Workshop on Autonomous Aerial Sensors for Wind Power Meteorology

- Challenges -

Risø-DTU, 12 July 2010

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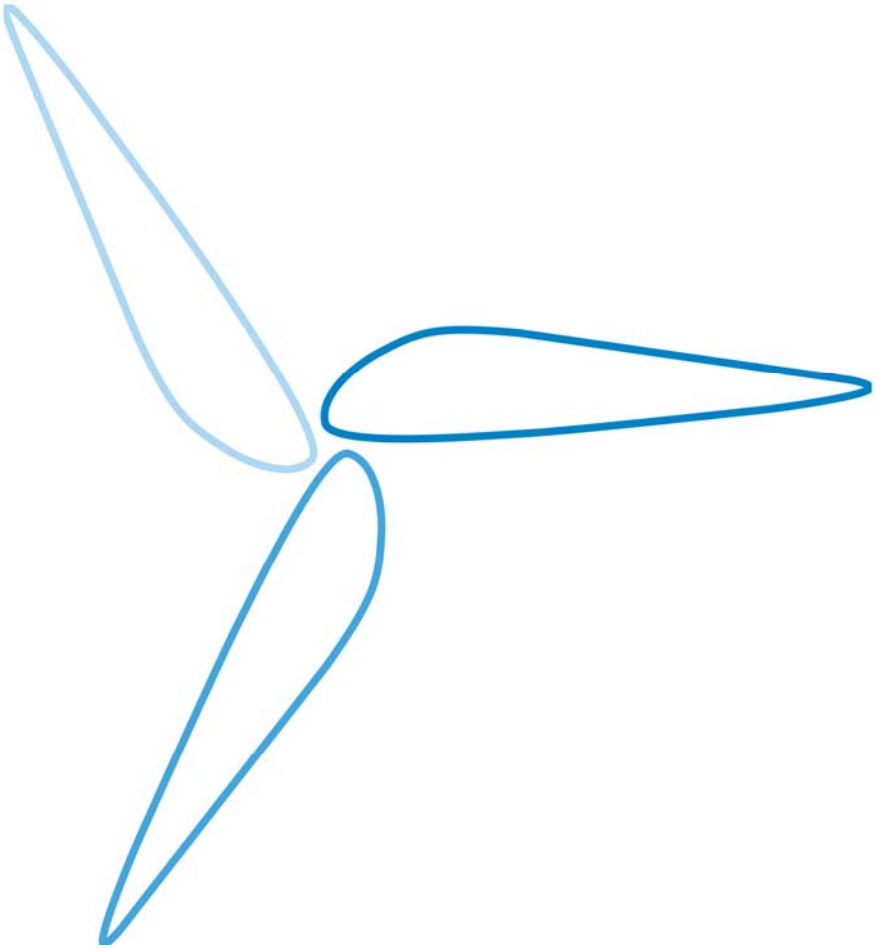

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University of Stuttgart

University of Stuttgart

- founded 1829, 19,897 students (WS 2008/09), ~ 65% engineering
- high share of third-party funding
- excellent regional R&D and industrial infrastructure
- 3.9% gross domestic product for R&D in federal state of Baden-Württemberg

Faculty of Aerospace Engineering & Geodesy

- 1700 students, 14 full chairs, 13 institutes

Institute of Aircraft Construction (IFB) www.ifb.uni-stuttgart.de

- Aircraft Construction & Fibre Reinforced Plastics (Prof. Drechsler)
- Aircraft Design, UAV (Prof. Voit-Nitschmann)
- Endowed Chair of Wind Energy Stuttgart (SWE) (A. Rettenmeier)
- Structures & Design (N.N., located at DLR)

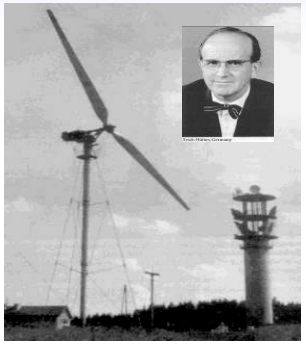
Institute of Aerodynamics and Gas Dynamics (IAG) iag.uni-stuttgart.de

2 of 9 research groups active in wind energy:

- Laminar Wind Tunnel (Würz)
- Aircraft Aerodynamics (Lutz)

Universität Stuttgart

Wind Research at University of Stuttgart



Tradition

Ulrich Hütter: pioneer work on wind turbine design and GRP use (IFB)

F.X. Wortmann: airfoil design, LWT (IAG)

Test site Schnittlingen: UNIWEX (ICA)

Endowed chair of wind energy (SWE, since 2004)

Current Research Fields

DLR

- Component tests

- Automated fibre composite manufacturing techniques
- UAV

SWE

- Operational behaviour
- Structural dynamics and design of off-shore offshore wind turbines
- Load monitoring and control

