Mesoscale and microscale modeling in NE China

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Abstract: A Sino-Danish project to map the wind resources of NE China (Dongbei) is described. Measurements, microscale and mesoscale modeling will be applied in the framework of the wind atlas methodology. Planned extensions to the standard methodology include comparisons of wind measurement systems as well as mesoscale (KAMM, MM5, WRF) and microscale (WAsP, MS-Micro) models. The final goal is to produce a reliable wind resource database for Dongbei and develop an improved, standardized framework for wind resource assessment and siting, as well as methods for uncertainty estimation.

Keywords: wind resource assessment, wind measurements, microscale modeling, mesoscale modeling, numerical wind atlas, siting, NE China.

1. Introduction

The China Meteorological Administration (CMA) and Risø National Laboratory for Sustainable Energy at the Technical University of Denmark (Risø DTU) has entered an agreement with the primary objective of assessing the wind resources of the three provinces of Liaoning, Jilin and Heilongjiang in NE China (Dongbei). This paper describes the conceptual design and contents of the project “Mesoscale and microscale modeling in NE China”.

2. Project conceptual design

NE China (Dongbei) covers an area of almost 800,000 km², spanning 15° of latitude and longitude, and with elevations from 0 to 2744 meters above sea level. In order to assess the wind resources of such a diverse geographical region – including provision of reliable data for physical planning (national,
regional or local), wind farm siting, project development, wind farm layout design and micrositing of wind turbines – the project has adopted the framework of the wind atlas methodology developed at Risø DTU (Frank et al., 2001; Badger et al., 2006; Hansen et al., 2007). Figure 1 below is a schematic presentation of this framework.

![Figure 1. Schematic presentation of the wind atlas methodology.](image)

The project “Mesoscale and microscale modeling in NE China” is implemented in four sub-projects: 1) mesoscale modeling, 2) measurements, 3) microscale modeling and 4) guidelines for application; each associated with extensive capacity building and R&D. These four sub-projects are described below; first with a general introduction to the methodology, followed by the project-specific extensions and special considerations.

### 3. Measurements

A number of high-quality and well-distributed wind measurement stations are needed to validate the model results for a given geographical area. A chain of carefully executed and well documented activities are needed to provide these locally measured data. The same careful approach is needed regarding the use and interpretation of externally measured wind data. In general, the use of existing meteorological stations only is not sufficient to ensure the quality and reliability of the wind atlas; some dedicated stations with tall masts (> 50 m) must usually be installed and operated at characteristic sites for verification.

This project has erected 12 dedicated meteorological stations; three 70-m masts and one 100-m mast in each of the three provinces of Dongbei. These masts serve three main purposes: as high-quality verification points for the mesoscale modeling, as reference stations for wind resource calculations at wind farm sites close to the masts, and as test beds for comparison of wind sensors and mounting arrangements. For the latter purpose, the masts have been instrumented doubly: on one side with state-of-the-art wind sensors and...
hardware specified according to international standards and on the other side with standard equipment commonly used in China. This comprehensive instrumentation at four levels on each mast will provide a unique data set for investigation of the uncertainties associated with wind measurements using different systems and microscale modeling of the wind profiles.

4. Microscale modeling – observational wind atlas

After pre-processing, wind measurements are used as input to a microscale model which is able to model the influence of the nearby terrain on the measurements. Employing detailed descriptions of terrain elevation, land-use and the occurrence of sheltering obstacles around each meteorological station, the observed wind climate is transformed into what would have been measured at the location of the station if the surroundings were completely flat and uniform with a certain roughness, and the wind measurements had been taken at certain standard heights. Through this transformation procedure, the observed wind climate is freed from the influence of local topography to become regionally representative.

This project will establish an observational wind atlas for Dongbei, based on WASP modeling (Mortensen et al., 2007) of the 12 dedicated stations and a number of existing CMA and provincial met. stations. This wind atlas will be used for comparisons and verification of the numerical wind atlas. In addition, the microscale modeling will be tested against the high-quality wind data from the dedicated met. stations. Sensitivity analyses and model parameter studies will serve as the basis for model adaptations and for developing methods for estimating the uncertainty. Other microscale models might be tested as well.

5. Mesoscale modeling – numerical wind atlas

Numerical wind atlas methodologies have been devised to solve the issue of insufficient wind measurements, which render wind resource mapping efforts through observational methodologies problematic. One such methodology is the KAMM/WAsP method developed at Risø DTU (Frank et al., 2001). In this methodology, an approach called statistical-dynamical downscaling is used. The basis for the method is that there is a robust relationship between meteorological situations at the large-scale and meteorological situations at the small-scale.

Information about the large-scale meteorological situation is available from the global NCEP/NCAR reanalysis data-set. Typically, a 30-year period of NCEP/NCAR data is used in the pre-processing stage to create approximately 150 different large-scale wind situations, called wind classes that represent the large-scale wind climate. For each wind class a mesoscale model simulation is performed in order to find out how the large-scale wind forcing is modified by regional scale topography. Typically, the domain size is 500 km × 500 km in the horizontal and 6 km in the vertical. Finally, the mesoscale modeling results are combined to give the predicted wind climates at the grid points of the model.
The result of the mesoscale modeling is estimates of the wind climate in the ‘mesoscale world’. These results are impacted significantly by the spatial resolution of the model, even at high resolutions, and therefore cannot be compared directly to measurements. The necessary step is to transform the model winds to certain standard conditions to account for the effects of the land-use and elevation differences as represented in the mesoscale model. Through the post-processing transformation procedures, the model winds are freed from the influences of the model topography to become regionally representative.

