LiDARs

The zapping competition

Tuesday 27 September 2016
14:30 - 16:00 / Hall G2

Chaired by: Mike Courtney
Lars Landberg
Stefan Ivanell

MAKING TRANSITION WORK

Wind EUROPE SUMMIT 2016
27-29 SEPTEMBER
HAMBURG

windeurope.org/summit2016

What will happen next

- 12 x 2 minute summary presentations
  - Please remember your favourtite 3 numbers!
- Voting for the most popular 3
  - There will be a summary slide to help you
  - You can vote 3 times
  - Please don’t vote for your own organisation
- 3 x (12+3) minute presentations

Summary – comes again later!

No.	Presenter	Short title	Votes
1	J. Gottschall	Floating lidar status	
2	W. Langreder	Seasonality kills Roaming Lidar….	
3	A. Clerc	Scanning LiDAR in Offshore Wind	
4	S. Sanquer	Post conversion of complex Lidar data	
5	M. Stephenson	Power Curve Validation using LiDAR	
6	A. Borraccino	V infinity is found!	
7	S. Sanz	A very complex LIDAR validation	
8	M. Zendehbad	Mobile Scanning LiDAR	
9	E.B. des Roziers	Uncertainties from on-site lidar measurements	
10	P. Mazoyer	Turbulence intensity challenges	
11	M. Schmidt	Profound Lidar data correction	
12	H. Mueller	A Novel Lidar System	

No. 1

Presented by: J. Gottschall

Short title: Floating lidar status

Floating Lidar Systems:
Current Technology Status and
Requirements for Improved Maturity

iea wind

task 32 lidar

FRAZER-NASH CONSULTANCY

CATAPULT Offshore Renewable Energy

DNV·GL

SWE Stuttgart Wind Energy @ Institute of Aircraft Design
University of Stuttgart Germany

ECN

NREL NATIONAL RENEWABLE ENERGY LABORATORY

Floating Lidar Systems:

Current Technology Status and Requirements for Improved Maturity

J. Gottschall (Fraunhofer IWES)
B. Gribben (Frazer Nash Consultancy)
J. Hughes (ORE Catapult)
D. Stein (DNV GL)
I. Würth, O. Bischoff, D. Schlipf (University of Stuttgart)
H. Verhoef (ECN)
A. Clifton (NREL)

Wind Europe Summit 2016, Hamburg – 27 September 2016

Fraunhofer IWES

Introduction I

Wind lidar technology…

onshore – accepted as (almost) standard tool

… for wind resource assessments

… power curve tests (in flat terrain)

→ cost-efficient, high data quality

Introduction II

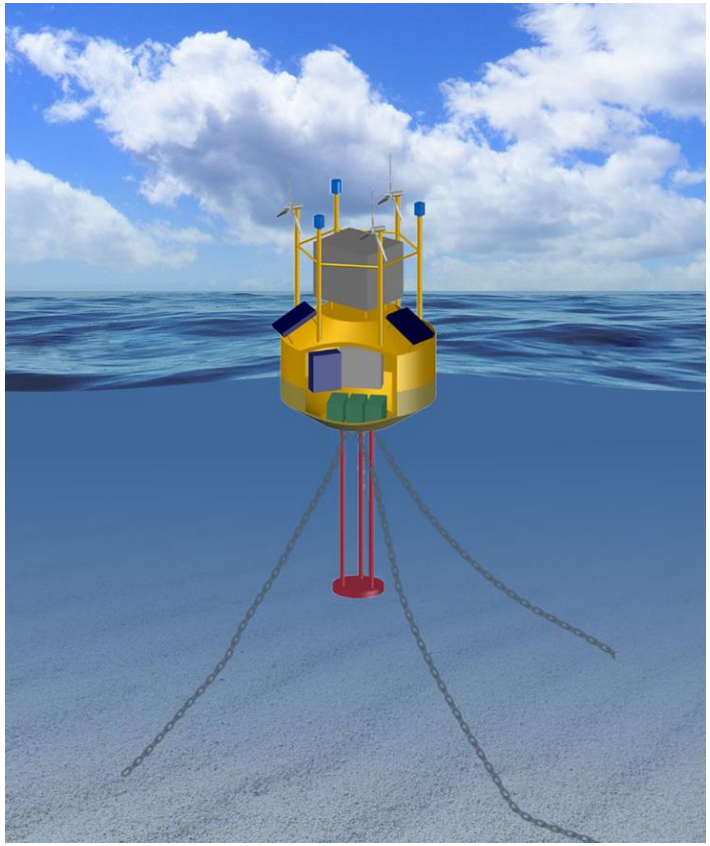
Wind lidar technology…

offshore – even larger cost benefits (!) –

with lidar devices integrated in / on top of

floating platforms or buoys, resp.

(→ *floating lidar systems*)



Introduction III






Variety of realisations / designs available today (→ picture gallery *and others*)

- Recommended configuration, mandatory and optional features?
- Requirements of wind industry on systems?
- Maturity of technology, and present technology gaps?

→ IEA Wind Task 32 activity – incl.

- collection of RP for the use of Floating Lidar Devices (with uncertainty assessment approach)
- technology review
- stakeholder workshop with pre-survey on maturity assessment, identification of most relevant technology gaps

Introduction III






Variety of realisations / designs available today (→ picture gallery *and others*)

- Recommended configuration, mandatory and optional features?
- Requirements of wind industry on systems?
- Maturity of technology, and present technology gaps?

→ IEA Wind Task 32 activity – incl.

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For details and outcome… our full presentation!

http://www.ieawindtask32.org/

Fraunhofer IWES

No. 2

Presented by: **W. Langreder**

Short title: **Seasonality kills Roaming Lidar….**

Roaming Remote Sensing – Quantification of Seasonal Bias

Seasonality kills Roaming Lidar....

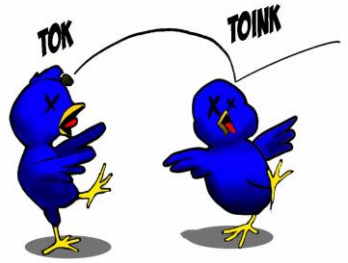
Roaming Remote Sensing – Quantification of Seasonal Bias

Wind Solutions

Wiebke Langreder

September 2016

Back to the basics:



What do you want with a roaming lidar?

- Kill two birds with one stone: More + higher measurements
- Aiming for reduced spatial extrapolation error

In reality you get:

- On some sites you can increase the error by using a roaming lidar compared to just one mast
- You might be better off without …
- Big provocation, right?

Why that?

- You need MCP to connect the data from roaming Lidar with the data from fixed mast

…which can be seasonally biased

- So, we trade spatial extrapolation error ⟷ seasonal bias

Pest ⟷ **Cholera**

How to quantify?

- Take two masts on one site, plot ratio of wind speed measurements from each mast against time

How to find out?

- Large seasonal variations
- Consequently, a short-term roaming lidar campaign will suffer from a seasonal bias when MCPed ☹

- The good news: Not on all sites! ☺

If you let me, I will show

- how to identify these sites
- So you can make a QUALIFIED decisions to design cost-effective measurement campaigns!

No. 3

Presented by: A. Clerc

Short title: Scanning LiDAR in Offshore Wind

Field testing scanning LiDAR systems in Dublin Bay

Scanning LiDAR in Offshore Wind

Field testing scanning LiDAR systems in Dublin Bay

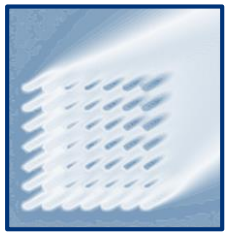
Michael Stephenson and Alex Clerc

Wind Europe Summit, 27th September 2016

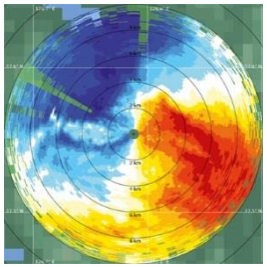
The opportunity

Technology	Disadvantages
Met Mast LiDAR	• High upfront cost • No spatial variation
Floating LiDAR	• No spatial variation
Scanning LiDAR	• Limited validation

