



# Turbulence-field estimation for LAC

Ongoing research from the CONTINUE project – Jenni Rinker (Assoc. Prof.)

# Presentation contents.

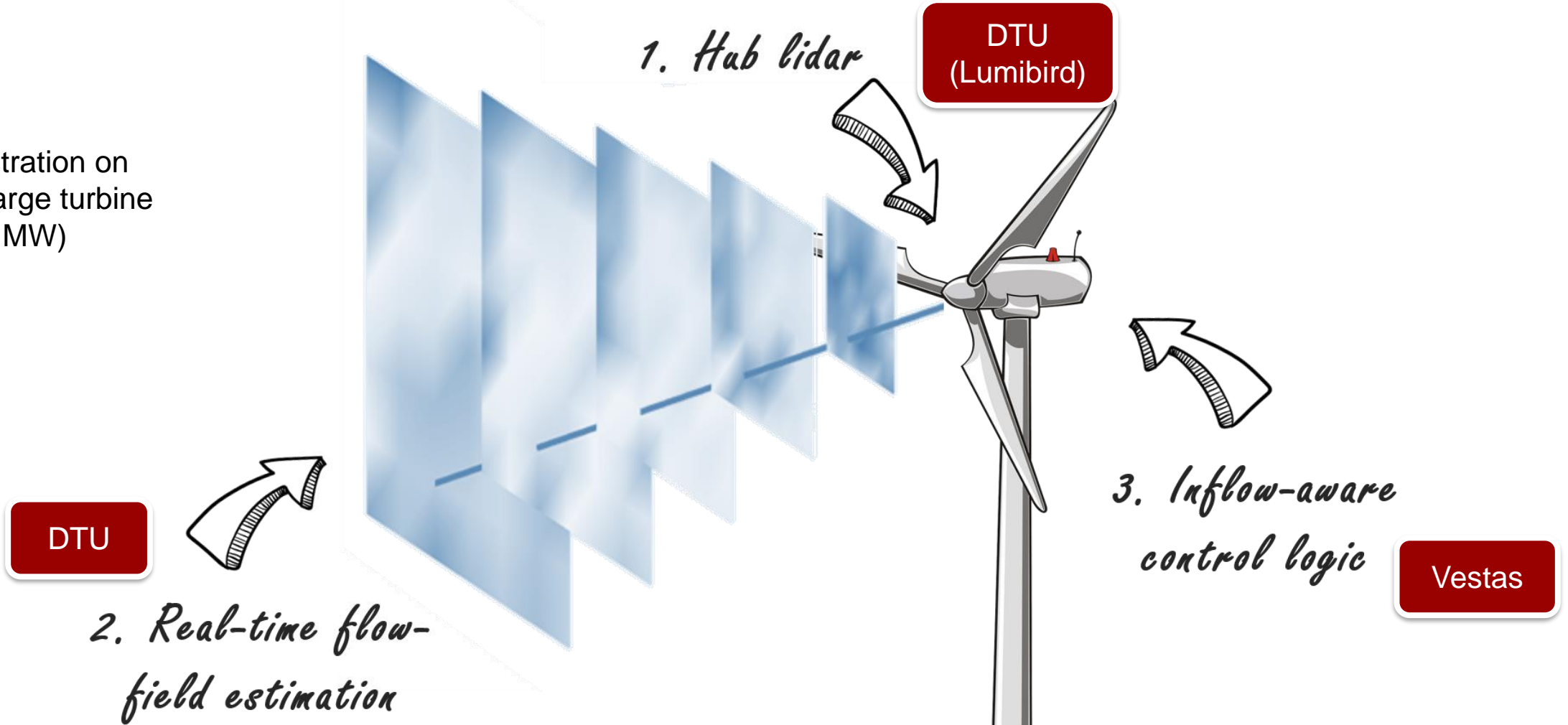
- The CONTINUE project
- Active research in turbulence-field estimation for LAC applications
  1. New/updated lidar sensors in HAWC2
  2. WindEurope paper: *A novel numerical hub-lidar for wind flow estimation.*
  3. Torque paper: *Wind-field characterization using synthetic lidar measurements and proper orthogonal decomposition.*
- Summary

