Analysing Data Availability as a Metric for Scanning Lidar Wind Resource Assessment Campaigns

A. P. Kidambi Sekar[1], P. Schwenk[1], A. Oldroyd[2]

[1] Offshore Wind Consultants (OWC)
[2] Oldbaum Services

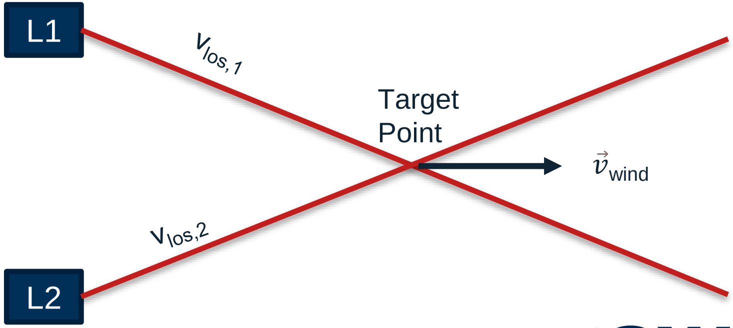
Mini-Symposia: IEA Task 52: Replacing met masts and accelerating offshore wind deployment
Wind Energy Science Conference, Glasgow

25.05.2023

owcltd.com

Introduction

- Wind data measured during surveys used in many project stages
    - Wind Resource & Energy Yield
    - Wind Turbine Design /Loads
- Scanning lidars in Dual-Doppler mode provide:
    - Flexible scanning for multi-point multi-height measurements
    - Measurements at long ranges
- **Advantages:**
    - Wind Resource & Energy Yield: Reduced measurement uncertainty improving P90/P50 ratio
    - Wind Turbine Loads: Estimate of cup-equivalent 10-minute TI



OWC An ABL Group Company

State of Affairs

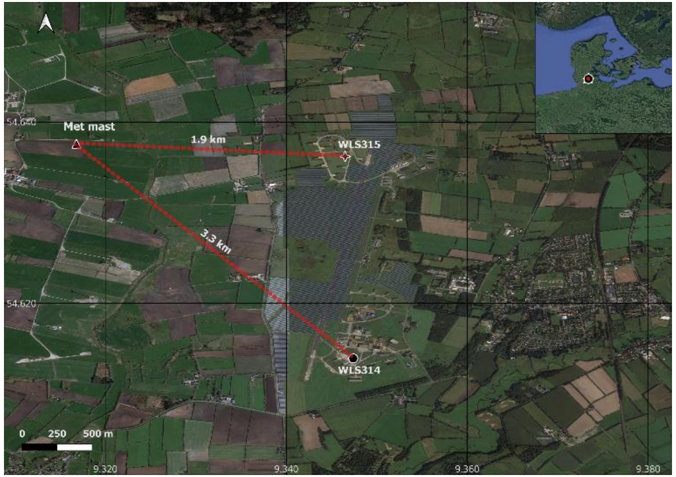
- Currently there are no best practice/ standards (yet) for scanning lidars
- Scanning lidar campaigns are evaluated against non-scanning lidar specific standards and best practices
- Direct applicability to scanning lidars is questionable due to differences in max range, wind field reconstruction philosophy and measurement versatility

Objective

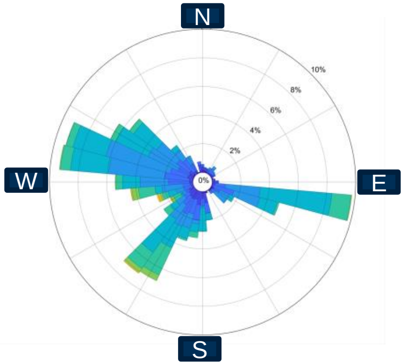
- Evaluate scanning lidar performance in reconstructing wind parameters from a performance verification test
    - Evaluate improvements and impact of **data availability** on wind field reconstruction
    - Investigate the **directional dependence** of wind field reconstruction

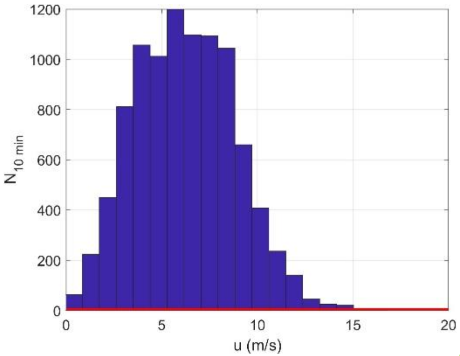
Device and Experimental Layout at Janneby, Germany

