UMBC- atmoSpheric Profiling for Advancing offshoRe wind research (U-SPARC): Measurements-2-Models (M2M) & Offshore Wind Farm Layout (OWL)

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U-SPARC

Maryland Energy ADMINISTRATION
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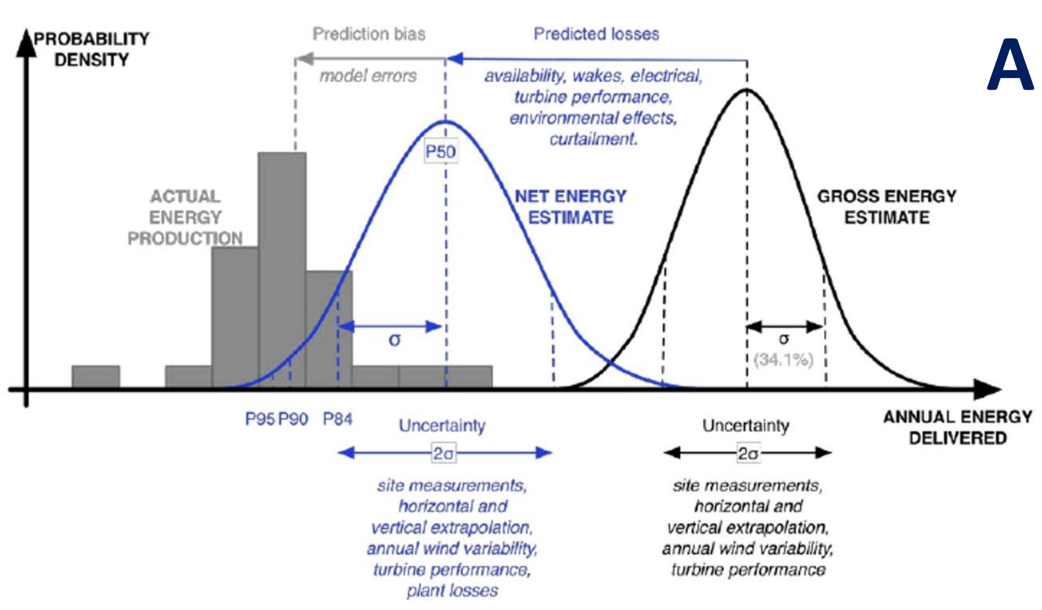
Summary

To justify an offshore wind project's economic viability, an accurate preconstruction energy yield estimate is required. Unfortunately, the behavior of the wind in a marine/coastal environment is complex, and often not well measured, modeled, nor understood; thus significant preconstruction energy yield uncertainties may be introduced when estimating a local wind resource and a turbine's available power. In part, such uncertainties contribute to the chronic industry challenge known as wind farm *underperformance bias*, in which operational energy yield is *less than preconstruction expected energy yield.* The consequence of underperformance bias is noteworthy, as an inaccurate expectation of available wind and turbine power may cause sub-optimal wind farm layouts, thus further delay the offshore wind cost-competiveness (Figure A) [1]. The **U**niversity of Maryland, Baltimore County (UMBC) atmo**S**pheric **P**rofiling for **A**dvancing offsho**R**e wind resear**C**h (U-SPARC) team was established in 2013 with a focus on reducing atmospheric-related offshore wind preconstruction energy yield uncertainties.

