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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

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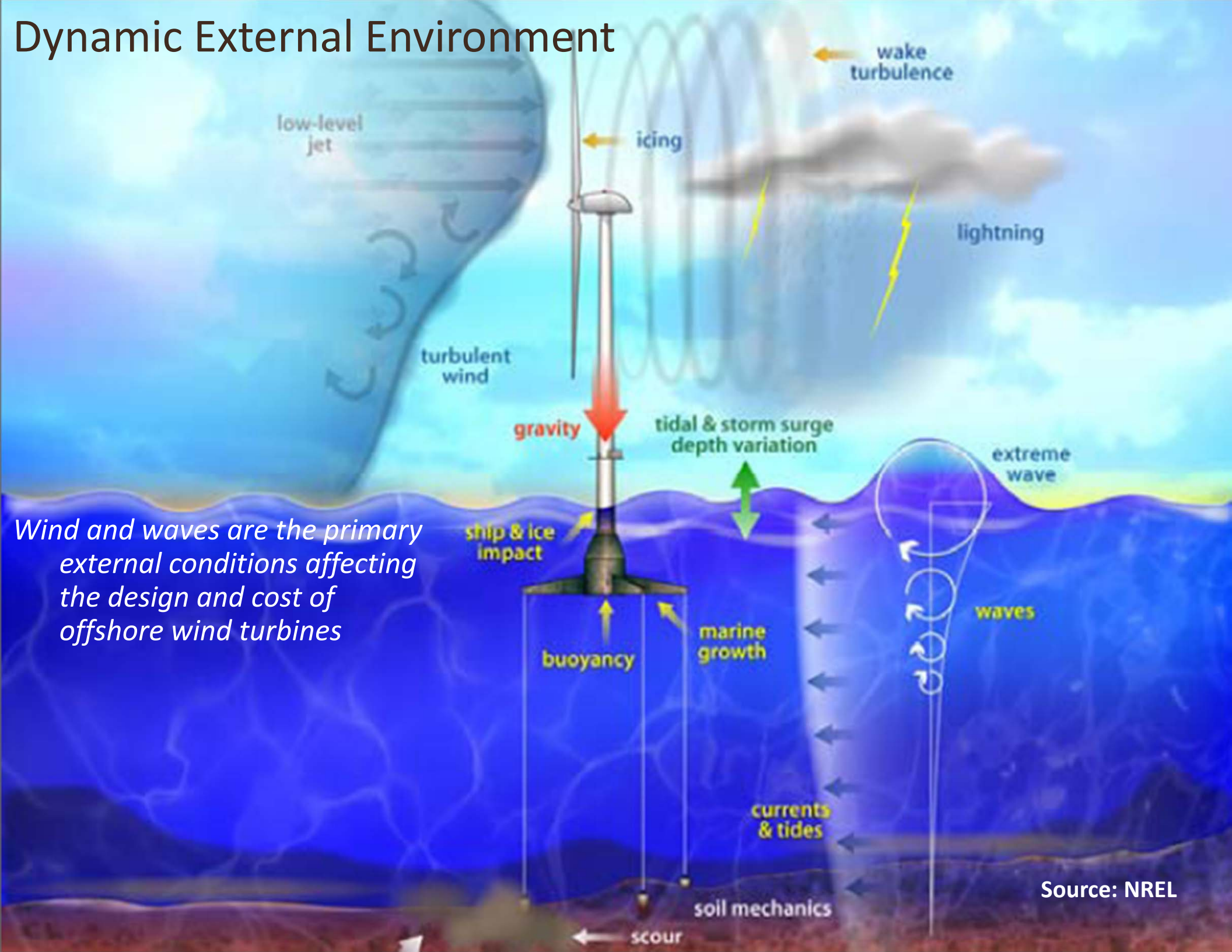
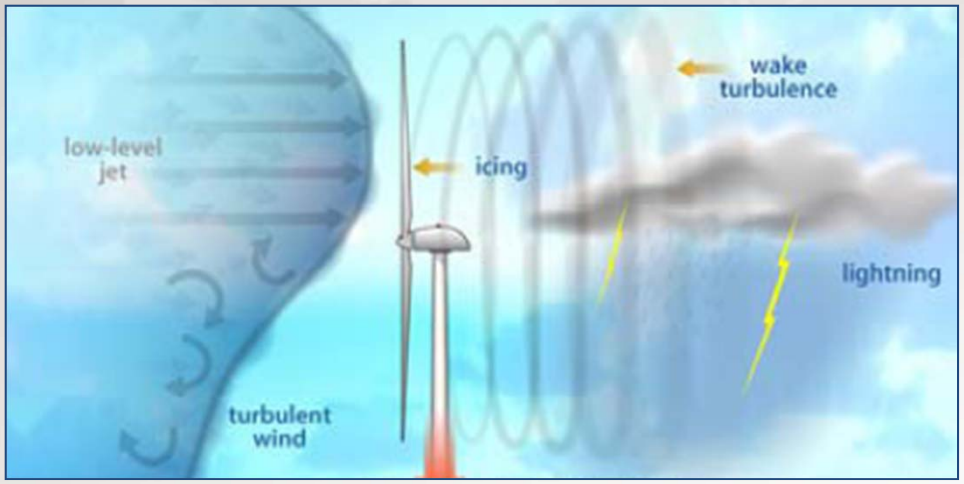
Dynamic External Environment



