Results and conclusions of a floating Lidar offshore test

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[Fraunhofer IWES Wind Lidar Buoy next to FINO1 met. mast]

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- Introduction
  - … Floating Lidar
- Fraunhofer IWES Wind Lidar Buoy
- Offshore test next to FINO1 met. mast
  - … Setup
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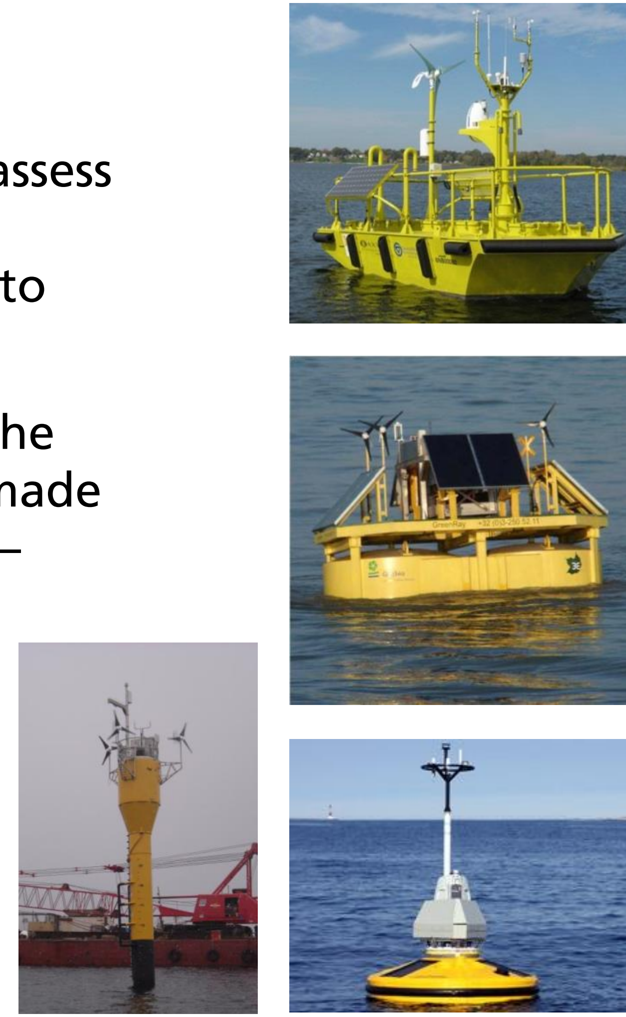
Introduction → Floating Lidar

- Floating-lidar system offer a great potential to assess offshore wind resources,
  and are a cost-effective and flexible alternative to offshore meteorological (met.) masts.
- Development of suitable (for an application in the offshore wind industry optimized) systems has made considerable progress during the last few years –
- Realisations vary in adapted lidar technology, buoy concepts, data handling, power supply, …

  as well as in the consideration of motion effects on the recorded data.



[Selected floating-lidar systems –
© system manufactureres / providers]

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Fraunhofer IWES Wind Lidar Buoy

- Developed within the R&D project 'Offshore Messboje' (funded by BMU, 2011-13), prototype completed in spring 2013
- Floating-lidar system integrating a Windcube® v2 lidar device in an adapted marine buoy ('Leuchtfeuertonne' LT81)
- Buoy dimensions: 7.2 m height, 2.55 m diameter, 4.7 t weight
- Encapsulated lidar device in custom-made housing
- Autonomous power system based on three micro-wind turbines, solar panels, AGM battery banks for energy storage
- Motion-correction algorithm developed by Fraunhofer IWES implemented as part of post-processing

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Offshore test next to FINO1 – Setup

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- Offshore test from 2 Aug – 6 Oct 2013 in 450 m distance (NW direction) to FINO1 met. mast (German North Sea, 45 km offshore)
- Representative offshore conditions: 30 m water depth, yearly-averaged wind speed of 9.9 m/s at 100 m height, mean wind direction SW, sea currents governed by tides
- Floating-lidar system was installed together with bottom-based AWAC system for recording of sea conditions
- Basic procedure of testing (verification / accuracy assessment): comparison of wind data (horizontal 10-min-mean wind speed, wind direction, turbulence intensity) measured by floating-lidar device with data from reference sensors of met. mast (cup anemometers, wind vanes)

