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Intercomparing WRF-LES based turbulence simulations with measurements from a 250-m tall meteorological mast

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We present an intercomparison of a one year of atmospheric simulations performed with a numerical atmospheric model system based on the WRF model with tall mast observations. We employ the nestinga capabilities of the WRF model to run up to high resolution large-eddy simulations (WRF-LES). The simulations aim at describing the wind climatology and the turbulence characteristics at Østeild, Denmark. There, DTU established the National Test Site for Wind Turbines, where some of the largest wind turbines prototypes are under testing. We evaluate the goodness of the simulations using the WRF-LES system by comparison with high-quality mean wind and turbulence observations from a 250-m meteorological mast. The main objective of the work is to demostraste that the WRF model does not only provide long-term time series of wind speed and direction but also turbulence characteristics and parameters, which are needed for the evaluation of the site conditions, and turbine design and peformance.

The WRF-LES based simulations are performed using four nested telescopic domains centered at the Østerild mast position. The outermost and largest domain has a horizontal resolution of 6250 m, whereas the innermost and smallest domain a horizontal resolution of 50 m. By modeling at these scales, we intend to resolve most of the turbulent scales. We run the two outermost domains in a traditional mesoscale fashion, which means we use a commmonly used planetary boundary layer (PBL) scheme, whereas the two innermost domains are run in large-eddy simulation mode, i.e., without a PBL scheme. A complete year is simulated through parallel ten day long simulations. The output for the innermost domain is produced at the model grid point closest to Østerild every 12 s, whereas that of the other domains is produced every 10-min.

After computing the 10-min statistics for the full year on the model output of the innermost domain output and the 1-Hz data of the cup anemometers at Østerild that cover the range of the mast, we find very good agreement between the observed and simulated wind climatology. Turbulence estimates from both observations and simulations are also in good agreement, even though from the observations the site shows a wide variety of atmospheric stability and turbulence conditions. The turbulence intensity changes with wind speed in a similar way both in the simulations and the measurements. Our work shows that numerical models can be used as a tool to describe turbulent site conditions required, among others, for the efficient siting of wind turbines.