Scanning LiDAR in Complex Terrain for Wind Ressource Assessment

IEA Wind Task 52 – Lunch Seminar, 14.02.2023

WHO IS GEO-NET?

+ **GEO-NET** is a consultant for wind resource assessment and environmental meteorology since 1995.

+ **GEO-NET** is an interdisciplinary team of 60 experts from the fields of meteorology, geography, environmental planning and engineering

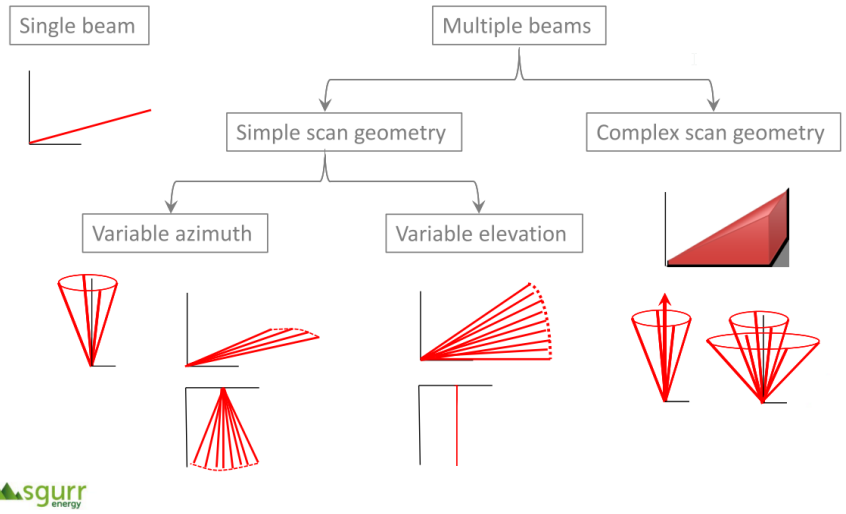
Services

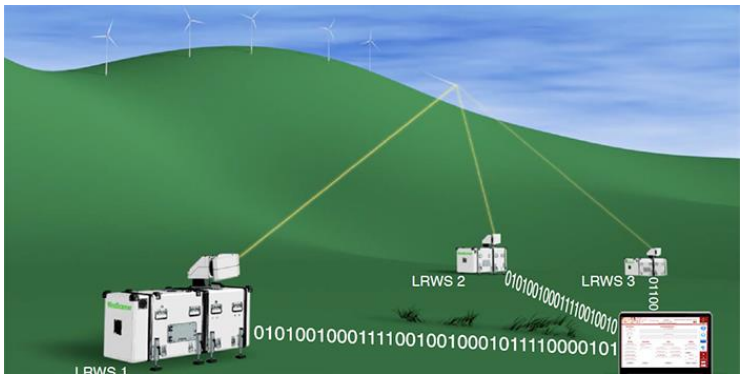
+ Wind potential studies
+ Wind measurement campaigns (mast / LiDAR)
+ Energy yield assessment
+ Turbulence assessments

DAkkS Deutsche Akkreditierungsstelle D-PL-11132-01-00

Application of Scanning-Lidar-Technology

- Scanning Lidar measures a single Line-Of-Sight (LOS) with adjustable / programable azimuth and elevation
- Line-of-Sight measurement ≠ horizontal windspeed used in WRA
- How to use it in wind ressource assessment??





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The EWINO Approach

Fraunhofer IWES

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What is EWINO?

Gefördert durch:
Bundesministerium für Wirtschaft und Energie
aufgrund eines Beschlusses des Deutschen Bundestages

Research project (10/2017 – 03/2020) to support wind farm developers for development of wind farms under tendering requirements of the German Renewable Energy Sources Act (EEG 2017)

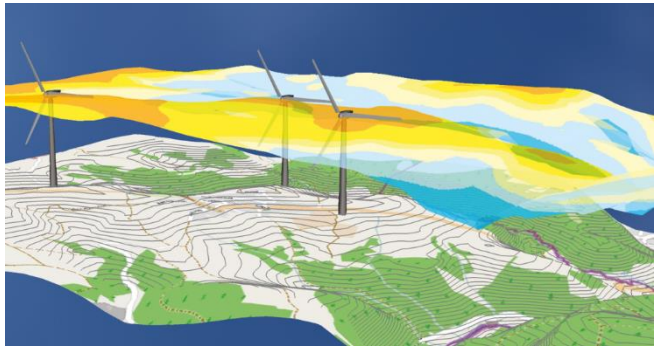
energiequelle
ENERGIE MIT ZUKUNFT.

