ISB

Invest to Save Budget

Improved Air Quality Forecasting
Invest to Save Report ISB52-07

Description of the RAF Northolt ISB-52 Dual Doppler Lidar Trial.

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Executive Summary ISB-52-07

This report ISB52-07 was produced under Project 52 of the Invest to Save Budget, or ISB. The aim of this project is to improve atmospheric pollution dispersion models with the goal of improving air quality forecasting. During the project life, the team will be developing a better understanding of airflow near the earth's surface, focussing especially on urban meteorology. This will be achieved through the gathering of accurate 3-Dimensional wind flow data using laser radars, also called lidars, and by incorporating that new knowledge into the dispersion models. In support of the dual lidar observations, measurements of other parameters describing the characteristics of the boundary layer will be made by single lidar.

Towards the gathering of lidar data a field trial involving simultaneous measurement of wind velocity and turbulence by two 10 μm Doppler lidar systems was conducted in July 2003 at RAF Northolt. It is believed that this is the first time that two identical lidar systems have been used to make simultaneous measurements of the wind field flow across a rural urban boundary. This use of two lidar systems enabled the independent, simultaneous measurement of two components of the wind flow on a second by second basis. Observations made included extensive monitoring of the planetary boundary layer as it evolved around sunrise and sunset to allow the collection of sufficient data to demonstrate proof of concept and be appropriate for comparison with the results of air quality forecasts.

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1. INTRODUCTION

The aim of this Project is the improvement of air quality forecasting for the urban environment through the use of lidar data. Lidar offers the ability to make some unique measurements within the urban environment that will be of great benefit to an improved understanding of pollution dispersal mechanisms within that environment. However care needs to be taken over deploying the lidars.

For example lidar achieves measurements of high angular resolution through the use of a narrow beam divergence. The down side of this is that it takes a long time for the beam to scan over a large angular range. Therefore a lidar cannot monitor a complete wind field instantaneously; also data is produced by the lidar over an extended region. Current air quality models require point source information so there is a need to map the lidar observations to the inputs of the dispersion models. There is also the requirement to ensure the lidar observations are made on scales commensurate with the models.

Previous work [1],[2] had developed a number of scanning patterns that optimised the monitoring of airflow over the urban environment by twin pulsed lidars. In support of this it had been decided that the optimum observation technique is to stare for long periods of time along a relatively low number of pointing angles in preference to trying to cover a large number of points for a short time period. In parallel to defining the experimental technique the 10 μm Pulsed Doppler lidars of Salford University and QinetiQ had been upgraded to a performance level necessary to meet the requirements of the intended ISB-52 observations.

In March 2003 first Dual Doppler Lidar trial was held at Malvern. The key results of that trial [3],[4] where that it had enabled the team to:

1. Deploy Dual Doppler Lidars simultaneously in the field.
2. Develop the technique for alignment of the two beams and locate the intersection point: the team believe this is the first time this has been attempted.
3. Compare the first results for the boundary layer depth obtained in several ways, especially NAME data, ADMS results, Doppler Lidar turbulence profile (as turbulence versus height), aerosol signal decay (as SNR versus height).
4. Evaluate the met pre-processor in the ADMS model using synoptic data as input from available meteorological observing stations.
5. Develop software to retrieve and process AMDARS data: evaluate these results for the potential temperature profile as a separate source of information on the boundary layer, to complement the other observations and model results.
6. Display dual Doppler lidar data as combined results in a sophisticated manner.

The boundary layer depth was identified by the Atmospheric Dispersion Group as a priority, followed closely by the wind and turbulence profiles, and eddy dissipation rate.

The Dual Doppler Lidars have been tested and shown to deliver useful results on these profiles especially at heights that conventional masts cannot reach (these are limited to 45 m in our experience). The improved power and signal to noise ratios of these new instruments means that the turbulence and aerosol concentration can be monitored through the top of the boundary layer.

In July 2003 the ISB-52 Project Team deployed their Dual Doppler Lidars to RAF Northolt. This report describes that trial, the second deployment of Dual Doppler Lidar in an experiment where the intention is to combine the lidar data to fully resolve the wind flow field over a rural urban interface for the first time.

Section 2 gives details of the trial. In section 3 a description of the trial data released for analysis is made. Section 4 presents preliminary results from the data analysis.

2 DESCRIPTION OF THE TRIAL.

2.1 GENERAL DETAILS

The trial was conducted from RAF Northolt. There were a number of advantages in working from RAF Northolt including it being a near optimum location for the lidars to monitor the rural urban boundary, the lidars could operate from an extended baseline with clear fields of view and the equipment could be left in position for the duration of the trial.

The location of RAF Northolt is the western edge of London. The station is about 10 km north of Heathrow Airport and 7 km to the west of the M25. From the airfield it is possible for the lidars to probe representative rural areas around Denham and the Grand Union Canal to the north west. When the wind was blowing from the south east the area to the immediate west of Uxbridge was also considered rural. Urban environments probed included Harrow (North east), Wembley (east) and Ealing (southeast).

The trial geometry is shown in figure 2.1. The QinetiQ lidar was located at the north west edge of the airfield. The Salford lidar was deployed in the south-east part, adjacent to the A40. The lidars were positioned either end of the runway with the north west-south east orientation, 127°. Further details of these locations are given in Table 2.1

Site Name	**Location**	
QinetiQ Lidar	85 4 N	09 1 W
Salford Lidar	84 6 N	10 5 W

Table 2.1 Lidar position information.

At RAF Northolt the baseline separation between lidar stations was 1574 m. Depending upon the mean wind direction and the nature of the dual lidar scan pattern being used beam intersections occurred at different locations. These locations are listed in Table 3.3. The key period for the observations was between the 8th and 23rdof July 2003. The weather throughout this period was variable, table 3.4 lists details of the general conditions around the Northolt area.

A general summary of the conditions is as follows:

From the 8th - 15th July there was a high pressure system situated over the north sea, which gave very light surface easterlies. During this period the temperature were extremely high, as were atmospheric aerosol concentrations. Lidar data, not shown, gives a low boundary layer height during daylight hours (approximately 600 m) during this period.

From the 16th to the 19th there were scattered and heavy thunderstorms throughout the south of the country. The central London region was hit by a series of thunderstorms that was tracked moving south easterly from France. The boundary layer throughout this period was therefore highly convective.

From the 20th to the 23rd July a low pressure system moved in from the south west giving southwesterly flow across the country. There was some stratocumulus cloud cover and the atmospheric boundary layer was well mixed with near neutral condition. Due to the rainfall in the past week and the well mixed atmospheric conditions the concentrations of aerosol in the atmosphere was much lower than previously.

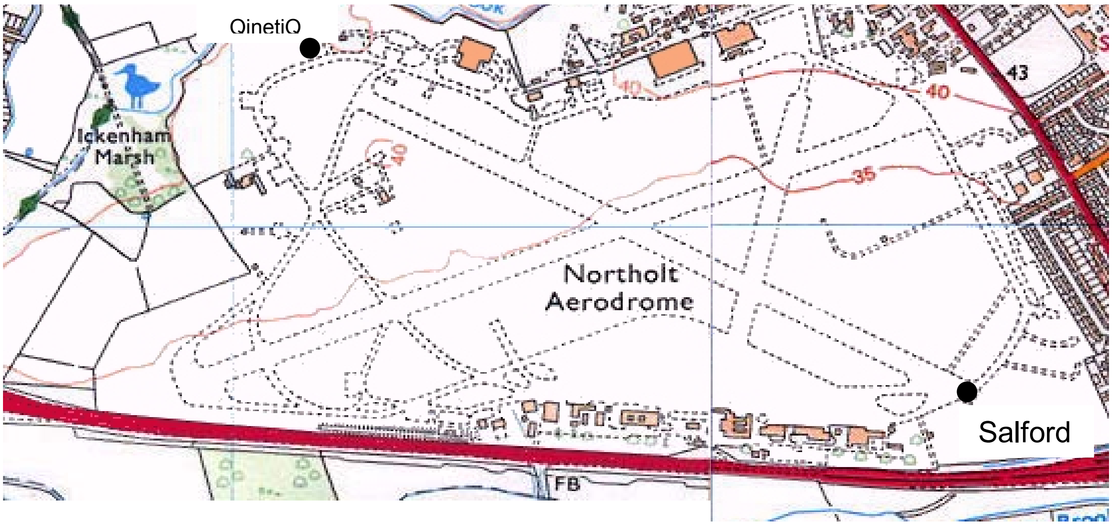


Figure 2.1 Map illustrating the trial geometry.

The general trial scheme was for both lidars to calibrate their alignment using local land marks after the vehicles had been levelled. For calibration of bearing and elevation angles it was found convenient to use the steeples of local churches, the Spire of an Ealing church for the QinetiQ lidar and the Harrow on the Hill spire for the Salford lidar. All data was time stamped from a GPS signal.

Once the lidar systems were calibrated a VAD was undertaken to determine the predominant wind direction. (The VAD data is also useful for comparing the results from the two lidars and checking system bias). Once the wind direction was identified the lidar beams were orientated to make the dual lidar observations. A number of scan patterns were employed, each designed to optimise the observation of a particular component of the wind flow field. Details of these scan patterns are given in section 3 and the appendices.

For much of the trial the lidars were operated in a real time data processing mode. This allowed the operator the ability to continually check that the lidar performance was satisfactory during a data collection base. The QinetiQ lidar sampling rate was of the order of 0.2 Hz, the Salford system was 0.12 Hz. Range gates were of 112 m length unless otherwise noted. A limited amount of data was collected by the QinetiQ lidar operating in 'raw' mode at 50 Hz. However it was observed that operation in this mode was causing excessive arcing across the anode which it was feared would lead to damage in the TEA laser head. Due to the concerns that raw mode operation would damage the lidar the mode was only used by a single lidar once to acquire sufficient data to allow subsequent assessment.

The two lidar systems have identical key features. They operate at a wavelength of 10.6 μm and have a spatial resolution of 112 m along the beam. Other system characteristics are detailed in table 1 of report ISB52-04 [5]. The minimum ranges of the systems are determined by the back reflections of the individual optical components within the lidar. The maximum ranges are dependent upon the alignment of components within the system and the aerosol loading of the atmosphere. The two lidar systems consequently show slightly different minimum and maximum ranges, due to their different alignments. These maxima and minima vary under different atmospheric conditions. The minimum and maximum ranges are approximately 700 m and 9000 m. The basic set-up of the two systems was detailed in report ISB52-02 [3],[6] and operation summarised in ISB52-06[4].

In support of the lidar observations an automated weather station with acoustic anemometer was located besides the Salford lidar. This system was deployed to gather surface meteorological data wind speed and direction, temperature and solar radiation measurements at 2m. From this data it is intended to calculate the atmospheric stability in order to classify and quantify the level of atmospheric stability under which the lidar observations were made

2.2 SCAN STRATEGIES

Prior to the trial a plan sets had been devised for selecting scan strategies according to the forecast meteorological situation. There are two basic strategies depending upon ambient conditions. If the situation is convective then VAD/Fixed & Dual measurements will be made. However if ambient conditions are near neutral the measurements will be VAD and scanning RHIs.