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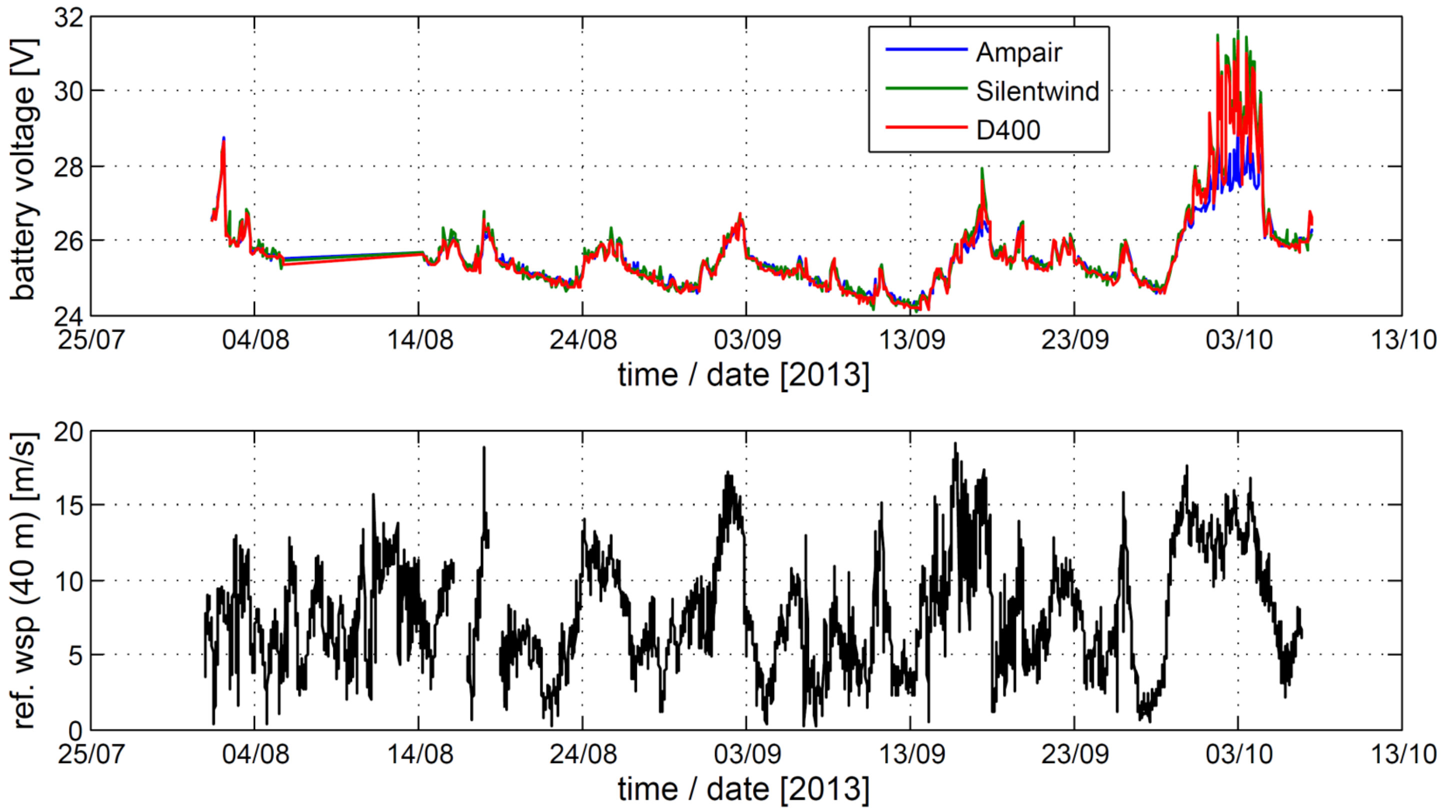
Offshore test next to FINO1 – Results



[Transmitted status data (voltages of battery banks assigned to micro-wind turbines) in relation to reference wind conditions.]