Uni Stuttgart

- Aeroelasticity (IAG + SWE)

IFB

IAG

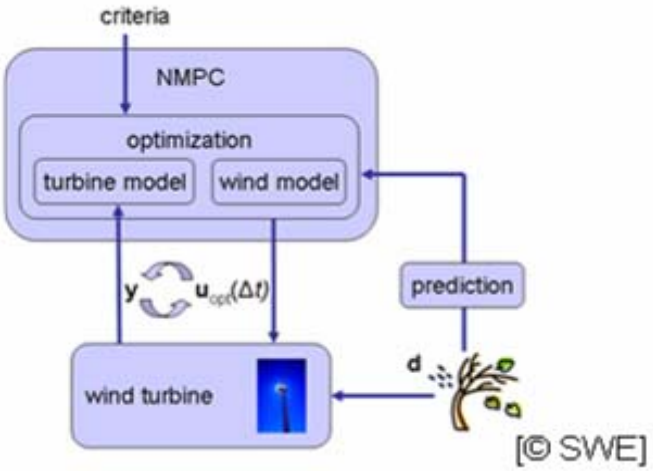
- Aerodynamics and aeroacoustics
- Airfoil design, wind tunnel tests

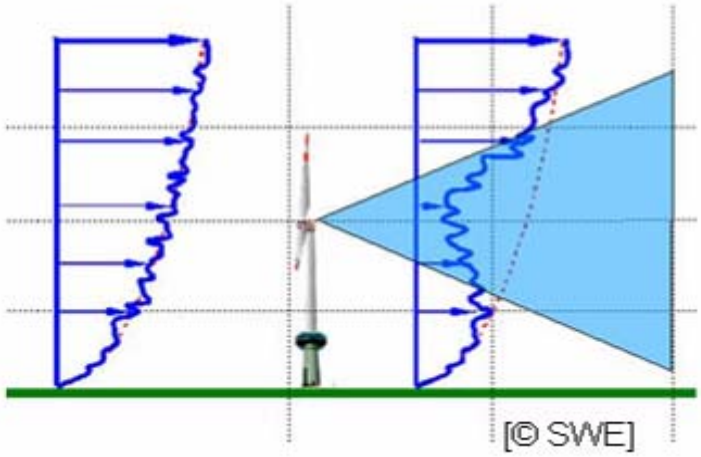
Motivation

Nacelle-based LiDAR technology allows

Measuring the turbines wake wind for
- Validation of wake models [1]

Measuring the incoming wind for
- Predictive control application [2]
- Power curve determination [3]



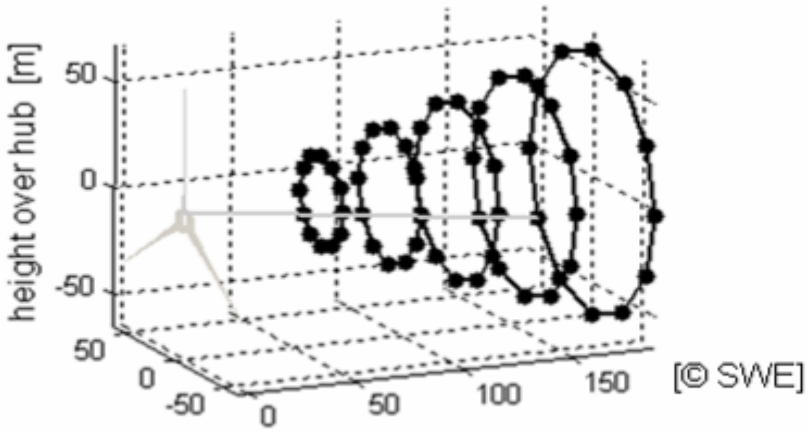


[1] Juan José Trujillo, former SWE, now ForWind
[2] David Schlipf, SWE
[3] Andreas Rettenmeier, SWE

