Decadal climate forecasting for the energy-sector

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Summary

- Power systems become more sensitive to meteorological conditions as the penetration of renewable energy technologies increases.
- There is skill in decadal forecasts of large modes of variability over the North Atlantic, such as the NAO.
- This project will make use of this skill to create decadal forecasts of energy-sector relevant variables (wind speed, temperature, solar irradiance).

Background

As power systems become more reliant on intermittent renewable sources, such as wind power and solar PV, there is need for longer range climate forecasting to inform the development and operation of these dynamic systems.

Decadal forecasts seek to make predictions of the evolution of large-scale climate features over 1-10 years. For these forecasts to have value, however, they must show skill. Due to the chaotic nature of the atmosphere, these forecasts are often very noisy (Eade et al., 2014). As a result, large multi-model ensembles are used to extract the predictable signal in decadal forecasts. These techniques have been used to produce skilful decadal forecasts of the North Atlantic Oscillation (NAO) and the Eddy-Driven-Jet in winter (Smith et al., 2020; Marcheggiani et al., 2023).

As research has demonstrated the value of seasonal forecasting for the energy-sector (Thornton et al., 2019), there is potential for extending this value to longer timescales by using skilful decadal forecasts. One mode of variability which is often used in long-range forecasts for the energy-sector is the NAO (**Figure 1**).

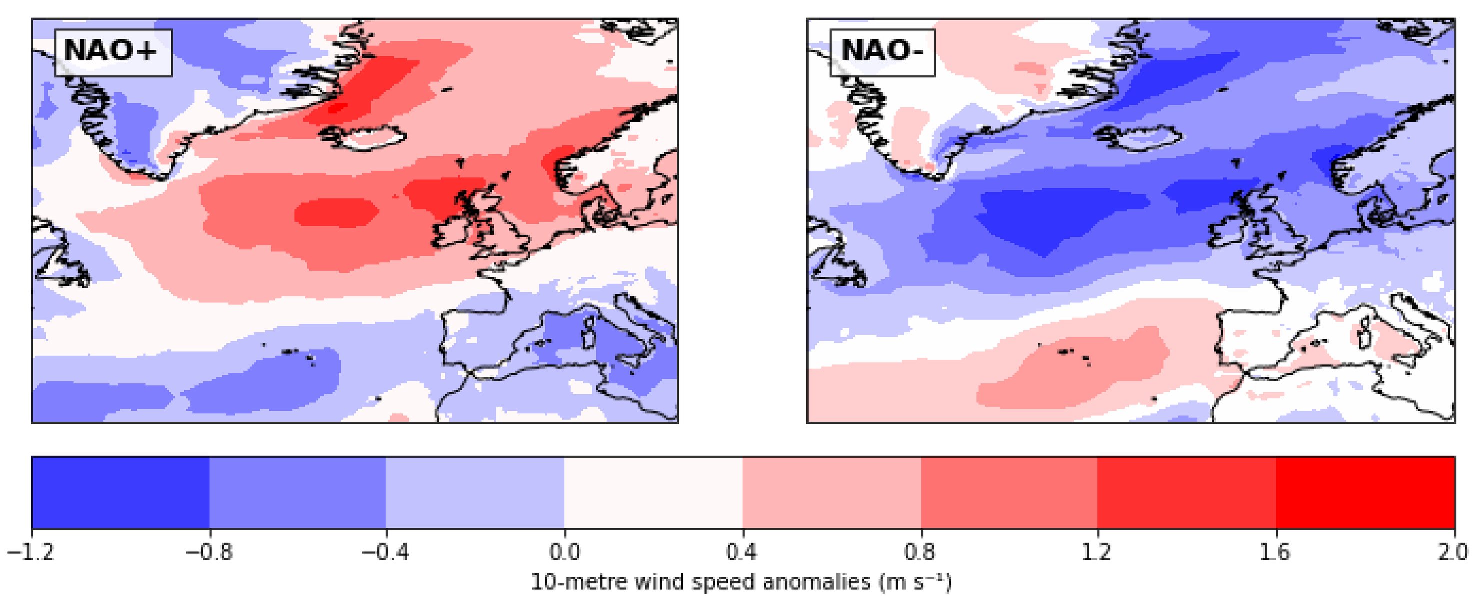

Figure 1 – Observed wind speed anomalies for NAO positive (NAO+) and negative (NAO-negative boreal winters (DJFM) with respect to other years (1960-2022). There are 8 NAO+ and 12 NAO- winters in this period.

Objectives

- To quantify the extent to which decadal forecasts can skilfully forecast relevant variables for the energy-sector. These include:
  - Mean production from renewables;
  - Mean demand for power.
- To quantify the extent to which large ensembles of decadal forecast data can be used to identify the potential for extreme events for the energy-sector, such as:
  - Extended low renewable energy production;
  - Extended energy shortfall (demand − renewables).

Initial Analysis

To examine years 2-9 prediction skill of the NAO, a 178-member ensemble of CMIP6 decadal predictions was constructed.

