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Multiscale modeling of wind during an OCC event over an offshore wind park: Implication on wake and loads

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Multiscale modeling is essential in atmospheric science as it allows for a better understanding of atmospheric processes at different scales, more accurate predictions of weather events, and specifically, it helps scientists and engineers in offshore wind to understand the complex flow physics involved in wind turbine operation. At the microscale, multiscale modeling for offshore wind applications may be based on Large Eddy Simulation of wind, which helps predict turbulent flow and mixing at small scales, and study the aerodynamic behavior and load characteristics of wind turbines. Simulations at small scales are further useful for optimizing the design of wind turbines for improved performance and efficient operations. At the mesoscale, multiscale modeling such as the Weather Research and Forecasting (WRF) provides capability to simulate a range of atmospheric phenomena from global climate patterns to regional weather episodes at coarse resolution. Since WRF at these coarse resolutions is not able to explicitly resolve the small-scale turbulence, the model-chain containing the WRF and LES combines the strengths of both models to resolve from several kilometers to several tens of centimeters.

This study presents our recent development on offline nesting of the Weather Research and Forecasting (WRF) model with the Parallelized Large Eddy Simulation (PALM) model to improve simulation resolution in the area of Alpha Ventus offshore wind park, while maintaining reasonable computational costs. The WRF model simulates the entire domain covering the Southern North Sea, while the higher resolution PALM model is used to simulate the finest WRF nested domain within the area of interest. We use then the LES simulation results to investigate the wake dynamics behind the wind turbines and provide insights into the loads of downstream turbines. It is noted that we focus on the LES simulations of an Open Cellular Convection (OCC) event and the study of impacts of this transition event on the dynamics of wind, atmospheric turbulence in modulating wakes, loads, and in general flow patterns in the area of Alpha Ventus offshore wind park (OCCs can cause strong variations in wind speed and direction leading to significant modulation of the aerodynamic behavior of wind turbines and their power outputs).