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Non-neutral wind conditions in complex terrain

Catherine Meissner (1), Carolin Schmitt (2), and Bernd Goretzki (3)

(1) WindSim AS, Norway (catherine@windsim.com), (2) Theolia, Germany (c.schmitt@theolia.de), (3) Wetter Jetzt GbR, Germany

Today wind resource assessment in complex terrain is often done by combining computational fluid dynamics (CFD) simulations with measurements. Usually the assumption of neutral stratification is used when studying the wind conditions of a wind farm site with CFD. This is justified because the atmospheric boundary layer is said to be neutral in the long term mean. However, meteorological investigations at our sites show that more stable stratifications can also prevail in the long term means. This means that a neutral stratification assumption for those sites would lead to erroneous simulation of wind shear. Blocking effects over hilly terrain would also be handled incorrectly by neutral flow simulations. These two effects can significantly affect the simulated wind profile and the spatial distribution of the wind speed and thus the calculated wind farm energy output and its variations in time.

The commercial CFD software WindSim is able to simulate thermal stratification effects in the atmosphere by solving the temperature equation explicitly using the Monin-Obukhov length as an index of stability. This allows a more sophisticated modelling when compared to other CFD tools which do not directly solve the temperature equation. WindSim is thus better able to simulate observed flow patterns created by the interaction of thermal stratification and terrain.

In order to calculate the Monin-Obukhov length from measurements at the site, temperature and wind data in at least two heights are required. Such measurements are not yet standard for wind resource assessment. We have therefore equipped several met masts with advanced measurement systems in order to investigate the stability effects, in particular on the wind shear. The met masts are placed in various geographic regions across Europe, where different atmospheric and orographic conditions can influence the development of the thermal stratification. This allows us to study the various stability characteristics across a range of timescales from diurnal to annual. From the observations it will be shown that especially during the winter time more stable conditions prevail.

The differences between CFD-simulated wind profiles with and without the inclusion of thermal effects will be assessed and validations will be shown using measured wind profiles. Simulations with neutral and stable stratification will be compared with measured stable wind profiles. In the case of neutral simulations, possible over- and underestimation of measurements will be investigated and quantified. In the case of stable simulations a better fit of the profiles is expected when using the optimal stratification parameters.

This work will take advantage of the diverse geographical positions of the sites to extend and compare the lessons learned across climatologically different sites. Inclusion of thermal stratification has proven to enhance CFD simulation results and lead to more precise calculations in wind shear and energy yield estimate.