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

C2WIND

2024-05-03 VindkraftNet meeting

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%

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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.

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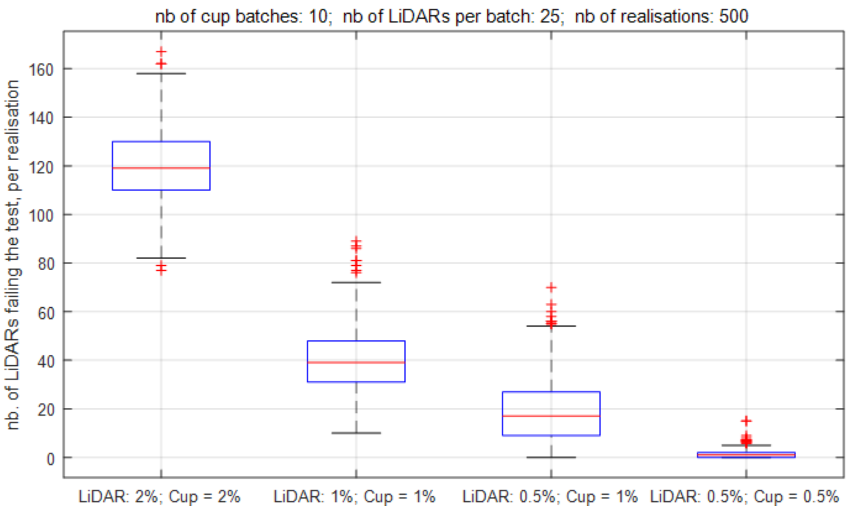
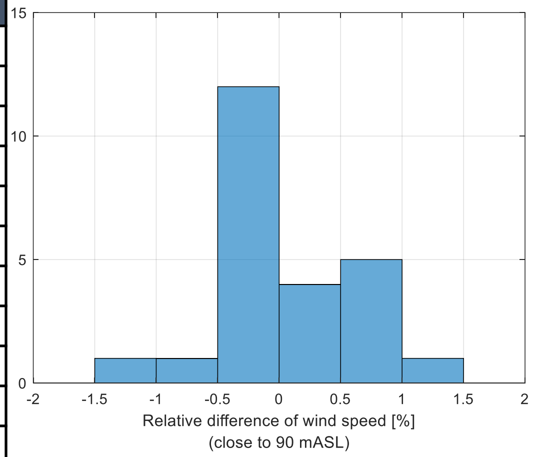
Case 1: Illustration from numerical experiment

- 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.



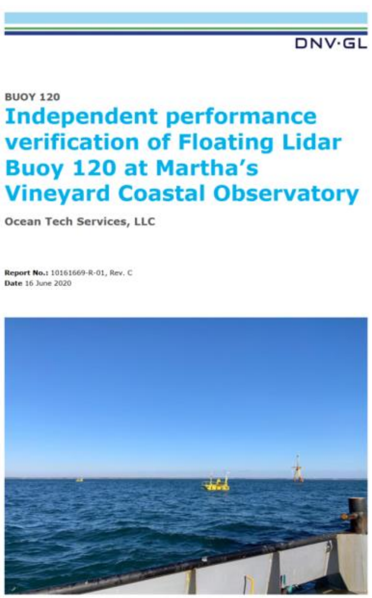
From real tests

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.


DNV·GL

BUOY 120

Independent performance verification of Floating Lidar Buoy 120 at Martha's Vineyard Coastal Observatory

