RAVE-LIDAR II: Stationary and Dynamical Power Curve Measurement in Inhomogeneous Inflow Using a Nacelle-based Lidar System

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WindForS Wind Energy Research Alliance

University of Stuttgart Germany SWE

Carl von Ossietzky universität Oldenburg

ForWind Center for Wind Energy Research

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RAVE RESEARCH AT ALPHA VENTUS

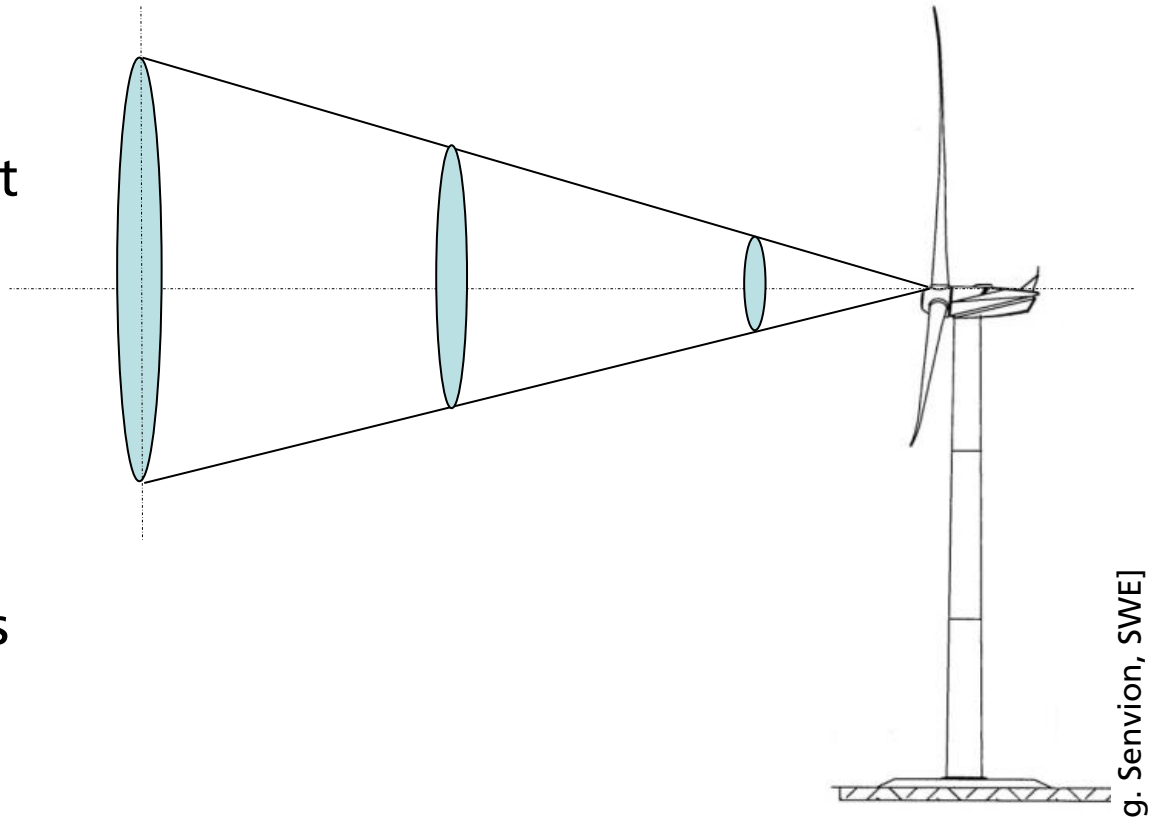
