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Evaluation of dynamic subgrid-scale models and wind-turbine models in large-eddy simulations of wind-turbine wakes in boundary layer flows

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Large-eddy simulation (LES), coupled with a wind turbine model, is used to investigate the characteristics of wind-turbine wakes in a neutrally stratified boundary layer flow. Three different subgrid-scale (SGS) models for the SGS stresses are tested: (1) the Smagorinsky model, (2) the Lagrangian dynamic model, and (3) the scale-dependent Lagrangian dynamic model (Stoll and Porté-Agel, 2006). The turbine-induced forces (lift and drag) are parameterized using blade element momentum theory. Three wind-turbine models, using different force integration over temporal and spatial resolutions, are applied: (a) the standard actuator-disk model without rotation (ADM-NR), (b) the actuator-disk model with rotation (ADM-R), and (c) the actuator line model (ALM). Simulation results obtained with all SGS models together with wind turbine models are compared to wind-tunnel measurements collected with hot-wire and cold-wire anemometry in the wake of a miniature 3-blade wind turbine at the St. Anthony Falls Laboratory atmospheric boundary layer wind tunnel. In general, the scale-dependent Lagrangian dynamic model is able to account (without tuning) for the local changes in the eddy- viscosity model coefficient at different positions in the wake. It can also capture the scale dependence of this coefficient associated with flow anisotropy in regions of the flow with strong mean shear. The characteristics of the wakes simulated with the proposed LES framework using the scale-dependent Lagrangian dynamic model together with the ADM-R and the ALM are in good agreement with the measurements. However, the ALM is better able to capture vortical structures induced by the blades in the near-wake region.