# The CONTINUE project.

- 3-year project, 2023 – 2026.
- Funded by the Danish Energy Technology Development and Demonstration Programme (EUDP).
- Partners: DTU and Vestas.
  - Ørsted and Lumibird in the Stakeholder Group.
  - Project leader: Jenni Rinker (DTU).
- Objective: *“to develop and demonstrate a novel wind-turbine controller that measures, estimates and reacts to the incoming turbulent field across the entire rotor. This controller should substantially reduce tower loads, saving approximately 1 million tons of CO2 per year in steel once implemented in the full market.”*
  - From project website: [Control of next-generation wind turbines | EUDP](#).

# Three key innovations of CONTINUE.

Demonstration on modern, large turbine (>2 MW)





# Expected FAIR databases and open science.

1. DS1: Risø test campaign, hub lidar on rotating test rig, some concurrent WindScanner measurements.
2. DS2: Numerical hub lidar database (HAWC2) for benchmarking exercises.
  - Can be resampled with different scanning patterns, tested with different estimation algorithms.
3. DS3: Hub lidar and field estimation from Demonstration.
4. All publications are open-source, many with git repos with code.

# Active research

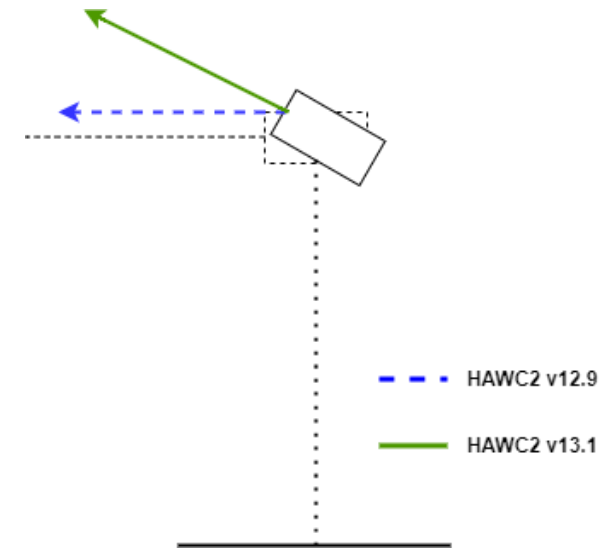
# Four main recent/ongoing publications.

Publications 1 through 3 driven by Esperanza. Publication 4 driven by Mikael Aslak Svenstrup from Vestas.

1. DTU report on new/updated lidar sensors in HAWC2.
2. WindEurope paper: *A novel numerical hub-lidar for wind flow estimation.*
  - Impact of sampling patterns with simple turbulence-field estimation scheme.
3. Torque Paper #1: *Wind-field characterization using synthetic lidar measurements and proper orthogonal decomposition.*
  - Accuracy of more advanced estimation schemes.
4. Torque Paper #2: *Robustness of LiDAR Assisted Controller towards measurement uncertainty.*
  - Not presented in this presentation.

# New/updated lidar sensors in HAWC2 v13.1.

- HAWC2: aeroelastic software.
  - Free academic license!
  - Version 13.1 to be released in the next few weeks.
- Version 13.1 features new hub lidar sensor.
  - Pulsed, rotates with the rotor.
- Also corrected nacelle-lidar sensor.
  - Previous implementation was missing tovertop rotation and sampling of relative, not absolute, wind velocity.
- Public report with more details.
  - [Link to report on Orbit.](#)

