Analysis of the wind speed distribution over real terrain topography using one- and three-dimensional models

K. Wędolowski$^1$ (kjwed@okwf.fuw.edu.pl)$^{1,2}$ and K. Bajer$^{1,2}$

$^1$Institute of Geophysics, Faculty of Physics, University of Warsaw, Poland
$^2$Interdisciplinary Centre for Mathematical and Computational Modelling, University of Warsaw, Poland

May 13, 2011

atmospheric boundary layer, wind energy, flow over complex terrain

Wind energy is one of the most developing branch of the power industry. Consequently, great efforts are now focused on increasing its efficiency and reliability. The leading challenge of the wind energy development is the question of the energy production predictability and the wind resource assessment [1], [3], [4]. Moreover wind turbines could have serious impact on the electric grid and on the quality of delivered power. This motivates us to investigate how different atmospheric conditions could influence the mean wind velocity and its variation in the neighbourhood of wind turbines.

Wind energy production strongly depends on the atmospheric conditions. Wind speed near the wind turbine is determined by both synoptic conditions and local characteristics of the site. The mesoscale forecast can be obtained from several available numerical weather prediction (NWP) models run by national meteorological services and research institutions. However, such models have limited horizontal resolution and therefore they cannot take into account the detailed topography and other characteristics of the site, such as, for example, land cover and associated terrain roughness. Moreover only a few vertical levels are located in the atmospheric boundary layer, which is the focus of our interest. For this reason additional CFD (Computational Fluid Dynamics) modelling of the atmosphere over the wind farm is often required.

In our simulations we use two models of the air flow. The first one is a one-dimensional model of the atmospheric boundary layer in which vertical transport occurs only due to turbulent diffusion [2], [5]. It is a consequence of the assumption that vertical component of the mean velocity identically vanishes. The second model is three-dimensional and solves full velocity field using simpleFOAM solver. It requires boundary conditions which are set using the one-dimensional model.

The three-dimensional model is meant to take into account topographical features of the land surface. It allows for the local wind speed-up to be revealed. The mesh was created based on the
DEM (Digital Elevation Model) [6] data. For this purpose we used the *snappyHexMesh* utility. Using detailed topography in the small scale model gives us much more precise information on the wind speed distribution due to topographical feature of the site. It can be seen in the figures 1 and 2.

![Figure 1: Vertical cross section of the domain coloured with the velocity magnitude from a simulation using detailed topography.](image1)

![Figure 2: Vertical cross section of the domain coloured with the velocity magnitude from a simulation using coarse topography (coming from the NWP model).](image2)

The one-dimensional model was created in order to represent different velocity profiles appearing due to different atmosphere stability conditions. It allow us to run three-dimensional simulations with quite reliable inlet profiles of the velocity and the turbulent kinetic energy.

References