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NORSEWInD Data Report and Correction Data for Berlengas

M T Stickland, S Fabre, T Scanlon

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Department of Mechanical and Aerospace Engineering
University of Strathclyde
75 Montrose St, Glasgow
G1 1XJ

Fax +44 141 552 5105 Email: matt.stickland@strath.ac.uk
Tel: +44 141 548 2842

ABSTRACT

The flow field over Berlengas has been simulated on both a sub scale wind tunnel model in a low speed wind tunnel and in a computational fluid dynamics simulation. The CFD model has been validated by the results of the wind tunnel simulation.

A simulation of measurements that would be made by a ZephIR LiDAR mounted on the island has been undertaken using the CFD results

A method by which the distortion to the flow field over an offshore platform, measured by either a met mast or LiDAR, can be corrected back to the free stream value has been presented and verified.

Correction factors have been calculated and are included in the appendix to this report.

Based on the CFD and wind tunnel data it is was evident that significant flow distortion exists up to 425m above the island.

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NOMENCLATURE

AMSL	Above Mean Sea Level
AGL	Above Ground Level
LAT	Lowest Astronomical Tide
MS	Model Scale
NDH	Non Dimensional Height
FS	Full Scale
MS	model scale
H	Reference height: location of LiDAR on island 0.078m MS, 97.5m FS
β	Rotation of island relative to wind tunnel axis
γ	Rotation of LiDAR relative to North
θ	Azimuthal angle of wind vector.
ϕ	LiDAR cone angle
φ	LiDAR asimuth angle
u, v, w	Orthogonal components of velocity vector
U	Magnitude of velocity vector
CTA	Constant Temperature Anemometry (Hot Wire)
CFD	Computational Fluid Dynamics
V_{los}	Component of the velocity vector in the direction of the laser beam
cff	correction factor LiDAR to free stream
cfp	correction factor LiDAR to point

INTRODUCTION

Wind Resource data is a key component for all offshore wind projects. As the deadline for the EU's promised 20% reduction in carbon emissions by 2020 fast approaches, offshore wind is the key area of expansion for most EU member states in order to meet their renewable energy obligations. However, there remain significant challenges ahead, not the least of which is the availability of good quality wind speed data to facilitate better project planning, accurate yield prediction, and a fundamentally better understanding of the offshore working environment.

To address this issue the EU, FP7 funded, NORSEWInD project was established in order create a wind atlas of the North, Baltic and Irish seas by mounting instrumentation on offshore installations to assess the local wind conditions. Because all offshore installations are large structures and therefore influence the local flow it was deemed necessary to assess the interference effect of the structures on the wind data acquired.

The University of Strathclyde in Glasgow was tasked with assessing the interference effect of the installation platforms on the data measured by the anemometers. There are several types of anemometers employed on the platforms: LiDAR (LEOSPHERE and ZephIR), the more conventional cup and vane met masts, and some derrick mounted met stations. The effect of flow distortion on the cup and vane type anemometer, being essentially point measurements, is easily understood and measured. However, the remote sensing devices, LiDARs and SoDARs, determine the wind vector from a spatially averaged set of measurements. The effect of the flow distortion in close proximity to a structure on these types of devices has not been investigated before.

This report discusses the effect of flow distortion on measurements made by a ZephIR LiDAR mounted on Berlengas, figure 1, and proposes a set of correction factors which may be applied to the measured data.

ISLAND DESCRIPTION

Full Island

Figure 1: Photograph of Berlengas

The Berlengas archipelago is a group of small islands 10 to 15 kilometres off the Portuguese coast, west of the town of Peniche. figure 2.

Figure 2; Berlengas location

LiDAR installation

At the time of writing this report there was no data available about the installation of the LiDAR on Berlengas so it was assumed that the LiDAR was installed next to the met mast in the centre of the island and aligned with magnetic north. The correction factors contained within this report are therefore valid for the position marked on figure 3.

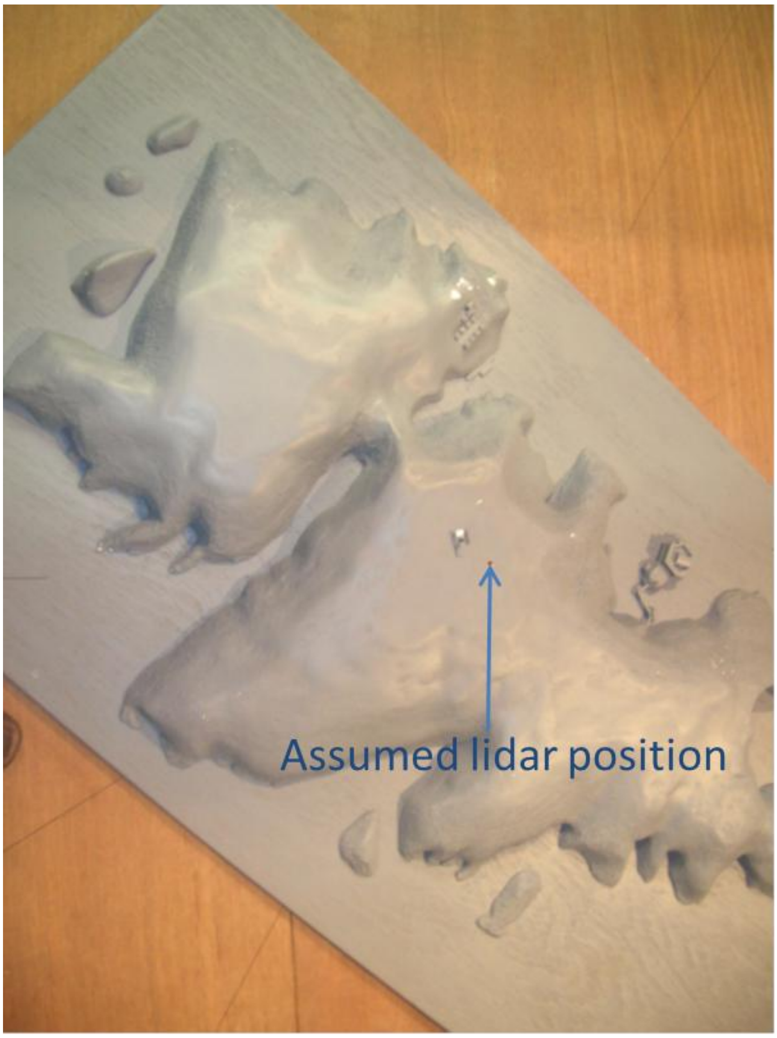


Figure 3; lidar location

WIND TUNNEL SIMULATION

Wind Tunnel Model

The wind tunnel model was created to 1/1250th full scale. Figure 4 shows the model mounted in the wind tunnel. Due to the difference in Reynolds number between the model and full scale flows the surface roughness of the model was increased slightly to ensure turbulent boundary layers and to reduce the possibility of early laminar separation occurring.

Figure 4; island in wind tunnel looking upstream

Velocity Measurement

The velocity in the wind tunnel was measured by a 3D hot wire (CTA) probe traversed above the rig.

Hot Wire Probe Coordinate System

The 55P91 triple wire CTA probe, figure 5, was mounted in a right angled probe support aligned with the centreline of the wind tunnel.

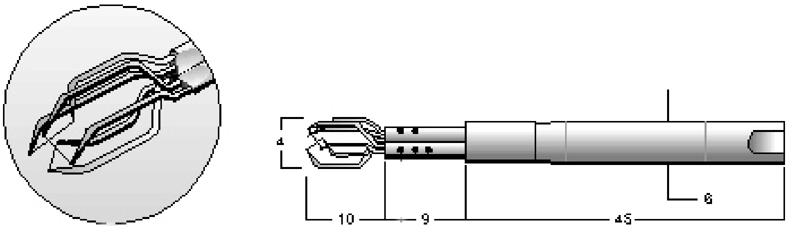


Figure 5; 55P91 probe

To simulate the wind approaching the island at different angles the model of the island was rotated by an angle β relative to the wind axis of the wind tunnel as shown in figure 6.

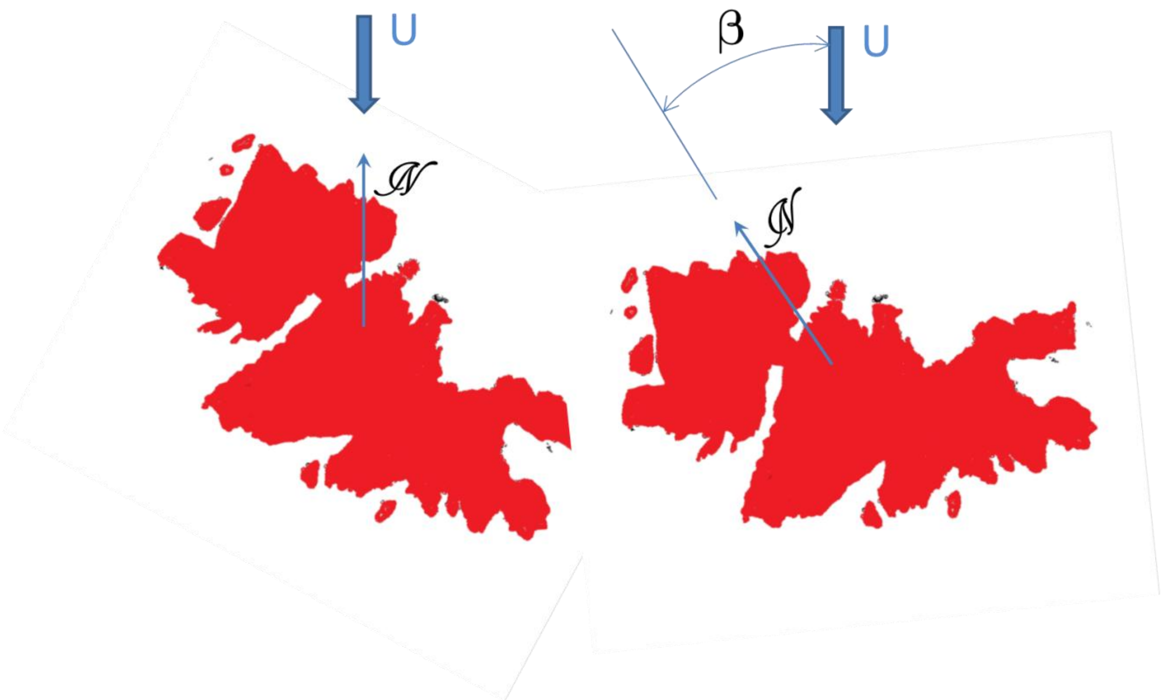


Figure 6: rotation of island relative to wind axis.

Reference Height

The reference height, H, used to normalise the hot wire measurement locations was 97.5m. This was the height AMSL of the location of the LiDAR.

Measurement Locations

The hot wire was traversed in the positive Z direction. The data for each location of a traverse is presented in the figures against full scale height above ground level (AGL) unless otherwise stated. Thus, the LiDAR is located at 0 m AGL which is 97.5m above mean sea level. The data from the CFD simulations are also presented in this format. If data are presented non-dimensionally the height is non-dimensionalised by the island height of 97.5m and the speed is non-dimensionalised by the tunnel reference speed

Tunnel Reference Speed

To normalise the wind tunnel speed data a reference velocity was recorded upstream and to the right of the model in the flow field undisturbed by the presence of the island model. This was then used to normalise all velocities measured. For the CFD data the magnitude of the velocity of the inlet boundary condition was used as the reference.

Wind Tunnel Corrections

Before the velocities above the rig were measured the undisturbed flow field in the tunnel at the traverse location was measured.

Results of the wind tunnel measurements may be found in the data file *Berlengas data summary.xlsx*. Figure 7 shows the non-dimensional velocity at the traverse location in the absence of the platform and also the wind speed measured in the presence of the island at $\beta=0^o$

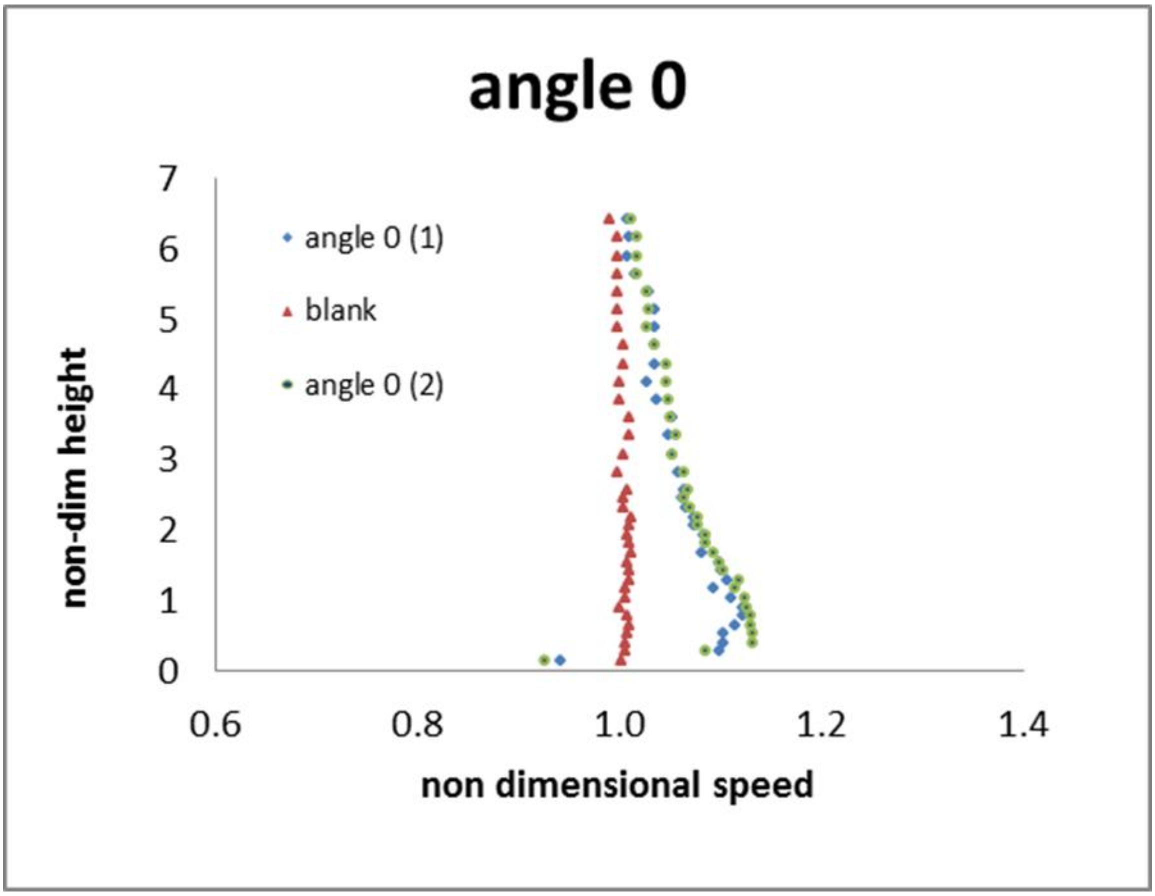


Figure 7; ratio of the empty tunnel point speed to the reference tunnel speed

From figure 7 it may be seen that the reference speed is slightly different to the speed measured at the location of the island model. It was therefore necessary to create a correction factor CF to correct for this.

Consider a point measure at NDH = 0.42 at this point the ratio of the point speed, Up, and the reference speed, Ur, is Up/Ur = 1.013

Therefore, in an undisturbed flow field Up = 1.013Ur and the ratio of the point to reference wind speeds in the empty tunnel may be used as the correction factor, CF, shown in equation 1

$$CF = \left[\frac{U_{point}}{U_{referece}}\right]_{empty\ tunnel} \qquad \text{equation 1}$$

Therefore, to normalise the wind speed measured at this height it is necessary to include the correction, CF, equation 2

$$U_{normalised} = \frac{U_{point}}{CF * U_{reference}} \qquad \text{equation 2}$$

Wind Tunnel Repeatability

Several traverses were undertaken at different times with the rig in the same position and also after the rig was removed from the tunnel and re-installed to check that the data was repeatable. Figure 8 shows a traverse with β=0° and proves that the experiments were repeatable.

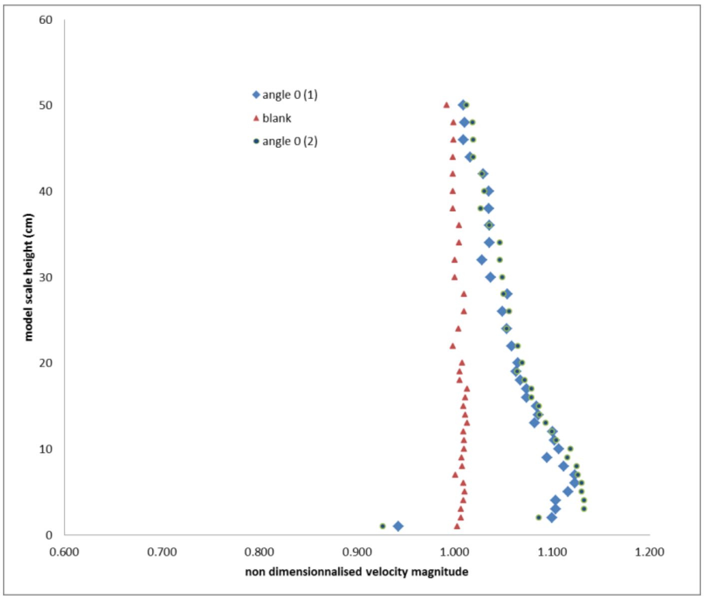


Figure 8; repeatability plot

Wind Tunnel Data

From the traverses undertaken in the wind tunnel it was possible to plot velocity profiles above the platform for different flow angles. Figure 9 shows the velocity profiles above the rig as the flow angle, β, was changed in 90^{o} steps. Positive β defined by an anticlockwise rotation of the rig.

