Technical University of Denmark

Real world offshore power curve using nacelle mounted and scanning Doppler lidars

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Real world offshore power curve using nacelle mounted and scanning Doppler lidars

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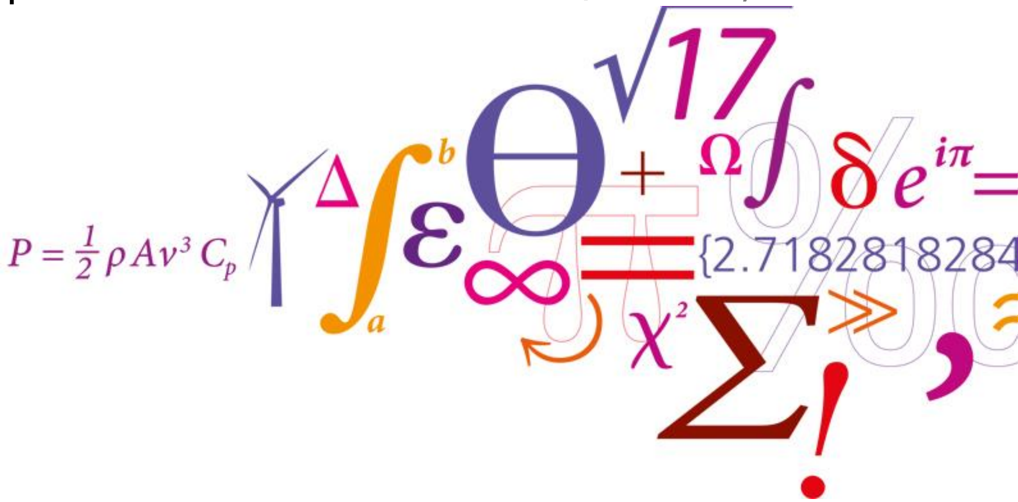


EWEA Offshore 2015
Copenhagen, DK
11th March 2015

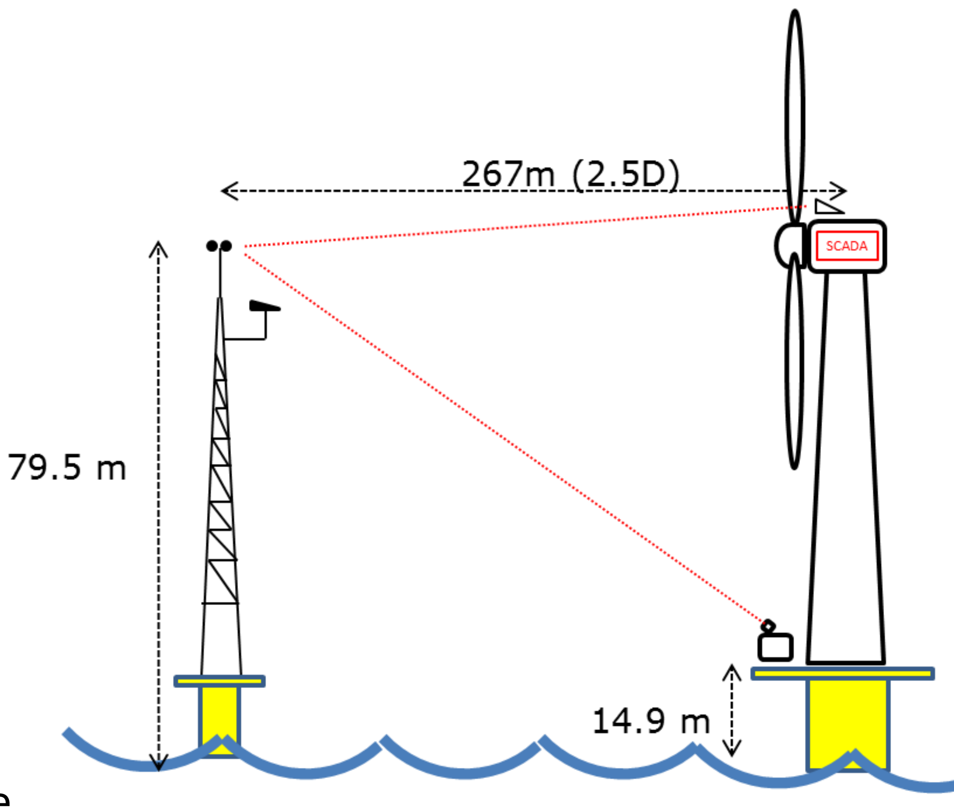
Project description

Objectives:

- Assess potential of lidars for power performance verification offshore. Could it replace a mast?

