



**Reducing mean wind speed uncertainty from floating
LiDARs: For a fairer energy yield uncertainty budget**



Introduction

- 1) Several of validation campaigns between cups and onshore lidars show that over the testing period (months), mean relative deviations are smaller than 2% (at 90-100 mASL).
- 2) Yet, mean wind speed values from both cups and LiDARs are typically assumed to have an uncertainty of 2%.
- 3) How can this be?
If both cups and LiDARs had an uncertainty of 2%:
 - We would see cases of mean relative deviations larger than 2%.
 - But we don't see these cases.

A possible explanation: LiDARs and cups uncertainties are smaller than 2%

Content

- Case 1: Illustration from numerical experiment
- Case 2: Application to floating LiDARs
- Discussion on existing validations above 100 mASL
- Conclusions

Case 1: Illustration from numerical experiment

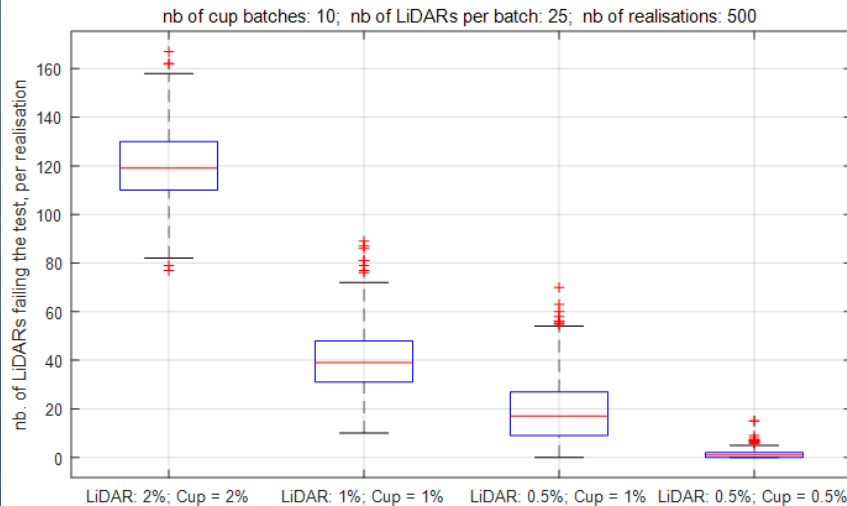
1. We assume that one cup anemometer is used for validating 10 LiDAR devices.
2. We assigned the following uncertainty to both cups and LiDAR measurements:

	Uncertainty	
	LiDAR	Cup
Scenario 1	2.0%	2.0%
Scenario 2	1.0%	1.0%
Scenario 3	0.5%	1.0%
Scenario 4	0.5%	0.5%

3. We consider 250 tests, and a single true value of 10 m/s.
4. For each test we randomly pick a value of measured wind speed from the LiDAR, and one for the cup anemometer (for the entire test period).
5. Then, we compute the relative difference between the two and check if it is larger than 2%.
6. We repeat the whole thing (i.e. the 250 tests) 500 times.

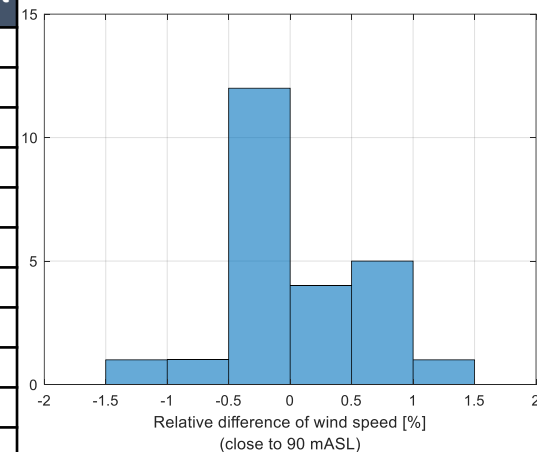
Case 1: Illustration from numerical experiment

- With 2% uncertainty for LiDARs and cup, between 80 and 160 LiDAR devices (out of 250) would fail.
- With 1% uncertainty, the number of failed test drastically reduces, but there are still dozens of failed test.
- 0.5% uncertainty to a very small numbers of failed test.