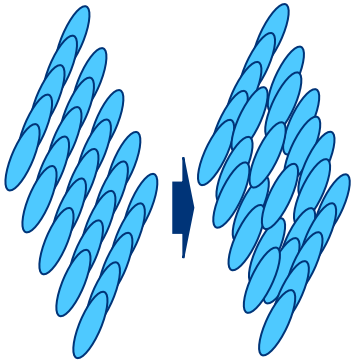
Wake uncertainties reduced



Wake models improved



Greater understanding of wind resource



Layouts optimised

The solution - Scanning LiDAR field trials

CARBON TRUST

CARBON TRUST

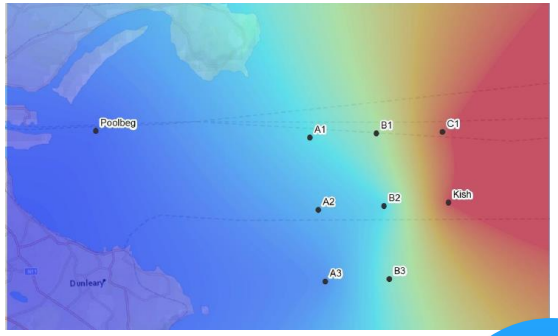
res powering change

Commissioners of IRISH LIGHTS | Navigation and Maritime Services

LEOSPHERE THE ATMOSPHERE IS YOURS

LOCKHEED MARTIN

The results



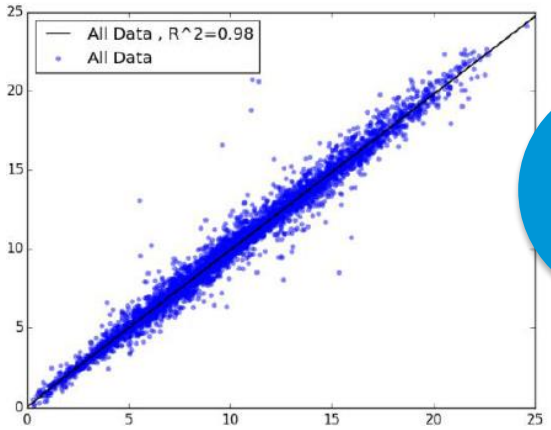
Lessons learned

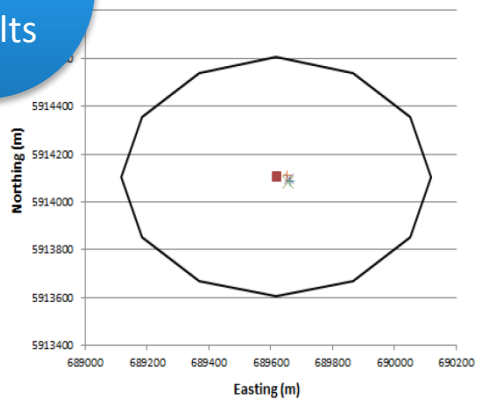
Wind density maps

Outcome

Single Doppler results

Dual Doppler results



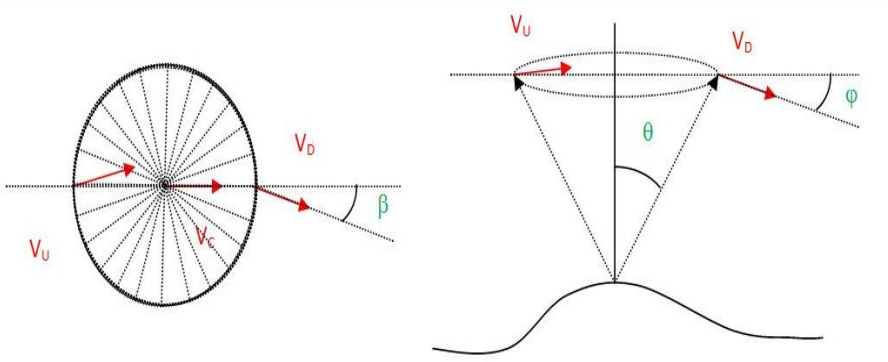


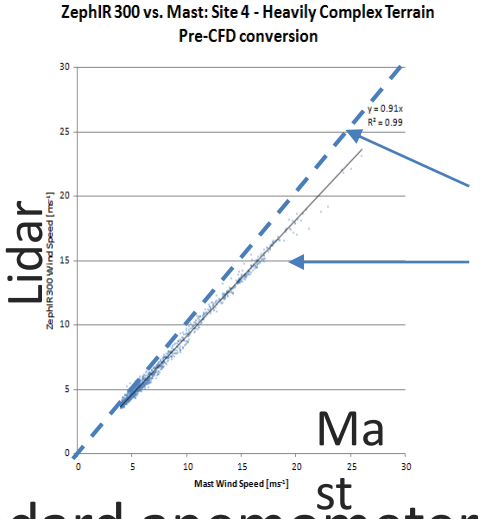
No. 4

Presented by: S. SANQUER

Short title: Post conversion of complex Lidar data

Post conversion of Lidar data on complex terrains



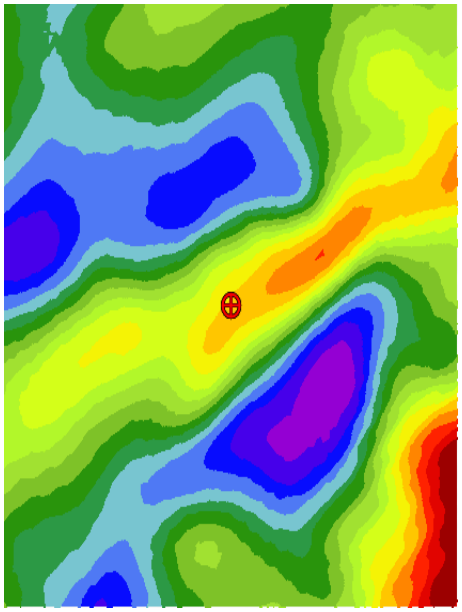


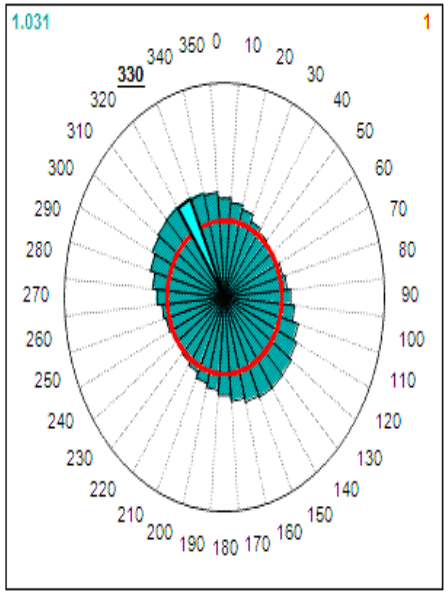
Flat terrain
Complex terrain

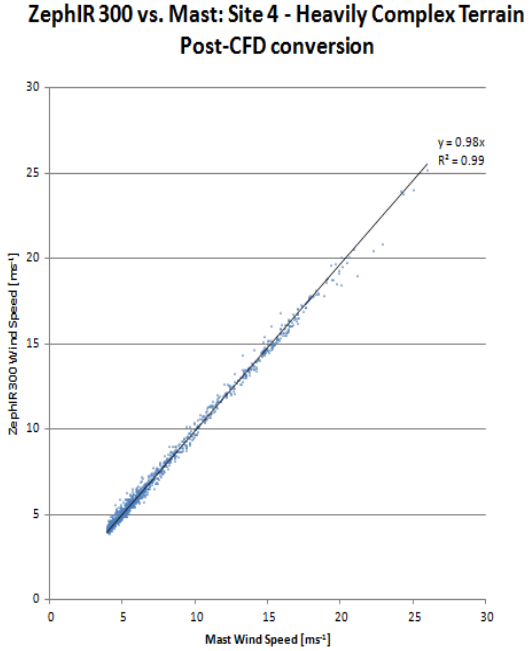
Some discrepancies may appear with standard anemometers above complex terrains => Post conversion of data

Level of terrain complexity

Applying CFD conversion to data from ZephIR 300 in complex terrain improves the agreement between wind speed measurements from RSD and masts







When should we use the post-conversion : level of terrain complexity ?

No. 5

Presented by: M. Stephenson

Short title: Power Curve Validation using LiDAR

Assessing the potential to validate turbine power curves using TP, nacelle and floating LiDAR

Power Curve Validation using LiDAR

Assessing the potential to validate turbine power curves using TP, nacelle and floating LiDAR

Michael Stephenson and Alex Clerc

Wind Europe Summit, 27th September 2016

Introducing the OWA

CARBON TRUST

¾ of installed capacity in Europe

- Objective to reduce cost of offshore wind to <£100MWh
- 5 research areas
  - Wakes and Wind Resource
  - Foundations
  - Access
  - Cable Installation
  - Electrical Systems
- £88m programme spend to date
- Research co-funded by UK and Scottish governments

