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Experimental investigation of complex terrain effects on wind dynamics within the lower atmosphere

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There are growing requirements for improved predictability of flow interactions with complex terrain within the lower Atmospheric Boundary Layer (ABL), particularly within the Atmospheric Surface Layer (ASL). While most investigations have been dedicated to speed-up predictions over hill crests for wind energy purposes, less attention has been given to the turbulence properties of such flows. The effects of different orographic structures on ASL flow turbulence are not fully understood, thus constraining accurate forecasts of turbulence characteristics in structured terrain. Numerical modelling approaches are the primary tool in providing sub-mesoscale flow predictions, but these have displayed limited performances close to the surface, with results exhibiting strong dependence on grid resolutions and turbulence closure approaches. Large-Eddy Simulation (LES) models are increasingly popular and are expected to outperform previous time-averaging numerical approaches, however these lack adequate validation due to the shortage of qualified experimental or field data as reference.

The current research project aims to address these issues through extensive physical modelling campaigns performed at the Environmental Wind Tunnel Laboratory (EWTL) of the University of Hamburg. These experimental campaigns are focused on providing a better understanding of how complex terrain geometries affect local shear-induced three-dimensional (3D) turbulence associated to neutrally-stable ABL flows. Of particular interest are the identification of the geometric parameters that exert greater influence on the flow, the upwind and downwind distances in which terrain structures influence near-surface turbulence and how the effects of local surface heterogeneities and roughness compare to the effects of the orographic structures on turbulence. Additionally the experiments intend to ascertain if characteristic terrain structures, such as ridges or valleys, can be classified according to the effects on turbulence parameters. To this purpose several 3D terrain structures are modelled at the EWTL facilities, with levels of terrain complexity ranging from single idealised terrain features, such as ridges and valleys, to real regions of structured terrain.

While providing accurate flow data for the respective study region, the high-detail real terrain models are found to be too complex to provide insight into which parameters are most influential to flow turbulence. Furthermore, the close proximity between different terrain structures complicates the task of identifying which of the observed flow effects are attributable to a specific terrain type. In this context idealised terrain geometries are advantageous in facilitating individual parameter variation to determine which parameters have greater influence on the flow and also enable a higher degree of data transferability between terrain structures of the same type.

Exemplary results of the modelling campaigns and corresponding analyses will be presented and the database generated will be introduced.