Measurement strategies using a single scanning lidar for reducing wind resource assessment uncertainty onshore (EWiNo project)

Wind Europe Resource Assessment 2019 Workshop

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27/06/2019

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Standard Wind Resource Assessment (WRA) procedure

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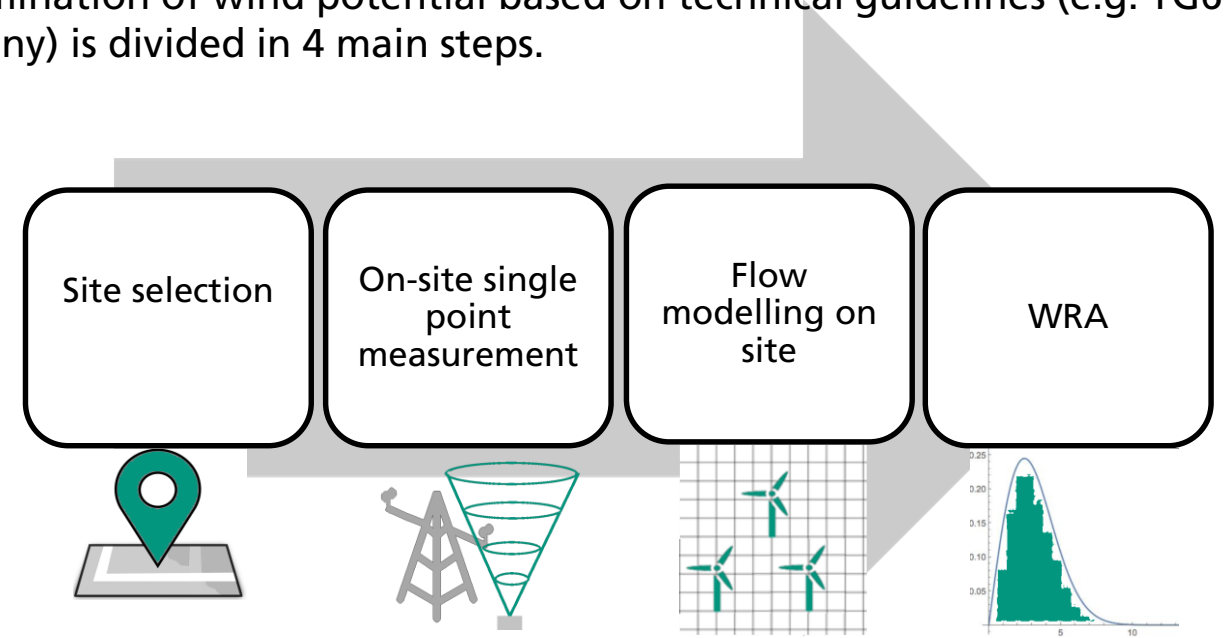
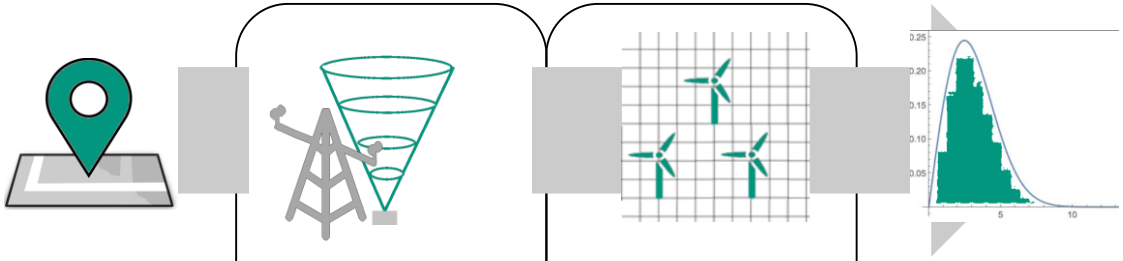
Standard Wind Resource Assessment (WRA) procedure

Wind potential estimation

- Determination of wind potential based on technical guidelines (e.g. TG6 by FGW in Germany) is divided in 4 main steps.



