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# NUMERICAL SIMULATION FOR WIND CHARACTERIZATION OF THE MACON SITE: A PRELIMINARY STUDY

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**Abstract**. The set up of a large telescope at a high altitude site requires a previous comprehensive study of the local meteorological and seeing conditions. The summit of mount Macón in Tolar Grande, province of Salta, Argentina has been studied for more than a year and excellent seeing conditions have been found. However, strong wind conditions drastically affect the selection of the best place where a large telescope may be installed. In the present work, a CFD study is performed in order to evaluate and analyze the wind speed distribution and flow pattern over the site. A high resolution topographical model was developed based on a GPS survey. The numerical formulation is a large eddy simulation (LES) of the incompressible Navier-Stokes equations approximated using the finite element method and results are compared to the experimental measurements.

# 1 INTRODUCTION

Setting up a large telescope at a high altitude site requires a previous comprehensive study of the local meteorological and seeing conditions. The Instituto de Astronomía Teórica y Experimental (IATE) in collaboration with the European Southern Observatory (ESO) has been studying summit of mount Macón in Tolar Grande, province of Salta, Argentina. One year of measurements of MASS and DIMM (seeing quality), three years of meteorological data and detailed studies of seismic activity has been collected. Besides, the essential parameters for construction and operation (e.g. accessibility, water and power supply, etc.) of an observatory facility were subject of analysis.

The study shows that Macón site is a high quality place to install a telescope facility, but strong wind conditions prevail. The final objective of this work is to determine the ideal localization for a potential telescope facility within the Macon mount summit taking into account the wind speed distribution.

The objective of this preliminary study is to evaluate the suitability of CFD as the tool for selection of the best site. As a first step, airflow pattern and wind speed distribution are calculated by CFD and compared to experimental measurements. IATE has two meteorological stations installed in Macon mount. The main station, named ‘NewSite’ is at the main summit and measures mean wind speed and direction 10m above the ground every minute. The secondary station, named ‘USite’, is 380m east from the summit station and measures only mean wind speed 9m above the ground every 10 minutes. In contrast to the NewSite station, that has been collecting data for more than a year, the USite station was installed at the same time this simulation work was in progress. So only one complete month overnight wind speed data from these stations was used to validate the CFD calculation.

Figure 1: Mount Macon summit

# 2 MATHEMATICAL MODEL

## 2.1 Governing equations

In this section we consider the flow problem for an incompressible fluid using the Navier-

Stokes equations,

$$\frac{\partial \mathrm{u}}{\partial t}+\mathrm{u}\cdot\nabla\mathrm{u}-\nu\Delta\mathrm{u}+\frac{1}{\rho}\nabla p=f \ \text{ in } \ \Omega\times\left(0,t_f\right) \tag{1}$$

$$\nabla\cdot\mathrm{u}=0 \ \text{ in } \ \Omega\times\left(0,t_f\right) \tag{2}$$

where $\Omega$ is the flow domain, t is the time variable, $\left(0,t_f\right)$ the time interval for the simulation, u the velocity field, $\nabla$ the gradient operator, $\nu$ the kinematic viscosity, $\Delta$ the Laplacian operator, $p$ the pressure and $f$ the external body forces (i.e. the gravity force). Denoting by an overbar prescribed values, the following boundary conditions are considered,

$$u=\bar{u} \ \text{ in } \ \Gamma_{\mathrm{u}} \tag{3}$$

$$\sigma\cdot n=\bar{t} \ \text{ in } \ \Gamma_{\sigma} \tag{4}$$

where $\sigma$ is the viscous stress tensor and $n$ is the unit outward normal to the boundary. The state of the airflows under consideration is generally turbulent, the Reynolds number being of the order of $10^5$ up to $10^7$, so that turbulence modeling is necessary. The standard Smagorinsky turbulence model is used (Smagorinsky 1963), being its expression,

$$\nu_T=c\cdot h\cdot\sqrt{\varepsilon:\varepsilon} \tag{5}$$

where $c$ is a constant, $h$ es the characteristic element size and $\varepsilon$ is the velocity strain rate tensor. Standard logarithmic wall law is applied on wall surfaces. Since we are considering summit local aerodynamics and high wind conditions, we assume density constant and convective flow contributions negligible in this preliminary study. Thus, the energy equation is decoupled and not taken into account.

