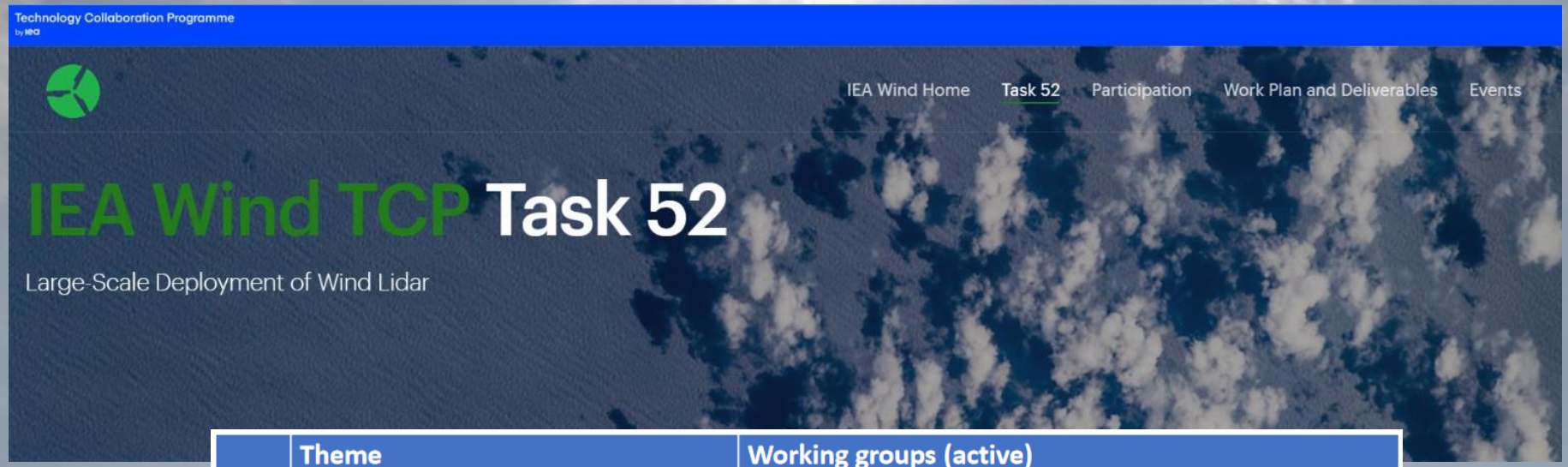
Task 52 General Meeting 2023
WG4 on Cold climate

Sara Koller, Meteotest

Online

June 13-14



	Theme	Working groups (active)
# 1	*Universal inflow characterisation*	(#1) Turbulence Intensity (TI) by Lidar (#2) Lidar Assisted Control (LAC)
# 2	*Replacing met masts*	(#3) Lidar in Complex Terrain (#4) Lidar in Cold Climate
# 3	*Connecting wind lidar*	(#5) Digitalization (#7) Lidar Ontology
# 4	*Accelerating offshore wind deployment*	(#6) Scanning Lidar Offshore

Objectives

Key questions

LiDAR data availability

- What are the reasons for the low data availability in cold climate regions?
- Is there a way to increase data availability in cold climate regions?

Meteorological icing detection

- Are LiDAR suitable to detect meteorological icing?
- Is it possible to estimate ice classes from LiDAR data?

IEA Task 54 (formerly 19)

IEA Ice Classification for wind energy sites

IEA Ice class	Meteorological icing	Instrumental icing	Production loss
	% of year	% of year	% of annual production
5	>10	>20	> 20
4	5-10	10-30	10-25
3	3-5	6-15	3-12
2	0.5-3	1-9	0.5-5
1	0-0.5	<1.5	0 - 0.5

