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Stickland, Matthew and Scanlon, Thomas and Fabre, Sylvie (2011) *Feasibility Study of using a LiDAR in the complex flowfield of an offshore platform, to measure wind shear profile*. In: EWEA Offshore 2011: Moving Ahead of the Energy Curve, 2011-11-29 - 2011-12-01, Amsterdam.

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Feasibility Study of using a LiDAR in the complex flowfield of an offshore platform, to measure wind shear profile.

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Abstract

Offshore wind is the major growth area in the wind industry sector today. However, there remains a key, fundamental missing element - a thorough understanding of the offshore wind climatology and likely wind resource. In 2008 the EU FP7 funded project NORSEWInD was created with a remit to deliver offshore wind speed data at a nominal project hub height acquired in offshore locations in the North, Baltic and Irish seas.

Part of the overall NORSEWInD project was the use of LiDAR remote sensing (RS) systems mounted on offshore platforms to measure wind velocity profiles at a number of locations offshore. The data acquired from the offshore RS measurements was fed into a large and novel wind speed dataset suitable for use by the wind industry. The data was also fed into key areas such as forecasting and MESOSCALE modelling improvements. One significant problem identified was the effect of platform interference effects on the RS data. Therefore, part of the fundamental research incorporated into the NORSEWInD project was an investigation into the possible extent and effect of the interference on the measured data from the various mounting platforms.

This paper reports on the Computational Fluid Dynamics (CFD) modelling of the wind flows over the platforms and the verification of the CFD models by the use of sub scale wind tunnel models employing three dimensional Constant Temperature Anemometers (CTAs) to measure local velocity vector data. The report discusses the levels of interference that might be found on a typical offshore platform; the transformer platform at the Horns Rev wind farm off of the coast of Denmark, figure 1.

