Validation and sensitivity testing of mesoscale generalisation procedure for the WRF model

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Introduction

Numerical Weather Prediction (NWP) models are increasingly being used for the estimation of wind resources over large regions. These large-scale wind resource maps are useful to identify favourable regions for wind energy in the prospection phase. However, due to the relative low resolution of the mesoscale model, the earth surface is represented in an unrealistic manner within it. This misrepresentation impacts the flow near the surface and means that the output from mesoscale models cannot be compared directly with on-site measurements or used directly for wind farm site selection and long-term energy production estimation.

In Hahmann et al. (2013) a generalisation procedure method for the Weather Research and Forecasting (WRF) model output was developed and validated against measurement masts. This procedure removes the unrealistic flow effects from the flow, which can then be reapplied by a microscale model to accurately downscale to a local wind climate. Application of this procedure has greatly improved the accuracy of modelled wind flows near the surface for most sites on which it has been tested.

This study performs a more in depth and extensive validation of the WRF generalisation procedure, done by comparing the generalised WRF simulated climates with dozens of observed wind climates obtained from measurements masts with different site conditions and geographical locations. To identify the optimal parameter choices, a sensitivity analysis on the generalisation procedure configuration is also performed.

Approach

Observations from multiple measurement masts in Europe, Asia and South Africa are used to test the WRF generalisation procedure. For every mast a full year of data is selected which are then generalised to observed wind climatologies with WAsP. WRF simulations are performed over the same area and covering the same period as the measurements. The output from these simulations are then generalised and compared with observed wind climates from on-site measurements.

The sensitivity analysis is performed by manipulating the size of the wind speed bins used in the procedure and by the application of a range of stability correction algorithms. A comparison between the resulting generalised wind climates and observed climates yields an optimal choice of these generalisation parameters for specific site conditions.

Main body of abstract

The WRF mesoscale model simulates wind flows using information on terrain orography, roughness and atmospheric flows and stability on a model grid with horizontal resolution in the kilometre range. These flows do not accurately reflect flows at the microscale. Therefore, the effects of the kilometre-scale-resolution model surface are removed, by generalising to homogeneous and flat terrains for a specified set of standard heights and surface roughness lengths. A statistical analysis then yields Weibull distributions and wind roses. These resulting generalised wind climates can be used as input for a microscale model where more accurate representations of local terrain effects are taken into account to estimate the local wind resource.

Hahmann et al. (2013) developed a procedure for the WRF generalisation based on the KAMM/WAsP method of Badger et al. (2014). First, the roughness and orography terrain effects are removed from the WRF wind simulations yielding intermediate wind speed and wind direction time series. Secondly, the influence of the model roughness length is removed by moving to a set of standard roughness lengths with the use of the logarithmic and geostrophic drag laws. Since the latter assumes stationarity, the formulas cannot directly be applied to the mesoscale simulation time series, but are rather applied to each bin to ensure stationarity. Finally, Weibull parameters are fitted to each section histogram and a stability correction is applied resulting in a generalised wind climate.

A sensitivity test on the wind speed binning revealed that this step in the generalisation procedure has a great influence on the resulting wind climate. Figure 1 shows the mean absolute error (MAE) from 7 sites in the annual-average generalised wind speed at the met mast height and a roughness length of 0.03 m as a function of the wind speed bin size. The MAE is calculated as follows:

$$MAE\ [\%] = \sum_{i=1}^{7} \frac{|U_{WRF,i_{gen}} - U_{obs,i_{gen}}|}{U_{obs,i_{gen}}} \cdot 100,$$

where $U_{WRF,i_{gen}}$ is the generalized wind speed from the WRF simulations and $U_{obs,i_{gen}}$ the generalized observed wind climate obtained from the microscale model WAsP at site i. The influence of the wind speed bin size is clearly visible and a right choice can lead to an MAE reduction of 7 % (0.5 m/s bin size versus 2 m/s bin size), but this will depend on the length and sampling of the time series. Ongoing work extends this sensitivity test with more masts and investigates the influence of the differences of WRF model roughness and WAsP roughness on the results.

