Day ahead wind farm power production forecast using a high resolution mesoscale model and various downscaling techniques

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windsim

Introduction

We present different forecast configurations to predict the day ahead production of a wind farm in semi-complex terrain.

The Numerical Weather Prediction (NWP) Model MetCoOp Ensemble Prediction System with 2.5 km resolution focusing on the wind farm area is dynamically downscaled by the CFD (Computational Fluid Dynamics) model WindSim. The transfer of the data from the NWP model to the CFD model can be done using NWP results from various heights above ground and using all or parts of the nodes of the NWP model within the wind farm area. Many different forecasting configurations are validated, and the presentation will highlight the best performing configurations.

The NWP-CFD downscaling results are compared to a day ahead forecasts obtained through ANN (Artificial Neural Network) technology and to the observed production. The idea is to understand if deterministic downscaling methods like CFD can perform as good or better than statistical approaches when using high resolution NWP models and more NWP model data.

Method

Forecast: covering the period from November 2016 to August 2017, hourly time step resolution, using the period from 0 to 24 hour ahead.

Observations: power production are available in 10 minute time steps. The concurrent period is cleaned out for periods of malfunctioning like maintenance etc. and is averaged from 10 minutes to 1 hour time steps.

Two Forecast methods are tested:

1. Direct coupling of the forecast into CFD simulations, the forecast nodes are used as climatologies in WindSim and the power history is exported.
2. ANN wind to power, one central node of the forecast model is chosen as reference, a ANN is trained to predict the power production of each turbine from the wind speed and direction of the model [1].

The dynamical downscaling by the CFD is using all, each single NWP node or some of the NWP nodes, selected as the better performing. The results of the dynamical downscaling are compared to the results of an ANN model that forecasts the power production of each turbine and the observed production. The comparison is focusing on Bias, correlation coefficient R^2 , the NMAE and the RMSE.

The ANN is trained on half of the available time series, the other half is use for the validation, the split is performed on a weekly basis, to avoid seasonal bias between the training and the validation periods.

Site

The NWP model is run with a 2.5 km horizontal resolution, focusing on the wind farm area which extends 5 km over a 300m high hill. 13 nodes of the NWP model cover that area and can be used for the forecast. The NWP model outputs are extracted at 10m and 120m height above ground.

A local model is build using the CFD code WindSim with 20 m grid resolution in the central area; 12 wind direction sectors are simulated.

The wind farm is composed of 24 full scale turbines. The power production is calculated per each turbine and summed to get merged power production per complete windfarm.

Results

The comparison of the two methods highlights the better accuracy of using 120m high NWP points instead of 10m high ones (Tab. 1). The height of those points is more similar to the turbine height and is less influence by the surface.

The ANN is performing better then the CFD approach in terms of RMSE while the CFD is better in terms of NMAE. This is due to the statistical vs deterministic nature of the two approaches as demonstrated in Figure 1. The ANN based forecast tends to follow the average of the real production.

Method	Bias	Correlation Coefficient (R^2)	NMAE	RMSE Normalized	Number of points
ANN (an ANN per turbine and sum)	342.023	0.76	**0.1054**	0.1592	2122
NWP points at 10m and CFD (all nodes)	-1679.174	0.667	**0.12**	0.1972	4509
NWP points at 120m and CFD (all nodes)	890.6	0.748	**0.102**	0.1722	4509

Table 1: Performance using different forecasting heights from the NWP model

This leads to a lower RMSE, while the CFD based power curve has a sharper shape, which produces a forecast more suitable for ramp detection.