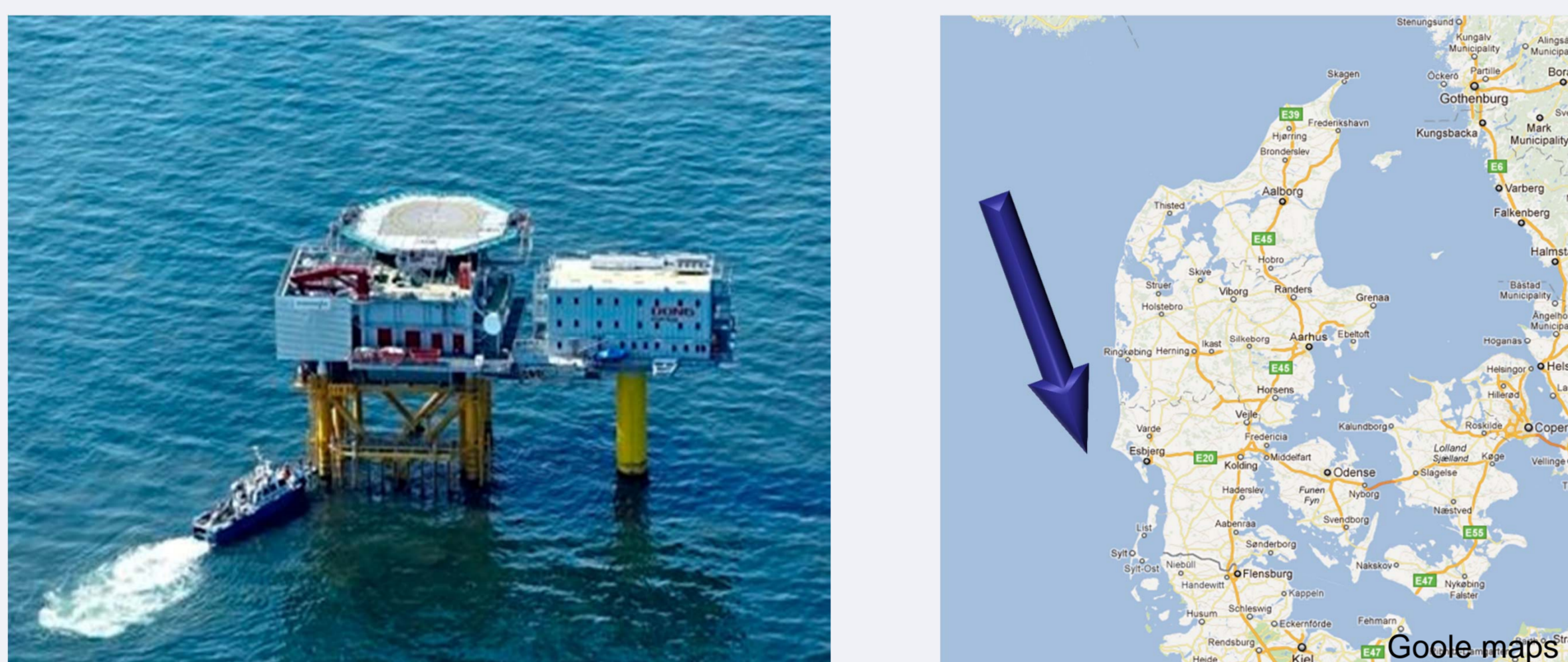


Figure 1: Horns Rev Transformer platform

Method

Whilst the CFD simulation of the flow over the platform can give an estimation of the distortion of the flow field on point measurement quite readily. The effect of the flow distortion on the output of the LiDAR required a more complex analysis. This analysis required the CFD data to be interrogated as if a LiDAR was actually present in the simulation which, in the case of a Leosphere Windcube, meant interrogating the flow field at four points on a cone expanding with height, figure 2.