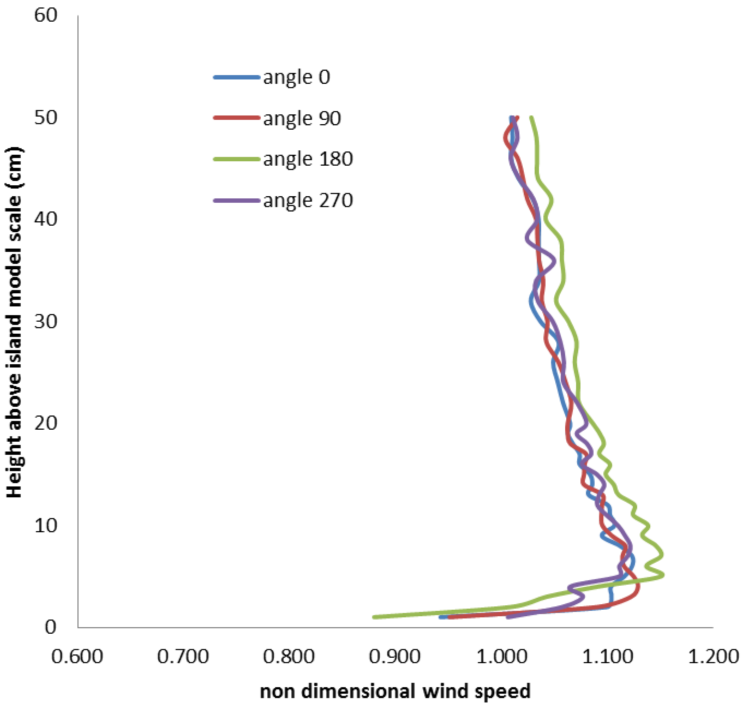


Figure 9; experimental velocity profiles above platform

For all other platforms modelled for the NORSEWInD project it was taken that the flow was free of distortion when the magnitude of the velocity vector measured by experiment was consistently between 99% and 101% of the undisturbed value. It was then possible, by rotating the rig in steps of 30^{o}, to plot a graph of flow angle against the height at which the flow was unaffected by the presence of the rig. However, for Berlengas it was found that even making measurements to 50cm model scale (625m full scale AGL) that the flow never fell within these limits. Relaxing the limits slightly to within ±2.5% of free stream and plotting the height at which this was achieved may be seen in figure 10

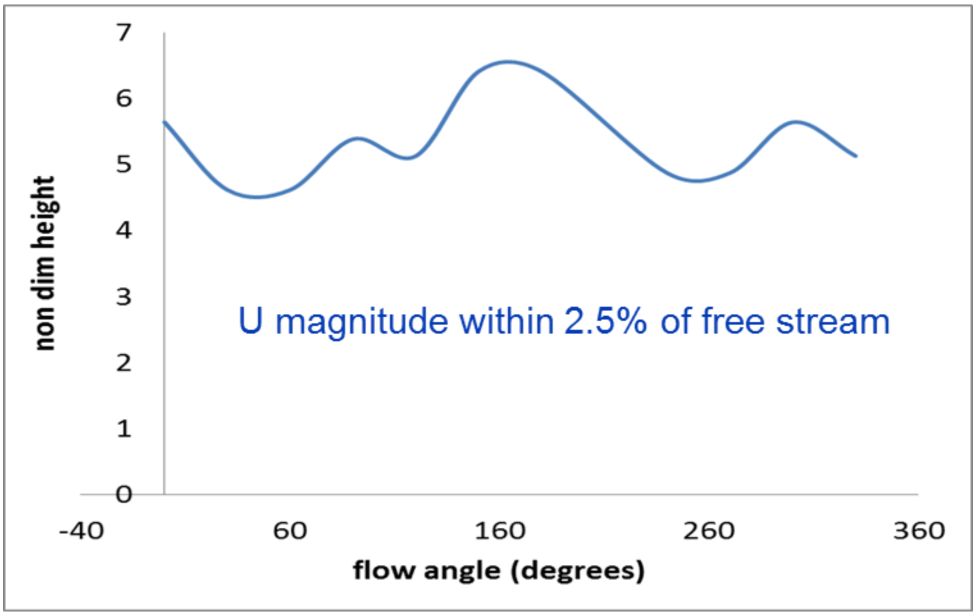


Figure 10: height to 97.5% free stream above island

CFD SIMULATION

CFD Coordinate System

To simulate the flows over the platform the general purpose CFD code, FLUENT was used. The CFD simulation used a right hand orthogonal coordinate system with the X direction pointing upwind and the Z direction pointing up. Within the CFD simulation, in a similar manner to the wind tunnel tests, the island was rotated through a series of angles, β, to simulate the wind approaching the island from different angles.

LIDAR SIMULATION

It was assumed that the LiDAR data was aligned with magnetic north and the rotation angle, γ, between the lidar coordinate system and magnetic north was not required.

Because the CFD and LiDAR coordinate systems are not the same, in order to compare data, it is necessary to rotate the velocity vector data acquired from the wind tunnel and CFD simulation into the same coordinate system. A full explanation of how this is accomplished may be found in reference 2.

For a full scale point measurement system such as a met mast the wind tunnel data would be sufficient to determine where data was unaffected by flow distortion. However, for remote sensing systems such as LiDAR and SODAR the effect of the platform on the velocity measurement is not as easy to determine and requires an understanding of the way that a LiDAR measures the wind speed and direction. Full details of how the ZephIR LiDAR measures the wind speed at a point above the device may be found in reference 2.

Briefly, to determine what the error in the velocity measured by a ZephIR when measuring flow close to the rig would be it was necessary to simulate both the flow field and also the ZephIR measurement technique. To do this it was necessary to model the flow field with CFD so that a simulation of the ZephIR measurement could be undertaken and the errors calculated. The data already collected by the hot wire traverses were used to validate the CFD model. Figure 11 shows a comparison between the experimental data measured by the hot wire and the output from the CFD simulation with the wind approaching at 120^{o} and 210^{o}.

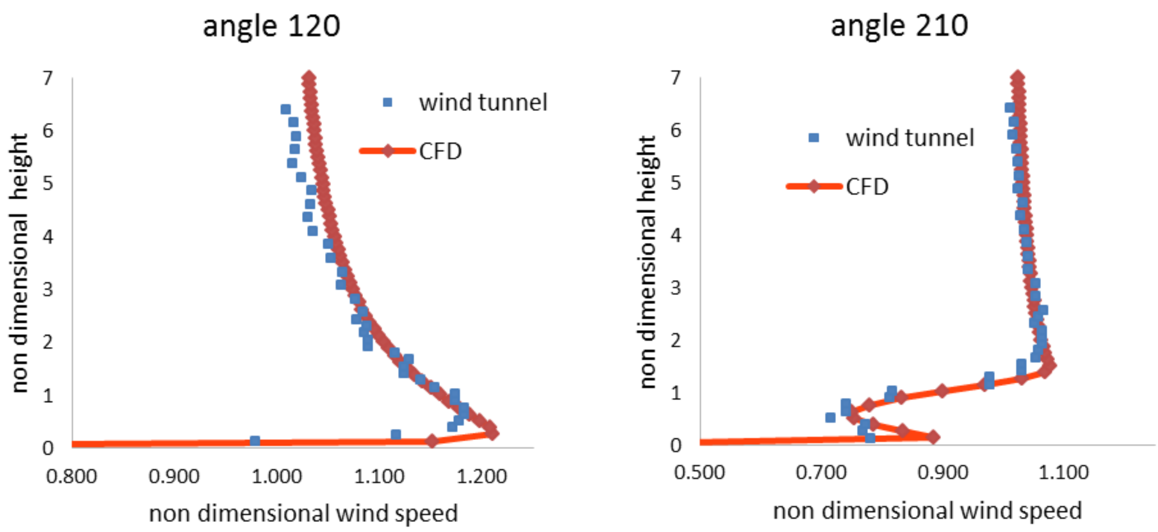


Figure 11; comparison between CFD and experimental data β=120^o and β=210^o

Comparing the results of the CFD simulation with the experimental data, gave confidence that the simulation was providing a faithful representation of the flow field.

Using the simulation data it was possible to model ZephIR measurements in the flow field above the platform. For example, taking an arbitrary point at a non-dimensional height of 0.76 (74 m full scale AGL) with the flow approaching the rig from angle of β=60^o at a free stream speed of 15 m/s it was possible to compare the components of the measured wind vector as seen by the LiDAR and a point measurement. The results of such a measurement are shown in table 1.

	Simulated ZephIR	Point measurement
u (m/s)	7.772	7.666
v (m/s)	-13.721	-13.96
w (m/s)	0.227	0.212
U (m/s)	15.769	15.926
$U/U_{freestream}$	1.05	1.06

Table 1; results of LiDAR simulation

It may be seen in table 1 that the measurement given by the simulated LiDAR differs from that of a point measurement. This is due to the LiDAR sampling the velocity vector at several points in the distorted flow field which produces a different result from a single point measurement.

Applying the same process at a range of heights it is possible to plot the wind speed magnitude in the horizontal plane that would be measured, by a point measurement technique such as a met mast, and the spatially averaged measurements from a ZephIR

LiDAR against height. Figure 12 shows these velocity distributions for the flow approaching the rig from angles β=0° and β=180°

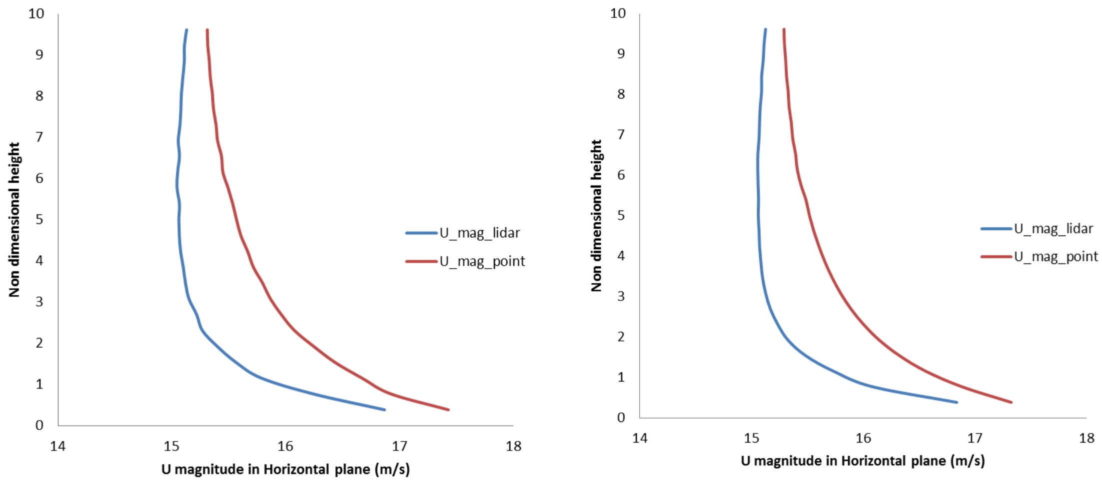


Figure 12; results of LiDAR simulation β=0° (left) and β=180°

From figure 12 it is obvious that the LiDARs measurements have been affected by the flow distortion next to an object. The errors are flow direction dependent with the system either underestimating or overestimating the point measurement value depending on wind direction and level of flow distortion. Close to the deck of the island, where flow distortion is significant, errors appear to become large. This would indicate that the LiDAR would not be suitable if required to measure a point velocity within the distorted flow field at a point close to the structure. However, the requirements of the NORSEWInD project are the measurement of the undistorted free stream. In this case the data needs to be reassessed.

Again, analysing the LiDAR simulation data at β=0° and β=180° but this time plotting, in figure 13, the percentage error in the measurement of the free stream velocity magnitude against non-dimensional height. Looking at the comparison between the LiDAR result and the point measurements of free stream velocity it may be seen that the LiDAR produces a much better estimate of the free stream velocity magnitude than a point measurement in the distorted flow. The LiDAR may produce a better estimate of the free stream in a distorted flow field due to the LiDAR creating its velocity measurement at fifty points over a large region that increases with height. Therefore, the measured result is not a single point in the disturbed flow field but an averaged result which may include a significant number of measurements out with the disturbed flow.

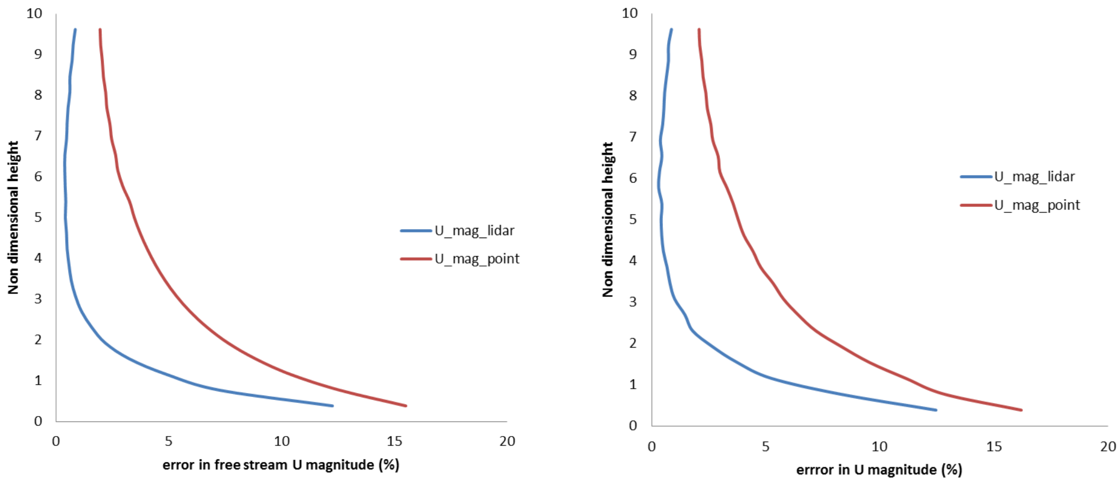


Figure 13; error in LiDAR and point measurement of undisturbed free stream (β=0^{o} left)

Transformation Of Data Into LiDAR Coordinate System

In the experimental and CFD simulation data were acquired in a fixed axis system and the island rotated about the Z axis. In this way the wind tunnel and CFD data were presented in an axis system different from the LiDAR placed on the island which would rotate with the rig. In order to transform the data from the wind tunnel and CFD axis systems the transformation shown in equation 3 was applied where β+γ is as shown in figure 14. It should be noted that the angle γ is required if the LiDAR coordinate system is not aligned to magnetic north.

$$\begin{bmatrix} u_{LiDAR} \\ v_{LiDAR} \\ w_{LiDAR} \end{bmatrix} = \begin{bmatrix} \cos(\beta+\gamma) & -\sin(\beta+\gamma) & 0 \\ \sin(\beta+\gamma) & \cos(\beta+\gamma) & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} u_{platform} \\ v_{platform} \\ w_{platfomr} \end{bmatrix} \qquad \text{equation 3}$$

Analysis Programs

The analysis of the CFD data is carried out by a user defined function in FLUENT

ZephIR_complete_sim is a user defined function (UDF) run in Fluent that interrogates the fluent data file to give the three components of the wind vector at the measurement points of a ZephIR LiDAR. The velocity data is then used to simulate the measurement of the local wind vector by a ZephIR LiDAR. Description of the function and operation of the UDF may be found in the report by Stickland et al [2]

SCALE EFFECT (REYNOLDS NUMBER)

To assess the effect of simulating the island at model scale the CFD simulations were run at full scale. From figure 11 it may be seen that the effect of scale on the simulation of the island is negligible and it may be said that the results of the wind tunnel modelling were Reynolds number independent.

EFFECT OF ATMOSPHERIC BOUNDARY LAYER

The effect of the presence of the atmospheric boundary layer on the analysis discussed in his report has been discussed in a previous NORSEWInD report by Stickland et al [2]

CORRECTION FACTORS

If it is taken that the wind tunnel and the CFD data were simulated in a free stream of 15 m/s aligned with the X axis, u=15 m/s, then any change in the magnitude of u and any component in the v and w directions, and therefore a change in the azimuth angle θ, must be due to interference caused by the presence of the island. Using the CFD data it is possible estimate the magnitude of the interference and therefore derive a correction factor to compensate for the effect of the interference. The process by which these correction factors are determined is described in reference 3.

To correct the u component of the LiDAR data to point data by rearranging equation 4 gives the correction factor in equation 5.

$$u_{point} = cfp_u * u_{lidar} \qquad \text{equation 4}$$

$$cfp_u = \frac{u_{lidar}}{u_{point}} \qquad \text{equation 5}$$

To correct the u and v LiDAR data to the undisturbed free stream values requires equations 6 and 7 which, when rearranged give the correction factors for these components in equations 8 and 9

$$u_{free\ stream} = cff_u * u_{lidar} \qquad \text{equation 6}$$

$$v_{free\ stream} = cff_v * v_{lidar} \qquad \text{equation 7}$$

$$cff_u = \frac{u_{free\ stream}}{u_{lidar}} \qquad \text{equation 8}$$

$$cff_v = \frac{v_{free\ stream}}{v_{lidar}} \qquad \text{equation 9}$$

Because the w component of the free stream will always be zero in the simulation a slightly different correction factor is derived. The correction factor to calculate the w component of the free stream velocity from the LiDAR data is given by equation 10

$$w_{free\ stream} = w_{lidar} + cff_w\, U_{free\ stream} \qquad \text{equation 10}$$

In the simulations the w component is zero hence the correction factor is given by equation 11

$$cff_w = -\frac{w_{lidar}}{U_{free\ stream}} \qquad \text{equation 11}$$

The correction addends for the azimuth angle are calculated by equations 12 and 13

$$\theta_{point} = \theta_{lidar} + cfp_\theta \qquad \text{equation 12}$$

$$\theta_{free\ stream} = \theta_{lidar} + cff_\theta \qquad \text{equation 13}$$

An example of the relevant correction factors for θ=60° can be found in table 2. The correction factors for all angles may be found in the appendix to this report.