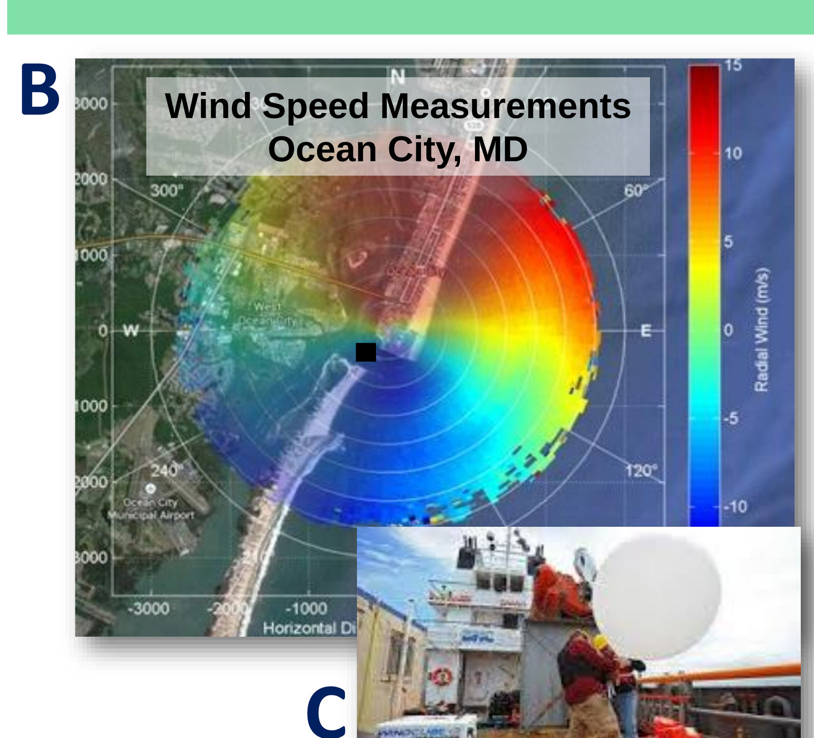


Motivation and Research Objectives

Motivation: The Measurements-2-Models (M2M) portion of U-SPARC aims to reduce modeling uncertainties by using observations obtained during the Research-to-Operations (R2O) phase in order to both validate and improve atmospheric modeling of the coastal region for wind energy. Optimizing Wind Farm Layouts (OWL) seeks to assess possible wind farm layouts for the MD WEA, and investigate possible regional impacts resulting from nearby farms in other state WEAs, such as Delaware.

Research Challenge & Objectives: Model uncertainty and variability is a significant barrier to thorough assessments of the expected power production of offshore wind farms [2]. Lidar observations of MD coastal and offshore area obtained during R2O can be assimilated into model runs of the Weather Research and Forecasting (WRF) model in order to improve weather forecast predictions of low level winds. This improved modeling can reduce wind resource uncertainties in forecast predictions for the MD WEA. Additionally, since WRF is a regional model, it allows for an investigation of regional interactions between multiple offshore farms along the Eastern United States, in order to minimize any possible power losses due to their close proximity to one another.