The VAD's are important for two reasons:

1) hourly boundary layer height is a priority for NAME and ADMS;
2) wind direction from VAD is needed to set the lidar beam orientations for an RHI.

2.2.1 Convective conditions

Under convective conditions the measurements would focus on deriving the wind profile and turbulence data. This would be achieved through the use of VAD and staring dual beam. Ideally this should be undertaken when conditions of strong day-time convection or strong urban nocturnal heat flux is expected. This can be further sub-divided into morning transition study from dawn until mid-afternoon maximum boundary layer turbulence and a separate evening transition study from mid-afternoon until stable/nocturnal conditions established. From this the boundary layer growth and its evening decline can be to followed. From the dual lidar information profiles of wind speed, direction and turbulence can be derived. Since convective scan pattern uses fixed beams (stand and stare) the time period of sampling (15 minutes) is designed for reliable turbulence statistics, turbulence spectra, and eddy dissipation rates.

The structure of the scanning for the convective pattern was set to be a VAD on the hour every hour with an allowed duration of 15 minutes. This would then be followed by three fixed dual beam stares with both lidars of 15 minutes each. If slippage in timing occurs due to on site practical limitations, it is important to keep VAD's on the hour to match ADMS model.

In practice VADs seldom occurred upon the hour for a number of practical reasons, however the trial team did their best to ensure that the VADs were made as close to the hour as possible. Also the practice was adopted of the QinetiQ lidar undertaken a hemispherical RHI along the mean direction of the wind whilst Salford did the VAD observation. To ensure that the lidar beams intersected the boundary layer at least once with a high SNR the experimental strategy was adjusted so that four or five heights were probed per column. To retain the hourly cycle the staring times were reduced to lengths of 10 minutes. This strategy meant that it took two hours to measure both the rural and urban columns of air. When conditions were deemed to be evolving more rapidly observations of the rural column were abandoned to allow the urban column to be monitored on an hourly cycle.

The geometry for the fixed dual measurements needed be designed to achieve the correct beam intersections. Typically angles were set to allow beam intersections at set heights in the column: typically these heights were 100, 200, 400, 800 and 1600 m. Further considerations are also necessary to determine the location of the vertical column. Such considerations needed to optimise these beam intersections to allow obtaining the flow vector and vertical fluctuations with the minimum number of assumptions. Further details about the variations in the scan geometry used are given in section 3.

2.2.2 Near Neutral Pattern

If the conditions are closer to near neutral then the measurements will concentrate on deriving surface layer parameters through the use of VAD plus RHI scans. This is optimum when moderate winds and cloud covers occur causing the dominant turbulence to be due to mechanical shear. Under these conditions the measurements will seek to highlight the effects of surface roughness and upwind fetch. It may also prove possible to identify spatial area averages of said parameters and detect differences in the flow field over the urban and rural environments.

Again emphasis was given to making a VAD on the hour every hour for which 15 minutes duration was allowed. (10 minutes for the scan and five to set up the VAD and analyse the results). A real time analysis of the VAD was used to determine the mean wind direction this is crucial for determining the orientation of the subsequent RHIs. As with a measurement made by conventional anemometer the turbulent flow is influenced by the upwind surface type over which the air has flown. Thus it is necessary to establish the wind directions at the edge of the rural to urban boundary and identify the type of substrate or surface type each beam is effectively observing above. Once the VAD had been analysed then two RHI scans would follow each of 30 minutes duration. The two lidars were deployed for RHI 1 & 2 as follows:

RHI 1 The Salford lidar pointed downwind over London and QinetiQ pointed upwind over the rural

RHI 2 Salford pointed orthogonal to the wind whilst QinetiQ pointed orthogonal to wind and at 180° from the Salford direction.

For the RHI scans the maximum elevation for both lidars was set at 45° to match the design limit of the Salford instrument. The experimental configuration is shown schematically in figure 2.3 of ISB52 MS3 [2]. A requirement for the subsequent theoretical analysis and the associated assumptions therein is that the RHIs should be made along bearings parallel and orthogonal to the mean wind direction.

3 KEY RESULTS SUBMITTED FOR FURTHER ANALYSIS.

The key data products that will be released for subsequent analysis are files containing the results of lidar observations. That data is too extensive for full inclusion here, instead a summary of observations is made.

The tables in appendix 1 and 2 summarise the lidar data files released for further analysis. These tables state details of the scans used and when the file was recorded. Where necessary additional information has been added as appropriate. Appendix 1 summarises the released QinetiQ data and Appendix 2 the released Salford data. Table 3.1 gives details of the locations of where the beams crossed and the accuracy of the beam intersection. Table 3.2 relates the synoptic situations around RAF Northolt for the duration of the trial. (The key observations of the July trial where made from the 8th to the 23rd July 2003).

Pattern No	Location	Intersection point co-ordinates		Reason
1	Rectory Park, Yeading	183630	512 838	Urban vertical
2	Ickenham	186 216	506 812	Rural vertical
3	South Ruislip	186000	512000	Urban horizontal
4	Mid point of runway	184 986	509 847	Resolved vertical

Table 3.1 Evaluation of the lidar beam crossing points.

Day	Date	Weather	Wind
Tuesday	8 July 2003	*Dry, humid and sunny with Cumulus forming through the morning.*	*Light SW*
Wednesday	9 July 2003	*Fine and dry. Cumulus developing through the morning.*	*Light SW*
Thursday	10 July 2003	An area of high pressure extending across the south of the UK will bring a light southwesterly flow across the area.	Light SW
Friday	11 July 2003	An anticyclone near the Azores extends a ridge of high pressure across England And Wales, given a northwesterly flow across the area.Dry and bright. Scattered cumulus developing by 0900Z.	Light NW
Tuesday	15 July 2003	*Dry sunny start. Turning cloudy late in the day with risk of thundery showers by evening.*	*Moderate ESE*
Wednesday	16 July 2003	A thundery area of low pressure centred over northern France will give a warm southeasterly flow across the area. Scattered showers and thunderstorms spreading from the south, continuing through this evening	Moderate and variable, mainly southesterly,
Monday	21 July 2003	Low pressure lies to the north of Ireland	

		with a trough moving east across Ireland, giving an unstable southwesterly flow across much of the country. Showers developing after 1000Z, isolated heavy, thundery this afternoon.	Moderate SW
Tuesday	22 July 2003	Cumulus developing after 0800Z, isolated light showers by afternoon.	Light SW
Wednesday	23 July 2003	A low pressure system centred just north west of Ireland with an associated occlusion west of Cornwall at 0500Z, moving east. Bright morning with scattered cumulus. Turning cloudier PM with patchy rain by evening.	Light SW

Table 3.2 Synoptic data for days of principle data gathering. Italics indicates information comes from a local forecast for a period of more than 12 hours in advance.

4 DATA ANALYSIS

4.1 PRELIMINARY RESULTS

The full complement of data that is available from this field trial is extensive and only a sample of it discussed in this report to indicate the value of the observations. The final year of ISB-052 will be given over to a complete analysis of this data set and comparison to predictions from pollution dispersal models and complementary data retrieved from the AMDARS programme, see MS6 [4].

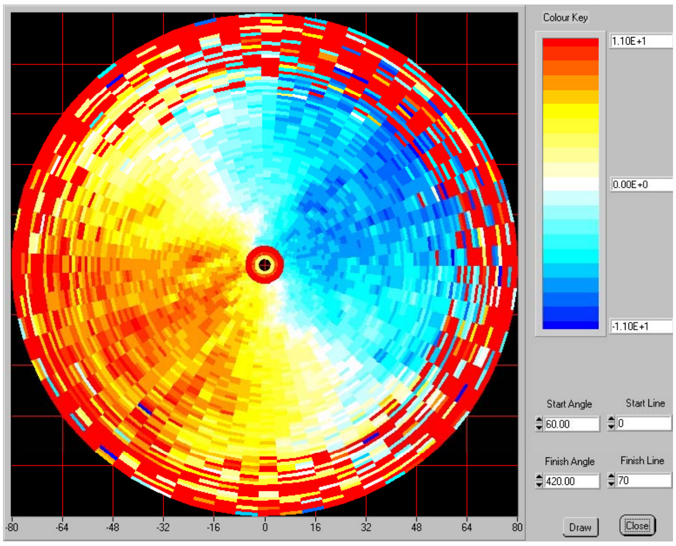


Figure 4.1 Doppler display VAD. VAD made on the 10th July 2003 at 14.19.

Figure 4.1 shows the results of a VAD made on the 10th July by the QinetiQ lidar. The measurement was made starting at an azimuth of 60° and rotating clockwise to 420° at a scan speed of 1° per second. North is at the top of the chart. This was undertaken at an elevation of 8°. In figure 4.2 the derived parameters from this VAD of the wind profiles as a function of altitude are shown. Following the analytic technique outlined in [3] the bias on this data was evaluated to be 0.26 m/s. This bias was used to modify the raw data prior to plotting in figure 4.2.

The system bias occurs due to a shift between the reference spectrum and the return spectrum [3]. The magnitude of the bias is expected larger for the Salford system than the QinetiQ system. This is because in the Salford system the bias will be accentuated due to the fact that the leading edge of the reference pulse is contaminated by electrical interference. This has the effect of suppressing the high frequency part of the reference waveform leading to a distortion towards lower frequencies, enlarging the bias. The exact correction required for the Salford system can be readily computed by taking a representative reference waveform and convolving it with sinc function associated with the range-gate window.