WINDWÄRTS

naturstrom
ENERGIE MIT ZUKUNFT

ENERTRAG
Eine Energie voraus

The EWINO Approach



Interviews with wind farm developers & financer revealed:

- Balance between:
  improvement of uncertainties ⇔ **invest** in measurement technology **is deciding**

- comparability of assessments must be improved

- Specific for Germany: Many wind farms only have 3 – 5 turbines
  => limited financial ressource for technology

Conclusion from interviews:
Application of a new technologies shall be time and cost effective

The EWINO Approach

Requirement: Application of a new technologies shall be time and cost effective

- The reconstruction of horizontal wind from LOS comes along with uncertainties
  and
- lots of technical and financial effort when using e.g. multiple scanning lidars

- … Using the horizontal wind component is a convention

- Keep it simple !

➔ Directly compare model output to Line of Sight measurements

➔Use a fixed measurement/scanning strategy and directly compare the LOS measurements to the model output

- Published in energies 06/2021

The EWINO Approach – Publication

energies

MDPI

Article

Advancing Wind Resource Assessment in Complex Terrain with Scanning Lidar Measurements

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Abstract: The planning and realization of wind energy projects requires an as accurate and precise wind resource estimation as possible. Standard procedures combine shorter on-site measurements with the application of numerical models. The uncertainties of the numerical data generated from these models are, particularly in complex onshore terrain, not just rather high but typically not well quantified. In this article we propose a methodology for using a single scanning Doppler wind lidar device to calibrate the output data of a numerical flow model and with this not just quantify but potentially also reduce the uncertainties of the final wind resource estimate. The scanning lidar is configured to perform Plan Position Indicator (PPI) scans and the numerical flow data are projected onto this geometry. Deviations of the derived from the recorded line-of-sight wind speeds are used to identify deficiencies of the model and as starting point for an improvement and tuning. The developed methodology is demonstrated based on a study for a site in moderately complex terrain in central Germany and using two rather different types of numerical flow models. The findings suggest that the use of the methodology and the introduced scanning wind lidar technology offers a promising opportunity to control the uncertainty of the applied flow models, which can otherwise only be estimated very roughly.

Keywords: wind resource assessment; scanning lidar; flow model calibration

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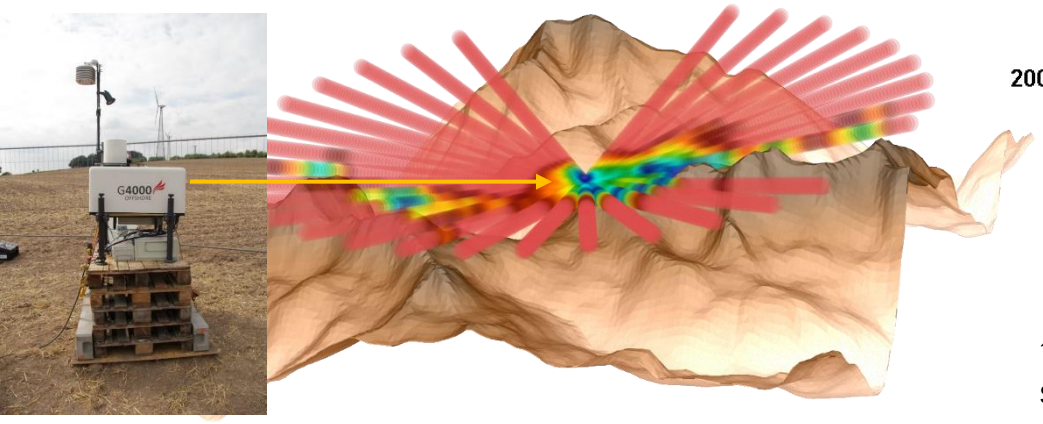
1. Introduction

