ASSESSING OFFSHORE WIND CONDITIONS: MEASUREMENT, MODELING, AND ANALYSIS APPROACHES
GREAT LAKES WIND ENERGY DEVELOPMENT IN NEW YORK STATE

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Talk Topics

- The Need for Atmospheric Data
- Conventional Sources vs. New Approaches
- Combining Measured Data with Modeled Data
Dynamic External Environment

Wind and waves are the primary external conditions affecting the design and cost of offshore wind turbines

Source: NREL
Atmospheric Data for Offshore Wind Plants

Applications
- Defining Environmental Conditions & Extremes
- Structural Loads
- Project Layout
- Performance/Energy
- Energy Value/Load Matching

- **Wind Speeds** – annual, monthly, hourly, sub-hourly
- **Speed Frequency Distribution** - # hrs/yr within discrete speed intervals
- **Wind Shear** – rate of change of wind speed with height
- **Wind Veer** – change of direction w/height
- **Turbulence Intensity** – std dev of speeds sampled over 10-min period as a function of the 10-min mean speed
- **Wind Direction Means, Time Series & Distribution** – joint with speed
- **Extreme Gusts** (3- and 5-sec) and **Return Periods** (50- and 100-yr)
- **Others**: air/sea temp. (stability), RH, pressure, density, solar, lightning
Great Lakes Vs. Oceans

- Continental climate
  - More land influences
  - Colder; lake ice
- More active weather
- Limited year-round lake data
  - Buoys don’t winter over
- Smaller waves
Conventional Sources of Wind Data

- **Surface**
  - Buoys and Coastal Marine Automated Network Stations (C-MAN) - NDBC
  - Coastal met. stations
  - Ships (seasonal, moving)
    - Voluntary observing ships
  - Commercial aircraft

- **Remote Sensing**
  - Weather balloons from land
  - Satellite (QuikSCAT, SAR)
Weaknesses of Conventional Data

- Low elevation measurement (<10 m)
- Low number and density of stations
  - Some buoys removed in winter
- Ship data – limited value
- Balloon trajectory is wind dependent
- Satellite coastal resolution (QuikScat)
- Accuracy (typically 1-2 m/s)

» Needed: Wind Modeling & New Measurements
Best Practice Assessment Approaches

- **Tall Met. Mast(s)**
  - Most credible & widely accepted
  - Multiple heights; rugged sensors
- **Complemented by:**
  - Lidar/sodar
  - Project weather buoys
  - Satellite imagery
- **Regional Weather Conditions**
- **Adjustments for Height, 2D Space & Climatology**
- **Mesoscale Modeling**

**Methods must be credible to 3rd parties and ‘bankable’**
Lake Condition Assessment Approaches

- Specialized sensors on the offshore met tower
- Dedicated onsite buoys
- Acoustic Doppler Current Profiler (ADCP)
- Other Inputs
  - Satellite data (waves)
  - Regional and historic data sources
  - CODAR (sfc current & waves)

Source: NOAA Great Lakes Ice Atlas
Lidar-Based Monitoring Approaches

Profiling
- Leosphere / NRG Windcube
- Natural Power ZephIR

Scanning
- Lockheed WindTracer
- Michigan Aerospace Site Assessor
- Sgurr Galion

Buoy-Based
- AXYS Technologies Wind Sentinel
- Others in development
Wind Modeling

- Wind maps developed from 3-D mesoscale numerical weather models
- Combine boundary layer properties & atmospheric databases to simulate all physics of the atmosphere
- Results independently validated

Key Inputs:
- Global Reanalysis Data (NCEP/NCAR)
- Water Surface Temperatures
- Elevation & Land Cover
- Differential Vegetation Index
- Ice Cover
Wind Modeling

**Key Outputs:**

- Speed/Dir. Freq. Distributions @ Multiple Heights
- Shear & Turbulence Intensity
- Hourly Time Series Values
- Air Temp, Density, Pressure, RH
- Stability
Map Validations

**Highest Confidence Stations - Offshore Atlantic**

*y = 0.9799x*

*R² = 0.77*

**Great Lakes Model Validation**

*R² = 0.6839*

- AWST Validation: R² = 0.74
- NREL Validation: R² = 0.68
Conclusions

• Wind assessment needs are well understood, but innovative approaches are necessary
• Offshore assessment differs from land-based assessment and is more reliant on remote sensing technologies and modeling
• Modeling is a powerful tool for understanding and predicting dynamic wind flow structures
Thank you!

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