IOP Conference Series: Earth and Environmental Science

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To cite this article: P J M Clive *et al* 2008 *IOP Conf. Ser.: Earth Environ. Sci.* **1** 012019

The Myres Hill remote sensing intercomparison study: preliminary results

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Abstract. Two remote sensing techniques (SODAR and LIDAR) have been developed for measuring wind speed and turbulence from ground level up to altitudes of 300 m or higher. Although originally developed in the defence sector, these techniques are now generating considerable interest in the renewable energy and meteorological sectors. Despite the benefits of these instruments they are not yet generally accepted for due diligence measurements by wind energy developers and financial institutions. There is a requirement for a series of independent assessments of these new metrology techniques, comparing their measurements with the approved cup-type anemometer readings. This is being addressed at TUV NEL's Myres Hill wind turbine test site in a measurement programme supported by the DIUS National Measurement Systems Measurement for Innovators scheme and a consortium of 21 industrial collaborators. Data from SODAR and LIDAR systems are being compared with results from cup-type anemometers mounted at different heights on an 80m meteorological mast. An ultrasonic sensor is also mounted on the mast. The objective of the test programme is to assess the effectiveness of SODAR and LIDAR wind speed measurement techniques under different operating regimes and atmospheric conditions. Results from the measurements will provide definitive data on the performance of the remote wind speed sensing techniques under test on complex terrain typical of many wind farm sites. Preliminary measurements based on data acquired during the initial measurement campaign are presented.

1. Introduction

Mature portable remote sensing technologies are now successfully being used for wind power applications [1, 2]. An intercomparison study of remote sensing devices has been undertaken at the TUV NEL Myres Hill test facility near East Kilbride, Scotland. The data acquired using an AQ

IOP Conf. Series: Earth and Environmental Science **1** (2008) 012019 doi:10.1088/1755-1307/1/1/012019

Systems AQ500 SODAR and a NPC/QinetiQ ZephIR LIDAR are being compared to the measurements obtained using conventional mast mounted cup anemometry and ultrasonic anemometry on an 80m tall guyed tubular tower. This study is distinguished by two features: 1) it is industry-led and is supported by a consortium consisting of 21 organizations and 2) the test site is more typical of the upland terrain where wind farms are installed than other test sites that have been used in the past characterized by flat featureless topography [3 - 8]. The study was undertaken to assess the suitability of remote sensing techniques for wind resource assessment applications in a manner that would inform the degree of confidence in the technologies of the industrial partners in the consortium. The process of adoption of remote sensing by the wind power industry is underway but is still at an intermediate stage. The accuracy of these devices, particularly in locations typical of real wind farms, requires further demonstration to support sufficient confidence for remote sensing data to be acceptable for due diligence purposes with a less strenuous requirement for continuous instrument validation than is presently the case [9]. In addition, one of the main objectives of the test is to assess these systems in their off-the-shelf configuration.

At the time of writing the measurement campaign was still underway and as a consequence of this preliminary measurements are presented here using data acquired between the dates 2008-02-05 and 2008-02-29. The ZephIR was co-located with the mast at E 256910, N 646490 whereas the AQ500 was deployed to E 256910, N 646270 some 300m distant to the South of the mast location. The initial test setup had placed the AQ500 system 80m due West of the intended mast location prior to mast erection. However, upon completion of mast installation, a clear fixed echo could be seen in both the shear profile and the system spectra. After consultation with the manufacturer, AQ Systems, the system was redeployed 300m from the reference mast in a South Westerly direction. Care was taken to ensure the AQ500 was located upwind of the reference mast in the predominant site wind direction. The configuration of the mast is illustrated in Figure 1 and the instruments installed on it are listed in Table 1. The locations of the devices relative to each other are shown in Figure 2. Figures 3 and 4 show the ZephIR and AQ500 respectively.

Two NEG Micon NEM 900/54 wind turbines are located at E 256959, N 646765 and E 256995, N 646490. These have a hub height of 60m and a rotor diameter of 54m and present obstacles that perturbed the flow in certain direction sectors relative to the mast/ZephIR and AQ500 locations. The free stream sectors at each location were calculated in compliance with IEC 61400-12 and are detailed in Table 2. Data acquired when the wind was blowing from these free stream directions at the relevant remote sensing device locations were included in the results presented here.

Table 1. Instruments installed on the mast.

Reference	Instrument			
	Type		Height (m)	Orientation (degrees)
WS1	Anemometer	Risø P2546A	80.35	306
WS2	Anemometer	A100L2	80.35	126
WS3	Anemometer	A100L2	65.00	182
WS4	Anemometer	A100L2	50.30	270
WS5	Anemometer	A100L2	50.05	182
WS6	Anemometer	A100L2	30.25	266
WS7	Anemometer	A100L2	30.00	182
WS8	Anemometer	A100L2	20.00	183
WS9	Anemometer	A100L2	10.00	183
DIR1	Wind Vane	W200P	77.70	222
DIR2	Wind Vane	W200P	45.00	221
DIR3	Wind Vane	W200P	25.00	222
TEMP_1	Temperature		76.90	-
TEMP_2	Temperature		1.00	-

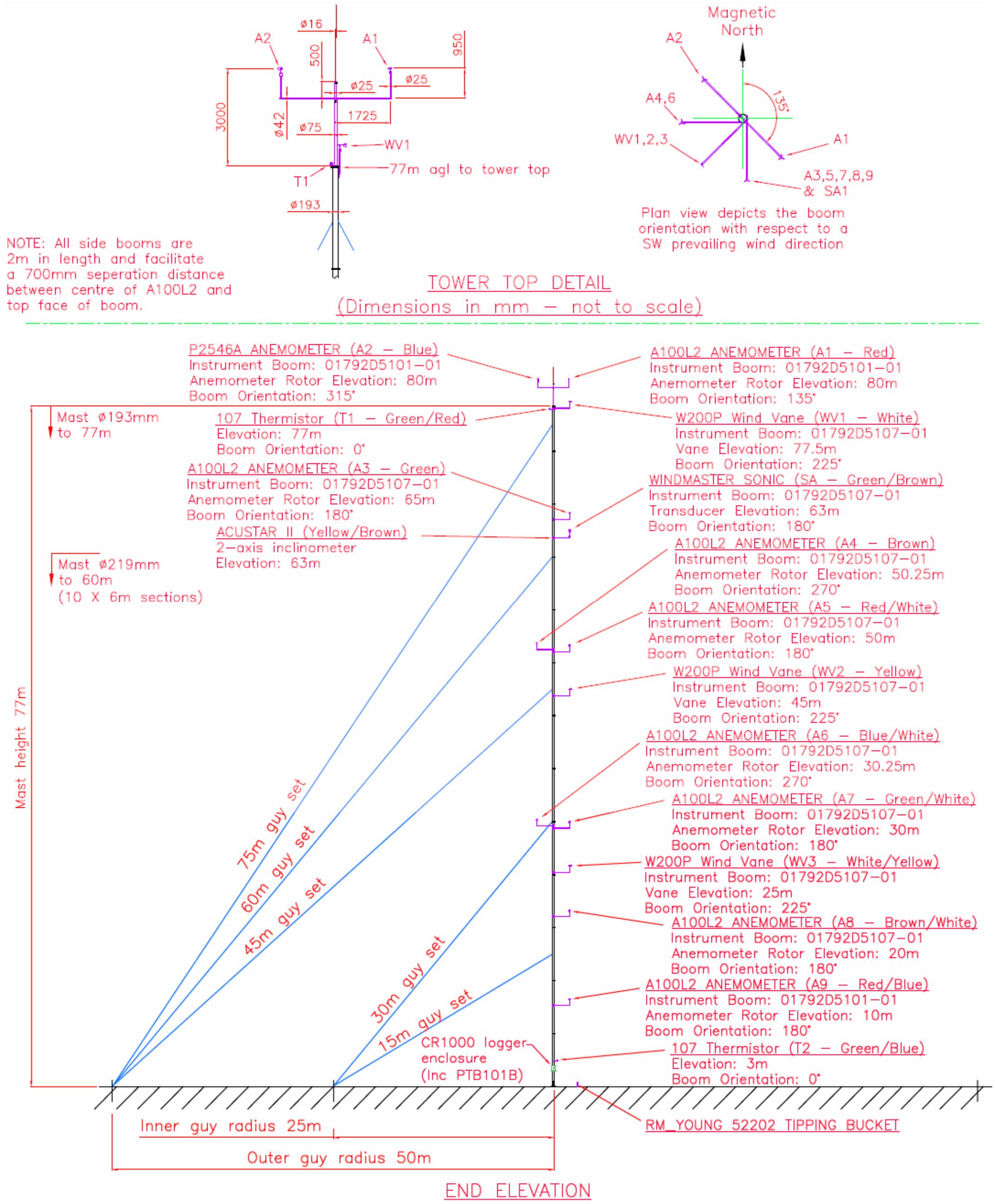

Figure 1. Mast configuration.

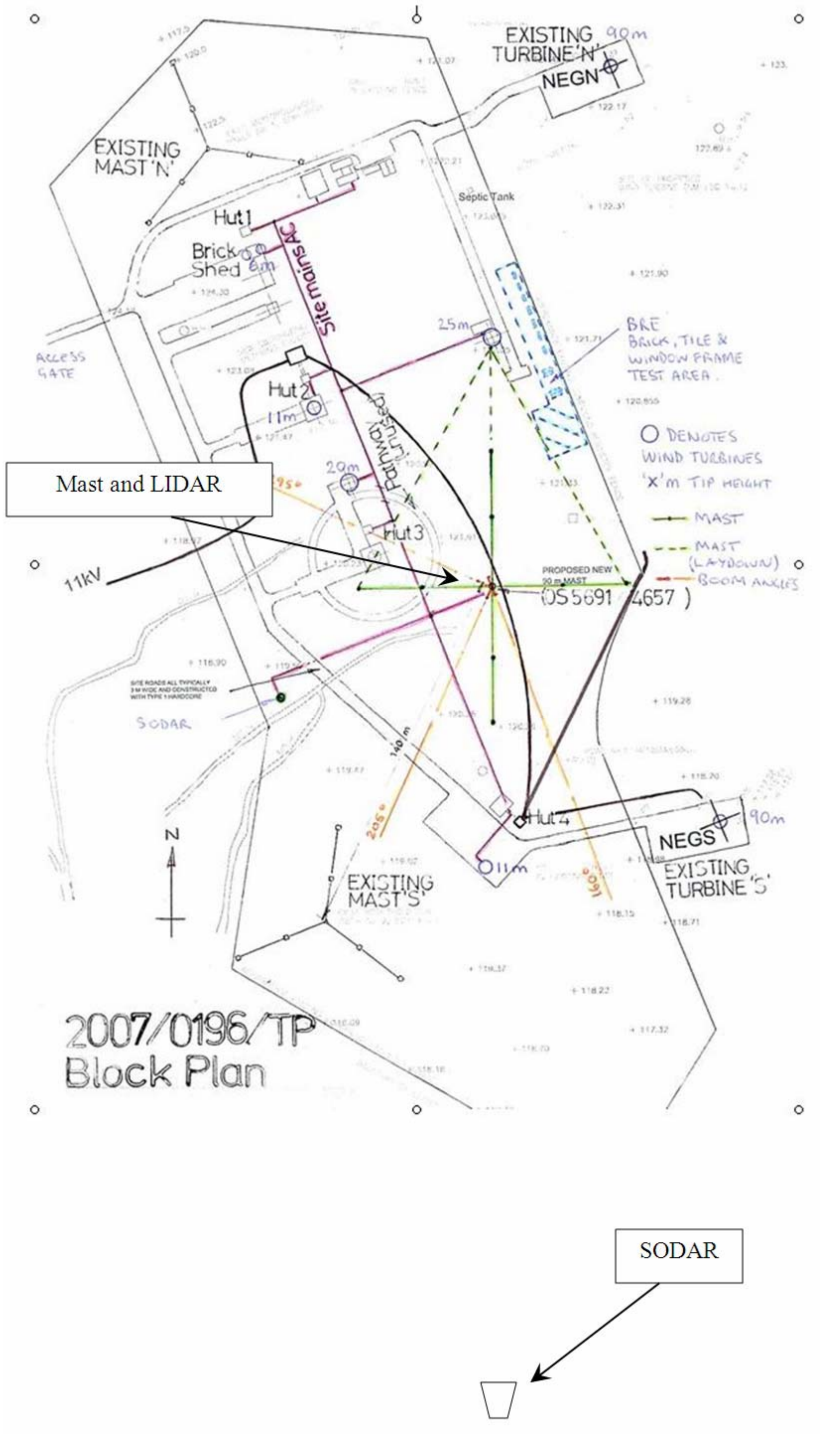

Figure 2. Instrument locations.

Table 2. Free stream sectors, clockwise from North.

Location	From (degrees)	To (degrees)
North turbine: E 256959, N 646765	205.14	139.95
South turbine: E 256995, N 646490	25.14	319.95
Mast/ZephIR: E 256910, N 646490	52.31	83.66
	182.87	335.90
AQ500: E 256910, N 646270	56.42	340.62

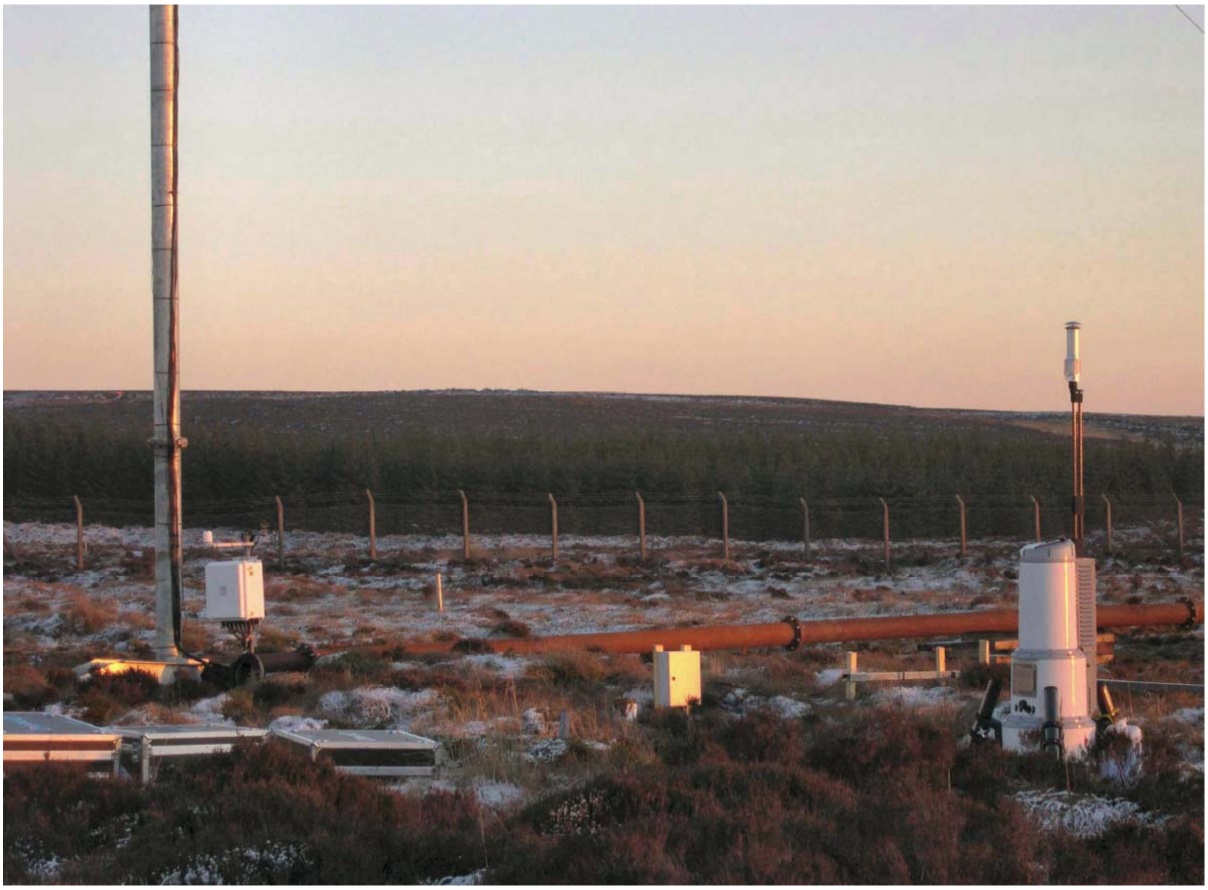

Figure 3. NPC/QinetiQ ZephIR Lidar co-located with mast.

2. ZephIR Measurements

Figure 5 shows a time series trace comparing the 80m ZephIR data to the 80m mast data. Figure 6 shows a time series trace of the difference between the mast and ZephIR measurements at this height. It is clear that there are periods when the ZephIR was not operating satisfactorily. Figure 7 shows the diurnal variation in the difference between the mast and the ZephIR measurements. There is some indication that the deterioration occurs mainly between the hours of 20:00 in the evening and 10:00 in the morning. Figure 8 shows the linear regression of the ZephIR data on the mast data.

Figure 4. AQ Systems AQ500 SODAR.

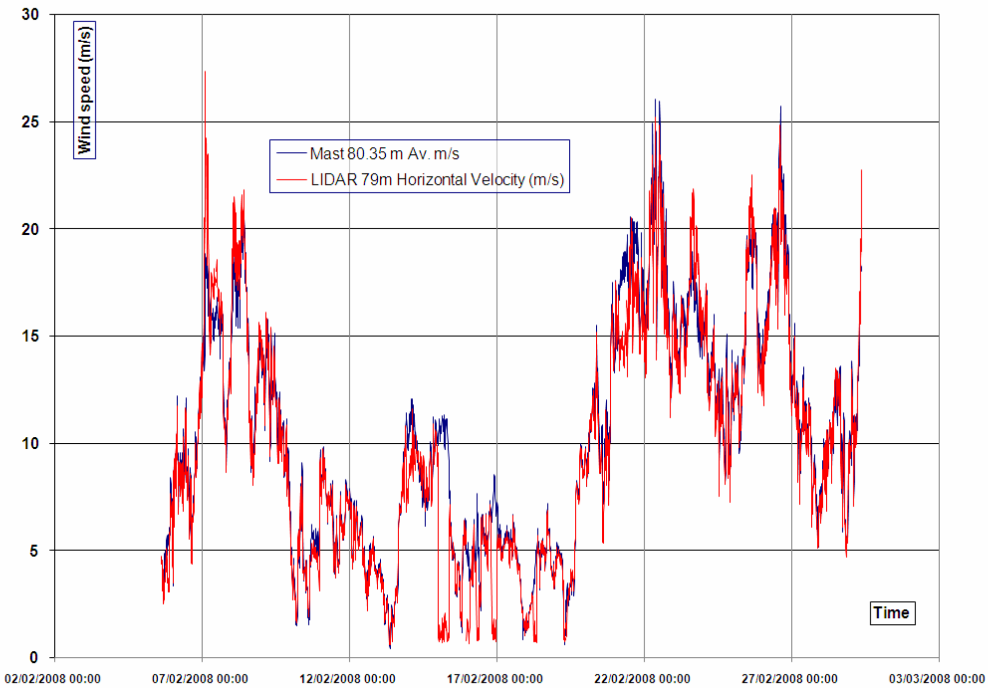

Figure 5. ZephIR and mast time series, 80m, 2008-02-05 to 2008-02-29.

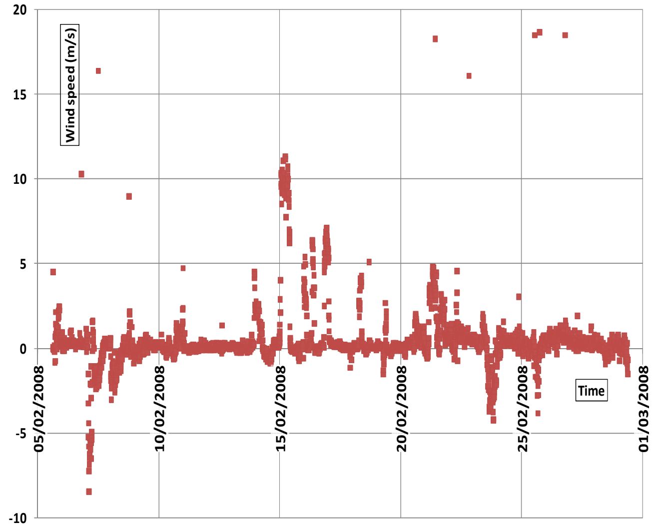

Figure 6. Time series of the difference between mast and ZephIR 80m data.

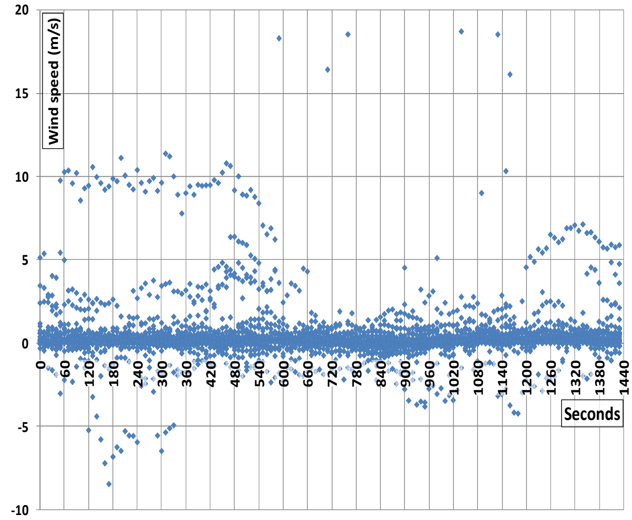

Figure 7. Diurnal variation in difference between mast and ZephIR 80m data.

It is clear that further investigation is required to ascertain the reasons for the anomalous behavior during the periods highlighted in Figure 6. Similar results are observed when comparing the data pertaining to the other measurement heights, which will be fully reported once the measurement campaign is concluded. The linear regression shown in Figure 8 has been constrained to pass through the origin to aid comparison with other, similar studies.

3. AQ500 Measurements

Figure 9 shows the time series trace of the 80m measurements from the mast and the AQ500. Figure 10 shows the linear regression of the free stream AQ500 data on the mast data at this height. This fit is not constrained to pass through the origin on the grounds that the measurement devices being compared are not co-located.

The agreement between the AQ500 and the mast was encouraging, given the distance of 300m between them. Again, a slope $m < 1$ is observed, however due to the fact that the devices are not co-located no conclusions can be drawn about possible volume averaging effects. However, the under-estimation of winds at low wind speeds is typical of the influence of echoes from fixed objects such as a mast or turbine. At low wind speeds the spectral peak from such echoes is close to that from the atmosphere and often a combined peak results, giving bias toward lower estimated wind speeds. Further analysis will be done on this.

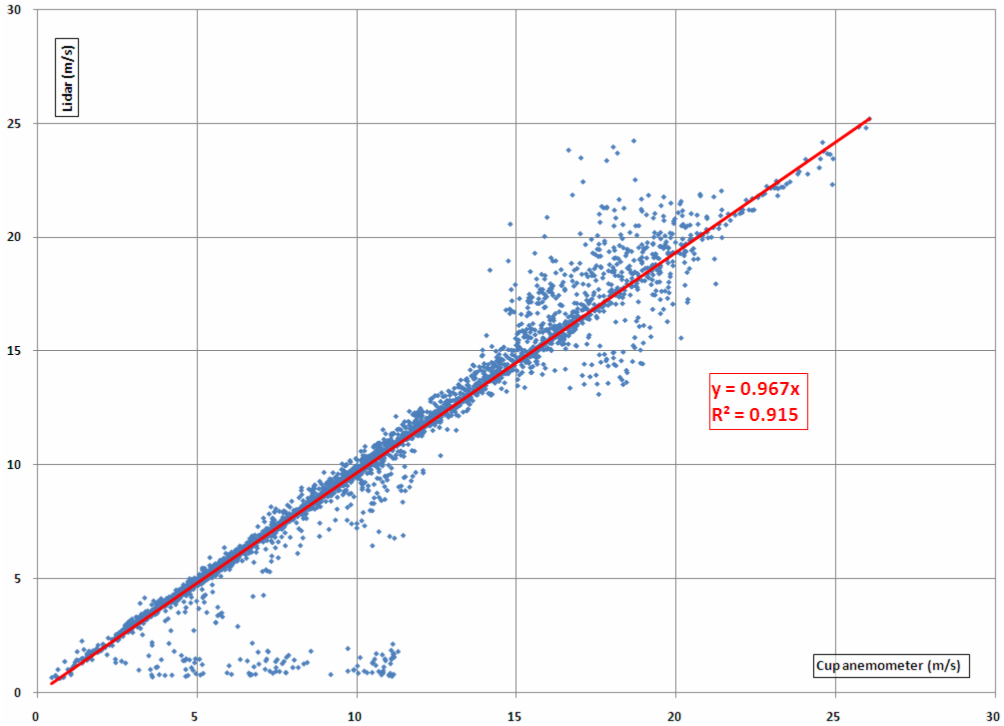

Figure 8. Linear regression of ZephIR and Mast 80m free stream measurements.

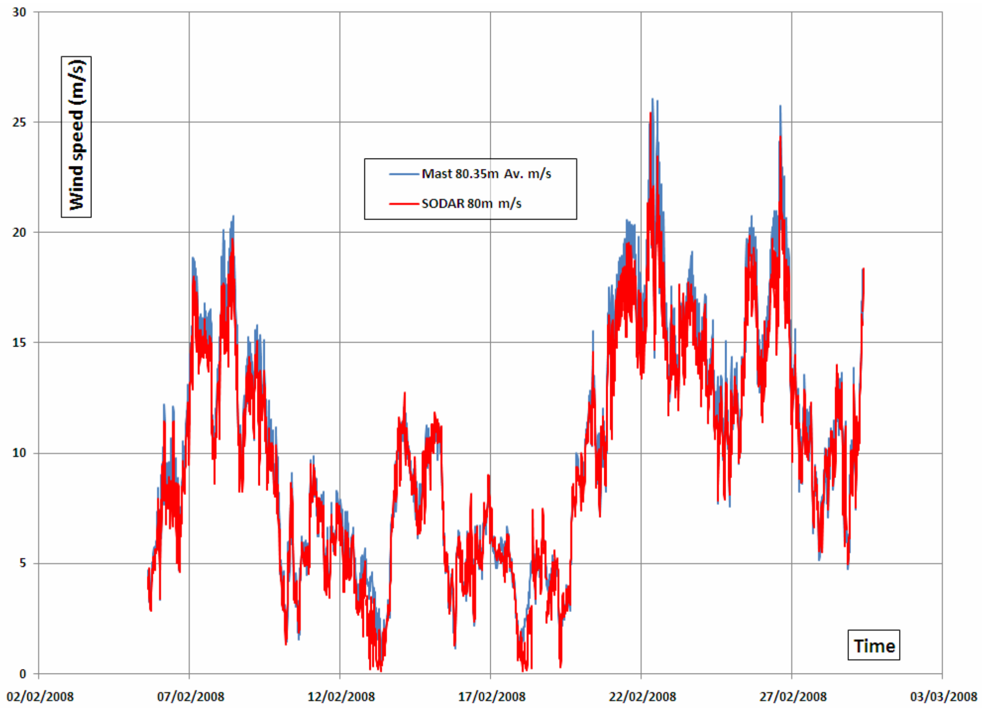

Figure 9. AQ500 and mast time series, 80m, 2008-02-05 to 2008-02-29.

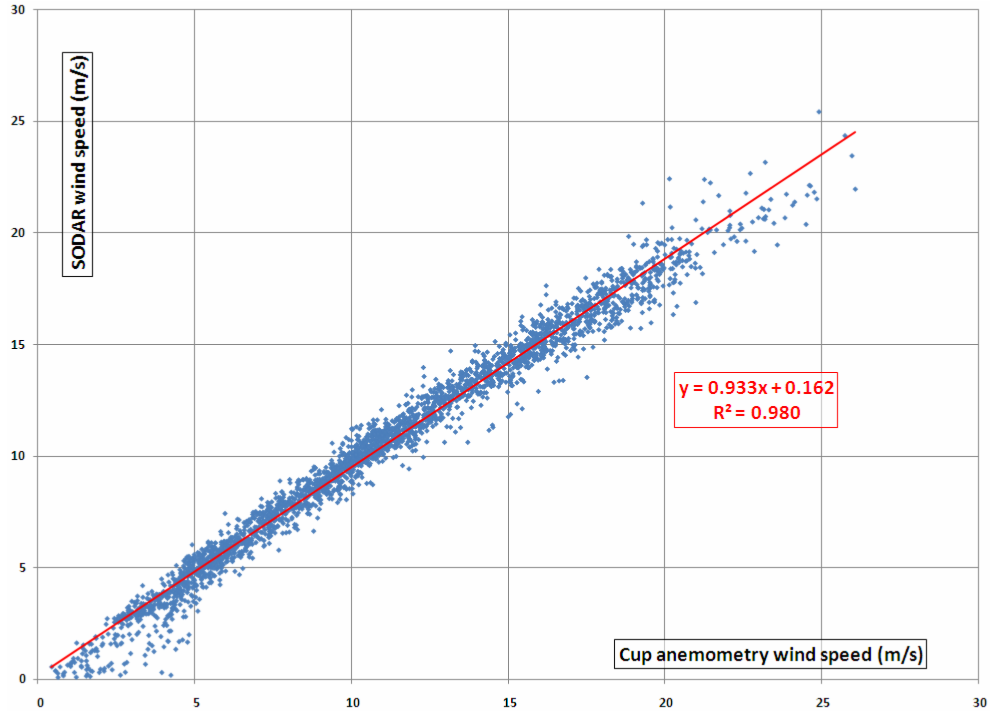

Figure 10. Linear regression of AQ500 and Mast 80m free stream measurements.

4. Conclusions

The data presented here are preliminary and the measurement campaign that produced the data has not yet concluded. The campaign is scheduled to conclude during April/May 2008 and the final analysis and results of this measurement campaign will be reported more fully in other publications in the near future, in particular at ISARS 2008 towards the end of June 2008.

Periods of anomalous behavior were observed in the ZephIR data, necessitating further investigation. It is likely that this behavior is attributable to unresolved issues around contamination of ZephIR data by higher-altitude cloud. This ZephIR is known to have a very extended range of sensitivity which, when coupled with the very high reflectance from overlying cloud, can give wind speeds from the cloud level rather than from the focal point of the laser beam. Since winds are frequently observed to increase in strength with height, this will tend to give overestimation of wind speeds. The ZephIR suppliers have developed, since these measurements were made, a new algorithm for largely removing this problem, and this algorithm will replace the current version in further comparisons.

Encouraging agreement between the AQ500 and mast data was observed.

The ongoing test program includes the co-location of the ZephIR and AQ500 to help mitigate terrain influence on the results. It is planned to use a second ZephIR unit in parallel with the current ZephIR unit. Initially, the second ZephIR will be co-located with the current unit for two weeks after which the current ZephIR will be co-located with the AQ500 for two weeks. This will allow direct comparison of the two sets of ZephIR measurements when co-located and when 300m apart. It will also provide a secondary set of ZephIR measurements that can be correlated against the mast when the AQ500 and primary ZephIR are co-located as well as a direct correlation between AQ500 and primary ZephIR at the same location.

Acknowledgements
The authors would like to thank the consortium members for their support, including:

Airtricity	NaREC	ScottishPower Renewables
AMEC Wind Energy	Natural Power	Shell WindEnergy
BP Alternative Energy	npower renewables	SgurrEnergy
E.ON UK	Oldbaum Services	TUV NEL
Garrad Hassan	REpower	University College Cork
Gamesa Energy UK	RES Group Ltd	University of Strathclyde
Mighty River Power	Scottish Enterprise	Vestas Northern Europe

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