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A UNIVERSAL MESOSCALE TO MICROSCALE MODELLING INTERFACE TOOL

Jake Badger, Xioali Guo Larsén, Niels Gylling Mortensen, Andrea Hahmann, Jens Carsten Hansen, Hans Ejsing Joergensen

Wind Energy Division, Risø National Laboratory for Sustainable Energy, Technical University of Denmark, Frederiksborgvej 399, Building 118, DK-4000, Roskilde, Denmark.

e-mail   : jaba@risoe.dtu.dk
telephone : +45 4677 5094
fax   : +45 4677 5970

Summary

Mesoscale modelling for wind energy resource mapping and forecasting is an established and ever growing area of study. A crucial limitation of the mesoscale model output is its resolution. Typically the horizontal resolution is between 2 and 5 km. Therefore it is not correct to directly compare winds based on the mesoscale model with wind measurements for the purpose of verification. Nor is it correct to directly apply the winds from the mesoscale model to a specific turbine site for power production calculations or assessment of the wind conditions. This is because important topographical features in the vicinity of the measurement station or turbine site are not resolved by mesoscale model.

A post-processing procedure able to use output from several different mesoscale models (KAMM, WRF, AROME) and link to microscale modelling is described here. This linkage means two things: 1. That a correct verification of modelling results with measurements can be performed. 2. That application of mesoscale model output can be extended to much finer resolutions for the purpose of wind resource assessment and wind conditions. Applying the mesoscale modelling results in WAsP gives capabilities for advanced wind resource calculations at very high resolutions.

Introduction and method

A universal mesoscale post-processing procedure is being developed based on the numerical wind atlas methodology developed at Risoe DTU. This procedure uses the WAsP concept of the generalized wind climate; the wind climate for standard conditions given by flat terrain of uniform roughness. Simulated boundary layer winds and profile information from mesoscale modelling, and the mesoscale description of the topography, are used to make the transformation to standardized conditions. The generalized wind climate thus produced can then be imported into WAsP in order to carry out very high resolution microscale modelling for specific measurement or turbine sites. Only then is a verification against measurements or an application for a turbine site and power production valid.

Figure 1 shows the statistical-dynamical downscaling method whereby a set of approximately 150 wind classes are determined, representing the large scale climatological atmospheric forcing, and used as mesoscale model forcing [1]. Combining the simulation results gives a wind resource map.
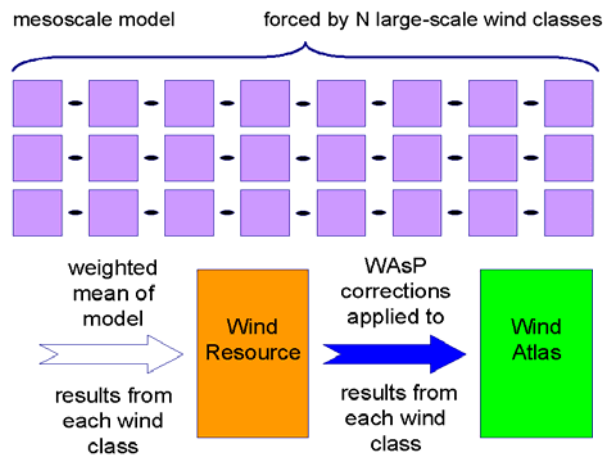

Figure 1. Schematic diagram of the KAMM/WAsP numerical wind atlas methodology

The simulated winds for any location will not agree with measurements made for the same location because topographic features are not fully resolved at the modelling resolution. A solution to this problem is to generalize the simulation winds. Generalization means that the effects of orographic speed up and roughness change by the resolved topographic features are removed. The result is a generalized wind climate, also called a wind atlas. This can be compared to generalized wind climates derived from measurements, making verification possible between modelling and measurements.

