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Demonstration of short-range wind lidar in a high-performance wind tunnel

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Abstract

A short-range continuous-wave lidar is tested in a high-performance wind tunnel. The lidar is tested in a low as well as a high speed regime ranging from 5-35 m/s and 40-75 m/s, respectively. In both low and high-speed regimes very good correlation with reference measurements is found, showing the high accuracy of the lidar and indicating a possible future for short range lidars as a complement to LDA and other standard equipment in wind tunnels.

Introduction

The use of lidars for e.g. site assessment has increased in the recent years as a logical consequence of improvement in accuracy and reliability. Also for use in active turbine control do lidars show great promise[1,2,3]. Some of the advantages of lidars for wind speed measurements lie in the fact that they measure remotely, meaning that no tall mast is necessary, and that they can easily be moved from site to site. This, however , not only applies for atmospheric measurements, but also could be utilized in e.g. wind tunnels where one would benefit from a spatially localised measurement at almost any point in space without disturbing the flow.

In this study we test a short-range continuous-wave (CW) lidar for use in a high-performance wind tunnel and compare its performance against a calibrated Pitot tube as well as a system of pressure sensors and extremely good correlation is found.

Methods

Figure 1

The lidar used is a ZephIR 300[4] with modified transceiver unit, consisting of a telescope with two-inch diameter lens and manually adjustable focus. The telescope is connected to the lidar base unit through fibre optic cables fed through a hole in the tunnel wall, and the base unit is thus placed outside the wind tunnel during operation. The focus of the telescope can be set from 1m to 20m and this short range is necessary due to the tight confinement of the tunnel.

Several configurations were investigated; for the results reported here the transceiver is attached to a crossbar in the centre of the tunnel and pointed horizontally into the wind flow with focus distance 3.3 m. The focus lies well inside the stable test section of the tunnel and only a few centimetres above a Pitot tube used as reference. Another reference is provided by a system of pressure sensors situated in the inlet contractor to the test section.

The wind speed is ramped up in discrete steps while measurements are carried out using the lidar, Pitot tube and pressure sensor system simultaneously. For each step, the period of stable speed is 2 minutes.

Figure 1.Photograph taken during the experiments showing two lidar transceivers mounted inside the wind tunnel.

