Research Alliance Wind Energy

# Fraunhofer IWES Wind Lidar Buoy Validation

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DEWEK – 20 May 2015, Bremen

QUALITY SYSTEM CERTIFICATION ISO 9001 DNV

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# Overview

- Introduction / Motivation
- Guidelines for application of floating LiDAR systems
- Fraunhofer IWES Wind Lidar Buoy
- Offshore test(s) next to FINO1 met. mast
- Summary

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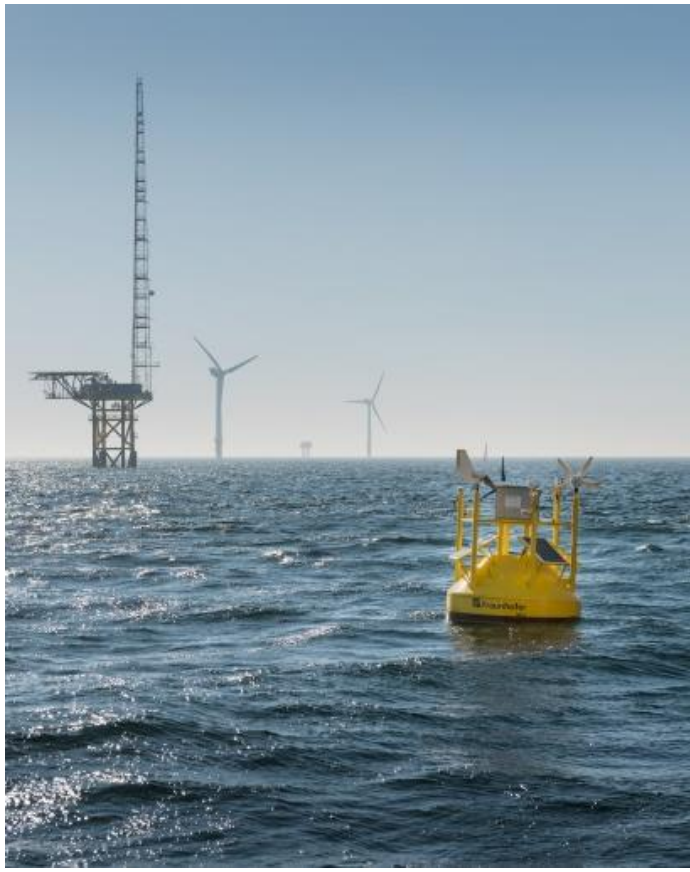
# Challenge: Wind measurements for resource assessment

- Wind speed at hub height (e.g. 100m)
- Very high accuracy required (2-3%)
- Standard solution: Offshore met mast (from onshore wind and met-ocean research)
- Innovative measurement method: Floating wind Lidar
- Much cheaper and more flexible
- Also suitable for deep water



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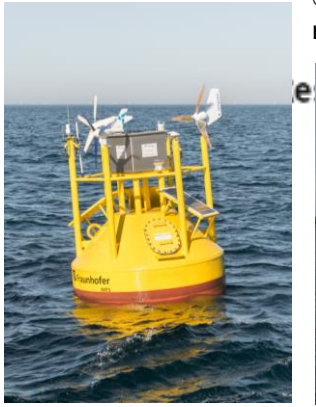
# Introduction / Motivation





- Development of suitable systems has made considerable progress
- Realisations vary in adapted lidar technology, buoy concepts, data handling, power supply, …
- … as well as in the consideration of motion effects
- Floating LiDAR technology was successfully introduced in the offshore wind industry during the last few years
- Bankability of measurement data and industry acceptance to be reached through appropriate validation



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# Challenges related to floating Lidar applications [1]

Offshore environment...

- Harshness of the offshore environment sets requirements on different system components;
- Unstability of environment poses need for adaptibility... to different water depths, wave conditions, currents;
- Limited access and O&M schemes affect availability of system, and reliability;
- Power supply may be a critical issue.

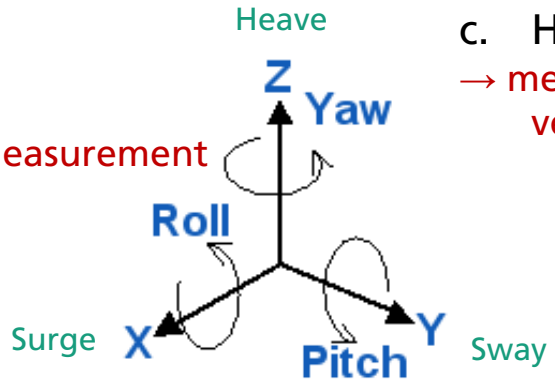
# Challenges related to floating Lidar applications [2]

... for quality of measurements...