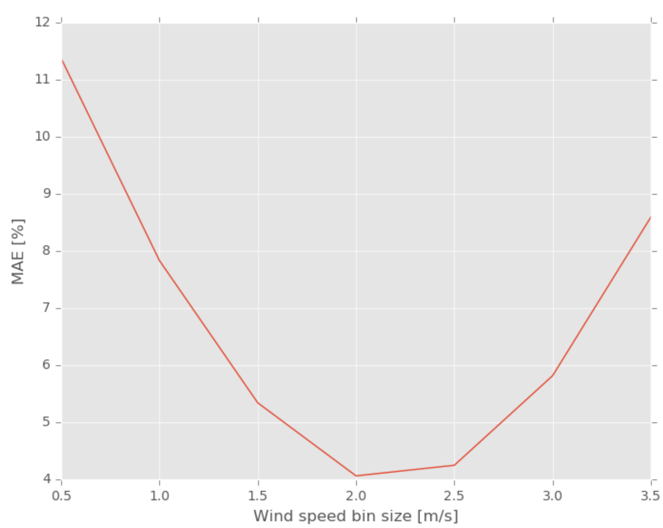

Figure 1: The MAE as a function of the wind speed bin size used in the WRF generalisation. The MAE is calculated by comparing the generalised mean wind speeds obtained from the WRF generalisation procedure and the generalisation of the measurements by WAsP.

In Figure 2 the need for the WRF generalisation becomes apparent when the errors of the raw and generalized mean wind speed are compared at the 7 sites. While the annual-average wind speeds from the WRF simulations can differ greatly form the observations with errors up to 27%, the generalisation procedure is able to reduce these errors drastically at all sites.

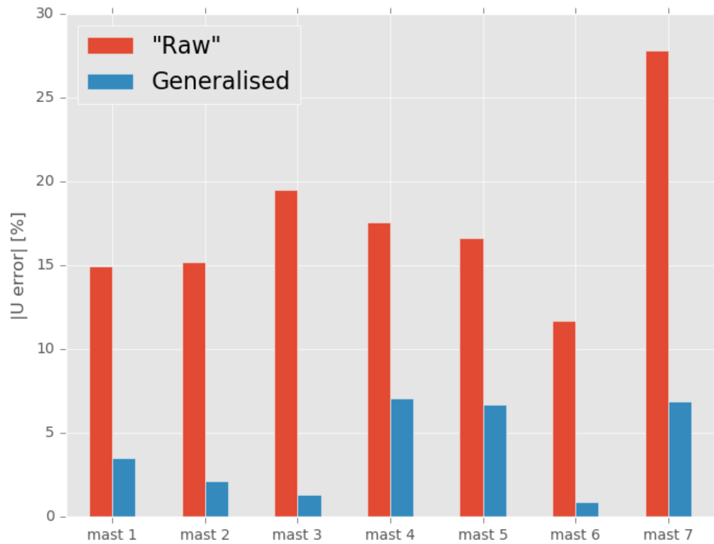

Figure 2: Comparison of the raw (red bars) and generalized (blue bars) mean wind speed at 7 sites. The generalisation is done for the met mast height and a roughness length of 0.03 m using a wind speed bin size of 2 m/s.

It has been shown that the stability correction on the WRF simulations also has an influence on the final generalised wind climate (Hahmann et al., 2014). That study is extended here to a larger scale validation, which covers regions outside South Africa as well to include different site stability conditions. The outcome of this study will be the correlation of the local stability regime and orography with generalisation parameter selection.

Conclusion

It is shown that on the 7 masts investigated, the raw WRF outputs have an inaccurate representation of the local wind climate. The WRF mesoscale generalisation procedure is able to greatly improve the wind climates, which can be downscaled further to a local climate using a microscale model resulting in improved mean wind speeds.

Both the wind speed bin size and the choice of the stability correction algorithm have a large effect on the final generalised wind climate. A cautious parameter selection for each case is therefore of great importance and can lead to an error reduction of more than 10 % compared to the use of raw WRF model output.

Learning Objectives

This paper gives guidance for wind energy professionals on the choice of generalisation parameters based on geography and stability regimes resulting in improved estimates of the wind energy resource.

References

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