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Mesoscale and microscale modelling in NE China: A new application-ready numerical wind atlas for Dongbei

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Mesoscale and microscale modelling in NE China: A new application-ready numerical wind atlas for Dongbei

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China Wind Power 2010

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Outline

- Introduction
  - Project description
  - Overview of project outputs and results
- Measurements
- Microscale modelling
- Mesoscale modelling
- Application
- Conclusions and recommendations
- Future work

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Mesoscale and microscale modelling in China
Project description

- Part of the Sino-Danish Wind Energy Development Programme (WED) 2008-2010; co-funded by China (MOFCOM and NDRC) and Denmark (Ministry of Foreign Affairs)
- Wind resource assessment in Dongbei (NE China) Research & Development in
  - measurement practices
  - observational and numerical wind atlas methodologies
  - verification and uncertainties
  - application aspects for wind energy planning and project preparation

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Overview of project results

- Wind resources of NE China mapped with mesoscale models
  - KAMM (Risø DTU) and WRF (CMA)
- Meteorological stations at 12 sites measured 1year+ used to
  - verify mesoscale modelling
  - test WAsP
  - compare measurement systems
  - analyse measurement uncertainties
- Sensitivity studies and uncertainty assessments
- 3 case studies to illustrate the application
- All reports and databases available from CMA and WED website - http://www.dwed.org.cn/ and http://cams.cma.gov.cn

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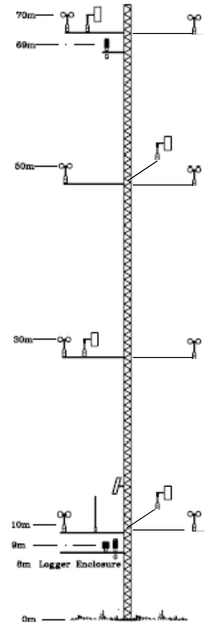
Measurements at 12 masts

- 70 m masts – wind speed at 4 levels
- Year 2009 for all 12 masts obtained (at 1 mast by combining data)
- 9 masts equipped with 2 different types of instruments
- Evaluation
  - fabrication, calibration, mounting and handling of sensors provide repeatability and precision
  - sensor type, mounting and position of sensors impact uncertainties and produce biases that can be mitigated by post-correction
  - **guidelines** provided
- 10-minute statistics of wind speed and direction as well as temperature and atmospheric pressure available in **database**



Mast layout

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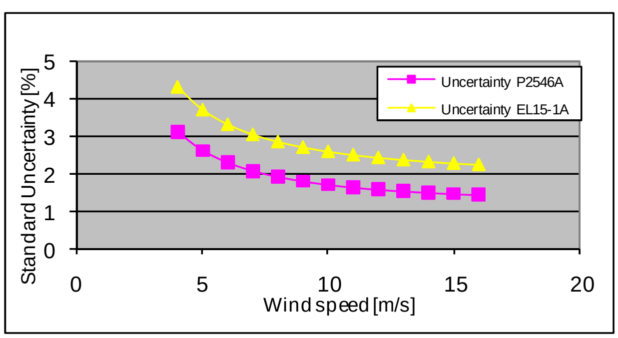
70-m masts installed in Dongbei – 1

70-m masts installed in Dongbei – 2

Sensitivity studies and uncertainties - measurements

- Many sensitivity studies performed
- Measurement uncertainties estimated based on guidelines in the IEC 61400



Standard uncertainty for the two types of cup anemometers used; can be improved by post-correction.

Microscale modelling

Microscale modelling carried out at the 12 meteorological stations

- WAsP (ver. 10.0) used for analyses
- Inputs derived from data using the WAsP Climate Analyst
- Topographical inputs (orography and roughness length) made from
  - SRTM 3 data
  - Google Earth
  - adjusted according to Chinese maps

Main results

- observational wind atlas at each of the 12 locations in NE China
- used for verification of the mesoscale modelling
- used for case studies
- microscale modelling of vertical wind profiles verified