- Two Windcube 400S lidars operated in Dual-Doppler mode at DNV Janneby site
- Test Duration 17-08-2022 to 24-10-2022 (~68 days)
- No scanhead steering → Dual-Doppler staring mode configuration
- Laser beam intersection next to fully instrumented 100m IEC compliant met mast
- Wind speed bins filled according to IEC 50-3 requirements

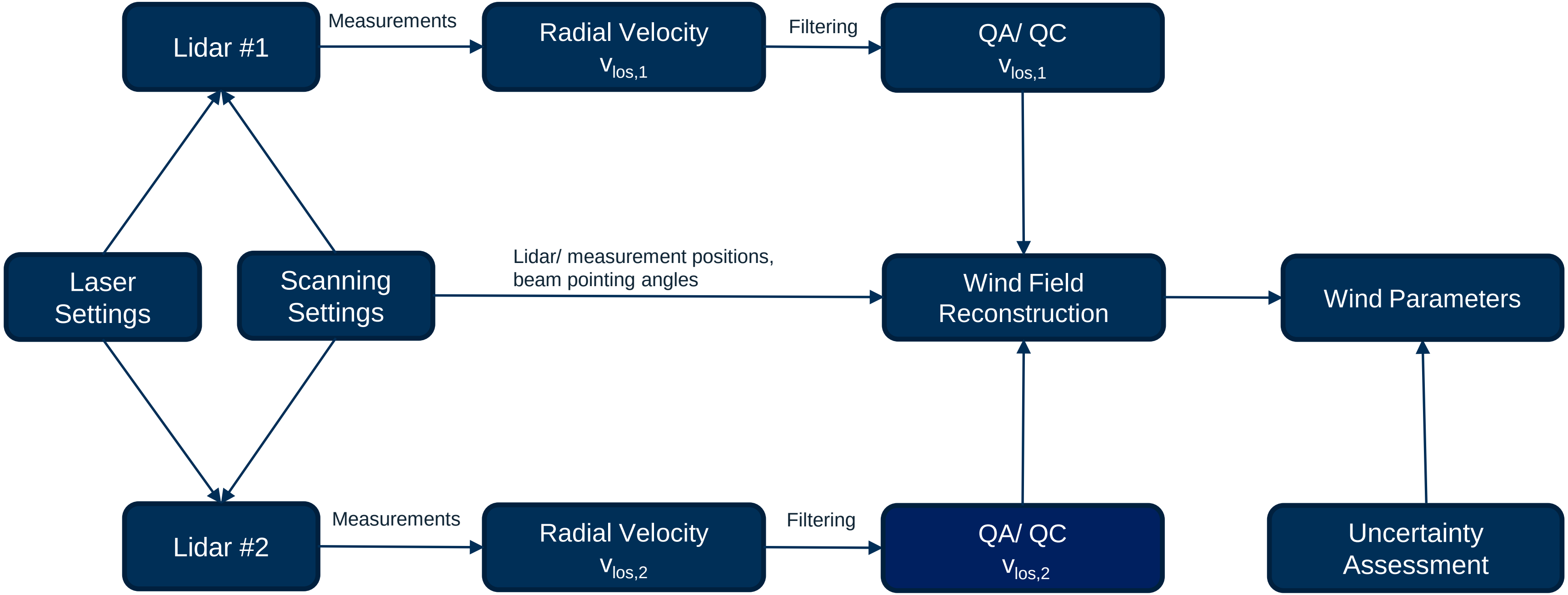


Parameter	Lidar 1 (WLS314)	Lidar 2 (WLS315)
Laser wavelength	1.55um	1.55um
Elevation	1.89°	2.72°
Probe Length	100 m	100 m
Accum time	1 s	1 s
Range met mast	3300 m	1900 m
Distance	100 m – 6000 m	100 m - 6000 m