Method:

- Two different lidars:
  - Sector scanning lidar (Windcube 100S) on turbine transition piece platform
  - Nacelle mounted lidar (Wind Iris)
- IEC compliant met mast for reference

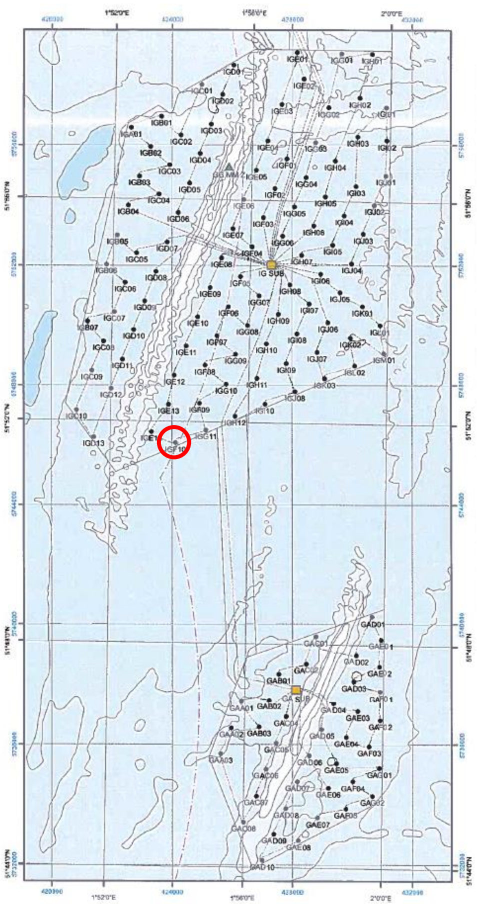


Outline

- Project description
- Lidars calibration
- Offshore deployment/measurement set up
- Availability of lidars' data
- Measurement height
- Comparison lidars/cup anemometer
- Power curves and AEP
- Uncertainties

Project place

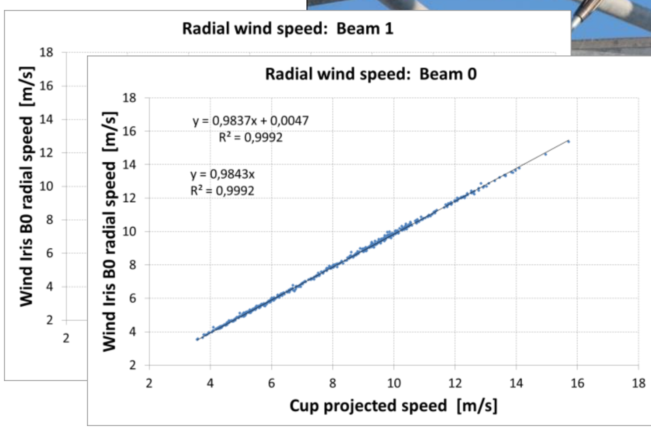
Greater Gabbard Offshore Wind Farm (GGOWL) in Lowestoft, Suffolk



Project timeline

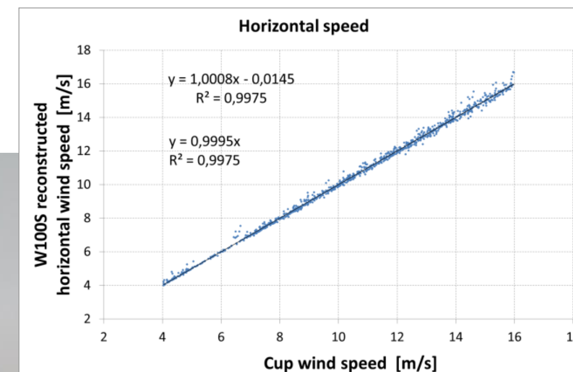
	13	2014												2015			
	12	01	02	03	04	05	06	07	08	09	10	11	12	01	02	03	04
W100S	CALIBRATION (Onshore)							Deploy		MEASUREMENTS (Offshore)							
Wind Iris	CALIBRATION (Onshore)											Deploy		MEASURE-MENTS (Offshore)			

Lidars calibration at Høvsøre



- Inclinometers offset
- Radial wind speed along 2 LOS [1]
- Horizontal wind speed measurement uncertainty: 1.7% to 2.9%
- 4 months

- Inclinometers offset [2]
- Reconstructed horizontal wind speed
- Horizontal wind speed measurement uncertainty: 1.9% to 2.9%
- 3.5 months