Research Alliance Wind Energy

ForWind Center for Wind Energy Research Bremen Hannover Oldenburg

Motivation

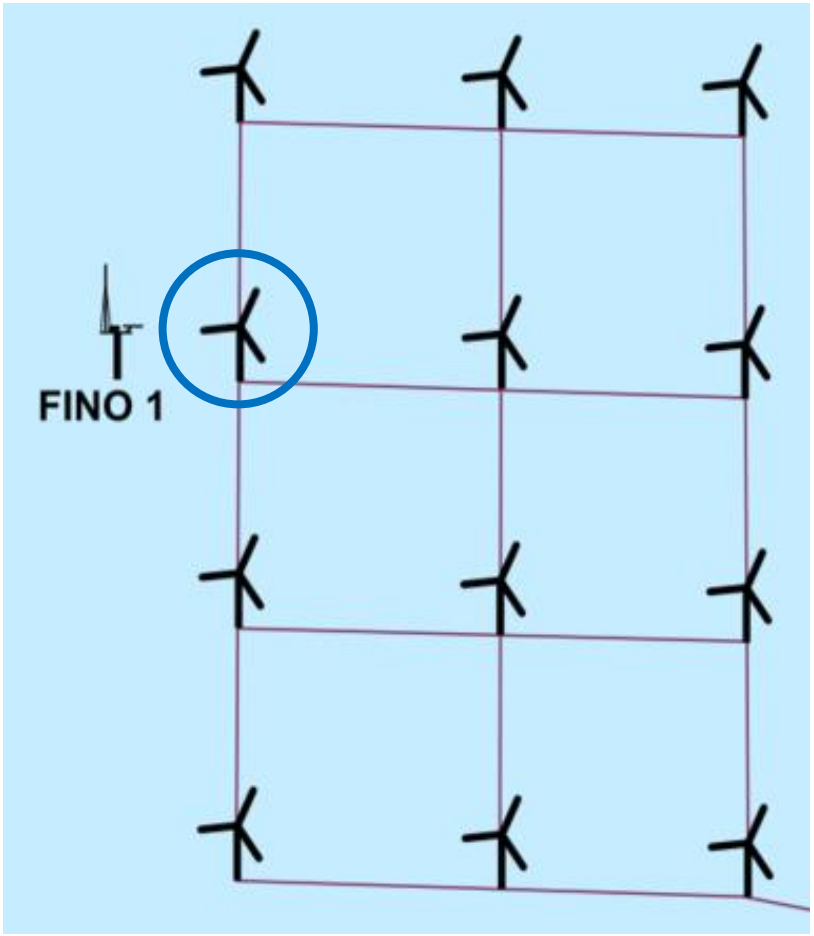
Nacelle based lidars …

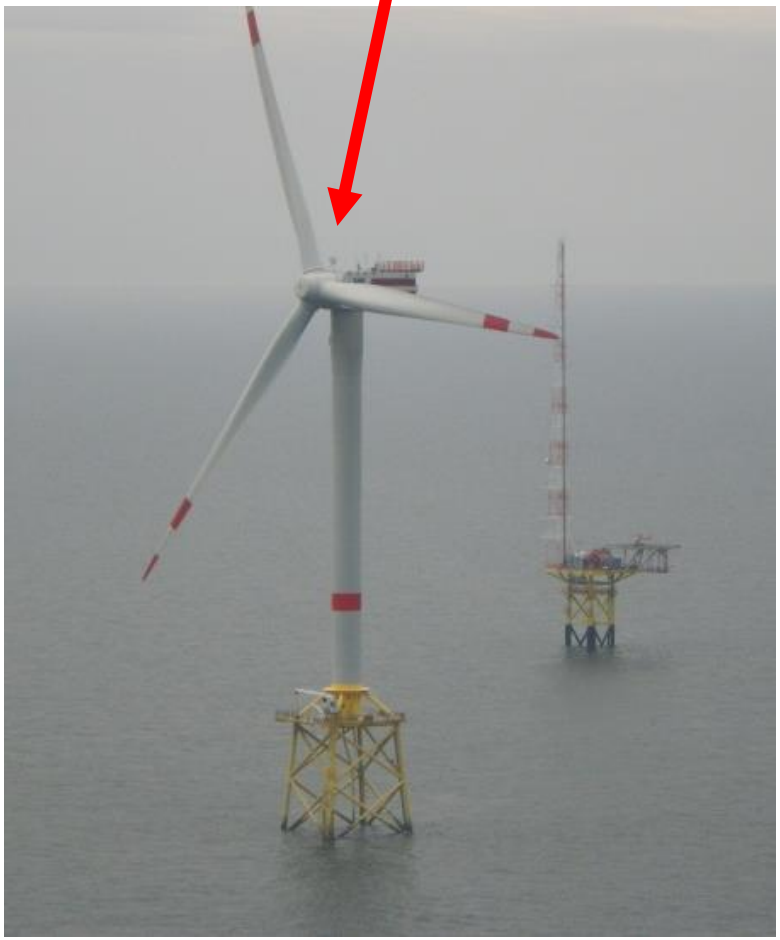
- measure wind field over whole rotor swept area
- include horizontal and vertical wind shear
- capture true inflow
  → less excluded sectors
  → shorter campaigns



[Fig. Senvion, SWE]

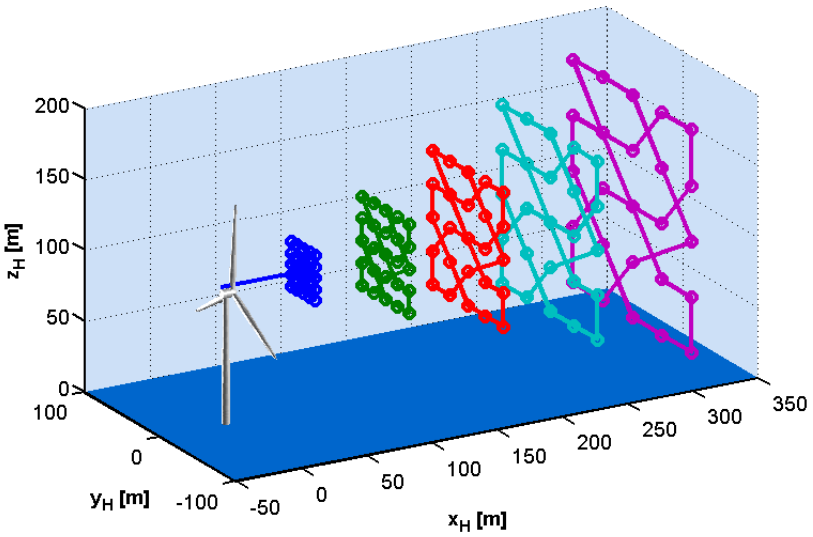
Measurement Setup





[Fig. DNV GL]

