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Micrometeorological Impacts of Offshore Wind Farms as seen in Observations and Simulations

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Large offshore wind farms represent an additional source of turbulence in the atmosphere and, hence, can influence the stratification of the marine atmospheric boundary layer (MABL). Changes in the temperature and moisture budget of the MABL can affect the stratification of the ocean and, hence, the food web of marine life.

In this work, we use 30 wake measurements conducted with a research aircraft within the research project WInd PArk Far Field (WIPAFF) between September 2016 and October 2017 at the North Sea to investigate the impact of large offshore wind farms on the MABL. In five out of the 30 cases do downwind measurements show a clear warming and drying in the wake at hub height (i.e. 90 m above mean sea level). We observed indications for a cooling in one case. Maximum warming at hub height is about 0.5 K and maximum drying is 0.4 g kg^{-1}, accompanied by wind speed deficits up to 3 m s^{-1}. The signal in potential temperature and water vapour mixing ratio were measured up to 60 km downwind of the relevant wind farm or wind farm cluster, while the wind speed deficit at 60 km downwind was up to 1.0 m s^{-1}. In four cases, the warming and drying are associated with a strong inversion at hub height, suggesting that the wind farms mix potentially warmer and dryer air, stemming from above the inversion, towards the surface. In contrast, cases with no inversion showed no warming – except one.

To test the representation of such events in numerical weather prediction models, we use the observations of one inversion-related warming event case study to evaluate the performance of a wind farm parameterization (WFP) in a mesoscale model (WRF). The WFP reproduces the warming and the drying within the wake, although the warming is underpredicted. More precisely, the simulation shows a warming of 0.2 K compared to 0.5 K in the observations, while the wind speed deficits of 3.0 m s^{-1} are simulated as 2.5 m s^{-1}. The weaker warming arises from errors in the model's representation of the upwind inversion. The air masses mixed towards the surface are colder in the model than in the observations.

Given the success with simulations for this case downwind of the measured wind farm, we conduct two more simulations for that case to estimate the overall impact of all wind farms that are existing and planned at the North Sea on the MABL. In the simulations, the wakes of several wind farms interact with each other, resulting in wakes of warmer and dryer air that extend over 100 km downwind, while the wind speed deficits exceed 150 km.