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Large Wind-Power Plants: Interaction, Control and Integration
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The Simulation of Wind Farm Wakes with Mesoscale Models

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With an increasing density of large wind farms in the North-Sea area, a better understanding of the interaction between individual wind farms is required. Mesoscale models simulate the atmospheric flow over large areas, which can cover the whole North Sea. This makes them suitable to model wakes behind large wind farms and study the influence of the wind farms to the atmosphere. However, the grid-mesh of the model is in the order of kilometres. Processes smaller than the grid-size remain unresolved and have to be accounted for in parametrisations. The effects of wind turbines to the flow is one example of an unresolved process.

The Weather Research and Forecast model [1] is released, from version 3.4 onwards, with a wind farm parametrisation (WRF-WF) [2]. The WRF-WF parametrization applies a local drag force to the grid-cell averaged Reynold Averaged Navier-Stokes (RANS) equations. Additionally, it adds a source term to the model's Turbulence Kinetic Energy (TKE) equation. At DTU Wind Energy a different approach has been developed [3]. In the Explicit Wake Parametrisation (EWP), we apply a grid-cell averaged drag force to the RANS equation, in which the volume averaged force accounts for the sub-grid scale turbine induced wake expansion. The additional TKE comes from the (vertical) shear (in mean horizontal velocity) production term of the Planetary Boundary Layer scheme, whereas the local turbine induced turbulence is on the grid-cell average neglected. The EWP approach has been implemented is the WRF model and compared to the WRF-WF parametrisation. The differences in the TKE budget between the WRF-WF and the EWP scheme, as well as the impact on relevant variables in the boundary layer will be presented.

For the European Energy Research Alliance - Design Tool for Offshore Wind Farm Cluster (EERA-DTOC) project, the EWP approach has been compared to Synthetic Aperture Radar (SAR) images. In the SAR images a flow reduction of several tens of kilometres behind offshore wind farms in the North-Sea can be recognised. The images show, furthermore, how large scale dynamics influence the wake propagation. For the selected cases, the extensions of the wind farm wakes, as well as their shape could be captured with the mesoscale model with wind farm parametrisation.

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[3] Volker, P.J.H. "Wake Effects of Large Offshore Wind Farms - a study of the Mesoscale Atmosphere," DTU Wind Energy, 132 (2014).