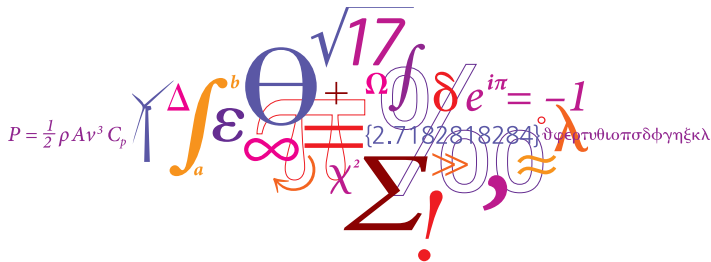# Carrier-to-Noise-Threshold Filtering on Offshore Wind Lidar Measurements

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DTU Wind Energy
Department of Wind Energy

Outline

- About me
- Motivation
- Theory and methods
- Results
- Conclusions and outlook

'Measuring and modelling of the wind'

Education

- 2010–2013: Ph.D., Technical University of Denmark, Roskilde, Denmark, "Measuring and modelling of the wind on the scale of tall wind turbines"

- 2004–2010: B.Sc. and M.Sc. Meteorology & Air Quality, Wageningen University, Wageningen, Netherlands

Professional

- Apr 2019 – Now: Senior Research scientist, Technical University of Denmark, Roskilde, Denmark

- Mar 2016 – Mar 2019: Research scientist, Technical University of Denmark, Roskilde, Denmark

- Dec 2013 – Feb 2016: Postdoctoral researcher, Technical University of Denmark, Roskilde, Denmark

Measuring wind with wind lidars

- Lidars increasingly used for wind resource assessment
- Common to apply filtering to get good quality data
- Does the wind climate depend on how you filter the data? (this talk)
- How can we minimize problems? (Leonardo's talk)
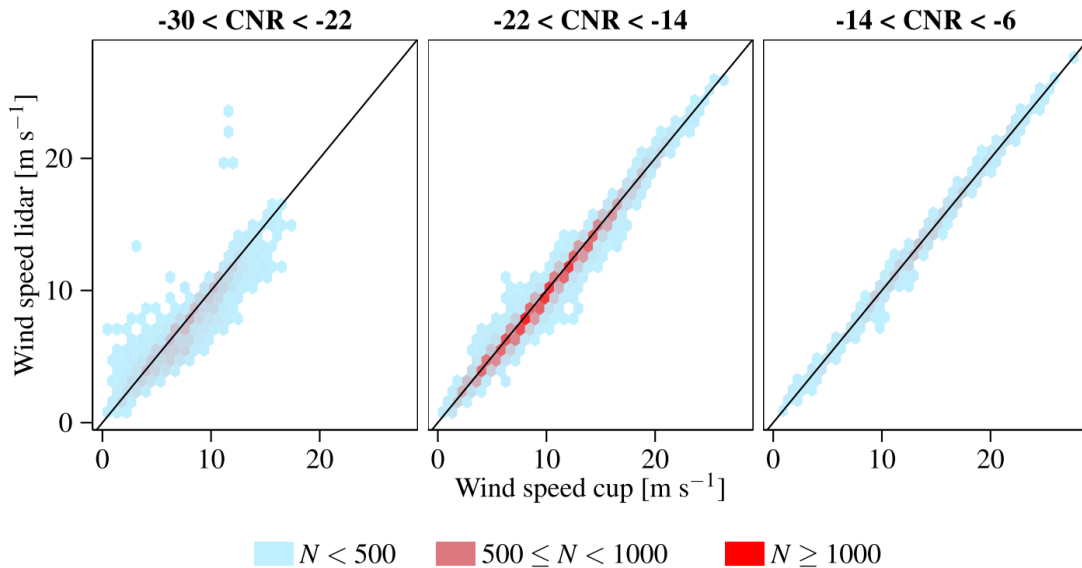- In this talk I consider only pulsed wind lidars
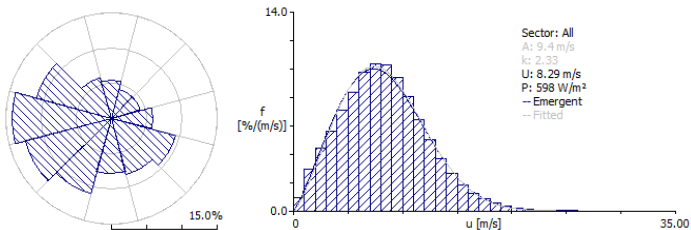
- CNR (Carrier-to-noise ratio) is a quality indicator of a wind lidar wind speed measurement

