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

ZephIR Dual-Mode

5-beam Avent demonstrator

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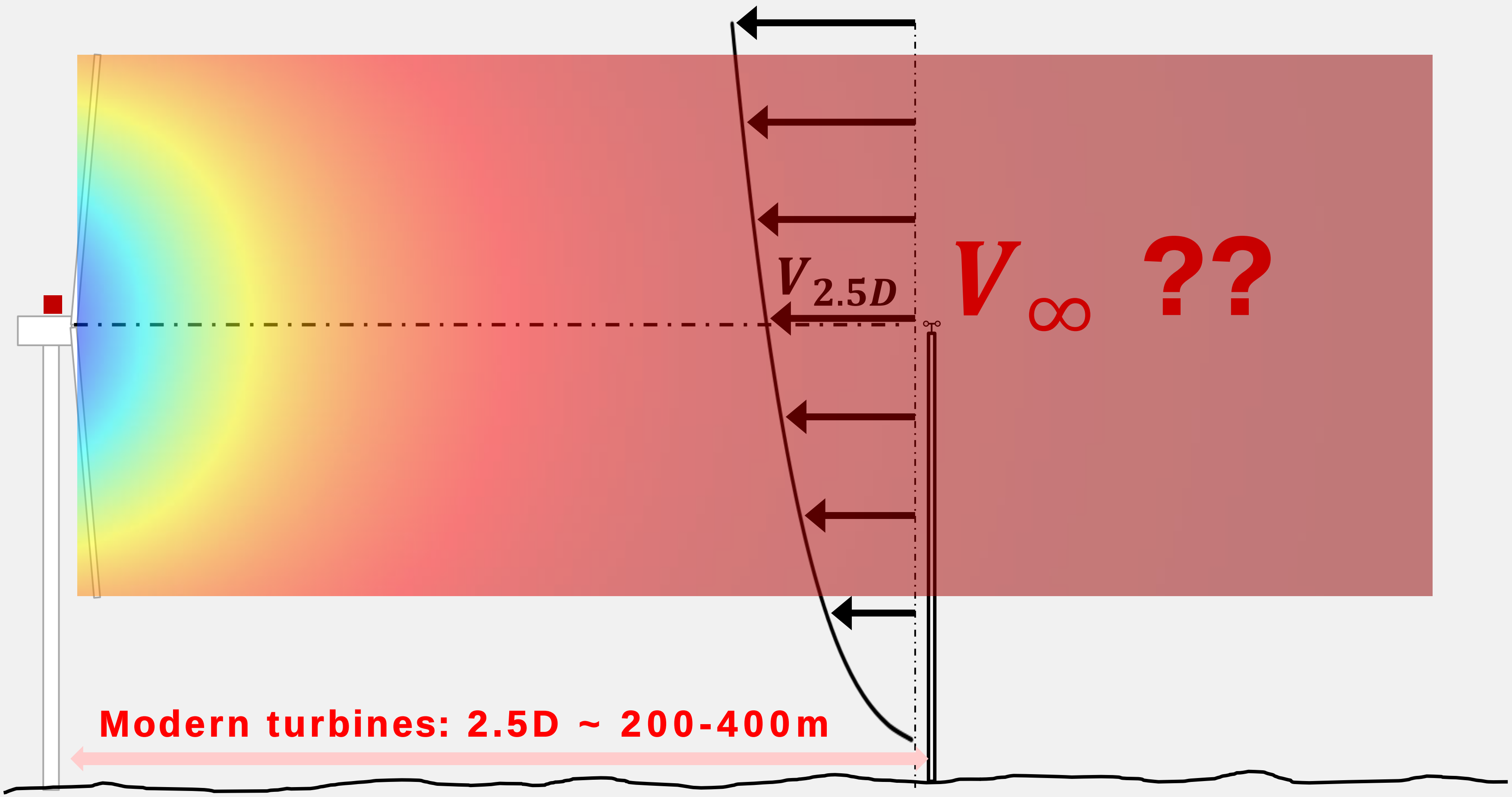
RESEARCH, TECHNOLOGY & GROWTH

Searching for free stream wind speed



- Decorrelation WSpeed / power
- H_{hub} speed insufficient?
- 2.5D not really free wind …

Does this make it any easier?

Perdigão.
credit: N. Vasiljevic

- In complex terrain:
  - any ”free stream” wind speed idea?
  - site calibration? Maybe