Uncertainty sources



Data pool uncertainty

Up to ~3%

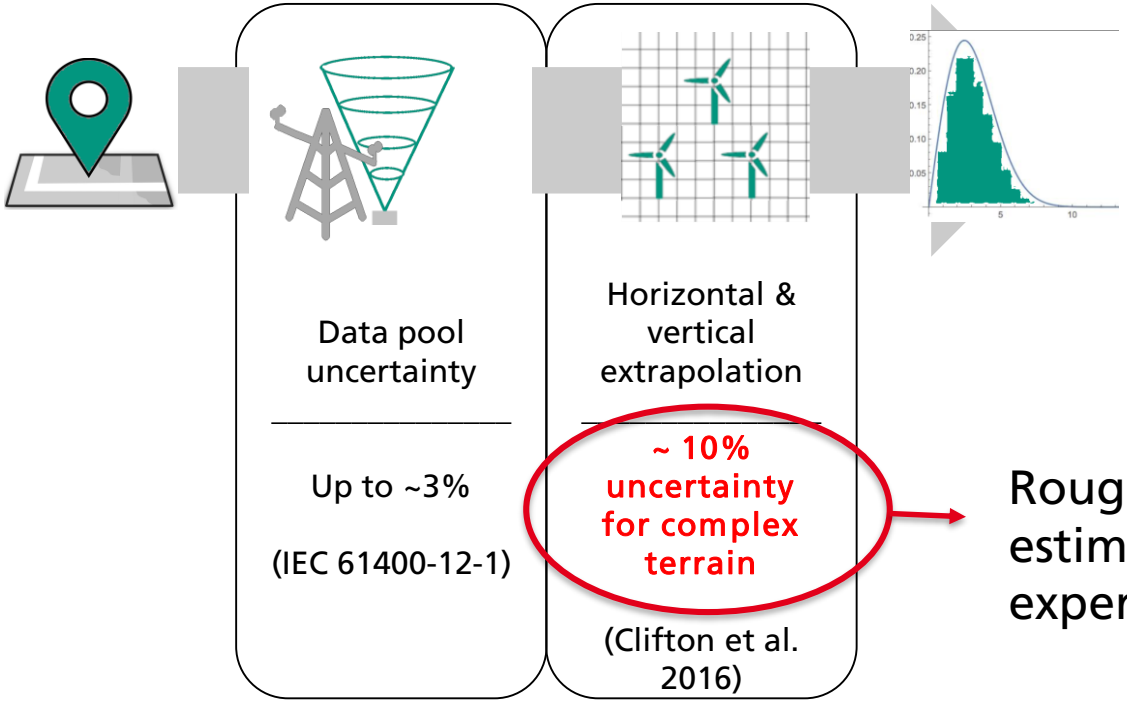
(IEC 61400-12-1)

Horizontal & vertical extrapolation

~ 10% uncertainty for complex terrain

(Clifton et al. 2016)

Uncertainty sources



Rough uncertainty estimation based on experience.

EWiNo project

Objective

Development of measurement strategies for WRA using a **single scanning lidar** in combination to conventional measurements in order to **identify** and **quantify uncertainty sources.**

Single scanning lidar measurement strategies

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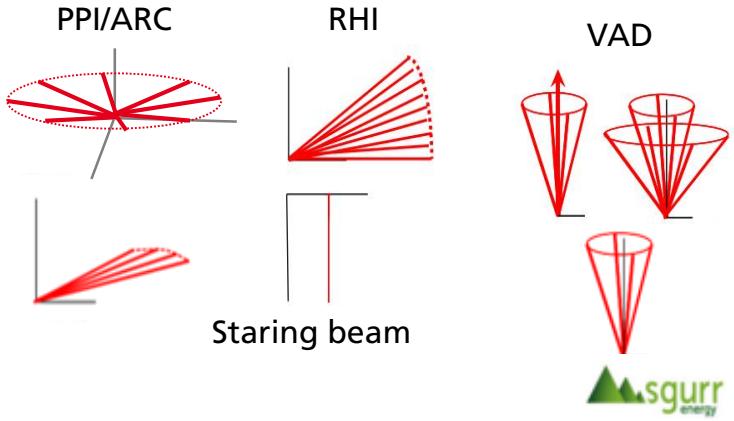
Single scanning lidar measurement strategies

- Single scanning lidar
  - Two degrees of freedom (azimuth & elevation): Scan flexibility
  - Pulsed instrument: Multiple range measurements
  - Long range



Measurement strategies to calibrate wind flow model methods and quantify uncertainties using short period scanning lidar measurements.

