PO.096

Enhancing Wind Measurement Data Availability Using Extrapolation Techniques

Seyi Latunde-Dada
ZX Lidars, Malvern, UK.

High data availability is critical for wind measurement campaigns. 'Gaps' can occur in any measurement sensor data for a variety of reasons hence, in this study, a range of gap-filling methods were investigated. CW Wind Lidars demonstrate extremely high levels of availability that can be further enhanced with an industry-standard power-law shear extrapolation.

NEED

Wind Lidars have become an established way to measure wind. Their measurement principles are well defined and understood. An extensive evidence base exists to demonstrate expected levels of performance and availability that largely support the broad needs of wind measurement campaigns.

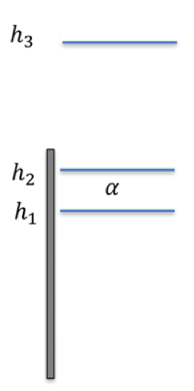
Certain, limited environmental conditions can cause a reduction in availability for any measurement sensor, for example the effects of icing on unheated cup anemometers. However, in situations where availability is reduced there is still an opportunity to enhance the availability by extrapolating from available measurement heights to a desired height, using well-established industry techniques.

CW Lidars focus all available laser power at each measurement height ensuring high levels of sensitivity and availability even in challenging conditions. In these conditions, the available measurements can then be used to extrapolate higher using industry-standard techniques previously used on traditional meteorological masts[1,2].

APPROACH

The methods investigated include the use of instantaneous and moving average shear exponents from two reference heights, least-squares fitting to more than two reference heights, shear exponent extrapolations and the use of look-up tables.

Simulated data gaps were used to evaluate the methods and instantaneous power law of shear exponents from the two nearest reference heights/distances (h_1 and h_2) were found to be the most accurate at estimating the wind speed at the target height/distance (h_3).



$$\alpha = \frac{\ln(v_2) - \ln(v_1)}{\ln(h_2) - \ln(h_1)} \rightarrow v_3 = v_2 \left(\frac{h_3}{h_2}\right)^{\alpha}$$

The metric used for assessing the methods is the Mean unsigned Relative Deviation (MRD)

$$\frac{100}{n} \sum_{i}^{n} \frac{|\hat{v}_i - v_i|}{v_i}$$

RESULTS

In this study, both mast and lidar datasets from a range of sites including complex terrain and foggy regions were used. Gaps of varying distances were simulated in the data by removing measurements randomly and extrapolations were then used to fill them. The errors in the extrapolations were then quantified.

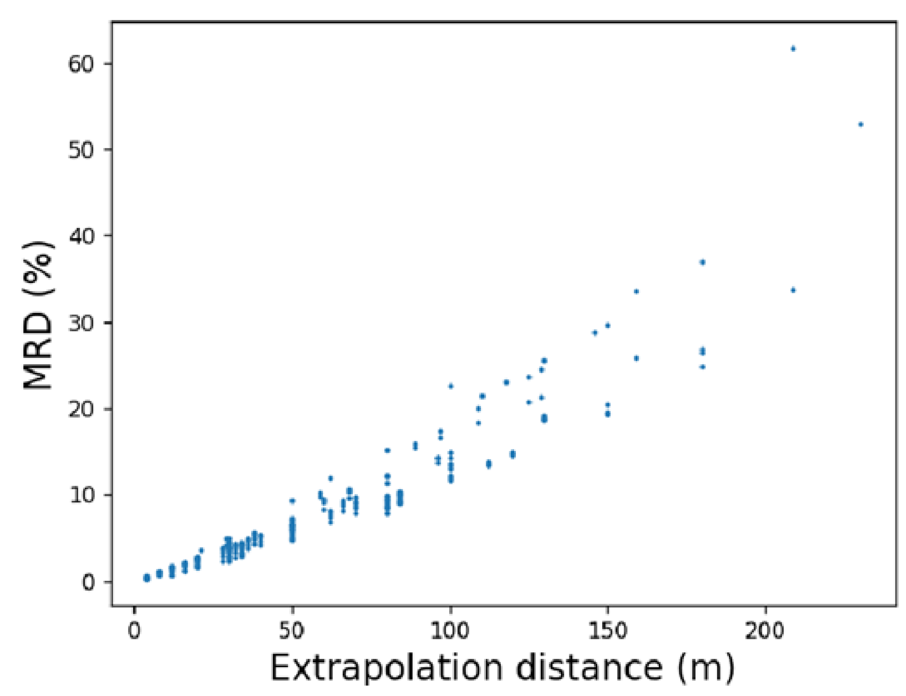
It was determined that the best accuracy (lowest MRD) could be achieved by extrapolating from the two reference heights closest to the gap.