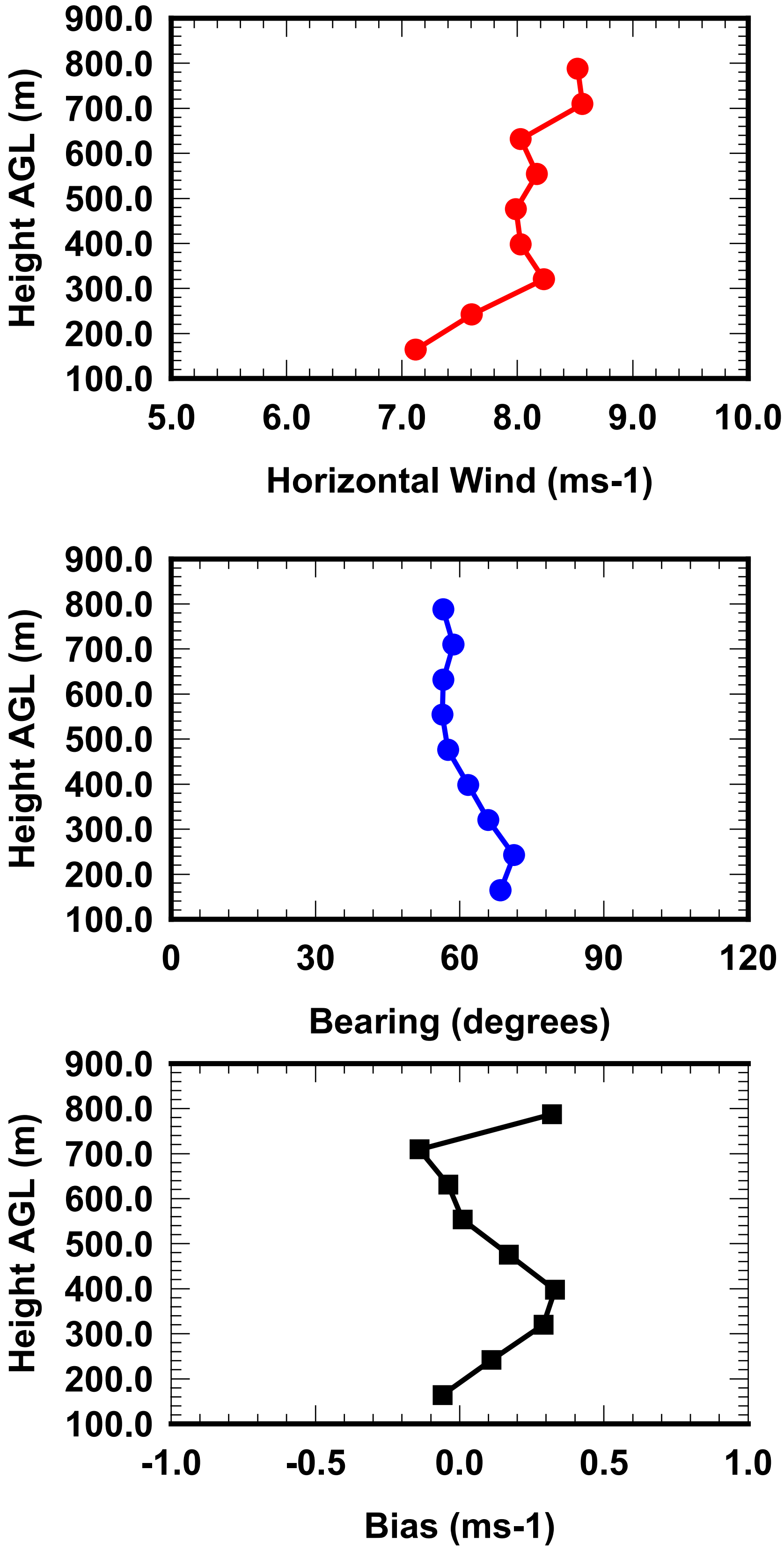


Figure 4.2 Wind profile derived from VAD020.

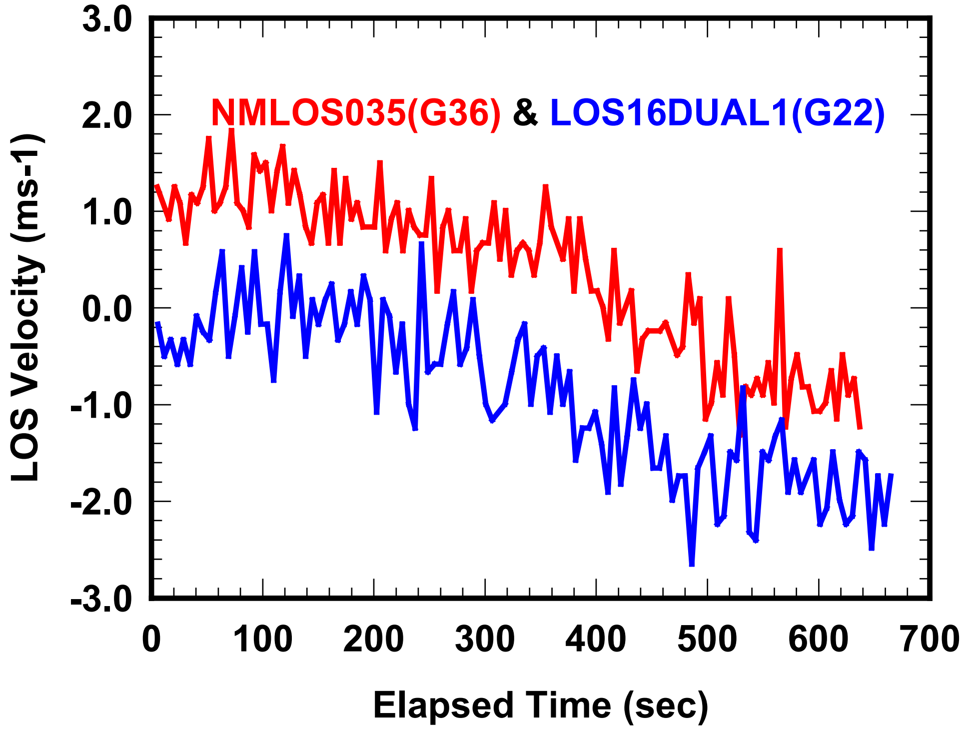


Figure 4.3 Corresponding line of sight velocities from observations made by the two lidars.

Figure 4.3 illustrates two sets of line of sight velocity data from observations made simultaneously by the two lidars. The data comes from range gate 22 of the Salford file LOS1DUAL1 and range gate 36 of the QinetiQ file NMLOS035. The two lidars were probing south eastwards at the time of these measurements over Greenford. The two lidars should be seeing approximately the same Doppler. The average difference between the QinetiQ and Salford measurements was an offset of 1.3 m/s. Assuming the QinetiQ measurements are absolute following derivation of bias, then the bias upon the Salford system is equivalent to this offset.

Figure 4.4 previews some of the Dual Doppler lidar data taken on the 23rd July 2003. It shows the variation in observed line of sight velocities at the four points in the sampling column where the beams crossed. This corresponded to heights of 100, 200, 400 and 709 m. These observations were made at a point halfway between the two lidars, corresponding to pattern 4 in table 3.1. During these measurements the plane of the lidars (118°) was within 5° of being perpendicular to the mean wind direction (203°). Therefore the contribution of the horizontal component of the wind is minimal during this experiment and this will allow the much smaller vertical wind component to be more accurately resolved. At low levels (100 m) the horizontal component dominates the observations and so the QinetiQ signal should be the negative of the corresponding Salford measurement. This is confirmed by inspection of the data from gate 7 (100 m). As the altitude increases the vertical component of the wind field governs the line of sight measurement made by the lidars so the Salford signal should correlate strongly with the QinetiQ signal This is confirmed by the variation in line of sight data displayed for gate 9 (709m).

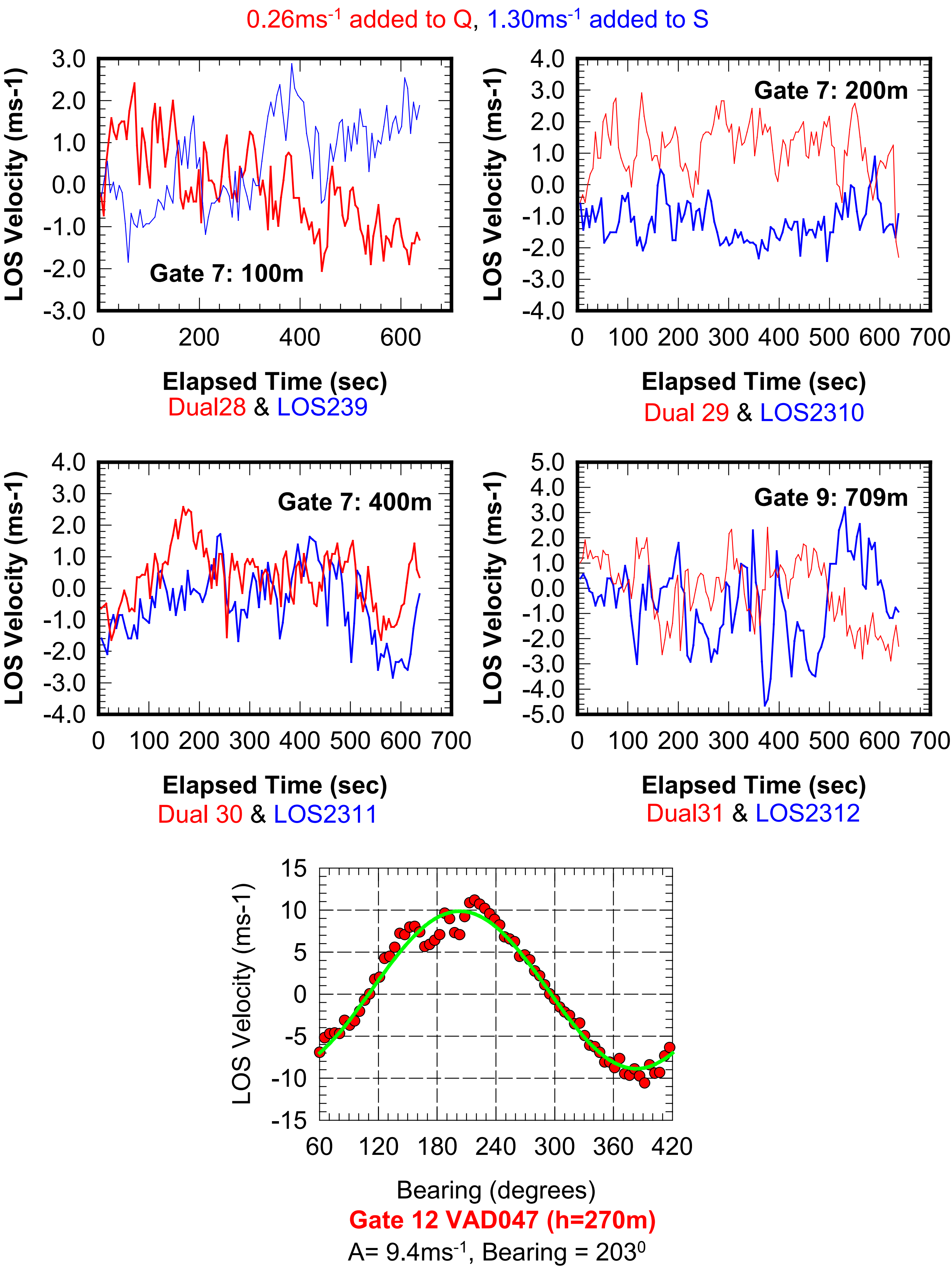


Figure 4.4 Dual Doppler Column data.