Methods

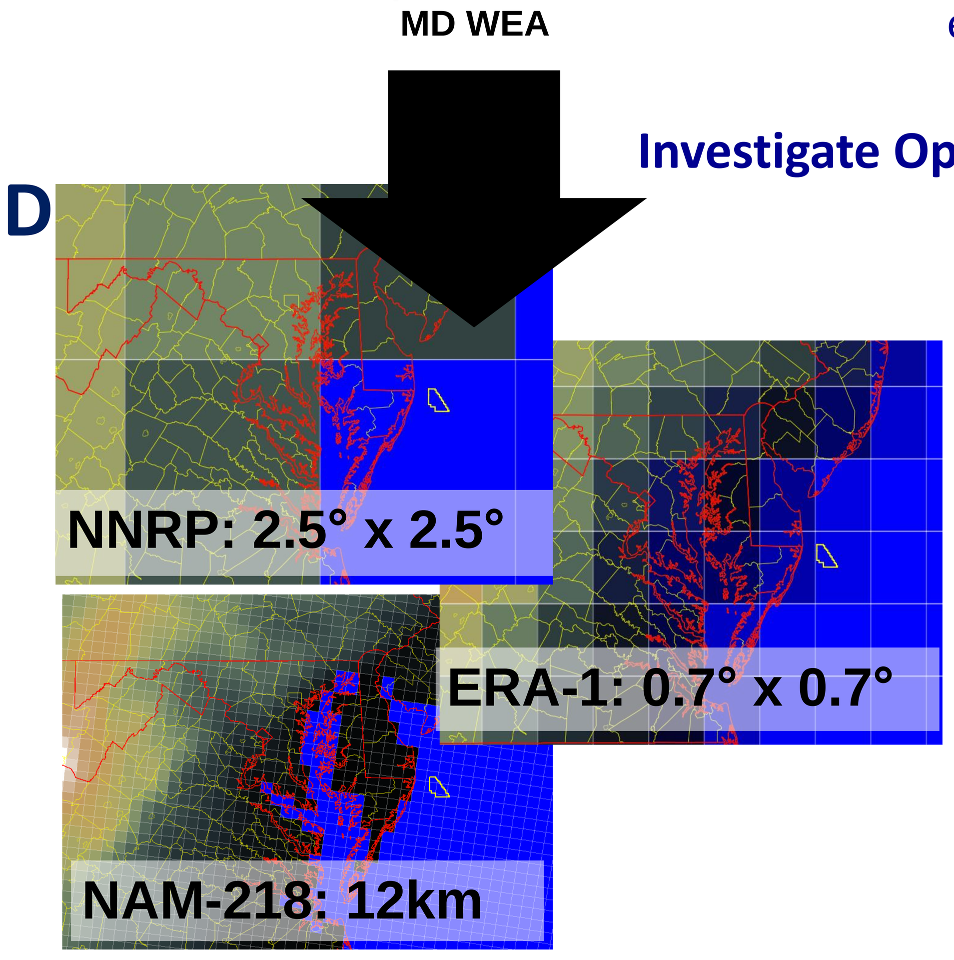


Wind & Atmospheric Measurements in MD WEA

Collect Offshore Measurements & Evaluate Model Predictions:

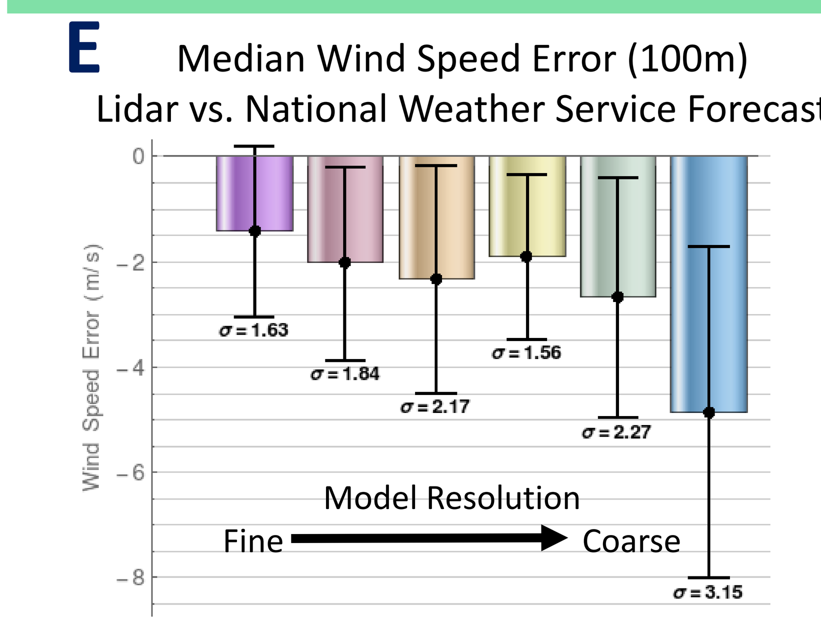
- Use coastal atmospheric & wind measurements (i.e. 'truth') to quantify model estimate error of the offshore wind resource (Figure B &C)
- Assimilate measurements into models to improve prediction
- Other model adjustments can be made in order to improve model representation of the dynamic coastal environment