Nacelle- based LiDAR measurements of the turbine's inflow

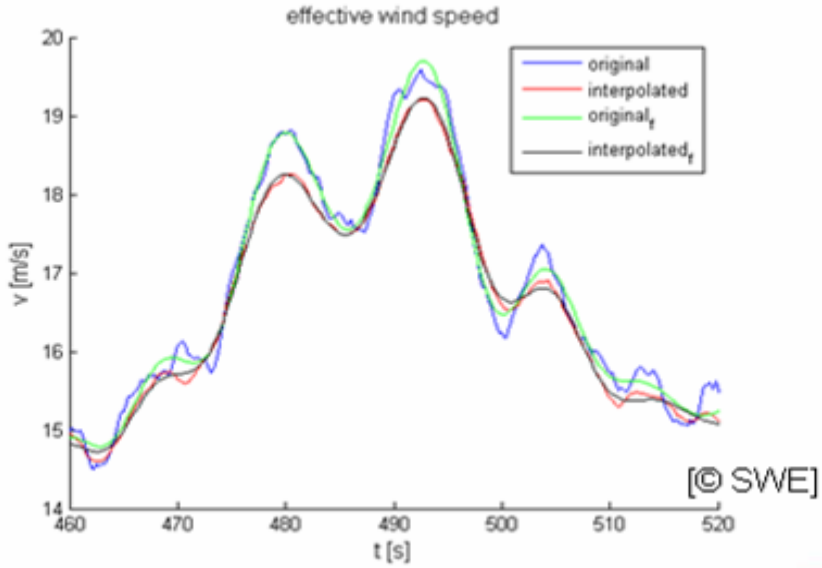
Advantages

- For on- and offshore purposes
- Determination of p-v curve:
  less sectors to exclude (according to IEC 61400-12)
- Covering the whole rotor disc
- Detection of yaw misalignment



Research topics

- Testing Taylor's hypothesis for wind turbine applications [1)]
- Influence of vertical wind shear
- Interpolation of missing measurement points (blade collision, bad CNR)
- Determination of average wind speed
- Influence of weather conditions to LiDAR availability (CNR) and accuracy

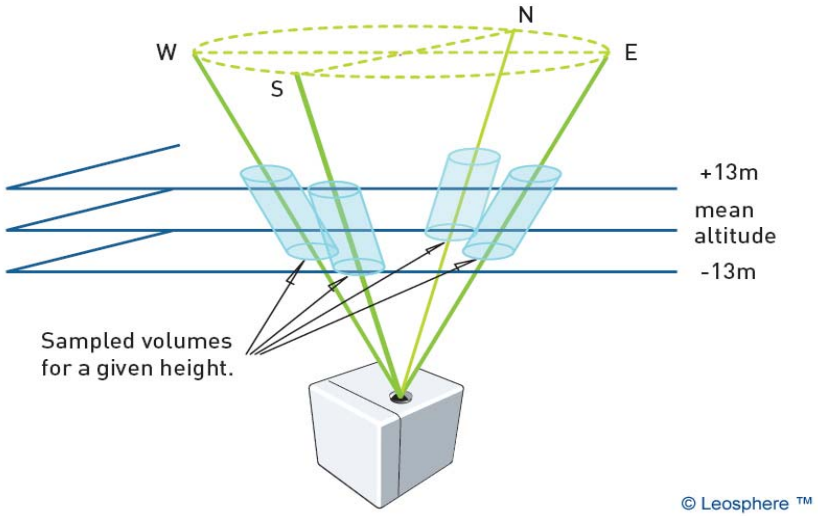


[1)] **Trabucchi et al., "Testing of Taylor's hypothesis of frozen turbulence for wind turbine applications with a scanning lidar", ISARS 2010**

LIDAR System

Standard Windcube™ system from Leosphere™ (ground based)

- Range 40m - 200m
- Spatial resolution 26m
- Speed Accuracy 0.2m/s



Modifications for nacelle installation

- Laser beam orientated almost horizontally
  → Replacement of the internal beam deviation (mirror)
- Development of a scanning system
- Integration of scanner unit
- Software development

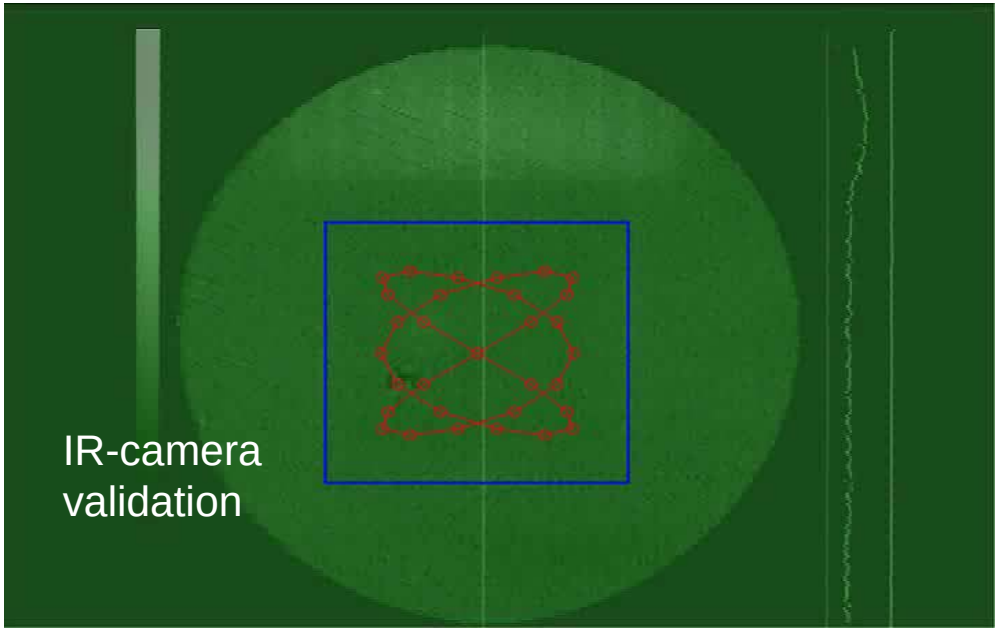
[Fig. Leosphere]