Data availability - past

energie werkstatt
TECHNISCHES BÜRO FÜR ERNEUERBARE ENERGIE

Bericht

Vergleichende Datenverfügbarkeit von LiDAR-Messkampagnen

Analyse und Bewertung im Rahmen der
IEA Wind Task 32 Forschungskooperation

Understanding Pulsed Lidar Data Availability

VAISALA

PO.164

Simulating with Reanalysis Data and Boosting with Convolutional Neural Networks

Andrew BLACK, Laurie PONTREAU, Pierre ALLAIN, Frederic DELBOS, Morgane KERVAON, Mehdi MACHTA
Vaisala France

Abstract

As wind energy development accelerates worldwide, many more campaigns are using profiling and scanning lidar, and more campaigns are occurring in locations with low aerosol density ("clean air" or "clear sky"). Lidar backscatter signal quality depends on the presence of aerosols advecting in the wind: clean air sites reduce lidar range and data availability and can lead to increased project uncertainties. Large scale deployment of wind lidar requires **(1) simulators that can reliably predict lidar data availability (2) novel techniques to improve range and availability to reduce energy yield assessment uncertainties.** Here we present:

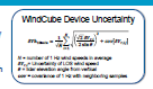
- New range data availability simulator using satellite and reanalysis data,
- Technique to maximize profiling lidar data availability with traditional algorithms via detailed study of lidar metrology and uncertainty, and
- MosquitoNet, a new lidar range boosting technique based on a convolutional neural network that can recover low CNR data.

Data Availability and Range Estimator

Why is it important to simulate the availability of a lidar before the campaign? Successful measurement campaigns require careful planning. The expected data availability of the sensors in your observation network is a key detail in allocating field engineering resources, sizing power supplies, and choosing the right sensors for your application's requirements. Vaisala's Data Availability and Range Estimator allows WindCube lidar users to simulate the performance of their devices based on historical weather and reanalysis data at the proposed measurement campaign site

Optimizing Traditional Filtering Thresholds

Lidar device uncertainty, independent of atmospheric sensitivities, can be derived by measuring the uncertainties of LOS measurements in the laboratory using Vaisala's Simulation of the Atmosphere with Fiber Optics (SAFO) test bench, and then propagating the measured uncertainties through the wind field reconstruction algorithm, and combining the uncertainties of *N* measurements in a 10-minute period, following the GUM (1995).



Using this description of lidar uncertainty, to maintain 0.1 m/s precision, **a 50% availability threshold can be used to boost data availability in bankable campaigns.**

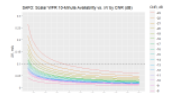


Figure 1: WindCube uncertainties as a function of CNR and 10-minute data availability

Figure 2: Simulated data availability for WindCube V2 profiling lidar compared to data availability observed in real measurement campaign. WindCube Data Availability filter threshold of 80% 10-minute availability

MosquitoNet – a Deep Learning Range Booster

Vaisala has developed an experimental **new filtering technique using a convolutional neural network** to perform semantic segmentation on LOS time series images, classifying pixel data into categories "wind", "hard target", or "outlier". After labeling, the CNR threshold is reduced from -23 dB to -26 dB and wind speeds are recalculated using only "wind" data. Validation of biases and uncertainties of these recaptured data is ongoing.

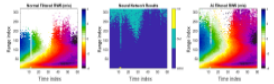


Figure 3: (A) Time series of one LOS, all heights, -23 dB threshold. (B) MosquitoNet semantic segmentation results. (C) Time series of same LOS, all heights, -26 dB threshold including only pixels classified as wind

Figure 4: (A) Time series of horizontal wind speed, all heights, -26 dB threshold, all "wind" classified LOS data included. 80% 10-minute availability threshold (B) Traditional threshold filter, -23 dB, 50% 10-minute Availability

Figure 5: Comparison of -23 dB, 80% filters, -23 dB, 90% filters, and -26 dB 90% filters data availability

Conclusions

Clean air conditions can be predicted with sufficient accuracy for lidar met campaign planning. Precise application of traditional filtering techniques enable 5-10% improvements in campaign availability. Deep learning-based filters can boost availability by up to 40%.