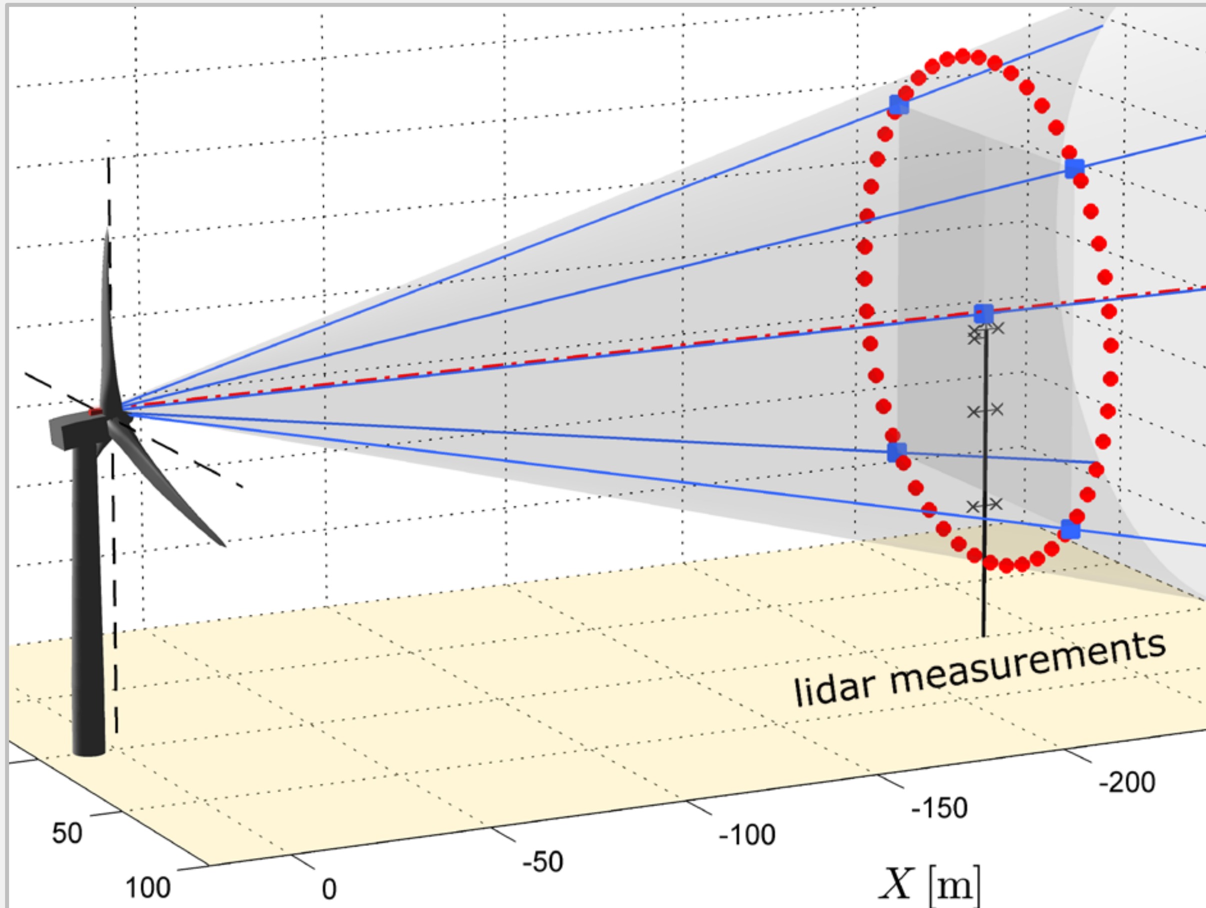
Does this make it any easier?

- In complex terrain:
  - any ”free stream” wind speed idea?
  - site calibration? Maybe
- Offshore:
  - mast expensive
  - free wind may not be measurable due to wakes

Power performance verification: nacelle-mounted lidars, the future?

- Several possibilities for lidar measurements:

1) <u>2.5D distance</u>
fitting wind speed + direction + shear to lidar-measured LOS velocities



Power performance verification: nacelle-mounted lidars, the future?