Sensitivity studies and uncertainties – microscale

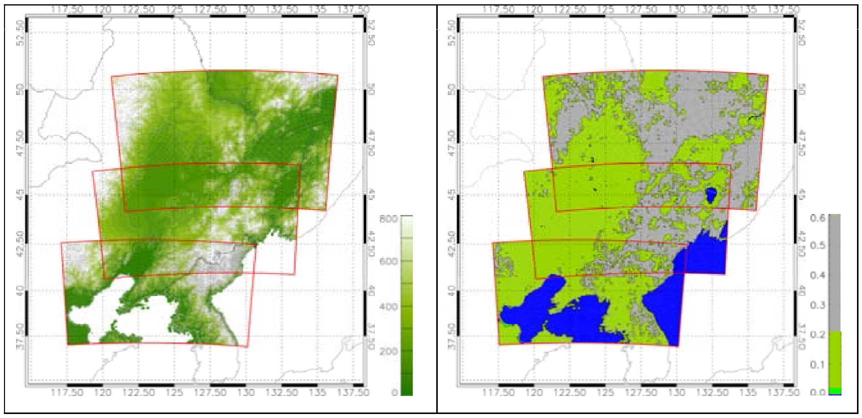
Uncertainties investigated through sensitivity studies of the WAsP modelling

Modelling is robust to changes in input data and parameters

Parameter	Input change	Change in AEP at 100 m
U calibration	± 1%	±2.1%
Anemometer height	±1%	±0.3%
Direction offset	10°	0.2%
Air density	±2.5%	±2.1%
Stability	neutral	-6.2%
Heat flux	10 Wm^{-2}	1.2%
BG roughness	half of 20 cm	0.6%
BG roughness	double of 20 cm	-1.5%
Position of mast	±10 m	0.2%
Elevation detail	SRTM 3 only	0.0%

Mesoscale modelling

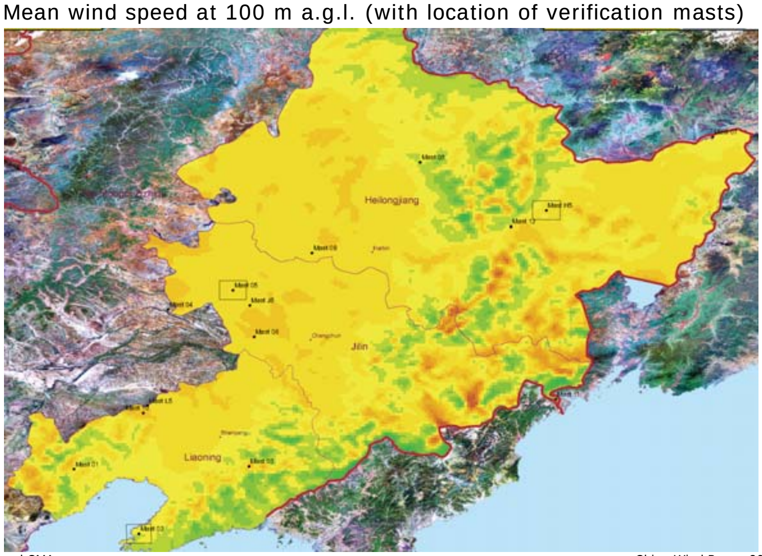
- 3 modelling domains with overlap
- 137, 124 and 128 wind classes represent large-scale climate conditions
- 5 km resolution



Calculation domains – orography (left) and surface roughness (right)

Numerical wind atlas

Mean wind speed at 100 m a.g.l. (with location of verification masts)



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Sensitivity studies and uncertainties – mesoscale

Largest uncertainties are related to mesoscale modelling

Main sensitivity impacts

- wind classes should be chosen to allow stability classes
- most sensitive regions are in mountain/hill terrain and/or coastal regions

Sensitivity test	Effect
Resolution (5km, 10km, 20km)	< 5%
Class definition location (2 different NCEP/NCAR reanalysis points)	< 2 %
Class definition height (0m, 1500m)	< 2 %
No. of stability classes (1, 2, 3)	< 1 %
Wind class number (100, 300)	< 1%
Surface roughness (halved, doubled)	< 6 %
Surface temperature (-4.5 deg C, +4.5 deg C)	<13 %

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Verification

- Overall agreement of the modelling and measured results is good
- Best modelling configuration for each station gives a
  - mean error of -1.25%
  - mean absolute error for the 9 stations of 8% for 50m wind speeds.
- Further improvement may be achieved through more specific configurations for smaller domains
- The WERAS and KAMM/WAsP simulated wind resources give similar results

Mean wind speed at z = 50 m; z_0 = 0.03 m			
mast	Observed wind atlas	Numerical wind atlas	Error [%]
M01	4.70	4.88	3.83
M02	6.81	5.66	-16.89
M03	5.51	6.22	12.89
M04	6.78	6.32	-6.78
M05	6.74	6.37	-5.49
M06	6.72	6.41	-4.61
M07	6.01	6.27	4.33
M08	5.60	6.20	10.71
M09	6.83	6.20	-9.22
Mean error			-1.25
Mean absolute error			8.31

