
DTU

UniTTe

Towards the end of site calibration?

PCV in complex terrain using multi- range nacelle lidar

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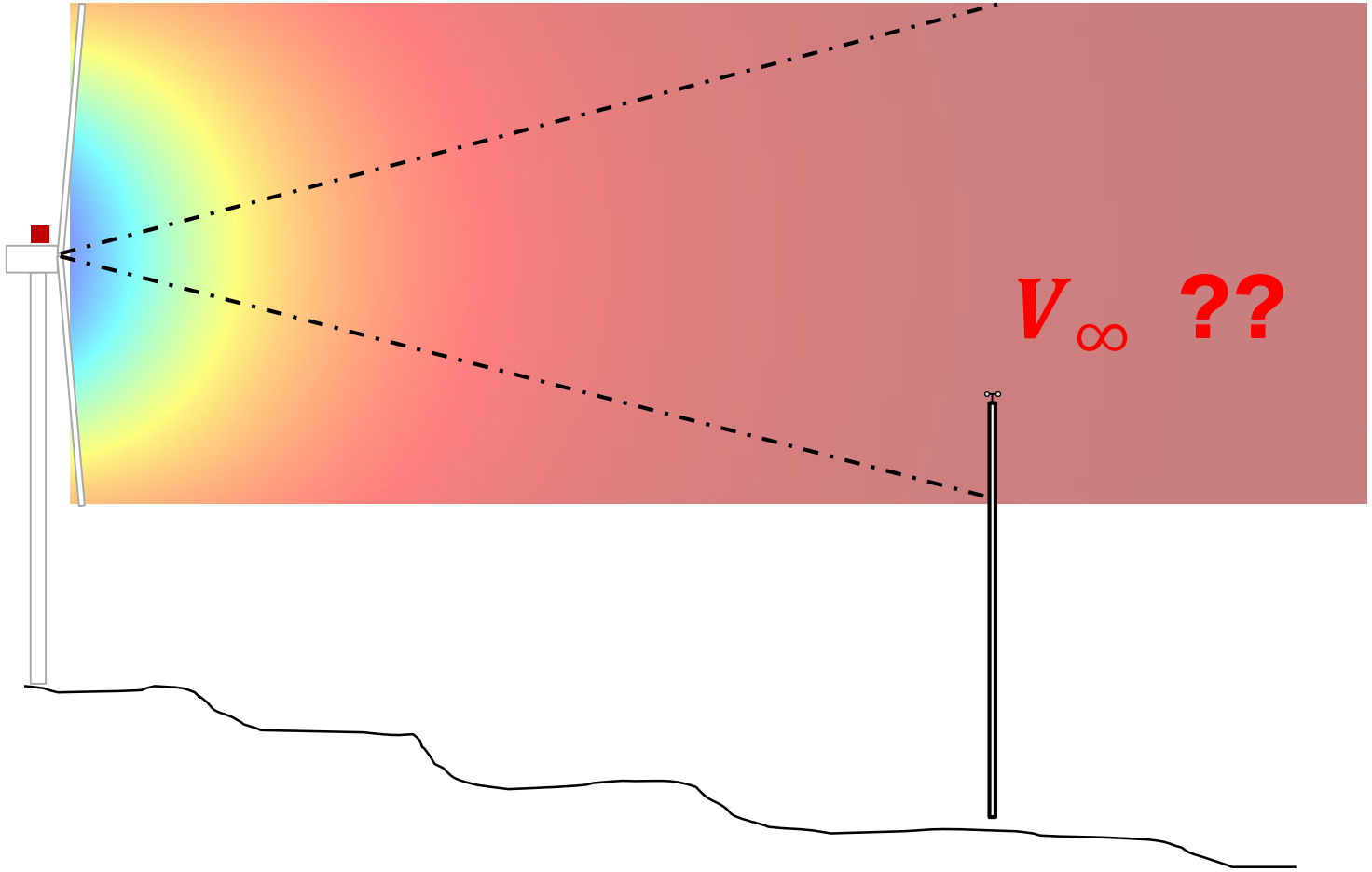
Motivation

Searching for the free wind speed



Content

- Wind Field Reconstruction concept
- Test in flat terrain – Nørrekær Enge
- Test in complex terrain A – Ogorje
- Test in complex terrain B – Hill of Towie (HoT)
- Results overview
- Conclusions
- Next