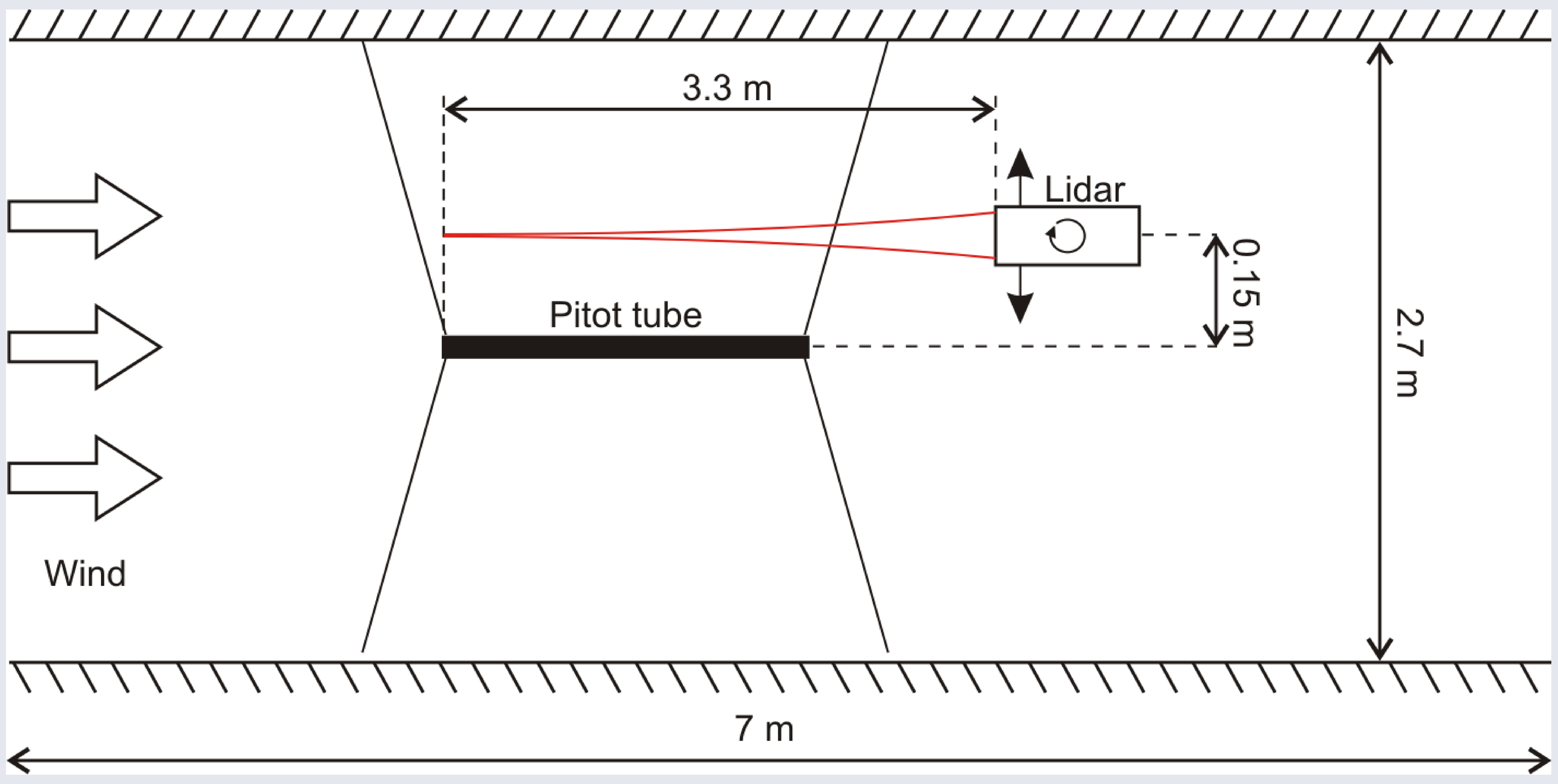

Figure 2

Figure 2 shows a sketch of the experimental setup. The lidar focus lies 15 cm above the Pitot tube well inside the stable test section of the tunnel.

Results

Low speed regime – 5-35 m/s

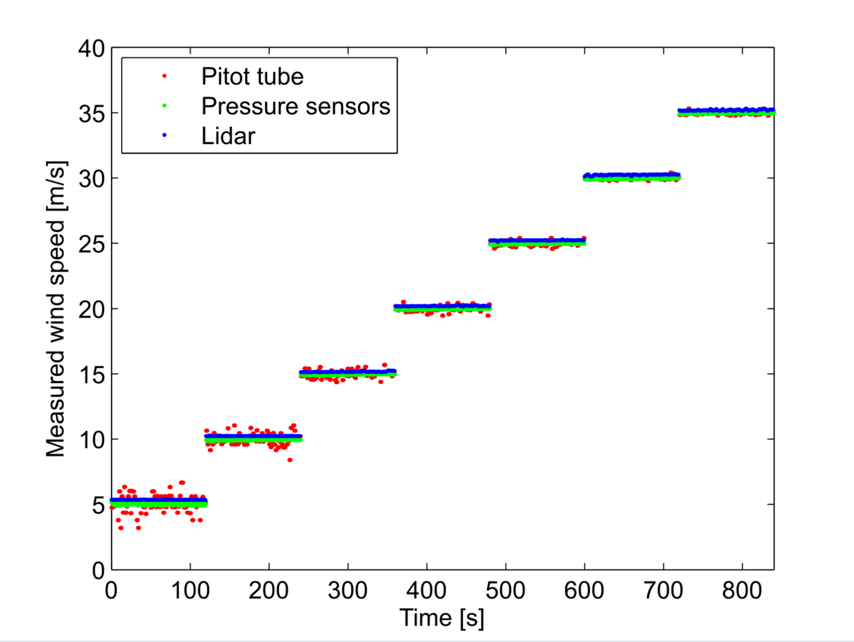

Figure 3(a)

