Wind Resource Assessment in Complex Terrain with a High-Resolution Numerical Weather Prediction Model

Karin Gruber¹, Stefano Serafin¹, Manfred Dorninger¹, Vanda Grubišić¹,², Martin Fink³, Rudolf Zauner³

¹ Department of Meteorology and Geophysics, University of Vienna
² National Center for Atmospheric Research, Boulder, Colorado
³ VERBUND Renewable Power GmbH, Vienna, Austria
Wind Power

\[ P = \frac{1}{2} \rho A V^3 \]

P ... Power
\( \eta \) ... Efficiency factor
\( \rho \) ... Density of air
A ... Area covered by the rotors
V... Horizontal wind speed

http://www.wind-power-program.com
Beyond horizontal mean wind speed

• Wind speed distribution over time
• Vertical wind speed
• Turbulence intensity

• Fast change of wind direction
• Wind shear
# Measurements versus models

<table>
<thead>
<tr>
<th>Measurements</th>
<th>Simple numerical models (e.g. WASP)</th>
<th>Complex numerical models</th>
</tr>
</thead>
<tbody>
<tr>
<td>benefit</td>
<td>• Real data</td>
<td>• Simulation of local wind systems</td>
</tr>
<tr>
<td></td>
<td>• Easy to compute</td>
<td>• Information about:</td>
</tr>
<tr>
<td></td>
<td>• Satisfying results in plain or hilly terrain</td>
<td>➢ vertical wind,</td>
</tr>
<tr>
<td></td>
<td></td>
<td>➢ turbulence,</td>
</tr>
<tr>
<td></td>
<td></td>
<td>➢ wind shear</td>
</tr>
<tr>
<td></td>
<td>• Information in a larger area</td>
<td></td>
</tr>
<tr>
<td>disadvantage</td>
<td>• Local and temporal representativeness questionable</td>
<td>• In complex terrain key assumptions break down</td>
</tr>
<tr>
<td></td>
<td>• High costs for measurement at hub height</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• High computer resources</td>
</tr>
</tbody>
</table>
Pilot project in the Styrian Alps

Cooperation between VERBUND and imgw, University of Vienna:

VERBUND:
• Choosing location
• Mast measurements for one year

IMGW:
• Remote sensing of the lower atmosphere (not done yet)
• Applying a high resolution NWP – model

Model Specifications

- WRF V3.4
- 3 domains:  
  - d01: 20 km,  
  - d02: 4 km,  
  - d03: 0.8 km
- Vertical resolution: 61 terrain following eta - levels (≈23 m)
- Time step in d03: 2 s
- Microphysics: Morrison 2-moment scheme
- Radiation:  
  - lw: rrtm scheme  
  - sw: Dudhia scheme
- PBL: Mellor Yamada Janjic (eta) TKE scheme
- Cumulus: Kain-Fritsch (new eta) scheme only in d01
Initialization with operational analyses data from ECMWF every 6 hours.
Data for verification

- TAWES sites from ZAMG in valleys
- Sites from LWD – Avalanche Warning Service of Styria near mountain tops
- Sites of VERBUND, masts on hills

Examples from:
Aigen, 641 m ASL
Grimming, 2172 m ASL

Simulated period:
20120618 12:00 – 20120623 12:00
Time series of 10 m - wind speed
10 minute mean

Windmonitoring Site aig 18-Jun-2012 18:00:00 - 23-Jun-2012 12:00:00

Windmonitoring Site gri 18-Jun-2012 18:00:00 - 23-Jun-2012 12:00:00

Aigen 641 m ASL

Grimming 2172 m ASL
Frequency of wind direction and speed

Aigen 641 m ASL

Grimming 2172 m ASL
Horizontal mean wind speed (5 days) at 100 m above ground
Frequency of wind speed (5 days) at 100 m above ground

$3 \text{ m s}^{-1} \leq V < 18 \text{ m s}^{-1}$

4 km

0.8 km
Frequency of vertical wind speed at 100 m above ground

\[ |w| > 1 \text{ m s}^{-1} \]
Frequency of TKE (5 days) at 100 m above ground

TKE $\geq 1.0 \text{ m}^2 \text{s}^{-2}$
Summary

• Successful application of a WRF real model for the assessment of mean wind speed at hub height in complex terrain.
• Only with a very high resolution model the estimate of the
  – Distribution of wind speed and wind direction in time,
  – turbulence and
  – vertical velocity

is sufficiently possible.

Outlook

• Simulate a longer period,
• Analyze additionally
  – wind shear and
  – fast change of wind direction.