Geophysical Research Abstracts
Vol. 16, EGU2014-8101, 2014
EGU General Assembly 2014

Influence of atmospheric stability on wind-turbine wakes: A large-eddy simulation study

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In this study, large-eddy simulation is combined with a turbine model to investigate the influence of atmospheric stability on wind-turbine wakes. In the simulations, subgrid-scale turbulent fluxes are parameterized using tuning-free Lagrangian scale-dependent dynamic models. These models optimize the local value of the model coefficients based on the dynamics of the resolved scales. The turbine-induced forces are parameterized with an actuator-disk model with rotation. In this technique, blade-element theory is used to calculate the lift and drag forces acting on the blades. Emphasis is placed on the structure and characteristics of wind-turbine wakes in the cases where the incident flows to the turbine have the same mean velocity at the hub height but different stability conditions. The simulation results show that atmospheric stability has a significant effect on the spatial distribution of the mean velocity deficit and turbulent fluxes in the wake region. In particular, the magnitude of the velocity deficit increases with increasing stability in the atmosphere. In addition, the locations of the maximum turbulence intensity and turbulent stresses are closer to the turbine in convective boundary layer compared with neutral and stable ones. Detailed analysis of the resolved turbulent kinetic energy (TKE) budget inside the wake reveals also that the thermal stratification of the incoming wind considerably affects the magnitude and spatial distribution of the turbulent production, transport term and dissipation rate (transfer of energy to the subgrid scales). It is also shown that the near-wake region can be extended to a farther distance downstream in stable condition compared with neutral and unstable counterparts. In order to isolate the effect of atmospheric stability, additional simulations of neutrally-stratified atmospheric boundary layers are performed with the same turbulence intensity at hub height as convective and stable ones. The results show that the turbulence intensity alone is not sufficient to describe the impact of atmospheric stability on the wind-turbine wakes.