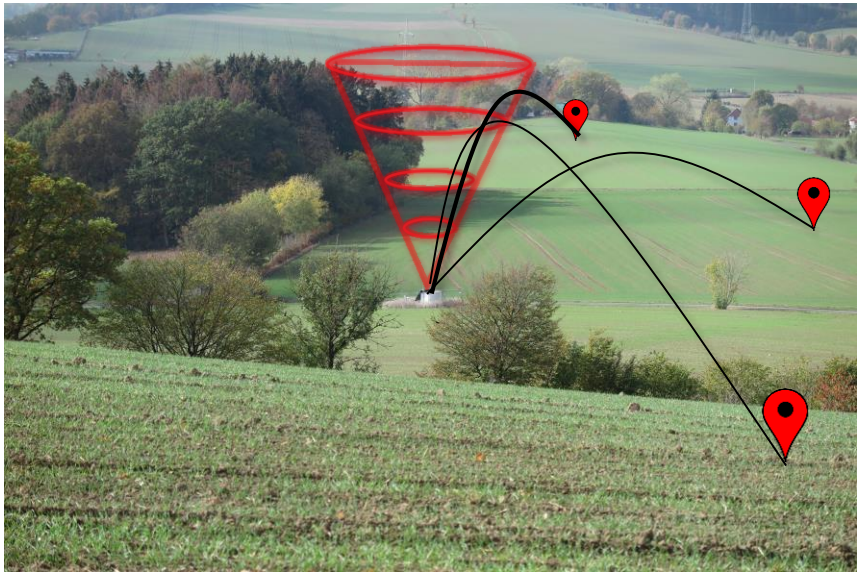
Measurement strategy: Wind field calibration

Standard method

Conventional data source

↓ Downscaling to terrain profile – scale factors (CFD model)

Determination of wind potential of site



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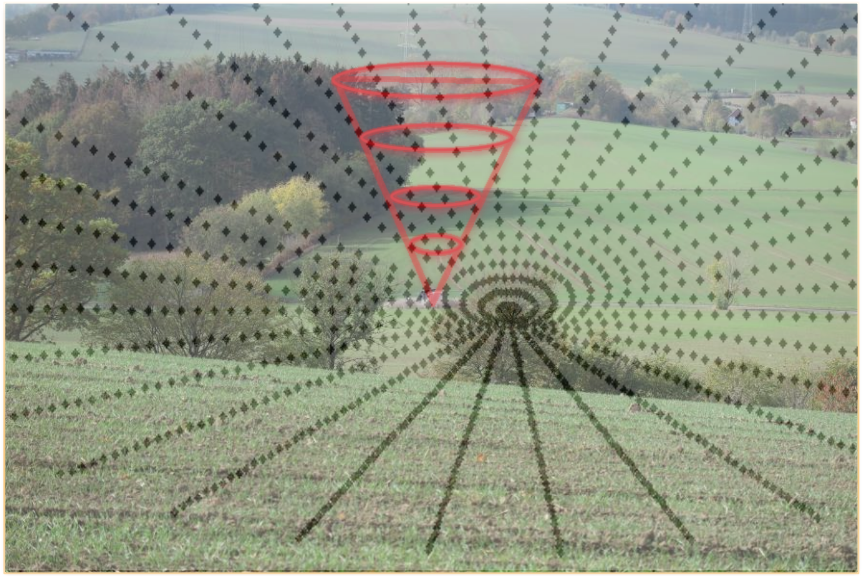
Measurement strategy: Wind speed field calibration