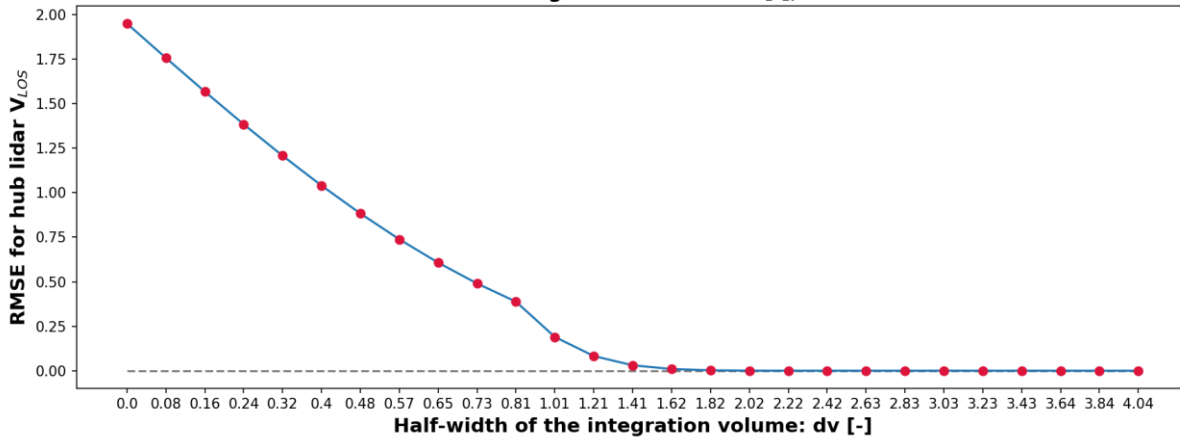




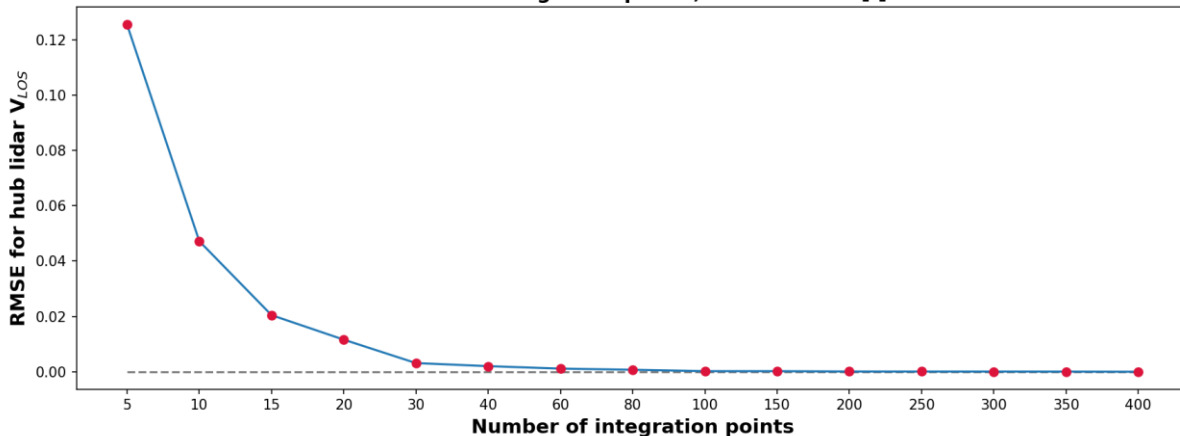
# Selection of results from verification report.

## Numerical convergence of integration parameters

Sensitivity analysis for HAWC2 Hub Lidar implementation  
Half-width of the integration volume:  $dv$  [-], with  $N = 200$ .



