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NATIONAL RENEWABLE ENERGY LABORATORY

# Workshop #10: Turbulence Intensity Measurements with LiDARs - Applications to Loads Verification and Site Suitability

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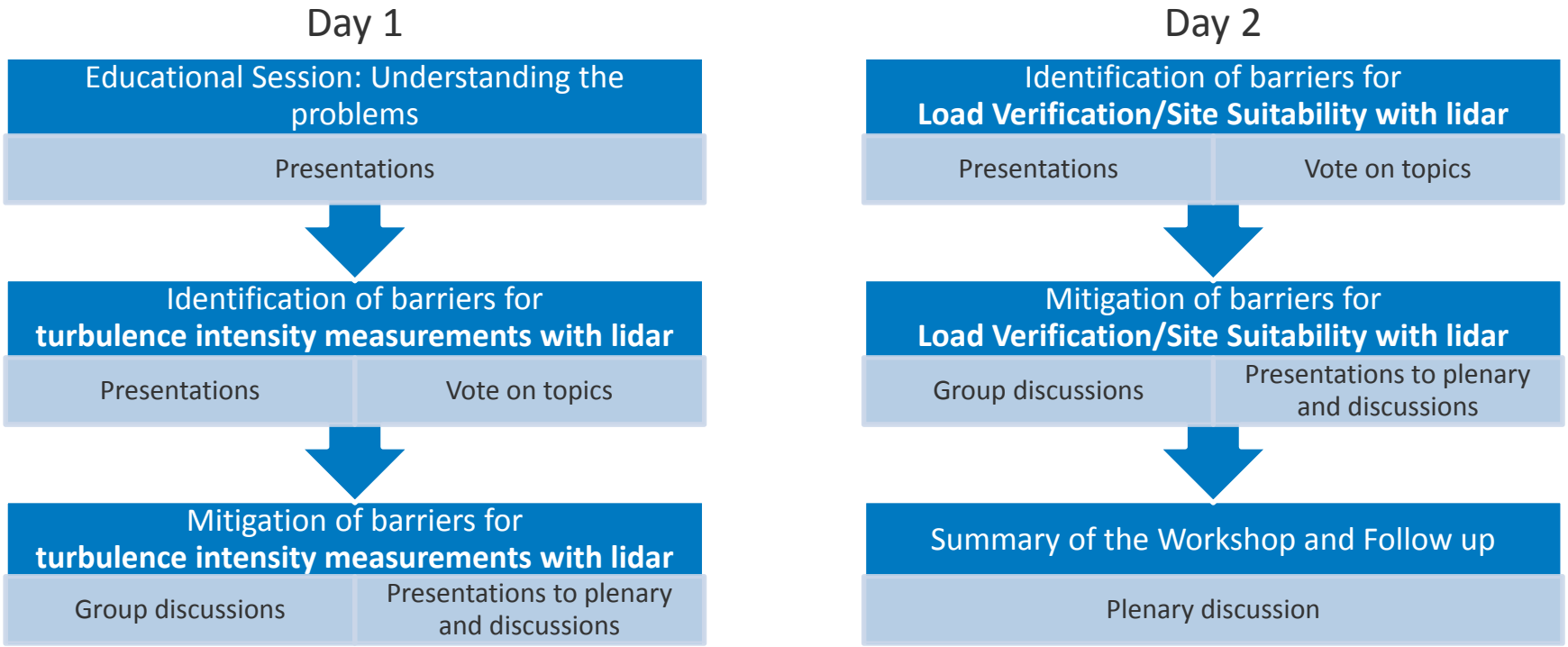
# Workshop Overview

- Workshop hosted by Ørsted in Gentofte, Denmark, September 2018
  - Workshop leader: Ameya Sathe, Ørsted

- Motivation
  - Site suitability and loads verification require measurements of turbulence intensity (TI)
  - Site suitability: assess environmental conditions to determine suitability of site for wind farm development
  - Load verification: assess whether models used to simulate loads for turbine design are sufficient, based on comparison with field measurements
  - If measurements are acceptable, lidars can serve as a more efficient and less expensive alternative to traditional sensors for determining TI

- Workshop Objectives
  - Are there barriers to estimating TI using lidars?
  - Do the barriers influence the use of lidars for load verification and site suitability studies of wind turbines/farms?