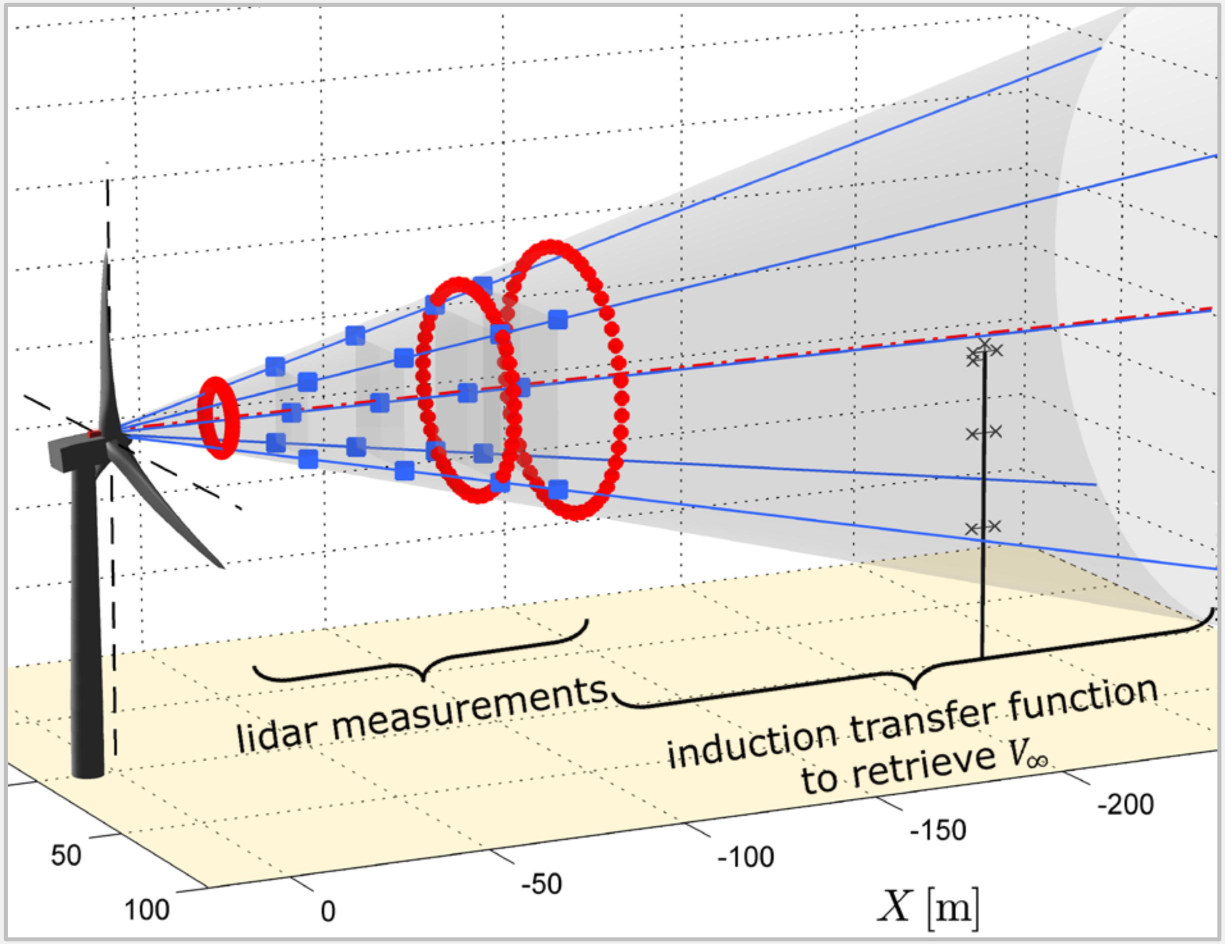
- Several possibilities for lidar measurements:

1) 2.5D distance
fitting wind speed + direction + shear to lidar-measured LOS velocities

2) Multiple distances close to rotor
induction integrated in wind field reconstruction

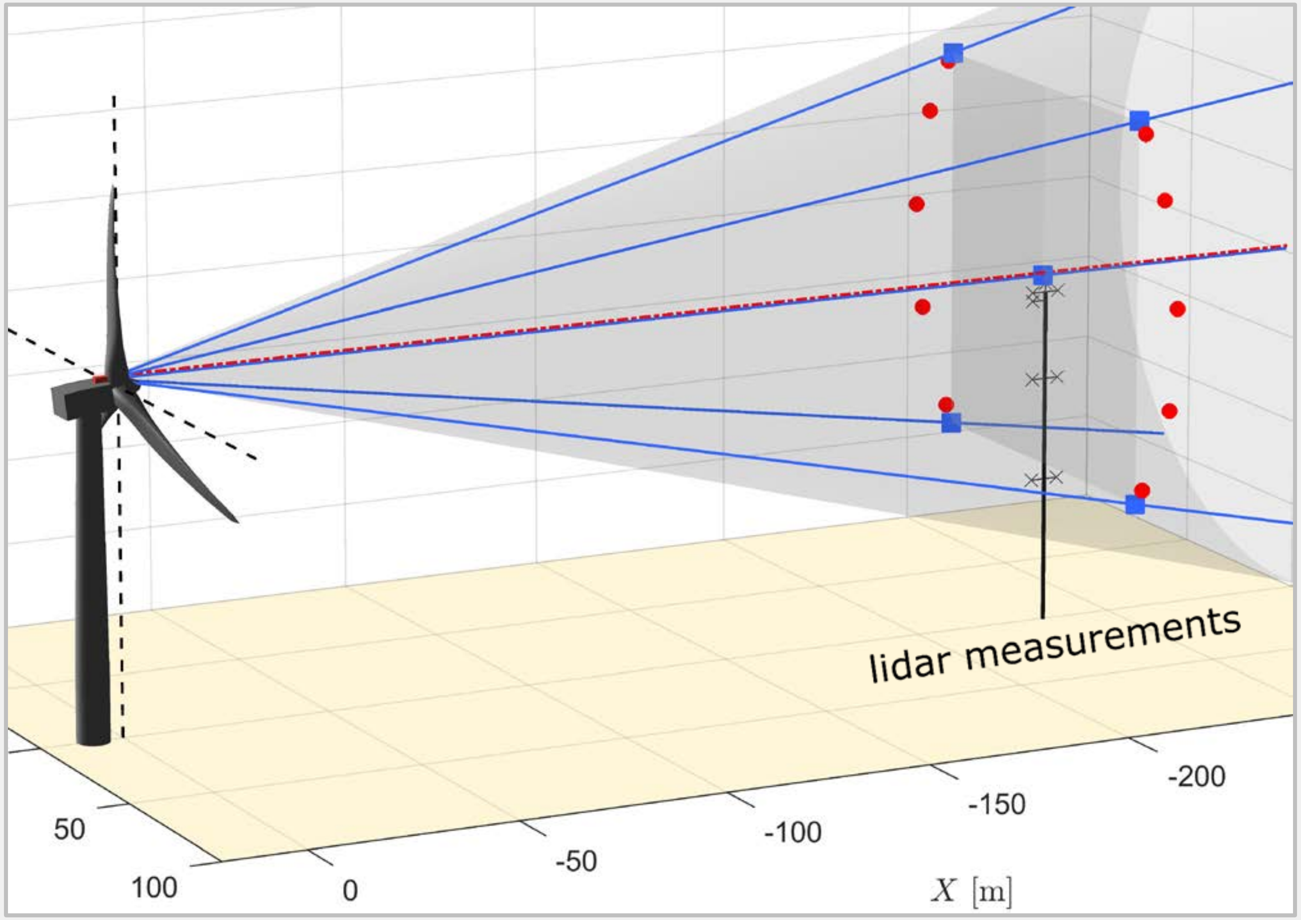
$$\frac{U(x)}{U_\infty} = 1 - a\left(1 + \frac{\xi}{\sqrt{1+\xi^2}}\right)$$

