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# Evaluation of Experimental Wind Tunnel, RANS and LES Analysis of Wind Flow over a Complex Terrain

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## Introduction/Objectives

A key aspect to determine the technical and economic viability for the wind power plant is the accurate assessment of the site distribution of wind speed. The correct definition of variables as the wind velocity profile and the turbulence intensity are fundamental elements for the feasibility analysis of wind farms. This work presents a study on two important tools for wind analysis, Computational Fluid Dynamics (CFD) and Wind Tunnel experiments. The Atmospheric Boundary Layer (ABL) in a complex area, formed with an asymmetric hill with a slope of 34° and three other small hills is investigated. Measured wind profiles over a wind tunnel model are compared with computational simulations of the experiment. Numerical analysis of the turbulent flow are developed using Reynolds Averaged Navier-Stokes (RANS) and Large Eddy Simulation (LES) methodologies

The profile of the mean speed, the turbulence intensity and the topographic effects over the wind are key elements for the evaluation of the micrositing for wind energy. Evaluations of those parameters, with experimental and numerical methods are the main objective of present work. The viability, application and quality of results obtained with the different methods are investigated.

## Methods

From the experimental simulation of a neutral Stratified ABL in the wind tunnel, it is possible to parameterize the effects of wind over complex terrain [1]. The wind tunnel simulations are developed in a main asymmetric hill included in a complex terrain using the scale of 1:1000 in Atmospheric Boundary Layer Wind Tunnel Prof Joaquim Blessmann at the Federal University of Rio Grande do Sul. The flow close to the surfaces of the hills were measured with a hot-wire anemometer. The Boundary Layer Wind Tunnel of the Federal University of Rio Grande do Sul, Brazil, is a closed return type wind tunnel, with a length/height ratio of the test chamber around 10, being 1.30 m wide, 0.90 m high and 9.32 m long as shown in Fig 1. The highest flow velocity in this camera, with smooth uniform wind and without any obstruction, exceeds 160 km/h.

The experimental measurements are developed in the wind tunnel to define the vertical profiles of the turbulence intensity and wind speed are performed at upwind, in the crest and downwind in the asymmetric hill (1:1000 scale) for two types of terrain related to a power law exponent p=0,11 and p=0,23, in nine points with twenty heights as shown in Fig 2.