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

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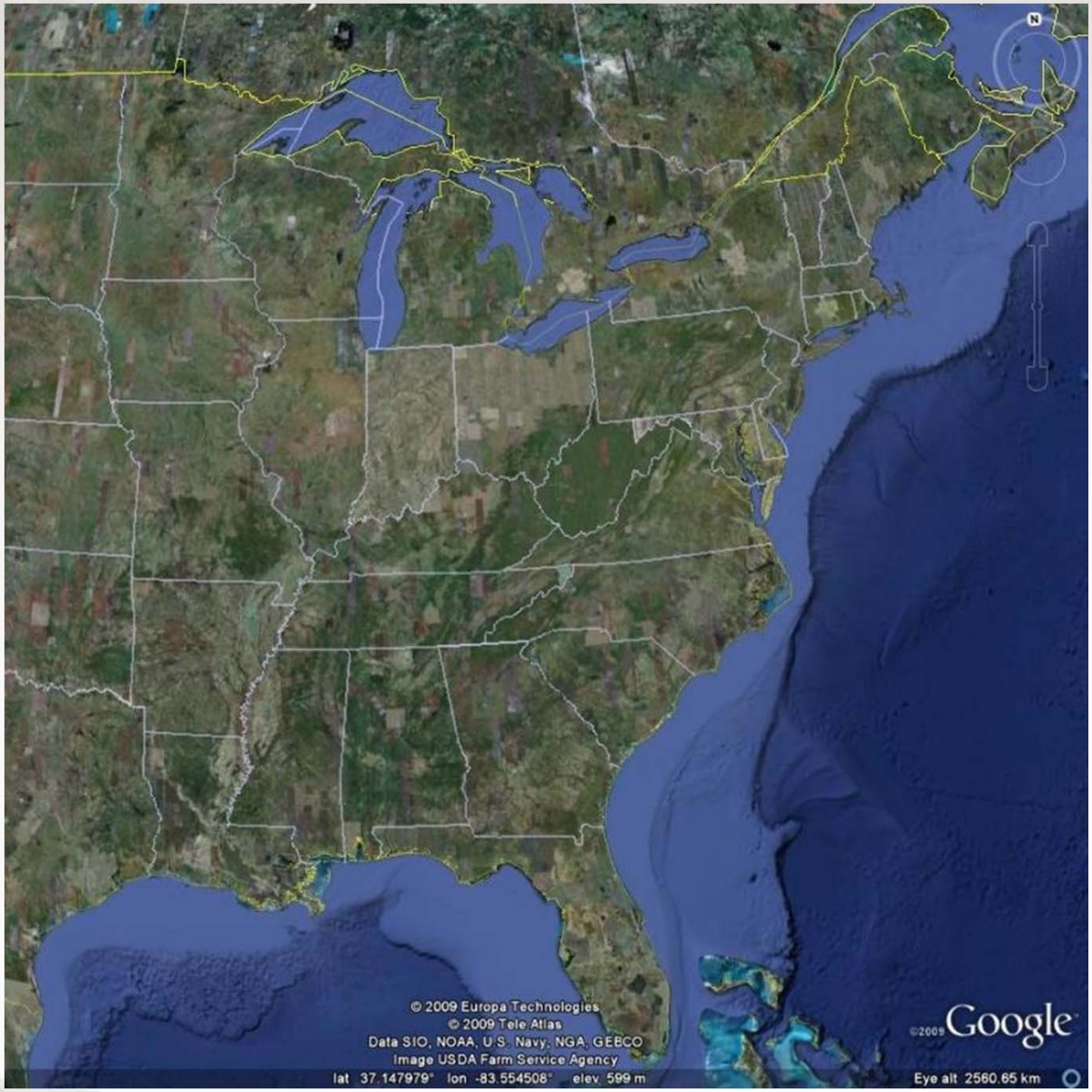
Great Lakes Vs. Oceans

- Continental climate
  - More land influences
  - Colder; lake ice
- More active weather
- Limited year-round lake data
  - Buoys don't winter over
- Smaller waves



