UMBC- atmoSpheric Profiling for Advancing offshoRe wind research (U-SPARC): Research-2-Operation (R2O)

Ruben Delgado (PI), Alexandra St. Pé (PhD Candidate)

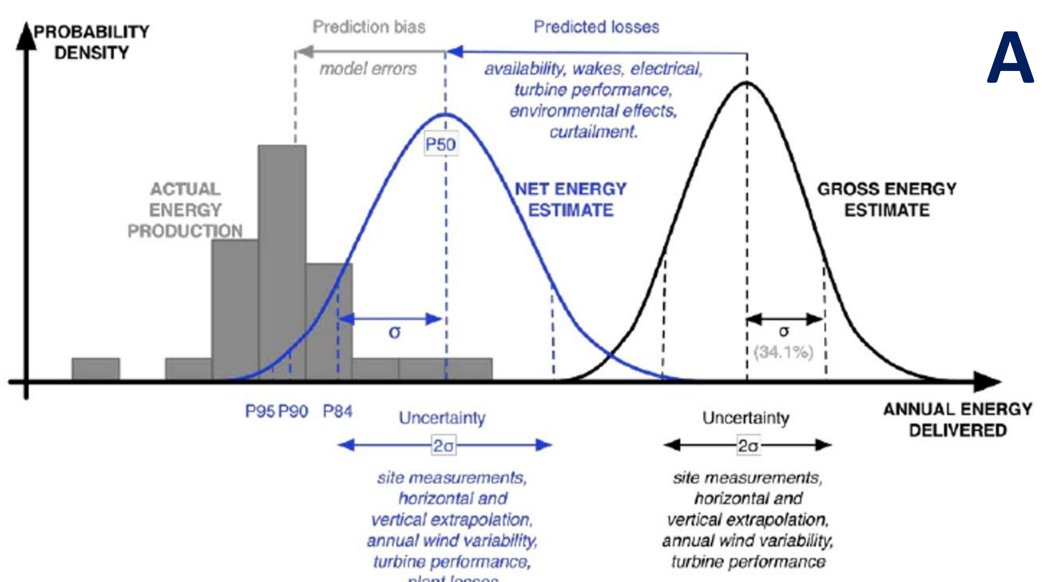
Joint Center of Earth Systems Technology (JCET)

University of Maryland, Baltimore County, (UMBC)

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

A

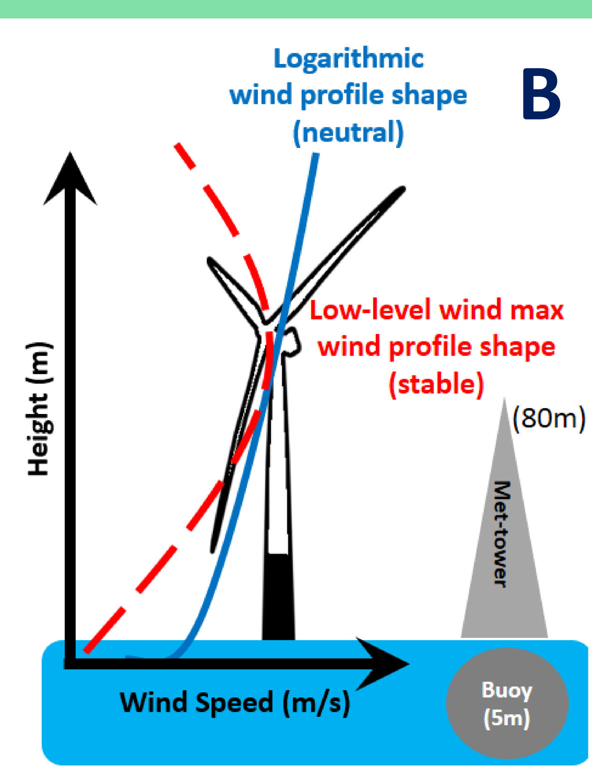


energy yield uncertainties may be introduced when estimating a local wind resource and a turbine's available power. In part, such uncertainties contribute to the chronic industry challenge known as wind farm *underperformance bias*, in which operational energy yield is *less than preconstruction expected 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 University of Maryland, Baltimore County (UMBC) atmoSpheric Profiling for Advancing offshoRe wind researCh (U-SPARC) team was established in 2013 with a focus on reducing atmospheric-related offshore wind preconstruction energy yield uncertainties.

R2O Motivation & Research Objectives

Motivation: The Research-2-Operation (R2O), branch of U-SPARC strives to advance understanding about the impact of complex coastal meteorological regimes, unique to the Mid-Atlantic, on offshore wind resource and available turbine power pre-construction uncertainty.

B



Research Challenge & Objectives: Given the lack of measurements offshore, the industry relies on extrapolation and assumptions that the vertical wind profile (i.e. wind resource), throughout a turbine's rotor-layer diameter, maintains a logarithmic 'shape', related to neutral atmospheric stability (Figure B). Research suggest this may not always be true; therefore R2O strives to develop methodologies that more accurately characterize Maryland's offshore wind resource 'shapes' and quantify associated impact on available turbine power uncertainty.

Methods

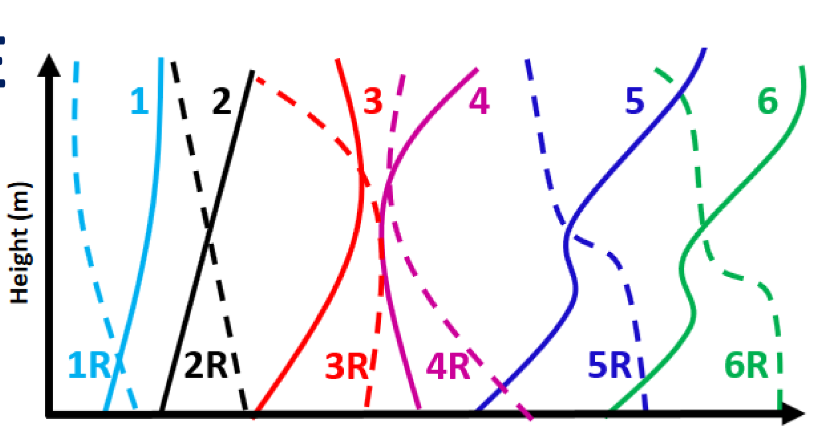
C

D

Offshore Measurement Campaign in Maryland's WEA:

- Collected high spatial and temporal Doppler wind lidar measurements in the Maryland's Wind Energy Area (WEA) during MEA sponsored geophysical survey (July-August 2013) (Figure C)
- Also launched weather balloons offshore and collected meteorological data from the nearest NOAA buoy (Figure D)

E



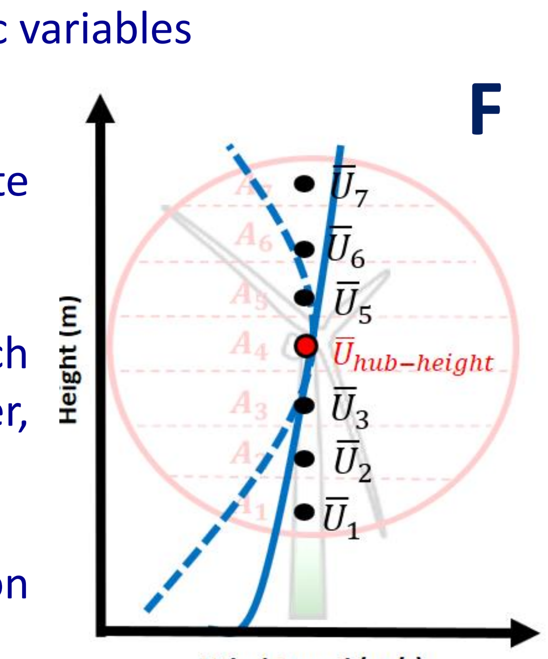
Characterizing Offshore Wind Resource & Atmospheric Drivers:

- Developed algorithm to classify vertical wind speed profile shapes (Figure E)
- Investigated relationships between classified wind profile shapes and atmospheric variables

Evaluating Available Turbine Power Uncertainty:

- Traditional turbine power estimates only incorporate hub-height wind speed conditions (Figure F)
- Novel Rotor-Equivalent Wind (REW) techniques, which account for wind conditions throughout a rotor-layer, are more accurate for power prediction [2]
- Evaluated the role of wind profile shapes on discrepancies between power estimate techniques

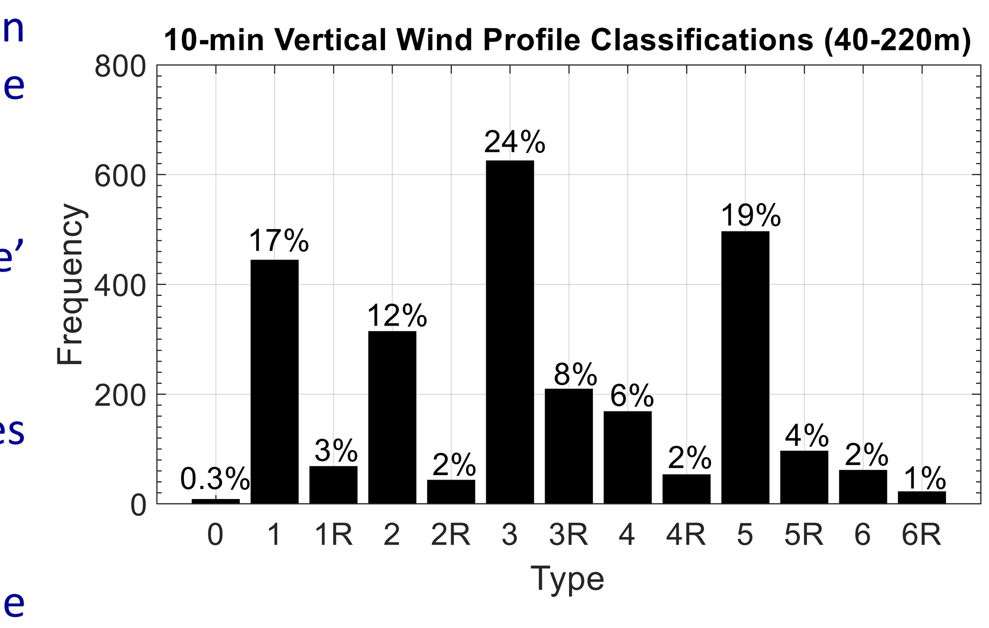
F



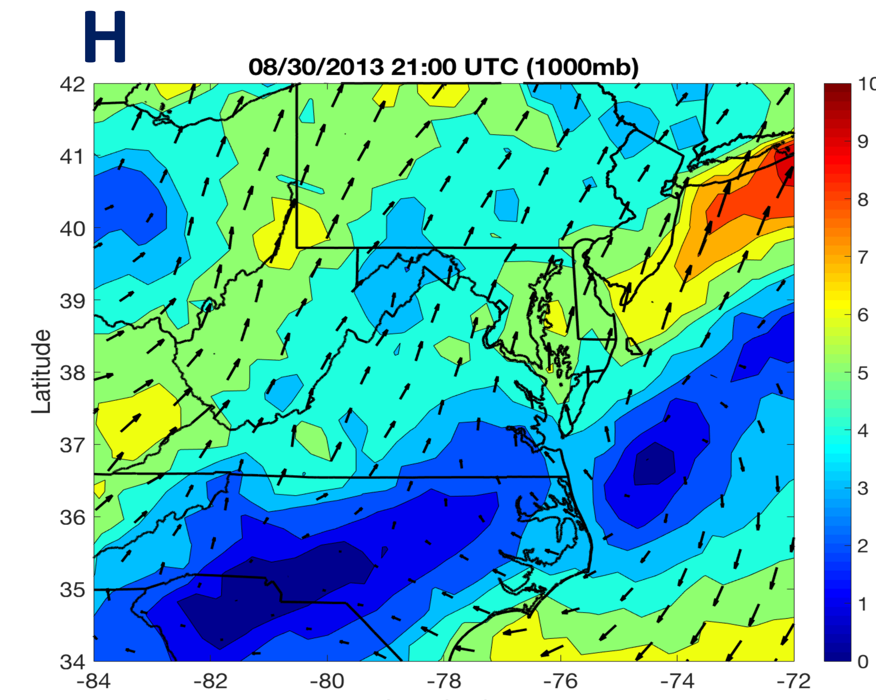
Result Highlights

- Results demonstrate immense variability in summertime 10-min averaged offshore wind profile shape [3] (Figure G)
- 17% = expected 'logarithmic-like' power law profile shapes (Type 1)
- 63% = unexpected profile shapes (Types 3-6)
- 18% = unexpected reversed profile shapes (Types "R")

G



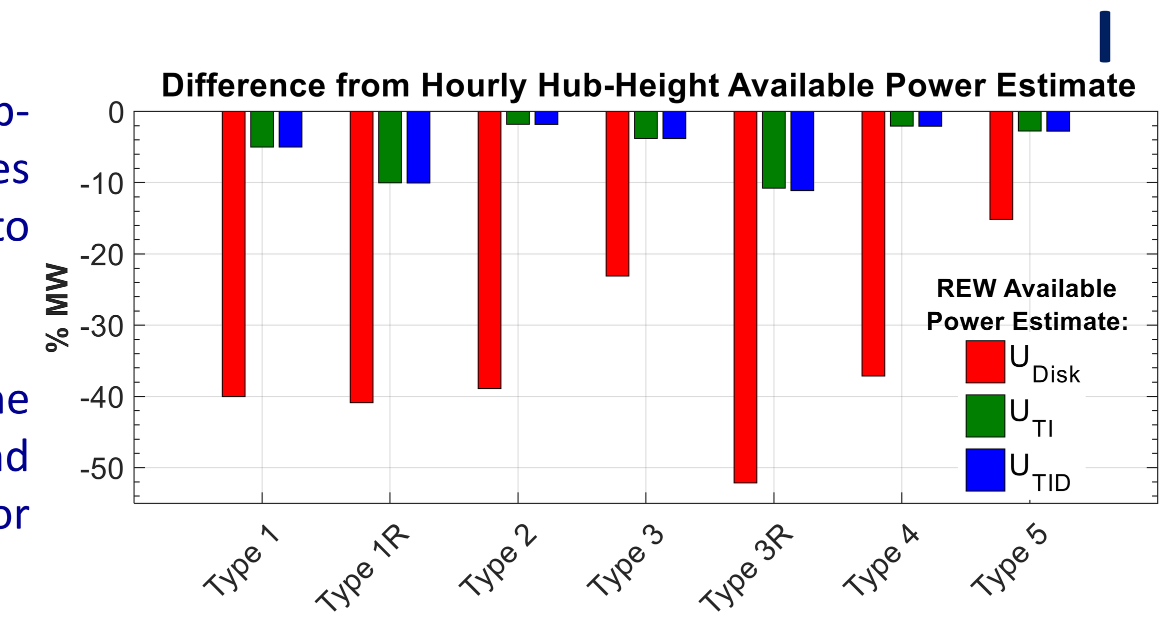
H



- Campaign average statistics suggest the frequent development of a regional, nocturnal coastal low-level jet, is in-part responsible for unexpected wind profile shapes (Figure H)
- Consistent with other results in New England [4]; however, compared to Europe, **unique to the offshore USA environment**

I

- Results demonstrate hub-height power overestimates available power compared to REW techniques (Figure I)
- The magnitude of the overestimate varies by wind profile shape & is larger for unexpected profile shapes



Conclusions

Driven by unique, summertime coastal weather regimes, the high incidence of unexpected offshore wind profile shapes and impact on pre-construction energy yield uncertainty, represents a possible concern for the USA offshore wind energy industry.

Value & Interfaces

The new wind profile 'shape' classification algorithm has potential value to the State of Maryland as it reduces wind resource and available power uncertainty in the State's WEA and potentially the USA offshore wind market.

Future Work

VERTical Enhanced MiXing (VERTEX) Measurement Campaign:

- Partnered with University of Delaware (Dr. Cristina Archer) in NSF funded project, to study atmospheric impacts on 2MW coastal turbine performance and turbine's wake effect in Lewes, DE (Figure J)
- Quantify impact of wind profile shapes & atmospheric stability on *actual turbine's power production
- Elucidate most accurate power estimate approach for unexpected wind profile shapes

J

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]Wagner et al. "The influence of the wind speed profile on wind turbine performance measurements." *Wind Energy* 12.4 (2009): 348-362.

[3]St. Pé et al. "Classifying Rotor-Layer Winds for Offshore Wind Resource and Avaialble Power Assessment." (final preparation, to be submitted to *Wind Energy*).

[4]Pichugina et al. "Doppler lidar-based wind-profile measurement system for offshore wind-energy and other marine boundary layer applications." *Journal of Applied Meteorology and Climatology* 51.2 (2012): 327-349.

We acknowledge Maryland Energy Administration, NOAA-CREST, Leosphere/Renewable NRG Systems, CB&I/Coastal Planning and Engineering Environmental and Infrastructure, Edward Strobach (UMBC) and Andrew Clifton (DOE-NREL).