Concept

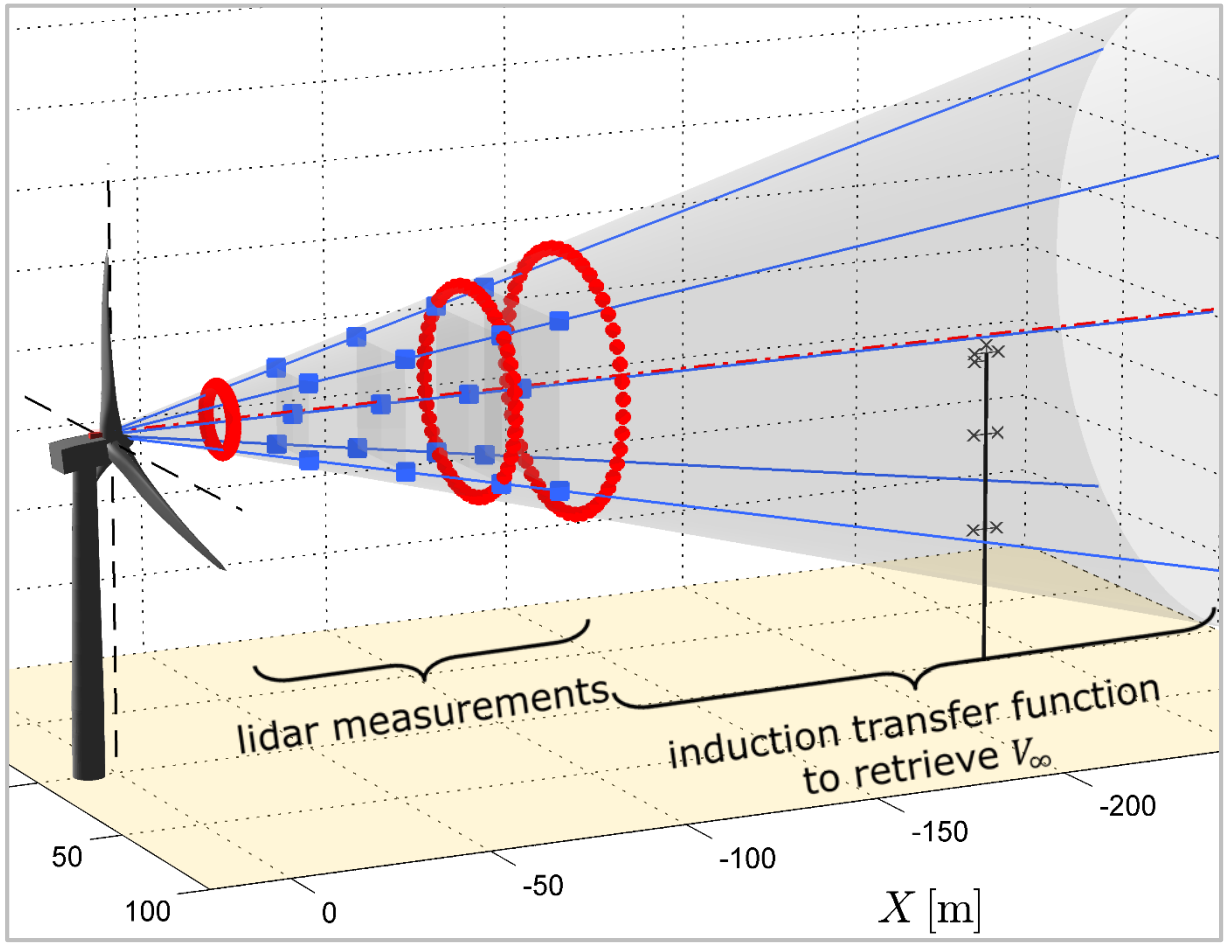
Model-fitting Wind field reconstruction

Lidar measurements at multiple distances close to rotor

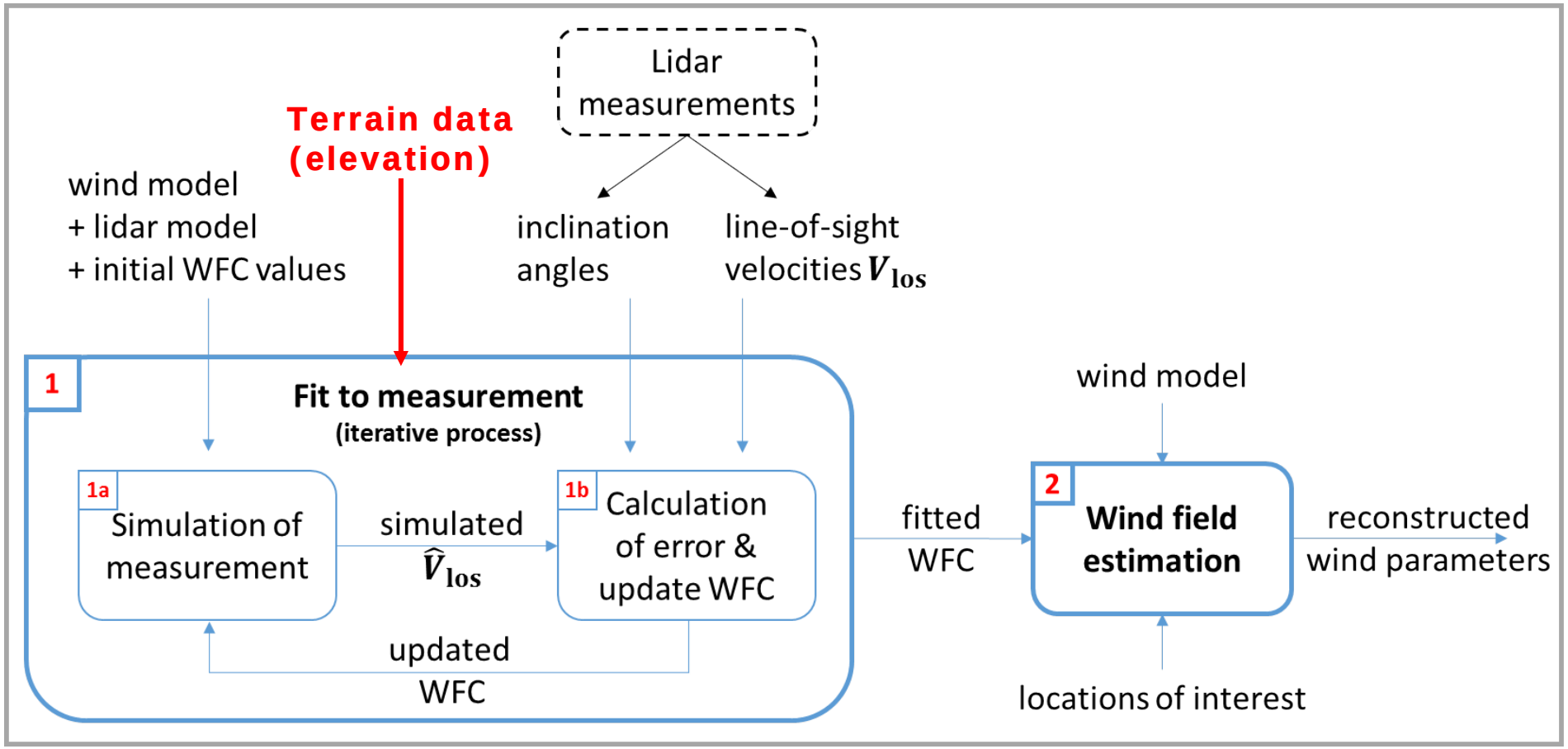
+