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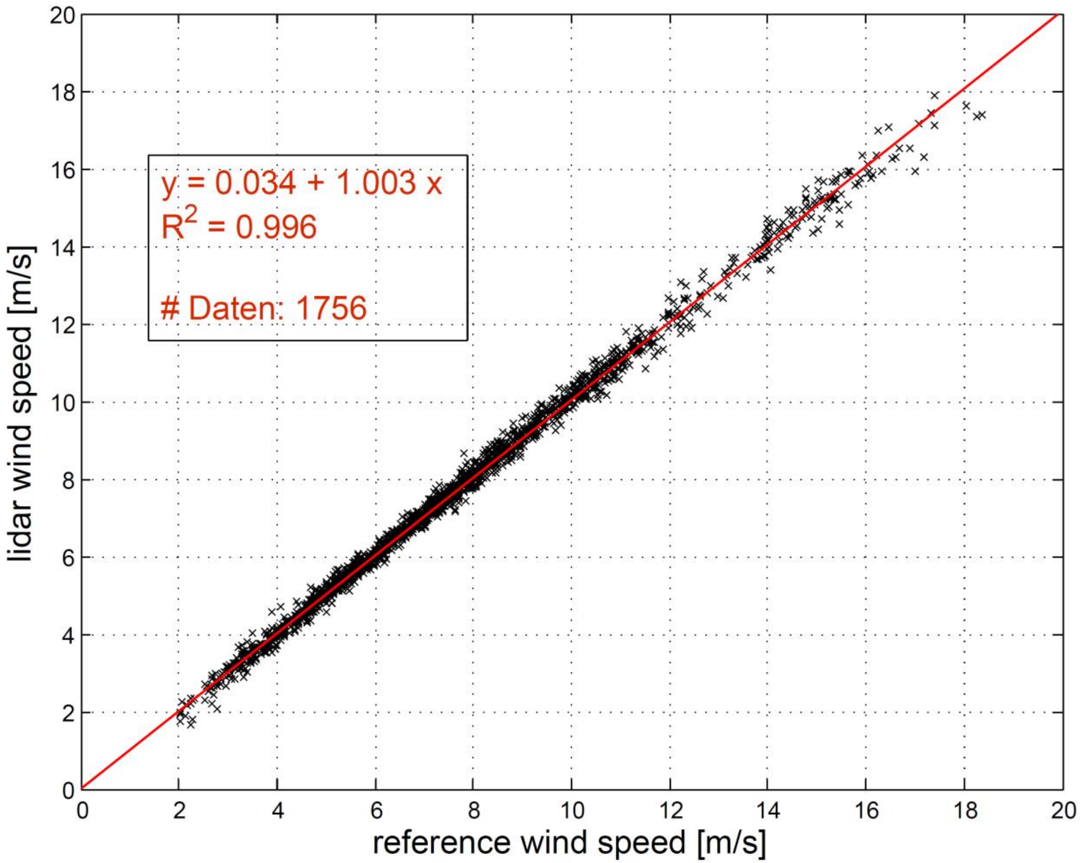
Offshore test next to FINO1 – Results



[Correlation between measured 10-min-mean (horizontal) wind speeds from floating-lidar device and cup anemometers at 100 m measurement height.]

→ very good correlation for uncorrected (!) data

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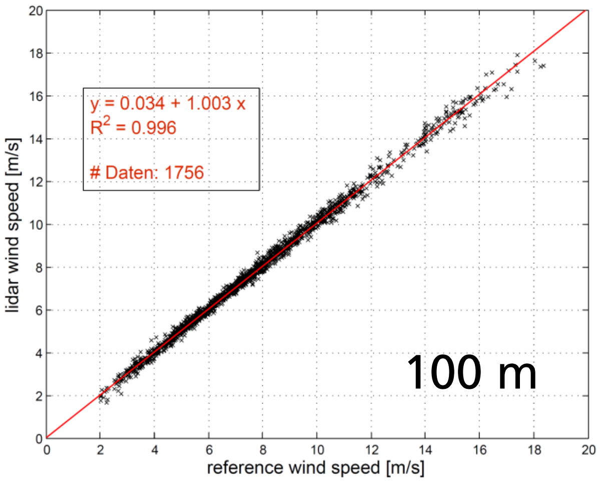
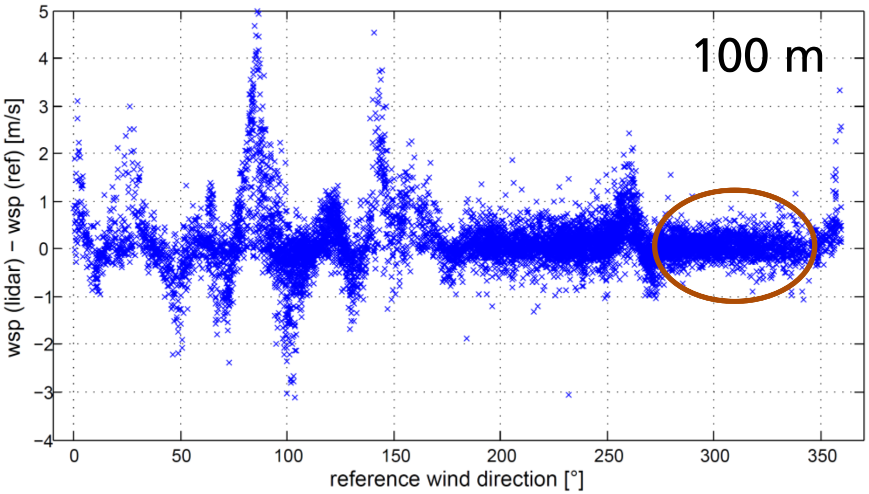
Offshore test next to FINO1 – Results