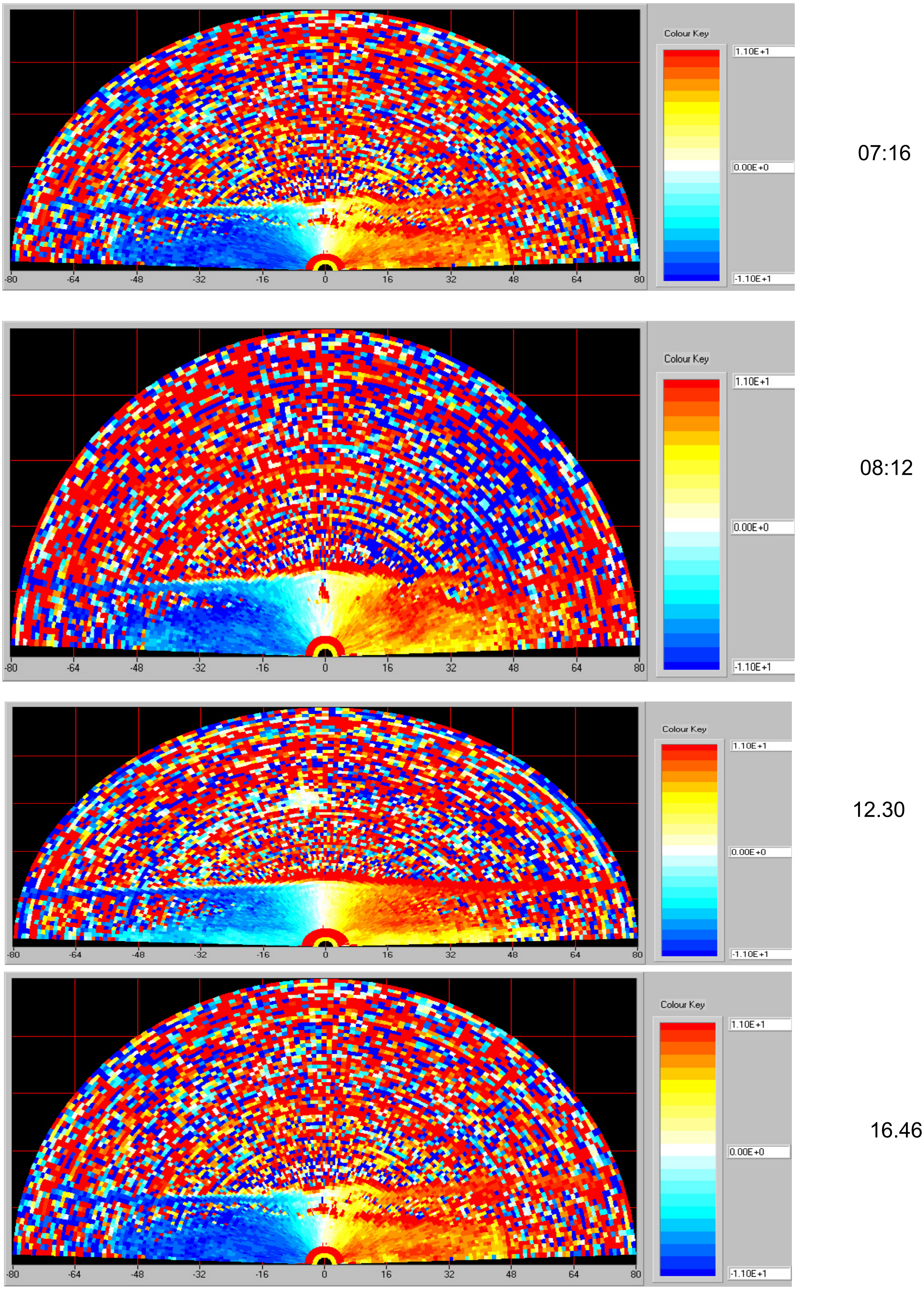


Figure 4.5 Doppler RHIs 23rd July 2003

Figure 4.5 shows a set of RHIs taken throughout the 23rd July 2003. On that day the synoptic situation was a low pressure system centred just north-west of Ireland with an associated occlusion lying west of Cornwall at 0500Z, that moved east during the day. The RHIs were along a bearing of 60° which is close to parallel with the ambient wind direction of that day (from the South West). The lidar started pointing towards London (Ealing) and scanned upwards over the vertical and into the rural, to a point just beyond Uxbridge. The left hand side of the figures relates to the urban environment and the right and side of the figure to the rural. These figures illustrate the evolution of the atmosphere throughout that day. Scanning was conducted at a rate of 0.25° per second.

It is seen that the well defined edge observed at 07:16 is breaking down by 08:12. At 12:30 mixing has occurred and there is evidence of some turbulence. By 16.46 the atmosphere is observed to be well mixed.

Further analysis of this data set is given in Figure 4.6. Figure 4.6 displays the same lidar data but now in terms of backscatter strength rather than line of sight velocity. (Backscatter data is in $m^{-1}str^{-1}$). The curved red line represents the cloud base. The top figure is the data from 07:16 GMT whilst the lower figure is for 12:30. At 07:16 there is a definite increase in backscatter strength over London as opposed to the rural. The difference in scatter strength less notable for the 12:30 observation, though that shows an increase in the top of the back scattering layer.

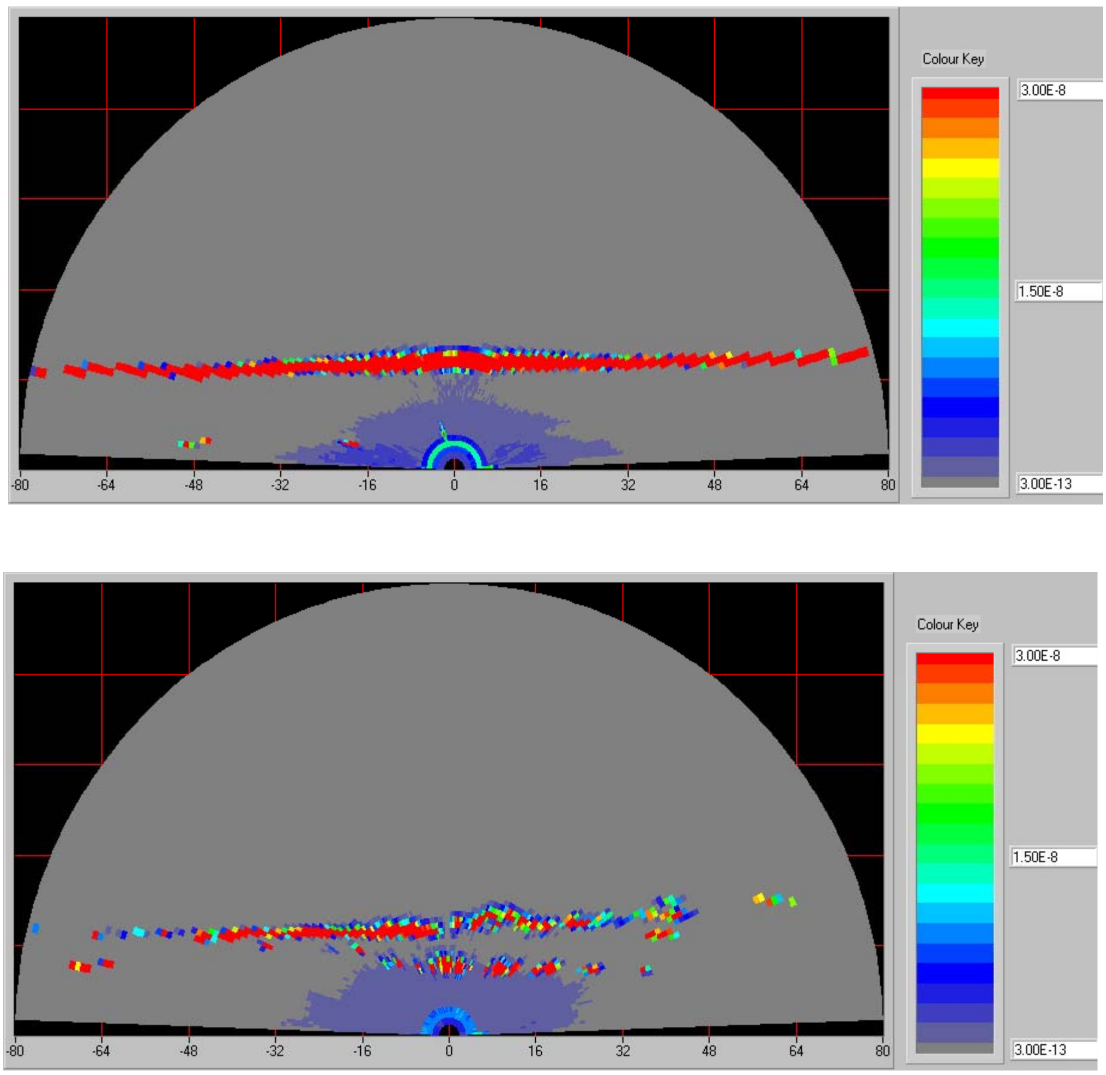


Figure 4.6 Derived backscatter profiles.

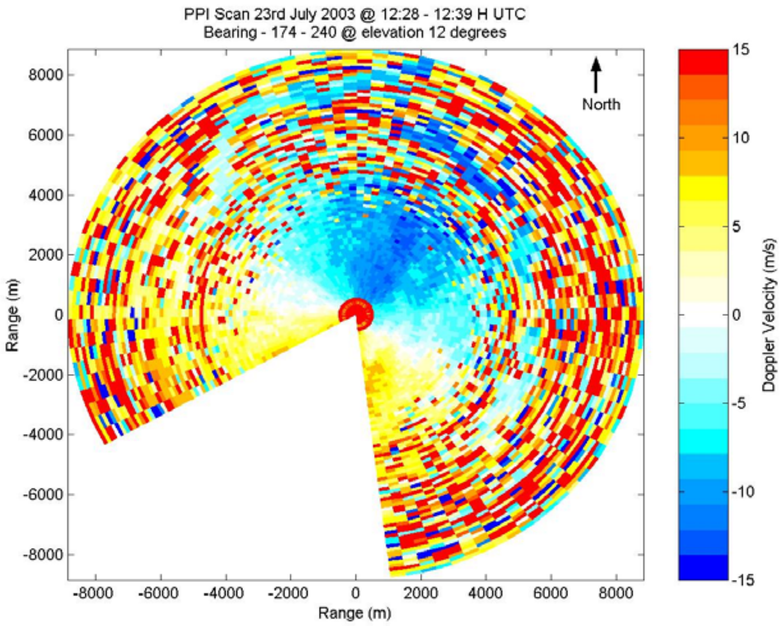


Figure 4.7 VAD scan taken on 23rd July 2003 between 12:28 – 12:39 H UTC.

Figure 4.7 shows the results of a VAD scan taken on 23rd July 2003 between 12:28 and 12:39 H UTC, corresponding to the RHI data shown in figures 4.5 and 4.6. The direction of north is indicated on the figure. The wind flow is from the southwest to northeast. In this example the blue colours, negative velocities, represents airflow away from the lidar, whilst red colours, positive velocities, are airflow towards the lidar. The lidar scanned from 174° to 240° and the colour key to the side is wind velocity in m/s bearing in an anticlockwise direction at an elevation angle of 12°. The minimum range of the measurements is 560 m and the maximum range for good velocity estimates is approximately 4000 m, at which point the beam was sampling the atmosphere 815 m above ground level. The backscattered return signal then falls below the level of the system noise. A cloud band can be seen between 5000 m - 7000 m in range.

