Environmental Research and Consultancy Department

# ERCD REPORT 0207

## Departure Noise Limits and Monitoring Arrangements at Heathrow, Gatwick and Stansted Airports

**R E Cadoux**
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## Summary

This report describes a study that was undertaken on behalf of the Department for Transport as part of the review of departure noise limits. The study considered both the monitoring arrangements (numbers and positions of monitors) and the limits themselves. Some improvements to the monitor arrays are proposed where there are currently large lateral separations between monitors. The study found that the daytime limit could be reduced by 1dBA, but larger reductions would lead to a high rate of infringements for some of the older Chapter 3 aircraft types currently operating at the London airports. Similarly, the night limit could only be reduced, by 3dBA, if a ban on QC/4 departures were to be imposed. Differential limits, affecting quieter aircraft types, were also considered, and the report recommends a trial to assess their feasibility.

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## Glossary of Terms and Abbreviations

| | |
|---|---|
| A-weighted | A weighting that is applied to the electrical signal within a noise-measuring instrument as a way of simulating the way the human ear responds to a range of acoustic frequencies. |
| ANCON | The UK civil aircraft noise contour model, produced and maintained by ERCD (see Refs 6 and 7). |
| ANMAC | DfT's Aircraft Noise Monitoring Advisory Committee. |
| ATC | Air Traffic Control. |
| BAA | BAA plc, the company which own and runs Heathrow, Gatwick and Stansted airports amongst others, and is responsible for the operation of the NTK system. |
| dB | Decibel units describing sound level or changes of sound level. |
| dBA | Units of sound level on the A-weighted scale. |
| DfT | Department for Transport (UK Government). |
| EPNL | Effective Perceived Noise Level, measured in EPNdB. Its measurement involves analyses of the frequency spectra of noise events and the duration of the sound as well as the maximum level. |
| ERCD | Environmental Research and Consultancy Department of the Civil Aviation Authority. |
| ICAO | International Civil Aviation Organization. |
| $L_{Amax}$ | The maximum A-weighted sound level (in dBA) measured during an aircraft fly-by. |
| LGW | Gatwick airport. |
| LHR | Heathrow airport. |
| $L_{RU}$ | Laterally adjusted Reference level – the level directly beneath the aircraft at 6.5km from SOR, airfield elevation |
| MTOW | Maximum certificated take-off weight*. |
| MTWA | Maximum take-off weight authorized*. |
| NATS | National Air Traffic Services Ltd. NATS provides air traffic control services at several major UK airports, including Heathrow, Gatwick and Stansted. |
| NPR | Noise Preferential Route; defined for the London airports in the Section 78 Notices in Ref 5. |
| NTK | Noise and Track Keeping monitoring system. The NTK system associates radar data from air traffic control radar with related data from both fixed (permanent) and mobile noise monitors at prescribed positions on the ground. |
| QC | Quota Count – the basis of the London airports Night Restrictions regime – see Ref 9. |
| Reference level | $L_{Amax}$ adjusted to the level at 6.5km from SOR, airfield elevation. |
| SOR | Start-of-roll: The position on a runway where aircraft commence their take-off runs. |
| STN | Stansted airport |
| TAS | True air speed |

| | |
|---|---|
| TOW | Take-off weight[*] |

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[*] In keeping with common usage, the term 'weight' is used in place of 'mass' throughout this report although, strictly speaking, they are different entities.

# 1 INTRODUCTION

## 1.1 Background

1.1.1 Departure noise limits have applied at Heathrow since 1959, at Gatwick since 1968 and at Stansted since 1993. The original limits were set in PNdB (Perceived noise decibel); this noise metric was superseded by dBA in 1993, but the noise limits remained effectively unchanged until the Government's decision of 18 December 2000 following the Review which was initiated in 1993. The reduced limits - 3dBA lower by day and 2dBA lower by night, and a shoulder period when the previous night limit applies - were implemented in February/March 2001[1]. The December 2000 decision confirmed the monitor placements which currently apply (ten monitors at Heathrow, five at Gatwick and eight at Stansted). There was also a revision to the positional adjustments, and a new allowance for departures in tailwind. Refs 1 and 2 were the technical studies which informed the review[2].

1.1.2 The minister announced at the same time a further departure limits review, covering both monitoring efficiency and noise limits, to be overseen by ANMAC and making appropriate use of NTK data at the fixed monitor positions. The main objectives for noise limits are to deter excessively noisy movements, by detecting and penalising those which exceed the limits, and to encourage the use of quieter aircraft and best operating practice. The review was to consider "any further improvements as and when practicable, and new, tougher limits, possibly incorporating a differential or tiered effect". The intention of the timing of this review was that any proposed practicable reductions in the noise limits should be put into place as soon as possible after 31 March 2002, the date when Chapter 2 aircraft[3] (other than those below 34000kg MTOW and with a passenger capacity of 19 or less) must cease operation in the EU.

## 1.2 Study outline

1.2.1 ERCD were asked by ANMAC to undertake the technical aspects of the review, and this report summarises the work completed. The study was in three main parts:

a) Devising a method for assessing the current monitoring arrangements, and considering proposed improvements;

b) Considering the scope for any reductions in the overall noise limits, taking into account the many factors that affect departure noise levels; and

c) Considering the possible basis, usefulness and practicalities of a differential limits scheme.

Section 2 of this report covers the assessment of monitoring arrangements, Section 3 the factors affecting departure noise levels, Section 4 the overall noise limits, Section 5 differential limits, and Section 6 the noise impact of any changes to the limits. The study conclusions are summarised in Section 7.

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[1] The time periods and limits are: "Day" 0700-2300, 94dBA; "Shoulder" 2300-2330 and 0600-0700, 89dBA; "Night" 2330-0600, 87dBA. All times are local, i.e. BST during the summer and UTC during the winter.

[2] An additional relevant document (on a specific topic raised during the consultation process, 'noise displacement') is Ref 3.

[3] Aircraft are certificated to ICAO noise standards, defined in Ref 4. The earliest standard for subsonic jet aircraft, Chapter 2, was set in 1969. Chapter 3, with tighter maximum noise levels, applied to new subsonic jet aircraft (and some heavier propeller aircraft) from 6 October 1977. A new standard, "Chapter 4", will come into effect for new aircraft on 1 January 2006.

# 2 MONITORING ARRANGEMENTS

## 2.1 Current monitor arrays

2.1.1 The present arrays of fixed noise monitors, deployed to monitor compliance with the noise limits described in paragraph 1.1.1, were largely derived from studies reported in Ref 1. The aim was to place monitors at a nominal distance of 6.5km from start-of-roll (SOR), which corresponds to the flyover measurement point in the ICAO Annex 16 noise certification procedure (Ref 4). The study was conducted on the basis of retaining the 6.5km reference distance, following earlier consideration by ANMAC and the government. The monitors in practice are typically located at distances of between 6 and 7km from SOR, depending on the local terrain. Figures 1 to 3 show for Heathrow, Gatwick and Stansted respectively the locations of the noise monitors relative to the nominal Noise Preferential Routes (NPRs).

2.1.2 At Heathrow, the array for westerly departures from the southern runway (27L) is seriously distorted from the nominal 6.5km arc because of the Wraysbury Reservoir. There are no fixed monitors for easterly departures from the Heathrow northern runway (09L), because this runway is not used for departures except in exceptional circumstances[4]. For Heathrow the NTK monitor numbers have generally been used in this paper; the official designators in Ref 5[5] for each monitor are as follows:

| | | |
|---|---|---|
| Runways 27L/R: E = 14 | B = 18 | Runway 09R: H = 10 |
| D = 15 | A = 19 | F = 11 |
| C = 17 | 6 = 6 | G = 12 |
| | | I = 13 |

## 2.2 Assessment of monitor array performance

2.2.1 In Ref 1 the arrays were assessed on the basis of ‘Monitoring Efficiency’, a measure which estimated the number of departures that would be expected to infringe a noise limit as a percentage of the number that would have infringed if every aircraft had flown directly overhead a noise monitor. The spacing between monitors for each runway was set with the aim of giving a uniform value of Monitoring Efficiency.

2.2.2 From NTK data it is not generally possible to know the noise levels directly beneath an aircraft, only those measured at the monitor, so Monitoring Efficiency cannot be directly measured. In the previous review (Ref 1) Monitoring Efficiency was determined by a somewhat complex and laborious method involving modelling the spread of noise levels, based on the measured noise level variability, to predict which flights would have been infringements. The results were liable to be distorted by a preponderance of predicted noise levels just fractionally above the limit.

2.2.3 Monitoring Efficiency, and its applicability to this study, is discussed further in Appendix A, which shows that Monitoring Efficiency provided a useful tool for assessing the locations of consistently performing arrays in the last review, but also indicates the need for an additional simple measure of monitor array performance that is independent of aircraft noise levels and of the noise limits. The V-analysis technique, as discussed below, is at least as rigorous in ensuring that monitors are well positioned to monitor departures. This study aims to ensure that all the monitor

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[4] However aircraft turning right from runway 09L are effectively monitored by the existing array. In 2002, when maintenance work on the southern runway led to use of 09L for departures, BAA deployed two mobile monitors at suitable locations to monitor departures turning left from 09L. These mobile monitors are not covered by the statutory requirements in Ref 5.

[5] Section 78 notice in AD2-EGLL-1

arrays provide the best possible coverage for detecting any infringements of the noise limits.

## 2.3 V-analysis technique

2.3.1 A new simple measure of monitor array effectiveness was proposed to and accepted by ANMAC. This uses as an indicator for event detection a $60^O$ "V" above each monitor, in the vertical plane perpendicular to the relevant NPR centreline – see Figure 4. For any given aircraft type on a particular route, the greater the percentage of departures that flies through at least one monitor V, the better the array performance.

2.3.2 The physics of sound propagation is such that for an 'acoustically simple' aircraft passing anywhere through the V, it may reasonably be assumed that the measured noise level will be less than the maximum noise - vertically below the aircraft - by a fixed margin (dependent only on the ratio of propagation distance to height).
For aircraft to the side of a monitor studies have shown no evidence of lateral directionality at angles less than $30^O$ from the aircraft vertical axis. An aircraft flying through the boundary of a V, i.e. at an elevation angle of $60^O$ from the noise monitor, would give a noise level approximately 1.7dBA lower than if it had directly overflown the monitor[6].

2.3.3 V-analysis can be undertaken using already collected radar track and height data from NTK, making use of tools provided on the NTK system and additional simple spreadsheet analysis. As track patterns in the vicinity of the noise monitors are different for each route at Stansted and Heathrow, each route from the runways at these airports was analysed separately where appropriate. At Gatwick, the NPRs only deviate from the extended runway centreline well after the noise monitors, so for each Gatwick runway data for departures on all routes was combined.

2.3.4 At 1000ft aircraft height[7] the V extends 175m either side of the monitor; at 2000ft the width is ±350m. At 6.5km from SOR, the width of the NPR swathe is approximately 800m either side of its centreline[8]. The very small number of flights outside the NPR swathe when passing the monitor were not analysed, as they are termed "track deviations"[9] (or, in a very small proportion of cases, had NTK track data which did not start until after the aircraft had passed the noise monitor[10]).

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[6] The expression 'acoustically simple' describes sound sources that radiate uniformly in all directions. Although aircraft do not fit this definition in general, it is essentially true of lateral radiation within ±30° of the vertical axis of the aircraft, i.e. within a V as described here. At elevation angles less than 60°, 'lateral attenuation' becomes significant – i.e. the radiation is no longer directionally uniform. Study has shown that in cases where aircraft are turning as they pass through the V, the effects of banking would be unlikely to compromise the results.

[7] The notices in Ref 5 (AD2-EGLL-1, AD2-EGKK-1 and AD2-EGSS-1), under the Civil Aviation Act 1982 Section 78(1) require aircraft to be at a height of not less than 1000ft above airfield level at 6.5km from SOR.

[8] The NPR swathe tapers from zero width at a nominal point representing lift-off to a maximum ±1500m width at a distance of 10.5km from SOR. The swathes have been defined to illustrate expected standards of track-keeping for jet aircraft and propeller aircraft with MTWA of 5700kg or more, and are used within the NTK system to identify flights with poor track-keeping. It should be noted that, at Heathrow and Gatwick between 0600 and 2330, ATC can legitimately 'vector' departures of propeller aircraft of not more than 17000kg MTWA (and the Dash 7 and Dash 8) outside the swathes. At all airports, once an aircraft is above the 'vectoring altitude' (3000ft at Gatwick and at Stansted daytime), 4000ft at Heathrow and at Stansted between 2330 and 0600), they can be given a route away from the NPR, although this rarely happens as close in as the vicinity of the noise monitors.

[9] Aircraft identified as flying outside the swathe below vectoring altitude – such flights are normally investigated by BAA.

[10] This can happen for example if the aircraft's transponder was switched on late or malfunctioned.

2.3.5 The vertical rectangular area shown in Figure 4 is termed a ‘gate’, and NTK provided the interception points for all aircraft flying through each gate in a given time period. (The height of the top of the gate was at least 10,000ft, so no aircraft were eliminated on grounds of height.) The interception points were then exported into a spreadsheet where the elevation angle for each point relative to the noise monitor was calculated, and the percentage determined of the total number of flights through the gate that was within the V (i.e. had an elevation angle greater than $60^0$).

## 2.4 Aircraft grouping

2.4.1 The V-analysis study was conducted for all aircraft types, not just those which are most likely to infringe the current noise limits, because it was necessary to determine whether the same monitor arrays were appropriate for both differential monitoring and for monitoring compliance with overall noise limits. Different aircraft types can have very different climb and track-keeping performance, both of which directly affect the percentage of flights within a V. For this analysis it was therefore necessary to split aircraft types into groups with similar performance. For convenience the fleets have generally been split into the Chapter 3 ANCON aircraft type groups, as the aim was simply to group together aircraft with similar performance. The following principal exceptions from the ANCON groups apply:

- Chapter 2 and Chapter 3 B747-200s were identified as separate groups.
- Different propeller aircraft groups were included. At Gatwick, good sample sizes of both of the main types then operating (ATR72 and Dash-8) enabled them to be analysed individually. At Stansted there was a greater variety of propeller types, with smaller numbers of operations of any one type, and therefore all significant propeller types were combined into a single group for the purposes of V-analysis (embracing a fairly wide range of maximum take-off weights[11,12]). At Heathrow there were no significant numbers of propeller aircraft movements.

2.4.2 This resulted in a total of 22 different groups of aircraft types (although not every type operates at every airport). The codes for each group are listed in Table 1; these aircraft type codes are used in the remainder of this report. (Note that there are different considerations when grouping aircraft for the purposes of assessing differential limits – see Section 5).

## 2.5 Study data

2.5.1 For the V-analysis study 24-hour data was used, with no differentiation between departures in the day, shoulder and night periods. Checks showed that there was generally little difference in typical tracks and heights between the periods, and the results of this study regarding monitor array performance are applicable to monitoring in all three periods.

2.5.2 Apart from one exception, the total NTK sample over the three months April-June 2001 was used for this study[13]. Sample sizes (total numbers of departures analysed) are shown in Table 2. An ‘X’ in the Table indicates cases that were not analysed, where an aircraft type/route combination had less than 100 departures in

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[11] In keeping with common usage, the term 'weight' is used in place of 'mass' throughout this report although, strictly speaking, they are different entities.

[12] Track-keeping differences in the vicinity of the noise monitors are likely to be particularly correlated with take-off weight for propeller types because of the NPR requirements – see footnote 8.

[13] The exception was at Gatwick for the 733, where a smaller subset was selected because of the large numbers of flights: approximately 17% of the total number of departures for 26L, and 50% for 08R.

the 3-month period – corresponding roughly to less than one movement per day on the route.

## 2.6 V-analysis results

2.6.1 Analysis results are illustrated in the following ways:

(i) Track plots (projections of the flight paths on a horizontal ground surface), such as the examples in Figures 5, 6 and 7 for Gatwick, Heathrow and Stansted respectively. Dashed lines indicate the nominal NPRs[14] and the swathe boundaries either side of the nominal NPR. The relevant noise monitors are indicated as small rectangles. For these plots, a sub-sample of about 100 flights was taken in each case, so that the track densities are comparable between plots. Appendix B gives similar track plots for most combinations of aircraft types and routes.

(ii) Scatterplots – such as the examples in Figures 8, 9, 10, 11 and 12 for Gatwick, Heathrow 09R, Heathrow 27R, Heathrow 27L and Stansted respectively – showing the points where each track intersects the appropriate gate through the noise monitor. The figures also show the $60^0$ V through the noise monitor, the NPR centreline (small vertical line) and the NPR swathe boundaries (vertical lines shown up to the daytime vectoring altitude) at the points where they cross the gate. On these diagrams the vertical axis is aircraft height in feet above aerodrome level, and the horizontal axis is lateral displacement – distance in metres to the side of the monitor[15]. It is not generally possible to use the same gate for more than one monitor, so it is not appropriate to attempt to show the scatterplots for all monitors for a particular route on one graph. Scatterplots for most combinations of aircraft types and routes are shown in Appendix C.

(iii) Quantifying the results by means of an analysis of the percentage (of all departures that passed through the appropriate gate) that flew through one or more V.

2.6.2 The performance of the Gatwick monitor arrays is illustrated for example by reference to the scatterplots in Figure 8(a) (Gatwick 26L 744 departures), which show that virtually all 744s flew through the V of the central monitor of the array, monitor 1. The few that did not (aircraft at heights between 1100 and 1250ft, lateral displacements 150-250m north of the NPR centreline) were all ‘captured’ by the northerly monitor, monitor 5. Similarly, for Gatwick 08R departures (where the two monitor distances are similar enough for a single gate to be used for both monitors), Figure 8(b) shows that all the 744s that flew through the gate were within one or both of the Vs of monitors 4 and 6.

2.6.3 Figure 9(a) illustrates the slightly lower effectiveness of the pair of monitors on the Heathrow 09R BPK/BUZ routes: some aircraft at low heights flew between the two Vs, and others flew north of the monitor 11 V. Similarly in Figures 9(b) and 9(c), for DVR and MID departures, a number of aircraft flew between the Vs for monitors 10 and 13. Figure 9(d) shows that for the 09R CPT route quite a large proportion of 744s flew south of the monitor 13 V.

2.6.4 Figures 10(a)-(d) show quite good coverage of all the Heathrow 27R routes, because most departures from this runway flew close to monitor 18.

---

[14] For cases where the NPR centrelines are not visible because of the density of tracks, they can also be seen on Figures 1 to 3.

[15] Distances north of the monitor are shown as positive.

2.6.5 For Heathrow 27L departures, monitoring performance of the WOB/BPK routes is reduced by the gap between monitors 6 and 17 (Figure 11(a)). Figures 11(b) and 11(c) indicate reasonable performance on the CPT/SAM and MID routes, but for the 27L DVR route Figure 11(d) indicates a number of flights south of the monitor 14 V.

2.6.6 For Stansted 05 departures, there is a large gap between monitors 10 and 7 for the BZD route, as illustrated in Figure 12(a). The remaining scatterplot figures show that performance is generally reasonable on the other routes and on runway 23 (Figures 12(c) and (d)).

2.6.7 For each aircraft type/route combination, the percentage (of all departures that passed through the appropriate gate) that flew through one or more V was calculated; these results are shown in Table 3. The cases where the percentage was less than 90% are shown in bold, to indicate poorer monitoring performance. It is clear that performance is consistently high for Gatwick (apart from some propeller types), for Heathrow runway 27R and Stansted runway 23, and for certain types on some of the other routes at Heathrow and Stansted. There are also clear differences between some of the aircraft types on a given route.

2.6.8 The results are plotted in Figures 13(a) (combinations where more than 90% of all flights were within a V) and 13(b) (90% or less within a V), which shows clearly the cases where current monitoring performance could be significantly improved.

2.6.9 The results in Table 3 can also be summarised (a) in terms of the performance of the arrays for each runway/route combination, and (b) in terms of the performance for each aircraft type (see Table 1 for the aircraft type codes). These percentages (of all departures that passed through the appropriate gate) are listed below, in descending order of performance, averaged over the cases analysed. The notes indicate some reasons for the higher and lower positions in the tables.

**Routes with a high proportion of departures passing through a V (greater than 95%):**

| Airport | Runway | Route(s) | Comments |
|---|---|---|---|
| LHR | 27L | MID | Fewer of the slow-climbing aircraft types use this route. Monitors 15 and 6 well-positioned for this route. |
| LHR | 27L | CPT/SAM | Straight-out route leads to good track-keeping. Monitors 15 and 6 well-positioned for this route. |
| LHR | 27R | DVR | Fewer of the slow-climbing aircraft types use this route. Monitor 18 well-positioned for this route. |
| LGW | 26L | ALL | Straight-out route leads to good track-keeping. Monitors 1, 3 and 5 well-positioned for departures from this runway. |
| LHR | 27R | CPT/SAM | Monitor 18 well-positioned for this route. |
| LHR | 27R | WOB/BPK | Monitor 18 well-positioned for this route. |
| LGW | 08R | ALL | Straight-out route leads to good track-keeping. Monitors 4 and 6 well-positioned for departures from this runway. |
| STN | 23 | BZD | Straight-out route leads to good track-keeping. Monitor 5 well-positioned for this route. |
| LHR | 27R | MID | Fewer of the slow-climbing aircraft types use this route. Monitor 18 well-positioned for this route. |
| STN | 05 | CLN | Monitors 10 and 8 well-positioned for this route. |
| STN | 23 | CLN | Monitor 3 well-positioned for this route, with 5 and 6 either side. |

**Routes with a medium proportion of departures passing through a V (91-94%):**

| | | |
|---|---|---|
| STN | 23 | DVR |
| LHR | 27L | WOB/BPK |
| STN | 05 | DVR |
| LHR | 09R | BPK/BUZ |
| LHR | 27L | DVR |

**Routes with a lower proportion of departures passing through a V (90% or lower ):**

| | | | |
|---|---|---|---|
| LHR | 09R | SAM | Gap between monitors 10 and 13: aircraft tend to fly midway between the monitors. 733 has worst performance for this route. 320s tend to fly north of the NPR centreline, closer to monitor 10. |
| LHR | 09R | DVR | Gap between monitors 10 and 13: aircraft tend to fly midway between the monitors.<br>744, 763 and 777 have relatively poor performance on this route. |
| STN | 05 | BZD | Gap between monitors 10 and 7 too large especially for aircraft at lower heights such as 146 and props which tend to turn away from 10 more sharply than other types. |
| LHR | 09R | MID | Gap between monitors 10 and 13: aircraft tend to fly midway between the monitors.<br>744, 146 and 763 performance is poor because of their lower heights (typically around 1100ft, 1600ft and 1700ft respectively). |
| LHR | 09R | CPT | Generally used by heavier aircraft (742Ch3 are typically at about 1100ft over monitor 10), some of which, as well as many 320s, tend to turn well inside the NPR centreline, i.e. south of monitor 13. Some aircraft fly midway between monitors 10 and 13. |

**Aircraft types with a high proportion of departures passing through a V (99 or 100%):**

| | |
|---|---|
| CRJ | Gatwick only (better performing arrays); and high altitudes achieved over monitors. |
| M90 | High altitudes achieved over monitors. |
| 762 | Gatwick only (better performing arrays). |
| D10 | Gatwick only (better performing arrays). |
| M80 | High altitudes achieved over monitors. |
| 738 | Tended to use mainly the routes with better monitor array performance. |
| 100 | High altitudes achieved over monitors. |

**Aircraft types with a medium proportion of departures passing through a V (92-98%):**

| |
|---|
| 757 |
| AT7 |
| 330 |
| 320 |
| 310 |
| 300 |
| 777 |
| 733 |
| 763 |

**Aircraft types with a lower proportion of departures passing through a V (92% or lower):**
(see paragraphs 2.7.2 and 2.7.3 below)

| | |
|---|---|
| Props (Stansted) | Slower-climbing aircraft type |
| 146 | Type achieving relatively low heights over noise monitors |
| DH3 | Slower-climbing aircraft type (see paragraphs 2.7.4 and 2.7.5 below).<br>Typically flies on tracks away from NPRs (see footnote 12) |
| 744 | Slower-climbing aircraft type |
| 340 | Slower-climbing aircraft type |
| 742Ch3 | Slower-climbing aircraft type |

## 2.7 Aircraft type effects

2.7.1 The results in Table 3 and Figure 13 show that most arrays give greater than 90% coverage. However, where there are relatively large lateral gaps between adjacent monitors, the percentage can be much lower for some types, especially for:

- slow-climbing aircraft types
- routes that involve a turn,
- types with higher than average track dispersion, or
- types with different mean tracks relative to the monitors.

2.7.2 Propeller aircraft tend to climb more slowly than most jets, and some, which are exempt from the requirement to follow NPRs, are given departure paths away from the NPR. Apart from these, the aircraft types with a consistently lower proportion of departures passing through a V are all the common 4-engined jets. These aircraft tend to be slower-climbing types, and the 744, 742Ch3 and 340 are also the heaviest and probably the noisiest types routinely operating at the London airports. The only small 4-engined jet is the 146: heights at the noise monitors are lower for the 146 than those of other small/medium jet types[16]. 146s also tend to exhibit more dispersed track-keeping on the turning routes at Stansted compared to other jet types[17].

2.7.3 With the current disposition of monitor arrays and aircraft tracks, the aircraft types which are least likely to be detected by a monitor (i.e. fly within a V) are the types with relatively slow climb rates. These include the noisiest types, which are most likely to exceed a maximum noise limit (e.g. Figure 29 shows the five noisiest types in the study were 743, 742, 744, 340 and D10), and also the 146 and propeller aircraft. Note that in the Stansted sample there were only relatively small numbers of these five noisiest aircraft types.

2.7.4 Average aircraft heights above the noise monitors for each type/route combination are plotted in Figure 14. For each type, the differences between the various routes are due to the different distances of the relevant monitors from SOR, differences in take-off weights (TOWs) and other factors. It can be seen that the four lowest types at the noise monitors (average heights typically less than 1500ft) are 340, 742Ch3, 744 and DH3; the highest (at more than 2500ft) are M80, M90, 100 and CRJ.

2.7.5 At Gatwick the straight-out departure routes and the close spacing of monitors ensures that high proportions of all critical types fly within a V. The results indicate that the current arrays at Gatwick (three monitors for westerly departures and two for easterlies) achieve very good detection rates, with 99% or more of all jet aircraft types on either runway flying through a V[18]. Some propeller aircraft are routinely vectored off the NPRs (i.e. the extended runway centreline here) before passing the noise monitors, so for some of these types smaller proportions of departures fly through a V (e.g. 84% of DH3s on 08R). If any differential monitoring scheme were to include propeller aircraft such as the DH3, additional noise monitors might be needed purely for that purpose (two at each end of the airport with their current track patterns at Gatwick) – but such monitors would make a negligible difference to the detection rates for almost all jet aircraft, and have not been considered further in this study.

## 2.8 Array improvements

2.8.1 The terms of reference of the review referred to proposing “further improvements [in monitoring efficiency] as and when practicable”. Having assessed in the analysis

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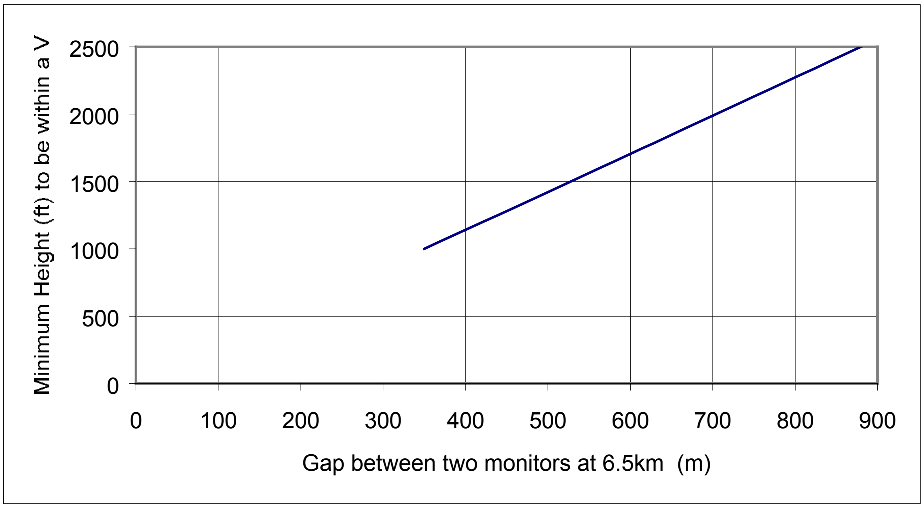
[16] 146s, having four engines, tend to climb at a slower rate than most similar sized twin-engined jet aircraft. They may also be affected to some extent by a proportion of departures not using the full runway length for their take-off roll, especially at Gatwick. 146 departure noise levels however are around 10-15dBA quieter than the heavy 4-engined types.

[17] Although 146 departure tracks at Stansted generally lie within the NPR swathes, their distributions tend to be more dispersed than the 733 and 738, particularly on the 05 BZD, 05 DVR and 23 CLN routes (see Appendix B Figures B5(a), (b) and (c)). 146 track dispersion on the 23 CLN route has been reduced since July 2001 as a result of an initiative by BAA Stansted and a major operator of the type, although the effect is more noticeable further out than in the region of the noise monitors.

[18] See Appendix A for an explanation why ‘Monitoring Efficiency’ (as defined in Ref 1) may nevertheless be much less than 99% in this case.

above where the current arrays are least effective, this part of the study considers the scope for further improvements by adding or moving noise monitors, and shows where the greatest benefits could be obtained.

2.8.2 For reference, the diagram below shows the theoretical relationship between the gap between a pair of monitors and the minimum height for an aircraft flying between them to always be within a V. If all aircraft were at the minimum permitted 1000ft height at 6.5km, the gap would need to be no larger than 350m; if departures were all at 1500ft or lower, a 530m gap would give 100% of flights within a V.



2.8.3 In a number of cases the gaps between monitors are significantly larger than the 350m maximum lateral separation which is needed to effectively monitor all slow-climbing aircraft such as the 744, resulting in poorer monitoring performance. An initial assessment was made of potential monitor array improvements based on the track plots and the results of the V-analysis in Table 3, as described below.

2.8.4 In some cases it is likely that the aircraft most effectively monitored by any additional monitors would be the quieter aircraft types (especially those at Stansted), so in these cases there would only be a real benefit from adding or moving monitors if differential monitoring were to be introduced (or if, in the case of Stansted, more slow-climbing 'noisy' aircraft – i.e. 742, 743, 744, 340 and D10 - were to operate there in the future).

2.8.5 Less than optimum monitor arrays can allow such aircraft to fly between adjacent Vs at heights below the height where the Vs intercept. In assessing the merits of different proposals for improving the current monitor arrays, it was therefore appropriate to give greater emphasis to those proposals for array changes that would be most likely to improve the chances of detecting infringements by the noisiest aircraft types.

2.8.6 The monitor arrays with the greatest scope for improvement – based on current track-keeping performance – have therefore been identified and ranked by taking into account the following:

a) The percentage of departures not flying within at least one V (based on the current monitor positions), for each aircraft type group and each departure route/runway combination. This corresponds to the assessments shown in Table 3. Cases where the proportion was less than 5% were not included as they made little if any difference to the final result.

b) A weighting based on aircraft type, such that greater emphasis is given to cases where the monitor arrays are less effective for the noisiest aircraft types such as the 742Ch3, 744 and 340.

c) The average number of relevant departures a day (note that types that operated very infrequently had already been eliminated in deriving the initial study data sample).

2.8.7 It happened that, of the eight cases where reasonable improvements could be expected based on the above criteria, the two leading scenarios are both routes which have quite a large number of average daily departures (over 90). These two scenarios are both at Heathrow and both involve a significant proportion of the noisiest 4-engined types. The other six scenarios are for routes with fewer flights (between 7 and 31 departures per day on average).

2.8.8 Details of all eight initial scenarios for monitor array improvements are shown in Table 4, in descending order relative to the benefits (in terms of improving the V-analysis performance) of each scenario. All the eight scenarios related to either Heathrow or Stansted.

### 2.9 Assessments of practicalities for new monitor locations

2.9.1 ERCD and BAA representatives have visited potential locations for new or moved monitors for all the scenarios identified in Table 4. Important considerations for any fixed monitor location are:

- Accessibility for installation (building works are required to lay a concrete base and to install the mast and equipment), and for routine servicing.
- Security, likelihood of vandalism (monitors and their associated equipment have been damaged and destroyed in the past by vandals).
- Acoustic suitability – background noise (distance from motorways, railways, roads, playgrounds and other sources of noise), reflections or absorption (e.g. proximity of buildings, trees, etc.), ground surface and other local factors.
- Possibility for installation of utilities (power and telephone connections). It is now possible under certain circumstances to operate fixed sites with solar panels charging suitable batteries and with ‘mobile phone’ technology. This is used particularly at Stansted but also at some of the Heathrow monitors, but incurs costly routine visits especially during winter when battery changes often become necessary. The presence of adjacent trees can seriously affect the performance of solar panels, and the panels can be an attractive target for vandals/thieves.
- Land ownership – permissions, restrictions, inconvenience to owner/occupier, environmental disbenefits.

2.9.2 The findings from the site visits and subsequent work are given in Appendix D. Maps illustrating potential new monitor locations for each scenario are given as Figures 15 (Heathrow westerly departures), 16 (Heathrow easterly departures) and 17 (Stansted 05 departures)[19].

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[19] Note that the “proposed NMT sites” shown on Figures 15, 16 and 17 are shown purely for illustrative purposes - any changes to monitor arrays are the subject of consultation, followed by ministerial decision and applications for any necessary planning permission as well as landowners’ permission. The sites are not depicted as precise locations; the fact that they are shown on these maps is not intended to indicate that such theoretical sites would necessarily be practicable for permanent noise monitors, nor to imply that landowners have been approached, consulted on or agreed to any installation.

## 2.10 Effect of "improved track-keeping"

2.10.1 Changes in track-keeping can have an impact on the proportion of flights within a monitor V[20] and hence on monitor array performance. Generally tracks are fairly well defined at the 6.5km monitoring distance, but an interesting example of the effect of track distribution is shown in Appendix B Figure B4(a)(iii). This figure shows two distinct track patterns for 738 departures on the Heathrow 27L BPK route. The northerly group are all of one airline ("A"), while the other group are all of another airline "B", indicating probable differences in the Flight Management System data for this route between the two airlines. The airline "B" flights tend to fly close to overhead monitor 17, which is near the NPR centreline. Improving the track-keeping[21] for airline "A" would move those flights closer to a noise monitor, and thus improve the overall performance of the 27L monitor array for this aircraft type.

2.10.2 The principal factors causing differences in track-keeping between routes are whether or not a turn is involved, and the provision of ground-based navigational aids. Thus the design of the monitor arrays needs to take account of the fact that it is likely that track spread will always be greater on some routes than on others.

2.10.3 The effect of turns is illustrated for example by comparing the scatterplots for straight-out routes, e.g. those at Gatwick (Figures 8(a) and (b)) and Heathrow 27L MID (Figure 11(c)), with those for routes where significant turns commence before reaching the noise monitors, e.g. Heathrow 09R CPT (Figure 9(d)), 27L DVR (Figure 11(d)) and Stansted 05 CLN (Figure 12(b)).

2.10.4 The question of the effect of improved track-keeping was initially raised in the context of monitor 9 at Stansted (particularly for 05 DVR departures). This monitor is located almost on the centreline of the DVR NPR (in fact just north of it), so, with current track dispersion, tracks that are within the swathe but significantly south of the centreline might not be in any V unless an additional monitor were installed SE of monitor 9 (Scenario 7). Improvements to track-keeping in this region – both in terms of the mean track and further increasing the concentration within the swathe – could obviate the need for an extra monitor.

2.10.5 BAA have recently been working to improve track-keeping on the Stansted 05 DVR route with two of the principal base airlines, which has resulted in an increase in the proportion of tracks within the swathe, and also a greater concentration of tracks nearer the NPR centreline. The vast majority of departures of these two airlines now pass between monitors 8 and 9. If other operators can achieve similar track-keeping performance (Scenario 8), and minimise the numbers of tracks towards the southern edge of the swathe, the existing array would be adequate without the need for improvement. Very few of the noisier Chapter 3 aircraft types turn sharply enough to fly very far south of monitor 9; and in the year April 2001 to March 2002 there was only one daytime noise limit infringement (a Chapter 2 B727), and no night infringements, at monitor 9.

2.10.6 A simple geometric assessment was made, at the monitor closest to each NPR centreline, to determine the minimum height that an aircraft on the centreline would have to be, to be within the $60^0$ V. The results are given in Table 5, and indicate

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[20] NPR track-keeping performance assessments generally cover the complete extent of the NPR out to the vectoring height, and are concerned with the percentage of tracks that are within the NPR swathes. For this study it is only the distribution of tracks at around 6.5km from SOR, relative to the noise monitor locations, that is relevant.

[21] "Track-keeping improvement" in this report refers only to the distribution of tracks at around 6.5km from SOR, and can mean changes to the distribution of tracks even when 100% are within the swathes at this point.

three routes where, if track-keeping in the vicinity of the noise monitors were ‘perfect’ (i.e. 100% of tracks on the NPR centreline), noise monitoring performance with the current arrays would probably not be adequate because the monitor is not close enough to the centreline. These are Heathrow 09R DVR, Heathrow 09R SAM, and Stansted 05 BZD. Additional monitors as discussed later (Scenarios 1 and 3 in Table 4) would dramatically improve the situation on these routes.

2.10.7 To provide more a realistic assessment of the effect of improved track-keeping (in the vicinity of the noise monitors) on monitor array performance, the following have been compared for a representative selection of routes and aircraft types:

(i) the current track distribution (the ‘baseline’ case), and

(ii) statistically normal distributions of tracks across the NPR swathe, centred on the NPR centreline, with a range of standard deviations (SDs) (representing varying degrees of further track-keeping ‘improvement’).

Note that actual SDs of lateral dispersion at 6.5km from SOR typically range between 50m (for straight out routes as at Gatwick) and 250m (turns such as Heathrow 09R CPT). The aircraft heights were also assumed to follow a statistically normal distribution, with the same mean and SD as the actual sample.

2.10.8 Table 6 illustrates current track-keeping performance in this region, relative to the noise monitors, by showing the lateral spread (SD), the average track displacement from the NPR centreline, and the percentage of tracks within the monitor V. By using recent data, the results take account of some significant improvements to NPR track-keeping that have been achieved since the last Review of noise limits. Any future changes to the lateral distributions of tracks on each route in the vicinity of the noise monitors would have a consequent impact on the results of this kind of analysis.

2.10.9 “Improved” track-keeping could be achieved in several ways[22], which could have different effects on noise monitoring performance:

- *Reducing the numbers of track deviations*. The noise monitors all lie within the relevant NPR swathe. Therefore any reduction in the number of ‘track deviations’ (aircraft flying outside the swathe below vectoring altitude) in the region of the noise monitors will usually result in an increase in the proportion of aircraft flying within a V. However, the numbers of track deviations are already relatively small[23], and most occurrences are well after passing the noise monitors, so improving track-keeping in this way would generally have only a small impact on noise monitoring performance.
- *Increasing the concentration of tracks close to the centreline*. Where there is a monitor close to the centreline of an NPR, increasing the concentration of tracks around the centreline in this vicinity will result in a greater proportion of flights within the V. If however the monitors are some distance either side of the centreline, such as a ‘gateway pair’, the effect of concentrating more tracks closer to the centreline could in some cases be to reduce the number of aircraft flying through a V, depending on the lateral separation between the monitors. This

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[22] This is a purely theoretical analysis, performed to follow up on the track-keeping improvements achieved with the Stansted 05 DVR route and the impact they have had on noise monitor array performance. It was beyond the scope of this study to determine how achievable other track keeping changes of the kind analysed here are in practice. A small proportion of tracks will always be affected by factors such as weather avoidance, unusual ATC instructions and maximum bank angle considerations.

[23] Currently (2001/2) around 5% at Heathrow, 2% at Stansted, and less than 1% at Gatwick.

effect was modelled by considering changes to both the position of the mean track at the gate through the noise monitor, and the spread of tracks through the gate.

2.10.10 The results for a sample of cases are plotted in Figure 18. The single diamonds show the performance of the current arrays with current track-keeping, from Table 3. The curves show theoretical statistically normal distributions of tracks. Where there is a large difference between a single diamond and its corresponding curve, it is because the current average track is not close to the NPR centreline.

2.10.11 The curves show that for arrays where there is a monitor close to the NPR centreline (the examples in the upper part of the graph), reducing the SD of the **spread** of tracks about the NPR centreline increases the percentage of flights within the V to 100%. These cases include the array improvement Scenarios 2, 5 and 6 identified in Table 4, showing that if track-keeping could be significantly improved on these routes the need for additional noise monitors is reduced, especially for the slow-climbing aircraft types.

2.10.12 Of these cases in the upper part of the graph, changing the **mean** track from its current position to the NPR centreline (with the current spread of tracks) only results in an increase in the proportion of flights within a V for the Heathrow 09R BUZ/BPK route (for 744 and 340). For the other cases there would be little or no change in the percentage, because the mean track is already quite close to the NPR centreline.

2.10.13 The bold lines on Figure 18 show cases with a larger distance between the closest monitor and the NPR centreline (200-400m). Even with very low SDs (high concentration of tracks) there is still a sizeable proportion of flights not passing through a V. In these cases (which include Scenarios 1 and 3 identified in Table 4), moving the mean track to the NPR centreline would result in a **reduction** in the proportion of flights within a V, because on average the tracks would be **further** from the nearest noise monitor.

2.10.14 For cases with the largest distances between the monitor and the NPR centreline (more than 400m - shown as the dashed lines on Figure 18), the percentage of flights within the V reduces as the track spread is reduced, because there are even fewer flights close to the monitor. It is these cases (which all correspond to Scenario 1) which would benefit most from an additional noise monitor close to the NPR centreline. In these cases, without the proposed new monitor, moving the mean track to the NPR centreline would also result in a major **reduction** in the number of flights within a V, because of the much greater distances of the nearest noise monitor from the centreline.

## 2.11 Effect of turns before reaching the noise monitors

2.11.1 For routes involving early turns, aircraft heights at 6.5 km will be lower than for straight out routes (due to the reduced vertical lift component of an aircraft in a turn), unless a higher initial take-off power setting is used. Greater track dispersion is also likely, especially where there are no navigational aids for track guidance in the turn. However, as aircraft height and lateral displacement are both taken into account in the V-analysis, the results are equally appropriate for assessing monitoring performance of turning and straight-out routes. (The effect of bank angle on departure noise is considered later in Section 3.10.)

## 2.12 Track density

2.12.1 Ground track plots, such as those in Figures 5, 6 and 7 and Appendix B, have the disadvantage of either showing only a small sample or not showing where tracks are concentrated – where the lines representing tracks are superimposed over each other, it is impossible to tell from the track plot whether a location is overflown by one or many more flights.

2.12.2 Hence Track Density plots have been produced as a further means of assessing the monitor improvement scenarios. The area overflown is divided into small cells (50m square for the purposes of this study), and different colours are used to indicate the number of flights, out of the total sample, which overfly each cell. The current monitors, and suggested additional positions as outlined in Table 4 and Appendix D, are also shown on each plot.

2.12.3 To ease comparisons, all the examples shown have a total number of departures of around 1,000 (made up of differing periods within the period 1/9/00 to 30/6/02[24]). The dark blue colouring at the outer edge of the track dispersion represents 50m cells overflown by at least 5 out of 1,000, or 0.5%, of flights. At the other end of the scale, the deepest red colouring represents the areas where tracks are most concentrated, cells overflown by more than 10% of flights. The full key of colours is shown in Figure 19.

2.12.4 It must be remembered that these plots in Figures 20 to 25, unlike the V-analysis, do not give any indication of aircraft height: an aircraft at 2000ft for example can be at twice the lateral distance from a monitor as an aircraft at 1000ft, but still be within the 60° V. Hence track density plots must be used in conjunction with V-analysis for assessing monitor arrays. The plots are for the common noisier aircraft types: 747s, D10, M11 and 340. Illustrative 265m radius circles were drawn around each existing and proposed monitor location, representing the 530m width of the V at a height of 1500ft.

2.12.5 Figures 20(a) and (b) show that, for both runway directions at **Gatwick**, all the coloured cells (i.e.99% of tracks) in the region of the monitors lie within 265m of at least one noise monitor, confirming that no improvements to the current arrays are required.

2.12.6 At **Stansted**, for runway 05 BZD departures (Figure 21(a)), monitor 10[25] is just beyond the westerly edge of the ‘red’ area, while monitor 7 is east of any coloured cells. Hence an additional monitor (or move of monitor 7) was suggested to ‘close the gap’ – Scenario 3. For the 05 DVR route (Figure 21(b)), a number of departures turn sharply right and fly significantly south of monitor 9, thus an additional monitor was suggested to monitor such flights (Scenario 8). However it can be seen from the distribution of blue cells that this would only detect a relatively small percentage of flights, and therefore ANMAC agreed that this location does not merit further assessment at present, pending the results of BAA Stansted’s work on track-keeping on the DVR route. Figure 21(c) for the 05 CLN route also illustrates the gap between monitors 7 and 10.

2.12.7 Figures 22(a) and (b), for Stansted runway 23 departures, show that most of the coloured cells in the region of the monitors lie within 265m of at least one noise monitor. The results show that the monitor arrays are not ideal in respect of the gap between monitors 3 and 5, but no additional monitor would be possible there due to

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[24] Apart from one case where a slightly longer period was required to achieve this sample size.

[25] (shown as “Monitor 1” on NTK outputs)

the M11 motorway. This particular situation was appreciated at the time of the last review.

2.12.8 Figure 23(a), for south-turning departures from **Heathrow** runway 09R, shows the significant gap between monitors H/10 and I/13. The originally suggested additional monitor location (see Appendix D) (marked “X” on Figure 23(a)) is not located in the red area, and the track density plot and further analysis indicates that it would not detect many more noise events than the existing monitor H/10. The alternative potential location (“Y”) would improve detection of flights through this gap, especially of the heavier noisier aircraft. Location X is at 6.55km from SOR, compared with 6.3km for location Y: site Y has the disadvantage of being closer-in than 6.5km from SOR[26], so at the request of ANMAC both locations were assessed as Scenario 1.

2.12.9 Figure 23(b), for north-turning departures from Heathrow runway 09R, shows that because of the distribution of tracks relative to the existing monitors F/11 and G/12, the benefits gained by the two suggested additional monitors would in both cases be smaller than for those for the proposed new monitor between 10 and 13 in Figure 23(a).

2.12.10 Figures 24(a) and 24(b) give an indication of the small proportion of 27R and 27L departure tracks impacted by the suggested additional monitor between monitors C/17 and B/18[27].

2.12.11 Figure 25 shows the track density plot for 27L DVR departures, indicating that while monitor E/14 is close to the mean track, the suggested additional monitor would effectively cover the wide spread of tracks which turn more sharply than the average.

## 2.13 Impact of new monitors

2.13.1 The benefits of each of the array improvement scenarios were quantified in terms of the numbers of noisier aircraft (747s, D10, M11 and 340) which fly closer to a proposed new monitor location than to any existing monitor. This was determined from each track density plot by summing the percentage values of each cell along a line between the two locations (Figure 26). The results below indicate, for each of the initial scenarios detailed in Table 4, the approximate percentage of departures on the appropriate route(s) which would be detected better at the suggested new monitor position than at any existing monitor:

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[26] Every attempt has been made in this Review to find appropriate new sites for monitors no closer in than 6.5km (although there are two existing monitors at Heathrow and one at Gatwick closer than 6.3km). However, differences in the track distance of each monitor from the reference 6.5km distance (and also differences between monitor and airfield elevation) are adequately taken into account in monitoring against the noise limits by means of appropriate adjustments based on nominal climb gradients and the decay of noise with height. Because some aircraft may have difficulty in cutting back power before passing a closer-in monitor, the limit is further increased in the case of monitors that are closer-in than 6.5km from SOR. This adjustment takes account of both the lower height and higher thrust before cutback. The distance component of the adjustment for monitors further out than 6.5km is 0.1dB for each 100m that the monitor lies beyond 6.5km; for monitors closer in, the adjustment is 1.0dB for each 100m that the monitor is short of 6.5km. The basis of the adjustments is described in Annex 5 of Ref 8. Note that from 1 November 2001 the minimum permitted cutback height in the UK was reduced from 1000ft to 800ft.

[27] Although the initial V-analysis that led to Scenario 2 (see Table 4) showed that an extra monitor here would provide a significant improvement in array performance based on the percentage of flights within a V, the track density results (see paragraph 2.13.1), and BAA’s analysis mentioned in paragraph 2.13.2, indicate that in fact very few of the noisiest aircraft types that are not already detected by one or other of the existing monitors would be detected by an additional monitor.

**Approximate percentage of departures on the appropriate route(s) which would be detected better at the suggested new monitor position than at any existing monitor**

| | | | |
|---|---|---|---|
| **Heathrow** | Scenario 1 | Location “X” | 63% |
| | Scenario 1 | Location “Y” | 78% |
| | Scenario 2 | Between 17 & 18 | 5% |
| | Scenario 4 | SE of 14 | 15% |
| | Scenario 5 | Between 11 & 12 | 40% |
| | Scenario 6 | N of 11 | 5% |
| **Stansted** | Scenario 3 | 7 closer to 10 | 45% |
| | Scenario 8 | SE of 9 | 10%[28] |

2.13.2 BAA Heathrow independently assessed the initial array improvement scenarios in Table 4 for ANMAC in a different way, considering the numbers of the noisier aircraft that flew through 350m-wide gates over each of the current monitors (corresponding to the width of the V at 1000ft). They then identified the extra flights that flew through similar sized gates over the proposed new monitor locations, but did **not** fly through the gates above any existing monitors. This analysis identified Heathrow Scenarios 1 and 5 as producing worthwhile benefits, with minimal benefits from the other three Heathrow options. BAA Stansted agreed to pursue Scenario 3.

2.13.3 BAA and ERCD have made detailed comparisons of the two potential monitor locations for Scenario 1, X and Y (see Figure 16). BAA’s analysis of 747, D10 and 340 ground tracks found that, of the flights that were south of the monitor 10 V at or above 1000ft, twice as many more would be detected at location Y than at X, and that a monitor at Y would represent a very much more worthwhile improvement to the current array. Other practicalities (see Appendix D), including site ownership, also favour location Y.

2.13.4 On the basis of the ERCD and BAA analyses, ANMAC agreed to progress Scenarios 1 (Y), 3 and 5 at this time. These three options are clearly significantly more beneficial than the remainder in terms of improving detection of the noisier aircraft types. Special considerations for differential monitoring are detailed in Appendix E; any improvements to the arrays which enhance performance for the noisier types will equally be at least as beneficial for quieter aircraft types (see paragraph 2.8.4).

## 2.14 Effect of accuracy of NTK data on study

2.14.1 The usefulness of such analyses is of course dependent on the accuracy of the NTK height and track data, which might affect the reliability of the results. Because only data from NTK was used in this study, the results are subject to exactly the same accuracy constraints as the data used in operational monitoring. This is discussed in more detail in Appendix F and Ref 12, where it is concluded that the NTK data used is of ample accuracy for this study. The maximum error from the resolution[29] of the individual height data points is ±50ft, and it was estimated that the additional

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[28] with 2001 track keeping – this figure is particularly sensitive to track-keeping changes on the 05 DVR route.

[29] The size of the discrete steps in which the data is provided.

causes of possible inaccuracy could at worst total a further ±75ft approximately. However a more realistic estimate of the overall error (assuming the individual errors are independent of each other) is ±75ft, and NTK smoothing of the height data tends to remove much of the point-to-point variation caused by the resolution.

2.14.2 Observation of the scatterplots in this report shows that incorporating a likely maximum uncertainty of ±75ft in height, and a 'round-figure' value of ±60m in lateral distance, would result in only minor changes to the overall V-analysis results. Moreover, because the results of the study are based on large samples of data rather than individual radar data points, the effect of much of the inaccuracy in the data is mitigated. (For example, because of data inaccuracy a certain number of data points might be erroneously shown as being outside a V – conversely it is probably equally likely that a similar number of other points would be erroneously shown as being inside the V).

2.14.3 The fact that the same Secondary Surveillance Radar provides the source of much of the information used by Air Traffic Control in itself provides some confidence in the NTK input data[30], but it is valuable to perform direct checks of the NTK against independently derived precision data. Ref 12 also provides details of a technical assessment comparing NTK data at all three airports against height and positional information recorded on board aircraft, using (i) flight calibration aircraft data and (ii) flight recorder information provided by a few operators for this Review.

2.14.4 The results from the sample of flights analysed in that study confirm that the NTK accuracy is within the estimates given above: average height differences were found to be within ±20ft, and the average positional error 40m. The results also show that there is no evidence of any consistent bias in either the height or positional data. Note that the analyses of NTK data for this review have used only data relatively close to the airport, so the positional errors would tend to be smaller than those seen in the more general comparisons given above. Any inaccuracies there may be in the radar data will not affect the overall conclusions on monitor array performance.

# 3 FACTORS AFFECTING DEPARTURE NOISE LEVELS

## 3.1 Reference Levels

3.1.1 For the purposes of this study, the term 'Reference level' is used to mean the A-weighted maximum noise level ($L_{Amax}$) measured at each monitor, adjusted to a reference distance of 6.5km from SOR (and to a monitor elevation equal to the runway elevation) using the appropriate monitor positional adjustments given in Ref 5[31]. Only measurements within a $60^0$ V were used to give Reference levels. Reference levels are relevant in terms of noise limits assessments, as they are representative of what is actually measured by the current monitor arrays and used for determining infringements of the noise limits.

3.1.2 For part of the analysis, Reference levels have had an additional lateral adjustment applied (lateral adjustments provide an estimate of the noise level under the flight path in cases where a track does not fly directly overhead a noise monitor). For flights within a V such adjustments increase noise levels by about 0.6dB on average and, for individual flights, 1.7dB at most[32]. These adjusted values are called

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[30] although ATC use the data in very different ways.

[31] AD2-EGLL-1, AD2-EGKK-1 and AD2-EGSS-1, Section 78(1)

[32] According to a standard lateral attenuation model.

"laterally adjusted Reference levels", $L_{RU}$. Laterally adjusted Reference levels are more relevant in theoretical assessments where the noise level under the flight path of an aircraft is of most interest.

3.1.3 Typical distributions of $L_{RU}$ are shown in Figures 27(a)-(e). Most distributions, such as those in Figures 27(a) to (c), are very close to statistically "Normal" (a theoretical bell-shaped distribution which occurs widely in many phenomena in nature and science). The Normal shape with the same mean and Standard Deviation (SD) has been superimposed on each graph for information. However there are some cases where there was clearly a non-normal distribution, including those shown in Figures 27(d) and (e). For example the Heathrow D10 and M11 distributions both appear to have two distinct peaks, while the Heathrow 330 and Gatwick 742 show noticeably 'skewed' distributions. It is important to understand the causes of such non-normality, especially as it could in some cases help to point to ways that the levels of the noisiest aircraft in a distribution might be reduced. In all cases, the results presented here include 95th percentile values calculated from the actual distributions, which illustrate the magnitude of the highest noise levels recorded.

## 3.2 Analysis of NTK data – Data and samples

3.2.1 Apart from Chapter 2 business jets (see paragraph 3.2.2 below), and medium/large propeller types, only Chapter 3 types were considered in this study. The analysis was limited to such types with typically at least one movement per day at an airport. The aircraft types analysed in this part of the study and the codes used are given in Table 7. In some cases a few similar types were grouped together; in others an aircraft type was split (e.g. by variant) where there were statistically significant differences and sufficient samples in each subgroup. (Statistical tests were carried out based on the stage length to the destination airport – an approximate indicator of TOW – and engine type, to determine if it was appropriate to further sub-divide any aircraft type.)

3.2.2 Chapter 2 jets under 34 tonnes MTOW and with a passenger capacity of 19 or less are allowed to continue to operate after 1 April 2002. These aircraft (coded "EXE2") were identified separately from the Chapter 3 business jets ("EXE3"), which are on average about 10dB quieter.