	Lidar to free stream					Lidar to point				
Height (m)	cff_u	cff_v	Cff_w	cff_U	cff_θ	cfp_u	cfp_v	cfp_w	cfp_U	cfp_θ
37.5	0.973	0.935	-0.014	0.944	-0.966	0.984	1.019	1.071	1.011	0.858
75	0.965	0.947	-0.015	0.951	-0.473	0.986	1.017	0.937	1.01	0.755
112.5	0.967	0.956	-0.013	0.959	-0.27	0.994	1.021	0.942	1.015	0.652
150	0.969	0.962	-0.011	0.964	-0.177	0.997	1.02	1.057	1.014	0.551
187.5	0.97	0.967	-0.01	0.968	-0.071	0.997	1.022	0.952	1.016	0.614
225	0.97	0.971	-0.008	0.971	0.023	0.997	1.022	0.959	1.016	0.593
262.5	0.972	0.974	-0.008	0.973	0.06	0.999	1.022	0.881	1.016	0.555
300	0.973	0.977	-0.007	0.976	0.107	0.999	1.021	0.954	1.016	0.532
337.5	0.975	0.98	-0.007	0.978	0.132	1.001	1.022	0.949	1.017	0.509
375	0.976	0.982	-0.006	0.981	0.16	1.002	1.022	0.92	1.017	0.482
37.5	0.978	0.985	-0.006	0.983	0.162	1.003	1.022	0.907	1.017	0.45

table 2; correction factors β=60°

APPLICATION OF CORRECTION FACTORS

During the NORSEWInD WP1 meeting July 2009, the most appropriate LiDAR based measuring heights were discussed for LIDARs located at ground level, on a 20 m platform, and on a 40 m platform. The consensus of the discussions held at the meeting was that the recommended measurement heights for the ZephIR and Windcube LiDAR should be as shown in figure 14.

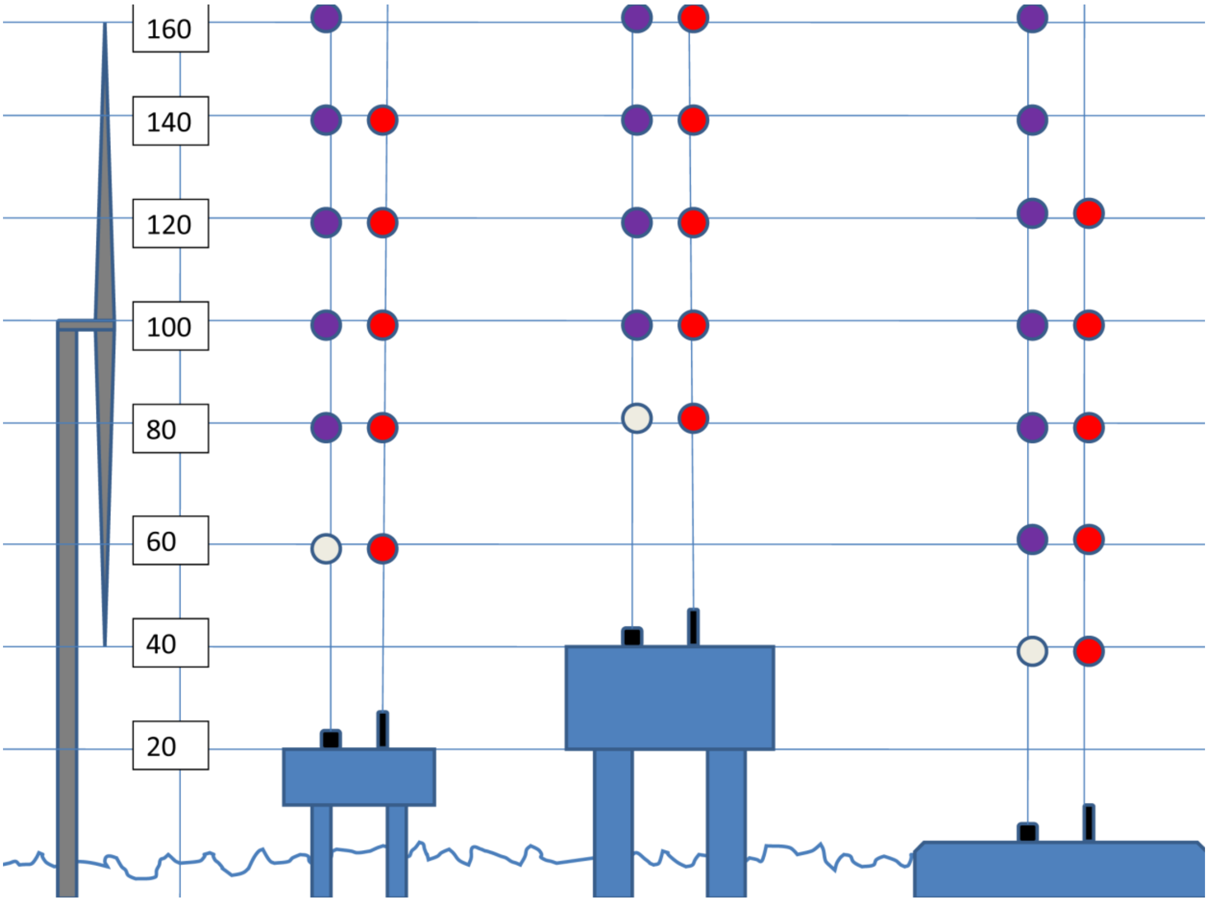


Figure 14; recommended measurement heights LiDAR installations.

The colour coding in figure 14 refers to;

Red – recommended Zephir Lidar measurement heights,
Blue - recommended Windcube lidar heights .
Gray –The 40 m Windcube measurement height is associated with unknown uncertainty due to the pulsed Windcubes relative big radial sampling volumes at these low heights. Windcube wind speed from 40 m range should be recorded but will have to be handled with uncertainty.

It was recommended that the LiDAR measurement heights on the platforms and on the ground in the NORSEWInD measurement campaigns will be set with these recommendations in mind.

If the recommendations are applied to Berlengas, which has a height AMSL of 97.5m to the location of the LiDAR then the first measurement height should be at 137.5m AMSL which is 40m AGL. It is therefore possible to decide whether or not the correction factors derived in this report should be applied. However, there are several criteria by which this decision could be made.

Requirement to apply correction factors

Considering the output from a LiDAR is the azimuth angle, θ, the magnitude of the horizontal component, U, and the vertical component, w, it is only these parameters that will be considered to see if the data requires correction.

An arbitrary limit to the tolerable interference of the island on the data needs to be defined. It is assumed that the accuracy of the CFD simulation is approximately ±2.5% and that the accuracy of a cup anemometer in situ is ±2.5% it is therefore not unreasonable to accept a tolerance of ±2.5% on the correction factors calculated by the LiDAR simulation. It was therefore decided that, if the correction factors for the U magnitude lie within the band $0.975 \leq cff\_Um \leq 1.025$ and the w component $-0.025 \leq cff\_w \leq 0.025$ then there is no requirement to correct the data. Similarly a tolerance of $\pm 0.5^{o}$ was used for the application of corrections.

Correction factors

Lidar to point

Considering now the influence of the island on the flow field based on correction factors Figures 15 and 16 show the correction factors for converting from LiDAR to point measurements for the U magnitude in the Horizontal plane and the addend to the flow angle, θ, against height AGL.

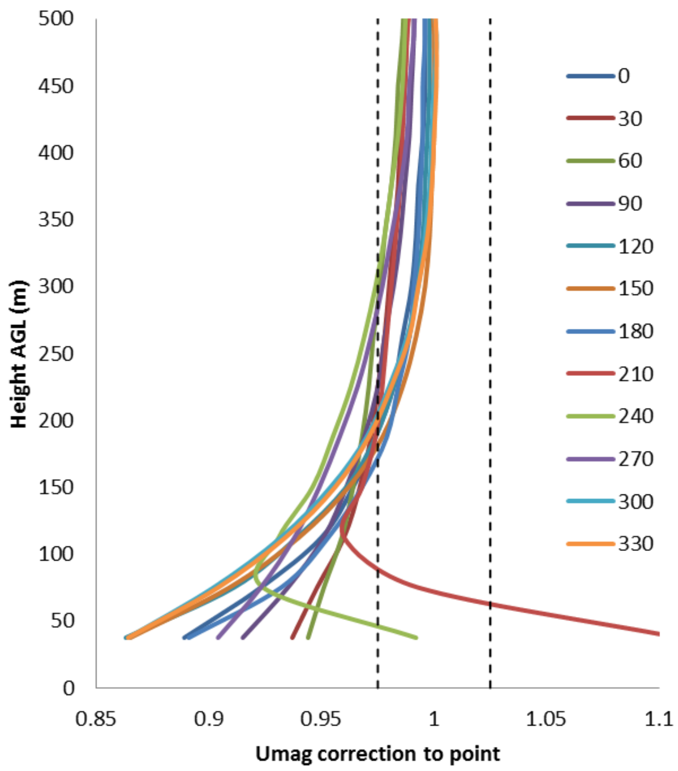


Figure 15; U magnitude correction

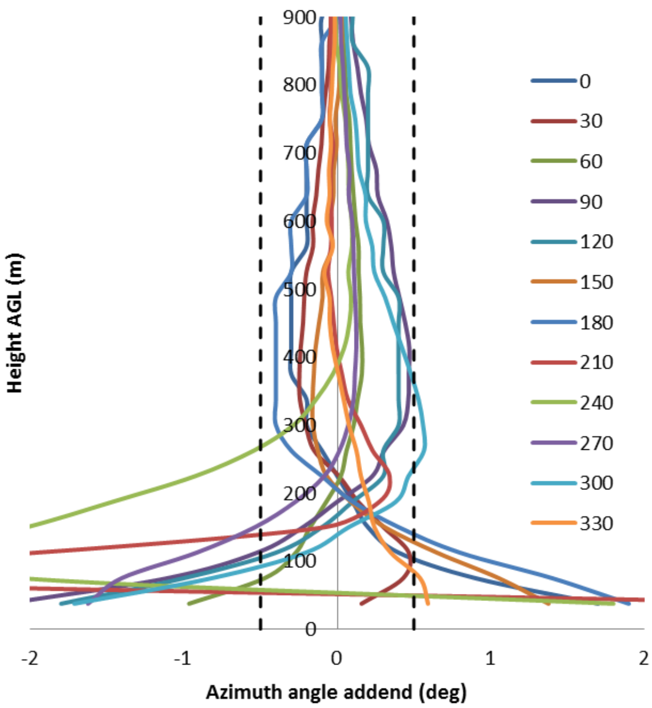


Figure 16; θ addend

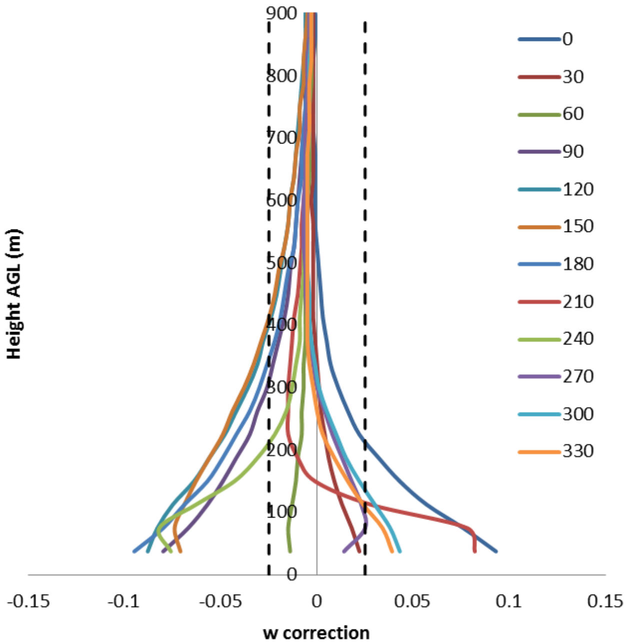


Figure 17; w magnitude correction

From figure 15 it may be seen that, above 300 m AGL, the correction factors to convert from U Magnitude LiDAR values to point values, for all flow angles, lie within the dashed lines of ±2.5%. From figure 16 it may be seen that the correction to the azimuth flow angle to a point value above a height of 350 m AGL lies within the dashed lines of ± 0.5^{o}. Figure 17 shows that the w correction factor lies within the limits of ±2.5% above 425m. From figures 15, 16 and 17 it may be concluded that, if the point data is to be inferred from the LiDAR data then below 425m AGL the flow is distorted to some extent or other.

LiDAR to free stream

Consider now the influence of the island on the correction factors for converting from a LiDAR to a free stream measurement. These are shown in figures 18 to 20 for the U magnitude, the addend to the flow angle and the w velocity component against height AGL.

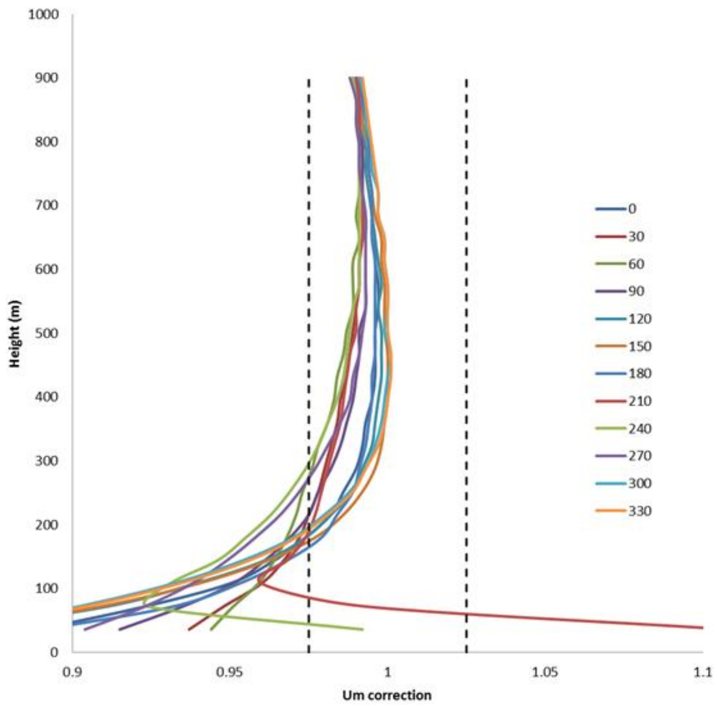


Figure 18: LiDAR to free stream U magnitude correction

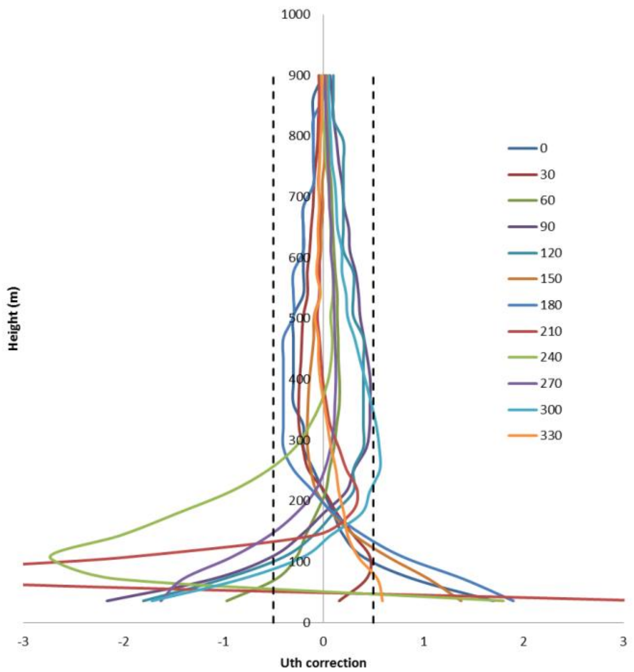


Figure 19: LiDAR to free stream θ correction

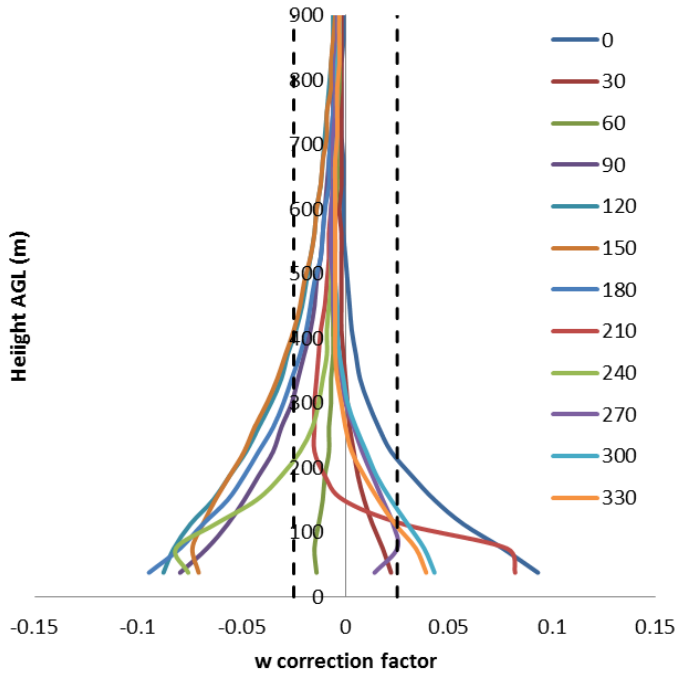


Figure 20: LiDAR to free stream w correction

From figures 18 to 20 it may be seen that the U correction is required below 300m, the θ addend below 350m and the w correction below 425m

Table 3 shows the height above which correction factors would need to be applied.

Component	height AGL (m)		criteria
	To free stream	To point	
U	300	300	$0.975 \leq$ cff_U≤ 1.025
w	350	350	$-0.025 \leq$ cff_w≤ 0.025
θ	425	425	$-0.5^{o} \leq \theta \leq 0.5^{o}$

Table 3: Minimum height for uncorrected data

Apendix B contains some images of the simulated flow field over the island.

DATA FILES

The data from this research may be found in the following files:

Fluent output in case (.cas) and data (.dat) files

Berlengas_ angle #.cas

Berlengas_ angle #.dat

where # is the flow platform angle 0, 30, 60, 90, 120, 150, 180, 210, 240, 270, 300, 330

Output from the Lidar simulation program, the wind tunnel data and the correction factors are in the file;

taqa data summary.xlsx

CONCLUSIONS

A method by which the distortion to the flow field over an offshore platform, measured by either a met mast or LiDAR, can be corrected back to the free stream value has been presented and verified.