## 3 NUMERICAL MODEL

The set of partial differential equations is solved using the finite element method (Sacco 2008). We will not give any detail concerning the precise numerical model used in this work but only mention the most important points.

The time-dependant fluid flow equations are solved by the fractional step (FS) method (Lohner 2001). The time integration uses the first-order accurate backward Euler scheme. It is also necessary to use a stabilization method capable of dealing with all the instabilities that the standard Galerkin method presents. The stabilization technique used here is the Orthogonal Subscale Stabilization (OSS) (Bell 1989; Codina 2000; Soto 2001).

## 4 SIMULATION

### 4.1 Topographic model

The modeling of Macón's summit and its soundrroundings was made by the combination of two sources of topographical information. A DGPS topographical survey of the summit carried out in 2008 by IATE (Geonorte 2008) was combined with a low resolution portion of the NASA Shuttle Radar Topographic Mission (SRTM) survey. Extensive use of topographic software tools was necessary to blend both surveys' clouds of points into a single cloud with no discontinuities at the interface. The final cloud was subdivided in smaller ones and NURBS surfaces were created for each by means of GiD preprocessing software.

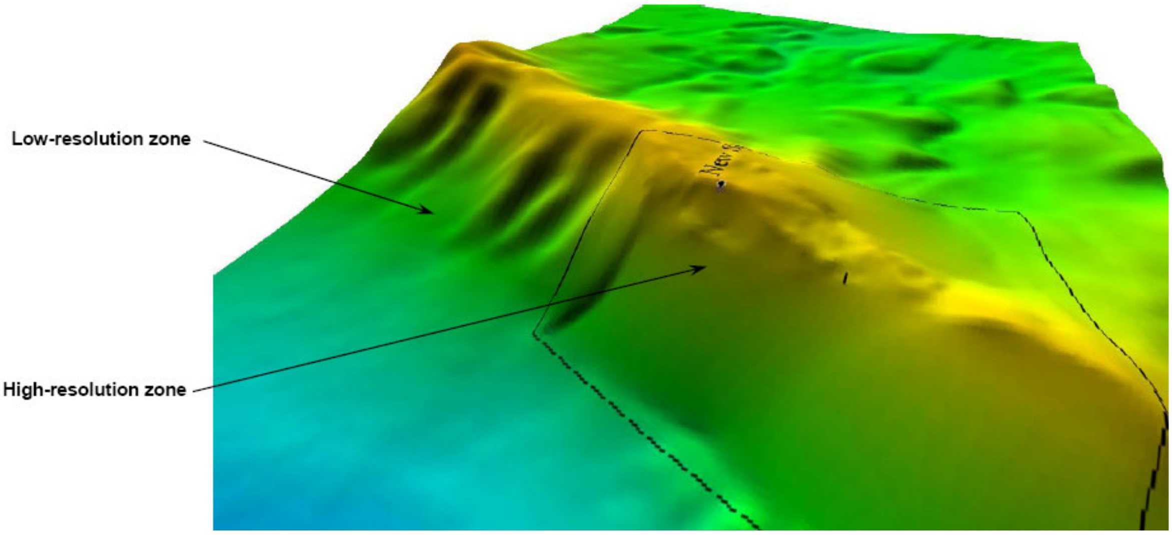

Figure 2: Blended topographical model

## 4.2 Computational domain

A single computational domain is considered to solve the airflow around the Macón mount summit. The discretized domain covered a section of 9.2 x 10.6km of terrain and extends to an altitude of 9.8km. The generated mesh for this domain was formed by 2.6 million tetrahedral elements and a boundary layer mesh was created on the ground.