induction integrated in wind field reconstruction

4 WFCs: spd V_∞, yaw mis. θ_r, shear α_{exp}, induction factor a_{ind}



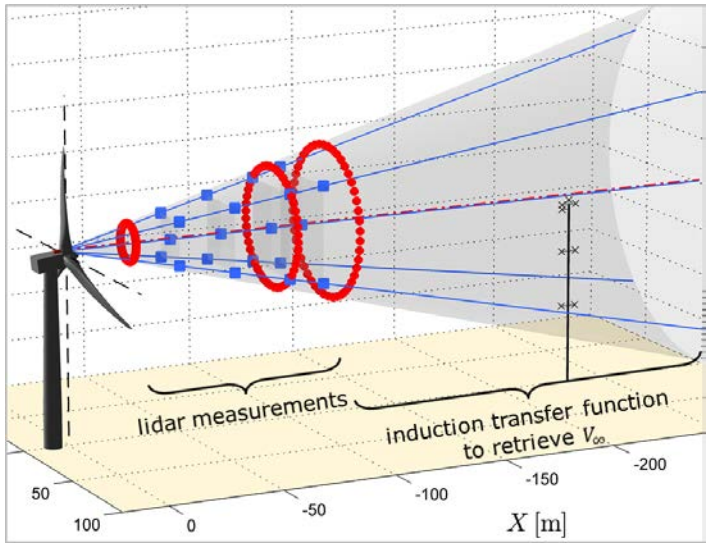
Wind Field Reconstruction (WFR) algorithm



