

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 $\beta(\pi)$ [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%.

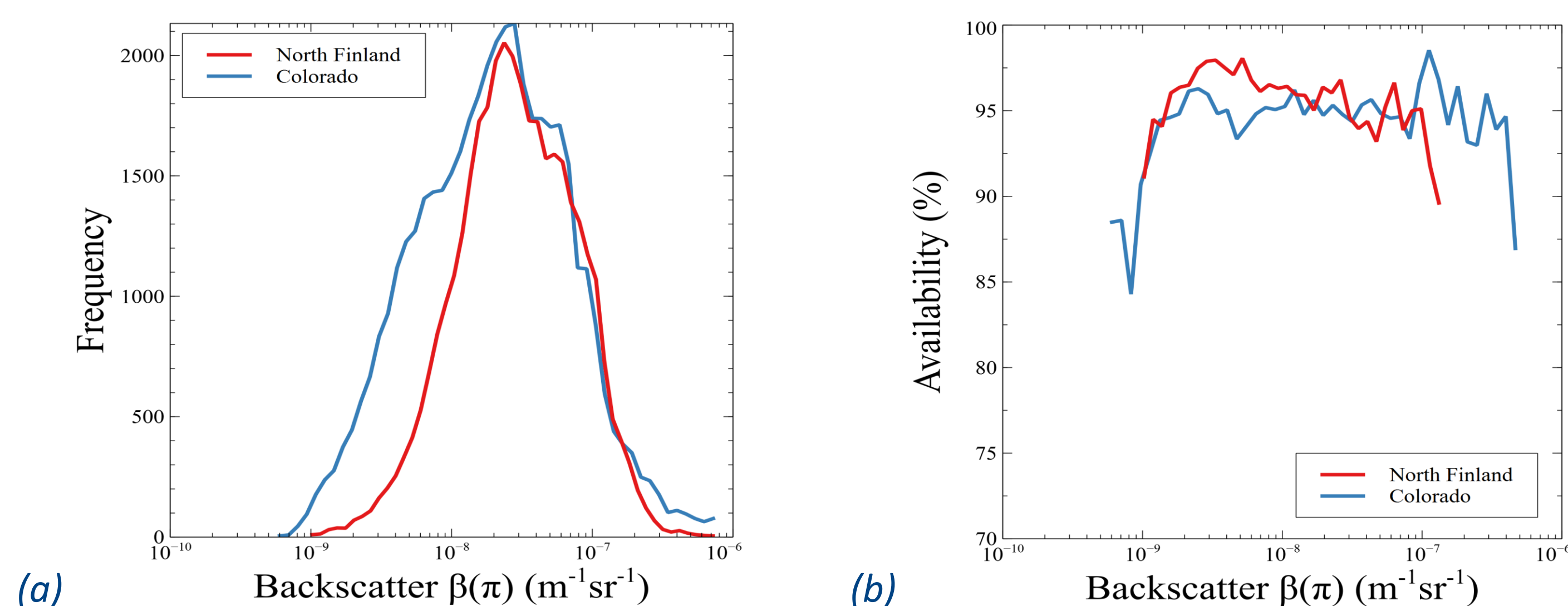


Figure 1: Analysis of turbine-mounted lidar trials at high latitude and high altitude:
(a) Histogram of backscatter frequency; (b) Data availability as a function of backscatter

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.

