Multi-decadal offshore wind power variability can be mitigated through optimized European allocation

Charlotte Neubacher[1,2], Jan Wohland[3], Dirk Witthaut[1,4]

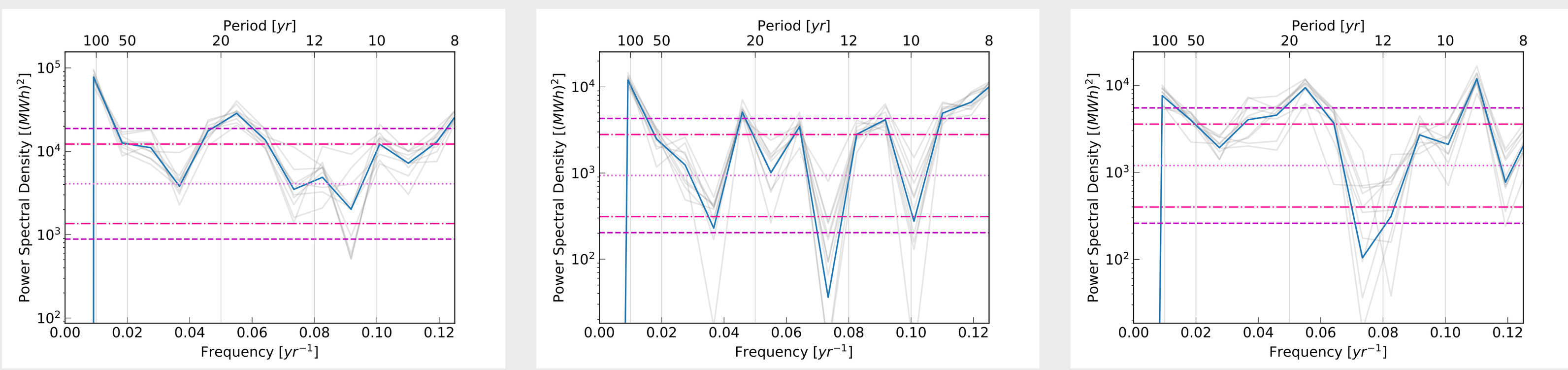
[1]Institute for Theoretical Physics, University of Cologne, 50937 Köln, Germany, [2]Forschungszentrum Jülich, Institute for Energy and Climate Research - Troposphere (IEK - 8), 52428 Jülich, Germany,
[3]Climate Policy Group, Department of Environmental Systems Science, ETH Zürich, 8092 Zürich, Switzerland,
[4]Forschungszentrum Jülich, Institute for Energy and Climate Research - Systems Analysis and Technology Evaluation (IEK - STE), 52428 Jülich, Germany

Introduction

High variability of wind power generation on many different timescales is a serious technical challenge for system integration and system security. Various studies investigate high frequency variability but timescales exceeding ten years got only few attention up to now.

Spectral Analysis reveals multi-decadal variability

- Spectral analysis of wind power time series derived from ECMWF's 20th century reanalysis CERA-20C [2]
- Power Spectral Density reveals two significant peaks at the Portuguese Atlantic Coast:
  - 50 - 100 yr period
  - 15 - 20 yr period
- Results confirmed by Singular Spectrum analysis (SSA [1]) (not shown)
- Further studies at different locations (not shown)



(a) annual (b) DJF (c) JJA

Figure: Power spectra of Portuguese potential offshore wind power generation. In (a) the spectrum of the full time series is shown whereas in (b) the winter term and in (c) the summer term is shown. The confidence level of 95% (dashed) and 99% (dash-dotted) is given by a χ^2-test.

