Research Summary: 34-year simulation of wind generation potential for Ireland and the impact of large-scale atmospheric pressure patterns

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Weather forecasters have recently improved their ability to predict some large-scale climate patterns up to a year ahead. These patterns have been shown to have an influence on wind power generation, but the relationships can be very location-specific. From a practical point of view, understanding the relationship with the country-wide total wind generation, given the current positioning of wind farms, could offer system operators the potential to plan generation mixes much further ahead than is currently possible.

To develop knowledge on how large-scale climate patterns and wind generation are related, many years of data are required. Being a relatively recent industry, the number of years of wind power data that could be considered representative of how the wind turbines are currently placed around the country, is limited to perhaps a decade or so. This is not sufficient to capture a wide range of climate conditions. A model is therefore required to estimate what the production would have been in years before the turbines were actually installed.

This study develops the dataset required using a weather model that has been run back in time over many years and produces an historical hourly simulation of the wind speeds over the world. The data corresponding to the location of each of the wind farms in Ireland are combined with a model of wind turbine production, and the total production for each hour is calculated. The spatial resolution of the weather model is relatively low, compared to how much wind speeds can actually vary in space, but when considering the whole country, it provides a good overall result compared with the most recent actual wind production data, as shown in Figure 1.

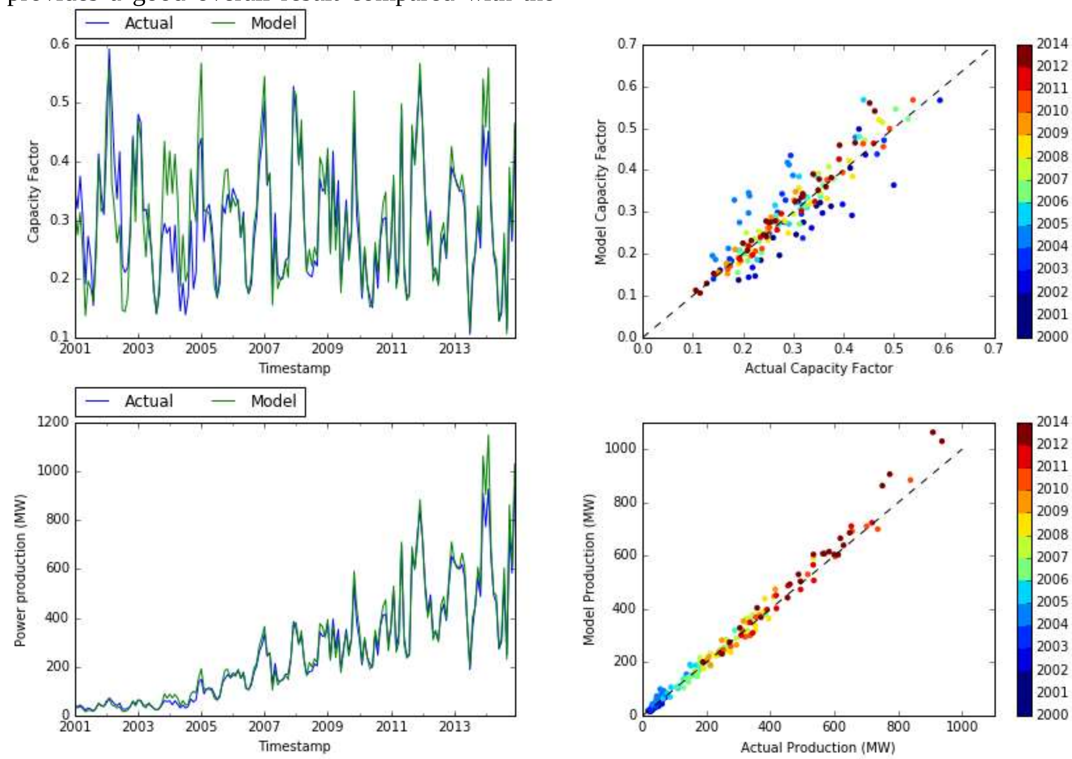

Figure 1 Monthly mean capacity factor (upper) and production values (lower) for the model calibration period (2001-2014). The correlation coefficient is 0.91 for monthly capacity factors and 0.99 for production.