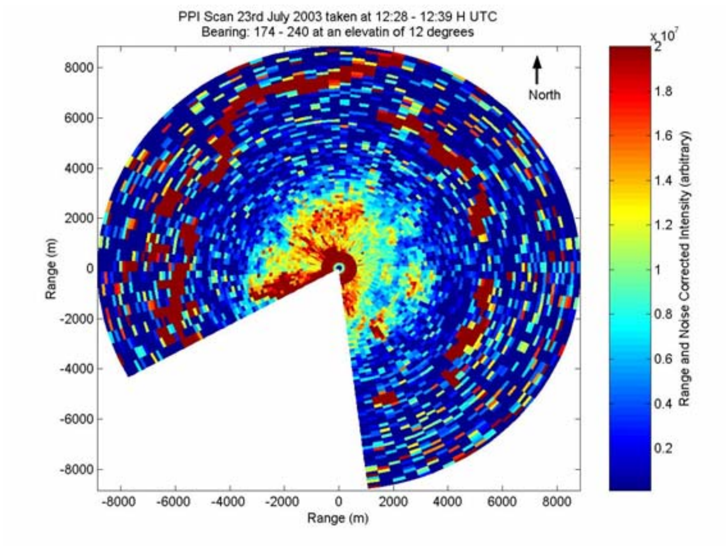
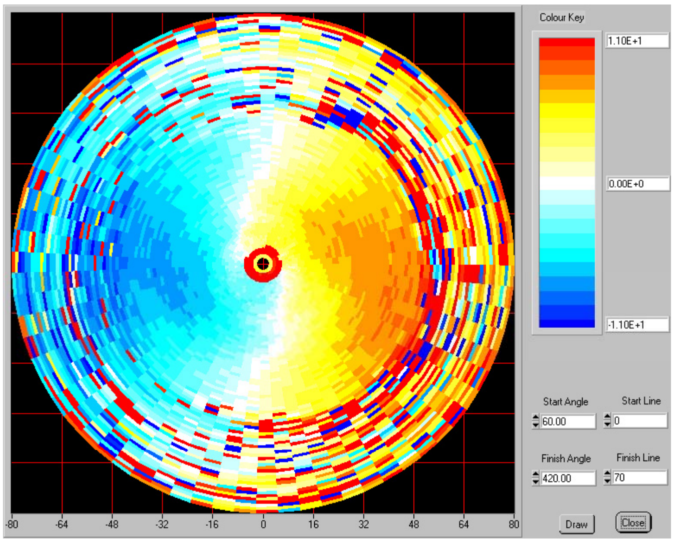


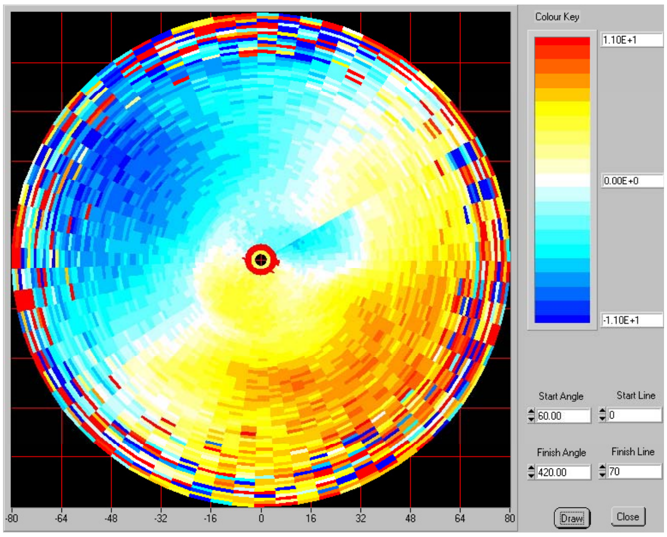
Figure 4.8. VAD scan data equivalent to 4.7 but showing range corrected backscatter intensity.

Figure 4.8 corresponds to figure 4.7, however this time backscatter intensity rather than line of sight velocity is displayed. The lidar return power is not a direct measure of the concentration of particles in the atmosphere, but the variations in the lidar return power are proportional to variations in the overall particulate concentration. Higher backscatter intensities imply higher particulate concentrations, represented by the yellow/red colours. The lighter colours are lower intensity and indicate lower concentrations. The cloud band becomes particularly apparent in this figure.

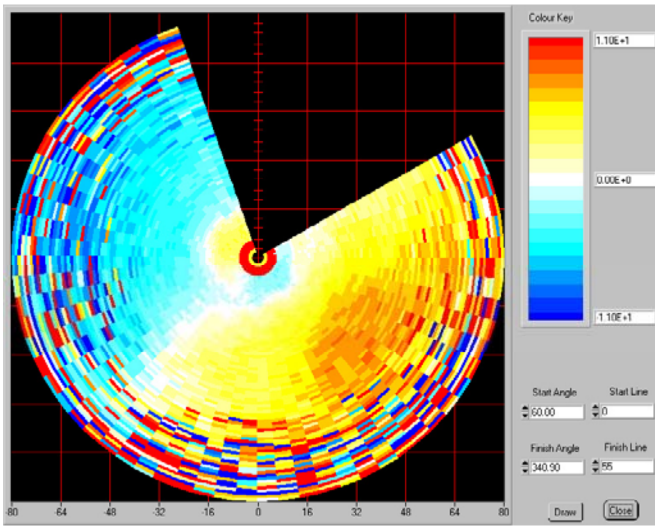
For this data there appears a notable difference in ceiling height of the cloud over the urban in comparison to the rural environments in the Northolt area. This difference in heights is ascribed as being due to the variation in moisture and temperature over these different areas. The area to the west and southwest of Northolt is rural with several distinct water sources there that will cause increased evaporation over this area. It is expected that these differences in conditions will cause clouds formation at differing heights which could account for the higher cloud levels seen over the rural area. This will be investigated further during the remainder of the ISB-52 project.



VAD027



VAD028



VAD031

Figure 4.9 Doppler VAD, made under conditions of dark storm clouds over London. (Details of observations given in the text).

Figure 4.9 shows Doppler VADs made of a thunder-storm approaching London from the south. All observations were made at a scan rate of one degree per second and with the lidar beam at an elevation of 10°. All VADs start at a bearing of 60° and revolve clockwise to 420°. These VADs show a rapid evolution of the flow to conditions of flow reversal.

This data was taken on the 16th July 2003 between 07.45 and 08:54. (VAD027 was recorded at 07.45, VAD028 at 08:38 and VAD031 at 08:48). The synoptic situation was an area of low pressure centred in the English channel moving slowly northwards. This led to the occurrence of thunder storms around the Northolt area.

4.2 REVIEW OF TRIALS EXPERIENCE

This trial was the first time that the project team had endeavoured to measure the wind flow field over the rural urban interface under evolving conditions. Despite the considerable planning that went into preparing for this trial a number of valuable lessons were learnt during the course of the trial.

Generally it was found that the dual lidar observations were too slow to be made to observe rapidly evolving conditions. Due to this, it was decided that for periods close to sunset scanning VAD and RHIs rather than staring measurements would be made. This was adhered to even for days when most of the time was spent in a staring configuration. For such days after the sun had set the project team would revert to making staring measurements.

After making a set of dual Doppler lidar measurements that feature observations into both the rural and the urban environments, subsequent days of dual Doppler lidar concentrated the dual observations solely on the urban. This approach was adopted to allow more observations to be made of the development of conditions in the urban environment. Under this regime conditions in the rural were tracked by the hourly VAD scan undertaken by the Salford lidar and an RHI from the urban to the rural by the QinetiQ lidar.

For the Dual Doppler lidar measurements to derive unambiguous vertical flow information initially the two intersection points were chosen in the plane of the lidars and beyond the lidars. This allowed one sampling column to be in the rural and the other in the urban. Whilst this configuration allowed vertical information to be extracted from rural and urban environments the penalty for doing this was the need to use low elevation angles, (typically 1.41°, 2.81°, 5.61° and 11.11°).

The justification for undertaking the in plane measurements at low elevation angles beyond was that the expected differences between the rural and urban environments would be more prominent in the layers closer to the surface. This is because higher in the atmosphere the turbulence due to the surface artefacts becomes increasingly mixed. The result of this mixing is that the region of the surface that is deemed to influence the turbulence structure of flow (or 'footprint') becomes increasingly large. To ensure that some measurements were made from which surface effects could be ascertained it was necessary to undertake some measurements as low as possible in the atmosphere.

The derived vertical velocity data is the line of sight velocity multiplied by the sine of the angle of elevation, which for a small angle of elevation gives a small vertical velocity component. An alternative in-plane scan strategy had to be devised to allow accurate monitoring of the vertical flow. A new experimental strategy was used where only a single column of air was sampled and the column occurred mid way between the two lidars. For such a configuration the angles of elevation become large (Typically 7.24°, 14.26°, 26.94° and 42.00°) but no comparison of the rural urban interface could be made. However given that it was felt that the observations to make these comparisons were taken too long this was not seen as a major issue.

The exceptionally hot conditions of the period of the 8th to the 15th July caused some technical difficulties. The heat caused thermal expansion in some of the optical component mounts leading to misalignments a loss of operational performance. This was compensated for in the field by adjustment of the appropriate optics. The heat also proved problematic for the QinetiQ laser cooler. That issue was resolved by removing the cooler from inside the QinetiQ lidar van, then repositioning it to allow the maximum amount of wind to blow over it.

5 SUMMARY

This report is the seventh milestone in the ISB52 Urban lidar project. The contents of the report are summarised below:

- A description of the second, summer trial.
- The first Dual Doppler lidar measurements over the rural urban interface have been completed.
- A review of the data released for subsequent analysis is given.
- A preliminary analysis of the data has been presented.

The summer trial for ISB-52 has now been completed. During this trial twin 10 μm Doppler lidar systems and a dedicated automatic weather station were deployed at RAF Northolt during the month of July 2003. The twin lidars made simultaneous measurements of wind velocities and back scatter strengths of the atmosphere over the rural urban boundary of West London.

It is believed that this is the first time that two identical lidar systems have been used to make such simultaneous measurements of the wind field flow across a rural urban boundary. This use of two lidar systems enabled the independent, simultaneous measurement of two components of the wind flow on a second by second basis. Observations made included extensive monitoring of the planetary boundary layer as it evolved around sunrise and sunset to allow the collection of sufficient data to subsequently demonstrate proof of concept and be appropriate for comparison to the results of the equivalent numerical modelling predictions.

The next stage of the project is to analyse the results of the Northolt trial. This work will include comparing the results for the boundary layer depth obtained in several ways, especially NAME data, ADMS results, Doppler Lidar turbulence profile (as turbulence versus height), aerosol signal decay (as SNR versus height). In support of this there is a requirement to evaluate the met pre-processor in the ADMS model using synoptic data as input from available meteorological observing stations. The developed software for retrieval and processing of AMDARS data will be used to obtain a set of complimentary data. Key to all of this work is the need to evaluate these results for the potential temperature profile as a separate source of information on the boundary layer, to complement the other observations and model results. It is expected that this data evaluation will last from August 2003 to project closure in September 2004.

5 REFERENCES

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[2] Identification of key flow parameters for visualisation. RI Young, S Siemen, AR Holt & GJG Upton ISB52-03 Aug 02.