Offshore deployment

Wind Iris

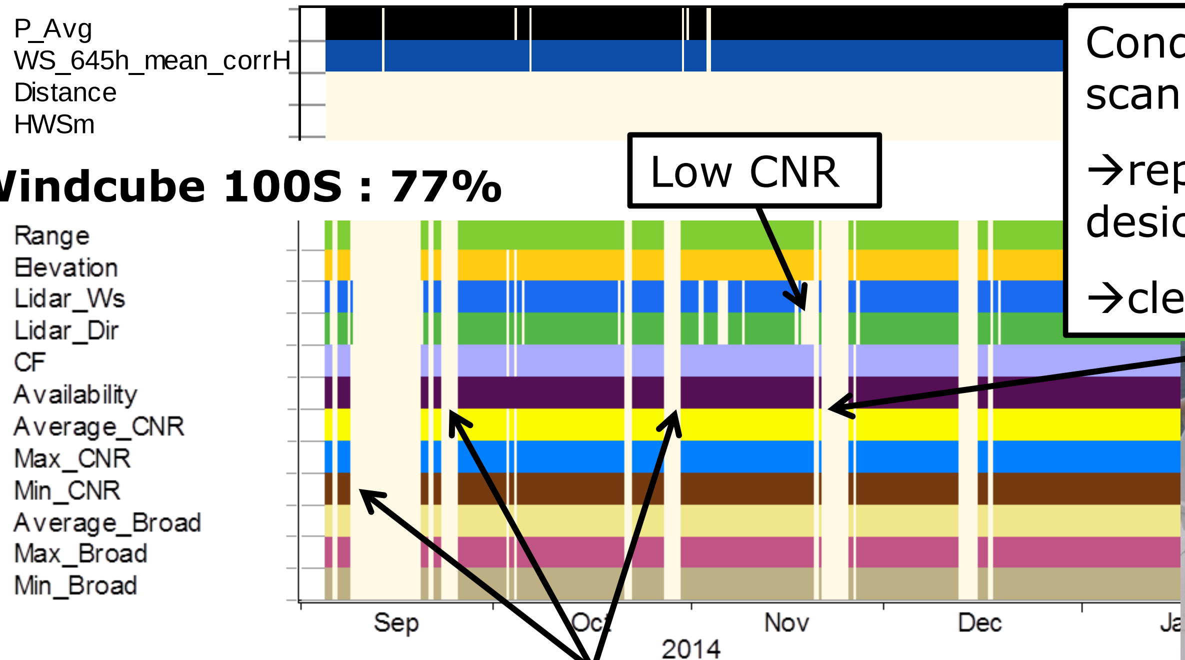
IEC compliant met mast

Windcube 100S

Data availability

Wind Iris : 100%

Windcube 100S : 77%



Low CNR

Condensation on the scanning head window

→replacement of desiccant bag

→cleaning of window

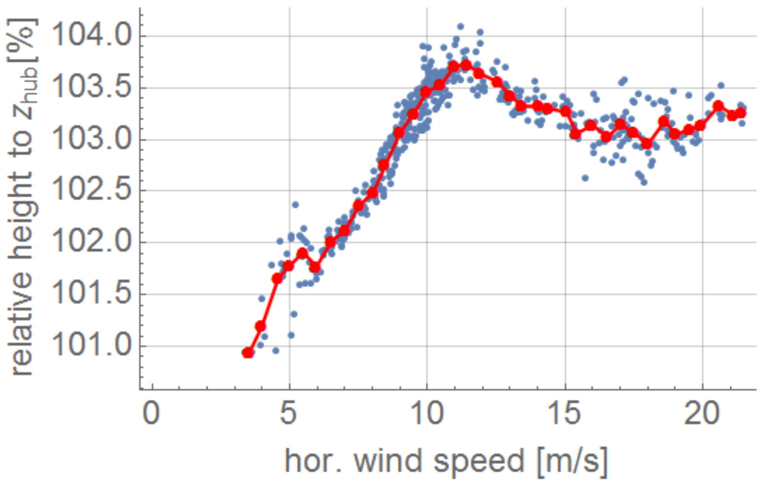
Lidar technical problems

→reboot (remotely)

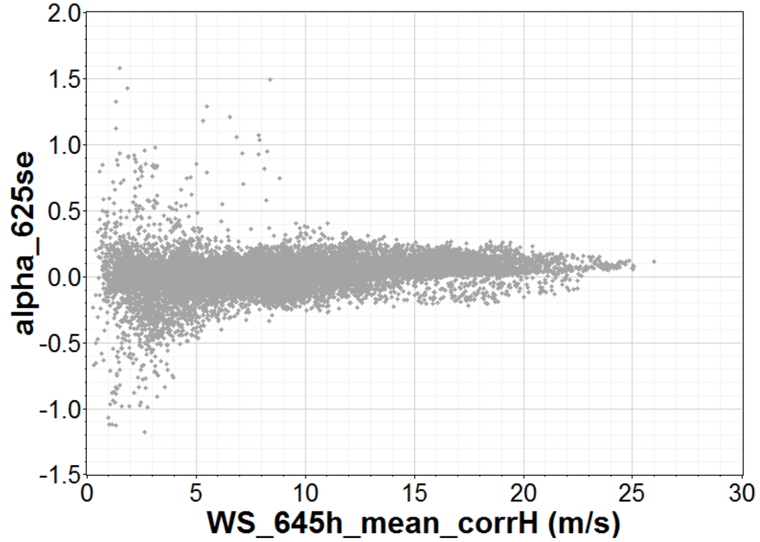
Sensing height for Wind Iris nacelle lidar

- Measuring above hub height
  → Optical head inclination adjusted to account for height of device and variations in tilt
  → But challenging adjustment as top of turbine is moving a lot (monopile foundation)
- Variations due to motion of turbine nacelle