Investigate Optimal Wind Farm Layout Strategies:

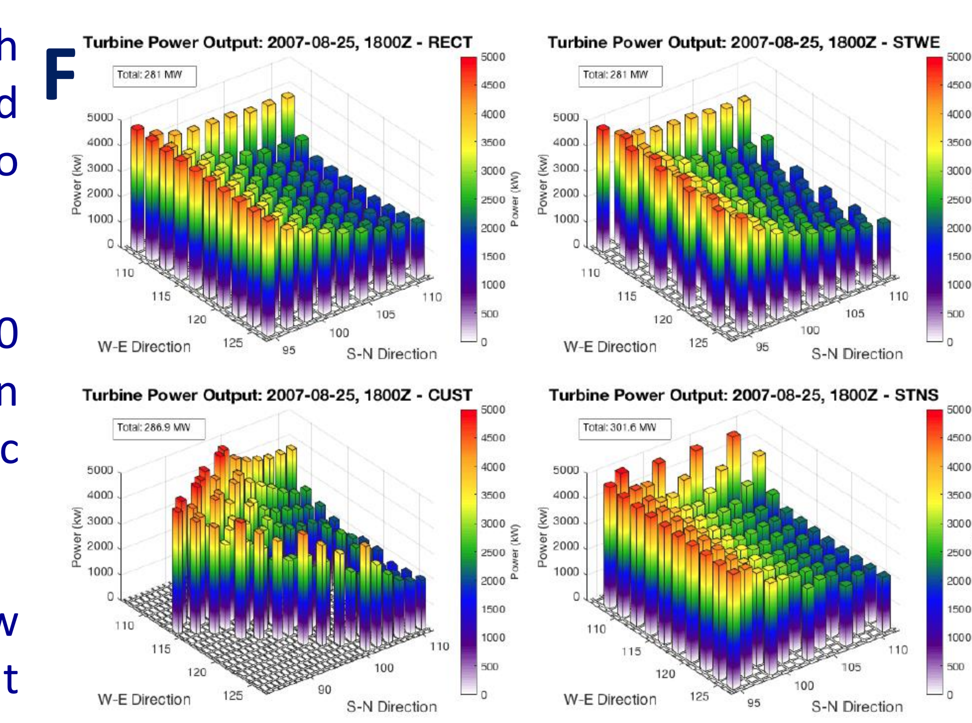


- Example of varying models' grid cell resolution and coverage near Maryland's offshore WEA (Figure D)
- Use improved models and observations to evaluate potential wind farm layouts in MD WEA (using WRF or commercial wind farm software)
- Use WRF to model regional wind farm impacts and interactions

