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CFD Validation – A Simple Approach

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windsim

Abstract

Historically there have been an overwhelming number of experimental and numerical studies characterizing the Atmospheric Boundary Layer. Still it is a great challenge to determine how wind turbines are affected by local wind fields.

Local wind fields are influenced by topography and vegetation, they are turbulent and often density stratified, and all of these effects interact in a non-linear manner. Computational Fluid Dynamics (CFD) like that used in the WindSim software has the capability to take all of these effects into account using fundamental equations.

The Bolund Experiment filled a need to obtain a large set of quality observations of a complex flow under well-defined conditions, and this data has been used to validate the flow fields modelled in WindSim over Bolund Hill during neutrally stratified conditions.

Objective

The main objective of this study was to validate the mean wind speed and turbulence modeled over Bolund hill using WindSim with the measurements.

Methods

A CFD model was created in WindSim using the terrain and roughness data provided by Risø. The resolution of the model was taken to be quite fine with a maximum horizontal resolution around the escarpment of 60 cm and tightly-packed nodes in the vertical direction starting with the first node at ca 20 cm above ground.

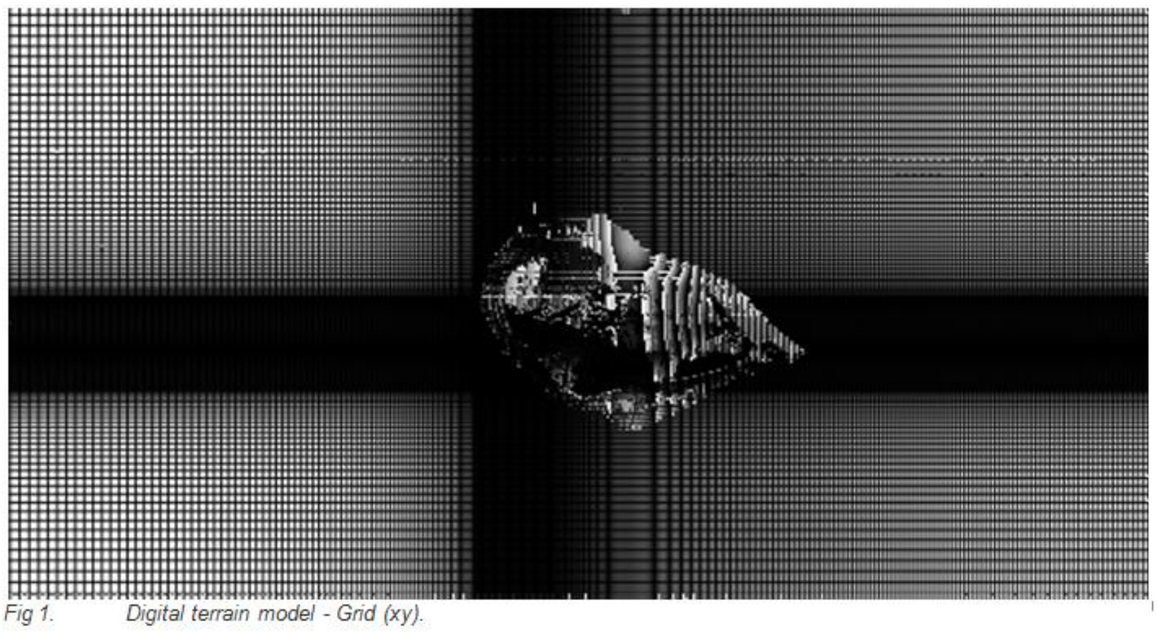

Fig 1. Digital terrain model - Grid (xy).

Body fitted co-ordinates (BFC) are used in grid generation. The above plot displays the resolution at ground level.

	x	y	z	total
Grid spacing, min - max (m)	0.6 - 6.8	0.7 - 8.2	Variable	-
Number of cells	365	175	40	2555000

Table 1. Grid data.

Figure 1: Horizontal grid used in WindSim showing refinement over the escarpment.

The model was then initialized using logarithmic wind profiles at the inlet boundary for wind direction sectors 90, 239, 255 and 270. The inlet logarithmic profiles were calculated using the provided model-roughness heights as well as a friction velocity provided for each sector.

Upon the creation of a satisfactory computational grid the model was iterated forward until a steady state was reached for each simulation.

In the beginning there were problems of model convergence due to the way the body-fitted grid followed the steep escarpment on the western side of the hill, and these problems had to be overcome by performing a smoothing on the terrain data just in the vicinity of the escarpment. This resulted in a smoothing of the escarpment from near 90 degrees inclination to around 60 degrees.

Results

The average errors in the wind speeds at 2 and 5 meters over line A were 15%. This put WindSim's results among the best submitted in Risø's blind comparison for the Bolund Experiment. The best submitted result had an error of 13%.