Scanner development for nacelle-based LiDAR system

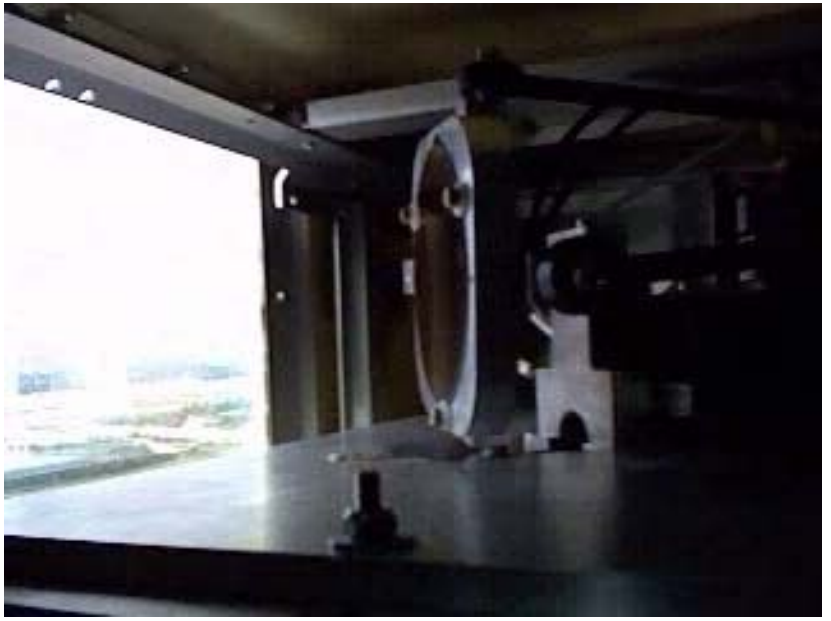
Scanner system requirements

- Angle of projection 53,2°
  → Coverage of ~0.8D transversal at 1.0D
- Flexible trajectories
- Max. 50 points per trajectory
- For each direction: 5 measurement points (line-of-sight) in 5 distances
- High speed and acceleration
  → Complete trajectory every 5–9s
- Repeatability accuracy

Evaluation and application of the scanning device



Lissajous figure with 32 points in ~5s



[Fig. SWE]

