Geophysical Research Abstracts
Vol. 16, EGU2014-6760, 2014
EGU General Assembly 2014

Modeling large wind farms in conventionally neutral atmospheric boundary layers under varying initial conditions

Dries Allaerts and Johan Meyers
KU Leuven, Department of Mechanical Engineering, Leuven, Belgium (dries.allaerts@mech.kuleuven.be)

Atmospheric boundary layers (ABL) are frequently capped by an inversion layer limiting the entrainment rate and boundary layer growth. Commonly used analytical models state that the entrainment rate is inversely proportional to the inversion strength. The height of the inversion turns out to be a second important parameter. Conventionally neutral atmospheric boundary layers (CNBL) are ABLs with zero surface heat flux developing against a stratified free atmosphere. In this regime the inversion-filling process is merely driven by the downward heat flux at the inversion base. As a result, CNBLs are strongly dependent on the heating history of the boundary layer and strong inversions will fail to erode during the course of the day. In case of large wind farms, the power output of the farm inside a CNBL will depend on the height and strength of the inversion above the boundary layer. On the other hand, increased turbulence levels induced by wind farms may partially undermine the rigid lid effect of the capping inversion, enhance vertical entrainment of air into the farm, and increase boundary layer growth.

A suite of large eddy simulations (LES) is performed to investigate the effect of the capping inversion on the conventionally neutral atmospheric boundary layer and on the wind farm performance under varying initial conditions. For these simulations our in-house pseudo-spectral LES code SP-Wind is used. The wind turbines are modelled using a non-rotating actuator disk method. In the absence of wind farms, we find that a decrease in inversion strength corresponds to a decrease in the geostrophic angle and an increase in entrainment rate and geostrophic drag. Placing the initial inversion base at higher altitudes further reduces the effect of the capping inversion on the boundary layer. The inversion can be fully neglected once it is situated above the equilibrium height that a truly neutral boundary layer would attain under the same external conditions such as geostrophic wind speed and surface roughness. Wind farm simulations show the expected increase in boundary layer height and growth rate with respect to the case without wind farms. Raising the initial strength of the capping inversion in these simulations dampens the turbulent growth of the boundary layer above the farm, decreasing the farms energy extraction.

The authors acknowledge support from the European Research Council (FP7–Ideas, grant no. 306471). Simulations were performed on the computing infrastructure of the VSC Flemish Supercomputer Center, funded by the Hercules Foundation and the Flemish Government.