From real tests

N Unit	LiDAR Unit	N Unit	LiDAR Unit
1	ZX961	13	ZP495
2	ZX987	14	ZX888
3	ZP597	15	ZX874
4	ZP594	16	ZX914
5	ZX842	17	ZX876
6	ZX844	18	ZX924
7	ZP585	19	ZP501
8	ZP585	20	ZP585
9	ZX802	21	ZX818
10	ZX818	22	ZX843M
11	ZP495	23	ZX862M
12	ZP442	24	ZX898M



Case 2: Application to floating LiDARs

- Results from 18 FLS publicly available validation reports were used.
- Relative difference of mean wind speed between reference instrument and FLS was calculated.
- Only wind speeds at, or close to, 100 mMSL were used.



BUOY 120
Independent performance verification of Floating Lidar Buoy 120 at Martha's Vineyard Coastal Observatory
 Ocean Tech Services, LLC

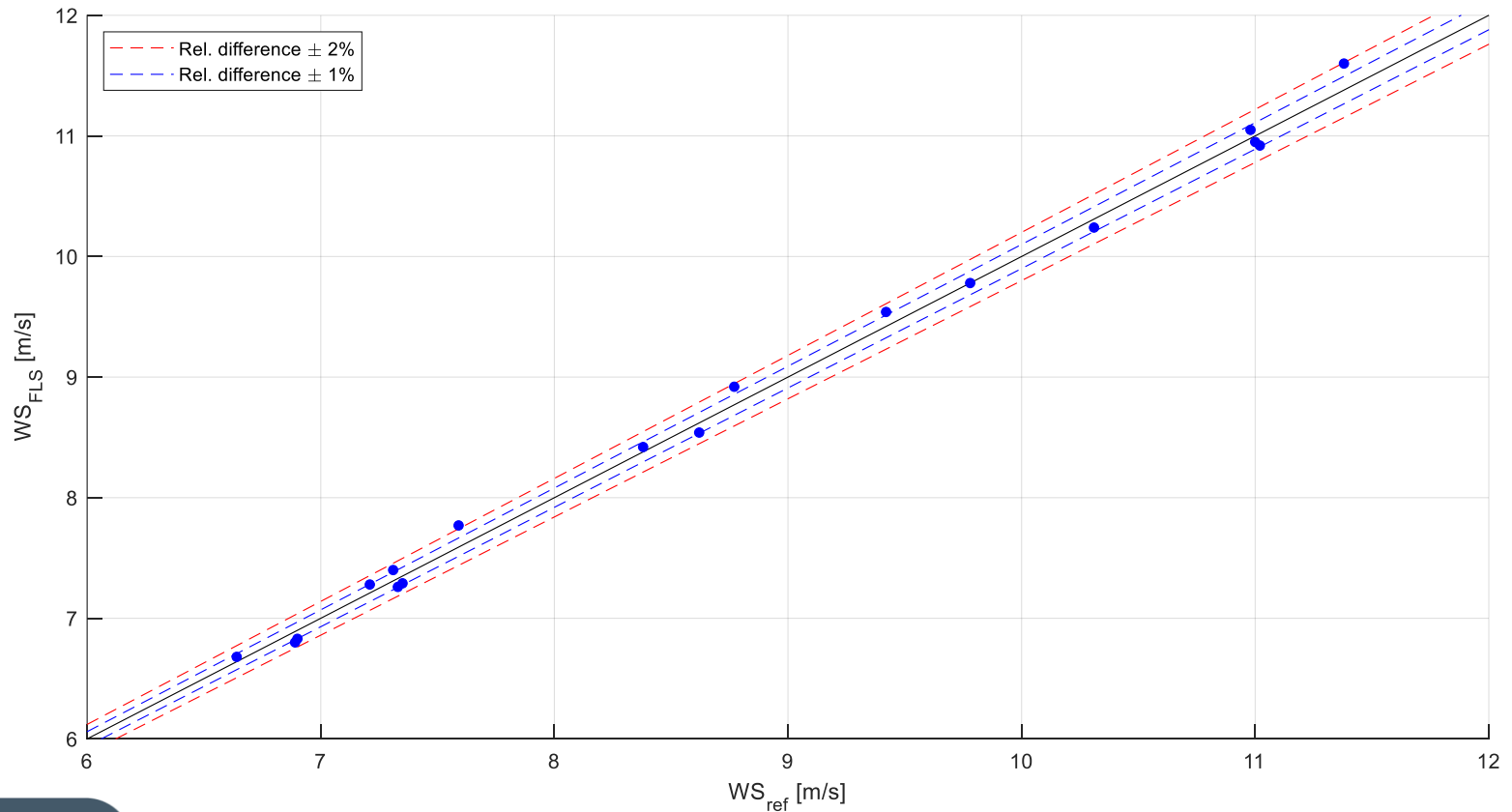
Report No. 10161669-R-01, Rev. C
 Date: 10 June 2020