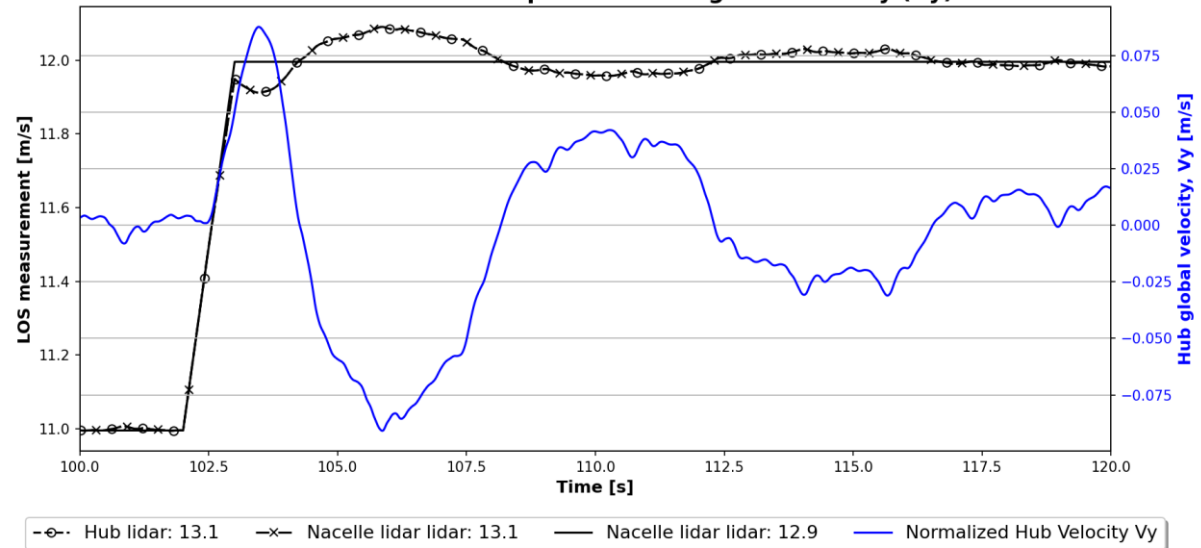
Sensitivity analysis for HAWC2 Hub Lidar implementation  
Number of integration points, with  $dv = 3.0$  [-].



## Demonstration of relative-wind sampling

- No tilt or half-cone (pointed directly upwind).
- Step-wind from 11 to 12.
- Old nacelle sensor measures step directly, does not capture tower velocity.