3.2.3 Medium/large propeller aircraft types, following initial analysis, were divided into three groups, based largely on their noise characteristics:

| | |
|---|---|
| PROPS1: | ATR42, ATR72, BAe ATP, Embraer 120, Saab SF340, Shorts 330 and 360, DHC-7, DHC-8, Fokker 50, Jetstream 31 and 41 |
| PROPS2: | Lockheed L188 Electra, BAe HS748, Fokker F27 |
| PROPS3: | Lockheed Hercules |

3.2.4 Generally NTK provided sufficient sample sizes for all analyses, using all available data in the year September 2000 to August 2001. Any advantages in using additional older data were considered to be outweighed by the disadvantages of possible changes in airlines, fleets, destinations and operating procedures over the years. In the QC Monitoring study (Ref 9), it was found that average day-night meteorological variations would be unlikely to cause significant differences of noise level. In a similar way, in this study the differences in Reference levels between the three noise limit periods (day, shoulder and night) were assessed – see paragraphs 3.7.1 and 3.7.2. It was concluded from this analysis that daytime samples can be pooled with the limited samples of night-time data to assess both day and night limits. Generally the analyses were therefore undertaken using 24-hour data.

3.2.5 Sample sizes are given for each airport in Table 7 and Figure 28, which show the number of noise events analysed for each aircraft type. Summing sample sizes from the three airports, the ten most common types (in descending order) were: 733, 757, 146, 320, 321, 744, 777, 738, 763 and M80. Data was also analysed for a further twenty aircraft types/groups with fewer movements. Apart from the 777, all the top ten types had sample sizes greater than 100 at all three airports.

3.2.6 The total sample sizes represent about 60% of all departures at Heathrow and Stansted, and 80% of all departures at Gatwick, involving a grand total of nearly half a million noise measurements. Only events matched to departures where the aircraft was within the $60^0$ V above the monitor have been included in this total. Of these measurements, where a departure caused a noise event at more than one monitor, the highest $L_{Amax}$ was used, and Table 7 shows the number of samples on the basis of only one measurement per flight (almost 300,000 measurements). The higher ‘capture rate’ of 80% at Gatwick is because nearly all departures fly straight out over the noise monitors, and because the monitors are more closely spaced; at the other airports most departures involve turns, and there are larger gaps between monitors, so a smaller proportion of flights are within a monitor V. The event detection thresholds at the Gatwick monitors also generally tend to be set lower than those at Stansted and Heathrow, resulting in more of the quieter aircraft events being identified.

3.2.7 Table 8 lists all the parameters for each event that were assembled for analysis in a database. Most of the data was exported directly from the NTK system, but additional data was obtained from the Met Office, from the Buchair aircraft information database, and from analysis of NTK radar data.

## 3.3 Analysis results: general

3.3.1 Appendix G Tables G1 and G2 give statistics for Reference level and $L_{RU}$ respectively, including the mean, maximum and various percentile values, for each aircraft type at each airport. Figure 29 illustrates these by showing the average and 95th percentile $L_{RU}$ values. Average levels cover a range from 64dBA (CRJ at Gatwick) to 91dBA (742Ch3 at Heathrow), though the majority lie between 70 and 80dBA. Only those aircraft types with average Reference levels greater than about 80dBA are likely to be affected by the current overall limits, because quieter types produce very few or no events exceeding the 87dBA night limit (compare the mean $L_{RU}$ values with the highest levels for the example distributions shown in Figures 27(a) to (e)). For these quieter types there are effectively no controls or incentives to minimise the noise of individual departures, although this of course does not mean that operators in most cases are not taking noise considerations into account in their procedures.

3.3.2 Standard deviations for each aircraft type are also shown on Figures 27(a) to (e) (and in Appendix G Tables G1 and G2). Values are mostly in the range 2.2 to 3.2dBA; a few types had greater variability, but these either had relatively small sample sizes or noticeably non-normal distributions.

3.3.3 Statistical analyses were carried out using the complete set of data shown in Table 7. This allowed the effect of the following potentially significant factors on laterally adjusted Reference levels to be determined:

- stage length (estimated from destination airport using standard airport-to-airport data)
- airline (comparisons only relevant where different operators fly to the same destinations or to others at a similar stage length)

- engine (where the same aircraft type can have more than one engine type)
- day/shoulder/night period
- surface temperature
- relative humidity
- air pressure
- surface headwind (as measured by the appropriate NATS on-airfield anemometer)
- bank angle (calculated from turn radius and ground speed)
- height
- aircraft speed.

3.3.4 Figures 30 to 41 show sample plots of $L_{RU}$ against variables listed above, for a range of types. More detailed results from the analyses are included in Appendix G, which also includes tables of statistical results, including slopes, correlation coefficients and significance values in Tables G3 and G4 to G6. The results are discussed below.

### 3.4 Analysis results: Stage length

3.4.1 As TOW is not known in NTK, stage length is used as an approximate indicator. Other factors being equal, an aircraft flying a long distance will carry a greater weight of fuel than one on a short flight. For a heavier aircraft, either the initial climb rate is reduced or extra thrust is needed to maintain the same climb performance as a lighter flight.

3.4.2 Figure 30(a) shows for the 744 the effect of stage length on $L_{RU}$; data from all three airports has been included. Where sample sizes are sufficient the mean $L_{RU}$ for each destination is plotted in Figure 30(b), which shows the trend more clearly. Most of the Stansted flights are relatively short range, and on average stage lengths from Gatwick are less than those from Heathrow. Although there is a wide spread in the individual noise levels plotted, the average levels for each destination follow a fairly consistent relationship against stage length, accounting for a range of about 15dBA between the short range positioning flights and the longest range flights. Reference levels at Heathrow for a given stage length tend to be higher than those at Gatwick.

3.4.3 Figure 31 shows the relationship between stage length and $L_{RU}$ for a selection of aircraft types at Heathrow. It is seen that the effect of stage length is more pronounced for some aircraft types than for others. Stage length is a much less critical factor for shorter-range aircraft (where the weight of fuel carried may have a smaller influence on TOW than the payload or other factors), but it also appears to have little effect for the 763, which is used over a wide range of stage lengths. Further examples of results are given in Appendix G Figure G1.

### 3.5 Analysis results: Airline

3.5.1 Detailed aircraft operating procedures can vary markedly between operators. Important factors are the engine thrust and flap settings during take-off, initial climb and after power cutback, which together have a major effect on the aircraft height and noise at the monitor. An airline will take into account the need to balance reductions in noise, engine wear and fuel consumption amongst other factors. This report has only analysed noise impacts at 6.5km; other effects, such as any additional emissions (e.g. of nitrogen dioxide) that might arise from the use of higher take-off power settings, have not been analysed.

3.5.2 Tables 9(a) and 9(b), and Figures 32(a) and (b), for Heathrow 744s and 320s respectively, compare mean $L_{RU}$ values between different airlines[33] flying to the same destination (thus eliminating the stage length effect). While for the 744 for some stage lengths there is very little difference between airlines, other cases show differences of more than 3dBA. This is partly due to airlines operating aircraft with different engines (see paragraph 3.6.1 below), and different load factors and policies on amount of fuel carried, but also probably due to some differences in operating procedures. For the 320, differences between airlines are mostly no more than 1dBA, but for one airline the noise levels are typically 5-6dBA higher than others, with similar engine types and departure routes[34]. Figure 32(c) shows similar results for the 320 at Gatwick, where there is a spread of about 3dBA between airlines. Further examples, for the 733 and 763, are given in Appendix G Figures G2(a) and (b).

### 3.6 Analysis results: Engine

3.6.1 Figure 33 illustrates the mean $L_{RU}$ values at Heathrow for each of the aircraft types for which there is more than one main engine type. The range of levels between different engine types is frequently in excess of 3dBA, showing that aircraft type alone is not necessarily an adequate indicator of noise performance. In any scheme of differential noise limits, a quieter engine type may be in a lower grouping than a noisier engine type for a particular aircraft type.

### 3.7 Analysis results: Day/shoulder/night period differences

3.7.1 Figures 34, 35 and 36 show the mean $L_{RU}$ at Heathrow, Gatwick and Stansted respectively for each period[35], for each aircraft type for which there were a sufficient number of departures in more than one period (minimum sample size = 20). For the purposes of this part of the analysis, aircraft were then grouped according to their QC rating. Table 10 indicates the difference in sample sizes for day, night and shoulder period showing (particularly at Heathrow) the difficulty in obtaining large samples of night-time data. The Table also gives the mean $L_{RU}$ values and SDs for the samples in each QC band[36].

3.7.2 Figures 34, 35 and 36 show that differences for individual aircraft types between the three periods are generally small; in many cases the differences are not statistically significant, but where differences are statistically significant there is no consistency – in some cases daytime levels are slightly higher than those at night or in the shoulder period, in other cases they are lower. The average day minus night difference, combining data from all three airports, is less than 0.3dBA. Differences within the QC bands in Table 10 can be attributed largely to different aircraft types within each QC group operating in the different periods. (This is illustrated by the differences between the three airports in the average levels of each QC group.) At Gatwick the average QC/4 night level is about 3dBA quieter than the day and shoulder levels; but at Stansted the night and shoulder period QC/4 levels are 2dBA higher than in the day – this is due both to differences in the aircraft types departing

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[33] The airlines are not identified for commercial reasons.

[34] It was subsequently found that this airline operates an older 320 variant with different aerodynamic characteristics.

[35] The time periods (local time) are: Day 0700-2300; Shoulder 2300-2330 and 0600-0700; Night 2330-0600.

[36] Some data is shown for the QC/8 group, but it should be noted that QC/8 aircraft are not permitted to be scheduled to take-off in the shoulder or night quota periods, and may not take off, except in certain circumstances, between 2300 and 2330.

at night at Stansted[37], and a difference between 744 stage lengths in the daytime and night-time[38].

## 3.8 Analysis results: Surface temperature

3.8.1 To some extent, ambient air conditions affect engine performance and both the generation and propagation of noise, but their principal influence in relation to noise at 6.5km is upon aircraft climb gradient. In the context of departure limits, any effect of temperature on propagation would be small because of the relatively small propagation distances to the monitors. The most readily available meteorological data is measured at ground level ("surface" conditions), and this has been used here. Meteorological conditions vary with altitude; for particular flights, information on conditions during an aircraft's climb-out can be obtained from FDR data, but FDR data cannot provide the large sample sizes of the kind needed for this type of statistical analysis.

3.8.2 Figure 37 illustrates the relationship between $L_{RU}$ and surface temperature for a selection of aircraft types. For most types at Heathrow there is a negative correlation (higher temperatures corresponding to lower noise levels), but correlations are by no means identical between different aircraft types. As the outside air temperature rises, air density reduces, causing reduced wing lift. At a given take-off weight, True Air Speed (TAS) and flap setting, therefore, aircraft will need a higher take off thrust setting at higher temperatures. For temperatures above that at which full power is required, a reduced take-off weight is necessary, achieved either by reducing fuel or payload. Assuming no engine malfunction during the take-off, the aircraft will have an excess of thrust. Since reduced thrust calculations have to be pessimistic, the thrust available, above that required, will increase as the outside air temperature increases, resulting in better climb profiles and in some cases slightly lower noise levels at higher temperatures.

3.8.3 Aircraft with the strongest relationship include PROPS1, 738 and 320. Only the 330, 743 and 146 show a statistically insignificant positive relationship. At Gatwick and Stansted there is less of a clear relationship between $L_{RU}$ and temperature. It should be noted that the temperatures used are hourly mean temperatures, which could have a minor effect on accuracy. Further examples of results are given in Appendix G Figure G3.

## 3.9 Analysis results: Surface headwind/tailwind

3.9.1 Because of the movement of the air, aircraft (at a given power setting) climb at steeper angles into headwinds than into still air, and hence are at a greater height, which would be expected to result in a lower noise level. Tailwinds have the opposite effect. It is also relevant, but difficult to take into account, that wind speed and direction can vary markedly with height above the ground. Analysis of flight recorder data may subsequently allow investigation of the effects of wind variation with altitude.

3.9.2 Figure 38 shows the relationship between $L_{RU}$ and surface headwind for a selection of aircraft types. Values of headwind (given each second by the appropriate NATS on-airfield anemometer at the 'far' end of the runway) were matched to each aircraft

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[37] Within the QC/4 group, in the daytime there was a higher proportion of D10 departures (which are quieter than the QC/4 744s), and a lower proportion of 744 and EXE2 departures, compared with the night and shoulder periods.

[38] 744s at Stansted at night were operating significantly longer stage lengths than the daytime flights.

departure, ensuring accurate wind data[39]. Negative values of headwind indicate a tailwind. With the exception of the 319, 320 and EXE3 types at Heathrow, the graphs show a consistent relationship of decreasing noise levels with increasing headwind. As with surface temperature, the correlations vary between different aircraft types: 340 and 744 exhibit a stronger relationship, but there is a great deal of scatter in the data caused by other factors. Further examples of results are given in Appendix G Figure G4.

## 3.10 Analysis results: Bank angle

3.10.1 For a given initial take-off power setting, aircraft heights at 6.5 km for routes involving early turns will be reduced compared to straight out routes. This is due to the reduced vertical lift component of an aircraft in a turn. To maintain the same climb gradient, a higher initial take-off power setting will generally be used. Either way, depending on the rate of turn, noise on the ground below turning aircraft will tend to be somewhat higher than below non-turning aircraft at the same track distance from SOR.

3.10.2 An estimate of the bank angle in the vicinity of the noise monitors was determined from NTK radar data, by calculating the turn radius and ground speed. As seen in the list of database variables (Table 8), an aircraft's bank angle can be further clarified by 'turn' and 'view'. 'Turn' indicates whether the aircraft is banking to port or starboard. 'View' indicates whether an observer would see more or less of the underside of a laterally displaced aircraft from the relevant noise monitor, compared with the aircraft at the same position flying straight with zero bank. A fuller view of the aircraft's underside is denoted by a positive bank angle, whereas the bank angle is given a negative value if the view of the underside of the aircraft is shielded. Results for Heathrow 733 departures are shown in Figures 39(a) and (b)) for "positive" and "negative" bank angles respectively. In both cases the line of best fit confirms a positive relationship between bank angle and $L_{RU}$, although there is much scatter from other factors.

## 3.11 Analysis results: Height

3.11.1 Figure 40 illustrates the relationship between $L_{RU}$ and height for 733, 320 and 744 departures at Heathrow. In all cases, as expected, there is a very strong negative relationship, with lower noise levels corresponding to greater heights. The relationship is particularly clear for the slower-climbing 744s; other types tend to have more flexibility in power settings on departure. Note that these heights have not been standardized to the reference distance of 6.5km. The scatter at any given height represents the effects of all the other variables discussed here, and height itself is strongly dependent on factors such as stage length, bank angle, temperature and headwind component.

## 3.12 Analysis results: Aircraft speed

3.12.1 Because the power from the engines during take-off can be used either to climb or to accelerate (or often a combination of both), there is a balance between aircraft height and air speed. Only ground speed can be determined from NTK, not air speed, but use of ground speed in this part of the study provides a reasonable indication of trends. Figure 41 illustrates the relationship between $L_{RU}$ and ground speed (at the closest point to the monitor) for 733, 320 and 744 departures at Heathrow. Ground speed determined from NTK is subject to some inaccuracy

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[39] At Heathrow. Similar data has not been able to be used for this study for Gatwick and Stansted – Met Office hourly wind data was instead used for these airports.

because of the quantization of radar data (see Appendix F), but the results do show in all cases that there is a strong positive relationship - the faster the aircraft, the higher the noise level[40]. The degree of correlation varies between aircraft types, with 744s displaying the strongest relationship. These ground speeds have not been standardized to the reference distance of 6.5km, but it is expected that such an adjustment would have little effect on the results.

### 3.13 Analysis results: Other meteorological parameters

3.13.1 Appendix G Figure G5 shows that $L_{RU}$ has a generally small and negative relationship with air pressure. There is an even less significant relationship with relative humidity (Appendix G Figure G6).

### 3.14 Analysis results: Summary

3.14.1 Of the factors analysed, it is clear that stage length has the biggest effect on the noise level (apart from aircraft height, which is itself dependent on TOW). Stage length is the best proxy available from NTK data for TOW, but there is no unique relationship.

3.14.2 The scatter in all the results illustrates that NTK data is not usually sufficient to determine the reasons for the few high noise levels in the distributions – these are more likely to have been caused by differences in power settings, or TOW variations dependent on payload, fuel load and weather conditions. The only source of information that can provide data on all these aircraft variables is the flight data recorder (FDR) from operators.

### 3.15 Analysis of data from airlines

3.15.1 The Scheduling Committee representatives on ANMAC offered to investigate the availability of FDR data for this study. Provision of FDR data by operators is not a simple matter. Where fitted, information can be extracted from Quick Access Recorders, but it can nevertheless be costly to the airlines to supply ad hoc data in a particular format, and there are often concerns over reimbursement of some of these costs and over confidentiality - both on the part of pilots and of airlines wishing to protect commercially sensitive information.

3.15.2 FDR data has been received from four operators, covering five different aircraft types. Each set comprises 50 departures from an appropriate runway or runways. The data was matched to NTK noise measurements at the relevant fixed monitors. It was hoped that the data would enable fuller assessments to be made of the causes of the noisier and quieter events, and provide greater understanding of the impact of some of the variables which are not determinable from NTK data (including for example the wind at altitude). The effect of a number of FDR variables, such as TOW, engine rpm and air speed, on noise levels is being assessed. However sample sizes are not sufficient for comparisons to be made of different take-off procedures, and in view of the limited quantity of data available results are not presented in this report.

3.15.3 Separate TOW data has also been supplied from one major operator for a much larger sample of flights, preliminary analysis of which is described in Appendix H. This shows a very similar relationship for 744 $L_{RU}$ against TOW to that given in

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[40] The initial climb speed is typically a fixed number of knots (e.g. 15 or 20) above $V_2$, the minimum safety speed. $V_2$ is directly related to the aircraft's weight. In some cases fast-climbing aircraft may commence their acceleration from this initial climb speed before reaching the noise monitor; this would generally result in a higher noise level at the monitor (either because of a lower height or a power increase) than a similar aircraft which commenced the acceleration later.

Ref 2, which was a principal source of information used in the previous Review of noise limits. It is important to note that results from such analyses apply only to that particular aircraft type (and to the engine fit and the way it is flown by the particular operator).

# 4 OVERALL NOISE LIMITS

## 4.1 Background

4.1.1 Departure noise limits have applied at Heathrow since 1959, at Gatwick since 1968 and at Stansted since 1993. The original limits were set in PNdB; this noise metric was superseded by the use of dBA in 1993, but the noise limits remained effectively unchanged until the Government's decision of 18 December 2000 following the Review which was initiated in 1993. The reduced limits - 3dBA lower by day and 2dBA lower by night, and a shoulder period when the previous night limit applies - were implemented in February/March 2001[41].

4.1.2 The main objectives for noise limits are to deter excessively noisy movements, by detecting and penalising those which exceed the limits, and to encourage the use of quieter aircraft and best operating practice. The review was to consider "any further improvements as and when practicable, and new, tougher limits, possibly incorporating a differential or tiered effect". The intention of the timing of this review was that any proposed practicable reductions in the noise limits should be put into place as soon as possible after 31 March 2002, the date when Chapter 2 aircraft (other than those below 34000kg MTOW and passenger capacity of 19 or less) ceased operation.

4.1.3 It is important to consider the limits in relation to operational noise levels at the reference monitoring position, and to understand the causes of variability of measured levels. In some cases such understanding might lead to the identification of particular procedures or techniques which could result in consistently lower noise levels than are currently recorded by a particular fleet. Statistical assessments have therefore been made not just in terms of mean noise levels, but also of measures which quantify distributions about the mean such as standard deviation and various percentile values (the 95th percentile for example indicates the noise level below which 95% of events for a particular aircraft type lie[42]).

4.1.4 Figure 42 shows the changes in the mean, 90th and 95th percentiles of all Heathrow B747 Reference levels[43] in the period April to September of the years from 1998 to 2002. The reduction in B747 noise levels over this 5-year period, in terms of mean,

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[41] The time periods and limits are: "Day" 0700-2300, 94dBA; "Shoulder" 2300-2330 and 0600-0700, 89dBA; "Night" 2330-0600, 87dBA. All times are local, i.e. BST during the summer and UTC during the winter. Concorde has never been subject to the departure noise limits.

[42] For the purposes of this study the mean values and the other statistics given provide fully adequate information on noise levels. Measured values of 50th and other percentiles can be seen in cumulative noise level distributions (see for example Figure 43). As well as mean values, the previous noise limits review included some discussion of levels for 50th percentiles (although where they were used they were in fact equivalent to the mean values because they were only used with theoretical perfectly Normal distributions) and "90% probability of compliance" (these are equivalent to 90th percentiles). For the present study 95th percentile values have also been included for illustrative purposes as they indicate a greater degree of certainty of compliance, but the conclusions apply whichever of these statistical measures is considered.

[43] No tailwind allowances have been applied.

90th and 95th percentiles respectively, was 1.8, 2.3 and 2.5dBA[44]. It was shown in the previous review, which was to a large extent based on analysis of data from 1994, that the present 94dBA daytime limit was compatible with B747 noise levels then. It is unlikely that B747 departure noise levels increased generally between 1994 and 1998, so these year-on-year reductions since 1998 indicate that with the current fleet, operations and procedures the daytime limit could probably be reduced by 1dBA.

4.1.5 The B747 95th percentile value in summer 1999 was 94.0dBA, indicating that in that 6-month period about 5% of monitored B747 levels (adjusted to 6.5km, airfield elevation) exceeded the current 94dBA daytime limit. Since then B747 levels (in terms of 95th percentiles) have been reduced by nearly 2dBA. The 95th percentile values represent the noisiest flights of each type, which include those departures where a high noise level would not be predicted simply from the aircraft's TOW, temperature and wind.

## 4.2 Additional adjustments

4.2.1 Adjustments are currently applied to the noise limits, or to the measured levels, before determining infringements, to account for:

- distance of the monitor from SOR, compared with 6.5km reference distance
- monitor elevation, compared with airfield elevation
- tailwind

4.2.2 In any scheme of noise limits, routine application of adjustments to take account of engine/aircraft variant, TOW, meteorological variables, turns and possibly other factors would not be practicable. This was confirmed by the complexity of the analyses carried out for this study, which have also shown that, apart from the major practical difficulties in implementation, there would not be any significant benefit in applying such adjustments.

4.2.3 Consideration has also been given to the possibility of adjusting measured noise levels for the lateral position of the aircraft relative to the noise monitor, before comparing with the noise limit. It was assumed that only cases where the aircraft was within the $60^0$ V from the monitor would be considered. (If outside the V, there would almost always be another monitor in the array where the flight was inside its V, and where the noise level would probably be higher.)

4.2.4 Although such an adjustment probably could be applied automatically within the NTK system, this would require the addition of suitable software to model lateral propagation effects for every matched noise event, which would greatly increase the amount of processing required, having knock-on effects in delaying the results of other analysis performed by the system. The costs and timescale for implementing such a change to the system have not been quantified (to do so would require the production of a detailed specification), but both would be significant. If a standard lateral attenuation method were to be used, the resulting adjustments to measured levels would generally be less than 1dBA, and would never exceed 1.7dBA (see paragraph 2.3.2).

4.2.5 The accuracy of the height and positional data from radar is critical in determining the correct value of such an adjustment. Overall it is considered that the disadvantages of applying such a small adjustment to a large proportion of all noise

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[44] The larger reduction in the high percentiles compared with the mean value indicates that occurrences of particularly noisy B747 departures have been reduced, in addition to the general reduction in B747 levels due primarily to changes in the fleet.

measurements in NTK outweigh the benefits, especially if the monitor spacings can be improved as suggested in Section 2.

### 4.3 Results from BAA actual infringement data

4.3.1 In assessing the overall limits, it is very useful to study what departures have actually been identified as noise infringements by BAA. The numbers of actual infringements of the current limits (from BAA data) during 2000/2001[45] and the infringement rates[46] are given in Table 11. Apart from infringements by the Chapter 3 B747 variants (mostly 742Ch3 and 744), the other aircraft types infringing during this period were all Chapter 2[47] except for small numbers of M11, 340, D10, M80, L1011 and Tu204. Of these, all were at night except for one M11 daytime infringement, indicating that B747s are significantly more likely to infringe any limit than any other Chapter 3 types.

4.3.2 The results in Table 11 confirm that the feasibility of lower overall limits can be determined to a very large extent by what is possible for Chapter 3 B747s. In the year considered, Chapter 3 types other than B747s accounted for only 7, 8 and 4 night and 3, 5 and 0 shoulder period infringements at Heathrow, Gatwick and Stansted respectively, and only one daytime infringement (at Heathrow).

4.3.3 Data for Heathrow for the first 9 months of 2002 show a continuing trend for lower B747 infringement rates, with 57 daytime and 125 night and shoulder infringements (compared with 144 day and 234 night and shoulder infringements in the 12 months of 2001). For other Chapter 3 types in 2002 there were 21 night infringements (including 13 by 340s and 5 D10s) but none in the day (in 2001 there were only two night infringements by each of these types, so this represents a worsening in noise impact at night from these particular types).

### 4.4 Noise level distributions

4.4.1 Analysis of NTK data for the 744 and 742Ch3 types for the year September 2000 - August 2001 at Heathrow and Gatwick has provided the cumulative Reference level distribution graphs shown in Figures 43(a) and (b) (a tailwind allowance has been applied to the Reference levels where appropriate, so the levels plotted represent those that would be compared with the overall limits). The results at Heathrow show that only a small percentage of departures exceeded the current daytime limit of 94dBA[48] (0.4% of 744 departures, and 3.5% of 742Ch3s). Levels at Gatwick are lower, and are even lower at Stansted because of the typical short stage lengths of 744s there (see Figure 30). (There were insufficient movements by 742Ch3 at Stansted to include data for them.) The differences between airports for a given aircraft type are to be expected and can be due to a number of factors, including predominately differences in airlines and routes (which can result in differences in TOWs, engine types and departure procedures).

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[45] Gatwick and Stansted September 2000 to August 2001, Heathrow January to December 2001.

[46] Infringement rate is the number of infringements as a percentage of the total number of departures of the type.

[47] Apart from B747s the principal Chapter 2 aircraft types causing infringements in 2000/2001 were: VC10, IL76, B727, AN-124, B707, B737-200 and DC8. Some of these types also have Chapter 3 variants, and it should be noted that Ilyushin are considering the possibility of re-certifying the IL76 (and IL62 and IL86) to Chapter 3. The effect of any modifications or weight reductions on their noise levels is not known, so it is not possible to include these aircraft in the database for analysis, but it is likely that the noise levels of such types would in some cases be as critical as those of B747s. Numbers of flights of these types are of course very much smaller than those of B747s.

[48] Note that BAA apply a measurement tolerance of 0.7dBA to the adjusted noise limits before determining infringements.

4.4.2 These values of predicted daytime infringement rates, and the shoulder period and night-time infringement rates estimated from the same distributions of monitored noise levels, are shown in the table below, which also illustrates the likely effect on infringement rates of any reductions in the limits from their current levels. For comparison, the results from the 1995 study in Ref 1 (for all Chapter 3 B747s) are also shown in the right hand column.

**Percentages of departures exceeding certain Reference levels**

| Current limits | Reference level dBA (+0.7dBA tolerance) | 744 | | | 742Ch3 | | Ref 1 All Ch3 B747s |
|---|---|---|---|---|---|---|---|
| | | Heathrow | Gatwick | Stansted | Heathrow | Gatwick | |
| Day | 94 | 0.4% | 0.0% | 0.0% | 3.5% | 1.9% | 10% |
| | 93 | 1.1% | 0.0% | 0.0% | 7.6% | 4.5% | 14% |
| | 92 | 3.0% | 0.0% | 0.2% | 16% | 8.9% | 20% |
| | 91 | 7.2% | 0.0% | 0.5% | 29% | 17% | 28% |
| | 90 | 15% | 0.4% | 0.8% | 44% | 26% | 37% |
| Shoulder | 89 | 28% | 1.7% | 1.0% | 58% | 37% | 46% |
| | 88 | 43% | 7.9% | 2.1% | 70% | 46% | 57% |
| Night | 87 | 58% | 21% | 5.0% | 79% | 57% | 66% |
| | 86 | 72% | 43% | 8.3% | 86% | 66% | 74% |
| | 85 | 82% | 64% | 14% | 91% | 75% | 81% |

4.4.3 This table shows that in terms of infringement rates there is a clear difference between the 744 and the 742Ch3, pointing to differential limits as a possible means of applying more realistic limits for each type, in addition to an overall limit. The overall limit would either be appropriate for the 744 and lead to an excessively high infringement rate for 742Ch3, or else, as with the present daytime limit, be more appropriate for the latter and have less impact on the 744 noise performance. The comparison with the 1995 study (where 744s and 742Ch3s were combined) shows significantly lower infringement rates at the noisiest noise levels in the present study data (especially for events of 92dBA and above).

4.4.4 The average number of departures per month of these types (in the 8-month period April to November 2002) at each airport is shown below.

**Average numbers of departures per month** (rounded to nearest 1)

| Period | 744 | | | 742Ch3 | |
|---|---|---|---|---|---|
| | Heathrow | Gatwick | Stansted | Heathrow | Gatwick |
| Day | 1915 | 156 | 49 | 68 | 14 |
| Shoulder | 48 | - | 2 | 12 | - |
| Night | 17 | - | 4 | - | - |

4.4.5 Based on these movements, the expected numbers of infringements by 744 and 742Ch3 aircraft are given below. The numbers of infringements by other aircraft types would assume increasing importance with lower noise limits. Note that in subsequent years it is likely that numbers of 742Ch3 movements will continue to decline. (There were also small numbers of movements by B747-100, B747-300 and B747SP in the period referred to above – these too are likely to continue to decline.)

**Predicted approximate numbers of monthly 744 and 742Ch3 infringements for different noise limits** (based on present noise level distributions and 2002 traffic)

| Current limits | Reference level dBA (+0.7dBA tolerance) | 744 | | | 742Ch3 | |
|---|---|---|---|---|---|---|
| | | Heathrow | Gatwick | Stansted | Heathrow | Gatwick |
| Day | 94 | 8 | 0 | 0 | 2 | 0 |
| | 93 | 21 | 0 | 0 | 5 | 1 |
| | 92 | 57 | 0 | 0 | 11 | 1 |
| | 91 | 138 | 0 | 0 | 20 | 2 |
| | 90 | 287 | 1 | 0 | 30 | 4 |
| Shoulder | 89 | 13 | 0 | 0 | 7 | 0 |
| | 88 | 21 | 0 | 0 | 8 | 0 |
| | 87 | 28 | 0 | 0 | 9 | 0 |
| Night | 87 | 10 | 0 | 0 | 0 | 0 |
| | 86 | 12 | 0 | 0 | 0 | 0 |
| | 85 | 14 | 0 | 1 | 0 | 0 |

4.4.6 This table shows that the actual numbers of infringements that would be likely to occur with lower noise limits are probably manageable by the airport Flight Evaluation Units.

### 4.5 Scope for reductions in the noise limits

4.5.1 Government policy, having regard to international commitments, is not to impose requirements with which aircraft permitted to fly at the relevant airports could not comply, however they were operated, on whatever route and however maintained[49]. Bearing this in mind, the results in paragraph 4.4.2 above indicate provisionally that there is scope to reduce the daytime limit from its present level of 94dBA by 1dBA, but any further reduction could result in large increases in the 742Ch3 (and Heathrow 744) infringement rates. If 742Ch3s generally could be operated more quietly, it might be possible to reduce the limit by somewhat more than 1dBA, but any reductions much larger than this would not be possible while such so-called “marginally compliant” Chapter 3 aircraft types remain in service[50].

4.5.2 It does not appear that either the current night or shoulder limits (87 and 89dBA respectively) could be reduced from their current levels with the present aircraft types legally operating in these periods. The night and shoulder period limits are broadly compatible with the night restrictions regime and reflect what is operationally practicable in that context. Aircraft with QC ratings of more than 4 may not be scheduled to depart at night (2300-0700)[51]. Figure 44 shows the mean and 95th percentile values of the measured Reference levels, combining the values for all aircraft types within each QC band and combining data from Heathrow and Gatwick.

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[49] See Ref 10 paragraphs 40-41.

[50] EC Directive 2002/30/EC defines marginally compliant types as aircraft that meet the certification standards of Chapter 3 by not more than 5EPNdB. Under the Directive, any new operating restrictions aimed at the withdrawal of aeroplanes are limited to such types.

[51] and may not take off, except in certain circumstances, between 2300 and 2330.

No exact equivalence is possible between the night restrictions and the departure limits[52], but Figure 44 shows that there is quite a close relationship, and that the measured noise levels in terms of dBA, like the QC boundaries in EPNdB, decrease by about 3dBA for each QC band (in fact the levels decrease by more than 5dBA between QC/4 to QC/2). If in the future QC/4 aircraft were to be not permitted to operate in the night quota period[53], it would be consistent to reduce the night limit by 3dBA, to 84dBA.[54]

# 5 DIFFERENTIAL NOISE LIMITS

## 5.1 Rationale for differential limits

5.1.1 As seen above, the overall limits have a significant impact only on a few particular aircraft types. A principal objective of differential limits is to encourage quieter departures by **all** types, and it is envisaged that such limits would be 'advisory' rather than carry any penalty for infringement. The special considerations for monitoring against differential limits were considered in paragraphs 2.7.1 to 2.7.5, 2.8.4 and 2.13.4, and in Appendix E.

## 5.2 Grouping aircraft types based on measured noise levels

5.2.1 Application of differential limits requires a manageable number of homogenous, clearly separated groups. Figure 45 shows, however, that there is little separation between the average Reference levels of the various individual aircraft types flying at each airport (typically about 0.8dBA separation between each of the different types when compared in the ranked orders shown, and even less when some types are sub-divided by engine type and/or stage length). Apart from the few types with the highest and lowest levels, there is little sign of any 'natural' groupings from the results in Figure 45.

5.2.2 Several different bases for grouping aircraft types have been assessed, but the variability within any arbitrarily defined group meant that it was often then necessary to combine types to obtain sufficient separation between adjacent groups.

5.2.3 Any groupings based on measured noise levels such as those in Figure 45 for individual aircraft types, further split in some cases by stage length and/or engine fit, would inevitably be on an arbitrary basis and would be difficult to defend. If for example a major operator of a type altered the departure procedure (perhaps in response to a differential noise limit), resulting in a noticeable reduction in its average noise level, there might then be a case for that type to be reclassified into a quieter group on the basis of measured data. But such an action would effectively be penalising the operator for a positive achievement. In addition, if groups are based on mean noise levels, the variability of noise levels within each group tends to obscure the required separation between groups. If stage length (or TOW) were to

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[52] because (i) the departure QC ratings are determined from a combination of flyover and sideline certification measurements, and (ii) QC ratings are based on certification measurements in EPNL, not $L_{Amax}$.

[53] There is currently a voluntary ban on the scheduling of services by QC/4 aircraft between 2330 and 0600.

[54] Figure 44 indicates that it should probably be easier for QC/2 aircraft to meet this lower limit than it is for QC/4 aircraft to meet the current 87dBA night limit, as the levels of the QC/4 aircraft in the sample tended to be higher than the level corresponding to the mid-point for that band. However, based on 24-hour statistics, more than 5% of departures of the following QC/2 types might infringe such a reduced night limit if they were to fly regularly at night: 340, 762, 763, 777, M11, M80.

be used, to take account of a large part of this variability, the complexity of assigning each flight (rather than each individual aircraft) to a group would also be an additional major administrative burden.

## 5.3 Grouping aircraft types based on QC ratings

5.3.1 Figure 44 indicated the possibility of an alternative method of grouping aircraft, based simply on their departure QC ratings. This would have the major advantage of determining the appropriate differential limit from the certificated noise levels for each aircraft. The QC bands are each separated by 3dB, providing up to seven groups to effectively cover the range of aircraft types operating at the London airports (exempt to QC/16). The study sample data was analysed on this basis as an initial test of the feasibility of grouping in this way.

5.3.2 The results from the QC monitoring study (Ref 9) show that day and night data can be pooled, and in this study the analysis described in paragraphs 3.7.1 and 3.7.2 showed that individual aircraft flying to similar destinations are generally not likely to be any quieter (or noisier) at night than by day. 24 hour data has therefore been pooled for this part of the study.

5.3.3 Figures 46(a) to (c) (for Heathrow, Gatwick and Stansted respectively) depict the measured Reference levels for each aircraft type within each QC band, by showing the mean values for each type and the 95th percentile values – i.e. 95% of noise events for that type were below the upper plotted level, whilst 5% exceeded it. Based on these results, an illustration of an initial suggestion for applying QC-based differential limits is given, which shows a limit equal to the current daytime limit (94 dBA) applying to QC/8 and QC/16 types[55], and limits reducing by 3dBA in each of the lower bands down to 79dBA for exempt aircraft.

5.3.4 These Figures show that most aircraft in the exempt and QC/0.5 groups are very unlikely to exceed the suggested limits for those groups[56], and are in any case generally much quieter than QC/1s. No additional monitoring of QC/8s (and the very few Chapter 3 aircraft that are QC/16[57]) would be needed, as the differential limit for these groups would be the overall daytime limit. Further consideration would be needed whether a differential limits scheme should also be applied at night[58].

5.3.5 There are some disadvantages in using QC bands. Certification measurements, the basis of the QC bands, are made in EPNL instead of $L_{Amax}$, and there is no unique relationship between the two units, although the comparisons using flyover noise measurements at Heathrow in Ref 9 show that there is generally a reasonably good correlation between them. For the purposes of this analysis there was also some

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[55] 742Ch3 aircraft are mostly QC/8 on departure, with a few QC/16.

[56] The Heathrow QC/0.5 point significantly above the line at 86dBA is the EXE3 executive jet group, which contains a few aircraft that appear to be exceptionally noisy for that QC band.

[57] heavy variants of some 742s with particular engines.

[58] In this illustration of a QC-based differential limits scheme, the existing overall shoulder and night limits are stricter than the suggested QC/4 limit. If QC/4 departures were to be completely banned from taking off in the night quota period, the noisiest types operating at night would be QC/2s, for which the suggested differential limit would be 88dBA (halfway between the current 87 and 89dBA night and shoulder period overall limits). Thus if differential limits were to be introduced on this basis, there would be a slight increase in stringency (1dBA) for QC/2 aircraft in the shoulder period (although penalties in that period would only apply for exceeding the 89dBA limit). Any more stringent night time limit, such as the limit of 87dBA which currently applies from 2330 to 0600, or any reduced limit that might be introduced, taking account of the findings described in paragraph 4.1.2, would of course take precedence.

difficulty in determining the QC ratings of aircraft - currently it is only already determined for those aircraft likely to operate at the London airports at night. For each individual aircraft, unless it is of an identical build (variant and engine fit) to a type already on the list, access to noise certification data will probably be needed to determine its QC rating definitively, as well as in many cases knowledge of any acoustic treatment and its maximum certificated TOW. A provisional list which contains the QC ratings of about 85% of the departures has been used in this study.

5.3.6 The departure QC criterion is made up of a combination of the flyover and the sideline (or lateral) certificated noise levels. Because departure noise limits are akin to the flyover measurements, it might be considered more relevant to base groupings on the certificated flyover noise levels (for example in 3dB-wide bands) rather than the QC ratings. The flyover level does provide a theoretical ‘target' for differential limits, as it represents the optimum noise level that could be achieved at 6.5km from SOR by an aircraft (at maximum TOW). This however would represent a further administrative exercise to process the certificated flyover noise level for every individual aircraft. It could conversely be argued that an advantage of the use of the departure QC rating is that it takes some account of any adverse effect that optimisation of the flyover level might have on the sideline noise.

5.3.7 Although a differential limits scheme would increase the pressure on operators of some of the less noisy aircraft types to minimise departure noise, the practical and administrative difficulties of operating such a scheme should not be under-estimated.

## 5.4 Suggested way forward on differential limits

5.4.1 An operational differential limits scheme requires some form of grouping of aircraft types. Grouping on the basis of average measured noise levels has been found to be impracticable, largely because of the small separation between different groups. An alternative basis, using departure QC bands, would be more feasible to operate, but could give practical and administrative difficulties.

5.4.2 It is suggested that a trial of differential limits based on QC bands be undertaken at one or more of the London airports, in order to assess the feasibility of such a scheme for routine advisory monitoring, and to see if it might have any impact on departure noise levels. The trial should show whether grouping aircraft based on QC ratings is appropriate, or whether more meaningful results would be obtained if the certificated flyover noise levels were to be used instead. The trial would also help determine the specific benefits and difficulties of applying differential limits to shoulder period and night departures.

5.4.3 The trial could include consideration of possible mechanisms for applying differential limits, including having the departure QC rating (and/or the certificated flyover noise level) for each aircraft stored in NTK. It would then be relatively simple for the system to produce a daily report listing those flights exceeding the limit for their QC band. The trial would also indicate what practical difficulties might arise in the operation of such a scheme at the airports, and how much extra effort would be required. A suggested outline for a differential limits trial is given in Appendix I.

5.4.4 The proposal is for an advisory letter to be sent to operators following infringements of the appropriate differential limit, and airports could work with persistent offenders to investigate reasons for the higher noise levels and possible amelioration measures. During the proposed trial it is anticipated that where potential noise improvements can be identified for specific operators of a particular aircraft type, those airlines be asked to amend their take-off procedures (at least for the duration of the trial), and “before and after” noise measurements be undertaken to determine any benefits in terms of noise reductions. Mobile monitors would be deployed so that, in addition to assessing the changes at the fixed monitors, any changes in noise levels at closer-in or further-out distances could be determined.

5.4.5 The analysis has shown (see Figures 46(a)-(c)) that most aircraft in the exempt and QC/0.5 groups are very unlikely to exceed the suggested limits for those groups, and are in any case generally much quieter than QC/1s. The trial should determine whether much would be gained from monitoring departures of aircraft in these groups, and whether it would be appropriate to take any action in respect of QC/0.5 and exempt types.

5.4.6 A different approach, which could be commenced after the conclusion and assessment of the proposed differential limits trial, would be to develop a Code of Practice for departure noise. The arrivals noise Code of Practice (Ref 11), which was a joint effort by BAA, NATS, CAA, DTLR[59] and two representative airlines[60], has been widely disseminated world-wide and has increased awareness of the issues surrounding approach noise and resulted in some important beneficial changes in the way ATC and pilots operate approaches. It is suggested that a similar group of organisations could be set up, possibly under the auspices of ANMAC, to produce guidance for operators, airports and ATC to minimise the noise impact of all departing aircraft. It is appreciated that different airports world-wide have different problems related to departure noise, so a single focus such as minimising noise at 6.5km from SOR is not appropriate everywhere. Nevertheless, airlines tend to prefer as far as possible to implement universally applicable departure procedures, so there would be much to be gained from discussions that covered all aspects of departure noise around airports.

# 6 ASSESSMENT OF THE NOISE BENEFITS OF PROPOSALS

6.1 Further work is being considered to model the noise impact of the various proposals in terms of changes in the population affected under and close to departure routes. It will be necessary to make various assumptions about the effect of noise limits on the subsequent noise levels of each type. Scenarios could include:

(i) possible outcomes of lowering the overall limits (which might result in some existing aircraft being flown with different, quieter procedures, reduced TOWs for some flights, or possibly a reduction or elimination of the use of some aircraft types with a switch to quieter types).

(ii) possible outcomes of the introduction of differential limits (which again might result in some existing aircraft being flown with different, quieter procedures, or reduced TOWs for some flights).

It is not expected that the slight increase in the effectiveness of the arrays, as a result of the proposed new monitors ‘closing the gaps’ between existing monitors, would have any direct impact on the way aircraft are flown and hence on their noise levels.

6.2 When considering ‘quieter’ procedures in terms of reducing the noise levels at the 6.5km noise monitors, the possibility of increases in noise elsewhere must be taken into account. This is most likely to occur at further out distances, for example as a result of a lower power setting, and hence climb gradient, after cutback. Production

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[59] The predecessor of DfT.

[60] British Airways and Airtours

of noise footprints or other methods of illustrating noise changes will enable such effects to be quantified.

6.3 Any results cannot be definitive because of the assumptions that will need to be made, but they should enable the benefits of a reduction in the overall limits (which would only affect the noisier aircraft type groups) to be compared with a base case, and also indicate the possible impact of introducing differential limits (which would affect most types).

## 7 CONCLUSIONS

7.1 It was decided to use V-analysis rather than 'Monitoring Efficiency' as previously defined to assess array performance. This provides a simple geometric technique which is independent of the noise limits or distributions of measured noise levels.

7.2 As a result of the development and assessment of various proposals for new or moved monitors, including the use of track density calculations, three new locations are proposed for monitor positions – two at Heathrow and one at Stansted. Some of the practical aspects of monitor sitings at these locations still need to be assessed, and the suggested sites should not be considered as final until it is confirmed that they are practicable.

7.3 If differential noise monitoring were to be introduced, the enhanced arrays as suggested here would probably be as suitable for monitoring quieter aircraft groups as for the noisiest, apart from propeller aircraft vectored off the NPRs. Further work would be needed to assess background noise levels at all locations to ensure that the quietest types could be monitored satisfactorily. However it is considered that the benefits of including propeller aircraft in any scheme for differential noise monitoring would not be sufficient to justify the additional monitors which would be needed at Gatwick because of their different tracks (and possibly also at Stansted).

7.4 If more tracks within the swathe were concentrated closer to the NPR centrelines at the 6.5km monitoring distance, monitor array performance would improve in some cases, but worsen in a few others where there is currently no monitor near the NPR centreline (although these are all cases where it is proposed to place extra monitors). It was beyond the scope of this study to determine the achievability (or desirability) of further concentration of tracks in the region of the noise monitors in the future.

7.5 The estimated infringement rates indicate that the daytime overall limit could be reduced by 1dBA, but with current fleets there is little scope for greater reductions unless 742Ch3 aircraft can be flown more quietly than at present. There is no scope at present for reducing the shoulder period or night limits, unless a ban on QC/4 departures in the night quota period were to be imposed, in which case a reduction in these limits by 3dBA might be appropriate.

7.6 The study has used the departure QC bands to provide a reasonably practicable basis for grouping aircraft for analysis, and initial indications are that this could be a possible method of implementing advisory differential limits. The limit for QC/8 types of aircraft could for example be set at the current daytime overall limit, and the differential limit could reduce by 3dBA for each quieter band. Although a differential limits scheme would apply some pressure onto operators of some of the less noisy aircraft types, the practical and administrative difficulties of operating such a scheme should not be under-estimated. A trial is proposed, which would enable the problems and benefits of operational differential monitoring to be assessed.

7.7 The production is proposed of an industry Code of Practice on departure noise, similar to the successful Arrivals Code.

# REFERENCES

1 Cadoux R E & Ollerhead J B: Review of the Departure Noise Limits at Heathrow, Gatwick and Stansted Airports: CS Report 9539, CAA, December 1995

2 Cadoux R E & Ollerhead J B: Review of the Departure Noise Limits at Heathrow, Gatwick and Stansted Airports: Additional study of Boeing 747 departures: CS Report 9539 Supplement, NATS Ltd, October 1996

3 Ollerhead J B, Rhodes D P & Monkman D J: Review of the Departure Noise Limits at Heathrow, Gatwick and Stansted Airports: Effects of Take-off Weight and Operating Procedure on Noise Displacement: R&D Report 9841, NATS Ltd, March 1999

4 International Standards and Recommended Practices, Environmental Protection, Annex 16, Amendment 7, Volume I, Aircraft Noise: International Civil Aviation Organisation (ICAO), Montreal, 1993

5 UK Aeronautical Information Publication (“Air Pilot”), CAA, October 2002

6 Ollerhead J B: The CAA Aircraft Noise Contour Model: ANCON Version 1: DORA Report 9120, November 1992

7 Ollerhead J B et al: The UK Civil Aircraft Noise Contour Model ANCON: Improvements in Version 2: R&D Report 9842, June 1999

8 Consultation Paper: Noise Limits for Aircraft Departing From Heathrow, Gatwick and Stansted Airports, DETR, November 1997

9 White S, Ollerhead J B, Cadoux R E, Smith M J T: Quota Count Validation Study: Noise Measurements and Analysis: ERCD Report 0205, CAA, April 2003

10 Noise limits for aircraft departing from Heathrow, Gatwick and Stansted airports: decision of December 2000: DETR, December 2000

11 Noise from Arriving Aircraft, An Industry Code of Practice: DTLR, BAA, British Airways, Airtours, CAA, NATS, September 2001

12 Cadoux R E, White S: An Assessment of NTK Radar Accuracy at Heathrow, Gatwick and Stansted Airports: ERCD Report 0209, CAA, March 2003

## LIST OF FIGURES

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## TABLE 1 Aircraft type groups for V-analysis

| Type group | Description |
|---|---|
| 100 | Fokker 70/100 series |
| 146 | BAe 146/Avro RJ series |
| 300 | Airbus A300 series |
| 310 | Airbus A310 series |
| 320 | Airbus A319/320/321 series* |
| 330 | Airbus A330 series |
| 340 | Airbus A340-200 and -300 series[x] |
| 733 | Boeing 737-300/400/500 series |
| 738 | Boeing 737-800/900 series |
| 742Ch3 | Chapter 3 Boeing 747-200s and B747-300s |
| 744 | Boeing 747-400 series |
| 757 | Boeing 757 series |
| 762 | Boeing 767-200 series* |
| 763 | Boeing 767-300 series* |
| 777 | Boeing 777 series |
| AT7 | ATR72 (Gatwick only) |
| CRJ | Canadair Regional Jet series |
| D10 | McDonnell Douglas DC10 series |
| DH3 | De Havilland Canada Dash 8 (Gatwick only) |
| M80 | McDonnell-Douglas MD80 series |
| M90 | McDonnell-Douglas MD90 series |
| Props | All principal propeller aircraft types at Stansted[†] |

* These groups were further subdivided in later analysis.

[x] A340-500 and -600 series aircraft were not yet in operation at the time the data for this study was collected.

[†] Principal propeller aircraft types at Stansted were:
ATR42, ATR72, BAe ATP, Embraer 120, Embraer 145, Fokker F27, HS748, Lockheed Electra, Lockheed Hercules, Piper PA31, Saab Fairchild SF340, Shorts 330, Shorts 360

## TABLE 2 Total number of departures on each route for V-analysis

| Airport | Run-way | Route | 733 | 738 | 742 Ch3 | 744 | 757 | 762 | 763 | 777 | 300 | 310 | 320 | 330 | 340 | 146 | M80 | M90 | AT7 | CRJ | D10 | DH3 | 100 | Props (STN) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| LGW | 26L | ALL | 1029 | 341 | 219 | 367 | 2296 | 321 | 1178 | 1009 | 265 | X | 1741 | 482 | X | 3854 | 465 | X | 733 | 314 | 288 | 283 | X | X |
|  | 08R | ALL | 1432 | 150 | 112 | 186 | 1105 | 129 | 630 | 479 | 130 | X | 882 | 255 | X | 1727 | 201 | X | 326 | 135 | 138 | 127 | X | X |
| LHR | 09R | BPK/BUZ | 1128 | 174 | 113 | 907 | 1401 | X | 284 | 321 | X | X | 2000 | X | 160 | X | 316 | 261 | X | X | X | X | X | X |
|  |  | DVR | 893 | X | X | 204 | 447 | X | 238 | 229 | 251 | 167 | 783 | 116 | X | X | X | X | X | X | X | X | X | X |
|  |  | MID | 652 | X | X | 106 | 622 | X | 230 | X | X | X | 1092 | X | X | 164 | 190 | X | X | X | X | X | X | X |
|  |  | CPT | X | X | 150 | 436 | X | X | 240 | 438 | 115 | X | 719 | X | X | X | X | X | X | X | X | X | X | X |
|  |  | SAM | 166 | X | X | X | 295 | X | X | X | X | X | 319 | X | X | X | X | X | X | X | X | X | X | X |
|  | 27R | WOB/BPK | 1135 | 226 | 108 | 886 | 1262 | X | 329 | 390 | X | X | 2170 | X | 176 | X | 369 | 262 | X | X | X | X | X | X |
|  |  | CPT/SAM | 242 | X | 175 | 456 | 339 | X | 230 | 490 | 139 | X | 1103 | X | X | X | X | X | X | X | X | X | X | X |
|  |  | MID | 664 | X | X | 103 | 538 | X | 230 | X | X | X | 1249 | X | X | 145 | 205 | X | X | X | X | X | X | X |
|  |  | DVR | 937 | X | X | 180 | 467 | X | 231 | 193 | 264 | 170 | 783 | X | X | X | X | X | X | X | X | X | X | X |
|  | 27L | WOB/BPK | 1147 | 217 | 113 | 1006 | 1475 | X | 298 | 342 | X | X | 2058 | X | 173 | X | 317 | 279 | X | X | X | X | X | X |
|  |  | CPT/SAM | 245 | X | 181 | 441 | 377 | X | 235 | 513 | 129 | X | 1077 | X | X | X | X | X | X | X | X | X | X | X |
|  |  | MID | 657 | X | X | 119 | 674 | X | 239 | X | X | X | 1194 | X | X | 174 | 205 | X | X | X | X | X | X | X |
|  |  | DVR | 921 | X | X | 243 | 427 | X | 240 | 251 | 288 | 184 | 813 | 115 | X | X | X | X | X | X | X | X | X | X |
| STN | 05 | BZD | 1209 | 632 | X | X | 114 | X | X | X | X | X | 189 | X | X | 367 | X | X | X | X | X | X | X | 605 |
|  |  | CLN | 334 | 306 | X | X | X | X | X | X | X | X | 107 | X | X | 317 | X | X | X | X | X | X | 296 | 189 |
|  |  | DVR | 403 | 685 | X | X | X | X | X | X | X | X | 114 | X | X | 363 | X | X | X | X | X | X | X | 305 |
|  | 23 | CLN | 492 | 414 | X | X | X | X | X | X | X | X | 150 | X | X | 456 | 100 | X | X | X | X | X | 436 | 310 |
|  |  | DVR | 589 | 984 | X | X | X | X | X | X | X | X | 151 | X | X | 595 | X | X | X | X | X | X | X | 435 |
|  |  | BZD | 1769 | 880 | X | X | 145 | X | X | X | X | X | 268 | X | X | 549 | X | X | X | 148 | X | X | X | 875 |

## TABLE 3 Percentage of the departures passing through a gate on each route that passed through at least one V

| Airport | Run-way | Route | Moni-tor | 733 | 738 | 742 Ch3 | 744 | 752 | 763 | 777 | 300 | 310 | 320 | 330 | 340 | 146 | M80 | M90 | AT7 | CRJ | D10 | DH3 | 762 | 100 | Props |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| LGW | 26L | ALL | 1 | 100% | 100% | x | 100% | 100% | 100% | 100% | 100% | x | 100% | 100% | x | 100% | 100% | x | 98% | 100% | 100% | 96% | 100% | x | x |
| | 08R | ALL | 4 | 100% | 100% | x | 100% | 100% | 100% | 99% | 100% | x | 100% | 100% | x | 99% | 100% | x | 97% | 100% | 100% | **84%** | 99% | x | x |
| LHR | 09R | BPK/BUZ | 11 | 99% | 100% | 90% | 90% | **88%** | 97% | 100% | x | x | 100% | x | **58%** | x | 100% | 100% | x | x | X | x | x | x | x |
| | 09R | DVR | 10 | 97% | x | x | **70%** | 93% | **78%** | **74%** | 96% | 97% | 96% | 96% | x | x | x | x | x | x | X | x | x | x | x |
| | 09R | MID | 13 | **73%** | x | x | **40%** | 91% | **69%** | x | x | x | 97% | x | x | **66%** | 98% | x | x | x | X | x | x | x | x |
| | 09R | CPT | 13 | x | x | **52%** | **74%** | x | 92% | **88%** | **85%** | x | 70% | x | x | x | x | x | x | x | X | x | x | x | x |
| | 09R | SAM | 13 | **77%** | x | x | x | 97% | x | x | x | x | 96% | x | x | x | x | x | x | x | x | x | x | x | x |
| | 27R | WOB/BPK | 18 | 100% | 100% | x | 99% | 99% | 99% | 100% | x | x | 100% | x | 98% | x | 100% | 100% | x | x | x | x | x | x | x |
| | 27R | CPT/SAM | 18 | 100% | x | x | 100% | 99% | 98% | 100% | 100% | x | 100% | x | x | x | x | x | x | x | x | x | x | x | x |
| | 27R | MID | 18 | 100% | x | x | 99% | 100% | 100% | x | x | x | 100% | x | x | 94% | 100% | x | x | x | x | x | x | x | x |
| | 27R | DVR | 18 | 100% | x | x | 99% | 100% | 100% | 100% | 100% | 100% | 100% | x | x | x | x | x | x | x | x | x | x | x | x |
| | 27L | WOB/BPK | 17 | 98% | 100% | x | **86%** | 100% | 98% | 100% | x | x | 100% | x | **82%** | x | 100% | 100% | x | x | x | x | x | x | x |
| | 27L | CPT/SAM | 6 | 100% | x | x | 100% | 100% | 100% | 100% | 99% | x | 100% | x | x | x | x | x | x | x | x | x | x | x | x |
| | 27L | MID | 15 | 100% | x | x | 100% | 100% | 100% | x | x | x | 100% | x | x | 100% | 100% | x | x | x | x | x | x | x | x |
| | 27L | DVR | 14 | **88%** | x | x | **88%** | **88%** | 92% | 100% | 92% | 95% | 92% | 91% | x | x | x | x | x | x | x | x | x | x | x |
| STN | 05 | BZD | 1 | 94% | 97% | x | x | 91% | x | x | x | x | 96% | x | x | **65%** | x | x | x | x | x | x | x | x | **70%** |
| | 05 | CLN | 1 | 94% | 98% | x | x | x | x | x | x | x | 100% | x | x | 100% | x | x | x | x | x | x | x | 99% | 95% |
| | 05 | DVR | 9 | 100% | 100% | x | x | x | x | x | x | x | 93% | x | x | **79%** | x | x | x | x | x | x | x | x | 92% |
| | 23 | CLN | 3 | 98% | 100% | x | x | x | x | x | x | x | 100% | x | x | 95% | 100% | x | x | x | x | x | x | 100% | 95% |
| | 23 | DVR | 3 | 98% | 90% | x | x | x | x | x | x | x | 99% | x | x | 98% | x | x | x | x | x | x | x | x | 98% |
| | 23 | BZD | 5 | 100% | 100% | x | x | 100% | x | x | x | x | 100% | x | x | 98% | x | x | x | 100% | x | x | x | x | 95% |

Numbers rounded to nearest integer.
Numbers in bold indicate values less than 90%.