- Common to use threshold in CNR to distinguish quality measurements:

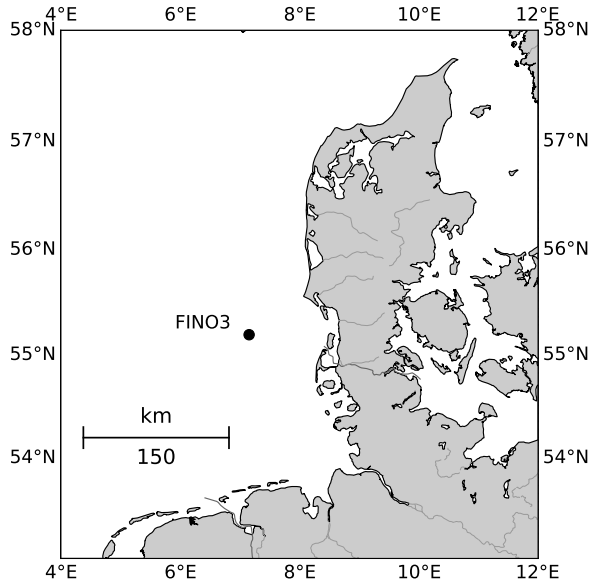$$\text{CNR} = \eta \, \frac{T^2 E_x}{h \nu B} \, \frac{c\beta}{2} \, \frac{A_r}{R^2} \tag{1}$$

  - β: Atmospheric backscatter
  - R: target range
  - E_x: laser pulse energy

- Therefore the appropriate CNR threshold value depends on the type of lidar you are using

- Four most important atmospheric factors influencing lidar performance are aerosol backscatter, relative humidity, precipitation, and atmospheric refractive turbulence (Aitken et al., 2012)

Example mean wind speed cup anemometer and lidar at Høvsøre mast at 100 m

$-30 < CNR < -22$ $-22 < CNR < -14$ $-14 < CNR < -6$

Wind speed lidar [m s^{-1}]

Wind speed cup [m s^{-1}]
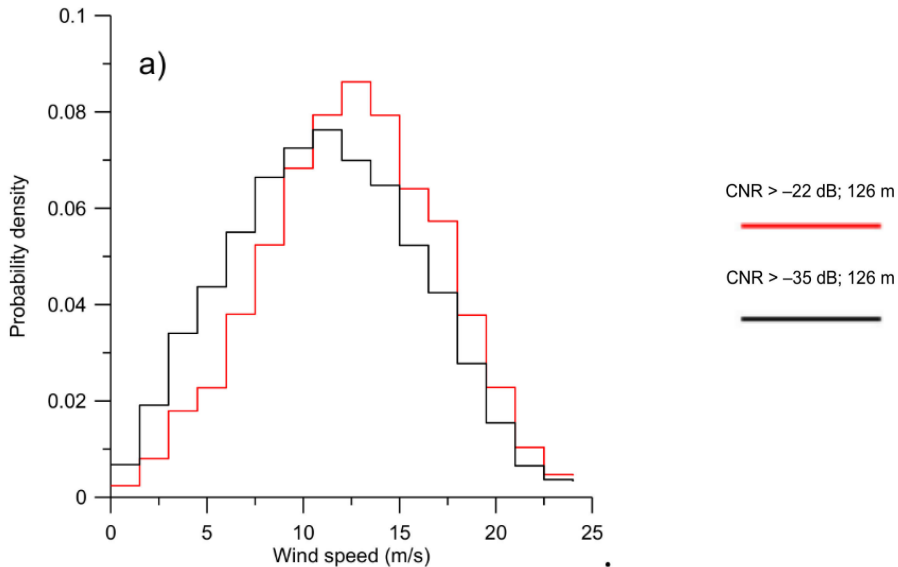
$N < 500$ $500 \leq N < 1000$ $N \geq 1000$