$$a = \frac{1}{2}\left(1 - \sqrt{1 - C_t}\right)$$



Case 1: lidar meas. @2.5D

5B-Demo: use the 5 pts   **ZDM**: use 10 pts



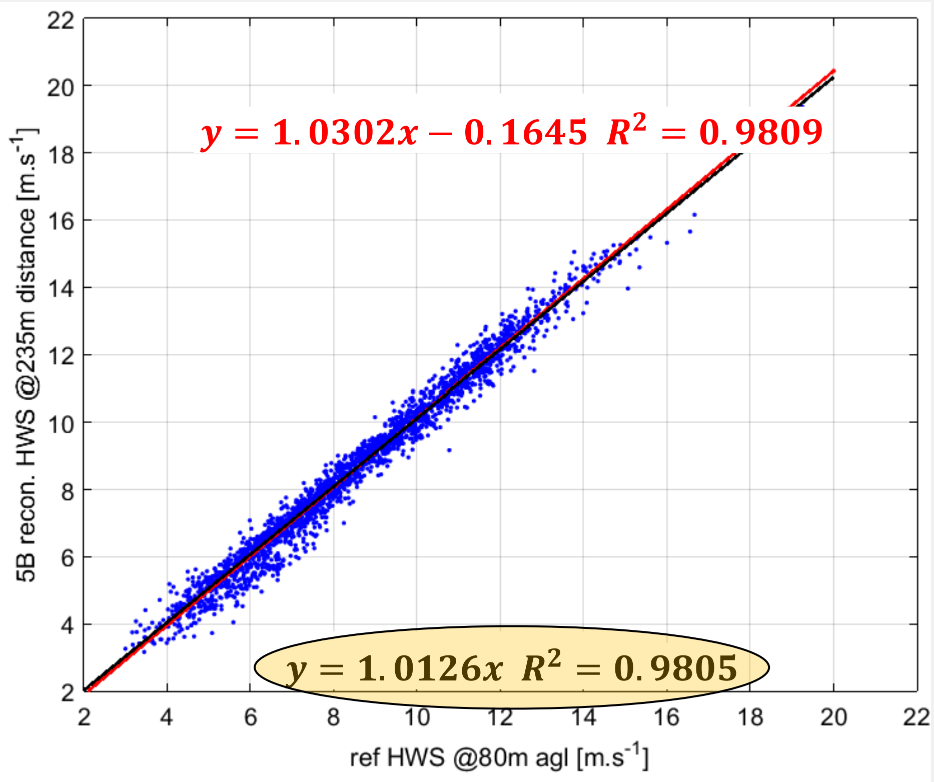
Case 1: lidar meas. @2.5D

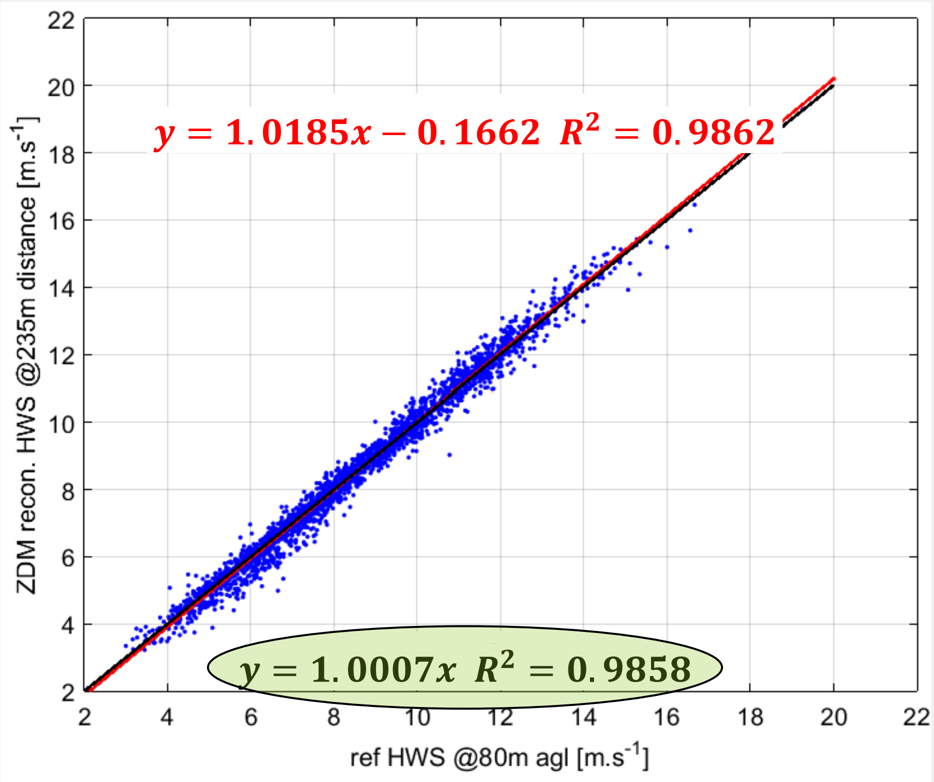