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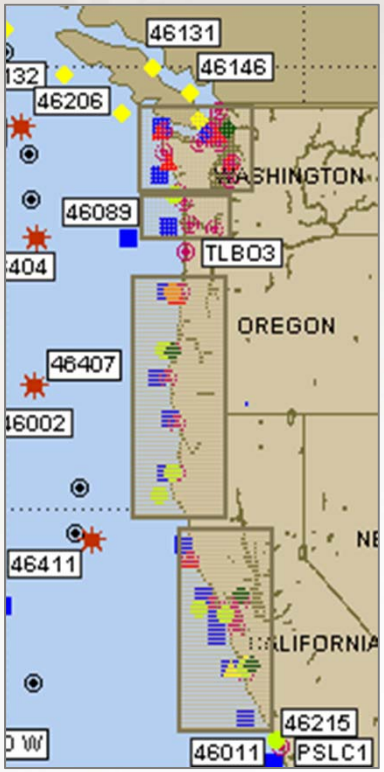
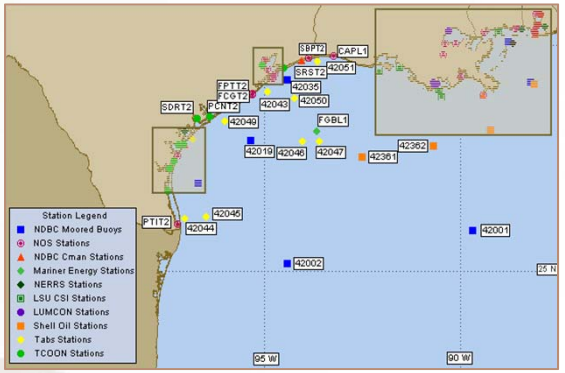
Conventional Sources of Wind Data

- **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)





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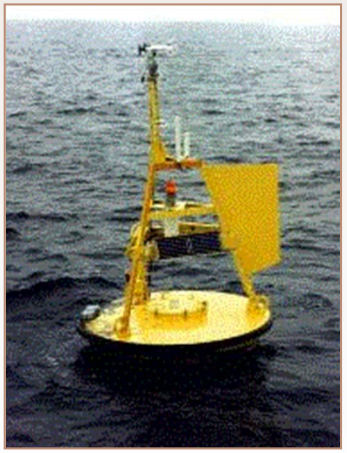
Weaknesses of Conventional Data

- 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

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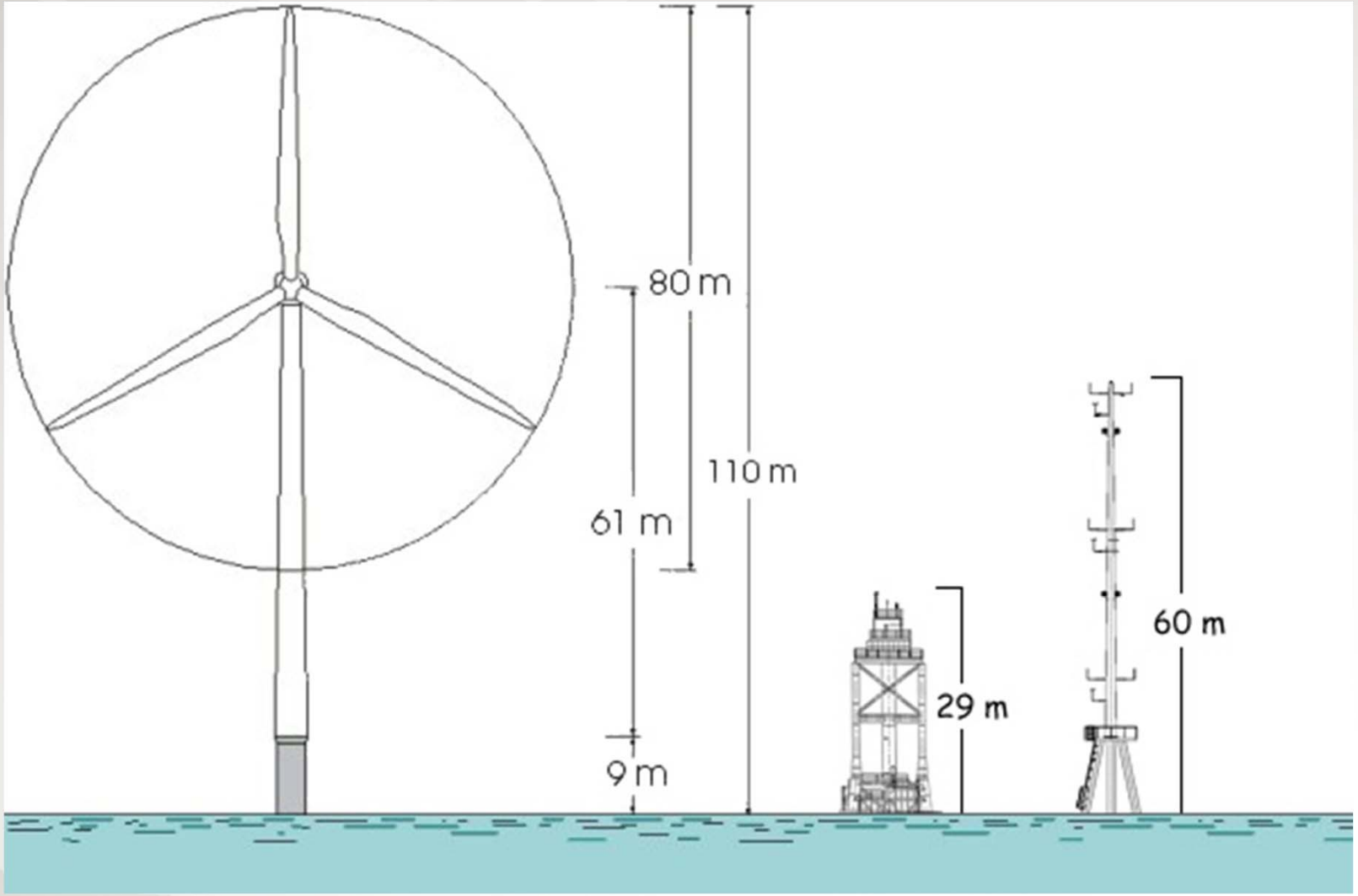

