UNCERTAINTY OF VERTICAL WIND SPEED EXTRAPOLATION

a terrain-dependent approach

PO.150

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Abstract

The vertical extrapolation of wind speed or production data is connected with an uncertainty. As a rule of thumb 1% uncertainty of the wind speed per 10m vertical extrapolation is often assumed, independent of siting conditions. Alternatively, DTU has prepared an uncertainty expression – motivated by the ongoing work for the new 61400-15 standard – for log-law expressions [1].
The **validity** of both expressions has been tested on 410 pairs of wind speeds at different heights from masts equipped with cup anemometry in various climatic and topographic conditions. The vertical wind speed prediction error has been quantified using **WAsP**. The sites have been split depending on the actual site conditions into four categories:

- Non-complex without forest
- Non-complex with forest
- Complex without forest
- Complex with forest

With the exception of one scenario, the rule of thumb (1% per 10m) **does not reflect reality**. Also, the uncertainty expression developed by DTU in 2016 [1], which is supposed to find entry in the IEC61400-15, **cannot be aligned** with the findings of this analysis. In addition to an uncertainty, in some cases, a bias has been identified.

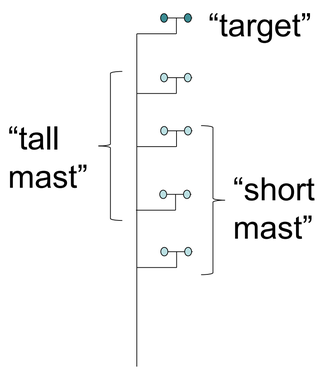
Objectives

In times of vivid attempts to bring down LCoE we need to be sharp on uncertainties. Rules of thumb are no longer satisfactory.
The result of this analysis is a much more comprehensive uncertainty description, which takes **site conditions** into account.

Methodology

The vertical wind speed changes were predicted using **WAsP** and compared with actual wind speeds based on cup anemometry measurements measured on tall masts up to 130m a.g.l. The stability settings within WAsP were adjusted relative to the local conditions, if found necessary. Also, displacement heights were introduced if required.

Additionally to the **four different terrain** scenarios, the results were filtered for more or less restrictive about the predictor heights, referring to “short” or “tall” masts. For “short” masts the predictor heights range from 40 to 75m, for “tall” masts from 60 to 80m



If you want to know more:
We present this work at our stand (1F38)
Wednesday 12:00-12:20

Results

Results are shown in two ways: First as the prediction error of the wind speed versus vertical distance, and secondly as the prediction error of the wind speed versus the natural logarithm of the ratio between predictor and target height.

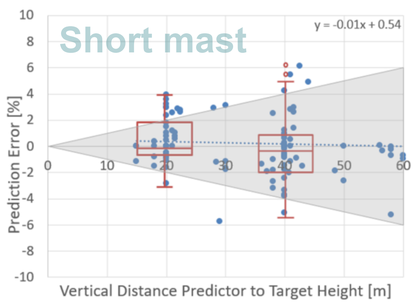
Blue dots: individual measurement pair

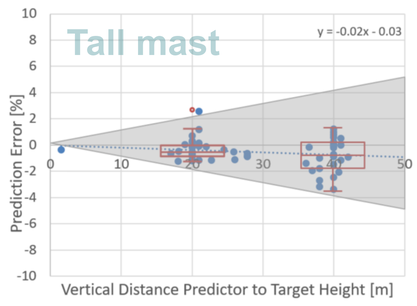
Grey shade: 1% uncertainty per 10m vertical, respectively uncertainty following [1] in case of the logarithmic presentation

Box-whisker plots: where the graph is sufficiently populated.