Significant multi-decadal peaks everywhere across Europe

- Does a significant multi-decadal mode exists across Europe and how pronounced is it?
- At least one significant multi-decadal peak exists everywhere in Europe (confirmed by power spectrum and SSA)
- The amplitude is strongest at the Portuguese Atlantic Coast (Fig. 2)

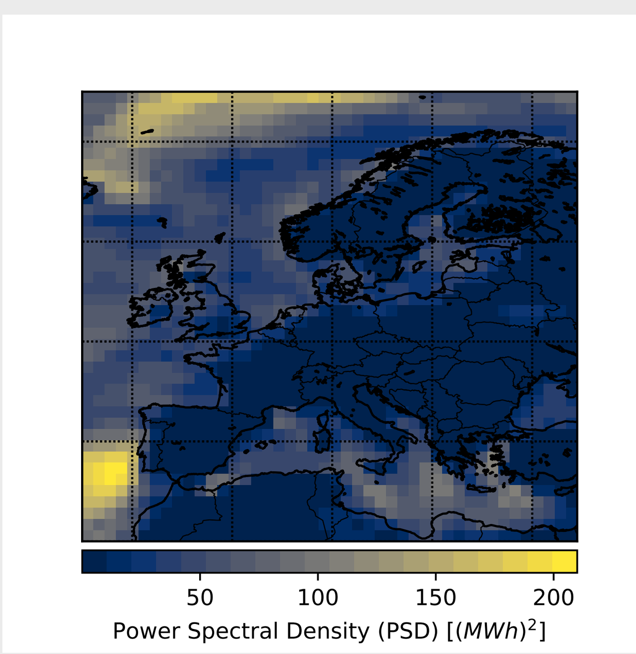
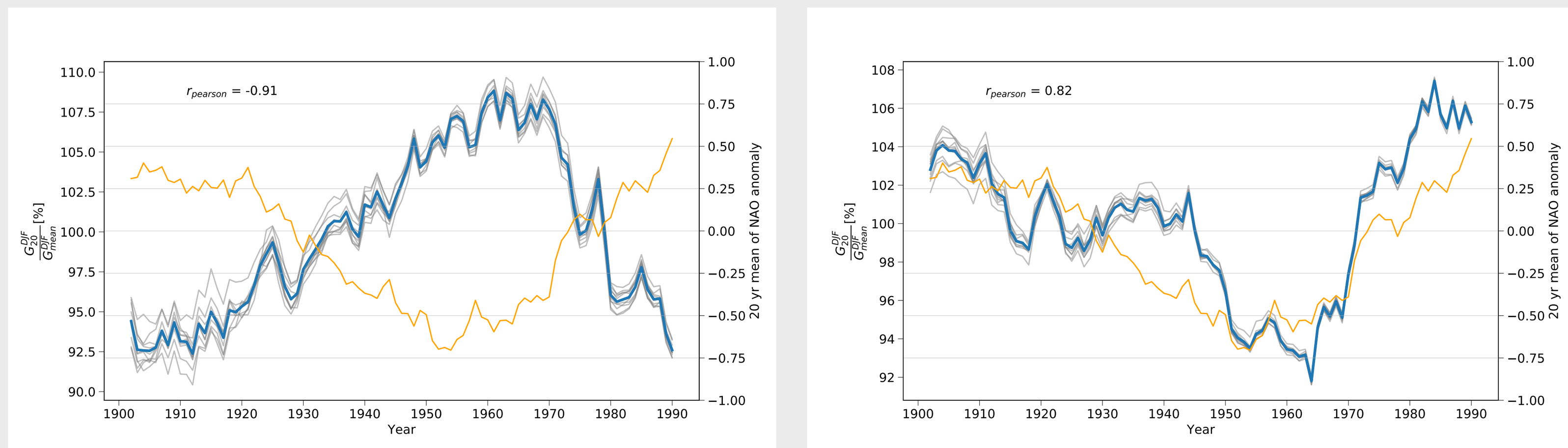


Figure: Analysis of multidecadal peaks in the power spectrum for each grid point in Europe. The maximum amplitude for multidecadal timescales $\nu < 0.1\,\mathrm{yr}^{-1}$. The shown signals are significant for a 90% confidence level at least.