Mast comparison

5B-Demo: use the 5 pts

ZDM: use 10 pts

HWS estimated @hub height

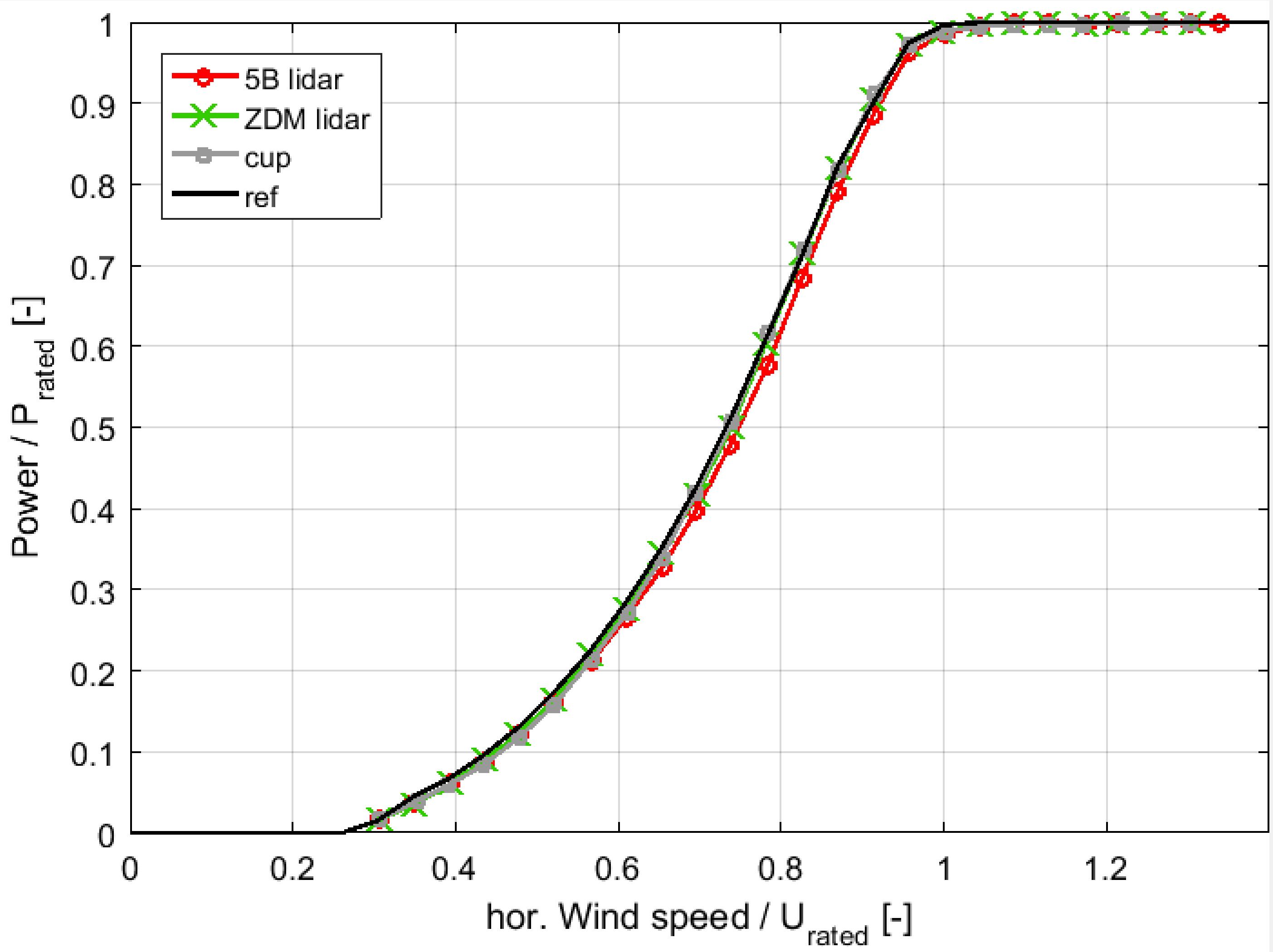




$$N_{points} = 2563$$

Case 1: lidar meas. @2.5D

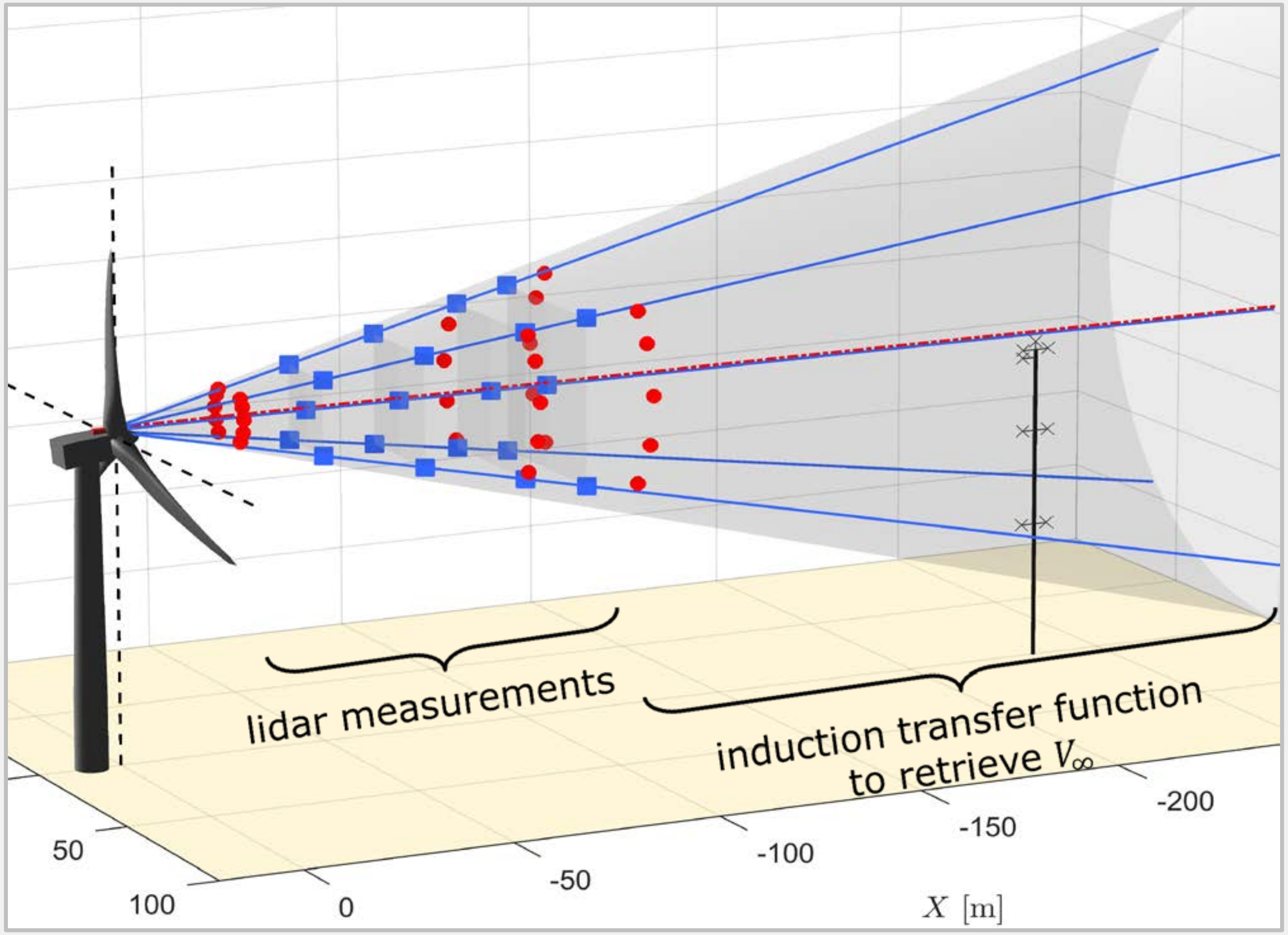
