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Turning the Tides on Wind Measurements: The Use of Lidar to Verify the Performance of A Meteorological Mast

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ZephIR Lidar

Abstract

The wind industry routinely compares the measured energy yield of constructed wind farms with the energy yield prediction from pre-construction analysis based on a set of measured wind speeds. Typical results published recently by consultants have shown a general over-estimation in pre-construction energy yield predictions in the region of 10%, reducing to 7% after availability and windiness normalisation.

The correct outcome of a wind resource assessment campaign is crucially dependent on the quality of the anemometry data. Cup anemometers, mounted on meteorological masts (met masts), are the industry standard for measuring wind speed at wind farms sites. Measurements from cups are, therefore, considered the "norm" against which any alternative measurement device is judged. Remote sensors, such as lidar, are continually judged against data from cup anemometers and as a result are now becoming increasingly used and accepted by the wind industry.

Even though cups are still considered the industry standard, there are several ways in which data from met masts can become compromised, e.g. flow distortion from the mast itself, out of date instrument calibrations, mounting irregularities, etc. Such problems, if undetected and uncorrected, will result in a degradation of the overall wind resource assessment at a site, with potentially damaging financial consequences for the project.

This work outlines, through a number of case studies, a cost-effective approach for verifying the performance of a met mast using a continuous wave lidar, ZephIR 300, ensuring that calibration of the data is both accurate and problem-free. Once deployed for mast verification, ZephIR 300 also provides the ability to validate the wind shear model used for a particular deployment, demonstrating a further reduction in the uncertainty associated with the extrapolation of mast data within the wind resource campaign.

Benefits of Mast Verification with Lidar – Case Studies

There are several ways in which wind data obtained from the current industry standard method of cup anemometers mounted on met masts can become compromised. Two case studies are presented here that demonstrate how ZephIR 300 data can be used to verify the performance of a met mast, whilst adding additional value to the wind resource assessment campaign:

Case Study 1 – Flow Distortion and Mast Shadowing

The met mast itself can distort to some extent the very airflow it is trying to measure. With care and sufficiently long booms, these effects can be minimised, but studies indicate that direction-dependent errors of order 1% in wind speed can be experienced [1] even when the stringent IEC guidelines [2] are followed.

This case study examines a 60 m mast installed at an onshore site in the North of England. The ZephIR 300 was installed at the base of the mast for the period 1st February 2009 to 28th February 2009. This highlights how a relatively short ZephIR 300 deployment can help identify under-performance of cup anemometers due to shadowing from an external obstruction.

Figure 1a shows the correlation between the ZephIR 300 wind speed at 48 m and the met mast wind speed at 50 m for a SW mounted anemometer. Figure 1b shows the same comparison with a NE mounted anemometer used instead. Excellent agreement between the ZephIR 300 and the met mast was obtained when using the SW anemometer, but a significant bifurcation in the correlation was seen for the NE anemometer. The same pattern can be seen in Figure 1c and Figure 1d: high correlation for the SW anemometer which is much lower when the NE anemometer is considered.

As both SW anemometers produce a coefficient of determination, R^2, greater than 0.99, and with gradients close to unity, when compared against the ZephIR 300 these were considered to be operating correctly. The NE anemometers, with R^2 less than 0.99 required further attention. After a visit to the site it was established that the wind being measured by the NE anemometers was being distorted by an adjacent lighting unit.

This short deployment drew attention to the fact that the instruments on one side of the mast were having their measurements biased by a previously unknown external blockage. This influence was a function of height also, which, if uncorrected, could cause severe errors in the prediction of both the mean wind speed and also the wind shear at this site. Errors in either of these quantities could have a detrimental effect on the quality of the wind resource assessment and vertical extrapolation of wind above the met mast.

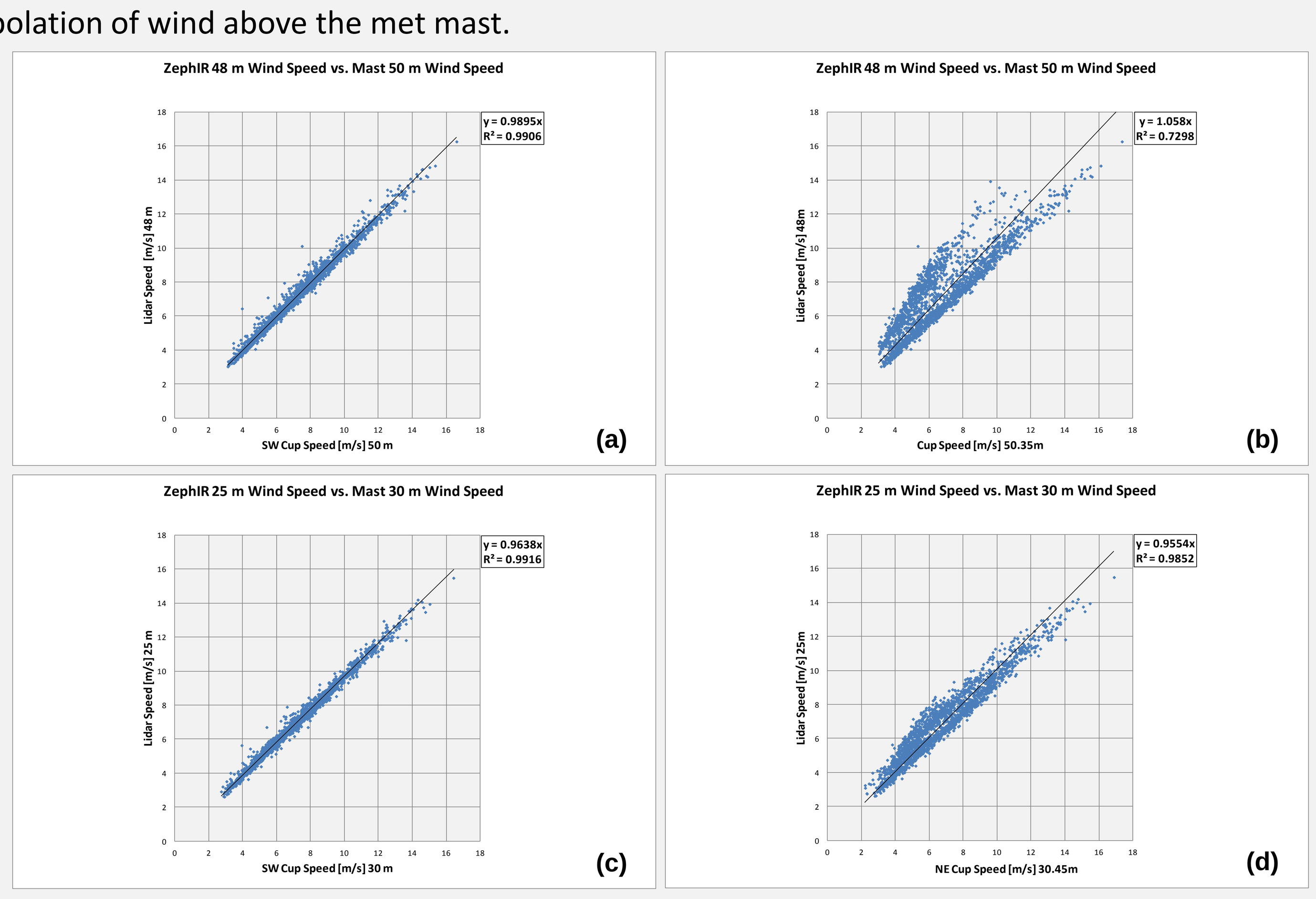
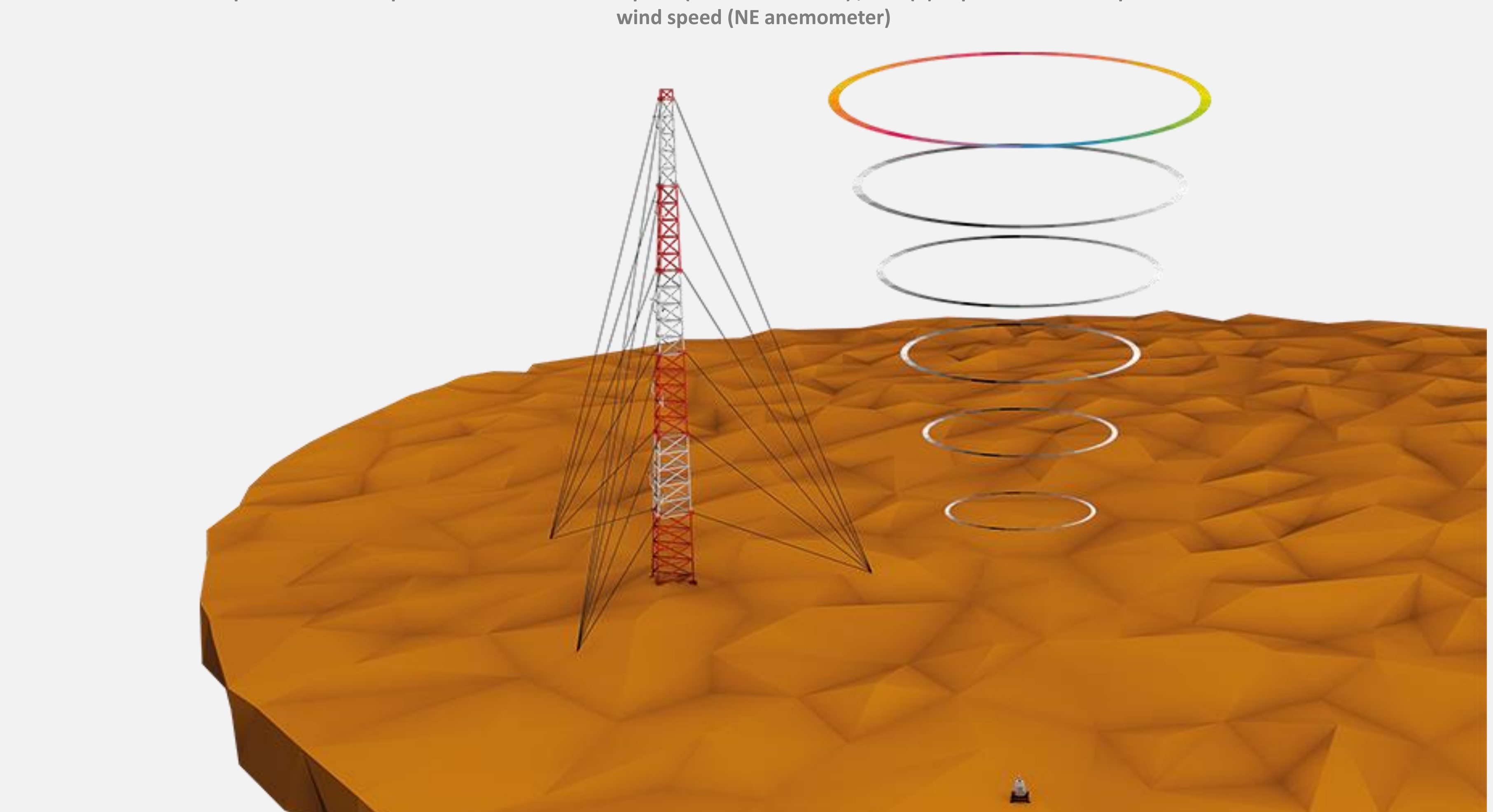


Figure 1: Correlation of horizontal wind speed between the met mast and ZephIR 300. (a) ZephIR 48 m wind speed vs. mast 50 m wind speed (SW anemometer) ; (b) ZephIR 48 m wind speed vs. mast 50 m wind speed (NE anemometer); (c) ZephIR 25 m wind speed vs. mast 30 m wind speed (SW anemometer) ; and (d) ZephIR 25 m wind speed vs. mast 30 m wind speed (NE anemometer)



Case Study 2 – Faulty Wind Vane and Logger Program Error

This case study examines a 110 m mast installed on an offshore platform in the North Sea. The ZephIR 300 was installed on the platform at the base of the mast for the period 9th May 2015 to 9th June 2015. This highlights how a relatively short ZephIR 300 deployment can identify a faulty wind vane and, as a result, an error in the directional offset entered into the mast logger program.

The ZephIR 300 wind direction was compared with concurrent wind vane data at three heights from the mast in question. The exact vane heights were not configured ZephIR 300 measurement heights, so the closest ZephIR height was used in the comparison. Figure 2a shows the wind direction comparison between the ZephIR 300 at 68 m and the vane at 63 m, Figure 2b shows the wind direction comparison between the ZephIR 300 at 83 m and the vane at 78 m and Figure 2c shows the wind direction comparison between the ZephIR 300 at 110 m and the vane at 104 m.

The correlations in Figure 2a and Figure 2b show excellent agreement between the ZephIR 300 and mast, whereas Figure 2c shows poor correlation. Some of this disagreement could have been attributed to mast shadowing. However, the disagreement appeared to be widespread and erratic, implying the vane was reporting the wrong direction from non-shadowed sectors also.

The orientation of the booms on this mast were 150° (South facing) and 330° (North facing). It was thought that the vanes were aligned with true North, but Figure 2a and Figure 2b show a near constant 30° offset between the ZephIR 300 and the vanes. This indicated that the wind vanes had actually been aligned with the booms, which is not uncommon, rather than with true North.

The findings from this short deployment drew attention to the fact that a faulty wind vane was in operation on the mast and that there was a 30° offset in the outputted mast directional data at all heights. High quality data is essential in any wind resource assessment campaign, especially offshore, so this study allowed the necessary operation and maintenance decisions to be made far earlier than if the ZephIR 300 had not been deployed. It also allowed the measurement campaign to proceed with correct data, instead of discovering at the end of a campaign that the data had quality issues.

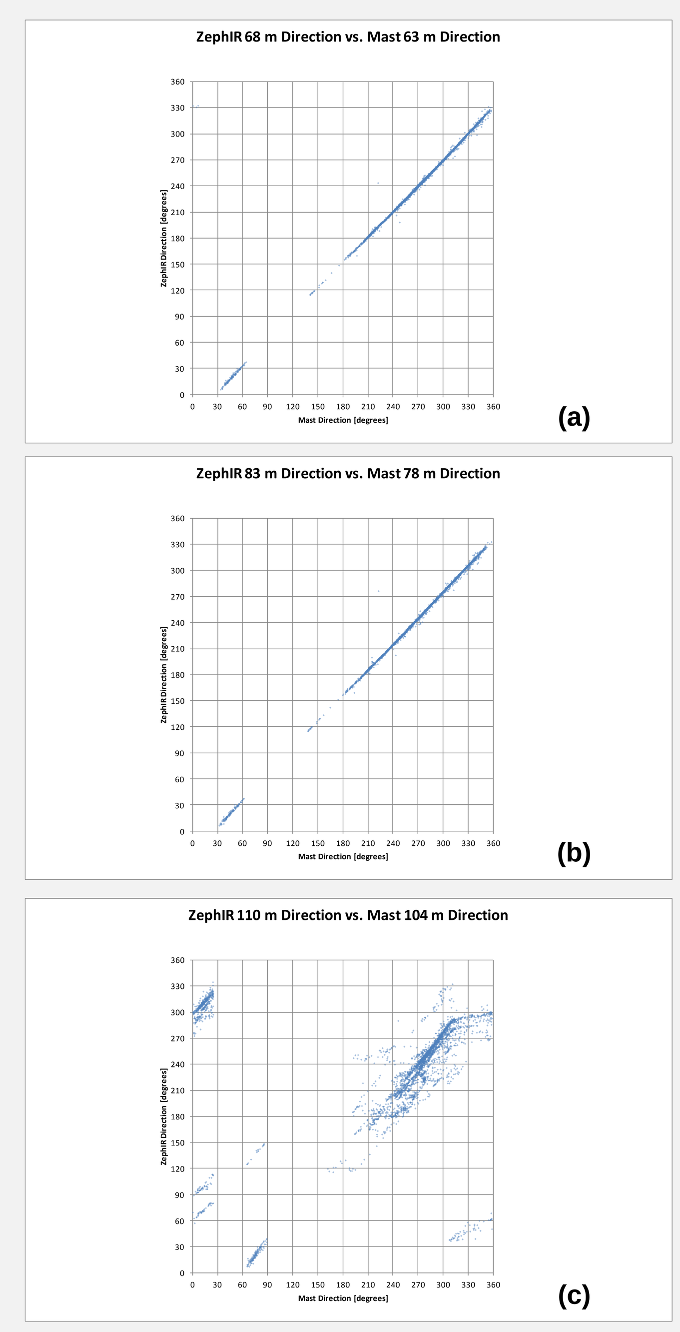


Figure 2: Correlation of horizontal wind speed between met mast and ZephIR 300. (a) ZephIR 68 m wind direction vs. 63 m wind direction; (b) ZephIR 83 m wind direction vs. mast 78 m wind direction; and (c) ZephIR 110 m wind direction vs. 104 m wind direction.

Figure 3: Example deployment of where a ZephIR 300 Lidar was installed at an operational wind farm. The ZephIR was installed close to (< 10 m) an operational met mast that was being used to obtain data on wind speed and direction that would've been used in post construction analysis of the wind farm.

Summary and Conclusions

This mast verification service has been developed in conjunction with renewable energy consultancy Dulas who, after three decades of experience providing renewable energy installations, have the depth and breadth of knowledge to engage positively with the wind industry and offer support to their customers and their existing fleet of masts.

The methodology outlined in detailed in [3] can confirm wind speed and direction performance from a mast to within industry accepted uncertainties, i.e. 1 – 2% for class 1 cup anemometers. The process can also help to identify the source of any discrepancy and point towards suitable remedial action(s). The financial benefit of carrying out the verification process for any given project will depend on the size of the project and the magnitude of any errors uncovered that require correction.

The mast verification campaign can also be configured to provide additional information and benefits, such as validation of shear extrapolation at a site as the lidar can measure above the mast height. This is particularly beneficial in cases where the mast does not reach hub height, and it also helps to inform the resource assessment to reach valuable conclusions about wind conditions right up to top tip height.

The additional measurements at greater heights allow the uncertainty associated with vertical extrapolation at the location to be assessed in more detail, which can provide significant benefits when coming to finance a wind farm based on pre-construction measurements. Analysis in [4] shows a reduction in uncertainty for energy yield of approximately 2% when a lidar is used next to a mast, compared with using a met mast only. More case studies and detail on the overall mast verification methodology is covered extensively in [3].

References

1. "Flow distortion on boom mounted cup anemometers", P Lindelow-Marsden et al, Risø-R-1738(EN) (2010); "Performance of wind measurement on the meteorological mast", NORSEwind consulting guidelines, NLT0903
2. "Power performance measurements of electricity producing wind turbines", IEC 61400-12-1
3. Mast verification Methodology: using lidar to reduce uncertainty in wind resource assessment (2016), ZephIR external report
4. Improved bankability: The Ecofys position on Lidar use", E Holtslag, Ecofys Technical Report (2013)

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