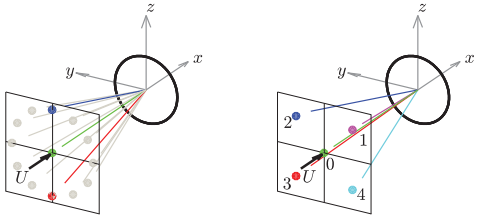
# Workshop Structure




- Expected outcome
  - Exchange of experience in TI measurements and load verification/site suitability studies with lidar
  - Initiation of a working group to write a common paper based on the results of the workshop

# Measuring TI with Lidars

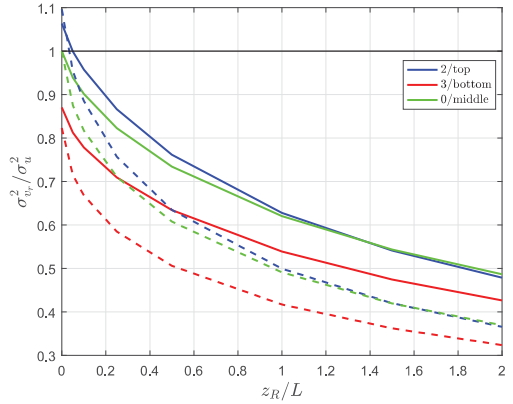
- Lidars considered
  - CW or pulsed
  - Ground based or nacelle mounted

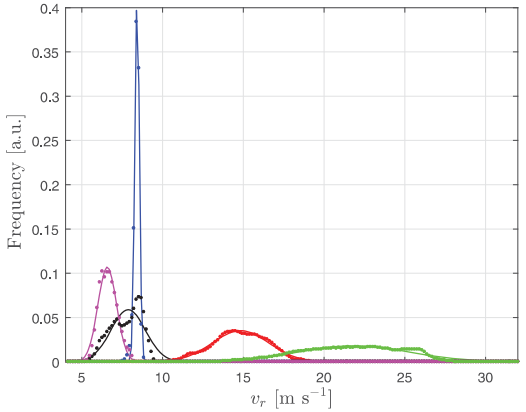



- Two main problems with lidar turbulence measurements
  - Measurement volume
  - Cross-contamination

- Turbulence models can be used to calculate ratio between lidar-measured TI and point TI
- Averaging in probe volume may be mitigated using the average Doppler spectrum

- Cross-contamination may be avoided by computing statistics before beams are combined




Figures from Peña, A., Mann, J., & Dimitrov, N. K. (2017). Turbulence characterization from a forward-looking nacelle lidar. *Wind Energy Science*.

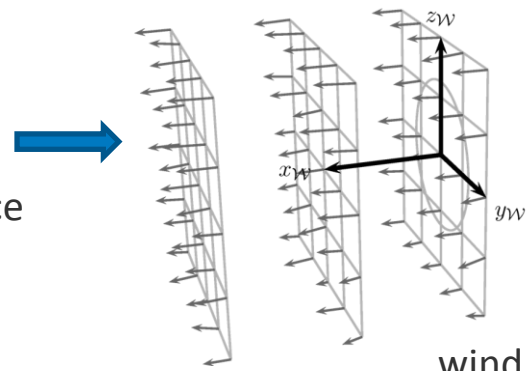
# Turbulence Intensity Measurements with Lidar

| Barriers Identified | Mitigation of Barriers |
|---|---|
| Volume measurements | Converging beams; tight probe volume; Doppler spectra averaging method; site and turbulence specific transfer function |
| No available method to get unfiltered variance for pulsed lidars | Determine if pulsed lidars provide useful measures of spectral broadening |
| Cross-contamination from other velocity components | Converging beams; 6-beam geometry |
| Different levels of knowledge and understanding, not enough transfer | Effective compilation and dissemination of information; recommended practices |

# Load Verification/Site Suitability Studies with Lidar

| Barriers Identified | Mitigation of Barriers |
|---|---|
| Lack of concrete guidance on acceptable level of accuracy | Agreement on needed accuracy; application specific; sensitivity study on loads |
| Uncertainties in lidar measurements present risk to OEMs and customers | sensitivity study on loads (e.g., field, CFD); start with simple terrain; quantify bias and uncertainty for many different sites |
| Many TI correction methods may be site/atmospheric condition specific | Doppler spectra averaging method; more work needed to develop site-independent correction methods |
| Best practices and expected correction methods must be defined for standard deployment scenarios | Form a working group to develop recommended practices; joint industry project |

# Outside the box: Is TI the Best Measure for Loads?




blade positions

Turbulence Models …

TI

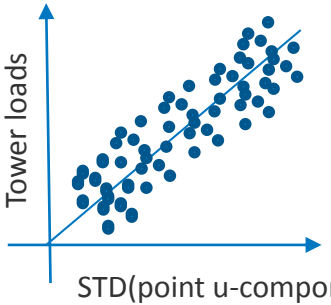
loads

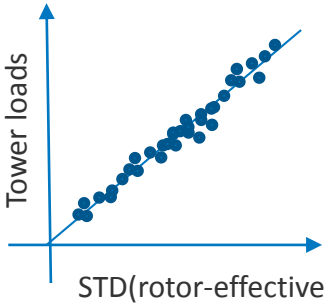
wind speeds at blades

~blade-effective wind speeds

~rotor-effective wind speeds

- hard to measure with lidar
- good indicator of loads




- easier to measure with lidar
- Very good indicator of loads

# Workshop Outcome

- Intention to create a roadmap for the use of lidar TI measurements for load verification and site suitability
- Exploring possibility of joint industry project to develop recommended practices