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Surface roughness and thermal stratification effects on the structure of wind turbine wakes

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Wind turbine wakes are known to have important effects on both power generation and fatigue loads in wind energy parks. Wake characteristics are expected to depend on the incoming atmospheric boundary layer flow statistics (e.g., mean velocity, turbulence intensity and turbulent fluxes). In this study, results are presented from wind tunnel experiments carried out at the St. Anthony Falls Laboratory atmospheric boundary layer wind tunnel using a model wind turbine placed inside the boundary layer. The structure and behavior of the wind turbine wake are analyzed under different conditions of thermal stratification and surface roughness. Different thermal stratification levels in the boundary layer were achieved by controlling the temperature of both the tunnel floor and the air flow. Hot-wire anemometry and Particle Image Velocimetry (PIV) were used to characterize the turbulent wake downwind of the turbine for the different boundary layer conditions.
This study provides valuable information about the effects of boundary-layer turbulence on the performance of wind turbines and the behavior of wind turbine wakes under different conditions (surface roughness and thermal stratification). This information is being used to test and guide the development of improved parameterizations of wind turbines in high-resolution numerical models, such as large-eddy simulations (LES).