The problem – power curve validation

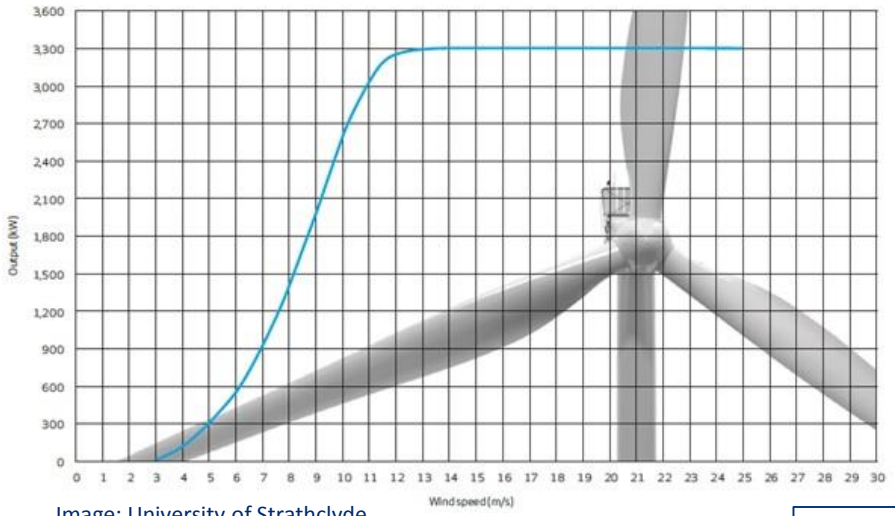


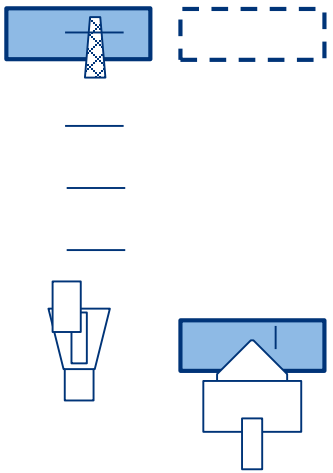
Image: University of Strathclyde

- **Why?**
  - Reduce risk
  - Optimisation
  - Maximise yield

Reliable…but expensive

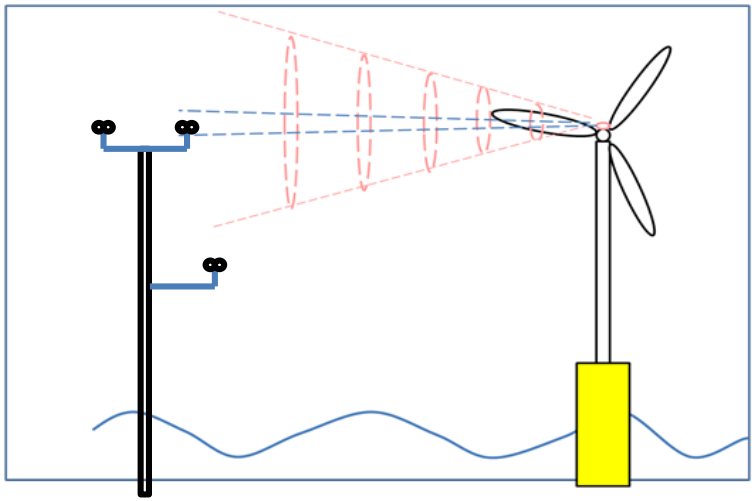
- **How?**
  - Met mast
  - LiDAR (TP, nacelle, floating)

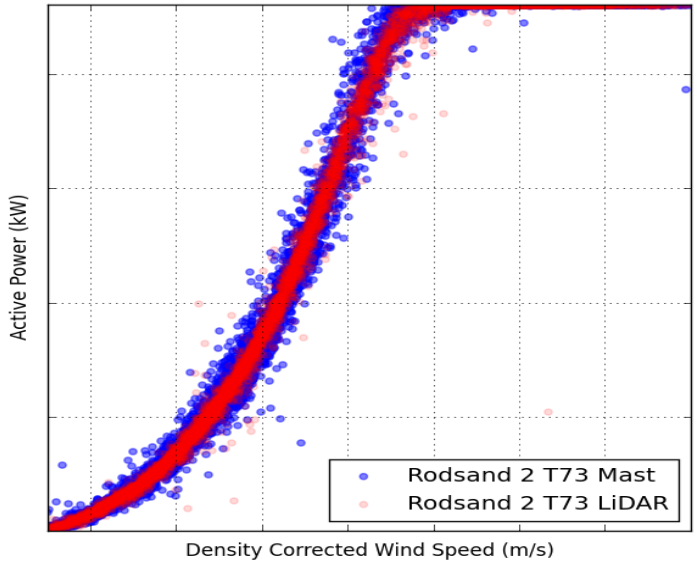
Cheaper and more flexible…but financiers see them as a risk and 'unproven'



The solution

- Evaluate current data
- Benchmark LiDAR – TP, nacelle and floating
- Test and prove…





- Nacelle
  - 5 datasets
- Scanning
  - 2 datasets
- Floating
  - 2 datasets

No. 6

Presented by: A. Borraccino

Short title: V infinity is found!

Near flow measurements with nacelle lidars:
the future of power performance verification?

Near flow measurements with nacelle lidars: the future of power performance verification?

ZephIR Dual-Mode

5-beam Avent demonstrator

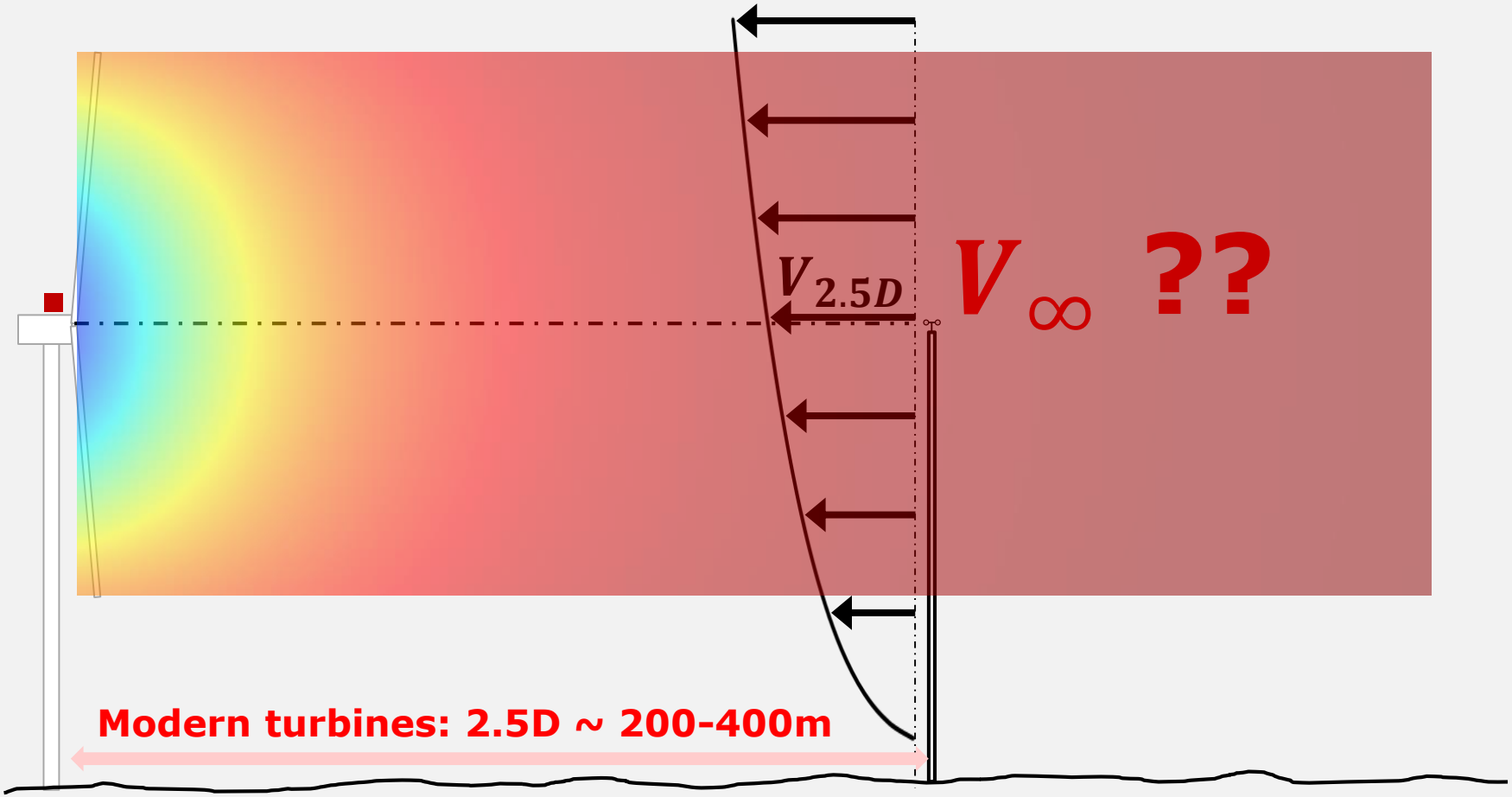
***A. Borraccino**, R. Wagner, DTU Wind Energy, borr@dtu.dk*