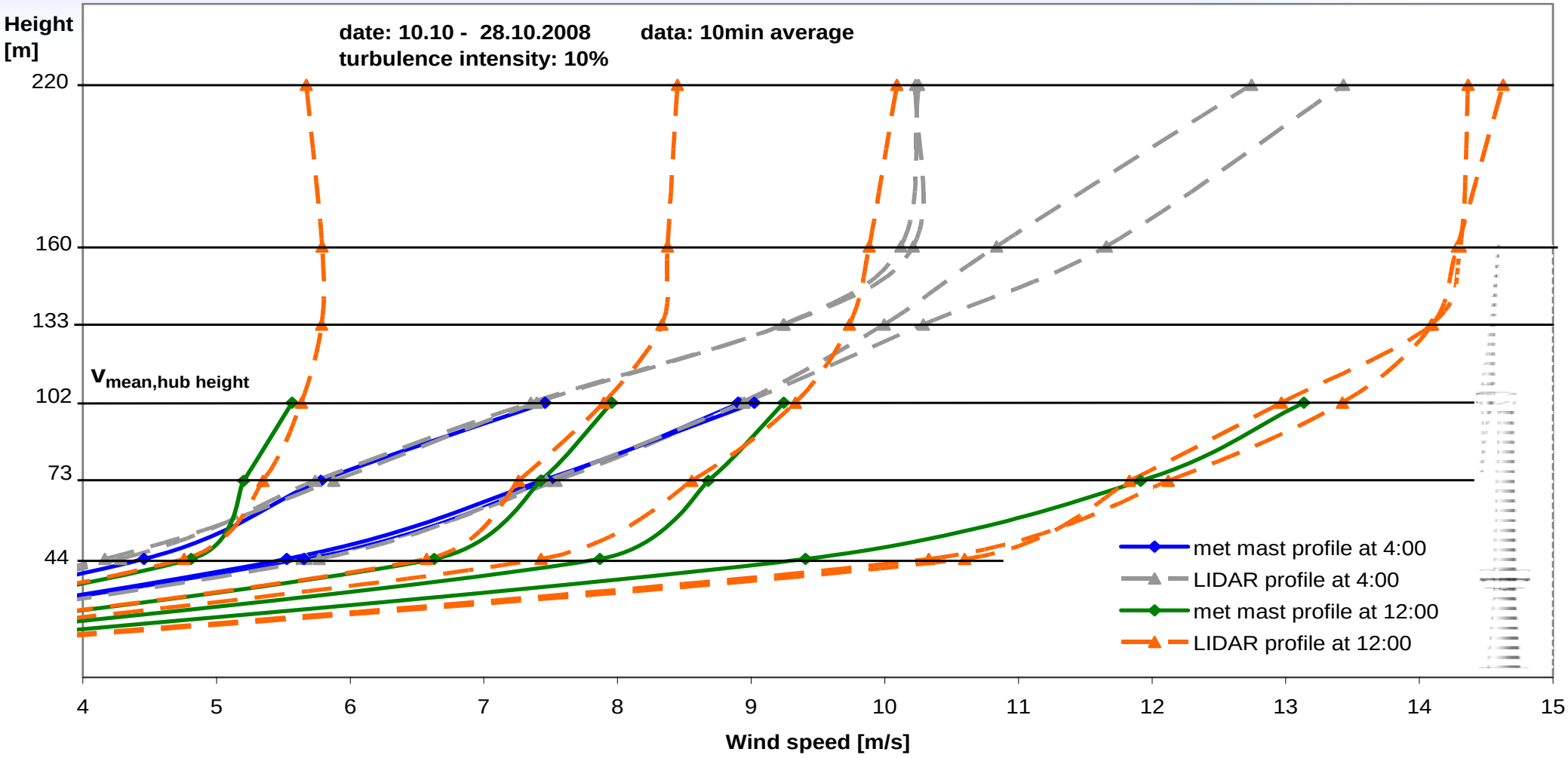
Experiment setup

AREVA-Multibrid M5000 prototype

- 5 MW with 116m rotor diameter
- 102m hub height
- Heavily equipped with sensors
- Mounted LIDAR system + scanner
- Meteorological mast

LIDAR system + scanner

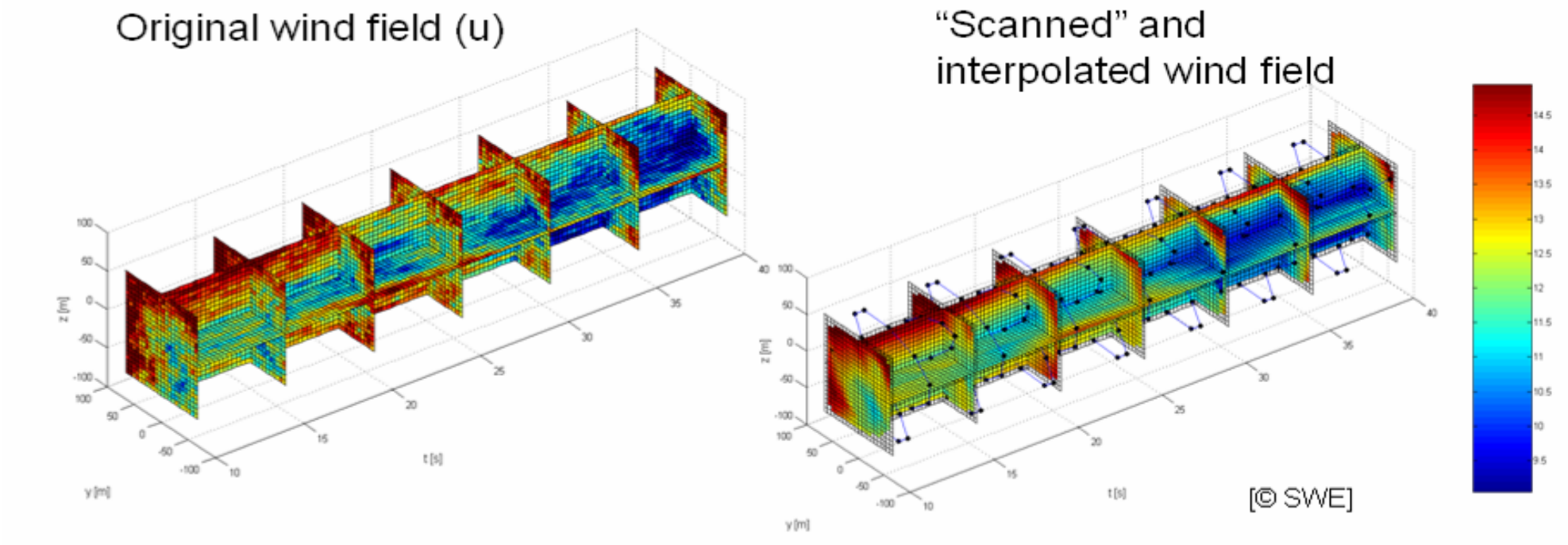
Examples of vertical wind shear



WITLIS (WInd Turbine LIdar Simulator)

