DTU Wind Energy

DTU

March 21. 2011

ZephIR 301 Evaluation Test

In the context of the work package *WP1.2 Production ZephIR Testing* of the Danish High Technology Fund (DHTF) project *Integration of Wind Lidars in Wind Turbines for Improved Productivity and Control*, Risø DTU has carried out an evaluation test of the new ZephIR 300 (Z300) wind lidar.
The Z300 was placed in the Danish test station of large wind turbines at Høvsøre, at a distance of approximately 37 m, in the NNW direction from the main meteorological mast of the test station. Simultaneous measurements of wind speed have been performed from the lidar and from calibrated cup anemometers at 40, 60, 80, 100 and 116m, in the period from the 9th of February till the 16th of March 2011. The lidar was operating in its standard mode throughout the whole period of the experiment. The measurements of the cup anemometers were screened in order to exclude dubious cup data from the analysis.

The Z300 operation was characterized by 100% system availability, while the data availability appeared to be in order of 91.7% – 98.5% depending on the height of the measurements. No additional quality control was applied to the ZephIR data.

The results of the evaluation test are presented in the form of parameters from a regression analysis using two different regression models; $y = ax + b$ and $y = mx$. Estimated parameters (a, b and m) are given together with the coefficient of determination (R^2) for both models.

The regression analysis was focused on data (10 minute mean values) with wind directions screened between 45° and 315° (wake free sectors) and wind speeds between 4 -16 ms^{-1} (i.e. the wind speed range over which the cups have been calibrated).

Table: Mean wind speed regression analysis

Height [m]	Total Data [#]	Screened Data [#]	y = a x + b			y= m x	
			a	b [ms^{-1}]	R^2	m	R^2
40	5184	3551	1.0250	-0.1671	0.9921	1.0066	0.9917
60	5184	3480	1.0149	-0.2398	0.9928	0.9902	0.9921
80	5184	3258	1.0092	-0.2577	0.9930	0.9840	0.9923
100	5184	3184	1.0131	-0.2805	0.9881	0.9866	0.9884
116.5	5184	3258	1.0136	-0.2184	0.9775	0.9934	0.9771

Best regards,

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COMPARISON OF ZEPHIR MEASUREMENTS AGAINST CUP ANEMOMETRY AND POWER CURVE ASSESSMENT

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ABSTRACT

We report the results of a measurement campaign in which wind turbine power curves have been evaluated using a ZephIR laser anemometer. The present study has been carried out in collaboration with EDF Energies Nouvelles. The test site, "Chemin d'Ablis A10", is situated to the south of Paris and consists of 26 REpower MM92/2000 wind turbines with a hub height of 78.5m. The surrounding topography and land cover is flat with no significant features in the direction of the prevailing westerly winds. The 5-week measurement period took place during April/May 2009.

The ZephIR was located 61m from a high-quality 80m mast, and roughly 300m from two wind turbines. After exclusion of sectors affected by turbine wake effects, various comparisons of the ten-minute averaged data from ZephIR and mast have been undertaken, including wind speed, wind direction, shear and turbulence. The two sets of measurement demonstrate excellent agreement; the wind speed correlation plots show gradients within 2% of unity for each cup with all remaining sectors included. The corresponding correlation coefficients (R^2) lie in the range 0.97 to 0.98.

A power curve assessment has been carried out on both the adjacent turbines, using ten-minute averaged wind speed data from three sources: ZephIR, mast and nacelle-mounted cup anemometer. In the relatively short trial duration it was not possible to generate a power curve fully in accordance with IEC guidelines; however the trial provides useful indicative results. The ZephIR and mast data are in extremely good agreement, and they both also fit well around the power curves provided by the manufacturer.

The scatter of the points in the power curve plots has been analysed in some detail. The nacelle anemometry shows the lowest standard deviation. The scatter in the power curve obtained using the ZephIR wind speed data is slightly lower than that for the mast wind speed data. This result needs further investigation and possibly is a consequence of the more effective sampling of the wind around the scan disk. It is possible that further reduction in scatter of the power curve may be achieved by making full use of the available ZephIR wind speed data at different heights spanning the rotor plane.

Overall we conclude from this study that ZephIR is well suited to the application of turbine power curve measurement, giving an almost identical power curve to the IEC-instrumented power performance mast.

1. INTRODUCTION

The test site, “Chemin d’Ablis A10” consists of twenty six REpower MM92/2000 wind turbines with a hub height of 78.5 m. The surrounding topography and land cover is flat with no significant features in the direction of the prevailing westerly winds.
REpower are undertaking a power performance measurement of two wind turbines according to IEC 61400-12. The site is therefore instrumented in accordance with this standard. EDF Energies Nouvelles and REpower Systems AG wish to evaluate the performance of the ZephIR laser anemometer against the mast, and for generation of wind turbine power curves.

This report relates to the results obtained during a measurement campaign undertaken from 23/04/2009 to 28/05/2009. This follows an earlier measurement campaign that took place from 10/09/2008 to 11/11/2008. The present study has been carried out in collaboration with EDF Energies Nouvelles.

The overall aims of this exercise are to:

- investigate correlations, as demonstrated in a previous campaign, of ZephIR measurements against cup anemometry
- generate turbine power curves, and hence investigate the effectiveness of the ZephIR lidar at predicting turbine power output, comparing this to classic anemometry.

2. SITE DESCRIPTION

The “Chemin d’Ablis A10” site is situated to the south of Paris along the A10 motorway, as shown on Figure A-1. It was commissioned in September 2008 and consists of twenty-six MM92/2000 wind turbines with a hub height of 78.5 m. The surrounding topography and land cover is flat with no significant features.

Two turbines are considered for this study: turbines 13 and 14. A power performance measurement mast is situated 266 m to the southwest of turbine 13 and 353 m to northwest of turbine 14. A ZephIR laser anemometer, deployed 61.5 m to the southwest of the mast, is situated 327 m to the southwest of turbine 13 and 317 m to northwest of turbine 14.

The site layout is shown on Figure A-2. The coordinates are shown on Table A-1. All coordinates are referred to the UTM Zone 31N coordinate system with WGS84, in metres. Distances between instruments and turbines are given in Table A-2. Land cover in the vicinity is agricultural land with a wood to the east of each turbine. The tree heights are estimated to be in the range 10-15m.

2.1. Mast and Instrumentation

The mast is 80 m high. Two anemometers are mounted side by side at the top of the mast (80 m). Orientations of the top booms are 298° and 118°, perpendicular to the main wind direction (210°-240°). In the present report, the anemometer oriented to 298° will be called WS80-1 and the one oriented to 118° will be called WS80-2. An anemometer is mounted at 34 m, on a boom oriented to 299°.

A first wind vane is mounted at 78 m, a second wind vane is mounted at 75 m and a third wind vane is mounted at 34 m. The orientation of the booms is respectively 119°, 298° and 122°. With regards to the mean wind direction on site, 210°-240°, these booms are relatively well oriented for measurements not to be too significantly affected by the mast. See Figure A-3 for an overview of the mast. A lightning conductor has been installed at the top of the mast, between the two anemometers at 80 m.

Instruments are of type Thies “first-class”, and have been calibrated to MEASNET standard.
Temperature was measured with this mast. Data are recorded with a sampling rate of one hertz, and averaged with a period of 10 minutes. The reference time is UTC + 2 hours. The time-stamp is modified to a UTC base to allow the comparison with ZephIR. The mast is situated 273 m southwest from turbine 13 and 349 m northwest from turbine 14.

2.2. ZephIR settings

The ZephIR lidar (unit 145), is situated 61 m southwest from the mast. The LIDAR is programmed to measure at 34, 50, 80, 110 and 128 metres above ground level. The reference time is UTC, the scan duration is 3s per height and the averaging period is 10 minutes.

3. METHOD

The analysis explores the following points:

- Quality check of mast and ZephIR data, determination of the availability
- Identification of sectors to be excluded due to wake effects
- Identification of sectors to be excluded due to mast shadow for the upper anemometers
- Identification and exclusion from the turbine data set, of downtime or non-standard turbine operation, due to effects other than incident wind.
- Sector wise quality of fit between ZephIR and mast wind speeds, standard deviations
- Quality of fit between ZephIR and mast wind directions.
- Sector wise comparison of shear factors between ZephIR and mast.
- Quality of fit between the ZephIR wind speed and turbine power output, and the same comparison for the mast data
- Power performance assessments based on mast data and ZephIR data

Data points where the wind speed is < 3.0 m/s, as measured by the mast at the top anemometer and ZephIR at 80 m, are excluded, except for standard deviation comparison for which data points where the wind speed is < 4.0 m/s, as measured by the mast at the top anemometer and ZephIR at 80 m, are discarded. In the present report, wind directions are binned in 16 sectors. The first sector is centred on 0 degrees.