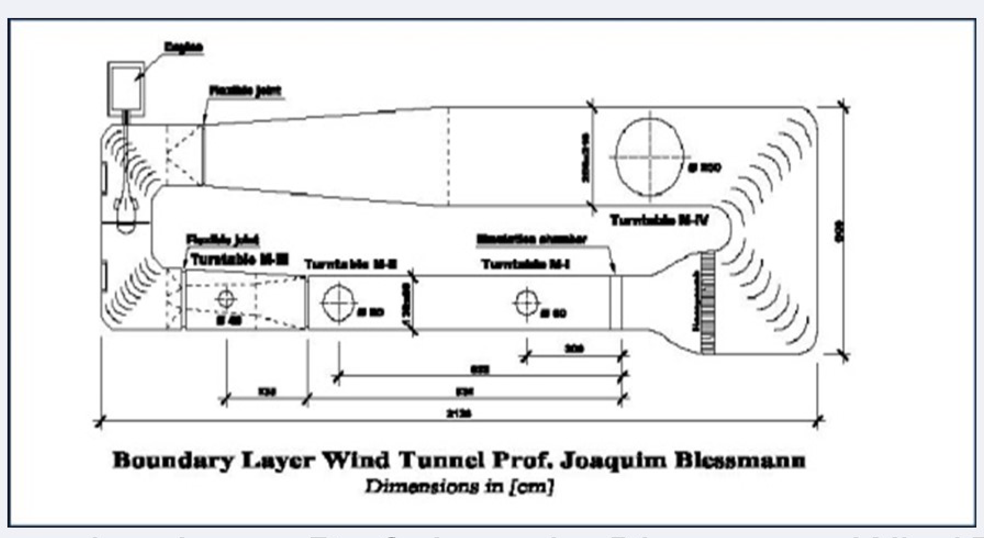


Figure 1. Boundary Layer Prof. Joaquim Blessmann Wind Tunnel

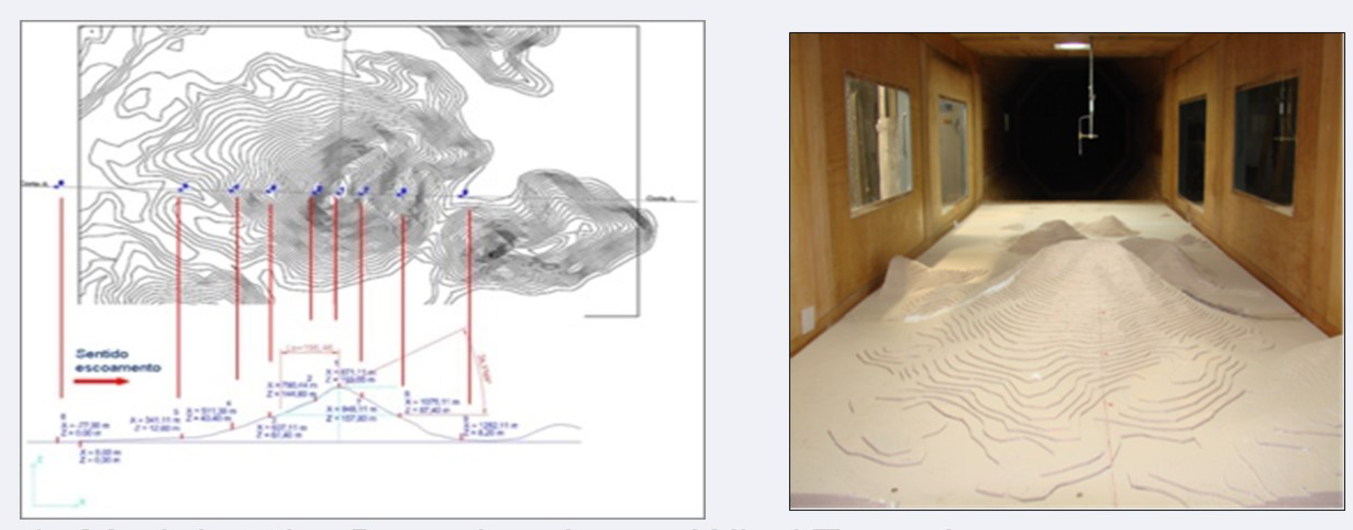

Fig 2. Model at the Boundary Layer Wind Tunnel

The numerical simulations of the turbulent flow are evaluated using ASYS Fluent commercial code. The discretization is done in finite volume with hexahedral refinement controlled near the surface, example of the domain discretization is presented in Fig. 3. Analysis with RANS [5] methodology are evaluated with κ-ω SST turbulence model, witch showed best fit with experimental results as demonstrated in previous works [2, 4]. LES analysis are developed with the Smagorinky Dynamic Subgrid Model [5].