References

1. Roquet, M., et al. Simulation of Doppler Lidar Measurement Ranges and Data Availability. J. Tech (2016)
2. Hoyt, P. et al. Innovative Method to Evaluate Data Availability of Doppler Lidar: the European Case. WMBI (2020)
3. Black, A. Ground-based lidar wind field reconstruction: uncertainty propagation compared to laboratory and outdoor manufacturing tests. WindKeeper Technology Workshop (2022)
4. Machine et al. Boosting Lidar Range using Convolutional Neural Network. CLRC (2022)

Special thanks to XWS for providing data. Plots generated with plotly and ggplot2. Buoy photo credit Jacques Vazillon of Nénuvent.

MEET US AT Booth D-D10

Watch this presentation — Replace with QR code
Download the poster — Replace with QR code

Wind EUROPE ANNUAL EVENT 2023 COPENHAGEN 25–27 APRIL
windeurope.org/annual2023
#WindEurope2023

PO.134

Clear-air data availability of continuous-wave scanning lidar

ZX Lidars

Nathan Smith , John Medley, Chris Slinger, Matt Smith
ZX Lidars

Abstract

A wind lidar operates by transmitting a laser signal and measuring the light scattered by particles carried by the wind. The intensity of this backscattered light is a function of the intensity of the incident light and scatterer density. Continuous-wave (CW) scanning lidars have the potential for higher sensitivity than a pulsed lidars by virtue of their greater photon flux and their focus of the laser power at each measurement height in sequence.
Here we describe an investigation into the availability of wind speed measurement data in the clear-air, low-backscatter conditions typical of high latitudes (such as Scandinavia, Northern Canada) and high altitudes (European Alps, Rocky Mountains of the USA). Wind speed measurement data collected by ZephIR 300 ground-based and ZephIR DM turbine-mounted lidars are used to predict data availability for the recently launched ZX 300 ground-based and ZX TM turbine-mounted scanning CW lidar systems.

Method

ZX Lidars has access to a significant database of historical lidar from around the world. The data have been analysed specifically to isolate clear-air conditions in which the backscatter, characterized by the parameter β(π) [1], is consistently low at all heights. Histograms of the measured backscatter level have been produced for a number of campaigns, for both ground-based and turbine-mounted lidar, in a range of clear air locations.
The latest ZX TM turbine-mounted lidar from ZX Lidars is an evolution of the previous ZephIR DM product and performance and availability statistics are expected to be similar for both systems.
The ZX 300 ground-based lidar features improved filtering when compared to the ZephIR 300 system and statistics for data availability with the ZephIR 300 system are not directly applicable to the ZX 300. To address this, data from the UK's remote sensor test site (UK-RSTS) at Pershore has been reprocessed with ZX 300 algorithms and data availability assessed as a function of backscatter.
Data availability for the ZX 300 lidar in similar clear-air conditions is predicted for various locations around the globe by combining the histogram of measured backscatter for that location with the plot of ZX 300 availability as a function of backscatter from the UK-RSTS.
NB: the availability figures quoted represent the percentage of valid 10-minute-averaged wind speed measurements during periods of clear-air conditions over the course of each measurement campaign.

Results: Turbine-mounted lidar

Figure 1, below, shows the results of two turbine-mounted lidar measurement campaigns in clear-air environments, one at high latitude (66° N) in northern Finland and one at high altitude (1800 m) in Colorado, USA.
Plot (a) shows the two campaigns have similar backscatter profiles, although the Colorado campaign has more measurements at the lowest signal levels.
Plot (b) shows the two campaigns have very similar levels of availability of 10-minute measurement data typically around 95%.