Data in this study: FINO3

- Offshore platform 80 km off the coast

- Long-range WLS70 Leosphere/Vaisala lidar, can in theory measure up to 2 km height
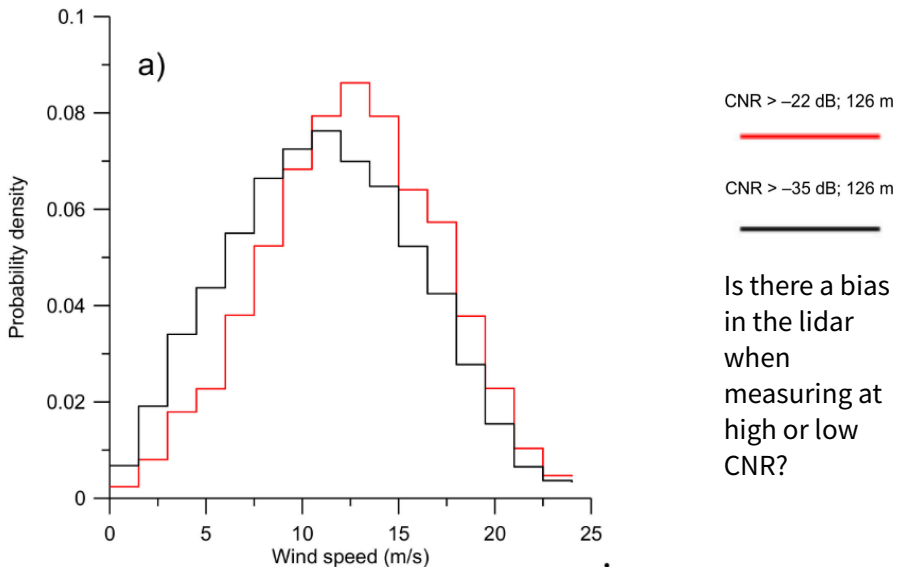
- Measurements from a meteorological mast are also available

Effect of filtering on wind distribution

Effect of filtering on wind distribution

CNR > –22 dB; 126 m

CNR > –35 dB; 126 m

Is there a bias in the lidar when measuring at high or low CNR?

Effect of CNR on mean wind speed

- If there was a problem with the lidar we would expect wind climate measured by cup anemometer to stay constant as a function of CNR

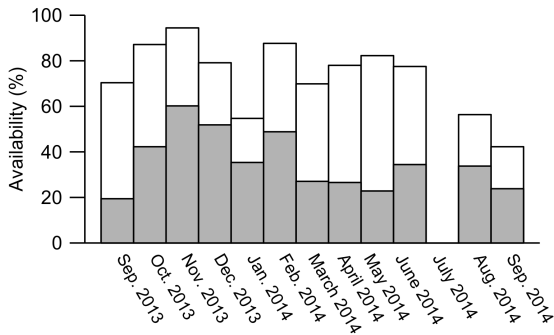- How is it possible that the effect is so much larger when we select a wind profile from 126 to 626 m?
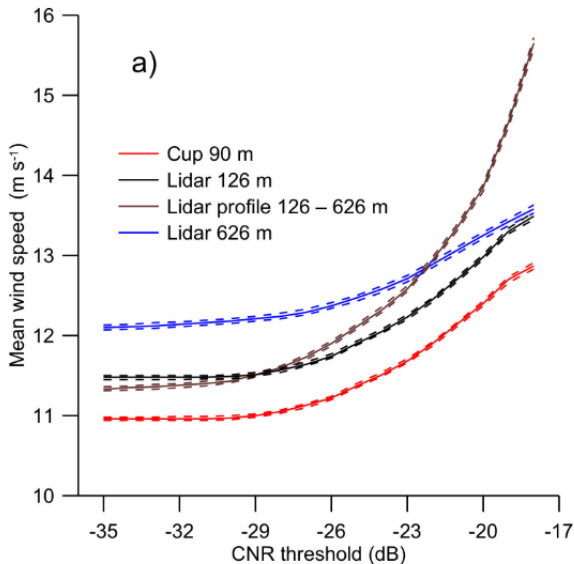
Availability decreases strongly with range of lidar

Monthly data coverage for Carrier-to-Noise-Ratio (CNR) > -35 dB (white plus grey) and CNR > -22 (grey only) at:
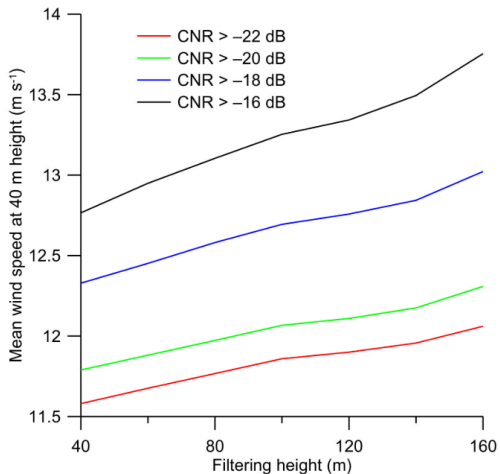
- 126 m level (a)