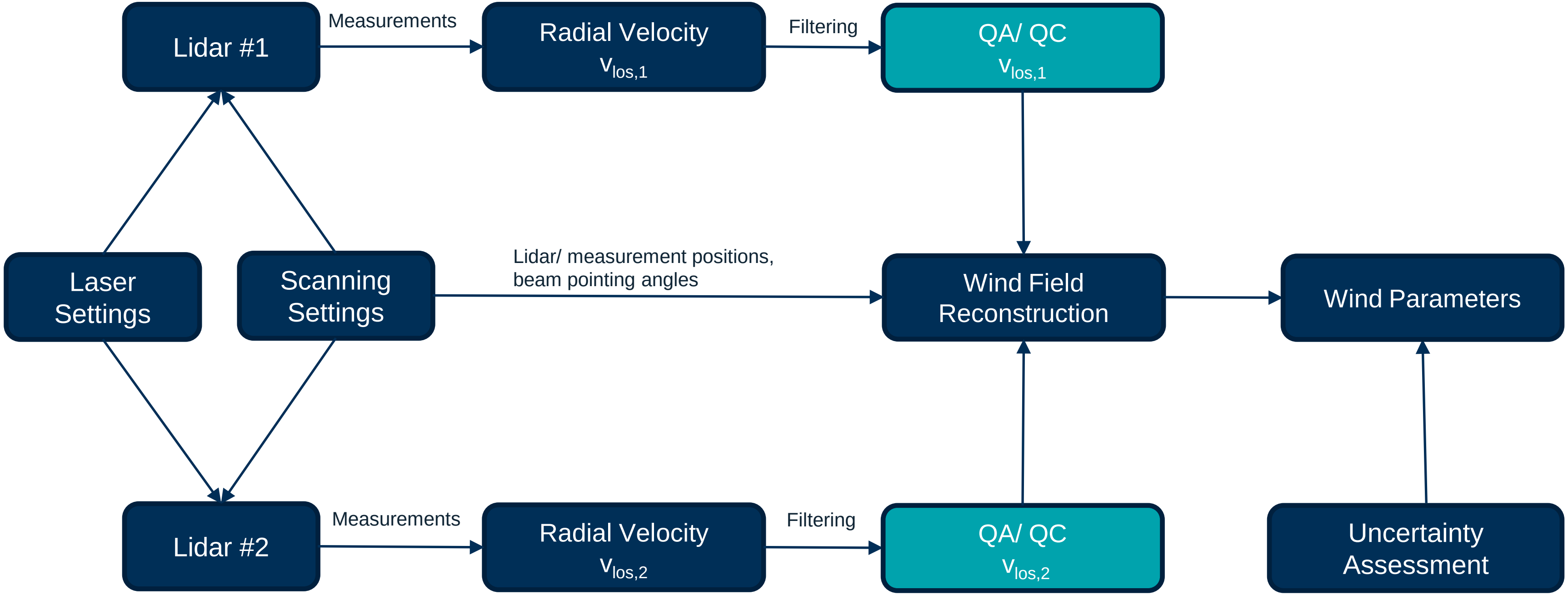




Dual-Doppler Scanning Schema for Wind Resource Assessment

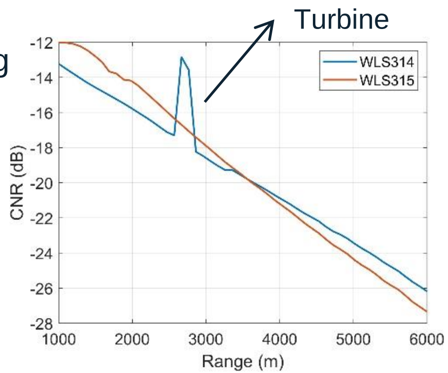


Dual-Doppler Scanning Schema for Wind Resource Assessment

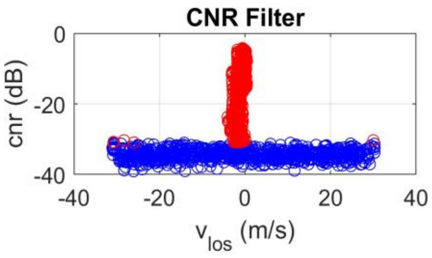


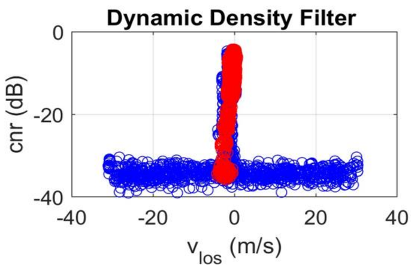
Data Filtering Techniques

- Distance dependency of Carrier-To-Noise (CNR) reduces availability at longer ranges for pulsed lidar systems
- Data recovery dependent on type of filter utilised → Quantified through 10-min data availability
- Filtering applied to every 10-minute measurement period in addition to lidar internal quality flag



