PO.025

Windcube Classification Sensitivity to Turbulence Intensity

Julien Tissot, Paul Mazoyer, Sébastien Combrexelle
Leosphere

Introduction

Proper assessment of wind sensor sensitivities is paramount for correct evaluation of wind speed measurement uncertainties. This is why the classification test of at least two remote sensing devices units at a minimum of two locations is a requirement of the latest edition of IEC61400-12-1 (Annex L). In 2018, Deutsche WindGuard delivered the third classification test: Windcube is now fully compliant with all requirements of IEC61400-12-1.

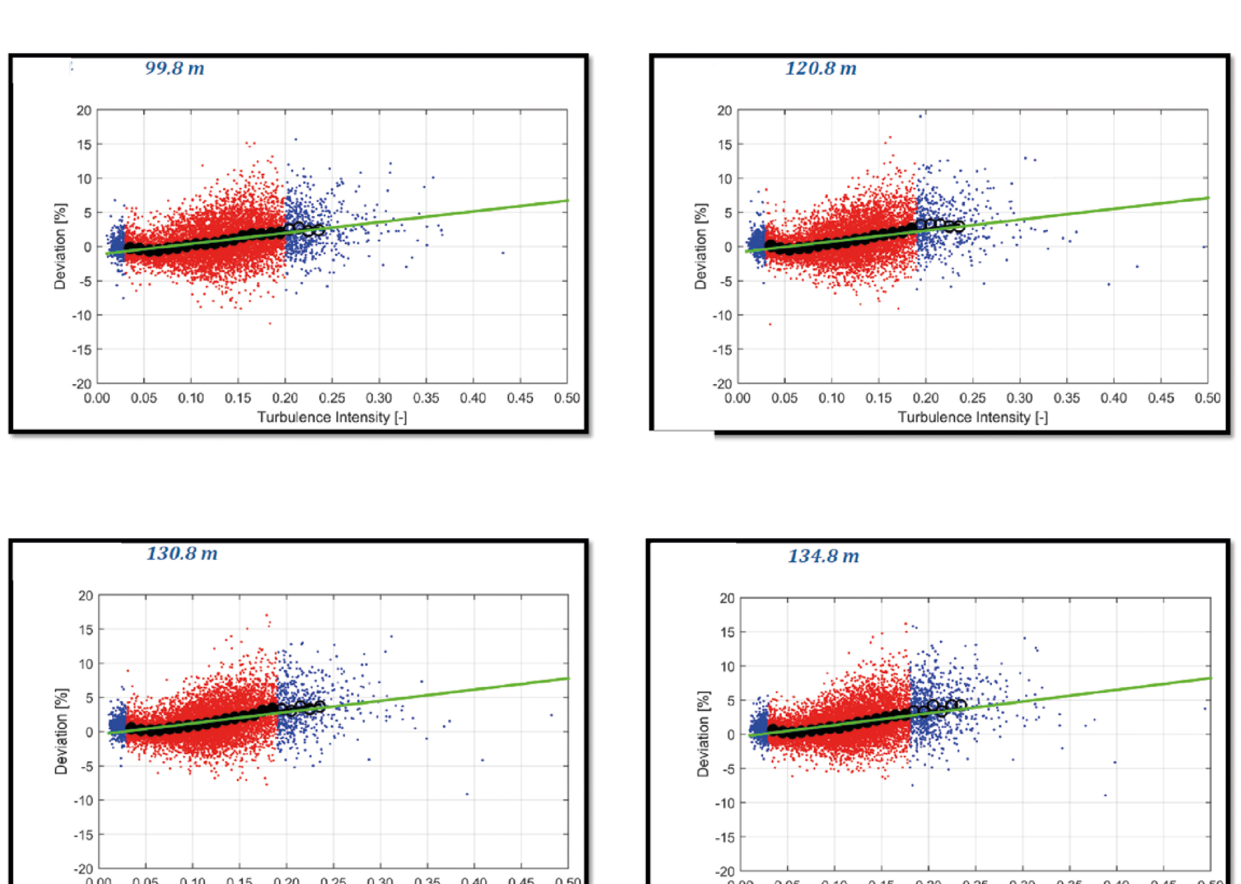
The classification test identified two influential environmental parameters: the turbulence intensity and the shear (to a lesser extent). The influence of turbulence intensity can be explained by the averaging method and confirmed with simulations.

The development of this understanding along with data analysis of several Windcube dataset highlights a less sensitive reconstruction method called "vector averaging". This method results in a lowering of the uncertainty for power curve and wind resource assessments.

Sensitivity to Turbulence Intensity

Within the Annex L, the sensitivity is defined as being the product of the slope of the regression (m) and the standard deviation of the studied environmental. If the result of this product is above 0.5, i.e. a threshold defined in the standard, the environmental variable is considered to have a significant influence on the accuracy of the measure. The value of m itself is an intuitive indicator as it directly reflects the behavior of the deviation against the variation of the considered environmental variable. It is also one of the main variables used during the final uncertainty calculation.