## TABLE 4 “Top 8” initial monitor array improvement scenarios

| Scenario no. | Runway | Suggested change | Approx. gap between monitors | Comments |
|---|---|---|---|---|
| 1 | LHR 09R | Extra monitor between H(10) & I(13) | 850m | Beneficial for all aircraft types. Needed to effectively monitor tracks near the NPR centrelines for DVR, CPT, MID & SAM. Two possible monitor locations identified: “X” and “Y”. |
| 2 | LHR 27L (&27R) | Extra monitor between C(17)& B(18) | 800m | Currently no monitor for tracks in the northern half of 27L WOB/BPK swathes (or the southern half of all 27R routes). |
| 3 | STN 05 | Move monitor 7 nearer 10 | 1150m | Currently no monitor for tracks in the northern half of BZD & CLN swathes: few if any jet aircraft currently fly near monitor 7, and a proportion of tracks currently lie outside (to the north-west) of the monitor 10 V (see the track plots in Figure 7(a) and Appendix B Figures B5(a)-(c)). Ranking position could increase if more heavy aircraft were operating at STN. |
| 4 | LHR 27L | Extra monitor SE of E(14) | n/a | Currently no monitor for tracks in the southern half of DVR swathe. Wraysbury Reservoir prevents ideal monitor locations for DVR route. |
| 5 | LHR 09R | Extra monitor between F(11)& G(12) | 500m | Currently no effective monitor for tracks in the southern half of BPK/BUZ swathe. 340s in particular often do not fly through either V. Extra monitor would not be needed if heights at 6.5km could be increased to ~1400ft minimum. Alternatively F(11) could be moved closer to G(12) in conjunction with Scenario 6. |
| 6 | LHR 09R | Extra monitor N of F(11) | n/a | Currently no effective monitor for tracks in the northern half of BPK/BUZ swathes. |
| 7 | STN 05 | Improve track-keeping (DVR & CLN) | n/a | Discourage tracks outside swathes, especially in the southern half of DVR swathe. Ranking position could increase if more heavy aircraft were operating at STN. |
| 8 | STN 05 | Extra monitor SE of 9, and possibly move 9 to the NW | 600m between 8 & 9 | Currently no monitor for tracks in the southern half of DVR swathe. Ranking position would increase if more heavy aircraft operated at STN. Improved track-keeping (Scenario 7) would reduce the need for an extra monitor. |

The “Approx. gap between monitors” column shows the lateral distance between the two specific monitors identified in the “Suggested change” column.

## TABLE 5 Minimum aircraft heights to pass through at least one V: aircraft flying on NPR centreline

| Airport | Runway | Route | Closest monitor to NPR | Min. height of aircraft on NPR centreline to be within the V (ft) |
|---|---|---|---|---|
| LGW | 26L | ALL | 1 | 400 |
| | 08R | ALL | 6 | 950 |
| LHR | 09R | BPK/BUZ | 11 | 50 |
| | | DVR | 10 | **1700** |
| | | MID | 13 | 1000 |
| | | CPT | 13 | 220 |
| | | SAM | 13 | **1210** |
| | 27R | WOB/BPK | 18 | 190 |
| | | CPT/SAM | 18 | 160 |
| | | MID | 18 | 130 |
| | | DVR | 18 | 240 |
| | 27L | WOB/BPK | 17 | 410 |
| | | CPT/SAM | 6 | 640 |
| | | MID | 15 | 280 |
| | | DVR | 14 | 750 |
| STN | 05 | BZD | 10 | **1650** |
| | | CLN | 10 | 780 |
| | | DVR | 9 | 230 |
| | 23 | CLN | 3 | 310 |
| | | DVR | 3 | 340 |
| | | BZD | 5 | 840 |

Heights are shown to nearest 10 ft.

Heights greater than 1000ft are shown in bold

## TABLE 6 Current track-keeping performance relative to noise monitors

| Airport | LGW | LGW | LHR | LHR | LHR | LHR | LHR | LHR | LHR | LHR | LHR | LHR | LHR | STN | STN | STN | STN |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Runway | 26L | 26L | 27R | 27R | 09R | 09R | 09R | 09R | 09R | 09R | 09R | 09R | 27L | 05 | 05 | 23 | 23 |
| Route | All routes | All routes | WOB/BPK | WOB/BPK | BUZ/BPK | BUZ/BPK | DVR | DVR | MID | MID | CPT | SAM | WOB/BPK | BZD | BZD | CLN | BZD |
| Monitor | 1 | 1 | 18/B | 18/B | 11/F | 11/F | 10/H | 10/H | 10/H | 10/H | 10/H | 10/H | 17/C | 10 | 10 | 3 | 5 |
| Aircraft type | 733 | 744 | 733 | 744 | 340 | 744 | 744 | 777 | 744 | 763 | 744 | 733 | 744 | 733 | 146 | 738 | 738 |
| Current track-keeping: Lateral SD  m | 83 | 56 | 103 | 72 | 123 | 206 | 171 | 116 | 173 | 162 | 250 | 144 | 187 | 104 | 221 | 148 | 63 |
| Current track-keeping: Average lateral distance from monitor  m | 60 | 62 | 84 | 33 | 244 | 205 | 164 | 276 | 277 | 394 | 595 | 408 | 75 | 190 | 223 | 52 | 81 |
| Lateral distance of NPR centreline from monitor  m | 70 | 70 | 33 | 33 | 8 | 8 | 299 | 299 | 622 | 622 | 559 | 598 | 72 | 291 | 291 | 54 | 149 |
| Current track-keeping relative to noise monitor: % in V | 99% | 98% | 98% | 97% | 58% | 88% | 69% | 73% | 38% | 67% | 69% | 75% | 86% | 92% | 63% | 98% | 99% |

## TABLE 7 Parametric analysis sample count

Each sample represents one noise event at a fixed monitor where the aircraft was within the relevant $60^o$ V.

Where a departure caused noise events at more than one monitor, only the highest Reference level is included.

Flights between 1 September 2000 and 31 August 2001. Types with less than 100 samples excluded.

| AIRCRAFT TYPE | CODE | STANSTED | HEATHROW | GATWICK |
|---|---|---|---|---|
| Fokker 70/100 | 100 | 2878 | 498 | 1294 |
| BAe 146/Avro RJ series | 146 | 6374 | 1423 | 19004 |
| Airbus A300 series | 300 | 501 | 3160 | 1458 |
| Airbus A310 | 310 | 544 | 1804 | - |
| Airbus A319 | 319 | - | 7876 | 482 |
| Airbus A320 | 320 | 1852 | 15182 | 5716 |
| Airbus A321 | 321 | 1575 | 13259 | 2188 |
| Airbus A330 | 330 | - | 1299 | 2378 |
| Airbus A340-200/300 series | 340 | - | 2052 | - |
| Boeing 737-300/400/500 series | 733 | 14888 | 22914 | 35903 |
| Boeing 737-600/700 series | 736 | 916 | 550 | 343 |
| Boeing 737-800/900 series | 738 | 10212 | 2017 | 1584 |
| Boeing 747-200 Chapter 3 variants | 742Ch3 | - | 2481 | 1271 |
| Boeing 747-300 series | 743 | - | 416 | - |
| Boeing 747-400 series | 744 | 446 | 11739 | 2772 |
| Boeing 757 series | 757 | 874 | 22531 | 11391 |
| Boeing 767-200 series | 762 | - | 830 | 2106 |
| Boeing 767-300 series | 763 | 247 | 7873 | 5564 |
| Boeing 777 series | 777 | - | 8809 | 5425 |
| Canadair Regional Jet series | CRJ | 310 | - | 1780 |
| McDonnell Douglas DC10 series | D10 | 267 | 311 | 1734 |
| Embraer RJ135/140/145/170/190 | ERJ | 388 | - | 339 |
| Chapter 2 executive jets | EXE2 | 193 | - | - |
| Chapter 3 executive jets | EXE3 | 841 | 299 | 347 |
| McDonnell-Douglas MD11 series | M11 | 869 | 486 | - |
| McDonnell-Douglas MD80 series | M80 | 489 | 5465 | 2839 |
| McDonnell-Douglas MD90 series | M90 | - | 2304 | - |
| Quieter commercial propeller aircraft | Props1 | 1756 | 716 | 6128 |
| Noisier commercial propeller aircraft | Props2 | 559 | - | 527 |
| Lockheed Hercules | Props3 | 256 | - | - |
|  | **TOTAL SAMPLES** | 47235 | 136294 | 112573 |

Propeller type codes:

Props1 = AT4, AT7, ATP, BAT, DH3, EM2,
F50, J31, J41, SF3, SH3, SH6
Props2 = F27, FKF, HS7, LOE, LOF
Props3 = LOH

## TABLE 8 Parameters in analysis database

| **Database Variable** | **Source** | **Comments** |
|---|---|---|
| Flight ID | NTK | Specific identifier for each flight |
| Time (local) | NTK | Time of first radar point of departure |
| Year | NTK | |
| Date (UTC) | NTK | |
| Month (UTC) | NTK | |
| Day | NTK | |
| Period | NTK | D=day 0700-2300, N=shoulder 0600-0700 & 2300-2330, C=night 2330-0600 |
| ANCON type | BUCHAIR | |
| Aircraft type local | NTK | |
| Callsign | NTK | |
| Runway ID | NTK | |
| Runway heading (deg) | Ref 5 | Bearing of runway relative to True North |
| Airport | NTK | Destination |
| Stage Length | ERCD | Range of journey (nm) |
| Aircraft Registration | NTK | |
| NMT ID | NTK | Only fixed monitors |
| NMT x | ERCD | Coordinates of noise monitor |
| NMT y | ERCD | Coordinates of noise monitor |
| NMT z | ERCD | Coordinates of noise monitor |
| $L_{Amax}$ (dBA) | NTK | Measured $L_{Amax}$ |
| Lateral adjusted $L_{Amax}$ (dBA) | ERCD | $L_{Amax}$ at reference level and including lateral attenuation |
| Reference level (dBA) | ERCD | $L_{Amax}$ at 6.5km from SOR, corrected for airfield elevation |
| Lateral attenuation (dBA) | ERCD | |
| SEL (dBA) | NTK | Measured SEL |
| Event duration (sec) | NTK | Between 5 and 100 sec |
| Buchair Type | BUCHAIR | |
| Buchair powered | BUCHAIR | Engine details |
| Engine type | BUCHAIR | |
| Ground speed (m/s) | ERCD | Ground speed at closest point to noise monitor |
| SORdist (m) | ERCD | Track distance from SOR |
| Dist. Past 6.5km (m) | ERCD | Distance after reference point |
| Node_clp (m) | ERCD | Closest radar point to monitor |
| trk_clp (m) | ERCD | Direct distance from NMT to closest point of approach |
| Beta (>60) deg | ERCD | Elevation angle (measured from horizontal) |
| Trk x (m) | ERCD | Coordinates of aircraft at closest point to NMT |
| Trk y (m) | ERCD | Coordinates of aircraft at closest point to NMT |
| Trk z (m) | ERCD | Coordinates of aircraft at closest point to NMT |
| Height (m) | ERCD | |
| Nominal route | NTK | NPR |
| Airline (local) | NTK | |
| Airline (ICAO) | NTK | |
| Airline (IATA) | NTK | |
| Temperature (deg C) | Met Office | Mean hourly dry bulb temperature |
| Wind speed (kt) | Met Office | Mean hourly data |
| Wind direction (bearing) | Met Office | Mean hourly data |
| Headwind (MET) (kt) | Met Office | [Wind Speed] * cos [runway heading-wind direction] |
| Crosswind (MET) (kt) | Met Office | [Wind Speed] * sin [runway heading-wind direction] |
| Headwind (kt) | NTK | NATS Wind data matched to exact flight time |
| Crosswind (kt) | NTK | NATS Wind data matched to exact flight time |
| Pressure | Met Office | Mean hourly mean sea level pressure |
| Weather Code | Met Office | Mean hourly data (indication of precipitation) |
| Relative humidity (%) | Met Office | Mean hourly data |
| Turning Flight | ERCD | 1=Flight Turning before monitor, 0=Straight flight |
| Bank angle | ERCD | |
| Turn | ERCD | Port/Stbd |
| View | ERCD | Indicator of whether aircraft is banking towards or away from the monitor |
| Gradient | ERCD | Climb gradient |
| QC Rating | ERCD | |
| MTOW | BUCHAIR | Maximum certificated TOW for aircraft |

Note: BUCHAIR is a proprietary database of aircraft information

## TABLE 9(a) Comparison of airlines: mean laterally adjusted Reference levels by stage length for Heathrow 744s

| AIRLINE | | 2989 | 3079 | 3185 | 3423 | 3631 | 4089 | 4649 | 4726 | 4896 | 5152 | 5175 | 5205 | 5223 | 5871 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A | Mean | 87.8 | 87.4 | 88.1 | 87.8 | 89.9 | 88.5 | 89.6 | 89.9 | 89.8 | 89.6 | 89.9 | 89.8 | 90.0 | 89.8 |
| | SD | 2.3 | 2.2 | 2.1 | 2.1 | 2.2 | 2.4 | 2.3 | 1.7 | 1.6 | 1.8 | 1.8 | 1.9 | 1.5 | 1.6 |
| | 95% | 91.1 | 91.1 | 91.3 | 91.0 | 92.5 | 91.8 | 92.7 | 92.6 | 91.9 | 91.9 | 92.4 | 92.4 | 92.1 | 92.0 |
| | Count | 1334 | 30 | 144 | 256 | 118 | 65 | 361 | 407 | 359 | 246 | 394 | 382 | 164 | 355 |
| B | Mean | 87.8 | | | 88.4 | 88.3 | | | | | | | | | |
| | SD | 2.2 | | | 2.0 | 2.3 | | | | | | | | | |
| | 95% | 91.9 | | | 91.8 | 91.9 | | | | | | | | | |
| | Count | 221 | | | 99 | 94 | | | | | | | | | |
| C | Mean | 85.9 | | 85.8 | | | | 88.6 | 88.7 | | | | | | |
| | SD | 2.1 | | 2.5 | | | | 2.5 | 2.3 | | | | | | |
| | 95% | 89.4 | | 89.1 | | | | 92.1 | 92.0 | | | | | | |
| | Count | 306 | | 144 | | | | 215 | 218 | | | | | | |
| D | Mean | | 90.0 | | | | 88.0 | | | | | | | | |
| | SD | | 2.4 | | | | 2.2 | | | | | | | | |
| | 95% | | 93.5 | | | | 91.6 | | | | | | | | |
| | Count | | 191 | | | | 54 | | | | | | | | |
| E | Mean | | | 87.5 | 87.8 | 89.1 | | 91.4 | | | | | | | |
| | SD | | | 2.2 | 2.6 | 3.2 | | 2.8 | | | | | | | |
| | 95% | | | 90.8 | 91.7 | 93.3 | | 95.2 | | | | | | | |
| | Count | | | 108 | 133 | 95 | | 224 | | | | | | | |
| F | Mean | | | | | | | | 88.9 | | | | | | |
| | SD | | | | | | | | 2.4 | | | | | | |
| | 95% | | | | | | | | 92.7 | | | | | | |
| | Count | | | | | | | | 234 | | | | | | |
| G | Mean | | | | | | | | | 87.2 | | | | 87.9 | |
| | SD. | | | | | | | | | 2.2 | | | | 2.3 | |
| | 95% | | | | | | | | | 91.3 | | | | 91.7 | |
| | Count | | | | | | | | | 129 | | | | 69 | |
| H | Mean | | | | | | | | | | 88.5 | | | | |
| | SD | | | | | | | | | | 2.5 | | | | |
| | 95% | | | | | | | | | | 93.0 | | | | |
| | Count | | | | | | | | | | 72 | | | | |
| I | Mean | | | | | | | | | | 90.7 | | | | 91.2 |
| | SD | | | | | | | | | | 2.2 | | | | 2.2 |
| | 95% | | | | | | | | | | 94.0 | | | | 94.4 |
| | Count | | | | | | | | | | 169 | | | | 275 |
| J | Mean | | | | | | | | | | 89.1 | | | | |
| | SD | | | | | | | | | | 2.6 | | | | |
| | 95% | | | | | | | | | | 92.8 | | | | |
| | Count | | | | | | | | | | 309 | | | | |
| K | Mean | | | | | | | | | | | 88.8 | | | |
| | SD | | | | | | | | | | | 2.6 | | | |
| | 95% | | | | | | | | | | | 93.1 | | | |
| | Count | | | | | | | | | | | 283 | | | |
| L | Mean | | | | | | | | | | | 86.8 | | | |
| | SD | | | | | | | | | | | 2.8 | | | |
| | 95% | | | | | | | | | | | 92.5 | | | |
| | Count | | | | | | | | | | | 238 | | | |
| M | Mean | | | | | | | | | | | | 90.6 | | |
| | SD | | | | | | | | | | | | 2.6 | | |
| | 95% | | | | | | | | | | | | 93.8 | | |
| | Count | | | | | | | | | | | | 531 | | |
| N | Mean | | | | | | | | | | | | | | 91.3 |
| | SD | | | | | | | | | | | | | | 2.3 |
| | 95% | | | | | | | | | | | | | | 94.6 |
| | Count | | | | | | | | | | | | | | 694 |

## TABLE 9(b) Comparison of airlines: mean laterally adjusted Reference levels by stage length for Heathrow 320s

| | | STAGE LENGTH nm | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Airline** | | **131** | **187** | **189** | **242** | **269** | **282** | **287** | **299** | **353** | **406** | **425** | **510** | **561** | **672** | **687** | **843** | **1975** |
| **A** | Mean | 78.4 | | 77.0 | | 78.3 | 78.5 | 77.9 | 78.4 | 76.6 | 78.5 | 78.3 | 77.4 | 79.3 | 79.0 | 78.5 | 78.5 | 75.7 |
| | SD | 2.6 | | 2.3 | | 2.4 | 2.8 | 1.7 | 2.2 | 2.4 | 2.2 | 1.8 | 2.4 | 1.9 | 2.3 | 2.4 | 2.2 | 2.1 |
| | 95% | 82.4 | | 80.5 | | 82.2 | 84.2 | 81.1 | 82.1 | 80.6 | 82.1 | 81.4 | 81.0 | 83.5 | 82.2 | 82.4 | 82.1 | 78.7 |
| | Count | 425 | | 183 | | 135 | 38 | 46 | 333 | 157 | 121 | 159 | 149 | 111 | 101 | 249 | 142 | 94 |
| **B** | Mean | 72.9 | 72.4 | 73.7 | 73.4 | | 73.2 | 73.4 | 73.5 | | | | | 73.4 | 73.6 | | | |
| | SD | 2.4 | 2.4 | 2.4 | 2.5 | | 2.3 | 2.2 | 2.3 | | | | | 2.0 | 2.0 | | | |
| | 95% | 76.0 | 75.7 | 77.2 | 76.9 | | 76.2 | 76.2 | 76.4 | | | | | 76.1 | 77.2 | | | |
| | Count | 564 | 42 | 90 | 137 | | 650 | 821 | 1494 | | | | | 56 | 47 | | | |
| **C** | Mean | | 73.8 | | | | | | | | | | | | | | | |
| | SD | | 2.3 | | | | | | | | | | | | | | | |
| | 95% | | 77.2 | | | | | | | | | | | | | | | |
| | Count | | 1184 | | | | | | | | | | | | | | | |
| **D** | Mean | | | | 72.5 | | | | 74.7 | | | | | | | | | |
| | SD | | | | 2.3 | | | | 1.4 | | | | | | | | | |
| | 95% | | | | 75.8 | | | | 76.6 | | | | | | | | | |
| | Count | | | | 216 | | | | 44 | | | | | | | | | |
| **E** | Mean | | | | | 74.5 | | | | 74.6 | | | 74.8 | | | | | |
| | SD | | | | | 2.7 | | | | 2.4 | | | 2.4 | | | | | |
| | 95% | | | | | 78.2 | | | | 77.9 | | | 78.4 | | | | | |
| | Count | | | | | 177 | | | | 220 | | | 498 | | | | | |
| **F** | Mean | | | | | | | | | | 73.3 | 73.5 | | | | | | |
| | SD | | | | | | | | | | 2.2 | 2.1 | | | | | | |
| | 95% | | | | | | | | | | 76.6 | 76.7 | | | | | | |
| | Count | | | | | | | | | | 299 | 256 | | | | | | |
| **G** | Mean | | | | | | | | | | | | | | 74.8 | | | |
| | SD | | | | | | | | | | | | | | 2.2 | | | |
| | 95% | | | | | | | | | | | | | | 78.0 | | | |
| | Count | | | | | | | | | | | | | | 203 | | | |
| **H** | Mean | | | | | | | | | | | | | | | 76.7 | | |
| | SD | | | | | | | | | | | | | | | 2.4 | | |
| | 95% | | | | | | | | | | | | | | | 79.6 | | |
| | Count | | | | | | | | | | | | | | | 145 | | |
| **I** | Mean | | | | | | | | | | | | | | | | 75.6 | |
| | SD | | | | | | | | | | | | | | | | 2.3 | |
| | 95% | | | | | | | | | | | | | | | | 79.6 | |
| | Count | | | | | | | | | | | | | | | | 209 | |
| **J** | Mean | | | | | | | | | | | | | | | | | 76.9 |
| | SD | | | | | | | | | | | | | | | | | 1.9 |
| | 95% | | | | | | | | | | | | | | | | | 80.7 |
| | Count | | | | | | | | | | | | | | | | | 30 |

## TABLE 10 $L_{RU}$ statistics by QC rating for day, night and shoulder periods

**HEATHROW**

| | Mean $L_{RU}$ | | | SD | | | Count | | |
|---|---|---|---|---|---|---|---|---|---|
| **QC** | **Night** | **Day** | **Shoulder** | **Night** | **Day** | **Shoulder** | **Night** | **Day** | **Shoulder** |
| **0** | 71.0 | 71.0 | 71.9 | 2.7 | 2.8 | 2.6 | 8 | 700 | 15 |
| **0.5** | 76.6 | 76.4 | 75.9 | 3.0 | 2.7 | 2.9 | 52 | 43902 | 752 |
| **1** | 76.8 | 76.7 | 77.3 | 3.7 | 3.8 | 3.9 | 85 | 36538 | 957 |
| **2** | 81.7 | 81.4 | 80.6 | 4.4 | 3.7 | 3.4 | 74 | 13318 | 267 |
| **4** | 90.2 | 88.6 | 89.8 | 2.8 | 3.0 | 2.1 | 47 | 6665 | 132 |
| **8** | 88.0 | 90.9 | 90.4 | 5.8 | 3.3 | 3.5 | 3 | 2534 | 35 |

**GATWICK**

| | Mean $L_{RU}$ | | | SD | | | Count | | |
|---|---|---|---|---|---|---|---|---|---|
| **QC** | **Night** | **Day** | **Shoulder** | **Night** | **Day** | **Shoulder** | **Night** | **Day** | **Shoulder** |
| **0** | 70.5 | 68.4 | 69.0 | 2.8 | 3.0 | 4.0 | 211 | 2769 | 16 |
| **0.5** | 73.8 | 74.5 | 74.1 | 3.3 | 3.4 | 3.2 | 944 | 66761 | 1701 |
| **1** | 74.1 | 76.6 | 74.0 | 3.2 | 4.1 | 2.9 | 713 | 9431 | 775 |
| **2** | 75.8 | 78.6 | 76.5 | 3.9 | 3.2 | 3.4 | 363 | 9438 | 351 |
| **4** | 83.4 | 86.1 | 85.8 | 4.3 | 3.3 | 3.4 | 114 | 3406 | 163 |
| **8** | - | 88.1 | 82.0 | - | 4.1 | - | - | 1479 | 1 |

**STANSTED**

| | Mean $L_{RU}$ | | | SD | | | Count | | |
|---|---|---|---|---|---|---|---|---|---|
| **QC** | **Night** | **Day** | **Shoulder** | **Night** | **Day** | **Shoulder** | **Night** | **Day** | **Shoulder** |
| **0** | 70.8 | 71.4 | 71.6 | 2.5 | 2.6 | 2.4 | 253 | 1198 | 95 |
| **0.5** | 76.6 | 77.4 | 76.9 | 3.2 | 3.0 | 2.8 | 774 | 34193 | 1615 |
| **1** | 76.2 | 71.4 | 71.6 | 3.2 | 2.6 | 2.4 | 131 | 3296 | 104 |
| **2** | 78.9 | 80.9 | 80.0 | 3.6 | 3.6 | 2.7 | 441 | 1642 | 281 |
| **4** | 83.6 | 80.8 | 82.4 | 5.4 | 4.4 | 3.9 | 33 | 722 | 108 |

"QC/0" indicates Exempt

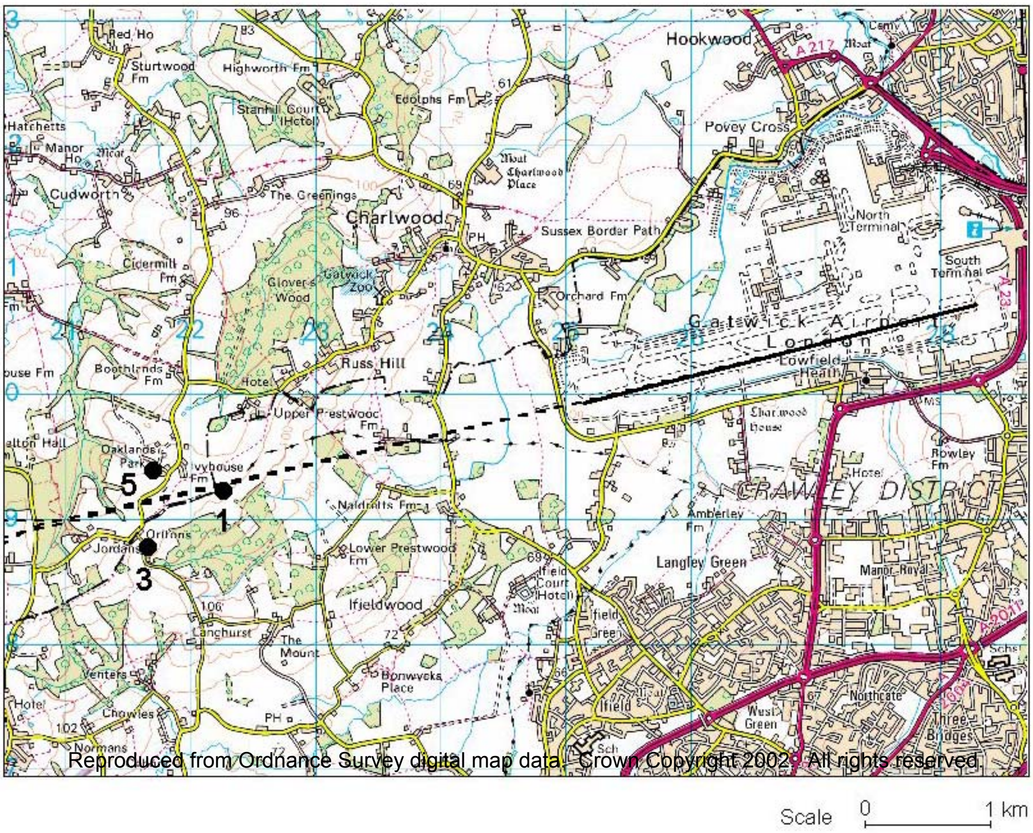
## TABLE 11 Infringements by all Chapter 3 types and all Boeing 747 variants (year 2000/2001[61]) – BAA figures

| | | All B747 & Ch3 infringements | | | Total departures (all types) | | | Infringement rate % | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Airport | Variant | Day | Shoulder | Night | Day | Shoulder | Night | Day | Shoulder | Night |
| Heathrow | 742 | 73 | 52 | 4 | 3848 | 143 | 5 | 1.9% | 36% | 80% |
| | 744 | 50 | 118 | 54 | 19659 | 328 | 112 | 0.3% | 36% | 48% |
| | B747SP | 0 | 1 | 0 | 247 | 4 | 0 | 0.0% | 25% | 0.0% |
| | B747-300 | 21 | 5 | 0 | 604 | 11 | 1 | 3.5% | 45% | 0.0% |
| | All B747s | 144 | 176 | 58 | 24436 | 487 | 118 | 0.6% | 36% | 49% |
| | M11 | 1 | 3 | 3 | 638 | 43 | 14 | 0.2% | 7.0% | 21% |
| | 340 | 0 | 0 | 2 | 3788 | 11 | 5 | 0.0% | 0.0% | 40% |
| | D10 | 0 | 0 | 2 | 461 | 24 | 13 | 0.0% | 0.0% | 15% |
| | All other types | 0 | 0 | 0 | 180235 | 3544 | 512 | - | - | - |
| Gatwick | 742 | 114 | 1 | 2 | 4199 | 18 | 16 | 2.7% | 5.6% | 13% |
| | 744 | 0 | 10 | 5 | 5839 | 132 | 30 | 0.0% | 7.6% | 17% |
| | All B747s | 114 | 11 | 7 | 10122 | 150 | 46 | 1.1% | 7.3% | 15% |
| | D10 | 0 | 3 | 8 | 3484 | 117 | 166 | 0.0% | 2.6% | 4.8% |
| | L1011 | 0 | 1 | 0 | 653 | 114 | 124 | 0.0% | 0.9% | 0.0% |
| | Tu204 | 0 | 1 | 0 | 20 | 1 | 0 | 0.0% | 100% | 0.0% |
| | All other types | 0 | 0 | 0 | 104653 | 3453 | 2935 | - | - | - |
| Stansted | 742 | 2 | 0 | 0 | 436 | 6 | 1 | 0.5% | 0.0% | 0.0% |
| | 744 | 0 | 0 | 3 | 252 | 28 | 83 | 0.0% | 0.0% | 3.6% |
| | All B747s | 2 | 0 | 3 | 799 | 35 | 84 | 0.3% | 0.0% | 3.6% |
| | M11 | 0 | 0 | 1 | 1646 | 80 | 61 | 0.0% | 0.0% | 1.6% |
| | M80 | 0 | 0 | 3 | 1507 | 6 | 80 | 0.0% | 0.0% | 3.8% |
| | All other types | 0 | 0 | 0 | 72191 | 3648 | 3372 | - | - | - |

---

[61] Gatwick and Stansted September 2000 to August 2001, Heathrow January to December 2001.

## FIGURE 1(a) GATWICK NOISE MONITOR ARRAYS AND NPRS RUNWAY 26L



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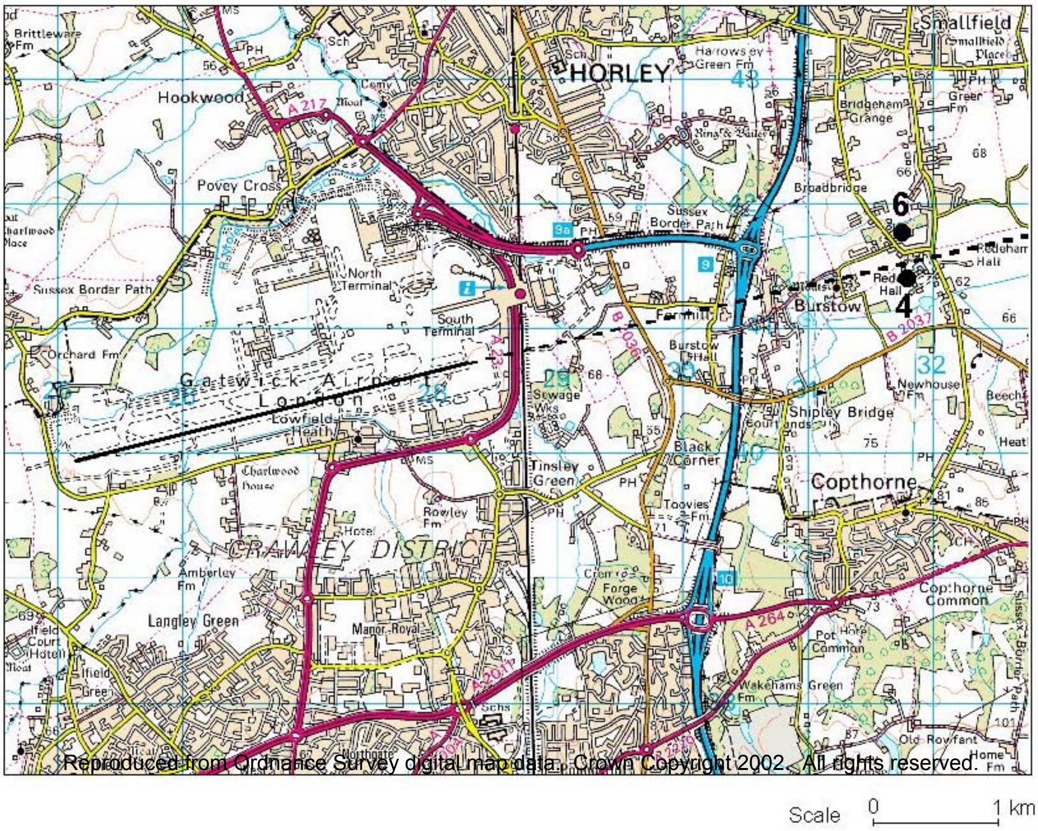
## FIGURE 1(b) GATWICK NOISE MONITOR ARRAYS AND NPRS RUNWAY 08R



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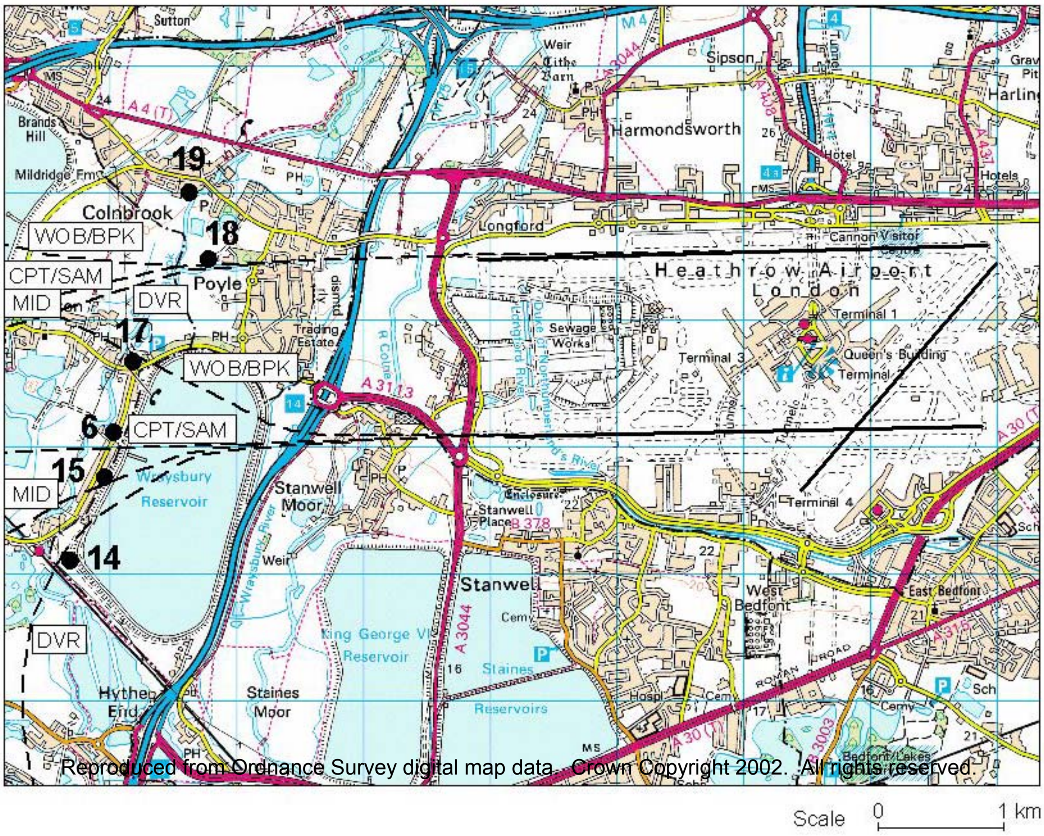
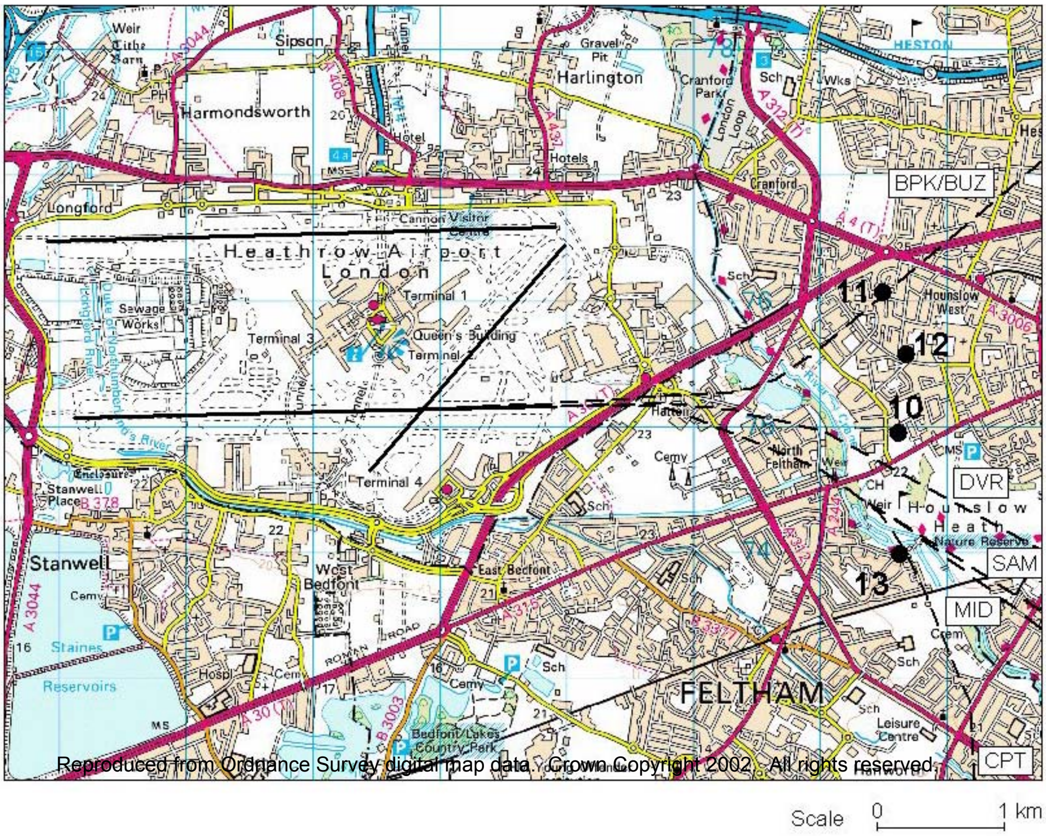
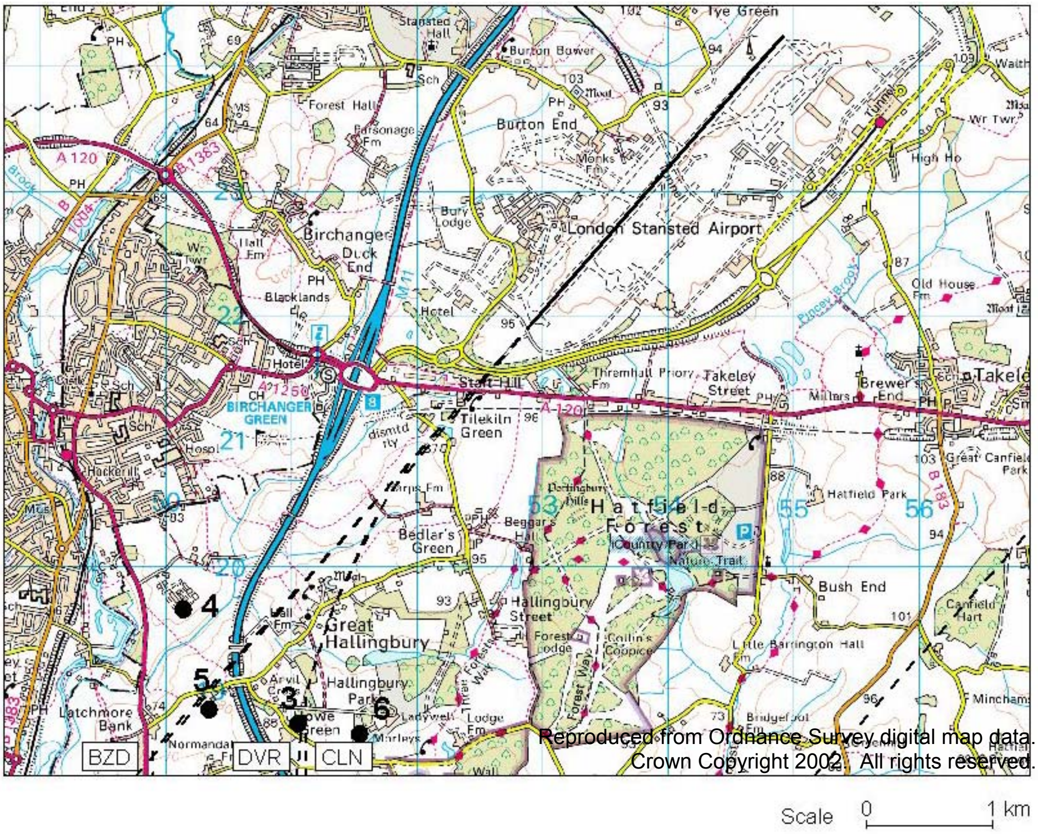
## FIGURE 2(a) HEATHROW NOISE MONITOR ARRAYS AND NPRS RUNWAYS 27L/27R



## FIGURE 2(b) HEATHROW NOISE MONITOR ARRAYS AND NPRS RUNWAY 09L



## FIGURE 3(a) STANSTED NOISE MONITOR ARRAYS AND NPRS RUNWAY 23



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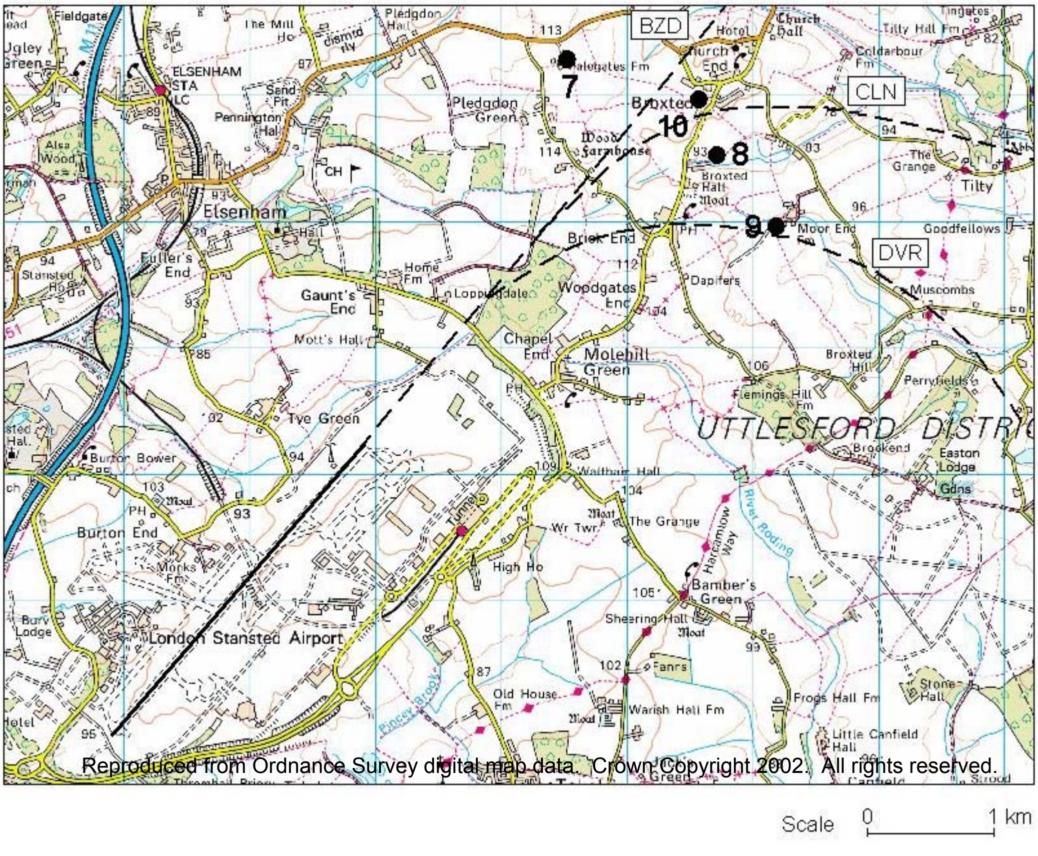
## FIGURE 3(b) STNSTED NOISE MONITOR ARRAYS AND NPRS RUNWAY 05



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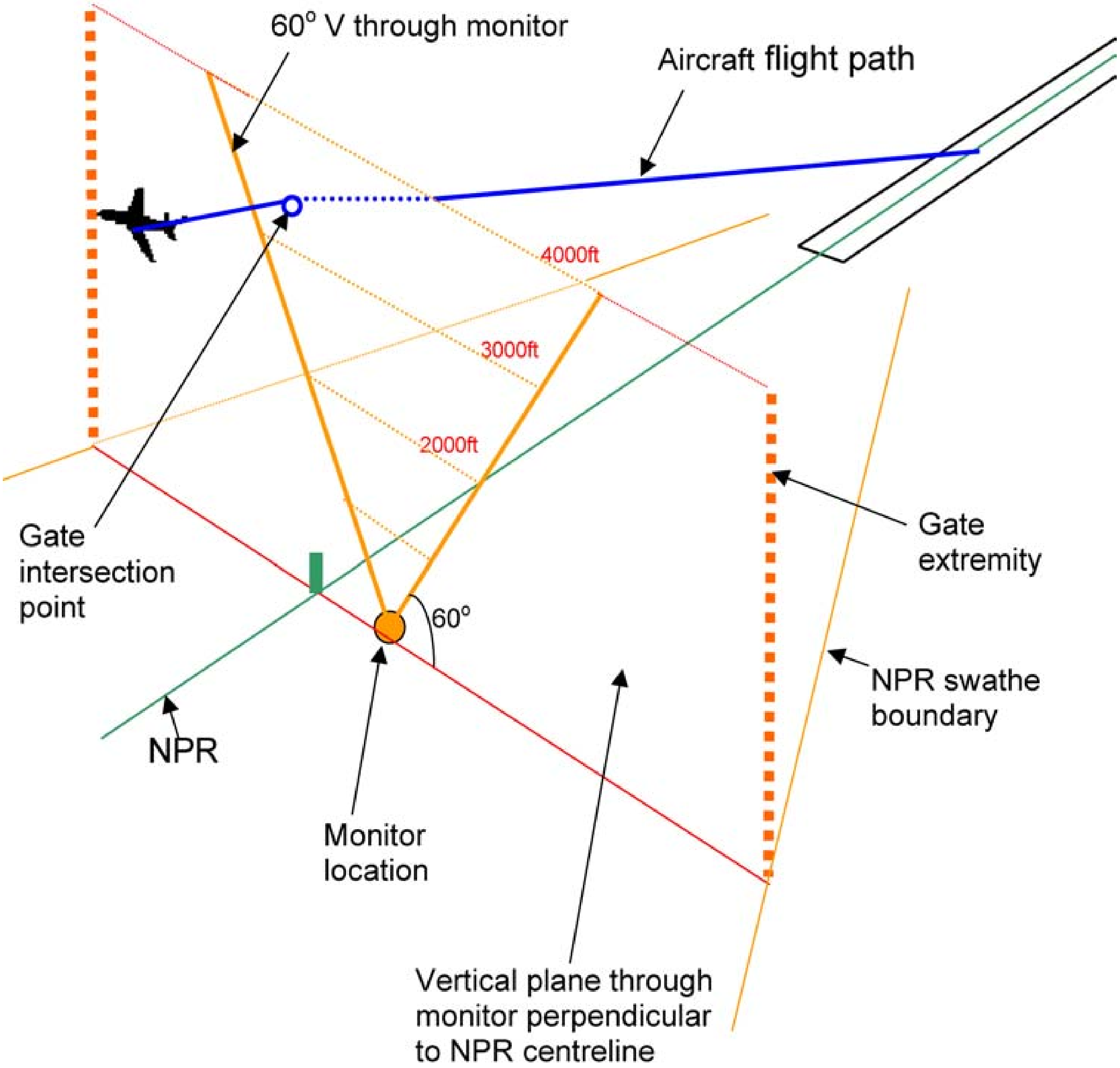
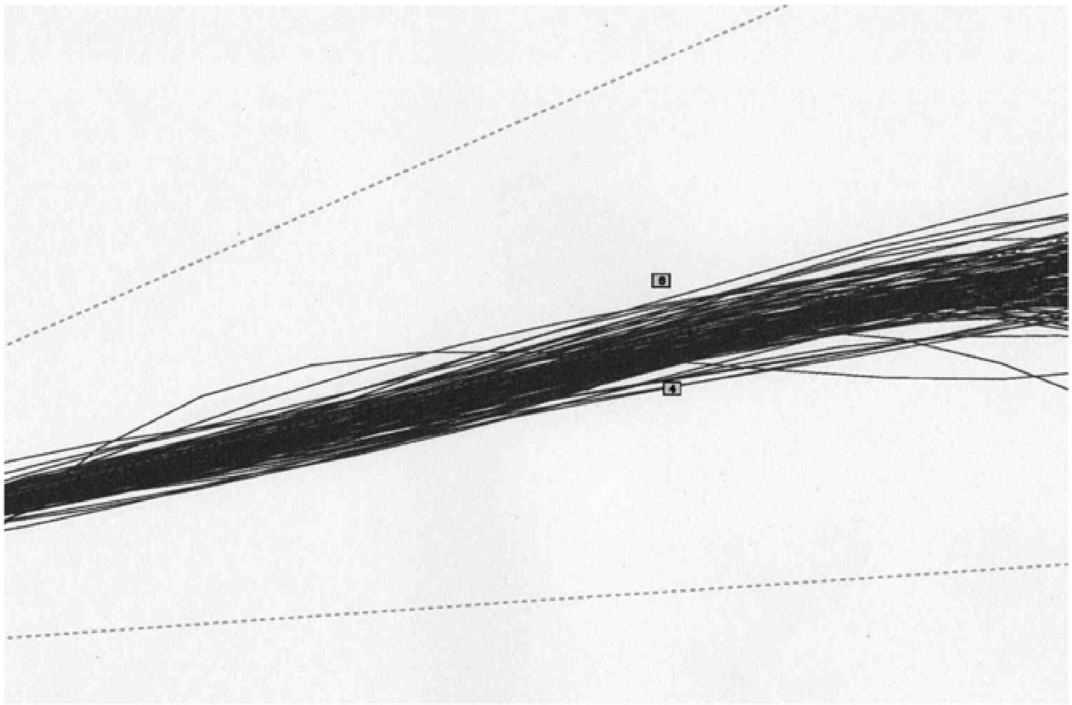
## FIGURE 4 DIAGRAM OF A MONITOR V