Correlation results (for measured wind speeds) are obtained for…

- limited wind direction sector and
- top height of meteorological mast.

80 m

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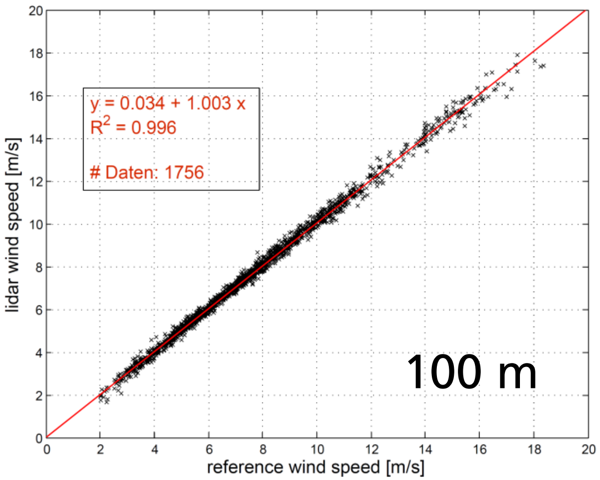
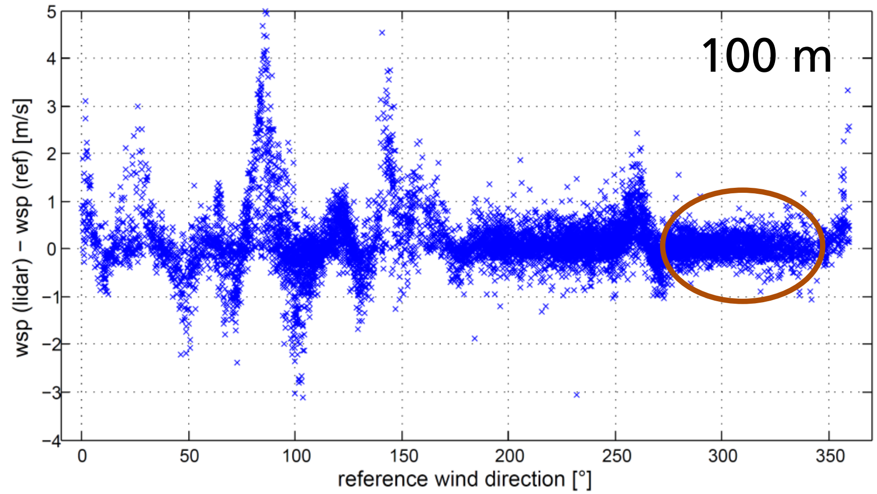
Offshore test next to FINO1 – Results





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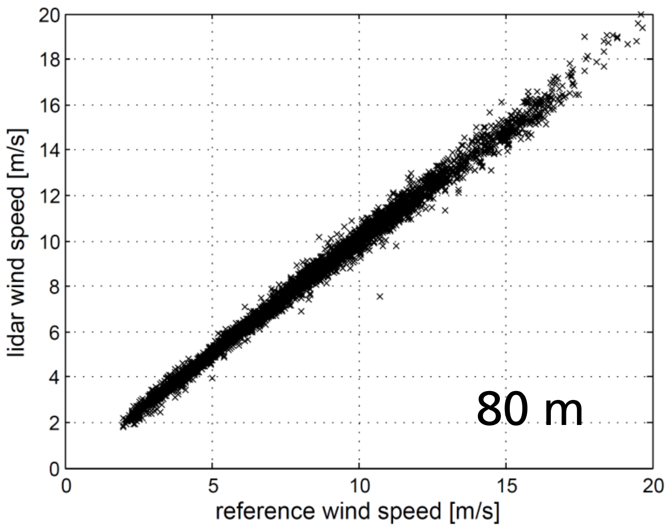

