# UMBC- atmoSpheric Profiling for Advancing offshoRe wind research (U-SPARC): Doppler Lidar Uncertainty (DLU)

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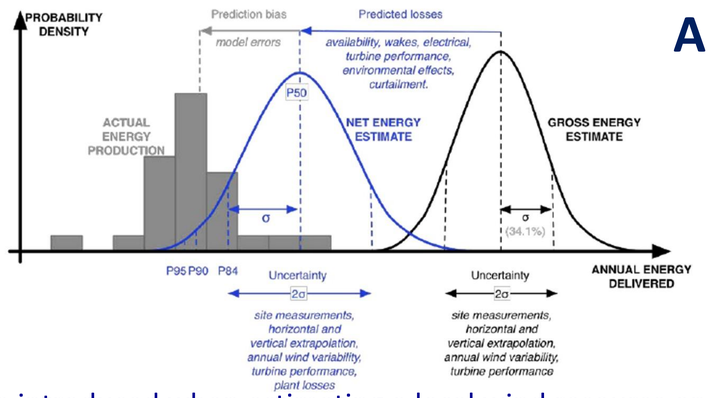
## Summary

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.

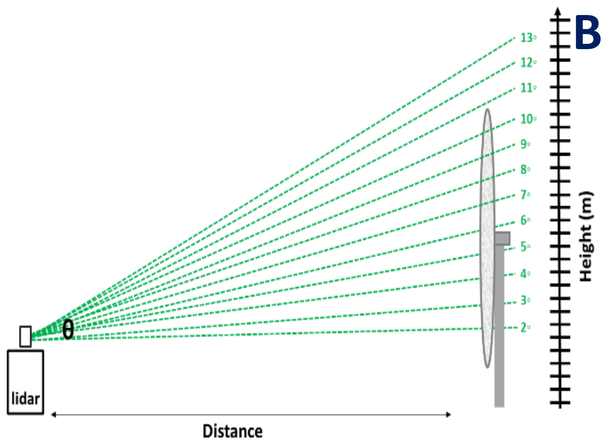
A




## DLU Motivation & Research Objectives

**Motivation:** The Doppler Lidar Uncertainty (DLU) branch of U-SPARC strives to understand the trade-offs of various Doppler lidar wind retrieval techniques and uses this information to further reduce site measurement, resource and wake effect related energy yield uncertainties.

B




**Research Challenge & Objectives:** High spatial and temporal wind coverage from scanning Doppler wind lidars add significant value to the offshore wind energy industry (Figure B). However, little is known about the comparative advantage, in terms of accuracy, of multiple lidar wind retrieval techniques. Therefore, DLU works with federal government collaborators to quantify wind speed and direction errors introduced from several retrieval methods as well as validate the UMBC lidar's accuracy with a 150m instrumented tower.

## Methods

### Collaborative Measurement Campaigns (NOAA ESRL, CIRES, UC-Boulder, NW Res. Assoc.):

DLU recently participated in two DOE funded measurement campaigns in Boulder, CO:

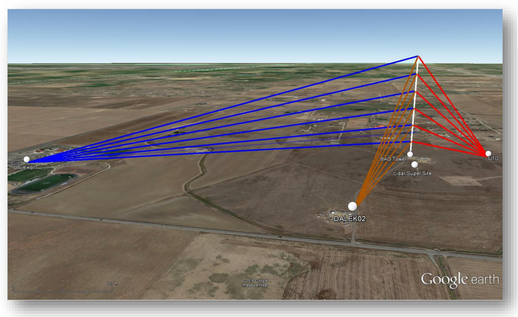
C

- Summer 2014: **L**idar **U**ncertainty **M**easurement **E**xperiment (LUMEX)
- Spring 2015: E**X**perimental Measurement Campaign for **P**lanetary Boundary Layer **I**nstrument **A**ssessment (XPIA) (Figure C)

### Measurement Strategies Evaluated:

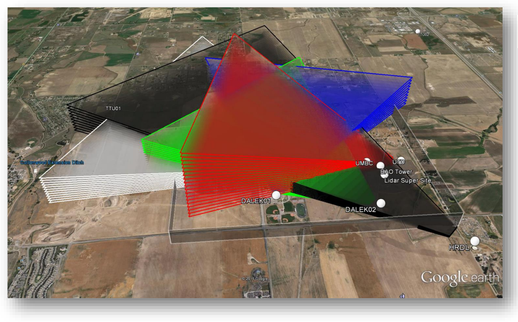
- Virtual Tower Stares (VTS) (Figure D)
- Coordinated Sparse Sampling
- Uncoordinated Volume Sampling
- Single Doppler Optimal Interpolation Technique (OI)