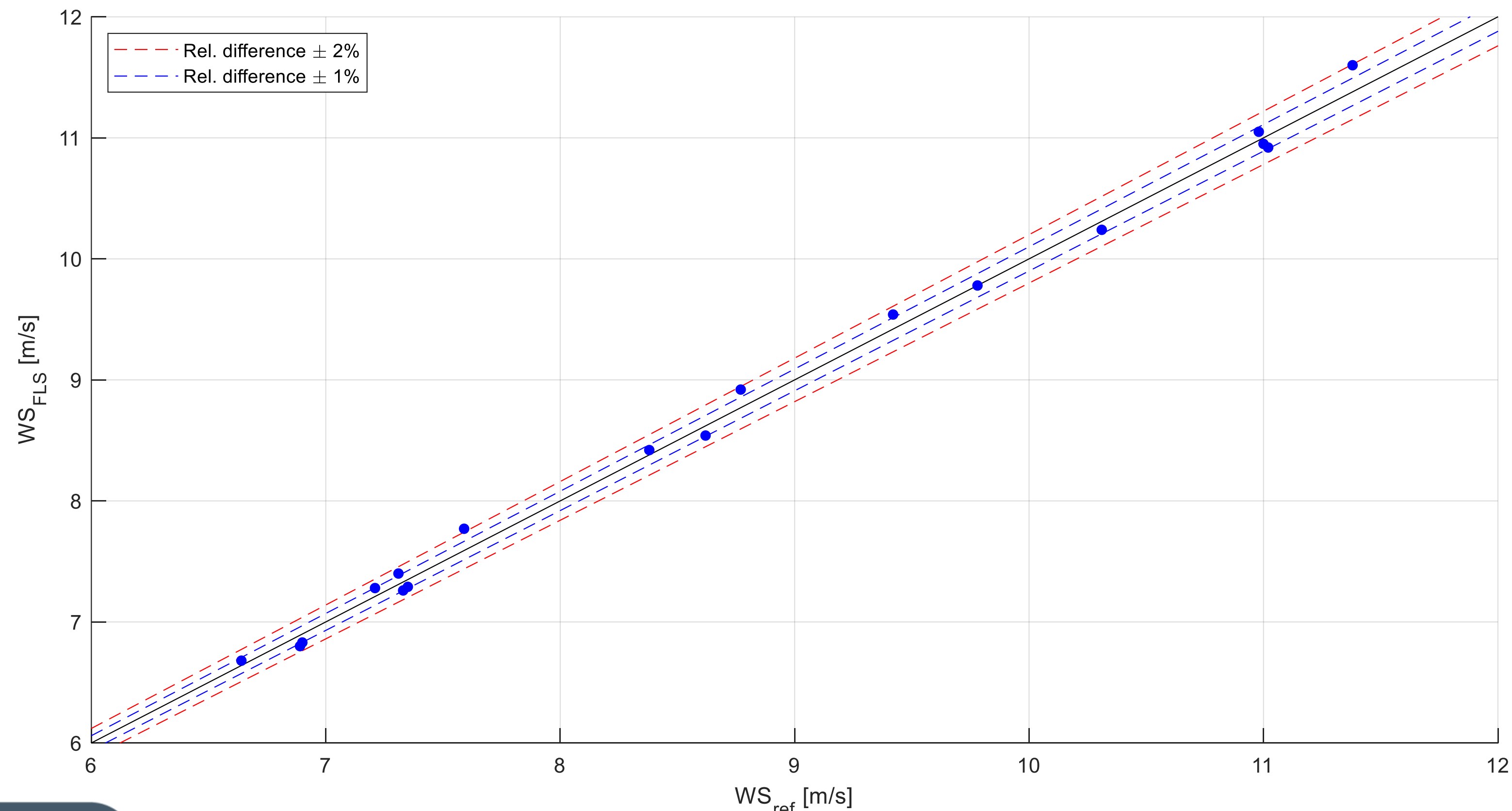
Ocean Tech Services, LLC

Report No.: 10161669-R-01, Rev. C
Date 16 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 ± 2% of relative difference.
- In 13 of all 18 cases analyzed the mean wind speed from the FLS is within an interval of ± 1% of relative difference.



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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:

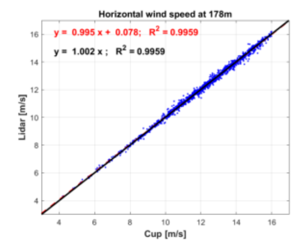


Figure 11.a 1-parametric regression between the 10 minute mean wind speed measurements from the Windcube at 178m and the cup anemometer at 178m.