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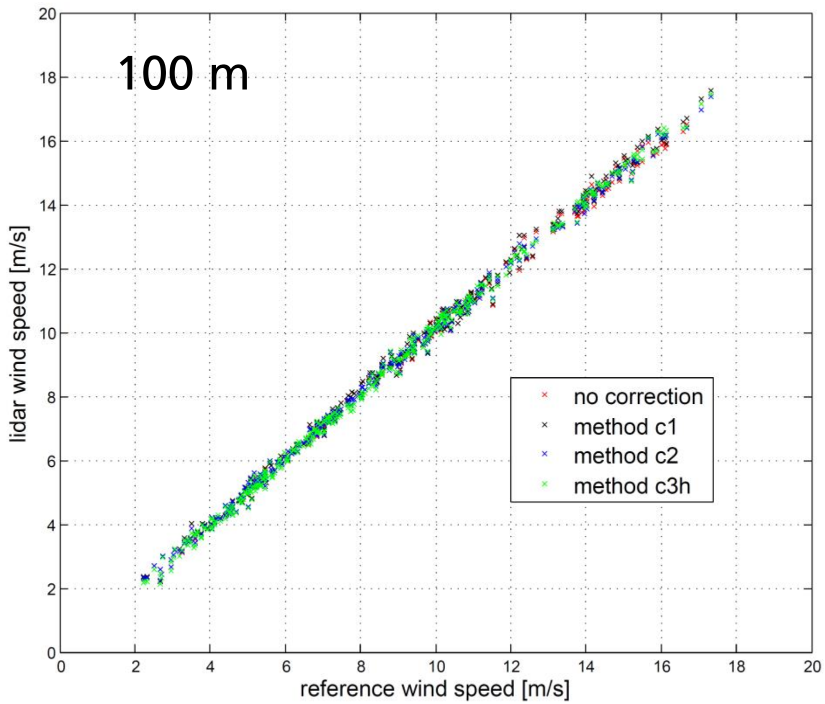
Offshore test next to FINO1 – Results



Application of motion correction (for limited dataset) further improves the correlation between wind measurements from floating-lidar device and reference cup anemometer.

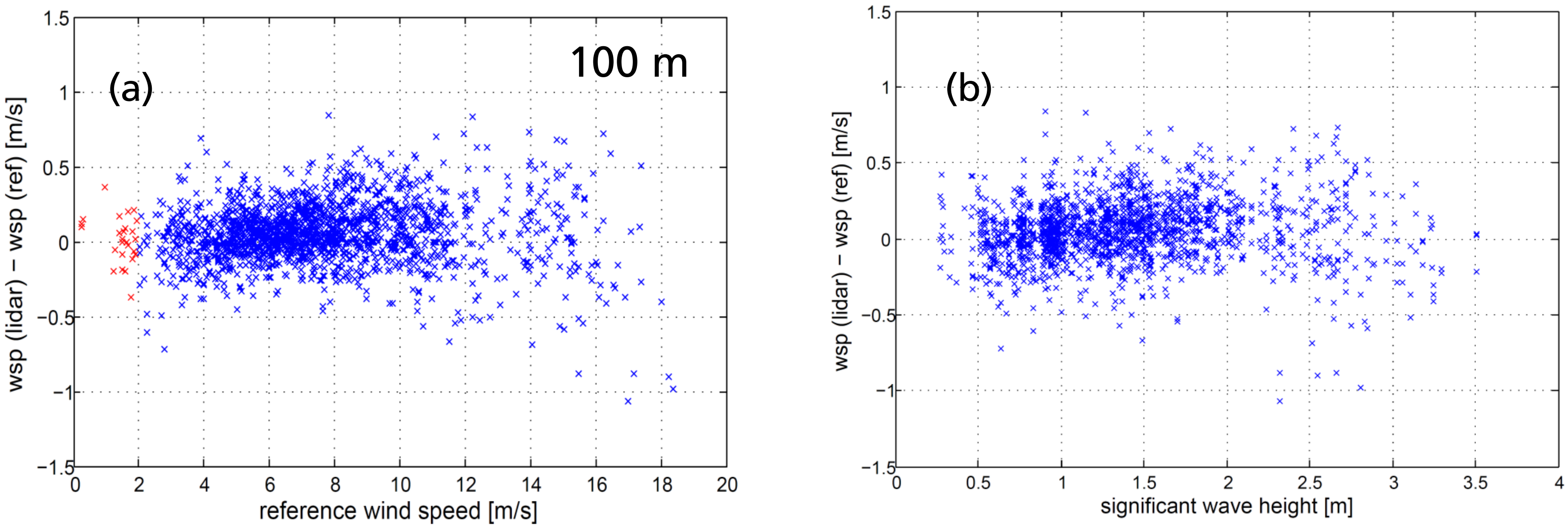
	#data	m [-]	C [m/s]	R^2	k [-]	R^2
no correction	375	1.0039	0.0538	0.9969	1.0092	0.9968
method c1	375	1.0138	- 0.0013	0.9970	1.0137	0.9970
method c2	375	1.0061	0.0241	0.9979	1.0085	0.9978
method c3h	375	1.0170	- 0.0880	0.9978	1.0083	0.9977