Beam height relative to hub height



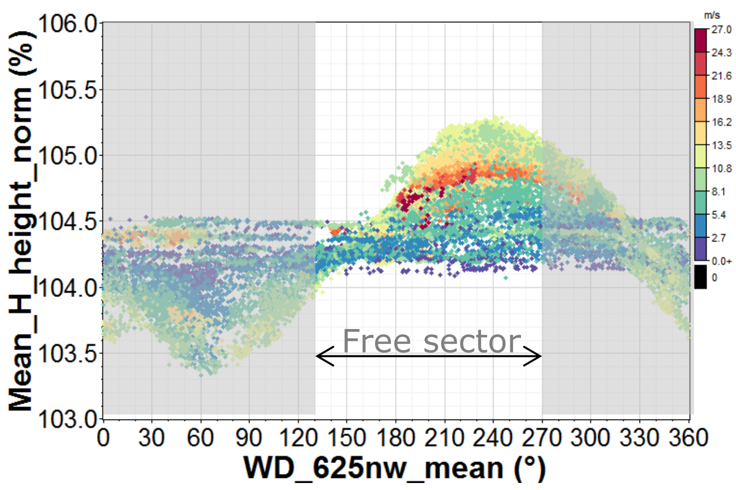
Alfa mast vs hub height WS

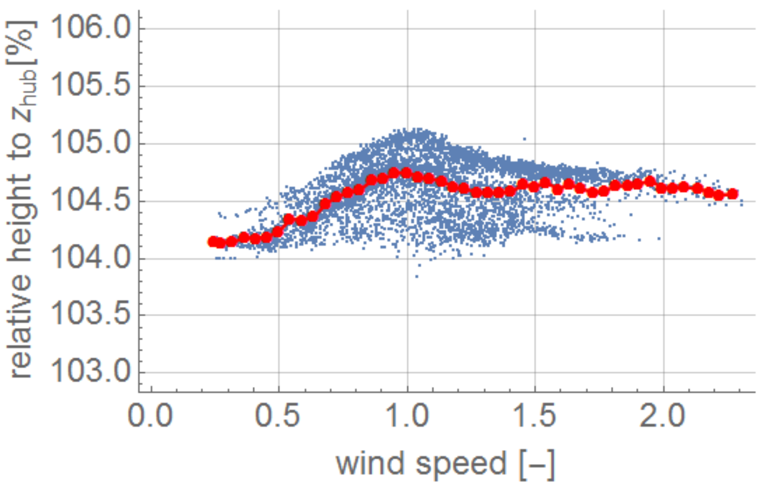


Sensing height for Windcube 100S

- Measuring above hub height (and above 2.5% of hub height)
- Scanning head elevation angle was slightly increased in order to avoid hitting the mast
- Variations due to motion of turbine and TP

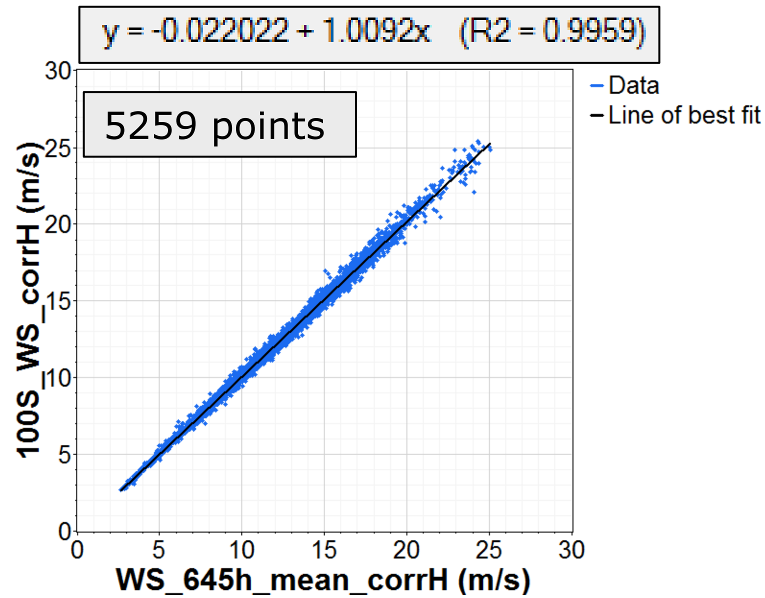
Beam height relative to hub height





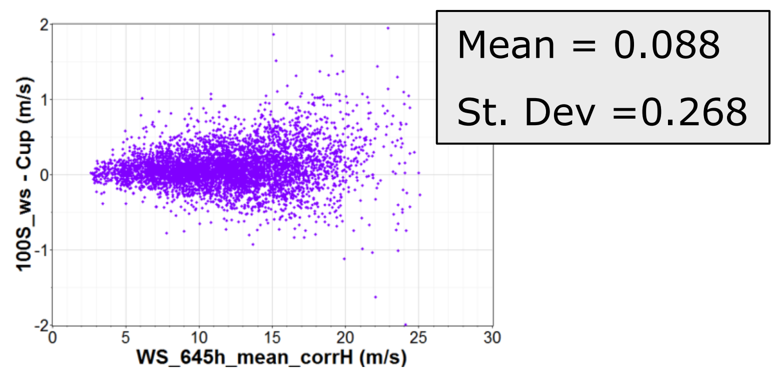
Windcube 100S/top cup comparison

Wind speed



Filters:

- wind sector: 128°-274°
- Lidar confidence factor (CF) in 10 min>85%
- Turbine Available and free of failure
- Cup concurrent with Lidar



→ Wind sector reduced compared to IEC sector in order to keep the full scan free from wakes