Two sets of results from different time periods are shown below:

Extrapolation distance (m)	MRD (%)
21 (20.5/70.5→91.5)	4.81
21 (45.5/70.5→91.5)	4.34
25 (20.5/45.5→70.5)	5.89
46 (20.5/45.5→91.5)	10.5

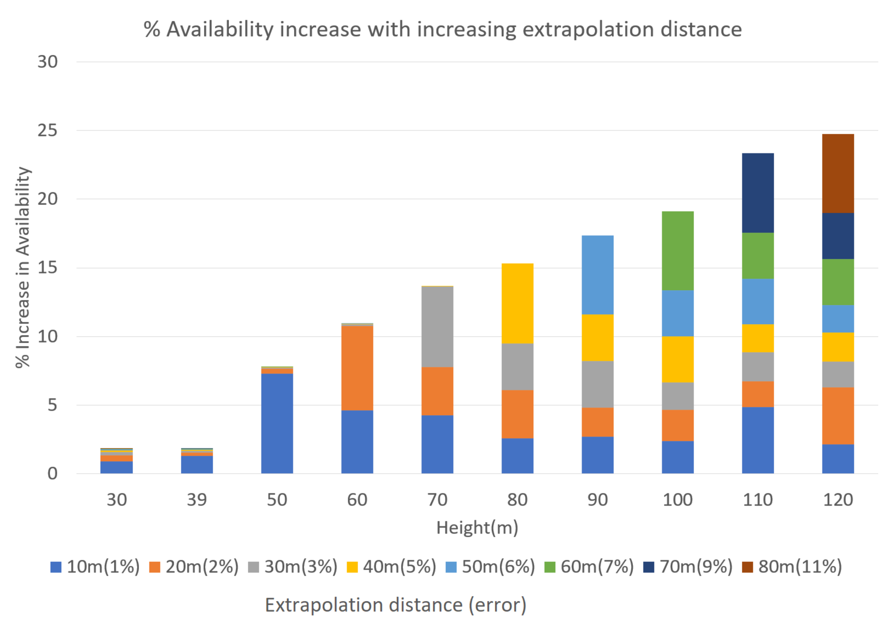
Extrapolation distance (m)	MRD (%)
81 (30/39→120)	10.7
70 (39/50→120)	8.85
60 (50/60→120)	7.00
50 (60/70→120)	5.81
40 (70/80→120)	4.76
30 (80/90→120)	3.06
20 (90/100→120)	2.07
10 (100/110→120)	1.25

Furthermore, the MRD was found to scale linearly for extrapolation distance for extrapolation distances less than 100m and quadratically above 100m.



BENEFITS

For a particular dataset, the relative increases in availability achievable by extrapolation are shown below as a function of extrapolation distance.



As may be seen, a maximum availability increase of about 25% is achieved with the maximum extrapolation distance set to 80m at 120m. This extrapolation has an associated error of about 11%. Likewise, an availability increase of about 7% is achieved at 120m by limiting the extrapolation distance to 20m with an associated error of just 2%.

Hence, for wind resource assessments, data availabilities can be augmented to meet requirements by varying the extrapolation distance as far as the limits on accuracy allow.

CONCLUSIONS

In this study, a range of gap-filling methods were evaluated using a range of datasets, and the power-law shear extrapolation from the two closest measurements was found to be the most accurate.

Furthermore, the errors were quantified as a function of extrapolation distance. This scaling by be used during wind resource assessments to strike a balance between accuracy and data availability requirements.

Further work in this area could include the extension of the method to real-time measurements where the most appropriate extrapolation method and distance can be assessed and adapted dynamically to datasets from different sites.

REFERENCES

1. *R. Mate-Toth, Wind Lidar Performance Verification Repeatability Study, Wind Europe 2022.*
2. *N. Smith et al, Clear-air data availability of CW scanning lidars, Wind Europe 2019*