Applied linear models:

$y = mx + C$

$y = kx$

Offshore test next to FINO1 – Results



[Deviation in measured 10-min-mean wind speeds from floating lidar* and cup anemometer versus
(a) reference wind speed values and
(b) simultaneously recorded (30-min-mean) significant wave height]

* again uncorrected

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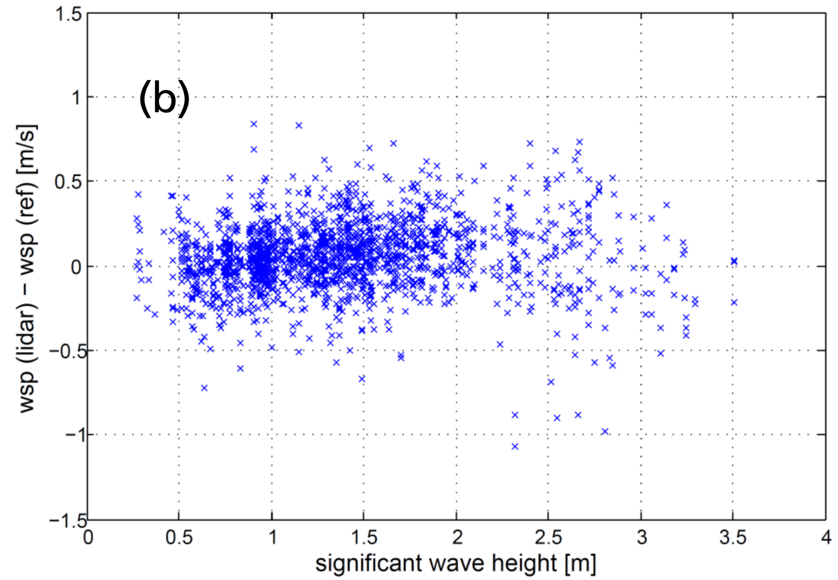
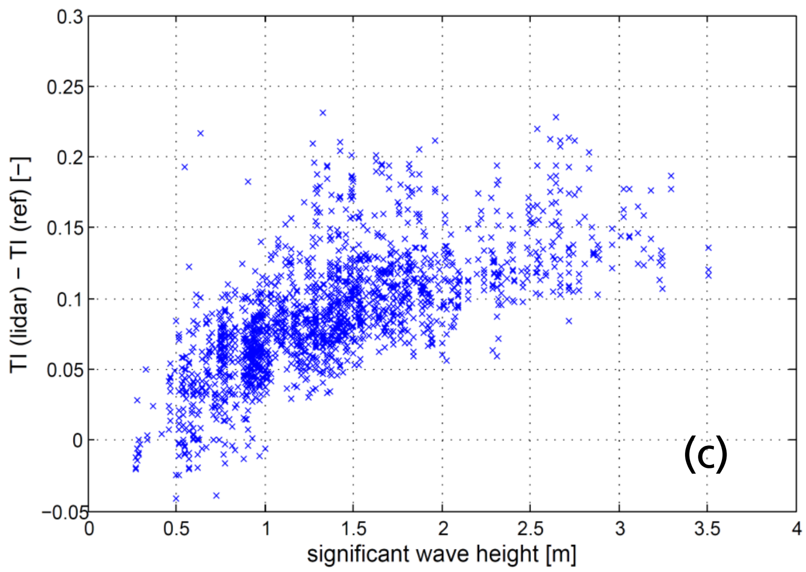
Offshore test next to FINO1 – Results





[← (c) Deviation in measured Turbulence Intensity (TI) values versus significant wave height …]