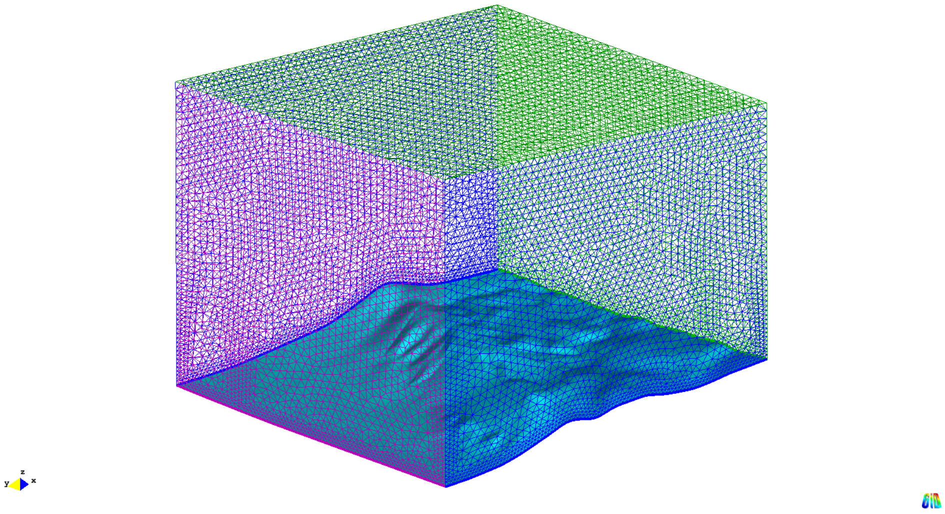

Figure 3: Computational domain

The domain is aligned with the predominant wind direction, which was obtained from IATE's 3-year meteorological statistics. It is important to notice that, as there were no data for far-field wind speed and direction, NewSite station data was used to set the inflow direction. The results presented in this paper correspond to a far-field wind velocity of 10m/s from West-northwest (292.5º). The following boundary conditions are considered in this work:

- Fixed velocity at inflow (atmospheric boundary layer inlet profile)
- Wall condition on the terrain surface
- Zero normal velocity at domain's lateral faces
- Fixed pressure at outlet (back and top domain face)

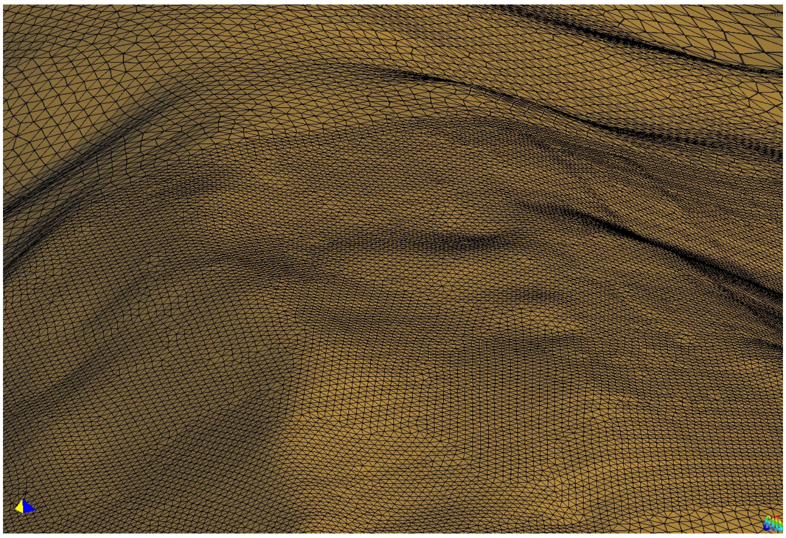

Figure 4: Summit zone surface mesh

### 4.3 Results

The solution obtained is not stationary. In the computed flow pattern, multiple vortex shedding and flow separation were observed, especially behind the mountain range. However, the flow pattern within the summit zone is steady, only partially affected by the downward vortex. These results are summarized in Figures 5-7.

