



**Comments in response to  
Ørsted's presentation to the  
Wind Europe Tech Workshop  
(June 2023) assessing  
commercial lidar performance**

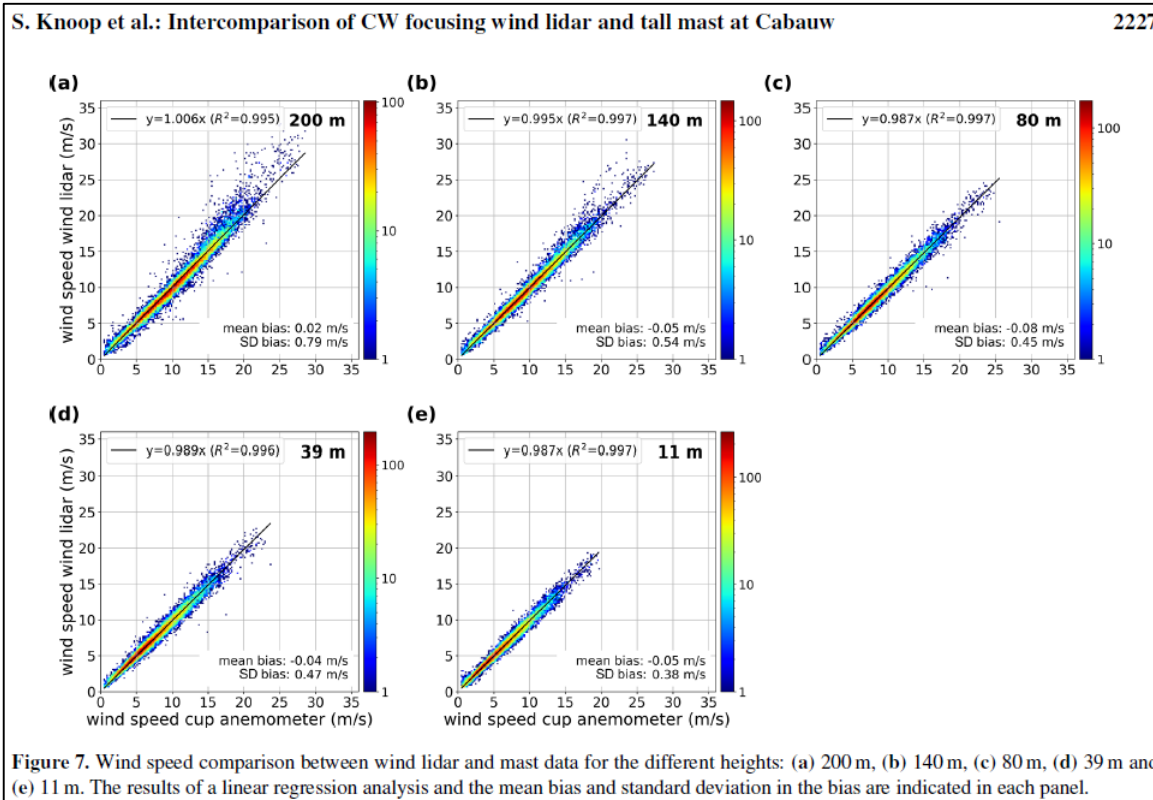
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# ZX Continual Development



- At WindEurope's Technology Workshop, June 2023, Ørsted presented trial results from both a ZX 300 (2019) and a ZephIR 300 (2016) lidar system, which feature different firmware versions
- ZX Lidars' strategy is one of continual product development, with updates available throughout a lidar system's lifetime
- Firmware development has looked to balance the high availability that can be achieved by a CW Lidar, which uniquely features constant sensitivity, with the data accuracy requirements of finance-grade wind data
- ZephIR 300 / Firmware v1.0x delivered almost 100% data availability at all heights. Whilst regression slope fell within best practice, the correlation coefficient exceeded minimum acceptable criteria at the very highest height in the Ørsted trial
- ZX 300 / Firmware v2.2x improved measurement accuracy, with regression slope and correlation coefficient within best practice. Availability observed during this trial was slightly reduced, but within best practice up to 250m
- Many other independent trials have been performed, both offshore and onshore, showing all acceptance criteria being met. Here are just some examples, results with thanks to KNMI, EOLOS, IDS/Green Rebel:

# 2-year comparison of ZX300 with KNMI's 200m Cabauw onshore mast



Height (m)	Slope	R <sup>2</sup>	Avail (%)
252	-	-	96.8
200	1.006	0.995	97.3
140	0.995	0.997	97.8
80	0.987	0.997	98.3
39	0.989	0.996	97.9
11	0.987	0.997	98.4

# 3-month EOL-FLS200 verification campaign



Summary of wind speed comparison between a floating ZX 300 on EOL-FLS200 buoy and adjacent platform-mounted Windcube:

WS comparison	#	slope	R <sup>2</sup> coeff.	WS CUP avg	WS LID avg	WS diff.	relative WS diff.
		KPIs					
Level / [m]		X <sub>mws</sub>	R <sup>2</sup> <sub>mws</sub>	m/s	m/s	m/s	
63	12680	1,003	0,996	10,96	10,99	0,03	0,3%
91	12585	1,000	0,997	11,48	11,47	-0,01	-0,1%
116	12560	0,998	0,997	11,79	11,76	-0,03	-0,3%
141	12532	0,997	0,997	12,05	12,00	-0,05	-0,4%
166	12484	0,995	0,995	12,29	12,22	-0,07	-0,6%