No	Filter Name	Filter Parameters
1	CNR Filter	$-29 \le cnr \le 5$
2	CNR + v_{los} Filter	$-29 \le cnr \le 5$ $v_{los} - 3\sigma_{Vlos} \le v_{los} \le v_{los} + 3\sigma_{vlos}$
3	Interquartile (IQ) Filter	$V_{los,25} - 1.5IQR_{Vlos} \le v_{los} \le V_{los,75} + 1.5IQR_{Vlos}$
4	IQ + Despiking Filter	IQ Filter + Despiking Filter
5	Dynamic Density Filter	Data density filter



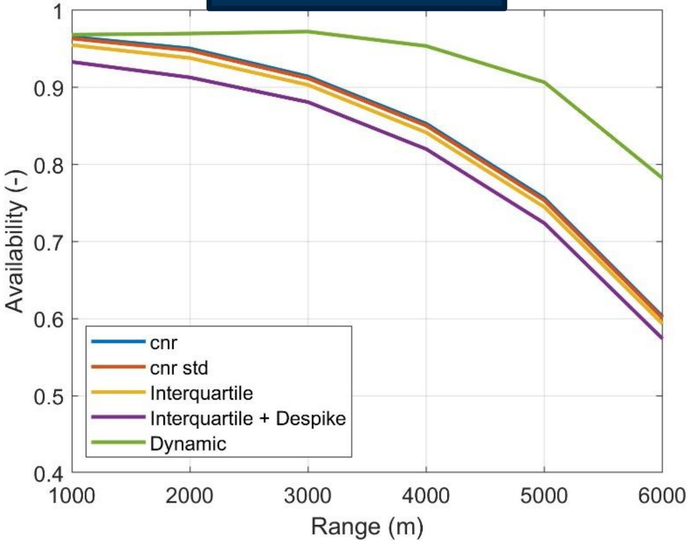


Data Availability

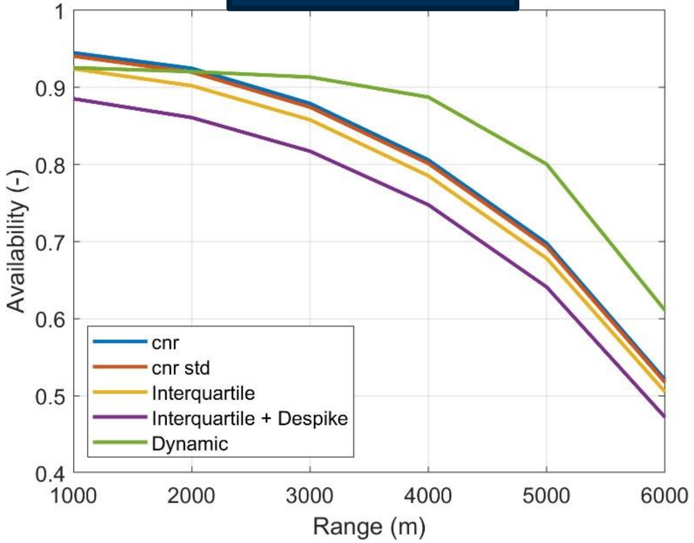
- Distance dependance of availability visible due to reduction in CNR

- Improvement in data availability
  - Single lidar availability up by 20 % at 6 km
  - Dual-Doppler availability up by 11 % at 6 km