Nørrekær Enge (flat terrain) – measurement campaign

Wind farm developed by *Vattenfall*, Denmark

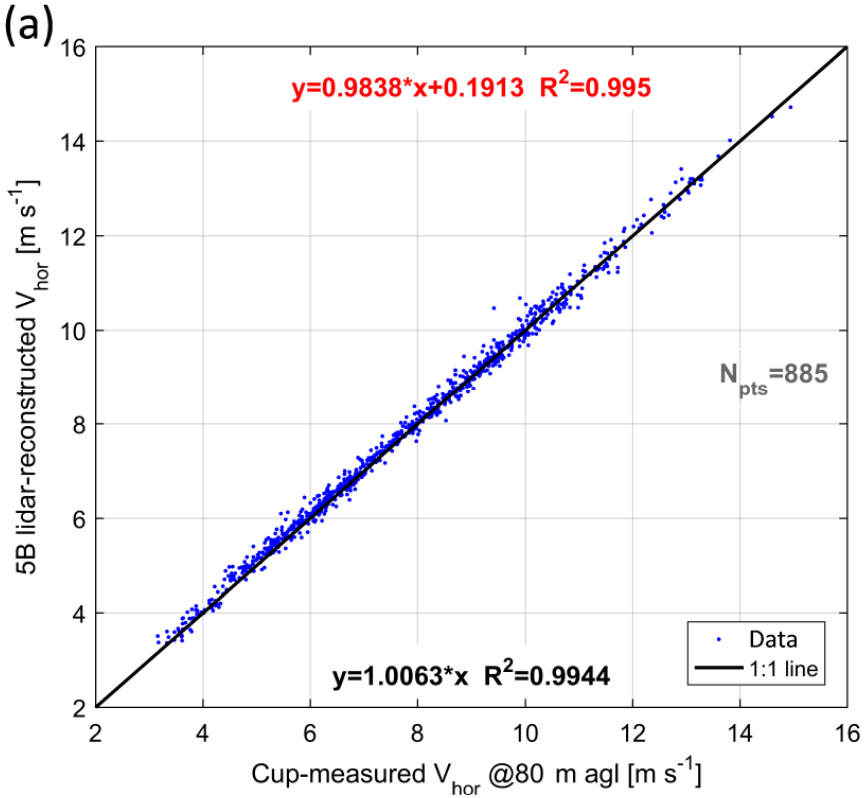
13 Siemens 2.3MW WTG – 80m/93.5m



- 5 beam Demonstartor (Leosphere) nacelle lidar
- ZephIR Dual Mode nacelle lidar
- Both nacelle lidars were calibrated.
- IEC compliant met mast

