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Benefits of using CFD for wind power forecasting in complex terrain

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Introduction

Nowadays, wind power forecasting is mostly done using statistical tools converting wind speeds calculated by weather prediction models to power production. Statistical tools find connections between historical mesoscale model output and observed power and can apply them to forecasted mesoscale model output to predict the power production. One type of statistical methods are Artificial Neural Network (ANN). ANN provides in average a good forecast but it is almost like a black box where it is not easy to understand what is physically happening and ANN has sometimes limits which can lead to a wrong forecast.

To provide a different approach Computational Fluid Dynamics (CFD) is used which describes the local wind field around the wind farm. It is a deterministic tool which dynamically downscales the wind speed from the mesoscale model onto the wind farm level. It has a deeper physical basis than the ANN forecast.

We present the case of a wind farm where the forecast using CFD performs better than the standard ANN and we explain the reason for that and the shortcomings in the ANN approach.

Approach

The wind power forecast is calculated and compared using two approaches:

1) One single ANN from the mesoscale model output to the power production of the whole wind farm (*ANN wind-power*).

2) An ANN connects the wind of the mesoscale model to observed wind conditions on site and this corrected wind is then used by the CFD to transfer it from the wind measurement position to the turbine positions (*ANN wind-wind + CFD*) as described in [1].

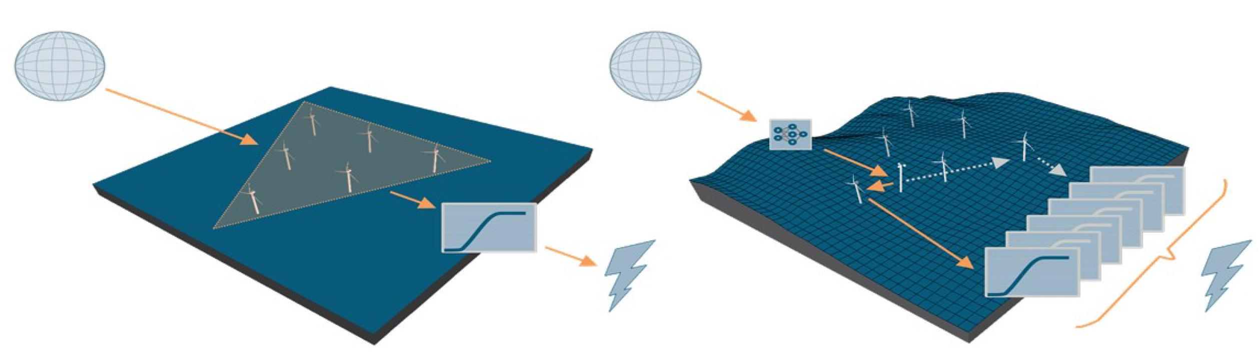

Fig. 1: Set-up of the forecasting strategy number 1 (left) and number 2 (right).

Wind farm

The wind energy forecasts are calculated for a wind farm with 6 turbines. To do so a CFD model is calculated on an area of 30x25 kilometres around the wind farm. The model takes into account roughness of some forested areas around the wind farm and the presence of some mountains about 9 kilometre on the east side of the farm (Fig. 2).

The presence of these mountains is quite important as the main wind directions on the site are NNW and SEE/SSE with most energy coming from SEE/SSE. The mountainous area is quite high with around 1000 metre a.s.l. while the wind farm is around 200 metre a.s.l (Fig. 3).