Correction factors have been calculated and are included in the appendix to this report.

Based on the CFD and wind tunnel data it is recommended that the velocity vector measured by a ZephIR LiDAR on Berlengas be corrected for flow angle distortion below 350m, U magnitude below 300m and w magnitude below 425m.

REFERENCES

1. Stickland, M., Scanlon, T., Fabre, S. “NORSEWInD Data Report And Correction Data for Utsira” report for EU NORSEWInD, UoSNW023, December 2011
2. Stickland, M., Scanlon, T., Fabre, S., "User Defined Function; ZephIR_complete_sim" report for EU NORSEWInD, UoSNW017, August 2011

APPENDIX A – CARSE GRID CORRECTION FACTORS

β=0°

	Lidar to free stream					Lidar to point				
Z(m)	cff_u	cff_v	Cff_w	cff_U	cff_θ	cfp_u	cfp_v	cfp_w	cfp_U	cfp_θ
37.5	0.89	0	0.093	0.889	-358.27	1.033	1.357	1.06	1.033	-0.542
75	0.924	0	0.076	0.923	-359.09	1.042	1.913	0.976	1.042	-0.762
112.5	0.95	0	0.057	0.95	-359.61	1.056	4.05	0.811	1.056	-1.107
150	0.964	0	0.043	0.964	-359.779	1.056	5.278	0.856	1.056	-0.887
187.5	0.974	0	0.032	0.974	-359.901	1.055	10.113	1.039	1.055	-0.856
225	-0.982	0	0.022	0.982	-180.027	-1.053	30.745	1.055	1.053	179.175
262.5	-0.986	0	0.016	0.986	-180.105	-1.049	7.472	1.044	1.049	179.15
300	-0.99	0	0.011	0.99	-180.185	-1.047	3.401	1.206	1.047	179.214
337.5	-0.992	0	0.007	0.992	-180.231	-1.045	2.428	1.376	1.045	179.233
375	-0.993	0	0.005	0.993	-180.255	-1.041	1.879	1.49	1.041	179.286
412.5	-0.995	0	0.003	0.995	-180.278	-1.039	1.54	1.894	1.039	179.311
450	-0.996	0	0.002	0.996	-180.28	-1.036	1.315	2.392	1.036	179.366
487.5	-0.996	0	0.001	0.996	-180.28	-1.034	1.186	4.733	1.034	179.399
525	-0.996	0	0	0.996	-180.251	-1.031	1.149	-2.138	1.031	179.47
562.5	-0.997	0	-0.001	0.997	-180.238	-1.03	1.013	0.286	1.03	179.528
600	-0.997	0	-0.001	0.997	-180.231	-1.026	0.961	-1.18	1.026	179.553
637.5	-0.996	0	-0.001	0.996	-180.186	-1.025	1.021	0.588	1.025	179.628
675	-0.996	0	-0.001	0.996	-180.19	-1.023	0.923	-0.344	1.023	179.639
712.5	-0.995	0	-0.002	0.995	-180.154	-1.021	1.058	-0.234	1.021	179.687
750	-0.995	0	-0.002	0.995	-180.141	-1.019	1.003	-0.087	1.019	179.72
787.5	-0.994	0	-0.002	0.994	-180.115	-1.018	1.106	0.557	1.018	179.761
825	-0.994	0	-0.002	0.994	-180.102	-1.016	1.115	0.529	1.016	179.787
862.5	-0.993	0	-0.001	0.993	-180.082	-1.015	1.313	0.521	1.015	179.812
900	-0.993	0	-0.001	0.993	-180.064	-1.014	1.538	0.446	1.014	179.839
937.5	-0.991	0	-0.001	0.991	-180.047	-1.012	2.075	0.071	1.012	179.857

β =30°

Lidar to free stream						Lidar to point				
Z(m)	cff_u	cff_v	Cff_w	cff_U	cff_θ	cfp_u	cfp_v	cfp_w	cfp_U	cfp_θ
37.5	0.935	0.941	0.022	0.937	0.158	1.019	0.998	1.218	1.014	-0.512
75	0.944	0.961	0.018	0.948	0.43	1.022	1.009	1.048	1.019	-0.318
112.5	0.956	0.974	0.013	0.96	0.466	1.027	1.019	0.724	1.025	-0.199
150	0.964	0.976	0.009	0.967	0.301	1.028	1.016	0.774	1.025	-0.294
187.5	0.971	0.976	0.006	0.972	0.135	1.028	1.013	1.121	1.024	-0.372
225	0.975	0.976	0.004	0.975	0.011	1.027	1.009	1.187	1.022	-0.418
262.5	0.979	0.973	0.002	0.978	-0.151	1.027	1.006	1.15	1.022	-0.516
300	0.982	0.974	0.001	0.98	-0.205	1.026	1.005	2.363	1.021	-0.514
337.5	0.984	0.975	0	0.982	-0.244	1.025	1.004	-4.185	1.02	-0.512
375	0.986	0.976	-0.001	0.984	-0.247	1.024	1.005	-0.098	1.019	-0.464
412.5	0.988	0.978	-0.002	0.985	-0.239	1.023	1.006	0.221	1.019	-0.425
450	0.989	0.98	-0.002	0.987	-0.223	1.022	1.007	0.4	1.018	-0.372
487.5	0.99	0.982	-0.002	0.988	-0.215	1.022	1.008	0.416	1.018	-0.341
525	0.991	0.983	-0.002	0.989	-0.201	1.021	1.008	0.695	1.018	-0.318
562.5	0.992	0.985	-0.002	0.99	-0.158	1.02	1.009	0.887	1.017	-0.257
600	0.992	0.986	-0.003	0.991	-0.161	1.018	1.01	0.425	1.016	-0.213
637.5	0.992	0.987	-0.002	0.991	-0.137	1.017	1.009	0.859	1.015	-0.205
675	0.993	0.988	-0.002	0.992	-0.123	1.016	1.01	0.44	1.015	-0.156
712.5	0.993	0.989	-0.002	0.992	-0.103	1.015	1.01	0.449	1.014	-0.131
750	0.993	0.989	-0.002	0.992	-0.094	1.014	1.01	0.429	1.013	-0.113
787.5	0.993	0.989	-0.002	0.992	-0.077	1.013	1.009	0.748	1.012	-0.109
825	0.992	0.99	-0.002	0.992	-0.057	1.012	1.009	0.68	1.011	-0.082
862.5	0.992	0.99	-0.002	0.991	-0.051	1.011	1.008	0.681	1.01	-0.073
900	0.992	0.99	-0.002	0.991	-0.039	1.01	1.008	0.587	1.01	-0.057
937.5	0.991	0.989	-0.002	0.991	-0.043	1.009	1.008	0.347	1.009	-0.046

β =60°

	Lidar to free stream					Lidar to point				
Z(m)	cff_u	cff_v	Cff_w	cff_U	cff_θ	cfp_u	cfp_v	cfp_w	cfp_U	cfp_θ
37.5	0.973	0.935	-0.014	0.944	-0.966	0.984	1.019	1.071	1.011	0.858
75	0.965	0.947	-0.015	0.951	-0.473	0.986	1.017	0.937	1.01	0.755
112.5	0.967	0.956	-0.013	0.959	-0.27	0.994	1.021	0.942	1.015	0.652
150	0.969	0.962	-0.011	0.964	-0.177	0.997	1.02	1.057	1.014	0.551
187.5	0.97	0.967	-0.01	0.968	-0.071	0.997	1.022	0.952	1.016	0.614
225	0.97	0.971	-0.008	0.971	0.023	0.997	1.022	0.959	1.016	0.593
262.5	0.972	0.974	-0.008	0.973	0.06	0.999	1.022	0.881	1.016	0.555
300	0.973	0.977	-0.007	0.976	0.107	0.999	1.021	0.954	1.016	0.532
337.5	0.975	0.98	-0.007	0.978	0.132	1.001	1.022	0.949	1.017	0.509
375	0.976	0.982	-0.006	0.981	0.16	1.002	1.022	0.92	1.017	0.482
412.5	0.978	0.985	-0.006	0.983	0.162	1.003	1.022	0.907	1.017	0.45
450	0.98	0.986	-0.006	0.984	0.15	1.005	1.021	0.873	1.017	0.398
487.5	0.982	0.988	-0.006	0.986	0.148	1.006	1.021	0.846	1.017	0.374
525	0.983	0.989	-0.005	0.987	0.139	1.007	1.02	0.905	1.017	0.317
562.5	0.985	0.99	-0.005	0.989	0.139	1.007	1.019	1.064	1.016	0.28
600	0.986	0.991	-0.005	0.989	0.119	1.008	1.019	0.596	1.016	0.27
637.5	0.986	0.99	-0.004	0.989	0.106	1.008	1.017	1.011	1.014	0.219
675	0.988	0.992	-0.004	0.991	0.094	1.009	1.017	0.588	1.015	0.218
712.5	0.988	0.991	-0.004	0.99	0.086	1.008	1.016	0.605	1.014	0.202
750	0.989	0.992	-0.004	0.991	0.079	1.008	1.015	0.562	1.014	0.182
787.5	0.989	0.991	-0.003	0.991	0.058	1.008	1.014	0.889	1.012	0.136
825	0.989	0.991	-0.003	0.991	0.053	1.008	1.013	0.805	1.011	0.125
862.5	0.989	0.991	-0.003	0.991	0.04	1.007	1.012	0.809	1.011	0.109
900	0.989	0.991	-0.003	0.99	0.037	1.007	1.011	0.706	1.01	0.102
937.5	0.989	0.99	-0.002	0.99	0.024	1.006	1.01	0.462	1.009	0.102

β =90°

	Lidar to free stream					Lidar to point				
Z(m)	cff_u	cff_v	Cff_w	cff_U	cff_θ	cfp_u	cfp_v	cfp_w	cfp_U	cfp_θ
37.5	0	0.916	-0.08	0.915	-2.163	1.831	1.012	1.069	1.014	1.745
75	0	0.935	-0.067	0.935	-1.106	2.473	1.018	0.998	1.019	1.578
112.5	0	0.951	-0.057	0.951	-0.522	4.271	1.028	0.921	1.028	1.645
150	0	0.961	-0.049	0.961	-0.224	8.057	1.03	0.916	1.031	1.525
187.5	0	0.969	-0.042	0.969	0	92854.09	1.031	0.978	1.032	1.455
225	0	0.975	-0.035	0.975	0.229	-5.305	1.031	0.972	1.031	1.41
262.5	0	0.978	-0.031	0.978	0.306	-3.421	1.031	0.921	1.031	1.321
300	0	0.982	-0.026	0.982	0.431	-2.013	1.03	0.977	1.03	1.272
337.5	0	0.985	-0.023	0.985	0.463	-1.633	1.03	1.01	1.03	1.198
375	0	0.987	-0.02	0.987	0.466	-1.347	1.028	0.99	1.028	1.076
412.5	0	0.989	-0.017	0.989	0.47	-1.173	1.028	1.016	1.028	1.006
450	0	0.99	-0.015	0.99	0.443	-1.043	1.026	0.991	1.026	0.894
487.5	0	0.991	-0.014	0.991	0.405	-1.027	1.026	0.993	1.026	0.811
525	0	0.991	-0.012	0.991	0.367	-1	1.025	1.022	1.025	0.725
562.5	0	0.993	-0.011	0.993	0.352	-0.877	1.025	0.847	1.025	0.654
600	0	0.993	-0.01	0.993	0.323	-0.791	1.022	0.782	1.022	0.572
637.5	0	0.993	-0.009	0.993	0.264	-0.885	1.022	0.845	1.022	0.492
675	0	0.993	-0.008	0.993	0.255	-0.774	1.02	0.794	1.02	0.448
712.5	0	0.993	-0.007	0.993	0.206	-0.882	1.019	0.82	1.019	0.384
750	0	0.992	-0.006	0.992	0.188	-0.829	1.017	0.775	1.017	0.341
787.5	0	0.992	-0.006	0.992	0.154	-0.945	1.016	0.797	1.016	0.296
825	0.001	0.992	-0.005	0.992	0.132	-0.964	1.015	0.698	1.015	0.257
862.5	0.001	0.991	-0.005	0.991	0.103	-1.168	1.014	0.744	1.014	0.221
900	0.001	0.991	-0.004	0.991	0.089	-1.222	1.013	0.646	1.013	0.195
937.5	0.001	0.989	-0.004	0.989	0.067	-1.545	1.011	0.635	1.011	0.169

β =120°

	Lidar to free stream					Lidar to point				
Z(m)	cff_u	cff_v	Cff_w	cff_U	cff_θ	cfp_u	cfp_v	cfp_w	cfp_U	cfp_θ
37.5	0.82	0.879	-0.088	0.863	-361.761	1.057	1.01	1.042	1.023	-358.814
75	0.884	0.92	-0.083	0.911	-361.01	1.089	1.039	1	1.053	-358.816
112.5	0.926	0.943	-0.075	0.939	-360.437	1.102	1.049	0.924	1.063	-358.741
150	0.958	0.961	-0.064	0.961	-360.085	1.11	1.055	0.942	1.069	-358.718
187.5	0.977	0.973	-0.056	0.974	-359.908	1.108	1.055	0.959	1.069	-358.772
225	0.99	0.979	-0.048	0.982	-359.717	1.105	1.053	0.944	1.066	-358.786
262.5	0.997	0.986	-0.042	0.989	-359.734	1.097	1.052	0.971	1.063	-358.949
300	1.003	0.988	-0.036	0.992	-359.645	1.09	1.047	0.952	1.058	-359.006
337.5	1.007	0.991	-0.031	0.995	-359.616	1.086	1.046	0.979	1.056	-359.062
375	1.009	0.992	-0.028	0.996	-359.587	1.08	1.042	0.961	1.052	-359.12
412.5	1.009	0.993	-0.024	0.997	-359.609	1.073	1.039	0.988	1.048	-359.214
450	1.009	0.994	-0.021	0.998	-359.634	1.067	1.037	0.973	1.045	-359.297
487.5	1.009	0.994	-0.019	0.998	-359.638	1.062	1.034	0.973	1.041	-359.349
525	1.008	0.994	-0.017	0.998	-359.653	1.056	1.031	1.064	1.038	-359.406
562.5	1.007	0.994	-0.015	0.997	-359.686	1.051	1.029	0.909	1.035	-359.476
600	1.006	0.995	-0.014	0.998	-359.707	1.047	1.027	0.846	1.032	-359.535
637.5	1.004	0.994	-0.012	0.997	-359.765	1.042	1.026	0.914	1.03	-359.61
675	1.003	0.993	-0.011	0.996	-359.76	1.038	1.023	0.847	1.027	-359.631
712.5	1.001	0.993	-0.01	0.995	-359.813	1.034	1.022	0.897	1.025	-359.696
750	1	0.992	-0.009	0.994	-359.821	1.031	1.02	0.837	1.022	-359.723
787.5	0.998	0.991	-0.008	0.993	-359.843	1.028	1.018	0.861	1.02	-359.753
825	0.997	0.991	-0.007	0.993	-359.846	1.026	1.017	0.783	1.019	-359.77
862.5	0.995	0.99	-0.006	0.991	-359.873	1.023	1.015	0.81	1.017	-359.803
900	0.994	0.989	-0.006	0.991	-359.89	1.021	1.014	0.708	1.015	-359.828
937.5	0.992	0.989	-0.005	0.99	-359.913	1.018	1.012	0.702	1.014	-359.855

β =150°

	Lidar to free stream					Lidar to point				
Z(m)	cff_u	cff_v	Cff_w	cff_U	cff_θ	cfp_u	cfp_v	cfp_w	cfp_U	cfp_θ
37.5	0.878	0.831	-0.071	0.865	1.377	1.041	1.02	0.877	1.035	0.504
75	0.919	0.881	-0.074	0.909	1.053	1.059	1.056	0.909	1.058	0.077
112.5	0.946	0.922	-0.069	0.94	0.65	1.062	1.074	0.898	1.065	-0.281
150	0.965	0.953	-0.063	0.962	0.31	1.068	1.091	0.902	1.074	-0.533
187.5	0.978	0.974	-0.056	0.977	0.088	1.068	1.096	0.902	1.075	-0.642
225	0.986	0.988	-0.049	0.986	-0.068	1.065	1.095	0.909	1.073	-0.696
262.5	0.991	0.996	-0.044	0.992	-0.127	1.062	1.09	0.909	1.069	-0.667
300	0.994	1	-0.038	0.996	-0.159	1.057	1.084	0.921	1.064	-0.625
337.5	0.996	1.003	-0.033	0.998	-0.161	1.053	1.078	0.924	1.06	-0.566
375	0.998	1.004	-0.029	0.999	-0.153	1.05	1.071	0.936	1.055	-0.507
412.5	0.999	1.005	-0.025	1	-0.142	1.046	1.066	0.942	1.051	-0.455
450	0.999	1.004	-0.022	1	-0.119	1.043	1.059	0.948	1.047	-0.397
487.5	0.999	1.003	-0.02	1	-0.096	1.04	1.054	0.948	1.043	-0.35
525	0.999	1.002	-0.017	0.999	-0.093	1.036	1.049	0.982	1.039	-0.311
562.5	0.999	1	-0.015	0.999	-0.033	1.033	1.041	1.065	1.035	-0.21
600	0.999	1.001	-0.014	0.999	-0.047	1.03	1.038	1.003	1.032	-0.208
637.5	0.997	0.998	-0.012	0.998	-0.025	1.027	1.035	1.053	1.029	-0.179
675	0.997	0.998	-0.011	0.998	-0.023	1.025	1.032	0.993	1.027	-0.164
712.5	0.996	0.996	-0.009	0.996	-0.004	1.023	1.029	1.052	1.024	-0.141
750	0.995	0.996	-0.009	0.995	-0.012	1.021	1.026	0.97	1.022	-0.14
787.5	0.994	0.994	-0.007	0.994	0.009	1.019	1.024	1.015	1.02	-0.115
825	0.994	0.993	-0.007	0.994	0.021	1.017	1.021	0.903	1.018	-0.097
862.5	0.993	0.991	-0.006	0.992	0.03	1.016	1.019	0.929	1.016	-0.086
900	0.992	0.991	-0.005	0.992	0.03	1.014	1.017	0.831	1.015	-0.082
937.5	0.991	0.989	-0.005	0.991	0.037	1.013	1.016	0.819	1.013	-0.073