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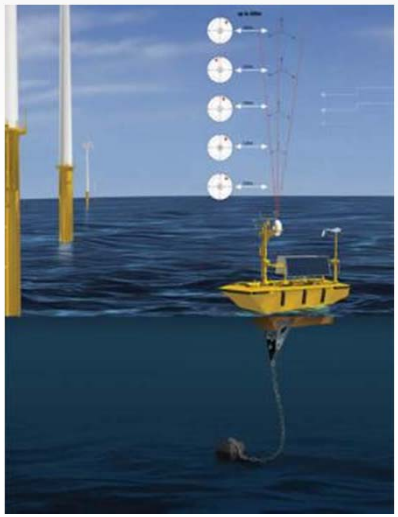
Best Practice Assessment Approaches

- **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**

FINO-1 Mast – Germany

Cape Wind Mast

Natural Power's OceanPod



Axys Technologies WindSentinel

Methods must be credible to 3rd parties and 'bankable'

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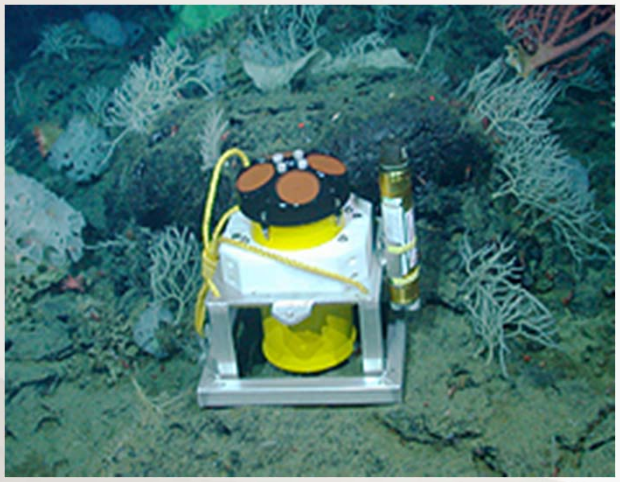
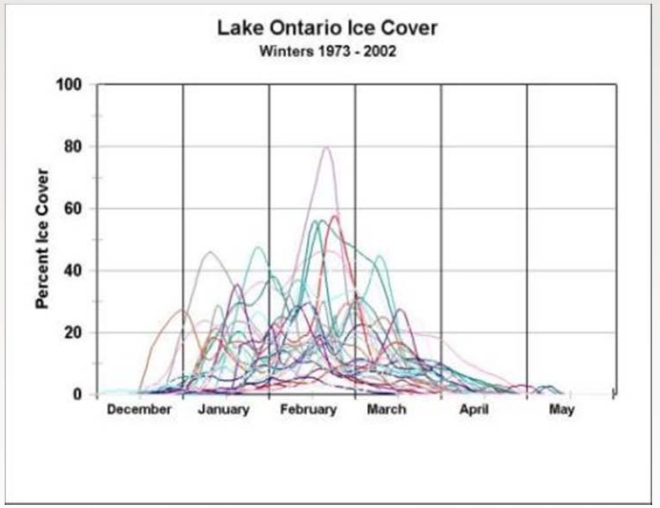
Lake Condition Assessment Approaches