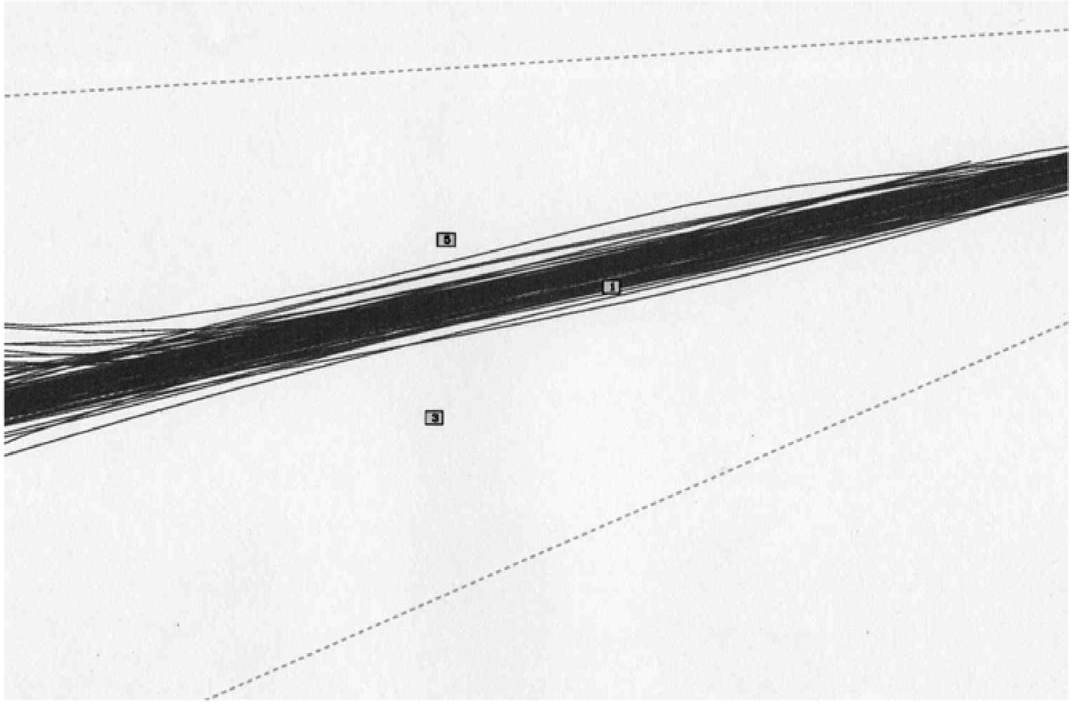


NB No upper height limits were applied for gates

## FIGURE 5 Typical 744 Departure Tracks for Gatwick Departures

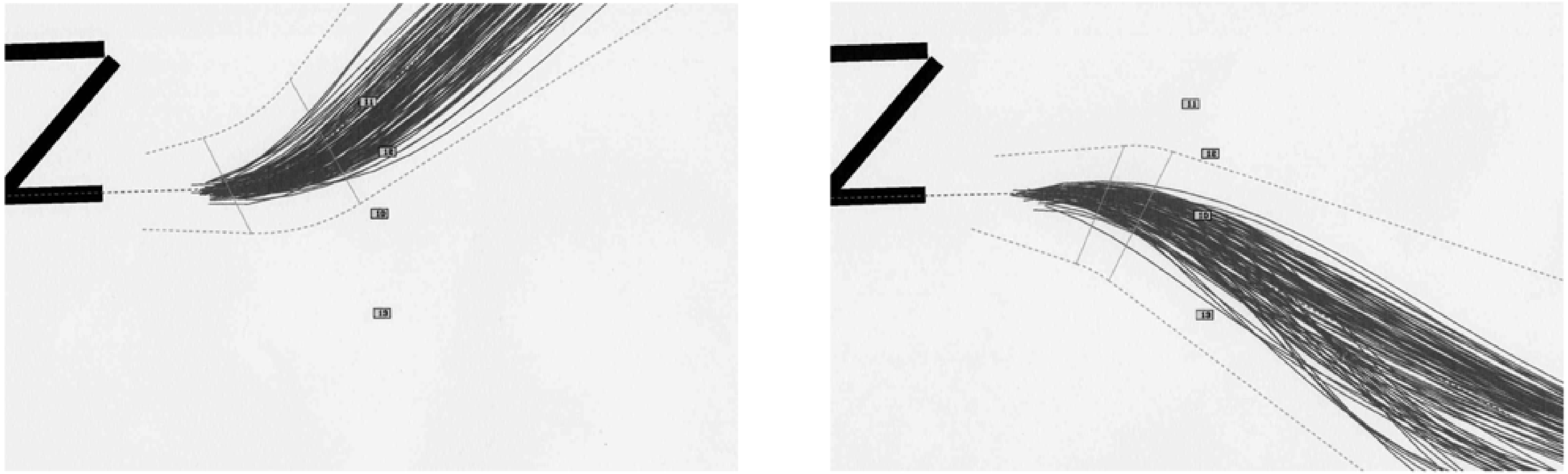


**Departure Tracks from Runway 08R**



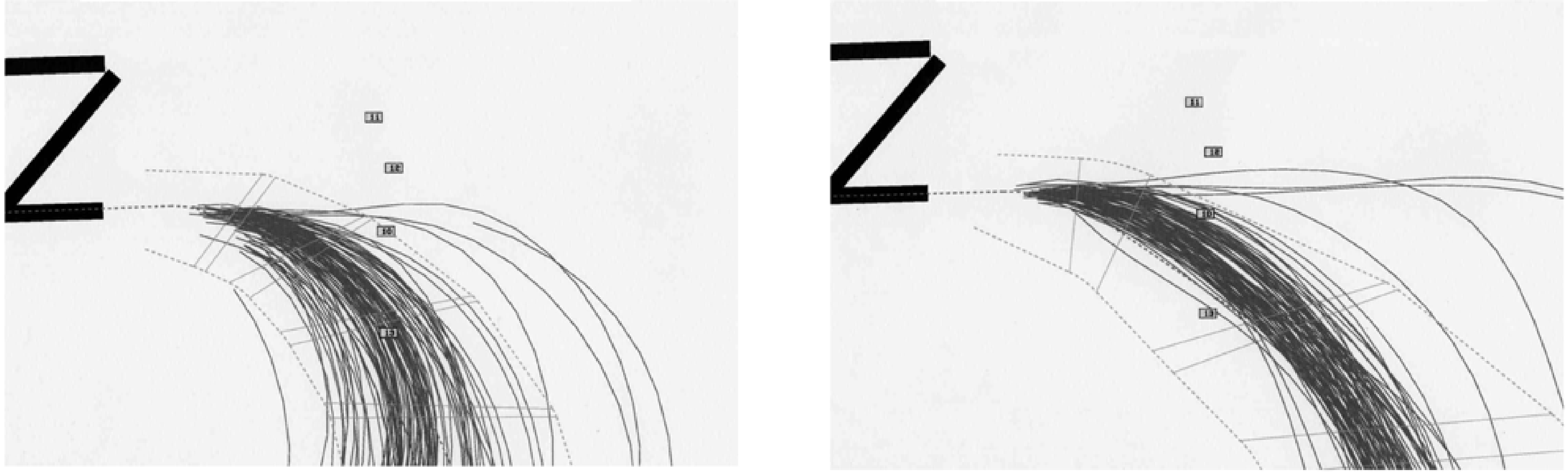
**Departure Tracks from Runway 26L**

## FIGURE 6(a) Typical 744 Departure Tracks for Heathrow 09R Departures



BPK Departures

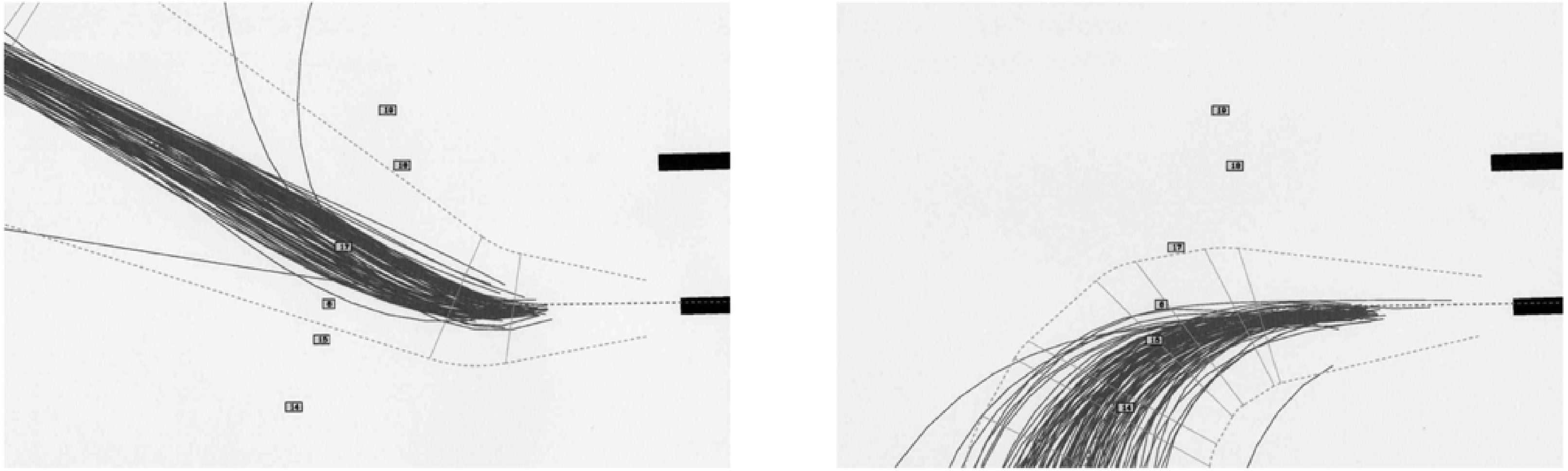
DVR Departures



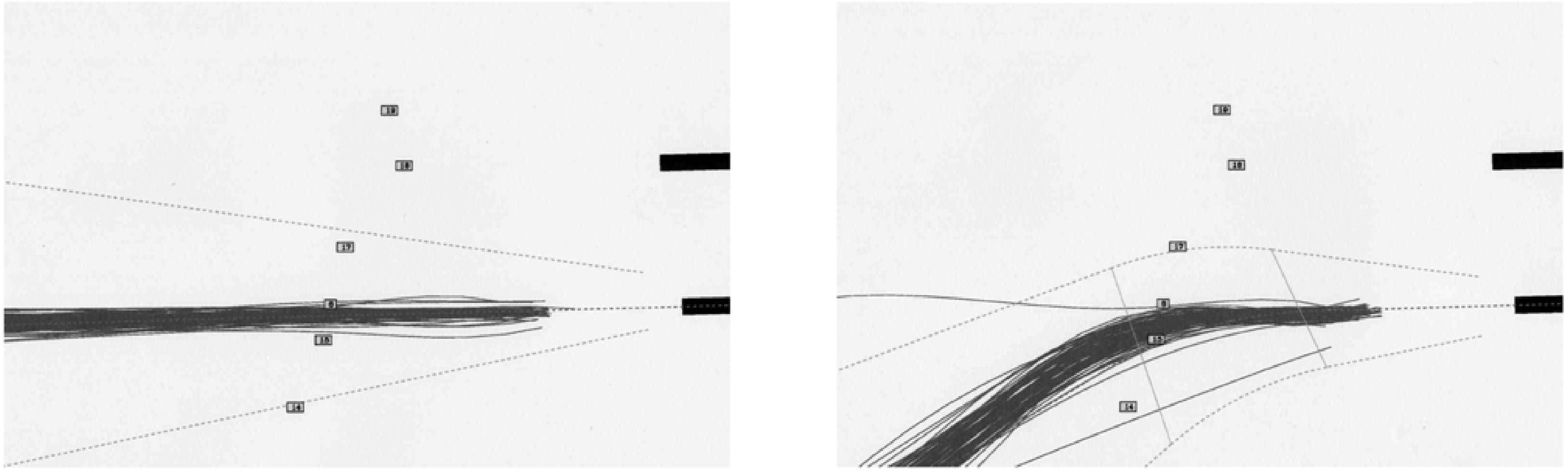
CPT Departures

MID Departures

## FIGURE 6(b) Typical 744 Departure Tracks for Heathrow 27L Departures

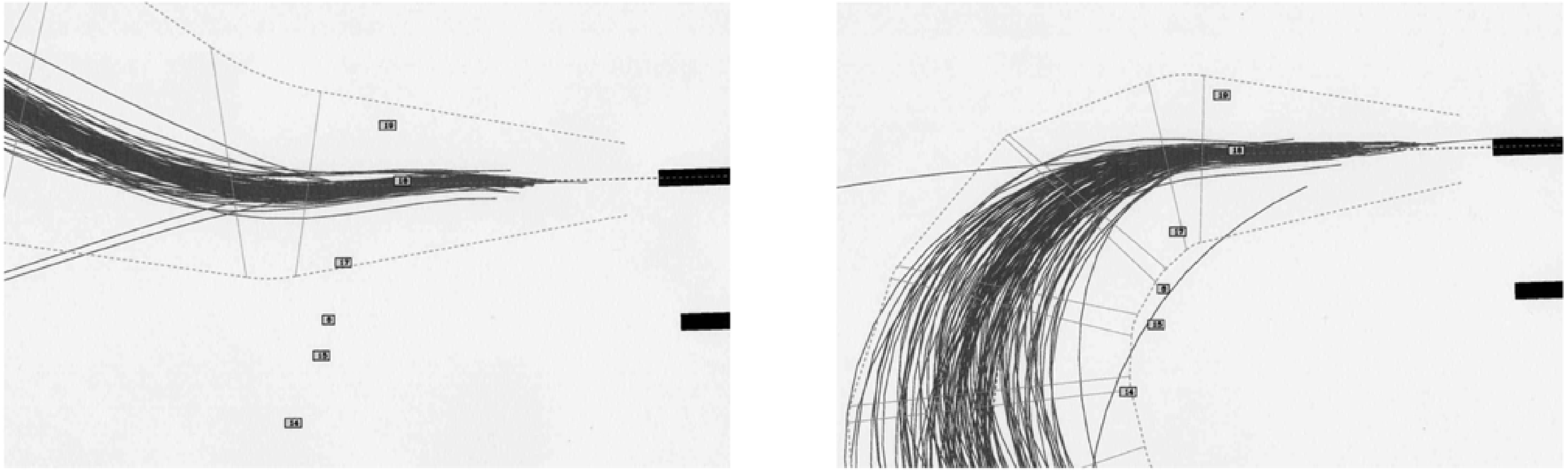


**BPK Departures** **DVR Departures**



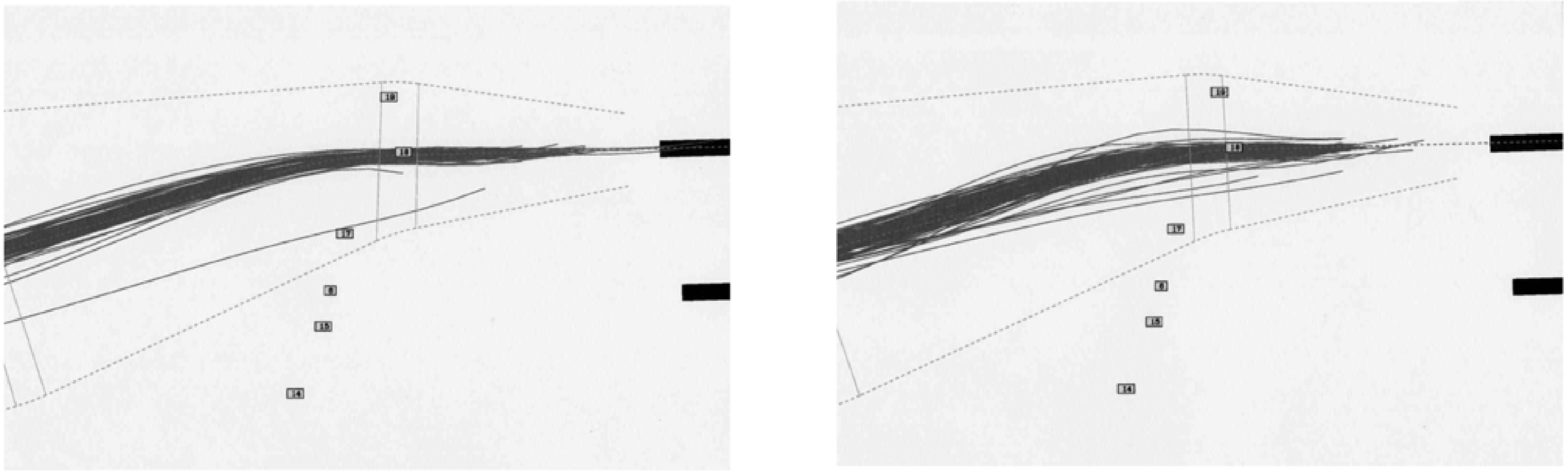
**CPT Departures** **MID Departures**

FIGURE 6 (c) Typical 744 Departure Tracks for Heathrow 27R Departures



BPK Departures

DVR Departures

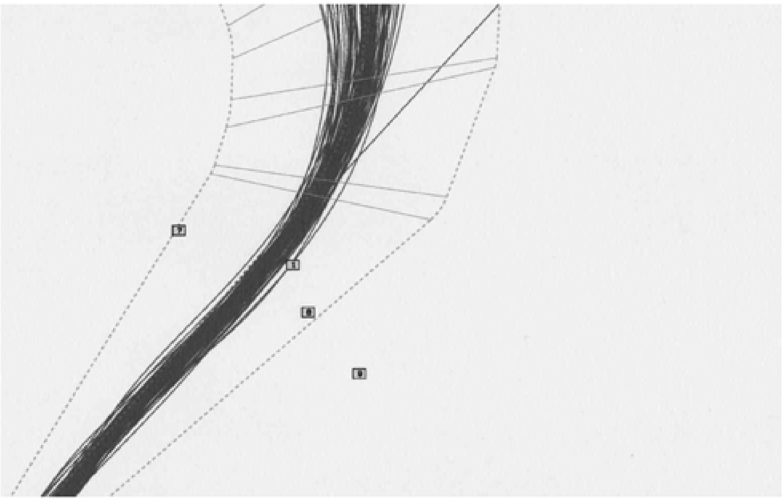


CPT Departures

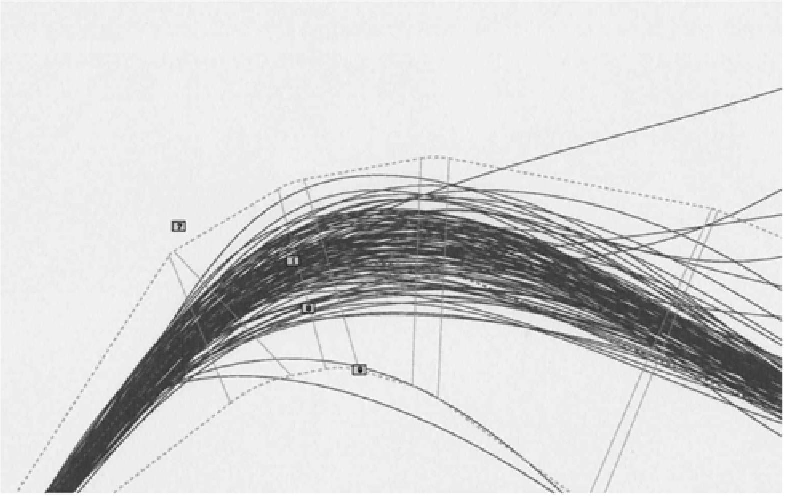
MID Departures

## FIGURE 7(a) Typical 738 Departures for Stansted 05 Departures

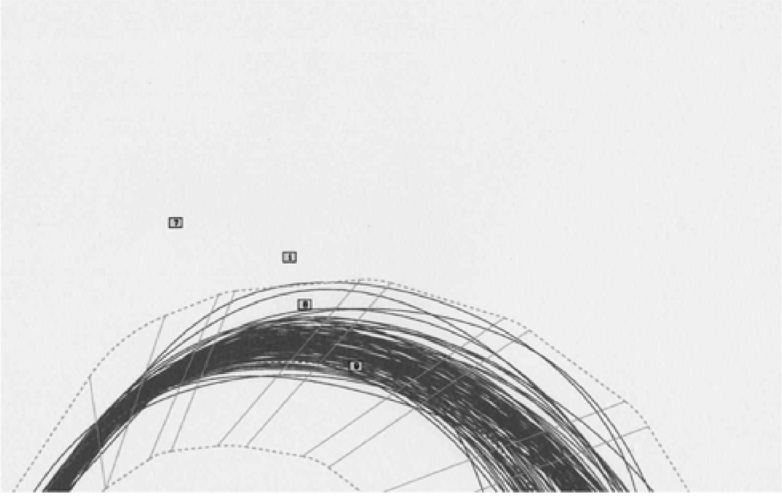
Note: In these figures monitor 10 is shown as monitor 1 (its designation in NTK).



**BZD Departures**

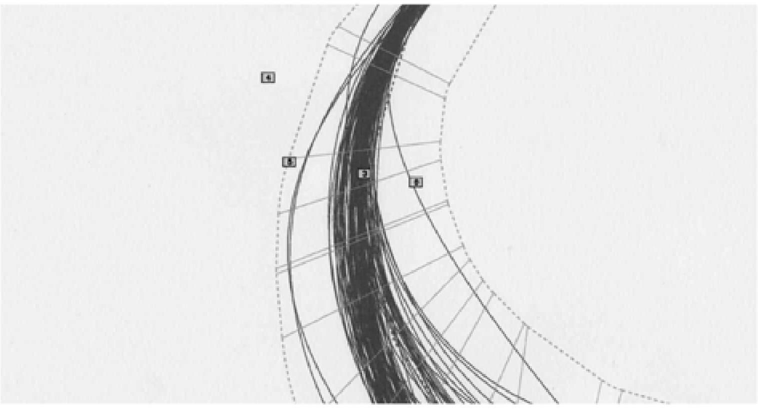


**CLN Departures**

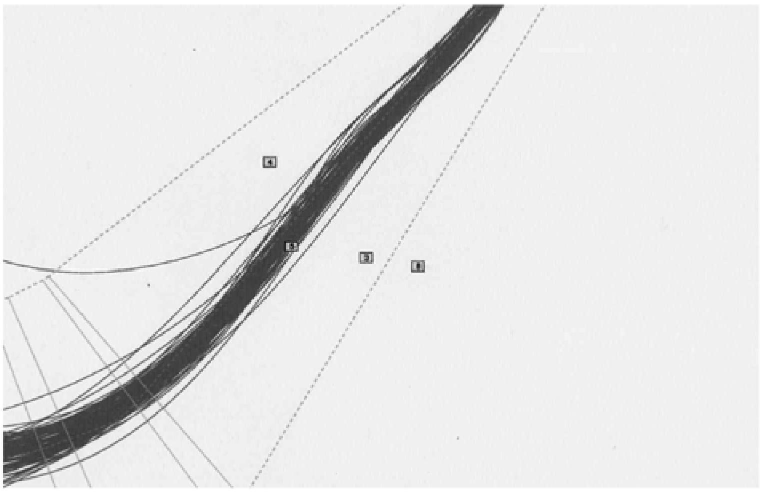


**DVR Departures**

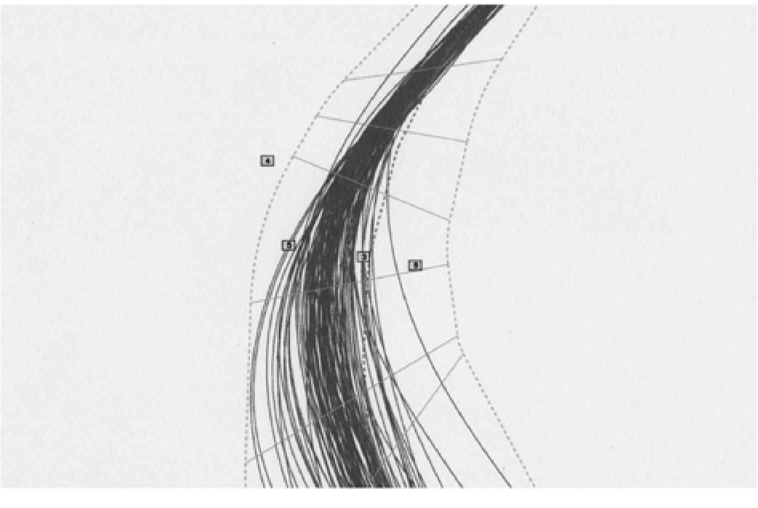
# FIGURE 7(b) Typical 738 Departures for Stansted 23 Departures



BZD Departures

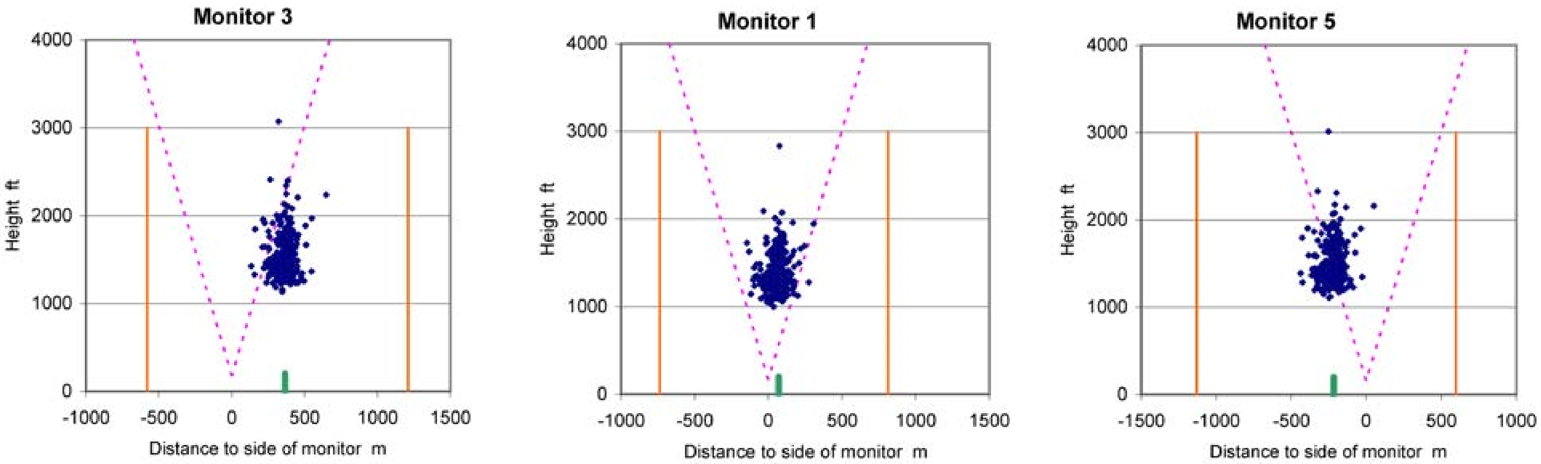


CLN Departures



DVR Departures

FIGURE 8(a) Sample scatterplots: Gatwick 744 26L departures (all routes)



FIURE 8(b) Sample scatterplots:Gatwick 744 08R departures (all routes)

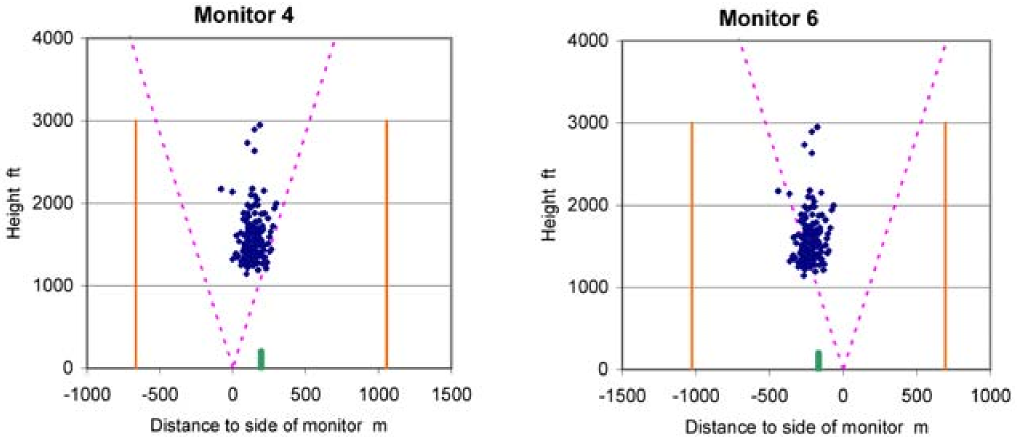


FIGURE 9(a) Sample scatterplots: Heathrow 744 09R BPK/BUZ departures

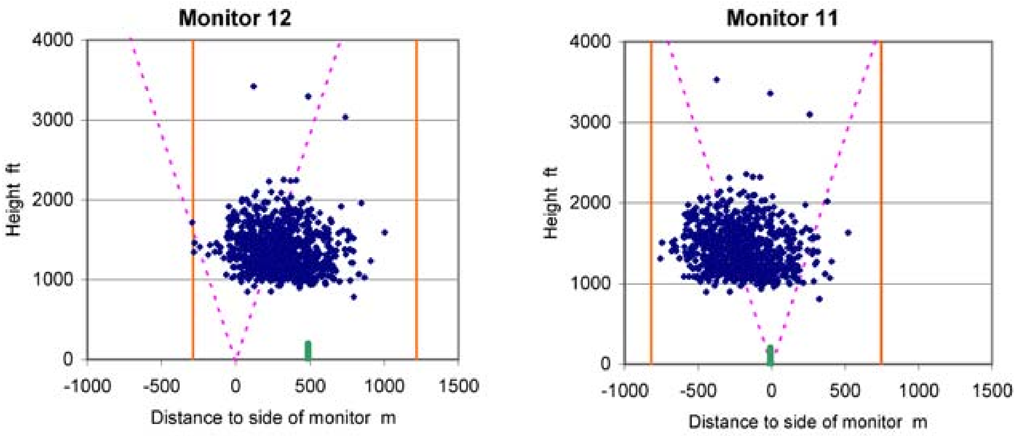
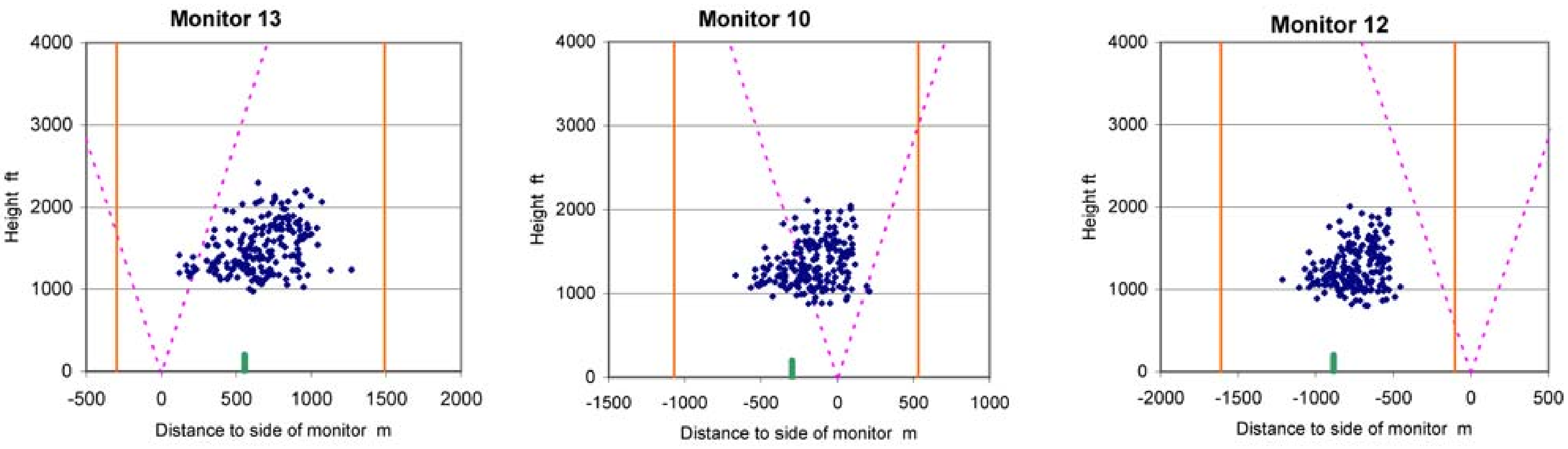
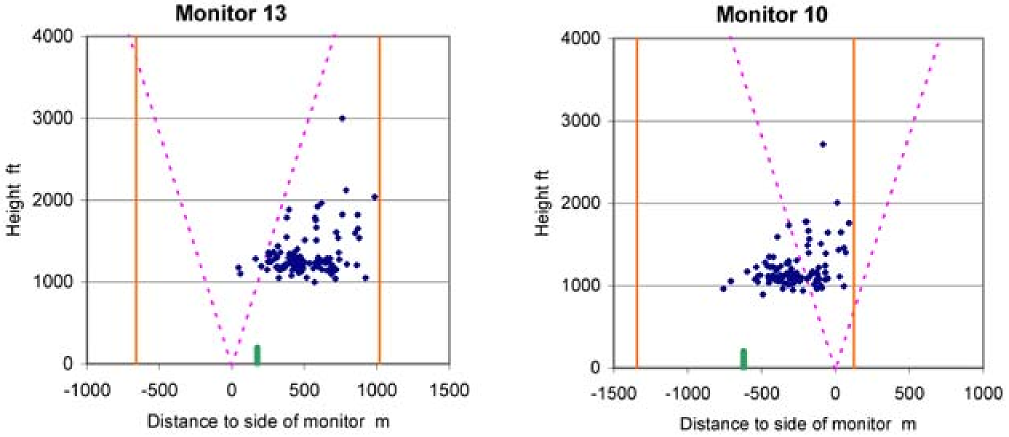


FIGURE 9(b) Sample scatterplots: Heathrow 744 09R DVR departures



## FIGURE 9(c) Sample scatterplots: Heathrow 744 09R MID departures



## FIGURE 9(d) Sample scatterplots: Heathrow 744 09R CPT departures

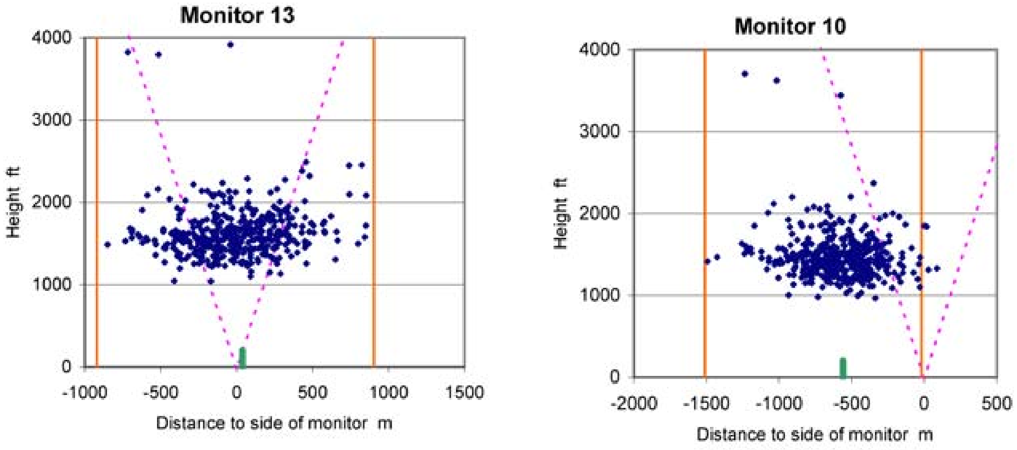


FIGURE 10(a) Sample scatterplots: Heathrow 744 27R WOB/BPK departures

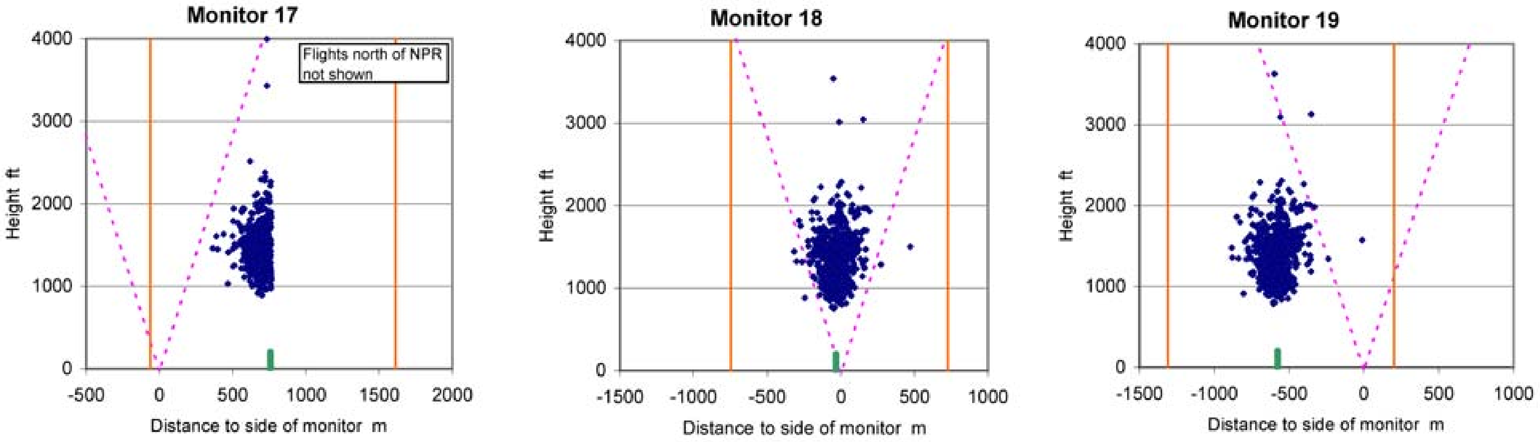


FIGURE 10(b) Sample scatterplots: Heathrow 744 27R CPT/SAM departures

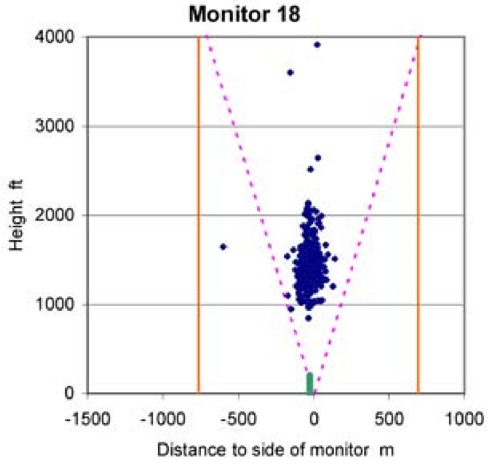


FIGURE 10(c) Sample scatterplots: Heathrow 744 27R MID departures

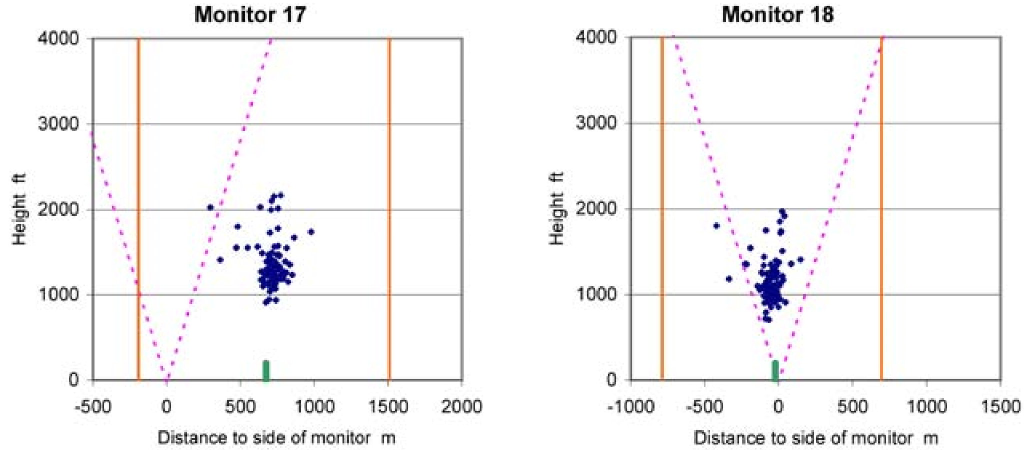


FIGURE 10(d) Sample scatterplots: Heathrow 744 27R DVR departures

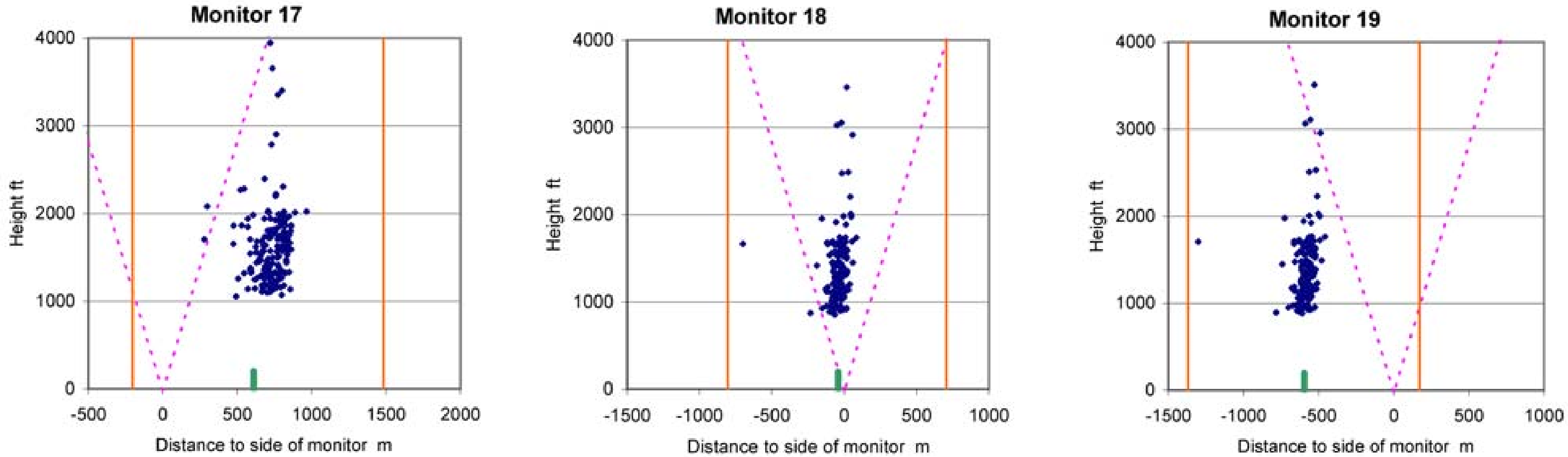


FIGURE 11(a) Sample scatterplots: Heathrow 744 27L WOB/BPK departures

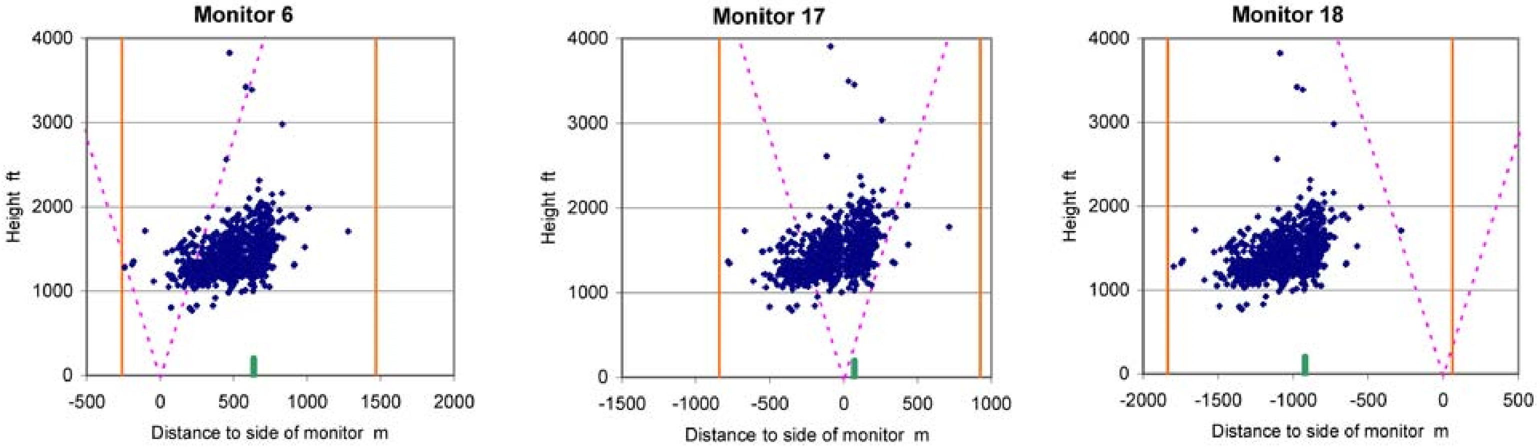


FIGURE 11(b) Sample scatterplots: Heathrow 744 27L CPT/SAM departures

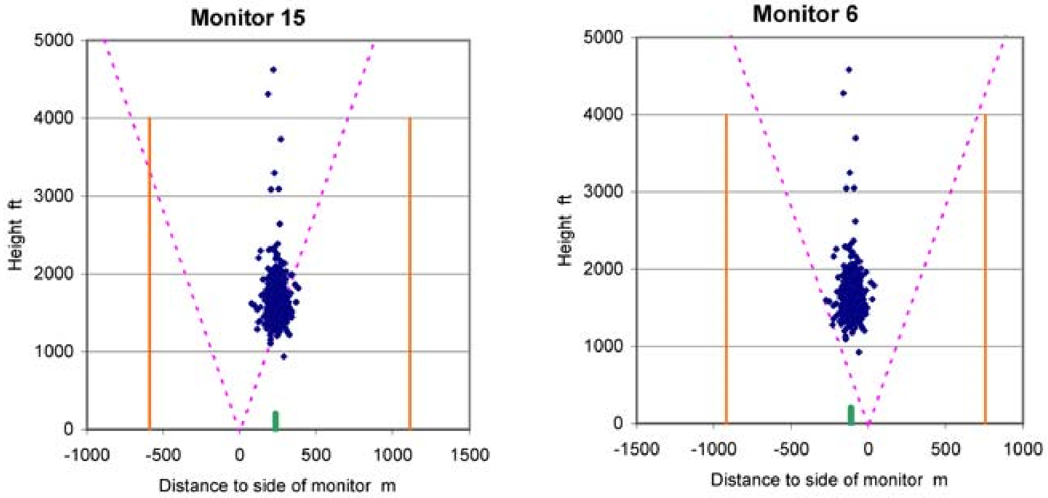


FIGURE 11(c) Sample scatterplots: Heathrow 744 27L MID departures

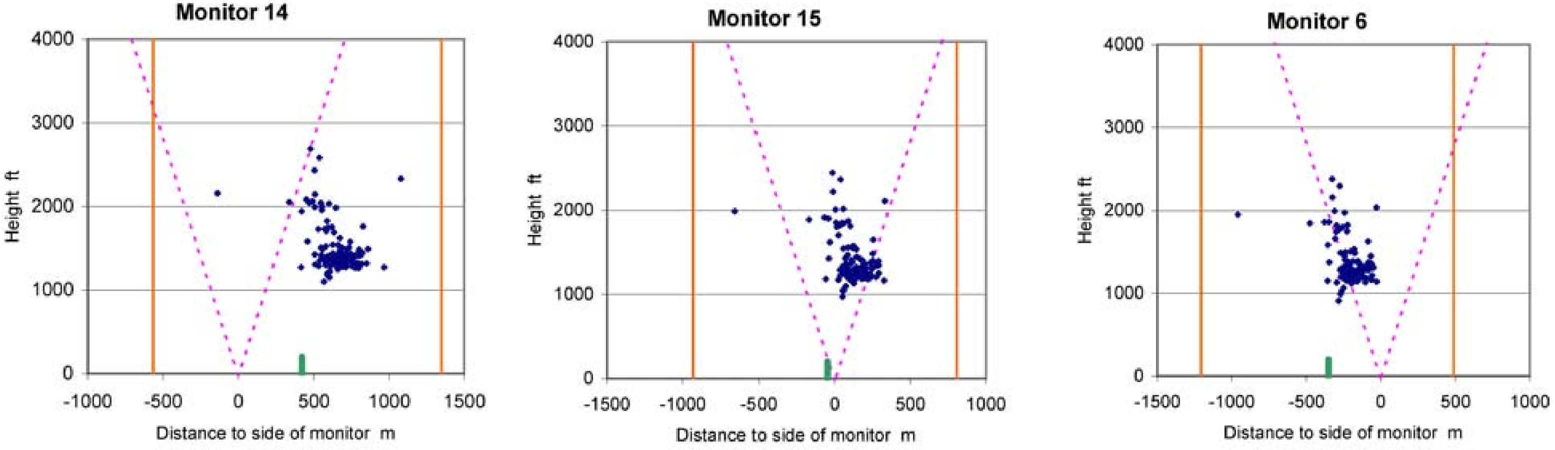


FIGURE 11(d) Sample scatterplots: Heathrow 744 27L DVR departures

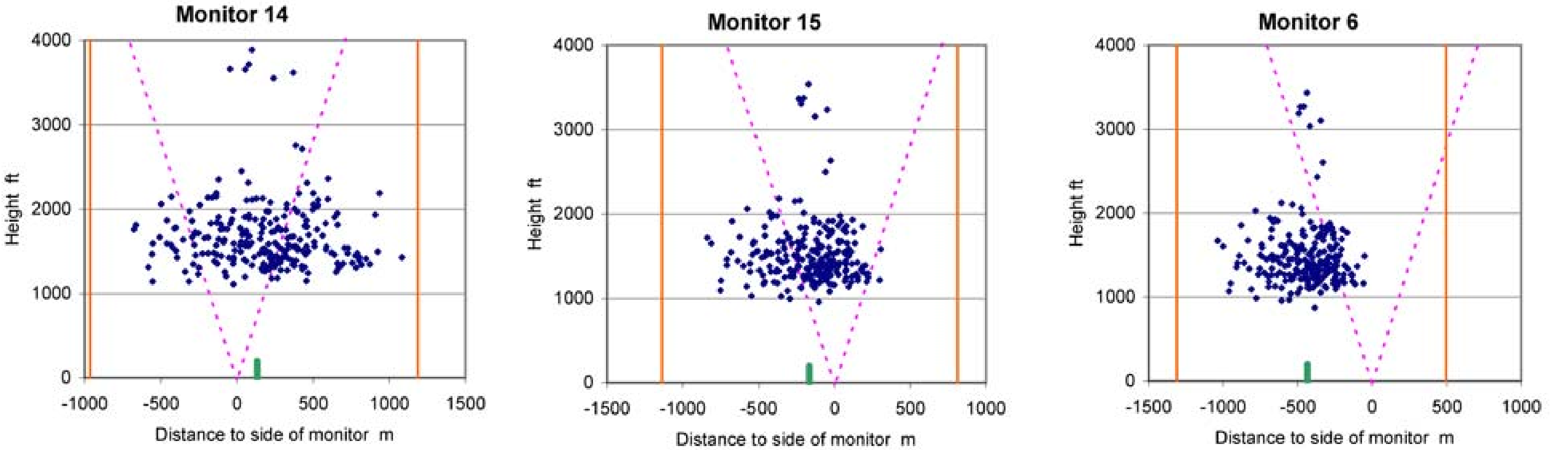


FIGURE 12(a) Sample scatterplots: Stansted 738 05 BZD departures

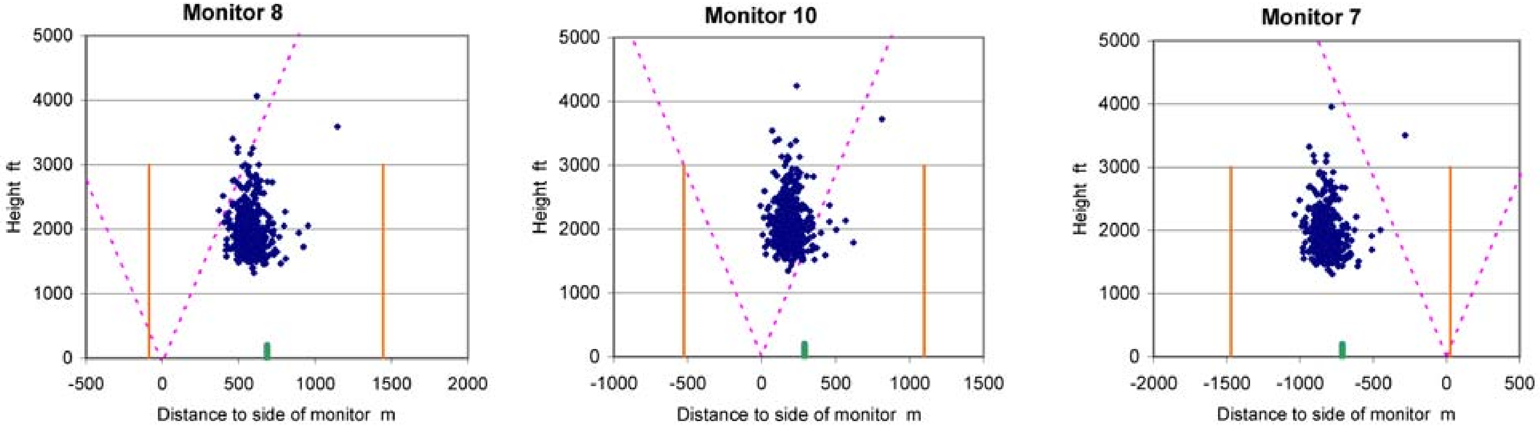


FIGURE 12(b) Sample scatterplots: Stansted 738 05 CLN departures

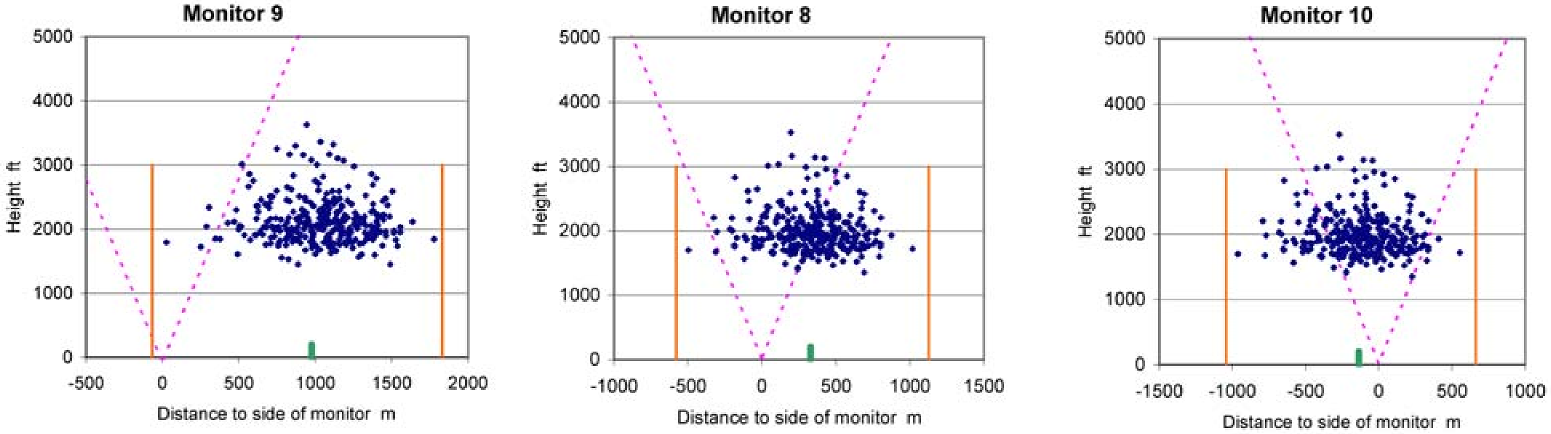


FIGURE 12(c) Sample scatterplots: Stansted 738 23 BZD departures

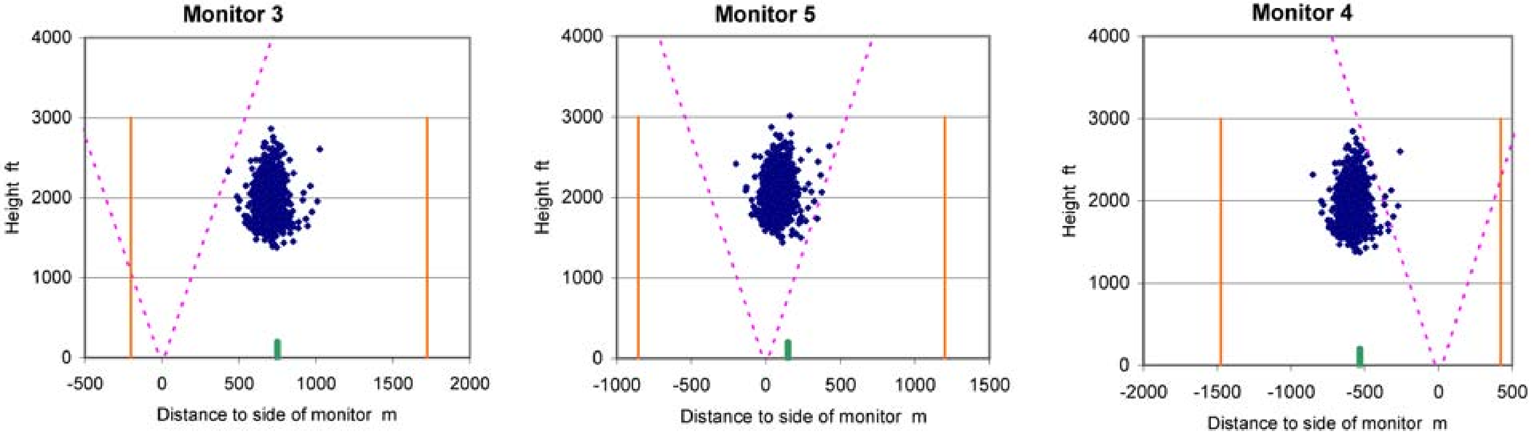


FIGURE 12(d) Sample scatterplots: Stansted 738 23 DVR departures

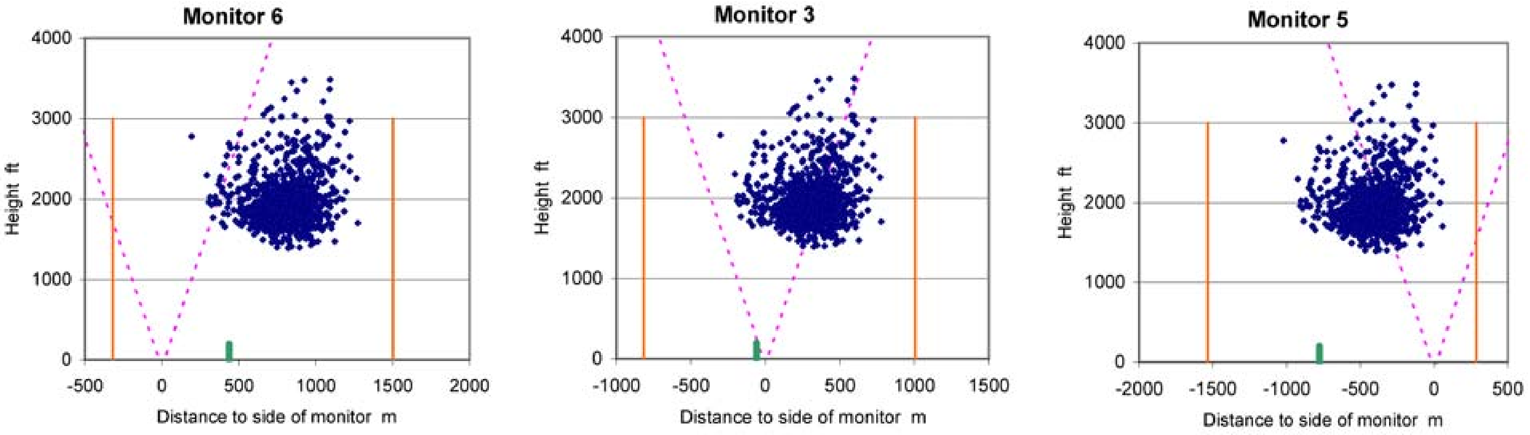


FIGURE 13(a) Percentage of all flights passing through a V (>90%)