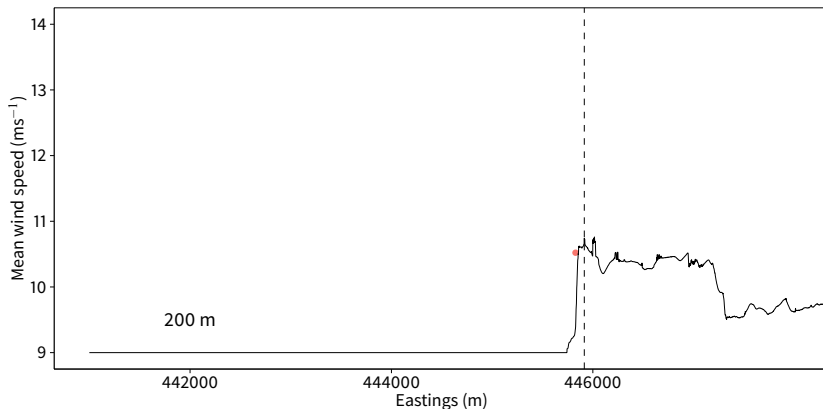- at all levels up to 626 m (b).

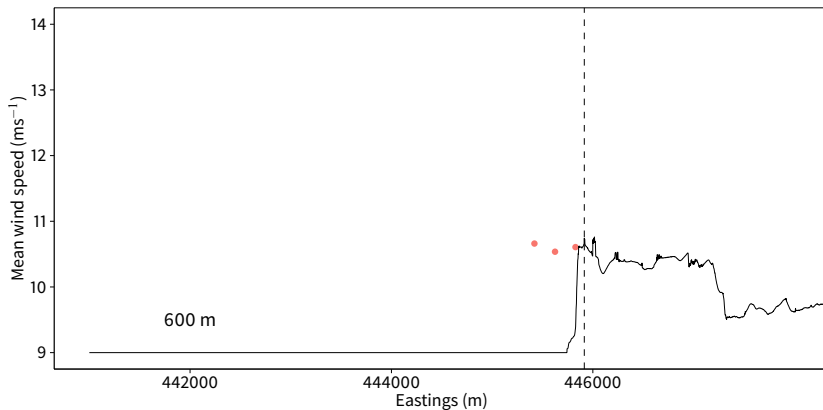**(a)**   **(b)**
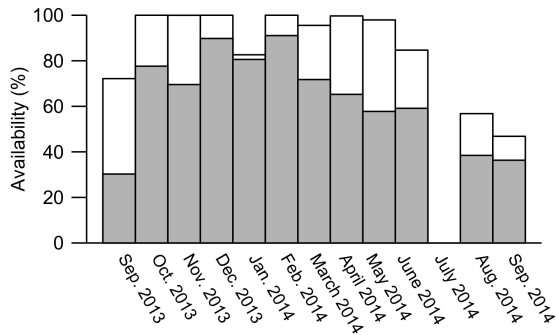
But is this also true for short-range lidars?

What about WindScanners?

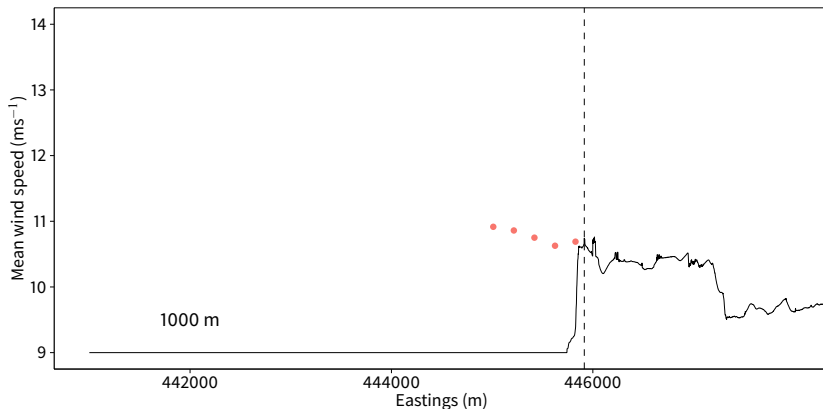RUNE experiment, measuring the wind offshore using land-based WindScanners (Floors et al., 2016)