Aim

- Development of trajectories considering the motor speed and acceleration
- Trajectories can be optimized depending on application
- Comparison of interpolation models
- Turbine interference
- Yaw correction

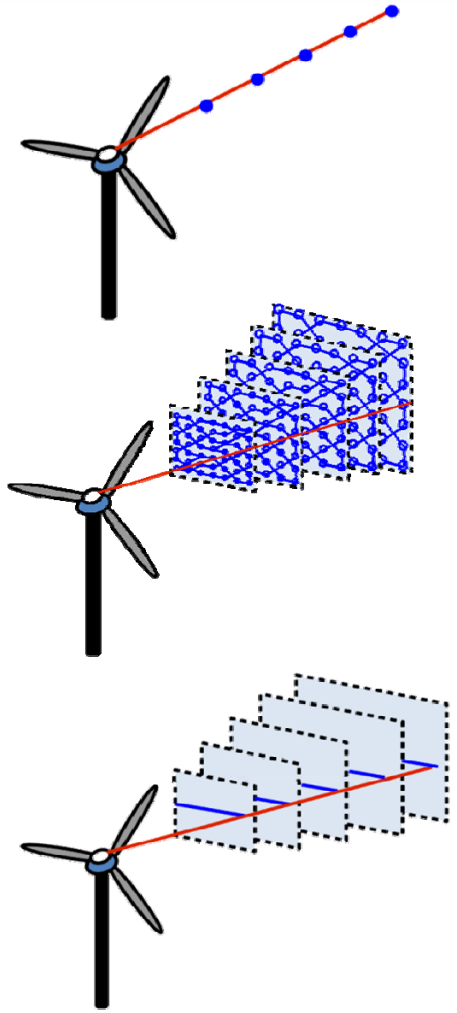


Measurement technique - Trajectories tested

- Staring

- In plane measurements
(Lissajous2grid figures)

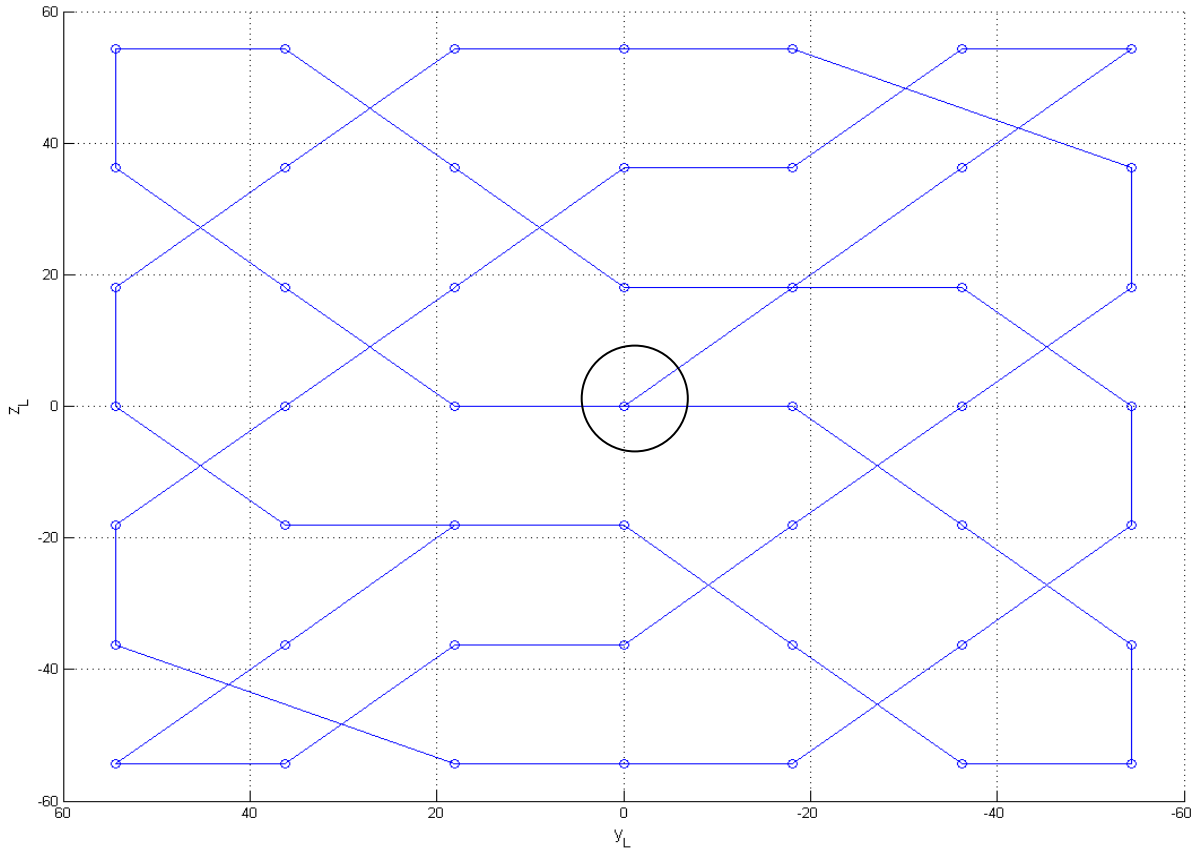
- Sliding



[Fig. SWE]