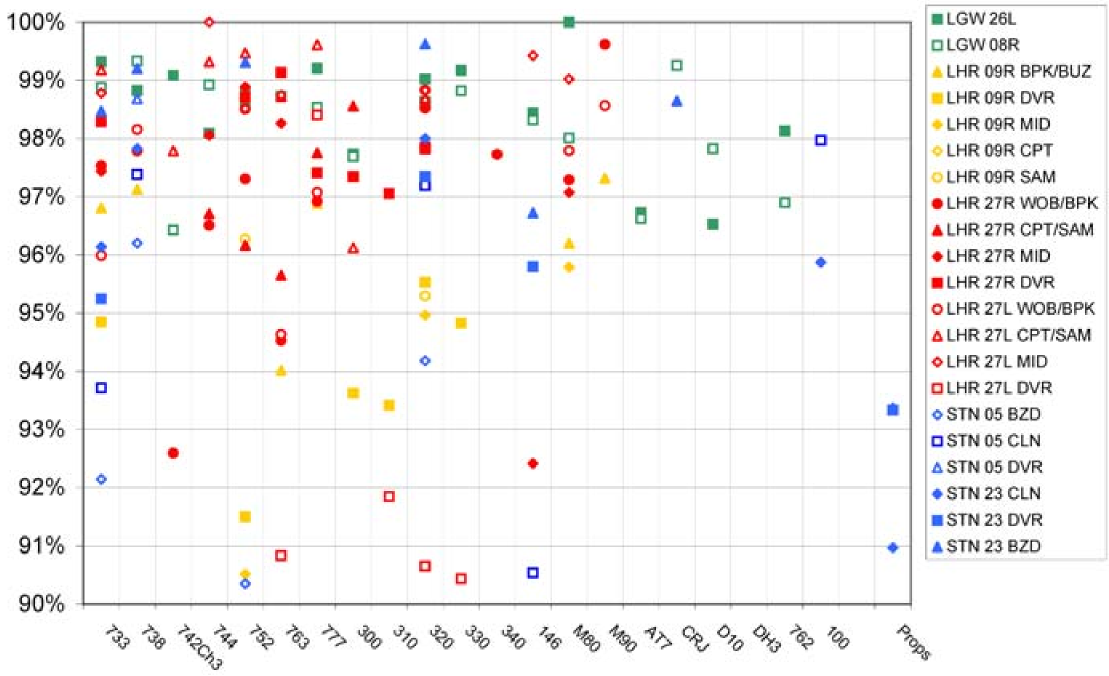


FIGURE 13(b) Percentage of all flights passing through a V (0-90%)

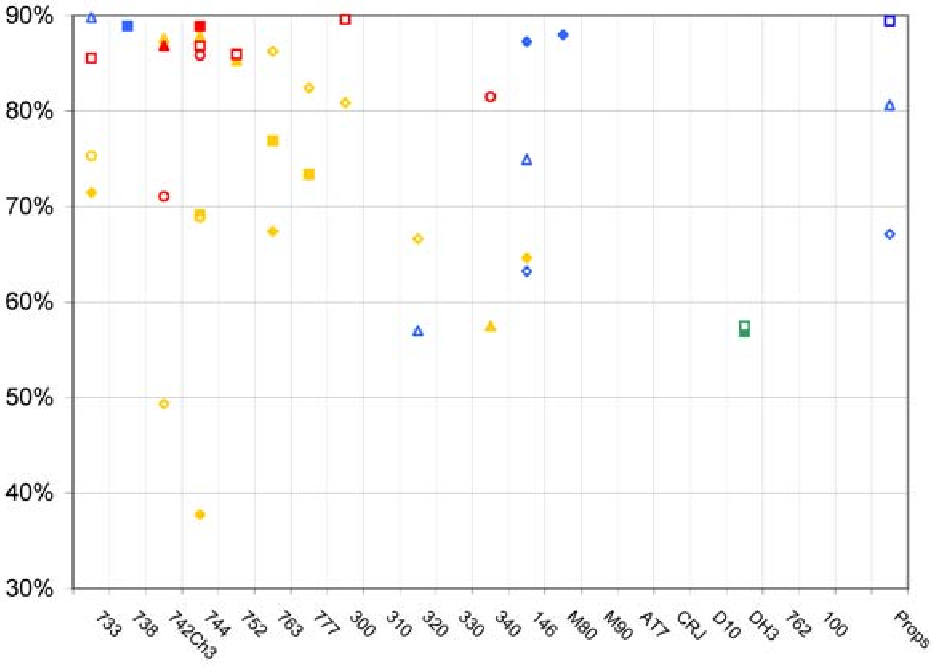
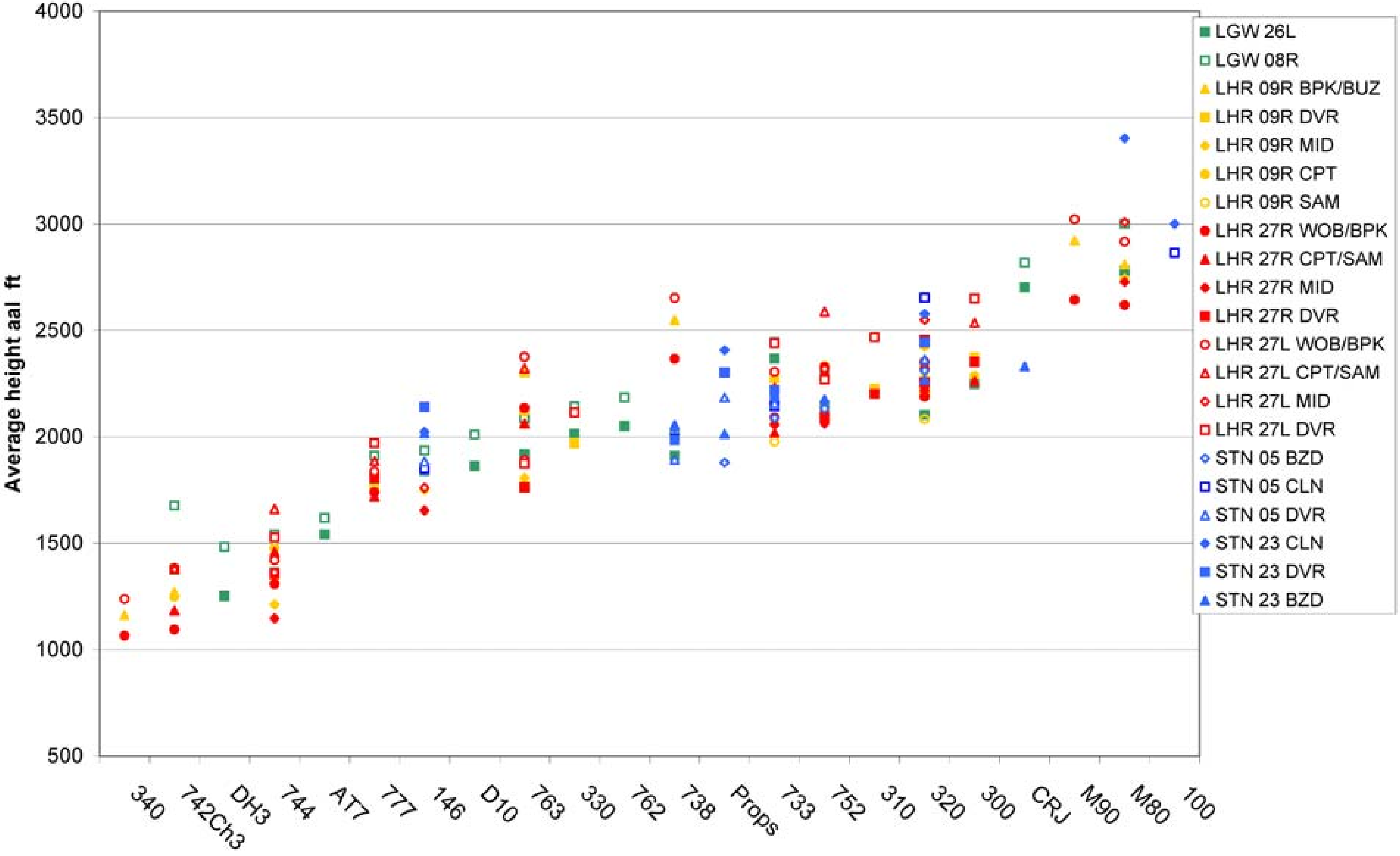
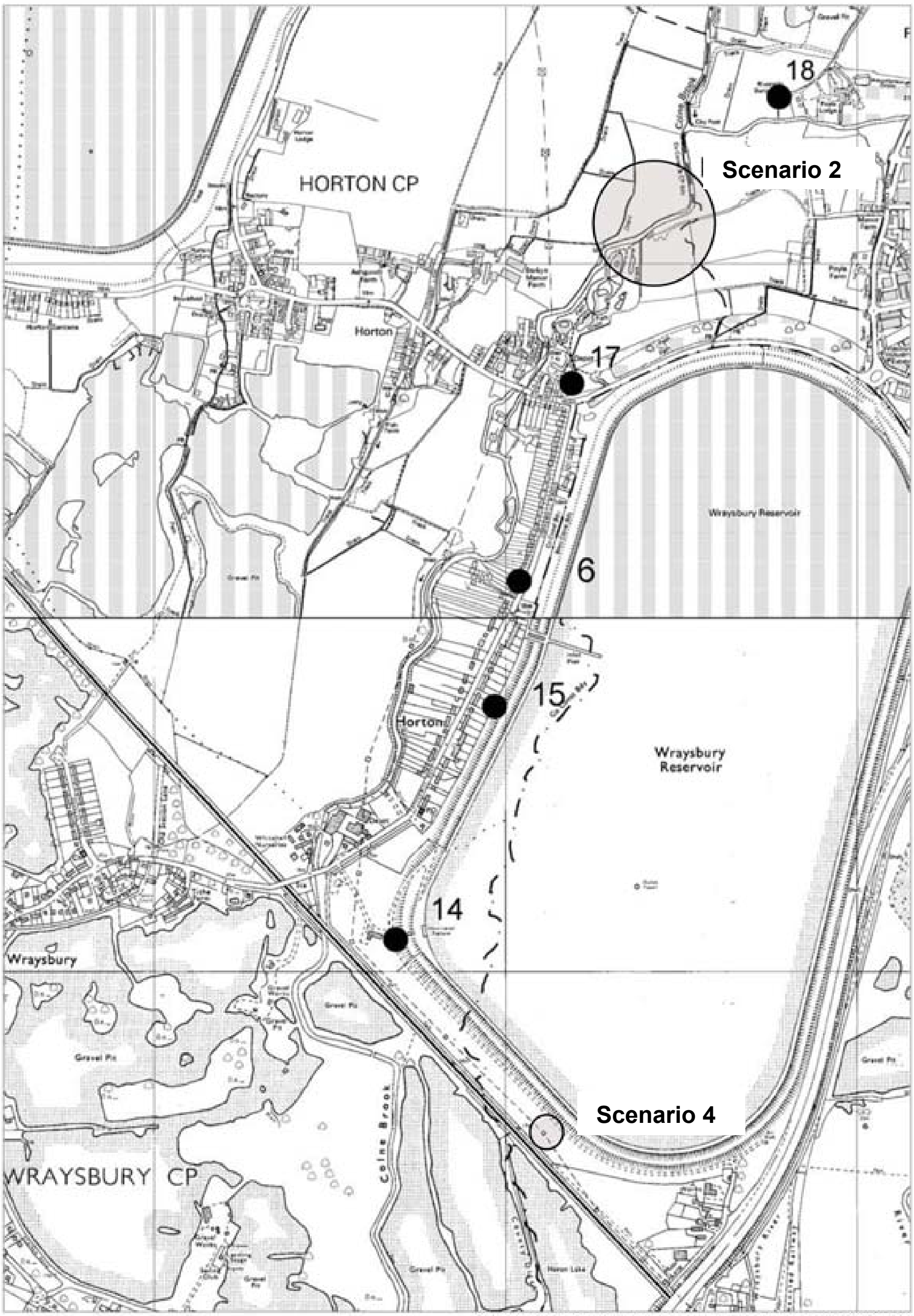


FIGURE 14 Average heights of aircraft passing through each gate



# FIGURE 15 HEATHROW RUNWAYS 27L/27R CURRENT MONITORS AND LOCATIONS FOR PROPOSED ADDITIONAL MONITORS



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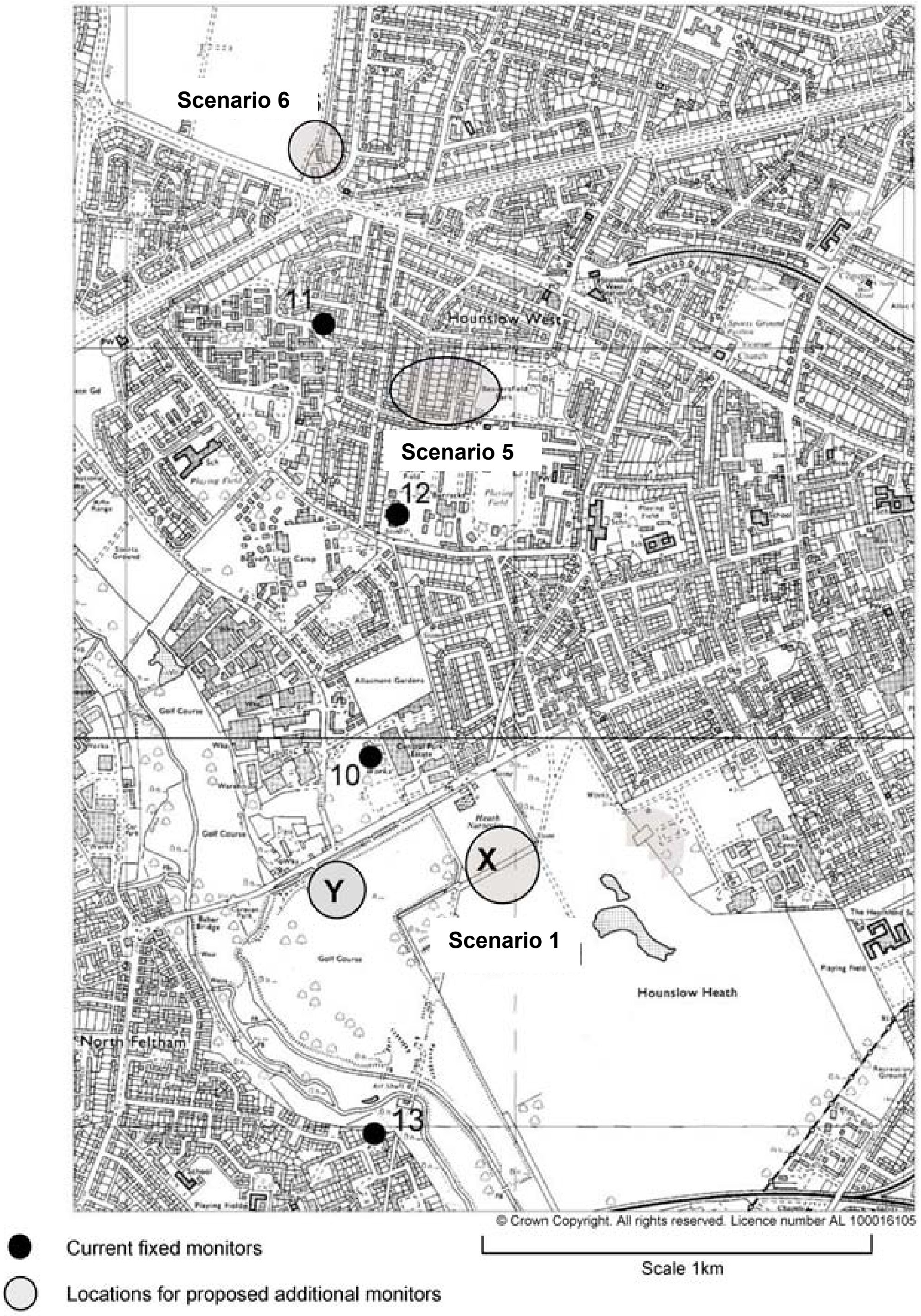
● Current fixed monitors

○ Locations for proposed additional monitors

Scale 1km

# FIGURE 16 HEATHROW RUNWAY 09R CURRENT MONITORS AND LOCATIONS FOR PROPOSED ADDITIONAL MONITORS



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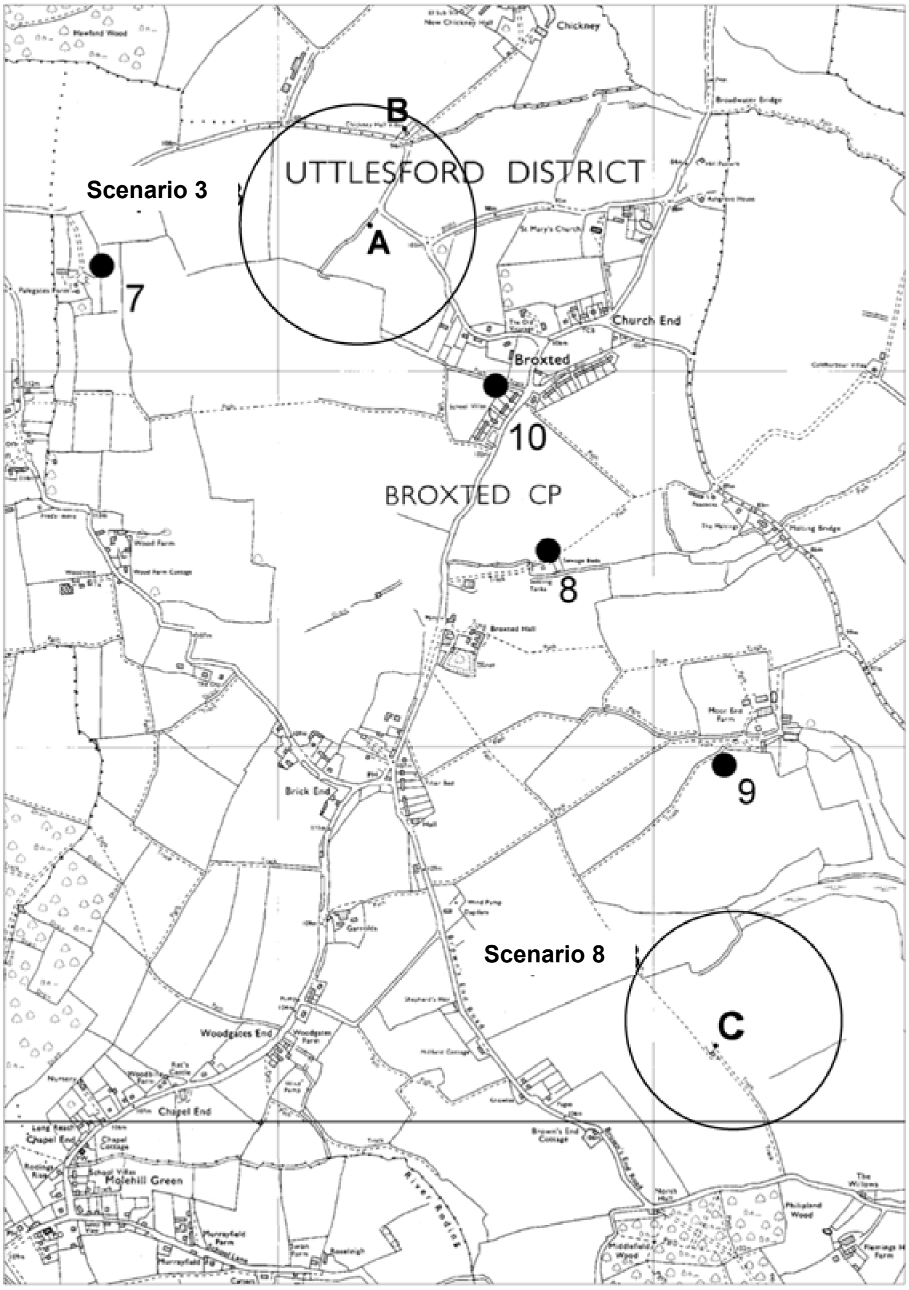
## FIGURE 17 STANSTED RUNWAY 05 CURRENT MONITORS AND LOCATIONS FOR PROPOSED ADDITIONAL MONITORS



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● Current fixed monitors

○ Locations for proposed additional monitors

Scale 1km

## FIGURE 18 Effect of track dispersion on monitor array performance for mean track on NPR centreline

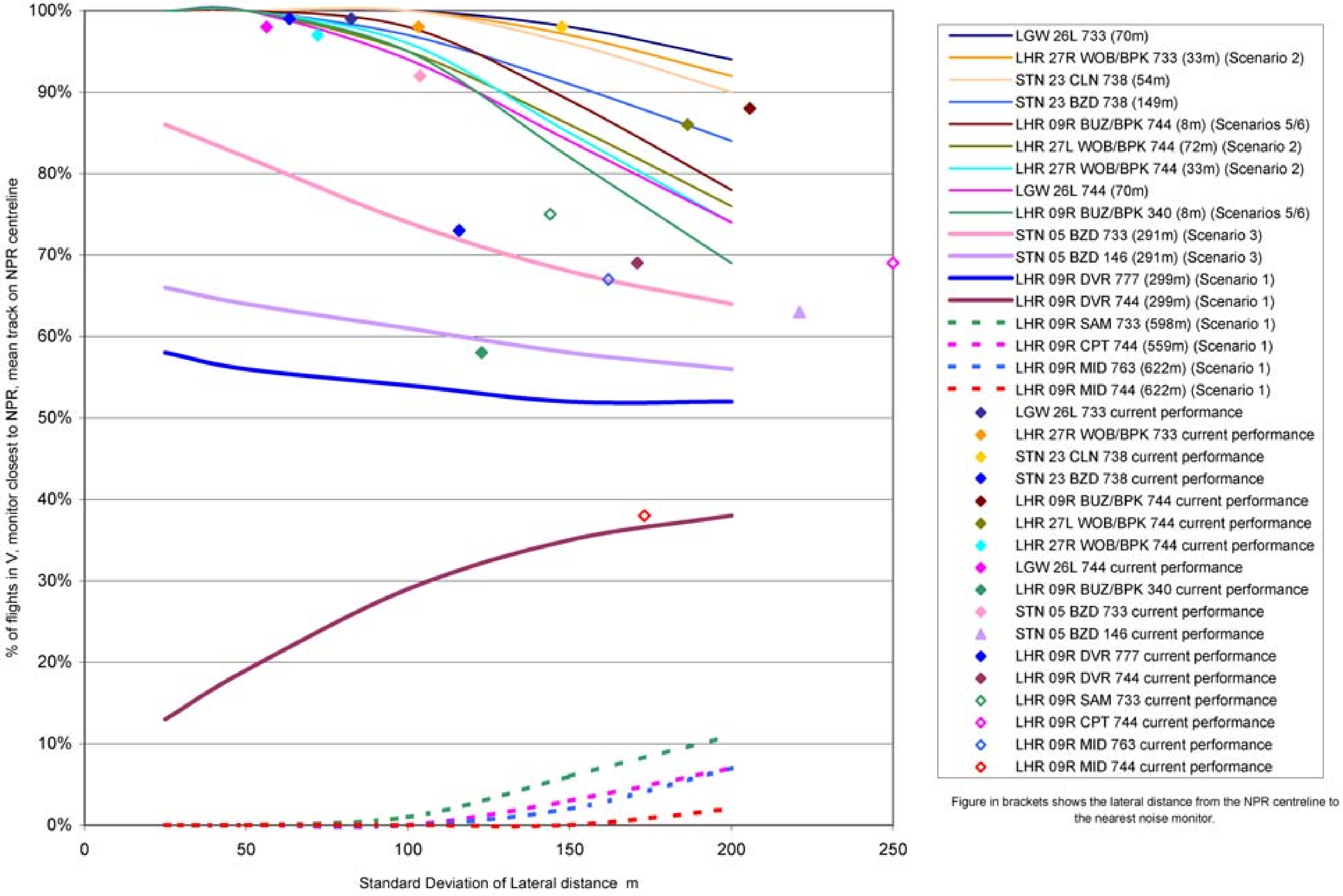
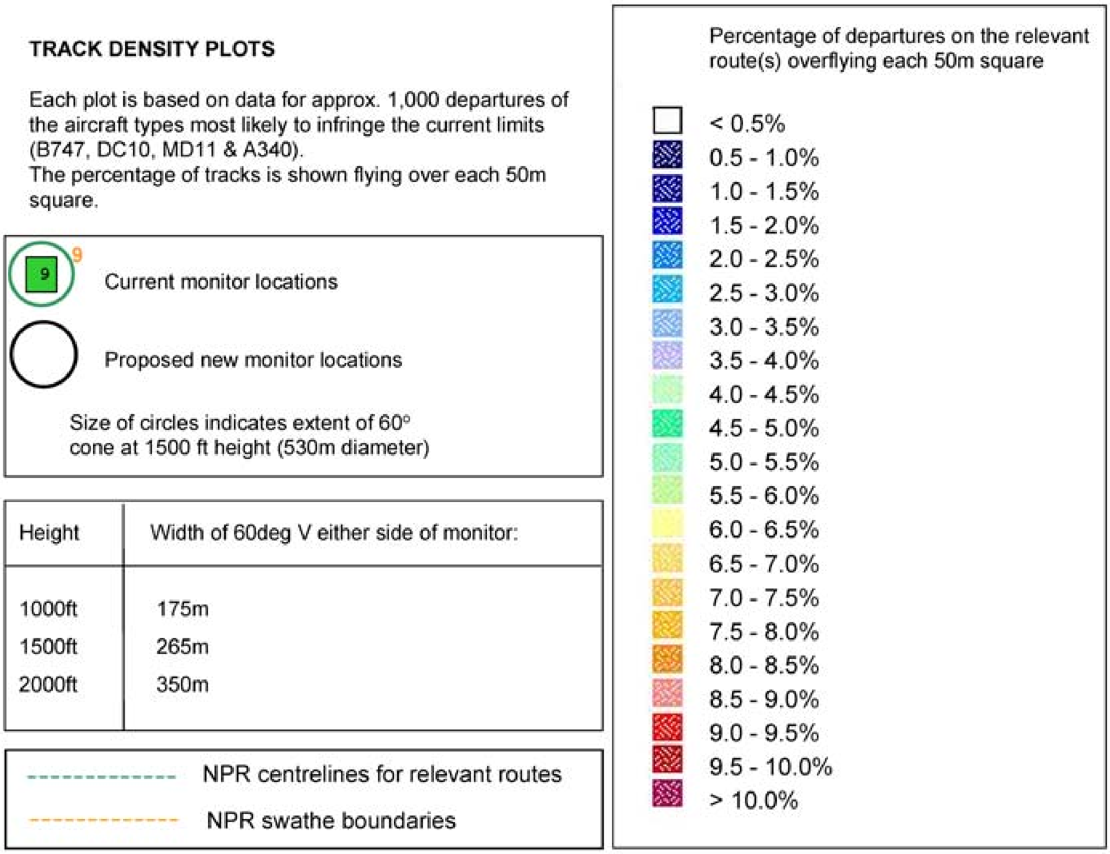


Figure in brackets shows the lateral distance from the NPR centreline to the nearest noise monitor.

## FIGURE 19 TRACK DENSITY PLOTS: EXPLANATION AND KEY



**TRACK DENSITY PLOTS**

Each plot is based on data for approx. 1,000 departures of the aircraft types most likely to infringe the current limits (B747, DC10, MD11 & A340).
The percentage of tracks is shown flying over each 50m square.

Current monitor locations

Proposed new monitor locations

Size of circles indicates extent of 60° cone at 1500 ft height (530m diameter)

| Height | Width of 60deg V either side of monitor: |
|---|---|
| 1000ft | 175m |
| 1500ft | 265m |
| 2000ft | 350m |

NPR centrelines for relevant routes

NPR swathe boundaries

Percentage of departures on the relevant route(s) overflying each 50m square

- ☐ < 0.5%
- ▨ 0.5 - 1.0%
- ▨ 1.0 - 1.5%
- ▨ 1.5 - 2.0%
- ▨ 2.0 - 2.5%
- ▨ 2.5 - 3.0%
- ▨ 3.0 - 3.5%
- ▨ 3.5 - 4.0%
- ▨ 4.0 - 4.5%
- ▨ 4.5 - 5.0%
- ▨ 5.0 - 5.5%
- ▨ 5.5 - 6.0%
- ▨ 6.0 - 6.5%
- ▨ 6.5 - 7.0%
- ▨ 7.0 - 7.5%
- ▨ 7.5 - 8.0%
- ▨ 8.0 - 8.5%
- ▨ 8.5 - 9.0%
- ▨ 9.0 - 9.5%
- ▨ 9.5 - 10.0%
- ▨ > 10.0%

**FIGURE 20(a) TRACK DENSITY PLOT: GATWICK 26L**

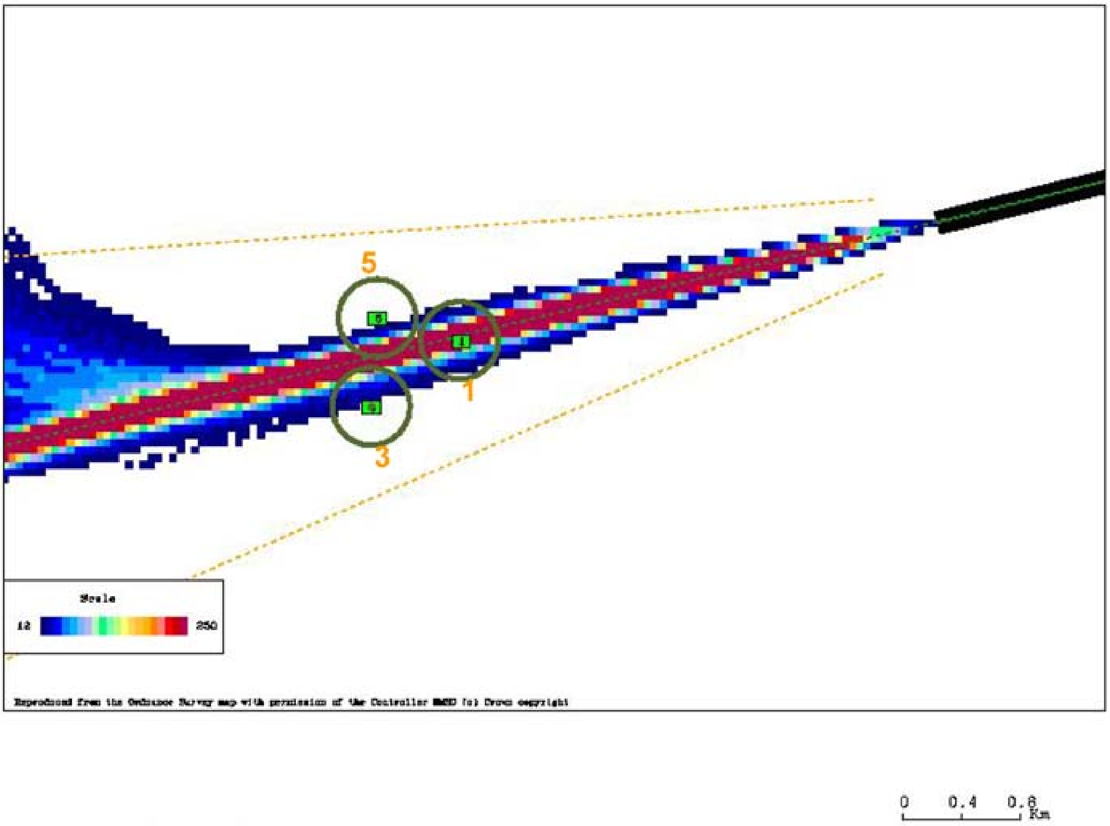
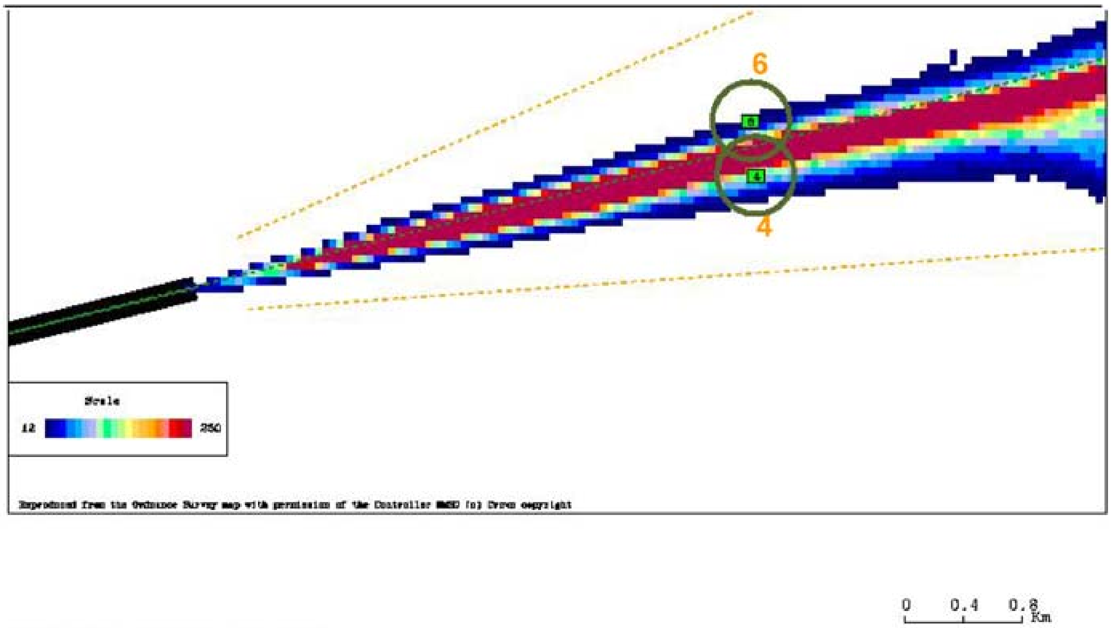
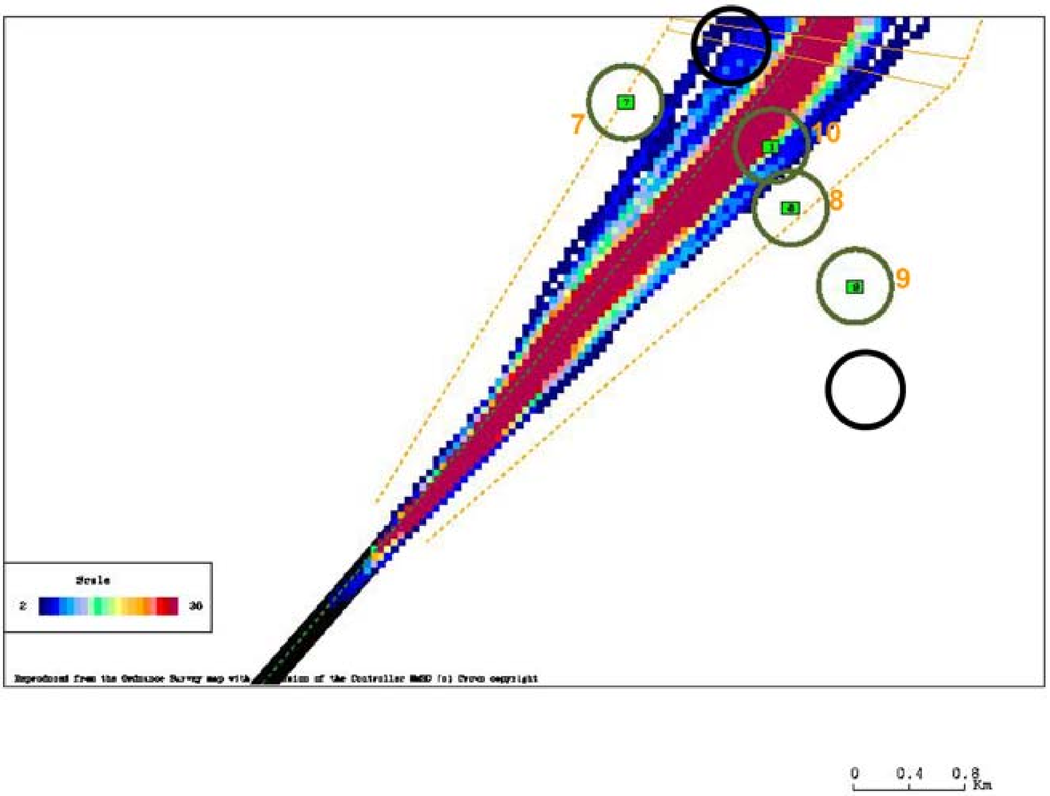


**FIGURE 20(b) TRACK DENSITY PLOT: GATWICK 08R**



## FIGURE 21(a) TRACK DENSITY PLOT: STANSTED 05 BZD



## FIGURE 21(b) TRACK DENSITY PLOT: STANSTED 05 DVR

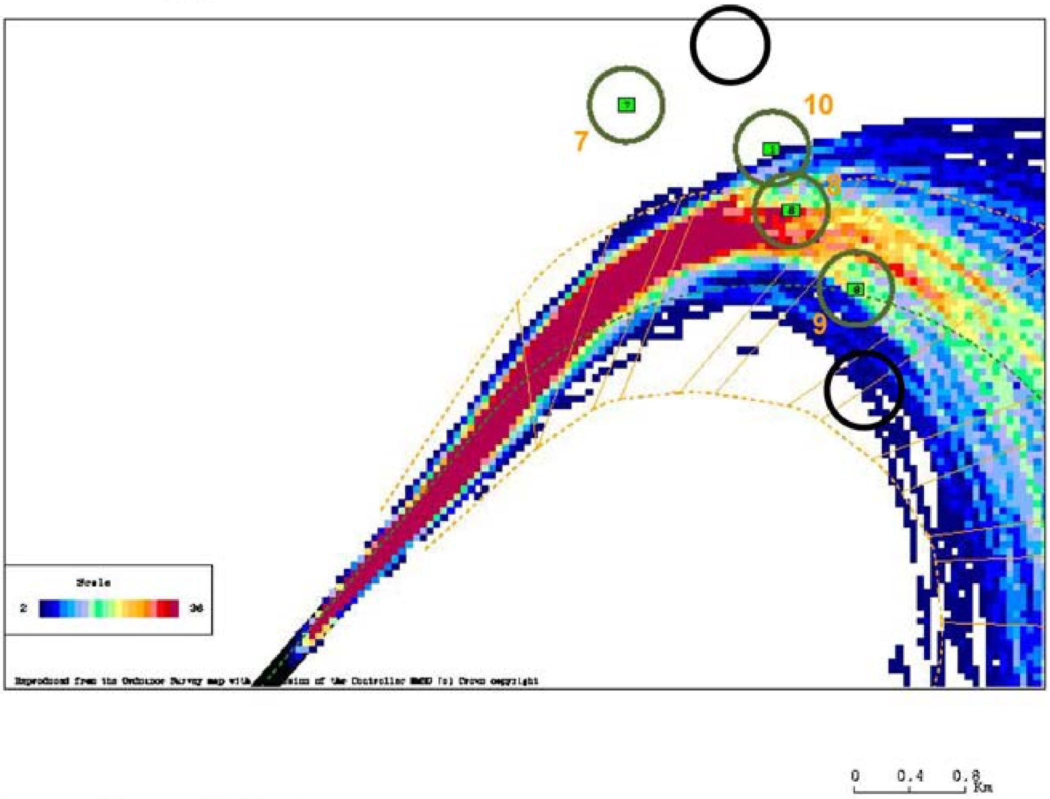
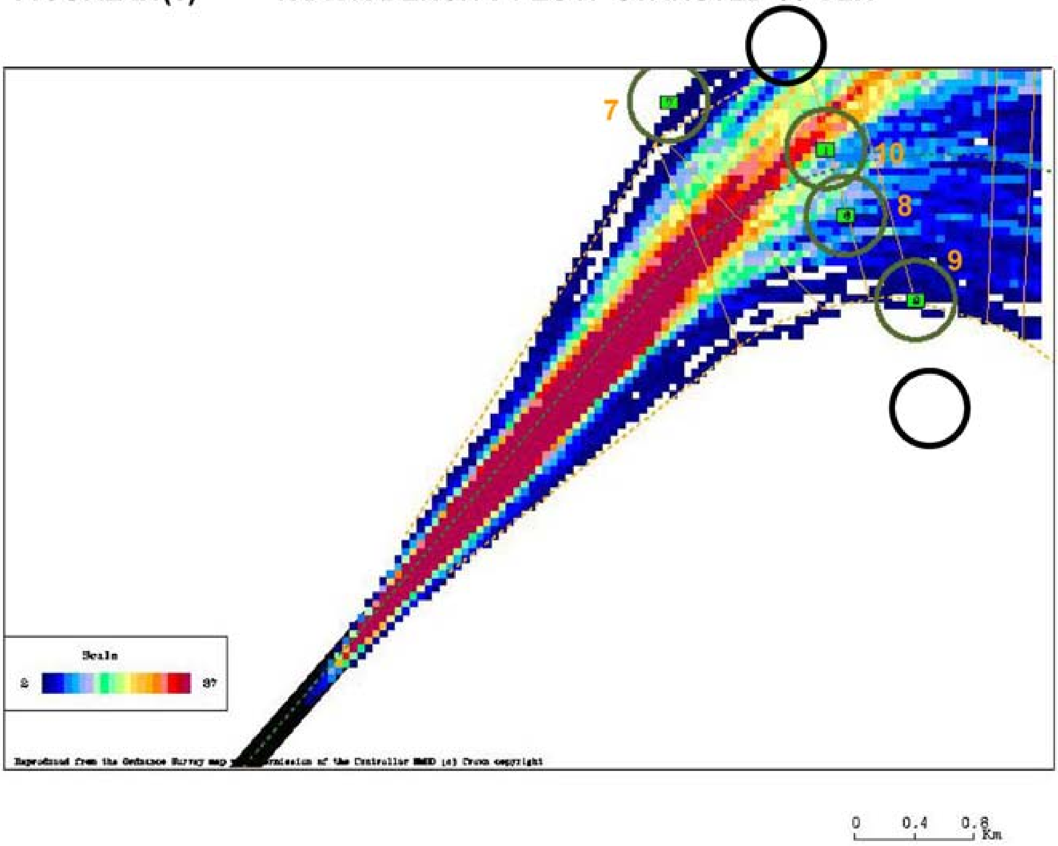
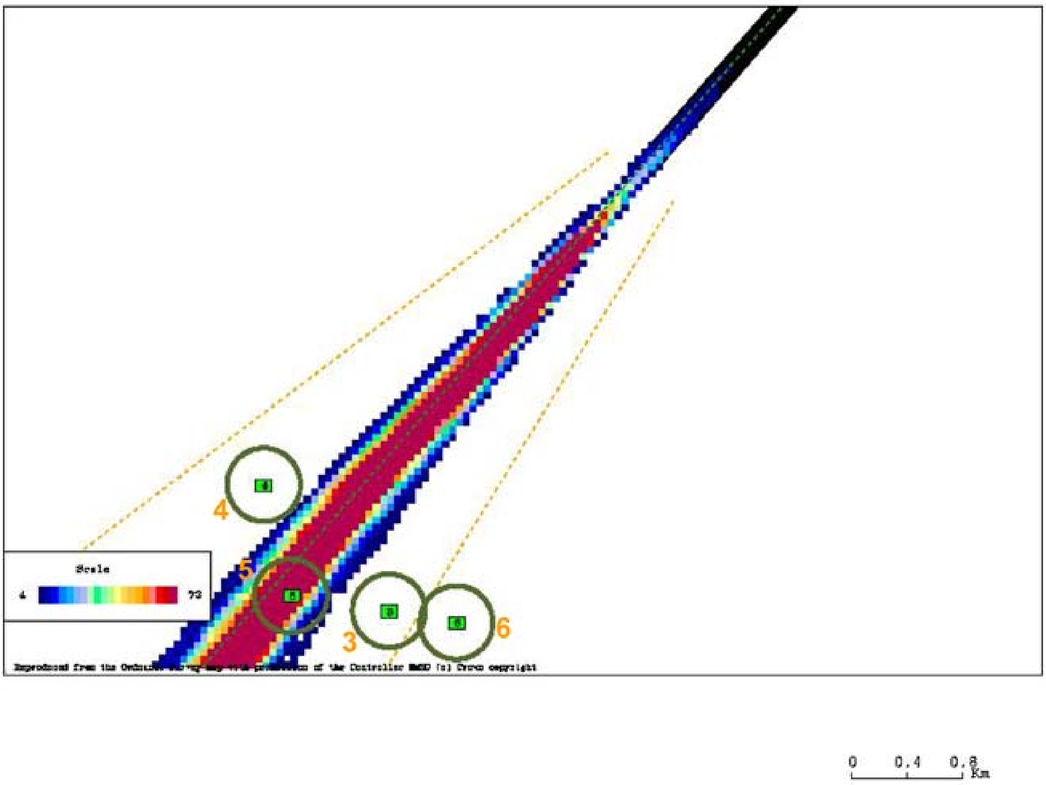


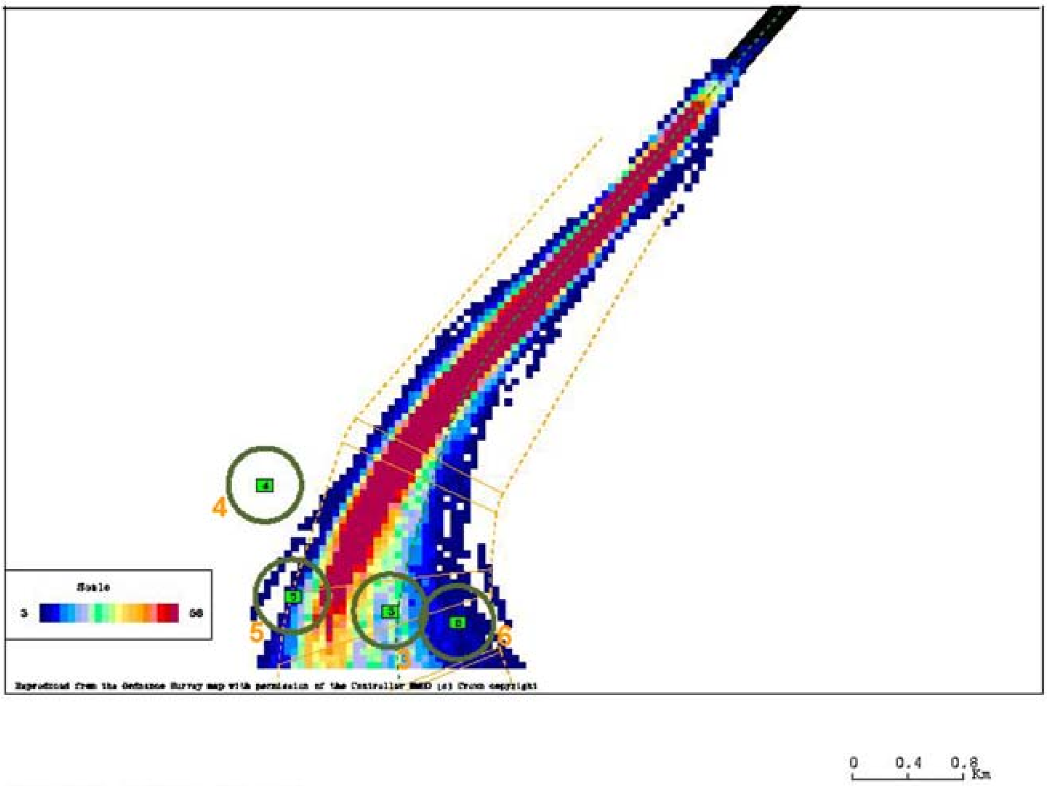
**FIGURE 21(c) TRACK DENSITY PLOT: STANSTED 05 CLN**