Concurrent data between mast, ZephIR and turbines are compared in detail, and the results are summarised here. When comparing instruments measuring at the same height, if a blank value occurs for the wind speed of one of the instruments, the entire time stamp is discarded.

4. RESULTS OF THE COMPARISON MAST-ZEPHIR

4.1. Raw data verification

The time series were checked for invalid data and any anomalies that may not be representative of true conditions at the time.

4.1.1. Mast data

Raw data was provided by the client in the form of Excel files. Calibration factors have been applied. Data covering the period 23/04/2009 – 28/05/2009 were obtained. The availability of the provided raw data is 100% for the 34 m and 80 m anemometers. Some data were discarded, giving an availability of 81.6% at 34 m and 80 m. The discarded time period is from 13/05/2009 07:10 to 18/05/2009 07:40 and from the 20/05/2009 06:50 to the end of the campaign. The 78 m wind vane provided wind direction data.

The correlation between wind speeds measured at 80 m by the two top anemometers is very good (r^2 = 0.995) (after data verification). The correlation between wind speeds measured at 34 m and 80 m is weaker (r^2 = 0.835 for WS80-1 and r^2 = 0.830) (after data verification).

4.1.2. ZephIR data

Raw data was provided by Natural Power in the form of CSV files. Data covering the period 23/04/2009 – 28/05/2009 were obtained. The ZephIR unit was not power supplied from the 13/05/2009 to the 15/05/2009 08:40 due to a grid power failure (work was undertaken on a nearby substation). Excluding this period of power supply failure, the availability of the provided raw data is 99.8% at all heights.

Some data were discarded following quality checks, giving an overall availability of 99.4% at 34 and 50 m, 99.3% at 80 and 110 m and 99.2% at 128 m (excluding the period of power supply failure). The discarded data correspond to 9999 values where no valid measurement was possible, primarily as a result of very low wind speeds.

After data verification, the correlation between wind speeds measured at 34 m and 80 m is similar to that observed by the mast ($r^2 = 0.865$), however this correlation does not exclude wake-affected sectors at this stage.

The concurrent period between the mast and ZephIR is from 23/04/2009 to 20/05/2009.

4.2. Sector exclusion

In order to obtain valid measurements, both the wind turbines under test and the instruments on the measurement mast must not be influenced by neighbouring wind turbines. If a neighbouring turbine is operated at any time during the power performance test, its wake shall be determined and accounted for as described in IEC-61400-12-1 standards (IEC 2005). The sectors to exclude due to wakes from neighbouring and operating wind turbines shall be taken from:

$$\theta = 1{,}3 \arctan(2{,}5D\text{n}/L\text{n} + 0{,}15) + 10$$

The dimensions to be taken into account are the actual distance *L*n and the rotor diameter *D*n of the neighbouring and operating wind turbine.

The table below presents the sectors to exclude due to wakes from turbines 13 and 14.

	Sectors to exclude due to wake effects
Mast	355°- 360°, 0° - 64° and 132°-192°
ZephIR	359°- 360°, 0°-61° and 122°-185°
Anemometer on the nacelle of turbine 13	153°-211°
Anemometer on the nacelle of turbine 14	334° - 360° and 0° - 30°

Table 4-1 Excluded sectors due to wake effects

Thereafter, the sectors mentioned above will be excluded for all comparison and calculation. Winds measured with the two 80 m anemometers on the mast subject to mast shadow were excluded. The table below presents the sectors to exclude due to mast shadow.

	Sectors to exclude due to mast shadow
80 m anemometer at 298° (WS80-1)	105° - 132°
80 m anemometer at 118° (WS80-2)	280° - 319°

Table 4-2 Excluded sectors due to mast shadow

4.3. Comparison mast - ZephIR

4.3.1. Frequency

The 16-sector wind direction frequency has been calculated for the mast and ZephIR. See Figure B-1, Figure B-2. The mast and ZephIR show a very similar frequency distribution. According to various previous campaigns, southwest is the predominant direction. Results will thereafter be given for the 195°-254° sector.

4.3.2. Wind speed

Wind speeds at hub height measured by the mast and ZephIR have been plotted for all sectors taken together, and for the predominant sector only. Data points where the wind speed is < 3.0 m/s, as measured by the mast at the top anemometer, have been excluded.

Hub height (80m)

The correlation between wind speeds measured at hub height by the mast (WS80-1) and ZephIR for all sectors taken together is good (r^2 = 0.980 for WS80-1 and r^2 = 0.979 for WS80-2). The correlation between wind speeds measured at hub height by the mast and ZephIR for sector 195° - 254° is good (r^2 = 0.979 for WS80-1 and r^2 = 0.980 for WS80-2). An example correlation plot is shown in Figure B-3.

The mean wind speed measured by ZephIR is slightly higher than the mast, by 2% for WS80-1 and 1% for WS80-2. As the level of agreement between two well-calibrated cup measurements is typically of order 2%, these results show that ZephIR and the mast provide a high level of agreement.

At 34 m

The correlation between wind speeds measured at 34 m by the mast and ZephIR for all sectors taken together is good (r^2 = 0.969). The correlation between wind speeds measured at 34 m by the mast and ZephIR for sector 195° - 254° is also good (r^2 = 0.972). See Figure B-4 as an example plot.

4.3.3. Standard deviation

Standard deviations at hub height measured by the mast (WS80-1 and WS80-2) and ZephIR have been plotted for all sectors taken together and South-west sector. A filter on wind speed below 4.0 m/s, as measured by the mast at the top anemometer, has been applied.

Hub height

An example correlation plot is given in Figure B-5. The correlation between standard deviation measured at hub height by the mast and ZephIR for all sectors taken together gives the following correlation coefficients: r^2 = 0.811 for WS80-1 and r^2 = 0.827 for WS80-2.

The correlation between standard deviation measured at hub height by the mast and ZephIR for sector 195° - 254° gives the following correlation coefficients: r^2 = 0.819 for WS80-1 and r^2 = 0.827 for WS80-2.

At 34 m

The correlation between standard deviation measured at 34 m by the mast and ZephIR for all sectors taken together gives the following correlation coefficient: r^2 = 0.827, see Figure B-6.

The correlation between standard deviation measured at 34 m by the mast and ZephIR for sector 195° - 254° gives the following correlation coefficient: r^2 = 0.850.

4.3.4. Wind direction

Directions at hub height measured by the mast and ZephIR have been plotted for all sectors. Data points where the wind speed is < 3.0 m/s, as measured by the mast at the top anemometer and ZephIR at 80 m, are excluded. The correlation between wind directions measured at 78 m by the mast and 80 m by the ZephIR for all sectors taken together is very good ($r^2 = 0.998$).

4.3.5. Wind shear

A comparison of the wind shear (34 m – 80 m) per sector calculated for the mast and ZephIR has been performed. Data points where the wind speed is < 3.0 m/s, as measured by the mast at the top anemometer and ZephIR at 80 m, are excluded. The table below gives the mean wind shear (α) calculated between 34 m and 80 m for the mast and ZephIR, where α is defined as:

$$\alpha = \ln.(V_{80}/V_{34})/\ln.(h_{80}/h_{34})$$

	Mast	ZephIR
Mean wind shear using WS80-1 for the mast	0.192	0.188

Table 4-3 Shear coefficients measured between 34 and 80 m

The mast and ZephIR give similar shear results. In some sectors, the mast gives slightly higher wind shear results in comparison with ZephIR. This could be explained by the different mounting arrangements of the anemometers on the mast, i.e. the boom-mounted lower anemometer will be subject to some blockage effect compared to the top-mounted anemometer.

4.3.6. Wind Speed Distribution

Mast and ZephIR distributions of the 10-minute averaged wind speeds are shown in Figure B-7 at hub height and in Figure B-8 at 34 m. The results for mast and ZephIR are very similar, as would be expected from the close level of agreement evident from the correlation plots.

5. RESULTS OF THE POWER CURVE ASSESSMENT

The power curve assessment has been undertaken on turbine 13 and 14, using 10-minute averaged values throughout. Very few events of non-standard turbine operation have been identified, and these invalid data have been excluded. The measured active power is plotted against mean wind speed measured with the anemometer on the nacelle, ZephIR and mast for turbines 13 and 14, see Figure B-9 and Figure B-10. Because of the relatively short trial duration, the analysis has used wind data from all sectors unaffected by wakes. A longer trial period would be necessary for investigations in conditions where the wind arrives only from the upwind direction of each turbine. The measurements are compared to a calculated and a measured power curve provided by the turbine manufacturer.

The power curve based on the measurements of the turbine 13 nacelle anemometer diverges significantly from the power curves provided by the manufacturer as well as from mast and ZephIR measurements. While the scatter of the nacelle anemometer is lower than the mast or ZephIR, there is a strong bias which is unaccounted for. The mast and ZephIR-based power curves are in extremely good agreement. They both also fit well around the power curves provided by the manufacturer.

In the turbine 14 comparison anemometer, mast and ZephIR, the turbine 14 nacelle anemometer measurements again give the lowest scatter, however there is still a small but significant bias compared to the measured or calculated power curves. The mast and ZephIR power curve data again show very similar behaviour, and a good average fit around the power curve. There are a number of outlying points which appear concurrently in both the mast and ZephIR datasets.

The scatter of the points in the power curve has been further investigated. In Figure B-11 and Figure B-12, the standard deviation of the active power weighted by the frequency against wind speed measured by the nacelle anemometer, the mast and ZephIR at 80 m has been plotted. Data were binned by wind speed in 0.5 m/s wide bins. For both plots, it is interesting that for the majority of bins (particularly those with most statistical significance), the standard deviation is somewhat lower for the ZephIR data than for the mast. A global assessment of the relative levels of scatter for the various instruments has been made by summing the values of standard deviation in the individual bins, weighted by frequency of occurrence. The results are shown in Table 5-1, from which it can be seen that the overall scatter in the power curve arising from the ZephIR data is lower than from the mast.

	Nacelle anemometer	Mast WS80-1	Mast WS80-2	ZephIR WS80
T13	85.5	141.0	140.6	129.6
T14	53.2	156.7	157.1	147.6

Table 5-1 Global scatter of power weighted by frequency (arbitrary relative units)

6. CONCLUSION

Directional analysis of the mast and ZephIR data shows a very similar frequency distribution. Wind speeds at 80 m are temporally well correlated. The correlation between mast and ZephIR measurements is better at 80 m than at 34 m.

The mast and ZephIR give highly correlated results in terms of 10-minute averaged wind speed, particularly at hub height. The correlation between mast and ZephIR direction measurements is also very good.

The mast and ZephIR give similar shear results. In some sectors, the mast gives slightly higher wind shear results in comparison with ZephIR, probably due to the anemometer mounting arrangements, or to the influence on the airflow of the areas of woodland that lie to the East.

The ZephIR gives an almost identical power curve to the IEC-instrumented power performance mast, suggesting that it is well suited to this application. Power curves derived using both measurement methods fit closely with the measured and calculated power curves for the considered turbine type.

The scatter in the power curve obtained using the ZephIR wind speed data is slightly lower than that for the mast wind speed data. This result needs further investigation and possibly is a consequence of the more effective sampling of the wind around the scan disk. It follows, interestingly, that remote sensing equipment that agrees perfectly with the mast would therefore have provided higher scatter in the power curve than ZephIR.

In the relatively short trial duration it was not possible to generate a power curve fully in accordance with IEC guidelines. The power curve analysis has used wind data from all sectors unaffected by wakes; the scatter should be improved if data is filtered to include only those sectors where the sensors are upwind of the relevant turbine. It is possible that further reduction in scatter of the power curve may be achieved by making full use of the available ZephIR wind speed data at different heights spanning the rotor plane.

A. WIND FARM LOCATION

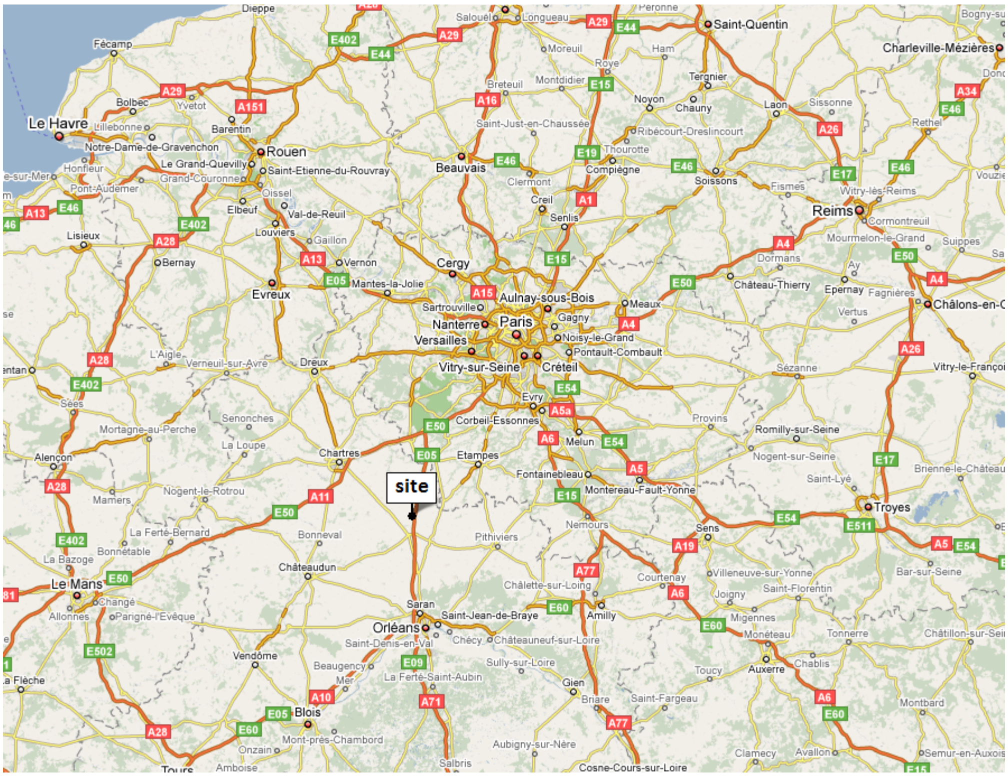

Figure A-1 Location of the site

Figure A-2 Background map with site layout

	Easting	Northing
ZephIR location	414465	5347931
Mast location	414494	5347978
Turbine 14	414603	5347646
Turbine 13	414632	5348213

Table A-1 Turbine and instruments locations in WGS84 datum, UTM 31N

Distance (m)	ZephIR	Mast	Turbine 13	Turbine 14	Control mast
ZephIR	-	61	337	327	1487
Mast		-	273	349	1451
Turbine 13			-	567	1235
Turbine 14				-	1790
Control mast					-

Table A-2 Distances in metres between turbines and instruments

Figure A-3 Mast overview

B. WIND MEASUREMENTS AND RESULTS

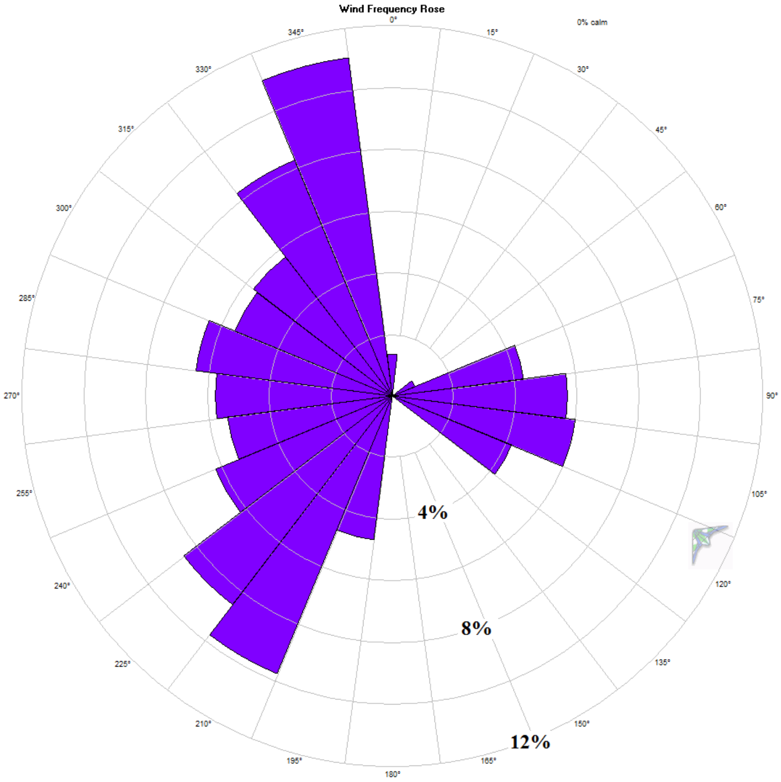

Figure B-1 Mast wind frequency rose (78 m)

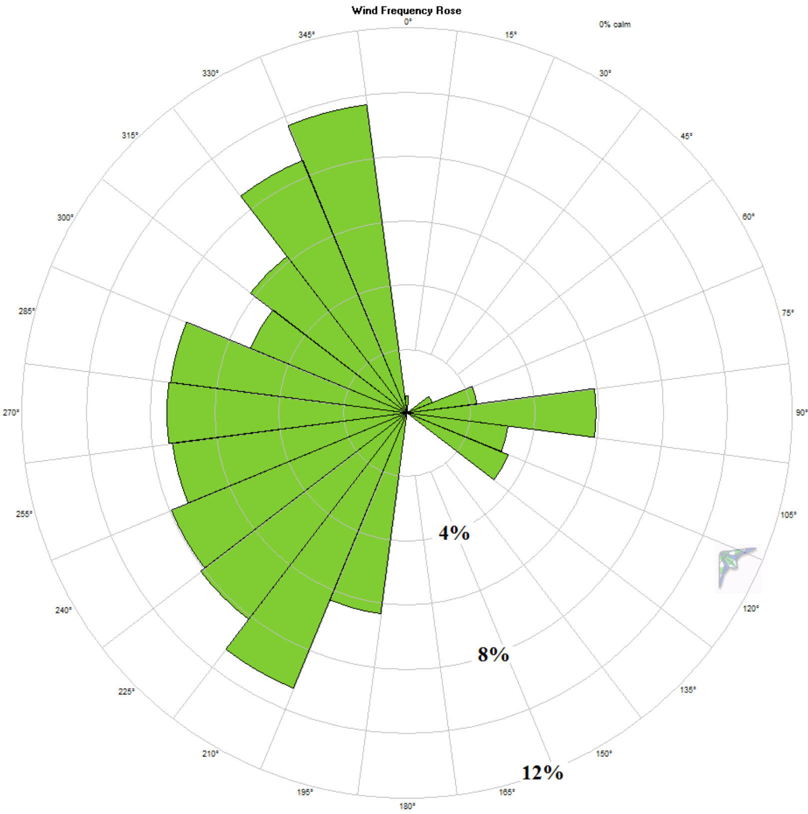

Figure B-2 ZephIR wind frequency rose (80 m)

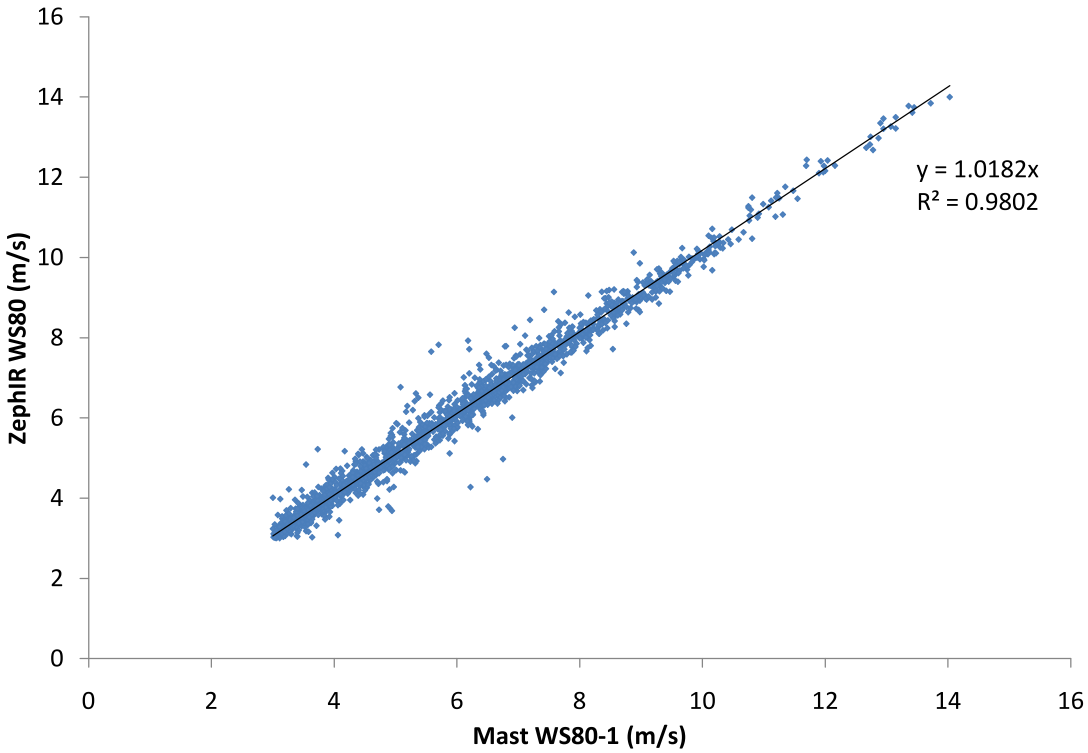

Figure B-3 Correlation plot of ZephIR and mast (WS80-1) wind speed measurements at hub height (80m) for all sectors (except sectors excluded due to wake effect)

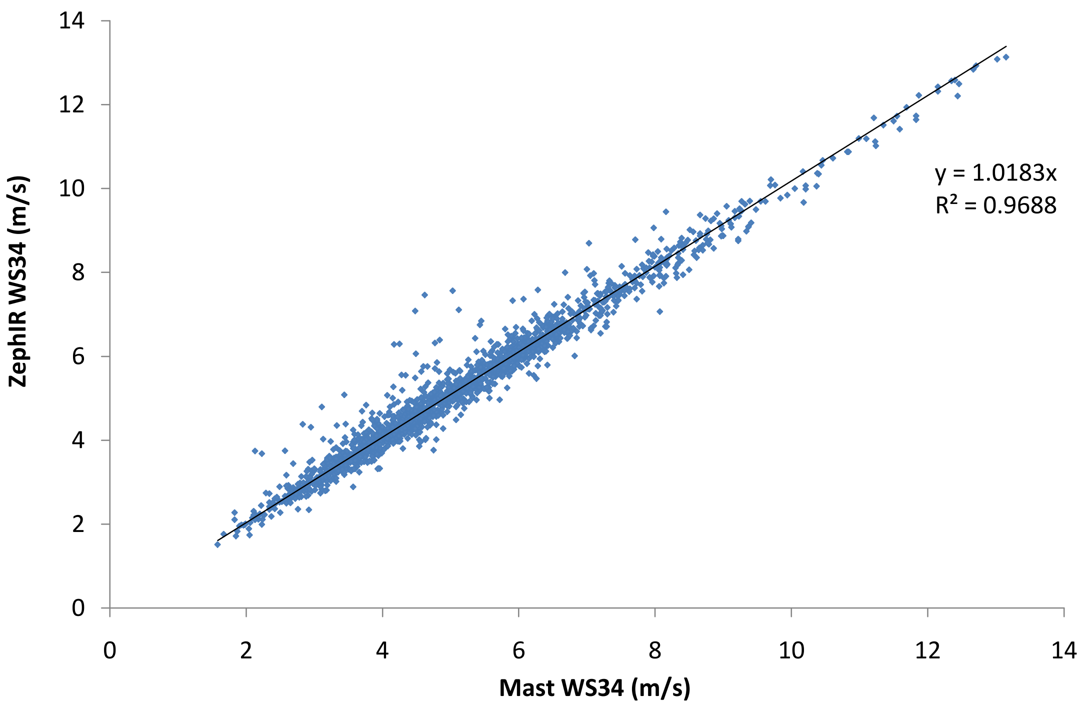

Figure B-4 Correlation plot of ZephIR and mast wind speed measurements at 34 m for all sectors (except sectors excluded due to wake effect)

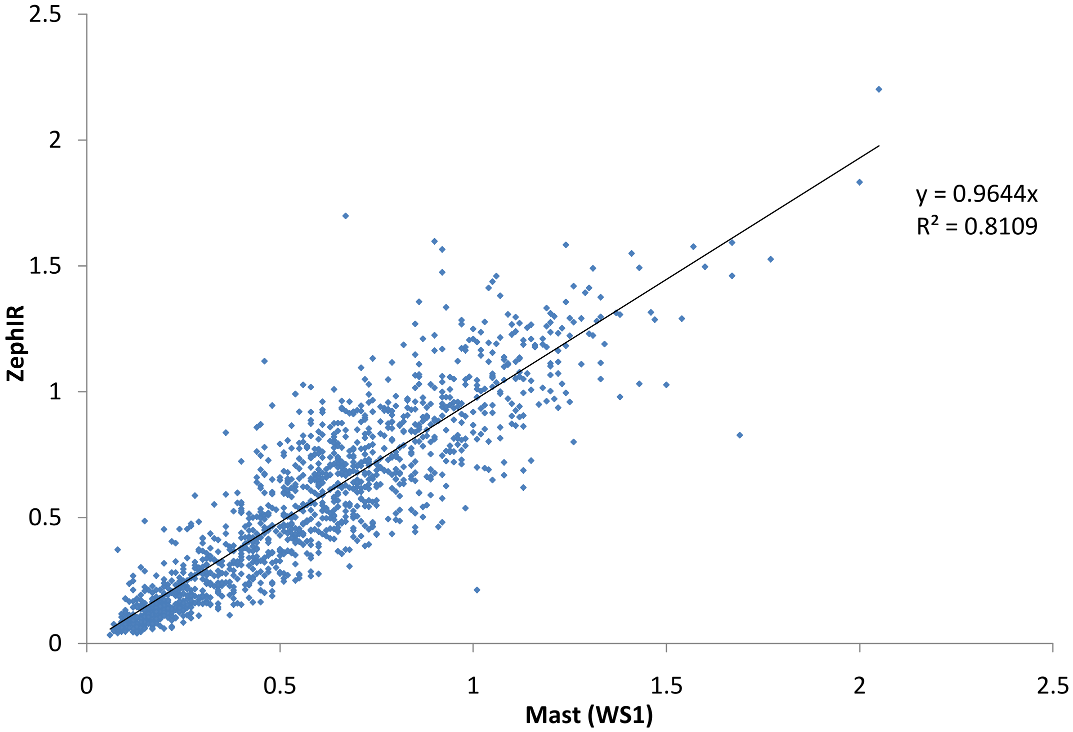

Figure B-5 Correlation plot of ZephIR and mast (WS80-1) standard deviation measurements at hub height (80m) for all sectors (except sectors excluded due to wake effect)

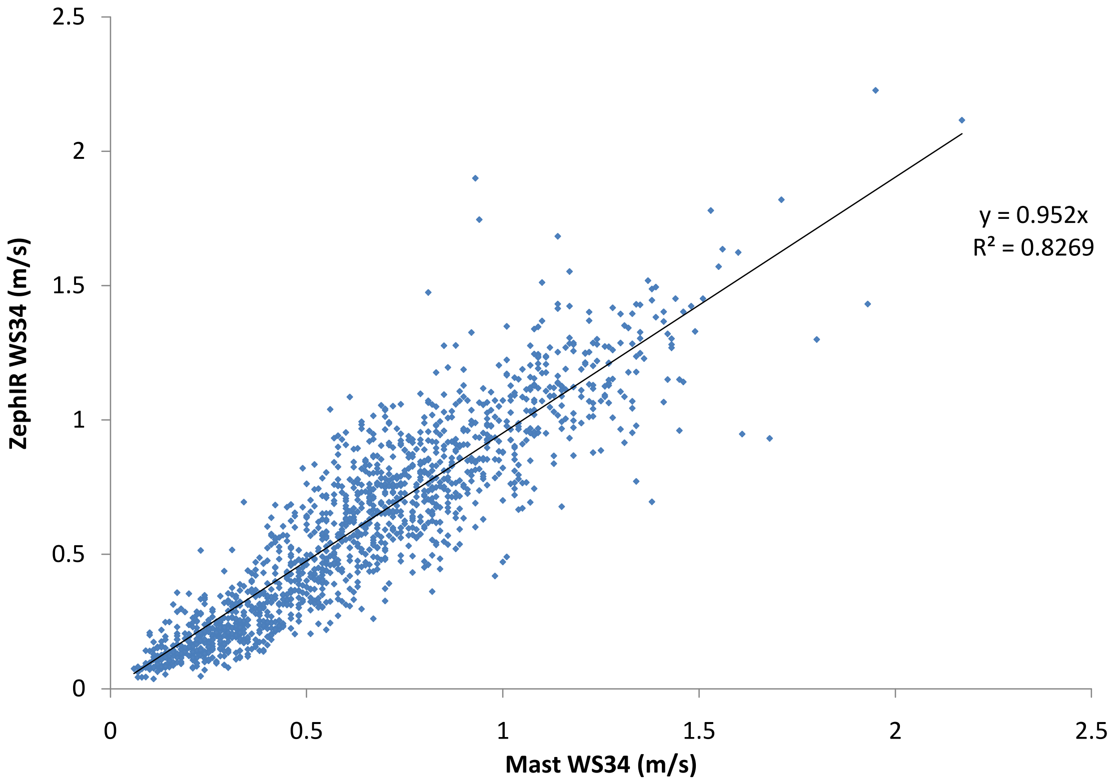

Figure B-6 Correlation plot of ZephIR and mast standard deviation measurements at 34 m for all sectors (except sectors excluded due to wake effect)