N	Document	Supplier	FLS type	LiDAR type	FLS unit	Reference device	Instrument reference	Location
1	10298247-R-1, Rev. A	Fugro	Seawatch	ZXM585	WS170	Offshore LiDAR	WLS7-258	LEG
2	10129033-R-6, Rev. E	Fugro	Seawatch	ZX818	WS187	Onshore LiDAR	ZP495	Frøya
3	10129033-R-7, Rev. D	Fugro	Seawatch	ZX802	WS188	Onshore LiDAR	ZP495	Frøya
4	GLGH-4270 16 13920-R-0002, Rev. C	Fugro	Seawatch	Z417	WS140	Onshore LiDAR	Z495	Frøya
5	GLGH-4257 13 10378-R-0004, Rev. A	Fugro	Seawatch	Z428	WS149	Onshore LiDAR	Z495	Frøya
6	GLGH-4270 17 14462-R-0001, Rev. D	Fugro	Seawatch		WS149	Onshore LiDAR		Frøya
7	GLGH-4257 13 10378-R-0005, Rev. E	Fugro	Seawatch	Z501	WS156	Onshore LiDAR	Z495	Frøya
8	GLGH-4257 13 10378-R-0006, Rev. C	Fugro	Seawatch	Z442	WS157	Onshore LiDAR	Z495	Frøya
9	GLGH-4270 16 13920-R-0001, Rev. D	Fugro	Seawatch		WS158	Onshore LiDAR		Frøya
10	GLGH-4270 17 14462-R-0002, Rev. C	Fugro	Seawatch	ZP585	WS170	Onshore LiDAR	ZP495	Frøya
11	10129033-R-10, Rev. B	Fugro	Seawatch	ZX843	WS190	Onshore LiDAR	ZP495	Frøya
12	10129033-R-11, Rev. B	Fugro	Seawatch	ZX862	WS191	Onshore LiDAR	ZP495	Frøya
13	10281716-R-2, Rev. B	Fugro	Seawatch	ZX759	WS191	Onshore LiDAR	ZX428	Frøya
14	10189146-R-3, Rev. B	Fugro	Seawatch	ZX898	WS199	Onshore LiDAR	ZX428	Frøya
15	10124962-R-2-A	Eolos	FLS-200	ZX842	E05	Offshore met mast	Anemometers	Narec NOAH met mast
16	10124962-R-3-A	Eolos	FLS-200	ZX844	E06	Offshore met mast	Anemometers	Narec NOAH met mast
17	10161669-R-01, Rev. C	AXYS	WindSentinel	WLS866-25	Buoy120	LiDAR	WLS7-436	ASIT
18	10161669-R-02, Rev. C	AXYS	WindSentinel	WLS866-24	Buoy130	LiDAR	WLS7-436	ASIT

Case 2: Application to floating LiDARs

- In 17 of all 18 cases analyzed the mean wind speed from the FLS is within an interval of $\pm 2\%$ of relative difference.
- In 13 of all 18 cases analyzed the mean wind speed from the FLS is within an interval of $\pm 1\%$ of relative difference.



Discussion on existing validations above 100 mASL

- Based on publicly available documents, validation of LiDAR measurements above 90-100 mASL show small deviations as well:
 - 1 x DTU Østerild: Vaisala WL866-26
 - 1 x KNMI Cabauw (<https://amt.copernicus.org/articles/14/2219/2021/>): ZX

3.4 Ten minute mean wind speed at 178 m:

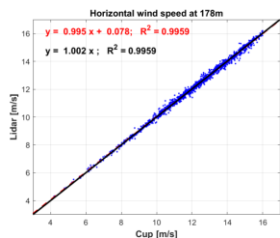


Figure 11.a 1-parametric regression between the 10 minute mean wind speed measurements from the Windcube at 178m and the cup anemometer at 178m.

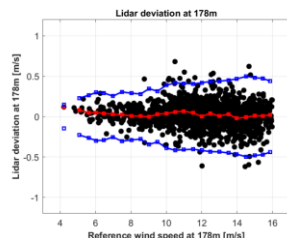


Figure 11.c Deviation at 178m versus reference wind speed. Each black dot represents a 10 min value; the red dots are the wind speed bin averages and the blue squares show $\pm 2\sigma_{lidar}$. The lines result from linear interpolation.