β =180°

	Lidar to free stream					Lidar to point				
Z(m)	cff_u	cff_v	Cff_w	cff_U	cff_θ	cfp_u	cfp_v	cfp_w	cfp_U	cfp_θ
37.5	0.891	0	-0.095	0.891	1.902	1.028	1.51	0.994	1.029	-0.889
75	0.933	0	-0.08	0.932	1.371	1.049	1.85	0.932	1.05	-1.046
112.5	0.953	0	-0.069	0.953	0.815	1.052	2.466	0.953	1.052	-1.094
150	0.969	0	-0.057	0.968	0.426	1.054	4.015	0.963	1.054	-1.196
187.5	0.979	0.001	-0.049	0.979	0.111	1.053	13.063	0.95	1.053	-1.268
225	0.984	-0.001	-0.042	0.984	-0.141	1.05	-8.767	0.959	1.05	-1.315
262.5	0.989	-0.001	-0.035	0.989	-0.271	1.047	-3.875	0.961	1.048	-1.272
300	0.991	0	-0.03	0.991	-0.359	1.044	-2.491	0.971	1.044	-1.215
337.5	0.993	0	-0.026	0.993	-0.407	1.041	-1.878	0.972	1.041	-1.142
375	0.994	0	-0.022	0.994	-0.413	1.038	-1.591	0.989	1.038	-1.046
412.5	0.995	0	-0.019	0.995	-0.41	1.035	-1.382	0.994	1.035	-0.957
450	0.995	0	-0.017	0.995	-0.379	1.033	-1.296	0.997	1.033	-0.855
487.5	0.996	0	-0.015	0.996	-0.356	1.03	-1.219	0.984	1.03	-0.778
525	0.996	0	-0.012	0.996	-0.296	1.028	-1.273	0.958	1.028	-0.663
562.5	0.996	-0.001	-0.011	0.996	-0.278	1.025	-1.095	1.08	1.025	-0.576
600	0.996	-0.001	-0.01	0.996	-0.262	1.023	-1	1.008	1.023	-0.518
637.5	0.996	-0.001	-0.008	0.996	-0.203	1.022	-1.203	1.089	1.022	-0.441
675	0.995	-0.001	-0.008	0.995	-0.198	1.02	-1.072	0.993	1.02	-0.407
712.5	0.995	-0.001	-0.007	0.995	-0.154	1.019	-1.295	1.073	1.019	-0.35
750	0.995	-0.001	-0.006	0.995	-0.143	1.017	-1.246	0.981	1.017	-0.318
787.5	0.994	-0.001	-0.005	0.994	-0.105	1.016	-1.606	1.017	1.016	-0.271
825	0.994	-0.002	-0.005	0.994	-0.087	1.015	-1.75	0.923	1.015	-0.239
862.5	0.993	-0.002	-0.004	0.993	-0.065	1.013	-2.239	0.954	1.013	-0.211
900	0.992	-0.003	-0.004	0.992	-0.046	1.012	-2.934	0.842	1.012	-0.181
937.5	0.991	-0.005	-0.003	0.991	-0.028	1.011	-4.717	0.83	1.011	-0.159

β =210°

	Lidar to free stream					Lidar to point				
Z(m)	cff_u	cff_v	Cff_w	cff_U	cff_θ	cfp_u	cfp_v	cfp_w	cfp_U	cfp_θ
37.5	1.076	1.232	0.082	1.109	3.241	1.064	0.931	0.944	1.039	-2.961
75	1.04	0.881	0.078	0.993	-4.285	1.1	0.91	0.795	1.043	-4.853
112.5	0.98	0.907	0.028	0.96	-1.939	1.041	1.004	0.99	1.031	-0.929
150	0.969	0.965	-0.001	0.968	-0.08	1.022	1.052	-4.129	1.03	0.72
187.5	0.971	0.982	-0.01	0.974	0.275	1.021	1.05	0.394	1.029	0.695
225	0.973	0.987	-0.015	0.977	0.341	1.019	1.049	0.622	1.027	0.714
262.5	0.977	0.986	-0.015	0.979	0.23	1.019	1.042	0.721	1.025	0.544
300	0.979	0.985	-0.015	0.981	0.154	1.019	1.036	0.792	1.023	0.419
337.5	0.982	0.985	-0.014	0.983	0.069	1.019	1.031	0.829	1.022	0.295
375	0.984	0.985	-0.013	0.985	0.03	1.019	1.029	0.846	1.022	0.234
412.5	0.986	0.986	-0.012	0.986	-0.004	1.019	1.027	0.873	1.021	0.178
450	0.988	0.987	-0.01	0.987	-0.023	1.019	1.025	0.886	1.02	0.141
487.5	0.989	0.987	-0.009	0.988	-0.039	1.018	1.023	0.877	1.02	0.11
525	0.99	0.988	-0.008	0.99	-0.06	1.018	1.022	0.831	1.019	0.083
562.5	0.99	0.989	-0.008	0.99	-0.041	1.017	1.021	0.978	1.018	0.111
600	0.991	0.99	-0.007	0.991	-0.036	1.016	1.02	0.938	1.017	0.102
637.5	0.992	0.99	-0.006	0.991	-0.042	1.015	1.019	0.929	1.016	0.092
675	0.992	0.99	-0.006	0.992	-0.043	1.015	1.018	0.926	1.016	0.086
712.5	0.992	0.991	-0.005	0.992	-0.027	1.014	1.018	0.943	1.015	0.097
750	0.992	0.99	-0.005	0.992	-0.05	1.014	1.017	0.942	1.014	0.071
787.5	0.992	0.99	-0.004	0.991	-0.041	1.012	1.015	0.877	1.012	0.073
825	0.992	0.99	-0.004	0.991	-0.042	1.011	1.014	0.858	1.012	0.07
862.5	0.992	0.99	-0.003	0.991	-0.044	1.01	1.013	0.832	1.011	0.066
900	0.991	0.99	-0.003	0.991	-0.041	1.01	1.013	0.78	1.01	0.067
937.5	0.991	0.989	-0.003	0.99	-0.046	1.009	1.011	0.735	1.01	0.06

β =240°

	Lidar to free stream					Lidar to point				
Z(m)	cff_u	cff_v	Cff_w	cff_U	cff_θ	cfp_u	cfp_v	cfp_w	cfp_U	cfp_θ
37.5	0.941	1.011	-0.076	0.992	1.8	1.108	0.951	0.862	0.997	-4.049
75	0.987	0.906	-0.082	0.924	-2.064	1.127	0.927	0.789	0.974	-4.892
112.5	1.016	0.907	-0.063	0.931	-2.734	1.11	0.945	0.968	0.982	-3.934
150	1.008	0.927	-0.043	0.946	-2.022	1.075	0.977	1.034	0.999	-2.33
187.5	1	0.942	-0.031	0.955	-1.461	1.056	0.996	0.988	1.01	-1.442
225	0.991	0.954	-0.022	0.963	-0.926	1.034	1.009	1.125	1.015	-0.597
262.5	0.986	0.964	-0.016	0.969	-0.544	1.026	1.018	1.132	1.02	-0.2
300	0.982	0.971	-0.013	0.974	-0.285	1.018	1.022	1.128	1.021	0.099
337.5	0.982	0.977	-0.011	0.978	-0.139	1.016	1.026	1.16	1.023	0.246
375	0.982	0.981	-0.009	0.981	-0.029	1.012	1.027	1.126	1.024	0.374
412.5	0.983	0.984	-0.009	0.984	0.043	1.012	1.028	1.115	1.024	0.396
450	0.984	0.987	-0.008	0.986	0.079	1.011	1.028	1.057	1.024	0.43
487.5	0.985	0.988	-0.007	0.987	0.09	1.011	1.028	1.043	1.023	0.4
525	0.986	0.989	-0.007	0.988	0.072	1.01	1.026	0.988	1.022	0.382
562.5	0.986	0.99	-0.006	0.989	0.096	1.009	1.025	0.858	1.021	0.38
600	0.988	0.991	-0.006	0.991	0.094	1.01	1.024	0.774	1.02	0.349
637.5	0.989	0.992	-0.005	0.991	0.075	1.01	1.023	0.82	1.02	0.317
675	0.989	0.992	-0.005	0.991	0.073	1.009	1.021	0.768	1.018	0.294
712.5	0.989	0.992	-0.005	0.991	0.065	1.009	1.021	0.785	1.018	0.277
750	0.99	0.992	-0.004	0.991	0.052	1.009	1.019	0.737	1.016	0.248
787.5	0.99	0.991	-0.004	0.991	0.028	1.009	1.017	0.744	1.015	0.217
825	0.991	0.991	-0.004	0.991	0.016	1.009	1.017	0.666	1.015	0.194
862.5	0.991	0.99	-0.003	0.99	-0.005	1.008	1.015	0.683	1.013	0.167
900	0.99	0.99	-0.003	0.99	-0.012	1.008	1.014	0.589	1.012	0.153
937.5	0.99	0.989	-0.003	0.989	-0.021	1.007	1.013	0.579	1.011	0.14

β =270°

	Lidar to free stream					Lidar to point				
Z(m)	cff_u	cff_v	Cff_w	cff_U	cff_θ	cfp_u	cfp_v	cfp_w	cfp_U	cfp_θ
37.5	0	0.904	0.014	0.904	-1.625	-1.067	1.034	1.455	1.034	-3.301
75	0	0.923	0.025	0.923	-1.405	0.026	1.031	0.885	1.031	-1.37
112.5	0	0.938	0.023	0.938	-0.917	0.436	1.033	0.741	1.032	-0.53
150	0	0.949	0.018	0.949	-0.536	0.883	1.036	0.738	1.036	-0.079
187.5	-0.001	0.958	0.013	0.958	-0.272	1.799	1.039	0.762	1.039	0.199
225	-0.002	0.966	0.008	0.966	-0.085	5.253	1.039	0.685	1.039	0.345
262.5	0.015	0.972	0.004	0.972	0.014	-27.621	1.039	0.75	1.039	0.383
300	0.003	0.977	0	0.977	0.072	-4.879	1.04	0.787	1.04	0.411
337.5	0.002	0.981	-0.002	0.981	0.106	-2.975	1.04	0.663	1.04	0.409
375	0.002	0.985	-0.004	0.985	0.115	-2.346	1.039	0.698	1.039	0.375
412.5	0.002	0.988	-0.005	0.988	0.124	-1.946	1.039	0.681	1.039	0.358
450	0.002	0.989	-0.006	0.989	0.123	-1.697	1.037	0.698	1.037	0.324
487.5	0.002	0.991	-0.006	0.991	0.116	-1.641	1.036	0.683	1.036	0.3
525	0.002	0.992	-0.007	0.992	0.109	-1.564	1.034	0.598	1.034	0.274
562.5	0.002	0.993	-0.007	0.993	0.106	-1.408	1.032	0.475	1.032	0.251
600	0.002	0.993	-0.007	0.993	0.097	-1.362	1.03	0.492	1.03	0.226
637.5	0.003	0.993	-0.006	0.993	0.075	-1.653	1.028	0.531	1.028	0.197
675	0.003	0.993	-0.006	0.993	0.08	-1.398	1.026	0.532	1.026	0.189
712.5	0.004	0.993	-0.006	0.993	0.061	-1.739	1.025	0.537	1.025	0.165
750	0.004	0.992	-0.005	0.992	0.056	-1.726	1.022	0.543	1.022	0.151
787.5	0.005	0.991	-0.005	0.991	0.046	-2.027	1.021	0.543	1.021	0.136
825	0.006	0.991	-0.005	0.991	0.038	-2.273	1.019	0.482	1.019	0.122
862.5	0.009	0.99	-0.004	0.99	0.025	-3.314	1.017	0.518	1.017	0.106
900	0.011	0.99	-0.004	0.99	0.02	-3.852	1.016	0.451	1.016	0.097
937.5	0.021	0.988	-0.003	0.988	0.01	-7.541	1.014	0.444	1.014	0.085

β =300°

	Lidar to free stream					*Lidar to point*				
Z(m)	cff_u	cff_v	Cff_w	cff_U	cff_θ	cfp_u	cfp_v	cfp_w	cfp_U	cfp_θ
37.5	0.822	0.88	0.043	0.864	-1.714	1.056	1.015	0.992	1.026	1.013
75	0.88	0.91	0.038	0.902	-0.817	1.082	1.032	0.779	1.045	1.205
112.5	0.926	0.934	0.03	0.932	-0.206	1.102	1.045	0.876	1.06	1.332
150	0.957	0.954	0.022	0.954	0.075	1.105	1.05	0.701	1.064	1.263
187.5	0.981	0.966	0.015	0.97	0.382	1.113	1.056	0.864	1.07	1.323
225	0.994	0.975	0.01	0.98	0.464	1.108	1.056	0.864	1.069	1.205
262.5	1.005	0.983	0.005	0.988	0.565	1.105	1.054	0.77	1.067	1.17
300	1.01	0.987	0.001	0.993	0.559	1.097	1.053	1.593	1.064	1.016
337.5	1.012	0.991	-0.001	0.996	0.53	1.089	1.051	-0.384	1.06	0.889
375	1.013	0.993	-0.003	0.998	0.48	1.081	1.048	0.432	1.056	0.761
412.5	1.012	0.995	-0.004	0.999	0.424	1.073	1.045	0.697	1.052	0.654
450	1.011	0.997	-0.004	1	0.366	1.066	1.043	0.69	1.049	0.545
487.5	1.01	0.997	-0.005	1.001	0.312	1.06	1.041	0.649	1.045	0.449
525	1.007	0.997	-0.005	0.999	0.241	1.052	1.037	0.552	1.041	0.339
562.5	1.007	0.998	-0.005	1	0.228	1.047	1.035	0.327	1.038	0.283
600	1.005	0.998	-0.005	1	0.186	1.042	1.032	0.495	1.034	0.228
637.5	1.004	0.997	-0.005	0.999	0.185	1.039	1.03	0.521	1.032	0.216
675	1.003	0.997	-0.005	0.999	0.142	1.034	1.028	0.516	1.029	0.156
712.5	1.001	0.996	-0.004	0.997	0.13	1.031	1.025	0.53	1.027	0.138
750	1	0.995	-0.004	0.997	0.117	1.028	1.023	0.466	1.024	0.112
787.5	0.998	0.995	-0.004	0.995	0.086	1.025	1.022	0.488	1.022	0.077
825	0.997	0.994	-0.004	0.995	0.076	1.022	1.02	0.444	1.02	0.062
862.5	0.995	0.993	-0.003	0.993	0.064	1.02	1.018	0.465	1.018	0.047
900	0.994	0.992	-0.003	0.993	0.055	1.017	1.016	0.426	1.016	0.034
937.5	0.993	0.991	-0.003	0.991	0.056	1.016	1.014	0.432	1.015	0.033

β =330°

	Lidar to free stream					Lidar to point				
Z(m)	cff_u	cff_v	Cff_w	cff_U	cff_θ	cfp_u	cfp_v	cfp_w	cfp_U	cfp_θ
37.5	0.87	0.849	0.039	0.864	0.591	1.034	1.024	0.869	1.032	0.238
75	0.909	0.89	0.034	0.904	0.54	1.054	1.043	0.781	1.051	0.261
112.5	0.937	0.924	0.024	0.934	0.349	1.062	1.069	0.788	1.064	-0.157
150	0.958	0.949	0.016	0.956	0.242	1.066	1.069	0.703	1.067	-0.07
187.5	0.973	0.965	0.009	0.971	0.206	1.07	1.078	0.765	1.072	-0.205
225	0.983	0.977	0.003	0.981	0.154	1.069	1.078	0.83	1.071	-0.215
262.5	0.99	0.985	0	0.989	0.125	1.067	1.073	3.874	1.068	-0.153
300	0.994	0.991	-0.002	0.993	0.076	1.063	1.072	0.777	1.065	-0.226
337.5	0.997	0.996	-0.004	0.997	0.042	1.059	1.069	0.791	1.061	-0.232
375	0.999	0.999	-0.005	0.999	0.007	1.055	1.065	0.78	1.057	-0.243
412.5	1	1.001	-0.005	1	-0.029	1.051	1.061	0.761	1.054	-0.242
450	1	1.002	-0.005	1.001	-0.049	1.047	1.057	0.781	1.05	-0.246
487.5	1.001	1.003	-0.005	1.001	-0.05	1.043	1.054	0.784	1.046	-0.243
525	0.999	1.003	-0.005	1	-0.084	1.039	1.05	0.68	1.042	-0.265
562.5	1	1.001	-0.005	1	-0.03	1.036	1.045	0.544	1.039	-0.2
600	1	1.002	-0.005	1	-0.068	1.033	1.042	0.48	1.035	-0.204
637.5	0.998	1	-0.005	0.999	-0.05	1.03	1.038	0.529	1.032	-0.18
675	0.998	1.001	-0.005	0.999	-0.054	1.028	1.035	0.499	1.03	-0.174
712.5	0.997	0.999	-0.004	0.997	-0.041	1.025	1.032	0.527	1.027	-0.156
750	0.997	0.998	-0.004	0.997	-0.048	1.023	1.03	0.557	1.025	-0.161
787.5	0.995	0.997	-0.004	0.996	-0.036	1.021	1.027	0.578	1.022	-0.144
825	0.995	0.996	-0.003	0.995	-0.029	1.019	1.024	0.54	1.02	-0.129
862.5	0.993	0.994	-0.003	0.994	-0.017	1.017	1.022	0.568	1.018	-0.114
900	0.993	0.993	-0.003	0.993	-0.016	1.016	1.02	0.448	1.017	-0.105
937.5	0.991	0.992	-0.002	0.992	-0.008	1.014	1.018	0.446	1.015	-0.096