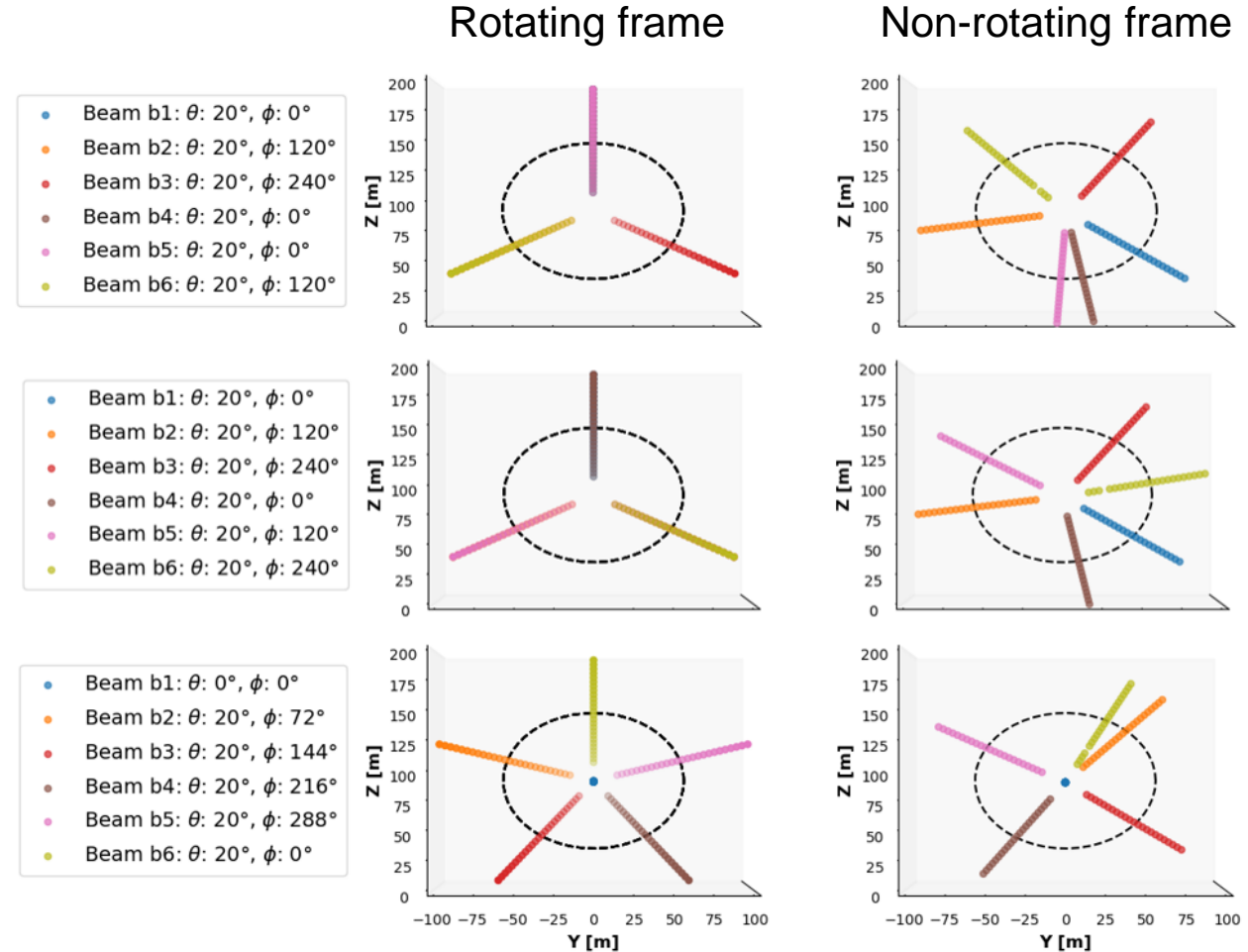
Normalized LOS wind speed and hub global velocity ( $V_y$ )