SWE Lidar System

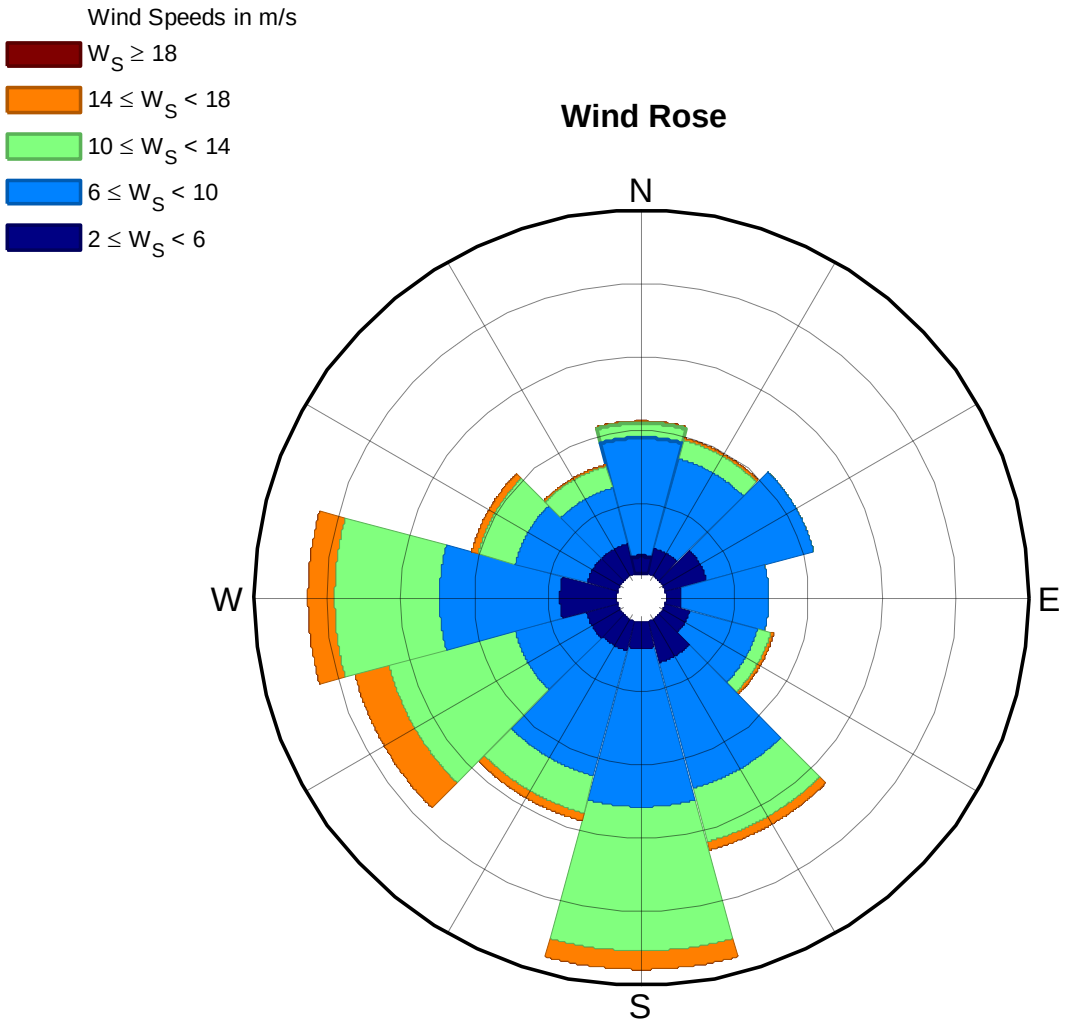


- Developed in Project LIDAR I
- Conventional Windcube + SWE Scanner
- Pulsed system measures at 5 focus planes simultaneously
- Arbitrary trajectories

[Fig. SWE]

Data Availability

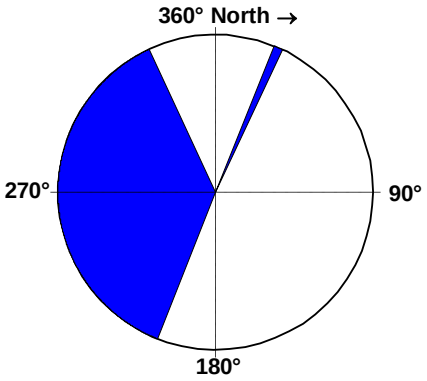
- Measurements Jun – Dec 2014
- 7423 ten min blocks,
  51 days



