Unique 700m range extension of nacelle lidars for modern offshore wind turbines

VAISALA

PO.003

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Abstract

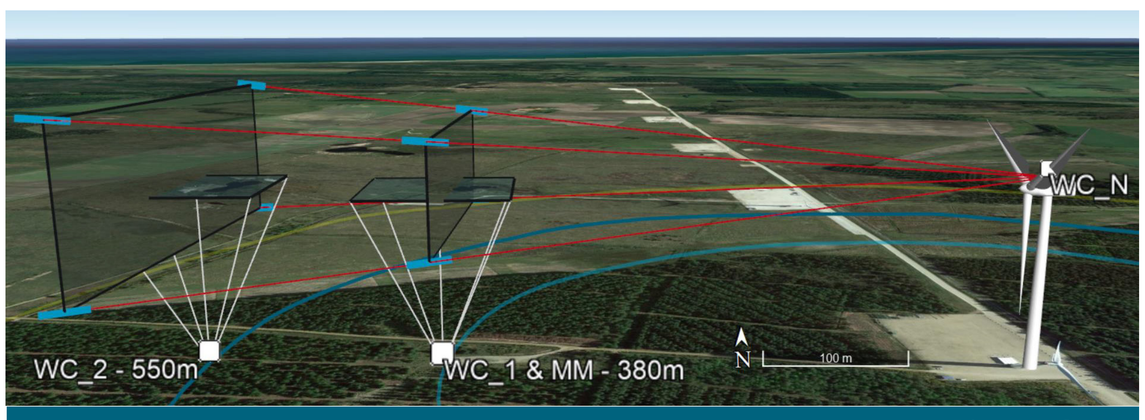
Lowering installation and operation costs of modern offshore wind turbines calls for ever-growing rotor diameters. Measurements of 150m in diameter have been surpassed, and 200m are being tested. Future technology will no doubt tackle 250m and greater. Optimizing the operation of such turbines at any moment in time is absolutely primordial in order to meet the expected return on investment. Here, nacelle-mounted lidars provide the essential wind information and thereby warrant the highest performance and most efficient diagnostics including contractual power curve verification (PCV). IEC 61400-12-1 ed.2 is the current reference document, and the suggested measurement of 2.5 rotor diameters in front of the turbine is widely adopted. This poster presents measurements up to 750m in front of an 8 MW, 167m diameter wind turbine (WTG) using Vaisala's latest nacelle-mounted 4-beam lidar.

Setup

A Vaisala WindCube® Nacelle, previously known as Wind Iris, installed on an 8 MW 167m diameter 120m hub height WTG is compared to one 120m height IEC met mast and two ground-based WindCube lidars placed respectively at 380m, 395m, and 550m from the WTG. Measurements were taken at DTU's Østerild wind turbine test field, a flat nearshore terrain, between June 2019 and February 2020 (nine months) and compared to the reference sensors on the following wind sectors:

- Sensors at **380m** — Wind Direction from MM: **273°+- 10°**
- Sensors at **550m** — Wind Direction from MM: **273°+- 15°**

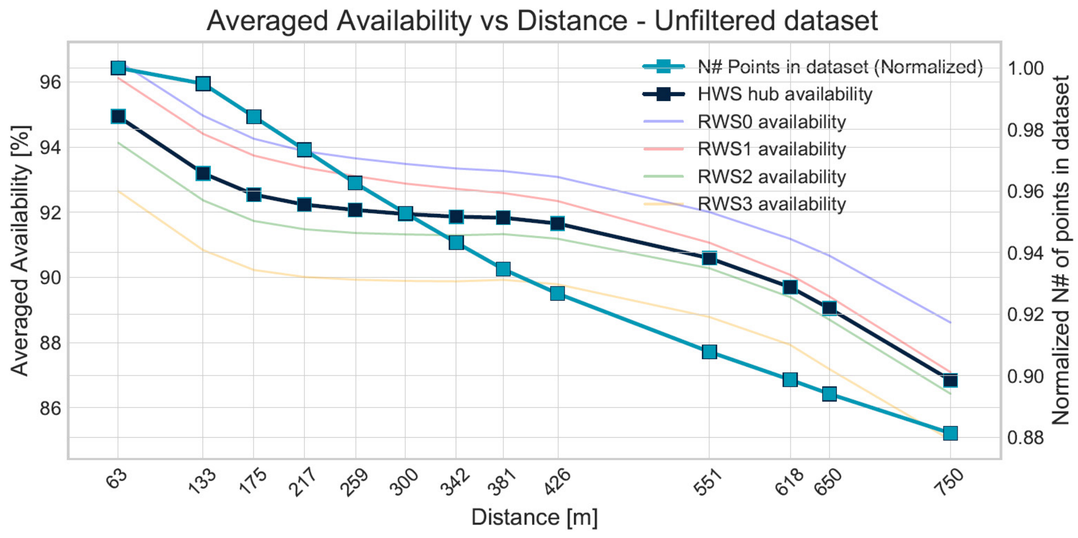
The difference in sector size accounts for wake from the met mast at 380m.



