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An evaluation of WRF-LES using measurements from a 250-m tower

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As part of the multi-scale and model-chain evaluation of wind atlases (MEWA) project, we are performing an evaluation of meso-micro-scale coupling techniques for wind resource and turbine site assessment. One of the techniques to be evaluated consists of dynamically downscaling a mesoscale flow solution through a large-eddy simulation (LES).

Here, the ability of the Weather Research and Forecasting (WRF) model to perform LESs is investigated. This is attempted by comparison of simulations of the WRF-LES setup with measurements from a 250-m lightning mast deployed at Østerild in northern Jutland, Denmark. This heavily instrumented mast is part of the test station with largest wind turbines in the world. Østerild is an area characterized by a flat orography but a relatively complex land use. For the predominant wind direction, i.e. westerly winds, the flow can be considered rough but homogenous; therefore, we can compare the mast measurements with LES of 'canonical' or idealized flows. The lightning mast is equipped with, i.a., Metek USA-1 sonic anemometers at five levels above ground (7, 37, 103, 175, 241 m) and cup anemometers nearly at the same levels. The cup and sonic anemometer measurements provide details on the mean and turbulence structure of the atmospheric flow at Østerild within the levels where current very large wind turbines, i.e. approx. 10 MW, operate.

The canonical flows that we are planning to simulate aim at representing the atmospheric flow under the three common stability regimes: convective, neutral and stable. From a preliminary analysis of the sonic anemometer measurements, we have observed a clear dependence of the three turbulence parameters that drive a 3D turbulence spectral model on both atmospheric stability and height above the ground. The flow becomes more isotropic the higher we measure and the more convective the atmosphere is. Further, we observe a decrease of turbulence dissipation the higher we observe from the ground; a behavior clearly observed for neutral atmospheric conditions. Lastly, we notice a decrease of the turbulence length scales the closer the measurements are to the ground; the length scales are systematically larger under convective conditions compared to neutral and the latter larger compared to stable conditions. Our main objective is to try to find out whether or not our WRF-LES setup can reproduce these findings