Regional wind-solar complementarity and atmospheric pressure patterns

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Introduction

Large-scale integration of renewable energy sources in our current energy systems requires better assessments of climate variability.

Here we focus on the wind and solar resources of the UK and Ireland region, as their variability has been linked previously with large scale atmospheric circulation patterns such as the North Atlantic Oscillation (NAO), the East Atlantic pattern (EA) and the Scandinavian pattern (SCAND) [1,2]. We use the recently available regional high resolution gridded dataset produced by Met Éireann (MÉRA Climate Reanalysis [3]) to assess the relationship between solar short-wave (SW) radiation and wind speed; and the relationship between these and the previously mentioned atmospheric pressure patterns, in the winter season.

Methodology

1. NOAA's Climate Precdiction center teleconnection patterns indices, for the winter season (December-January-February) corresponding to time-period in analysis 1982-2016 were used.

2. Met Éireann's MÉRA Climate Reanalysis' SW solar radiation and wind speed (height = 100 meters) data for the winter season and same period. The data was normalized against their climatological monthly mean and standard deviation before proceeding to the analysis.

3. These datasets were then aggregated in seasonal means for the winter, to generate a gridded time-series dataset for 35 winters seasons. The time series of solar and wind data for each grid point was then compared with the teleconnection indices (Pearson's score).

Results

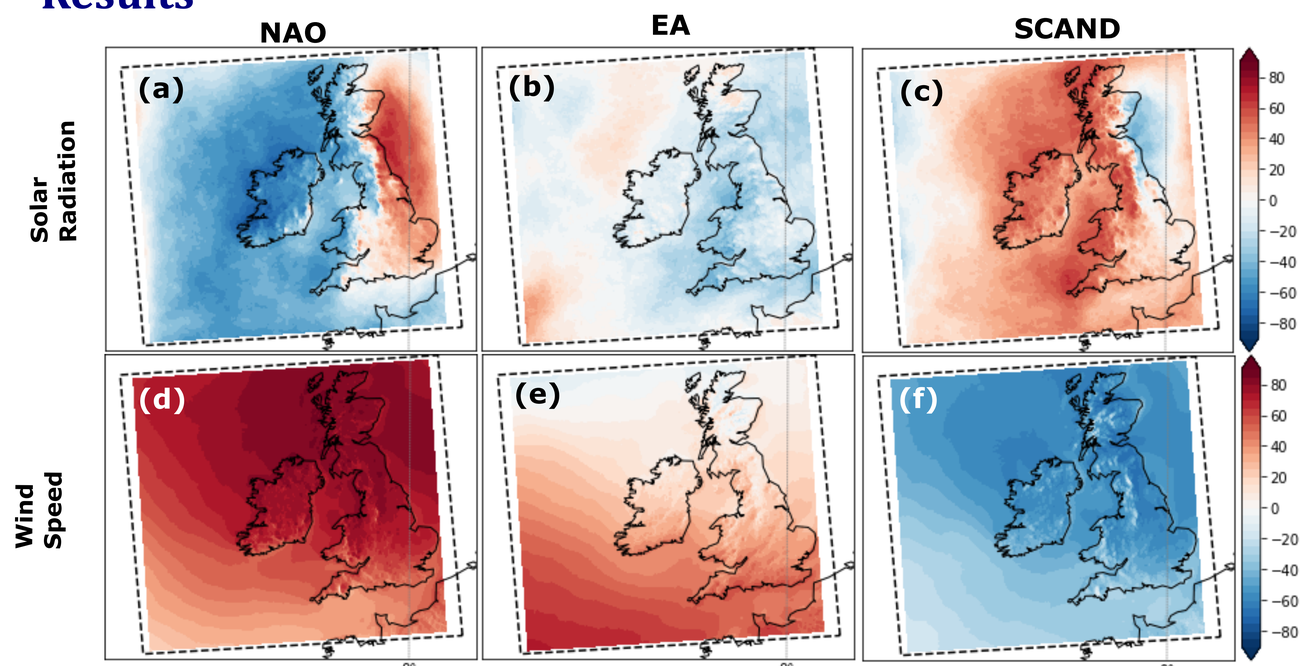

Figure 1: Pearsons correlation scores (R x 100) for MÉRA's SW radiation (top row) and 100 meter wind speed (bottom row), for the winter seasons of the period 1982-2016. Plots (a), (b) and (c) refer to the correlation scores between radiation and the NAO, EA, & SCAND patterns, respectively. Plots (d), (e) and (f) refer to the scores between wind speed and the same patterns, respectively.