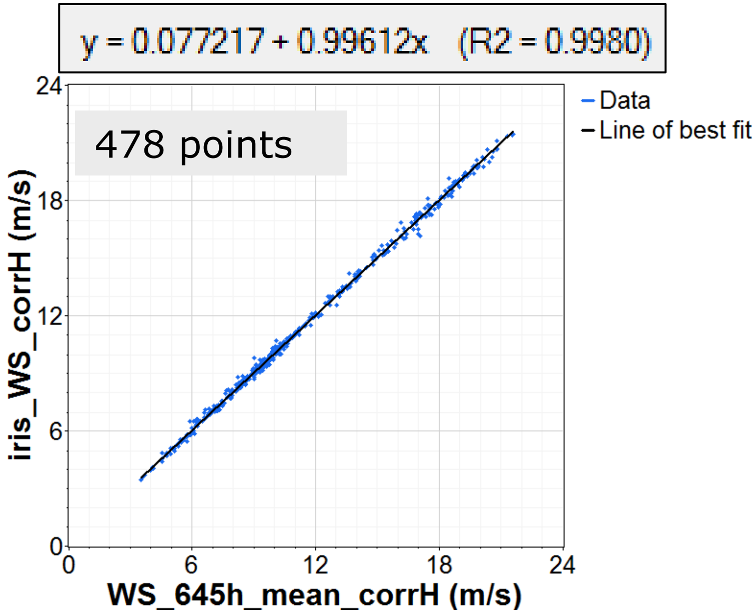
→ Good comparison on average; 0.7% higher wind speed

→ Spread increasing with wind speed

→ Similar observation during calibration

Wind Iris/top cup comparison

Filters:
- IEC power curve wind sector
- Radial wind speed availability:
  RWS0>0.55 and RWS1>0.60
- Turbine Available and free of failure
- Cup concurrent with Lidar

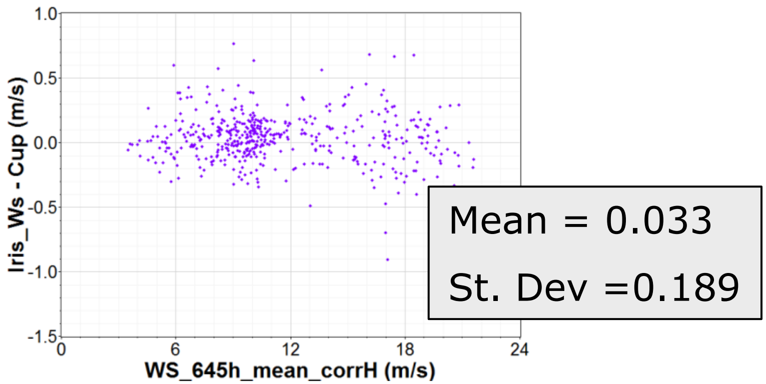


→ Good comparison on average

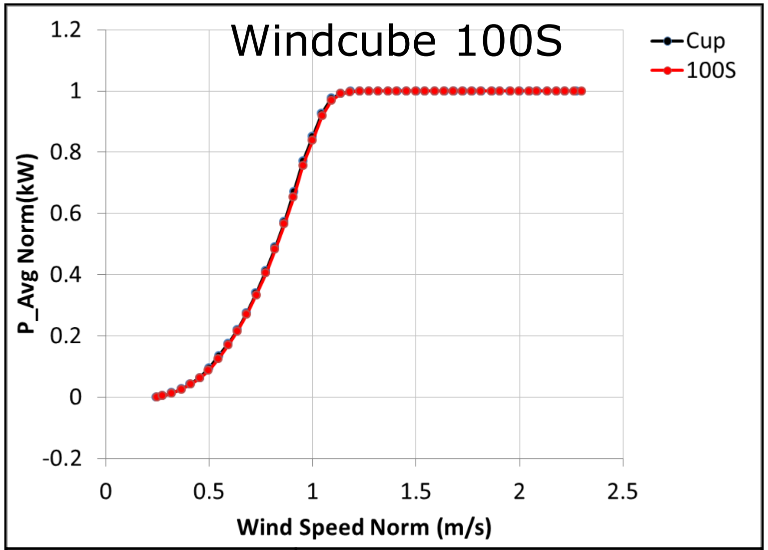
→ Spread smaller than the Windcube 100S

→ Always measuring upstream[3]