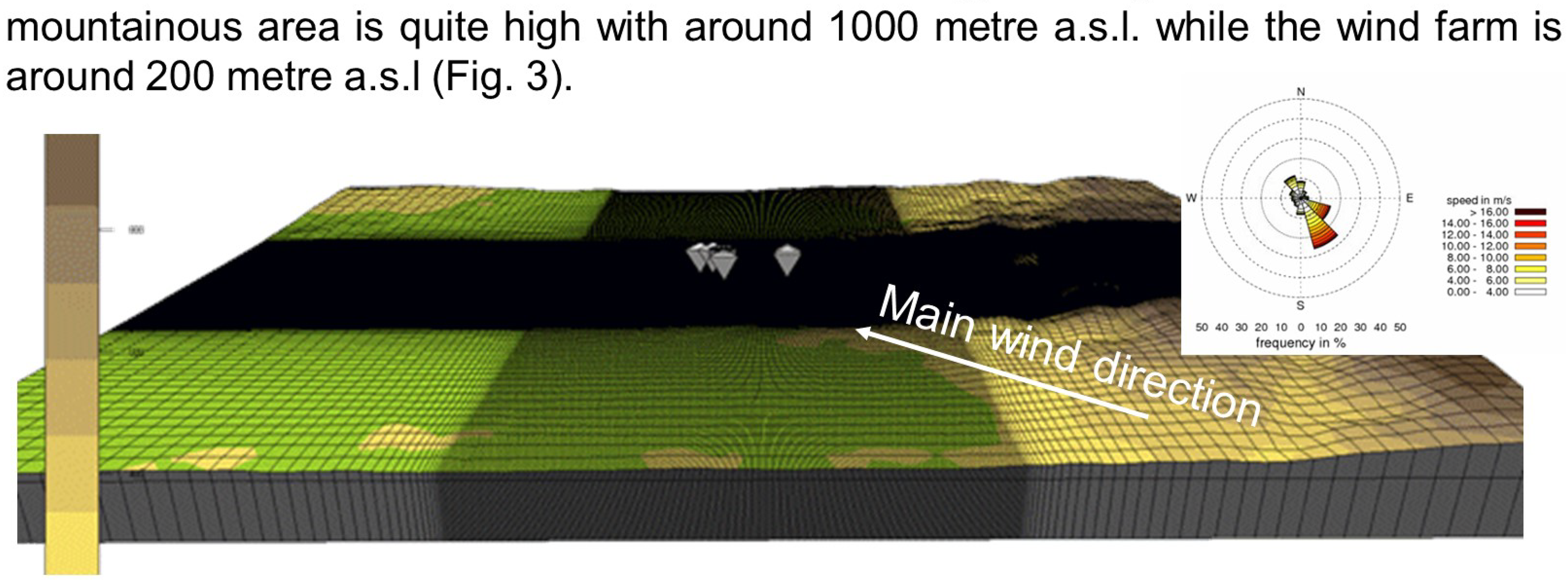

Fig. 2: CFD terrain model including turbines with the main wind direction from SSE.