An as accurate and precise as possible estimation of the wind resource, and the calculation of the prospective energy yield based on it, are important prerequisites for the successful design of a wind farm. The difficulty of the task increases with the complexity of the site under consideration, but also with the advancing point in time within the project

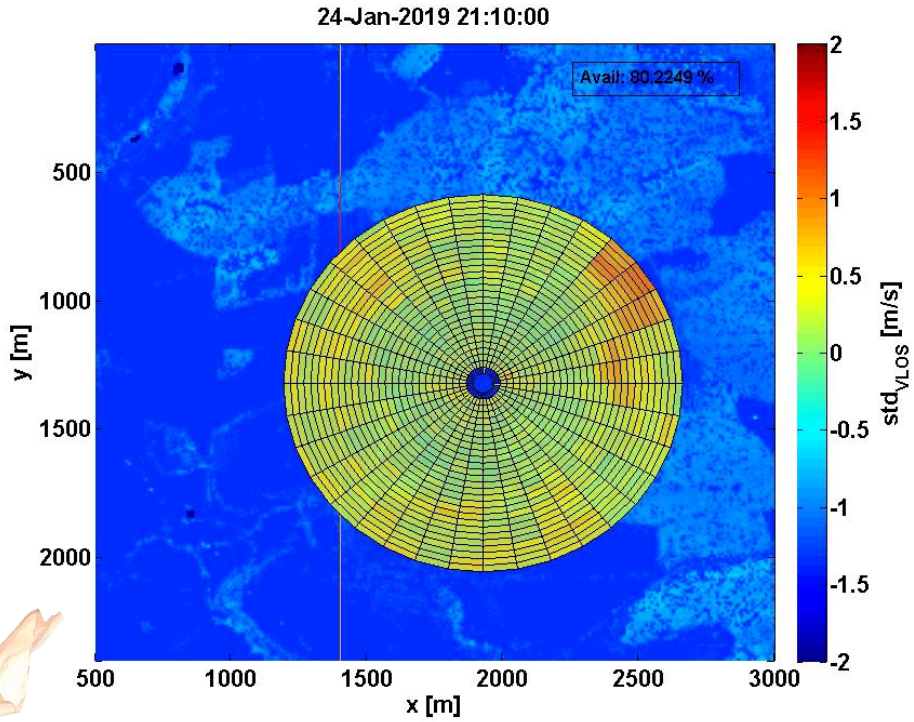
EWINO Approach applied

Direct comparison of the scanning LiDAR measurement with wind flow model FITNAH 3D, by reproducing the line-of-sight measurement in the model
=> Direct determination of uncertainties possible

=> No error for reconstruction of horizontal wind component



↑ Reproduction of PPI Scan in the wind flow model FITNAH 3D



↑ Data of a PPI scan averaged over 10 min each (36 single scans at a distance of 10°, elevation of 34°)

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Uncertainty components for wind ressource assessment

Topic	Uncertainty Component
Measurement	Wind speed Anemometer classification according to IEC 61400-12-1 [6], [7] Anemometer calibration Measurement set-up (mast influences) Data logger (resolution) Quality of correction method applied Wind direction Direction sensor characteristics Measurement set-up (mast influences, accuracy of north gap orientation, in-situ comparison) Quality of correction method applied Remote sensing Verification test Sensitivity on environmental conditions Variation of wind conditions across probe volume or uncertainty of respective corrections Alignment of RSD Control mast deviations / 2nd verification test Availability of raw data Data quality (signal to noise ratio, possible fixed echoes (SODAR)) Representativeness of measurement period: duration and availability with respect to seasonal and diurnal variation
Data Integrity	Uncertainty substitute value (section 8.1)
Data Analysis	Uncertainties coming from the data filtering Uncertainties coming from the data filling
Derived parameters	Air density Uncertainty of measured air pressure and temperature Turbulence intensity Number of counts on which turbulence intensity is based Temporal resolution of input data Completeness of data base Extreme winds Comparative analysis of different methods Sensitivity analysis (different time periods, independency criteria etc.) Length of input time series
Correlation and long-term extrapolation	Overlapping period Correlation between site and reference data Consistency of reference station Consistency of scaling factor Length of past period Future period Used method Inter-annual variability
Flow modelling	Vertical extrapolation Horizontal extrapolation Sensitivity on wind direction Limitations of models