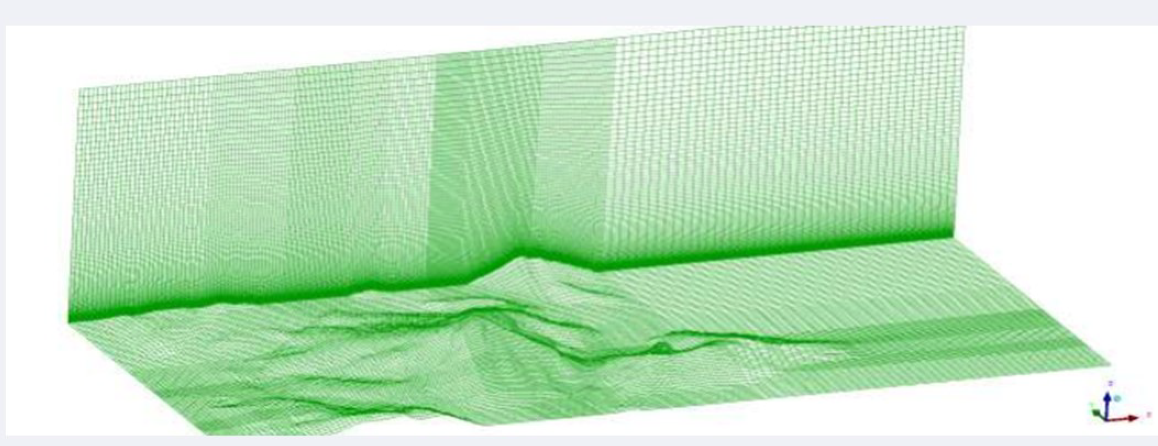

Figure 3. Computational domain and example of discretization.

Boundary conditions for the problem was defined as no-sleep/wall condition for the surface of the model and surfaces of lateral and top walls of the tunnel, pressure for the outflow and a velocity field profile for the inlet boundary. The inlet velocity field is defined according to the experimental atmospheric boundary layer simulated profile. For reproducing the profile of wind speed it is programmed a user function that represents the velocity profile expressed in Eq. 1.

$$\begin{cases} U/U(0{,}8) = 1 - \left|\left((z-0{,}8)/0{,}8\right)^{0{,}23}\right| & 0 < z < 0{,}8 \\ U/U(0{,}8) = 1 - \left|\left((z-0{,}8)/0{,}8\right)^{0{,}11}\right| & 0{,}8 \le z < 0{,}9 \end{cases} \qquad (1)$$

## Results

The experimental and numerical results are presented and compared, as the example results showed in Fig. 4, 5, 6 and Fig.7. Velocity profiles obtained with LES fit better with experimental data.