Power curves



Case 2: lidar meas. @ multiple distances close to rotor

5B-Demo : use the 5 pts @[0.5 0.75 1.0 1.15] D

ZDM: use 10 pts @[0.3 1.0 1.25] D



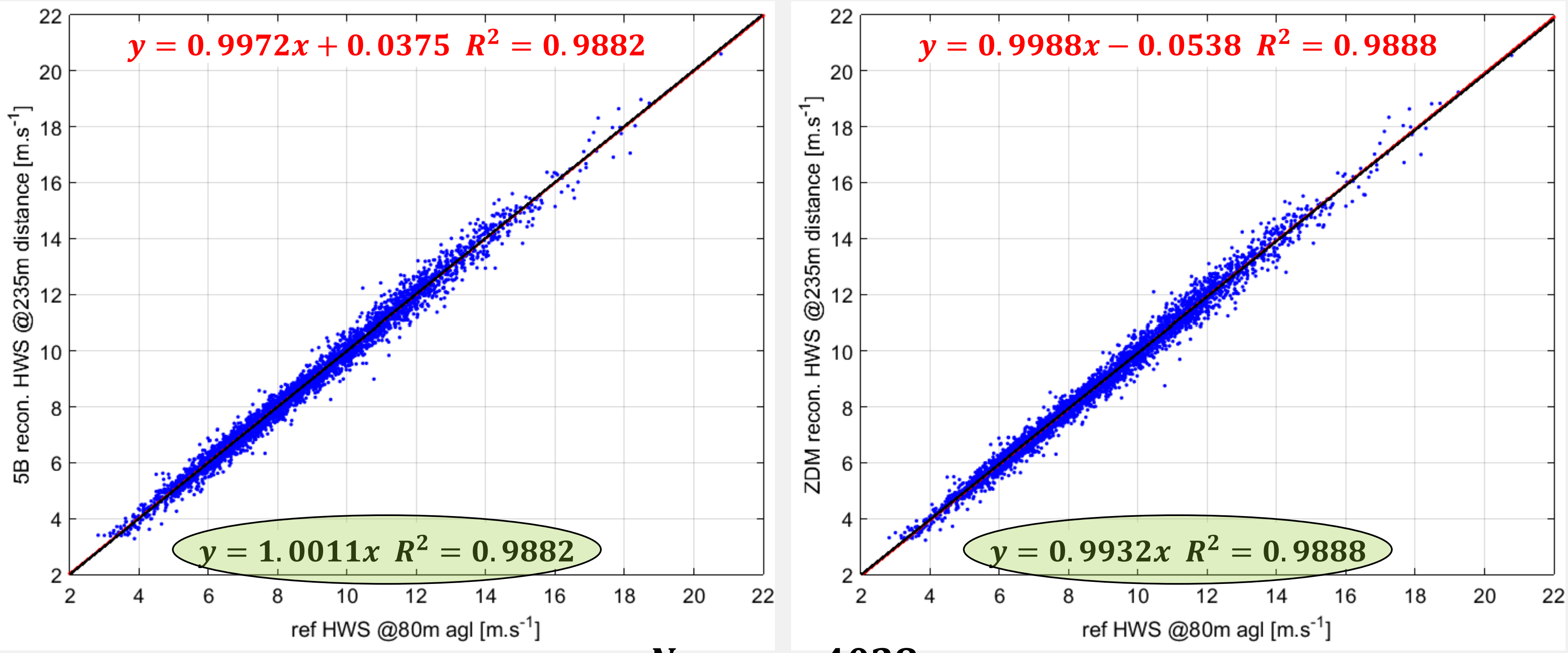