Instrumentation	Type	Measurement ranges gate / Height (m)	Distance from WTG (m)	Distance from WTG in [D] with D: 167m
Nacelle-based lidar	WindCube Nacelle	50m-750m	50m-750m	0.3D – 4.5D
Met mast	IEC compliant	120m	380m	2.3D
Ground-based lidar n°1	WindCube	40m-200m	395m	2.4D
Ground-based lidar n°2	WindCube	40m-200m	550m	3.3D

Lidar signal availability and data rate

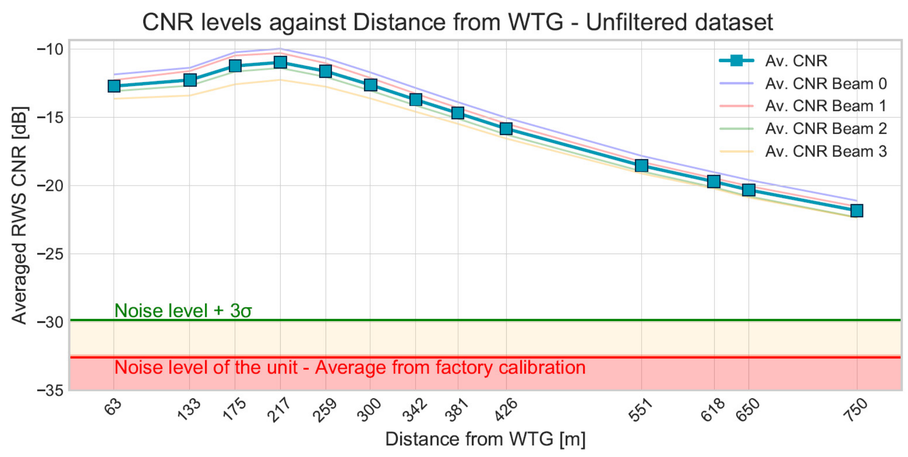
Lidar signal availability and rate of data collection are two key quantities for efficient Power Performance Testing.



- The observed lidar signal **availability drops by only 8%**, from 95% at 50m to 87% at 750m distance. (Slight availability differences between the four lidar beams are due to blocking from the turbine blades.)
- The number of data points in the infiltered set **drops by only 12%** at 750m when normalized to the first range gate (34,000 pts). The drop is quasi linear in range.

CNR levels

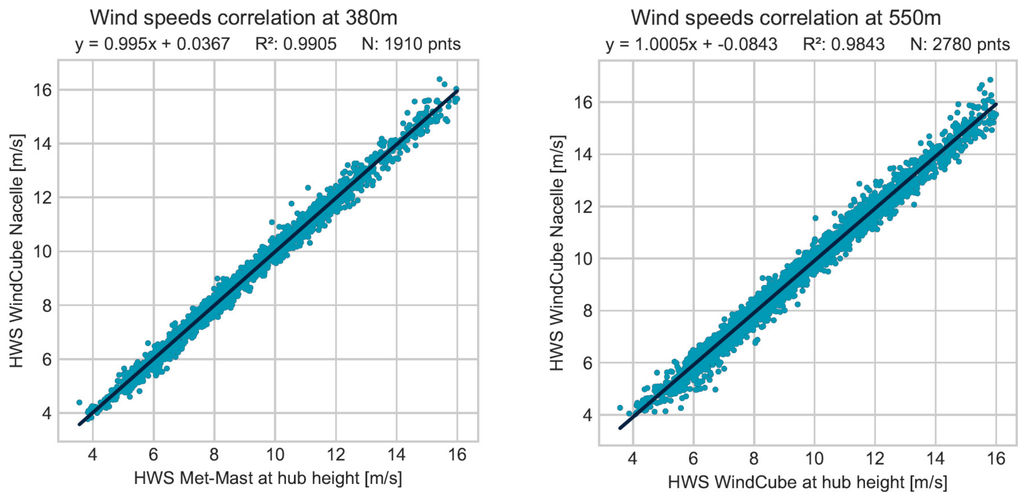
The carrier-to-noise ratio (CNR) indicates the strength of the Lidar return signal. The graph below shows the CNR for each beam and their average per range gate.



At all ranges, including 750m, the signal is **more than 15dB above the system noise level**. The **CNR peaks near 220m**, which is the chosen focal distance for this long-range lidar.

Results – Black box comparisons

Wind speed measurements were compared to the ground-based sensor, when wind direction and data filters allowed it. The figures below show the horizontal wind speed at hub height as measured by WindCube Nacelle against the ground sensors. The data are very well fitted by linear regression.



Distance from WTG (m)	Slope	Offset	R^2	N# of points in dataset	Reference instrument
380m	0.995	0.0367	0.9905	1910 (~318 h)	IEC Met Mast
550m	1.0005	-0.0843	0.9843	2780 (~463 h)	WindCube

- Correlation between WindCube Nacelle and both references, WindCube and met mast, are as expected. Slope and offset of the linear regressions are in agreement with the nacelle-lidar "white-box" calibration criteria, which is current industry best practice.

Conclusion

This campaign proves that the new Vaisala long-range WindCube Nacelle can measure wind fields up to 750m ahead with availabilities exceeding expectations and metrological performances equivalent to the previous 450m range version. Horizontal windspeed measurements are consistent with the lidar calibration best practices. Evaluation of other wind field characteristics was equally performed and results can be provided upon request.