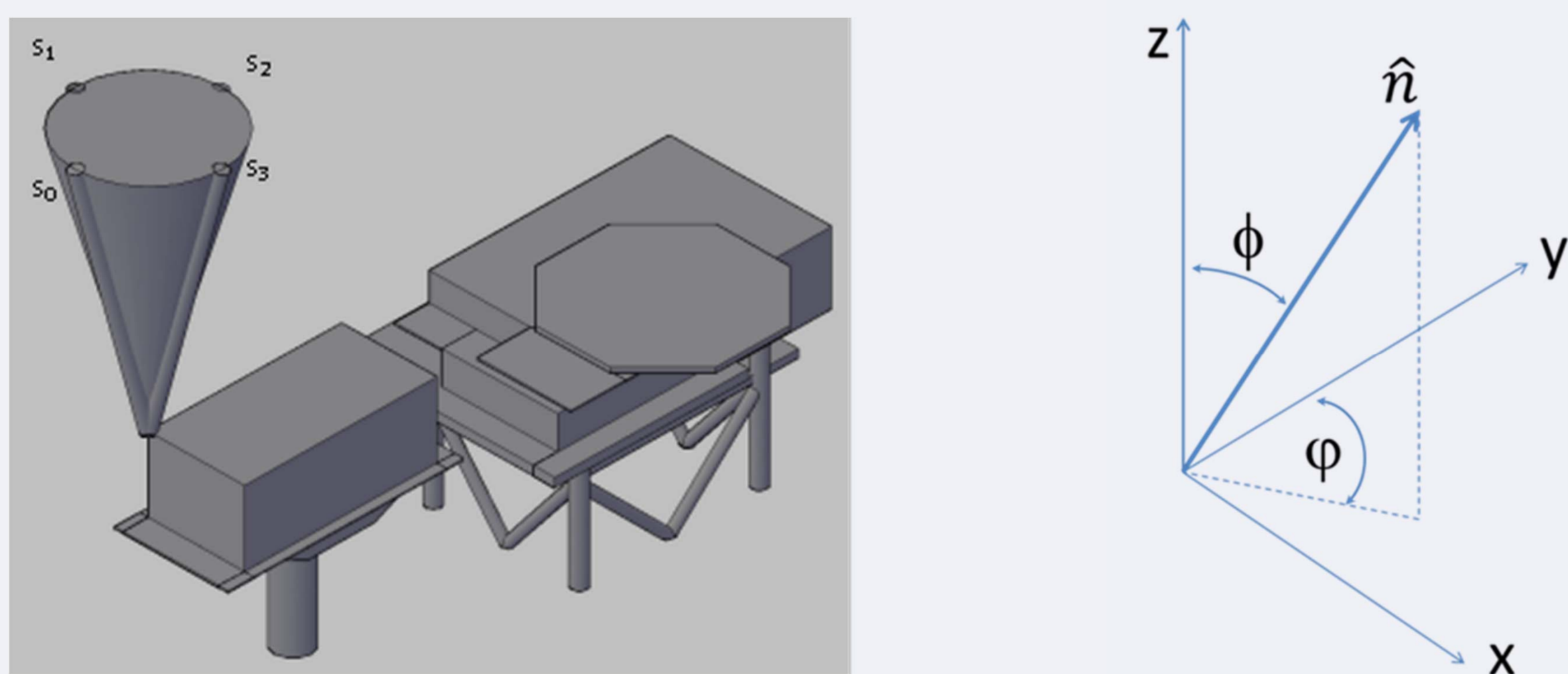


Figure 2: Leosphere Windcube measurement locations

The Windcube calculates the wind speed by measuring the Doppler shift in light reflected from particles entering a laser beam projected into space. The speed measured is the projection of the wind vector on to the unit vector in the direction of the laser beam, V_{los} , given in equation 1 by Bingöl et al (2008).

$$V_{los} = u \sin \phi \sin \varphi + v \sin \phi \cos \varphi + w \cos \phi \quad \text{Equation 1}$$

From the four measurement points the velocity is calculated from equations 2, 3 and 4

$$u = \frac{S_1 + S_3}{2 \cos \phi} \quad \text{Equation 2}$$

$$v = \frac{S_0 - S_2}{2 \sin \phi} \quad \text{Equation 3}$$

$$w = \frac{S_0 + S_2}{2 \cos \phi} \quad \text{Equation 4}$$

By interrogating the flow field above the platform in the CFD simulation in the same way it is possible to calculate what the output of a LiDAR would be. The velocity measured by the simulated LiDAR may then be compared with the free stream at the measurement height and a correction factor determined for the velocity magnitude in the horizontal plane and a correction added for the azimuth angle, equations 5 and 6.

$$c_{ff_u} = \frac{u_{free\ stream}}{u_{lidar}} \quad \text{Equation 5}$$

$$c_{ff_\theta} = \theta_{free\ stream} - \theta_{lidar} \quad \text{Equation 6}$$

Results

Plotting the calculated correction factors against height for different wind directions, figure 3, it was possible to determine the extent of the flow distortion above the platform.