[3] Assessment of lidar performance and data from the first dual doppler lidar trial. GN Pearson & DV Willetts ISB52 TWP March 2003

[4] Boundary Layer Measurements of Dispersion Model Parameters using Dual Doppler Lidar at Malvern, UK. F Davies, C Collier, A Holt, D Middleton, G Pearson, S Siemen, DV Willetts & RI Young. ISB52 -06 July 2003

[5] Identification of key parameters for dispersion models. F Davies, C Collier, K Bozier & DR Middleton ISB52-04 Feb 2003

[6] Boundary layer meteorology by pulsed lidar. Pearson, GN DV Willetts & RI Young. ISB52-02. April 02.

6 GLOSSARY

AWS Automatic weather station

PBL Planetary Boundary Layer

RHI Range Height Indicator

PRF Pulse Repetition Frequency

PPI Plan Position Indicator

VAD Velocity Azimuth Display

APPENDIX 1 QINETIQ LIDAR DATA RELEASED FOR FURTHER ANALYSIS.

Data File	Start Time	Finish Time	Az	El	Angle File	Comments
07/07/03 Monday						
NVAD001.dpd	17:22:10	17:34:24	60 – 420	30	ANGL0000.txt	
NVAD002.dpd	17:37:36	17:44:13	60 – 420	10	ANGL0002.txt	
08/07/03 Tuesday						
NVAD003.dpd	09:03:34	09:11:21	60 – 420	12	ANGL0003.txt	
NMLOS001.dpd	09:03:34	10:02:40	90	12	n/a	
NMLOS002.dpd	10:05:21	10:26:40	299	12	n/a	
NVAD004.dpd	10:34:58	10:41:05	60 – 420	5	ANGL0005.txt	
NMLOS003.dpd	10:45:52	11:07:11	90	5	n/a	
NMLOS004.dpd	11:28:17	11:37:56	299	5	n/a	
NMLOS005.dpd	11:48:10	12:09:50	299	5	n/a	
NVAD005.dpd	12:12:35	12:19:23	60 – 420	5	ANGL0006.txt	
NMLOS006.dpd	12:30:56	12:52:20	90	7	n/a	
NMLOS007.dpd	12:53:36	13:15:01	299	7	n/a	
NVAD006.dpd	13:35:02	13:40:47	60 – 420	7	ANGL0008.txt	
NVAD007.dpd	13:47:34	13:54:29	60 – 420	7	ANGL0010.txt	
NMLOS008.dpd	16:19:39	16:41:18	90	7	n/a	
NMLOS009.dpd	16:44:20	17:05:40	299	7	n/a	
NVAD008.dpd	17:12:10	17:18:58	60 – 420	7	ANGL0011.txt	
NMLOS010.dpd	17:41:55	18:03:14	90	7	n/a	
NMLOS011.dpd	18:08:30	18:30:08	299	7	n/a	
NVAD009.dpd	18:30:02	18:38:50	60 – 420	7	ANGL0012.txt	
09/07/03 Wednesday						
NVAD010.dpd	07:47:07	07:53:55	60 – 420	7.19	ANGL0013.txt	
NMLOS012.dpd	07:56:51	08:18:07	90	7	n/a	
NMLOS013.dpd	08:20:20	08:43:49	299	7	n/a	Sun went in at about 8.30. At line 43 detector lost lock for about 40 seconds.
NVAD011.dpd	08:46:52	08:53:40	60 – 420	7	ANGL0013.txt	
NMLOS014.dpd	08:57:33	09:18:48	90	7	n/a	
NMLOS015.dpd	10:43:51	11:13:24	299	10.2	n/a	Stopped due to detector fault at about 185 of 250.
NMLOS016.dpd	11:58:33	12:19:57	90	10	n/a	
NRHI001.dpd	12:23:54	12:27:18	90	5 - 175	ANGL0015.txt	
VIRTICAL0001.dpd	12:28:56	12:32:20	n/a	n/a	n/a	
NMLOS017.dpd	13:20:27	13:41:42	299	10*	n/a	*Half way changed to 20
NMLOS018.dpd	13:44:33	14:05:58	90	20*	n/a	* Half way through changed to 10
NVAD012.dpd	14:07:00	14:13:48	60 – 420	20	ANGL0016.txt	
NRHI002.dpd	14:16:38	14:20:02	90	5 – 175	ANGL0017.txt	
NRHI003.dpd	14:22:53	14:34:37	90	5 – 175	ANGL0018.txt	
NRHI004.dpd	14:35:35	14:47:29	90	5 – 175	ANGL0019.txt	
NRHI005.dpd	14:48:44	15:12:32	90	5 – 175	ANGL0020.txt	Two sweeps

Data File	Start Time	Finish Time	Az	El	Angle File	Comments
NVAD013.dpd	15:25:28	15:32:16	60 – 420	40	ANGL0022.txt	
SSTARE01.dpd	15:34:24	15:44:36	90	20		**RHI step stare sequence**
SSTARE02.dpd	15:46:14	15:56:26	90	40		
SSTARE03.dpd	15:57:15	16:07:27	90	160		
SSTARE04.dpd	16:08:08	16:18:20	90	140		
SSTARE05.dpd	16:19:05	16:29:17	90	90		
NVAD014.dpd	16:31:13	16:38:01	60 – 420	40	ANGL0023.txt	
NRHI006.dpd	16:47:11	17:10:59	90	5 – 175	ANGL0025.txt	Two sweeps
ELSCAN01.dpd	17:17:04	17:34:04	90	5 – 20	ANGL0026.txt	
NVAD015.dpd	17:35:37	17:41:59	60 – 420	40	ANGL0027.txt	
NVAD016.dpd	17:44:06	17:50:54	60 – 420	8	ANGL0028.txt	
ELSCAN02.dpd	17:53:19	18:04:11	90	175 – 145	ANGL0029.txt	
ELSCAN03.dpd	18:11:11	18:21:23	90	5 – 35	ANGL0031.txt	
10/07/03 Thursday						
NVAD017.dpd	08:29:25	08:36:13	60 – 420	15	ANGL0033.txt	
NRHI007.dpd	08:42:04	08:53:59	90	1 – 179	ANGL0034.txt	Noise floor not too good. LO fallen away since noise taken
NRHI008.dpd	09:05:26	09:17:20	43	2 – 178	ANGL0036.txt	Set azimuth to be approximately along the direction of the wind as derived from NVAD017
NMLOS019.dpd	09:23:05	09:44:20	43	10	n/a	
NMLOS020.dpd	09:45:33	10:06:48	43	170	n/a	
NVAD018.dpd	10:08:34	10:15:22	60 – 420	10	ANGL0037.txt	
NRHI009.dpd	10:18:04	10:29:58	43	2 – 178	ANGL0038.txt	
NMLOS021.dpd	10:32:25	10:53:40	43	10*	n/a	***** Changed to 5 half way through
NMLOS022.dpd	11:03:44	11:24:59	43	175	n/a	
NMVAD019.dpd	11:52:29	11:59:17	60 – 420	5	ANGL0040.txt	Hits the trees at some azimuths when elevation 5
NMRHI010.dpd	12:03:57	12:15:52	43	2 – 178	ANGL0041.txt	
NMLOS023.dpd	12:20:16	13:50:24	43	8	n/a	
NMLOS024.dpd	13:57:16	14:18:31	43	8	n/a	
NMVAD020.dpd	14:19:44	14:26:42	60 – 420	8	ANGL0042.txt	
NMLOS025.dpd	14:30:46	14:52:01	43	172	n/a	
NMRHI011.dpd	14:53:37	15:05:31	43	2 – 178	ANGL0043.txt	
NMVAD021.dpd	15:07:48	15:14:36	60 – 420	30	ANGL0044.txt	
NMLOS026.dpd	15:18:36	15:39:31	43	12	n/a	
NMLOS027.dpd	15:40:29	15:48:35	43	168	n/a	Stopped after 80 due to loss of lock
NMLOS028.dpd	15:49:35	16:02:20	43	168	n/a	
NMVAD022.dpd	16:03:42	16:10:30	60 – 420	12	ANGL0045.txt	
NMRHI012.dpd	16:11:44	16:23:38	43	2 – 178	ANGL0046.txt	
VERTICAL002.dpd	16:25:03	16:33:23	n/a	90	n/a	
11/07/03 Friday						

Data File	Start Time	Finish Time	Az	El	Angle File	Comments
NMVAD023.dpd	08:33:26	08:40:14	60 – 420	12	ANGL0047.txt	
NMRHI013.dpd	16:11:44	16:23:38	105	0.5–179	ANGL0049.txt	Hits trees at end (about 175)
NMLOS028.dpd	09:05:26	09:38:41	105	8	n/a	This file name was used earlier, assuming it was used twice by mistake and both files are valid
NMLOS029.dpd	09:27:32	09:38:09	105	25	n/a	
NMLOS030.dpd	09:38:45	10:00:00	105	172	n/a	
NMLOS031.dpd	10:02:17	10:12:54	105	155	n/a	
NRHI014.dpd	10:16:38	10:28:32	105	0.5–177	ANGL0050.txt	
NMVAD024.dpd	10:31:24	10:38:12	60 – 420	10	ANGL0047.txt	
RAW01n.dat				90		**Raw data** (45 x 50Hz pulses then wait for next second boundary 600 times – 10 minutes) Not sure if this picked up all the pulses.
VIRTICAL003.dpd	11:08:35	11:16:35	n/a	90	n/a	
VIRTICAL004.dpd	11:19:57	11:22:12	n/a	90	n/a	
VIRTICAL005.dpd	11:23:07	11:27:27	n/a	90	n/a	
NMLOS032.dpd	11:38:20	11:38:20	110	10	n/a	Changed elevation to 25 about half way
NMRHI015.dpd	12:01:51	12:13:56	110	1 – 179	ANGL0054.txt	
NMLOS033.dpd	12:14:59	12:36:14	110	170	n/a	Changed elevation to 155 about half way
NMVAD026.dpd	12:36:56	12:43:44	60 420	10	n/a	
NMLOS034.dpd	12:46:17	13:07:32	390	10*	n/a	*Changed to 25 about half way. Across wind stare.
16/07/03 Wednesday						
NMVAD027.dpd	07:45:53	07:52:31	60 – 420	10	ANGL0058.txt	Azimuth over Salford Liadar = 118.75
NMVAD028.dpd	08:18:15	08:25:03	60 – 420	10	ANGL0059.txt	
NMVAD029.dpd	08:29:15	08:36:03	60 – 420	15	ANGL0060.txt	
NMVAD030.dpd	08:38:47	08:46:25	60 – 420	10	ANGL0061.txt	
NMVAD031.dpd	08:48:19	08:54:10	60 – 420	10	ANGL0061.txt	
NMLOS035.dpd	09:27:22	09:37:59	118.75	1.41*	n/a	**Dual Doppler Measurements** *(2.5 km from Salford in 118.5 degrees and 100 m above AGL(?) direction.)
NMLOS036.dpd	09:40:04	09:50:41	118.75	2.81	n/a	
NMLOS037.dpd	09:52:40	10:03:17	118.75	5.61	n/a	
NMLOS038.dpd	10:05:14	10:15:51	118.75	11.11	n/a	
NMLOS039.dpd	10:20:30	10:31:07	118.75	21.44	n/a	
NMLOS040.dpd	10:34:52	10:45:29	118.75	90*	n/a	*Vertical
NMLOS041.dpd	10:47:42	10:58:19	118.75	177.71	n/a	
NMLOS042.dpd	11:01:13	11:07:29	118.75	174.28	n/a	Rain stopped play about half way through