Reduction of uncertainties through better measurement approaches „standard“ WRA

EWINO APPROACH:

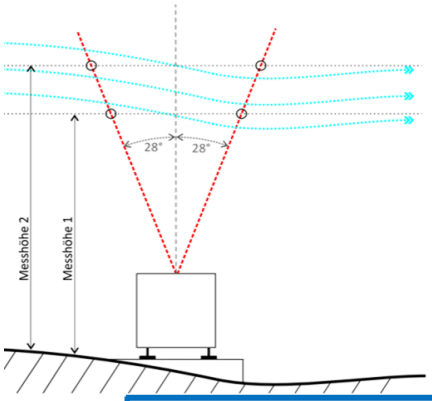
+ Reduction of flow **modelling uncertainty by** comparison of model and scanning lidar output

Source: MEASNET – evaluation of site specific wind conditions v3 (09/2022)
http://www.measnet.com/wp-content/uploads/2022/09/Measnet_Evaluation-of-Site-Especific-Wind-Conditions_v3-1.pdf

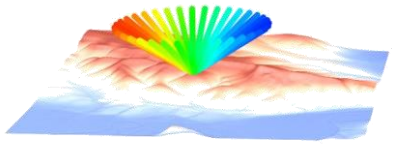
Application of Scanning-Lidar-Technology

- **Significant difference** to “standard” WRA: The measurement is used to check the consistency of the flow model in order to reduce the uncertainties of the transmission

- The general concept for a combined scanning-LiDAR measurement necessarily includes a standard 12 month measurement in the wind farm and ideally the measurement of atmospheric stability



Duration of the measurement with Scanning LiDAR, until relevant/representative inflow conditions for the site have been recorded.



Months 1
Start of Campaign,
using LiDAR / Met mast

Month 1 + x
Start of additional measurement
using a Scanning LiDAR

Months 12
End of campaign,
with LiDAR or Mast

Application complex terrain

Application case: Complex terrain

- Wind farm in highly complex terrain in Austria, up to 14 turbines

- Conception, supervision of measurements, wind flow modelling and EY and turbulence assessments by GEO-NET

- Conception of scanning LiDAR measurement jointly Fraunhofer IWES and GEO-NET

Application case: Complex terrain

Main challenges:

- Measurement sites for a met mast are rare (=1)

- Representation of wind flow at the mast for the wind farm area is limited

- Using a standard (VAD) LiDAR is not reasonable due to terrain error, and restrictions due to low laser power (expected low availability due to low aerosol concentration and cloud cover)

Method – application of EWINO approach:

➔ Scanning LiDAR (SL) provides higher power than standard vertical LiDAR

➔ The SL can cover almost the entire wind farm area using a PPI scan

➔ The wind flow model output can be compared and validated against the SL measurement to identify areas with low and high uncertainties