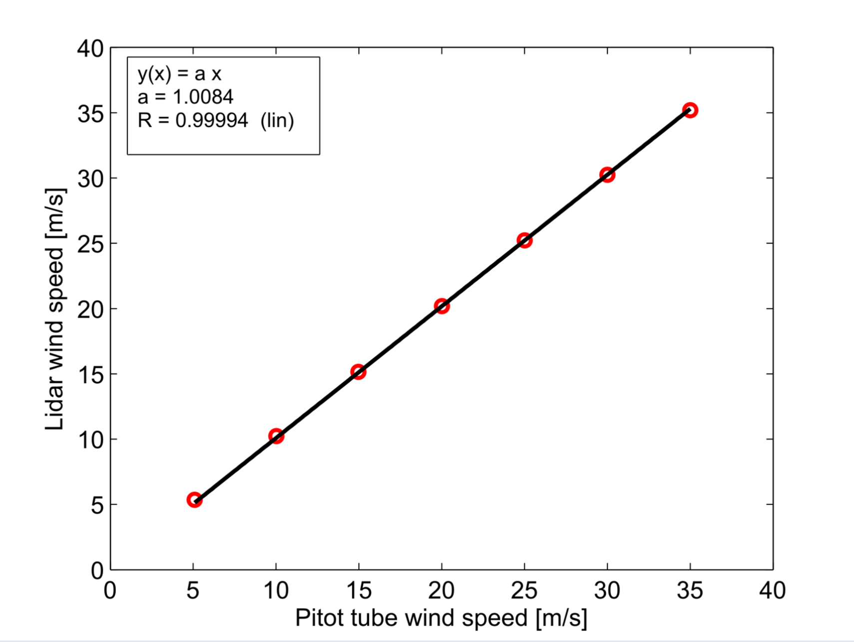

Figure 3(b)

High speed regime – 40-75 m/s

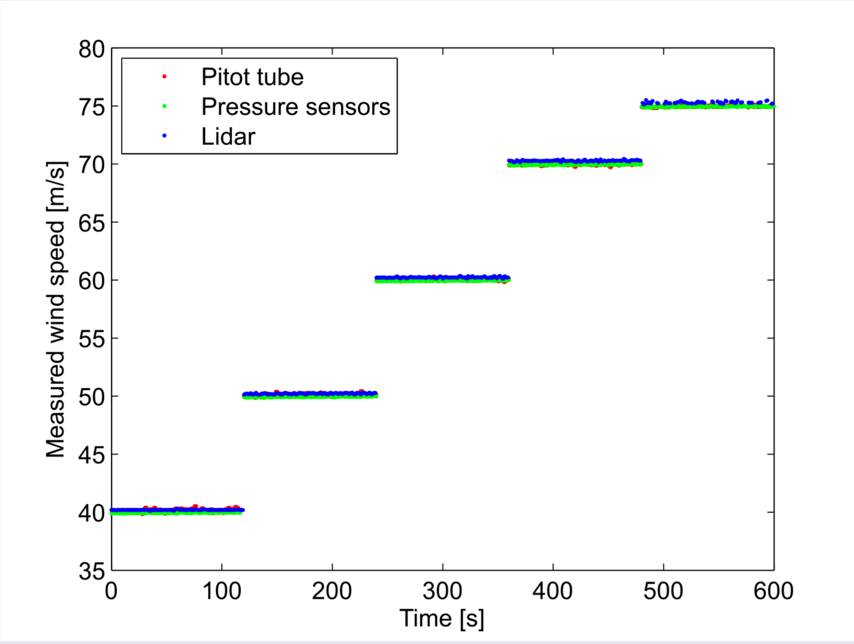

Figure 4(a)

