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Does the measuring mast need to exceed 100m high for hub heights planned up to 125m?

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Abstract

In the wind industry, the technology of wind turbines has been evolving significantly leading to bigger turbines with higher hub heights. Nowadays, most of wind projects developed in France involve hub heights ranging between 100 and 125 m. However, measuring above 100 m high requires a significant increase of mast installation costs as well as maintenance fees, and imposes burdensome administrative constraints.

Above 100 m high, as the vertical wind speed variation is very low and less dependent from the surface roughness, the wind resource at 120 m should, in theory, be quite accurately predictable from measurements at close lower heights (for example 100 m high).

Through a statistical analysis, based on 17 wind measurement campaigns located in France, in non-complex areas, this study highlights the fact that the uncertainty associated to a vertical wind speed extrapolation from 100 m to 120 m could be within the range of the uncertainty on the wind speed measured directly at 120 m. Consequently, the level of uncertainty of a wind measurement at 120 high and a wind speed extrapolated at 120 m from 100 m measurements should be relatively close under certain conditions (good quality measurements and non complex site).

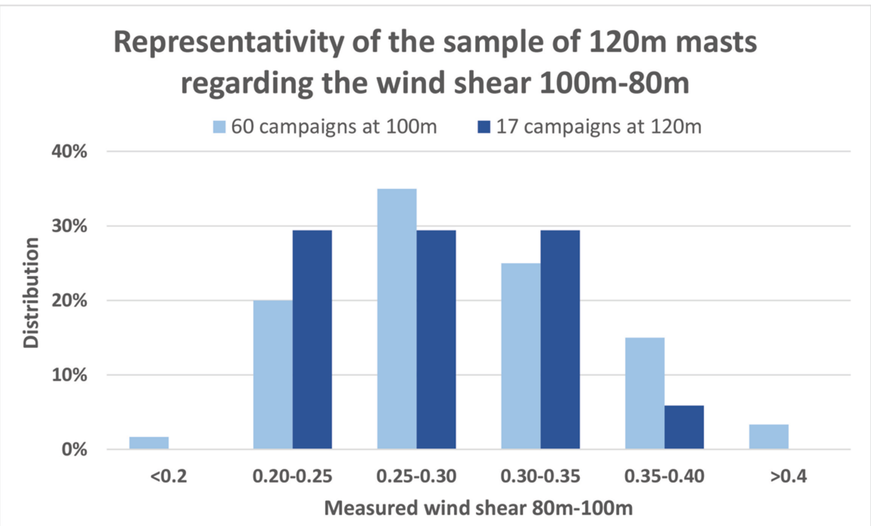
Thus, even if measuring at hub height remains the main recommendation, above 100 m the interest of measuring systematically at hub height could be in specific situations limited as the uncertainty should not be increased.

Objectives

The main objective is to carry out a statistical analysis to determine how predictable is the wind resource at 120 m high from measurements around 20 m below. This analysis which considers 3 different extrapolation methods aims to quantify the level of uncertainty on wind speeds extrapolated at 120 m associated to such calculation.

Sample data

In this study, 17 wind measurement campaigns of 120 m were considered (12 masts and 5 LiDARs).



In order to generalize the results on a larger scale, the wind shears between 80 m and 100 m were compared for these 17 installations and for 60 installations of 100 m.

The adjacent graph compares the wind shear between 100 m and 80 m for these two samples.

The wind shear observed between 80 and 100m for the 100 m installation is quite representative of those observed for the 120 m installations. Thus, as all the sites correspond to similar types of environment (simple topography), we assume that the results observed for the 17 installations at 120 m should be valuable for the 60 installations at 100 m high.

Methods

A statistical analysis was carried out to predict the mean wind speed at 120 m high from measurements at 100 m and 80 m using three different methods. These tests were carried out for the 17 installations.