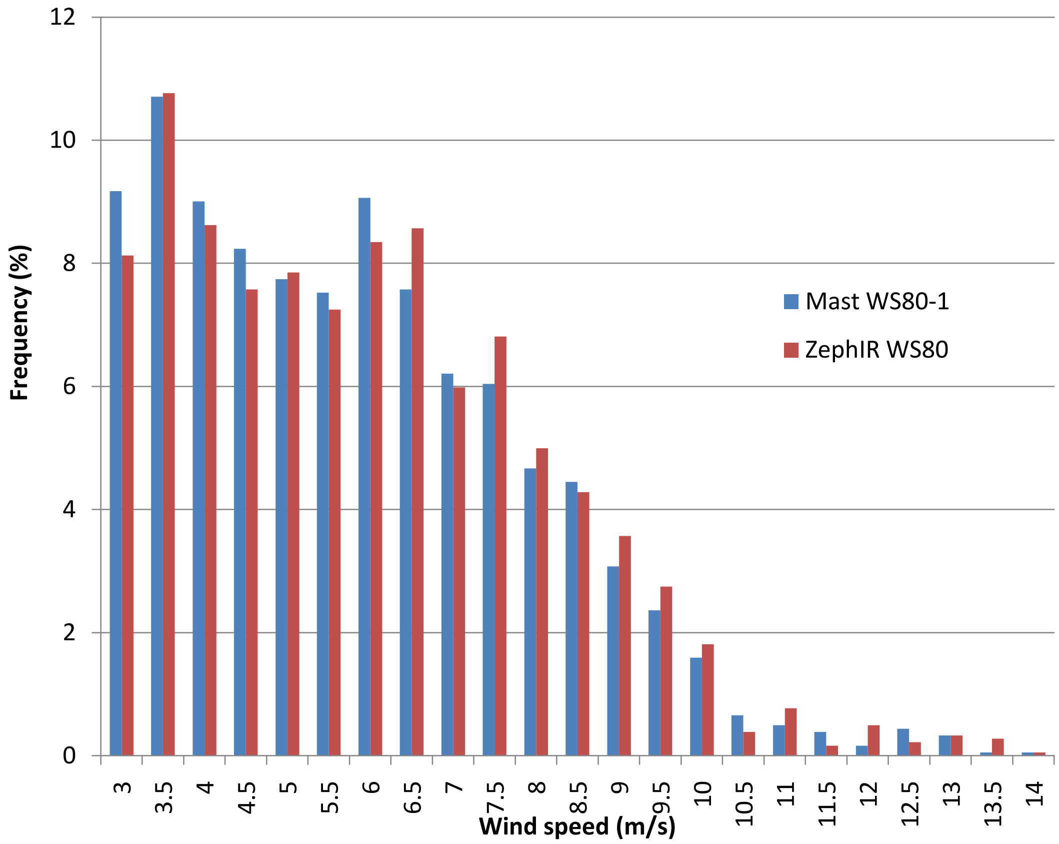

Figure B-7 Mast (WS80-1) and ZephIR distribution at 80 m

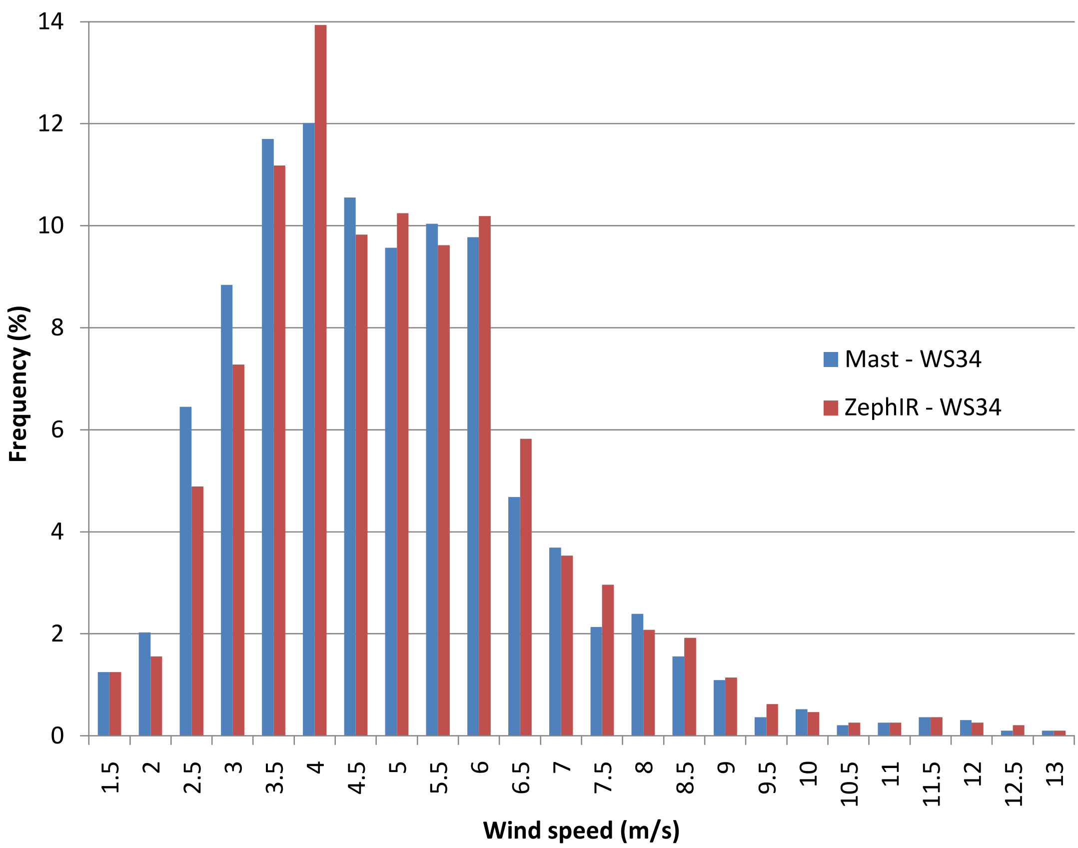

Figure B-8 Mast (WS80-1) and ZephIR distribution at 34 m

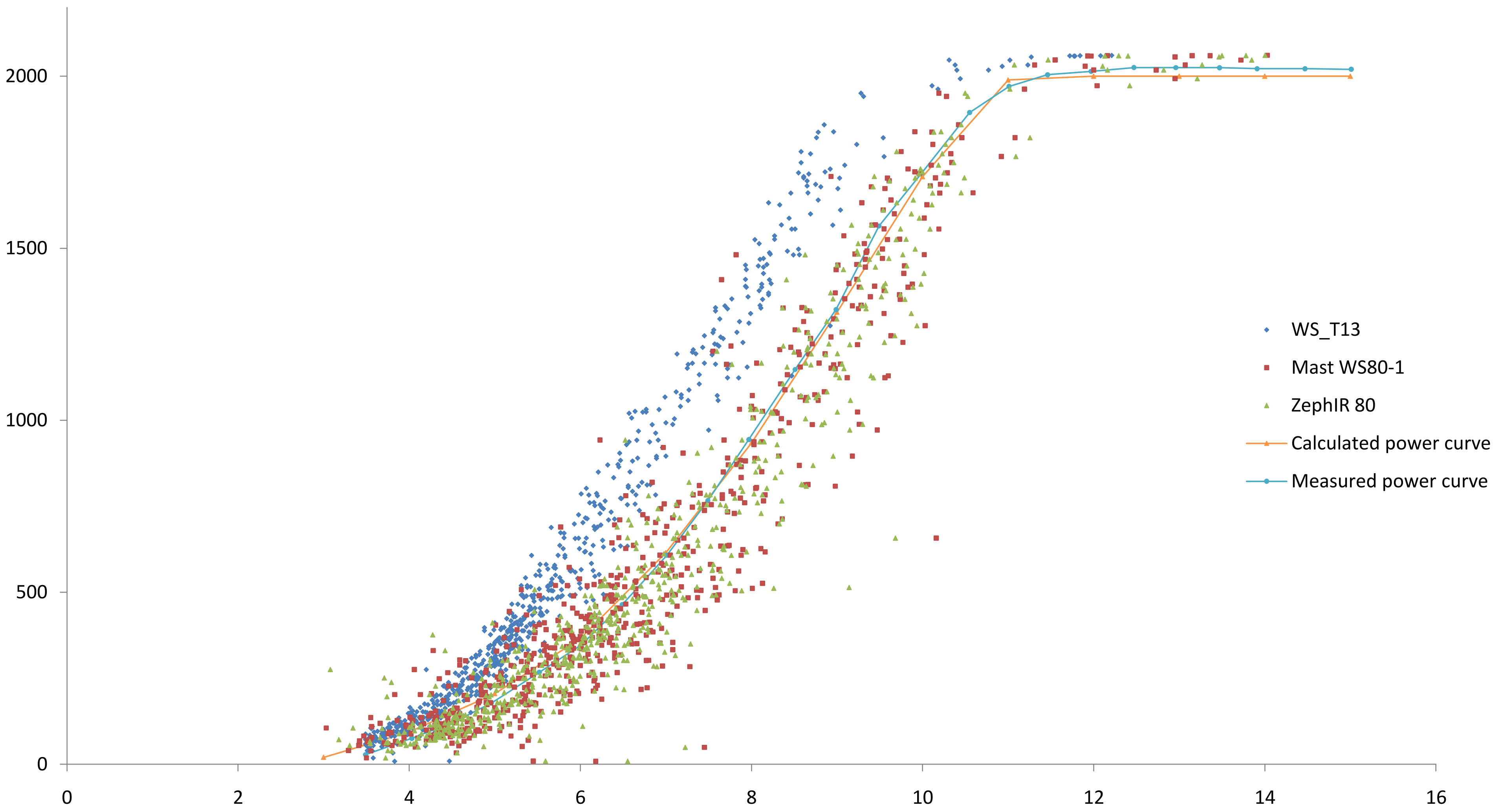

Figure B-9 Power produced by turbine 13 against mean wind speed measured with nacelle anemometer, the mast (WS80-1) and ZephIR at 80 m