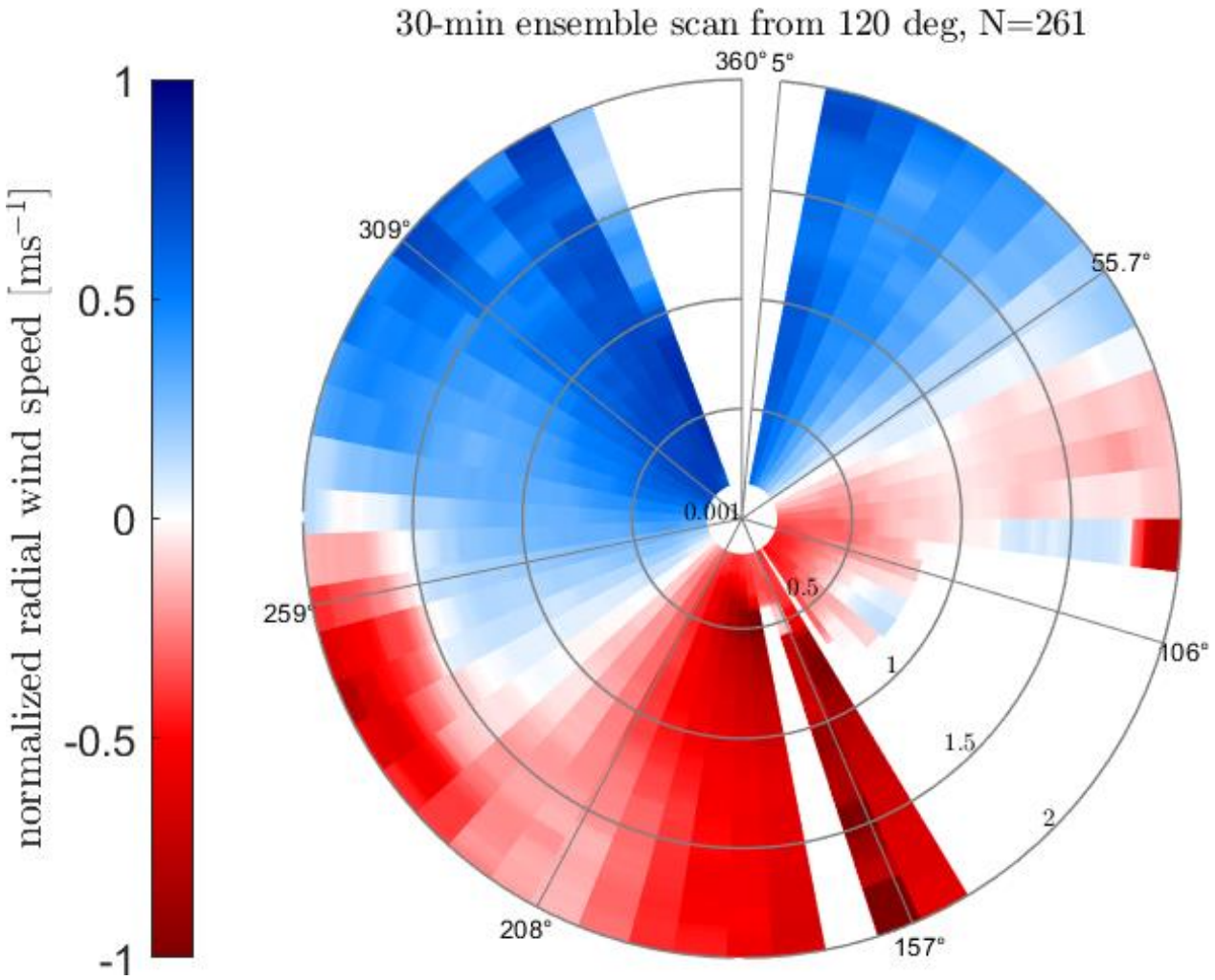
Measurement setup

100m met mast with heated equipment:
5 heated Cup Anemometer
2 heated wind vanes
2 heated 3D sonics
(> 12 months)

2 secondary measurements @ 45m
(heated 3D Sonics + Cup Anemometer)
for wind vector + atmospheric stability

1 Scannling LiDAR measurements with view on core wind farm area
Halo Photonics StreamLineXR, laser range up to 10km (…under given circumstances range is ~2km)

Scanning LIDAR output (LOS, ppi 7°)