Platform-typical motions cause systematic lidar measurement errors – up to six degrees of freedom are to be considered*:

(*depending on... the platform concept, Lidar measurement priciple and the met-ocean conditions)

b. Yaw
→ wind direction measurement




c. Heave
→ measurement height, vertical velocity component

a. Horizontal tilting**
(ie roll / pitch)
→ projection of wind velocity vector (and measurement height)

d. Horizontal translations
(ie surge / sway)
→ added velocity component

**differentiate between static tilt (due to tides or steady currents) and low-frequency periodic tilt (may be averaged out)

# Fraunhofer IWES Wind Lidar Buoy

- Dimensions: 7.2 m height, 2.55 m diameter, 4.7 t weight
- Buoy design based on marine light buoy with decades of track record
- Fully enclosed, integrated Lidar device
- Redundant power supply and large storage
- Motion-correction algorithm developed by Fraunhofer IWES
- Developed and validated for two different Lidar systems (Leosphere and Zephir)

# Guidelines for application of floating LiDAR systems

OWA Roadmap*

- introduced different stages of maturity (Baseline, Pre-commercial, Commercial) with associated prerequisites
- for Pre-Commercial – pilot validation trial with independent confirmation of defined acceptance criteria

IEA Annex 32 WP 1.5 Recommended Practice for floating LIDAR Systems (to be delivered by summer/autumn 2015)

- Guidelines on system configuration, characterisation, assessment of suitability, WRA campaign design and execution;
- Testing includes initial trial for assessment of accuracy, availability and sensitivity to metocean conditions as well as pre-(post-)deployment validations.

* Carbon Trust Offshore Wind Accelerator roadmap for the commercial acceptance of floating LIDAR technology, CTC819 Version 1.0, Nov. 2013

# Offshore tests next to FINO1

- Floating LiDAR offshore test next to (NW direction / met. mast (German North Sea, 45 km offshore);
- representative offshore conditions: 30 m water dept speed of 9.9 ms-1 at 100 m height, mean wind direc governed by tides.

© Fraunhofer IWES / Photograph: Caspar Sessler

- Duration of trials:
- #1 – from 2 Aug. to 6 Oct. 2013
- #2 – from 5 Aug. to 30 Sept. 2014
- #3 – since Jan 2015


http://www.fino-offshore.de/de/

# Accuracy (Leosphere Lidar)

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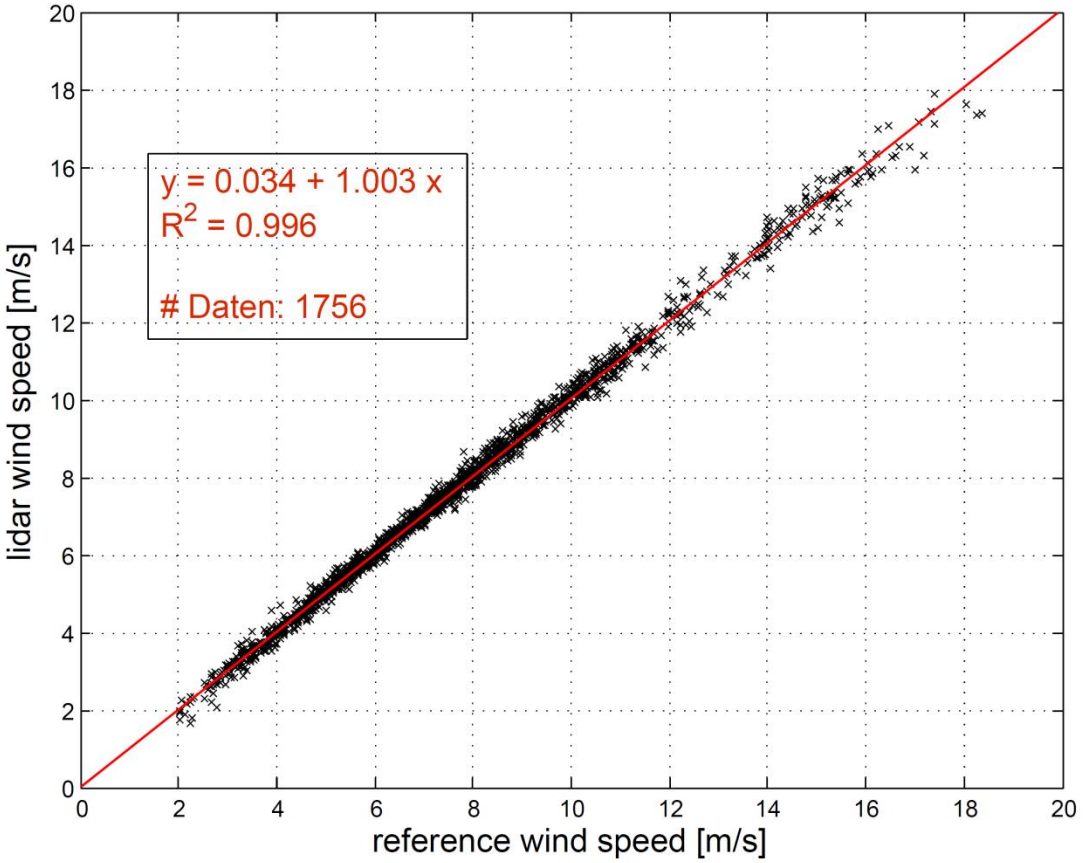