Single Lidar



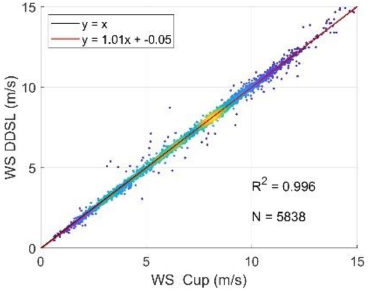
Dual Lidar

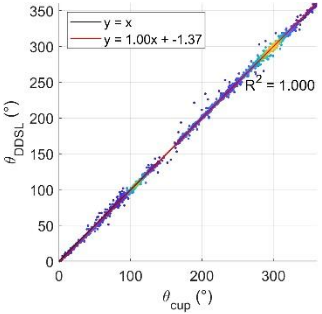


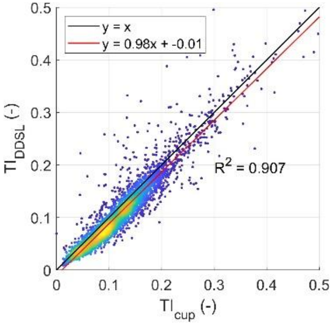
OWC
An ABL Group Company

Validation Results Against Reference Met Mast

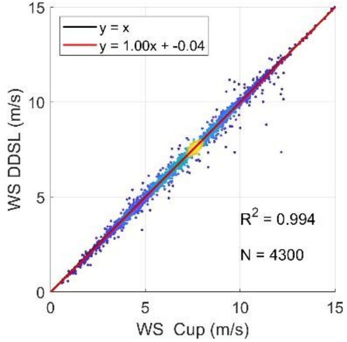
At met mast

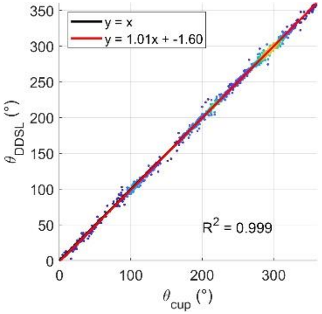


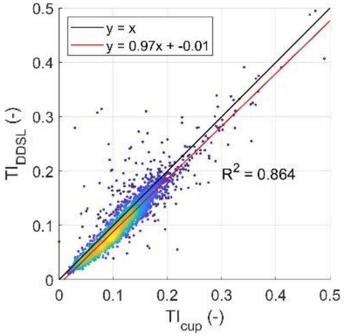




At 6 km (Max range during campaign)



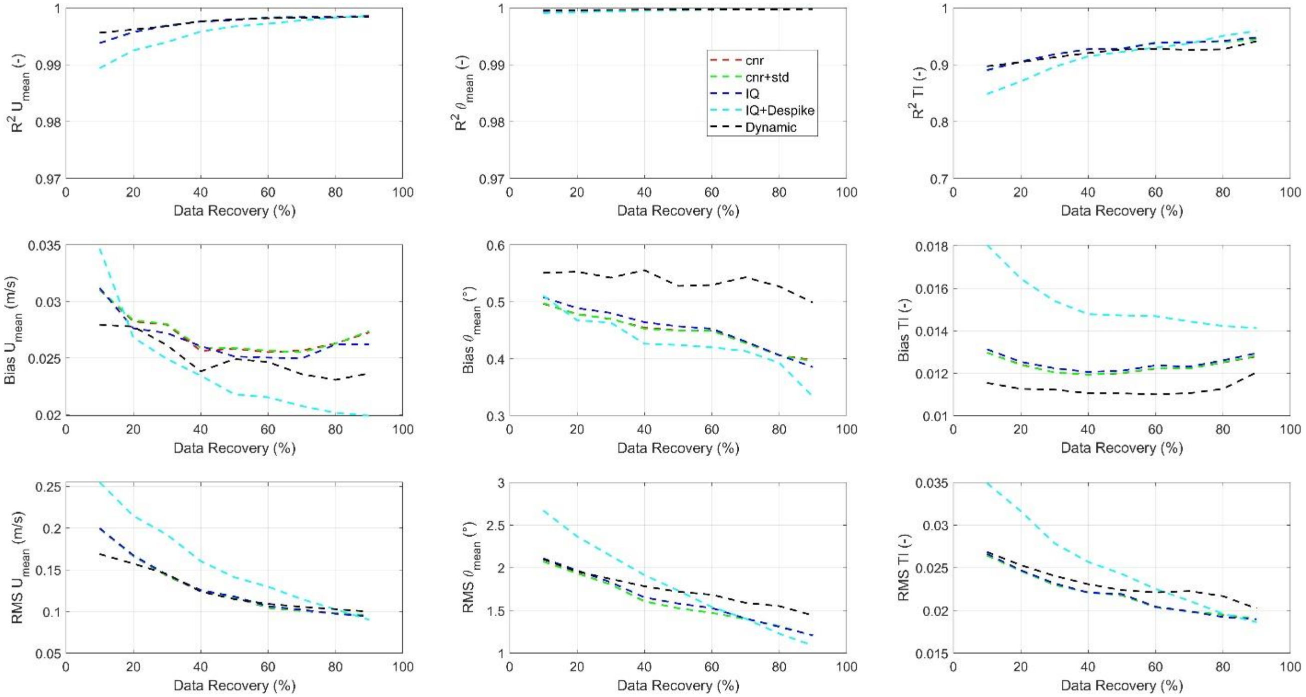




- Reconstructed 10-minute wind quantities compared against mounted anemometer
- Simple CNR + 3σ V_{los} lidar filter. Cup data filtered for mast effects.
- 10-min sample is marked valid if it contains more than 50% valid data
- The number of valid samples drop at max range, but similar regression results
- Excellent agreement between wind speed and directions from DDSL and met mast
- DDSL TI exhibits turbulent attenuation