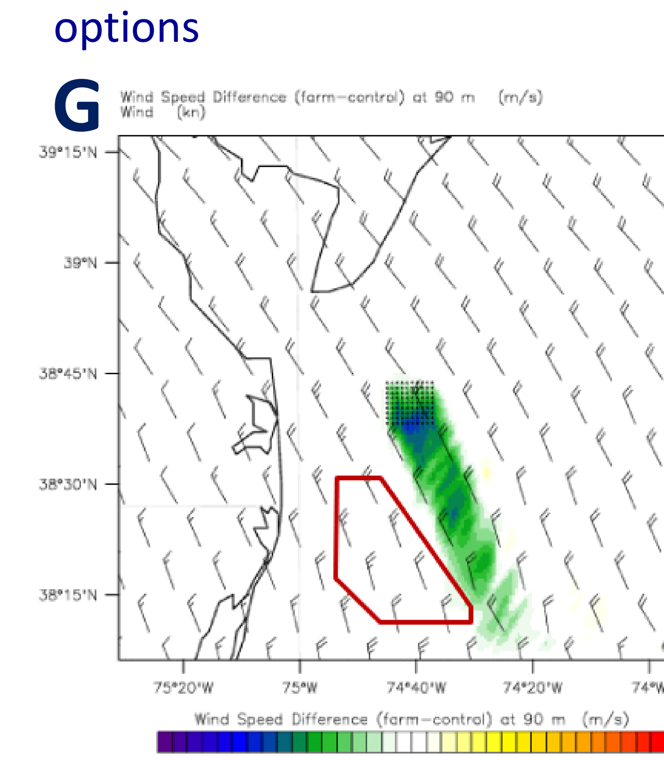
Result Highlights



- Models consistently underestimate the hub height wind resource (Figure E)
- High variability in model data, due to differences in model physics and grid resolution
- High resolution WRF model runs that incorporate observations can improve weather forecast



- Important to consider high resolution measurements and climatology of a site in order to optimize layout for maximum yield
- Modeled farms in WRF show a 20 MW difference in power production (~7%) under identical atmospheric conditions (Figure F)
- Industry-standard models also allow for detailed examinations of layout options



- Regional impacts of wind farms need to be evaluated, including wake effects. Wake effect is the influence on the energy production of the wind farm, which results from the changes in **wind** speed caused by impact of the **turbines** on each other
- Model results showing hypothetical Delaware wind farm impacting wind resource in Maryland's WEA (Figure G)
- Atmospheric stability affects the magnitude of regional wind farm interactions

Conclusions

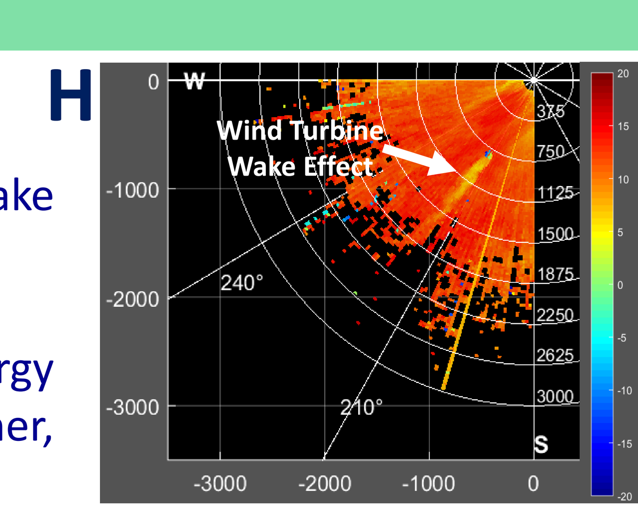
Wind farm layout strategies need to account for local climatology and wake interactions, as different layouts can result in dramatic differences in power production [3]. Results demonstrate regional modeling with WRF can estimate how wind farms in adjacent offshore wind energy areas interact. Understanding such exchanges during the pre-construction wind resource assessment stage is critical, as it directly affects a project's optimal layout strategy and expected energy yield.

Value and Interfaces

Improvement in regional modeling would benefit the wind energy industry, as well as other State users of coastal forecasts, including beach tourism, fishing, and commercial shipping.

Future Work

- Incorporate R2O observations into WRF model
- Evaluate models' ability to predict a turbine's wake effect (measured by Doppler wind lidar) (Figure H)
- Model wind farms in multiple offshore wind energy areas to assess how farms interact with one another, and improve farm layout strategy



References & Acknowledgements

[1]Clifton et al. "Wind Plant Preconstruction Energy Estimates: Current Practices and Opportunities." NREL (2016). http://www.nrel.gov/docs/fy16osti/64735.pdf

[2]Rabenhorst, S. and Delgado, R., "Validating Model Simulations Using Wind Profiles Near the Maryland Wind Offshore Wind Energy Area" (2014), American Wind Energy Association Offshore WINDPOWER Conference and Exhibition, Virginia Beach, VA.

[3]Archer, C. L., Mirzaeisefat, S., and Lee, S., "Quantifying the sensitivity of wind farm performance to array layout options using large-eddy simulation" (2013), *Geophysical Research Letters*, 40 (18)

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