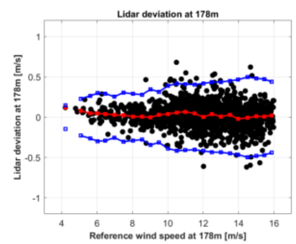


Figure 11.c Deviation at 178m versus reference wind speed. Each black dot represents a 10 min value; the red dots are the wind speed bin averages and the blue squares show $\pm 2u_{lidar}^{(2)}$. The lines result from linear interpolation.

3.5 Ten minute mean wind speed at 244 m:

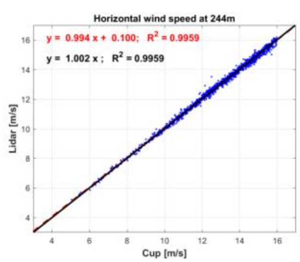


Figure 12.a 1-parametric regression between the 10 minute mean wind speed measurements from the Windcube at 244m and the cup anemometer at 244m.

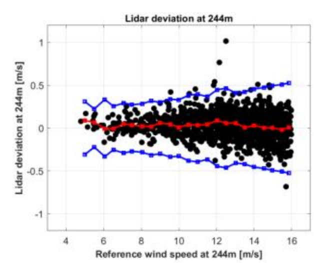


Figure 12.c Deviation at 244m versus reference wind speed. Each black dot represents a 10 min value; the red dots are the wind speed bin

DTU

DTU Wind Energy LC I-167 (EN)

Calibration of ground-based lidar instrument: WLS866-26

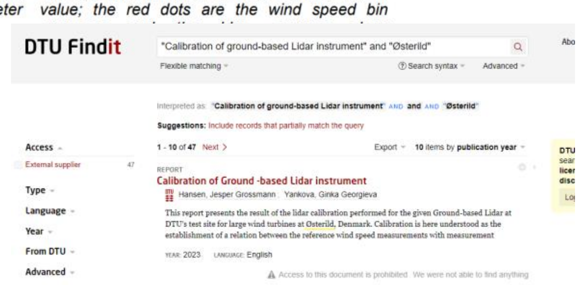
Østerild Test Site

Denmark

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

DTU – Wind Energy
Risø Campus
Roskilde, Denmark
March 2020

47 reports at Østerild ?



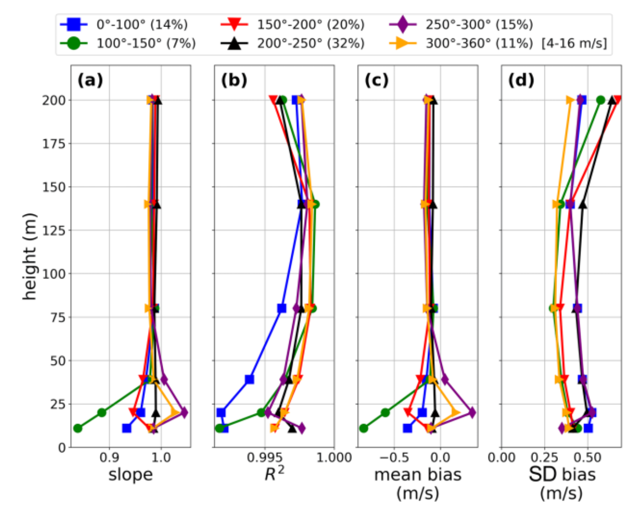
Atmos. Meas. Tech., 14, 2219–2235, 2021
https://doi.org/10.5194/amt-14-2219-2021

Atmospheric Measurement Techniques
Open Access
EGU

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 Haij, and Arnoud Apituley
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



Mean bias doesn't seem to variate with elevation

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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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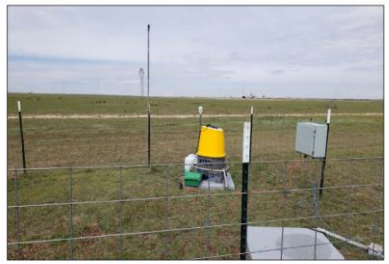