# WindEurope paper.

## A novel numerical hub-lidar for wind flow estimation.

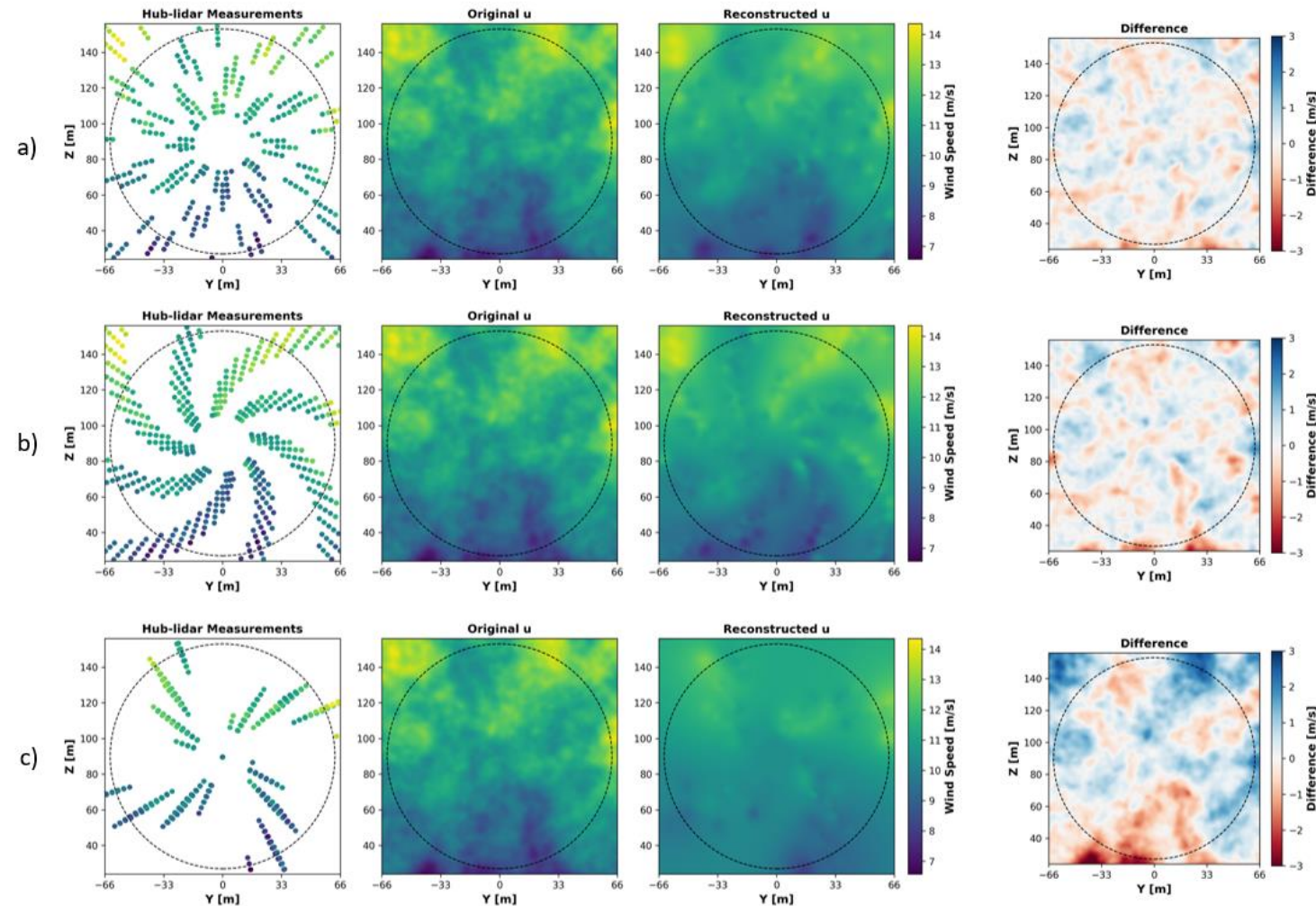
- Main author: Esperanza Soto Sagredo.
- Paper investigates effect of sampling patterns on estimation accuracy.
- Three configurations, shown at right.
  - Non-rotating frame has rotational speed of 12.1 RPM.
- Simple estimation via inverse-distance weighting.