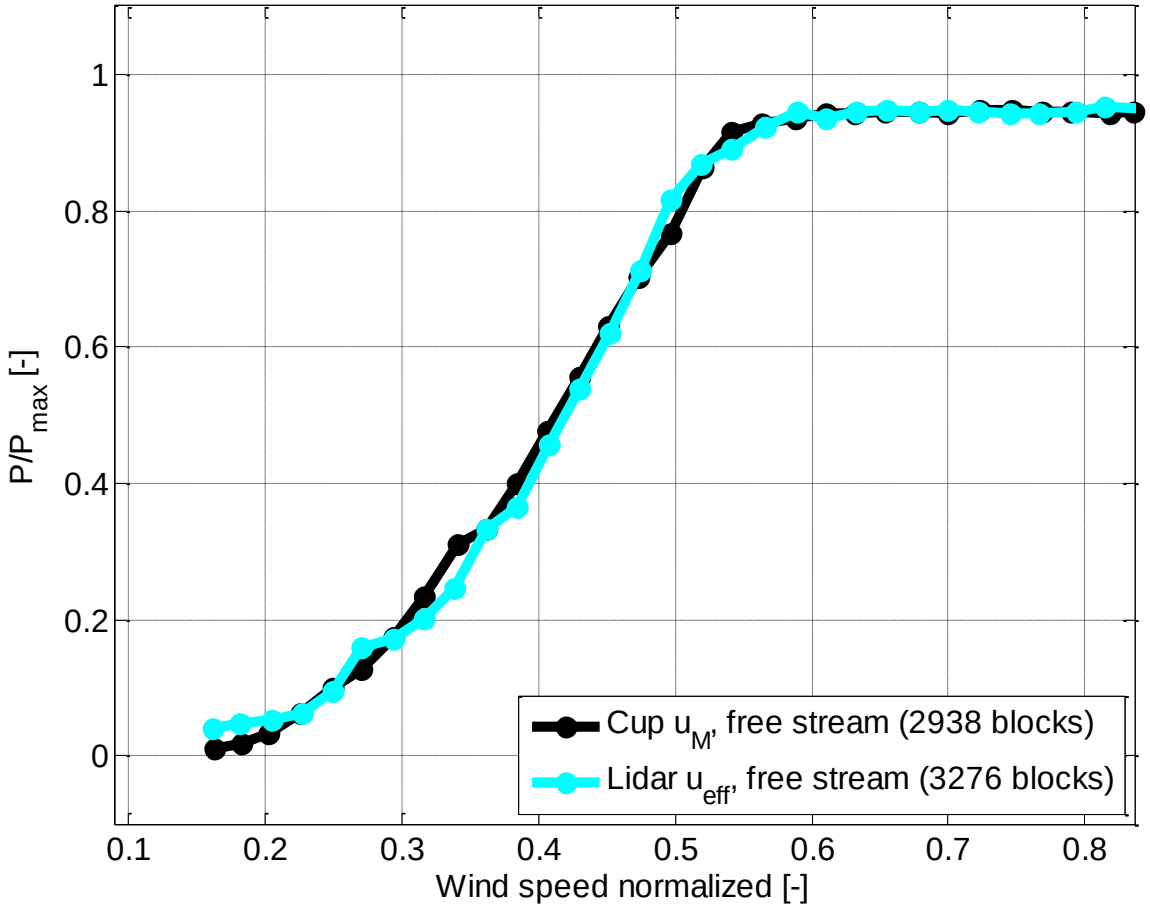
Stationary Power Curve – Results I

Free stream

- Cup and Lidar measure the same power curve



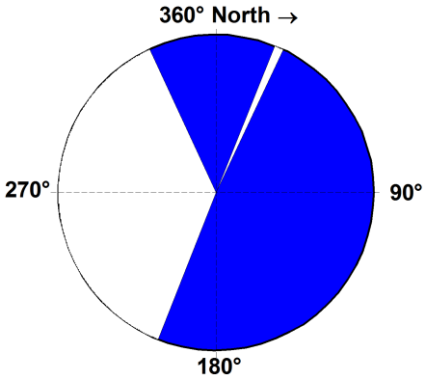
[Fig. SWE]