Figure 3.5: Photo of the RSD

Photo taken 2021-05-19

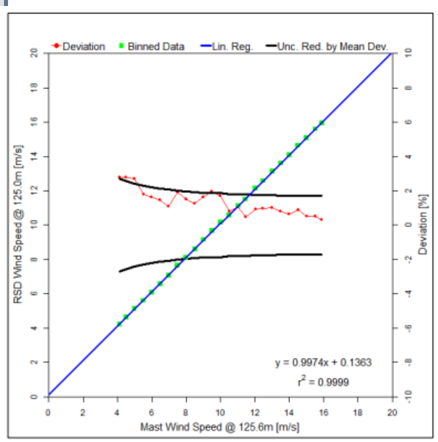

Figure 6.8: 125-m Binned Wind Speed and Deviation

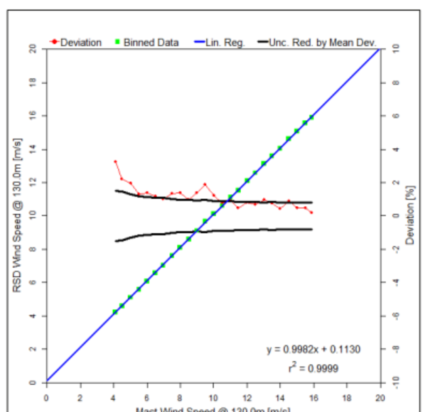

Figure 6.10: 130-m Binned Wind Speed and Deviation

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/)

CALIBRATION REPORT OF LIDAR UNIT "WLS7-436"

PREPARED FOR:
MASSACHUSETTS CLEAN ENERGY CENTER

Report No.: CalibrationReport_WLS7-436

WEST TEXAS
Texas
USA

18 October 2019

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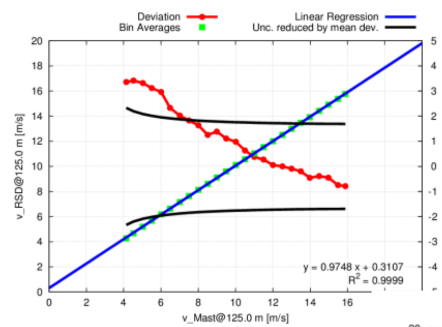