Nørrekær Enge (flat terrain) - results

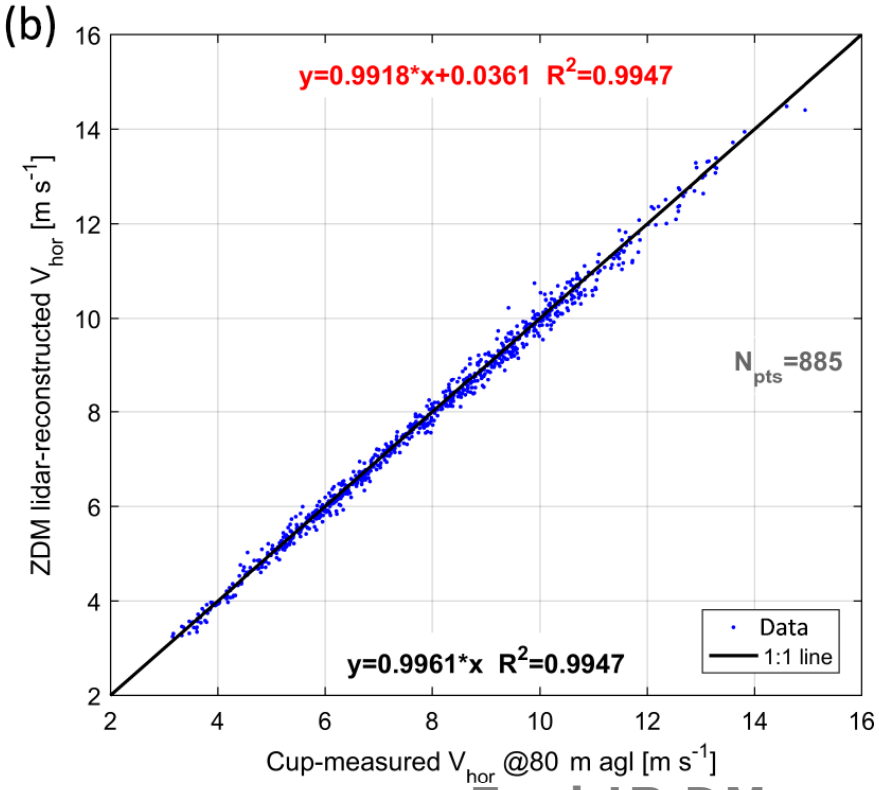
lidar reconstructed V@2.5D vs. mast spd



5B Demonstrator

5 LOS

4 ranges @[0.5; 0.75 ; 1.0 ; 1.15] D_{rot}



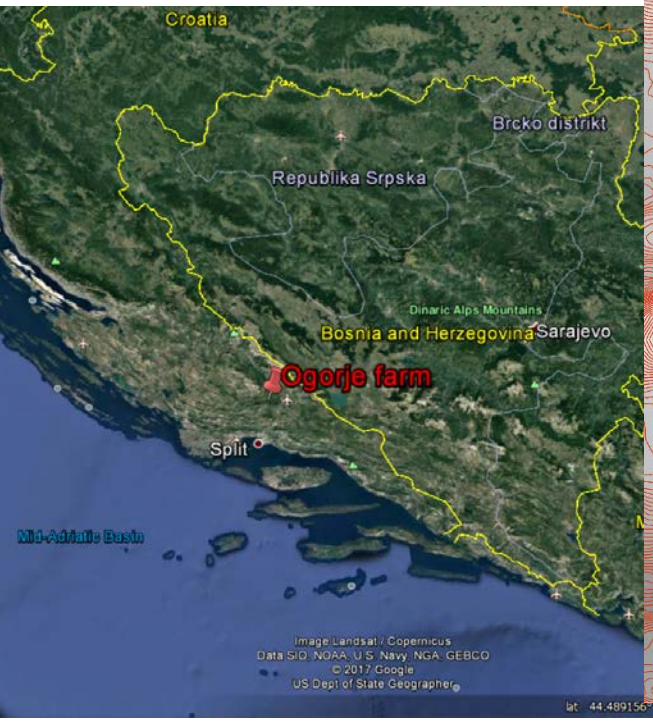
ZephIR DM

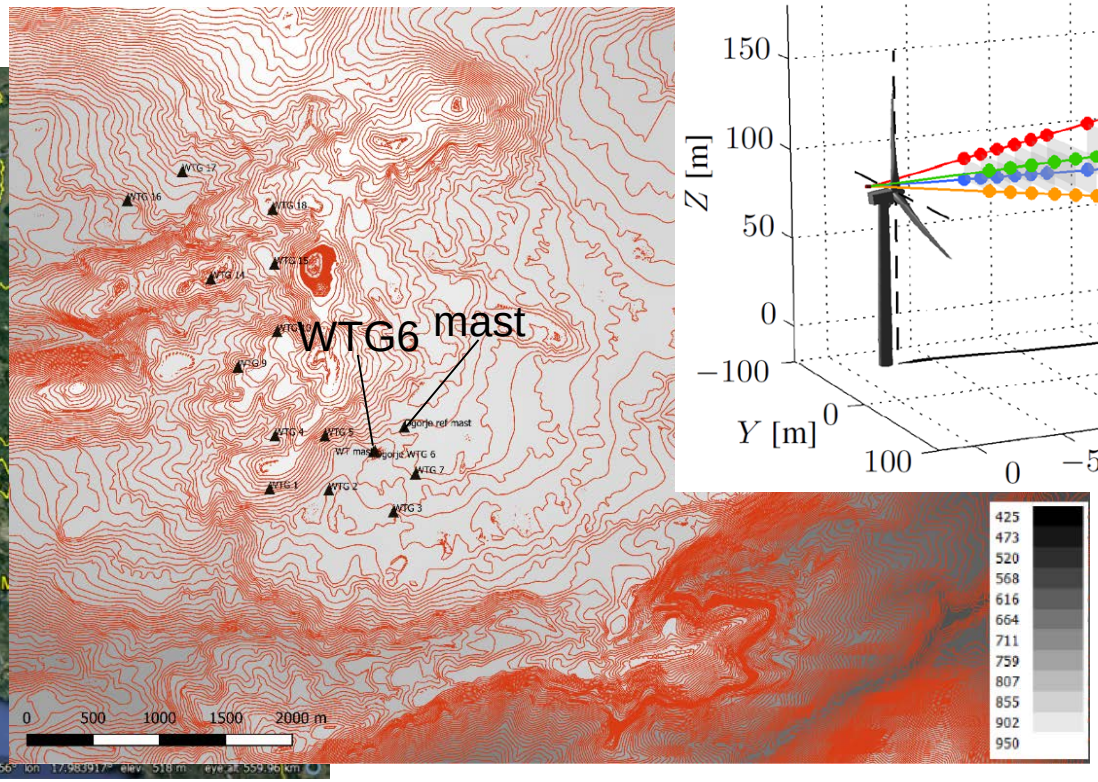
6 LOS

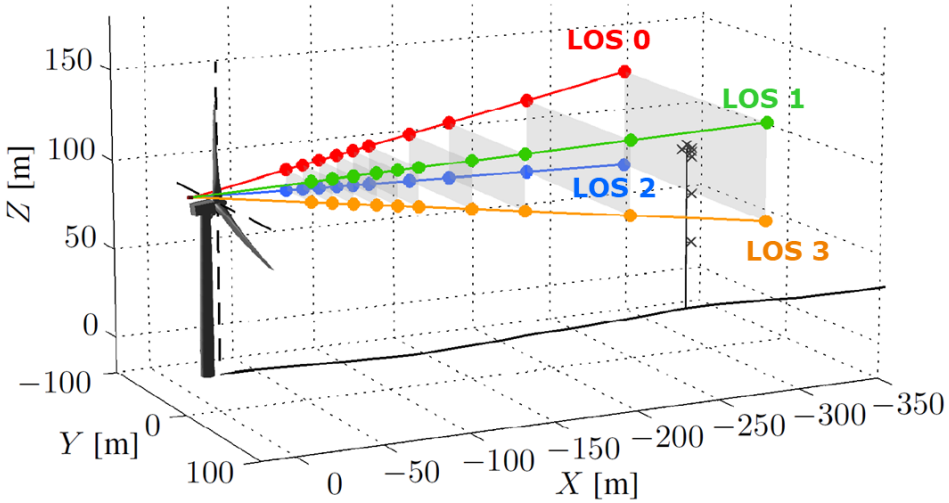
3 ranges @[0.3 ; 1.0 ; 1.25] Drot