Wind Field Reconstruction Sensitivity to Filtering And Recovery Rates

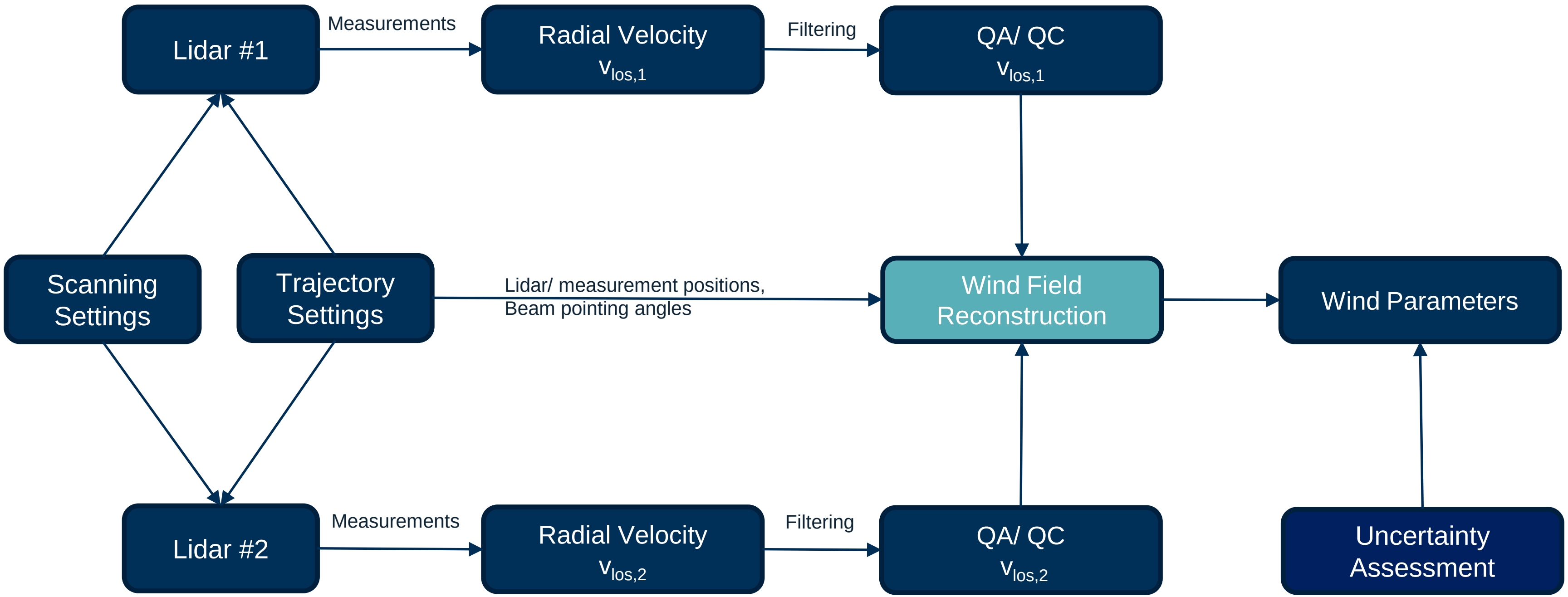
Wind Speed | **Wind Direction** | **Turbulence Intensity**



- Recovery rate: The ratio of the % of valid samples to all possible samples inside a 10 min period
- Similar trend is observed for all filters and KPI's
- Wind field reconstruction shows minimal sensitivity to improved data availability
- Excellent performance for wind speed and direction reconstruction even with 10% recovery rate
- TI reconstruction requires more samples