The relationships between this long-term simulated wind generation and two large scale climate patterns, the North Atlantic Oscillation (NAO) and the East Atlantic pattern (EA), are studied. Generally in winter, there is a low pressure situated around Iceland, and a high around the Azores, but the relative difference between the strength of these two pressure systems can oscillate. Whether the difference in pressure at two locations is greater or less than average gives rise to an index of positive and negative values, known as the NAO. A positive NAO will result in strong westerlies and typically warmer, wetter winters in northern Europe; a negative NAO means the westerly conditions are less dominant, and weather will be cooler and drier than average. The EA represents a similar phenomenon but with the pressure centres shifted south-eastwards compared to the NAO. It is has been shown that the state of the EA, whether negative or positive, can strengthen or weaken the influence of the NAO on the weather.

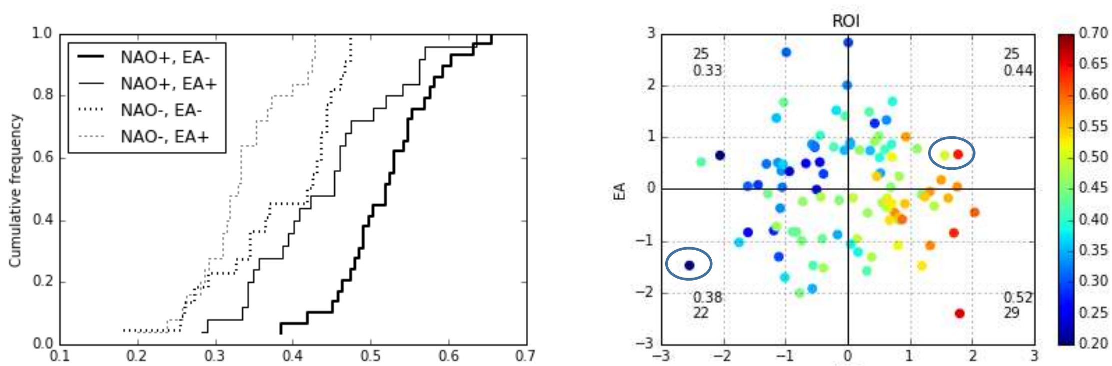

Figure 2 Influence of the NAO and EA on mean monthly aggregate wind generation capacity factors for December, January and February 1980-2013 in the Republic of Ireland. Left panel – cumulative frequency of capacity factors for each NAO/EA combination. Right panel – Individual monthly NAO/EA combinations, colour scale is the corresponding capacity factor. (Number of months represented by the number in the twenties, and mean capacity factor by the lower number.)

The monthly average wind power capacity factors and the associated combinations of NAO and EA state have been examined, with the results shown in Figure 2, indicating that, on average, months with the combination of NAO+ and EA- are likely to have a high capacity factor, and those with NAO-

/EA+ likely to have lower capacity factors. Furthermore, the incidence of so-called 'ramping events', where the total wind power output on the grid increases by 20% or more – creating difficulties for grid management – for different combinations of NAO and EA is shown in Table 1, again with the NAO+/EA- combination producing the most ramping events. Persistent high output events were defined as periods greater than 12 hours where total output remained at 74% capacity factor or higher. The frequencies of such events were associated to the NAO and EA states, with months with a positive NAO tending to have more frequent persistently high output events.

Table 1. Ramping events under NAO/EA combinations

State	*% of hours preceding a ramp >20% at 6-hour horizon*
NAO+	21%
NAO-	14%
NAO+ / EA+	18%
NAO+ / EA-	23%
NAO- / EA+	12%
NAO- / EA-	17%

Key findings

- Months with positive NAO and negative EA are found to have the greatest wind power output, whilst the opposite – months with negative NAO and positive EA – have the lowest wind output. It is of note that these are also known to be the coldest months.
- In keeping with this pattern, ramping events were most prevalent during NAO+/EA- months and least prevalent during NAO-/EA+ months.
- A more positive NAO was found to be positively correlated to the number of persistent high output events but there was no evidence of a relationship with the EA.

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