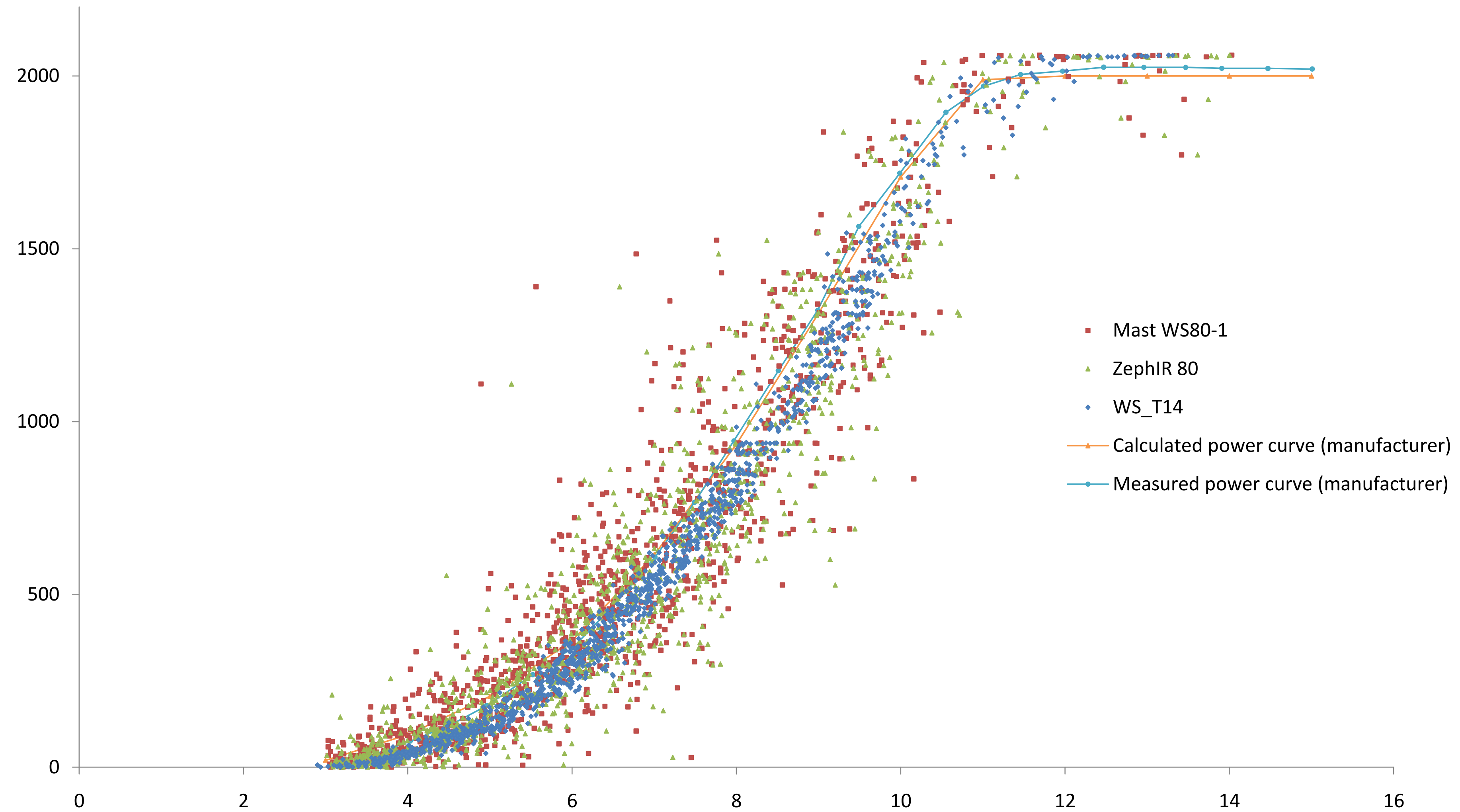

Figure B-10 Power produced by turbine 14 against mean wind speed measured with nacelle anemometer, the mast (WS80-1) and ZephIR at 80 m

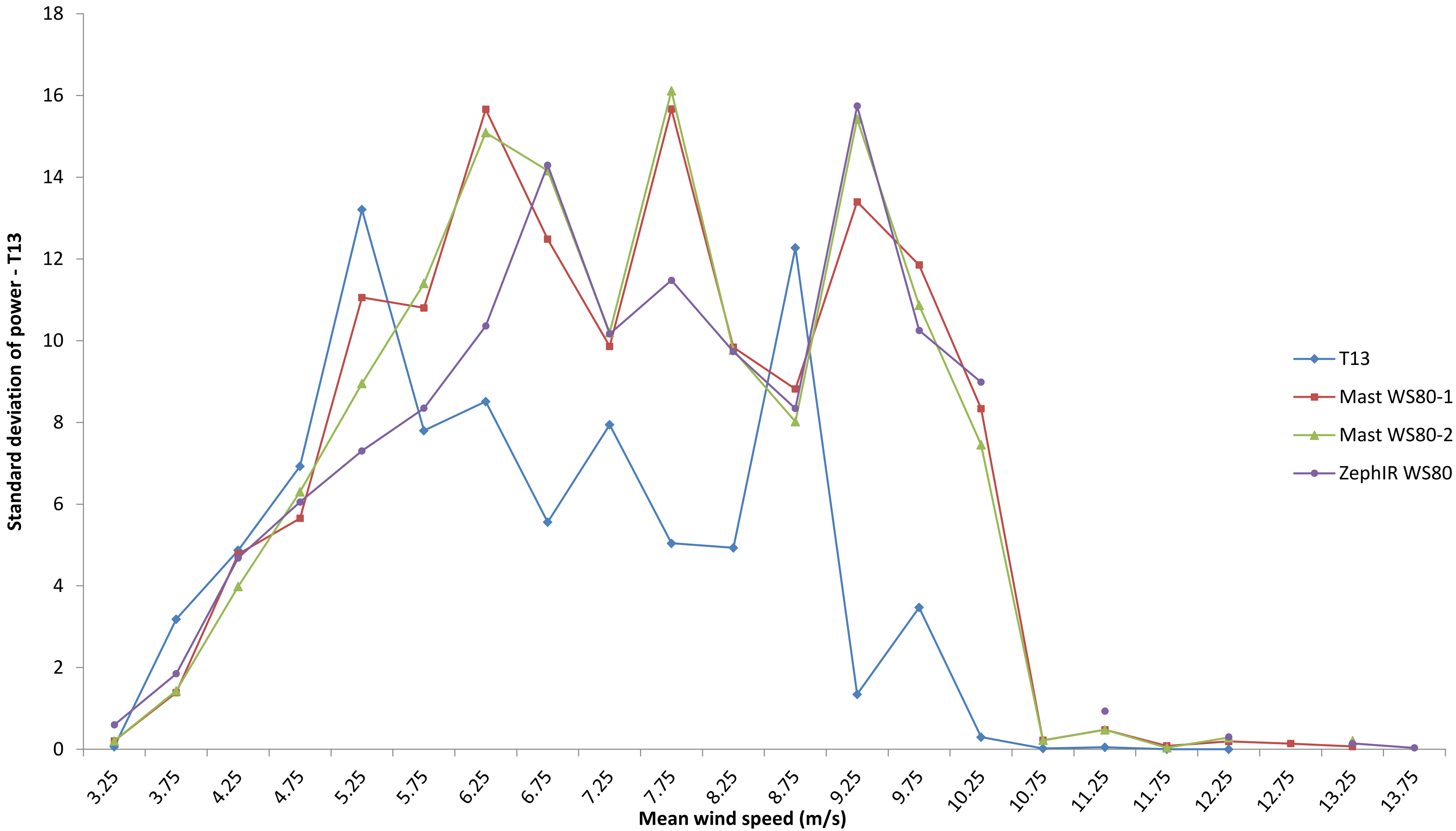

Figure B-11 Standard deviation of power weighted by frequency produced by turbine 13 against mean wind speed measured by the different anemometers

