Model Forecasting Accuracy Along an East Coast Offshore Grid Corridor

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Wind Energy Symposium
University of Delaware
February 27, 2013

Funding: US DOE Mid-Atlantic Offshore Integration & Interconnection (MAOWIT), DE-EE0005366
Overview

• East Coast offshore wind during peak-electricity demand times
• Seasonal East Coast wind resource
• Attributes of an ideal offshore grid
• Mid-Atlantic Offshore Wind Integration & Transmission (MAOWIT) region
• Forecast performance of WRF in MAOWIT
East Coast Modeling Domains

- WRF-ARW. 5.0 km res.
- 41 vertical levels (2, 5, 7, 10, 12, ..., 45, 90 m, ...)
- NARR (~32 km) initial and lateral boundary conditions
- 2006-2010 (5 years)
- Reinitialized every 4 days

Validation Time Series

color=observation, black=WRF-ARW
WRF-ARW Validation

- Compared all available buoy and tower data hourly from 2006-2010

- NOAA National Data Buoy Center buoys (23) and tall towers (9)

- Met the following criteria to show modeling skill [Pielke Sr., 2002]:
  \[
  \begin{align*}
  (1) & \quad \sigma \approx \sigma_{obs} \\
  (2) & \quad \text{RMSE} \ < \ \sigma_{obs} \\
  (3) & \quad \text{RMSE}_{\text{UB}} \ < \ \sigma_{obs}
  \end{align*}
  \]

WRF-ARW showed modeling skill for winds off the East Coast (i.e. passed three criterion)
All of US East Coast or about 1/3 of US electric demand could be generated with offshore wind

90m WRF-ARW model results 2006-2010

What Time is Offshore Wind Power Most Useful?

- Analyzed hourly electric-load data
  - Developed **method to detect peaks** for shown load regions over 4-5 years
  - Found East Coast **peaks** between **08:00-21:00 EST** (median)

Example “**single peak**” (summer)
Seasonal Peak-Time Resource

Virginia-to-Maine – 08:00 – 21:00 EST

Region has:
1) best wind resource
2) shallow water
3) lower hurricane risk

Can we meet all peak-time demand with offshore wind?

Mostly! We can meet all Virginia-to-Maine peak-time demand with wind off those states.... except in the summer (only 79%).

Winter 2006-2010 – 08:00-21:00 EST

Capacity Factor

- Used a REpower 5M, 5 MW power curve, determined capacity factor out to 200-m depth
- Incredibly strong resource
- CF as high as 65%

Winter Nor’Easter

Download video [here](#)

**Legend**

**Red** - 100% power

**Blue** - 10% power

**Black** - No power

2010-01-17 03:00 EST
Capacity Factor

- Resource is diminished from winter but still strong
- Interesting observation with Block Canyon, suggests sea breeze driven by SST


East Coast Sea Breeze Drivers

- The sea breeze present to varying extents along the entire eastern seaboard
- **Ekman pumping** off the New Jersey and New York coasts responsible for upwelling, creating lower SSTs
- **Peaks during late spring**, early summer when ocean temperatures are still cold [Gedzelman et al., 2005]
- A moderate synoptic-scale **westerly** wind may **kill** the sea breeze

Source: NOAA

Photo credit: Ralph Turncotte. From *Sea Breeze and Local Winds* by John E. Simpson.
Sea breeze likely dominant where resource is best.

Long Island to Cape Cod ideal.

Gulf of Maine great but deep water.

Summer - The Bermuda High

- **Clear skies** dominate, due to westward migration of the Bermuda High
- **Winds** relatively slow compared to other seasons
- Mid-latitude **storm track** well to the north
- Occasional **hurricane** is always possible...
  - Virginia-to-Maine safer for development
  - No Saffir-Simpson Category 4 or 5’s

Source: e-education.psu.edu
Summer Sea Breeze

Surface Weather Map at 7:00 A.M. E.S.T.

2010-07-03 07:00 EST

Chart: NOAA
Summer Sea Breeze

Download video here

Legend
Red - 100% power
Blue - 10% power
Black - No power

Surface Temp: 11-37 deg C
Locating the Best US Offshore Grid Location

Twelve candidate 500 MW farms
- best overall
- best summertime resource
- water ≤50 m

What's the best subset four of these farms? (i.e. 4x500 MW=2000MW grid)

Building the Ideal Offshore Grid

Wind farms combined to

- Reduce power correlation
- Increase average power
- Reduce ramp rates

Conclusions:
• Found **interconnection benefits** at smaller distances than previously found
• Greater than **450 km** separation **required** for synoptic and mesoscale interconnection

Power Forecasting - MAOWIT

- Analyzing large build out of the **Atlantic Wind Connection** (~80 GW)
- What is the **effect** of wind forecasting errors on **grid** stability?
- **Designed** overlapping 48-hr **forecasting system**
  - Used in Princeton Mid-Atlantic power grid model
MAOWIT Offshore Grid Forecast Performance

- 48-hour power-grid forecast
  - WRF-ARW 5.0-km resolution
  - 24-hour overlap
  - 10-min output
  - Jan, Apr, Jul, Oct 2010

  - Compared to 8 buoys and 1 tower
  - WRF and obs. scaled via log-law to 90-m
  - 78 GW max

Table: **0-24 hour** forecast performance  (all stats in **GW**)

<table>
<thead>
<tr>
<th></th>
<th>Obs. mean power</th>
<th>Obs. std. dev.</th>
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<td>Jan</td>
<td>42.8</td>
<td>23.5</td>
<td>23.6</td>
<td>-2.8</td>
<td>13.1</td>
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<tr>
<td>Apr</td>
<td>24.6</td>
<td>18.3</td>
<td>21.8</td>
<td><strong>6.9</strong></td>
<td>15.2</td>
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<tr>
<td>Jul</td>
<td>17.4</td>
<td>13.9</td>
<td>20.6</td>
<td><strong>8.0</strong></td>
<td>16.3</td>
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<tr>
<td>Oct</td>
<td>36.1</td>
<td>23.4</td>
<td>24.2</td>
<td>-0.6</td>
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<tr>
<td>all</td>
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MAOWIT Offshore Grid Forecast Performance

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- Overall, **good forecast** given assumptions and amount of **observations**
- **Bias** in Apr and Jul could likely be improved with more resolved **sea surface temperatures** + more **coastal observations**
Summary / Future

• **East Coast** offshore wind resource **strong** during **peak-electricity** demand times

• **Sea breeze** important to keep turbines generating during **summer months**

• More **research** needed to model **stable boundary layer** better – sea breeze driver

• Need more **tower observations** offshore to **validate** models – publically available

Questions/comments: Mike Dvorak <mike@sailorsenergy.com>