APPENDIX B – FINE GRID CORRECTION FACTORS

β=0°

	Lidar to free stream					Lidar to point				
Z(m)	cff_u	cff_v	Cff_w	cff_U	cff_θ	cfp_u	cfp_v	cfp_w	cfp_U	cfp_θ
5	0.941	0	0.077	0.937	4.957	0.956	0.788	0.735	0.955	0.87
10	0.878	0	0.12	0.875	4.656	1.005	0.789	0.98	1.004	0.997
15	0.855	0	0.106	0.854	3.526	1.007	0.876	1.013	1.007	0.458
20	0.855	0	0.106	0.854	3.526	0.997	0.718	1.062	0.996	0.985
25	0.849	0	0.11	0.848	3.099	1.007	0.788	1.087	1.006	0.673
30	0.868	0	0.104	0.867	2.792	1.045	0.932	0.91	1.045	0.302
35	0.877	0	0.104	0.876	2.469	1.04	1.05	1.072	1.04	-0.023
40	0.88	0	0.104	0.879	2.397	1.047	1.102	0.839	1.047	-0.127
45	0.884	0	0.102	0.883	2.142	1.051	1.238	0.861	1.051	-0.382
50	0.889	0	0.1	0.889	1.912	1.043	1.354	1.063	1.043	-0.569
55	0.899	0	0.098	0.899	1.579	1.049	1.578	1.048	1.05	-0.796
60	0.909	0	0.095	0.909	1.4	1.056	1.714	1.04	1.056	-0.872
65	0.912	0	0.096	0.912	1.281	1.06	1.88	1.033	1.06	-0.991
70	0.916	0	0.093	0.916	1.145	1.064	2.034	0.875	1.065	-1.043
75	0.919	0	0.09	0.919	1.036	1.062	2.142	0.875	1.062	-1.054
80	0.922	0	0.087	0.922	0.915	1.056	2.462	0.97	1.057	-1.218
85	0.931	0	0.084	0.931	0.714	1.063	3.063	0.959	1.063	-1.345
90	0.934	0	0.083	0.934	0.642	1.065	3.148	1.019	1.066	-1.256
95	0.938	0	0.081	0.938	0.561	1.066	3.454	0.998	1.066	-1.256
100	0.939	0	0.078	0.939	0.483	1.062	3.833	0.996	1.063	-1.259
105	0.941	0	0.074	0.941	0.492	1.061	3.607	0.997	1.062	-1.18
110	0.946	0	0.071	0.946	0.321	1.064	5.313	0.992	1.064	-1.284
115	0.95	0	0.069	0.95	0.276	1.064	5.951	0.985	1.065	-1.267
120	0.953	0	0.068	0.953	0.293	1.069	6.285	0.947	1.069	-1.43
125	0.953	0	0.065	0.953	0.274	1.065	6.463	0.948	1.066	-1.389

β=30°

	Lidar to free stream					Lidar to point				
Z(m)	*cff_u*	*cff_v*	*Cff_w*	*cff_U*	*cff_θ*	*cfp_u*	*cfp_v*	*cfp_w*	*cfp_U*	*cfp_θ*
5	1.331	1.856	0.043	1.42	7.507	1.051	1.118	1.112	1.061	1.281
10	1.132	1.513	0.058	1.2	6.642	1.07	1.121	1.207	1.078	0.979
15	1.04	1.288	0.048	1.089	5.001	1.038	1.052	1.221	1.041	0.291
20	1.04	1.288	0.048	1.089	5.001	1.002	0.984	1.066	0.999	-0.381
25	0.995	1.158	0.045	1.029	3.619	1.018	0.999	1.046	1.014	-0.43
30	0.992	1.074	0.038	1.011	1.913	1.053	0.994	0.714	1.041	-1.364
35	0.986	1.024	0.033	0.995	0.921	1.057	1.013	1.093	1.047	-1.03
40	0.993	1.025	0.033	1.001	0.789	1.076	1.047	0.642	1.069	-0.664
45	0.978	0.99	0.029	0.981	0.305	1.06	1.011	0.726	1.048	-1.148
50	0.962	0.962	0.026	0.962	-0.019	1.02	0.998	1.228	1.015	-0.537
55	0.953	0.947	0.023	0.951	-0.138	1.027	0.999	1.246	1.02	-0.683
60	0.949	0.942	0.022	0.947	-0.166	1.033	0.999	1.223	1.025	-0.835
65	0.951	0.942	0.022	0.949	-0.247	1.036	0.998	1.231	1.026	-0.917
70	0.946	0.945	0.021	0.945	-0.023	1.038	1	0.891	1.028	-0.897
75	0.945	0.947	0.02	0.945	0.075	1.037	1.001	0.87	1.028	-0.854
80	0.946	0.952	0.02	0.948	0.158	1.035	1.006	0.996	1.028	-0.692
85	0.95	0.958	0.02	0.952	0.197	1.036	1.01	0.982	1.03	-0.622
90	0.951	0.961	0.019	0.954	0.237	1.037	1.012	1.102	1.031	-0.601
95	0.952	0.962	0.019	0.955	0.265	1.035	1.013	1.067	1.03	-0.541
100	0.953	0.966	0.018	0.956	0.336	1.033	1.015	1.059	1.029	-0.438
105	0.952	0.968	0.018	0.956	0.401	1.031	1.017	1.052	1.028	-0.347
110	0.955	0.972	0.017	0.959	0.439	1.032	1.02	1.04	1.029	-0.287
115	0.957	0.974	0.016	0.961	0.449	1.032	1.021	1.025	1.029	-0.259
120	0.959	0.974	0.016	0.963	0.396	1.035	1.022	0.972	1.032	-0.302
125	0.959	0.975	0.015	0.963	0.418	1.033	1.022	0.977	1.031	-0.263

β=60°

	Lidar to free stream					Lidar to point				
Z(m)	cff_u	cff_v	Cff_w	cff_U	cff_θ	cfp_u	cfp_v	cfp_w	cfp_U	cfp_θ
5	1.414	1.117	-0.008	1.173	-5.488	1.009	1.07	4.93	1.059	1.239
10	1.125	0.991	0.017	1.02	-3.026	0.983	1.073	1.201	1.055	1.98
15	1.053	0.934	-0.003	0.96	-2.895	0.997	1.043	-0.447	1.034	1.052
20	1.053	0.934	-0.003	0.96	-2.895	1.014	1.038	-6.382	1.033	0.527
25	1.008	0.918	-0.003	0.938	-2.275	1	1.029	-5.154	1.023	0.682
30	0.99	0.929	-0.007	0.943	-1.563	0.996	1.037	1.644	1.028	0.948
35	0.978	0.936	-0.008	0.946	-1.077	0.987	1.039	-0.06	1.027	1.237
40	0.974	0.938	-0.008	0.947	-0.919	0.987	1.035	1.518	1.024	1.125
45	0.974	0.938	-0.011	0.947	-0.907	0.987	1.035	1.14	1.024	1.137
50	0.972	0.937	-0.012	0.946	-0.893	0.978	1.029	1.116	1.017	1.214
55	0.966	0.943	-0.014	0.948	-0.59	0.974	1.031	1.022	1.017	1.369
60	0.961	0.945	-0.016	0.949	-0.409	0.971	1.03	0.979	1.016	1.415
65	0.959	0.947	-0.016	0.95	-0.333	0.97	1.032	0.96	1.017	1.491
70	0.96	0.948	-0.016	0.951	-0.308	0.977	1.029	1.188	1.016	1.27
75	0.96	0.948	-0.016	0.951	-0.329	0.979	1.026	1.163	1.015	1.15
80	0.959	0.948	-0.016	0.95	-0.298	0.976	1.028	0.681	1.015	1.248
85	0.96	0.95	-0.016	0.952	-0.267	0.978	1.028	0.703	1.016	1.203
90	0.96	0.951	-0.016	0.953	-0.219	0.978	1.027	0.943	1.015	1.208
95	0.96	0.952	-0.016	0.954	-0.199	0.979	1.026	0.934	1.015	1.155
100	0.962	0.952	-0.015	0.955	-0.247	0.982	1.025	0.936	1.015	1.042
105	0.963	0.953	-0.015	0.955	-0.247	0.984	1.024	0.934	1.014	0.982
110	0.963	0.955	-0.015	0.957	-0.199	0.985	1.025	0.927	1.015	0.976
115	0.963	0.956	-0.015	0.958	-0.165	0.986	1.025	0.92	1.015	0.96
120	0.962	0.957	-0.015	0.958	-0.138	0.985	1.027	0.766	1.017	1.035
125	0.964	0.957	-0.014	0.959	-0.17	0.988	1.027	0.776	1.017	0.955

β=90°

	Lidar to free stream					Lidar to point				
Z(m)	cff_u	cff_v	Cff_w	cff_U	cff_θ	cfp_u	cfp_v	cfp_w	cfp_U	cfp_θ
5	0	1.412	0.01	1.366	-14.643	0.912	1.029	1.733	1.022	-1.607
10	0	1.245	-0.015	1.214	-12.713	0.949	1.026	1.62	1.022	-0.925
15	0	1.201	-0.012	1.18	-10.779	0.989	1.138	3.694	1.133	-1.384
20	0	1.113	-0.035	1.096	-10.099	0.98	1.055	1.247	1.052	-0.705
25	0	1.02	-0.053	1.011	-7.71	1.011	1.053	1.13	1.052	-0.301
30	0	0.969	-0.067	0.965	-5.219	1.242	1.046	1.033	1.047	0.973
35	0	0.947	-0.074	0.945	-3.753	1.533	1.042	0.992	1.045	1.758
40	0	0.948	-0.072	0.946	-3.642	1.468	1.052	1.036	1.054	1.433
45	0	0.932	-0.078	0.931	-2.917	1.802	1.034	0.955	1.037	2.158
50	0	0.926	-0.082	0.925	-2.314	2.115	1.029	0.914	1.032	2.434
55	0	0.924	-0.083	0.924	-1.617	2.626	1.022	1.067	1.025	2.53
60	0	0.925	-0.081	0.925	-1.07	3.738	1.022	1.055	1.024	2.838
65	0	0.925	-0.081	0.925	-0.92	4.35	1.023	1.06	1.025	2.988
70	0	0.927	-0.079	0.927	-0.817	4.94	1.023	0.894	1.026	3.121
75	0	0.929	-0.077	0.929	-0.848	4.472	1.023	0.899	1.025	2.854
80	0	0.933	-0.075	0.933	-0.859	3.93	1.024	1.021	1.026	2.434
85	0	0.936	-0.072	0.936	-0.634	5.045	1.025	1.026	1.026	2.484
90	0	0.94	-0.072	0.94	-0.569	5.644	1.029	1.036	1.03	2.549
95	0	0.941	-0.07	0.941	-0.472	6.441	1.028	1.023	1.029	2.485
100	0	0.942	-0.068	0.942	-0.557	5.199	1.028	1.023	1.029	2.257
105	0	0.946	-0.067	0.946	-0.56	4.938	1.03	1.01	1.031	2.124
110	0	0.948	-0.064	0.948	-0.46	5.754	1.03	1.011	1.031	2.108
115	0	0.95	-0.063	0.95	-0.395	6.418	1.03	1.002	1.031	2.064
120	0	0.952	-0.063	0.952	-0.287	8.859	1.033	1.004	1.034	2.173
125	0	0.953	-0.061	0.953	-0.339	7.181	1.032	1.004	1.033	2.019

β=120°

	Lidar to free stream					Lidar to point				
Z(m)	cff_u	cff_v	Cff_w	cff_U	cff_θ	cfp_u	cfp_v	cfp_w	cfp_U	cfp_θ
5	0.973	1.117	-0.093	1.075	-3.533	1.095	0.917	1.333	0.975	4.829
10	0.795	0.947	-0.087	0.901	-4.514	1.066	0.996	0.805	1.019	1.827
15	0.809	0.969	-0.08	0.92	-4.655	1.084	1.018	0.88	1.04	1.687
20	0.753	0.894	-0.073	0.852	-4.421	1.035	0.997	0.984	1.009	0.995
25	0.746	0.871	-0.079	0.834	-3.986	1.029	0.999	0.967	1.009	0.768
30	0.777	0.86	-0.083	0.837	-2.573	1.06	0.997	0.953	1.016	1.603
35	0.793	0.86	-0.085	0.842	-2.062	1.066	1	0.942	1.019	1.664
40	0.805	0.867	-0.086	0.85	-1.87	1.082	1.007	0.936	1.029	1.856
45	0.814	0.873	-0.087	0.857	-1.764	1.081	1.014	0.932	1.033	1.668
50	0.827	0.883	-0.09	0.868	-1.651	1.087	1.023	0.919	1.041	1.575
55	0.842	0.886	-0.09	0.874	-1.273	1.096	1.02	1.019	1.041	1.844
60	0.855	0.891	-0.091	0.881	-1.044	1.102	1.024	1.006	1.045	1.904
65	0.858	0.893	-0.09	0.883	-1.003	1.106	1.025	1.017	1.047	1.945
70	0.868	0.901	-0.09	0.892	-0.952	1.11	1.035	0.921	1.055	1.793
75	0.876	0.91	-0.09	0.901	-0.953	1.111	1.041	0.92	1.06	1.655
80	0.888	0.915	-0.09	0.908	-0.763	1.117	1.043	0.979	1.063	1.757
85	0.897	0.918	-0.088	0.913	-0.567	1.12	1.043	0.977	1.063	1.835
90	0.901	0.92	-0.088	0.915	-0.518	1.125	1.045	0.986	1.066	1.884
95	0.906	0.924	-0.086	0.919	-0.476	1.124	1.046	0.988	1.067	1.817
100	0.915	0.933	-0.086	0.928	-0.488	1.127	1.053	0.966	1.073	1.706
105	0.917	0.938	-0.084	0.933	-0.559	1.122	1.056	0.964	1.073	1.542
110	0.925	0.938	-0.083	0.935	-0.354	1.125	1.053	0.96	1.072	1.661
115	0.93	0.94	-0.081	0.938	-0.288	1.124	1.053	0.956	1.071	1.647
120	0.936	0.943	-0.08	0.941	-0.185	1.132	1.056	0.968	1.076	1.75
125	0.94	0.949	-0.079	0.946	-0.233	1.13	1.059	0.965	1.078	1.626

β=150°

	Lidar to free stream					Lidar to point				
Z(m)	cff_u	cff_v	Cff_w	cff_U	cff_θ	cfp_u	cfp_v	cfp_w	cfp_U	cfp_θ
5	1.192	1.056	-0.023	1.153	3.1	0.979	0.865	1.929	0.946	3.163
10	0.998	0.95	-0.021	0.985	1.229	1.052	1.051	0.978	1.052	0.032
15	0.998	0.952	-0.022	0.986	1.206	1.053	1.053	0.953	1.053	0.01
20	0.929	0.84	-0.042	0.904	2.56	1.049	1.012	0.759	1.039	0.938
25	0.899	0.811	-0.049	0.874	2.619	1.054	1.008	0.774	1.041	1.166
30	0.878	0.796	-0.053	0.855	2.483	1.051	0.992	0.785	1.034	1.463
35	0.874	0.802	-0.061	0.854	2.176	1.054	0.997	0.772	1.038	1.431
40	0.876	0.807	-0.062	0.857	2.087	1.056	1.002	0.75	1.041	1.341
45	0.876	0.812	-0.066	0.859	1.907	1.056	1.006	0.784	1.042	1.252
50	0.882	0.823	-0.068	0.866	1.749	1.058	1.016	0.825	1.047	1.046
55	0.888	0.831	-0.07	0.872	1.662	1.059	1.023	0.856	1.049	0.864
60	0.897	0.841	-0.073	0.882	1.64	1.064	1.032	0.858	1.055	0.766
65	0.903	0.845	-0.073	0.887	1.654	1.07	1.038	0.847	1.061	0.78
70	0.907	0.853	-0.075	0.893	1.534	1.069	1.044	0.853	1.062	0.614
75	0.912	0.861	-0.076	0.899	1.448	1.07	1.049	0.865	1.064	0.499
80	0.917	0.871	-0.074	0.905	1.31	1.073	1.056	0.918	1.068	0.395
85	0.921	0.879	-0.074	0.91	1.166	1.072	1.062	0.916	1.069	0.223
90	0.928	0.885	-0.076	0.917	1.202	1.08	1.069	0.893	1.077	0.259
95	0.932	0.889	-0.076	0.921	1.19	1.08	1.07	0.885	1.077	0.227
100	0.936	0.899	-0.076	0.926	1.013	1.079	1.077	0.883	1.078	0.038
105	0.941	0.903	-0.075	0.931	1.038	1.081	1.078	0.889	1.08	0.056
110	0.943	0.91	-0.074	0.935	0.882	1.078	1.083	0.894	1.08	-0.1
115	0.949	0.916	-0.074	0.941	0.893	1.086	1.09	0.89	1.087	-0.09
120	0.951	0.923	-0.074	0.944	0.751	1.084	1.093	0.873	1.086	-0.228
125	0.953	0.931	-0.074	0.948	0.6	1.082	1.098	0.872	1.086	-0.373