Figure 2 gives examples of maps showing mean simulated wind and mean generalized wind for Egypt from [2]. One of the marked differences between the two maps is the wind speed values given over the Nile River and Nile Delta. In the simulated wind map, the wind speed is reduced compared to the surroundings. This is because of the increased roughness associated with the vegetation and agriculture in the vicinity of the Nile River. In the case of the generalized wind map, the wind values are more uniform, because now the wind is shown as it would be for homogeneous roughness and flat terrain. The generalized wind map shows the variations in wind resource due to mesoscale flow features, rather than due to the local orography and roughness.
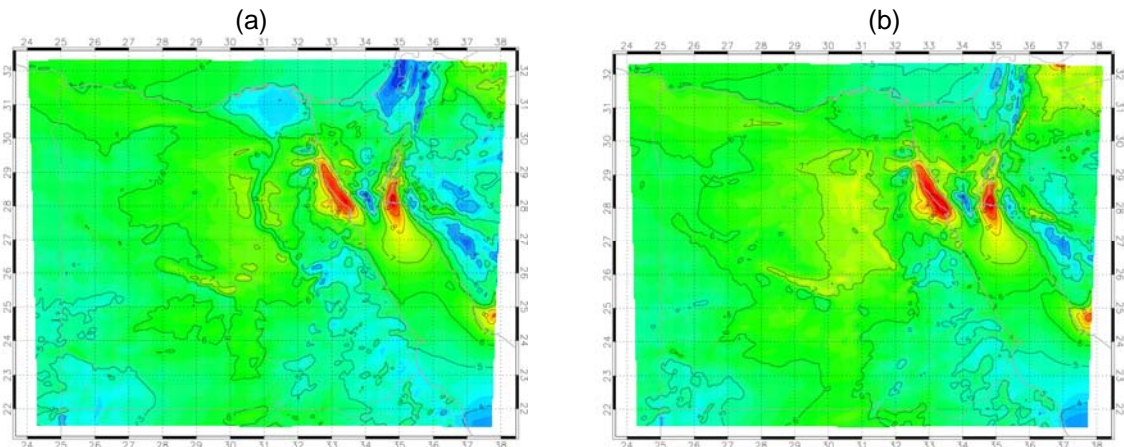
Figure 2: (a) Wind resource map for Egypt at 50 m a.g.l. and (b) wind atlas map for Egypt at 50 m a.g.l. and z_0=2 mm. Both maps are from [2].

Generalization is carried out by evaluating direction dependent effective upstream roughness length, and roughness and orographic generalization factors. Figure 3 gives the orography and surface roughness lengths for the 5 km resolution innermost domain used in a WRF simulation of a storm event effecting Denmark in December 1999. The wind direction depend upstream roughness is evaluated using the linear model LINCOM, developed at Risø DTU. The effective upstream roughness is show in Figure 4a for westerly winds (270°). LINCOM also gives, for all grid points, the perturbation to the wind speed given by i) the orography (i.e. speed up at hill tops) and ii) roughness changes. These perturbations can be expressed as generalization factors (shown in Figures 4b and 4c): values >1 indicate a speed-up of wind is occurring, and conversely values <1 indicate a slow-down of wind is occurring, with respect to the mesoscale local orography and effective roughness length. Applying the generalization factors to the simulated wind, and using the effective roughness length in the geostropic drag law yields the geostrophic wind. Applying the geostrophic drag law again, to solve for friction velocity, for a specific standard roughness and then using the logarithmic wind profile gives the generalized wind at a specific standard height. The geostrophic drag law and logarithmic wind profile can include corrects for atmospheric stability.
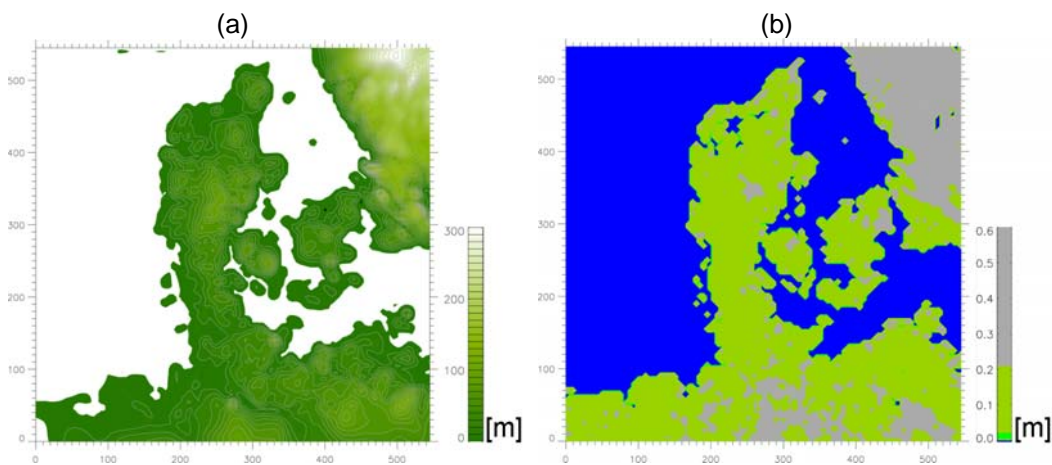
Results and conclusions