Advanced method

Conventional data source + Single scanning lidar

PPI scan – grid of scanning lidar measurements

Grid of measured site parameters

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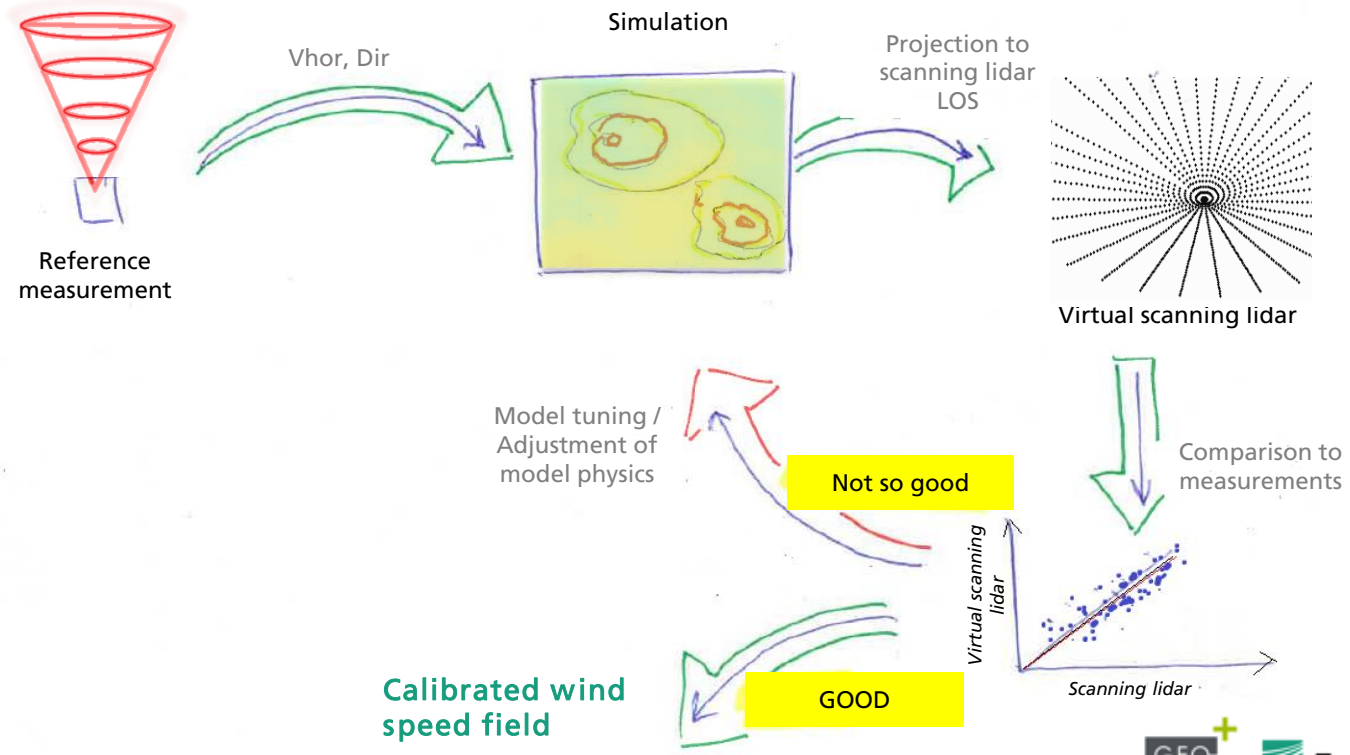
Wind speed field calibration