3.5 Ten minute mean wind speed at 244 m:

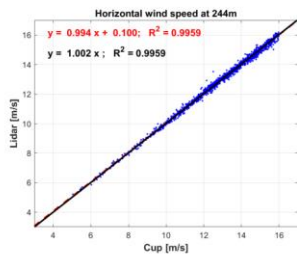


Figure 12.a 1-parametric regression between the 10 minute mean wind speed measurements from the Windcube at 244m and the cup anemometer at 244m.

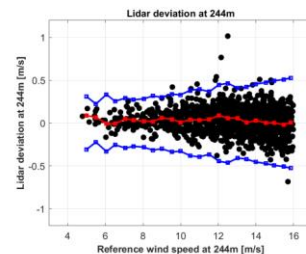


Figure 12.c Deviation at 244m versus reference wind speed. Each black dot represents a 10 min value; the red dots are the wind speed bin averages and the blue squares represent $\pm 2\sigma_{lidar}$. The lines result from linear interpolation.

47 reports at Østerild ?

DTU Findit search results for "Calibration of ground-based Lidar instrument" and "Østerild".

Interpreted as: "Calibration of ground-based Lidar instrument" AND AND "Østerild"

Suggestions: Include records that partially match the query

1 - 10 of 47 Next >

External supplier 47

REPORT

Calibration of Ground-based Lidar instrument

Hansen, Jesper Grossmann; Yanikova, Genka Georgieva

This report presents the result of the lidar calibration performed for the given Ground-based Lidar at DTU's test site for large wind turbines at Østerild, Denmark. Calibration is here understood as the establishment of a relation between the reference wind speed measurements with measurement

YEAR: 2023 LANGUAGE: English

Access to this document is prohibited. We were not able to find anything



Calibration of ground-based lidar instrument: WLS866-26

Østerild Test Site
Denmark

Héctor Villanueva L. (Measurement Engineer)
Paula Gómez (Reviewer)



Atmos. Meas. Tech., 14, 2219–2235, 2021
<https://doi.org/10.5194/amt-14-2219-2021>
 © Author(s) 2021. This work is distributed under the Creative Commons Attribution 4.0 License.



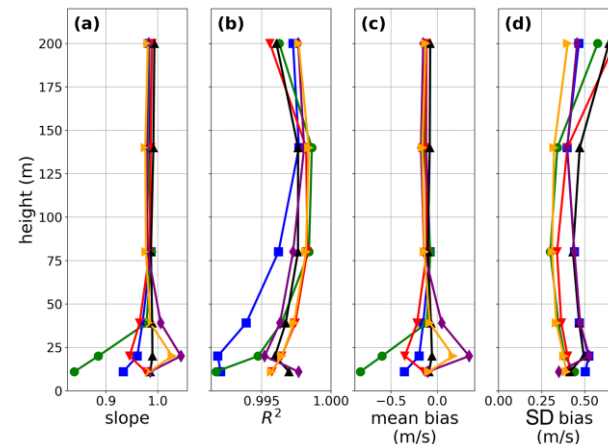
A 2-year intercomparison of continuous-wave focusing wind lidar and tall mast wind measurements at Cabauw

Steven Knoop, Fred C. Bosveld, Marijn J. de Haaj, and Arnold Aptuley
 Royal Netherlands Meteorological Institute (KNMI), Utrechtseweg 297, 3731 GA, De Bilt, the Netherlands

Correspondence: Steven Knoop (steven.knoop@knmi.nl)

Received: 30 July 2020 – Discussion started: 8 September 2020
 Revised: 18 January 2021 – Accepted: 23 January 2021 – Published: 22 March 2021

Legend for Figure 13: 0°-100° (14%), 100°-150° (7%), 150°-200° (20%), 200°-250° (32%), 250°-300° (15%), 300°-360° (11%) [4-16 m/s]



Mean bias doesn't seem to vary with elevation



Discussion on existing validations above 100 mASL

2 x UL Texas: Vaisala and ZX



Remote Sensing Device Verification
Report
ZX Lidars ZX 300M Serial No. 1166

PREPARED FOR:
Woods Hole Oceanographic
Institution

Ref. No. PR-016453

MORS-1 Lidar Validation

18 August 2021

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Figure 3.5: Photo of the RSD

Photo taken 2021-05-19

Windcube: ~2-3% deviation is likely caused by scalar average + highly convective ABL during day (see <https://eo-winds.net/2021/10/31/scalar-and-vector-wind-speeds-with-a-doppler-beam-swinging-lidar/>)