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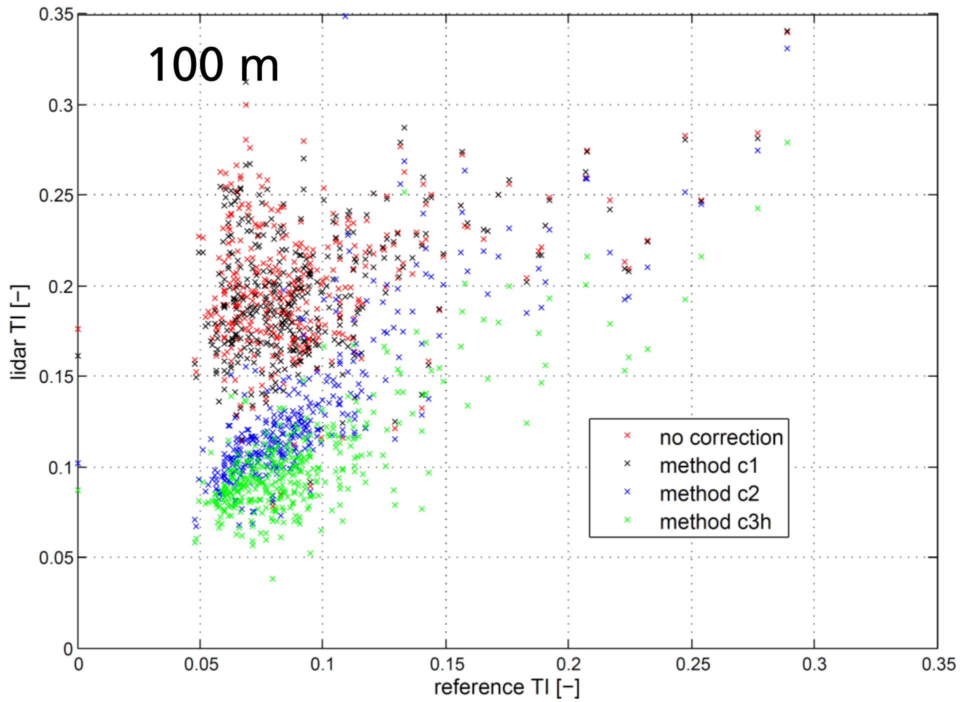
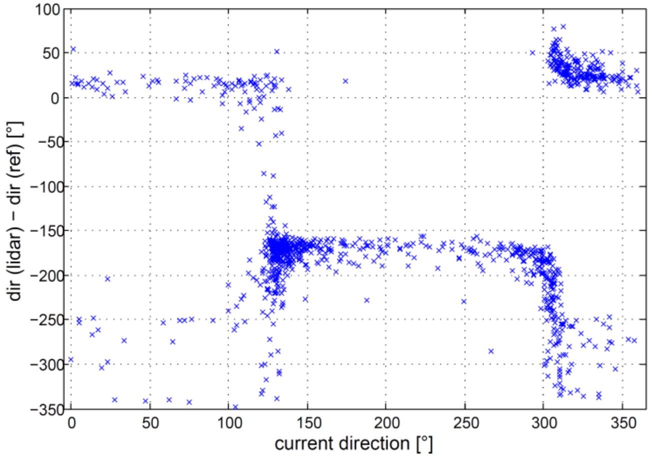
Offshore test next to FINO1 – Results



Application of motion correction (for limited dataset) significantly improves the correlation between TI values based on measurements from floating-lidar device and reference cup anemometer.

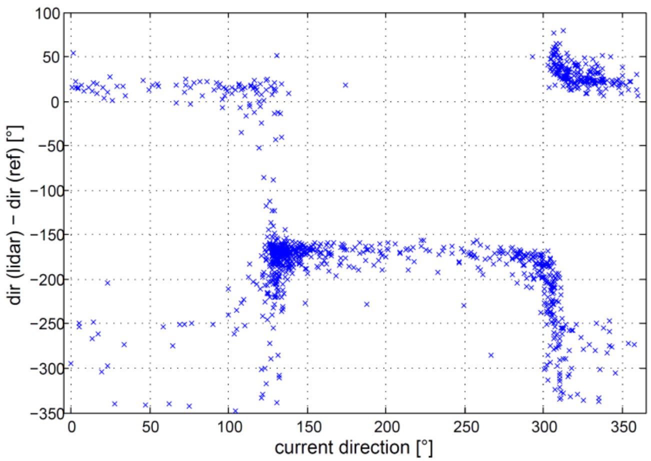
	#data	m [-]	C [m/s]	R^2	k [-]	R^2
no correction	375	(linear regression not applicable)				
method c1	375	(linear regression not applicable)				
method c2	375	0.922	0.042	0.703	1.314	0.556
method c3h	375	0.651	0.042	0.582	1.049	0.332