Method



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Demonstration campaign I

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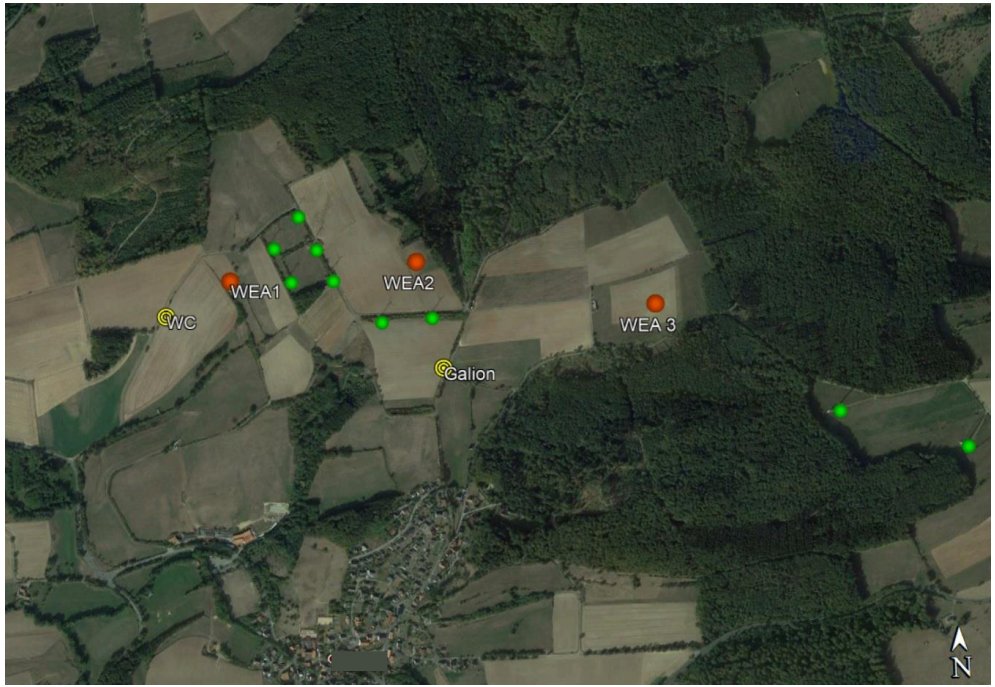
Demonstration campaign I

Demonstration site

- Moderately complex terrain often interrupted by forests.
- Three WT (WEA1, WEA2, WEA3) planned on site. (●)
- Instruments:
  - Windcube V2 (1,5 years of measurements) (◎)
  - Galion-4000 (scanning lidar) (3 months of measurements) (◎)

Fig. 1: Instrumentation map. (Green dots: existing WT)



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Scanning lidar measurements

Scan design

- Scanning lidar in the center of the site of interest.
- Scan set up:

Beams in scan	36
Azimuth ϕ [°]	0-360
$\Delta\ \phi$ [°]	10
Elevation θ [°]	34
Completition time (min,sec)	1,25

  - Horizontal range: ~1km
  - Vertical range: ~600m

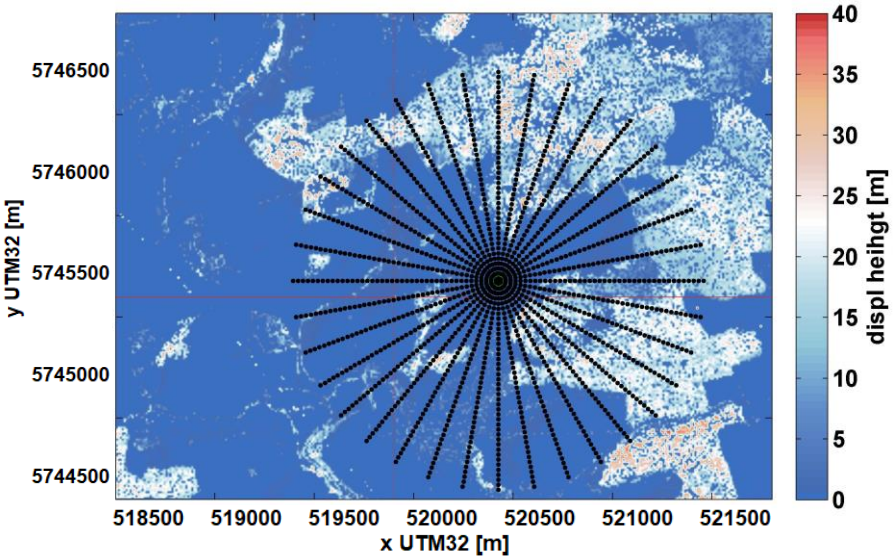

Fig. 2: PPI scan design at demonstration site.