D. Schlipf, F. Haizmann, Stuttgart Wind Energy

DTU Wind Energy
Department of Wind Energy

Innovation Fund Denmark
RESEARCH, TECHNOLOGY & GROWTH

Searching for free stream wind speed



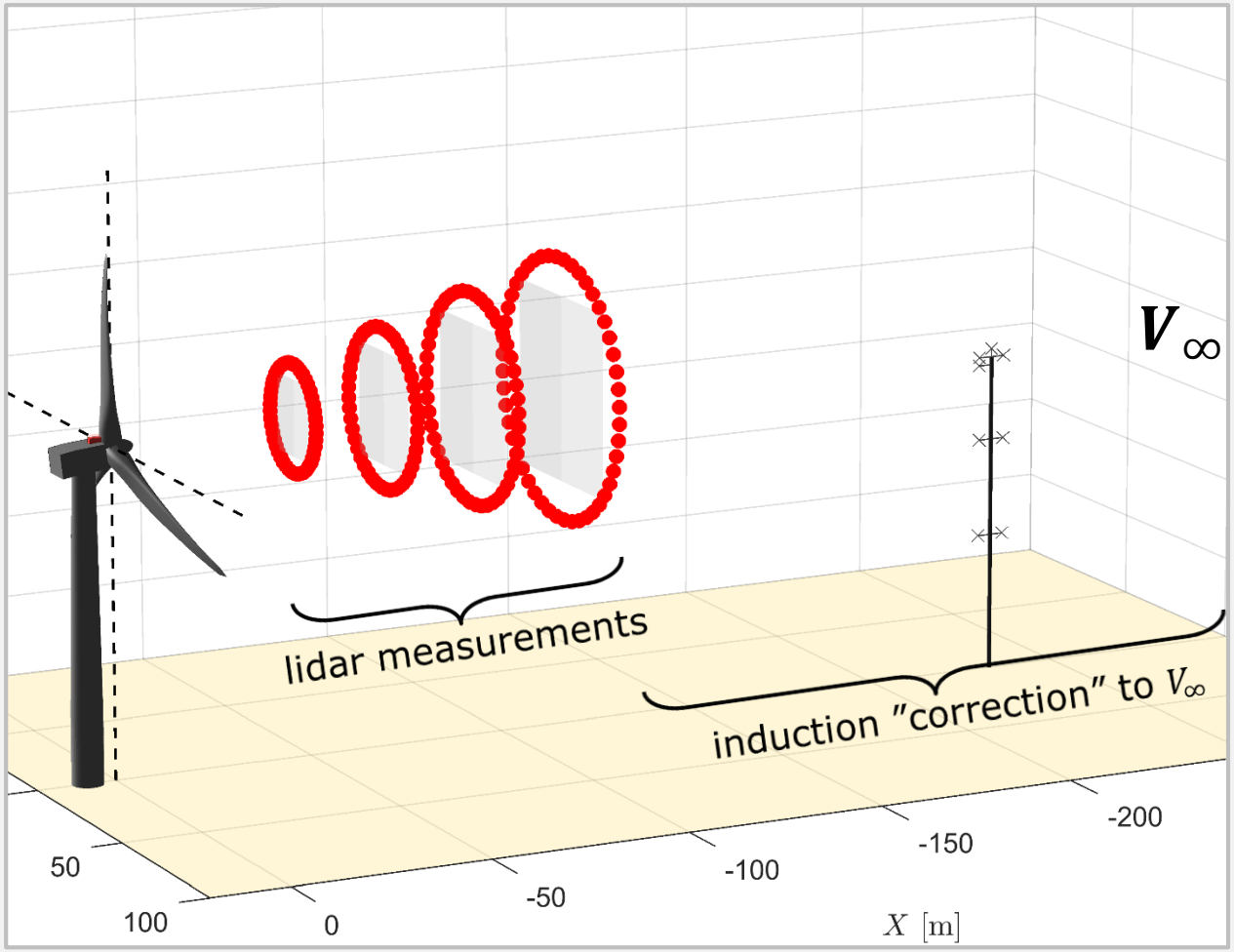
Does this make it any easier?

Perdigão.
credit: N. Vasiljevic

Or this?

Measuring multi-ranges close to the rotor is the solution!

- We can get V_∞ by fitting a simple induction model to nacelle lidar measurements at multiple ranges



- Vote! abstract ID:133
  - find out how
  - power curve & AEP results

borr@dtu.dk

No. 7

Presented by: S. Sanz

Short title: A very complex LIDAR validation

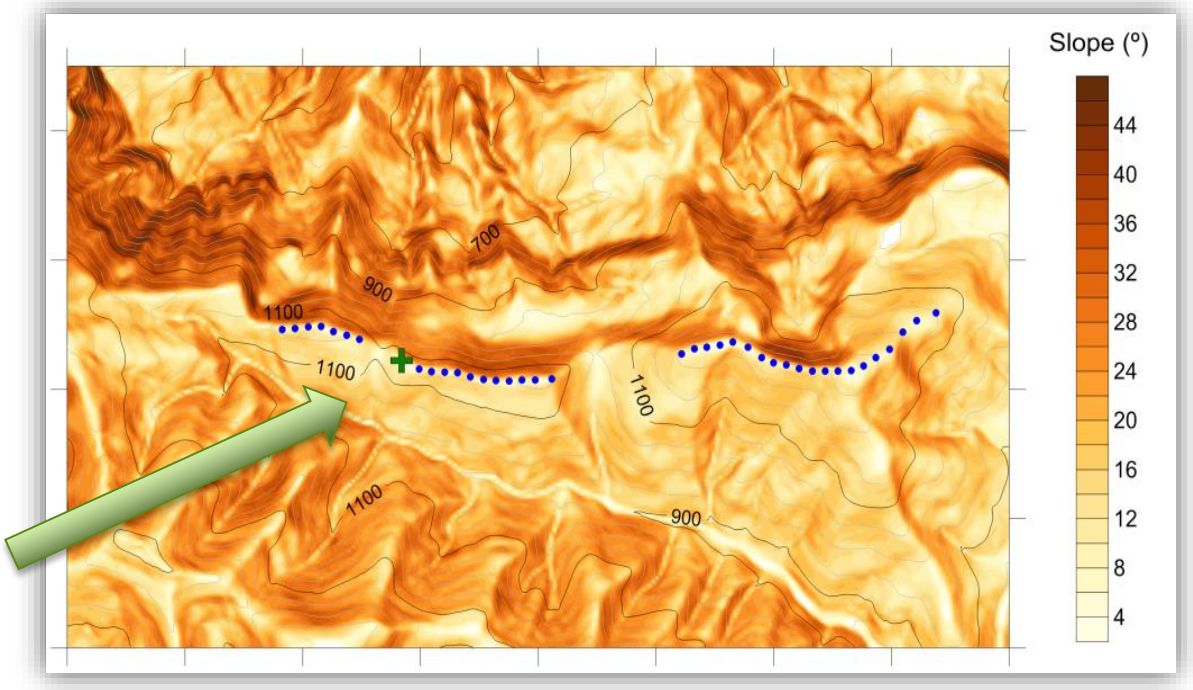
Validation of LIDAR measurements in extremely complex terrain

IBERDROLA
Engineering & Construction

Wind Europe Summit
September 2016

Validation of LIDAR measurements in extremely complex terrain

An extremely complex site for LIDAR testing



Comparison of LIDAR and mast measured variables as *mean wind speed or turbulence intensity*

Some interesting analysis and results

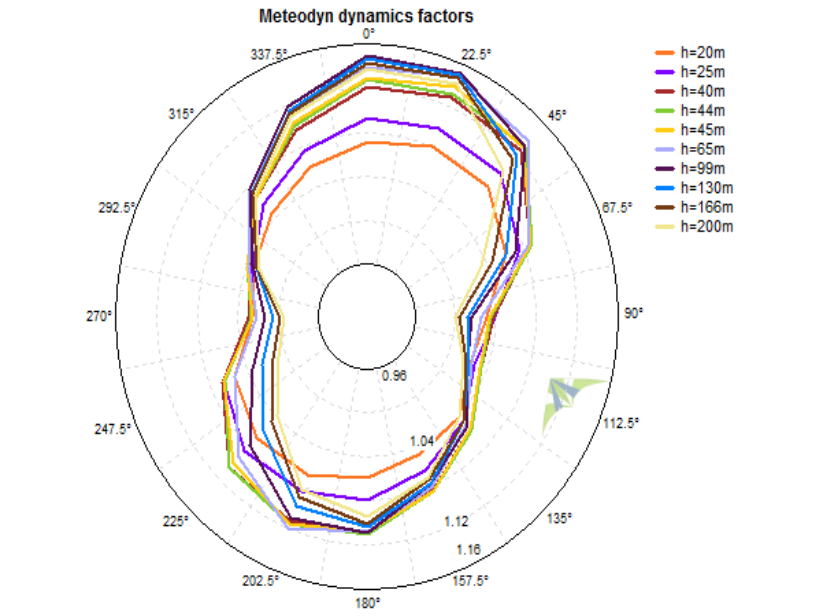
A ***suitable set of dynamic correction factors*** was found and ***LIDAR-mast WS BIAS was reduced in an almost 10%*** (!!)

Significant ***decrease in data availability with height*** was related with site climatology

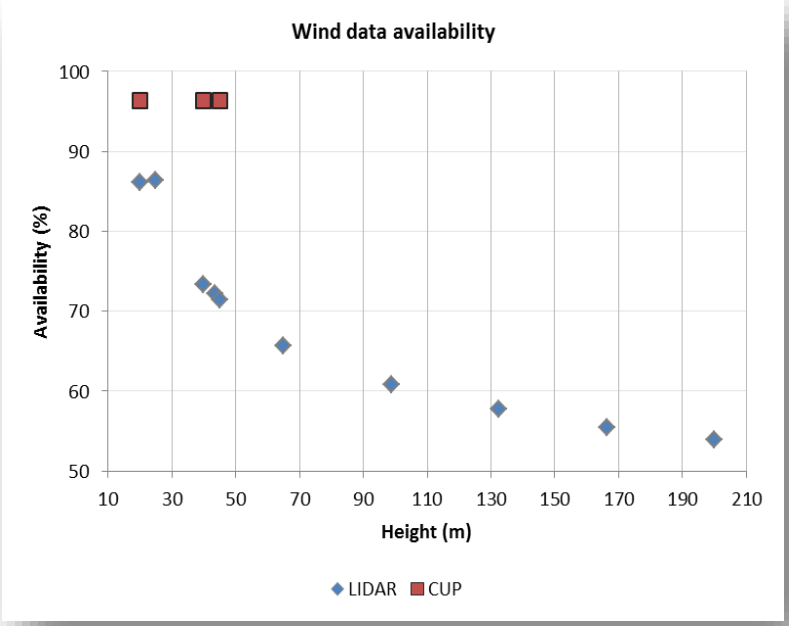
Focus on ***Site Assessment*** and ***directional analysis*** of variables as TI

Graphs preview

Directional correction factors at different heights (36 sectors from 20 to 200m)