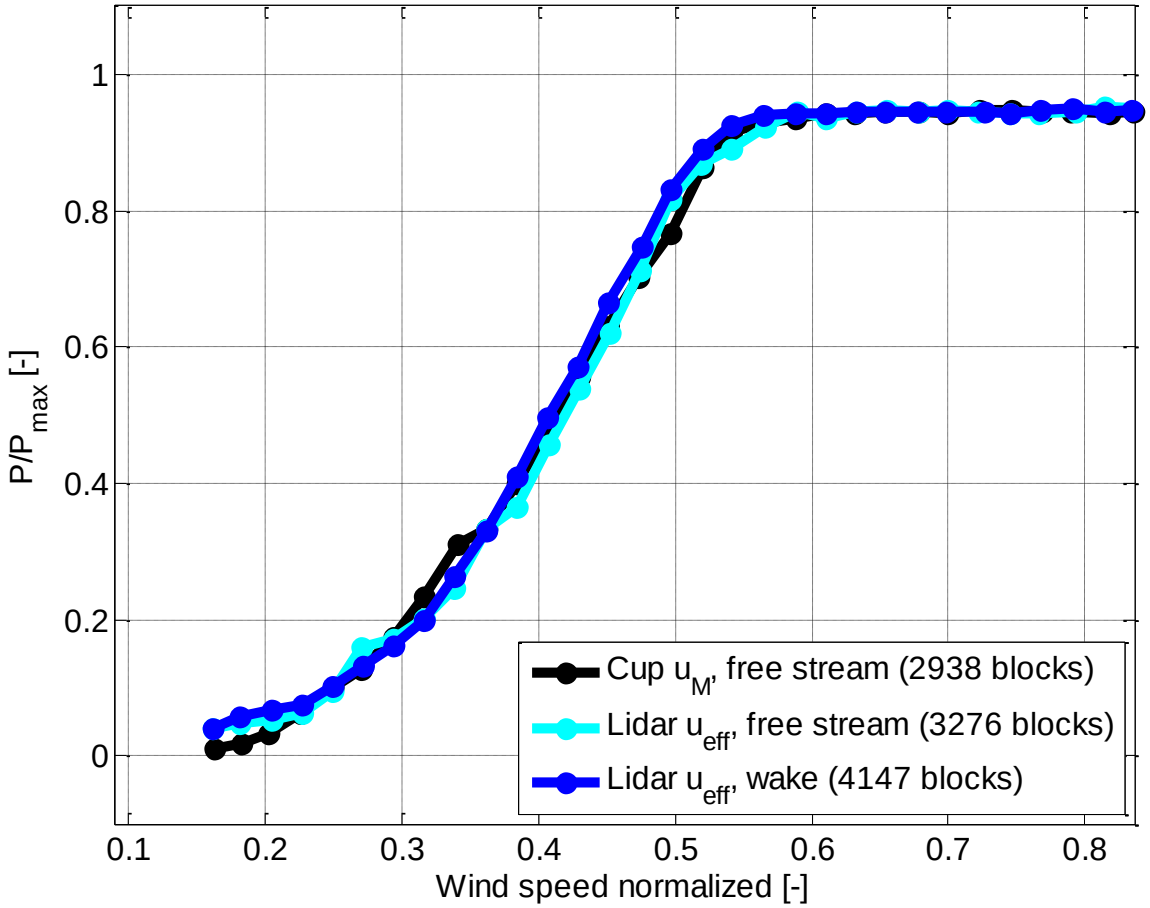
Stationary Power Curve – Results II

Wake

- No influence on lidar power curve
- Lidar measures inflow of turbine



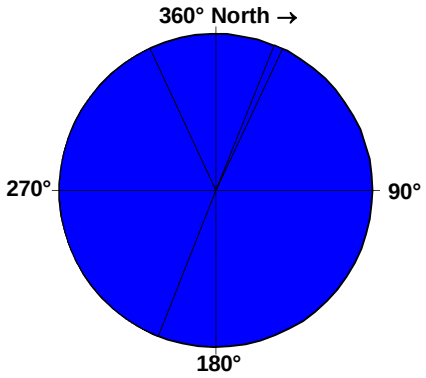
[Fig. SWE]



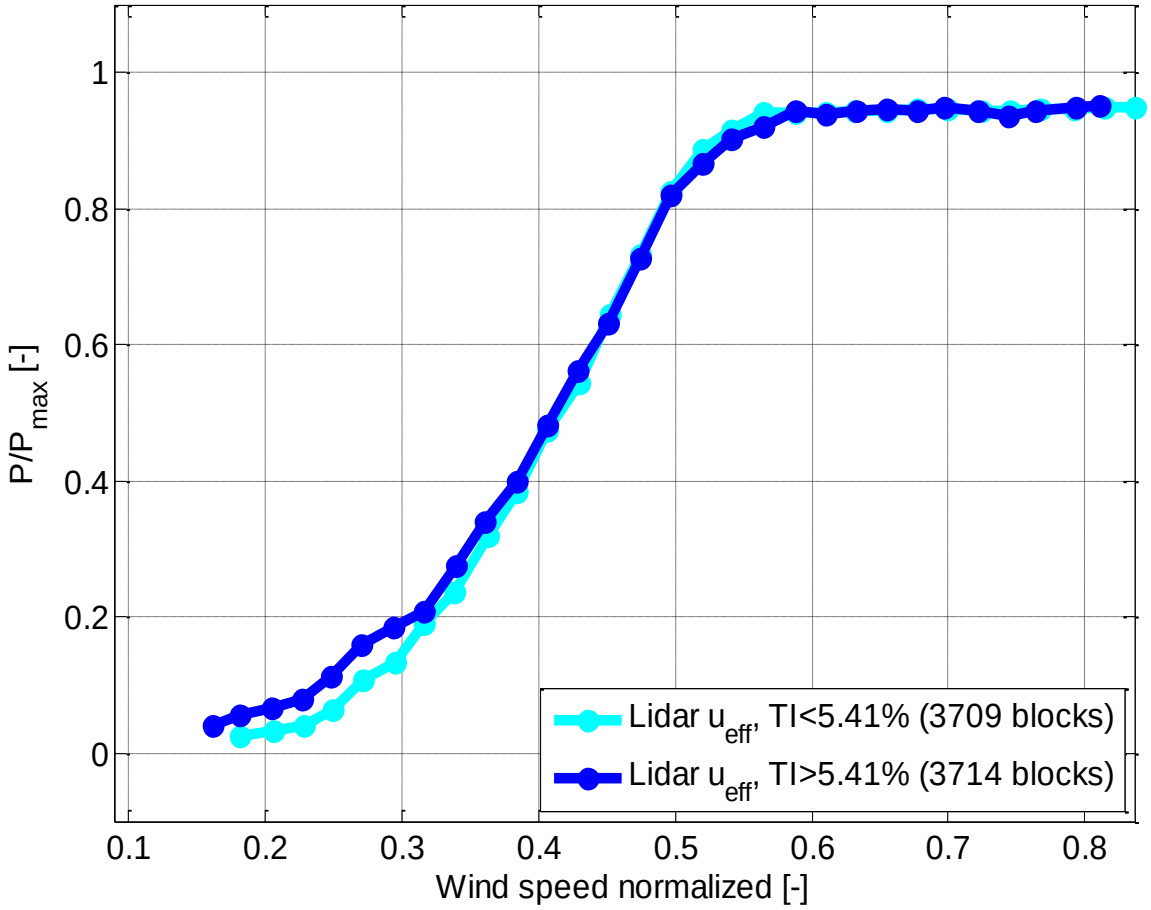
Stationary Power Curve – Results III

Turbulence Intensity

- Typical influence on lidar power curve



[Fig. SWE]