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Flow model

Set-up

- Model: IWES in-house tool based on OpenFOAM[i] (incompressible flow solver)
- Input parameters:
  - 12 directional sectors
  - V_{hor} = 10 m/s
  - Neutral stratification
- Multiple extracted heights at measurement altitudes.

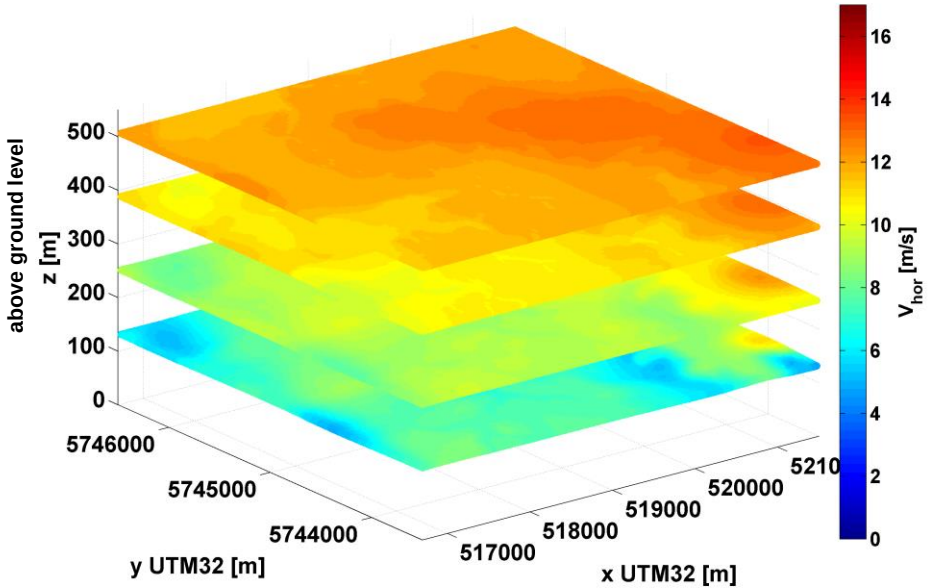

Fig. 3: Terrain following slices of the wind flow simulation at the demonstration site for the heights 126m, 243m, 378m, 495m.

[i] *Chang C., Schmidt J., Dörenkämper M., Stoevesandt B., A consistent steady state CFD simulation method for stratified atmospheric boundary layer flows, 2017, JWEIA, vol. 172.*