Figure 3: (a)The orography and (b) the surface roughness length at 5 km resolution used in WRF for a simulation of a storm event in Denmark in December 1999.
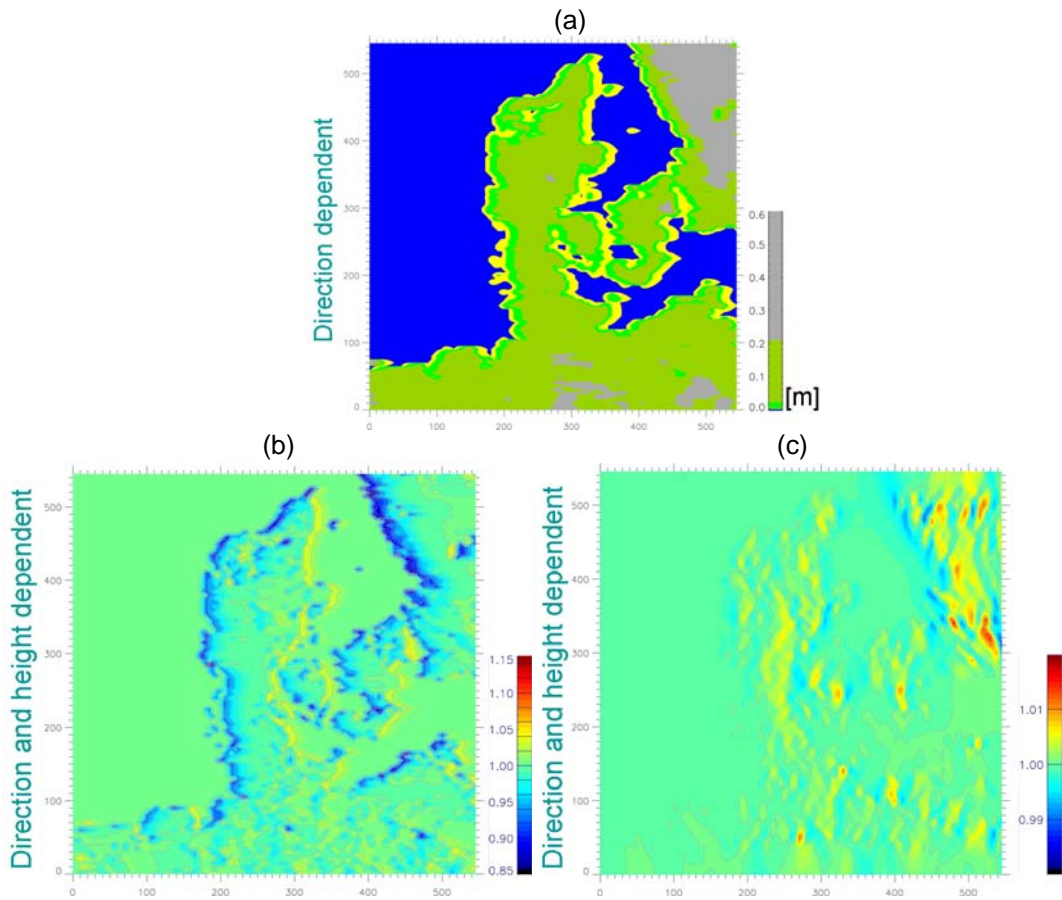
Figure 4: Direction dependent (a) effective upstream roughness length, (b) roughness generalization factor and (c) orography generalization factor, given for a uniform wind direction of 270° over the entire domain, based on the 5 km resolution topography in Figure 3.

The generalization procedures can be applied to simulations representing climate, or applied to single events, or a series of episodes such as storms, for evaluation of generalized extreme wind climates. In these cases, the wind directions from the simulations are required to calculate the appropriate generalization factors and effective roughness lengths. Figure 5 shows the simulated and generalized winds for 18Z on 3rd December 1999 during a storm episode.
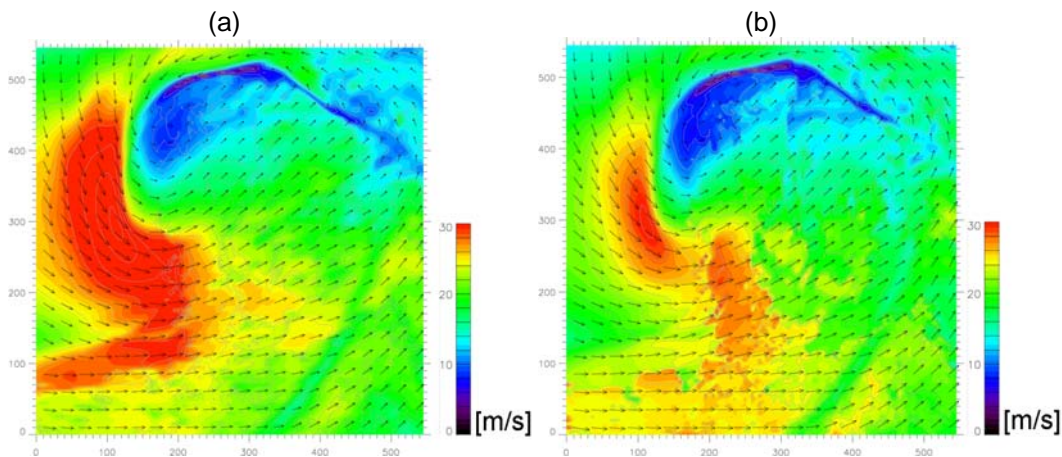