Data File	Start Time	Finish Time	Az	El	Angle File	Comments
NMLOS043.dpd	11:42:59	11:53:36	118.75	174.28	n/a	Same scan as above. Rained again
NMLOS043.dpd	11:59:51	12:04:41	118.75	168.68	n/a	Rained again
21/07/03 Monday						
NMVAD032.dpd	13:46:44	13:53:32	60 – 420	12	ANGL0063.txt	
NMELSCAN001.dpd	14:06:57	14:35:39	230	2.5 – 45	ANGL0064.txt	PZT drifted to end stop and lost lock. LO power about 1/3 of last week.
NMELSCAN002.dpd	14:48:45	15:08:35	320	2.5 – 45	ANGL0066.txt	Lock problems, stopped scan early
NMLOS045.dpd	16:08:39	16:27:53	320	10	n/a	
NMVAD033.dpd	16:30:00	16:36:38	60 – 420	10	ANGL0069.txt	Extended pulse to try and improve lock
NRHI016.dpd	16:48:15	17:00:38	220*	3 – 178	ANGL0070.txt	*With wind
NRHI017.dpd	17:02:16	17:14:39	130*	1 – 178	ANGL0071.txt	*Across wind
NMVAD034.dpd	17:18:44	17:25:22	60 – 420	20	ANGL0072.txt	
NMVAD035.dpd	18:32:26	18:39:04	60 – 420	10	ANGL0074.txt	
22/07/03 Tuesday (Note: Pulled tea laser out and cleaned brewster)						
NMVAD036.dpd	11:22:15	11:28:37	60 – 420	12	ANGL0075.txt	
VRHI018.dpd	11:37:49	11:49:33	118.75	1 – 178*	ANGL0076.txt	* Only got to 148
NMVAD037.dpd	13:07:22	13:13:44	60 – 420	12	ANGL0078.txt	
Dual01.dpd*	13:18:35	13:29:12	77.39	1.97	n/a	*Column with next four
Dual02.dpd	13:31:51	13:42:28	77.39	3.93	n/a	
Dual03.dpd	13:44:19	13:54:56	77.39	7.82	n/a	
Dual04.dpd	13:44:19	13:54:56	77.39	15.36	n/a	
DUALVERT01.dpd	14:07:55	13:18:32	77.39	90	n/a	
NMVAD038.dpd	14:19:39	14:26:01	77.39	1.97	n/a	
Dual05.dpd*	14:28:44	14:39:21	77.39	1.97	n/a	* Column with next four
Dual06.dpd	14:40:30	14:51:07	77.39	3.93	n/a	
Dual07.dpd	14:53:22	15:03:59	77.39	7.82	n/a	
Dual08.dpd	15:05:53	15:16:30	77.39	15.36	n/a	
DUALVERT02.dpd	15:17:42	15:28:19	77.39	90	n/a	
NMVAD039.dpd	15:29:05	15:35:27	77.39	12	ANGL0080.txt	
Dual09.dpd	15:37:20	15:47:57	77.39	1.97	n/a	Salford didn't save so start again with VAD
NMVAD039.dpd	15:51:10	15:57:32	77.39	12	ANGL0081.txt	
Dual10.dpd*	16:03:14	16:13:51	77.39	1.97	n/a	* Column with next four
Dual11.dpd	16:15:13	16:25:50	77.39	3.93	n/a	
Dual12.dpd	16:31:44	16:42:21	77.39	7.82	n/a	
Dual13.dpd	16:44:22	16:54:59	77.39	15.36	n/a	
DUALVERT03.dpd	16:55:32	17:06:09	77.39	90	n/a	
NMVAD041.dpd	17:07:03	17:13:25	60 – 420	12	ANGL0082.txt	az 248 direction of wind, 158 right angle to wind
NRHI019.dpd	17:15:54	17:27:48	248*	1.5 – 178	ANGL0083.txt	* With mean wind
NRHI020.dpd	17:29:18	17:41:12	158*	2 – 178	ANGL0084.txt	* Right angle to mean wind

Data File	Start Time	Finish Time	Az	El	Angle File	Comments
NMLOS046.dpd	17:49:45	18:15:15	68	10	n/a	
NMVAD042.dpd	18:23:32	18:29:54	60 – 420	12	ANGL0087.txt	
NRHI021.dpd	18:42:12	19:17:54	68	2 – 178	ANGL0088.txt	
NRHI022.dpd	19:18:58	19:30:57	68	2 – 178	ANGL0088.txt	
DUAL14.dpd	19:40:17	19:47:19	77.39	15.36	n/a	Stopped early because Salford not seeing far enough
DUAL15.dpd	19:48:38	19:59:15	77.39	7.82	n/a	
DUALVERT04.dpd	20:02:28	20:05:26	77.39	90	n/a	
DUAL16.dpd*	20:06:18	20:16:55	77.39	11.64	n/a	* Column with next four
DUAL17.dpd	20:18:04	20:28:41	77.39	3.93	n/a	
DUAL18.dpd	20:29:55	20:40:32	77.39	1.97	n/a	
DUAL19.dpd	20:41:06	20:51:43	77.39	3.93	n/a	
NMVAD043.dpd	20:52:37	20:58:59	60 – 420	12	ANGL0090.txt	
NRHI023.dpd	21:01:07	21:13:01	60	2.5–178	ANGL0091.txt	
23/07/03 Wednesday						
NMVAD044.dpd	06:57:09	07:03:32	60 – 420	12	ANGL0093.txt	
VIRTICAL05.dpd	07:04:56	07:15:33	60	90	n/a	
NRHI024.dpd	07:16:14	07:28:08	60	2 – 178	ANGL0094.txt	
STARE06.dpd	07:29:15	07:40:43	60	20	n/a	
STARE07.dpd	07:42:22	07:52:59	60	160	n/a	
NMVAD045.dpd	07:53:44	08:00:06	60 – 420	12	ANGL0095.txt	
VIRTICAL06.dpd	08:01:00	08:11:37	60	90	n/a	
NRHI025.dpd	08:12:12	08:24:06	60	2 – 178	ANGL0096.txt	
STARE08.dpd	08:26:14	08:36:51	60	20	n/a	
STARE09.dpd	08:37:39	08:48:16	60	160	n/a	
NMVAD046.dpd	08:49:12	08:55:44	60 – 420	12	ANGL0097.txt	
VIRTICAL07.dpd	08:56:22	09:06:08	60	90	n/a	
NRHI026.dpd	09:06:44	09:18:38	60	2 – 178	ANGL0098.txt	
DUAL20.dpd*	09:22:36	09:33:13	77.39	11.64	n/a	* Column with next four
DUAL21.dpd	09:35:07	09:45:44	77.39	7.82	n/a	
DUAL22.dpd	09:47:00	09:57:37	77.39	3.93	n/a	
DUAL23.dpd	09:59:14	10:09:51	77.39	1.97	n/a	
NRHI027.dpd	10:12:30	10:24:24	60	2 – 178	ANGL0100.txt	
STARE10.dpd	10:26:53	10:27:38	60	20	n/a	
DUAL24.dpd*	10:28:50	10:39:26	77.39	11.64	n/a	* Column with next four
DUAL25.dpd	10:40:57	10:51:34	77.39	7.82	n/a	
DUAL26.dpd	10:53:46	11:04:23	77.39	3.93	n/a	
DUAL27.dpd	11:05:40	11:16:17	77.39	1.97	n/a	
NRHI028.dpd	11:17:56	11:29:50	60	2 – 178	ANGL0101.txt	
DUAL28.dpd*	11:34:52	11:45:29	118.75	7.24	n/a	* Column with next four
DUAL29.dpd	11:50:31	12:01:08	118.75	14.26	n/a	
DUAL30.dpd	12:02:15	12:12:52	118.75	26.94	n/a	
DUAL31.dpd	12:14:13	12:24:50	118.75	42	n/a	
NMVAD047.dpd	12:25:41	12:32:03	60 – 420	12	ANGL0102.txt	
NRHI029.dpd	12:33:33	12:45:27	60	2 – 178	ANGL0103.txt	

Data File	Start Time	Finish Time	Az	El	Angle File	Comments
AZSCAN01.dpd	13:02:29	13:13:06	280 – 310	5.1	ANGL0106.txt	
NMVAD048.dpd	13:20:09	13:26:31	60 – 420	12	ANGL0108.txt	
ELSCAN10.dpd	13:32:26	14:04:18	298.71	1.5 – 45	ANGL0109.txt	
NMVAD049.dpd	14:05:22	14:11:44	60 – 420	12	ANGL0110.txt	
ELSCAN11.dpd	14:16:34	14:39:21	208.75	1.5 – 45	ANGL0111.txt	Stopped early due to light rain
ELSCAN12.dpd	14:52:53	15:24:45	298.75	1.5 – 45	ANGL0113.txt	
ELSCAN13.dpd	15:29:16	16:00:33	208.78	1.2 – 45	ANGL0114.txt	
NMVAD050.dpd	16:01:23	16:07:44	60 – 420	12	ANGL0115.txt	
ELSCAN14.dpd	16:14:40	16:44:35	298.75	1.5 – 45	ANGL0117.txt	
NRHI030.dpd	16:46:18	16:58:12	60	2 – 178	ANGL0103.txt	
DUAL32.dpd*	17:02:55	11:45:29	118.75**	42	n/a	*Next four column over middle of runway (in plane) ** Salford 42° Azimuth 23585 (Sal units)
DUAL33.dpd	17:14:36	17:25:13	118.75	26.94	n/a	
DUAL34.dpd	17:26:10	17:36:47	118.75	14.26	n/a	
DUAL35.dpd	17:37:35	17:40:58	118.75	7.24	n/a	

APPENDIX 2 SALFORD LIDAR DATA RELEASED FOR FURTHER ANALYSIS.