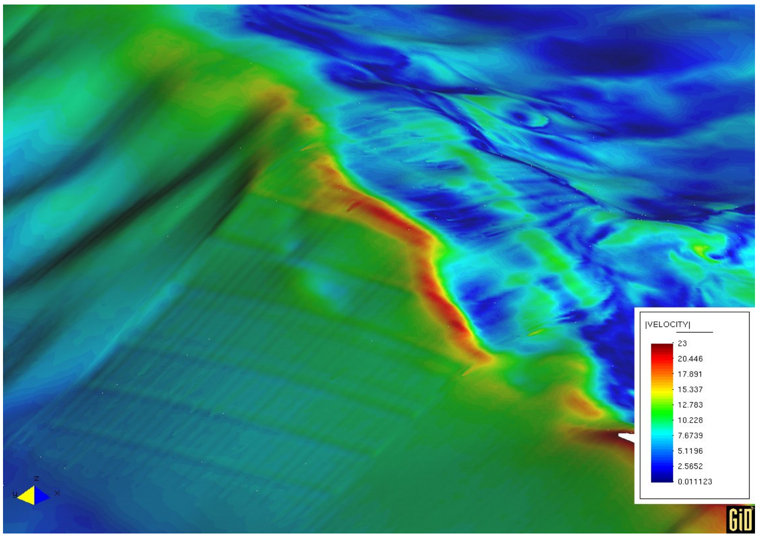

Figure 5: Velocity distribution – Summit zone

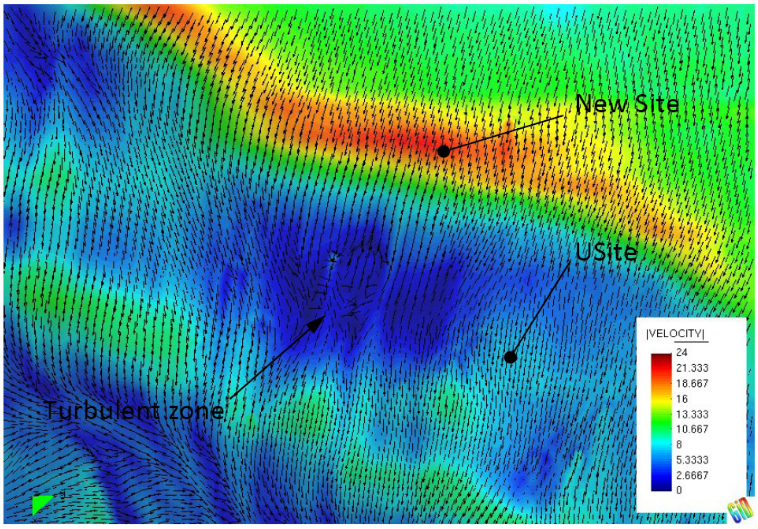

Figure 6: Velocity vectors and experimental stations locations

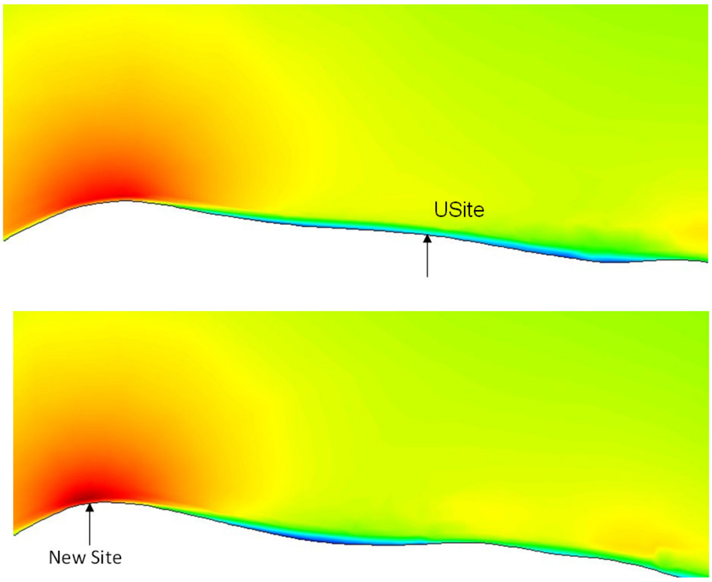

Figure 7: Vertical cuts of velocity over the experimental stations

The simulated evolution of the wind speed at the NewSite and USite at 10mts and 9mts above the ground respectively is shown in Figure 8. According to the simulation, wind over the USite station averages 59% of the corresponding wind speed over the NewSite station.

Figure 9 and Figure 10 show the average evolution of the wind speed based on the experimental data collected by NewSite and USite stations respectively during the month of May 2009. This shows that wind speed at USite is between 62% and 75% of the NewSite station, what compares well with the simulation.