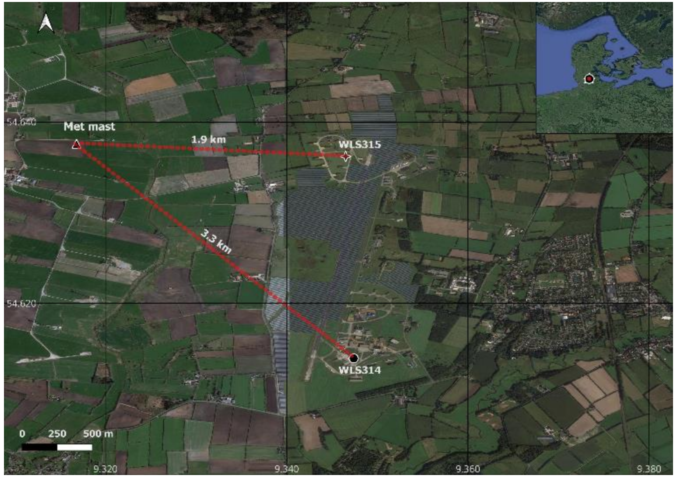
OWC
An ABL Group Company

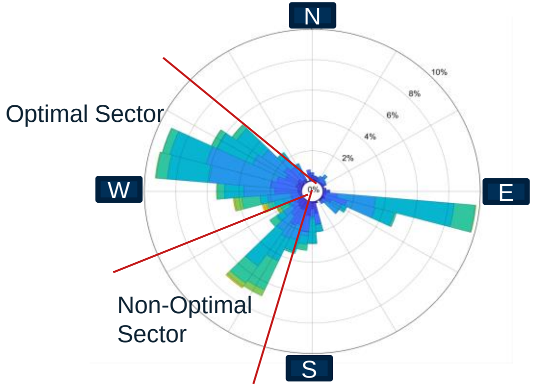
Dual-Doppler Scanning Schema for Wind Resource Assessment



OWC
An ABL Group Company

Laser Beam – Wind Direction Misalignment





- Dual-Doppler WFR dependent on beam-intersection angles between the laser beam and wind direction
- Changes in wind direction creates a range of intersection angles between the laser beam (s) and the inflow
- **Sectorwise analysis:** Sensitivity to the laser beam – wind direction alignment
  - Optimal Sector: line-of-sight *aligned* into the inflow
  - Un-Optimal Sector: line-of-sight is *not aligned* into the inflow