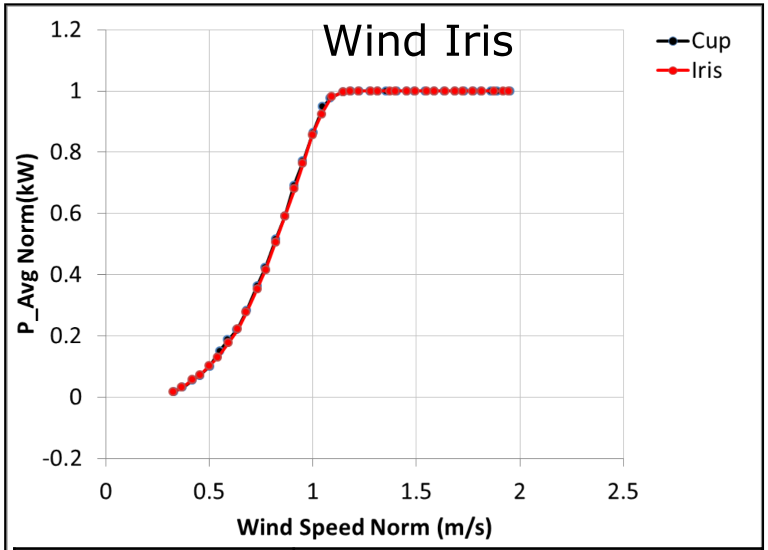
→ Smaller dataset



Power curves and AEP



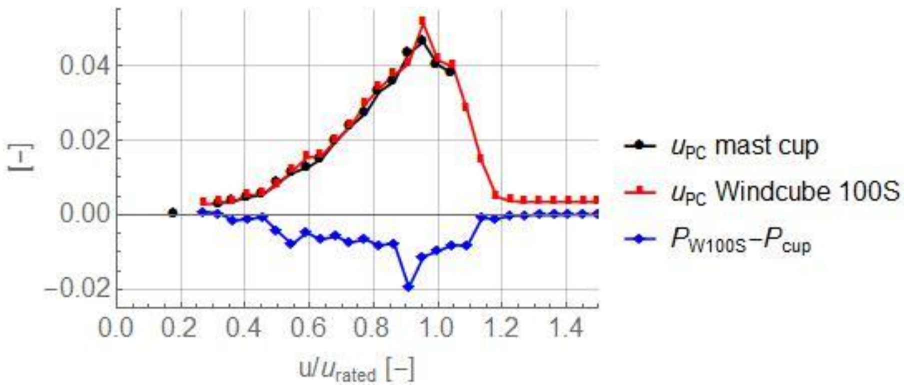
Hub height annual average wind speed	AEP relative to cup AEP
m/s	[%]
4.0	97.20%
5.0	97.75%
6.0	98.21%
7.0	98.57%
8.0	98.86%
9.0	99.13%
10.0	99.42%
11.0	99.72%

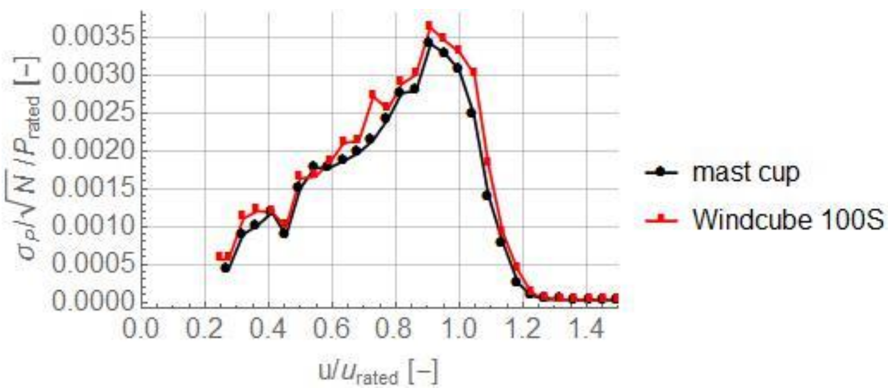


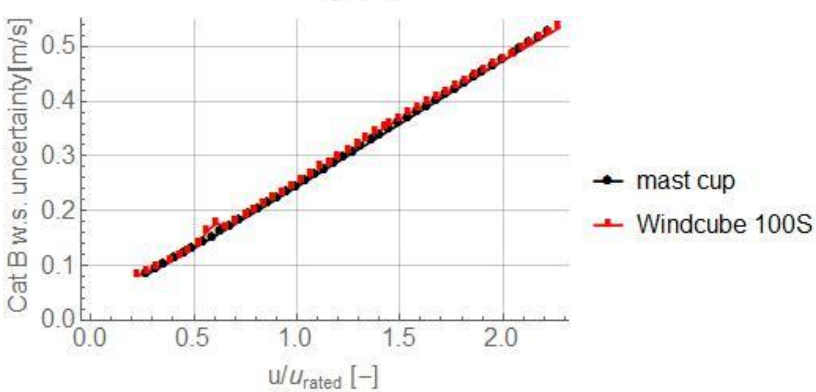
Hub height annual average wind speed	AEP relative to cup AEP
m/s	[%]
4.0	97.96%
5.0	98.22%
6.0	98.56%
7.0	98.85%
8.0	99.06%
9.0	99.22%
10.0	99.34%
11.0	99.42%