β=180°

	Lidar to free stream					Lidar to point				
Z(m)	cff_u	cff_v	Cff_w	cff_U	cff_θ	cfp_u	cfp_v	cfp_w	cfp_U	cfp_θ
5	1.081	0	-0.053	1.061	11.079	1.056	0.752	1.363	1.046	3.143
10	0.978	0	-0.032	0.972	6.328	0.958	1.368	1.548	0.964	-2.671
15	0.989	0	-0.036	0.982	6.518	0.969	1.342	1.395	0.974	-2.481
20	0.942	0	-0.067	0.937	5.624	1.005	1.32	1.244	1.008	-1.752
25	0.911	0	-0.086	0.908	4.512	1.024	1.331	1.152	1.026	-1.344
30	0.893	0	-0.098	0.892	2.675	1.031	1.756	1.062	1.033	-1.873
35	0.885	0	-0.102	0.884	1.984	1.032	1.953	1.029	1.034	-1.766
40	0.891	0	-0.105	0.89	1.812	1.039	2.152	1.003	1.04	-1.938
45	0.897	0	-0.105	0.897	1.712	1.049	2.041	0.987	1.05	-1.618
50	0.9	0	-0.103	0.9	1.655	1.049	1.948	0.978	1.05	-1.415
55	0.905	0	-0.101	0.904	1.437	1.05	2.125	0.97	1.051	-1.471
60	0.909	0	-0.097	0.908	1.459	1.048	2.007	0.975	1.049	-1.332
65	0.913	0	-0.098	0.913	1.338	1.054	2.199	0.972	1.054	-1.453
70	0.92	0	-0.095	0.92	1.364	1.056	2.082	0.964	1.057	-1.323
75	0.927	0	-0.092	0.926	1.379	1.059	1.986	0.972	1.06	-1.206
80	0.931	0	-0.089	0.931	1.381	1.06	2.053	0.905	1.061	-1.294
85	0.935	0	-0.087	0.935	1.247	1.06	2.194	0.903	1.061	-1.334
90	0.939	0	-0.085	0.939	1.196	1.064	2.297	0.923	1.065	-1.385
95	0.942	0	-0.085	0.942	1.153	1.064	2.303	0.899	1.064	-1.343
100	0.946	0	-0.082	0.946	1.081	1.065	2.38	0.904	1.065	-1.335
105	0.95	0	-0.08	0.95	1.07	1.065	2.333	0.903	1.066	-1.272
110	0.953	0	-0.078	0.953	0.901	1.065	2.685	0.9	1.066	-1.37
115	0.954	0	-0.076	0.954	0.868	1.062	2.696	0.896	1.063	-1.335
120	0.959	0	-0.076	0.959	0.857	1.068	2.748	0.899	1.069	-1.347
125	0.962	0	-0.073	0.962	0.804	1.069	2.843	0.906	1.069	-1.335

β=210°

	Lidar to free stream					Lidar to point				
Z(m)	cff_u	cff_v	Cff_w	cff_U	cff_θ	cfp_u	cfp_v	cfp_w	cfp_U	cfp_θ
5	0.965	2.478	-0.028	1.087	17.328	1.025	0.972	1.293	1.023	-0.635
10	0.938	2.008	-0.003	1.045	14.912	1.034	0.948	4.573	1.028	-1.211
15	0.938	2.015	-0.004	1.046	14.958	1.034	0.951	4.21	1.029	-1.165
20	0.941	1.932	0.008	1.046	14.294	1.032	0.999	0.197	1.03	-0.484
25	0.957	1.817	0.022	1.057	13.098	1.034	0.999	0.738	1.031	-0.533
30	0.981	1.623	0.029	1.07	10.757	1.045	0.946	1.017	1.035	-1.715
35	1.004	1.5	0.039	1.081	8.865	1.057	0.929	1.09	1.041	-2.367
40	1.021	1.41	0.044	1.088	7.309	1.075	0.873	0.959	1.047	-3.923
45	1.024	1.386	0.048	1.088	6.896	1.068	0.916	1.098	1.046	-3.014
50	1.039	1.298	0.06	1.089	5.195	1.076	0.915	1.035	1.049	-3.355
55	1.052	1.186	0.065	1.081	2.869	1.086	0.89	1.051	1.048	-4.344
60	1.068	1.104	0.072	1.077	0.805	1.101	0.879	1.021	1.052	-5.145
65	1.078	1.094	0.07	1.082	0.383	1.11	0.872	1.041	1.057	-5.568
70	1.078	1.032	0.074	1.066	-1.097	1.113	0.868	1.021	1.053	-5.903
75	1.08	0.982	0.077	1.053	-2.418	1.119	0.867	0.979	1.052	-6.224
80	1.075	0.943	0.079	1.037	-3.341	1.05	0.835	1.228	0.99	-5.715
85	1.08	0.907	0.079	1.027	-4.509	1.065	0.843	1.171	0.999	-5.97
90	1.085	0.903	0.077	1.029	-4.752	1.07	0.839	1.201	1.001	-6.214
95	1.074	0.883	0.073	1.015	-5.091	1.074	0.855	1.181	1.007	-5.859
100	1.067	0.872	0.069	1.006	-5.252	1.083	0.875	1.124	1.019	-5.532
105	1.051	0.868	0.063	0.994	-4.947	1.084	0.896	1.103	1.026	-4.92
110	1.038	0.865	0.056	0.985	-4.697	1.086	0.913	1.076	1.033	-4.51
115	1.031	0.864	0.051	0.98	-4.557	1.079	0.912	1.179	1.028	-4.37
120	1.027	0.873	0.047	0.981	-4.176	1.088	0.934	1.076	1.042	-3.935
125	1.015	0.882	0.04	0.976	-3.595	1.083	0.951	1.064	1.044	-3.358

β=240°

	Lidar to free stream					Lidar to point				
Z(m)	cff_u	cff_v	Cff_w	cff_U	cff_θ	cfp_u	cfp_v	cfp_w	cfp_U	cfp_θ
5	1.351	1.492	-0.036	1.453	2.521	1.018	0.941	1.255	0.964	-2.067
10	1.168	1.222	-0.024	1.208	1.13	0.972	0.927	1.314	0.939	-1.234
15	1.179	1.25	-0.019	1.231	1.459	0.982	0.948	1.673	0.957	-0.904
20	1.125	1.137	-0.044	1.134	0.269	0.975	0.936	1.335	0.946	-1.038
25	1.1	1.111	-0.056	1.108	0.25	0.982	0.921	1.276	0.937	-1.625
30	1.103	1.116	-0.056	1.112	0.291	1.021	0.9	1.433	0.932	-3.242
35	1.095	1.122	-0.058	1.116	0.611	1.059	0.881	1.463	0.93	-4.802
40	1.084	1.107	-0.06	1.101	0.512	1.048	0.869	1.415	0.918	-4.9
45	1.061	1.086	-0.062	1.079	0.559	1.076	0.852	1.387	0.915	-6.144
50	1.017	1.057	-0.065	1.047	0.982	1.085	0.86	1.34	0.925	-6.17
55	0.998	1.008	-0.07	1.006	0.268	1.148	0.908	0.859	0.974	-6.149
60	0.992	0.969	-0.076	0.974	-0.58	1.168	0.911	0.868	0.979	-6.429
65	1.003	0.962	-0.077	0.971	-1.031	1.181	0.905	0.852	0.976	-6.879
70	0.985	0.928	-0.082	0.941	-1.46	1.156	0.884	1.144	0.953	-6.876
75	0.984	0.912	-0.086	0.928	-1.869	1.161	0.893	1.085	0.959	-6.671
80	0.998	0.901	-0.088	0.923	-2.471	1.177	0.906	0.794	0.97	-6.563
85	1.036	0.889	-0.091	0.92	-3.642	1.209	0.9	0.75	0.968	-7.294
90	1.052	0.884	-0.092	0.918	-4.133	1.228	0.895	0.743	0.967	-7.786
95	1.055	0.88	-0.092	0.916	-4.271	1.216	0.896	0.725	0.965	-7.461
100	1.05	0.88	-0.089	0.914	-4.187	1.2	0.9	0.733	0.964	-7.015
105	1.045	0.881	-0.085	0.915	-4.034	1.186	0.905	0.744	0.965	-6.588
110	1.059	0.881	-0.083	0.917	-4.336	1.193	0.908	0.741	0.968	-6.599
115	1.062	0.883	-0.08	0.919	-4.371	1.187	0.913	0.738	0.97	-6.319
120	1.073	0.885	-0.079	0.923	-4.532	1.199	0.915	0.746	0.974	-6.481
125	1.06	0.89	-0.074	0.925	-4.136	1.177	0.924	0.77	0.977	-5.823

β=270°

	Lidar to free stream					Lidar to point				
Z(m)	cff_u	cff_v	Cff_w	cff_U	cff_θ	cfp_u	cfp_v	cfp_w	cfp_U	cfp_θ
5	0	-1.235	-0.042	1.079	29.158	-0.659	-0.994	2.562	0.925	49.456
10	0	-1.287	0.017	1.17	24.555	-0.726	-1.038	-2.671	0.991	42.287
15	0	-1.349	0.001	1.26	20.915	-0.599	-1.071	-75.896	1.023	32.971
20	0	-1.309	-0.007	1.237	19.199	-0.638	-1.04	9.288	1.004	31.255
25	0	-1.341	-0.019	1.311	12.227	-0.424	-1.061	3.626	1.04	17.177
30	0	-1.27	-0.015	1.257	8.077	0.107	-1.057	4.127	1.047	7.254
35	0	-1.132	-0.009	1.127	5.168	0.628	-1.063	5.428	1.06	2.108
40	0	-1.073	0.009	1.068	5.27	0.59	-1.132	-3.989	1.129	2.517
45	0	-1.01	-0.001	1.008	3.577	0.82	-1.066	25.162	1.065	0.824
50	0	-0.944	0.005	0.943	2.968	0.725	-1.057	-4.848	1.056	0.931
55	0	-0.923	0.012	0.922	2.946	0.813	-1.05	1.632	1.05	0.666
60	0	-0.919	0.019	0.918	3	0.587	-1.052	1.104	1.051	1.324
65	0	-0.923	0.021	0.922	3.178	0.556	-1.056	0.992	1.055	1.502
70	0	-0.923	0.023	0.922	2.831	0.303	-1.049	0.155	1.048	2.013
75	0	-0.924	0.024	0.923	2.477	0.24	-1.045	0.327	1.044	1.907
80	0	-0.926	0.025	0.925	2.199	0.282	-1.047	0.918	1.046	1.606
85	0	-0.927	0.026	0.926	2.061	0.193	-1.044	0.875	1.044	1.679
90	0	-0.931	0.027	0.93	2.007	0.199	-1.049	0.857	1.048	1.625
95	0	-0.932	0.027	0.932	1.937	0.116	-1.047	0.827	1.047	1.723
100	0	-0.933	0.027	0.932	1.708	0.047	-1.045	0.822	1.044	1.631
105	0	-0.935	0.026	0.934	1.542	-0.024	-1.044	0.835	1.044	1.578
110	0	-0.936	0.026	0.936	1.419	-0.094	-1.043	0.818	1.043	1.546
115	0	-0.938	0.026	0.938	1.329	-0.158	-1.043	0.811	1.043	1.531
120	0	-0.94	0.026	0.94	1.326	-0.159	-1.045	0.802	1.045	1.528
125	0	-0.941	0.025	0.941	1.191	-0.23	-1.044	0.796	1.043	1.454

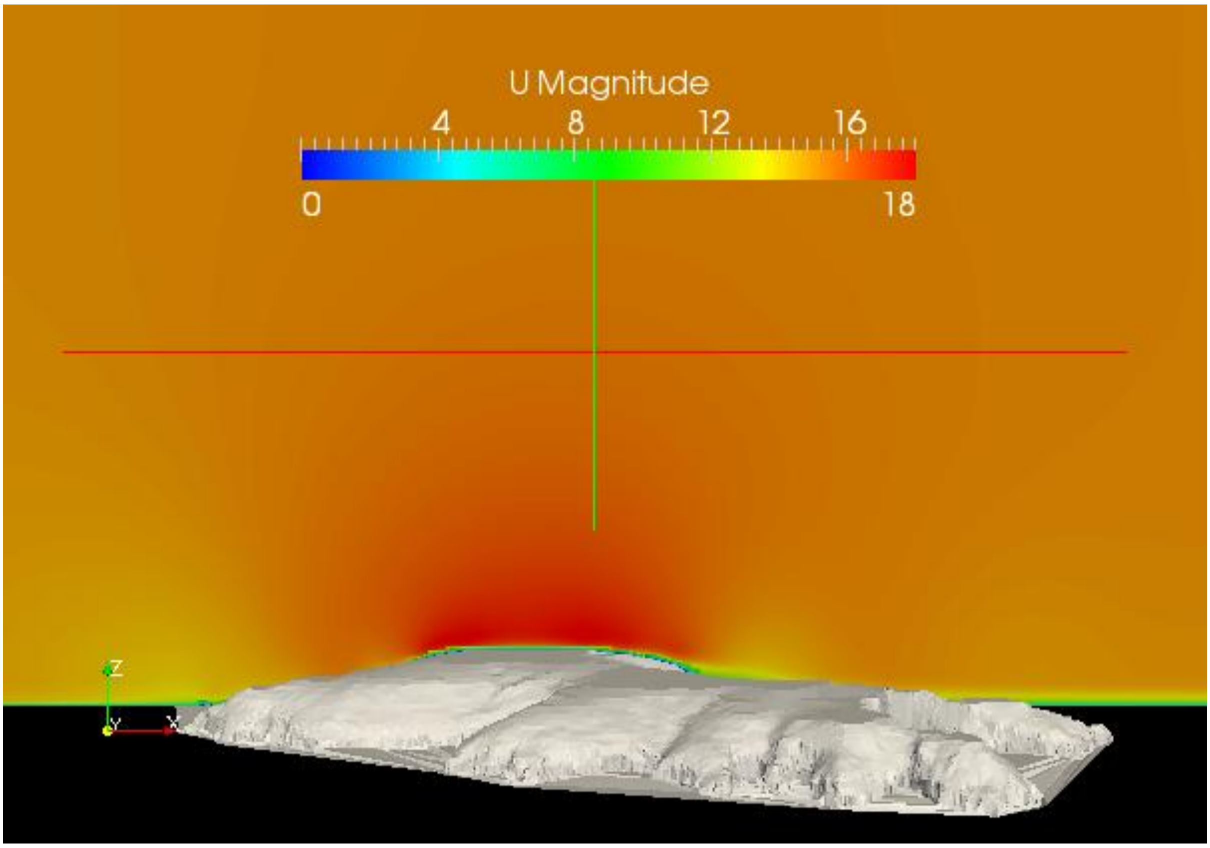
β=300°

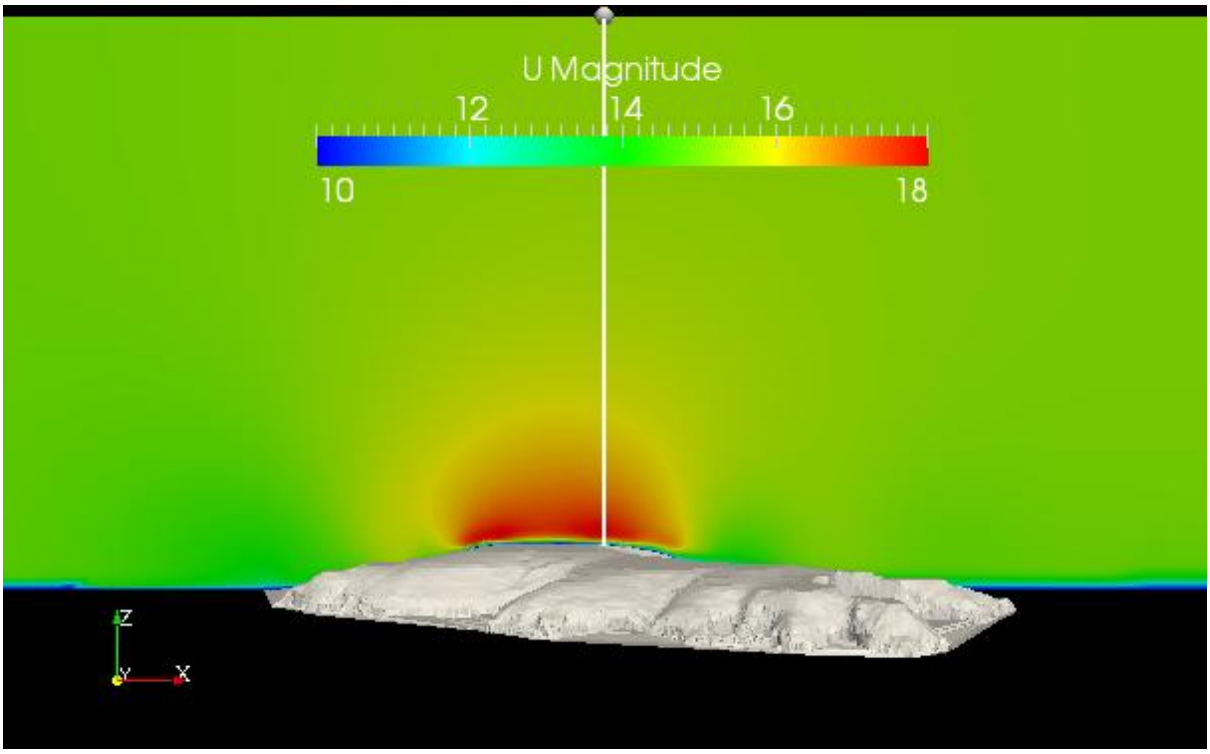
	Lidar to free stream					Lidar to point				
Z(m)	cff_u	cff_v	Cff_w	cff_U	cff_θ	cfp_u	cfp_v	cfp_w	cfp_U	cfp_θ
5	0.861	1.123	0.008	1.036	-6.977	1.081	0.957	3.844	1.004	3.411
10	0.792	0.944	0.043	0.898	-4.539	1.039	0.974	0.658	0.996	1.751
15	0.792	0.943	0.043	0.898	-4.528	1.04	0.974	0.66	0.996	1.762
20	0.779	0.894	0.036	0.86	-3.52	1.035	0.983	0.585	0.999	1.383
25	0.774	0.877	0.044	0.847	-3.171	1.048	0.999	1.271	1.014	1.278
30	0.797	0.862	0.041	0.844	-2.004	1.07	0.997	1.236	1.018	1.858
35	0.804	0.866	0.044	0.849	-1.867	1.07	1.005	1.119	1.023	1.648
40	0.813	0.867	0.045	0.852	-1.626	1.082	1.006	1.113	1.027	1.888
45	0.815	0.87	0.045	0.855	-1.656	1.074	1.009	1.055	1.027	1.614
50	0.825	0.877	0.044	0.863	-1.564	1.077	1.016	1.043	1.033	1.504
55	0.835	0.88	0.043	0.868	-1.338	1.08	1.017	1.022	1.035	1.549
60	0.849	0.886	0.044	0.876	-1.072	1.09	1.022	0.983	1.04	1.654
65	0.856	0.889	0.045	0.88	-0.949	1.099	1.025	0.961	1.045	1.778
70	0.86	0.892	0.044	0.884	-0.926	1.095	1.027	0.937	1.045	1.655
75	0.868	0.899	0.043	0.891	-0.865	1.097	1.032	0.927	1.049	1.582
80	0.877	0.905	0.042	0.898	-0.775	1.099	1.035	0.778	1.052	1.541
85	0.887	0.908	0.041	0.902	-0.586	1.103	1.035	0.776	1.053	1.625
90	0.895	0.911	0.042	0.907	-0.439	1.107	1.036	0.729	1.055	1.674
95	0.9	0.917	0.041	0.913	-0.474	1.112	1.043	0.749	1.061	1.64
100	0.905	0.92	0.04	0.916	-0.41	1.112	1.043	0.736	1.061	1.612
105	0.912	0.924	0.038	0.921	-0.33	1.114	1.046	0.76	1.064	1.606
110	0.921	0.927	0.036	0.926	-0.15	1.119	1.046	0.766	1.065	1.704
115	0.929	0.932	0.036	0.931	-0.071	1.122	1.049	0.726	1.068	1.707
120	0.934	0.936	0.036	0.935	-0.058	1.128	1.053	0.732	1.073	1.72
125	0.935	0.938	0.034	0.937	-0.074	1.124	1.054	0.737	1.072	1.632