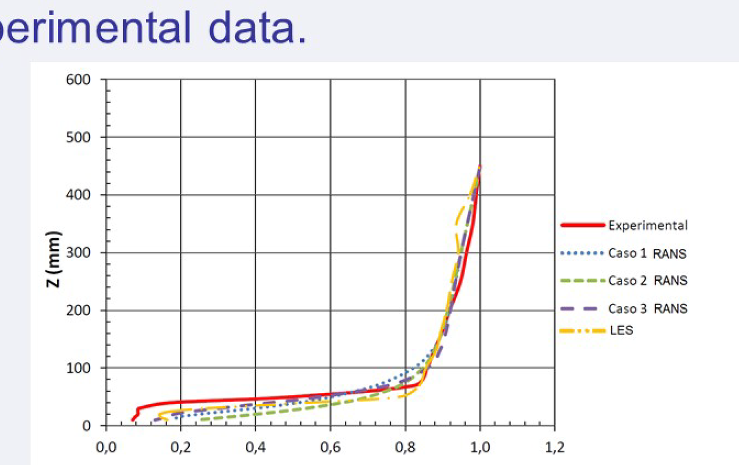

Figure 4. Velocity profiles: Experimental x LES x RANS

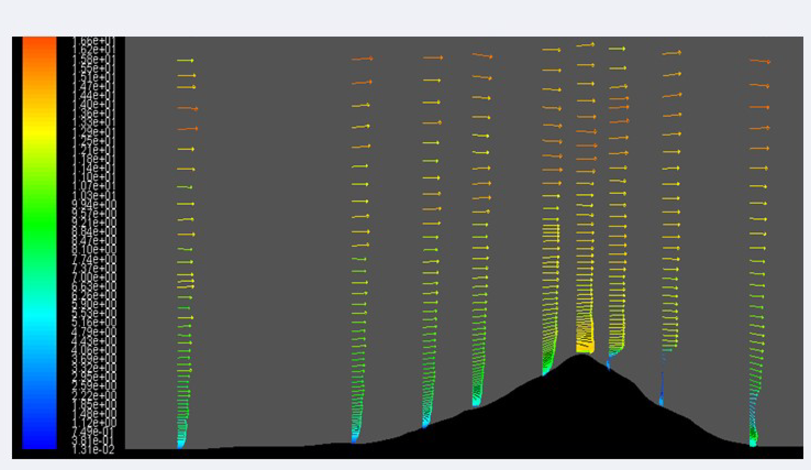

Figure 5. Velocity profiles: LES

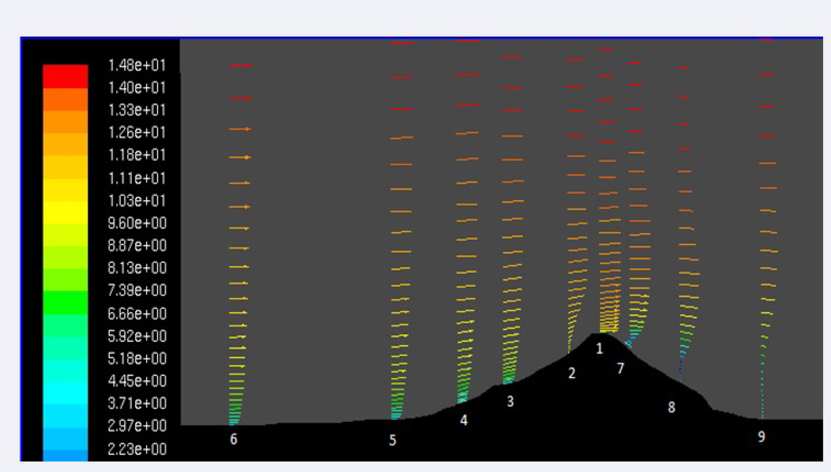

Figure 6. Velocity profiles: RANS

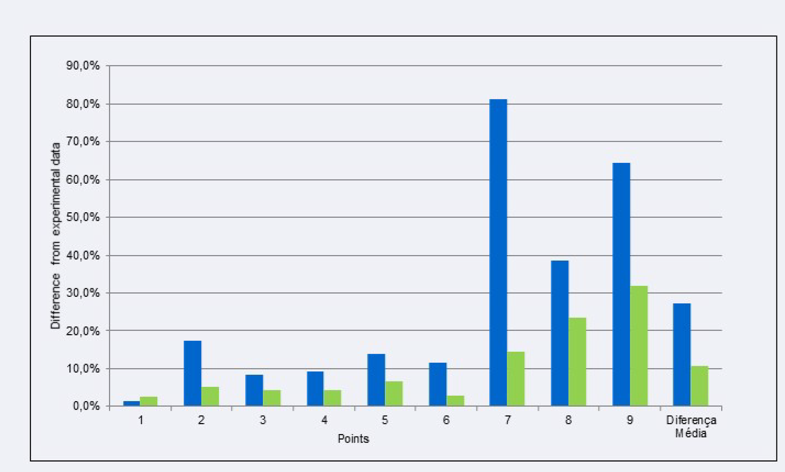

Figure 7. Relative differences with experimental results: LES, RANS

## Conclusions

The wind tunnel results indicate extent and magnitude of the influence of complex terrain over the wind flow and suggest that significant changes in velocity occur in the wake region and at crest of the hill. The turbulence model has important influence on results, for RANS, κ-ω SST showed better fit to experimental data just for the first point of measurement. LES showed best fit for all other investigated points, as is presented in Fig. 7. For the region of separated flow, after the crest of the hill, points 7,8 and 9, LES simulation is significantly better than RANS. Despite of the long time needed to obtain LES results, about 5 days of processing instead of 5 hours of RANS, in the same computer, LES is a viable methodology to obtain more detailed information about transient and turbulent behavior of the wind over complex terrain. Previous studies showed that RANS may provide better results when roughness of the model surface is better modeled [2]. Future works will study other experimental cases, turbulence models, numerical modeling of roughness and site experiments, to verify conclusions obtained at the present work.

## References

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