Correlation between Fraunhofer IWES Lidar Buoy (with Leosphere) and Fino 1:

- 100 m measurement height
- 10-min-mean (horizontal) wind speeds

Slope: 1,003

Offset: 0,034

$R^2$: 0,996

→ very good correlation

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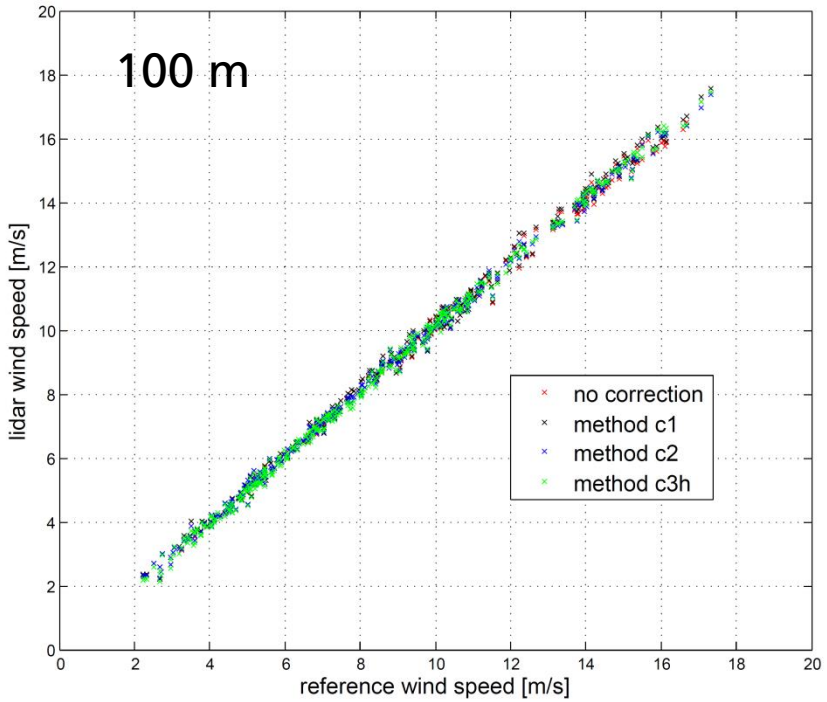
# Motion correction




Application of motion correction (for limited dataset)

- further improves the correlation

| | #data | m [-] | C [m/s] | $R^2$ | k [-] | $R^2$ |
|---|---|---|---|---|---|---|
| **No correction (Leosphere)** | 375 | 1.0039 | 0.0538 | 0.9969 | 1.0092 | 0.9968 |
| **Corrected (Leoshere)** | 375 | 1.0170 | - 0.0880 | 0.9978 | 1.0083 | 0.9977 |

Applied linear models:

$y = mx + C$

$y = kx$

# Fraunhofer IWES Bouy Offshore Test at FINO1 – Results

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| | Fraunhofer IWES Wind-Lidar-Buoy w. Leosphere Lidar | OWA Acceptance Criteria * |
|---|---|---|
| **Monthly System Availability – 1 Month Average** | (Aug.) 97% (Sept.) 99% | ≥ 90% |
| **Overall System Availability – Campaign Average** | 98% | ≥ 95% |
| **Mean Wind Speed – Slope** | 1.01 | 0.98 – 1.02 |
| **Mean Wind Speed – Coefficient of Determination** | 1.00 | > 98 |