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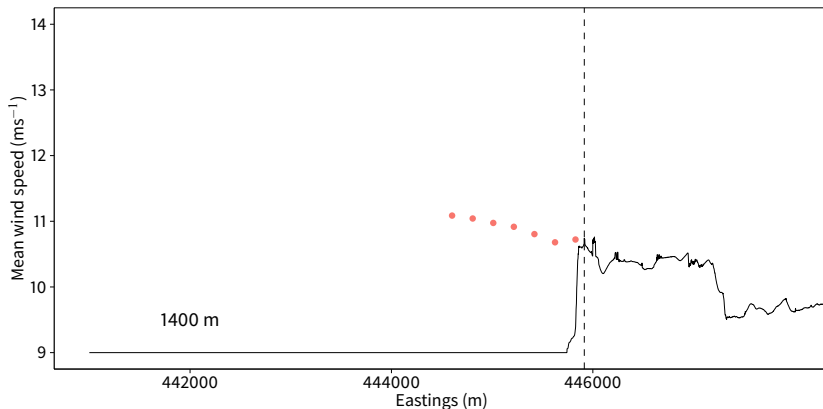RUNE experiment, measuring the wind offshore using land-based WindScanners (Floors et al., 2016)
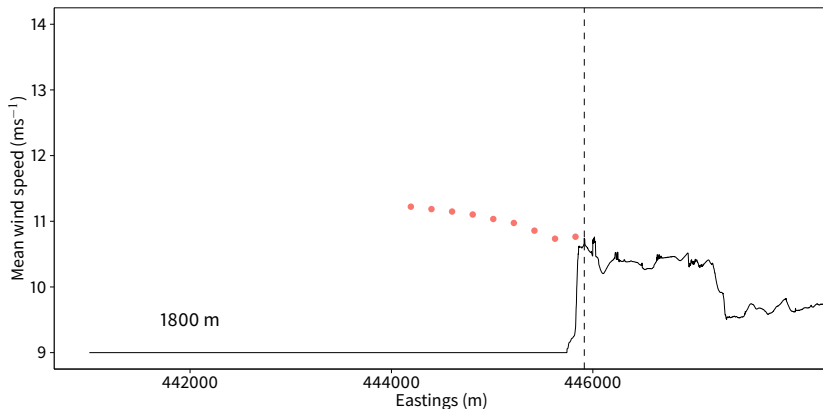
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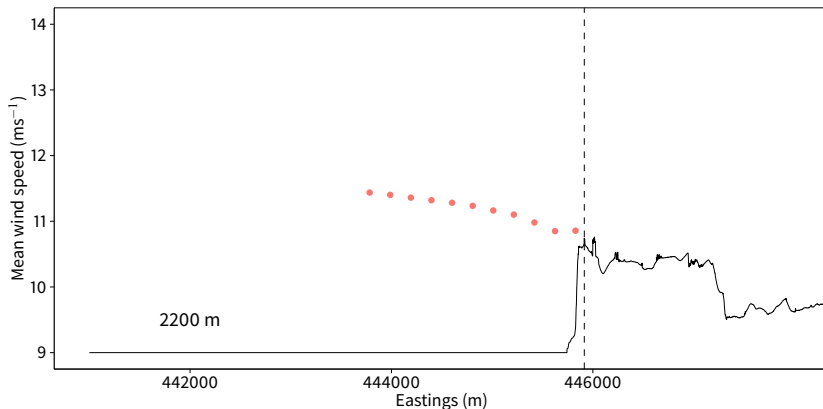RUNE experiment, measuring the wind offshore using land-based WindScanners (Floors et al., 2016)
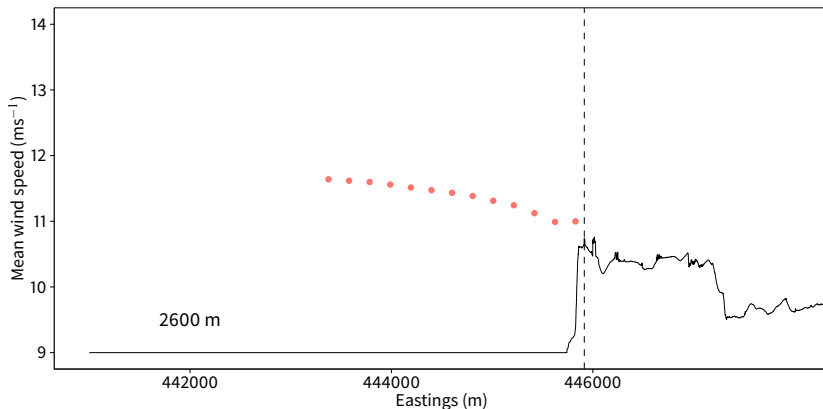
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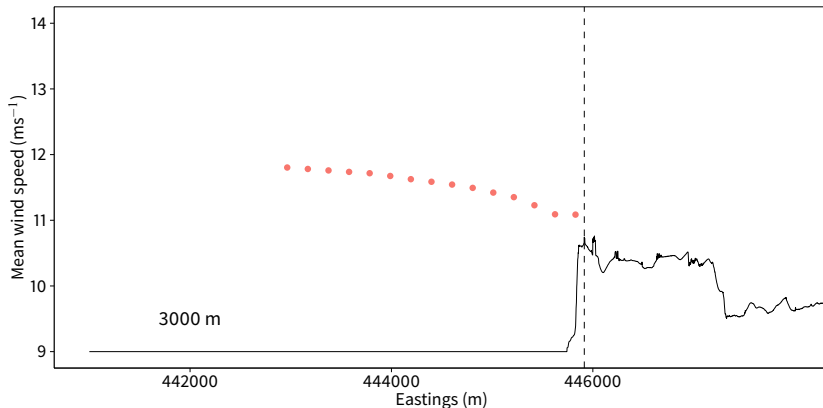RUNE experiment, measuring the wind offshore using land-based WindScanners (Floors et al., 2016)