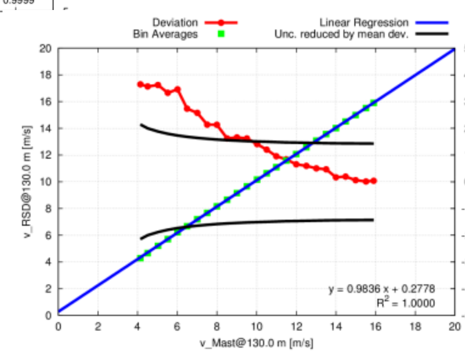

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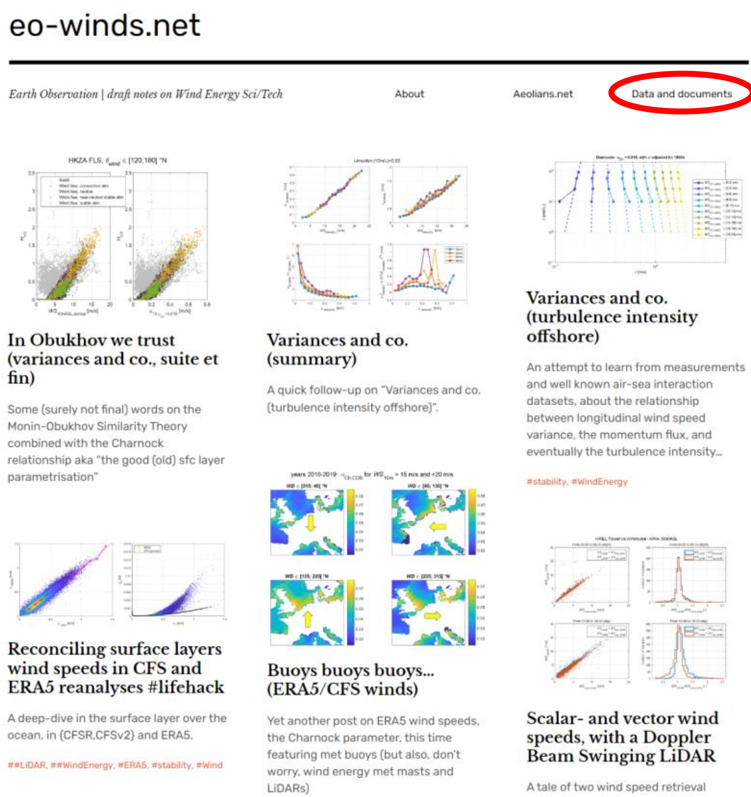
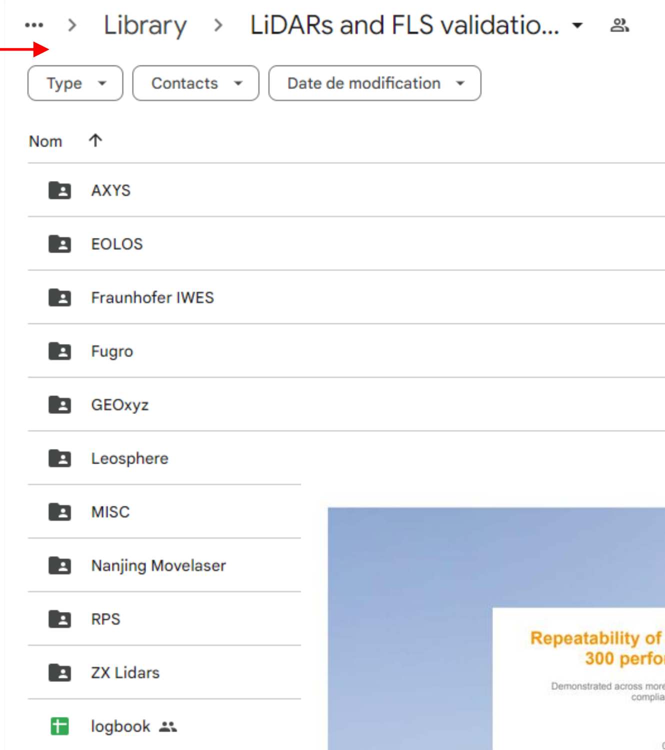
Conclusions

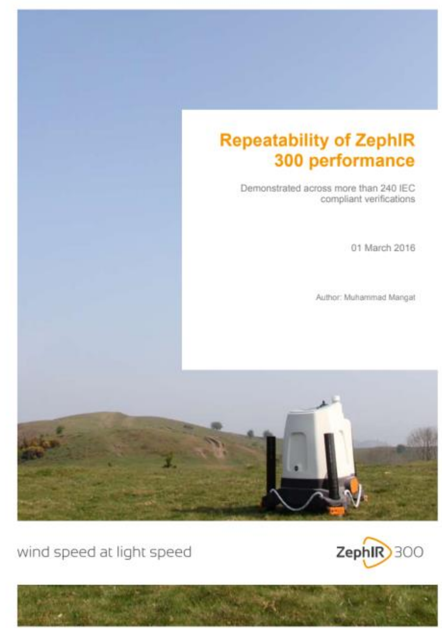
- Onshore LiDAR and FLS uncertainty equal to 2% appears to be too conservative.
- Limited validation studies above 100 mASL show deviation smaller than 2%.
- Most of the validation reports were carried out in well known sites in Europe, atmospheric stability conditions and aerosol content may lead to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

Where to find validation reports (all public)





100+ validation reports, including repeatability studies.



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