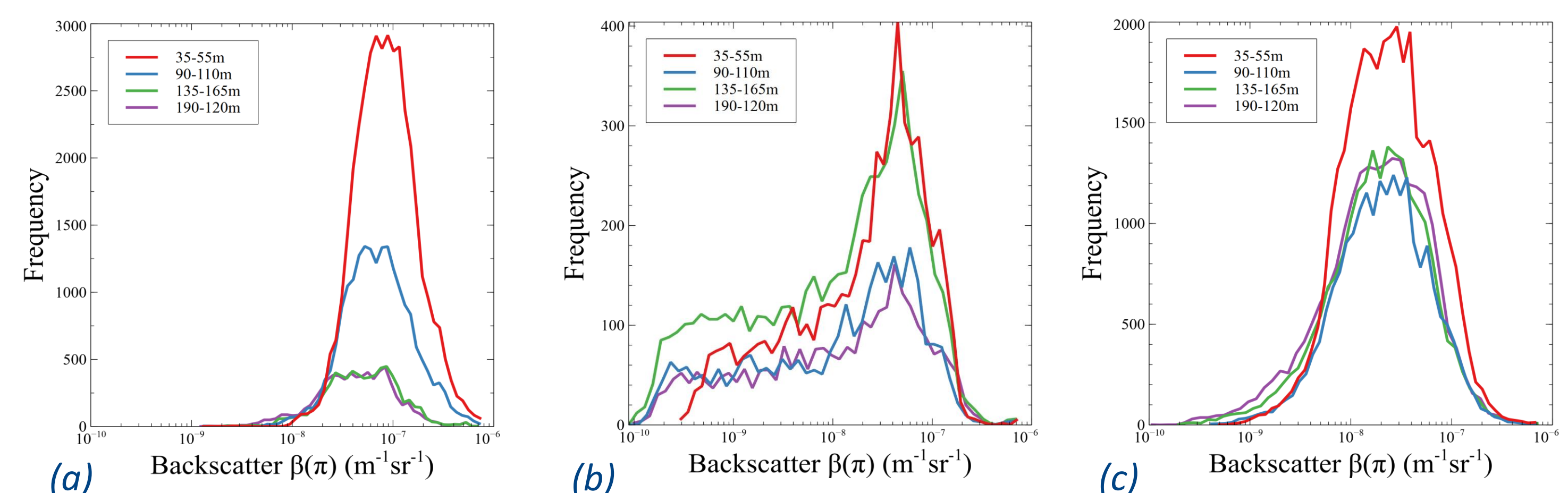


Figure 2: Histograms of backscatter for "ground-based" lidar at various heights
(a) Offshore US Atlantic coast; (b) Swiss Alps – 1240 m; (c) Central Finland – 63° N

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 backscatter. The vertical line indicates the theoretical minimum detectable level of backscatter ($6 \times 10^{-9} \text{ m}^{-1} \text{ sr}^{-1}$) given in [1]. Bins below $1 \times 10^{-9} \text{ m}^{-1} \text{ sr}^{-1}$ 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).

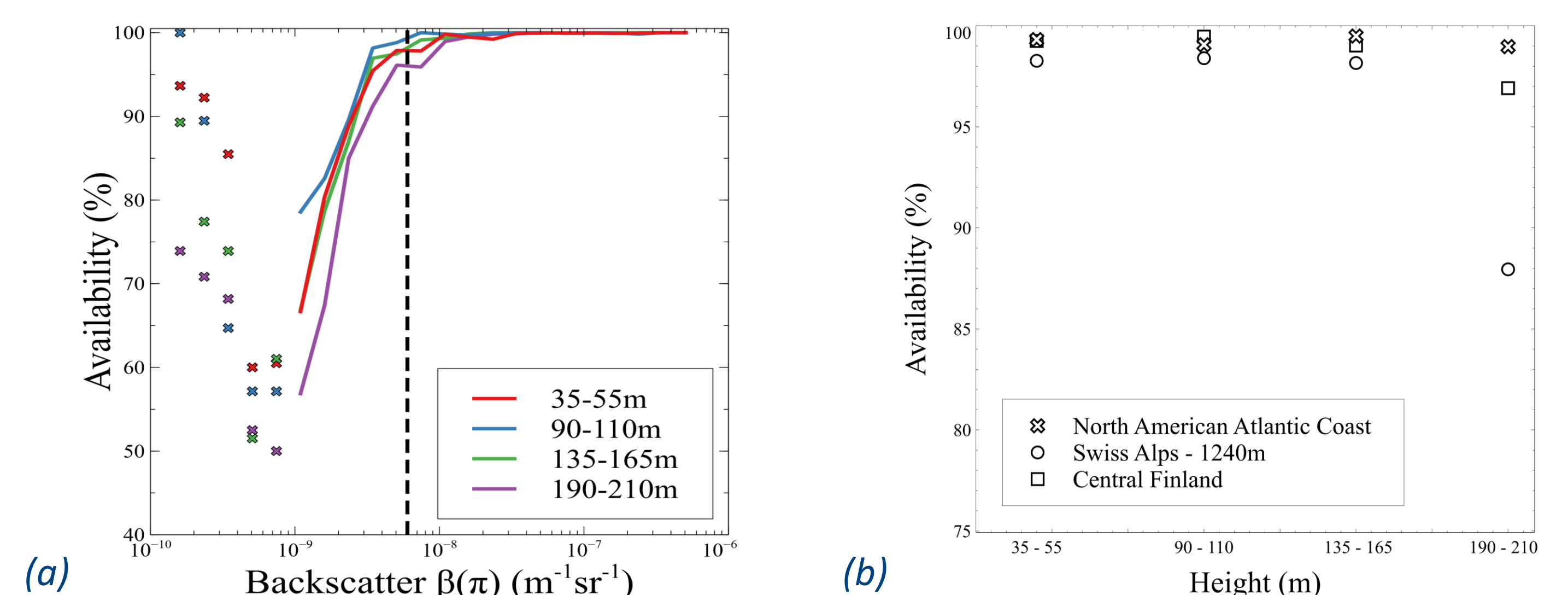


Figure 3 (a): ZX 300 data availability as a function of backscatter in clear air at UK-RSTS
(b): Predicted availability of ZX 300 as a function of height in clear air conditions

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.

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