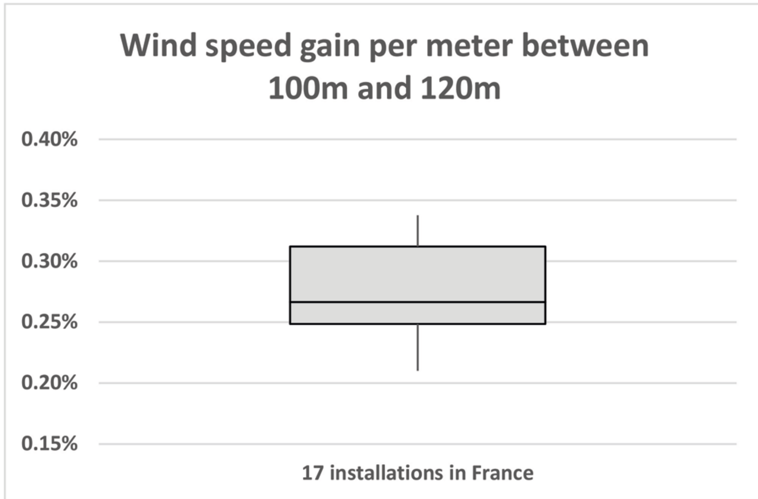
In the formulas below, H1 corresponds to the height closest to 120 m, H2 the height closest to 100 m and H3, the height closest to 80 m.

- **Method 1**: using the power law (wind shear between 80 m and 100 m ($\alpha_{80m-100m}$ calculated from the power law)

The wind speed at 120 m high (WS_{H1}) was calculated using the formula below:

$$WS_{H1} = WS_{H2} \times \left(\frac{H1}{H2}\right)^{\alpha_{H3-H2}}$$

- **Method 2**: considering a median variation of the wind speed between 100 m and 120 m

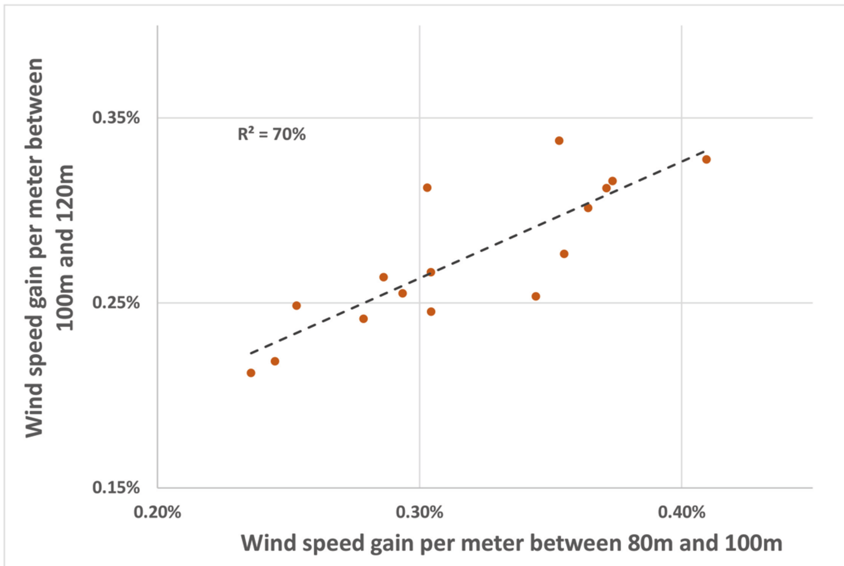


The wind speed gain per meter (WS_{gain_m}) between 100 m and 120 m is relatively stable for all the installations (variation between 0.21% and 0.31%). In this method, a median of 0.27% wind speed gain per meter was considered for all projects.

The formula considered is the following:

$$WS_{H1} = WS_{H2} \times (1 + 0.27\% \times (H1 - H2))$$

- **Method 3**: considering a specific variation of the wind speed between 100 m and 120 m from the variation of wind speed between 80 m and 100 m.