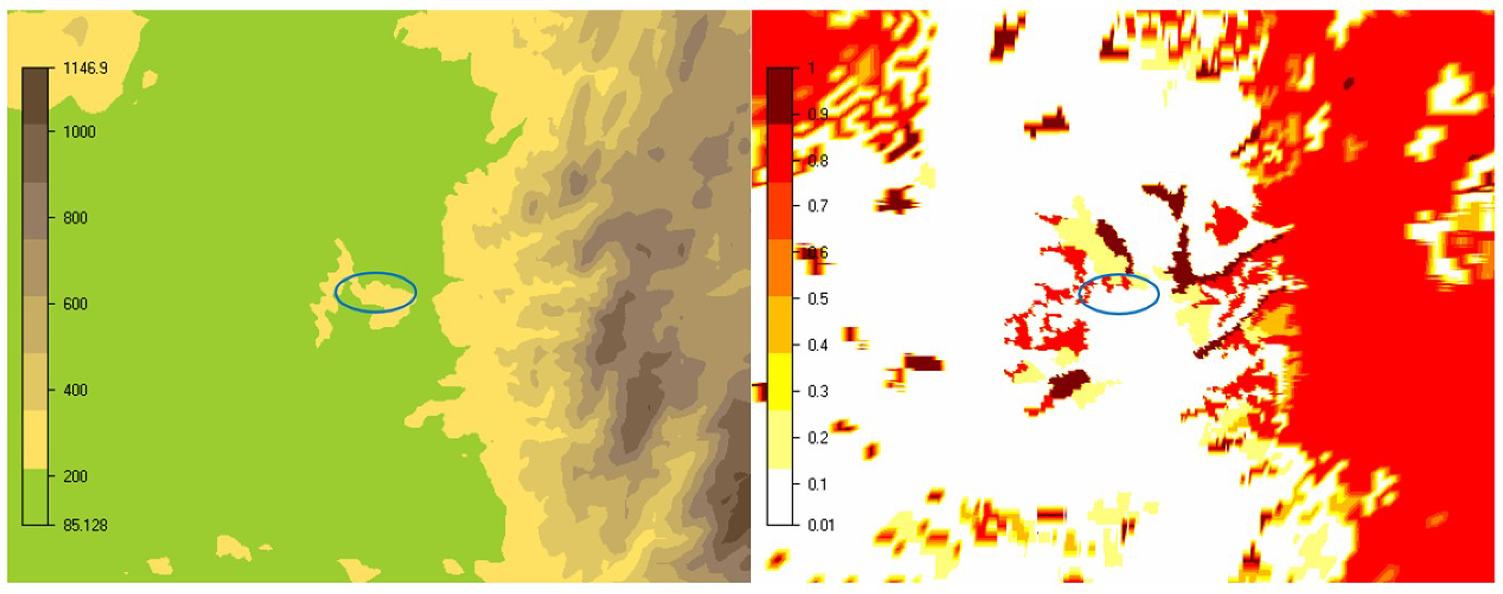

Fig. 3: Elevation (left) and roughness map (right) of the CFD model. Highlighted in blue the windfarm area

Results

The forecast with the two approaches are run on this site using as training data set data from the year 2014 and the validation is performed over four months from February to May 2015.

The CFD shows a better performance than the single ANN approach. Analysing the periods where the CFD performs better we can recognize that those are mainly cases of wind coming from sectors E and SEE. The CFD is able to recognize the local recirculation of the wind caused by the mountains upstream of the wind farm and describes the under performance of the wind farm due to that.

	NMAE:	RMSE Normalized:	Number of points:
ANN wind-power	0.0964	0.1504	3128
ANN wind-wind + CFD	0.0907	0.1606	3128

Tab.1: Validation results over the period February to May 2015.

The CFD shows a better performance than the single ANN approach with lower mean absolute error (Tab. 1). Analysing the periods where the CFD performs better we can recognize that those are mainly cases of wind coming from sectors E and SEE (Fig. 4). The CFD is able to recognize the local recirculation of the wind caused by the mountains upstream of the wind farm and describes the under performance of the wind farm due to that.