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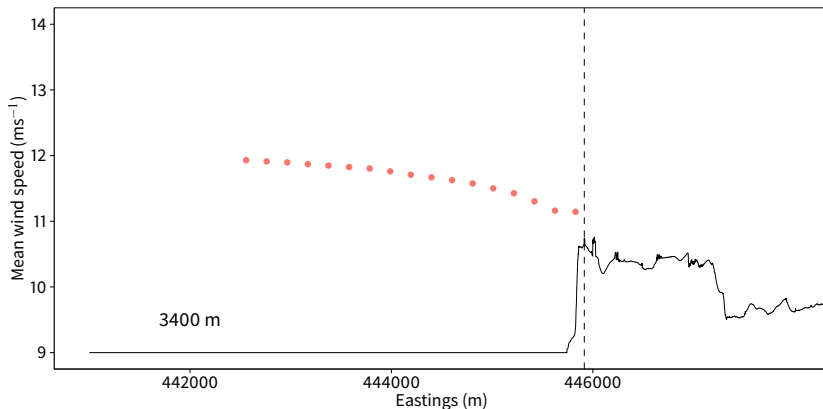RUNE experiment, measuring the wind offshore using land-based WindScanners (Floors et al., 2016)

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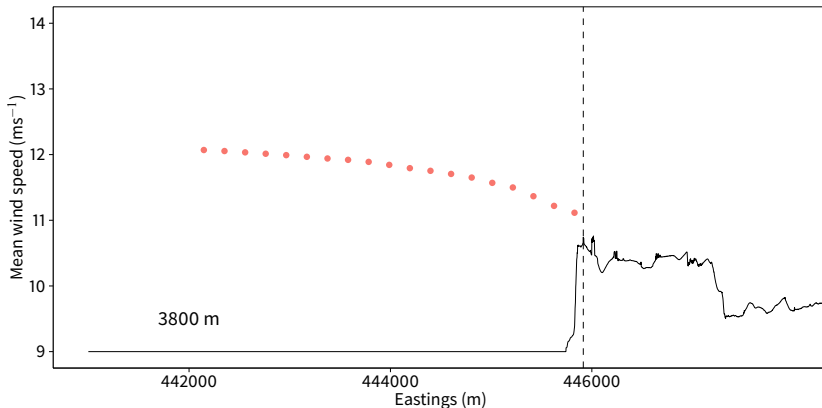
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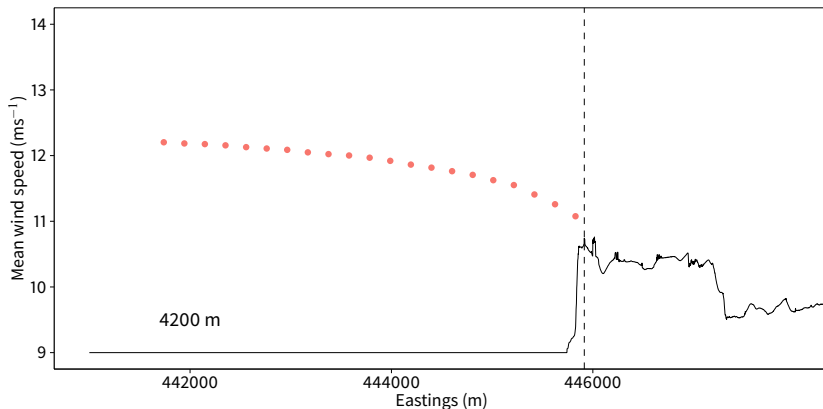RUNE experiment, measuring the wind offshore using land-based WindScanners (Floors et al., 2016)