Ogorje (complex terrain) – measurement campaign

- Wind farm developed by *Akuo Energy*, Croatia
- *14 Vestas* V112-3.0 ($H_{hub} = 94m$)



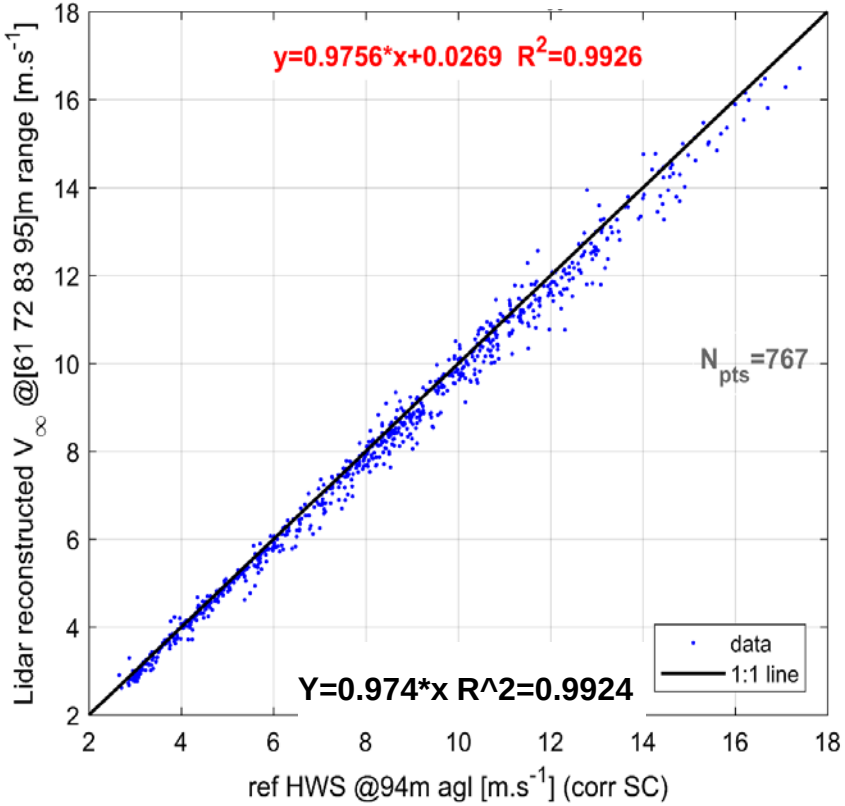




- 4 beam Wind Iris nacelle lidar
- IEC compliant met mast
- IEC compliant site calibration

Ogorje (complex terrain) – Results

lidar fitted V_∞ vs. mast spd (with SC corr.)