The following graphs show the linear regression (in green) of the binned mean relative deviation (in black) against turbulence intensity.



The values of m are identical across the different heights. It shows that the Windcube technology inherently induces a high stability and reproducibility of performances across the different heights. The device is then highly predictable which fosters a reliable estimation of uncertainty for any Windcube unit at any heights. Then, the stability of the results induces that the bridge between turbulence intensity and accuracy can be captured regardless of the height of measurement.

Understanding the deviation

In the Windcube, the current reconstruction method is geometrical and scalar-averaged and is defined as such:

$$Vh_{lidar} = \frac{1}{N}\sum_{t=1}^{N}\sqrt{U(t)^2 + V(t)^2}$$

Where $U(t)$ and $V(t)$ are the horizontal component of Vh, each retrieved from the individual lines of sights (LOS) as such :

$$U(t) = \frac{S_N(t) - S_S(t)}{2sin\theta} \text{ and } V(t) = \frac{S_E(t) - S_W(t)}{2sin\theta}$$

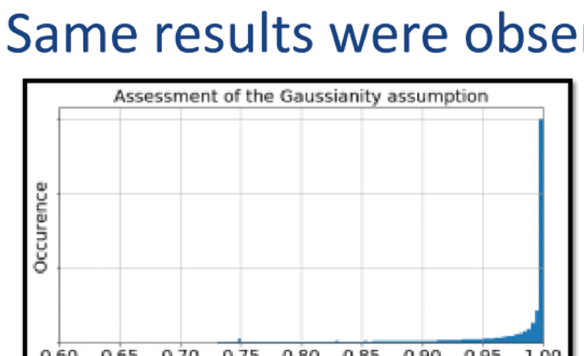
Where S_N, S_S, S_E and S_W are the radial wind speeds measured respectively on LOS North, South, East and West.

On an ideal 10min period with a data acquisition rate of 1hz, the horizontal reconstruction of the wind vector would thus be composed of N=600 quadratic sums, averaged once. It is suspected that by using multiple quadratic sums, the scalar averaging method would essentially add up all the small variations that occurred along the U and V components throughout the period. In other words the bigger the turbulence intensity, the highest the expected deviation.

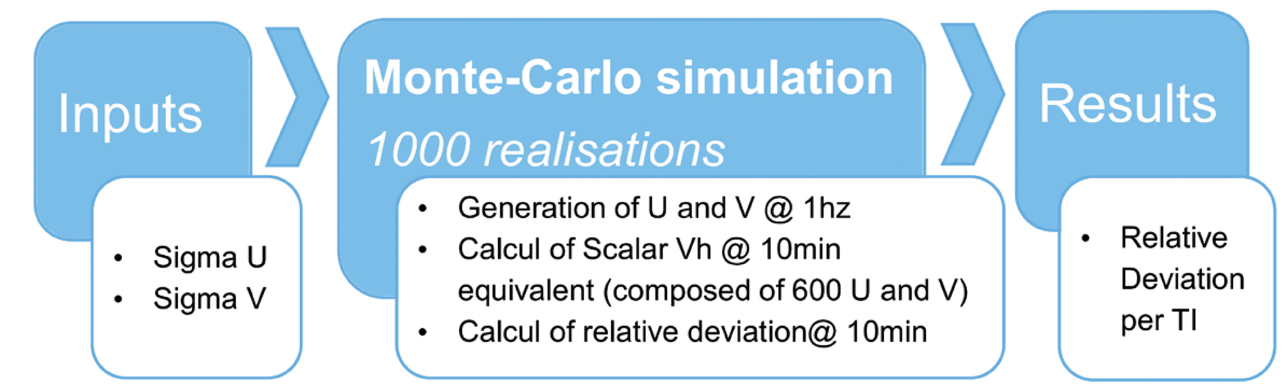
Modeling the deviation

It is possible to create a statistical model to evaluate this deviation by assuming that the inputs of the reconstruction, i.e. U and V components, are Gaussian variables with respective average $\overline{U}$ and $\overline{V}$, and standard deviation σ_u and σ_v. In this model $Vh_{real} = \sqrt{\overline{U}^2 + \overline{V}^2}$ designates the wind speed that we try to measure.