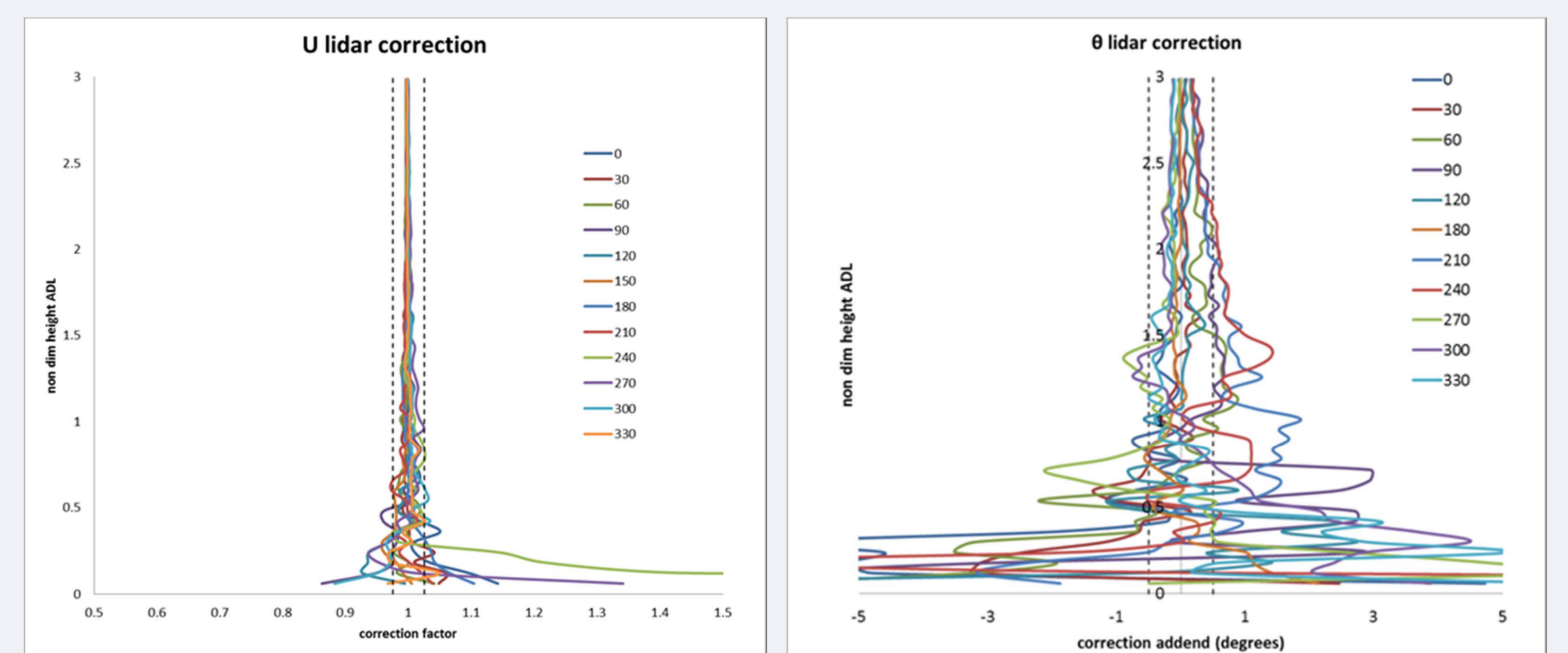


Figure 3: U_{mag} and θ correction factors

To determine the height at which the flow could be considered outwith the distortion field the accuracy of a standard cup and vane anemometer was considered. Assuming that the accuracy of a cup anemometer is $\pm 2.5\%$ and the direction vane is $\pm 0.5^\circ$ then, if the difference between the free stream and the velocity measured above the platform is within these tolerances then it is assumed that any interference is negligible. For the Horns Rev 2 transformer platform considered in this paper the Windcube measurements were made at 40, 60, 80, 100, 120, 140, 170, 200, 230 and 160 metres above deck height.