* see: Carbon Trust Offshore Wind Accelerator roadmap for the commercial acceptance of floating LIDAR technology, CTC819 Version 1.0, 21 November 2013

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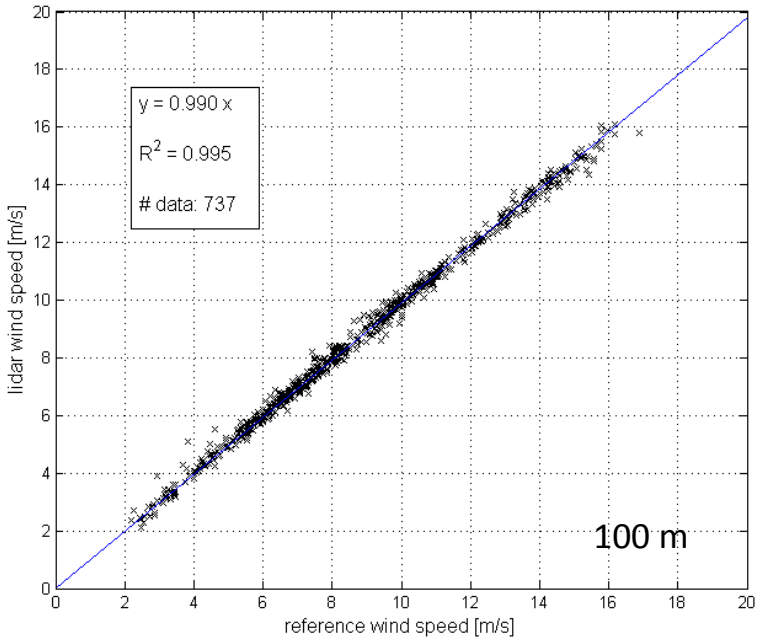
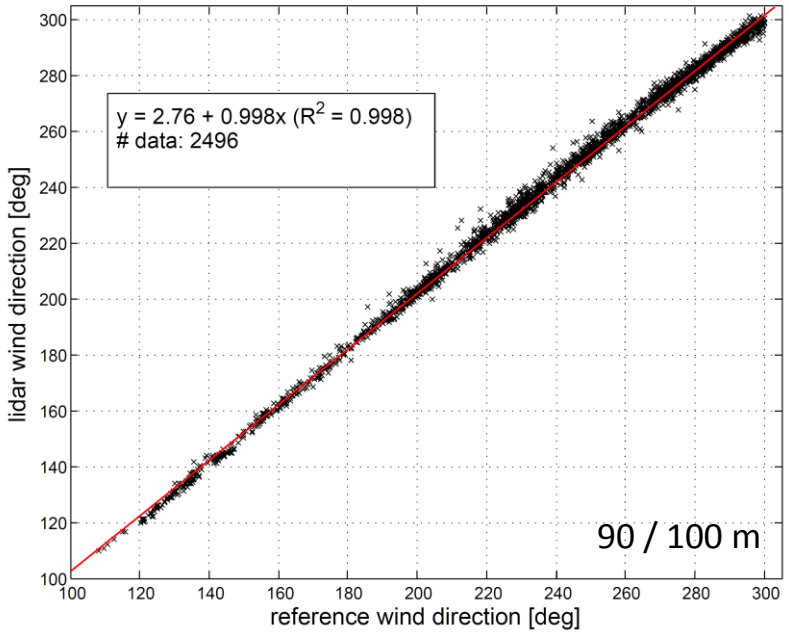
# Accuracy (Zephir Lidar)

Correlation between Fraunhofer IWES Lidar Buoy (with Zephir) and Fino 1:

- 30 days data, 100 m measurement height, 10-min-mean (horizontal) wind speeds
- Slope: 0,99, $R^2$: 0,995 → very good correlation



# Summary / Conclusions

- Testing of floating LiDAR systems offshore as a crucial prerequisite for their application in offshore wind industry / for WRA.
- Reasonable and complete (as possible) guidelines are needed – as well as appropriate reference infrastructures / like e.g. FINO1-3.
- Fraunhofer IWES Wind Lidar Buoy fullfils the Best Practice acceptance criteria of OWA Roadmap for measurement accuracy

# Offshore Wind R&D Conference 2015

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International Conference on R&D for Offshore Wind Energy in the North Sea
Organized by RAVE (Research at alpha ventus)


October 13-15, 2015 in Bremerhaven, Germany

## Deadline for abstracts: 31.5.

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# THANK YOU FOR LISTENING

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