Offshore test next to FINO1 – Results

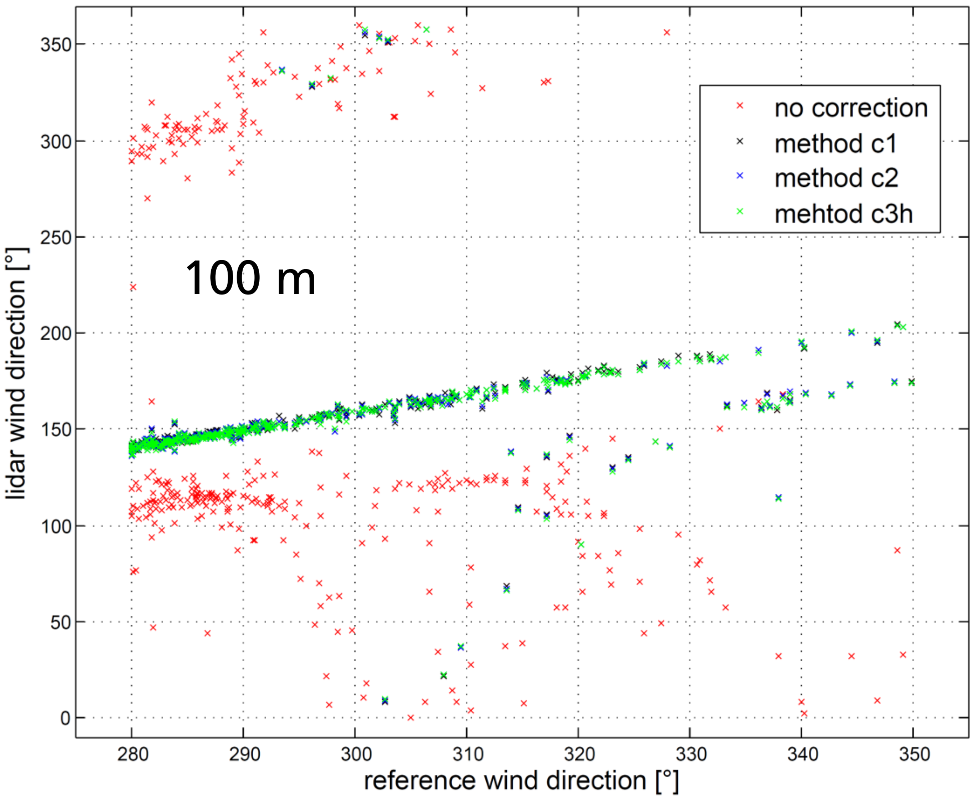


[← Deviation in measured (10-min-mean) wind directions versus current direction …]

Offshore test next to FINO1 – Results



[← Deviation in measured (10-min-mean) wind directions versus current direction …]



Yaw correction basically solves the wind-direction confusion in the measurements of the floating-lidar device.

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Overview

Offshore test next to FINO1 – Conclusions

- Results of floating-lidar offshore test (for Fraunhofer IWES Wind Lidar Buoy) are largely in line with the acceptance criteria for KPIs defined in *Carbon Trust OWA roadmap for the commercial acceptance of floating LIDAR technology* (published Nov. 2013).
- Further analysis (e.g. sensibility study with respect to different external parameters, investigation of motion correction on different levels) extremely helpful to assess the performance of the floating-lidar device under test in more detail → and necessary to estimate the complete uncertainty budget for the final application.
- Further work on Recommended Practices for the use of floating-lidar systems is scheduled within IEA Task 32 WP 1.5 (our results and conclusions will be an input to this work).

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Summary

- Introduction of the Fraunhofer IWES Wind Lidar Buoy as a compact floating-lidar concept with an encapsulated (well-protected) lidar device, a reliable power supply strategy, and an efficient (in-house developed) motion correction algorithm.

- Wind speed measurements show very good correlation with reference data from FINO1 met. mast (in nine-weeks trial from August to October 2013), wind direction and Turbulence Intensity data require motion correction.

- System availability close to 100% (98%) – definition of post-processed data availability depends on needed motion data and applied correction.

- Further work on the Fraunhofer IWES Wind Lidar Buoy is in progress – a second offshore test with a modified prototype is planned for the first half of 2014.

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Thank you for listening.*

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