Nacelle- based power curve determination: example trajectory

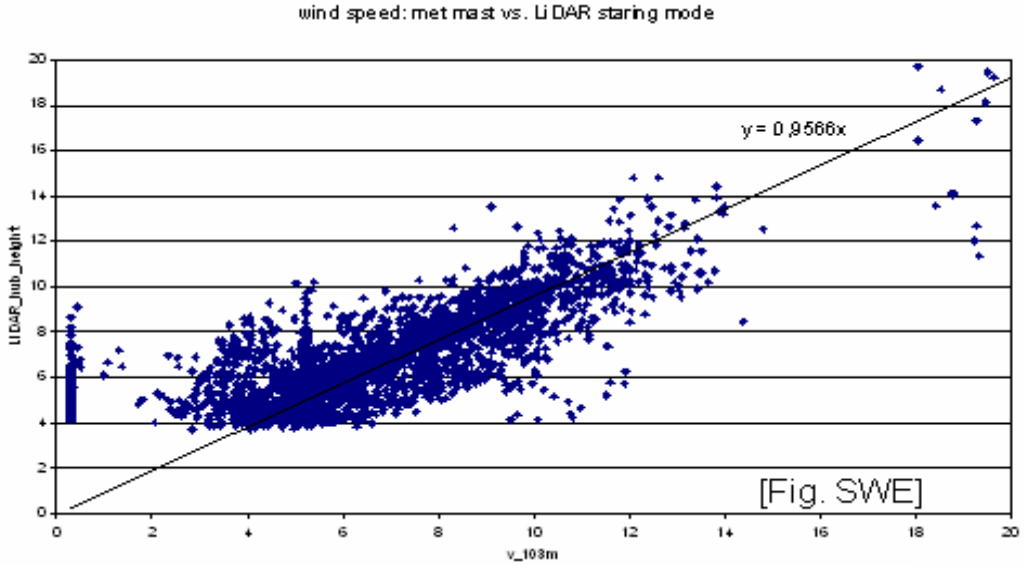
- 145m in front of turbine
- 49 measurement points
- Fast scan ~9sec.
- Staring-mode

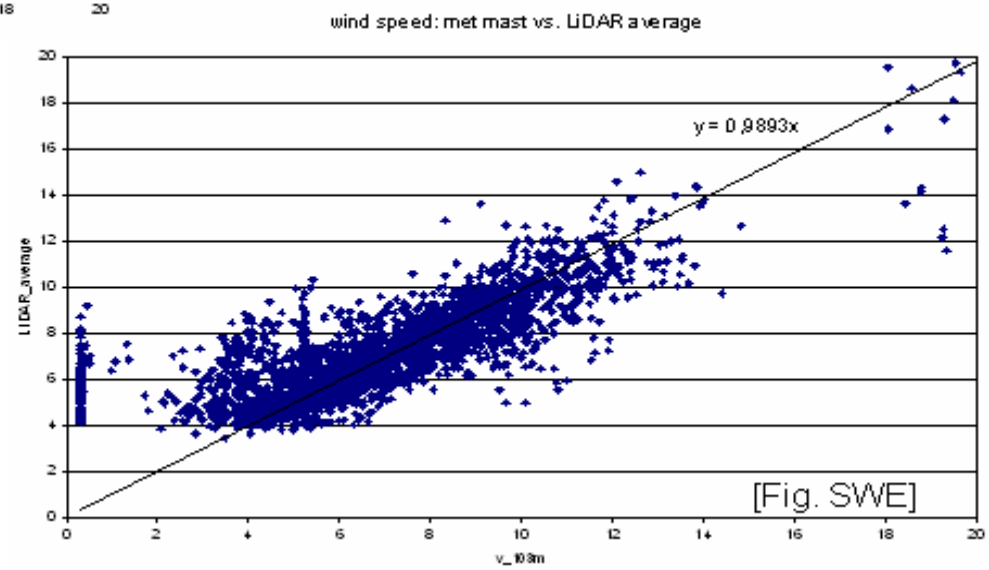


[Fig. SWE]

