Validation and comparison of numerical wind atlas methods: the South African example

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Validation and comparison of numerical wind atlas methods: the South African example

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Outline

• Introduction to the WASA project
• Downscaling methods
  – KAMM/WAsP
  – WRF-based
• Microscale modeling at verification sites
• Generalization procedure
• Validation and comparisons
• Conclusions
The Wind Atlas for South Africa (WASA) Project

- Objectives: to develop, verify and employ numerical wind atlas methods and to develop capacity to enable large scale of exploitation of wind energy in South Africa.
- The project includes:
  - 10 measurement masts (top anemometer 62 meters); most sites operating September 2010 – present (data freely available: http://wasadata.csir.co.za/wasa1/WASAData)
  - Two numerical wind atlas; preliminary statistical-dynamical downscaling (KAMM/WAsP); final WRF-based dynamical downscaling
  - wind resource assessment and siting tools for planning purposes that can be used for feasibility studies in support of projects.

First preliminary wind atlas made available in 2012

The (WRF-based) atlas will be freely available to all interested parties on the completion of the project (31 March 2014)
What is the difference between the KAMM and WRF numerical wind atlases?

**Statistical-dynamical method**  
**KAMM-based (1st wind atlas)**
- “steady-state” simulations from 100+ wind situations (sets of initial conditions)
- each initialized with a single vertical representation of the atmosphere
- lower boundary conditions: uniform land and sea temperatures

**Dynamical downscaling**  
**WRF-based (WASA phase 2)**
- “sequential” simulation that provides time-series for each grid point in the domain
- initialized with a 3-dimensional state of the atmosphere
- lower boundary conditions: interactive land + time-varying sea surface temperatures
KAMM-based simulation

surface roughness

surface elevation

3 separate domains, 5 km grid spacing
Meteorological forcing – KAMM simulations

Forcing profile described at 0 m, 1500 m, 3000 m, 5500 m

0 m winds shown
• each x indicates a different forcing of the mesoscale model

• frequency of occurrence of each wind varies within domain

West domain
Polar plots:
• Angle – wind direction
• Distance – wind speed
• Frequency – size of cross
• Stability – color of cross

South domain

East domain
First Verified Numerical Wind Atlas 2012
Verified Numerical Wind Atlas for South Africa
VNWA launched March 2012

- the KAMM/WAsP method
- verified against 1 year of data
- a map – and much more

*Generalized climatological (30-year) annual mean wind speed [m/s] 100 m above ground level, flat terrain, 3 cm roughness everywhere*
Very large (309 x 435) inner grid (3km grid spacing)

Changes to standard WRF land use and roughness

Simulations: 8 years for (27/9/3 km);
24 years (27/9 km)

ERA-Interim forcing, 1/12 degree SSTs; MYJ PBL; 41 vertical levels.

Extensive set of year-long simulations were performed to optimize domain size and location and various parameterizations.

Very little sensitivity to most of these, except for the grid configuration (size, grid spacing, location)
Difference in MODIS Landcover

Difference in land cover classes between what is currently used in WRF and the new MODIS climatology (2001-2012)
Microscale modelling at the 10 WASA masts
Some background

- Wind-climatological inputs
  - Three-years-worth of wind data
  - Five levels of anemometry

- Topographical inputs
  - Elevation maps (SRTM 3 data)
  - Simple land cover maps (SWBD + Google Earth); water + land

- Preliminary results
  - Microscale modelling verification
    - Site and station inspection
    - Simple land cover classification
    - Adapted heat flux values
  - Wind atlas data sets from 10 sites

![Graph depicting wind speed vs. height above ground level for different mast types.](image)
Validation after generalization

Nature

Mesoscale Model

WAsP “lib” files

GENERALIZATION

DTU Wind Energy, Technical University of Denmark

NorseWind 6/25/12
Similar generalization procedure for KAMM and WRF simulations.

In KAMM – generalization applied to the results of the simulations for each wind class (under neutral assumption)

In WRF – results from simulations are binned according to wind direction, wind speed, and stability (1/L).

Each binned wind class is then generalized and aggregated using their frequency of occurrence

Neutral or non-neutral assumption was tested
Verification at WASA Masts

Numerical wind atlas (NWA) compared to observational wind atlas (OWA) Generalized annual mean wind speed at 100 m, $z_0 = 3$ cm [m/s]

Error = $(U_{\text{model}} - U_{\text{obs}})/U_{\text{obs}}$, $U =$ long-term mean wind speed

Verification site

Absolute Mean

<table>
<thead>
<tr>
<th>WRF-based</th>
<th>Non-neutral (4.4%)</th>
<th>Neutral (7.8%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>KAMM-WAsP</td>
<td>(6.4%)</td>
<td>(based on two years of data)</td>
</tr>
</tbody>
</table>
Numerical wind atlas – WRF 3km simulation

Generalized wind speed, $h=100$ m, $z_0=0.03$ m
Comparison at specific sites

Observed versus numerical wind atlas at 3 sites
h=100 meters, \( z_0 = 0.03 \) m
October 2010-September 2013
Example: WASA site 1, far northwest

- Observed wind atlas
- Weighted (solid) 
- Re-fit (dashed)

Numerical wind atlas
  - KAMM
  - WRF

File = WM01.lib
z0 = 0.03 m  h = 100 m
Comparison at specific sites

Observed versus numerical wind atlas at 3 sites
h=100 meters, z0=0.03 m
October 2010-September 2013
Example: WM05, southern coast

Observed wind atlas

Numerical wind atlas KAMM

Numerical wind atlas WRF
Comparison at specific sites

Observed versus numerical wind atlas at 3 sites
h=100 meters, z0=0.03 m
October 2010-September 2013
Example: WM10, Eastern cape

Observed wind atlas

Numerical wind atlas KAMM

Numerical wind atlas WRF
Summary and conclusions

• Results from two verified numerical wind atlas for South Africa are presented

• KAMM/WAsP method, numerically very cheap, gives good results
  – underestimation of mean wind speed at most sites; specially at sites influenced by thermal processes
  – resulted in a quite conservative wind resource atlas

• WRF method, numerically very expensive, gives excellent results
  – Stability conditions should be taken into account at generalization
  – Stability conditions should be taken into account when applying WRF-derived wind atlas – where should this come from? How to verify?
  – New dimension to numerical wind atlases
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WASA Project Steering Committee:
DoE (chair), DEA, DST, UNDP, Danish Embassy, SANEDI