Pre-Construction

Post-Construction
WRF LES Time-Series Energy Modeling and Validation

Time-Series Energy Modeling and Validation Session
AWEA Wind Resource & Project Energy Assessment Workshop 2016
Background

Power Times Series Modeling

WRF-LES & Wakes

WRF-LES Power Times Series Validation

Last slides (comments)
Background: VORTEX

Wind & Solar Resource Model Data

Anywhere - Anytime

Automatization

WRF as core modeling stream

Reanalysis as driver

20 years wind and meteo time series

Windfarm suitability information

Retrospective Power Time Series for operating windfarms

WRG files at 100m

Icing occurrences

Power Forecasting

Wind & Solar regional maps

GHI/DNI/GTI time Series & TMY

VOmEST

www.vortexfdc.com
**Background:** Consolidate Wind Conditions Mesoscale Modeling Stream

**CREDENTIALS:**
- High Correlation with Observations
- Accurate Average Statistics
- Multiyear hourly time series everywhere anytime

**EXAMPLES:**
- Use of Downscaling Products
- Bank acceptance
- Tenders
- Publications
- Sessions on Specialized Fora
- Moments of Panic when MERRA went offline

Global Long-term average 80m Wind Speed Distribution at 9KM resolution
Source: WRF Downscaling driving by CFS/CFSR - VORTEX

www.vortexfdc.com
Background: **Moving forward** (m/s into MW)

- More and more realistic turbulence
- Able to determine shear and veer
- Accurate tails (high and low winds)
- Everything within the 10’ life
- A safer site classification tool
- Indistinguishable model and observation
- Plug power curve & wake deficit
WRF-LES: Modeling wind conditions at 10' sampling

- WRF-LES: Real terrain / Real Conditions
- One complete year (52660x 10’)
- Turbulence enable simulations
- 100m resolution
- 10’ sampling output (4hz time-setps)
- Outputs: average wind speed, direction, STD, shear, veer, stability and other meteo variables (icing classes)
- Any position within the windfarm

- Plug a Power Curve & Wakes Deficit
- 3-5 days computing time for one year

Check references: Alex Monternes at AMET SOC Turbulence Workshop
Alos works by Branko Kosovic (NCAR) and Mark Zagar (Vestas)
Wake model

- WS Deficit binned look-up table at Wind Turbine Locations
- Wind speed vs Wind Directions vs Intensity of Turbulence
- Jensen family wake model (like WAsP Park)
- Wake merging = sum of squares
- Expansion factor as function of the Intensity of Turbulence
- Anyhow, this is an active topic of research (complex vs light schools)

More details? Check works of Paula Doubrawa
PRE-CONSTRUCTION Time Series Modeling

- **WRF-LES @100m - 10’ avg**
  - Turbulence enable
- **Wake Modeling (Jessen)**
- **Power Curves**
  - Standard (inner)
  - Non standard (outer)
- **Non-environmental**
- **Curtailment**
- **Environmental**

**CHALLENGES:**
- Computing time & robustness
- Accuracy
- Limited Bias correction
- Wake ()
- Turbulence & shear
- Environmental conditions & Real Power Curve (PCWG)
VALIDATION

TOY Cases
65 sites

10' WRF LES Time Series

Power Curves
Air density (inner)
Different Models

REAL
5 Farms

10' WRF LES Time Series

Wake Modeling
(Jensen family)

Power Curves
Standard (inner)

Non-environmental
Comparison of 10' WRF-LES (100m) vs Observation times series
One complete year
Observed measurements == hub height
Standard atmosphere
4 differentes model (~2MW)

<table>
<thead>
<tr>
<th>Quantiles across 65 sites</th>
<th>P25</th>
<th>P50</th>
<th>P75</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual Wind Speed bias [%]</td>
<td>-7.1</td>
<td>-2.6</td>
<td>2.68</td>
</tr>
<tr>
<td>Annual Yield bias [%]</td>
<td>-9.90</td>
<td>-3.0</td>
<td>3.8</td>
</tr>
<tr>
<td>Daily Power Correlation, R2 (365 days)</td>
<td>0.72</td>
<td>0.77</td>
<td>0.82</td>
</tr>
<tr>
<td>Monthly Power Correlation, R2 (12 months)</td>
<td>0.75</td>
<td>0.86</td>
<td>0.92</td>
</tr>
</tbody>
</table>
### Validation

<table>
<thead>
<tr>
<th>Windfarm</th>
<th>Annual Yield Mean Error [%]</th>
<th>Daily R2</th>
<th>Monthly R2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flat</td>
<td>-4.9</td>
<td>0.78</td>
<td>0.85</td>
</tr>
<tr>
<td>Forrest</td>
<td>-5.6</td>
<td>0.72</td>
<td>0.82</td>
</tr>
<tr>
<td>Maritime</td>
<td>-6.8</td>
<td>0.75</td>
<td>0.86</td>
</tr>
<tr>
<td>Complex</td>
<td>-5.6</td>
<td>0.80</td>
<td>0.83</td>
</tr>
<tr>
<td>Complex</td>
<td>-10.4</td>
<td>0.69</td>
<td>0.75</td>
</tr>
</tbody>
</table>

**5 Real Windfarms**  
Location: Brazil (NE), Spain (Center), UK (Onshore) & Germany (North / Forest)  
Nominal Power: 30-50 MW

**One year of observed hourly aggregated production data**  
Layout / CT & CP (air density)

**WRF-LES 10' wind conditions including intensity of turbulence**  
Wake model (standard - no tuning) - Lu
### CONTEXT: No Observation employed to calibrate the modeling stream, WRF-LES

<table>
<thead>
<tr>
<th>ONE</th>
<th>A</th>
<th>We need to make more efforts in improving results for 60% sites</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>B</td>
<td>Considering using bias correction to rectify model systematic bias</td>
</tr>
<tr>
<td>TWO</td>
<td>A</td>
<td>About 40% of the sites are candidates to accept modeling information with accuracy in production of order of (+/-) 5% Error</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>Temporal variability is very well portrayed at 10’ scale</td>
</tr>
<tr>
<td>THREE</td>
<td>A</td>
<td>Aggregated production for Windfarms Error is low (surprise) “Friend of the model” Sites Good Representation for variability and turbulence</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>Caveat: limited sample of real windfarm</td>
</tr>
</tbody>
</table>
Pre-Construction

Model wind in the time domain to model energy in time domain

Power time series products to meet industry needs

The 8760 hours challenge (or the 52560 x 10’ challenge)
WRF LES Time-Series Energy Modeling and Validation

Modeling & Development: Alex Monternes / VORTEX
Computing Analyst: Pau Casso / VORTEX

Wake Analysis: Paula Doubrawa / CORNELL University
Scientific Support: Branko Kosovic / UCAR
Realworld Exchanges: Mark Zagar / VESTAS
Analysis, Views & Speaking: Gil Lizcano / VORTEX

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