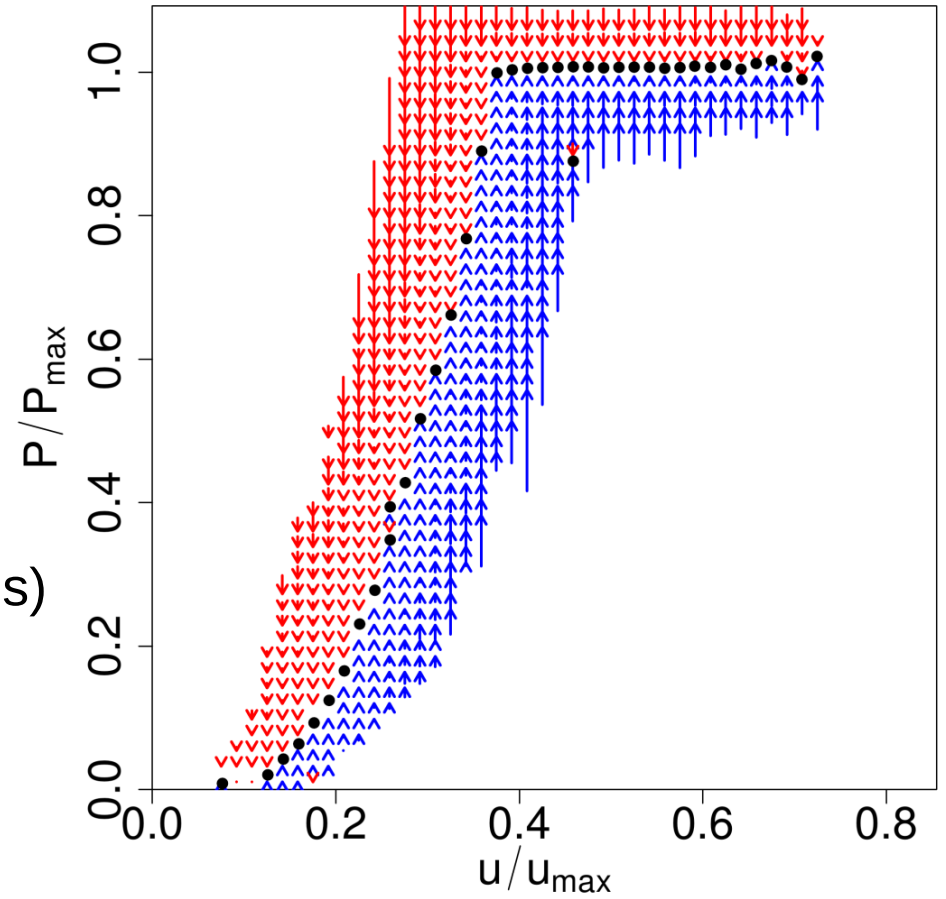


Dynamical or Langevin Power Curve

- Drift function reflects average slope of power signal
- Drift field shows deterministic dynamics of energy conversion
- Stable fixed points constitute Langevin Power Curve (LPC)

Important properties

- Shows short-time dynamics (~1s)
- Quick detection of changes
- Multiple fixed points possible