D




- Virtual Tower Stares (VTS)
- Coordinated Sparse Sampling
- Uncoordinated Volume Sampling (Figure E)
- Single Doppler Optimal Interpolation Technique (OI)

E




## Result Highlights

### Precisions of Lidars' Wind Retrieval Techniques:

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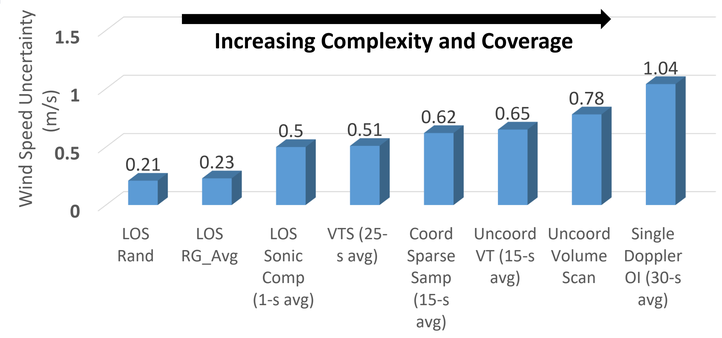


- Results demonstrate as Doppler wind lidar retrievals increase in complexity and coverage, uncertainty in both wind speed & direction increase [2] (Figures F & G)

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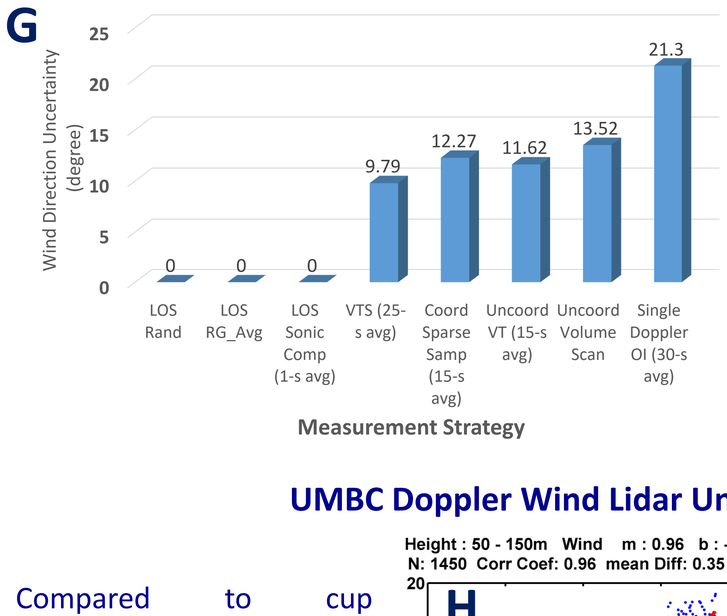
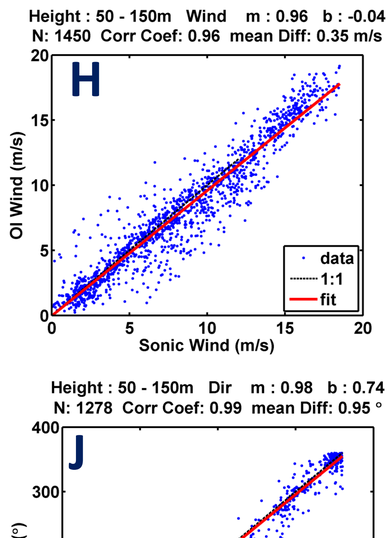



- Although associated with largest uncertainty for wind speed direction retrievals, ~1 m/s & ~21° respectively, single scanning Doppler OI is the most comprehensive technique for wind resource characterization (Figure F & G)

### UMBC Doppler Wind Lidar Uncertainty:

- Compared to cup anemometers, UMBC's 200s Doppler wind lidar maintains accurate wind speed & direction retrievals, with mean bias of ± 0.35 m/s & ± 0.95◦, respectively (Figures I & K)
- Comparison results also demonstrate excellent wind speed & direction correlation coefficient values ($R^2$), 0.96 & 0.99, respectively (Figure H & J)