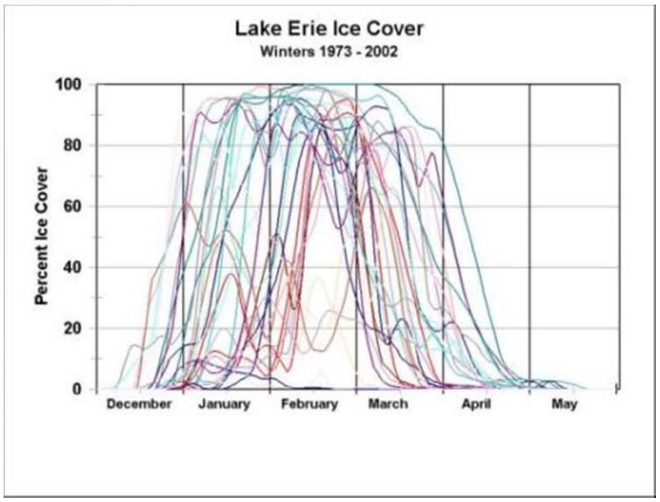
3m Disc Buoy



Bottom-mounted ADCP

- 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

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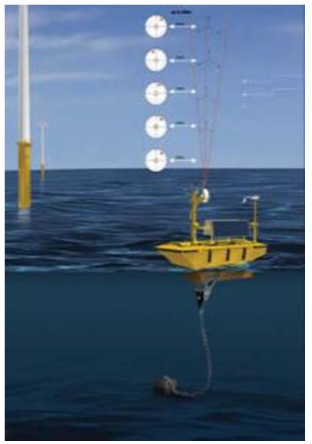
Lidar-Based Monitoring Approaches

Profiling
- Leosphere / NRG Windcube
- Natural Power ZephIR

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

Buoy-Based
- AXYS Technologies Wind Sentinal
- Others in development



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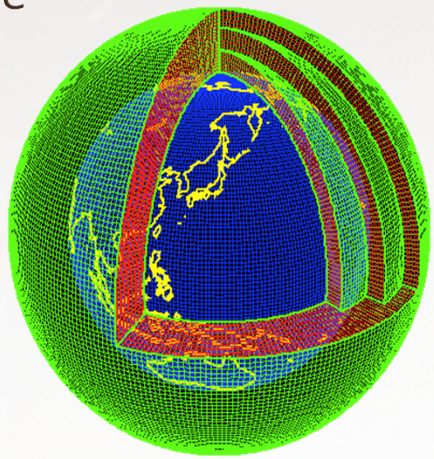
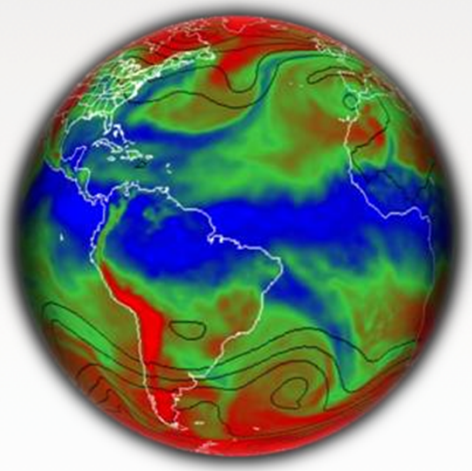
Wind Modeling

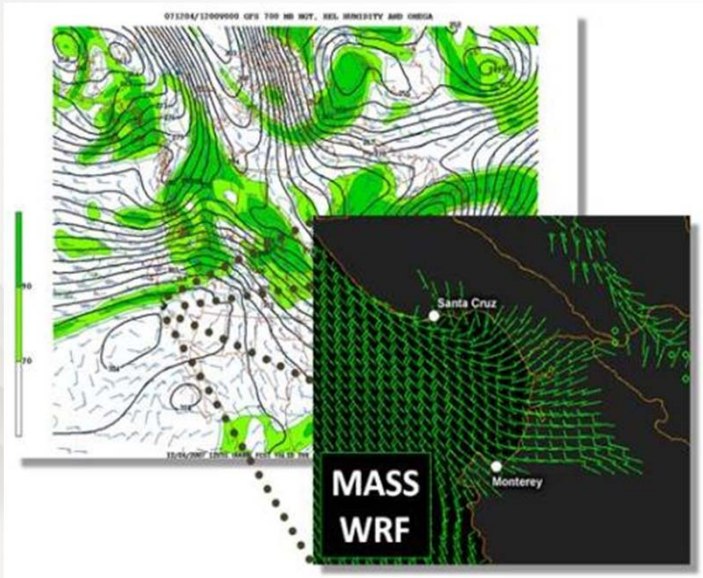
- Wind maps developed from 3-D mesoscale numerical weather models
- Combine boundary layer properties & atmospheric databases to simulate all physics of the atmosphere
- Results independently validated