Figure 5: (a) WRF simulated winds at 76 m a.g.l. and (b) WRF generalized winds 76 m a.g.l..

The procedure is also being developed further for application to dynamical downscaling using WRF and other statistical-dynamical downscaling methods. Generalized wind climate data derived from mesoscale modelling can be applied in WAsP to calculate wind resources at very high resolution, Fig 6. A similar method for extreme winds climates using WAsP Engineering is in development.
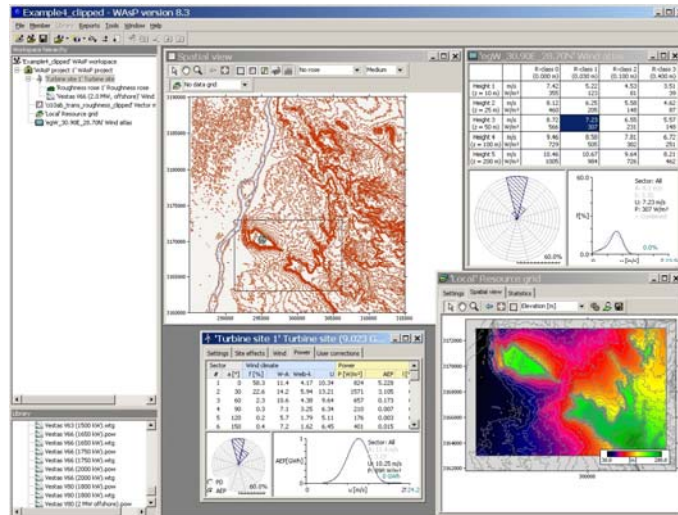

Figure 6: Screen shot of the WAsP software using a generalized wind climate derived from numerical wind atlas to calculate wind resource at high resolution.
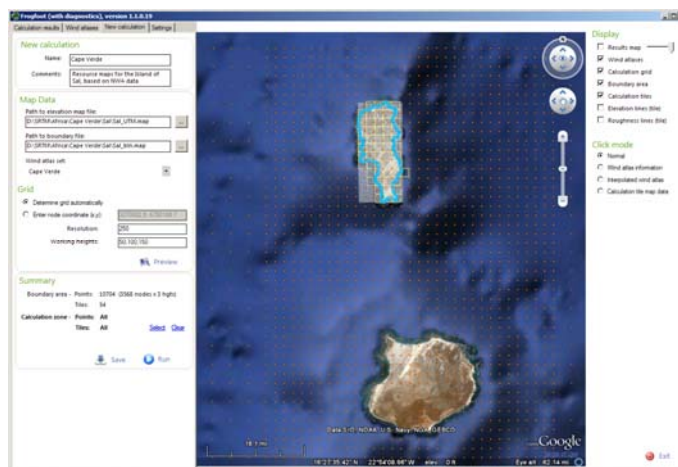

Figure 7: Screen shot from a tool allowing display and application of many generalized wind climates. Each red dot represents a generalized wind climate dataset. A high resolution wind resource calculation for a selected area can be configured and carried out using the tool.

The universal post-processing procedure has been used with the KAMM (Karlsruhe Atmospheric Mesoscale Model), WRF (Weather Research and Forecasting Model) and a national meteorological centre's operational mesoscale model. This procedure opens up valuable capabilities to apply mesoscale modelling data in a more sophisticated way and to much higher resolutions, via the generalized wind climate linkage to microscale models. Furthermore a powerful new tool to provide a user interface for a grid of generalized wind climate data for display and application is in development, Fig. 7.

Acknowledgements and references

1. Frank et al 2001.The numerical wind atlas - the KAMM/WAsP method. Risø-R-1252(EN) 60 p.

2. Mortensen, N.G et al, 2006. Wind Atlas for Egypt: Measurements, micro- and mesoscale modelling. Proceedings of the 2006 European Wind Energy Conference and Exhibition, Athens, Greece, February 27 to March 2. 10 pp.