Nacelle- based power curve determination

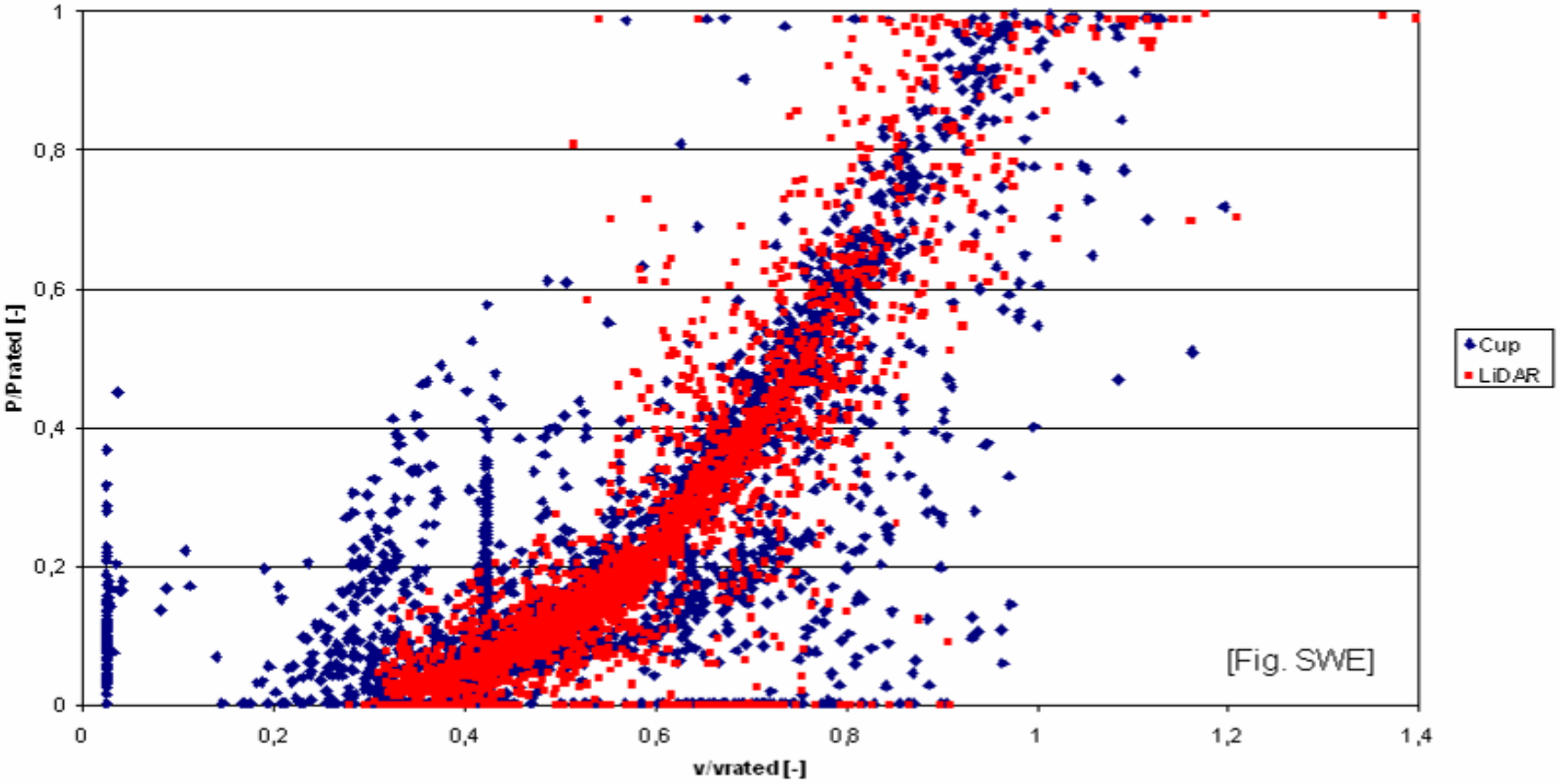
Comparison of nacelle-mounted Windcube™ and cup anemometer





Nacelle- based power curve determination

Power curves: cup 1st class vs. LiDAR (average)



Outlook & Conclusions

- LIDAR: remote sensing technique with high spatial and temporal resolution
- Direct application in wake wind field analysis, wind turbine control and power curve determination
- Nacelle-based measurement methods show a great potential on- and offshore

[Fig. BMU]

Future work

- Further evaluation of measurement data
- LIDAR measurements on two offshore wind turbines (AREVA-Multibrid M5000& REpower 5M) at the offshore-test site “alpha ventus”, autumn 2010

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Thank you for your attention!

Tak for din opmærksomhed!

Contact

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http://www.uni-stuttgart.de/windenergie/LIDAR.html

Acknowledgement

The project “LIDAR-Development of LIDAR technologies for the German offshore test field” (No. 0327642) is funded by the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU).