PO.256

Turbulence Intensity measurement techniques for pulsed Lidars – the Current Status

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Introduction

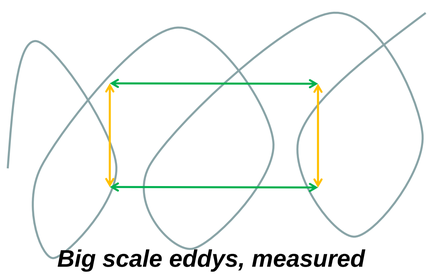
- Windcube Lidars are widely used in the wind industry for yield assessment and power curve measurement with high level of confidence in accuracy and precision of wind speed and direction measurement due to successful classification [1], stage 3* status granted by DNV-GL [2] and more than 100 successful comparison with mast in various locations.
- An expert group, IEA Task #32, has dedicated a report [3] to the measurement of turbulence intensity with Lidar which conclude on the high potential of Lidar to accurately measure TI

"lidars […] do not exhibit any significant limitation in the technology. […] Some additional tricks […] in either post-processing or scanning configurations are therefore required to obtain meaningful turbulence quantities . "

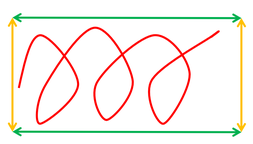
- This poster presents innovative methods for turbulence intensity measurement and their current industrial stage
- The most advanced method is being tested worldwide by Windcube users and early results are shown

Understand Lidar turbulence intensity measurement

1- Wind flow turbulence can be described as a entanglement of eddys of different size. Lidar is measuring with a certain space resolution (20 meters) and time resolution (1 Hertz). If eddy size is bigger than the resolution then it is measured otherwise it filtered



Big scale eddys, measured



Low scale eddys, filtered out

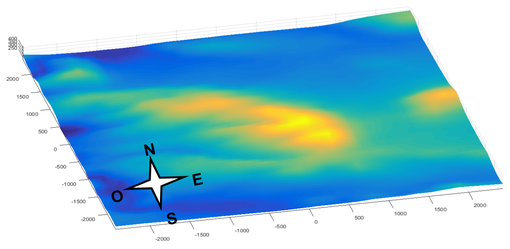
Measurement were conducted to display this effect [2] comparing a sonic anemometer (dotted line) and a Lidar (full line). Evidence is shown that big scales are well measured and not small scale.

$$R = \begin{bmatrix} \langle u'^2 \rangle & \langle u'v' \rangle & \langle u'w' \rangle \\ \langle v'u' \rangle & \langle v'^2 \rangle & \langle v'w' \rangle \\ \langle w'u' \rangle & \langle w'v' \rangle & \langle w'^2 \rangle \end{bmatrix},$$

2- Lidar measures the wind probing the atmosphere with several laser beams which are inclined. Statistically, when measuring the standard deviation, the reconstruction implies some pollution from other components.

<u> Lidar = <u> Real + <u v> Lidar + …

3- **In complex terrain**, the wind flow homogeneity is broken inducing more uncertainty when calculating the turbulence intensity



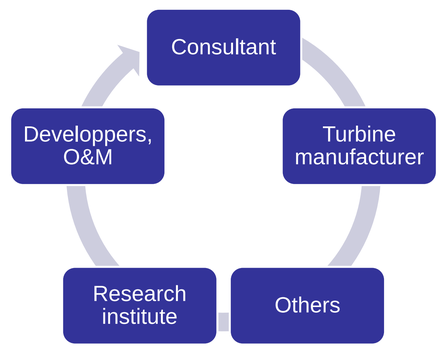
Innovative methods

Three different methods have been identified and classified by technology readiness level. All methods are developed by recognized international research institute and classification is done to Leopshere best knowledge.

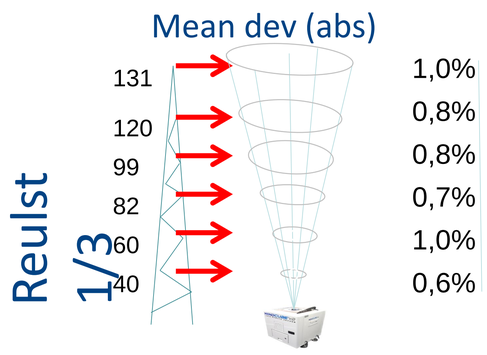
TRL3/4: proof of concept	TRL5/6: tested in intended environment	TRL 6/7: Proofs in operationnal environment
Machine learning NREL	SLEMT Model DTU	Model based optimal filtering technique , IFPEN
+ Improvements shown - Works on conditions similar to the conditions used for learning the correction	+ Improvements shown + « Easy » to apprehend and use - Correction derived for simple homogeneous terrain only - Requires atmospheric stability information	+ Improvements shown + Automatic algorithm applicable in all terrain types - May not fully eliminate the errors
Paper published in Wind Energy Science	EWEA 2015	EWEA 2015

Test of model based techniques

Starting mid-2016, a representative set of Windcube end-users are testing the Model-based filtering technique on their own existing data sets where a met mast is available.