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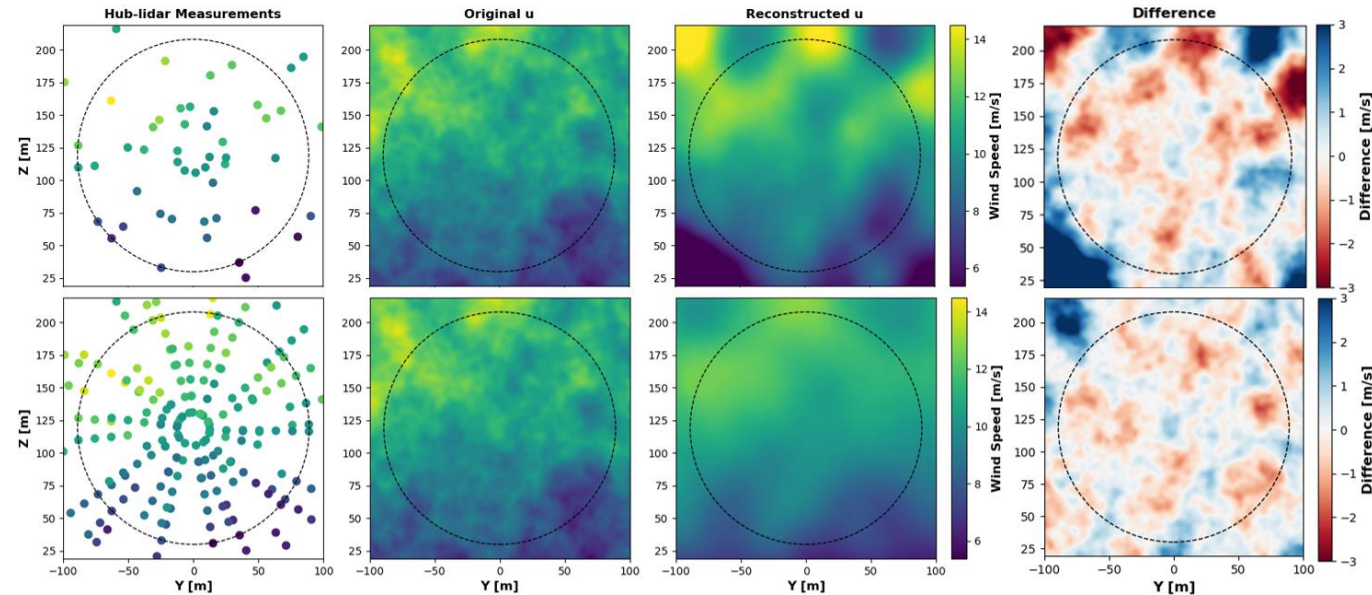
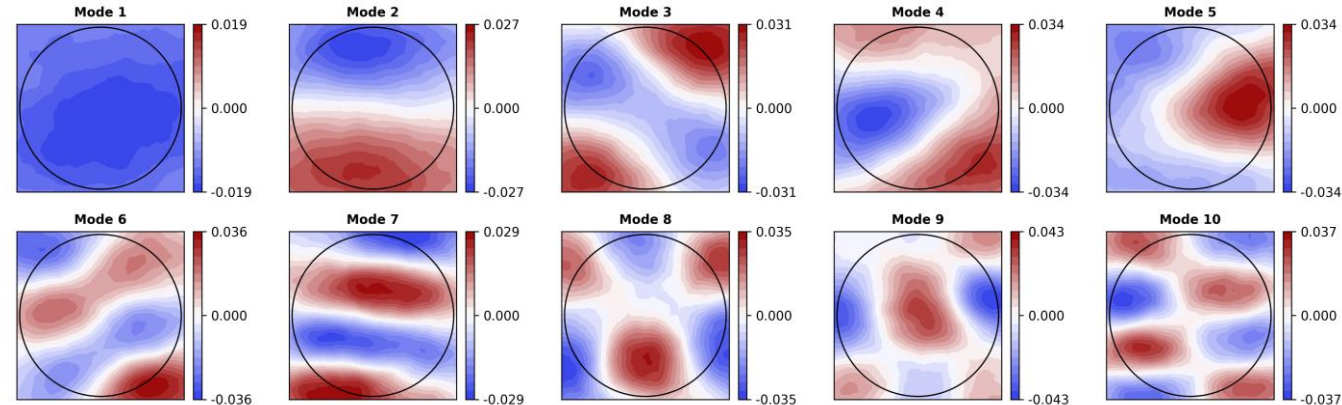




# Torque paper.

## Wind-field characterization using synthetic lidar measurements and proper orthogonal decomposition.

- Main author: Esperanza Soto Sagredo.
- Paper investigates accuracy of turbulence-field estimation with hub lidar and POD.
- POD modes fit to multiple wind speeds, “global” basis.
  - Fit to lidar “measurements” using least-squares.
- Utility of multiple scans, assuming Taylor’s frozen turbulence hypothesis.