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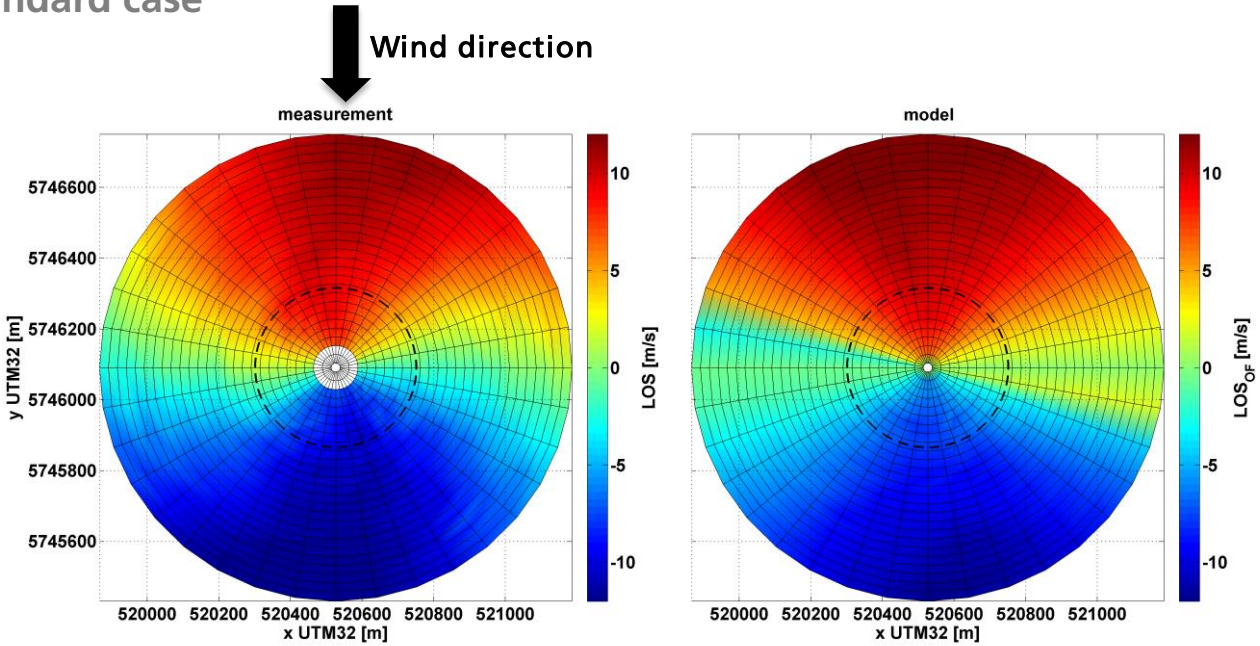
Virtual scanning lidar versus measurement

Standard case



30 minute averaged LOS measurements

Virtual scanning lidar LOS

– – – 125m height

$$V_{hor} = 10.5 \frac{m}{s}.$$

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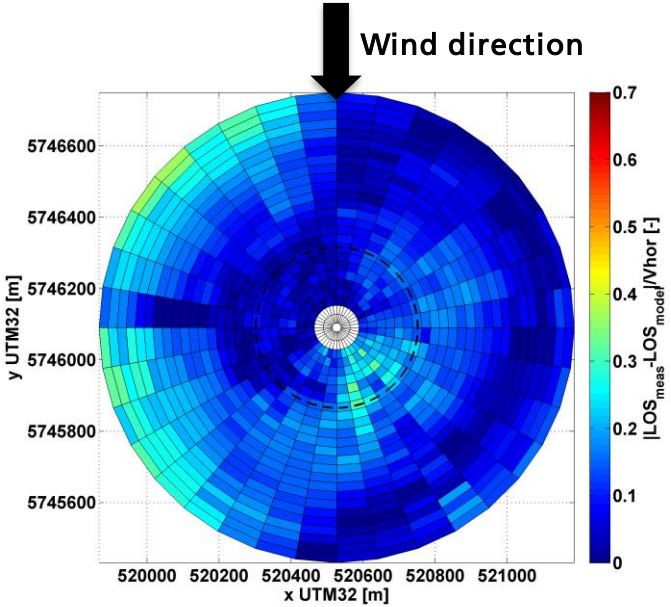
Virtual scanning lidar versus measurement

Standard Case



Absolute differences between measured and modelled LOS.

$$\Delta LOS = \frac{||LOS_{measurement}| - |LOS_{model}||}{Vhor}$$

- Blind wind directions to be rejected (~±90°)
- Visible forest induced mismatch
- Overall good agreement for lower altitudes.