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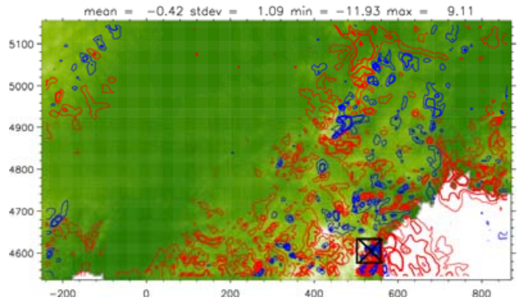
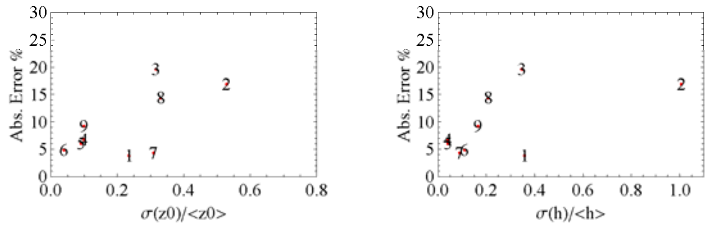
Uncertainties - mesoscale

Sensitivity map - effect of including stability classes in atlas calculation. Biggest differences seen at the most complicated terrain areas, and offshore areas bordering elevated terrain.





Error of generalized winds against mesoscale complexity - roughness (left) and surface elevation (right)

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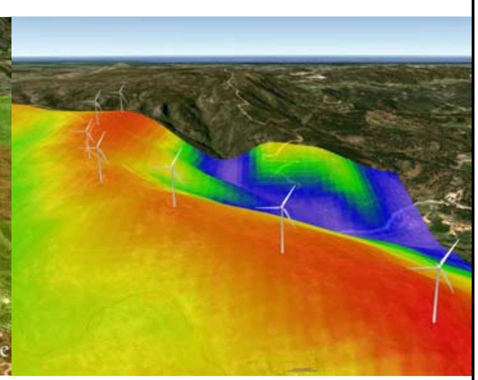
Application

Results of the “Meso-Scale and Micro-Scale Modelling in China” project, is available in public domain, containing description of the Wind Atlas Method and how to apply the Numerical Wind Atlas



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Case studies

Case studies illustrate application of the Numerical Wind Atlas.

Each of the three case study sites are 15 × 15 km^2 (corresponding to 9 mesoscale grid cells).

Calculations include

- Wind resource from measurements as well as from generalized wind climate for the nearest Numerical Wind Atlas grid cell
- Wind farm calculations – PWC and AEP
- Verification comparing measurements to Numerical Wind Atlas

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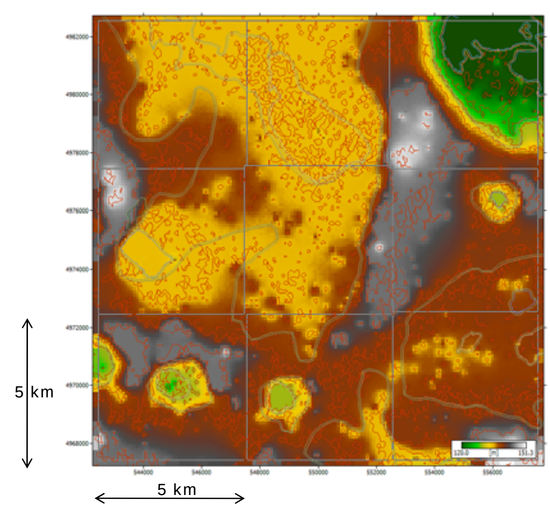
Case studies

Terrain – digitised orography and roughness



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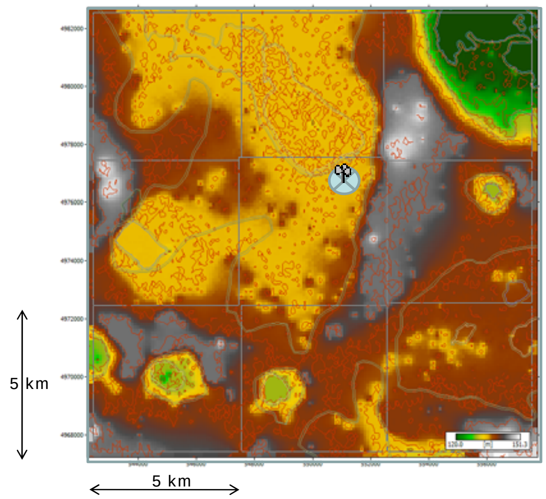
Case studies
Mast – Observed Wind Climate and Observed Wind Atlas