Case 2: lidar meas. @ multi-dist (near flow)

Mast comparison

5B-Demo: use the 5 pts @[0.5 0.75 1.0 1.15] D

ZDM: use 10 pts @[0.3 1.0 1.25] D

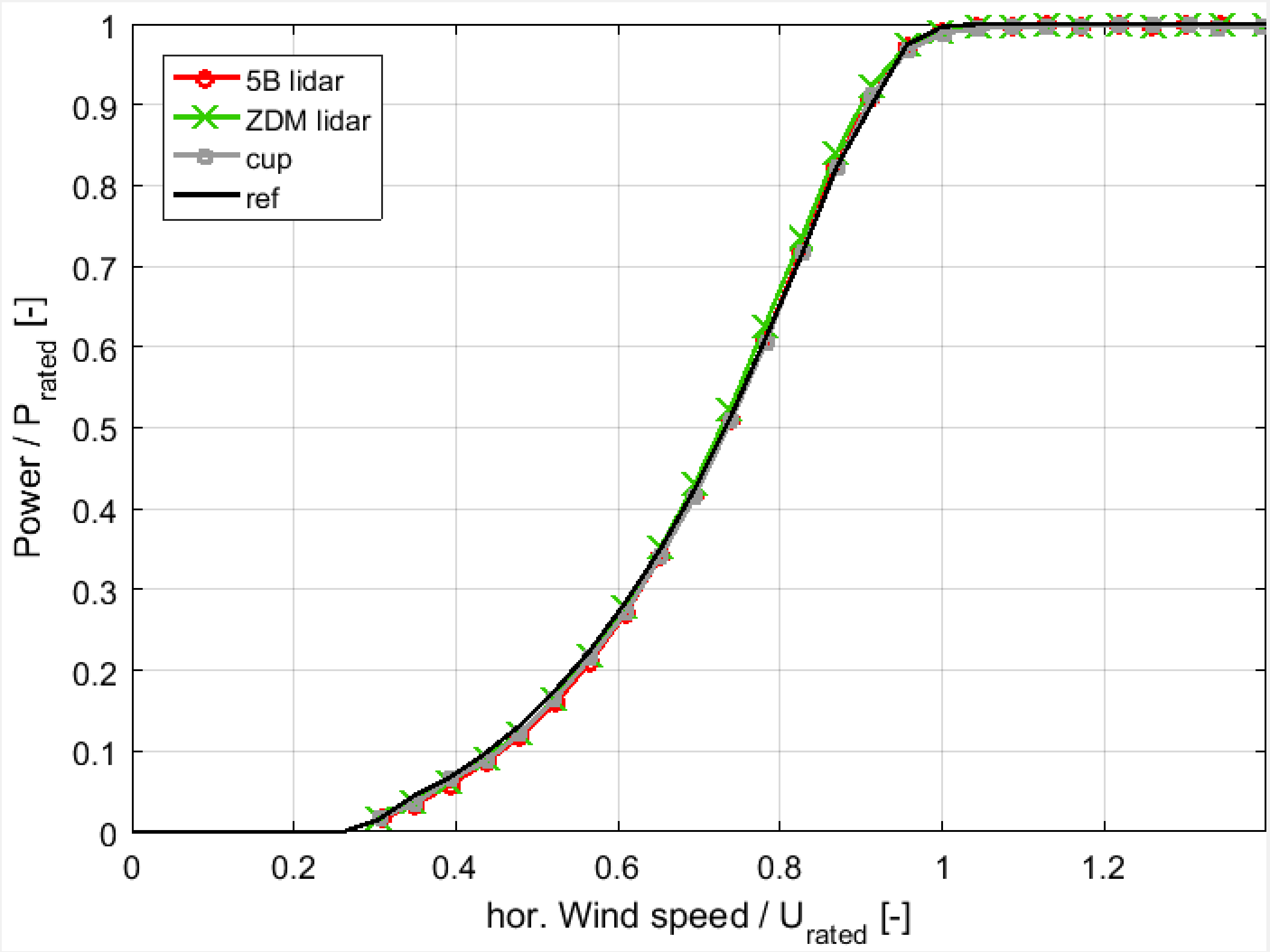
HWS estimated @hub height and @2.5D distance