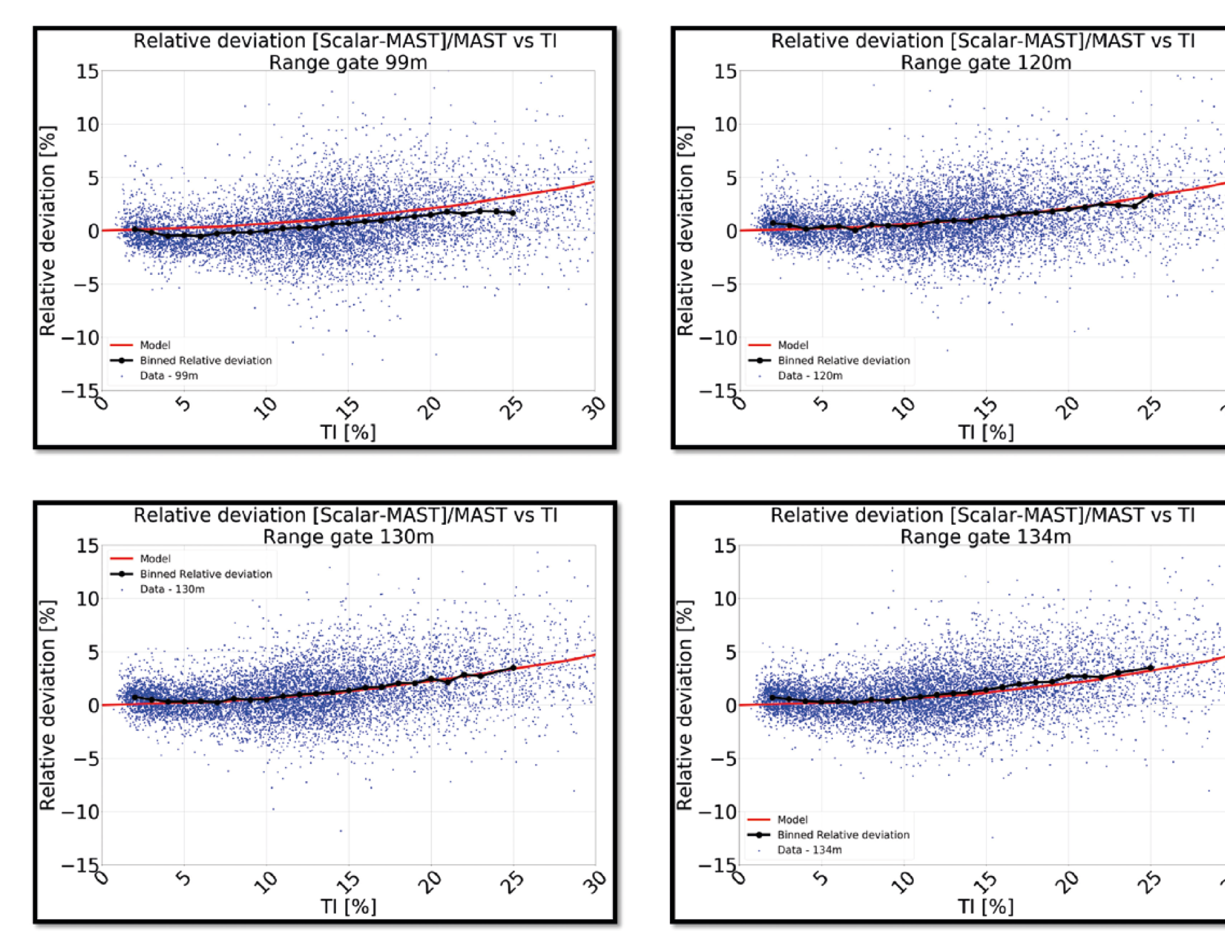
We verified and validated the hypothesis of gaussianity on high frequency data from lidars. For example, the following graph illustrates the degree of gaussianity of U observed in the second classification dataset, where a value of 1 would mean a perfect agreement with this hypothesis. The 10min groups of data can almost all be considered as Gaussian. Same results were observed for V.



We then used Monte-Carlo simulations, i.e. the realization of multiple random sampling of a model, to obtain an estimation of the mean relative deviation of the scalar reconstruction per TI. For these simulations to be accurate, little iteration were needed.



In the graph below we put into perspective the mean relative deviations predicted by the model (in red), the ones measured during the second classification (in blue) and their binned averages (in black) against various level of TI.



Simulations demonstrate excellent correlation with the measured relative deviation and clearly captures its trend. It confirms that the current scalar reconstruction algorithm is responsible for most of the sensitivities to the TI discovered during the campaigns.

Conclusions

The scalar averaging is responsible for the sensitivity of remote sensors to turbulence intensity. Scalar averaging basically converts turbulence into overestimation.

This sensitivity is well captured by classification test and Monte-Carlo simulation. The sensitivities are predictable and ensure a reliable uncertainty estimation. The model highlight the very positive impact of vector averaging for remote sensors. The turbulence intensity sensitivity is deemed negligible with this model. This is shown by several Windcube data analysis.

References

- Annex L, *IEC 61400-12-1 ed2*
- Windcube classifications ,Deutsche WindGuard, *Available upon request*