DOWNSCALING A WRF-GENERATED WIND CLIMATOLOGIES TO HIGH SPATIAL RESOLUTION

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WIND PROJECT DEVELOPMENT STAGES

Prospecting (low-res NWP) → Assessment Study (hi-res NWP) → Design and Construction (very hi-res CFD or LES)
Global 5 km Wind Resource Map (based on 10-year WRF simulations)
Q4, 2009 Wind Speed Variance from Average

Q1, 2010 Wind Speed Variance from Average

Legend:
-10 -5 0 5 10 %

Departure from normal (percent)
3TIER Prospecting Tool:

10-year climatology generated with 5-km WRF simulations (global land coverage)
WIND PROJECT DEVELOPMENT STAGES

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### WALLCLOCK TIME FOR CONUS SIMULATIONS (440 PROCESSORS)

<table>
<thead>
<tr>
<th>Resolution</th>
<th>Wallclock time for 1 year of simulation</th>
<th>Wallclock time for 10 years of simulation</th>
</tr>
</thead>
<tbody>
<tr>
<td>15 km</td>
<td>8 hours</td>
<td>3.5 days</td>
</tr>
<tr>
<td>5 km</td>
<td>9 days</td>
<td>3 months</td>
</tr>
<tr>
<td>1.67 km</td>
<td>8 months</td>
<td>7 years</td>
</tr>
<tr>
<td>555 m</td>
<td>19 years</td>
<td>190 years</td>
</tr>
<tr>
<td>185 m</td>
<td>500 years</td>
<td>5,000 years</td>
</tr>
</tbody>
</table>
WIND RESOURCE
DOWNSCALING OPTIONS
(from simpler and cheaper to more complex and expensive)

- Interpolate to fine grid (just as a benchmark)
- Simple terrain adjustment
- Diagnostic models based on terrain-altered flow (e.g., CALMET)
- Diagnostic models based on linearized steady-state N-S equations (e.g., WAsP)
- Diagnostic models based on nonlinear steady-state N-S equations (a.k.a. CFD)
- Time-dependent PBL modeling (a.k.a. LES)
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CALMET

• Part of the “CALPUFF” air quality and dispersion modeling system
• Also being used in wind energy applications
• Uses coarse-grid input of meteorological fields, and makes adjustments to wind field based on coarse versus fine-grid terrain and land use fields
  • Forces flow to be terrain-parallel, modulated by stability
  • Requires along-terrain flow where Froude number < 1
  • Removes the consequent 3D divergence with an iterative procedure
  • Makes adjustments for underlying roughness using similarity theory
EXPERIMENT

Run WRF for 4 random days at 15, 5, 1.67, and 0.55 km
EXPERIMENT 1
Comparison of raw mean wind fields at 80 m AGL – 15 km grid

Mean wind speed (m s$^{-1}$) at 80 m AGL – 15 km grid
Mean wind speed (m s\(^{-1}\)) at 80 m AGL – **5 km** grid
Mean wind speed (m s\(^{-1}\)) at 80 m AGL – 555 m grid
COMPARISON OF 3 METHODS OF DOWNSCALING FROM 5 km TO 555 m:

• Simple interpolation
• Simple terrain adjustment
• Downscaling model
Simple terrain adjustment from 5 km to 555 m
Downscaling model from 5 km to 555 m
“Truth” (WRF at 555 m)
Equitable Threat Score with respect to 555-m “truth”, versus threshold mean wind speed

ETO, and fraction of exceeding points

Fraction of points exceeding threshold

Thick: Downscaling model
Dash: Simple terrain adjustment
Thin: Simple interpolation

from 1.67 km (R.R.=3)
from 5km (R.R.=9)
from 15 km (R.R.=27)

Threshold mean wind speed (m s⁻¹)
EXPERIMENTAL DOWNSCALED DATA SET OVER THE PACIFIC NORTHWEST

• WRF simulations at 2km for 1 year
• Downscaled to 200 m
Existing 5 km Prospecting data set

2 km WRF downscaled to 200 m
CONCLUSIONS

• Wind project developers are increasingly demanding higher resolution wind prospecting data sets.

• While WRF is computationally prohibitive as a tool for directly creating wind climatologies on ~200 m grids, a computationally cost-effective downscaling model (e.g., CALMET) can be used in conjunction with WRF to add useful information to the high-resolution wind climatology.
2009 Wind Speed Variance from Average

Departure from normal (percent)

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3TIER, INC.

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