AN OPENFOAM SET-UP FOR SIMULATING THERMAL WINDS IN MOUNTAIN/VALLEY CONFIGURATIONS

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Exploring novel renewable energy resources such as thermal winds in mountainous areas and valleys is critical to reduce the energy production from fossil fuels and thus mitigating climate change. These winds occur due to thermal gradients and related buoyancy effects. Basically, the latter are mainly associated with the diurnal heating-cooling cycles of the lower layers of the atmosphere. Thermal winds usually develop by convection over complex terrains of different scales, and they invert their direction twice a day, driven by the emergence and dissipation of temperature inversions. Namely, these winds will blow up-valley (anabatic winds), or from the plain to the mountain massif during day-time. Contrary, during night-time, these winds will blow down-valley (katabatic winds), or from the mountain massif to the plain. Former investigations have shown that thermal winds can reach comparably high speeds [1], which could be interesting for wind energy applications. Moreover, in comparison with synoptic winds, thermal winds exhibit higher periodicity and regularity, resulting in better predictability of wind energy production, which is key to the energy market and matching the demand, given that wind and solar energy cannot be controlled at will.

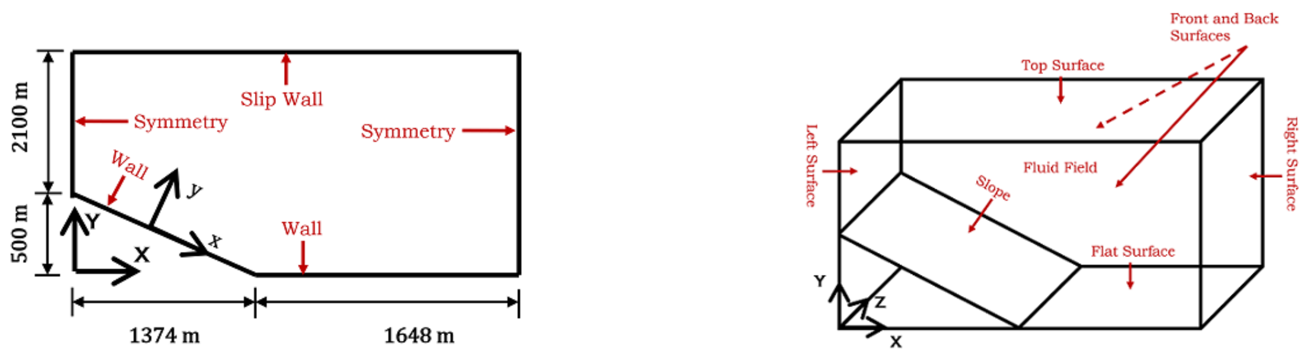

Figure 1: Domain with boundary conditions: 2D view (left) and 3D view (right)

The present work analyses the generation of thermal winds in mountainous areas and valleys using OpenFOAM, which is an open source C++ code used for computational fluid dynamic (CFD) simulations. For our simulations, an idealized mountain-valley model with a mountain slope angle of 20^o was used (see Fig. 1), and the domain was discretized using $blockMeshDict$ file. The $buoyantBoussinesqPimpleFoam$ solver was first validated along with boundary conditions by reproducing the results of Schumann [2] and Axelsen and van Dop [3]. In addition, the effect of different turbulence models and boundary conditions on the top surface was evaluated (see Fig.1) and compared with those previous investigations. Results have shown that a K-epsilon turbulence model with a slip wall boundary condition on the top surface was able to simulate accurate data, when compared with RNG-K-epsilon model. Altitude dependent and altitude independent types of initial conditions were implemented in the fluid field to investigate the stability of the flow. Results proved to be very sensitive to the choice of field temperature initial conditions, and it was found that the evolution of up-slope and down-slope winds was satisfactory simulated by applying constant temperature as initial condition of the domain field (see Fig. 2). Effect of pressure initial conditions was also studied by comparing altitude-dependent and constant pressure conditions. Results showed that the error between these two initial conditions was less than 1%, so for consistency reason with the chosen temperature initial conditions, an altitude-independent pressure initial condition was selected.

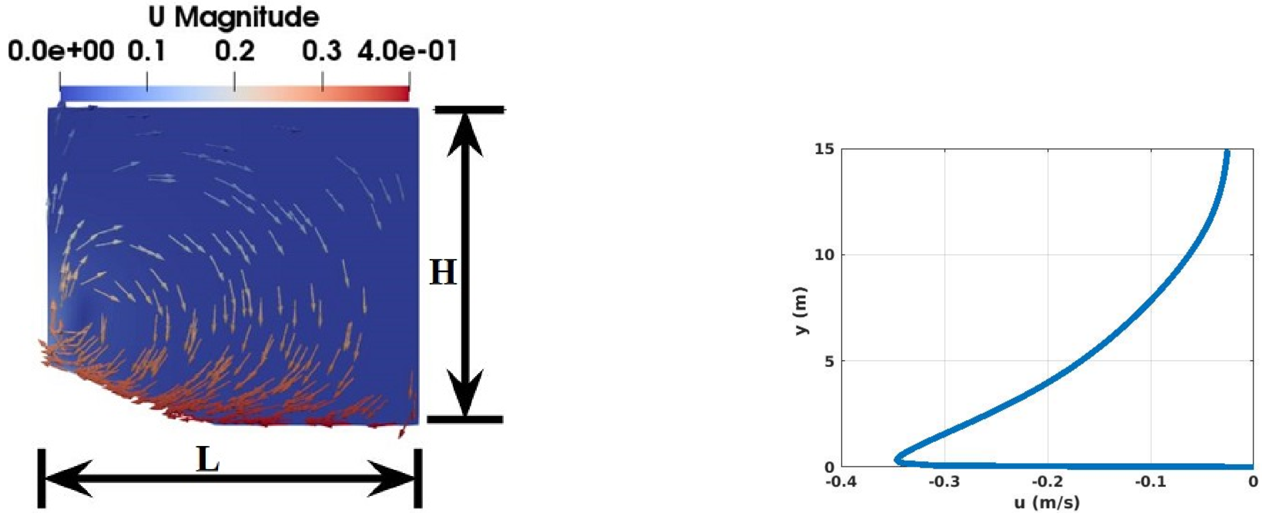

Figure 2: Contour plot of velocity vectors [m/s] (left), where L = 3022 m and H = 2600 m and variation of up-slope velocity component with distance normal to the mountain slope (right)

Following the study of the impact of the choice of initial conditions, a domain height independency study was made to validate the final computational domain dimensions. Different values of valley widths and slope angles were then analysed, to show the impact of some geometric parameters on the wind field. Finally, a 24-hour cycle simulation was performed to study the formation of a complete cycle of up-slope and down-slope thermal winds .

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