Decadal predictions for the energy sector

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Summary

- As the power system transitions to use more variable renewable energy sources, the system becomes more sensitive to changes in weather and climate.
- There is potential for skilful prediction of energy sector relevant quantities on decadal timescales, such as Northern Europe offshore wind capacity factors.
- A large ensemble of decadal predictions can be aggregated to create an event set of physically plausible extremes, such as extended winter wind droughts.

Background

To ensure security of electricity supply, the impacts of weather and climate on the power system should be well understood. As decadal predictions sample the uncertainty from both internal climate variability and climate change, these predictions allow us to estimate the potential risks to supply security on longer timescales. Decadal predictions can be used to identify risks to the energy sector in two ways:

1. Forecasts can be used to try to **predict** how a variable of interest (e.g. precipitation) may vary over the next year to decade (Hermanson et al., 2022).
2. Predictions can be aggregated to **explore physically plausible extremes**, such as winter wind droughts, in a very large synthetic event set (Kay et al., 2023).

As previous work has demonstrated the value of these methods on seasonal timescales (Clark et al., 2017, Kay et al., 2023), there is potential for applying similar techniques to explore energy sector applications on multi-annual to decadal timescales.

Prediction skill

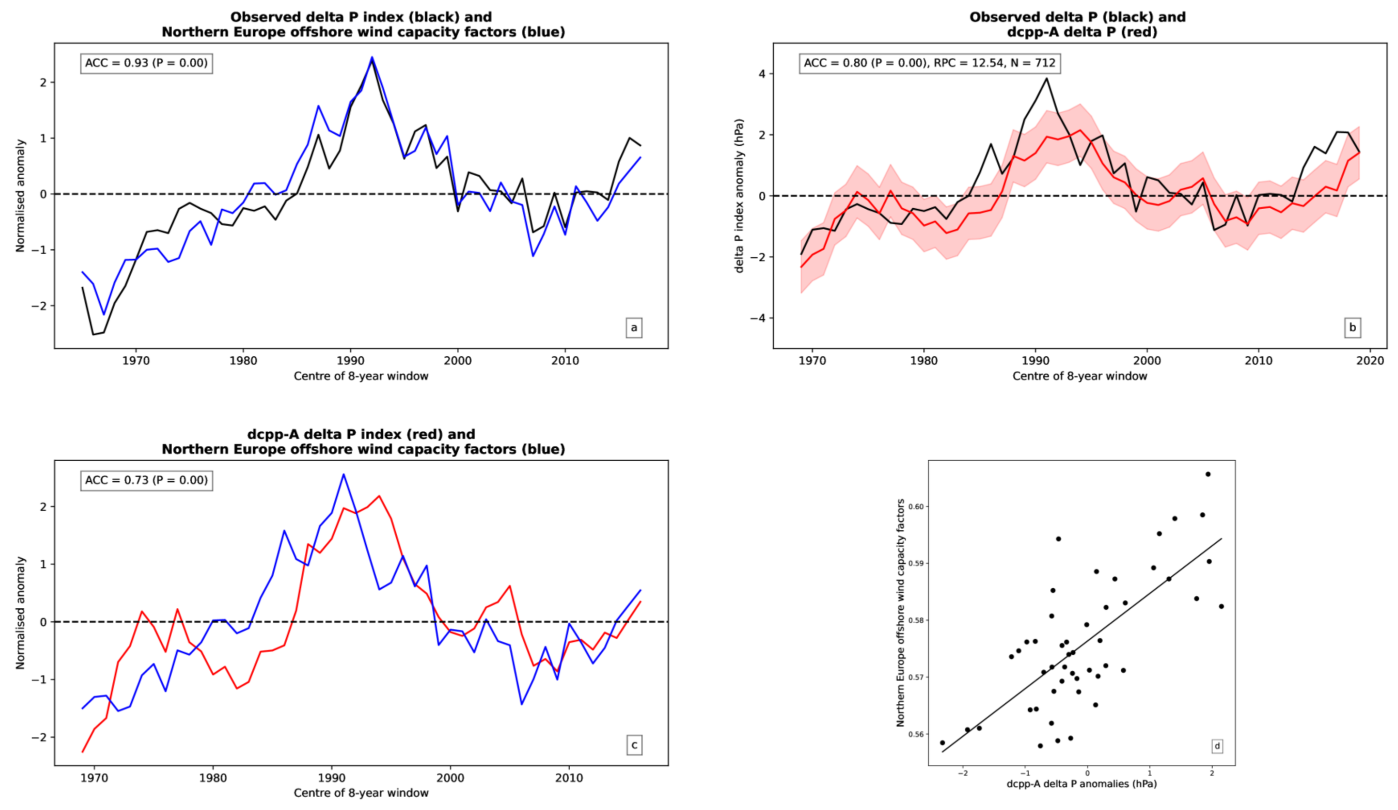