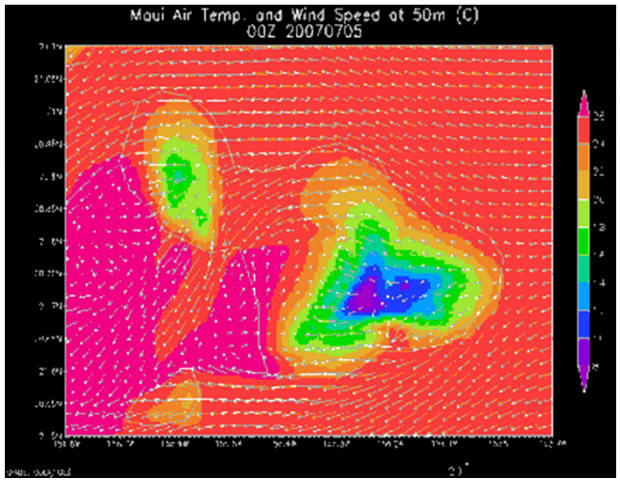




Key Inputs:

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





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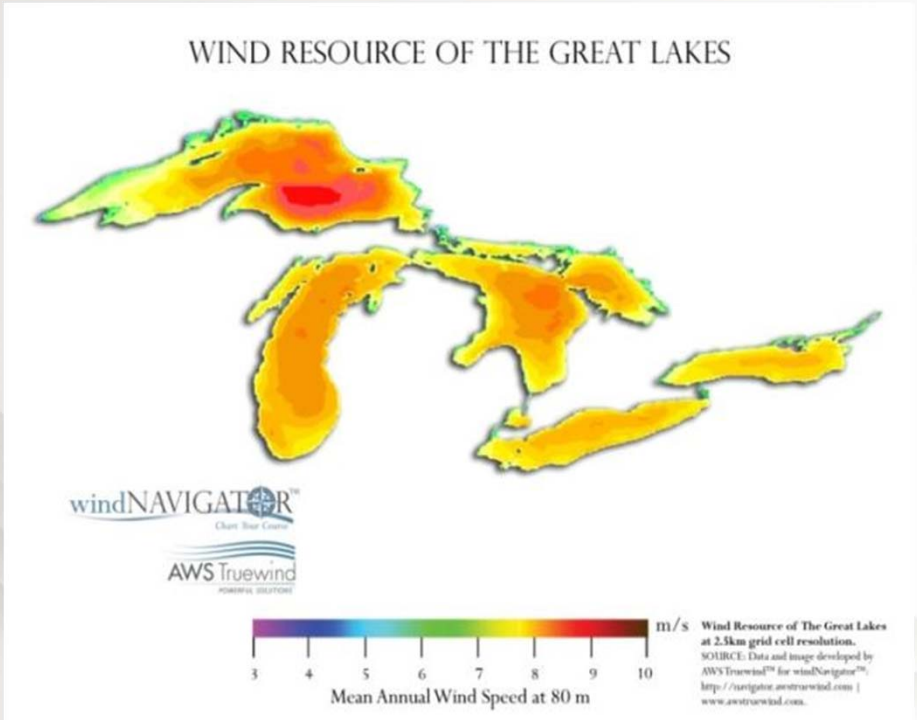
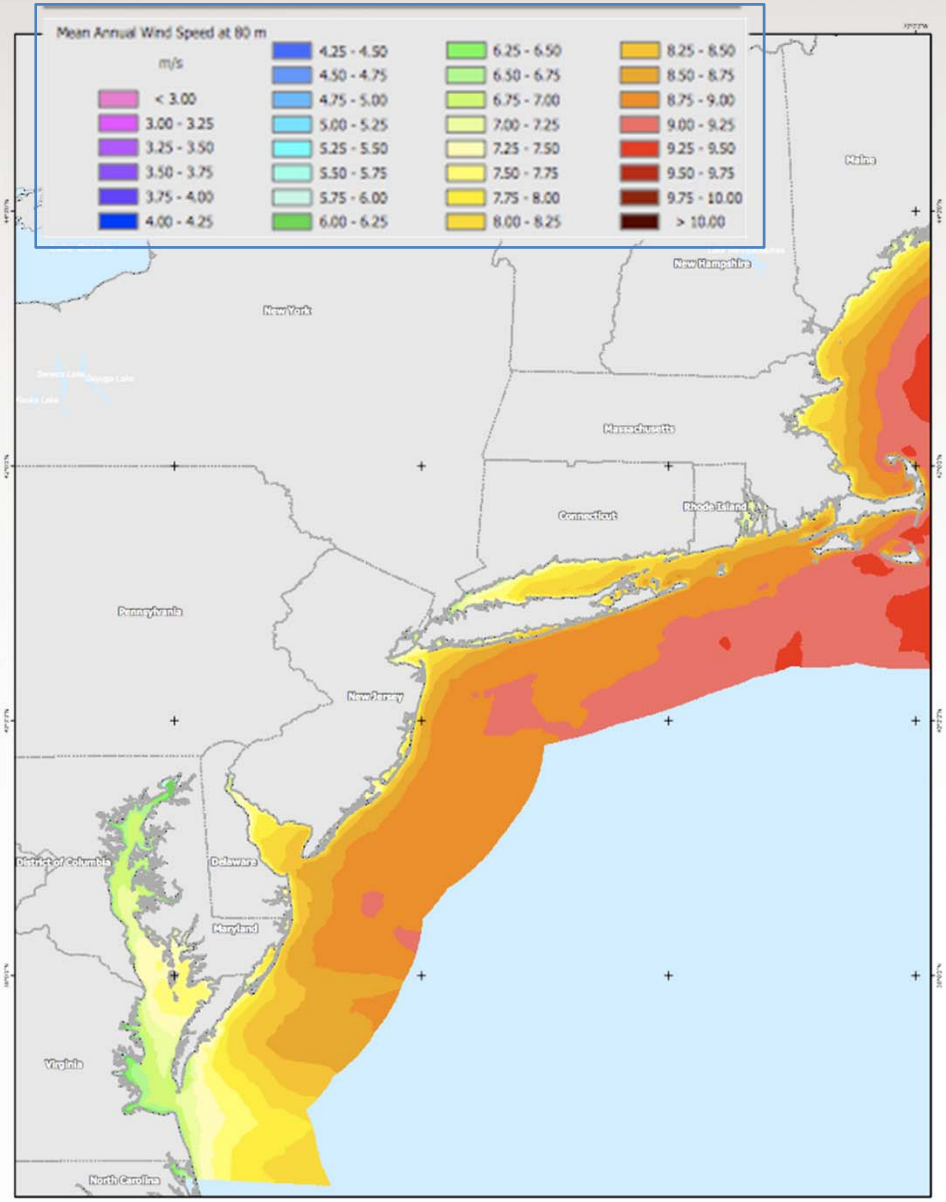
Wind Modeling