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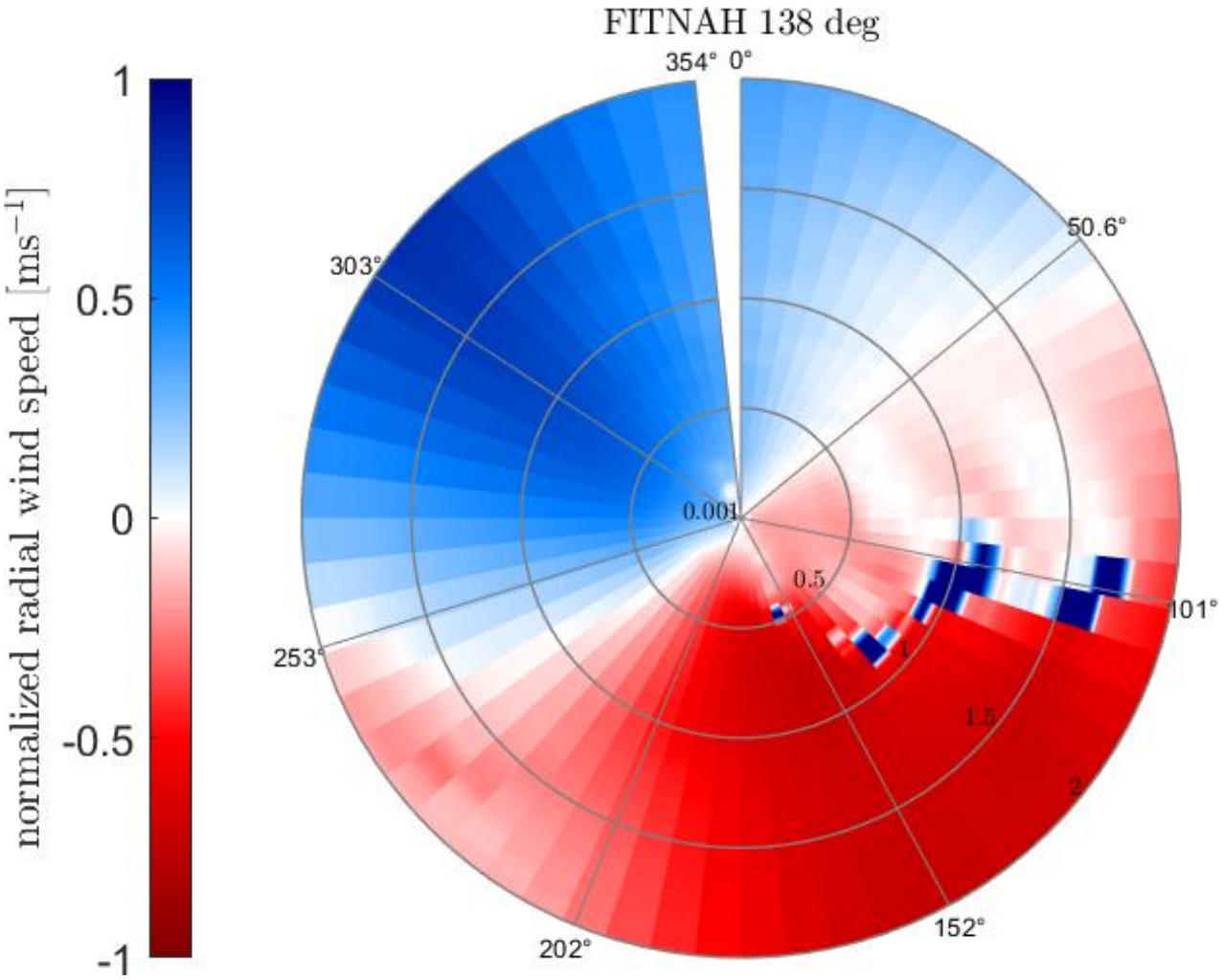
Scanning LIDAR output (LOS, ppi 7°)



Conclusion & Publications

- The application of the approach is site depending – not suitable/effective for all sites

- Selection of scanning strategy, flow model and measurement location must be done carefully

- The EWINO approach offers a effective solution to validated flow model output for an area – not only measurement points

Advanced Wind Ressource Assessment:
https://doi.org/10.3390/en14113280

Business case for scanning LiDAR
doi.org/10.5281/zenodo.5722362

Thank you for your attention!

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