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High-resolution offshore wake simulations with the LES model PALM

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The turbulent wake of a wind turbine is important especially in wind farms, as it can affect the flow and power output of downstream turbines. Upstream turbines extract momentum of the mean flow so that the power output of subsequent turbines is reduced. On the other hand, the turbulence intensity is significantly enhanced 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.

Several wind turbine models have been implemented in the LES model PALM: a simple uniformly loaded actuator disk model, an enhanced non-uniformly loaded actuator disk model which also accounts for rotational effects and an actuator line model. The comparison of the three turbine models for the wake of a single turbine shows, that the enhanced actuator disk model is a significant improvement and provides similarly good results as the computationally unfeasible actuator line model.

With the enhanced actuator disk model simulations of a single wake have been conducted, using different inflow boundary conditions. The results have been compared with observations from the offshore test site “alpha ventus”. So far, only cyclic inflow boundary conditions have been used for wake simulations, whose major drawback is the re-inflow of air already modified by the wind turbine. With non-cyclic boundary conditions, used for the first time in wake simulations, the inflow profile at the turbine remains undisturbed and constant in time. The additional application of a turbulent inflow results in a fully turbulent flow already at the inflow boundary, so that the model domain can be significantly reduced.

Finally, results of a simulation of the offshore wind farm “alpha ventus“ will be shown.