Evolution of LIDAR (blue) and CUP (red) wind data availability with height



No. 8

Presented by: M. Zendehbad

Short title: Mobile Scanning LiDAR

Wind-Farm-Scale Measurements Using Mobile-Based LiDAR

ETH
Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

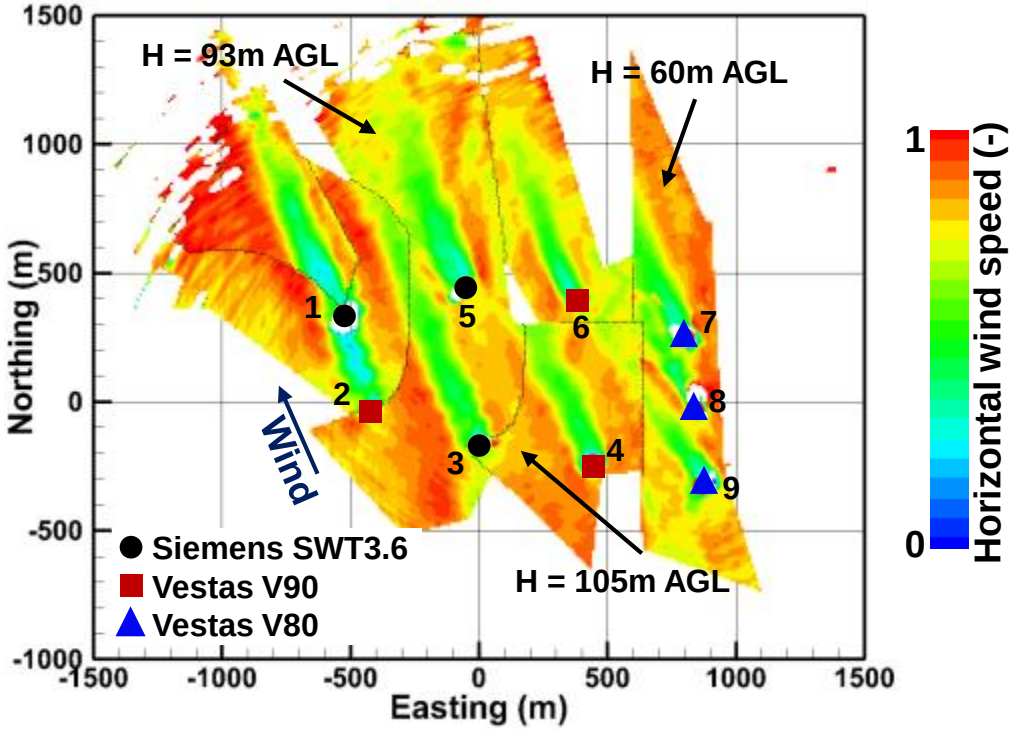
LEC
Laboratory for Energy Conversion

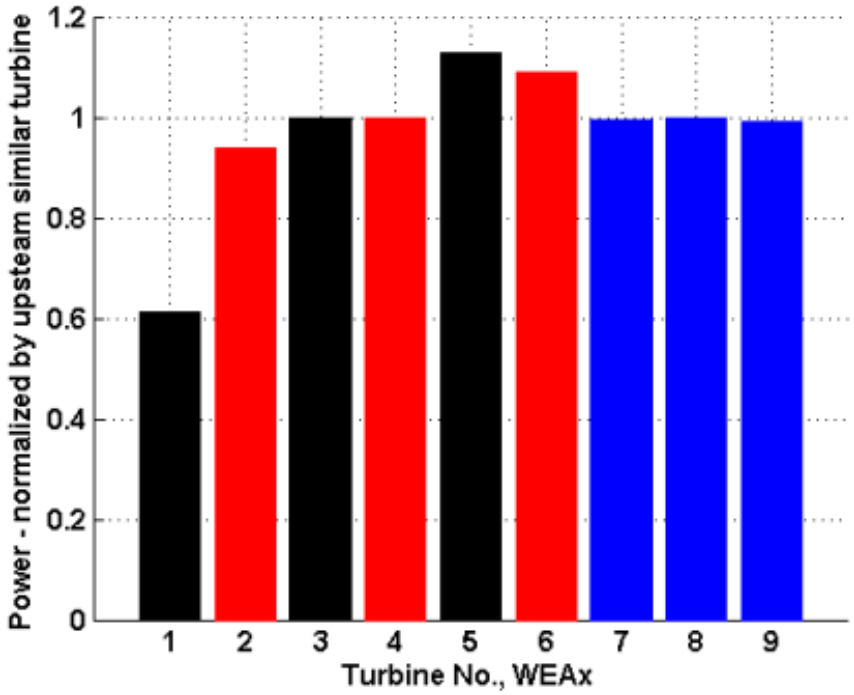
Wind-Farm-Scale Measurements Using Mobile-Based LiDAR

M. Zendehbad, N. Chokani, R.S. Abhari
ETH Zurich, Switzerland

WindEurope Summit 2016
27 September 2016

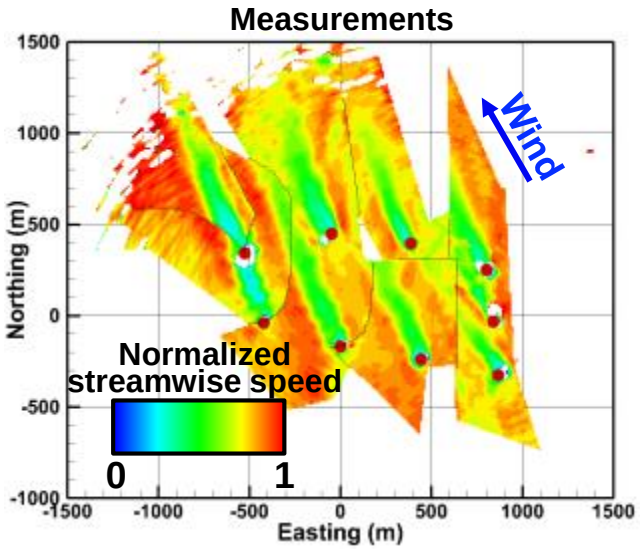
Measurements Made in Utility Scale Wind Farm

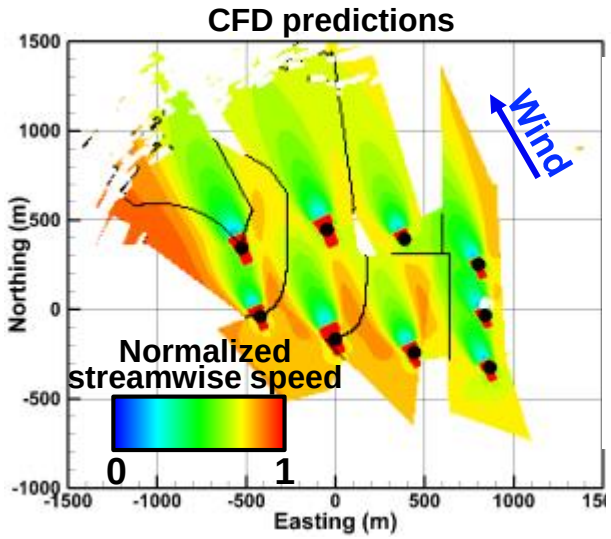


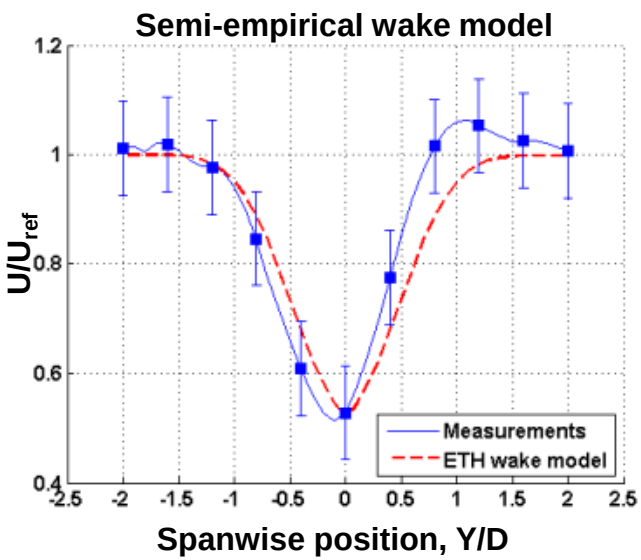


- Using one mobile scanning LiDAR, we have measured flowfield including wakes, in 26MW wind farm
- Wakes result in both underperformance and overperformance of wind turbines

Measurements Are Used to Validate Prediction Tools







- Predictions from CFD and semi-empirical wake model show good agreement with our field measurements
- New measurement approach is well suited to improve performance of wind farms in flat and complex terrain