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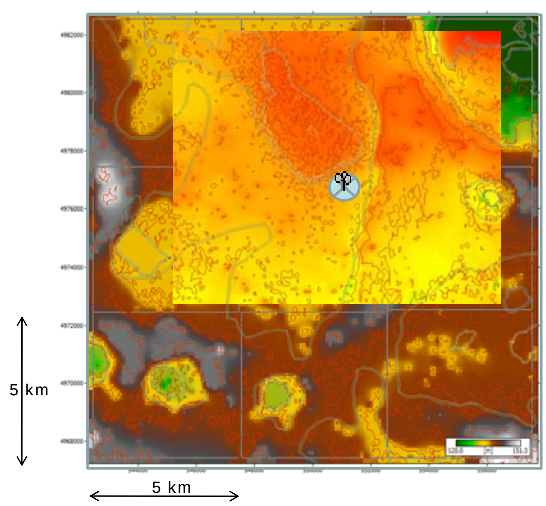
Case studies
Wind resource – surface wind predicted from measurements



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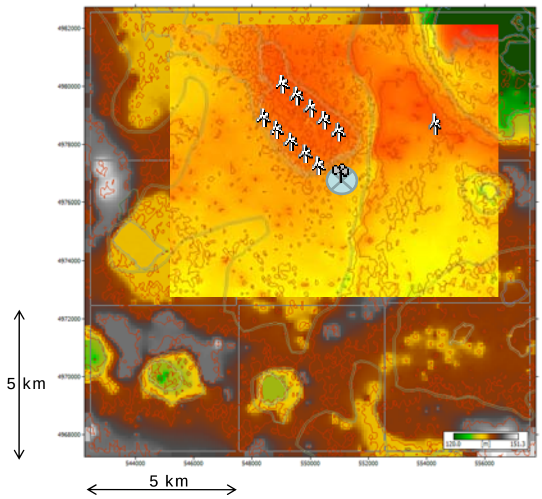
Case studies
Wind farm at mast – PWC and AEP



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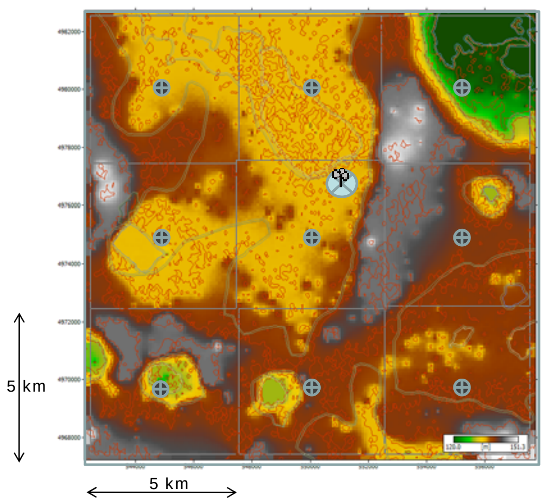
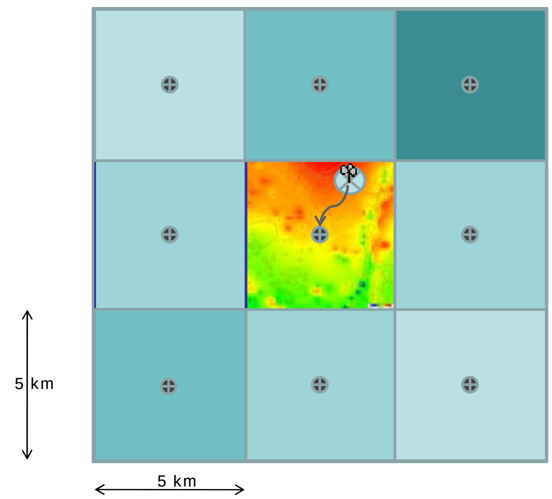
Case studies
Mesoscale modelling at mast – 5 km x 5 km grid