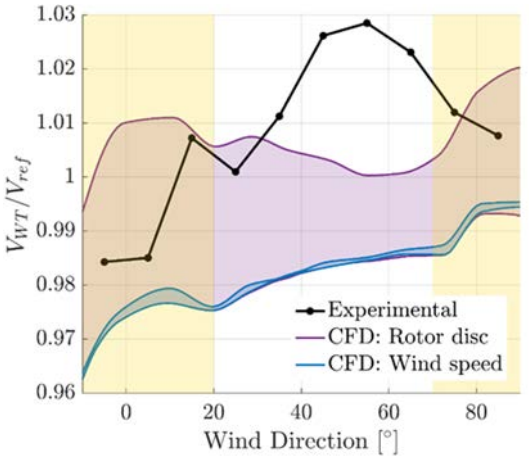


4B WindIris

4 LOS

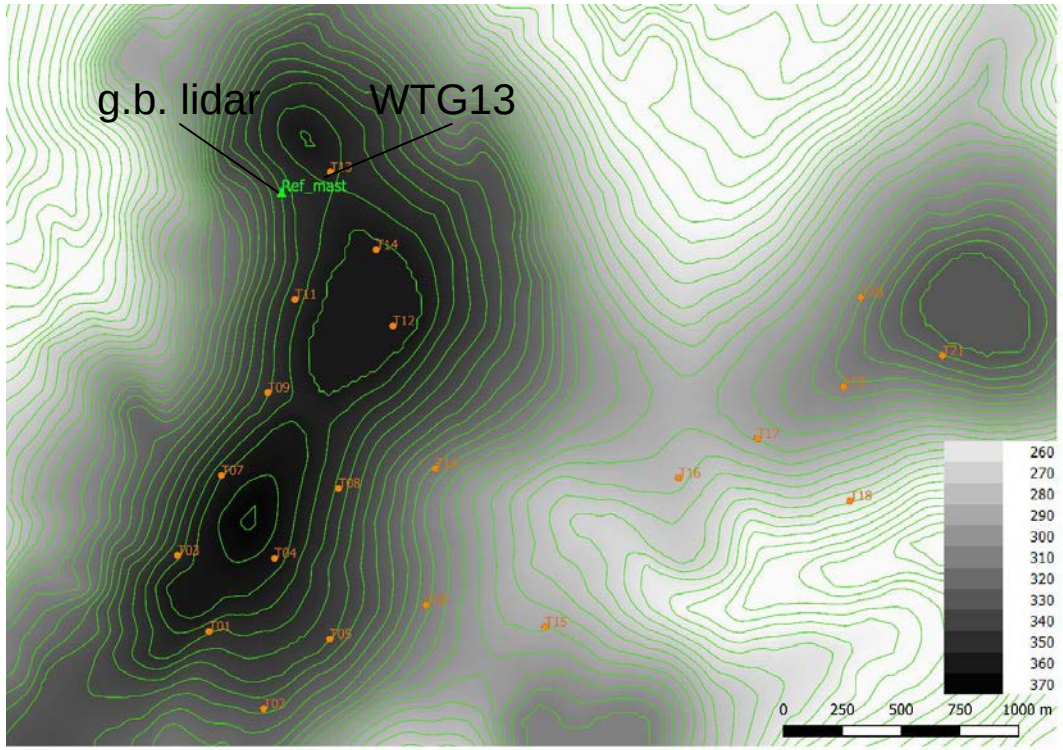
4 ranges @0.42, 0.52, 0.62; 0.72 D_{rot}

- Lidar accuracy?
- Wind-induction model?
- Reference accuracy?

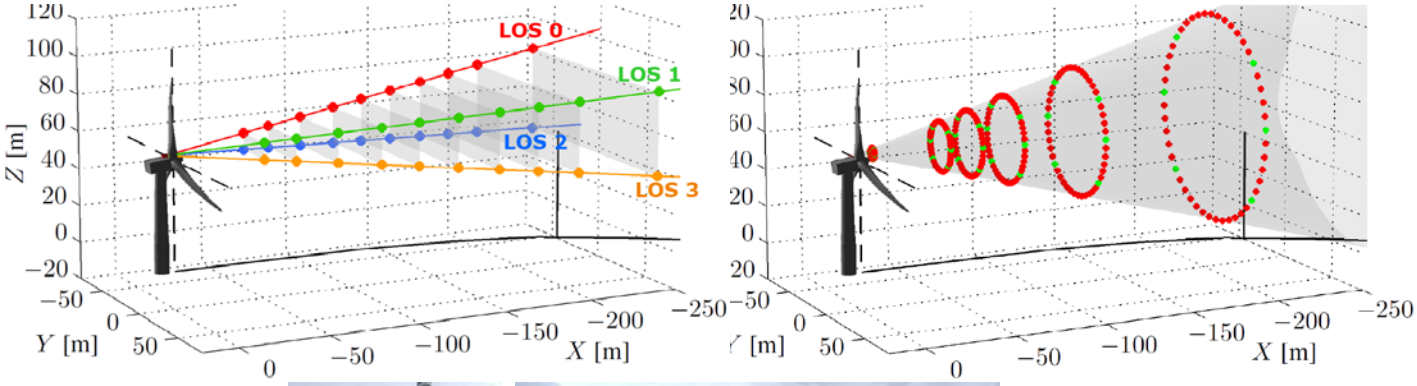


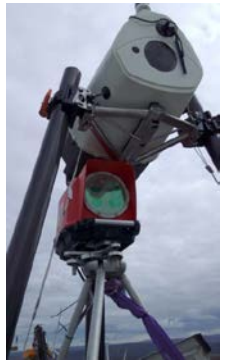
HoT (complex terrain) – measurement campaign