$N_{points} = 4028$

Case 2: lidar meas. @ multi-dist (near flow)

Power curves



AEP results

- IEC -12-1 methodology
- extrapolated AEPs
- 0.5 m/s bin width
- Relative difference in % of cup-based AEP

Lidar measurements	@2.5 D (case 1)			@multiple distances (case 2)		
Rayleigh avg wind speed	6 m/s	8 m/s	10 m/s	6 m/s	8 m/s	10 m/s
Avent 5-Beam demonstrator lidar	Wspeed difference: +1.2%			Wspeed difference: +0.1%		
	-2.0%	-1.6%	-1.2%	-0.4%	-0.1%	+0.0%
Zephir Dual Mode lidar	Wspeed difference: +0.1%			Wspeed difference: -0.7%		
	+0.4%	+0.2%	+0.1%	+2.0%	+1.3%	+0.9%

➔AEP estimations as good with the “multi-distances” method as with the 2.5D (<1.5% difference)

Take-aways

- **V_∞ is found!** The solution: measurements close to rotor, within the induction zone, at multiple distances, e.g. with nacelle lidars

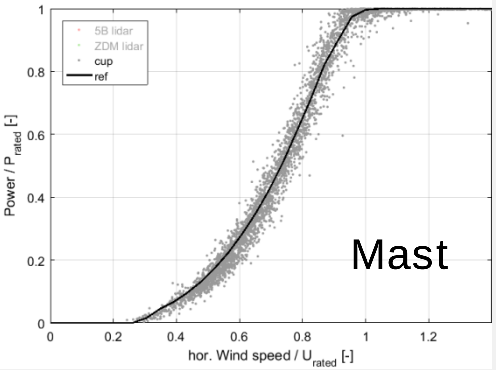
- Wind Field Reconstruction algo. provide estimates comparable classic mast instrumentation ($< 1\%$ difference)

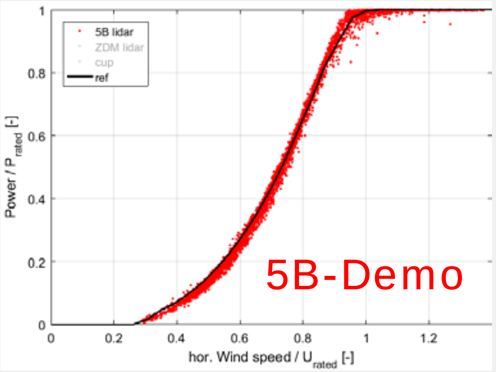
- Power curves in flat terrain verified accurately, reduced scatter (as usual with nacelle lidars)

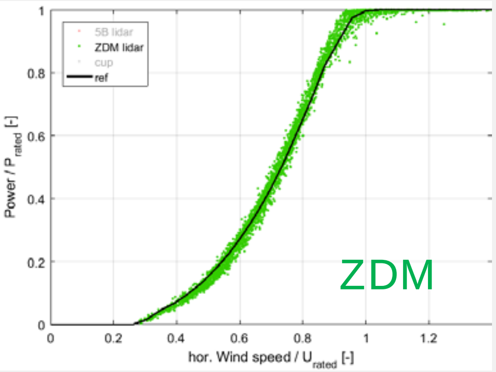
  ➔next generation of IEC61400-12-1 standards? (NWIP)

- **Further work** :
  - Two-dimensional induction? (ongoing)
  - Adaptation and testing of method in complex terrain (campaign in Hill of Towie, Zephir DM+4-beam Wind Iris)
  - Uncertainty assessment of Wind Field Characteristics: speed, direction, shear, induction factor / Ct, ...

Thanks for your attention!







More info:

- website www.unitte.dk
- contact borr@dtu.dk

Acknowledgements

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