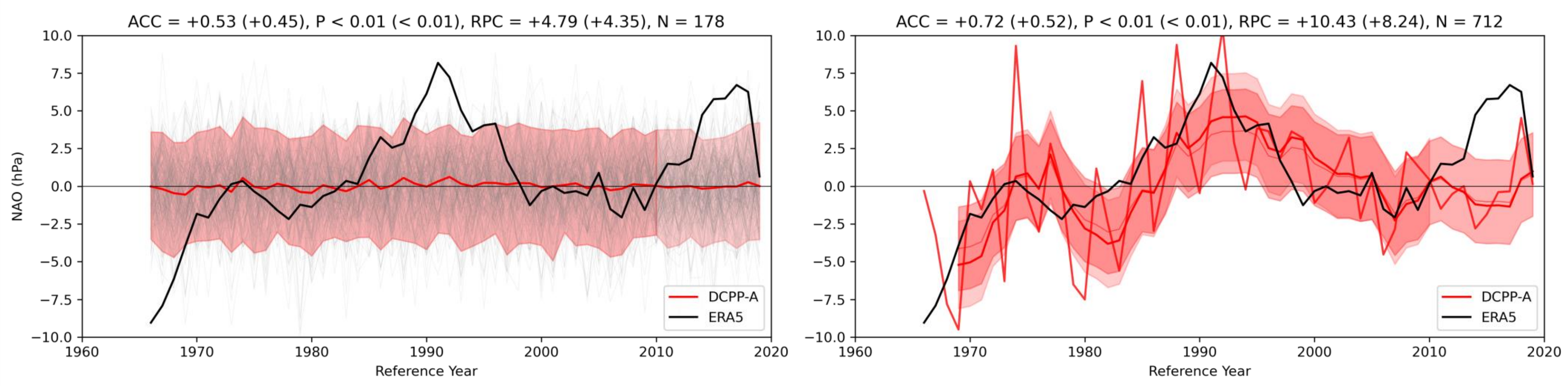

Figure 2 – Left. Observed (black, ERA5) and model-forecast (red, DCPP-A) 8-year running means for the boreal winter (DJFM) NAO index. The ACC of the ensemble mean, its significance and the RPC are indicated for both the short period (1961-2005 initialization) and long period (1961-2014 initialization). Right. as in left, but with a lagged ensemble consisting of 712 members and with the variance of the ensemble mean scaled by the RPS.

In the raw ensemble (**Figure 2**, left) models show skill in predicting the phase of the NAO, despite failing to capture the observed decadal variability. By lagging the ensemble and rescaling the variance to the observed (**Figure 2**, right), the signal is better captured by the models and the skill improves. However, there is a substantial drop in skill caused by the models failing to capture a return to positive NAO post-2010 (**Figure 3**).

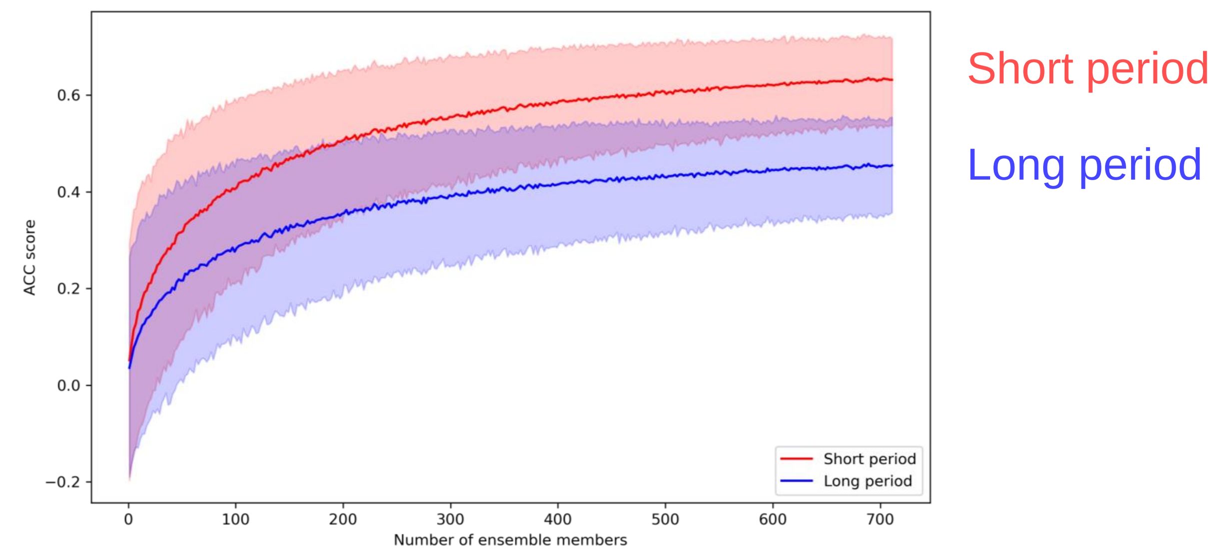

Figure 3 – The ACC score calculated as ensemble size increased (step size = 2) over 1000 resamples for the short period (1961-2005 initialization, red) and long period (1961-2014 initialization, blue).

Next Steps

- Explore the spatial variability of decadal forecast skill over the North Atlantic by using skill maps, considering different variables and seasons.
  - Quantify the decadal predictability of the East Atlantic Pattern.
- Replicate the results of Moemken et al. (2016) by evaluating the decadal predictability of wind speed and wind energy for Europe, using both grid point and pattern forecast approaches.
- Quantify extreme events for the European energy-sector using a multi-model ensemble and explore the benefits of using multiple models for quantifying extremes.

References

1. Eade, R. et al. Do seasonal-to-decadal climate predictions underestimate the predictability of the real world?: Seasonal to decadal predictability. *Geophys. Res. Lett.* 41, 5620–5628 (2014).
2. Marcheggiani, A. et al. Decadal Predictability of the North Atlantic Eddy-Driven Jet in Winter. *Geophys. Res. Lett.* 50, e2022GL102071 (2023).
3. Moemken, J. et al. Decadal predictability of regional scale wind speed and wind energy potentials over Central Europe. *Tellus A: Dynamic Meteorology and Oceanography* 68, 29199 (2016).
4. Smith, D. M. et al. North Atlantic climate far more predictable than models imply. *Nature* 583, 796–800 (2020).
5. Thornton, H. E. et al. Skilful seasonal prediction of winter gas demand. *Environ. Res. Lett*. 14, 024009 (2019).

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