Decadal predictability of North Atlantic blocking and the NAO in large-ensemble hindcasts.

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As a large-scale circulation anomaly, atmospheric blocking is directly related to the North Atlantic Oscillation (NAO)[1] and strongly affects the intensity and distribution of weather extremes, such as snowstorms, heat waves and cold spells over Europe[2]. Therefore, modelling and predicting changes in blocking at different timescales (from day to day forecasting, to seasonal and near-term climate predictions and climate projections) is of paramount importance for a wide range of human activities and applications. Skilful predictions of blocking variability and the NAO can be turned into useful information for policy making, risk management and general planning, ultimately benefiting society.

For both North Atlantic blocking and the NAO, recently, significant predictability has been demonstrated in the seasonal range[3,4,5]. This study assesses the respective predictability in the decadal range. Utilizing the power of large-ensemble decadal hindcasts, unprecedented significant predictive skill is found in wintertime. Our study indicates that this atmospheric predictability is linked to correctly predicting oceanic anomalies (in particular, sea surface temperature anomalies over the subpolar gyre) that drive the predictable atmospheric response.

Community Earth System Model – Decadal Prediction Large Ensemble

Model: Atmosphere Ocean Ice Land	**CESM1.1** CAM5 (1°, 30 levels) POP2 (1°, 60 levels) CICE4 (1°) CLM4
Forcing:	–2005: CMIP5 historical 2006–: CMIP5 RCP 8.5
Initialization: Method Atmosphere Ocean Ice Land	 Full field UI CORE*-forced FOSI CORE*-forced FOSI UI
Ensembles: Ensemble size Start dates	 40 Annual, Nov. 1st 1954–2015 (N=62)
Ensemble generation:	Round-off perturbation of atmospheric initial conditions (only)
Simulation length:	122 months
Uninitialized Ensemble:	40-member CESM 20th century Large Ensemble (Kay et al., 2015)

Blocking detection method in 2D

$$GHGS(\lambda_0,\Phi_0) = \frac{Z500(\lambda_0,\Phi_0) - Z500(\lambda_0,\Phi_S)}{\Phi_0 - \Phi_S},$$

$$GHGN(\lambda_0,\Phi_0) = \frac{Z500(\lambda_0,\Phi_N) - Z500(\lambda_0,\Phi_0)}{\Phi_N - \Phi_0}$$

where Φ_0 ranges from 30°N to 75°N

λ_0 ranges from 0° to 360°

$\Phi_S = \Phi_0 - 15°$, $\Phi_N = \Phi_0 + 15°$.

Instantaneous blocking is identified when:

$GHGS(\lambda_0,\Phi_0) > 0$ and

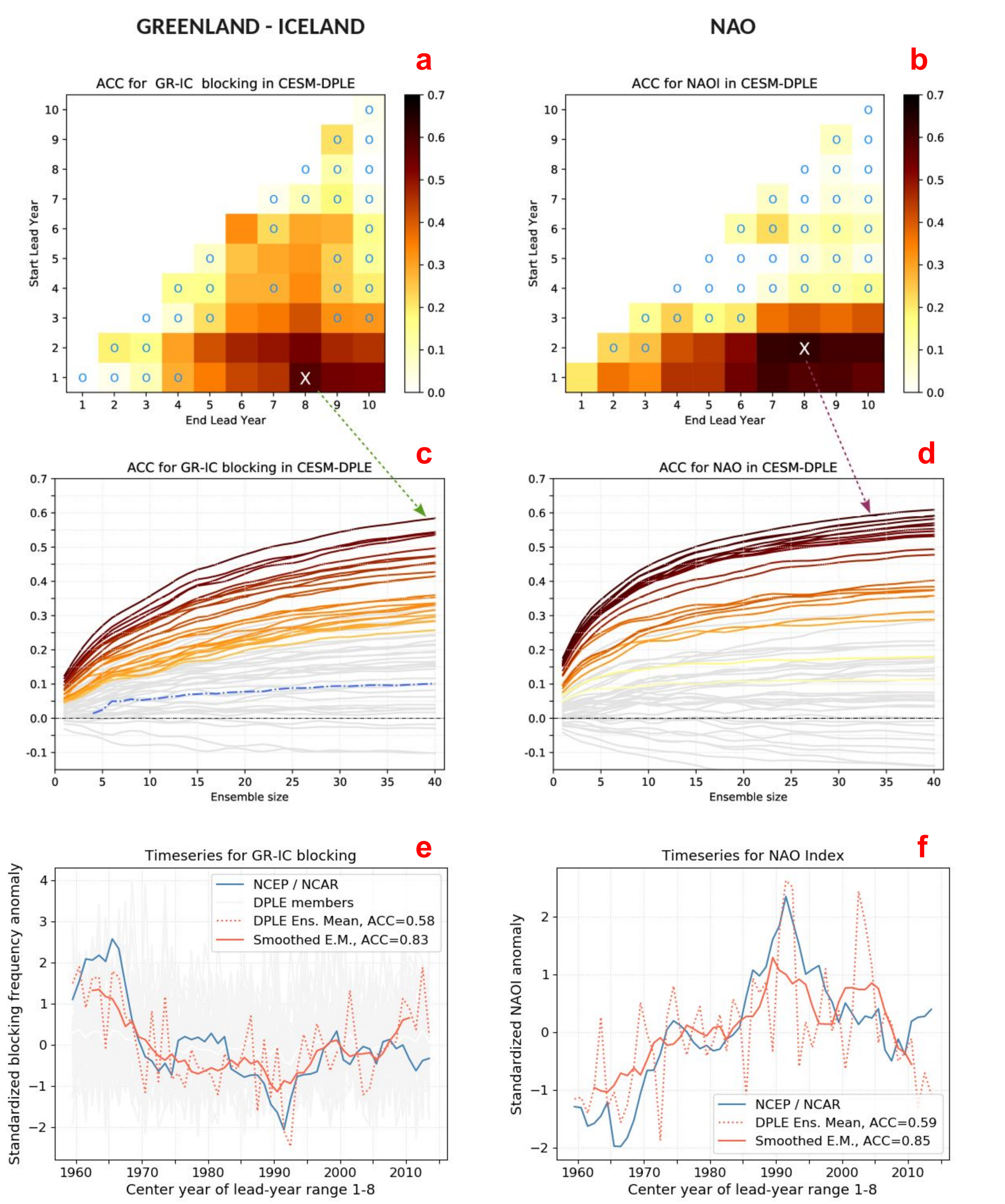
$GHGN(\lambda_0,\Phi_0) < -10 m/°lat$

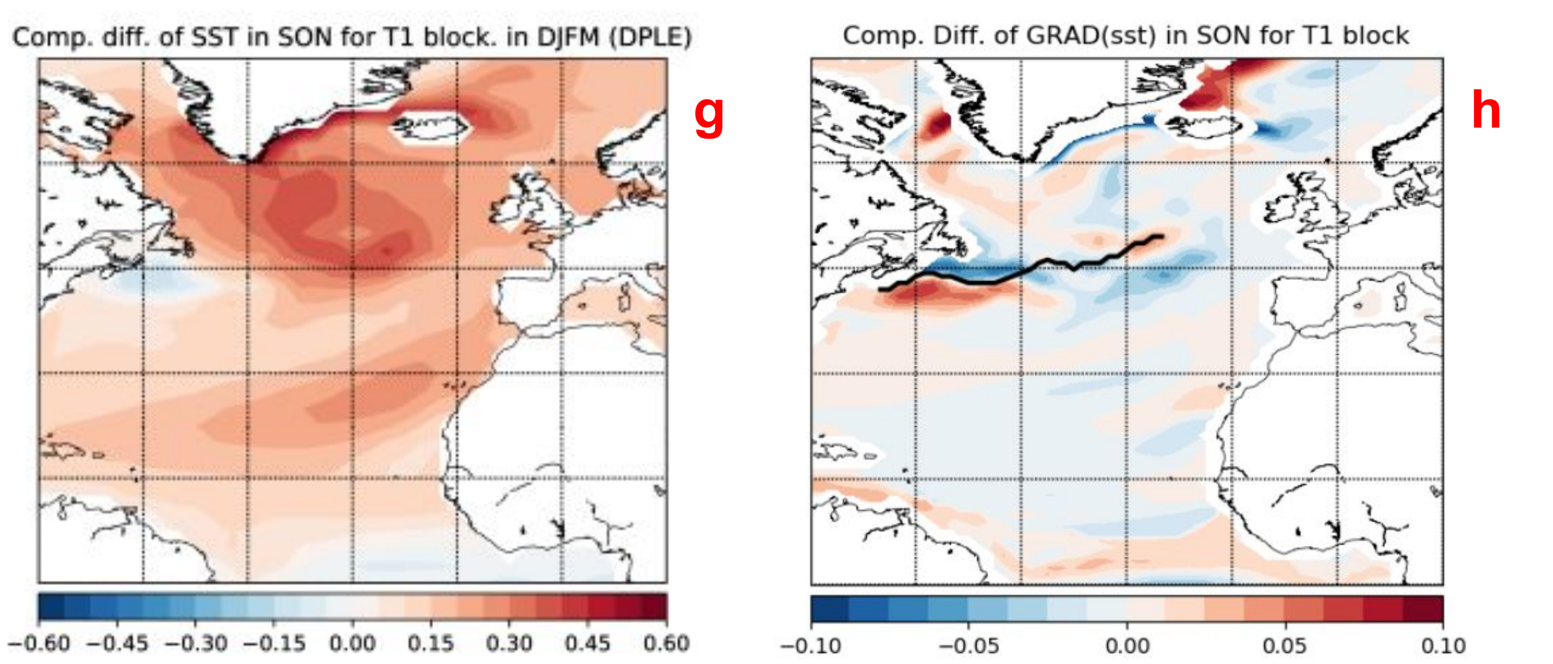
Minimum persistence of 5 days.

Scherrer et al. (2006)

- We use a unique data set: NCAR's Decadal Prediction Large Ensemble (CESM-DPLE, 40 members)[6] that allows the atmospheric response to oceanic forcing to emerge from the inherently unpredictable internal atmospheric variability.
- We apply 2D blocking[7] detection to daily Z500 fields from each individual member (62 initialization years: 1954–2015, 10 lead years with 121 days per DJFM season). For the NAO[8], ensemble-mean MSLP monthly-mean fields are used, instead.
- Predictive skill is assessed against the NCEP / NCAR reanalysis (Kalnay et al., 1996) via Anomaly Correlation Coefficient (ACC).
- The statistical significance is thoroughly assessed[9] accounting for auto-correlation in the timeseries, which reduces the effective sample size. One-sided T-test against the null hypothesis of non-positive correlation.

On the right, **(a-b)** show the predictive skill for Greenland and Iceland blocking and the NAO in different lead-year ranges. Blue circles indicate that the correlation was not found to be statistically significant. **(c-d)** show how the respective predictive skill increases with the ensemble size. Each color line corresponds to a lead-year range for which the correlation was found to be statistically significant (no blue circle in the corresponding box). The same color map has been used for identification. The dashed blue line shows the ACC between a member of the ensemble and the ensemble mean of the remaining members - the low skill of the model predicting itself is a characteristic feature in climate predictions (low signal-to-noise ratio). **(e-f)** The respective timeseries for the lead-year range 1-8 exhibiting the highest skill for Greenland and Iceland blocking and comparable skill for the NAO. The correlations arise from the multi-decadal variations associated to the Atlantic Multidecadal Variability[10].





Above, **(g)** shows the composite difference in autumn sea-surface temperature (SST) anomalies preceding winters of maximum and minimum ensemble-mean frequency of Greenland and Iceland blocking. The identified SST pattern strongly resembles the AMV, the variability of which is very well predicted by the model. According to previous studies[11,12], such oceanic anomalies may drive an NAO-like atmospheric response by modifying the SST gradient at the Gulf Stream Extension region and consequently, via the associated changes in surface turbulent heat fluxes, modify the baroclinic activity of the North Atlantic stormtrack impacting on the eddy-driven jet and blocking[13]. **(h)** shows the modification of the SST gradient corresponding to (g).

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