CFD wind farm evaluation in complex terrain under free and wake induced flow conditions

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Introduction

Objectives:

- **Modelling of a real forested highly complex terrain scenario.**
- **Validate the model with experimental data.**
- **Modelling of wind turbines (WTs) wakes and study of their evolution and impact on potential positions for other wind farms**

CENER Experimental Wind Farm
1200 m a. s. l.

Hight Complex Terrain

Vegetation diversity

6 Met masts data available:
- MC: calibration met mats
- MP: permanent met masts

6 NREL 5MW Wind Turbines

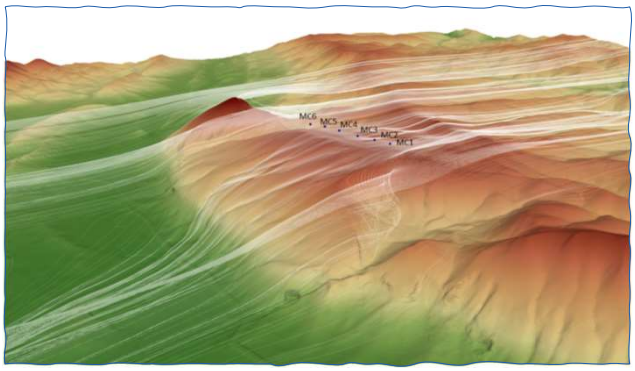


Figure 1: CENER Experimental Wind Farm 6 available locations

1. Complex Terrain Model

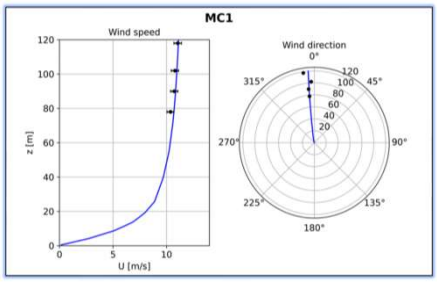
Main considerations:

- **Steady-state Computational Fluid Dynamics (CFD) model.**
- **Reynolds-averaged-Navier-Stokes (RANS) approach.**
- **$k-\epsilon-f_P$ eddy viscosity model (EVM).**
- **North wind direction.**
- **Neutral atmospheric stability.**
- **Coriolis force.**
- **Vegetation zones effect by means of aerodynamic roughness.**

Figure 2: Model vegetation zones

2. Validation of the Model

Validation of the model in terms of wind speed and direction with 6 available met masts. Maximum speed deviation of 0.768 m/s at 102 m for MP5. Maximum wind direction deviation of 12.02° at 78 m for MP1.



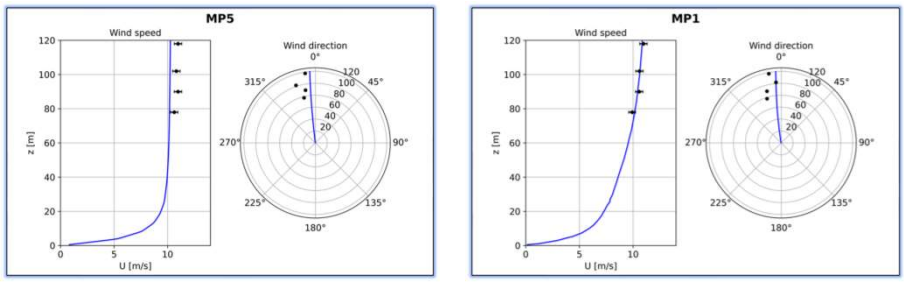


Figure 3: Wind speed and direction at MC1, MP5 and MP1 sites.

3. Wind Farm Wake

The wind farm wake is introduced in the validated model by means of the Actuator Disk Method (AD). The C_p and C_T values are calibrated for each wind turbine depending on the wind speed value at hub height (90 m).

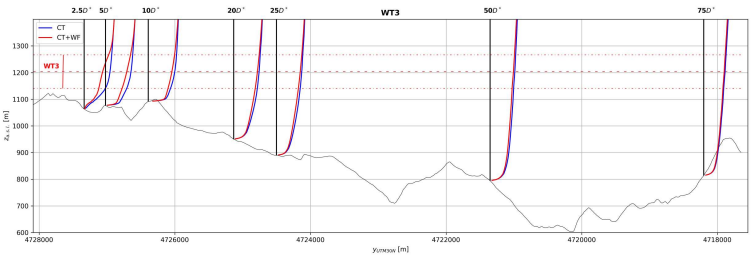


Figure 4: WT3 (MC3) transect. Comparison between the complex terrain without (CT) and with (CT+WF) the wake influence.

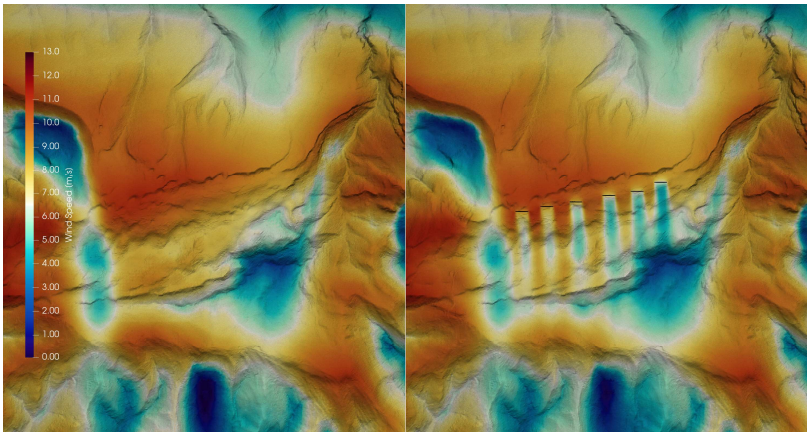


Figure 5: Velocity field at hub height above ground level. Model without wake (left). Model considering the wake of the WTs (right).

Conclusions and Future Work

The complex terrain model showed a good agreement with the met masts data. The slight wake deflection on easter WTs positions was justified by the orography effect on the easter wind component in those positions. The impact of the modelled wind farm wake showed wind speed loses up to 1 m/s in affected neighbour ridges at 10D*.

Future work:

- **Study more wind sectors.**
- **Validate the wind farm model with higher fidelity wake models (Actuator Line Model) and approaches (Large Eddy Simulation).**

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