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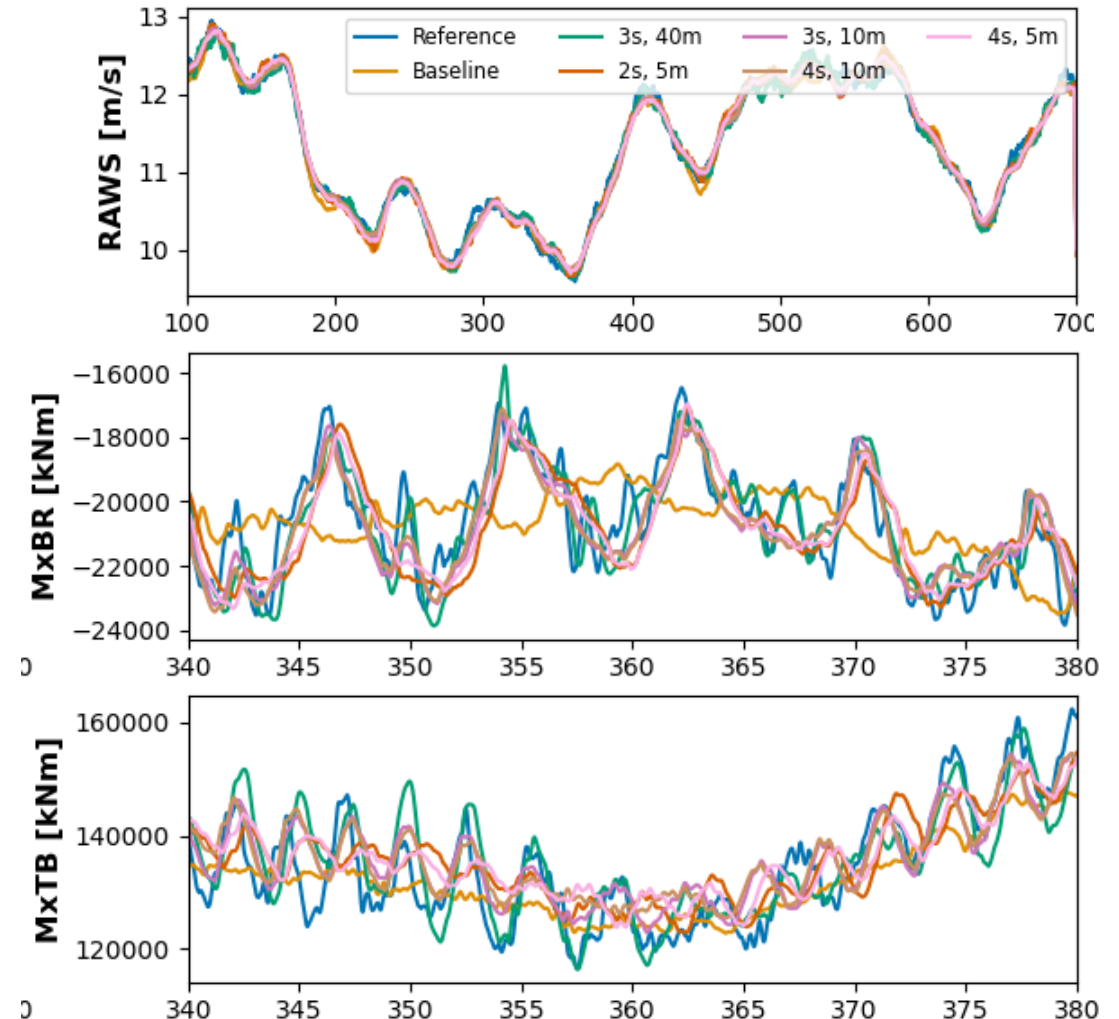
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Reference: original turbulence

Baseline: mean wind speed estimated from lidar “measurements”

“s” = “scan”, “m” = “modes”



# Summary.

- New/corrected sensors in HAWC2 version 13.1 that can be useful for LAC applications.
- Poster/paper at WindEurope investigating impact of sampling configuration on estimation accuracy.
- Poster/paper at Torque investigating utility of POD for turbulence-field estimation with hub-lidar data.
- Paper at Torque on robustness of LAC with measurement uncertainty.
- You're welcome to visit our posters! Espe and I are at Wind Europe, and all of us are at Torque.
  - Email me if you want to meet: [rink@dtu.dk](mailto:rink@dtu.dk).



# Technology for People



Questions?