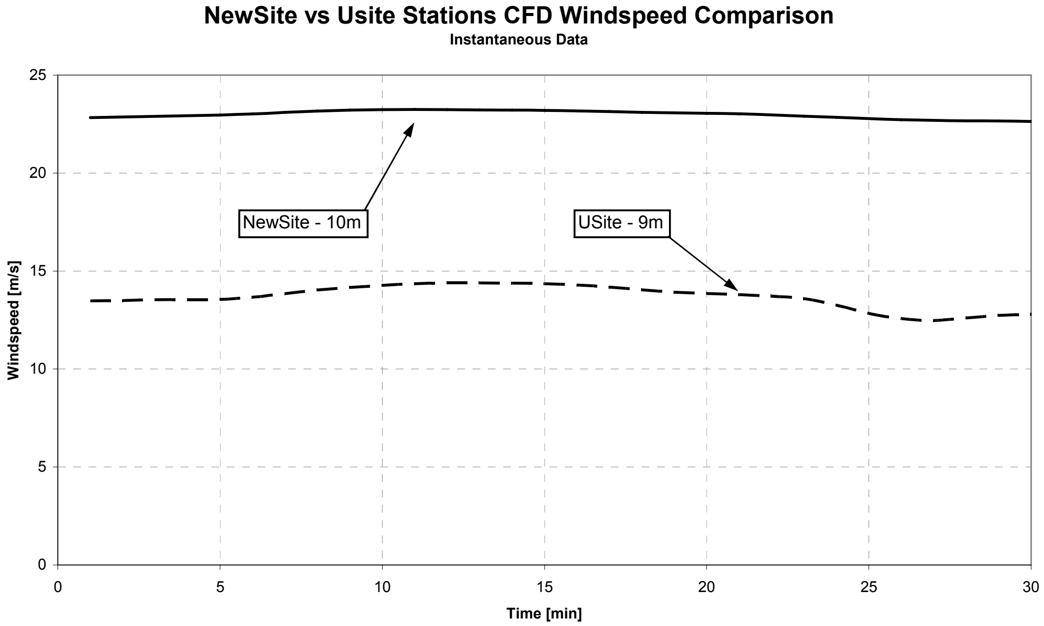

Figure 8: Simulated evolution of wind speed

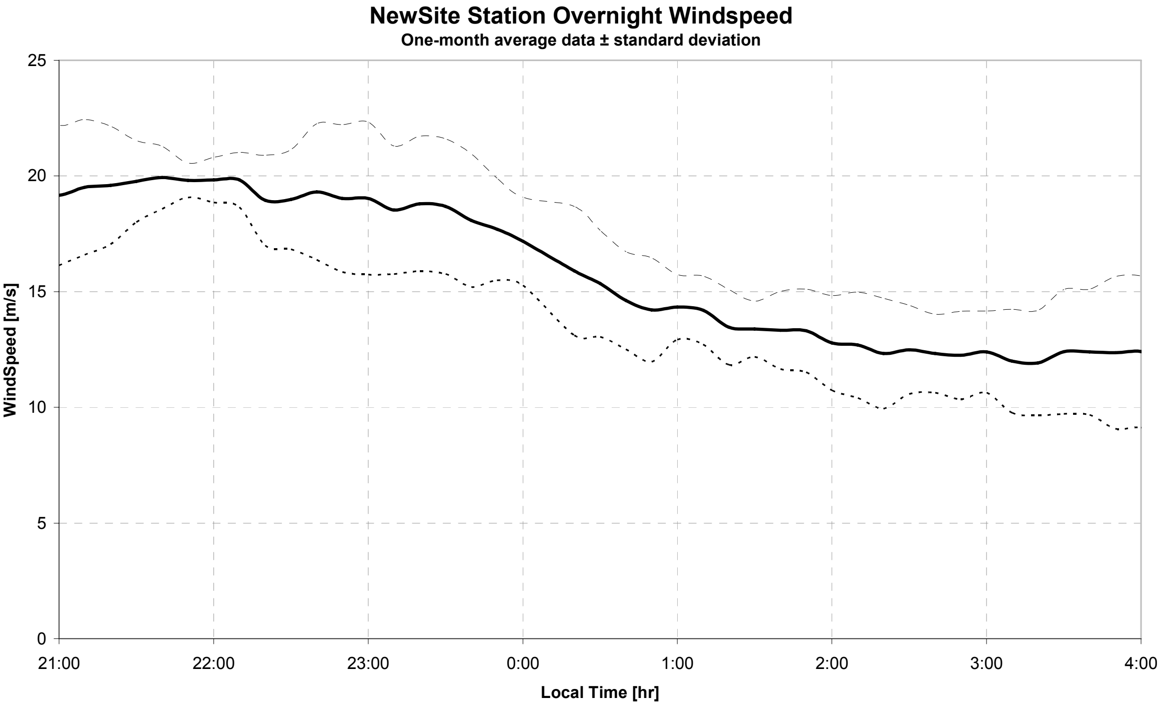

Figure 9: One-month averaged experimental evolution of wind speed

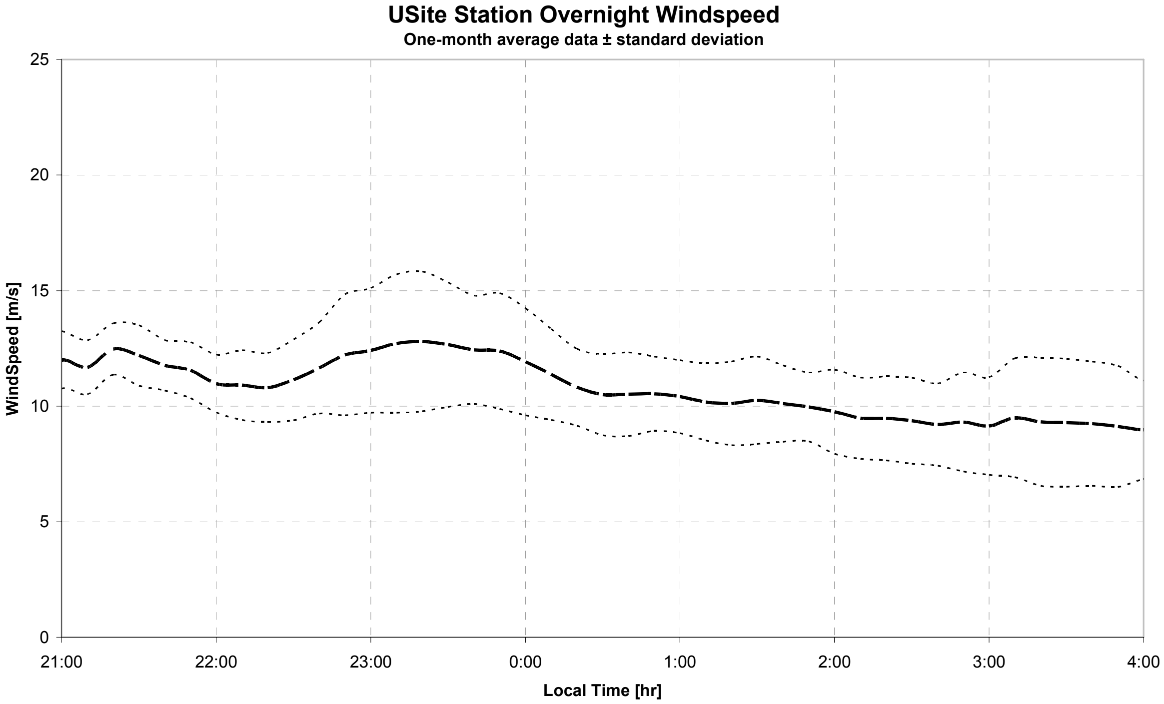

Figure 10: One-month averaged experimental evolution of wind speed

## 5 CONCLUSIONS

In this paper an external aerodynamic analysis of a small topographic region has been presented. In particular, the local aerodynamics of a mountain summit in the Province of Salta, Argentina was simulated and compared to experimental data.

The study was initially carried out at a higher than average wind speed in order to evaluate the high wind condition. The USite station was installed as this work was in progress, so the stations comparison was not possible until the simulation was completed. Nevertheless, the measured ratio between wind speed at NewSite and USite compares well with the simulation results. From the design point, this work shows that CFD is a powerful tool to decide which location is the best to place a new station to study the potential installation of a telescope facility. This may shorten the site testing time and save money.

Future work may includes an average wind speed simulation to validate the model with the recently acquired data, heat transfer addition and the modeling of the potential telescope buildings.

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