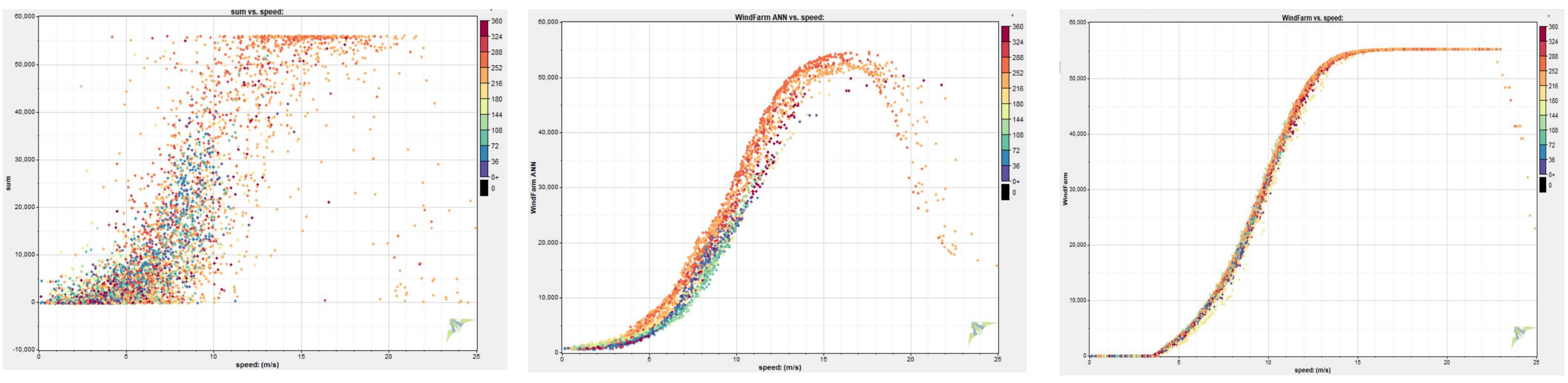

Figure 1: Power curves colored by direction referring to speed at node 7. Left real production, middle ANN forecast, right CFD based forecast.

The performance of the forecast using the single nodes of the NWP is calculated and enables to classify the nodes focusing on NMAE.

The best performing nodes are placed in an open region upfront the main wind direction (2-4-5), or are in the central area (7) (Fig. 2).

Average performing nodes are upfront the hill in the main wind direction (1-3-6), near the top of the hill but behind the edge (10), or in a recirculation area (13).

The worst performing nodes are in recirculation areas for the main wind direction (8-11-9-12).