Data File	Start Time	Finish Time	Az	El	Angle File	Comments
16/07/03 Wednesday						
VAD161.dpd	10:34:50	10:44:31	0 – 295	15		PPI Scans
LOS16DUAL1.dpd	09:27:20	09:38:25	55.9	2.3		Dual Lidar Measurements
LOS16DUAL2.dpd	09:40:02	09:46:35	55.9	4.6		Rain interrupted measurements
LOS16DUAL3.dpd	09:52:38	10:03:44	55.9	9.1		
LOS16DUAL4.dpd	10:20:28	10:31:20	55.9	32.6		
LOS16DUAL6.dpd	10:47:41	10:58:40	236.0	1.4		
LOS16DUAL7.dpd	11:01:11	11:04:53	236.0	3.2		Rain interrupted measurements
LOS16DUAL7A.dpd	11:42:57	11:53:50	236.0	3.2		
LOS16DUAL8.dpd	11:59:49	12:03:40	236.0	6.4		
21/07/03 Monday						
VAD211.dpd	13:13:56	13:23:35	0 – 295	21		PPI Scans
VAD212.dpd	13:25:38	13:35:16	0 – 295	10		
VAD213.dpd	13:50:26	14:00:22	0 – 295	5		
VAD214.dpd	15:12:08	15:21:52	0 – 295	30		
VAD215.dpd	18:26:47	18:36:36	0 – 295	20		
VAD216.dpd	19:37:10	19:46:58	0 – 295	17.6		
VAD217.dpd	20:15:27	20:25:08	0 – 295	17.6		
VAD218.dpd	20:54:35	21:04:22	0 – 295	17.6		
RHI211.dpd	13:40:22	13:48:58	115	0 – 45		RHI Scans
RHI212.dpd	14:06:52	14:36:01	124.6	0 – 45		

Data File	Start Time	Finish Time	Az	El	Angle File	Comments
RHI213.dpd	14:38:58	15:08:12	34.6	0 – 45		
LOSDUAL211.dpd	18:42:06	18:53:05	55.9	7.6		Dual Lidar Measurements
LOSDUAL212.dpd	18:57:05	19:08:23	55.9	14.9		
LOSDUAL213.dpd	19:09:08	19:20:41	5.9	28.1		
LOSDUAL214.dpd	19:21:40	19:33:05	55.9	38.7		
LOSDUAL215.dpd	19:48:06	19:58:37	236.0	3.7		
LOSDUAL216.dpd	20:01:56	20:13:45	236.0	7.4		
LOSDUAL217.dpd	20:26:41	20:52:36	236.0	14.6		
LOSDUAL218.dpd	20:41:04	20:52:36	236.0	21.3		
22/07/03 Tuesday						
VAD221.dpd	08:55:24	09:01:37	0 – 295	20		PPI Scans Not a full scan to 295, ~ 270
VAD222.dpd	09:04:53	09:09:22	200 – 295	20		This scan finishes off the VAD221.dpd angles
VAD223.dpd	09:11:56	09:19:00	0 – 295	10		
VAD224.dpd	10:05:29	10:15:07	0 – 295	17		
VAD225.dpd	10:58:51	11:08:34	0 – 295	14.9		
VAD226.dpd	12:04:50	12:14:30	0 – 295	14.9		
VAD227.dpd	12:43:22	12:53:48	0 – 295	17.1		
VAD228.dpd	12:55:49	13:06:02	0 – 295	7.5		
VAD229.dpd	14:10:33	14:20:58	0 – 295	17.1		
VAD2210.dpd	15:20:44	15:31:08	0 – 295	17.1		
VAD2211.dpd	15:51:12	16:00:46	0 – 295	17.1		
VAD2212.dpd	16:56:30	17:06:49	0 – 295	17.1		
VAD2213.dpd	17:08:33	17:18:29	0 – 295	17.1		
VAD2214.dpd	17:20:07	17:49:03	0 – 295	17.1		
VAD2215.dpd	17:54:16	18:22:39	0 – 295	17.1		
VAD2216.dpd	18:25:07	18:53:25	0 – 295	17.1		
VAD2217.dpd	18:56:39	19:26:39	0 – 295	17.1		
VAD2218.dpd	19:29:27	19:39:00	0 – 295	17.1		
LOS221.dpd	09:27:06	09:38:50	295	3.5		LOS Measurements
LOS222.dpd	09:39:23	09:50:30	295	10		
LOS223.dpd	09:53:42	10:03:31	295	20		
LOS224.dpd	10:18:34	10:28:12	115	3.5		
LOS225.dpd	10:37:13	10:46:52	115	10		
LOS226.dpd	10:47:44	10:57:23	115	20		
LOS227.dpd	11:12:58	11:22:59	205	3.5		
LOS228.dpd	11:24:58	11:35:12	205	9.8		
LOS229.dpd	11:36:11	11:46:24	205	20		
LOS2210.dpd	11:49:17	11:59:30	25	3.5		
LOS2211.dpd	12:15:40	12:25:53	25	10		
LOS2212.dpd	12:26:26	12:36:39	25	20		
LOS2213.dpd	13:18:33	13:28:46	128.2	2.8		Dual Lidar Measurements
LOS2214.dpd	13:31:48	13:42:13	128.2	5.6		

Data File	Start Time	Finish Time	Az	El	Angle File	Comments
LOS2215.dpd	13:44:17	13:54:41	128.2	11.3		
LOS2216.dpd	13:56:26	14:06:51	128.2	21.6		
LOS2217.dpd	14:28:41	14:39:06	128.2	2.8		
LOS2218.dpd	14:40:27	14:50:51	128.2	5.6		
LOS2219.dpd	14:53:19	15:03:43	128.2	11.3		
LOS2220.dpd	15:06:50	15:16:14	128.2	21.6		
LOS2221.dpd	16:03:10	16:13:35	128.2	2.8		
LOS2222.dpd	16:15:10	16:25:34	128.2	5.6		
LOS2223.dpd	16:31:40	16:42:05	128.2	11.3		
LOS2224.dpd	16:44:18	16:54:43	128.2	21.6		
LOS2225.dpd	19:40:12	19:46:13	128.2	21.6		
LOS2226.dpd	19:48:34	19:59:10	128.2	11.3		
LOS2227.dpd	20:06:14	20:16:38	128.2	16.5		
LOS2228.dpd	20:18:00	20:28:24	128.2	5.6		
LOS2229.dpd	20:29:51	20:40:53	128.2	2.8		
23/07/03 Wednesday						
VAD231.dpd	09:06:19	09:16:20	0 – 295	12		PPI Scans
VAD232.dpd	10:12:24	10:22:37	0 – 295	12		
VAD233.dpd	11:17:24	11:27:49	0 – 295	12		
VAD234.dpd	12:28:27	12:39:03	0 – 295	12		
VAD235.dpd	12:42:54	12:55:08	46.6–86.6	2.5		
VAD236.dpd	13:59:48	14:09:55	0 – 295	12		
VAD237.dpd	15:14:06	15:24:11	0 – 295	12		
VAD238.dpd	16:50:35	17:01:11	0 – 295	12		
VAD239.dpd	17:50:48	18:01:36	0 – 295	12		
RHI231.dpd	13:40:30	13:55:54	55.9	0 – 45		RHI Scans TEA laser stopped firing
RHI232.dpd	14:16:30	14:41:03	145.9	0 – 45		
RHI233..dpd	14:43:57	15:13:12	55.9	0 – 45		
RHI234.dpd	15:29:12	15:42:32	55.9	0 – 45		TEA laser stopped firing
RHI235.dpd	15:44:17	16:04:59	55.9	0 – 45		
RHI236.dpd	16:14:36	16:46:30	145.9	0 – 45		
LOS2313.dpd	12:57:54	13:06:54	58.6	1.9		LOS Measurements
LOS2314.dpd	13:07:38	13:22:32	58.6	2.5		
LOS231.dpd	09:22:34	09:34:02	128.2	16.5		Dual Lidar Measurements
LOS232.dpd	09:35:04	09:46:26	128.2	11.3		
LOS233.dpd	09:46:58	09:57:39	128.2	5.6		
LOS234.dpd	09:59:12	10:10:23	128.2	2.8		
LOS235.dpd	10:28:47	10:39:30	128.2	16.5		
LOS236.dpd	10:40:54	10:51:19	128.2	11.3		
LOS237.dpd	10:54:25	11:04:49	128.2	5.6		
LOS238.dpd	11:05:37	11:16:02	128.2	2.8		
LOS239.dpd	11:34:49	11:45:26	235.9	7.2		

Data File	Start Time	Finish Time	Az	El	Angle File	Comments
LOS2310.dpd	11:50:28	12:00:53	235.9	14.2		
LOS2311.dpd	12:02:13	12:12:49	235.9	26.9		
LOS2312.dpd	12:14:10	12:24:47	235.9	42.0		
LOS2315.dpd	17:02:51	17:13:40	235.9	42.0		
LOS2316.dpd	17:14:32	17:25:20	235.9	26.9		
LOS2317.dpd	17:26:06	17:36:55	235.9	14.2		
LOS2318.dpd	17:37:32	17:48:22	235.9	7.2		

APPENDIX 3 AWS DATA FROM ISB52, NORTHOLT JULY 2003

Date July 2003	Time hh:mm UTC	Period data averaged (minutes)
8	00:00 – 23:59	2
9	00:00 – 23:59	2
10	00:00 – 23:59	2
11	00:00 – 10:32 20:56 – 23:59	2 2
12	00:00 – 23:59	2
13	00:00 – 23:59	2
14	00:00 – 23:59	2
15	00:00 – 12:00 12:10 – 23:59	2 10
16	00:00 – 23:59	10
17	00:00 – 23:59	10
18	00:00 – 23:59	10
19	00:00 – 23:59	10
20	00:00 – 23:59	10
21	00:00 – 23:59	10
22	00:00 – 23:59	10
23	00:00 – 23:59	10
24	00:00 – 07:50	10

The data collected with the AWS (automatic weather station) are: average wind direction, standard deviation of wind direction, maximum wind direction, minimum wind direction, average wind speed, standard deviation of wind speed, maximum wind speed, relative humidity, air temperature, dew point, net radiation and pressure. These are averaged over 10 minute or 2 minute periods as stated.

APPENDIX 4 SONIC DATA FROM ISB52, NORTHOLT JULY 2003

Date July 2003	Time hh:mm UTC	Data Collection Rate Hz
8	13:30 – 18:26 18:34 – 23:59	10 1
9	00:00 – 08:29 08:39 – 11:50 17:03 – 23:59	1 10 1
10	00:00 – 12:09 11:48 – 23:59	1 1
11	00:00 – 10:55	1
12	no data	-
13	no data	-
14	10:36 – 23:59	1
15	00:00 – 23:59	1
16	00:00 – 07:53	1
17	no data	-
18	no data	-
19	no data	-
20	15:05 – 23:59	1
21	00:00 - 15:29 21:13 – 00:00	1 1
22	00:00 – 08:08 08:15 – 20:42 20:52 – 23:59	1 10 1
23	00:00 – 08:14 10:09 –18:21 18:22 – 23:59	1 10 1
24	00:00 – 07:57	1

The data collected with the sonic are: u, v and w wind components, the temperature retrieved from the sonic and normal air temperature. The data is collected at a rate of 1 or 10 Hz as stated.

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8 DISCLAIMER

The author of this report is employed by QinetiQ and Salford University. The work reported herein was carried out under a Contract CU016-0000014438 Version 1.0 and sub contract CU016-0000014436 placed on 26 October 2001 between QinetiQ and the Secretary of State for Environment, Food and Rural Affairs. Any views expressed are not necessarily those of the Secretary of State for Environment, Food and Rural Affairs.

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