No. 9

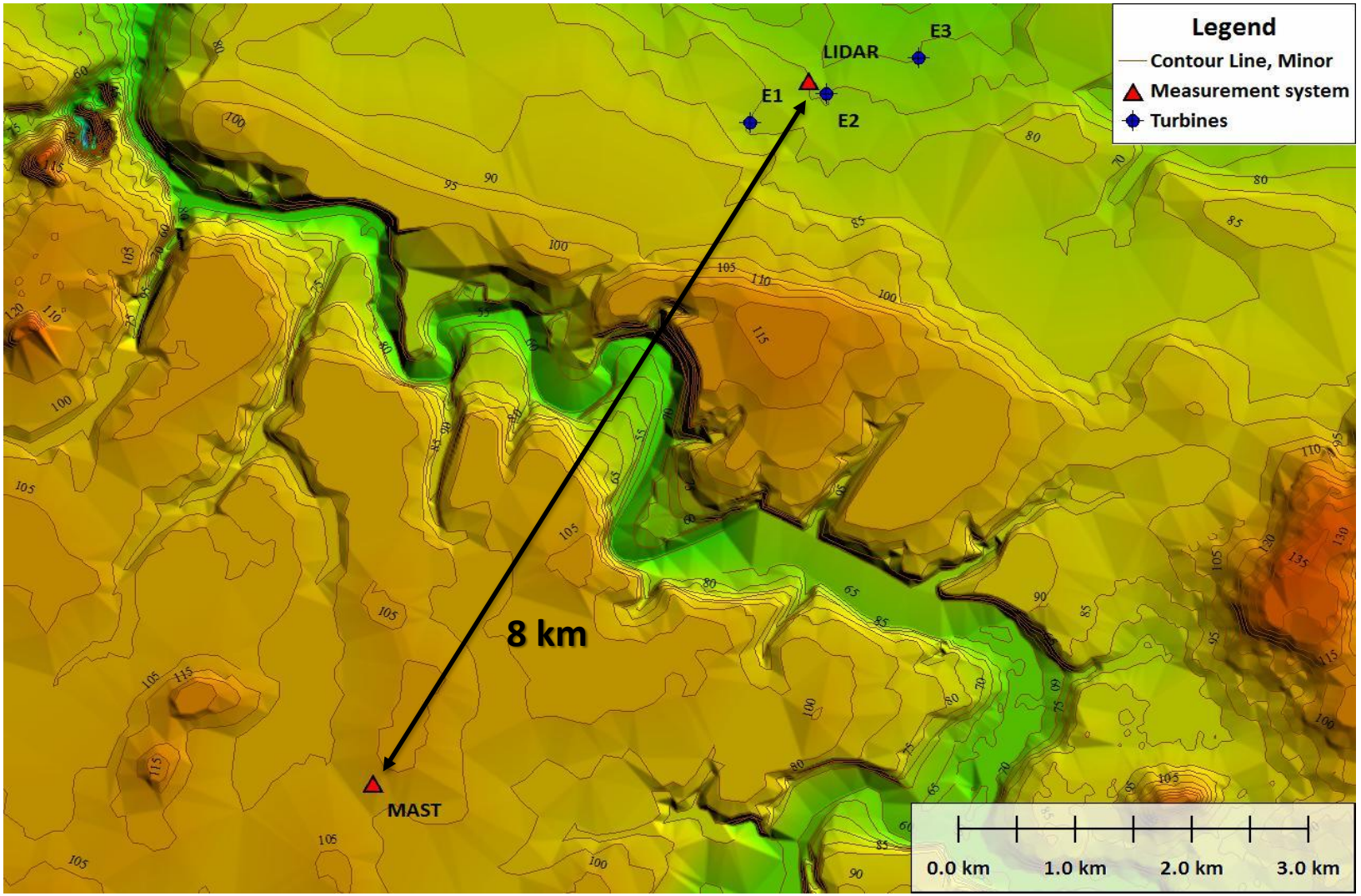
Presented by: E. B. des Roziers

Short title: Uncertainties from on-site lidar measurements

Comparison of Uncertainties in Wind Resource Assessment With and Without On-site LiDAR Measurement

Comparison of Uncertainties in Wind Resource Assessment With and Without On-site LiDAR Measurement

Edward Burin des Roziers, Anaïs Madaule, Jérémy Tahar, Stéphanie Pham, Julien Leon



Two approaches to wind measurement strategy

Approach 1: Mast Only

- Correction of mast data with long-term data source (MERRA)
- Wind characteristics at target site (~8 km) (WASP)

- Calculation of turbine production and uncertainties
- Exceedance probabilities

Approach 2: Mast + LiDAR

- Extension of LiDAR data to 2 years using mast data (MCP)
- Correction of LiDAR data with long-term data source (MERRA)
- Wind characteristics at target site (WASP)

- Calculation of turbine production and uncertainties
- Exceedance probabilities

Comparison of Strategies

Uncertainties

- LiDAR: classification and calibration
- MCP: correlations between the LiDAR and the reference mast
- Spatial extrapolation: distance between mast location to target site

Important questions

- How do the uncertainties balance out against each other in this case?
- What affect does this have on exceedance probabilities?
- Considerations for other cases?

No. 10

Presented by: P. Mazoyer

Short title: Turbulence intensity challenges

Turbulence intensity measurement techniques for pulsed LIDARs – the current status

Turbulence intensity challenges

Lidar TI measurement?

2015, IEA Task 32 reported

"lidars […] do not exhibit any significant limitation in the technology. […] Some additional tricks […] in either post-processing or scanning configurations are therefore required to obtain meaningful turbulence quantities . "

Machine learning

NREL NATIONAL RENEWABLE ENERGY LABORATORY

+ Improvements shown
- Works on conditions similar to the conditions used for learning the correction

« SLEMT » Model

DTU Technical University of Denmark

+ Improvements shown
+ « Easy » to apprehend and use
- Correction derived for simple homogeneous terrain only
- Requires atmospheric stability information

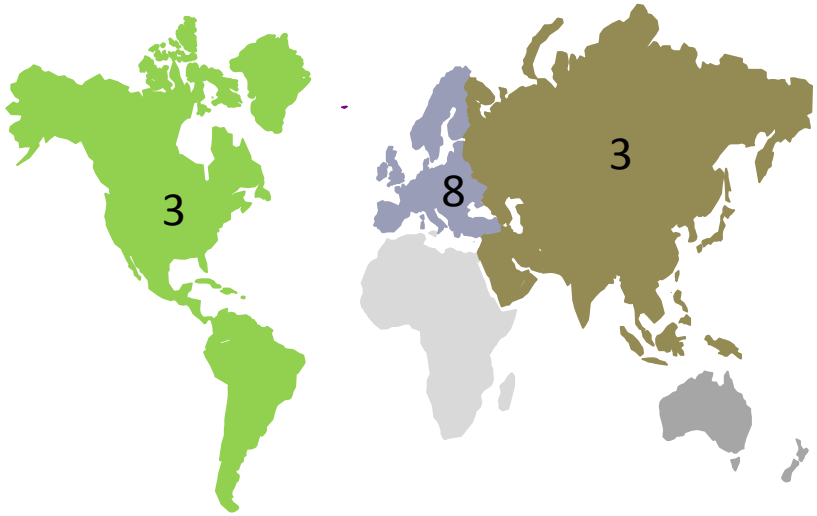
Model based optimal filtering technique

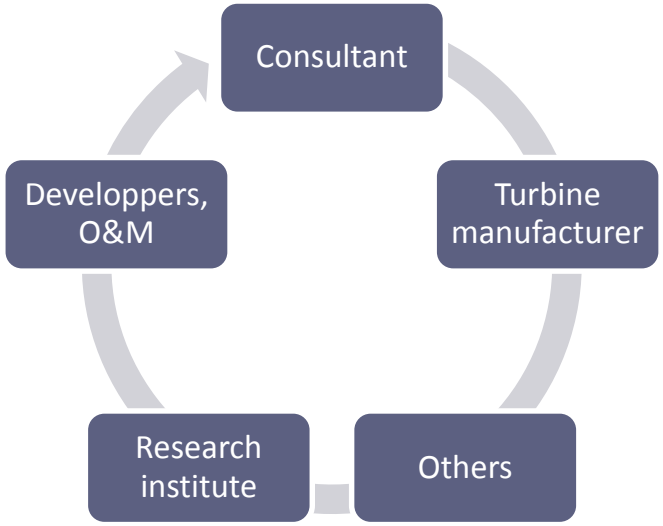
IFP Energies nouvelles

+ Improvements shown
+ Automatic algorithm applicable in all terrain types
- May not fully eliminate the errors

A worlwide trial

- From mid-2016, a representative set of Windcube end-users are testing the Model-based filtering technique on their own existing data sets where a met mast is available





+ others

Promising results

- 3 Wind Energy important players have processed 10 months of data through model based filtering algorithm over 4 different sites.
- Comparisons with masts at different heights show promising results.

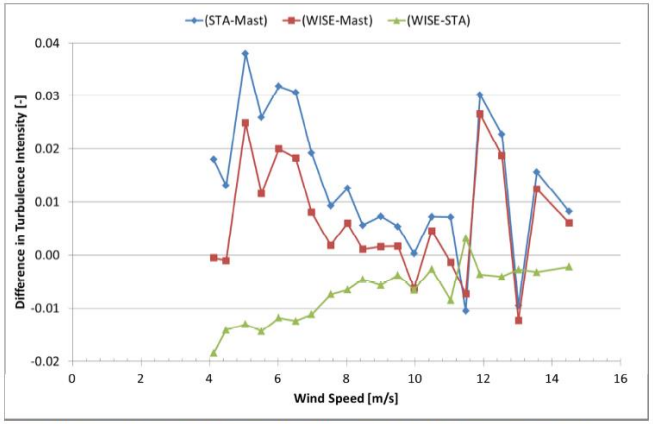
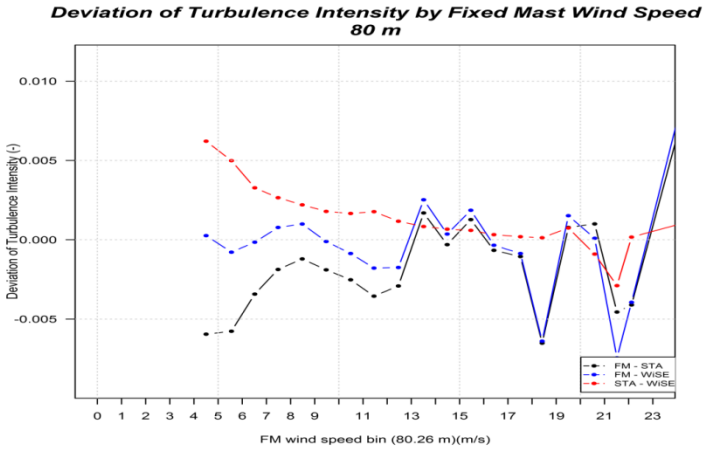