Uncertainty

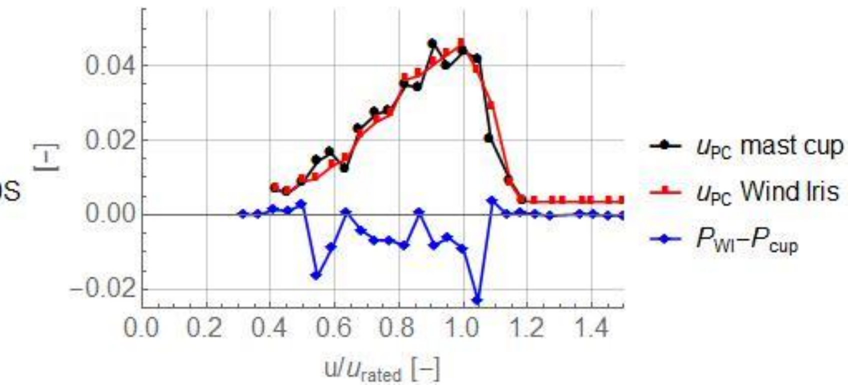
Windcube 100S

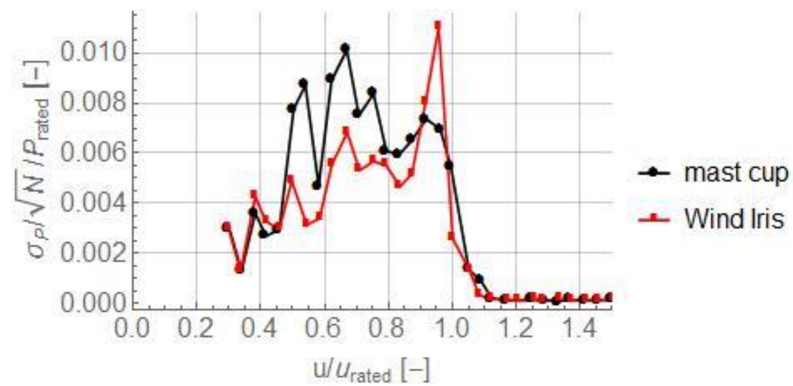


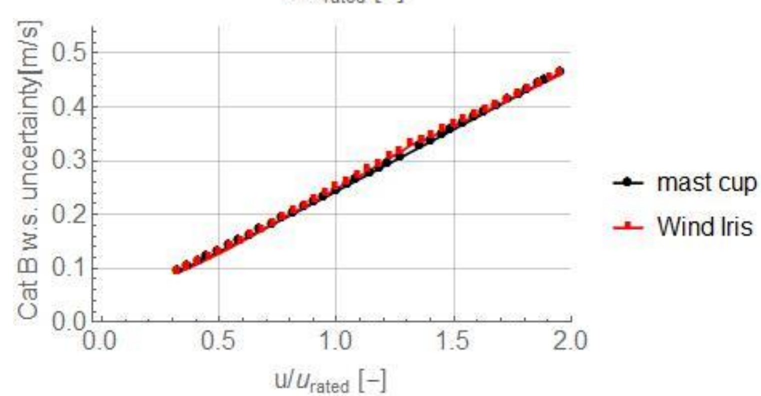




Wind Iris







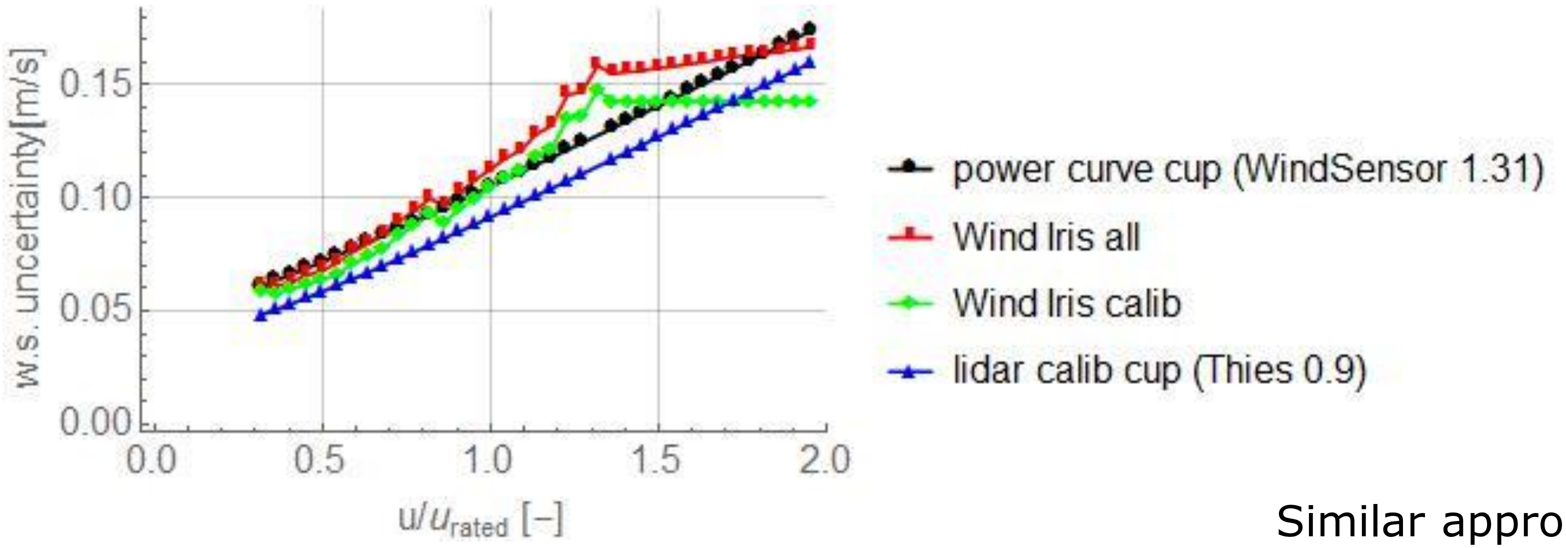
What drives uncertainty?