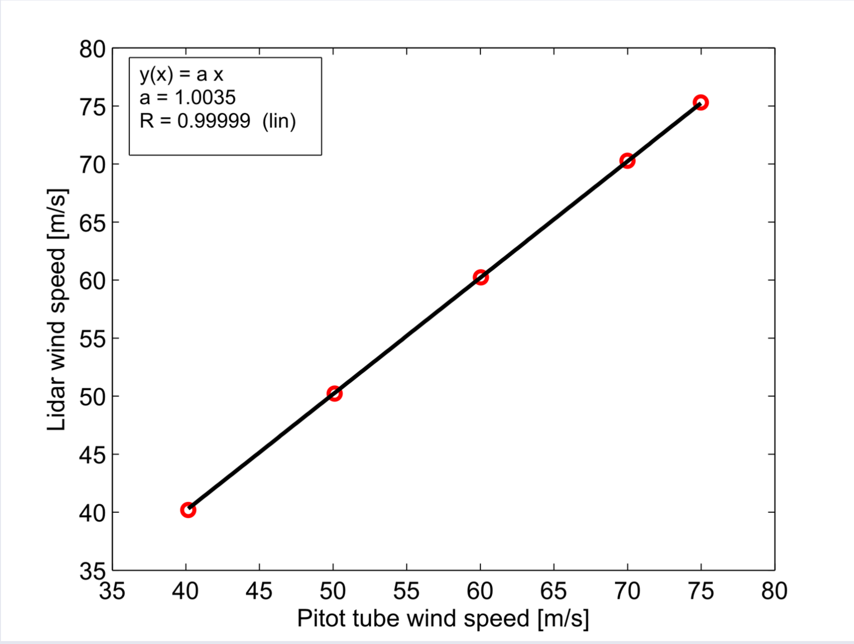

Figure 4(b)

Figures 3(a) and 4(a) show the wind speed measured using the lidar and the two reference systems as function of time. Each step represents two minutes with the wind tunnel running at a constant speed. Figures 3(b) and 4(b) shows the measured mean wind speed over each stable two minute period plotted against the measurements of the reference Pitot tube. Shown is also a linear fit and very good correlation is found in both regimes.

Conclusions

Wind speeds compare very highly against the tunnel's calibrated sensor systems across the entire range, providing further confidence in the long-term calibration of lidar for resource assessment, or for e.g. enhanced turbine pitch control via small telescopes integrated into the blades. Due to the absolute nature of the lidar measurement, no calibration of lidar speed was required either before or during the tests. In addition, the high stability and accuracy of lidar calibration suggests a possible use for cross-calibration of different wind tunnels, as well as potential for lidar to supersede cup anemometry as a primary standard.

Other experiments were performed, including investigations at different range settings and angles to the flow. Turbulence studies were also undertaken, and in a subsequent trial, a dual-telescope arrangement was successfully employed to characterise the flow in 2D. Analysis of these tests is ongoing and the results will be reported at a later date.

References

1. Harris, M., Bryce, D., Coffey, A., Smith, D., Birkemeyer, J., Knopf, U., Advance measurement of gusts by laser anemometry, *Journal of Wind Engineering and Industrial Aerodynamics,* 95, 1637-1647, 2007
2. Mikkelsen, T., Hansen, K. H. Angelou, N. Sjöholm, Harris, M., Hadley, P. Scullion, R., Ellis, G., Vives, G., Lidar wind speed measurements from a rotating spinner, *EWEC 2010 online Proceedings*, 8 pp, 2010 European Wind Energy Conference and Exhibition, Warsaw (PL), 20-23 Apr, 2010.
3. http://www.windscanner.dk
4. http://www.yourwindlidar.com/

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