Figure 9 Wind speed dependent bin averaged turbulence intensity at 131 m measurement height



VOTE " TI measurement techniques for pulsed Lidars – the Current Status "

No. 11

Presented by: M. Schmidt

Short title: Profound Lidar data correction

Orientation correction of wind direction measurements

by means of staring Lidar

New alignment method reduces Lidar errors substantially

Orientation correction of wind direction measurements by means of staring Lidar

Michael Schmidt, Juan Jose Trujillo, Hauke Beck and Martin Kühn
WE-Sys - ForWind - Carl von Ossietzky University Oldenburg
michael.schmidt@forwind.de

WindEurope Summit
2016

Lidar, measures

$V_{line-of-sight}$

Leosphere WINDCUBE 200s-600

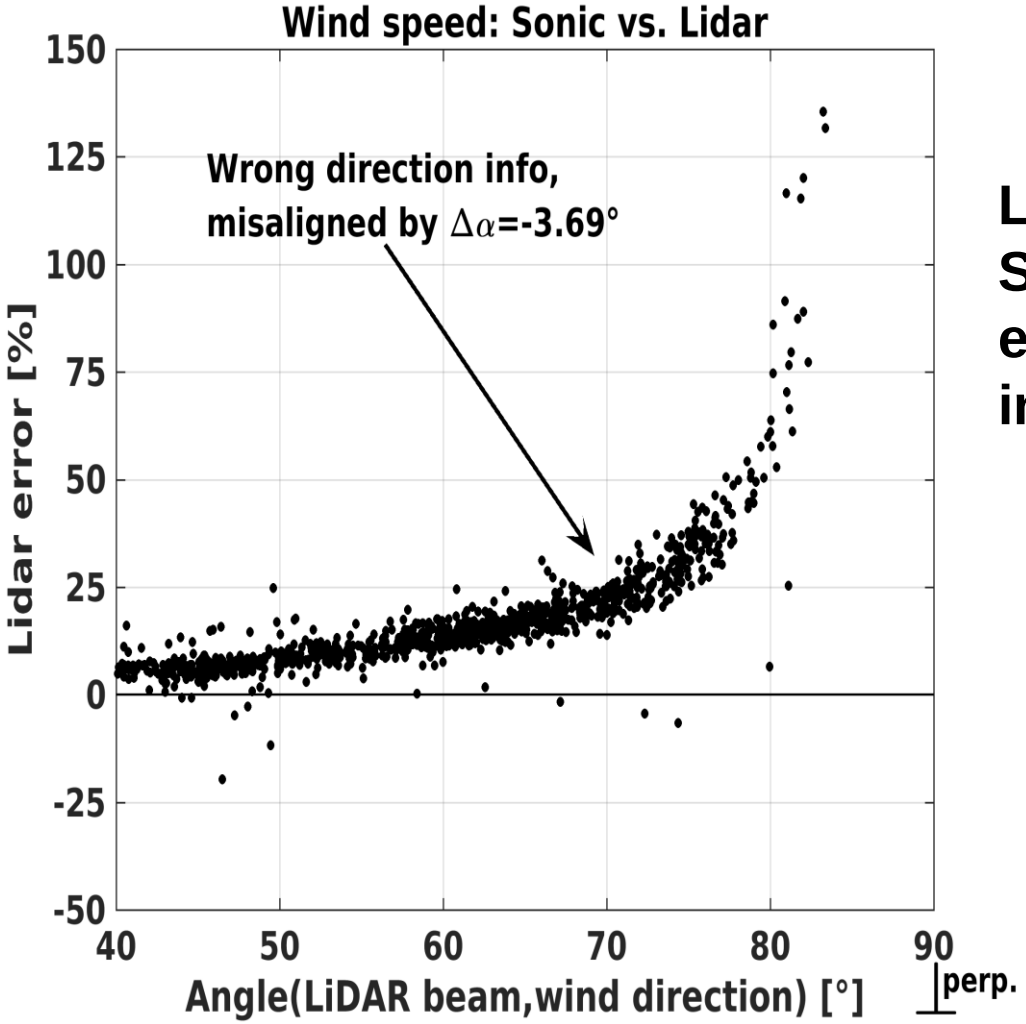
Lidar $V_{line-of-sight}$ + wind direction → Lidar wind speed, ...

↑

... but misalignment provokes huge Lidar errors ...

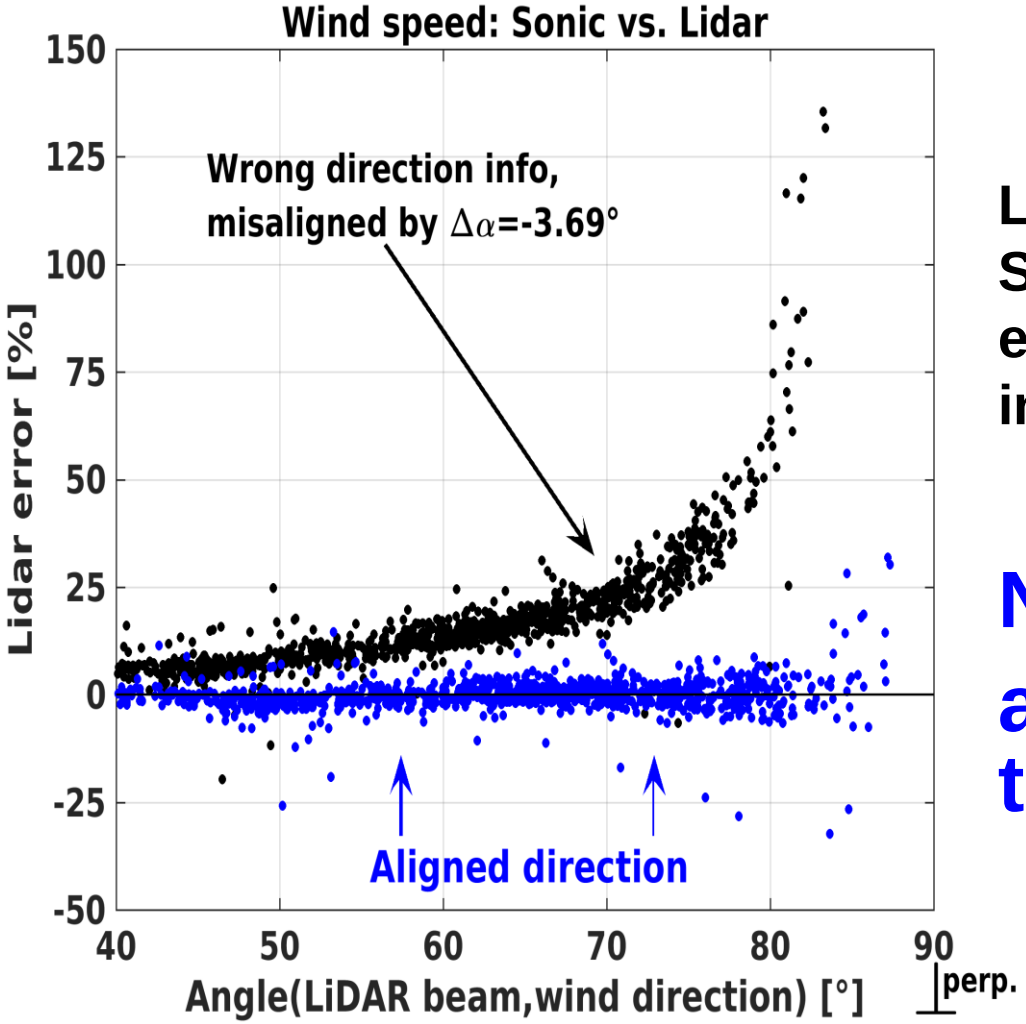
↓ rotated by 4° ↑

... like this.



Lidar compared to Sonic: wind speed error grows up to infinity,

... like this.



Lidar compared to Sonic: wind speed error grows up to infinity,

NEW:

alignment method to correct them.

Zapping 2 flies at once:

a) wrong direction information, and

Zapping 2 flies at once:

a) wrong direction information, and

b) faulty Lidar wind speed.