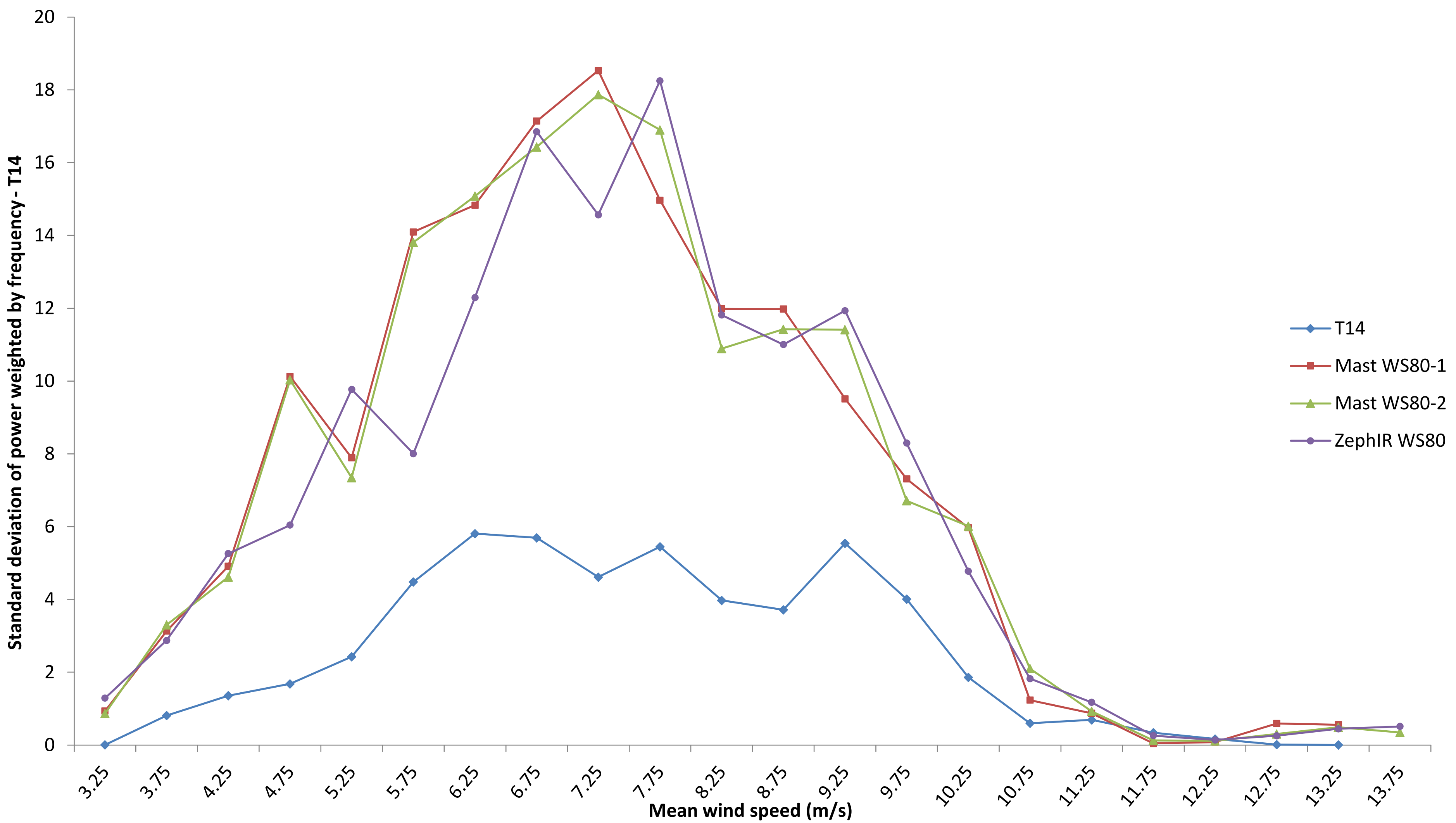

Figure B-12 Standard deviation of power weighted by frequency produced by turbine 14 against mean wind speed measured by the different anemometers

ZephIR 301 Evaluation Test

Nikolas Angelou and Torben Mikkelsen

26th May 2011

In the context of the work package *WP1.2 Production ZephIR Testing* of the Danish High Technology Fund (DHTF) project *Integration of Wind Lidars in Wind Turbines for Improved Productivity and Control*, Risø DTU has carried out an evaluation test of the new ZephIR 300 (Z300) wind lidar.

The Z300 was placed in the Danish test station of large wind turbines at Høvsøre, at a distance of approximately 37 m, in the NNW direction from the main meteorological mast of the test station. Simultaneous measurements of wind speed have been performed from the lidar and from calibrated cup anemometers at 40, 60, 80, 100 and 116m, in the period from the 9th of February till the 16th of March 2011. The lidar was operating in its standard mode throughout the whole period of the experiment. The measurements of the cup anemometers were screened in order to exclude dubious cup data from the analysis.

The Z300 operation was characterized by 100% system availability, while the data availability appeared to be in order of 91.7% – 98.5% depending on the height of the measurements. No additional quality control was applied to the ZephIR data.

The results of the evaluation test are presented in the form of parameters from a regression analysis using two different regression models; $y = ax + b$ and $y = mx$. Estimated parameters (a, b and m) are given together with the coefficient of determination (R^2) for both models.

The regression analysis was focused on data (10 minute mean values) with wind directions screened between 45° and 315° (wake free sectors) and wind speeds between 4 -16 ms^{-1} (i.e. the wind speed range over which the cups have been calibrated).

Table: Mean wind speed regression analysis

Height [m]	Total Data [#]	Screened Data [#]	y = a x + b			y= m x	
			a	b [ms^{-1}]	R^2	m	R^2
40	5184	3551	1.0250	-0.1671	0.9921	1.0066	0.9917
60	5184	3480	1.0149	-0.2398	0.9928	0.9902	0.9921
80	5184	3258	1.0092	-0.2577	0.9930	0.9840	0.9923
100	5184	3184	1.0131	-0.2805	0.9881	0.9866	0.9884
116.5	5184	3258	1.0136	-0.2184	0.9775	0.9934	0.9771

Natural Power's ZephIR wind lidar demonstrates world-first matched performance in high-performance wind tunnel

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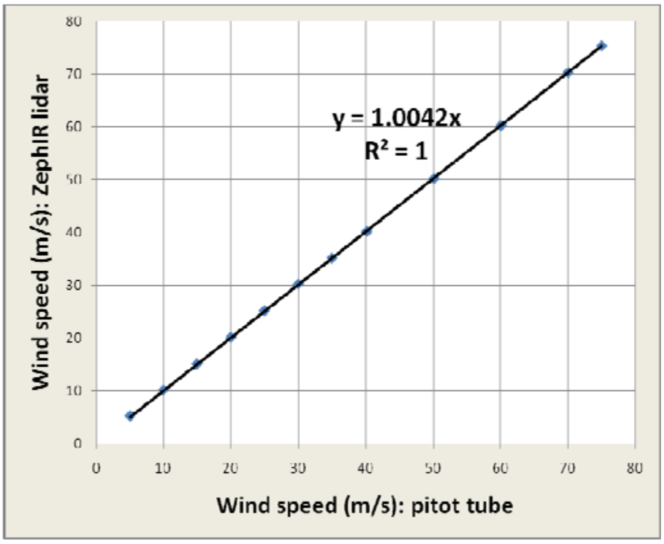

Leading renewable energy consultancy group, Natural Power, has achieved a world first in demonstrating matched performance of its continuous wave wind lidar, ZephIR, to a calibrated wind tunnel as part of a Danish National Advanced Technology Foundation (DNATF) project with Denmark's National Laboratory for Sustainable Energy, Risø DTU, global manufacturer of wind turbines blades, LM Wind Power and optical and laser solutions provider, NKT Photonics.

ZephIR 300 – a lidar system for measuring wind speed and characteristics from ground level up to 200 metres - was deployed in LM Windpower's wind tunnel in Denmark and successfully measured wind speeds from 5m/s to 75 m/s with an averaged difference of just 0.4% for a sustained period of time and across all measured speeds. To the company's knowledge, these are the first reported tests in the world to accurately measure the performance of a lidar in a wind tunnel and help demonstrate ZephIR's ability to measure low and high wind speeds for wind resource campaigns in the renewable energy sector.

These successful test results feed in to the DNATF project 'Integration of Wind LIDAR's in Wind Turbines for Improved Productivity and Control'. They also demonstrate the performance of a sister product of ZephIR 300 developed by Natural Power called ControlZephIR which is based on a ZephIR but with different system software and mechanical housing to allow the unit to be either spinner or nacelle mounted. ControlZephIR provides wind turbine control systems with the necessary data from a number of distances in front of the turbine. It is this data that allows the turbine to steer in to the wind to maximise performance but, more importantly, steer out of the wind safely in high gusts or turbulence aimed at reducing through-life costs of a wind turbine generator due to operations & maintenance downtime.

Ian Locker, ZephIR MD within Natural Power commented: "We are very proud to be supporting Risø DTU, LM Wind Power and NKT Photonics to demonstrate how ZephIR can be used to improve wind turbine control. These independent results show that whether ZephIR is looking forward for turbine control, or looking up for resource measurement, the system is highly accurate and can actually match the performance of a calibrated wind tunnel. By the end of the year we will have accumulated over 2.5 million operational hours on ZephIR systems globally, and we will also be launching a full commercial ControlZephIR system which has already undergone extensive testing across prototype installations in 2003, 2009 and 2010 and is currently being mass produced in the UK prior to roll-out."

The LM Wind Power wind tunnel is a closed circuit wind tunnel with a closed test section with flow driven by a 1MW fan. A flow speed of up 105m/s can be reached and the good flow quality is achieved with aerodynamically treated corner vanes, a honeycomb structure, 3 screens and a nozzle with a contraction ratio of 10 to 1. The test section is 7m long and has a cross section of 1.35m of width and 2.7m of height.

For more information zephir@yourwindlidar.com or visit www.yourwindlidar.com

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Notes for Editors:

Natural Power provides Practical Consulting, Management Services and Product Innovations across the wind, wave, tidal and biomass arena. Employing over 220 people worldwide, the company has worked on more than 25GW of client projects across Europe and the Americas, whilst also providing extensive due diligence services on portfolios and projects on behalf of major lenders, investors and financial institutions. The group includes offshore experts **SeaRoc** and Turkish based consultancy **re-consult** and has offices across the UK, France, Turkey, Chile and the US. See www.naturalpower.com for more information. *Natural Power – "the international turn-to experts in renewable energy."*

ZephIR wind lidar provides remote resource measurements of wind quality and characteristics from just 10 metres (30 ft) up to 200 metres (650ft) from ground level. Data is transmitted over all types of communications networks and can be accessed 24/7 through Natural Power's secure web portal vuWind. ZephIR has amassed over 2 million operational hours and over 7 years field experience across 450 system deployments. Each system is subject to an industry approved validation process including correlations against the UK's lidar and sodar IEC standard test site. See www.yourwindlidar.com for more information. *ZephIR – "designed by wind engineers for wind engineers."*