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Wind farm effects on weather forecast using the operational model HARMONIE-AROME

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Wind farms extract kinetic energy from the flow to generate electricity. Thereby, they modify the wind and turbulence fields upwind, at the side and especially downwind of the farm. Due to the induced enhanced mixing, other meteorological variables such as temperature and humidity are also affected by the presence of wind farms. With the massive growth of installed capacity both on- and offshore, these wind farm effects play an increasing role in numerical weather forecasts. This study will investigate the impact of currently installed wind farms in Europe on the weather forecast accuracy.

We performed forecasts for central and northern Europe with and without wind farm parameterizations. We used the operational mesoscale model HARMONIE-AROME equipped with the wind farm parameterization (WFP) by Fitch et al. (2012) as implemented by van Stratum et al. (2021). We added another WFP, the explicit wake parameterization (EWP, Volker et al. 2015). We created a European wind turbine data set by combining different data sets and using a machine learning gap-filling approach. This data set includes turbine locations and their characteristics. Different scenarios were tested using this data set: (A) including only offshore turbines in the German Bight and surrounding Denmark, (B) including all on- and offshore turbines present in the European wind turbine data set.

The simulation results from HARMONIE-AROME indicate that wind farms affect near-surface wind speed, temperature and humidity. The magnitude of these differences decreases with increasing distance from the farm, but still amounts to ±0.5 m/s in 10-m-wind or ±0.25 K in 2-m-temperature at a non-negliable number of locations in Denmark for an investigated exemplary summer day compared to the scenario without wind farms. The impact of onshore turbines is generally smaller than that of offshore turbines. However, the response to scenarios (A) and (B) differ, indicating that it is necessary to include both on- and offshore turbines to capture the full effect of wind farms in Europe. The wind farm effect also depends on the chosen wind farm parameterization, and both schemes provide plausible results. Future studies are necessary to better evaluate the two parameterizations and derive possible fine-tuning or combinations of the schemes. Overall, an ensemble consisting of both wind farm parameterizations could give a more reliable forecast in the future.

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