Key Outputs:

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





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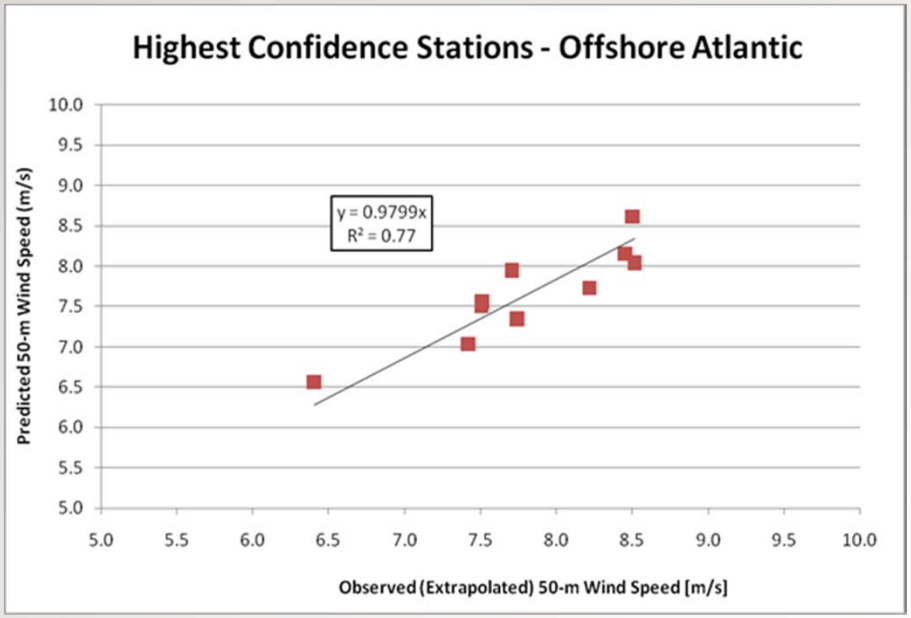
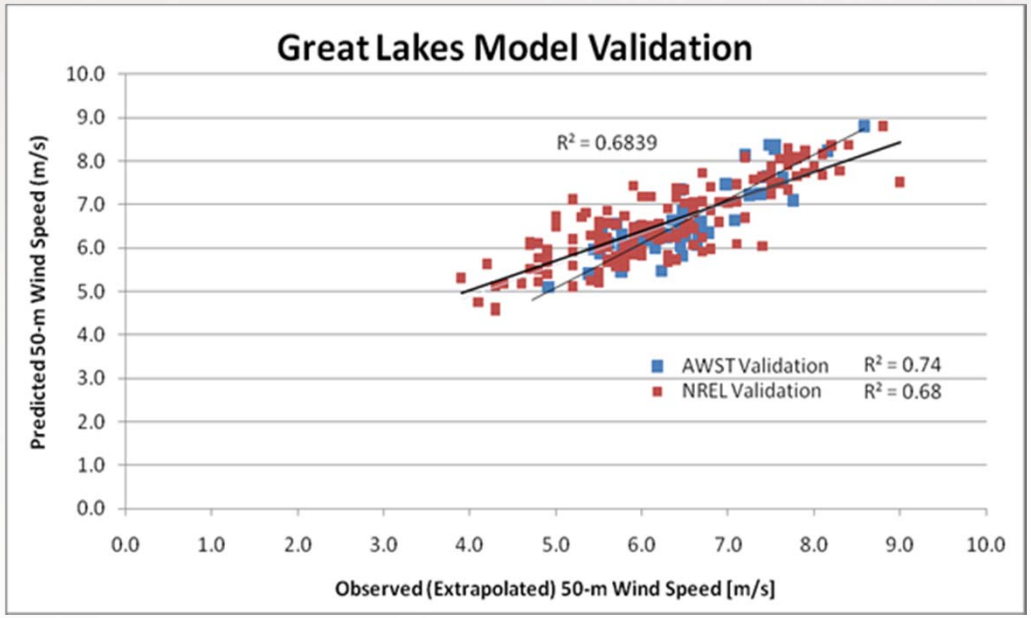
Map Validations