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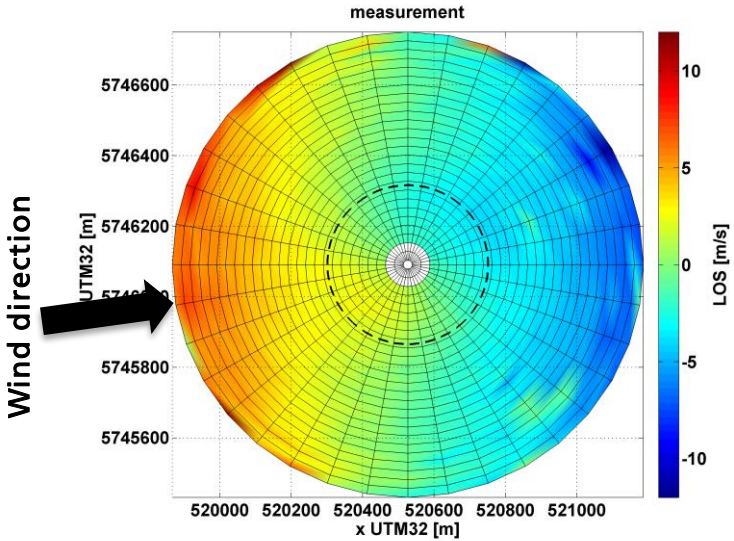
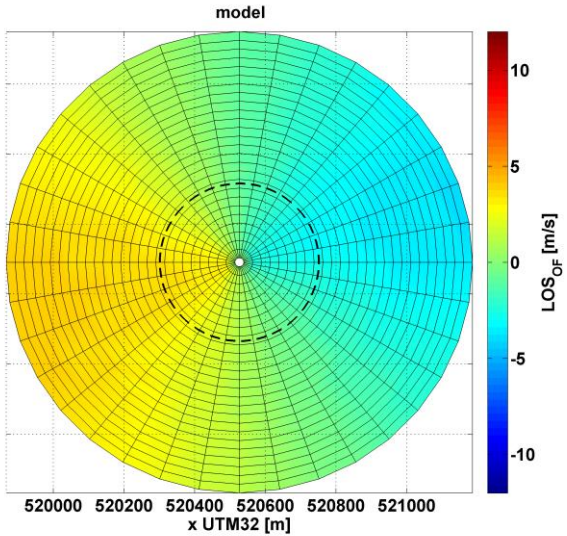
Virtual scanning lidar versus measurement

Strong shear case



30 minute averaged LOS measurements



Virtual scanning lidar LOS

- - - 125m height

$$V_{hor} = 3.5 \frac{m}{s}.$$

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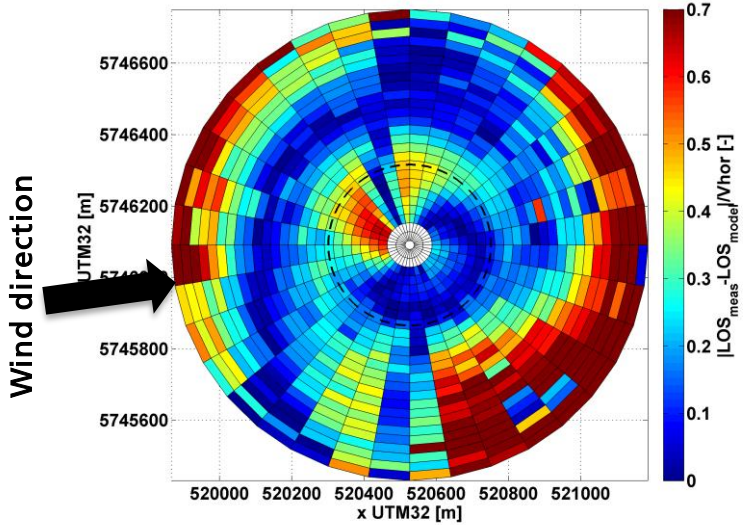
Virtual scanning lidar versus measurement

Strong shear case



Absolute differences between measured and modelled LOS.

$$\Delta LOS = \frac{||LOS_{measurement}| - |LOS_{model}||}{Vhor}$$

- Strong shear behavior not included in the model

Integration of atmospheric stability in the model.

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Conclusions/Further work

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Conclusions/Further work

Conclusions

- A single standing scanning lidar is capable of adding realistic information to the parameters produced by flow modelling.
  - Identification of uncertainty sources: Thermal stratification has a big impact on the comparison

Further work

- Quantification of the uncertainty.
- Adopt flow model modifications for the observed uncertainty sources. Further development of methods for derivation of directional corrections.

Thanks a lot for your attention!

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Questions ??

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