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Large-eddy simulation of multiple wakes in the offshore wind farm Baltic I

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The turbulent wakes of wind turbines are of special importance in wind farms as they can affect the flow and power output of downstream turbines. Upstream turbines extract momentum from the mean flow so that the power output of subsequent turbines may be reduced. Furthermore, the wakes feature a significantly enhanced turbulence intensity which results in an increased load for downstream turbines. The marine atmospheric boundary layer is different from that onshore, especially in terms of a lower turbulence intensity and a higher wind speed due to the smaller roughness. So far, there has been little experience in simulating a realistic marine boundary layer. Models used for the design and energy yield prediction of offshore wind farms usually base upon onshore measurements.
With turbulence resolving large-eddy simulations (LES) it is possible to investigate the interaction between the turbulent atmospheric boundary layer and the turbine wakes as well as the interaction between the individual wakes in a wind farm.

Baltic I is Germany's first commercial offshore wind farm in the Baltic Sea. It consists of 21 2.3 MW turbines and is in operation since May 2011. The layout of Baltic I is designed so that, depending on the wind direction, very different wake conditions can be observed. Due to a triangular farm layout, for a wind direction parallel to one of the farm edges both single and multiple (up to six successive) wakes would coexist.
High-resolution large-eddy simulations are performed with the LES model PALM in which the wind turbines are parameterized with an enhanced actuator disk approach including the effect of the turbine towers. The simulation of a single wind farm is realized by a stationary model domain with a turbulent inflow instead of cyclic boundary conditions. Baltic I is simulated in full scale with high resolutions of less than 10 m. The intra wind farm wake characteristics are investigated for different atmospheric conditions as wind speed and direction or atmospheric stability.