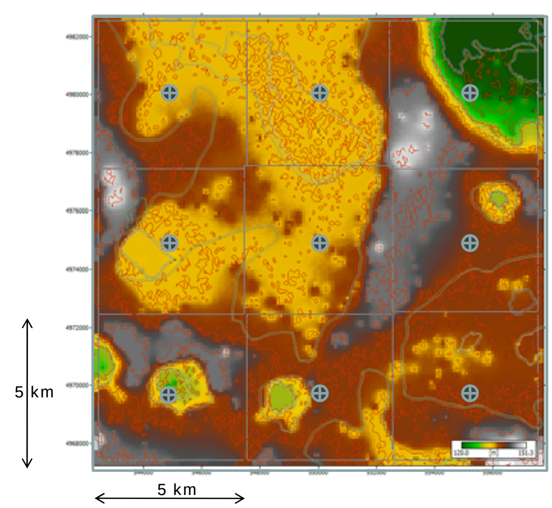


Case studies
Verification

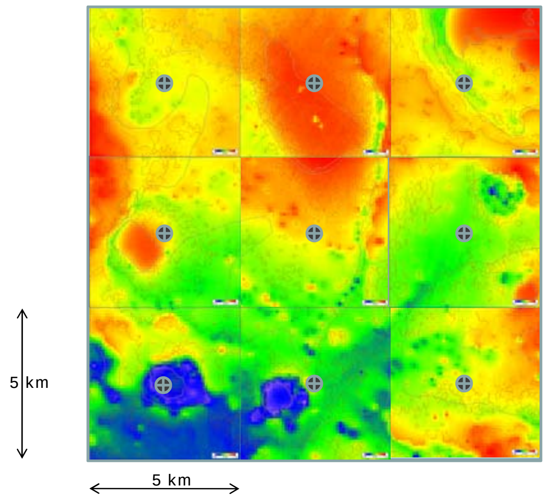


Compare measurements to Numerical Wind Atlas for nearest cell

Case studies
Mesoscale modelling at anywhere – 5 km x 5 km grid

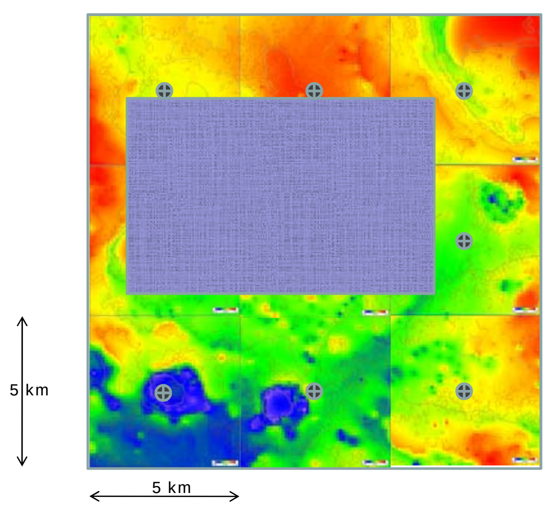


Case studies
All grid cells in Dongbei can now use Numerical Wind Atlas



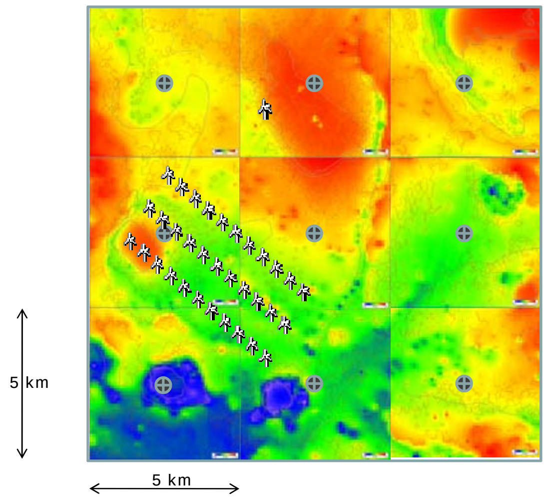
WAsP and microscale terrain

Case studies
Planning anywhere in Dongbei



Case studies

Wind farm projects anywhere in Dongbei – bankability ??



Conclusions and recommendations

- Model-derived Numerical Wind Atlas and Measured datasets for wind resources of NE China are available
  - methods improved and sensitivity studies
  - verification on 1 year of measurements at 12 locations
  - mean absolute error for wind resource estimates is less than 10%
  - procedures for transforming the mesoscale results to wind resource assessments on the microscale with guidelines and best practices
  - WAsP generally works well for microscale though hilly-forested and complex sites are less well modelled
- Bankability of wind farm projects requires on-site measurements
- Recommendations for measurements have been made

- Any use of these databases will be fully at the users own risk

Future work

- **Improve modelling methods**
  - for importing WRF results into WAsP
  - developing more direct relationships between the model sensitivity analysis and uncertainties
- **Continue the measurements**
  - to improve and enhance the verification analysis and
  - to possibly be able to reduce project development time and cost through MCP
- **Design conditions for wind turbines**
- **Investigate tall wind profiles at 100-m masts**
- **Numerical wind atlas for other provinces in China**
- **Offshore and near-shore wind**