Evento	Salão UFRGS 2018: SIC - XXX SALÃO DE INICIAÇÃO CIENTÍFICA DA UFRGS
Ano	2018
Local	Campus do Vale - UFRGS
Título	NUMERICAL SIMULATION OF TURBULENT FLOWS OVER COMPLEX TERRAINS USING THE OPEN SOURCE CFD SOFTWARE OPENFOAM
Autor	GABRIEL BARBIERI DUMONT
Orientador	ADRIANE PRISCO PETRY

NUMERICAL SIMULATION OF TURBULENT FLOWS OVER COMPLEX TERRAINS USING THE OPEN SOURCE CFD SOFTWARE OPENFOAM

Author: Gabriel Barbieri Dumont
Supervisor: Adriane Prisco Petry
Institution: Federal University of Rio Grande do Sul

In this work, the open source software OpenFOAM is used to simulate the atmospheric wind flow over two complex terrains: Bolund Hill, located in Denmark, and Askervein Hill, located in Scotland. These hills were chosen as the meteorological data for both of them is widely available and extensively documented in the literature, allowing the validation of the model without need of further measurements. The objective of this study is to verify the model's consistency and then perform a sensitivity analysis by varying mesh refinement, divergence schemes and turbulence model parameters.

The simulated region is the atmospheric surface layer, which represents the lower 200 m of the atmospheric boundary layer. By neglecting the Coriolis force and the stratification effects, it can be modeled by the standard k - ε turbulence model. However, the model's standard constants were defined for engineering-scale flows, and, as such, should be adjusted for atmospheric flows, which represents part of the sensitivity analysis. In particular, the constant $C\mu$ is changed, and can be fitted from meteorological values or expressed as a function of the friction velocity, as is done in the *Fitted* and *Atmospheric* models, respectively; however, the Prandtl number of the turbulence dissipation rate must also be changed. Furthermore, under assumptions of negligible vertical velocity, constant pressure and constant shear stress, the model has known analytical solutions for the velocity (U), turbulent kinetic energy (k) and turbulence dissipation rate (ε) transport equations.

To check if the model is consistent, a plain, bi-dimensional empty fetch with uniform rugosity and the profiles given by the solutions of the U, k and ε equations applied at the inlet is simulated. The profiles should remain unchanged; however, using the regular sand-grain roughness wall-functions creates inconsistencies. To remedy this, the *epsilonWallFunction* file at the OpenFOAM source code is modified.

The analyzed turbulence model properties are those defined by the standard, *Atmospheric* and *Fitted* models, defined above. The analyzed divergence schemes are the first-order *upwind*, the second-order *linear* and the third-order *QUICK* schemes. For Bolund Hill, meshing is done using the *snappyHexMesh* OpenFOAM application for unstructured grids, and three meshes of increasing refinement are analyzed. For Askervein Hill, meshing is done using the third-party *terrainBlockMesher* utility and four meshes of increasing refinement are analyzed. In total, 36 simulations are run for Askervein, and 27 for Bolund, all with the following boundary conditions: *wall* at the ground, *free-slip* at the sides and top, *constant pressure* at the outlet, and the above mentioned U, k and ε profiles at the inlet. Both computational domains consist of a box centered on the hill, with the hills themselves placed far away from the computational boundaries so that errors caused by interactions with the boundary conditions are reduced.

Python scripts used by the research group were adapted for data treatment and to automate the simulation processes. The results showed that all models underpredicted the turbulent kinetic energy at the lee of both hills, though the effect is much more pronounced in the *upwind* simulations, possibly due to the scheme's parabolic bias not fully capturing the recirculation zone. Also, in general, simulations that employed the constants given by the *Atmospheric* model and one of the higher-order divergence schemes presented speed-up ratios that were in better agreement with the measured data.