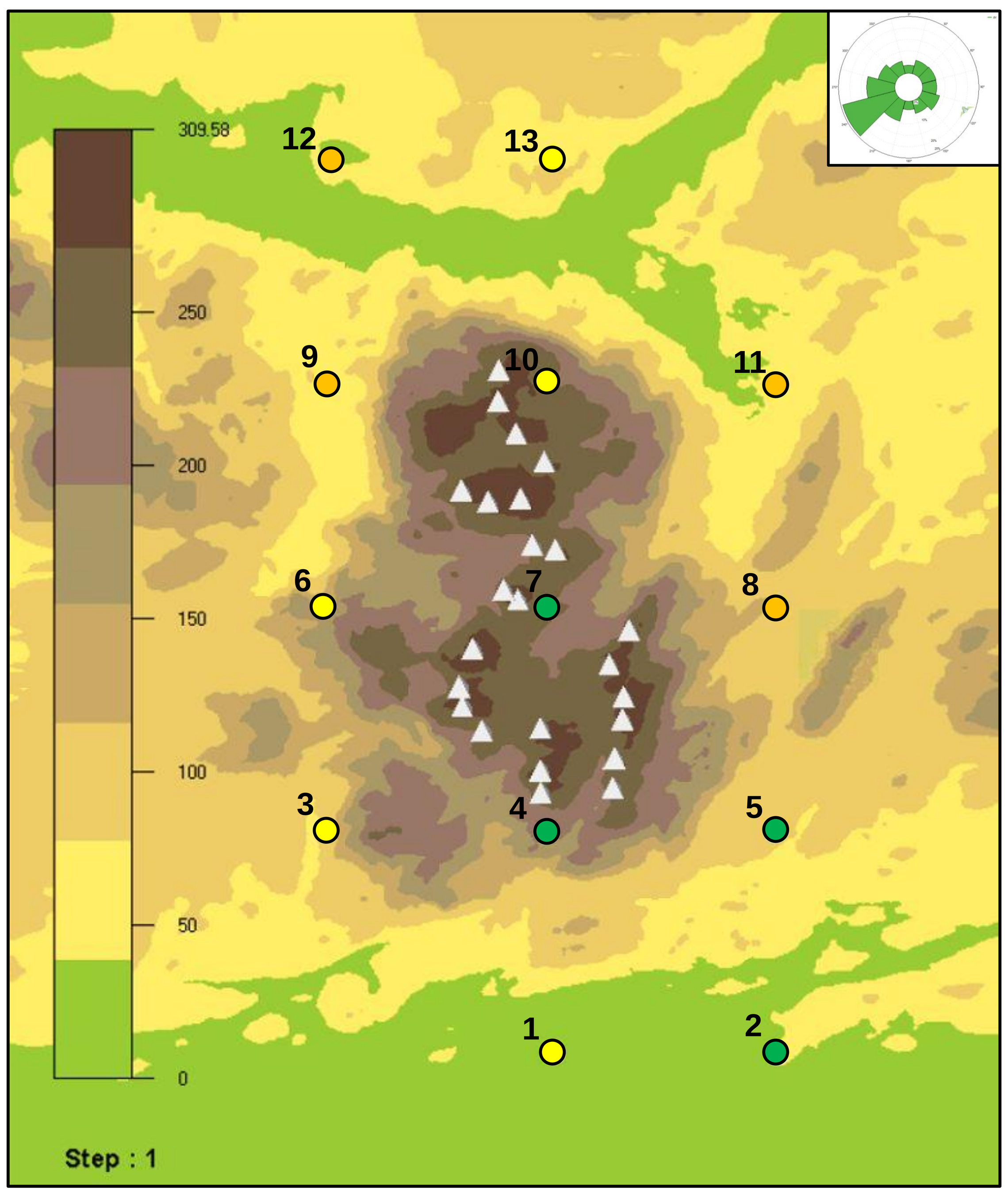

Figure 2:. Turbine layout (triangles) and wind rose. NWP nodes: green best performing, yellow and orange lower performing.

The performance using subgroups of nodes is investigated. The best performance is achieved using the better nodes: 9.8% NMAE.

Adding the northern node (10) improves the forecast of the turbines in the northern area of the layout but not the performance on the wind farm level.

The usage of the nodes in the open area (2-5) improve the overall performance of the forecast in particular in the southern area of the layout.

NWP points at 120m and CFD (subgroup of nodes)	Bias	Correlation Coefficient (R^2)	NMAE	RMSE Normalized	Number of points
Central single node (node 7)	1148.17	0.737	**0.1053**	0.1763	4509
Better nodes (nodes 2-4-5-7)	-186.967	0.751	**0.0985**	0.1688	4509
Better nodes plus 10 (node 2-4-5-7-10)	-282.108	0.745	**0.0994**	0.1704	4509
Hill top nodes (node 4-7-10)	-142.469	0.735	**0.1022**	0.1734	4509

Table 2: performance using subgroups of nodes

Conclusions

NWP nodes around the hub heights are preferable.

The selection of the better performing nodes improves the CFD forecast performance.

The NWP node in open area for the main wind directions are the best performing.

The CFD based forecast performs as good as ANN or better. Depending on which error calculation is important different forecasting methods should be used.

References & Acknowledgement

[1] Mana, M., Burlando, M., Meißner, C., "Evaluation of two ANN approaches for the wind power forecast in a mountainous site" INT. JOURNAL of RENEWABLE ENERGY RESEARCH, Vol.7, No.4, 2017

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