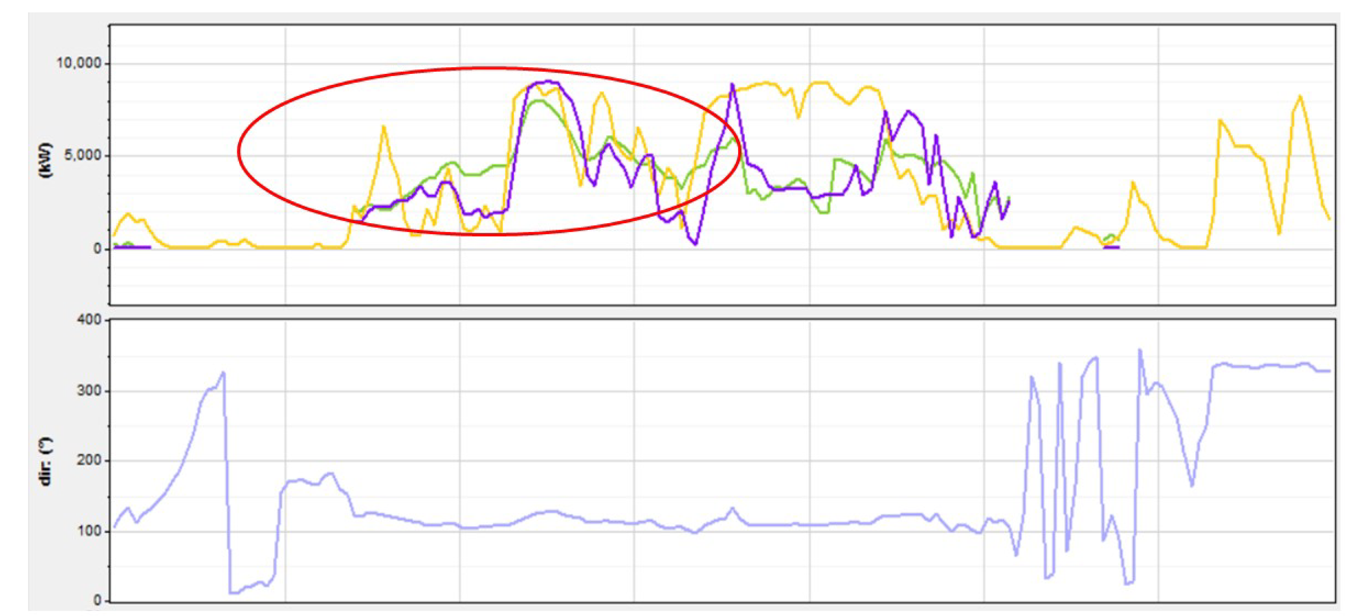

Fig. 4: Example of a period when approach 2 (top, violet line) performs better then approach 1 (top, green line) compared to observed production (top, yellow line).The wind direction is around 100-150 degree (bottom).

This under performance happens only in those directions and the decrease in power production affects mainly some of the wind turbines (Fig. 5). A small wind direction shift makes a large change in the final power production that is why the simple ANN forecast is not able to recognize it.

Note that the presence of mountains on the east affect the local wind speed in particular for the turbines on the east side of the layout (Fig.5).

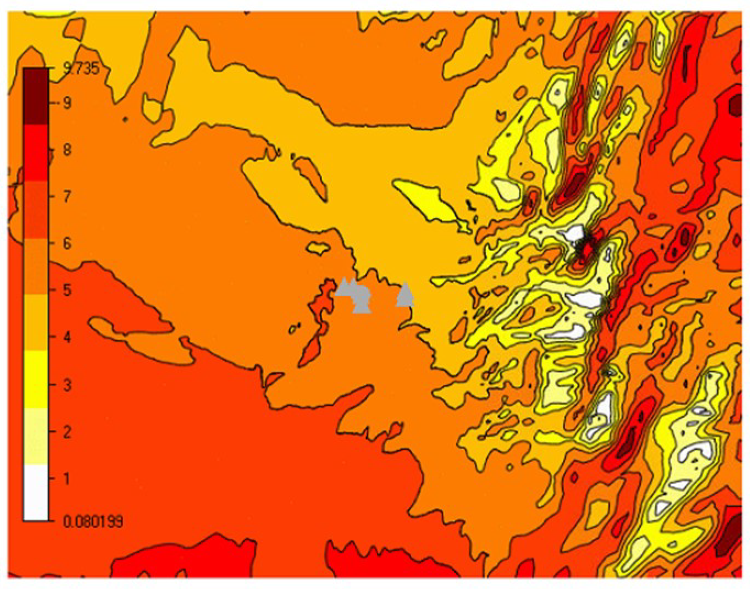

Fig. 5: Horizontal wind speed for wind direction 120 degree. Grey triangles represent turbine positions.

Conclusions

WindSim AS has developed a flexible power forecasting system. Statistical (ANN) and physical (CFD) models are combined in an optimal way depending on available input data and required accuracy level.

The studied wind farm shows a specific behaviour depending on the direction of the wind. This is due to the presence of high mountains in the east side of it which influence the local wind field. The CFD simulation is able to recognize this and to describe this behaviour. Using the approach *"ANN wind-wind + CFD"* to do power forecasting improves the forecast performance compared to forecasts with only ANN.

- *[1]. M. Mana, F. Corbo, C. Meißner, Short-term Forecasting of wind energy production using CFD simulations., Poster at EWEA 2013, PO ID. 287.*