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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

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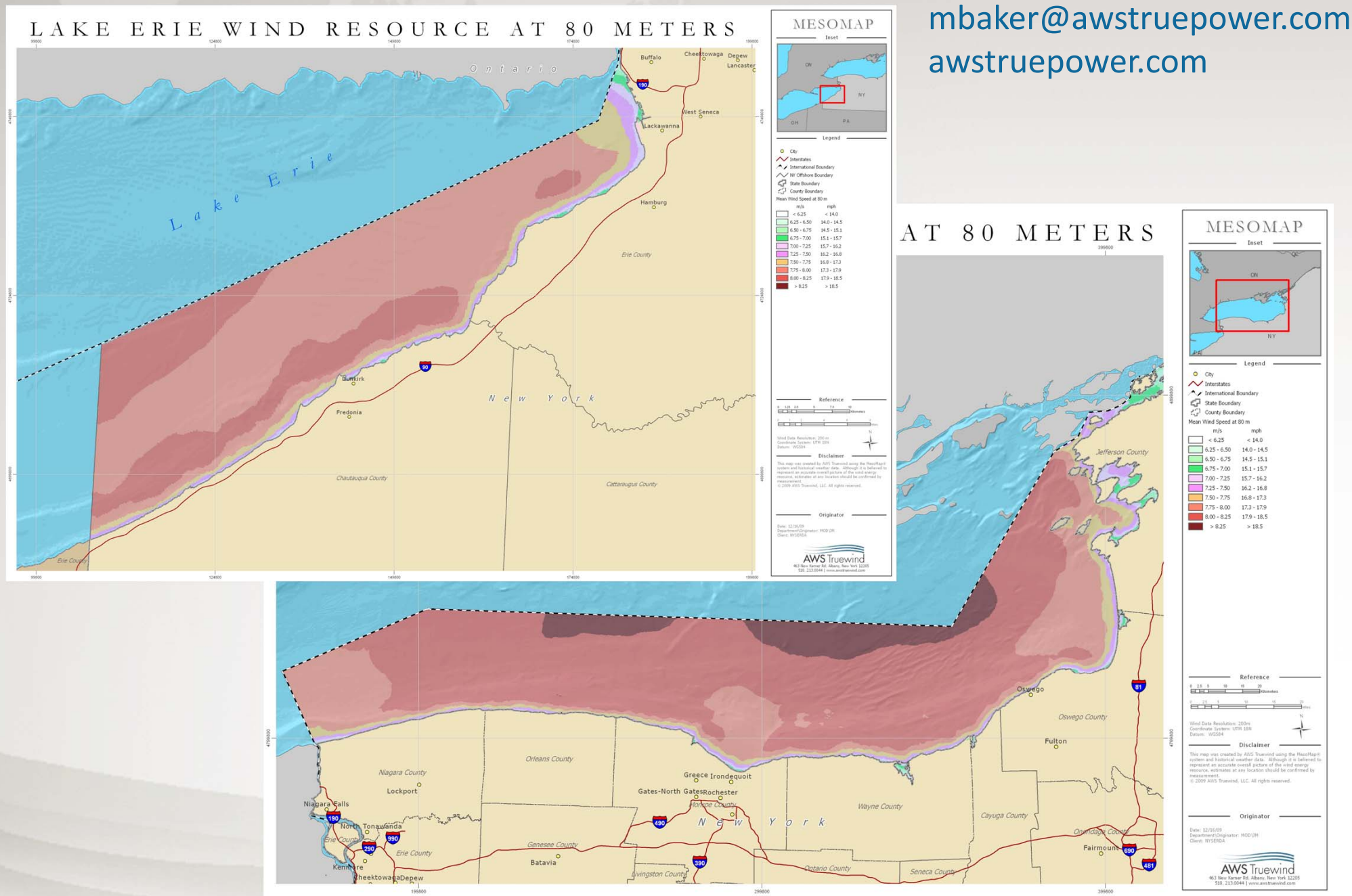
Thank you!



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