H

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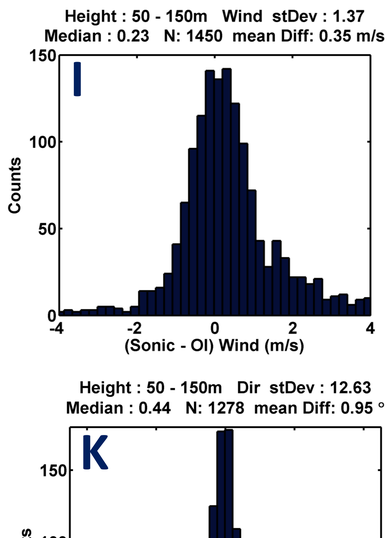


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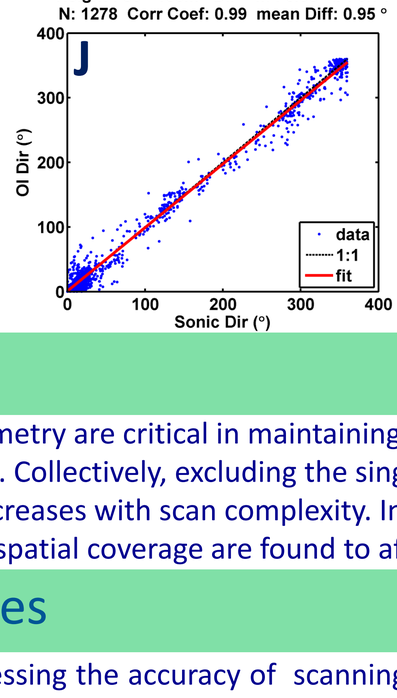


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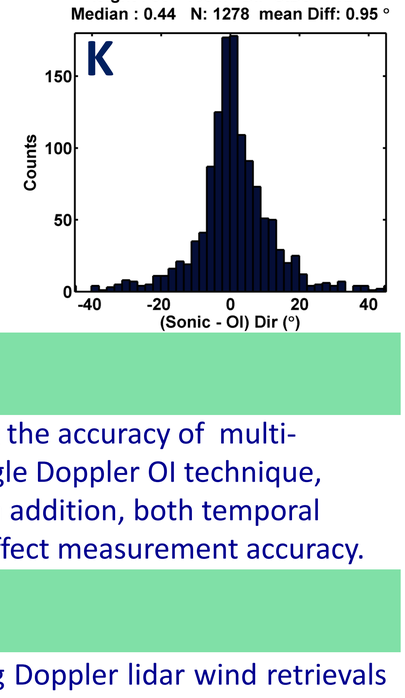


## Conclusions

Instrument location and geometry are critical in maintaining the accuracy of multi-Doppler wind measurements. Collectively, excluding the single Doppler OI technique, measurement uncertainty increases with scan complexity. In addition, both temporal resolution (update rate) and spatial coverage are found to affect measurement accuracy.

## Value & Interfaces

Now that an experiment assessing the accuracy of scanning Doppler lidar wind retrievals has been established and verified, providing baseline error results, similar assessments characterizing wind retrieval uncertainty in an offshore environment may be designed, potentially adding value to the Maryland and USA offshore wind market.

## Future Work

Future collaboration with universities and government research laboratories to study the accuracy of similar Doppler lidar wind retrieval techniques in an offshore environment, on both a stable and moving platforms, are anticipated (Figure L).

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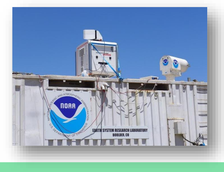

## References & Acknowledgements

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

[2]Lundquist, J., Wilczak, J., Ashton, R., Bianco, L., Brewer, A., Choukulkar, A., Clifton, A., Debnath, M., Delgado, R., Friedrich, K., Gunter, S., Hamidi, A., Valerio, G., Kaushik, A., Kosović, B., Langan, P., Lass, A., Lavin, J., Lee, Y., McCaffrey, K., Newsom, R., Noone, D., Oncley, S., Quelet, P., Sandberg, S., Schroeder, J., Shaw, W., Sparling, L., St. Marin, C., St.Pé, A., Strobach, E., Tay, K., Vanderwende, B., Weickmann, A., Wolfe, D., Worsnop, R., Assessing State-of-the-Art Capabilities for Probing the Atmospheric Boundary Layer : the XPIA Field Campaign, *Bulletin of American Meteorological Society*, doi:10.1175/BAMS-D-15-00151.1, 2016, in press.

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