## FIGURE 22(a) TRACK DENSITY PLOT: STANSTED 23 BZD



## FIGURE 22(b) TRACK DENSITY PLOT: STANSTED 23 DVR



## FIGURE 22(c) TRACK DENSITY PLOT: STANSTED 23 CLN

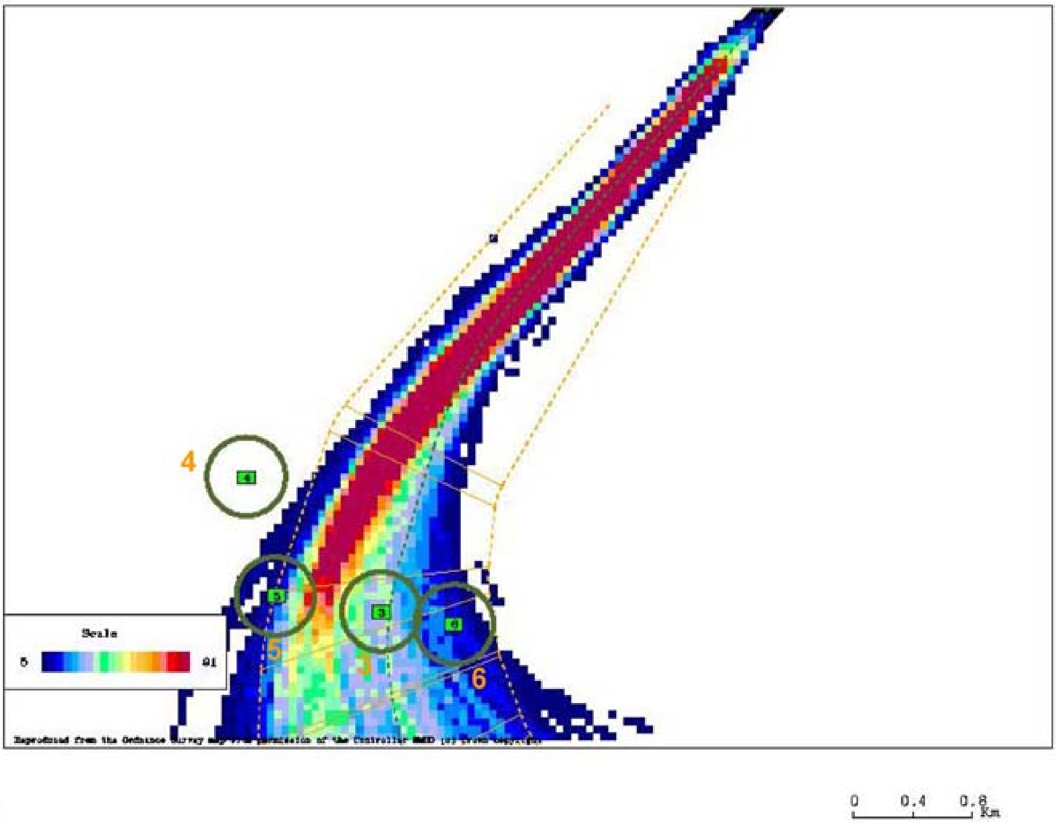


**FIGURE 23(a) TRACK DENSITY PLOT: HEATHROW 09R DVR/CPT/MID/SAM**

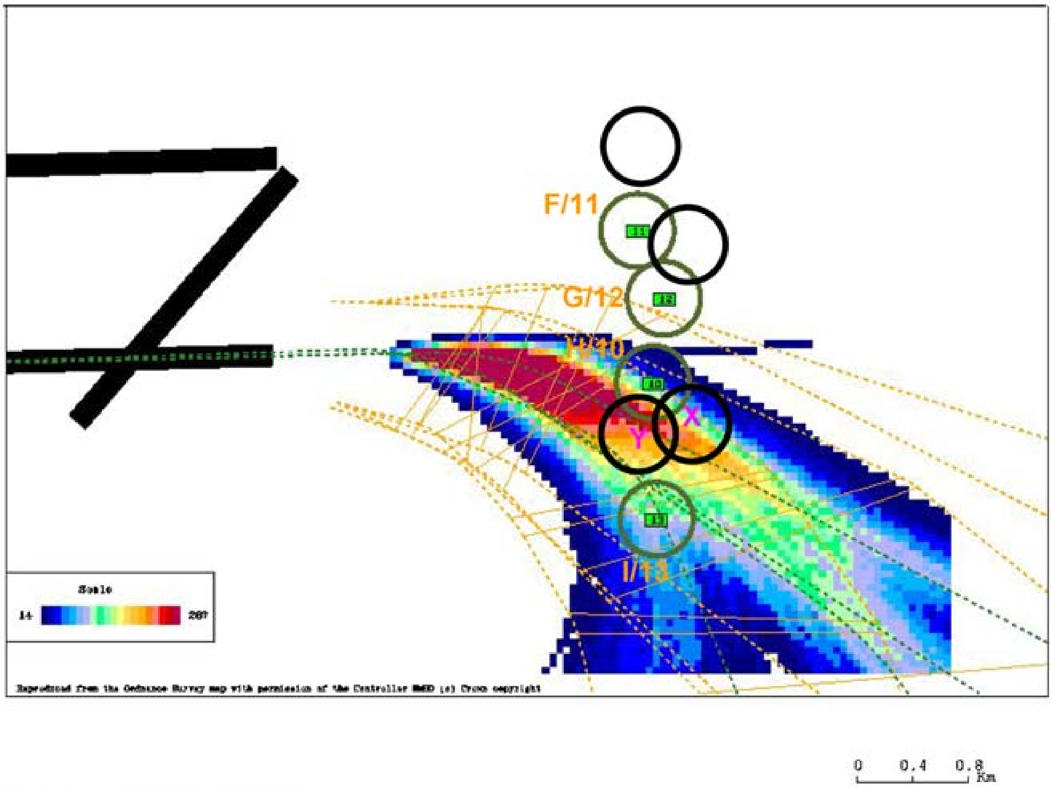


**FIGURE 23(b) TRACK DENSITY PLOT: HEATHROW 09R BPK/BUZ**

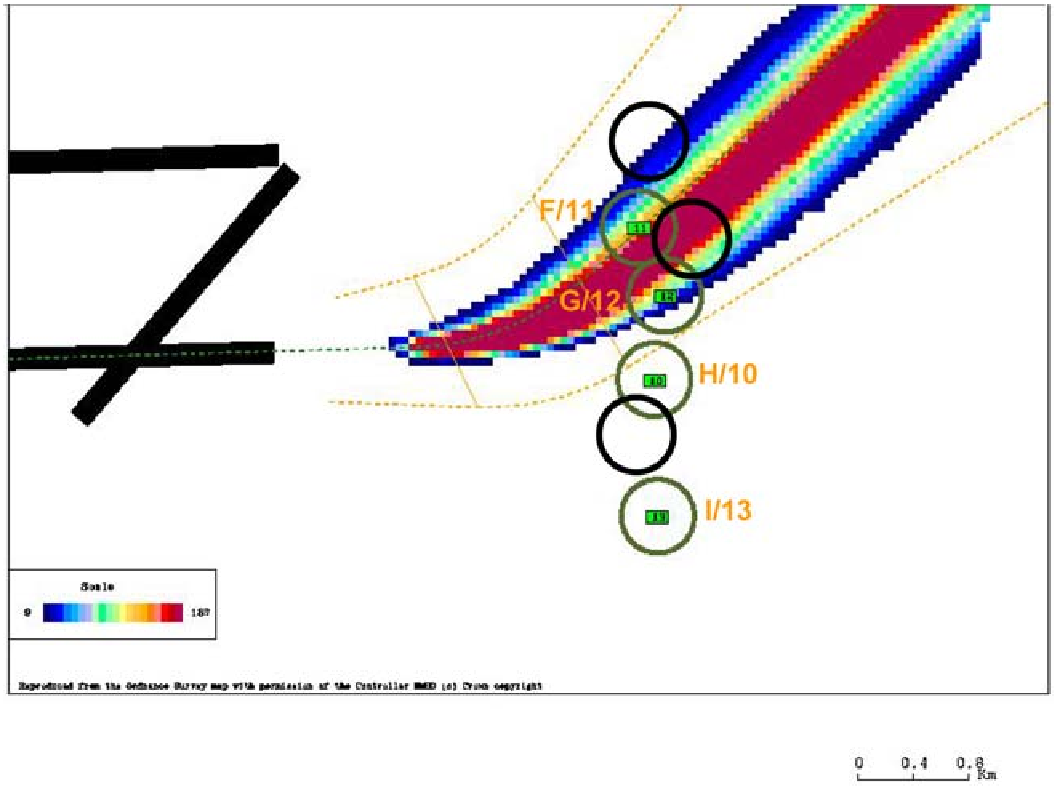


FIGURE 24(a) TRACK DENSITY PLOT: HEATHROW 27R DVR/CPT/MID/SAM

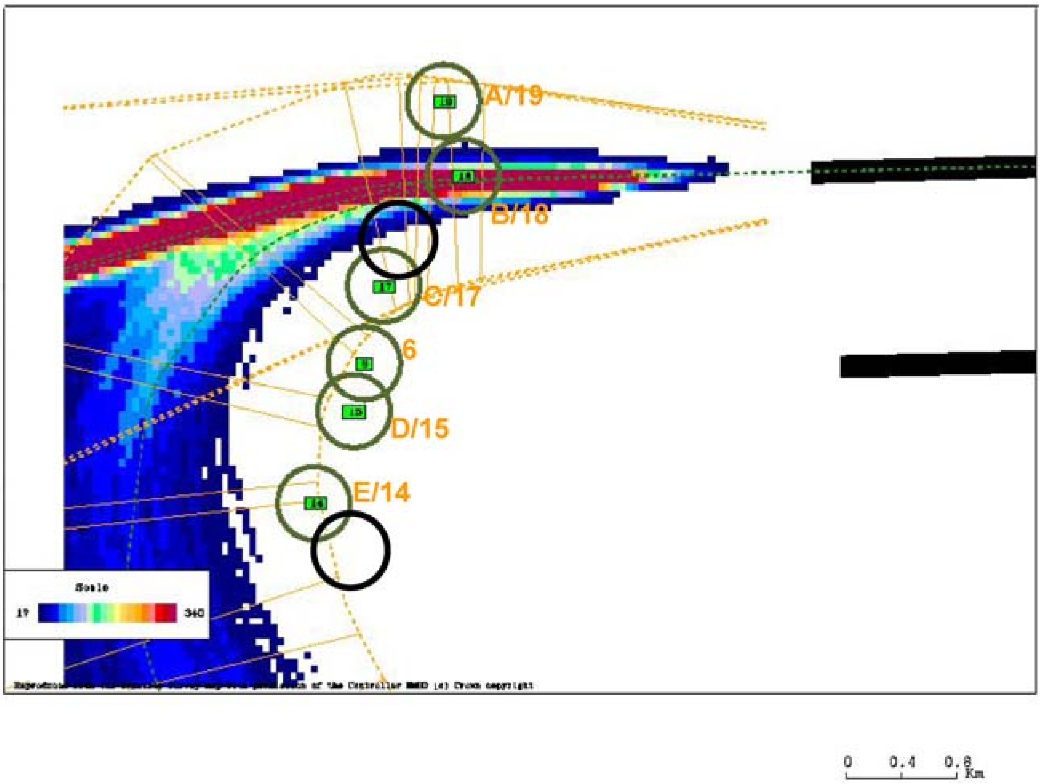
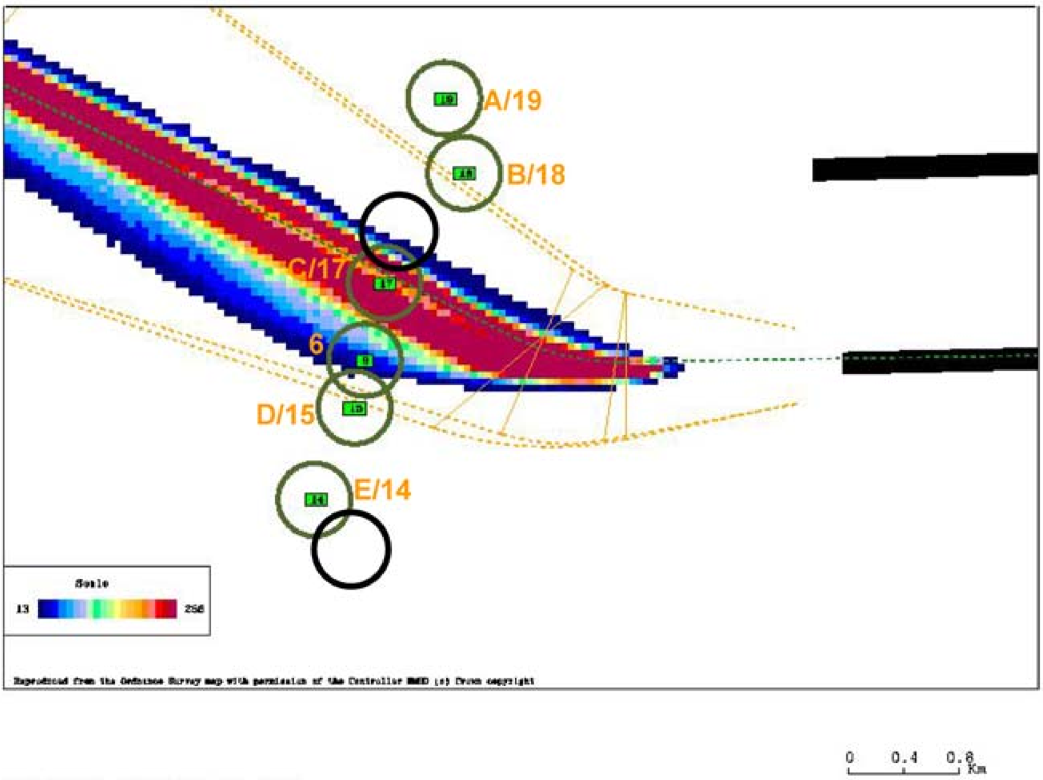
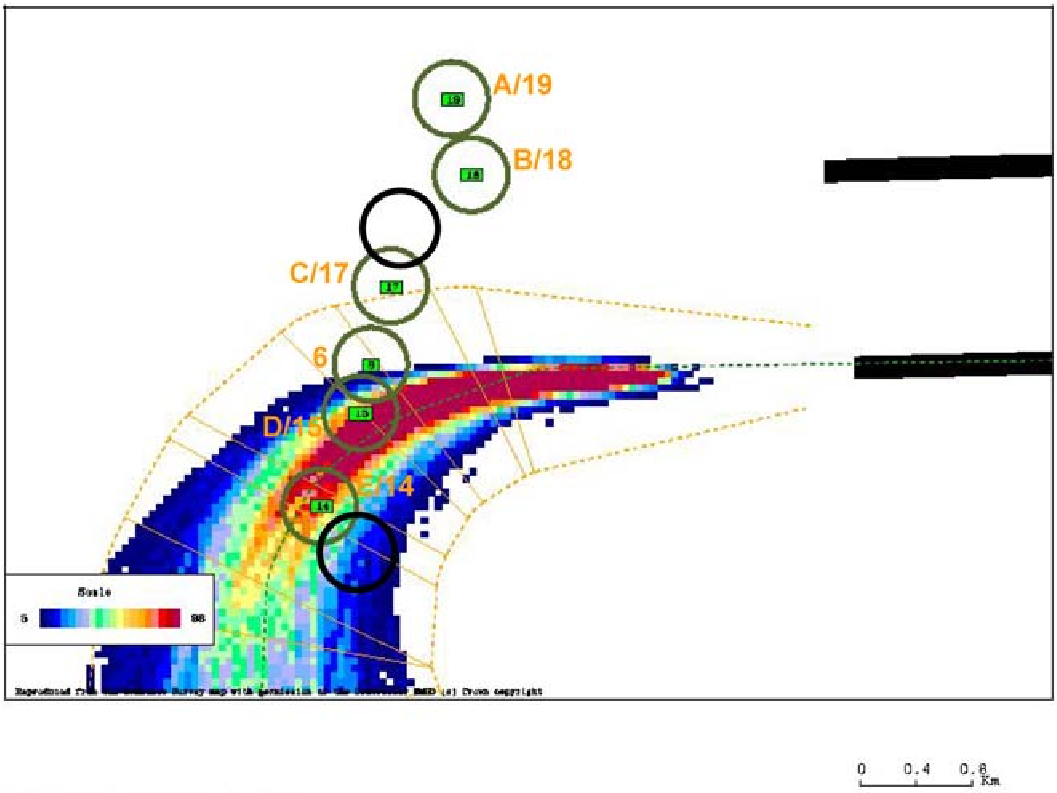


FIGURE 24(b) TRACK DENSITY PLOT: HEATHROW 27L WOB/BPK



## FIGURE 25 TRACK DENSITY PLOT: HEATHROW 27L DVR



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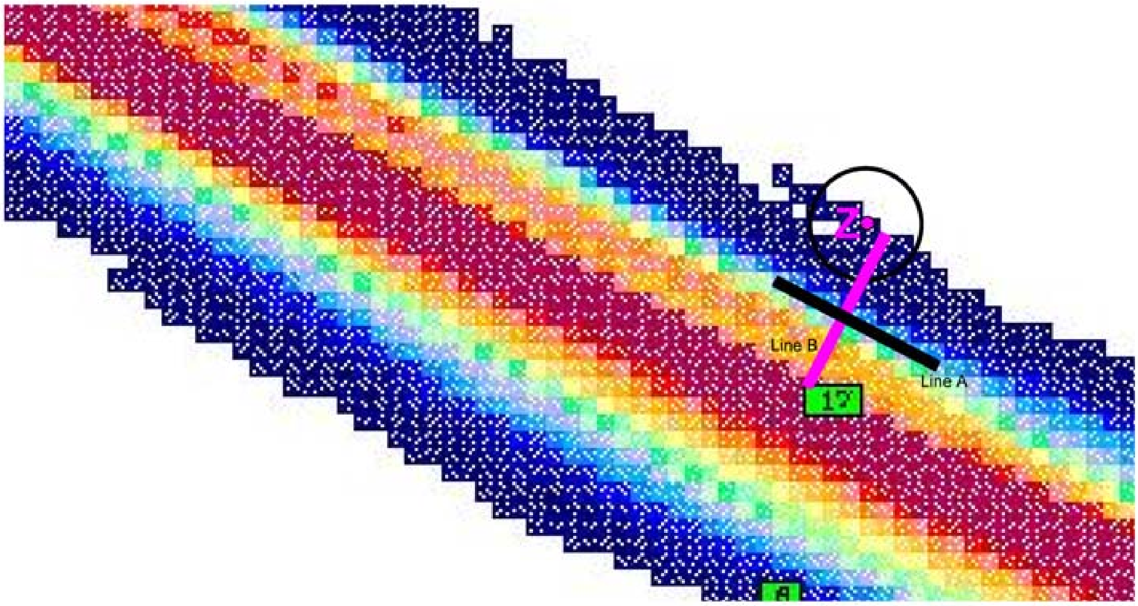
## FIGURE 26 TRACK DENSITY PLOTS: METHOD OF QUANTIFYING ARRAY IMPROVEMENT BENEFIT



**Example: to determine the percentage of flights that are closer to a proposed new monitor location "Z" than to the existing monitor 17.**

Step 1

▬ Draw line "A", in the direction of the NPR centreline, midway between the monitors being compared.

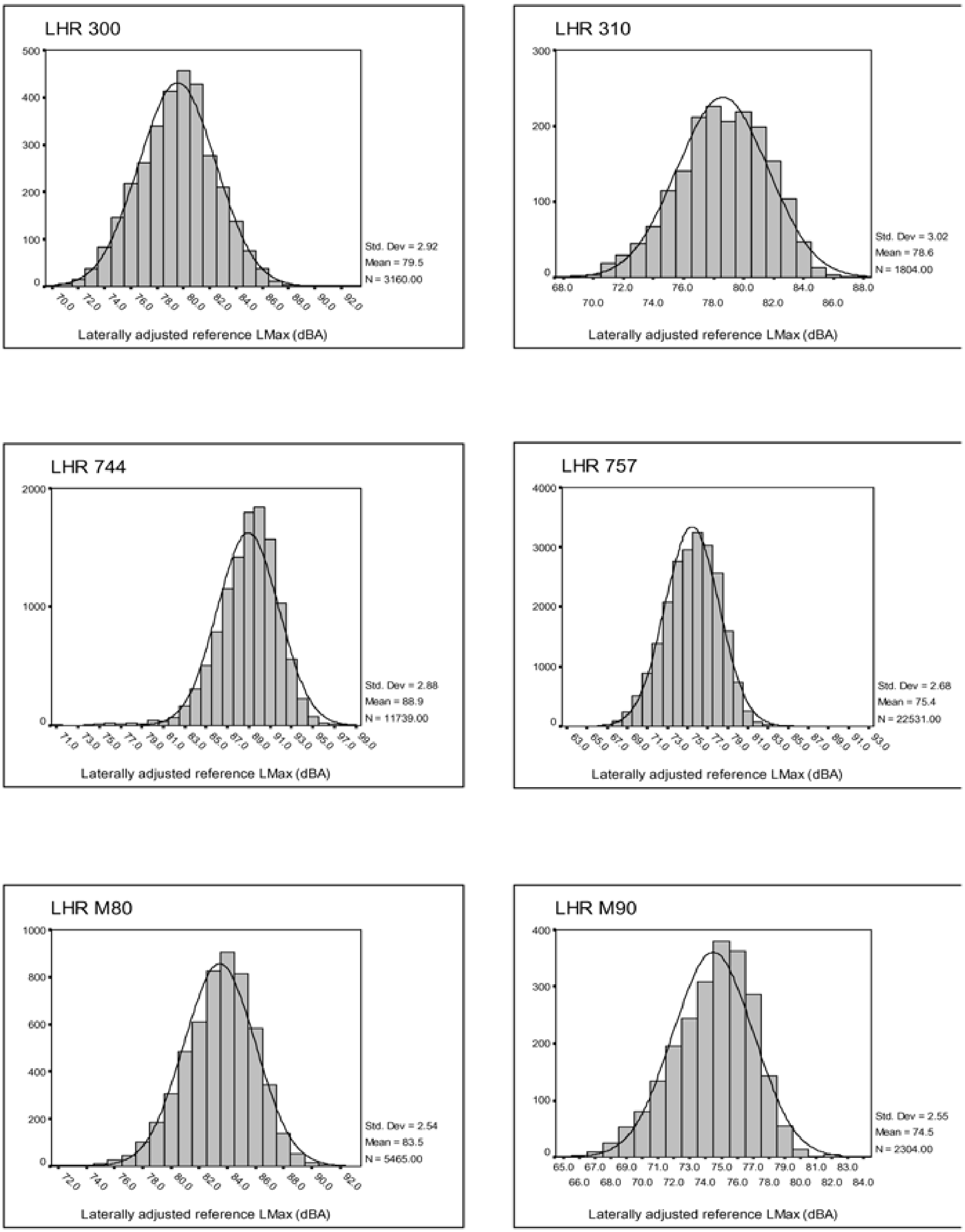
Step 2

▬ Draw Line "B", perpendicular to line "A", midway between the monitors being compared.

Step 3

Summate the density percentage values for each cell along each half of Line "B" (see key Figure 19). Gives the percentage of flights passing between 17 and Z that are (i) closer to 17, or (ii) closer to Z.

**FIGURE 27(a) Sample Distributions of Laterally Adjusted Reference Levels for Heathrow Types**



## FIGURE 27(b) Sample Distributions of Laterally Adjusted Reference Levels for Gatwick Types

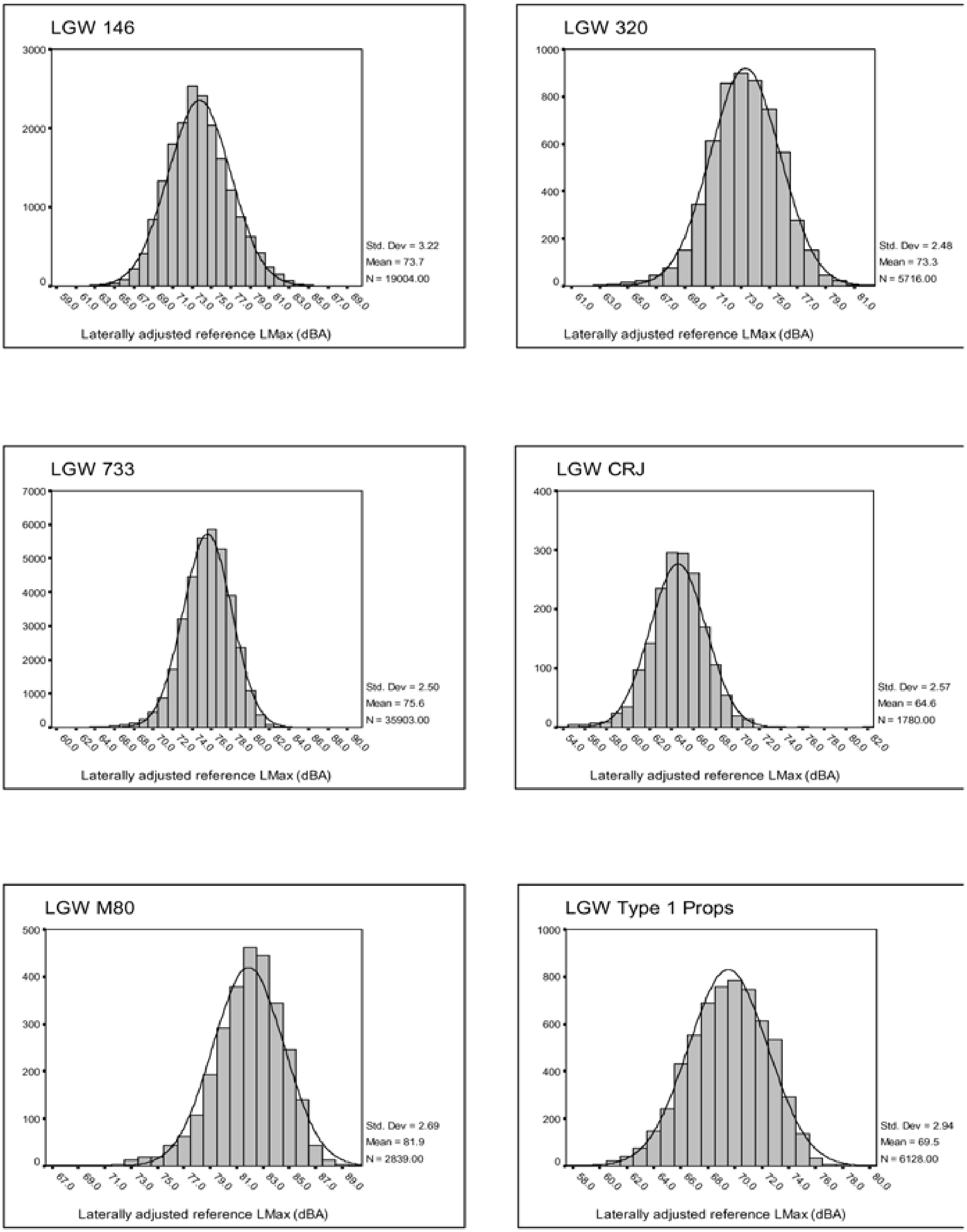


**FIGURE 27(c) Sample Distributions of Laterally Adjusted Reference Levels for Stansted Types**

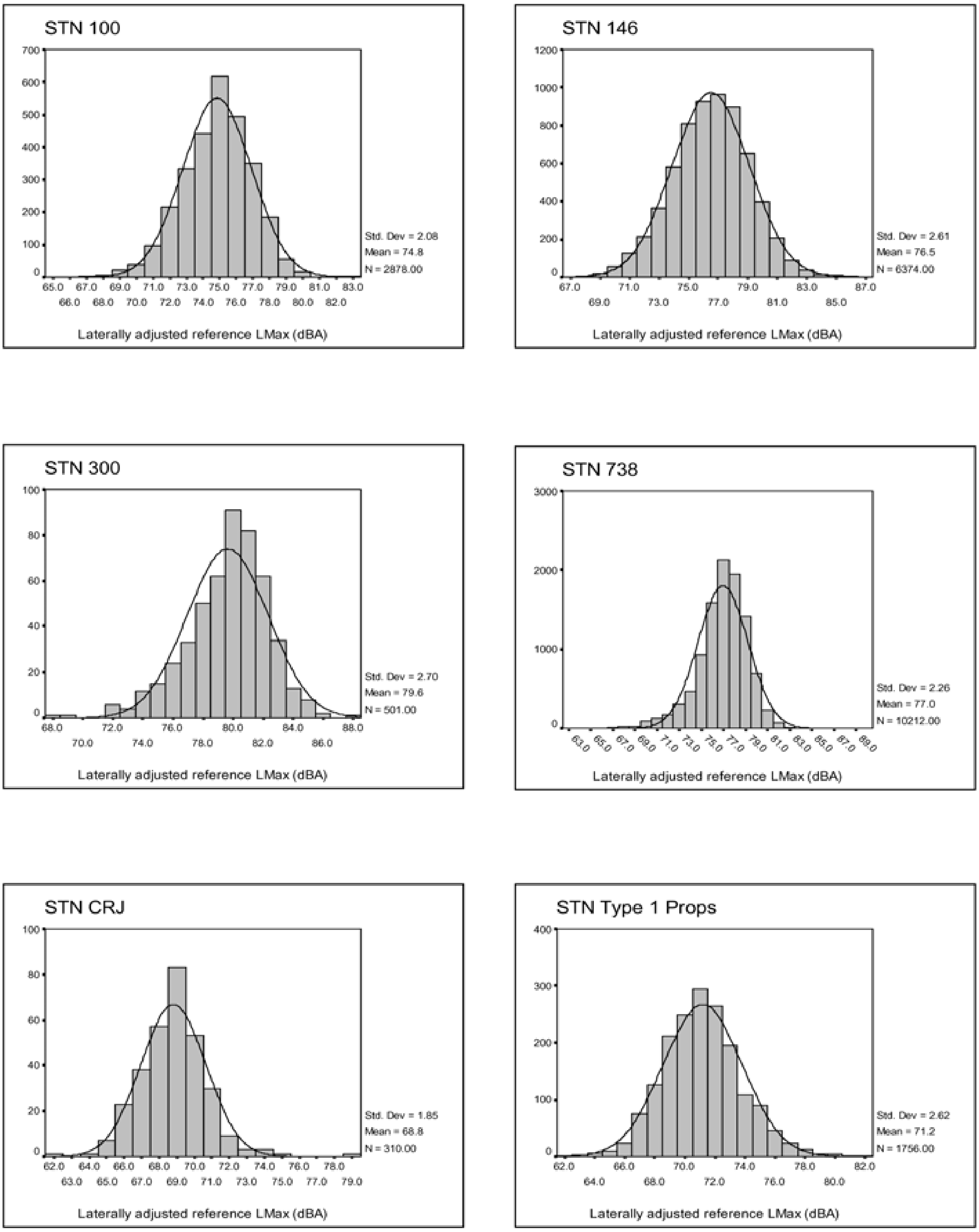
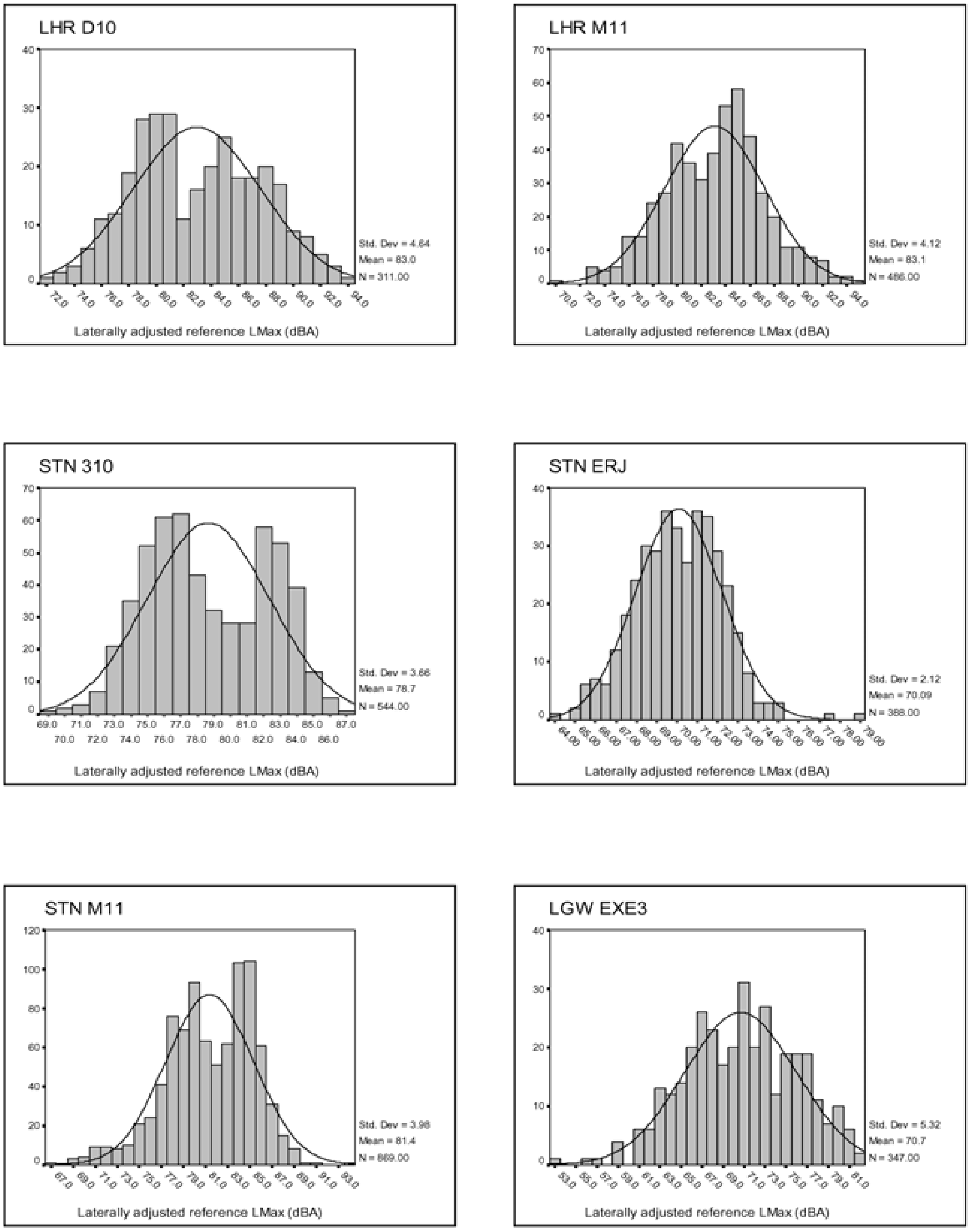


**FIGURE 27(d) Sample of Non-normal Distributions of Laterally Adjusted Reference Levels**



## FIGURE 27(e) Sample of Non-normal Distributions of Laterally Adjusted Reference Levels

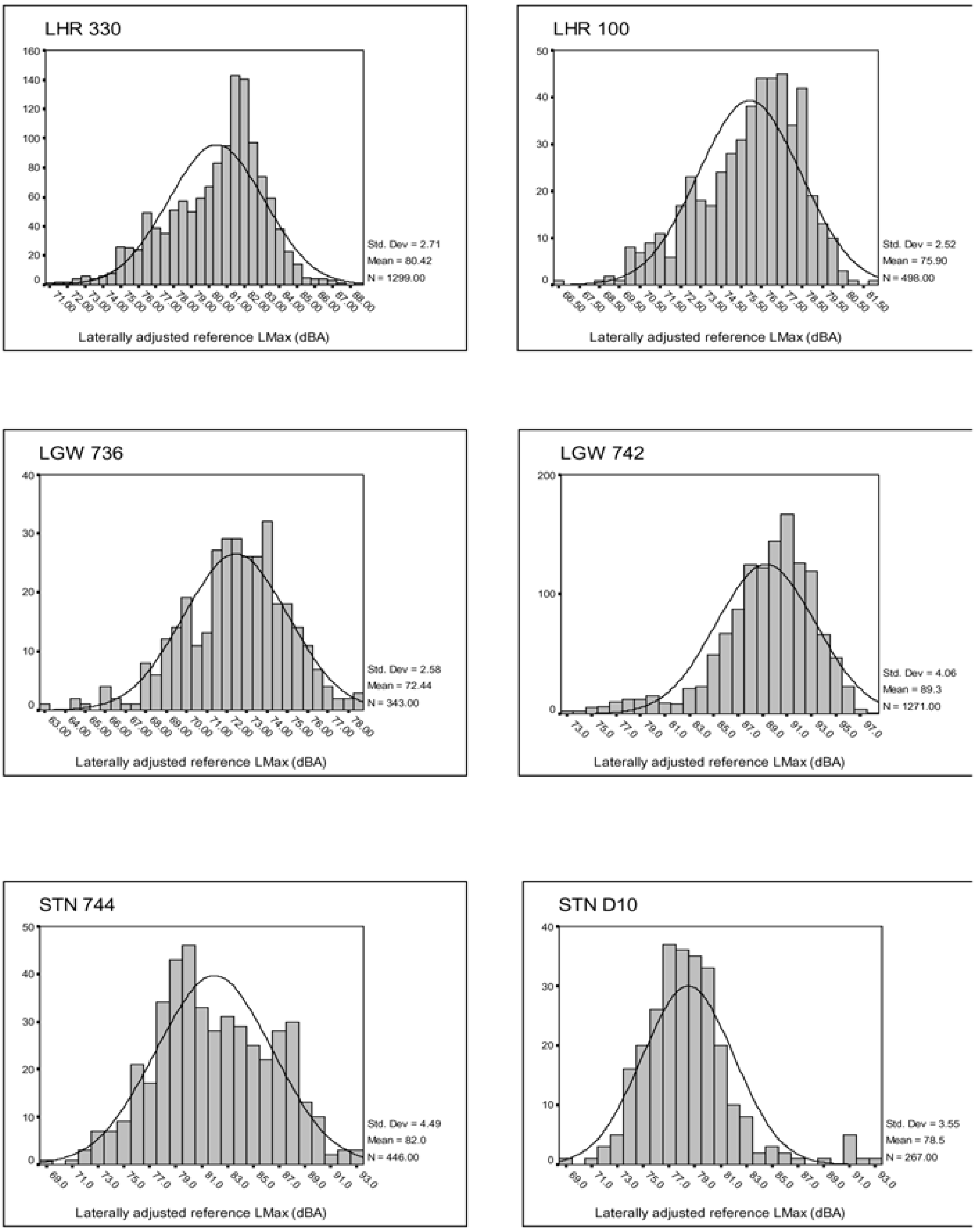


**FIGURE 28 Sample sizes of laterally adjusted Reference levels**

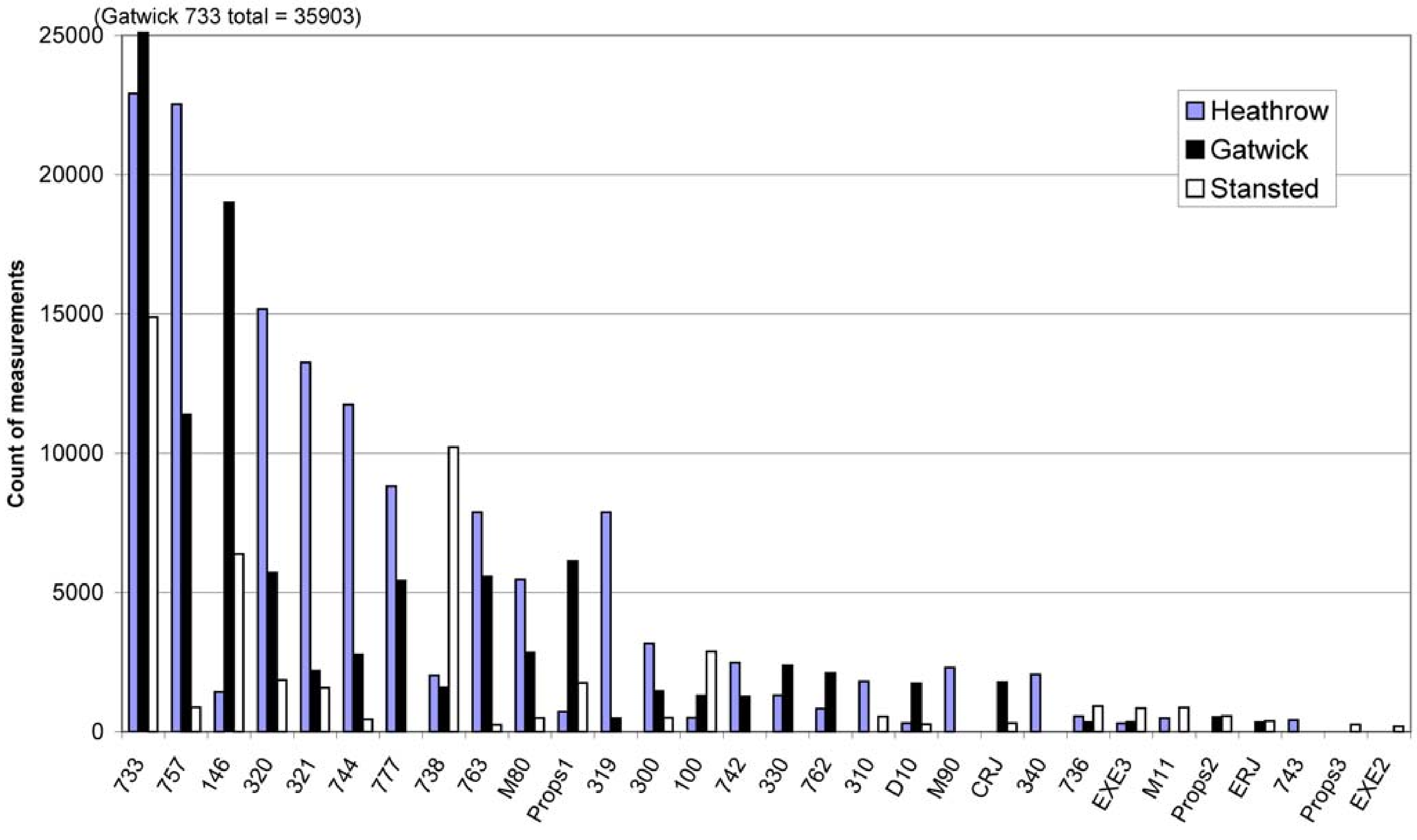


FIGURE 29 Laterally adjusted Reference levels at each airport for each aircraft type

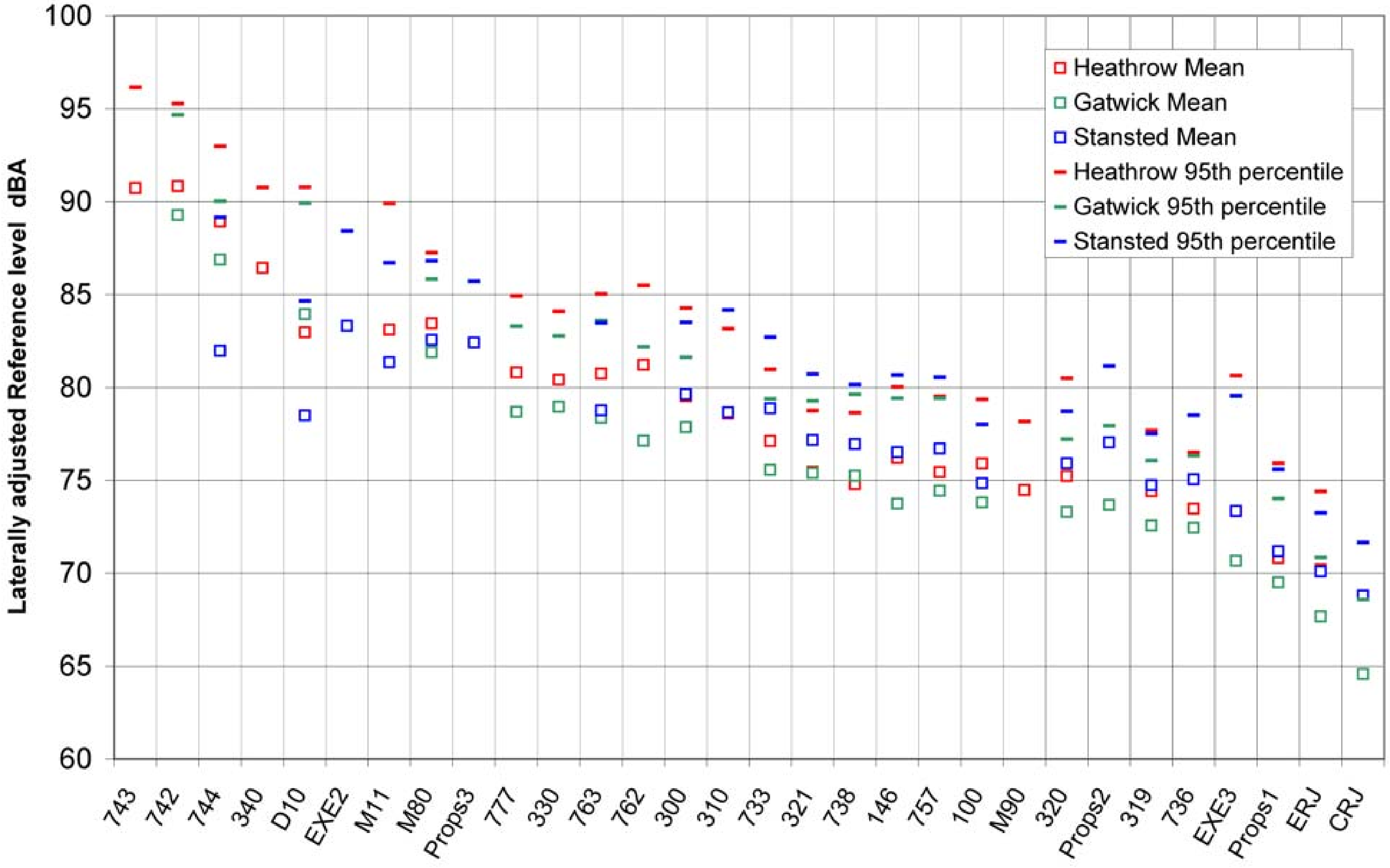


FIGURE 30(a) Effect of stage length on laterally adjusted Reference level: 744, individual flights

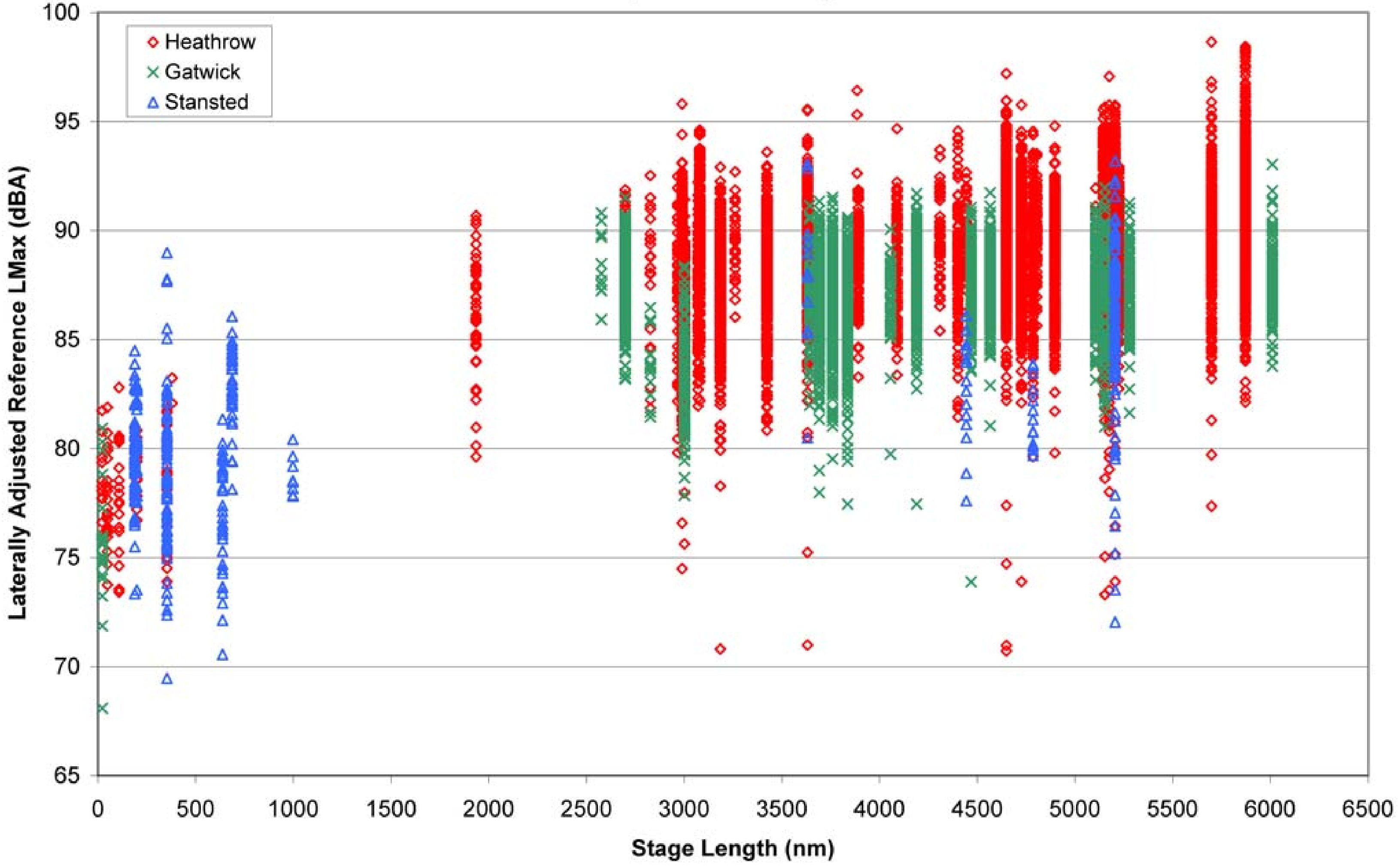
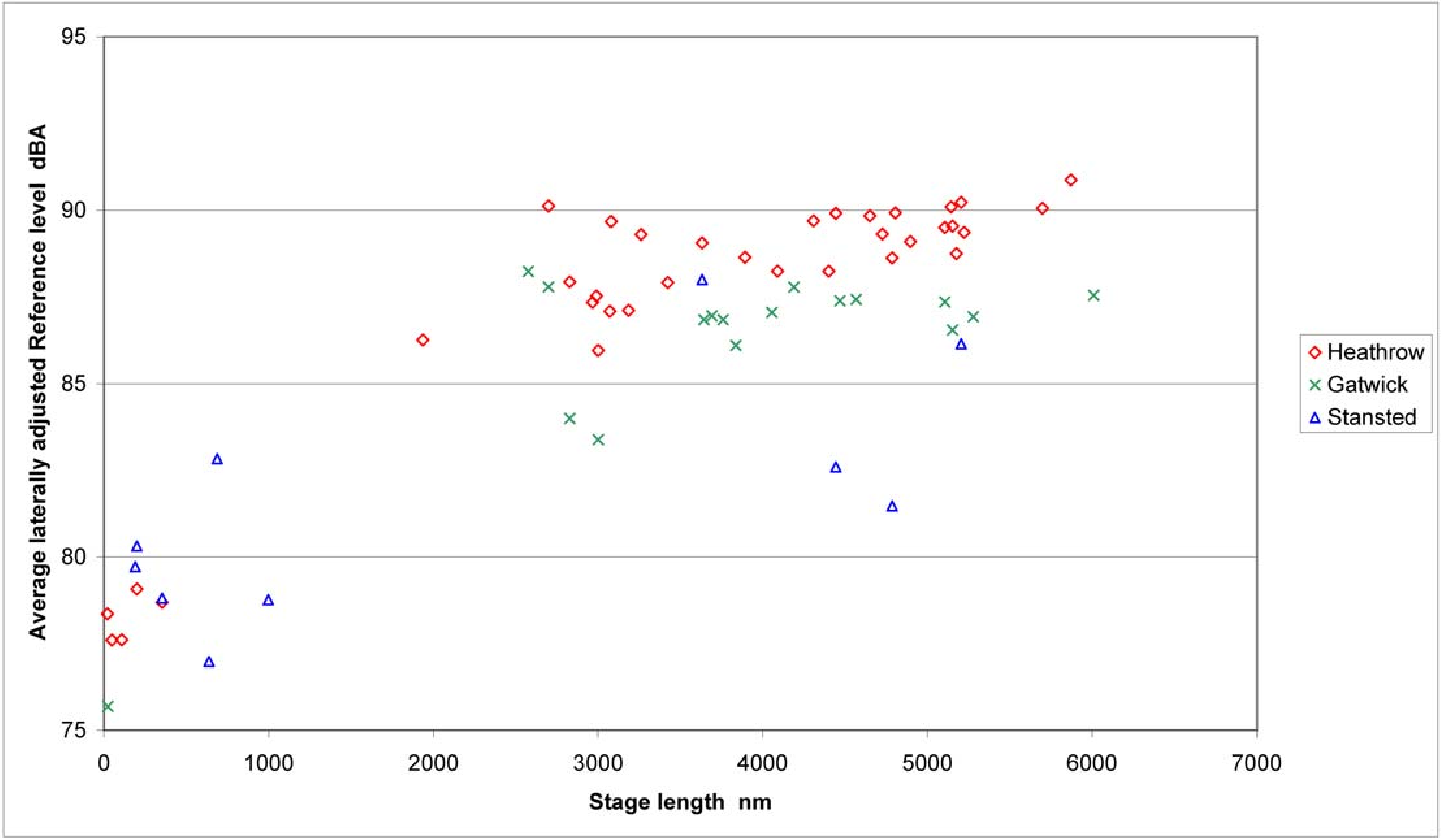


FIGURE 30(b) Effect of stage length on average laterally adjusted Reference level: 744



# FIGURE 31 Effect of Stage Length on Laterally Adjusted Reference Level: Heathrow

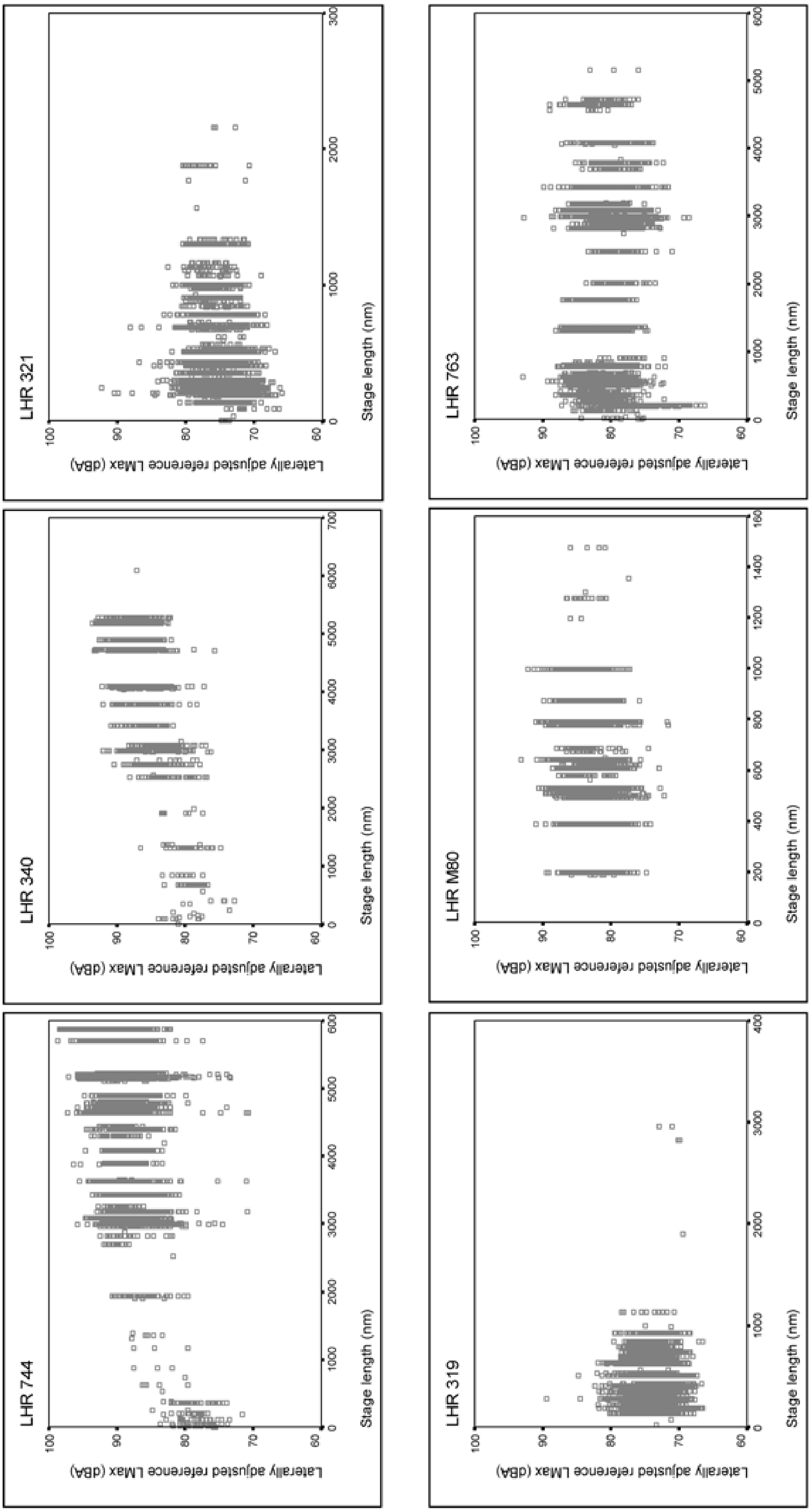


**FIGURE 32(a) Effect of airline on laterally adjusted Reference level: Heathrow 744**

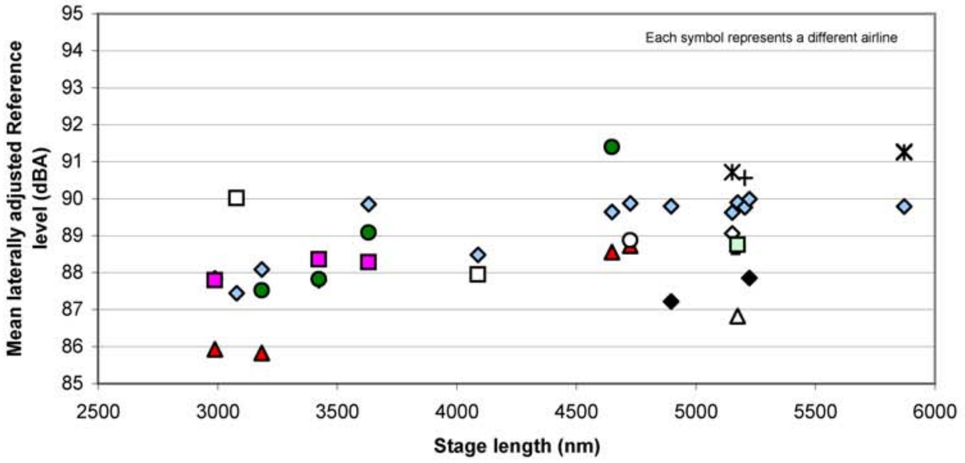


**FIGURE 32(b) Effect of airline on laterally adjusted Reference level: Heathrow 320**

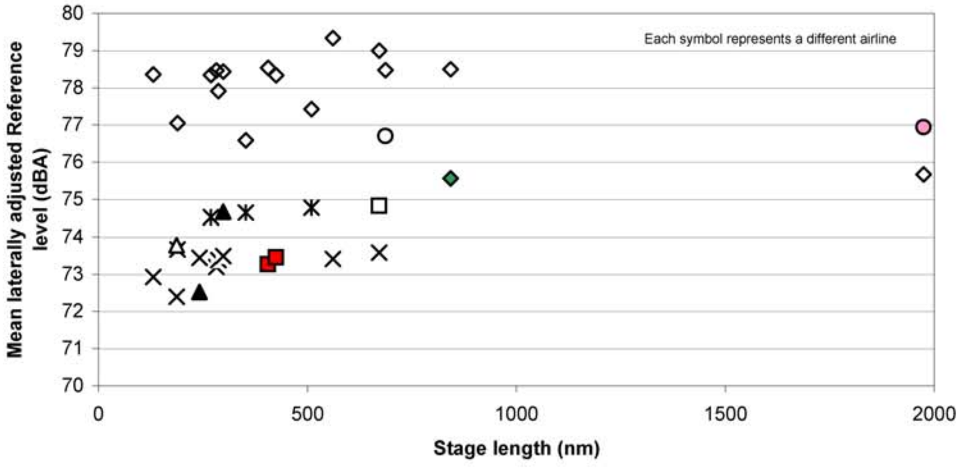
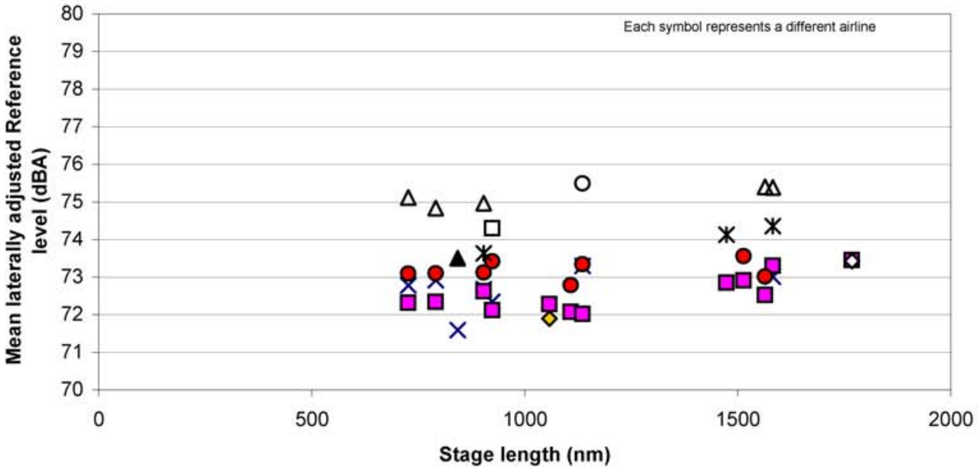
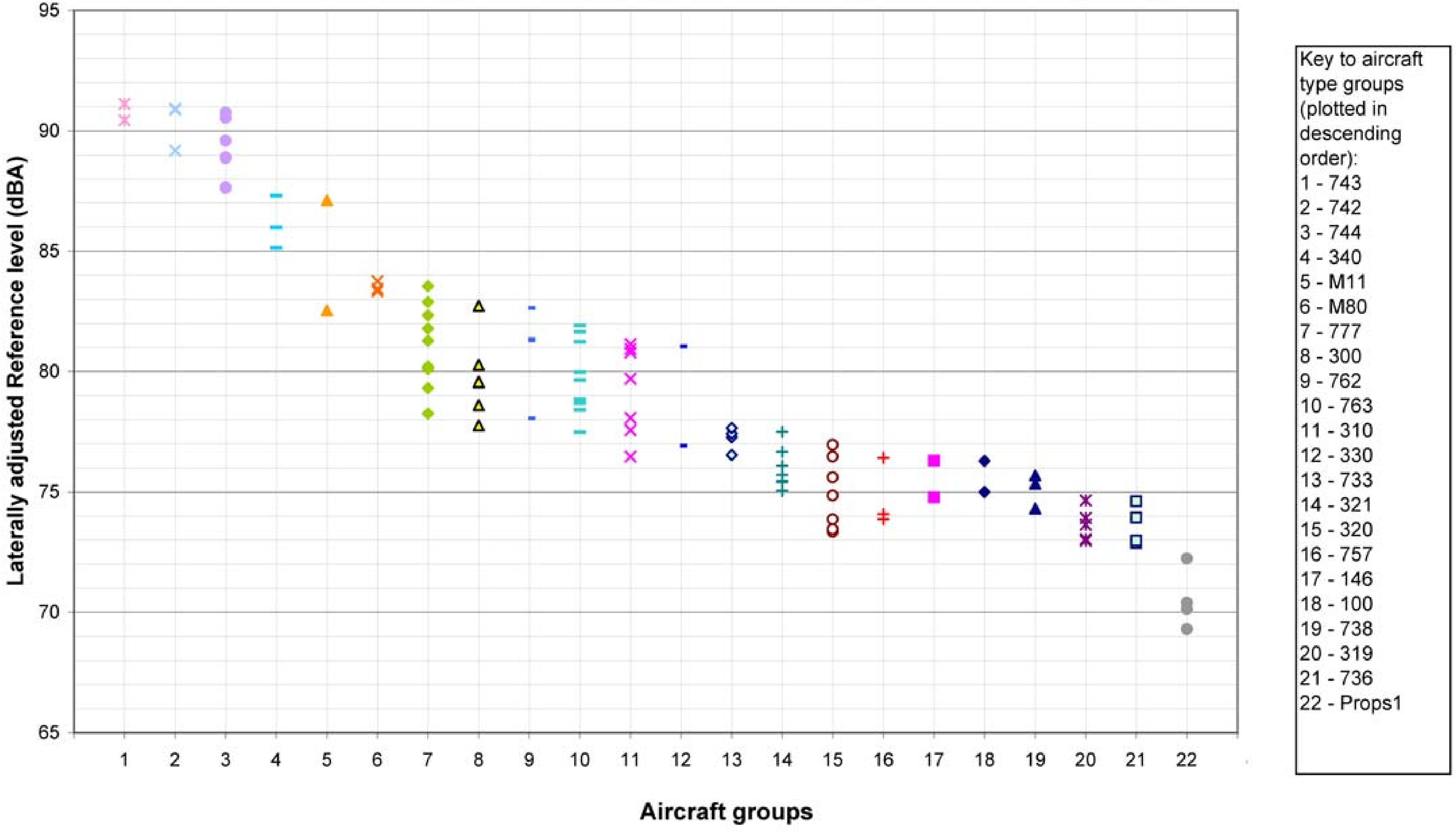