This project will establish a numerical wind atlas for Dongbei, based on the KAMM mesoscale model, which was originally used in the development of the numerical wind atlas methodology. More than 10 years of experience exists with the KAMM/WAsP setup and it will therefore form a solid starting point for further developments. As a first step, we aim at generalizing the methodology in order to provide a much more systematic and flexible framework that could accommodate different mesoscale models. As an example, this requires that the interfaces between the different ‘cells’ in Figure 1 are standardized. With a more general framework, different mesoscale models can be tested: CMA plan to apply MM5 and WRF and Risø DTU will use KAMM and WRF.

Sensitivity analyses and model parameter studies will serve as the basis for model adaptations and improvements, but also for developing methods for estimating the uncertainty. This part of the work is a much desired aspect of any wind mapping procedure.

6. Verification

Accounting for the topographical effects on the flow is the backbone of the wind atlas methodology. In the observational wind atlas, the observed wind climates are transformed into regional wind climates at each meteorological station. In the numerical wind atlas, the modeled (predicted) wind climates are transformed also into regional wind climates, but for each model grid point. In the verification process, only wind climates transformed to these standard conditions are compared, i.e. winds at standard heights over flat terrain with a single homogenous surface roughness. This is the only fair way to make the comparison; otherwise, output from models handling different scales will quite surely deviate.

In this project, both micro- and mesoscale models will be adjusted and model parameters changed to reflect local and regional climatic conditions. Sensitivity analyses, model intercomparisons and verification against high-quality wind data should provide the necessary information for assessing the uncertainty of the modeling and of the wind atlas data sets.

7. Application

Wind resource assessment for determination of wind conditions and estimation of annual energy production may be applied for many purposes, including
physical planning (national, regional or local), wind farm siting, project
development, wind farm layout design, micro-siting of wind turbines and wind
farm performance verification.

The different purposes require modeling of different size geographical domains
and different levels of accuracy. However, the wind atlas method described
above provides opportunities to serve all these purposes; by applying the
methodology with lower or higher resolution in the data and modeling.
Implementation may then be planned with a successive refinement of
resolution for the regions and areas of interest for wind farm development.

For wind farm siting and design, and estimation of annual energy production
and wind farm efficiency, a microscale model is used to transform the regional
wind climates of the wind atlas to the predicted wind climates at the turbine
sites. And, a wake model is used to estimate the wind farm efficiency.
Bankable estimates may be obtained where the wind farm sites are close to
dedicated measurement stations.

Table 1. An overview of the wind atlas approach applied for four different purposes,
including estimates of the uncertainty (Hansen et al., 2007).

<table>
<thead>
<tr>
<th></th>
<th>National planning</th>
<th>Regional planning</th>
<th>Wind farm siting</th>
<th>Wind farm layout and micro-siting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model type</td>
<td>Mesoscale</td>
<td>Mesoscale</td>
<td>Meso + microscale</td>
<td>Meso + microscale</td>
</tr>
<tr>
<td>Domain size</td>
<td>(\approx 500-1000) km</td>
<td>(\approx 100-500) km</td>
<td>(\approx 20-100) km</td>
<td>10-20 km</td>
</tr>
<tr>
<td>Map resolution</td>
<td>5-10 km</td>
<td>1-5 km</td>
<td>10-100 m</td>
<td>1-10 m</td>
</tr>
<tr>
<td>Wind data</td>
<td>NCEP/NCAR reanalysis data</td>
<td>NCEP/NCAR reanalysis data</td>
<td>NCEP/NCAR + met. stations</td>
<td>Dedicated met. stations</td>
</tr>
<tr>
<td>Verification</td>
<td>Existing met. stations</td>
<td>Existing met. stations</td>
<td>Dedicated met. stations</td>
<td>Dedicated met. stations</td>
</tr>
<tr>
<td>Uncertainty on speed</td>
<td>10-30%</td>
<td>10-20%</td>
<td>5-15%</td>
<td>1-5%</td>
</tr>
</tbody>
</table>

This project seeks not only to confirm the uncertainty estimates given in Table
1, but also to decrease their magnitude. This may be obtained through all of
the activities described in Sections 3 to 6 above, but also through development
of guidelines and best practices for application of the wind atlas methodology
and the wind resource databases in Dongbei. Another important aspect will be
dissemination of the project results to relevant stakeholders and development
of training materials and training courses for professional staff employed in
wind resource assessment and siting.
8. Concluding remarks

The mesoscale numerical wind atlas in combination with an observational wind atlas offers new opportunities for doing wind energy planning on a large scale, even with limited availability of wind data from meteorological measurement stations. At wind farm sites and in project preparation, it provides a consistent basis for verification of model results against each other and against measurements and the methodology may be applied with a view to reducing uncertainties and risks in wind farm planning and development.

The “Mesoscale and microscale modeling in NE China” project will provide comprehensive and reliable wind resource data for Dongbei within this framework, including guidelines and best practices for application of these data. Furthermore, the project should provide improvements and further developments of the modeling and measurement methodologies – which, in a broader perspective, will help to improve wind resource assessment and siting in all of China and elsewhere in the world.

9. Acknowledgements

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10. References