An east-west gradient is verifiable in the response of SW radiation variability to both the NAO and SCAND teleconnection patterns (plots (a) and (c), respectively). Comparing those maps with the correlation maps for wind (plots (d) and (f)) leads to the conclusion that wind-solar radiation complementarity exists for most of Ireland and west of the mainland UK. Choosing Ireland as representative of this region's wind-solar complementarity area, while taking advantage of the recently available renanalysis dataset, we have assessed the complementarity of these resources according to the NAO phase (Figures 2 and 3).

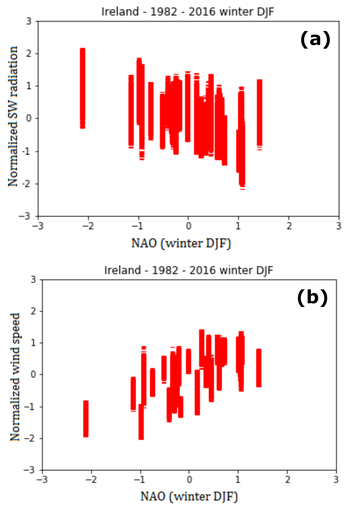

Figure 2 (left): Scatter plots of the NAO index against normalized SW radiation (top) and normalized wind speed (bottom), for every Irish land grid point, for the whole period. Every vertical bar is composed of all the anomalies (solar (a); wind (b)) for a particular winter NAO value.

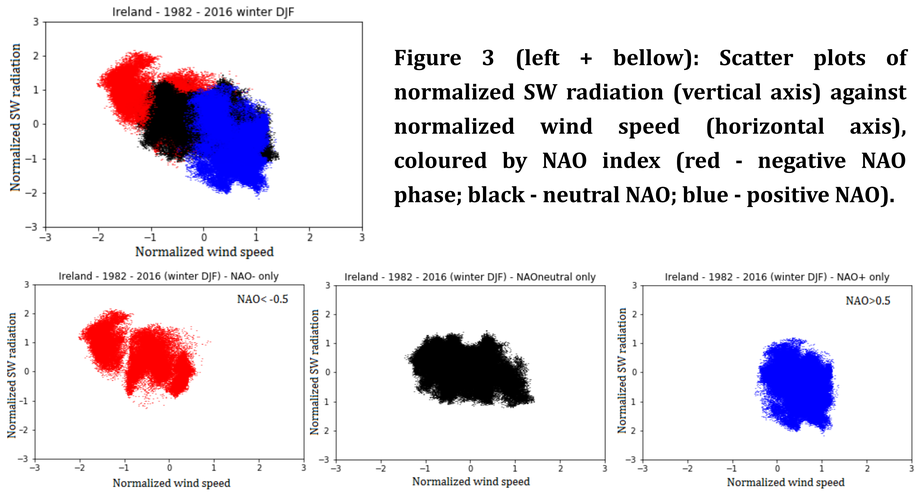

Figure 3 (left + bellow): Scatter plots of normalized SW radiation (vertical axis) against normalized wind speed (horizontal axis), coloured by NAO index (red - negative NAO phase; black - neutral NAO; blue - positive NAO).

Conclusions

- Winter solar radiation variability is strongly linked to the NAO & SCAND modes (Figure 1) .
- Different solar radiation responses to the NAO and SCAND patterns (e.g. compare east UK with west UK in Figure 1 (a) and (c)) indicates regional scale complementarity.
- Some degree of local complementarity between wind and solar resources exists on most of Ireland (Figure 2) and west UK. The opposite (non-complementarity) happens in east UK.
- In the areas of wind-solar complementarity, this balance appears to be present according to the non-neutral phases of the NAO pattern (Figure 3). However, even within Ireland there is some regional scale differences in the response of this complementarity to different NAO phases.

Future work

- Assess physical drivers of the patterns-solar radiation relationship. This can be done with other variables linked to solar radiation variability: cloudiness related variables, such as water vapour and ice water column content.
- Understand the physical relationship causing these east-west differences of atmospheric response to large-scale climate variability may offer insights on how to apply recent [4] seasonal forecasts advances in predictability.
- Conversion of these energetic resources to actual renewable power output may inform resilient future renewable energy mixes (e.g. ratio wind-solar power generation), and optimum spatial deployment of power facilities.

References

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[4] Dunstone et al. (2016); *Nature Geoscience* **9**, 809-814.

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