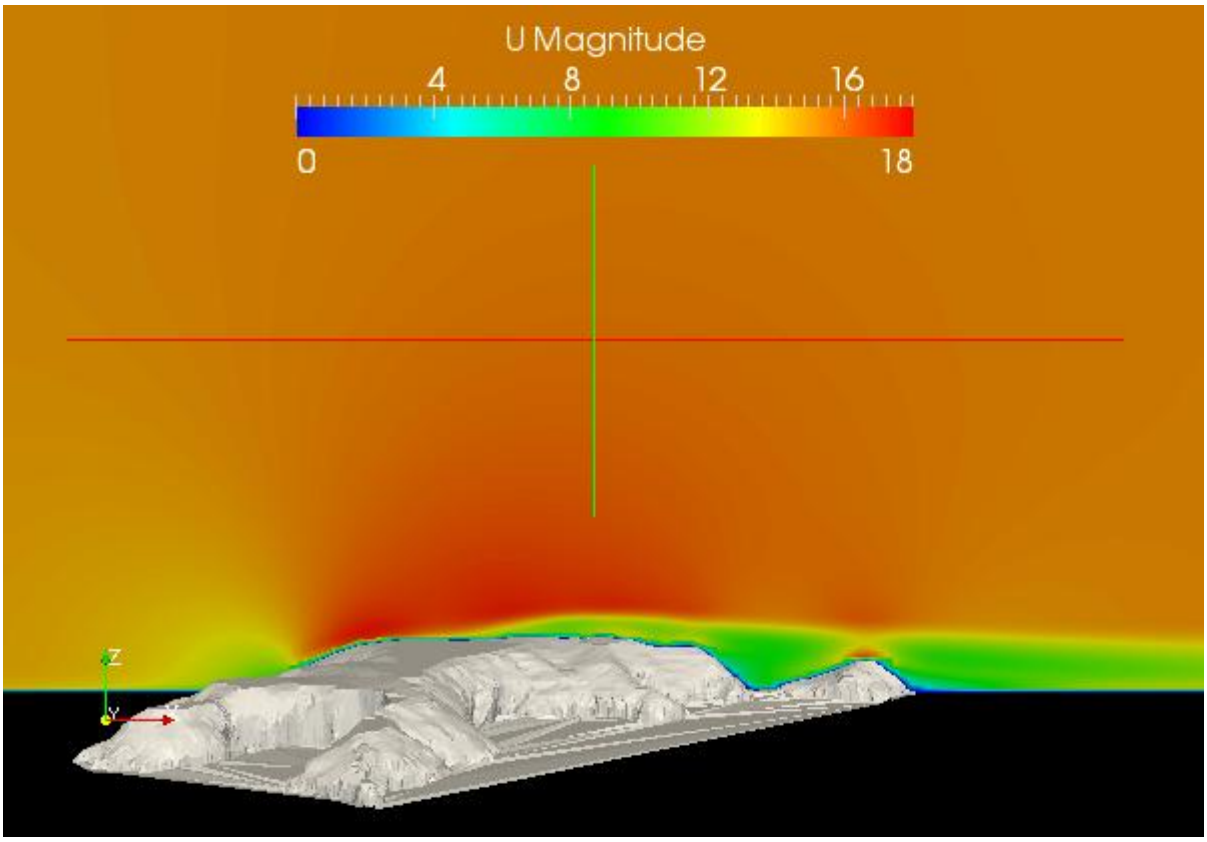
β=330°

	Lidar to free stream					Lidar to point				
Z(m)	cff_u	cff_v	Cff_w	cff_U	cff_θ	cfp_u	cfp_v	cfp_w	cfp_U	cfp_θ
5	0.952	1.011	0.001	0.966	-1.458	1.009	0.994	4.588	1.006	0.372
10	0.871	0.884	0.018	0.874	-0.366	1.001	0.984	0.772	0.997	0.404
15	0.871	0.885	0.018	0.874	-0.405	1.001	0.986	0.76	0.997	0.365
20	0.853	0.853	0.021	0.853	-0.002	1.008	0.99	0.623	1.004	0.45
25	0.85	0.841	0.027	0.848	0.261	1.023	1.01	1.078	1.02	0.328
30	0.85	0.826	0.029	0.844	0.727	1.03	1.002	1.006	1.023	0.677
35	0.858	0.828	0.035	0.85	0.885	1.039	1.009	0.917	1.031	0.744
40	0.861	0.831	0.037	0.853	0.889	1.043	1.013	0.887	1.035	0.749
45	0.864	0.835	0.038	0.856	0.857	1.044	1.017	0.866	1.037	0.652
50	0.872	0.843	0.039	0.864	0.831	1.048	1.024	0.877	1.042	0.584
55	0.878	0.85	0.039	0.871	0.822	1.051	1.029	0.869	1.045	0.527
60	0.888	0.858	0.041	0.88	0.851	1.056	1.035	0.828	1.05	0.498
65	0.893	0.862	0.042	0.885	0.884	1.062	1.04	0.808	1.056	0.531
70	0.897	0.868	0.042	0.89	0.819	1.061	1.044	0.79	1.057	0.411
75	0.902	0.875	0.041	0.895	0.787	1.063	1.049	0.789	1.059	0.335
80	0.907	0.883	0.038	0.901	0.682	1.066	1.047	0.777	1.061	0.45
85	0.911	0.89	0.037	0.906	0.585	1.066	1.052	0.78	1.062	0.332
90	0.918	0.895	0.038	0.912	0.622	1.069	1.053	0.72	1.065	0.355
95	0.921	0.898	0.037	0.915	0.639	1.073	1.057	0.74	1.069	0.371
100	0.925	0.906	0.036	0.92	0.514	1.073	1.063	0.741	1.07	0.236
105	0.931	0.91	0.033	0.925	0.566	1.075	1.063	0.758	1.072	0.278
110	0.933	0.916	0.031	0.929	0.464	1.074	1.066	0.768	1.072	0.168
115	0.938	0.921	0.031	0.934	0.481	1.076	1.068	0.737	1.074	0.18
120	0.941	0.926	0.031	0.937	0.384	1.078	1.075	0.737	1.078	0.083
125	0.943	0.932	0.029	0.94	0.283	1.078	1.078	0.738	1.078	-0.023

APPENDIX C – CFD IMAGES



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18
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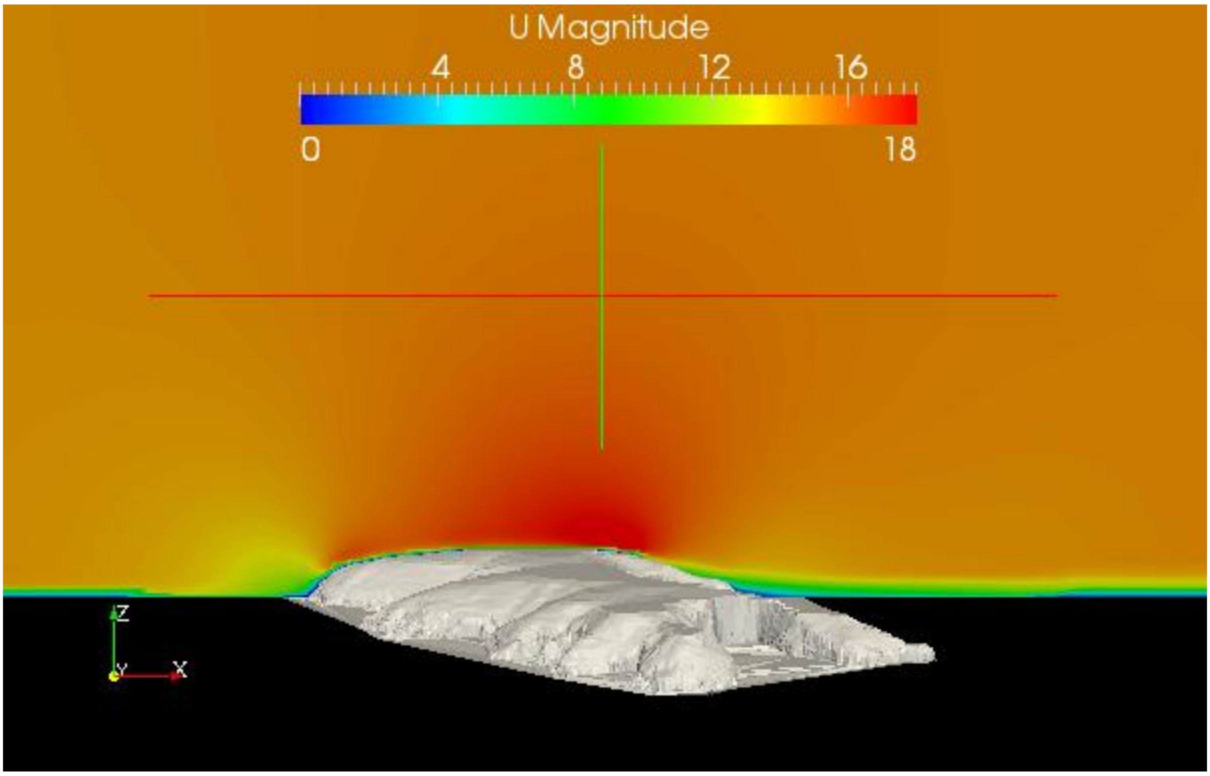
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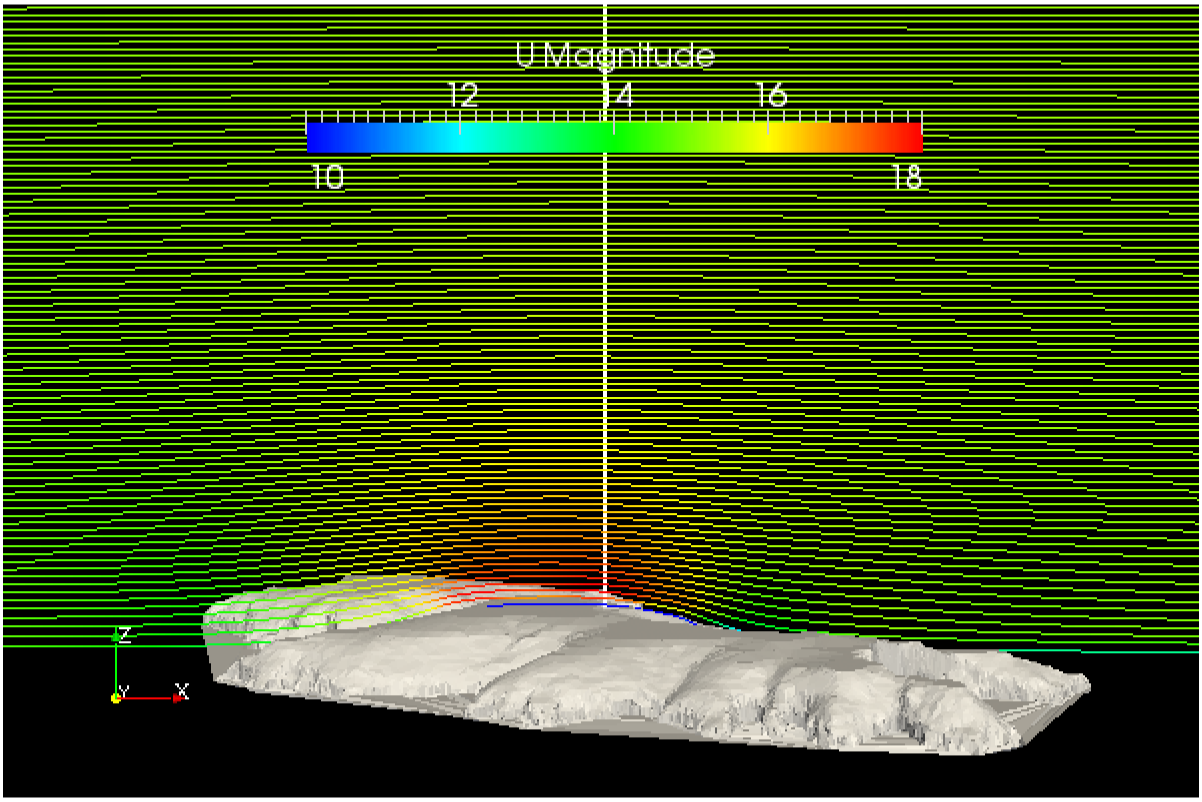
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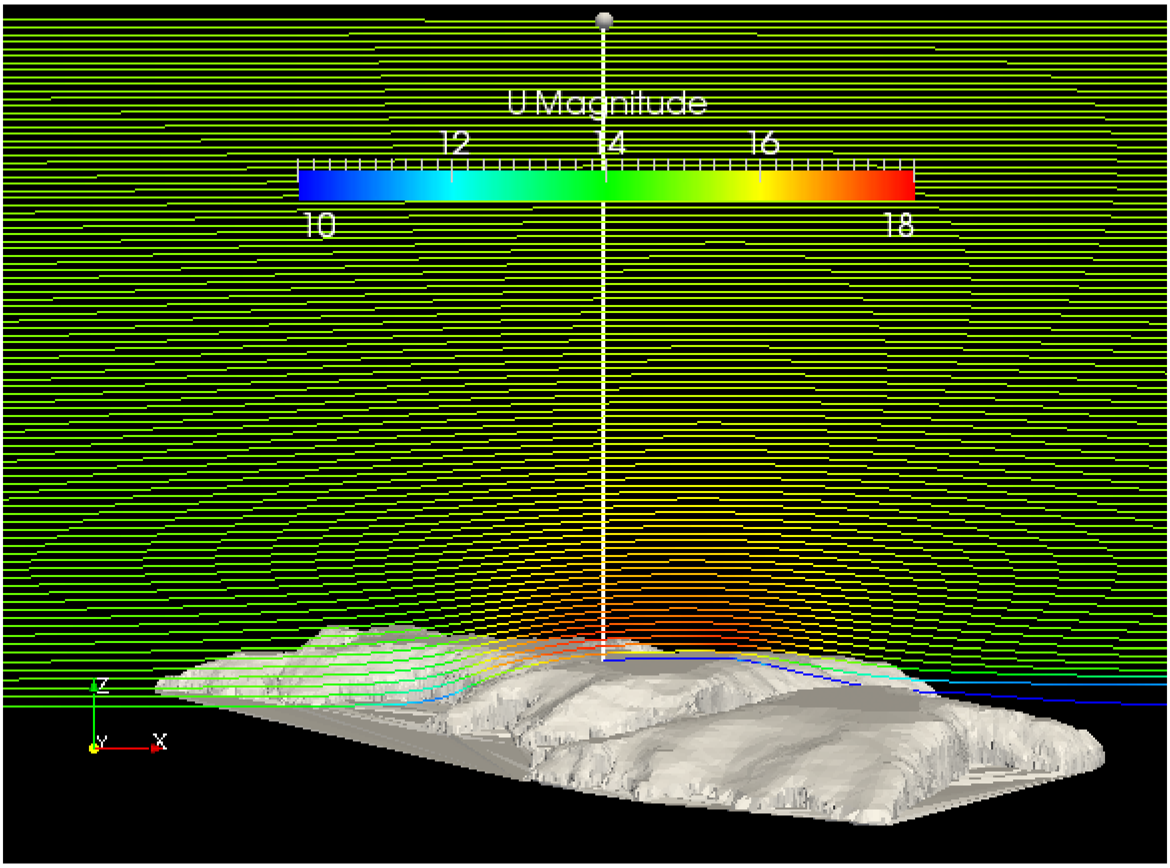
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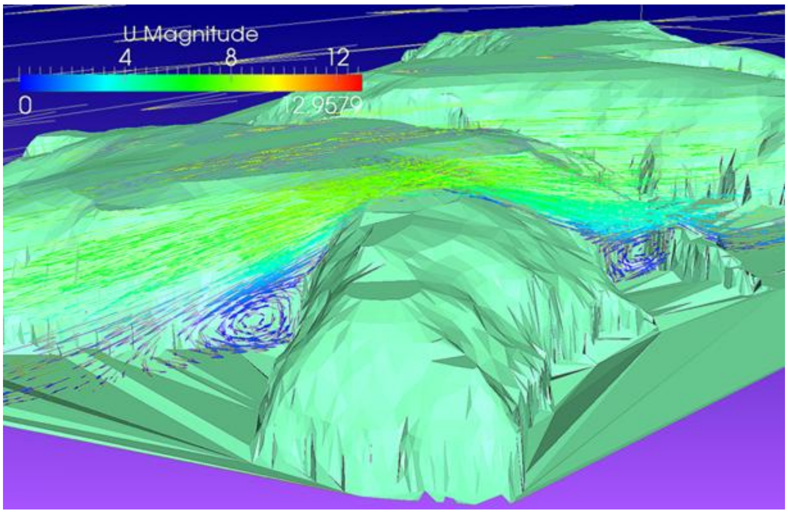
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