**FIGURE 32(c) Effect of airline on laterally adjusted Reference level: Gatwick 320**

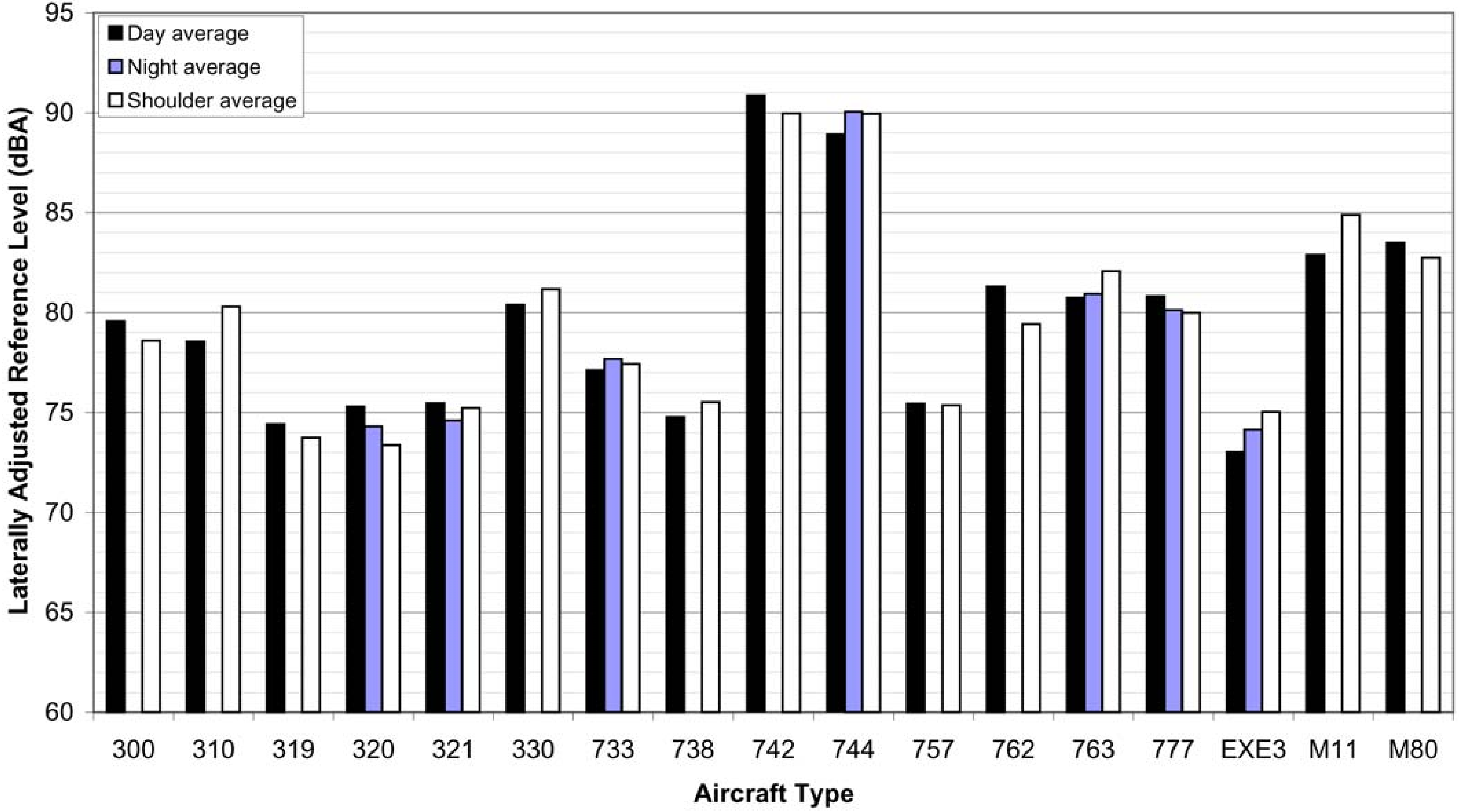


## FIGURE 33 Effect of engine type on mean laterally adjusted Reference level: Heathrow

Each point within a given aircraft type group represents the average level for a particular type of engine



## FIGURE 34 Comparison of Average Laterally Adjusted Reference Levels by Day, Night and Shoulder Period for Heathrow Types



## FIGURE 35 Comparison of Average Laterally Adjusted Reference Levels by Day, Night and Shoulder Period for Gatwick Types

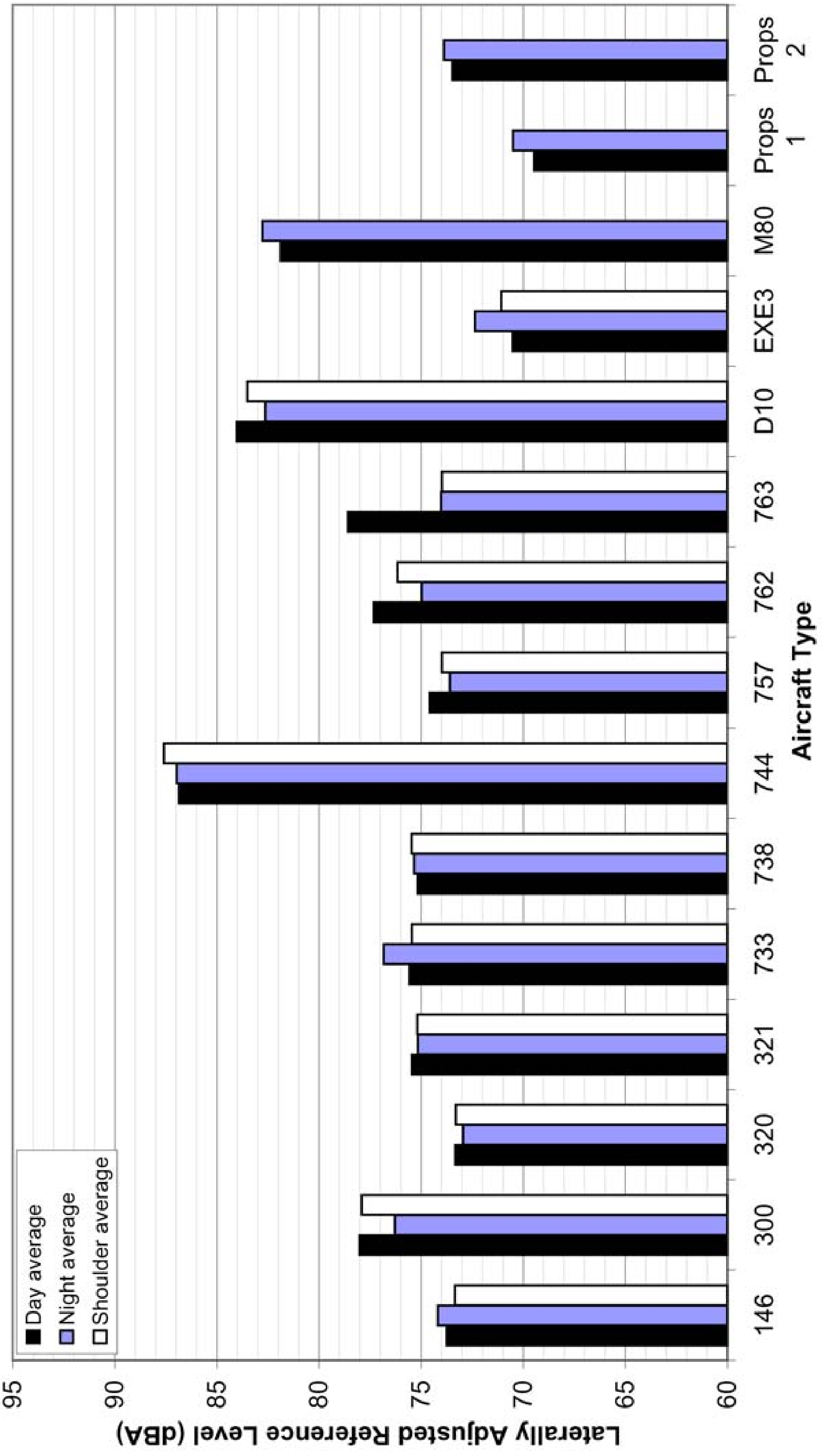


**FIGURE 36 Comparison of Average Laterally Adjusted Reference Levels by Day, Night and Shoulder Period for Stansted Types**

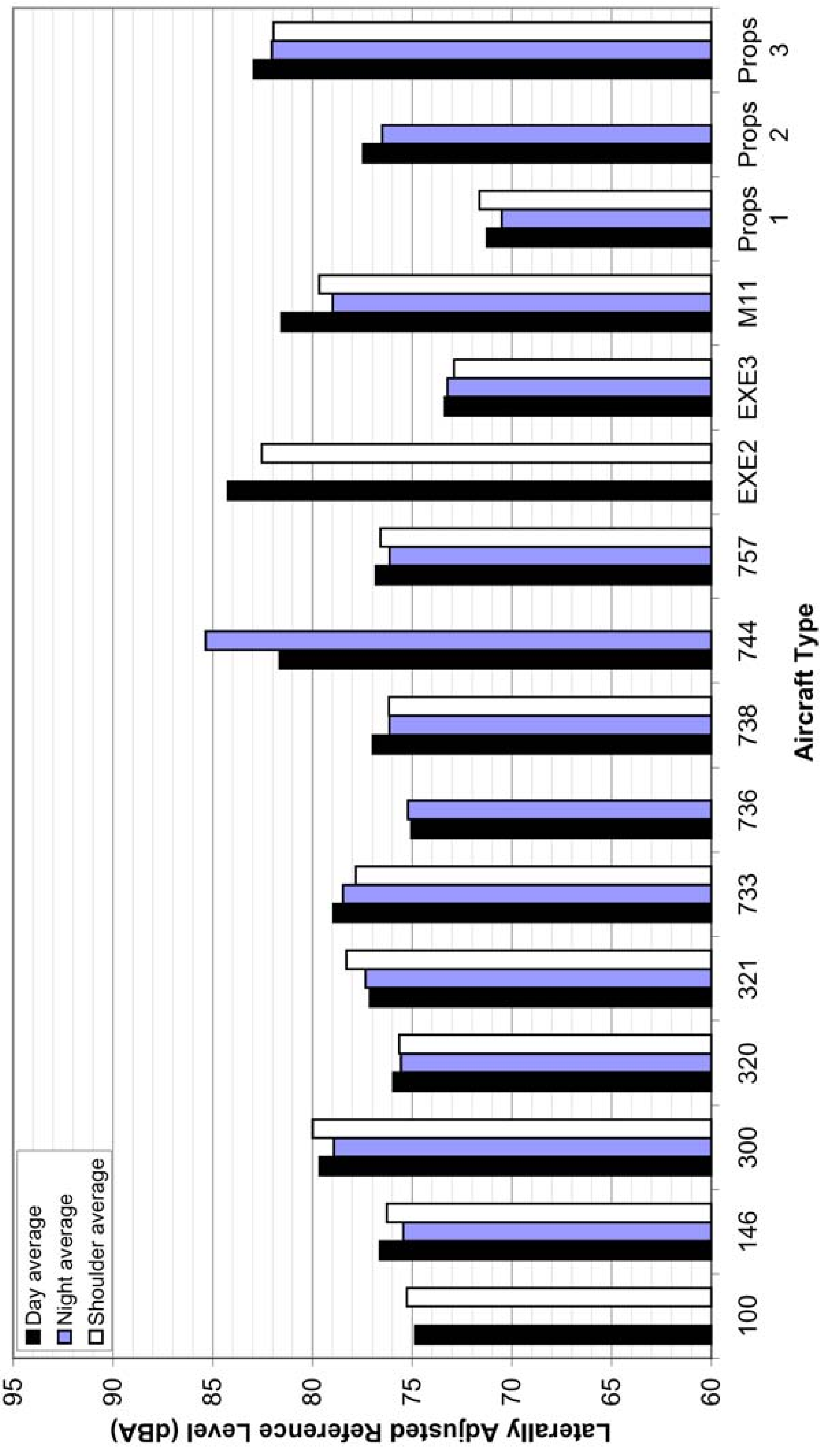


FIGURE 37 Sample of Laterally Adjusted Reference Level vs Temperature for Heathrow Types

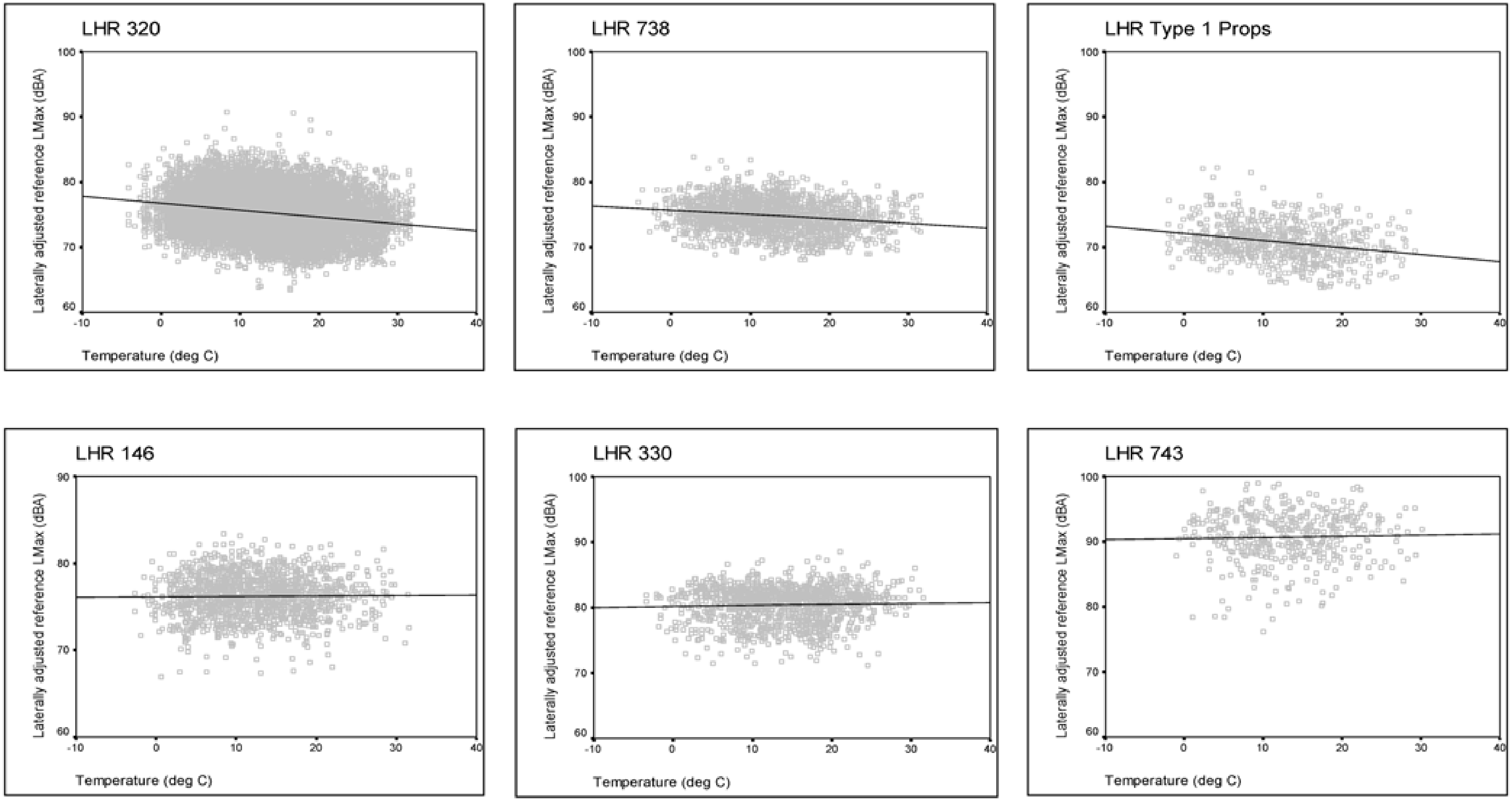
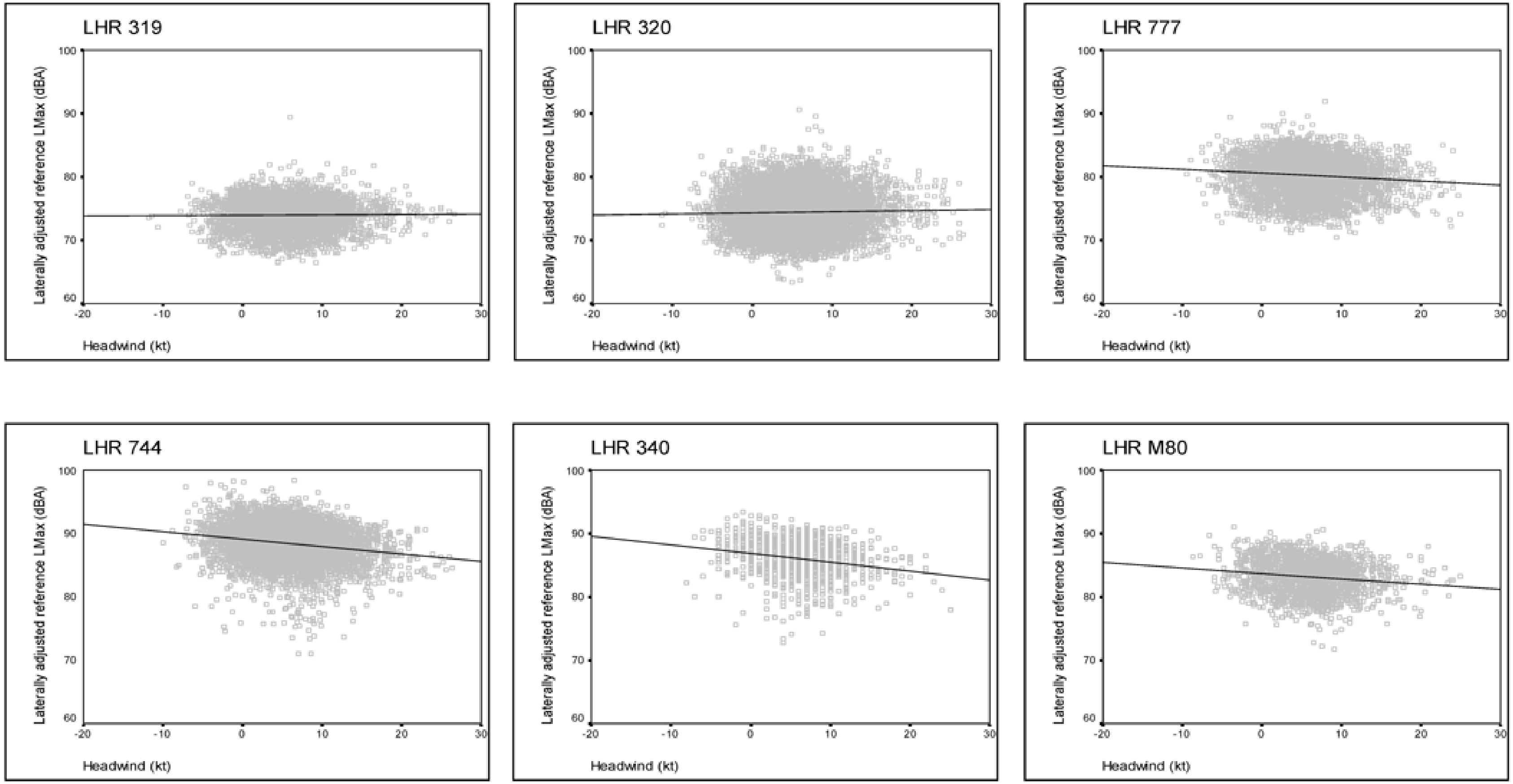
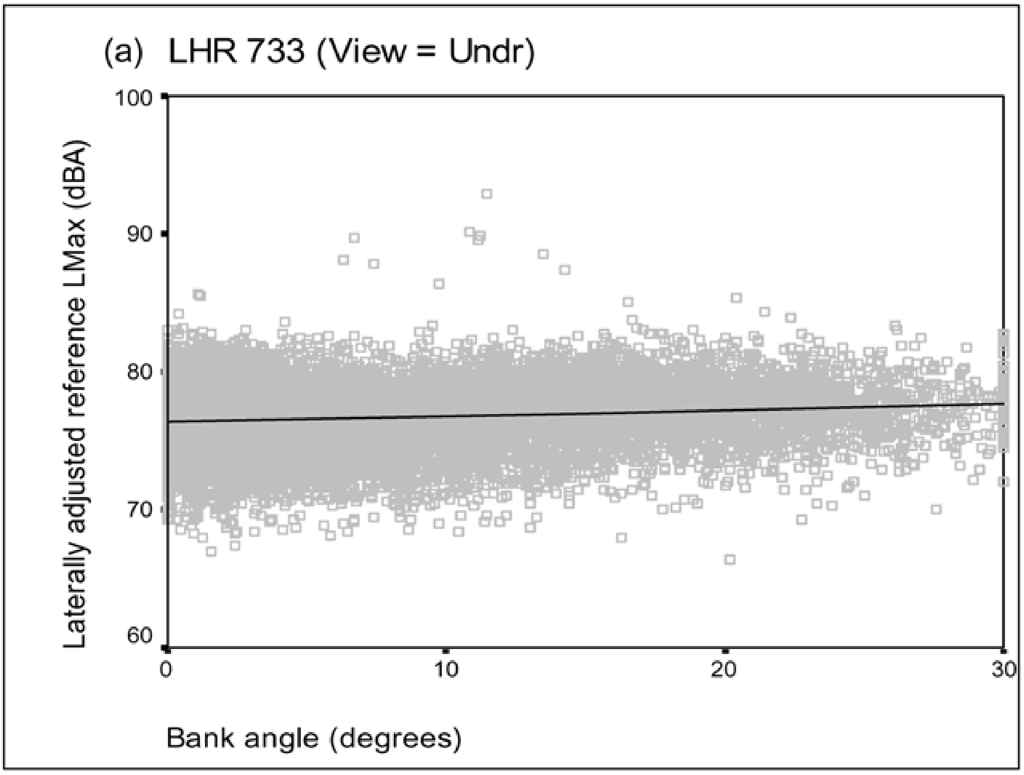
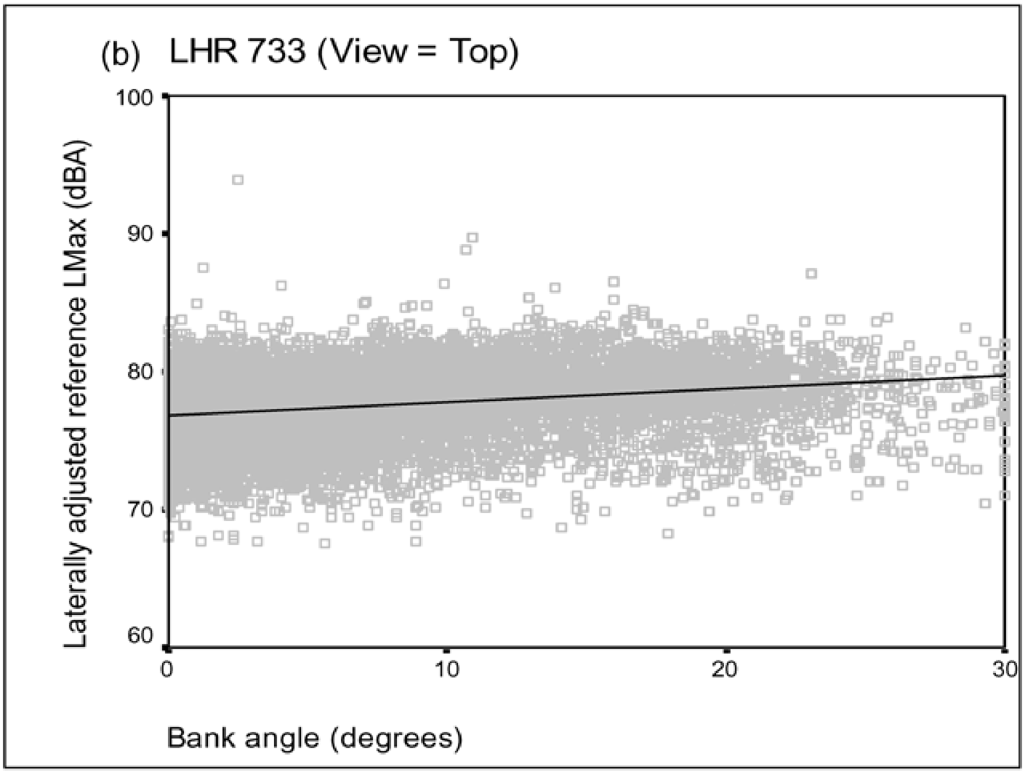


**FIGURE 38 Sample of Laterally Adjusted Reference Level vs Headwind for Heathrow**

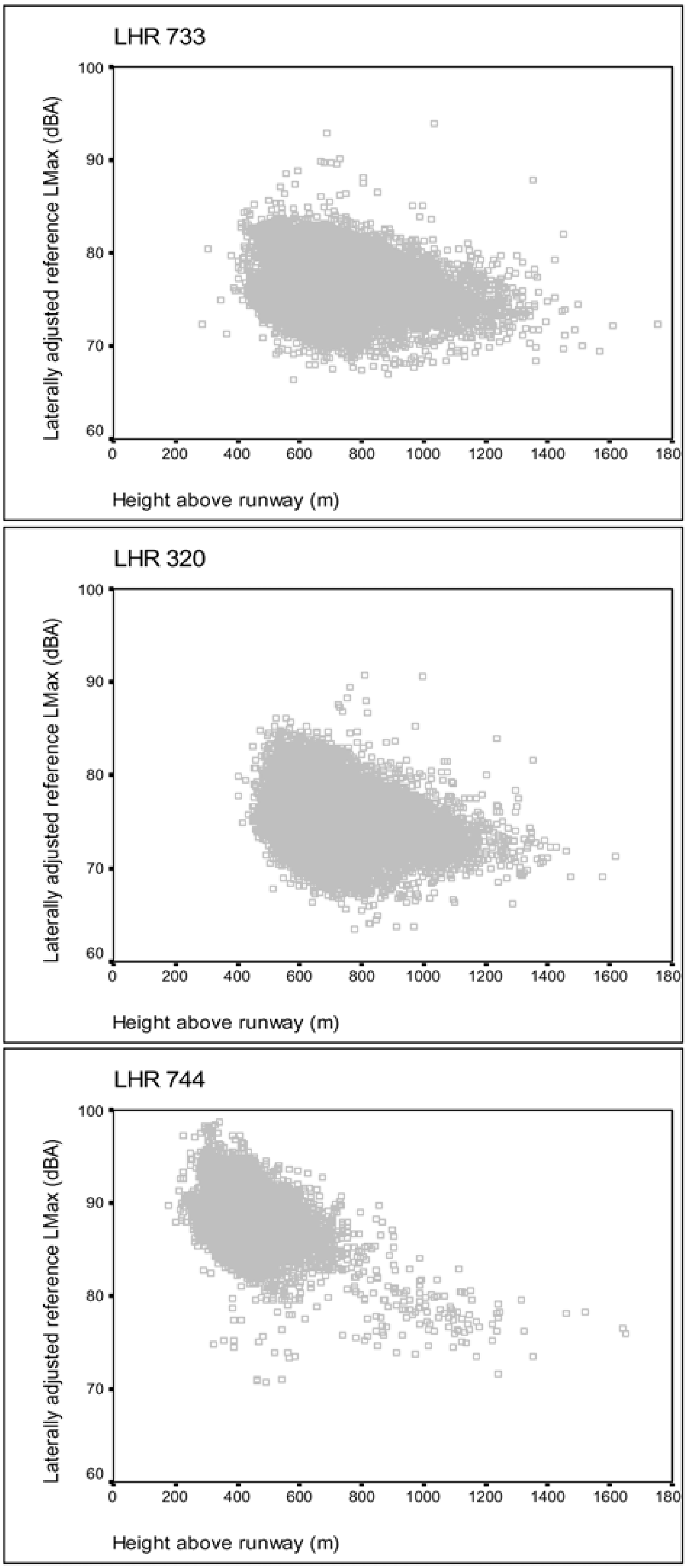


## FIGURE 39 Effect of bank angle on laterally adjusted Reference level





## FIGURE 40 Effect of height on laterally adjusted Reference level



## FIGURE 41 Effect of ground speed on laterally adjusted Reference levels

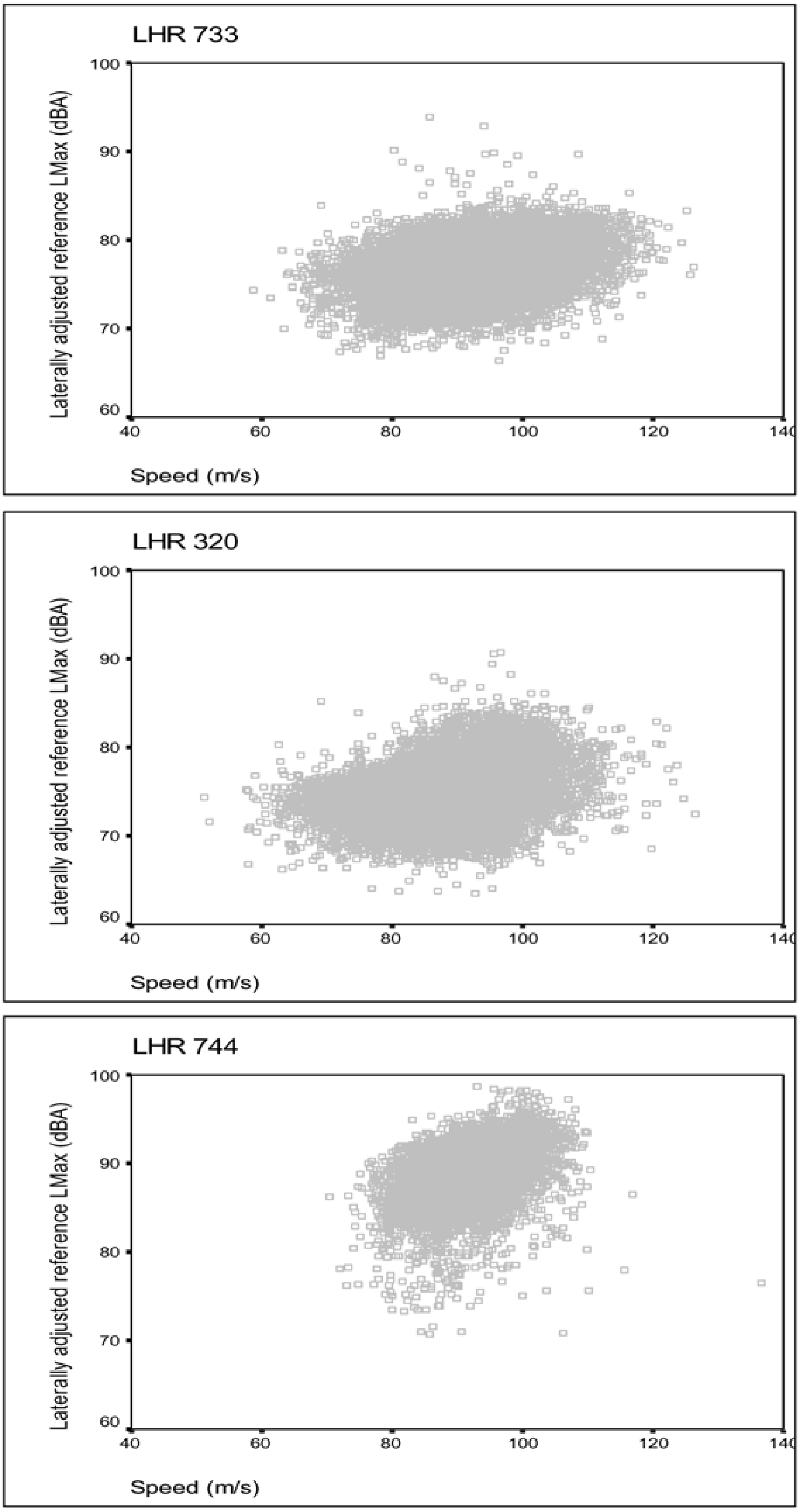


**FIGURE 42 Heathrow B747 Reference level: 1998 to 2002**

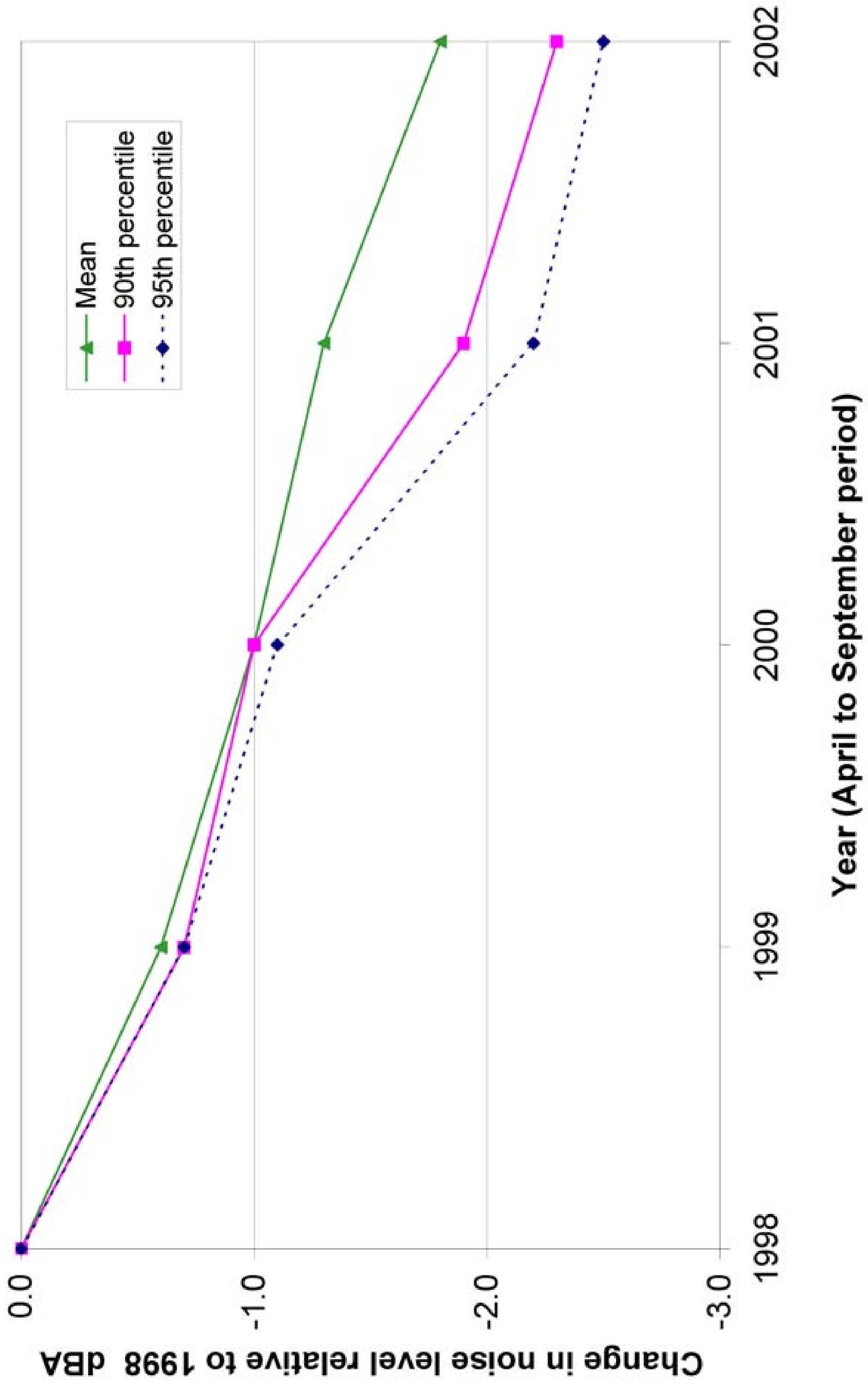


**FIGURE 43(a) Cumulative Reference level distributions: 744**

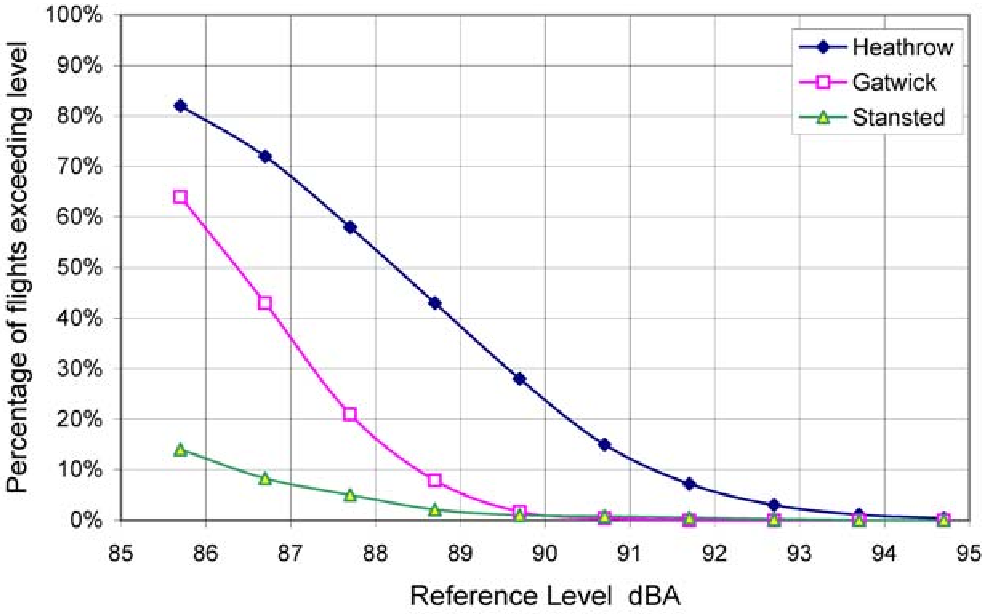
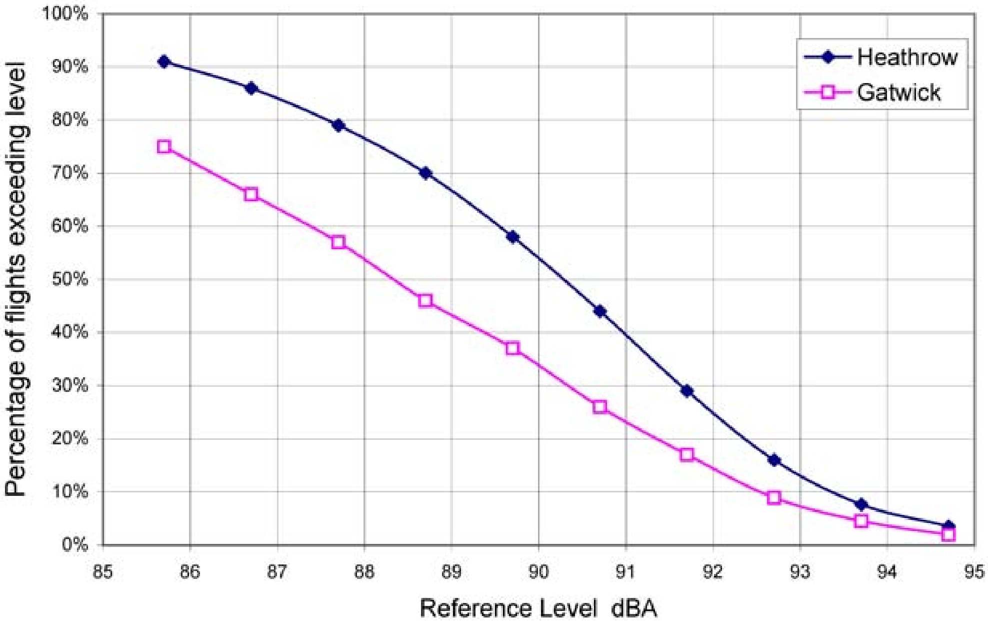
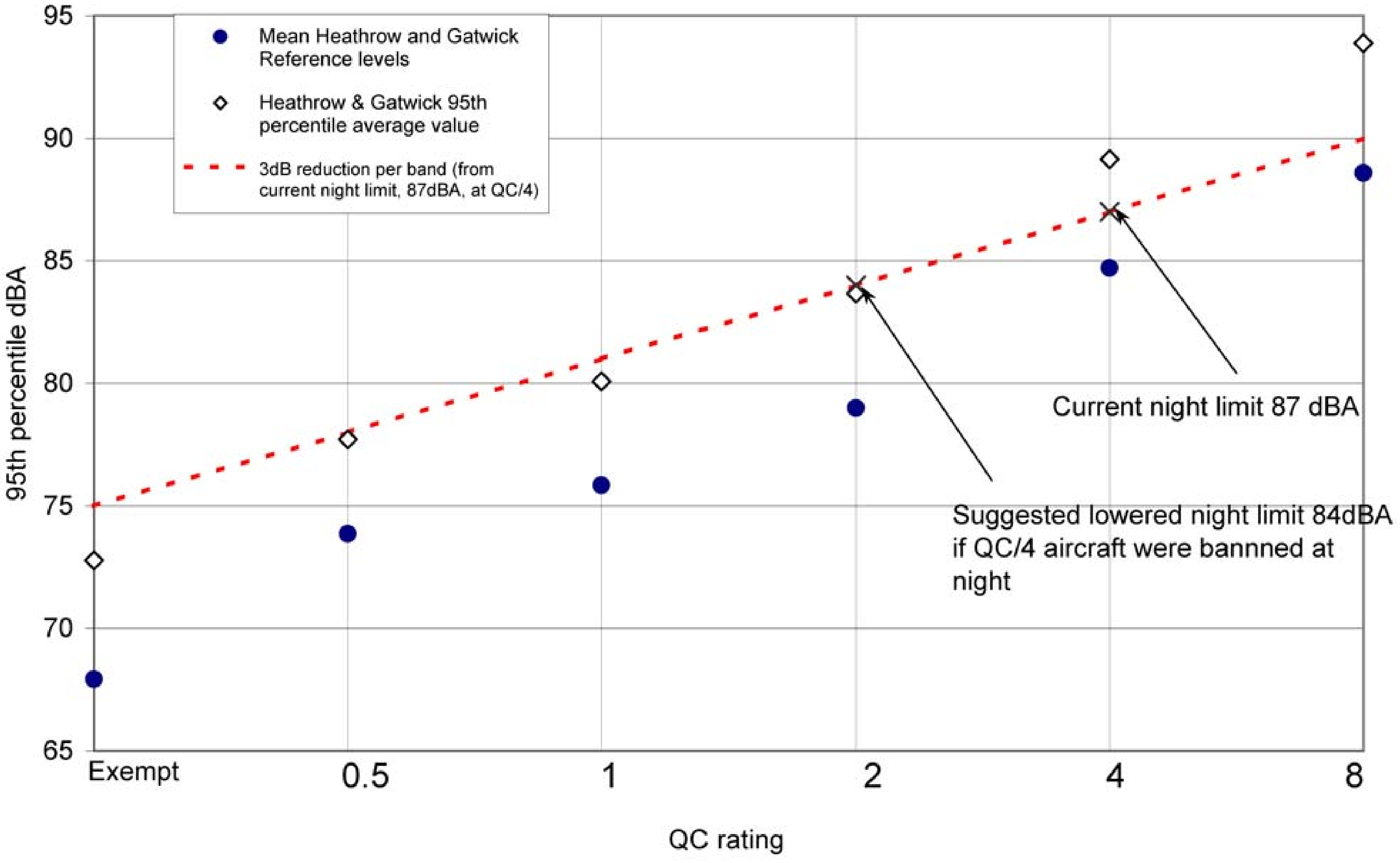


**FIGURE 43(b) Cumulative Reference level distributions: 742Ch3**

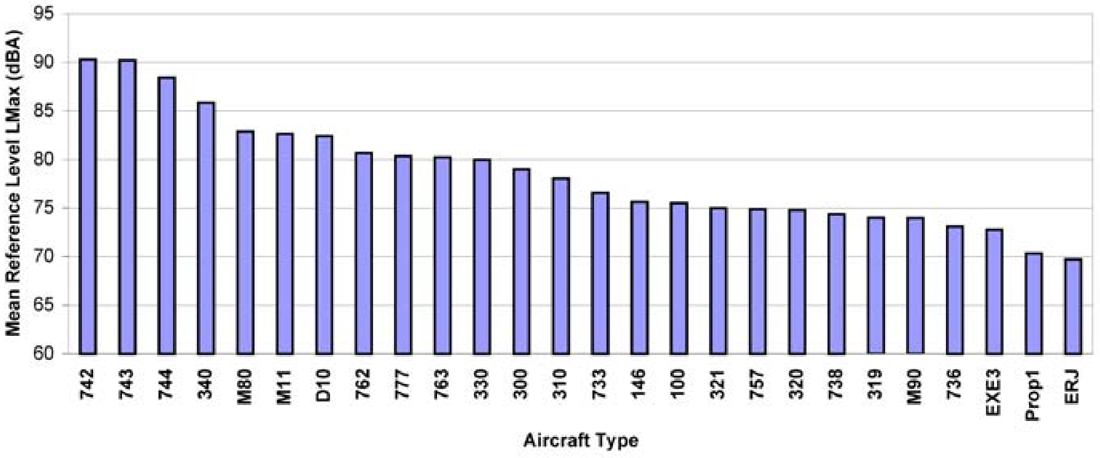


# FIGURE 44 Mean and 95th percentiles of Reference levels for each QC band

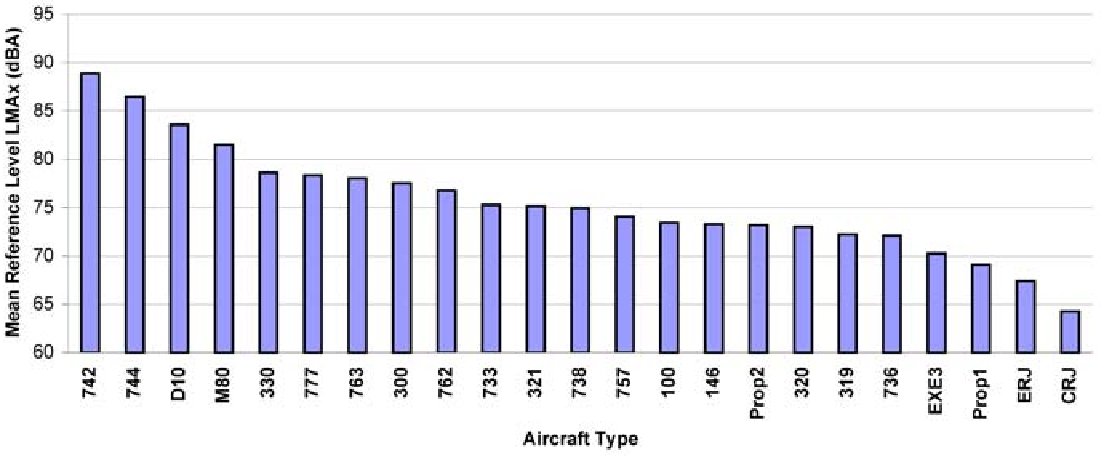


## FIGURE 45 Average Reference levels

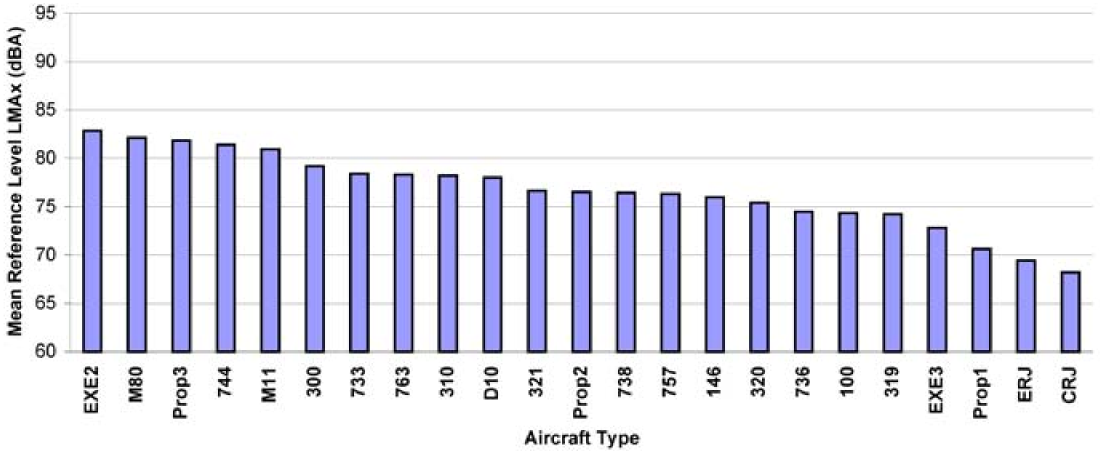
(a) Heathrow



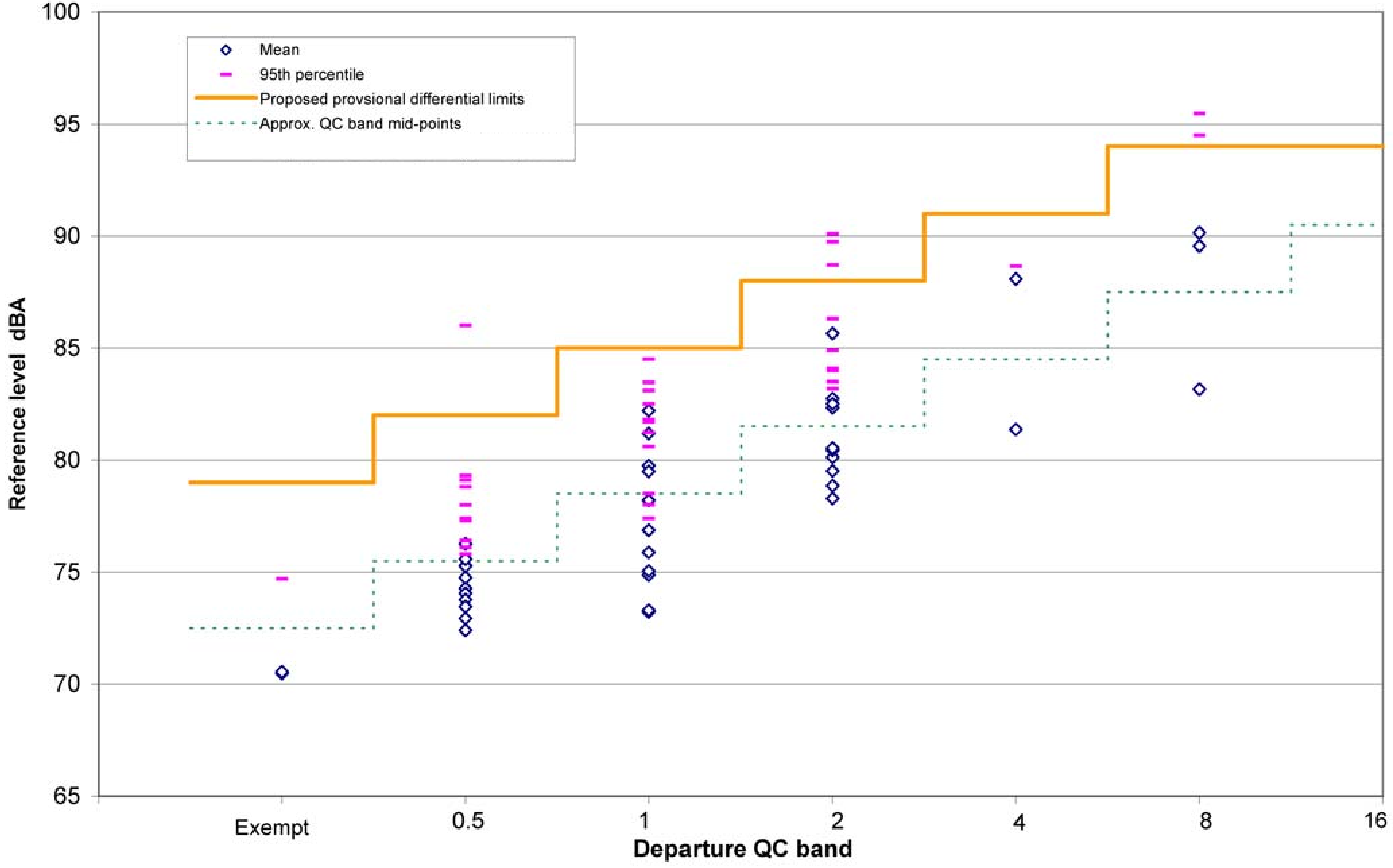
(b) Gatwick



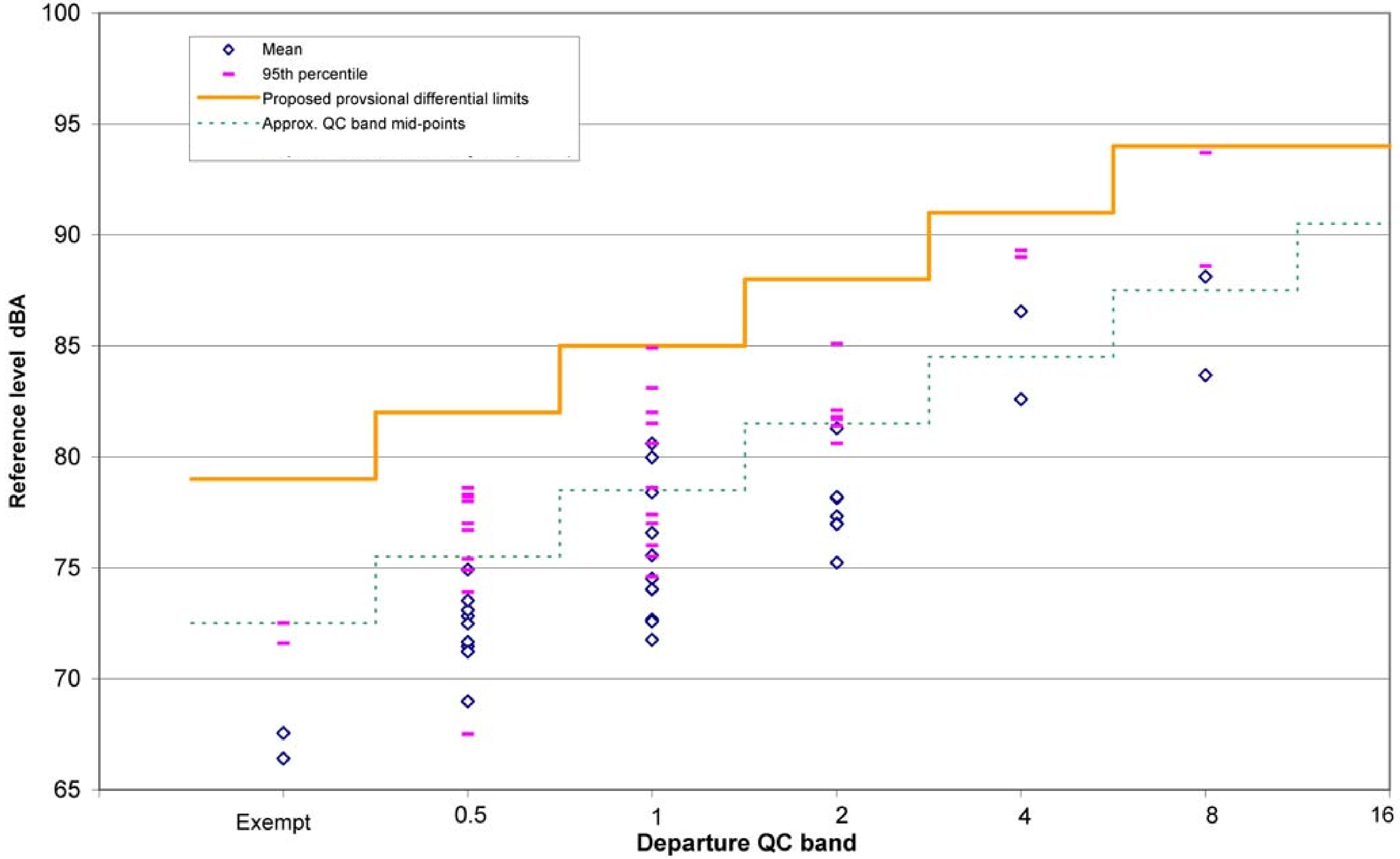
(c) Stansted



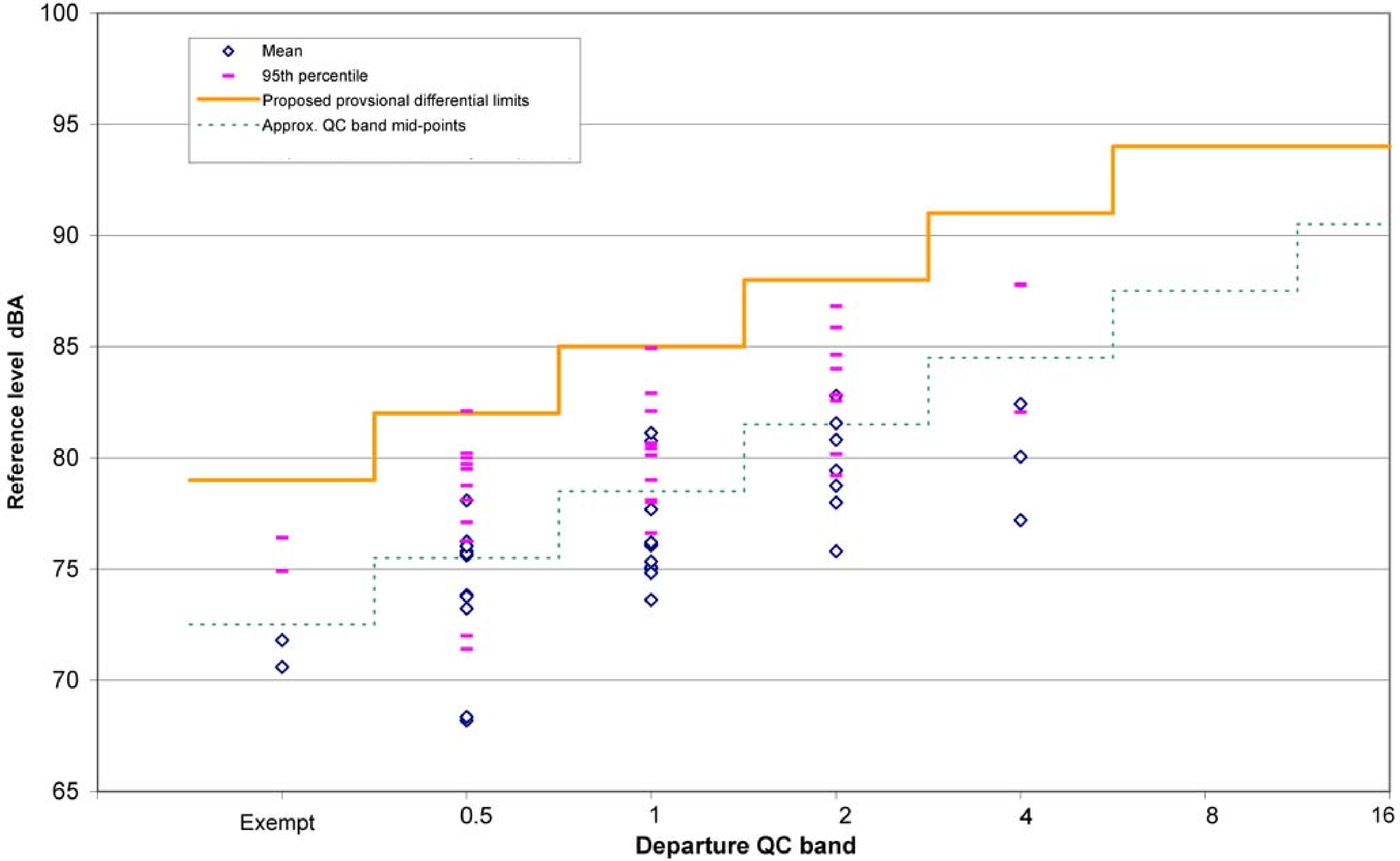
# FIGURE 46(a) Example of Differential Limits based on QC ratings: Heathrow



## FIGURE 46(b) Example of Differential Limits based on QC ratings: Gatwick



## FIGURE 46(c) Example of Differential Limits based on QC ratings: Stansted



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# APPENDIX A MONITORING EFFICIENCY

A1 For the previous review, 'Monitoring Efficiency' was derived in Ref 1 as a means of comparing the different runways' arrays. Monitoring Efficiency, in the words of Ref 1, means "the percentage of offenders that are recorded as infringements at one or more of the monitors in the array". The efficiency of the monitoring system "depends on the number of monitors and where they are positioned in relation to the departure routes and the actual tracks flown. It also depends on the number of noise events which exceed the noise limits and the amount by which they exceed the limits." Thus Monitoring Efficiency depends on the magnitude of the 'exceedances' (by how much the noise directly beneath the aircraft exceeds the limit) and the displacement of the flight tracks to the side of the monitor (in relation to the height of the aircraft). In simple terms, the smaller the exceedance, and the greater the displacement, the less likely it is that an infringement will be recorded.