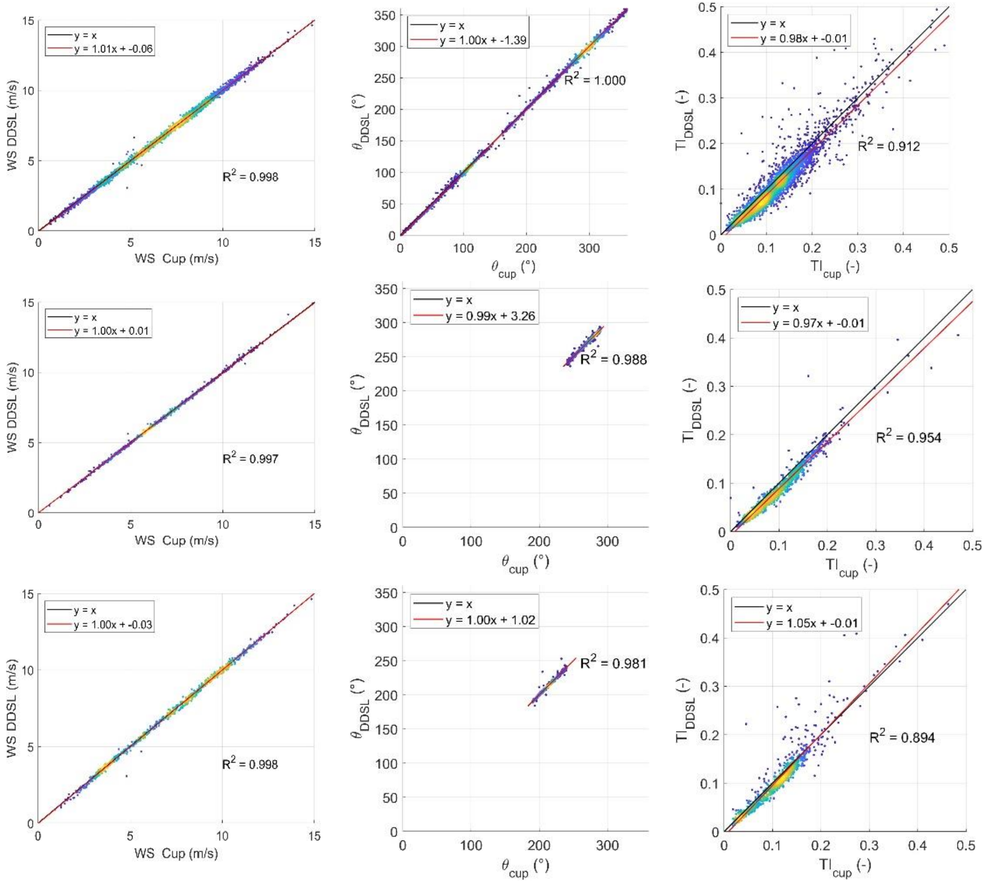
OWC
An ABL Group Company

Sectorwise Regression Results

All Sectors

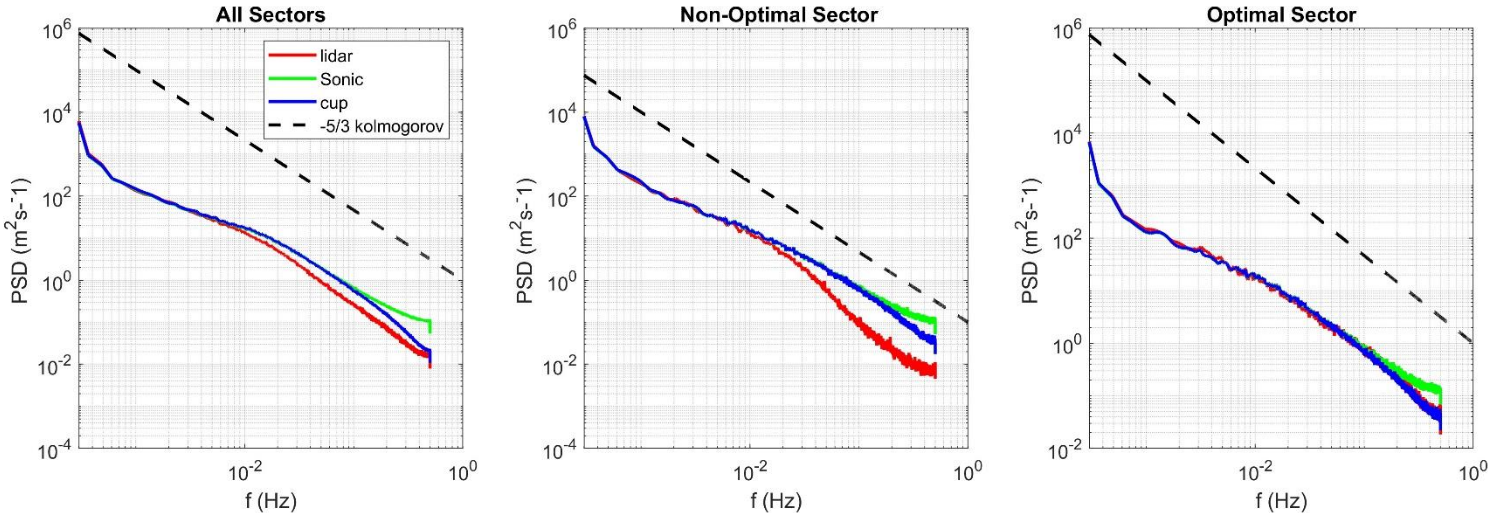
Optimal Sector

Non-Optimal Sector



- Negligible effect of wind direction on reconstruction of wind speed and direction regression
- Regression results for TI are improved for the optimal sector in comparison to all sectors
- TI Regression results for the un-optimal sector differs from the optimal sector

Reconstruction of Turbulent Spectra



- Turbulence spectra estimated from 1Hz reconstructed horizontal wind speeds
- Lidar reconstructed spectra follows -5/3 turbulence decay till lidar cut-off frequency
- For the optimal sector, reconstructed spectrum overlaps the cup estimated spectrum
- For non-optimal sector, reconstructed spectrum drops off earlier

OWC
An ABL Group Company

Conclusions

- Data collected from a dual-doppler scanning lidar performance verification test used to investigate sensitivity of reconstructed wind field parameters to data availability and wind direction-laser beam alignment

- Excellent performance of Dual-Doppler scanning lidars in reconstructing wind speed, wind direction and turbulence intensity

- Data availability increased for long-range scanning lidars by careful decision on filtering routine

- However, increased data availability did not translate to substantial improvements in KPI’s at least until the 6 km range

- Reconstruction of 10-minute turbulence intensity is sensitive to the alignment between the laser beam and wind direction

OWC
An ABL Group Company

Analysing Data Availability as a Metric for Scanning Lidar Wind Resource Assessment Campaigns

A. P. Kidambi Sekar

E: anantha.kidambi@owcltd.com

Thank You

West of Orkney Windfarm

Thanks to the Offshore Wind Power Ltd (OWPL) consortium and West of Orkney Wind Farm development