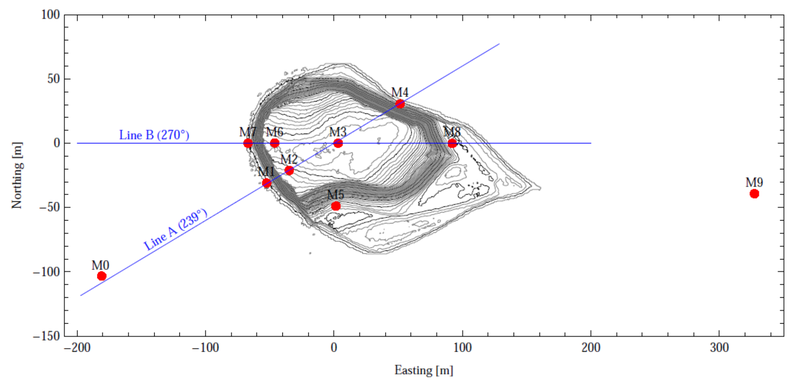

Figure 2: Bolund topography and measurement mast locations.

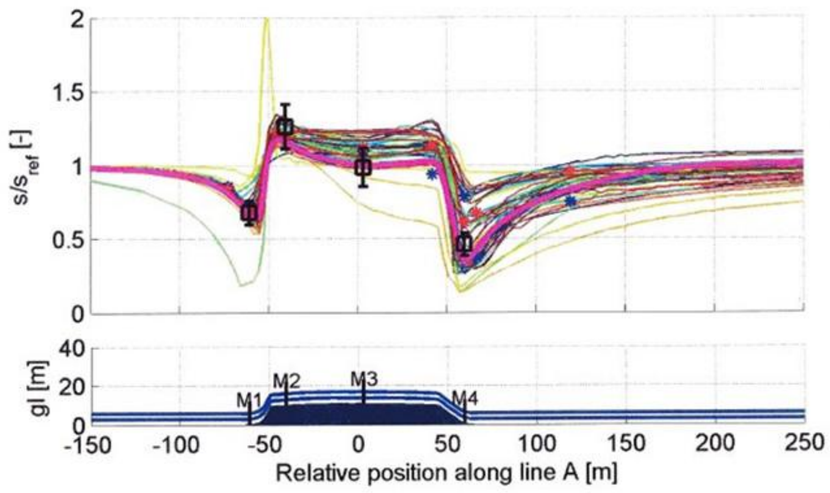

Figure 3: Normalized wind speed at 5 meters height with wind direction from 239 degrees for the Bolund experiment. Measurements are given by black boxes. The solid pink line shows the WindSim results. The other lines are results from other models submitted to the Bolund Blind Comparison.

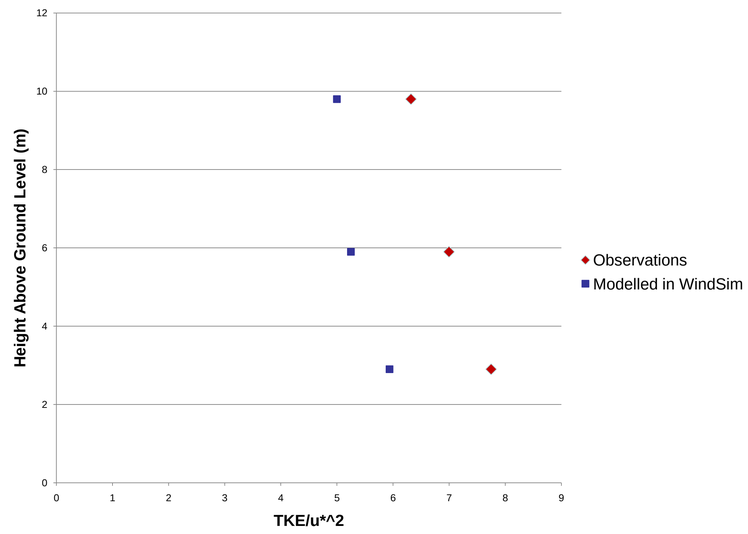

Figure 4: Measured and modeled profiles of TKE/u^2 at Mast 1 for sector 270.*

Modeled TKE values in WindSim were consistently too low. This could be a result of model resolution and smoothing of the terrain. But profiles and spatial variation of turbulence are captured reasonably well and scaling can thus be used to improve results.

Conclusions

WindSim was run over Bolund hill for validation against the measurements obtained in the Bolund Experiment. The errors in the wind speeds modeled by WindSim were among the lowest submitted to the Bolund Blind Comparison.

Further investigation into the turbulence modeled by WindSim has shown WindSim to consistently underestimate the turbulence for this case, Simulations using less smoothing of the terrain would likely improve results by resolving sharp features which generate turbulence.

References

A. Bechmann, J. Berg,M.S. Courtney,H.E. Jørgensen, J.Mann and N.N.Sørensen. The Bolund Experiment: Overview and Background. Technical Report Risø-R1658(EN), Risø DTU, National Laboratory for Sustainable Energy Roskilde, Denmark, 2009.