Multi-decadal variance differs vastly throughout Europe

- How does large-scale climate dynamics manifest at different locations?
- Long-term evolution visualized by 20yr running mean (cf. [3])
- Opposite evolution in Northern and Southern Europe
- Anti-correlated with NAO at Portuguese coast, correlated with NAO in North Sea

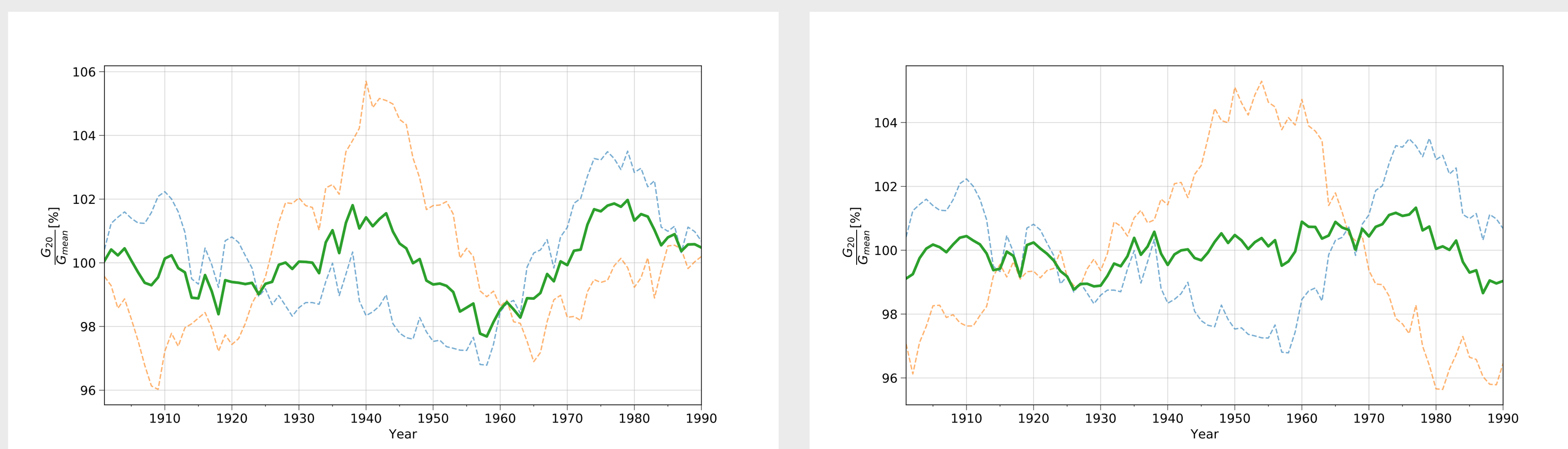


(a) Portuguese Atlantic Coast (b) German North Sea

Figure: Correlation of the winter 20 yr running mean and the 20 yr NAO anomaly. The normalized 20 yr running mean for DJF is shown in blue, the North Atlantic Oscillation anomaly in orange and their Pearson correlation.

Different multidecadal evolution allows for efficient balancing

- Can we exploit the different evolution to balance variability?
- Consider total generation of a wind turbine fleet at different locations: $G_{\mathrm{tot}}(t,\lambda) = \lambda G_1(t) + (1-\lambda) G_2(t)$
- Choose mixing parameter λ to minimize the variance of G_{tot}
- **Significant variance reduction possible through continental balancing**



(a) Balancing of Greece and Germany (b) Balancing of Germany and Portugal

Figure: Combined 20 yr running mean of three locations. Each panel shows the balancing of two locations. The dotted blue and yellow curves show the 20 yr running mean of the wind power generation, whereas the green curve shows the superposition, G_{tot}, of both with minimized variance.

Conclusion

- We report two significant multi-decadal modes of wind power generation potential in Europe
- The amplitude is strongest at the Portuguese Atlantic coast, and the relation to the NAO differs from North to South
- There is potential to mitigate multi-decadal variability through spatial balancing
- Wind park combinations in Portugal and Germany improve most significant variance reduction

References

[1] Michael Ghil et al. "Advanced spectral methods for climatic time series". In: *Reviews of geophysics* 40.1 (2002), pp. 3–1.

[2] European Centre for Medium-Range Weather Forecasts. *CERA-20C Data Set*. URL: https://www.ecmwf.int/en/forecasts/datasets/reanalysis-datasets/cera-20c (visited on 10/04/2018).

[3] Jan Wohland et al. "Significant multidecadal variability in German wind energy generation". In: *Wind Energy Science* 4.3 (2019), pp. 515–526.