Figure 1 – **a.** Observed time series of the UK delta P index and offshore wind power capacity factors aggregated over the Northern European EEZ regions. **b.** Observed (ERA5) and model (dcpp-A) time series for the UK delta P index. **c.** Time series of model delta P anomalies and wind power capacity factors for the Northern European EEZs. **d.** Scatter plot of **c**. All show extended winter (ONDJFM) and 8-year running means.

We find predictive skill at decadal timescales for surface variables over Europe during both winter (ONDJFM) and summer (AMJJAS). While skill is patchy, there are notable regions where this emerges, such as over Spain for solar irradiance. We compare the predictive skill achieved when using either direct model output or pattern based approaches for predicting offshore wind capacity factors over Northern Europe. We find significant skill when using the difference in pressure over the UK (delta P index) for predicting capacity factors (**Fig. 1**). Suggesting that at decadal timescales, large-scale indices may be more useful predictors than direct model output, like Tsartsali et al. (2023). This highlights the potential for skilful prediction of energy sector relevant quantities on decadal timescales.

Exploring extremes

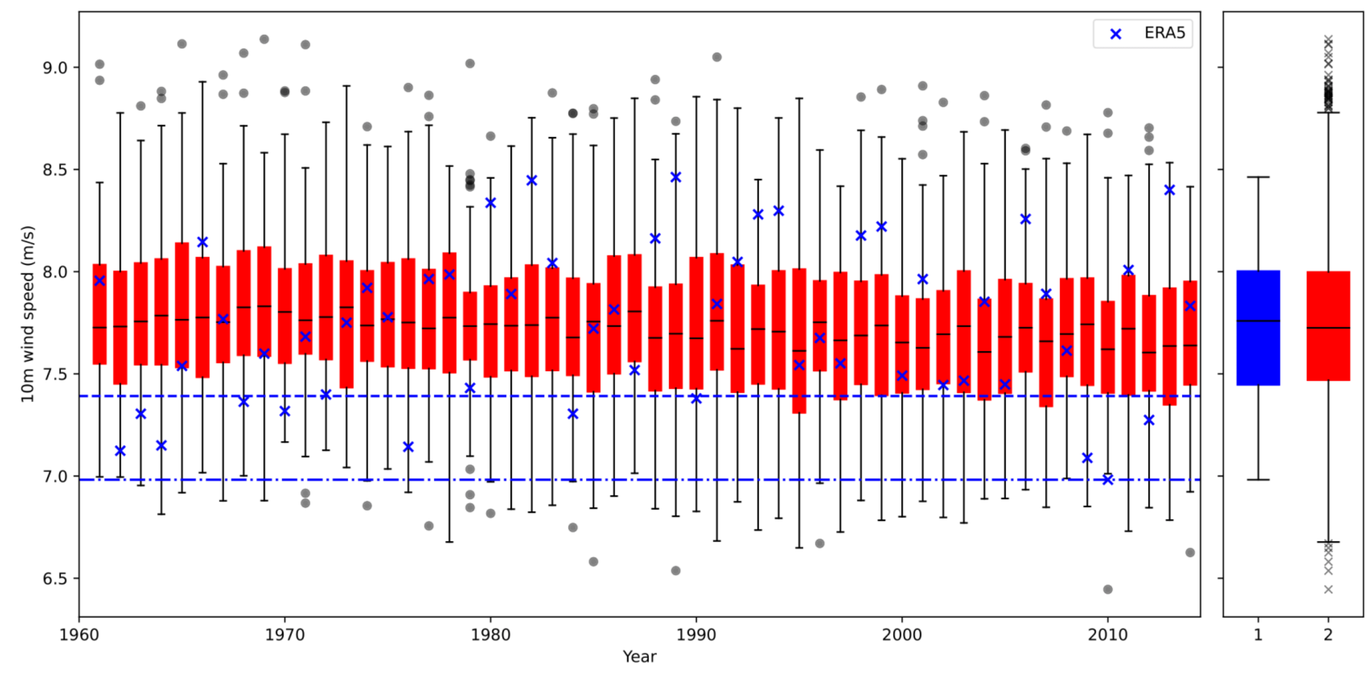

Figure 2 – Time series of 10m wind speeds over the UK from October-March between 1961 and 2014. Blue crosses represent ERA5 and red boxplots represent the HadGEM3-GC31-MM decadal hindcast. The blue boxplot shows the distribution for ERA5, while the red boxplot shows the distribution for HadGEM3-GC31-MM. The dashed and dot-dashed blue line show the 20th percentile and minimum value of the observed distribution from ERA5.