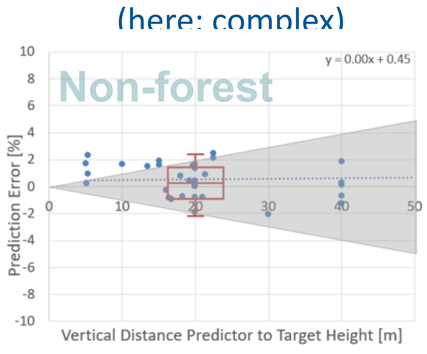
The Expected Results

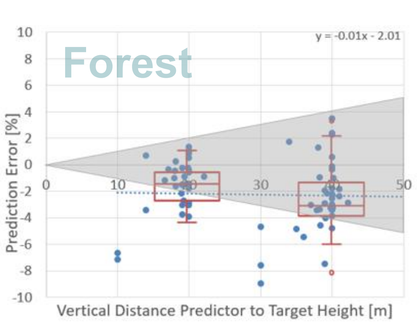
1. Taller masts result in much lower error (here: flat, non-forest)





2. Forested sites show higher prediction error (here: complex)

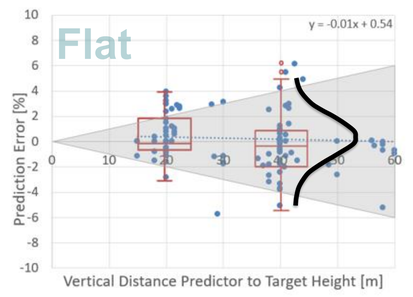


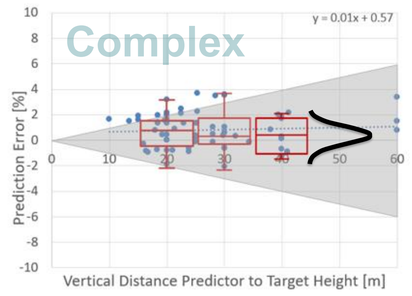


Results continued

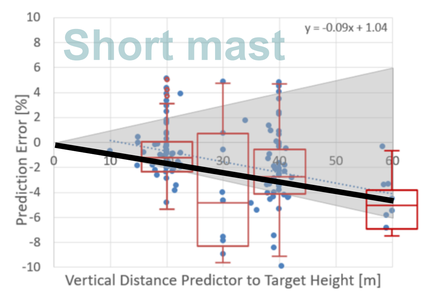
The Unexpected Results

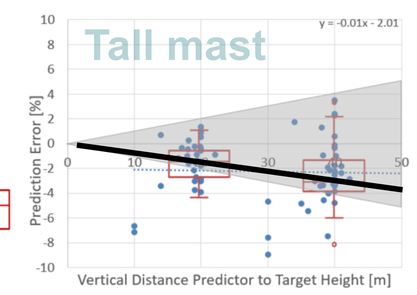
1. Smaller error in complex than in flat terrain (here: non-forested)





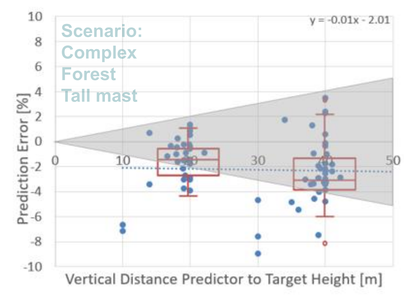
2. Forested sites show a bias! Tall masts show a smaller bias than short masts (here: complex forested terrain)

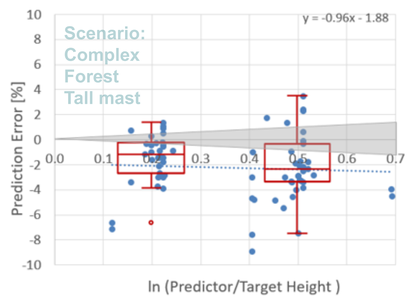




3. 1% per 10m vertical extrapolation seems to **over-estimate** the uncertainty (with the exception of complex forest)

4. The observed errors **exceed** in all cases the uncertainty descriptions proposed by DTU [1] which has been prepared for the IEC-15.





Conclusions

General:

- **Forest** is nasty – not only large uncertainty but also bias! Even though stability and displacement heights have been used!
- **Steep terrain** is not as nasty as thought, which is simply related to the low shear and consequently the lower probability of “doing it wrong”.

With respect to uncertainty:

- Results clearly indicate need for **differentiation** depending on terrain/roughness.
- Industry practice is **not reflected** in our analysis – we would raise an alarm in respect to what might find entry in the **IEC-15**!
- For quantitative uncertainty description statistical validity has to be reached – stay tuned!

References

[1] M. Kelly: Uncertainty in vertical extrapolation of wind statistics: shear-exponent and WAsP/EWA methods, 2016, DTU Wind Energy. (DTU Wind Energy E; No. 0121)

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