Source of predictive skill in the NAO

Predictive skill for the NAO index is at least equal to that from Smith et al. (2020)'s initialized ensemble.



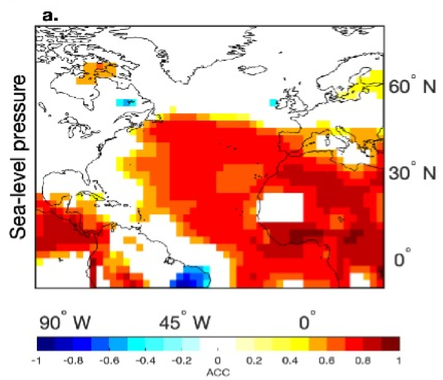
Comparison of NAO predictive skill from an initialized large ensemble (left; Smith et al. (2020)'s Figure 2a) and an uninitialized large ensemble (right; Klavans et al. (2021)'s Figure 1a).

Predictability of the NAO index increases with ensemble size, as in the initialized forecast system.



We create an ensemble of increasing size (x-axis) by subsampling (with replacement) from all ensemble members, calculating the filtered ensemble mean, and finding the ACC with observations (black) and a random ensemble member (blue). For each ensemble size, we repeat this process 10,000 times and report the mean (thick dot) and 95% confidence interval (colored cloud).

More generally, the uninitialized ensemble exhibits predictive skill for SLP across the North Atlantic basin

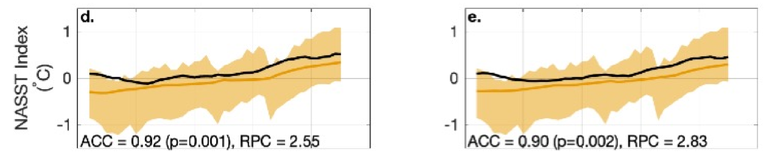


Map of ACC values for SLP. We only color those pixels with ACC values that are statistically significant at the 95% level.

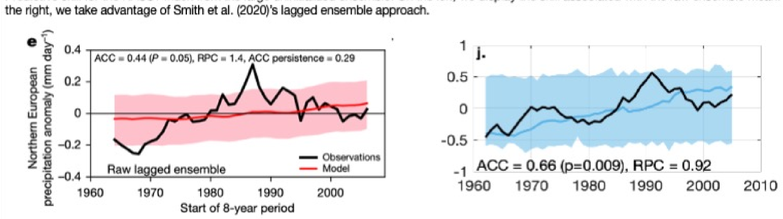
Predictive skill in the NAO primarily from external forcing. This forced signal is potentially under-represented in models, as described by the signal-to-noise paradox.

Predictive skill for NAO covariates

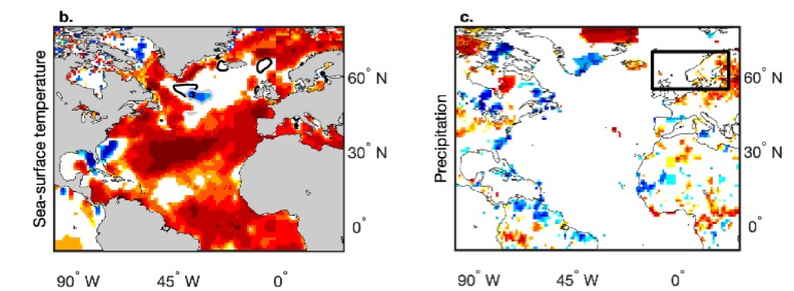
Our large uninitialized ensemble also has predictive skill for NAO covariates and impacts. We find robust predictability for the NASST index and Northern European rainfall. The ACC decreases when we remove the global mean warming signal to calculate the AMV index (as in Trenberth and Shea 2006).



Predictive skill for the NASST index from the large uninitialized ensemble. On the left, we display the skill associated with the raw ensemble mean. On the right, we take advantage of Smith et al. (2020)'s lagged ensemble approach.



Predictive skill for an index of Northern European precipitation. On the left, we display results from Smith et al. (2020)'s initialized large ensemble; on the right, we show results from our uninitialized large ensemble.



Predictive skill for SST and precipitation around the Atlantic basin. On the left, we display results from Smith et al. (2020)'s initialized large ensemble; on the right, we show results from our uninitialized large ensemble.

Summary

In agreement with Smith et al. (2020), we find that climate models can predict the NAO on near-decadal timescales in sufficiently large ensembles of climate models. We echo their claim that the NAO's signal-to-noise ratio in climate models is too small. We show that the ensemble mean in an uninitialized large ensemble has commensurate predictive skill to that from an initialized large ensemble. High predictive skill for NAO covariates offers hope that improving climate model's response to external forcing may help improve projections and predictions.

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