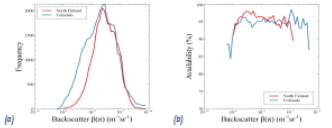


Figure 1: Analysis of turbine-mounted lidar trials at high latitude and high altitude: (a) Histogram of backscatter frequency; (b) Data availability as a function of backscatter

Reference

1. Lidar availability report, *Chris Hill, Project Upwind Report, 10 November 2010.*

Results: "Ground-based" lidar

Figure 2 shows histograms of backscatter in clear-air conditions from 3 measurement campaigns featuring vertical-profiling ZephIR 300 lidars.
Plot (a) is from an offshore deployment. Backscatter is low for an off-shore location but is still significantly higher than the other campaigns. (NB: a mid-campaign set-up change lead to more measurement data at lower heights.)
Plot (b) is from a measurement campaign at an altitude of 1240 m in the Swiss Alps. It shows the lowest backscatter values of the campaigns presented.
Plot (c) shows the clear air backscatter distribution for a high latitude (63° N) campaign in Finland.

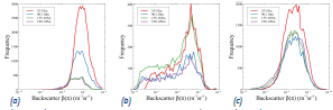


Figure 2: Histograms of backscatter for "ground-based" lidar at various heights (a) Offshore US Atlantic coast; (b) Swiss Alps – 1240 m; (c) Central Finland – 63° N

In order to predict the data availability for a ZX 300 lidar system in clear air at the locations presented in Figure 2, the actual data availability for the ZX 300 in clear air / low backscatter conditions has been assessed from the large quantity of data that ZX Lidars have from the UK-RSTS.
Figure 3(a) shows the mean data availability in clear air as a function of back-scatter. The vertical line indicates the theoretical minimum detectable level of backscatter (6×10^{-9} m^{-1} sr^{-1}) given in [1]. Bins below 1×10^{-9} m^{-1} sr^{-1} have a low number of observations and hence higher uncertainty.
Multiplying these availability functions by the histograms of back-scatter values shown in Figure 2 gives the predicted availabilities in Figure 3(b).

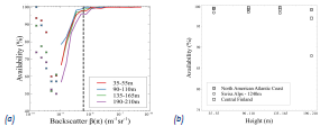


Figure 3 (a): ZX 300 data availability as a function of backscatter in clear air at UK-RSTS (b): Predicted availability of ZX 300 as a function of height in clear air conditions

Figure 3(a) shows that availability of the ZX 300 in clear air is still over 90% at the theoretical minimum detectable backscatter, only dropping below 90% for extremely low backscatter.
The predicted clear-air availabilities in Figure 3(b) for the offshore deployment stay above 99% up to 200 m. At higher latitudes, the backscatter level is lower and predicted availability drops to around 97%. While the backscatter level is significantly lower at high altitude, predicted availability is still 98% at 150 m.

Conclusions

Analysis of existing measurement data predicts high data availability for the latest generation of lidars from ZX Lidars in the most challenging of clear-air conditions from around the globe.
Data availability for the turbine-mounted ZX TM is expected to be comparable to the 96% achieved with the ZephIR DM at high latitudes and altitudes.
Availabilities of well over 95% are predicted for the ground-based ZX 300 even at high latitudes, with availability only expected to drop below 90% at measurement heights of 200 m in high altitude campaigns.
Such high sensitivity is particularly relevant in applications such as lidar-assisted turbine control.

MEET US AT 1-B40

Wind EUROPE CONFERENCE & EXHIBITION 2019 2–4 APRIL
windeurope.org/confex2019
#WindEurope2019