Hill of Towie, Wind farm developed by *RES*, UK



6 m height difference

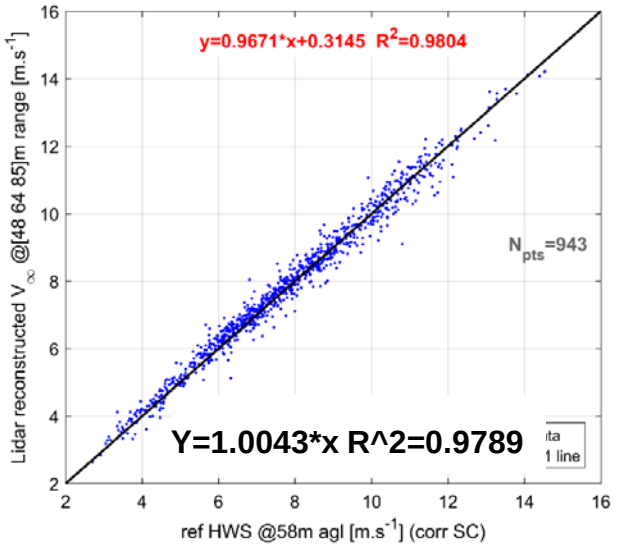




- 4 beam Wind Iris nacelle lidar
- ZephIR Dual Mode nacelle lidar
- IEC compliant site calibration, trees cut aftwewards
- Ground based ZephIR 300 lidar

HoT (complex terrain) – Results

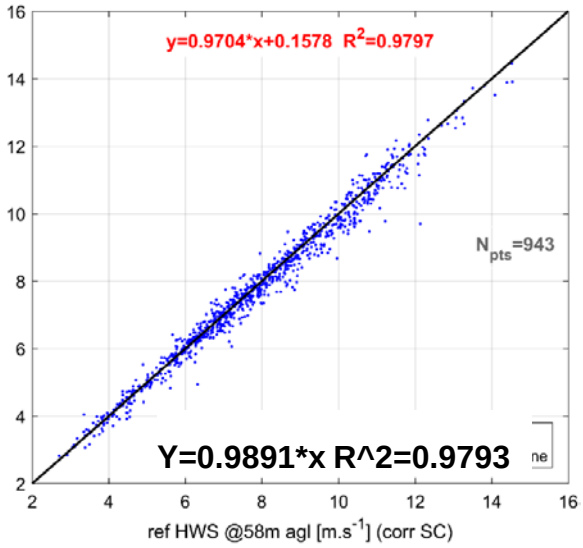
lidar fitted V_∞ vs. gb lidar (with SC corr.)



4B WindIris

4 LOS

3 ranges @0.55, 0.75, 1.01



ZephIR DM

6 LOS

3 ranges @0.55, 0.75, 1.01

Results summary

Campaign	Linear reg (gain R^2) 5B Demo/4B WI	 ZephIR DM
Nørrekær Enge (Flat)	**Y=1.0063*x R^2=0.9944**	**Y=0.9961*x R^2=0.9947**
Ogorje (moderately complex)	**Y=0.974*x R^2=0.9924**	
Hill of Towie (moderately complex)	**Y=1.0043*x R^2=0.9789**	**Y=0.9891*x R^2=0.9793**

Reference uncertainty (rough estimate):

- Cup anemometer in flat terrain: 1 to 2%
- Cup anemometer in complex terrain (including site calibration): 5-6%
- Ground-based lidar in complex terrain (inc. Site calibration): from 6-7%

Conclusions

- Site calibration: large uncertainty
- New method cannot be assessed more precisely than reference accuracy
- What would it take to move towards nacelle lidar PCV w/o site calibration?
  - Nail down the method/model/algorithm/lidar flaws in ”ideal conditions” first (flat terrain, offshore) – next presentation?
  - More demo campaigns, but:
    - Met mast in complex terrain for PCV – very seldom
    - Ground based lidar have large uncertainties in cpx terrain

      → Need to evaluate gains (simpler method – faster, cheaper) vs losses (uncertainty? Years of experience - and frustration!)

Coming …

IEC 61400-50-3 CD under commenting phase until 23/08/2019 (FDIS: end of 2020)

→ complex terrain out of scope of edition1

IEA Task 32 – preparing edition 2

→ Round Robin and Workshop 14: Site calibration and PCV using nacelle lidar in complex terrain

Interested in participating? Contact rozn@dtu.dk

Info to be released soon on: https://www.ieawindtask32.org/

Thank you

Aknowledgement to:
- UniTTe project consortium
- InnovationFund Denmark
- Akuo Energy

References:

1. Borraccino et al. Wind Energ. Sci.,2,269-283,2017
2. Power performance verification in complex terrain using nacelle lidars: the Hill of Towie (HoT) campaign. / Borraccino, Antoine; Wagner, Rozenn; Vignaroli, Andrea; Meyer Forsting, Alexander Raul. DTU Wind Energy E-0156
3. Power performance verification in complex terrain using nacelle lidars: the Ogorje campaign. / Wagner, Rozenn; Borraccino, Antoine; Vignaroli, Andrea DTU Wind Energy E-0157

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More info: www.UniTTe.dk