- **10 months of data** were compared to mast inducing consistent statistical representative comparison
- Different heights were tested to comprehensively assess the height dependency : **40 meters to 131 meters**
- Coastal, forested, farmland terrains: all moderately complex.
- Climates mild and wet
- Mean temperatures **from 8 to 16°**



Deviations with wind speed at 131 meters

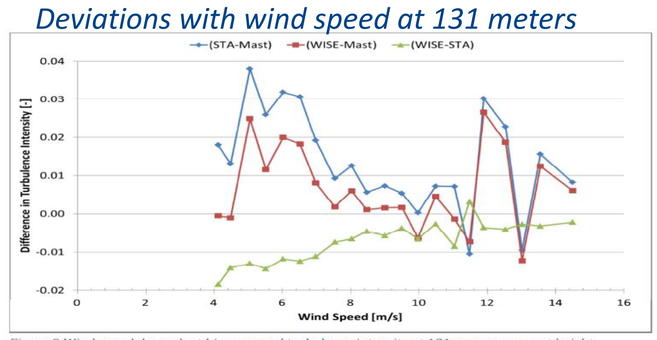
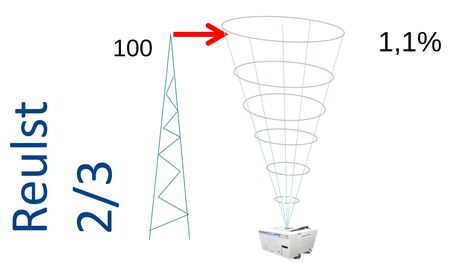
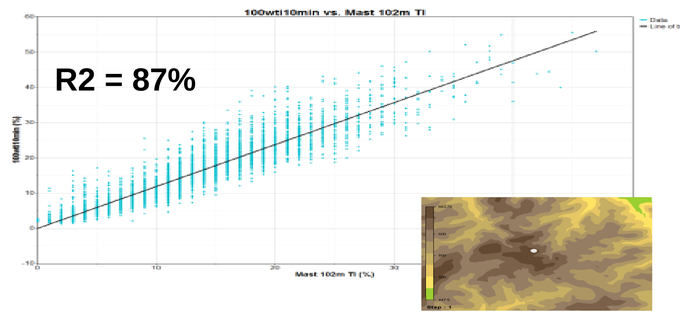
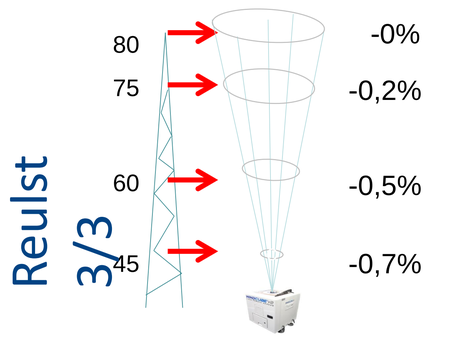
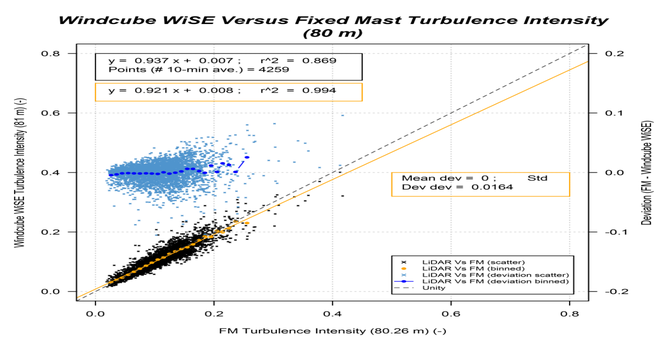


Figure 9 Wind speed dependent bin averaged turbulence intensity at 131 m measurement height









Conclusion

- **Reasons for differences between mast and Lidar are known (see IEA Task #32)**
- **Model-based filtering is deemed to be the most advanced algorithm in terms of industrialization process although interesting techniques are being developed (Neural network, SLEMT)**
- **4 dataset of at least one month has been processed through model-based filtering:** Deviations from mast are less than 1% and are de-trended with wind speed
- **Test will be conducted till end of 2016 : report will be released early 2017**

"The WiSE algorithm has clearly made an excellent improvement to the Windcube measure of turbulence intensity in comparison to a cup anemometer" Windcube user.

Reference

1. Full Report_Classification of WINDCUBE v2, Deutsche WindGuard, 2013
2. Position Statement WINDCUBE, GL Garrad Hassan, 2012
3. Estimating Turbulence Statistics and Parameters from Ground- and Nacelle-Based Lidar Measurement, IEA Task #32, 2015