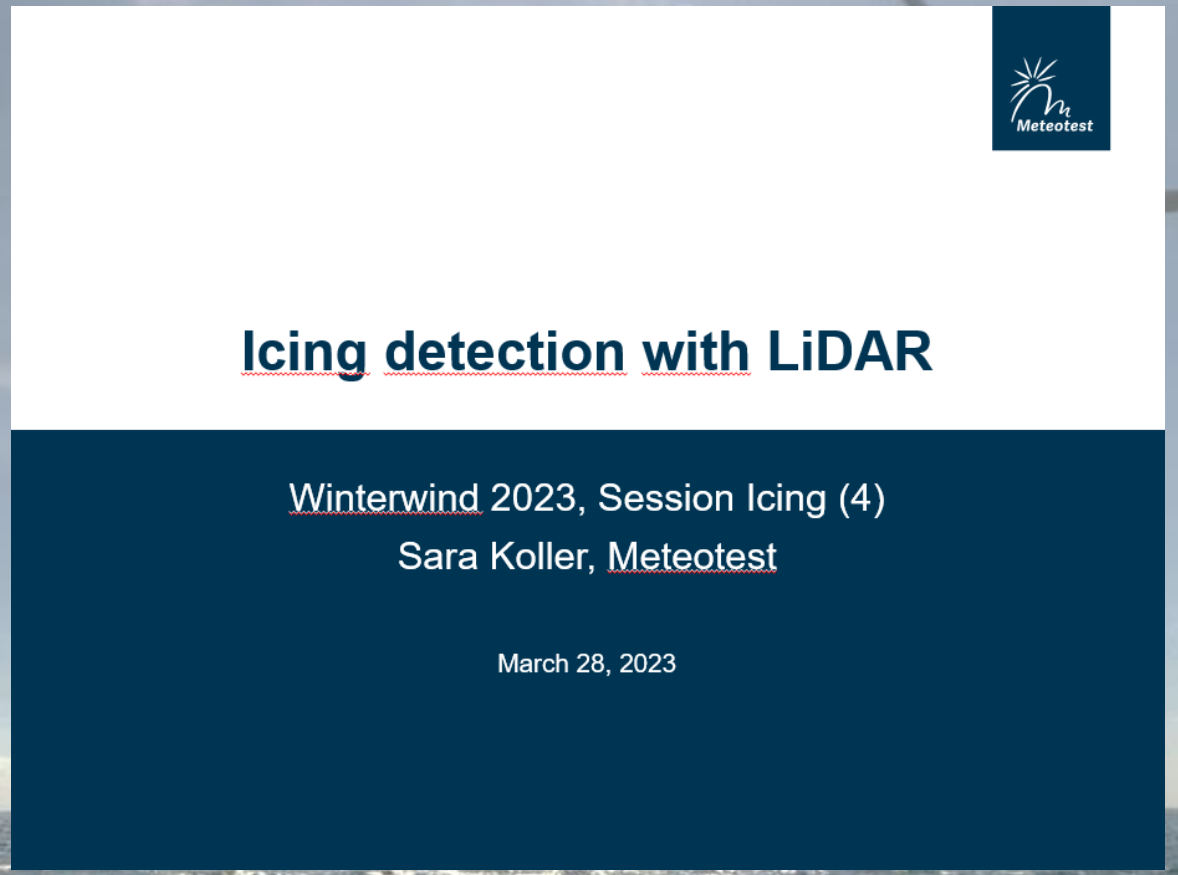
Download the poster

Data availability - future

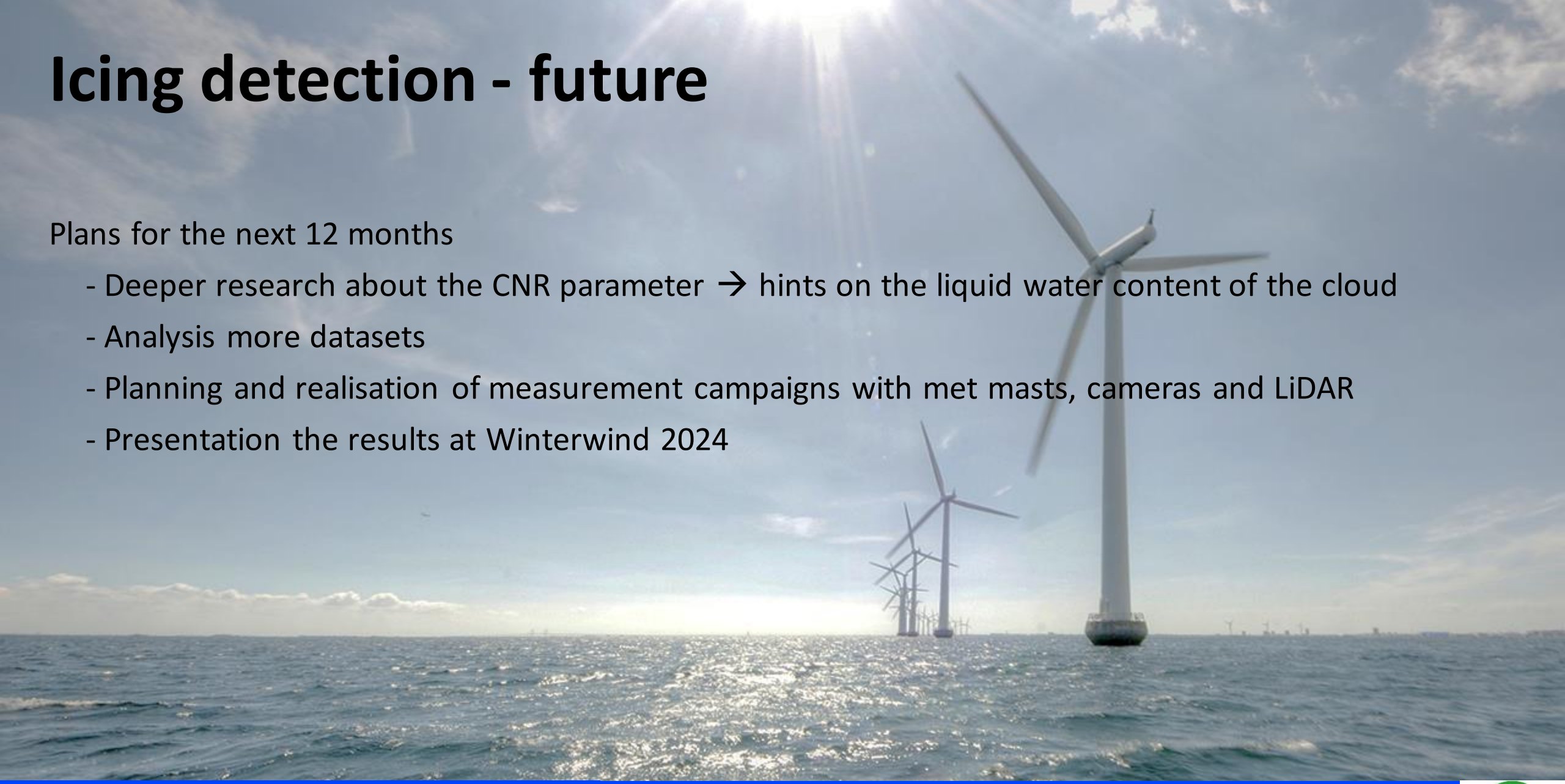
Plans for the next 12 months

- Compare data availabilities of lowland and highland measurement campaigns
- Try to understand in which conditions data availability drops

Icing detection - past



Icing detection - future



Plans for the next 12 months

- Deeper research about the CNR parameter → hints on the liquid water content of the cloud
- Analysis more datasets
- Planning and realisation of measurement campaigns with met masks, cameras and LiDAR
- Presentation the results at Winterwind 2024

Stand: 06-06-2023

IEA Wind TCP Task 52 (Wind Lidar)

Working group (4): Cold climate

Summary of the objectives:
The work of the group concentrates on two main objectives and tries to answer the following key questions:

- LiDAR data availability: What are the reasons for the low data availability in cold climate regions? Is there a way to increase data availability in cold climate regions?
- Meteorological icing detection with LiDAR: Are LiDAR suitable to detect meteorological icing? Is it possible to estimate ice classes from LiDAR data?

Additional objectives might be added in the future.

Planned deliverables:
The expected deliverables will be in the form of technical notes or presentations (all to be published on Task 52 Zenodo site and LinkedIn). They will concern the key questions described in the objectives.

Group approach:
The group will meet online every four weeks to discuss general progress. There may also be participation in face-to-face conferences.

Timeline:
The schedule is not strictly defined. Note that the activities build on the working group already established in Task 32, but new participants are very welcome.

Contact:
Sara Koller, Head of Wind&Ice at Meteotest, sara.koller@meteotest.ch

iea wind