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The Association of Large-Scale Climate Variability and Teleconnections on Wind Energy Resource over Europe and its Intermittency

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In times of increasing importance of wind power in the world's energy mix, this study focuses on a better understanding of the influences of large-scale climate variability on wind power resource over Europe from 34°N to 71,5°N latitudes and from 11°E to 41°W longitudes. The impact of the North Atlantic Oscillation, the Arctic Oscillation, the El Niño Southern Oscillation and the Atlantic Multidecadal Oscillation are investigated in terms of their correlation with wind power density at 80 m hub height. These wind power densities are calculated based on the MERRA Reanalysis data set covering 31 years of measurements with a time resolution of an hour and a spatial resolution of 1/2° latitudes 2/3° longitudes. Not surprisingly, the Arctic Oscillation and the North Atlantic Oscillation are highly correlated with the time series of wind power density, especially for northern Europe. This correlation can also be found in the first principal component of a Principal Component Analysis of wind power density over Europe explaining 14% of the overall variance. Coefficient of determination studies for linear regression between wind power density time series and the teleconnections reveal that for northern Europe up to 30% of the variation of wind power density can be explained by the North Atlantic Oscillation, for example. Further, cross-correlation analyses indicate the strongest associated variations are achieved with the Arctic Oscillation and the North Atlantic Oscillation leading wind power density by at most one day. Furthermore, the impact of high and low phases of the respective oscillations has been assessed to provide a more comprehensive illustration. In the case of high Arctic and North Atlantic Oscillation, wind power density can vary by a factor of three in northern Europe between negative and positive phases, and a similar effect (but opposite in sign) is seen for southern Europe, with wind power density varying by a factor of two. Similar results are obtained by calculating the energy output of three hypothetical wind turbines for every grid point over Europe as more pragmatic measure. In this way, we have identified an interconnection potential between wind farms in northern and southern Europe in order to reduce intermittency at an aggregate scale, one of the primary challenges in wind power generation.