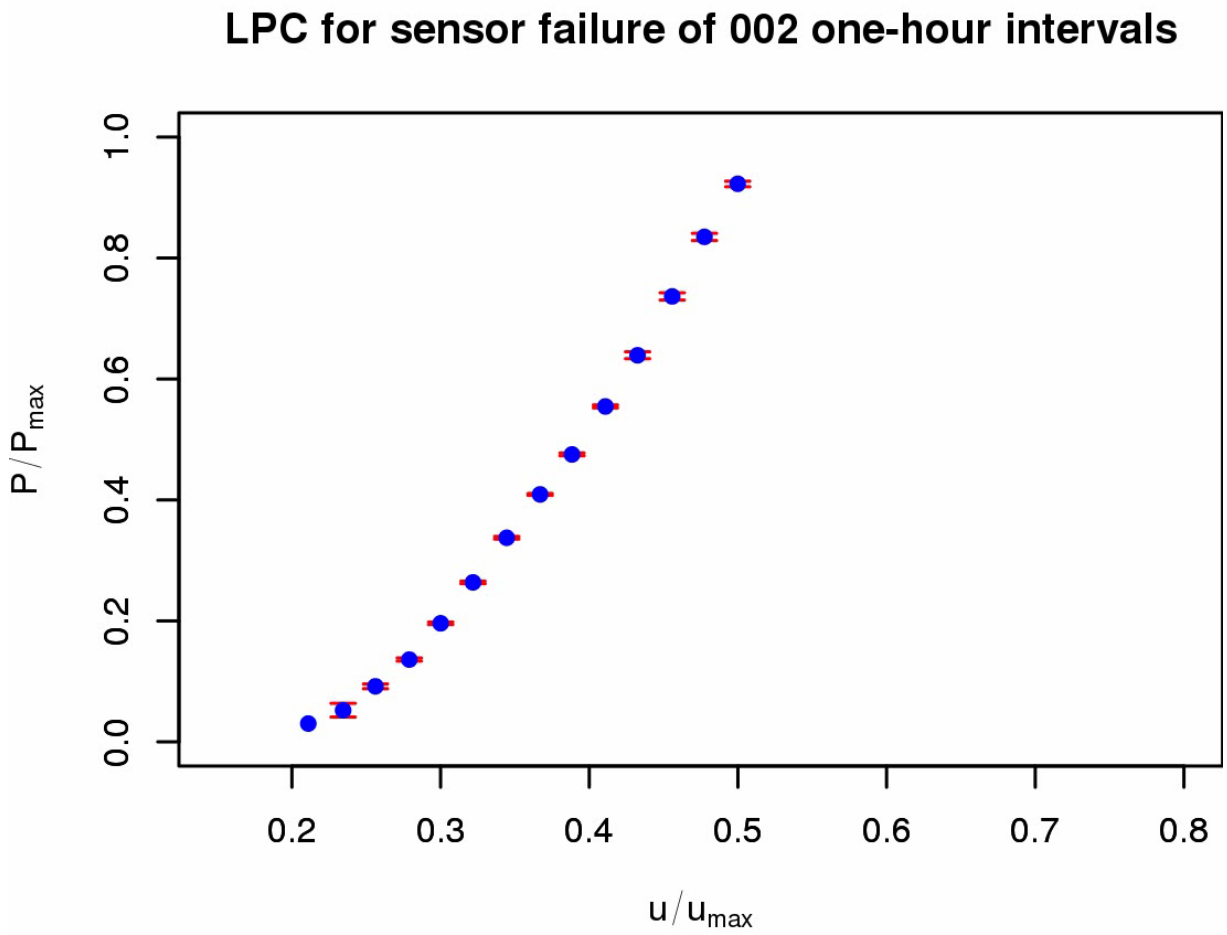


[Fig. ForWind]

LPC Performance Monitoring

Detection of sensor failure

- Calculation of hourly LPC
- 2 weeks of data

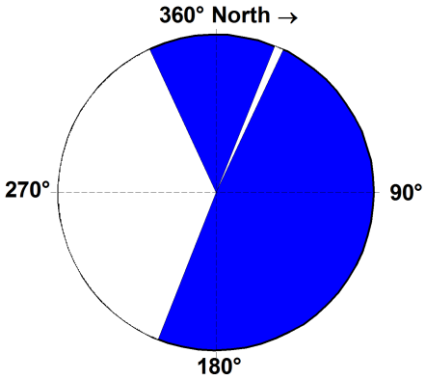


[Fig. ForWind]

