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Modeling subgrid-scale fluxes and wind-turbine forces in large-eddy simulation

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Large-eddy simulation (LES) offers a great potential to study the effects of turbulent atmospheric boundary layer flow on the performance of wind turbines and wind energy parks. The accuracy of the simulations, however, depends on two types of parameterizations: A subgrid-scale (SGS) model for the SGS fluxes of momentum and heat, and a parameterization for the SGS forces resulting from the interaction between wind turbines and the turbulent flow. This presentation focuses on recent developments in the modeling of both SGS turbulent fluxes and turbine forces. The models are tested against measurements from experiments carried out using miniature wind turbines at the stratified boundary layer wind tunnel facility of the St. Anthony Falls Laboratory. The best results are obtained with a combination of tuning-free Lagrangian scale-dependent dynamic models for SGS stresses and SGS heat fluxes (Stoll and Porte-Agel, 2006), and a blade-element method to distribute the force loading of the blades on the turbine rotor disk. Simulation results are also used to study the effects of boundary layer turbulence on the structure of wind turbine wakes, which affect turbine performance and fatigue loads in wind parks.