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# Effects of wind direction and wind farm layout on turbine wakes and power losses in wind farms: An LES study

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A recently-developed large-eddy simulation (LES) framework is validated and used to investigate the effects of wind direction and wind farm layout on the turbine wakes and power losses in wind farms. The subgrid-scale (SGS) turbulent stress is parameterized using a tuning-free Lagrangian scale-dependent dynamic SGS model. The turbine-induced forces are computed using a dynamic actuator-disk model with rotation (ADM-R), which couples blade-element theory with a turbine-specific relation between the blade angular velocity and the shaft torque to compute simultaneously turbine angular velocity and power output. Here, we choose the Horns Rev offshore wind farm as a case study for model validation. A series of simulations are performed for a wide range of wind direction angles. Results from the simulations are in good agreement with observed power data from the Horns Rev wind farm, and show a strong impact of wind direction on the farm power production and the spatial distribution of turbine-wake characteristics (e.g., velocity deficit and turbulence intensity). This can be explained by the fact that changing the wind angle can be viewed as changing the wind farm layout relative to the incoming wind, while keeping the same wind turbine density. To further investigate the effect of wind farm layout on the flow and the power extracted by the farm, simulations of wind farms with different circular and elliptic layouts are performed to compare with the results of the Horns Rev wind farm simulations. The results show that the proposed layouts not only provide more stable power output with different wind directions, but also enhance the performance of the total farm power production.