Abstract

The application of numerical simulations to preliminary wind resource assessment requires an extensive validation effort in order to better assess the uncertainties arising from such method. This paper has the main objective of exposing the verification of applicability and perceived accuracy of simulated wind data against local observations, through the characterization of errors between the distinct data sources.

The methodology applied is based on the numerical simulation of the wind resource of four different areas, with the same set of parameterizations and numerical configurations, in order to better represent a blind test. Data obtained using the Weather Research and Forecasting (WRF) model is evaluated against wind resource assessment campaigns.

Comparisons are carried out with horizontal wind speed measurements and its respective prevailing direction, using simultaneous data at equivalent heights, exclusively with measurements containing over 85% valid data. The test cases were summarized and further divided according to local characteristics, such as average wind speed, altitude, altitude difference, distance to coastal area, terrain complexity, Weibull distribution shape factor and frequency, as were as seasonal behavior. With this analysis probable tendencies in errors can be assessed according to each parameter.

Objectives

Corroborate the known applicability of mesoscale numerical simulations on preliminary wind resource characterization, and identifies specific tendencies on some of the parameters evaluated.

Methodology

The employed approach is based on using data from wind measurement campaigns to assess results from the WRF numerical model. Since the simulated results represents instantaneous values, its results are only compared against instantaneous hourly wind measurements. Invalid or non-existent records from local measurements were equally invalidated on the simulated results. Only measurement masts with over 85% of the data available were considered.

In order to better assimilate large-scale conditions, three numerical domains were used during the numerical integration, employing a two-way nested scheme. Domain placement takes into consideration major local characteristics (such as valleys and mountains) located near or at domain boundaries, thus being properly placed to include said characteristics in the simulation, allowing for a better representation of the local flow (Figure 1). Since a two-way nested scheme is used, results from the inner domain replace the coincident points on its parent domain, thus smaller scale phenomena can be better described and propagated to outer domains.

Each test case was evaluated using a single numerical simulation, with the same parameterizations options and configurations, in order to better represent a blind test.

Several comparison indicators were used in order to evaluate the modeled results, using the horizontal wind speed and prevailing directions as variables, assessing deviations in Weibull distribution parameters and statistical analysis.

Data used in this validation analysis were obtained from wind measurement campaigns with the only sole purpose of wind resource assessment. These wind data is from anemometrical masts equipped with sensors from either NRG or Thies, calibrated according to IEC/MEASNET parameters, in multiple heights. The standard data acquisition frequency is 1 Hz, however measurements are integrated in 10 minutes intervals. A throughout quality check is performed, invalidating any record that contains anomalies, generally occurring during extreme weather events or due to equipment failure.

To validate the simulated data were used records from 14 masts in Portugal (center and shore regions), 6 in eastern Poland, and 14 in southeast Romania (Figure 1). Due to different measurement campaigns characteristics comparisons were carried out using 6 or 12 consecutive months.

During the validation procedure the test cases were organized according to several factors (average wind speed, altitude, altitude difference, distance to coastal area, terrain complexity, k-shape factor, Weibull distribution, and seasonal behavior), with the objective of identifying a relation from such factor to observed deviations.

Local data obtained from measurement masts were not assimilated on the numerical model initialization, and are not part of the data used on the Reanalysis project.

Results

In order to establish the model capability and limitations of describing the wind resource of a region, different validation experiments were undertaken. Three distinct regions, ranging from a low complexity coastal terrain to complex sites, located in different countries and climates, are presented. The data obtained from such simulations were compared against different met masts, with wind speed and direction records mostly at 60m a.g.l.

Table 1. Statistics for all the cases.

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<th>Obs.</th>
<th>Sim.</th>
<th>Deviation (%)</th>
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<tr>
<td></td>
<td>5.78</td>
<td>5.69</td>
<td>-0.89</td>
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<tr>
<td></td>
<td>1.30</td>
<td>1.20</td>
<td>-0.10</td>
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Figure 2. Wind Speed Histogram and Wind Rose, station (blue), WRF (grey).

Table 6. Weibull parameters (observed, simulated) and respective deviations.

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<tr>
<td></td>
<td>1.91</td>
<td>2.09</td>
<td>0.18</td>
<td>6.50</td>
<td>6.60</td>
<td>0.20</td>
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Conclusions

Based on statistical parameters analysis the following conclusions can be drawn:

- The Global results analysis shown that mesoscale model can produce acceptable results for a preliminary stage of the wind resource assessment.
- Analysis made against other physical parameters didn’t show any marked tendency on results, as would be expected. Further analysis should be made to clarify this evidence.
- For a specific case located near to the Black Sea in Romania, characterized by low complexity, the model present an underestimation of 0.09 m/s in yearly average wind speed. The mesoscale model was able to reproduce with confidence the most frequent wind directions. In terms of wind distribution pattern the model can reproduce with small deviations almost all wind speed bins.
- Complexity of terrain presented indicate that the Weibull distribution shape factor is consistently higher on simulated results, representing that the numerical model tends to skew the results on a shorter distribution, therefore under-estimating extreme values.