The decadal predictions produce many more realizations of winters with mean wind speeds below the 20th percentile of the observations than have occurred (**Fig. 2**). They also simulate winters where mean wind speeds are lower than the lowest recorded year in the observations, representing unprecedented extremes. To ensure credibility of the winters generated, we consider the stability, independence, and fidelity of the simulations (**Fig. 3**).

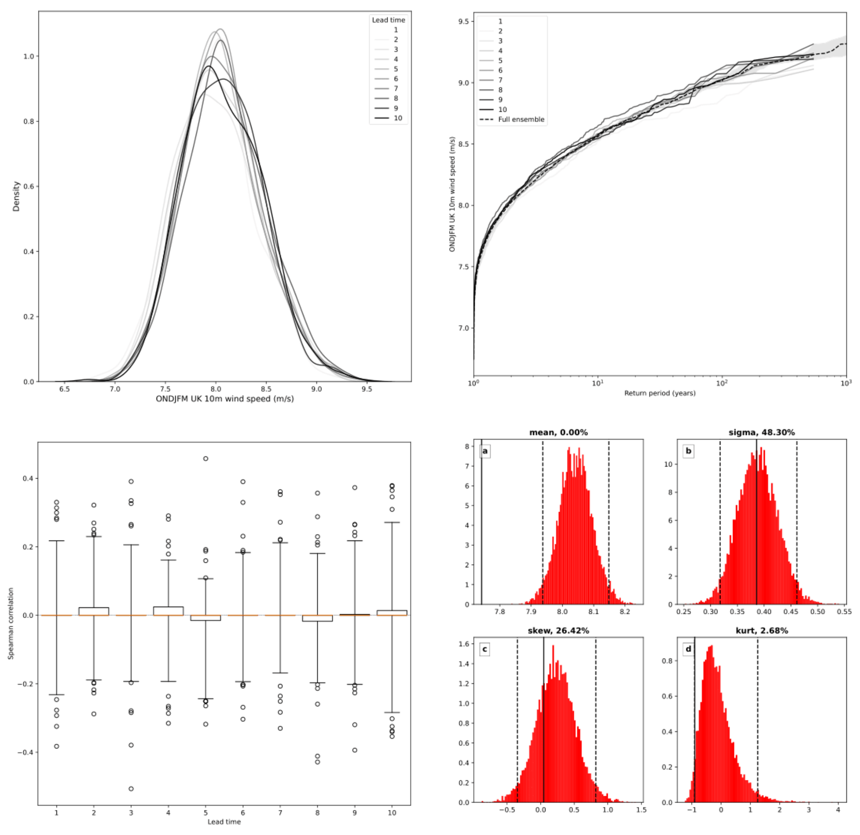

Figure 3 – **a.**, **b.** Stability, **c.** independence and **d.** fidelity of the ensemble for 10m wind speeds over the UK from October-March between 1961 and 2014. The probability density (**a.**) and extreme value distribution (**b.**) of UK wind speeds for each lead time. Box plots in (**c.**) show the correlation between ensemble members for each of the lead times (detrended). **d.** the UK extended winter 10m wind speed distribution characteristics for HadGEM3-GC31-MM (bootstrapped distribution) for the mean, standard deviation, skewness, and kurtosis, and for ERA5 (solid black lines).

Next Steps

- Quantify the impacts of unprecedented weather extremes, such as multi-year wind droughts, on the power system by passing the output from decadal predictions through a power system model.
- Evaluate the return periods for extremes events, such as the low winds between 2009-2011, using the UNSEEN ensemble.
- Develop decadal predictions of energy-sector relevant quantities, such as gas demand, electricity demand, and demand-net-wind.

References

1. Hermanson, L., et al. (2022). WMO Global Annual to Decadal Climate Update: A Prediction for 2021–25. *Bulletin of the American Meteorological Society, 103*, E1117–E1129.
2. Kay, G., et al. (2023). Variability in North Sea wind energy and the potential for prolonged winter wind drought. *Atmospheric Science Letters, 24*, e1158.
3. Tsartsali, E.E. et al. (2023). Predicting precipitation on the decadal timescale: A prototype climate service for the hydropower sector. Climate Services 32, 100422.

Acknowledgements

- I would like to thank my supervisors for all their support and guidance.