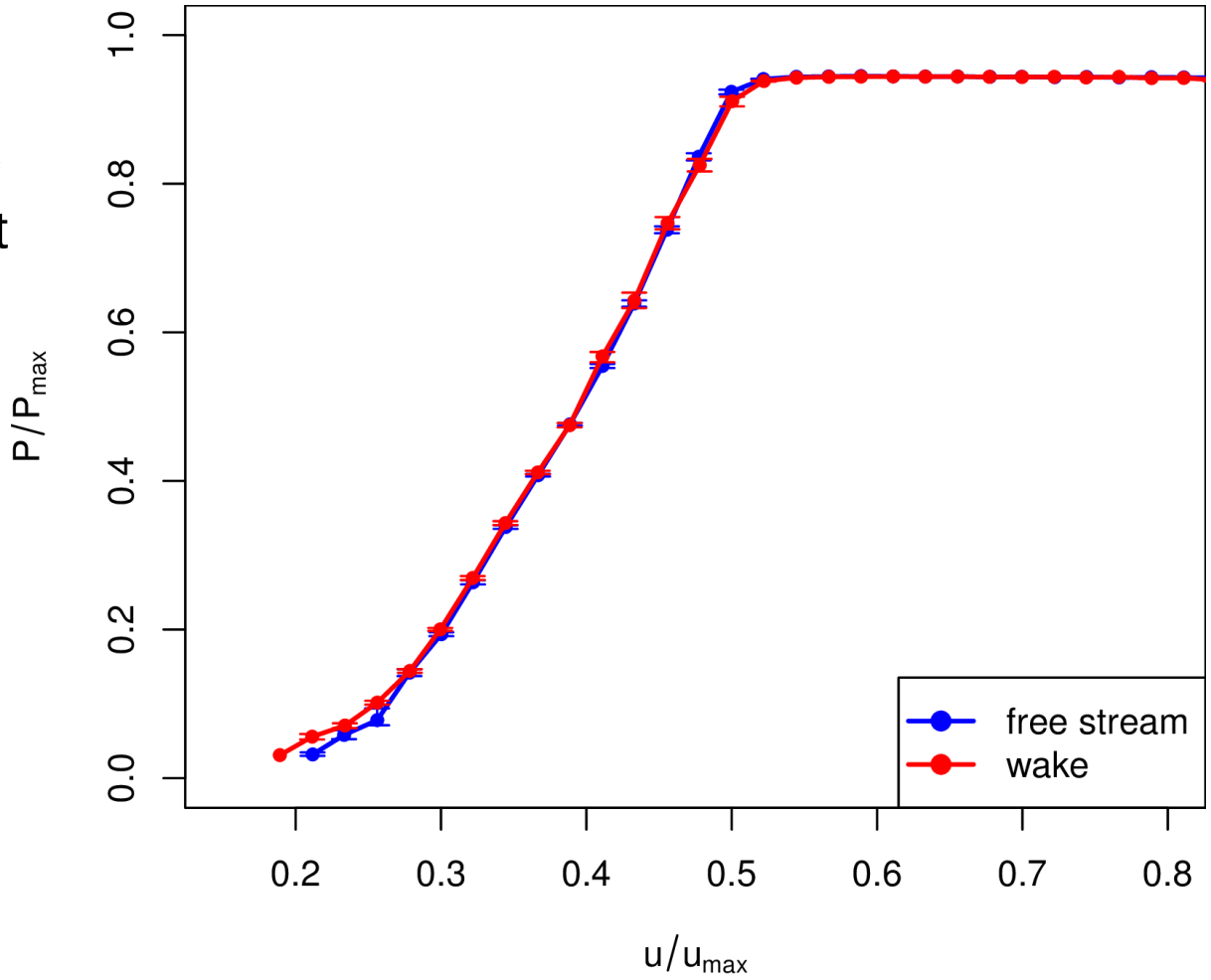
Langevin Power Curve: Results I

Wake

- No influence on LPC
- Lidar measures what turbine sees



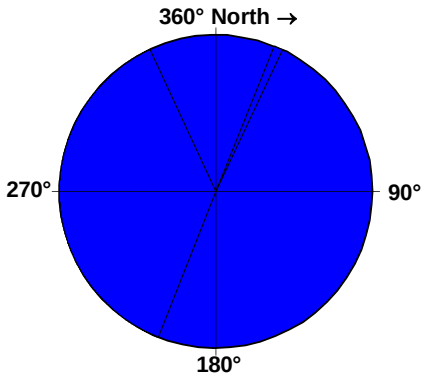
[Fig. ForWind]



Langevin Power Curve: Results II

Turbulence intensity

- No influence on LPC
- Deviation due to limited TI representation of Lidar



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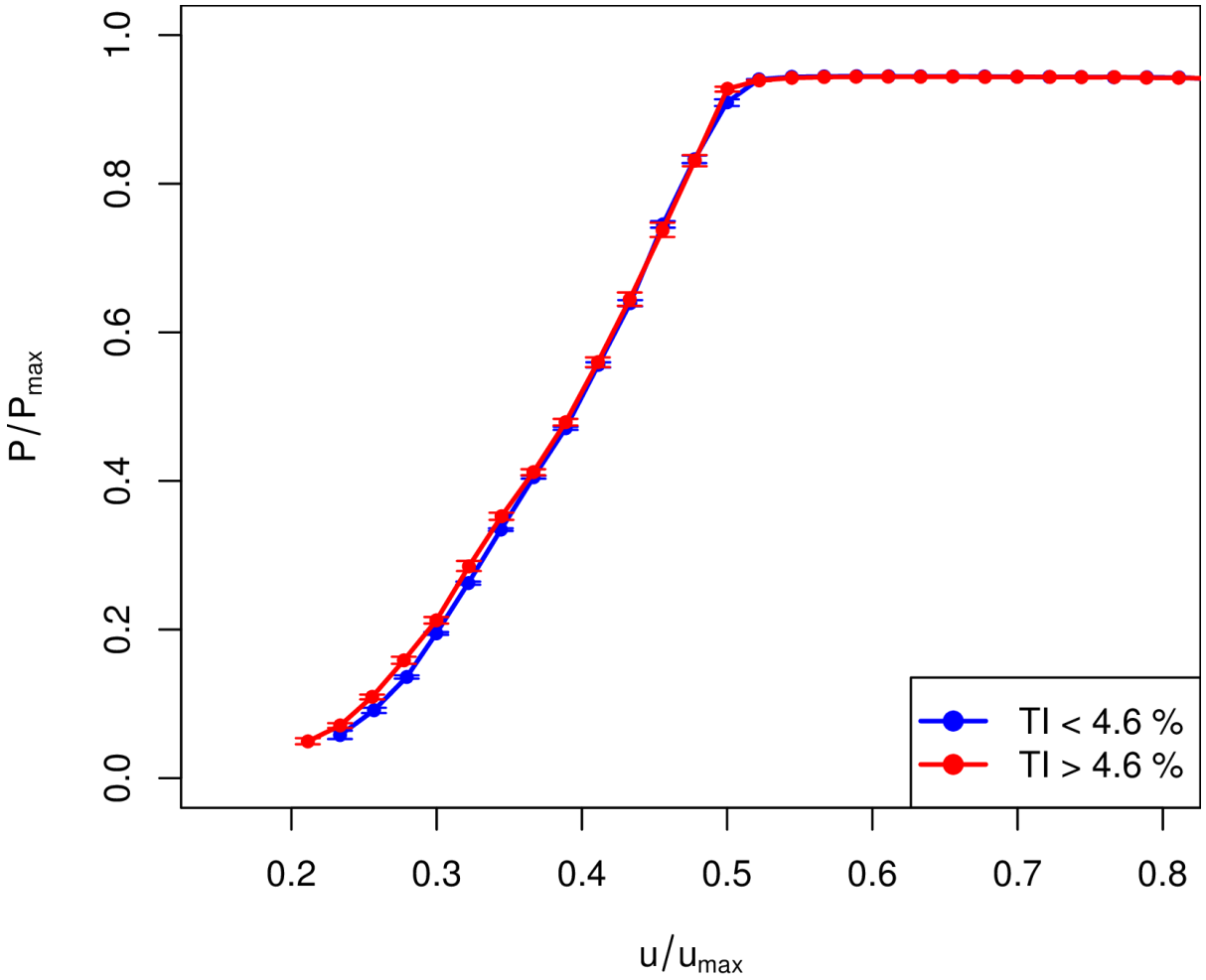

Conclusion

- Met mast and lidar measure the same stationary power curve (SPC) in free stream
- Wake has no influence on SPC and LPC as nacelle-based lidar measures “what turbine sees”
- Turbulence intensity has typical effect on SPC
- Deviation in LPC due to limited TI representation of Lidar

→ Nacelle-based Lidar well-suited for power curve measurement offering advantages over classical met mast approach

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