PREPARED FOR:
MASSACHUSETTS CLEAN ENERGY
CENTER

Report No.: CalibrationReport_WLS7-436

WEST TEXAS
Texas
USA

18 October 2019

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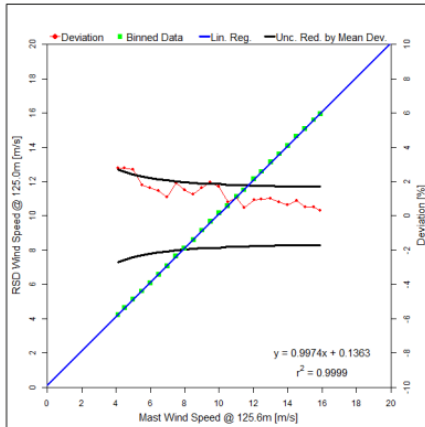


Figure 6.8: 125-m Binned Wind Speed and Deviation

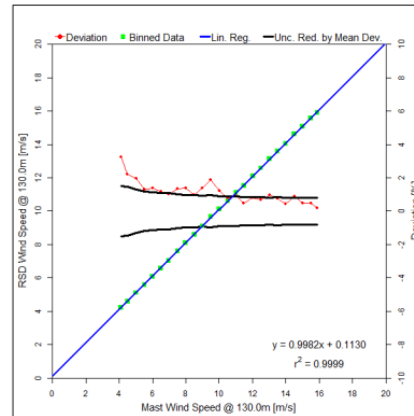
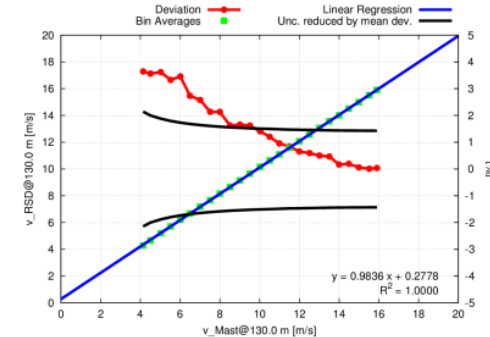
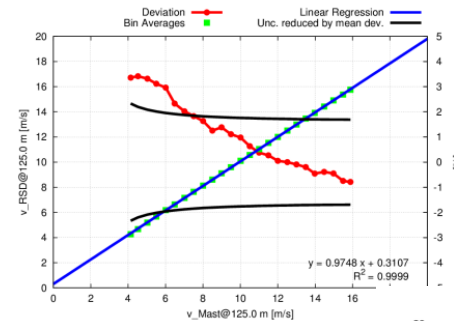


Figure 6.10: 130-m Binned Wind Speed and Deviation



Conclusions

- Onshore LiDAR and FLS uncertainty equal to 2% appears to be too conservative.
- Limited validation studies above 100 mASL show deviation smaller than 2%.
- Most of the validation reports were carried out in well known sites in Europe, atmospheric stability conditions and aerosol content may lead to deviations between lidars.

Where to find validation reports (all public)

eo-winds.net

Earth Observation | draft notes on Wind Energy Sci/Tech

About Aeolians.net **Data and documents**

HRZA-FLS, v_{hub} (120-180) m

In Obukhov we trust (variances and co., suite et fin)

Some (surely not final) words on the Monin-Obukhov Similarity Theory combined with the Charnock relationship aka "the good (old) sfc layer parametrization"

Variances and co. (summary)

A quick follow-up on "Variances and co. (turbulence intensity offshore)".

Variances and co. (turbulence intensity offshore)

An attempt to learn from measurements and well known air-sea interaction datasets, about the relationship between longitudinal wind speed variance, the momentum flux, and eventually the turbulence intensity...

Reconciling surface layers wind speeds in CFS and ERA5 reanalyses #lifehack

A deep-dive in the surface layer over the ocean, in (CFSR,CFSv2) and ERA5.

Buoys buoys buoys... (ERA5/CFS winds)

Yet another post on ERA5 wind speeds, the Charnock parameter, this time featuring met buoys (but also, don't worry, wind energy met masts and LiDARs)

Scalar- and vector wind speeds, with a Doppler Beam Swinging LiDAR

A tale of two wind speed retrieval

Library > LiDARs and FLS validatio...

Type Contacts Date de modification

Nom ↑

- AXYS
- EOLOS
- Fraunhofer IWES
- Fugro
- GEOxyz
- Leosphere
- MISC
- Nanjing Movelasar
- RPS
- ZX Lidars
- logbook

Repeatability of ZephIR 300 performance

Demonstrated across more than 240 IEC compliant verifications

01 March 2016

Author: Muhammad Mangat

100+ validation reports, including repeatability studies.