Wind Speed accuracy levels comfortably achieve best practice

Overall data availability:

EOLOS FLS-200 E02		Data Availability Percentage				
Level [m]	63	91	116	141	166	
Overall	99.1%	99.1%	99.0%	98.8%	98.6%	

Data availability figures exceeds required threshold



# 6-month Green Rebel FLS validation campaign



Summary of wind speed comparison between a floating ZX 300 on Green Rebel FLS buoy and adjacent platform mounted Windcube:

WS comparison	#	slope	R <sup>2</sup> coeff.	WS CUP avg	WS LID avg	WS diff.	relative WS diff.
		KPIs					
Level / [m]		X <sub>mws</sub>	R <sup>2</sup> <sub>mws</sub>	m/s	m/s	m/s	
62	25935	0,994	0,995	9,37	9,31	-0,06	-0,7%
90	25498	0,992	0,996	9,89	9,79	-0,09	-1,0%
115	25120	0,991	0,997	10,18	10,08	-0,10	-1,0%
140	24965	0,992	0,997	10,39	10,29	-0,10	-0,9%
165	24862	0,992	0,996	10,54	10,44	-0,10	-0,9%
190	24483	0,993	0,994	10,65	10,55	-0,10	-0,9%
215	23584	0,994	0,993	10,68	10,60	-0,08	-0,8%
240	22251	0,994	0,991	10,72	10,64	-0,08	-0,7%
265	20239	0,995	0,991	10,73	10,67	-0,06	-0,6%
290	18526	1,003	0,988	10,66	10,67	0,01	0,1%

Wind Speed accuracy levels comfortably achieve best practice

## Monthly and overall data availability:

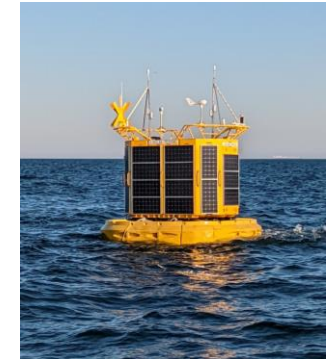
IFLB01-LEG	Data Availability Percentage											
	Level [m]	62	90	103	115	140	165	190	215	240	265	290
Overall		98,3%	97,3%	97,1%	96,3%	95,6%	95,2%	94,8%	94,4%	94,0%	93,3%	93,1%

Data availability figures exceed all stage 2 acceptance criteria thresholds

# 6-month Green Rebel FLS validation campaign



KPI	Definition / Rationale	Stage-2 Acceptance Criteria across total campaign duration
OSA <sub>CA</sub>	Overall System Availability – Campaign Average.	≥ 95% <b>99.6% - PASSED</b>
MSA <sub>1M</sub>	Monthly System Availability – 1-Month Average.	≥ 90% <b>99.0 % to 99.8 % - PASSED for all 6-months</b>
OPD <sub>CA</sub>	Overall (post-processed) Data Availability – Campaign Average.	≥ 85% <b>93.1 % to 98.3 % - PASSED for all compared heights</b>
MPDA <sub>1M</sub>	Monthly Post-processed Data Availability – 1-Month Average.	≥ 80% <b>82.1 % to 99.6 % - PASSED for all months and compared heights</b>



KPI	Definition / Rationale	Acceptance Criteria across total campaign duration	
		Best Practice (Stage 3*)	Minimum
X <sub>MWS</sub>	Mean Wind Speed – Slope. Assessed for wind speed range: [all above 2 m/s]	0.98 – 1.02 <b>ZX: 0.991 to 1.003 - PASSED at all levels</b>	0.97 – 1.03
R <sup>2</sup> <sub>MWS</sub>	Mean Wind Speed – Coefficient of Determination. Assessed for wind speed range: [all above 2 m/s]	> 0.98 <b>ZX: 0.988 to 0.997 - PASSED for all 6-months</b>	> 0.97
M <sub>MWD</sub>	Mean Wind Direction – Slope. Assessed for wind speed range: [all above 2 m/s] regardless of wind direction, i.e. no WD filtering applied	0.97 – 1.03 <b>ZX: 0.990 to 0.994 - PASSED at all levels</b>	0.95 – 1.05
OFF <sub>MWS</sub>	Mean Wind Direction – Offset, in terms of the mean absolute WD difference over the total campaign duration. (same as for M <sub>MWD</sub> )	< 5° <b>ZX: 1.56° to 2.67° - PASSED at all levels</b>	< 10°
R <sup>2</sup> <sub>MWD</sub>	Mean Wind Direction – Coefficient of Determination. (same as for M <sub>MWD</sub> )	> 0.97 <b>ZX: 0.968 to 0.995 - PASSED at all levels</b>	> 0.95

# Summary

- Ørsted's presentation at WindEurope's Technology Workshop (June 2023) reported a difference in performance between the ZephIR 300 and the ZX 300 - it should be noted that the firmware versions are different and span several years of development
- ZX Lidars continually works on enhancements to retain very high data availability whilst maintaining accuracy within the best practice class. All major firmware changes are delivered in consultation with Independent Engineer DNV
- It has been suggested that ZX customers would benefit from a better understanding of the impact of software changes. Agreed!

