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Impact of Wind Farms on the Marine Atmospheric Boundary Layer

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Abstract

In the past decade the turbine technology has matured significantly, especially the offshore wind farm one. Whereas ten years ago Horns Rev I with a total capacity of around 160 MW was the largest wind farm. Today we find the Greater Gabbard wind farm in the North Sea which has a capacity over 500 MW, this using 3.6 MW turbines. However the current state of the art turbines are already beyond 7 MW. Since the offshore area in northern Europe is limited and wind farm sizes are expected to increase in the future, the study of wind farm interaction will gain importance. From a financial perspective it will be important to determine optimal wind farm locations for future wind farms, since lower wind speeds effect the production, and from the ecological point of view the possible impact on the local climate has to be investigated.

For both studies the domain of interest will be several hundred kilometers. Apart from LES models which have the great advantage of capturing the turbulent part of the spectrum, but which are currently too computationally expensive, the wind farm interaction can be analyzed with Mesoscale and (linearized) CFD-Models. Both models do not resolve the turbulent part of the spectrum. Mesoscale Models take into account atmospheric conditions which can be important for the wake extension, but it lacks in resolution compared to CFD-Models. This means that the single turbine wake can not be described explicitly with a Mesoscale Model. However, since we are mainly interested in large scale features, we choose to use Mesoscale Models for our further analysis.

In this presentation we will introduce wind farm parametrisation developed at DTU Windenergy (Risø-Campus), which mimics the wind turbines by effecting the velocity field based on similarity principles. It has been implemented in the Mesoscale Model (Weather Research and Forecast Model) WRF, which is a publicly available open source model. The required unresolved hub-height velocity is obtained once via look-up tables, produced by any CFD-Model, and once by the parametrization itself.

We verified the wind farm parametrization against long term in-situ measurements from the Horns Rev I wind farm. The Mesoscale Model has been run in the idealized case mode with a relatively high horizontal resolution of 1.12 km. The vertical resolution was in the boundary layer in the order of 10 m. In the idealized case mode the model is

initialised with a homogeneous dry atmosphere and open boundaries, which means that no forcing from the boundaries takes place. Furthermore the heat and moisture fluxes from the surface were set to zero. In this way the model converge to an equilibrium state determined by the constant initial geostrophic wind. This state is expected to be comparable to the long term measurement average.

The results show that the hub-height velocity deficit produced by the parametrisation is comparable to the local turbine velocity deficit obtained from turbine power measurements. We found also that the Mesoscale Model WRF is able to advect the velocity deficit similar to that observed at 2 km and 6 km downstream.