Cup anemometer

1. Calibration
2. Class (operational)
3. Mounting
4. Data acquisition

Wind Iris

1. Calibration [1]
2. Sensing height
3. Inclinometer



Similar approach and results for the **Windcube 100S**

Conclusions

- Generally good availability of data;
- but need proper monitoring and possibility of fast maintenance

- Good comparison lidar/mast on average
- Lidars power curves uncertainty very close to cup power curve uncertainty
  - Lower uncertainty of cup used for calibration of lidars than cup used for the power curve

- Using lidars for power performance verification require a calibration before deployment offshore (couple of months)
- Lidar deployment faster and cheaper than mast
  - Challenge: setting up height accurately
- None of these techniques is formally accepted by the new IEC standard 61400-12-1 ver.2 Draft CDV

From the perspective of the end user

- Significant CAPEX saving
- Encouragement that uncertainties are comparable to mast
- Challenge going forward – reduce uncertainties further
- Question - long-term operability of lidars if being viewed as a permanent mast replacement. What is the OPEX cost?

Project finalisation

→ Measurement campaign on-going for a couple of months

→ Report about results for a concurrent dataset
Publically available
Expected in May 2015

Acknowledgment

To colleagues in DTU who have helped with the data analysis

To technical staff from DTU, SSE and GGOWL who took care of the lidar installation and maintenance

References

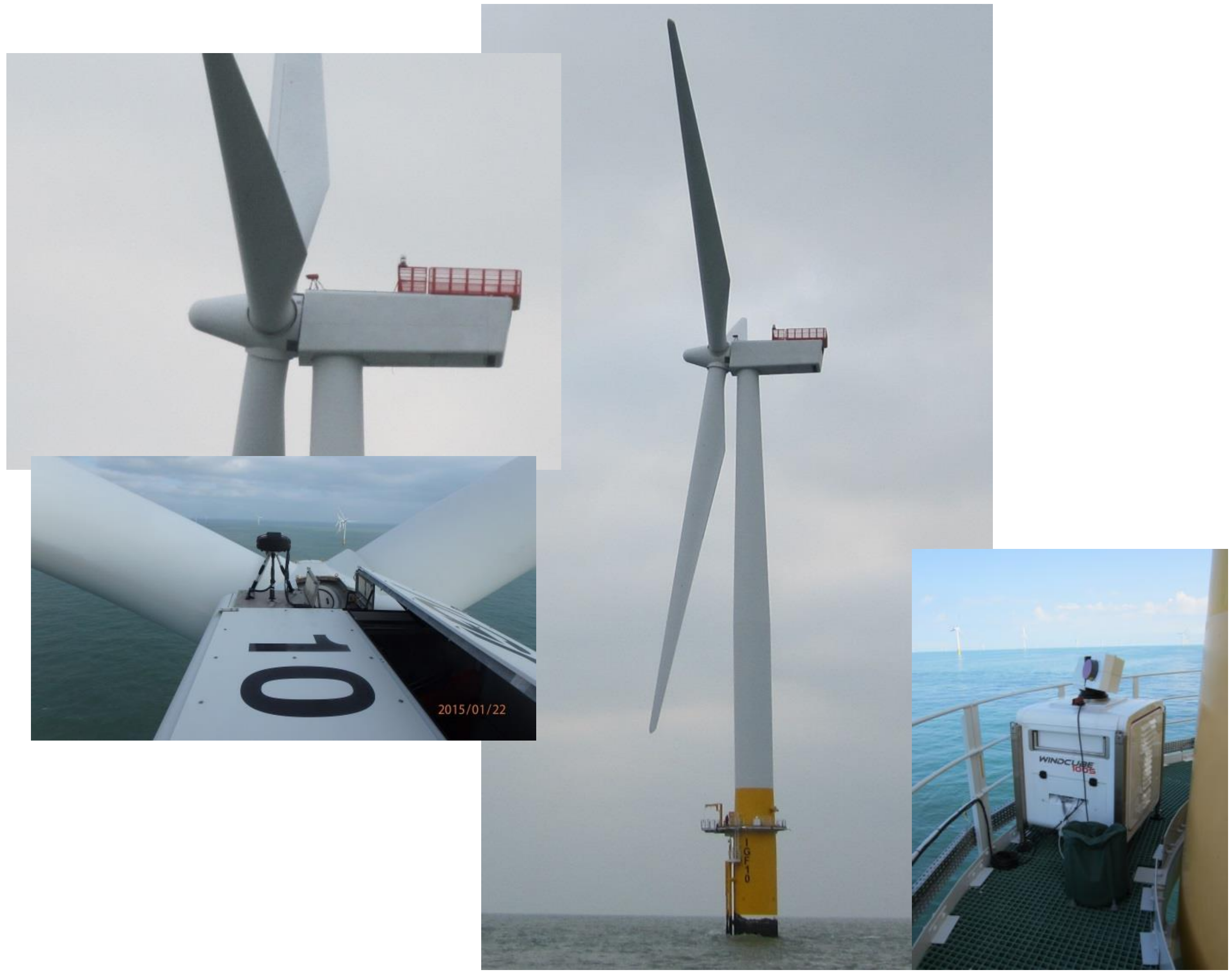
[1] Courtney M, *Calibrating Nacelle lidars*, DTU Wind Energy-0016

[2] Wagner R & M Courtney, *Comparison test of WLS200S-22 (Final),* Report LC-I-046(EN)

[3] Wagner et al., *Power curve measurement with a two-beam nacelle lidar*, Wind Energy 17-9: 1441–1453, 2014

Thank you for your attention

Questions



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