No. 12

Presented by: H. Mueller

Short title: A Novel Lidar System

First Results of Highly Resolved Wind vector measurements

Physikalisch-Technische Bundesanstalt
Braunschweig and Berlin
National Metrology Institute

A Novel Lidar System –
First Results of Highly Resolved Wind vector measurements

Wind Europe Summit 2016

27 September 2016, Hamburg

Session: **LIDARs - the zapping competition** **(short version)**

Harald Mueller[(1)] Michael Eggert[(1)] Christian Gutsmuths[(1)]
Axel Albers[(2)] Klaus Franke[(2)] Ailt-Wiard Janssen[(2)]
[(1)] Physikalisch-Technische Bundesanstalt, Braunschweig, Germany
[(2)] Deutsche WindGuard Consulting GmbH, Varel, Germany

DEUTSCHE WINDGUARD

Wind Lidar Measurements - Challenges

Main wind Lidar applications: - Site assessment
- Power curve measurement

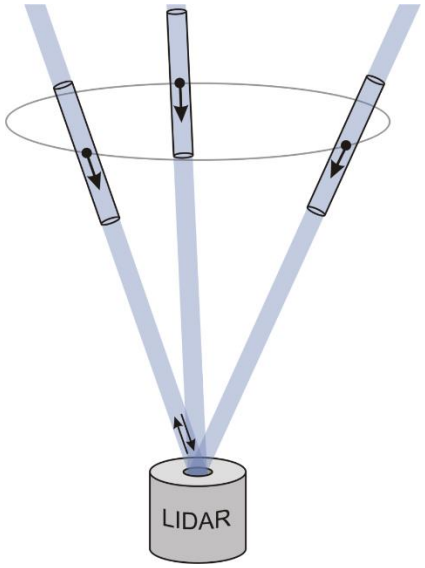
Conventional wind Lidar systems: Monostatic principle

One measurement beam tilted into different directions

Measurement cone: Diameter at 100 m ~ 100 m
Length ~ 20 m

Requirement: Almost homogenious wind fields

Challenges: - Traceability
- Complex terrain



Novel high-resolution wind Lidar system:

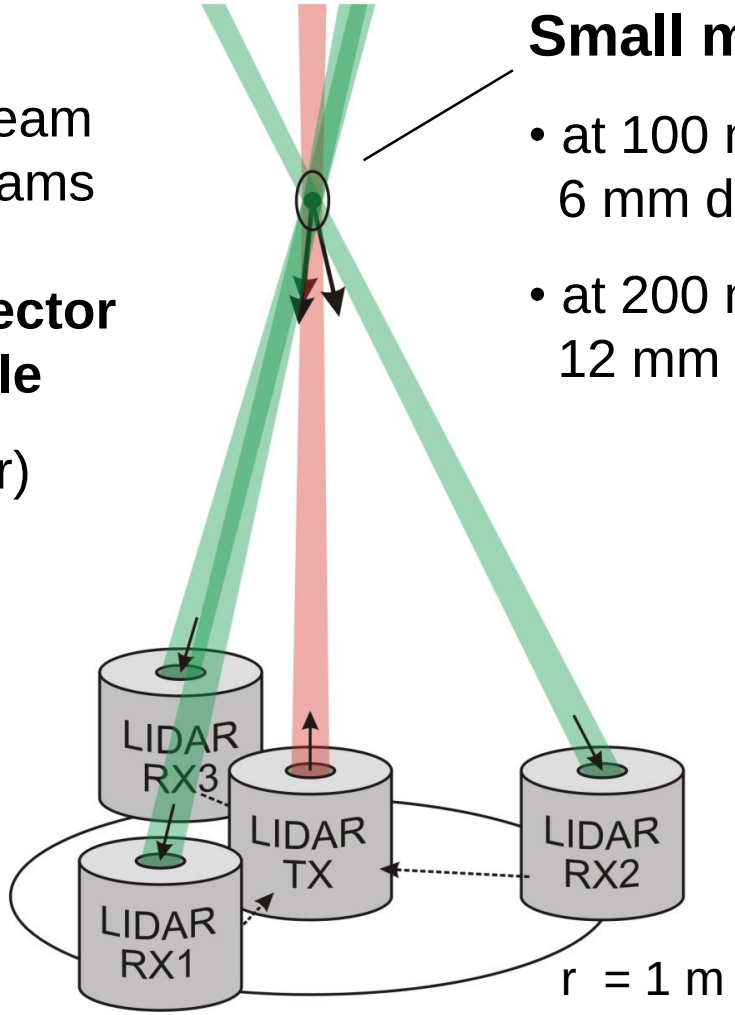
Advantages: - Small measurement volume
- Accuracy independent of wind conditions
- Future use as standard independent of met masts

Novel bistatic Lidar Configuration (PTB)

- One transmitter beam
- Three receiver beams

- Complete **wind vector of a single particle**

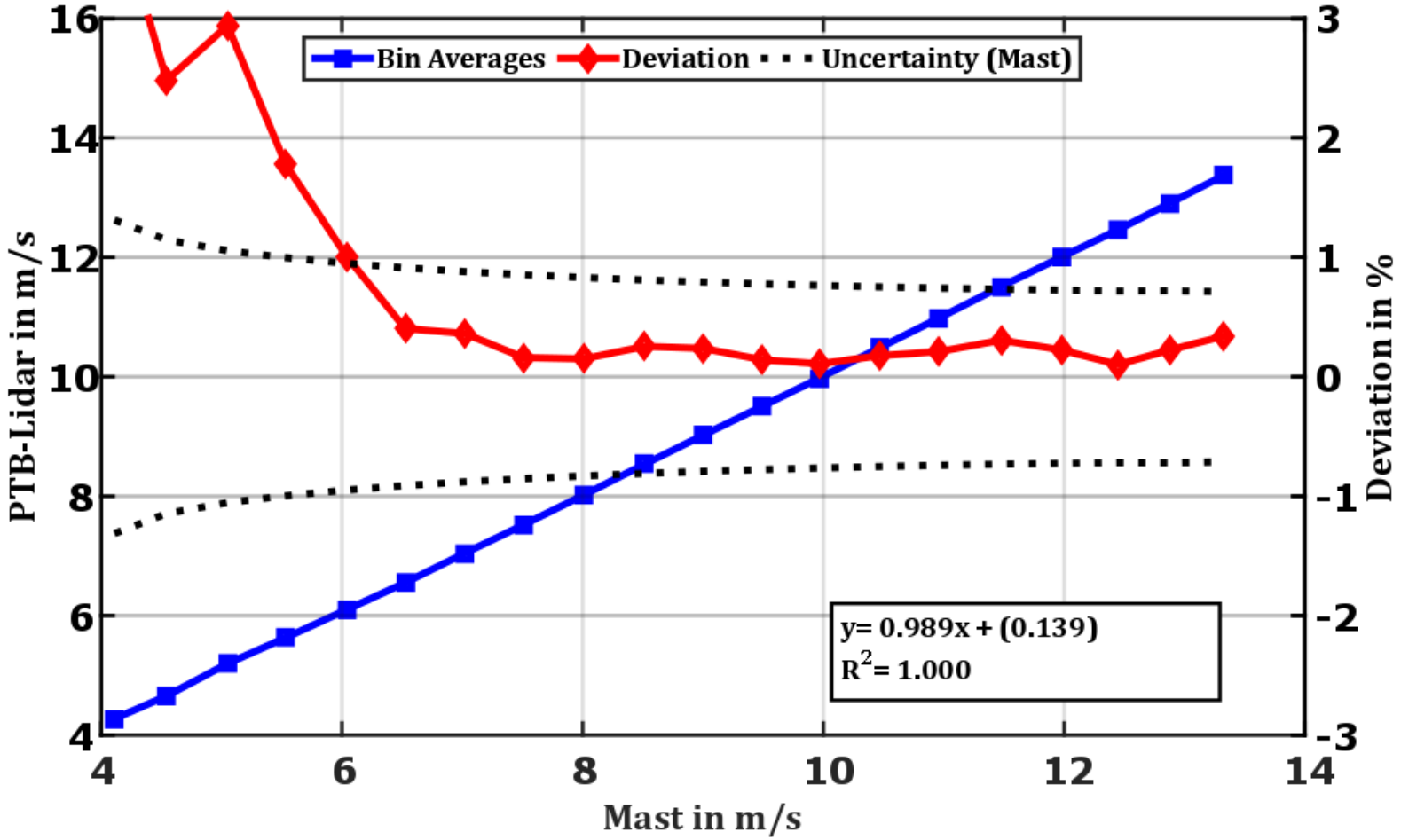
(aerosols in the air)



Small measurement volume

- at 100 m height:
  6 mm diameter x 0.6 m length
- at 200 m height:
  12 mm diameter x 2.4 m length

In field validation with met mast



(Measurement period: 28 h, evaluation time intervall: 1 s, time delay: distance correlated 1,1 s)

Observed deviations < 0,5 % - within cup anemometer uncertainties!

Voting process

- You can vote for 3 presentations
- Please do not vote for a presentation from your own organisation

- The presentations will be announced one-at-a-time

- Vote YES by pressing 1 on the keypad

How to use the voting keypad ?

The polling is open when a question is on screen with a green informer in the right top corner.

responses: 0	polling: open

You can vote when the polling is open (green).

Press 1 to vote for a presentation.

Your vote is registered when the light on your voting pad flashes green.

Your vote is anonymous.

Please return your voting pad when you leave the room.

Thank you!

Summary

No.	Presenter	Short title	Votes
1	J. Gottschall	Floating lidar status	
2	W. Langreder	Seasonality kills Roaming Lidar….	
3	A. Clerc	Scanning LiDAR in Offshore Wind	
4	S. Sanquer	Post conversion of complex Lidar data	
5	M. Stephenson	Power Curve Validation using LiDAR	
6	A. Borraccino	V infinity is found!	
7	S. Sanz	A very complex LIDAR validation	
8	M. Zendehbad	Mobile Scanning LiDAR	
9	E.B. des Roziers	Uncertainties from on-site lidar measurements	
10	P. Mazoyer	Turbulence intensity challenges	
11	M. Schmidt	Profound Lidar data correction	
12	H. Mueller	A Novel Lidar System	