Validation of a CFD model with lidar-based wind scanners upstream of a wind turbine in complex terrain

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ABSTRACT

A CFD – Reynolds Averaged Navier Stokes (RANS) solver is validated in the upstream region of a wind turbine in complex terrain with measurements taken by several synchronised multi-lidar systems. The underlying field measurement campaign investigated the flow developing over two parallel running ridges and its interaction with a wind turbine located on top of one of them. The high temporal and spatial resolution of the acquired data allows for not only the verification of global flow features in complex terrain but also the small scale interactions of the wind turbine with this flow-field. The validation methodology incorporates the aleatory uncertainty of the “free” undisturbed wind speed. The measured probability density function of this velocity is then recreated by weighing several steady-state RANS simulations. Accounting for the variability of the flow far upstream of the turbine enables matching of the measurements with the numerical model. Furthermore, modelling the flow upstream of a wind turbine in complex terrain relies on an accurate representation of the local orography. The finite volume code EllipSys3D [2] solved the incompressible RANS equations over the multi-block domain. The turbulence was modelled with the two-equation k-epsilon-fp closure [3]. In the Bolund blind test [6] the two-equation closures showed the best agreement with measurements taken in complex terrain. A modified k-epsilon closure is used to improve the estimation of the eddy-viscosity in the wake of the wind turbine. The surface roughness is estimated from lidar forest canopy measurements. The turbine itself is represented by a permeable disc over which the rotor forces are applied inside the flow domain. Incorporating the variability of the free wind speed allows for verification of the computational model in complex terrain. Estimating the variability of the flow in complex terrain is only possible due to the extensive measurement data taken far upstream of the ridge. The effect of the turbine on the flow upstream is limited to an area in close proximity to the turbine (one diameter upstream), as the orography dictates the major flow features. Consequently, the surface roughness from forested areas in combination with high resolution map data becomes essential in accurately modelling wind turbines in complex terrain.

References