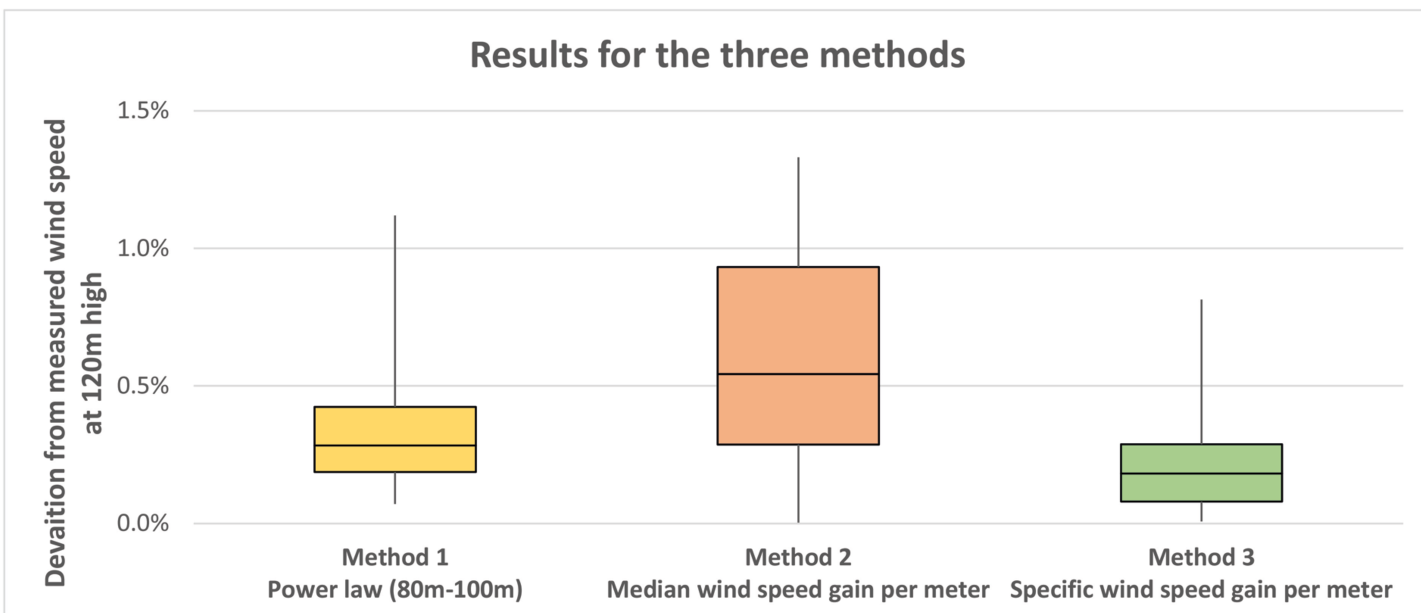
A linear regression (Y = AX + B) between the WS_{gain_m} established between 120 m and 100 m and the one established between 100 m and 80 m was considered.

The formula considered is the following:

$$WS_{H1} = WS_{H2} \times (1 + (A \times WS_{gain\_m(H2-H3)} + B) \times (H1 - H2))$$

Results

The graph below displays the deviation between the wind speeds actually measured at 120 m high and the wind speeds extrapolated at 120 m using each of the three methods.



The following points can be highlighted:

- For all three methods, the deviations never exceed 1.5 %
- For methods 1 and 3, the median deviations are inferior to 0.5 %.
- Method 1, which is the most common method considered today in the wind industry leads to small deviations (3/4 of the sample below 0.5 % deviation)
- Using method 3, deviations on the wind speed at 120 m high are constantly below 1.0 % (3/4 of the samples below 0.3% deviation).

Conclusions

This study has shown that wind speeds at 120 m high are pretty predictable from measurements slightly below as 20 m (deviation << 1.0 % depending on the method). As the uncertainty on measured wind speed on a mast is above 1.0 %, these results can be considered as satisfactory. Hence, from this study, the uncertainty on wind speeds at 120 m established from measurements at 100 m should be close to the uncertainty on direct measurements at 120 m. As the data sample is limited for this study, more tests should be carried out to comfort this conclusion.

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