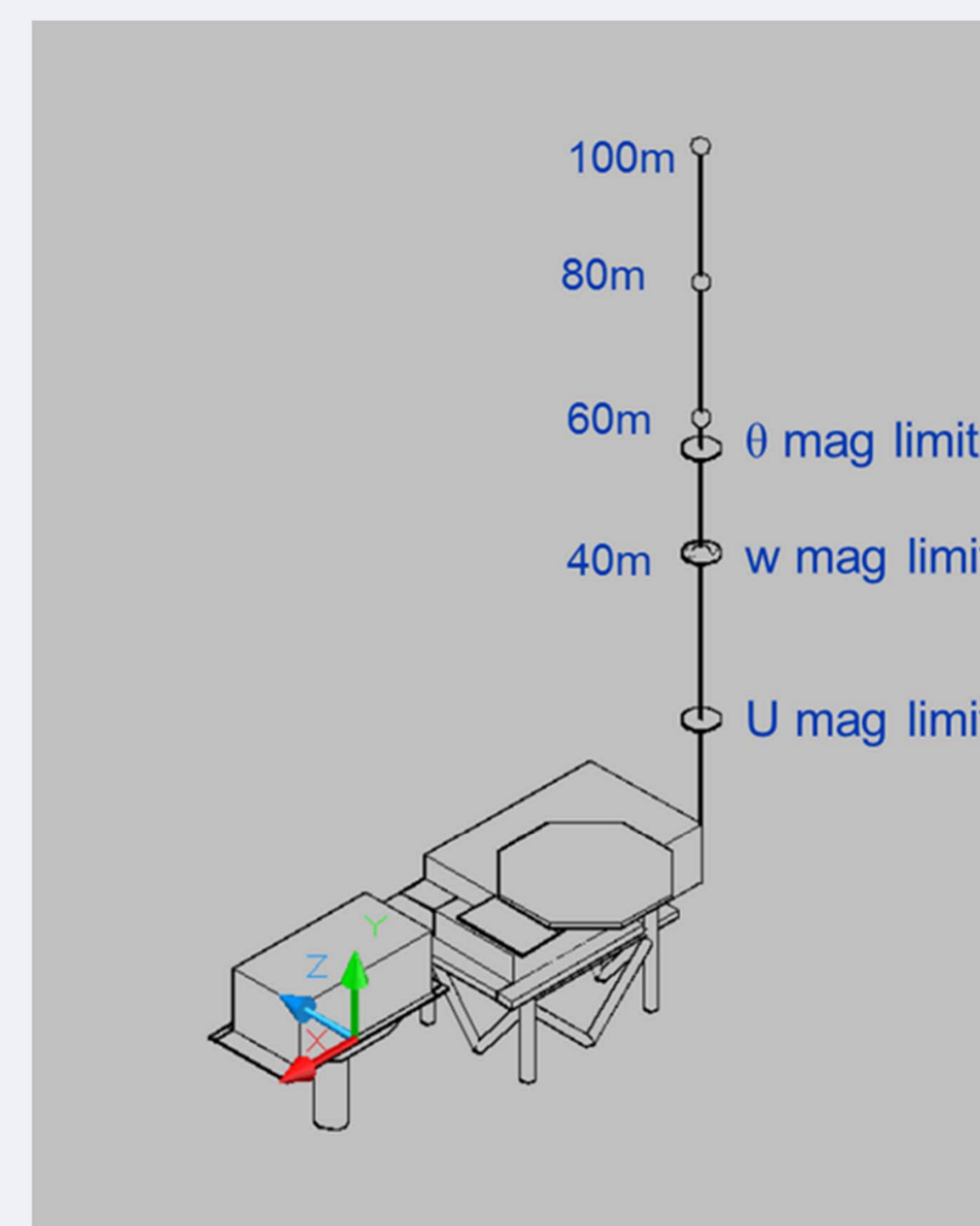


Figure 4: distortion limit

From figure 3 it may be seen that the U magnitude correction factor falls within the tolerance of $\pm 2.5\%$ by 15m and the theta correction factor within the tolerance of 0.5° by 58m. This would indicate that all velocity magnitude data was unaffected by flow distortion and that the wind direction data was unaffected at all heights apart from the very lowest, 40m, height. However, as the difference between the free stream and measured data is known it is possible to correct the measured, distorted, data to account for the flow distortion by rearranging equation 5 and calculating the free stream flow angle.

Conclusions

A technique for estimating the effect of flow distortion on the measurements made by a Windcube LiDAR mounted on an offshore platform has been presented. The method has been applied to the LiDAR mounted on the Horns Rev platform and has shown that all data measured above 40m is unaffected by flow field distortion

References

LiDAR error estimation with WASP Engineering F Bingöl, J Mann and D Foussekis 14th International Symposium for the Advancement of Boundary Layer Remote Sensing. IOP Conf. Series: Earth and Environmental Science 1 (2008) 012058