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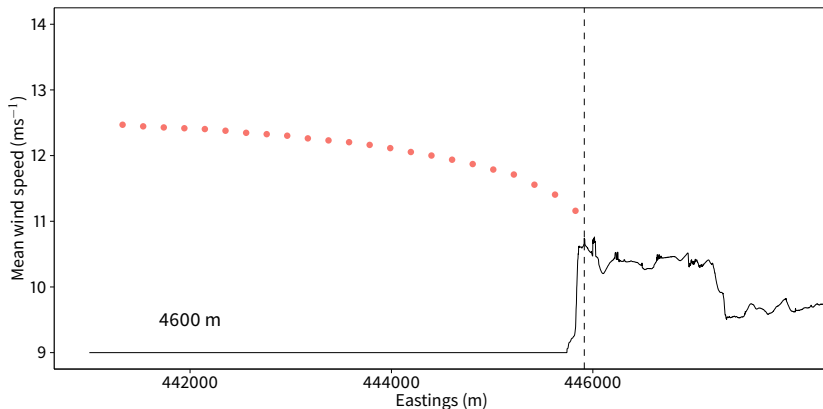
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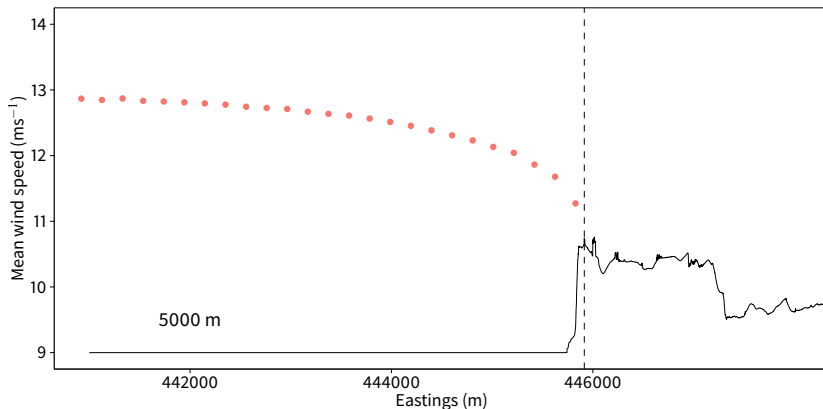
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- Filtering based on CNR can have profound influence on wind speed distribution.
- Requiring fulfilled CNR threshold at all range gates significantly increases the problem
- Effect was observed for short-range & long-range profilers and for WindScanners
- More details in Gryning and Floors (2019)

Aitken, M. L., Rhodes, M. E., and Lundquist, J. K. (2012). Performance of a Wind-Profiling Lidar in the Region of Wind Turbine Rotor Disks. *J. Atmos. Ocean. Technol.*, 29(3):347–355.

Floors, R., Peña, A., Lea, G., Vasiljević, N., Simon, E., and Courtney, M. (2016). The RUNE Experiment—A Database of Remote-Sensing Observations of Near-Shore Winds. *Remote Sens.*, 8(11):884.

Gryning, S.-E. and Floors, R. (2019). Carrier-to-Noise-Threshold Filtering on Off-Shore Wind Lidar Measurements. *Sensors (Basel).*, 19(3).

Extra slide: other lidars and locations