A2 This approach provided a good basis for comparing different arrangements of monitors in combination with different departure tracks from different runways. For one aircraft type and one noise limit, the different combinations could be ranked directly in the order of their Monitoring Efficiencies.

A3 Determining Monitoring Efficiencies in the previous review involved complex analysis of substantial quantities of data. The calculations required estimates of the numbers of both infringements and offenders (aircraft that would have been detected as infringements had they flown directly overhead a noise monitor at the reference distance and elevation, whether or not they are detected as infringements); the latter could only be estimated by modelling the under-flight-path noise levels of an idealised set of actual departures. The numerical values of Monitoring Efficiency varied with both the noise limit and with aircraft type (giving a lower value of efficiency for quieter aircraft, but a higher efficiency for a lower noise limit, e.g. at night). The calculations only produced a single value for each departure direction, not differentiating between the different departure routes (or between runways 27L and 27R at Heathrow).

A4 The benefits of repeating similar analyses for this present review would be questionable because of the key influence of the 'exceedance' factor, particularly when some predicted aircraft noise levels are just fractionally above the limit. As exceedances fall, for example due to the introduction of less noisy aircraft and operating procedures, so too does the numerical value of Monitoring Efficiency - unless the spacings in the monitor arrays were to be decreased or the limits further reduced. In other words, the more effective the system is in encouraging reductions, the less 'efficient' (by this measure) it becomes.

A5 In the analysis in Ref 1, Monitoring Efficiencies were determined as theoretical functions of estimates of the magnitude of exceedances and of the displacement of the flight tracks to the side of the monitor (in relation to the height of the aircraft). From that analysis, 'ideal' and 'practical' monitor locations were defined. But the actual monitor sites differ from these in varying degrees, due mainly to limited accessibility of many of the sites. This, together with differences between assumed and actual noise and flight path statistics, means that the arrays could not fully achieve the ideal theoretical efficiencies.

A6 In Ref 1 Monitoring Efficiency values were estimated for both Chapters 2 and 3 Boeing 747s, showing the results of calculations for 'practical' monitoring options - monitor arrays broadly similar to those now in place. The values of Monitoring Efficiency for the current daytime noise limit are shown in the Table below.

**Estimated Monitoring Efficiencies (%) for current daytime noise limit (94dBA)** [62]

| Airport / Runway | Chapter 2 B747s | Chapter 3 B747s[63] |
|---|---|---|
| Heathrow 09R | 62 | 49 |
| Heathrow 27L/27R | 56 | 42 |
| Gatwick 08R | 59 | 48 |
| Gatwick 26L | 58 | 50 |
| Stansted 05 | 50 | 40 |
| Stansted 23 | 65 | 51 |

A7 These Monitoring Efficiency values would increase with further lowering of the limit or by adding more monitors, but conversely would reduce if the average noise levels of these aircraft types reduced. The present monitoring arrangements were intended to achieve a daytime efficiency value of at least 50% for the noisiest Chapter 2 jets. Because of the phase-out of Chapter 2 jet aircraft, this criterion was outdated after 31 March 2002.

A8 For this review, it was concluded that noise monitor arrays should be assessed in a way that was independent of aircraft noise levels; the method chosen was the V-analysis technique, subsequently augmented by track density assessments. To provide a comparison with the previous review it is interesting to compare Monitoring Efficiency values against the percentage of aircraft flying through a V.

A9 For daytime Gatwick Chapter 3 B747 departures, with the current daytime limit (94dBA), the Table above shows the Monitoring Efficiencies for runways 08R and 26L as 48% and 50% respectively. In other words, it was estimated that the present arrays at Gatwick would record only about half as many daytime infringements than if there were a very large number of monitors closely spaced along the 6.5km arcs. (For the current shoulder period limit, Ref 1 gave the Monitoring Efficiencies for the two runways as 66% and 64%, and for the night limits 74% and 72%.)

A10 At first sight, this does not seem to be consistent with the statement in paragraph 2.7.5 that 99% or more of all jet aircraft types on either Gatwick runway fly through a V. This is because, intentionally, the V analysis takes no account of aircraft noise levels. The Monitoring Efficiencies are lower than the V capture percentages because most undetected offenders would have only just exceeded the limit had they flown directly over a monitor (mostly by less than 1dB). When not overhead, the effect of the extra distance to the nearest monitor can be to reduce the measured noise level from just above the limit to just below it.

A11 For example, calculations indicate that an aircraft at 1000ft height, 170m to the side of a monitor (i.e. just within the $60^0$ V), will register a noise level 1.7dBA lower than if the aircraft had overflown the monitor. Of the Chapter 3 B747 departures studied in Ref 1, about 12% would be offenders having Reference levels in excess of 94dBA (the current daytime limit). About 6% of the levels would be in excess of 95.7dBA (the reference level that would be needed for a flight on the edge of the V to record 94dBA at the actual monitor and register as an infringement). Hence the daytime Monitoring Efficiency (the proportion of offenders that are infringements) for typical flights on the edge of the V could be estimated as 6% out of 12%, i.e. of the order of

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[62] From Ref 1 Table 8.

[63] The Chapter 3 B747 group used in Ref 1 combined 744s with Chapter 3 742s. The 744s tend to be quieter than the 742s, so the Monitoring Efficiencies for the noisiest Chapter 3 B747s would be a little greater than shown in this table.

50%. In practice, of course, tracks are distributed within a swathe, aircraft heights vary (including some B747s below 1000ft), and the noise levels themselves have an inbuilt variability – the determination of Monitoring Efficiency for a given runway in Ref 1 took all these factors into account, but was complex and time-consuming.

A12 If all 'offending' flights are inside one or more V, and if their noise levels under the flight path are all at least 1.7dB above the adjusted limit, the Monitoring Efficiency of the array would be 100%. In practice, Monitoring Efficiency can be reduced dramatically by either of the following two kinds of offenders which would not register as infringements:

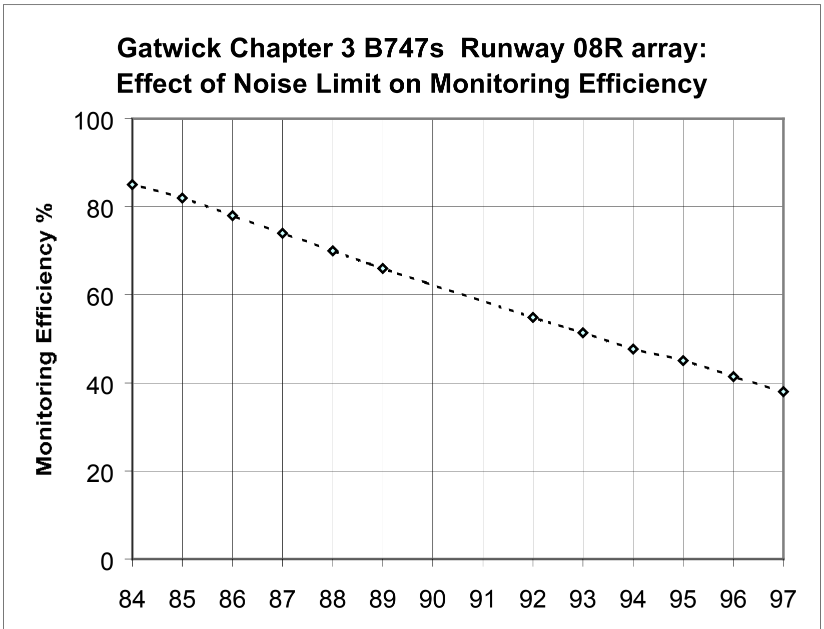
(a) offenders with tracks outside any V, and with noise levels not more than 1.7dB above the limit.
e.g. adjusted limit = 88.0dBA; aircraft's noise level under flight path = 89.0dBA; noise level measured at monitor = 87.0dBA.

and

(b) offenders inside a V but near the 60° boundary and with a noise level only just above the adjusted limit – flying overhead the monitor such aircraft would be detected as infringements, but as they are to the side of the monitor the level measured at the monitor is reduced to below the limit, so they are not detected as infringements.
e.g. adjusted limit = 88.0dBA; aircraft's noise level under flight path = 89.0dBA; noise level measured at monitor = 87.5dBA.

It was a through a consideration of such factors that a target 50% value of Monitor Efficiency was deemed reasonable in the earlier study.

A13 There is no simple relationship between Monitoring Efficiency and the results of the V-analysis (which is purely geometrical). It has been emphasised that Monitoring Efficiency varies significantly with the noise limit (other factors being equal) – this can be seen in the example plot below - whereas the V-analysis result is dependent only on the aircraft heights and tracks relative to the noise monitors.



from Ref 1 Tables 8 and 9

A14 Table A1 gives results derived from the cumulative distributions for Chapter 3 B747s in the current Heathrow and Gatwick datasets[64] (September 2000 to August 2001). These are compared with the results of the previous review (Ref 1). It can be seen that although the current **mean** reference levels are comparable with the 1995 values, the percentages of flights estimated to be offenders (Reference levels exceeding 94dBA) and infringements are almost all lower in the current data than in the Ref 1 data, resulting in **lower** estimated values of Monitoring Efficiency at the edge of a V. The reduction in the small number of 'noisy' departures may be due to improved departure procedures for some operators, and/or to fleet changes. This is a practical illustration of the way in which a reduction of Monitoring Efficiency can be an indication of improved noise performance, i.e. lower operational noise levels. The alternative V-analysis in fact confirms that the existing Gatwick monitors are well positioned to monitor the noise of jet aircraft departures.

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[64] B747s did not operate in sufficient numbers to include Stansted in this part of the study.

## Table A1 Noise levels, Monitoring Efficiency values and V-analysis results for Chapter 3 B747s

| Airport/Runway | Gatwick Runway 08R | | | Gatwick Runway 26L | | | Heathrow Runway 27L | | | Heathrow Runway 27R | | | Heathrow Runway 09R | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Period | Sep. 2000 to Aug. 2001 | | 1995 review | Sep. 2000 to Aug. 2001 | | 1995 review | Sep. 2000 to Aug. 2001 | | 1995 review | Sep. 2000 to Aug. 2001 | | 1995 review | Sep. 2000 to Aug. 2001 | | 1995 review |
| Aircraft type | 742 Ch3 | 744 | Ch3 B747 | 742 Ch3 | 744 | Ch3 B747 | 742 Ch3 | 744 | Ch3 B747 | 742 Ch3 | 744 | Ch3 B747 | 742 Ch3 | 744 | Ch3 B747 |
| Mean reference level dBA | 89.6 | 86.8 | **89.2** | 87.2 | 85.7 | **89.2** | 90.4 | 88.3 | **89.2** | 87.0 | 86.0 | **89.2** | 90.9 | 89.0 | **89.2** |
| Percentage of flights with reference level exceeding 94.0dBA (2000-01 data).<br>1995: Percentage of Offenders | 11.7% | 0% | **12%** | 0.3% | 0% | **12%** | 11% | 1.6% | **12%** | 1.2% | 0.2% | **12%** | 18% | 1.9% | **12%** |
| Percentage of flights with reference level exceeding 95.6dBA (2000-01 data).<br>1995: Percentage of Infringements | 2.9% | 0% | **5.6%** | 0% | 0% | **5.9%** | 3.4% | 0.4% | **5.0%** | 0% | 0% | **5.0%** | 4.0% | 0.5% | **5.8%** |
| Monitoring Efficiency (estimate for flights at edge of V, limit =94.0dBA). | 25% | - | **47%** | - | - | **49%** | 31% | 23% | **42%** | - | - | **42%** | 22% | 26% | **48%** |
| 1995: Monitoring Efficiency modelled for all flights, limit =94.0dBA | - | - | **48%** | - | - | **50%** | - | - | **42%** | - | - | **42%** | - | - | **49%** |
| Percentage of flights flying through at least one V (range of values at Heathrow depending on departure route) | 96% | 99% | - | 99% | 98% | - | 71 to 98% | 86 to 100% | - | 87 to 93% | 89 to 98% | - | 49 to 88% | 38 to 88% | - |

Figures derived from Ref 1 are shown in bold.

Heathrow runways 27L and 27R were combined for analysis purposes in Ref 1.

Tailwind allowance has not been considered.

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# APPENDIX B TRACK PLOTS

This appendix shows samples of typical departure tracks for most available combinations of aircraft types and routes, relative to the noise monitors and the NPRs. (The NPR swathes and centrelines are shown on each figure, although in general the centreline is not visible under the spread of tracks.)

## List of Figures

**Figure B1 (i) Gatwick typical departure tracks relative to noise monitors and NPRs: 742Ch3, 744, 777, 330**

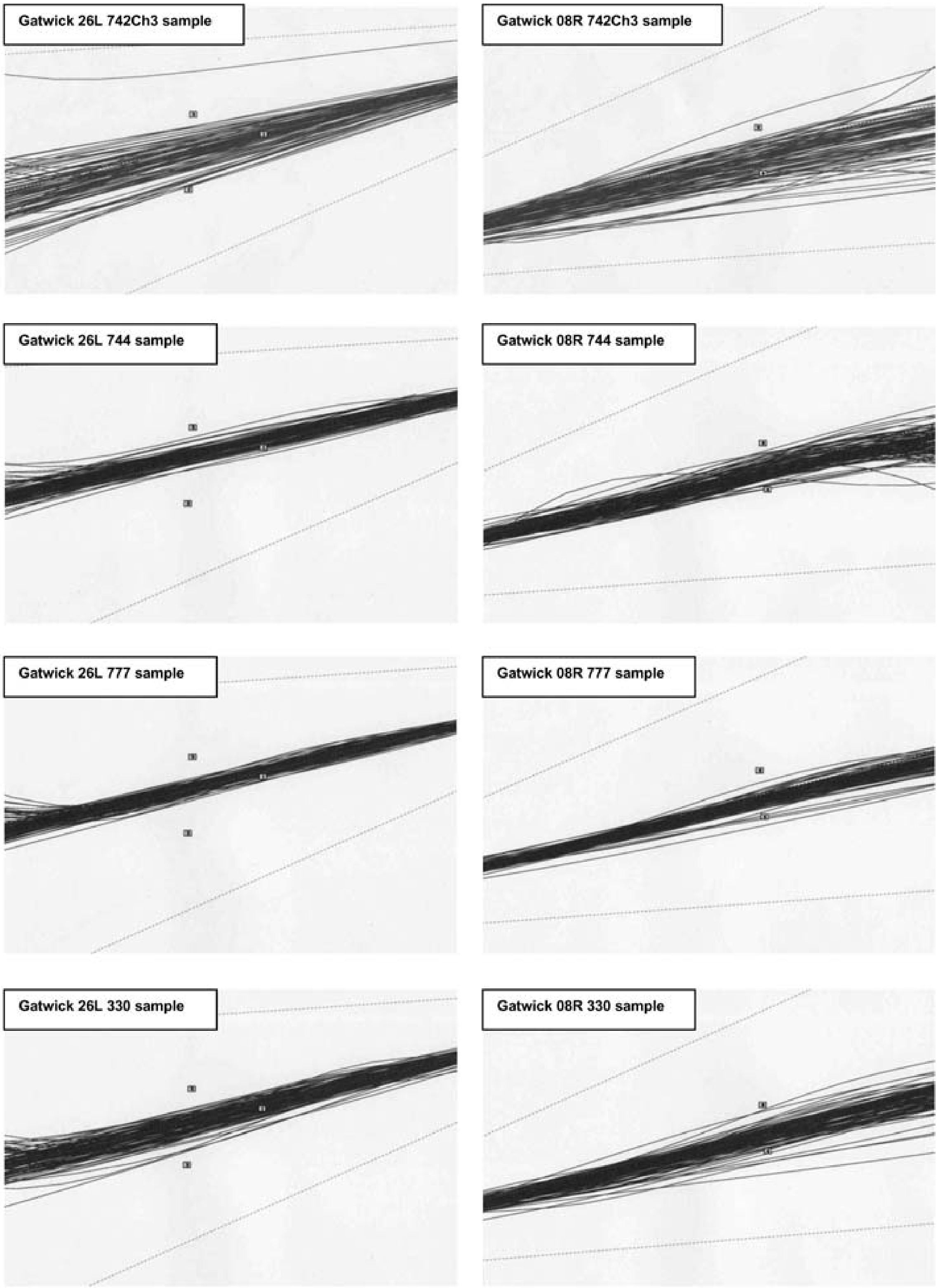
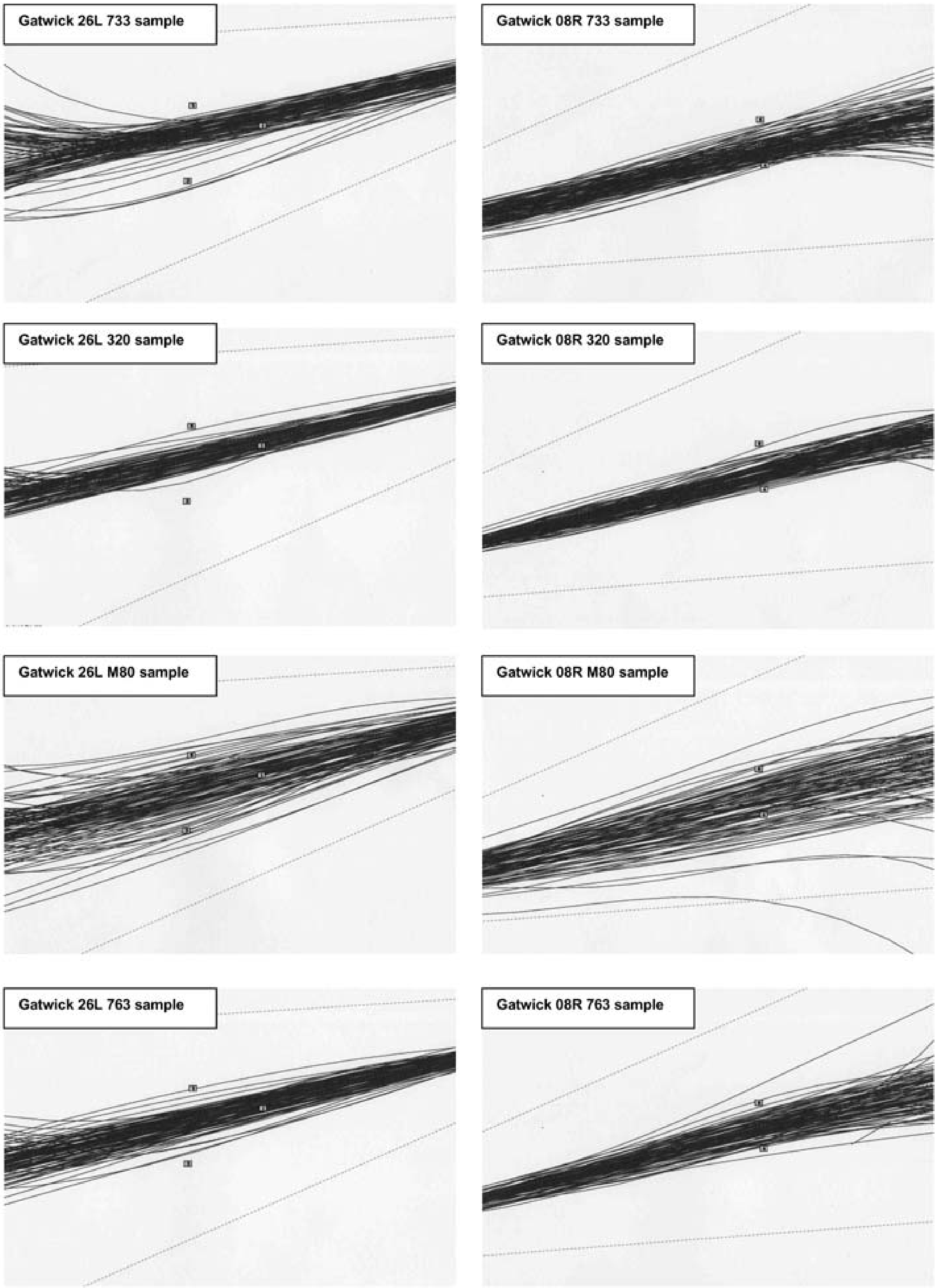


**Figure B1 (ii) Gatwick typical departure tracks relative to noise monitors and NPRs:
733, 320, M80, 763**



Gatwick 26L 733 sample

Gatwick 08R 733 sample

Gatwick 26L 320 sample

Gatwick 08R 320 sample

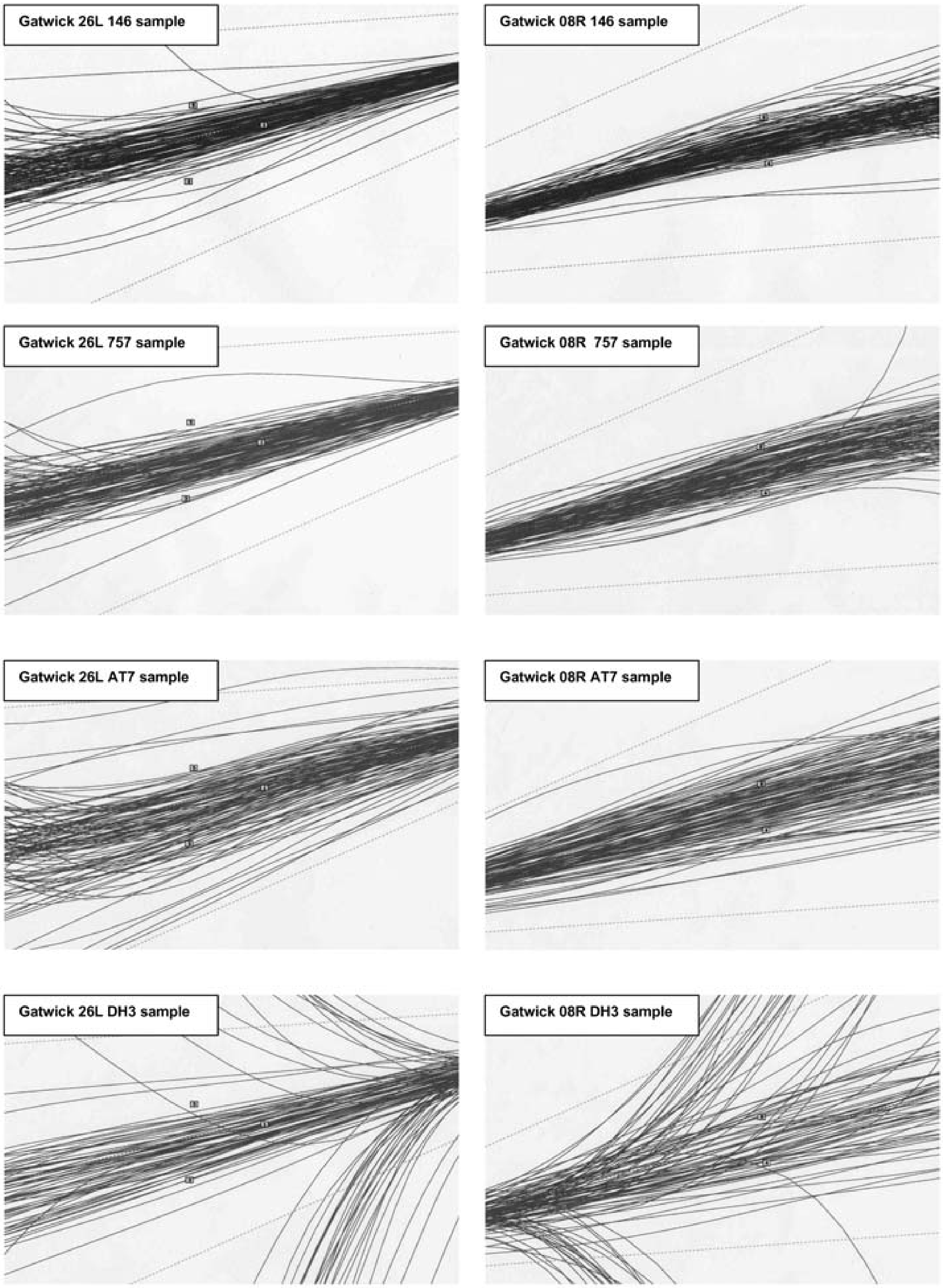
Gatwick 26L M80 sample

Gatwick 08R M80 sample

Gatwick 26L 763 sample

Gatwick 08R 763 sample

**Figure B1 (iii) Gatwick typical departure tracks relative to noise monitors and NPRs: 146, 757, AT7, DH3**



Gatwick 26L 146 sample

Gatwick 08R 146 sample

Gatwick 26L 757 sample

Gatwick 08R 757 sample

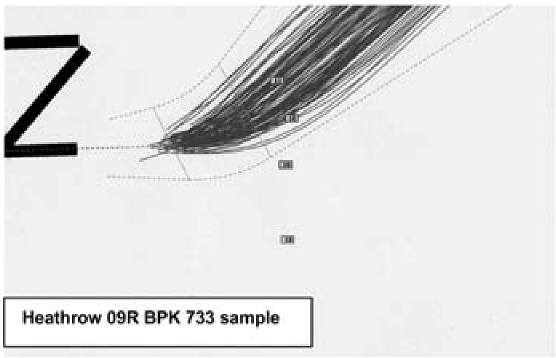
Gatwick 26L AT7 sample

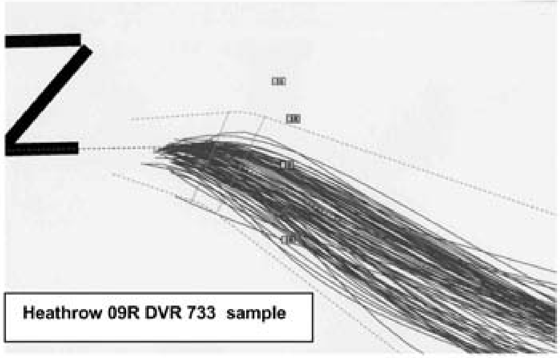
Gatwick 08R AT7 sample

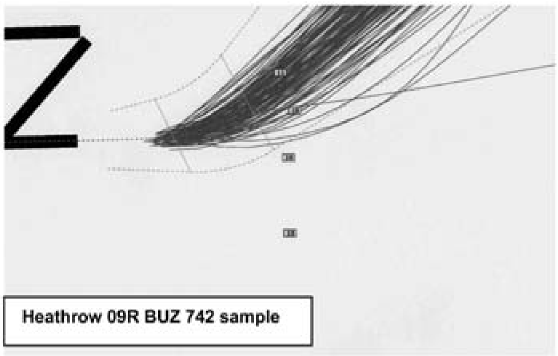
Gatwick 26L DH3 sample

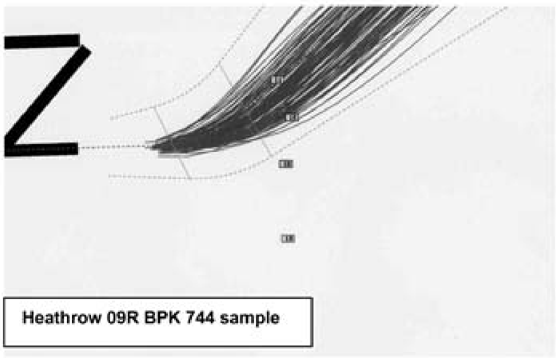
Gatwick 08R DH3 sample

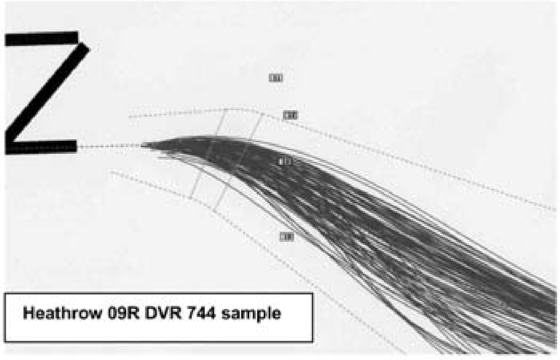
Figure B2 (a) (i) Heathrow typical departure tracks relative to noise monitors and NPRs

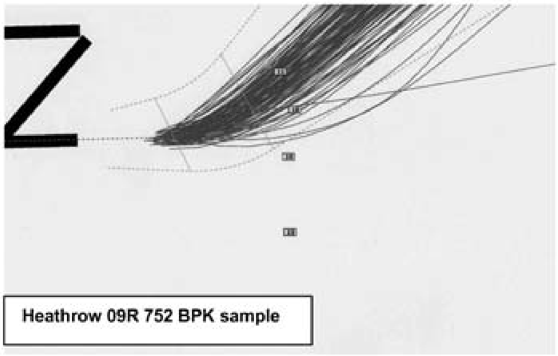

Heathrow 09R BPK 733 sample


Heathrow 09R DVR 733 sample


Heathrow 09R BUZ 742 sample


Heathrow 09R BPK 744 sample


Heathrow 09R DVR 744 sample


Heathrow 09R 752 BPK sample

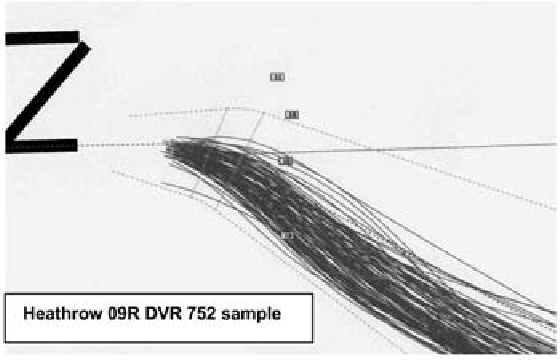
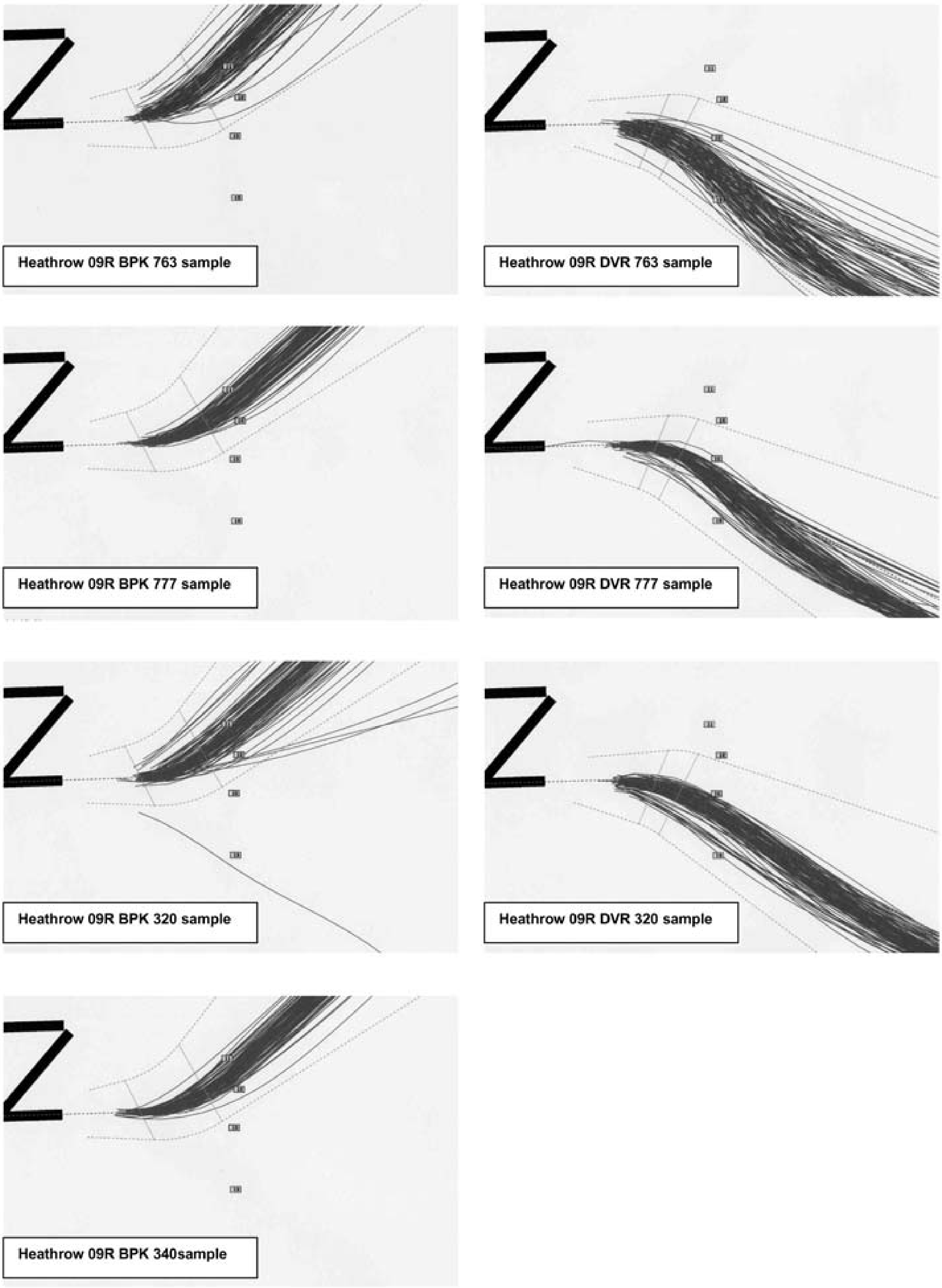

Heathrow 09R DVR 752 sample

Figure B2 (a) (ii) Heathrow typical departure tracks relative to noise monitors and NPRs



Heathrow 09R BPK 763 sample

Heathrow 09R DVR 763 sample

Heathrow 09R BPK 777 sample

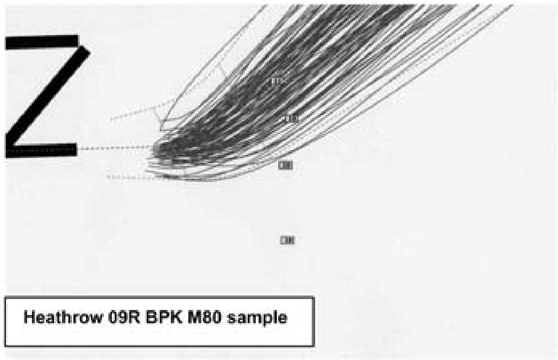
Heathrow 09R DVR 777 sample

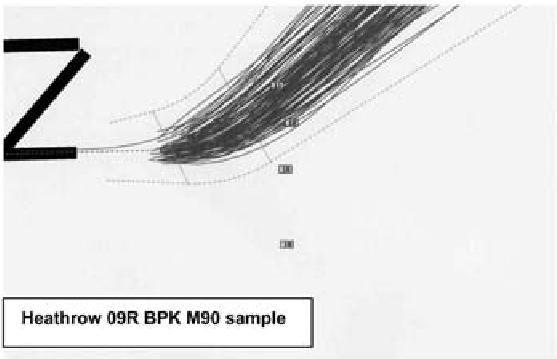
Heathrow 09R BPK 320 sample

Heathrow 09R DVR 320 sample

Heathrow 09R BPK 340sample

## Figure B2 (a) (iii) Heathrow typical departure tracks relative to noise monitors and NPRs





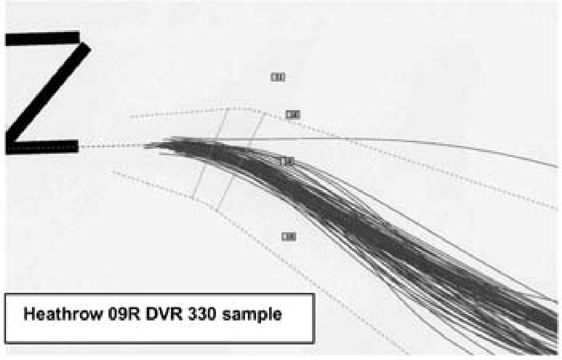


**Figure B2 (b) (i) Heathrow typical departure tracks relative to noise monitors and NPRs**

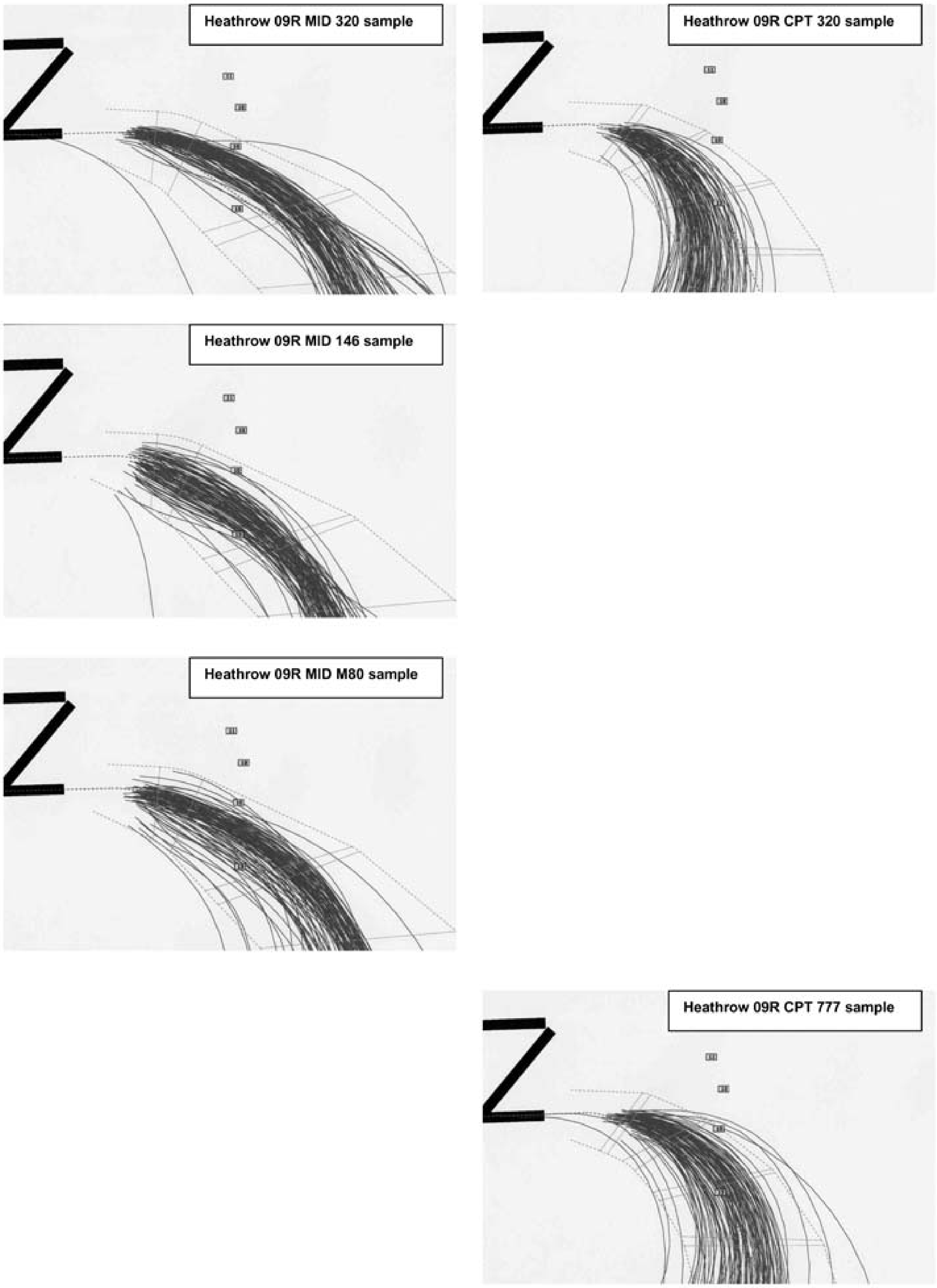


Figure B2 (b) (ii) Heathrow typical departure tracks relative to noise monitors and NPRs

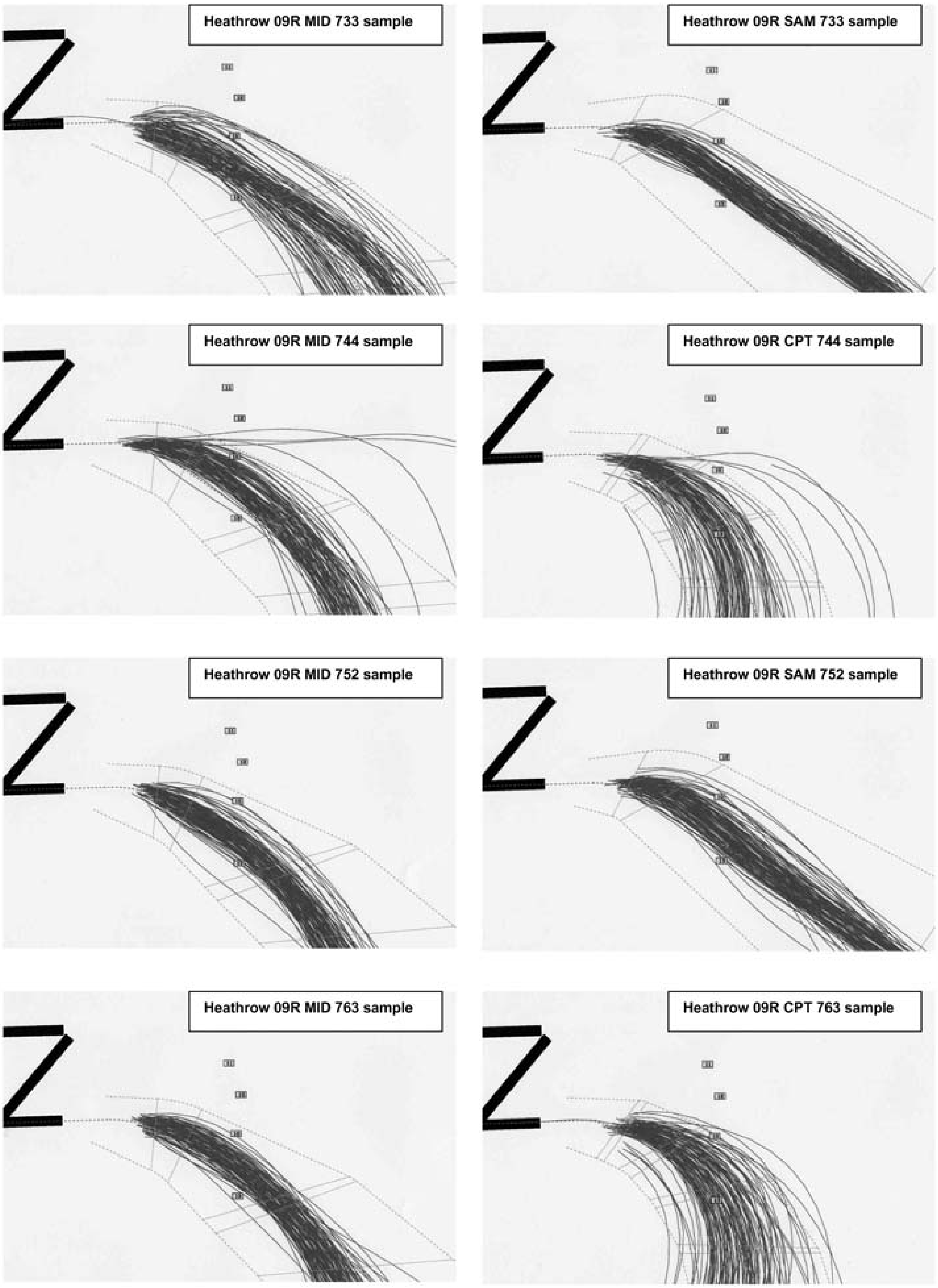
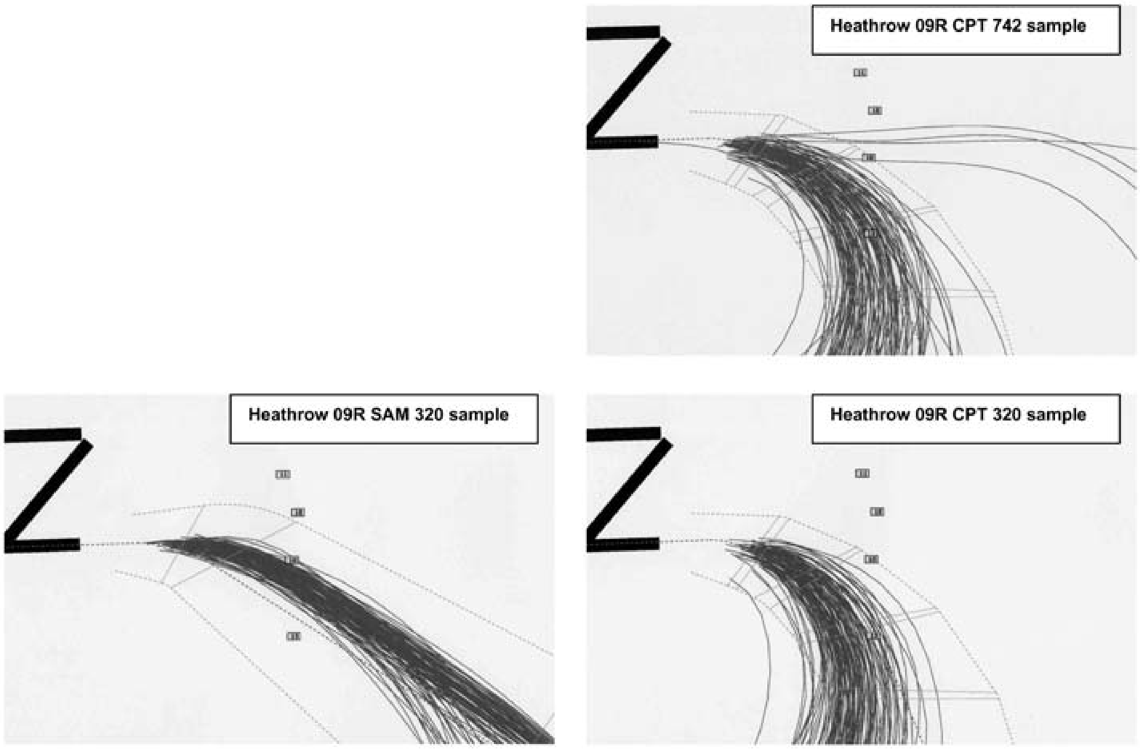


**Figure B2 (b) (iii) Heathrow typical departure tracks relative to noise monitors and NPRs**



Heathrow 09R CPT 742 sample

Heathrow 09R SAM 320 sample

Heathrow 09R CPT 320 sample

Figure B3 (a) (i) Heathrow typical departure tracks relative to noise monitors and NPRs

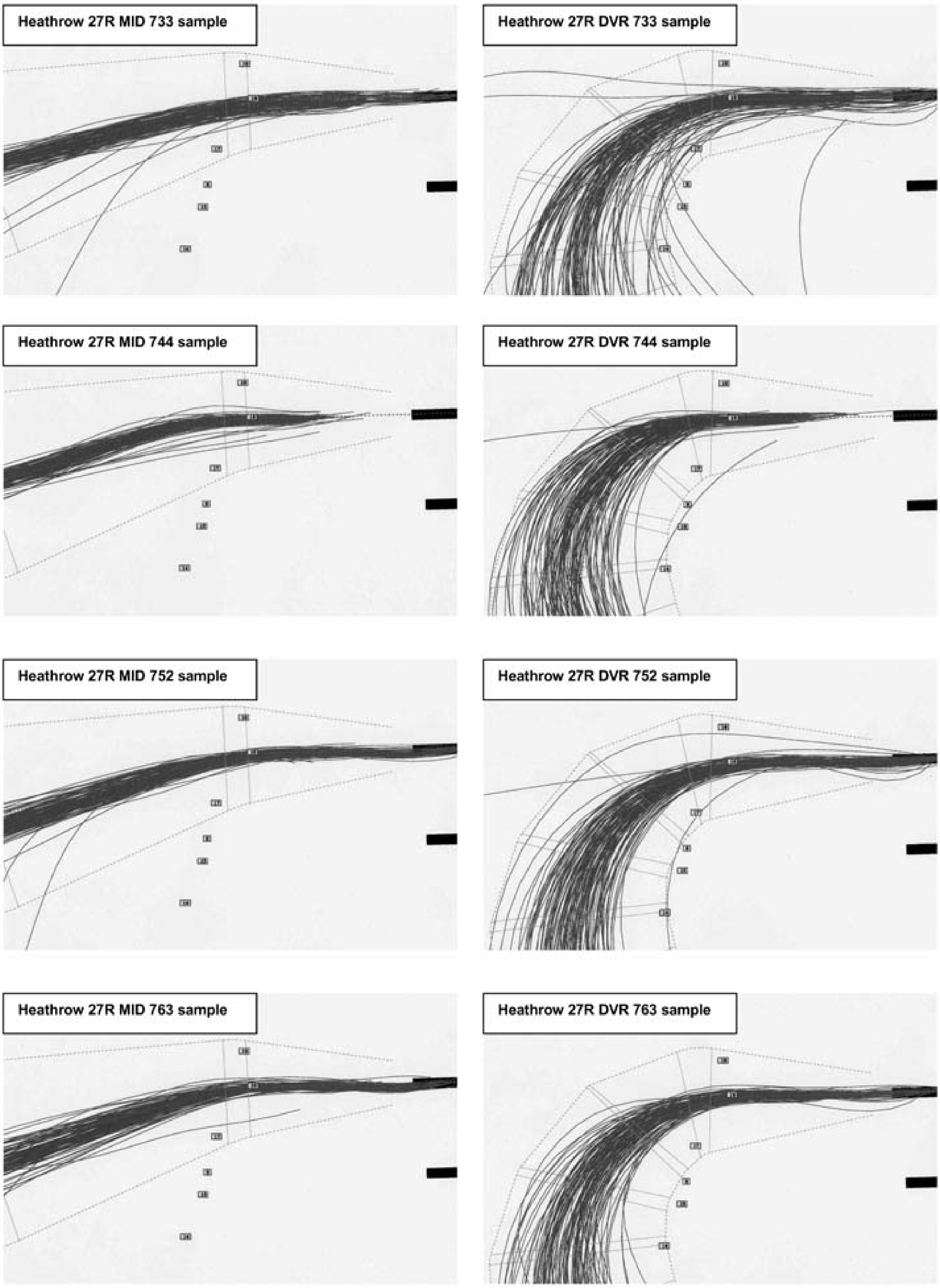
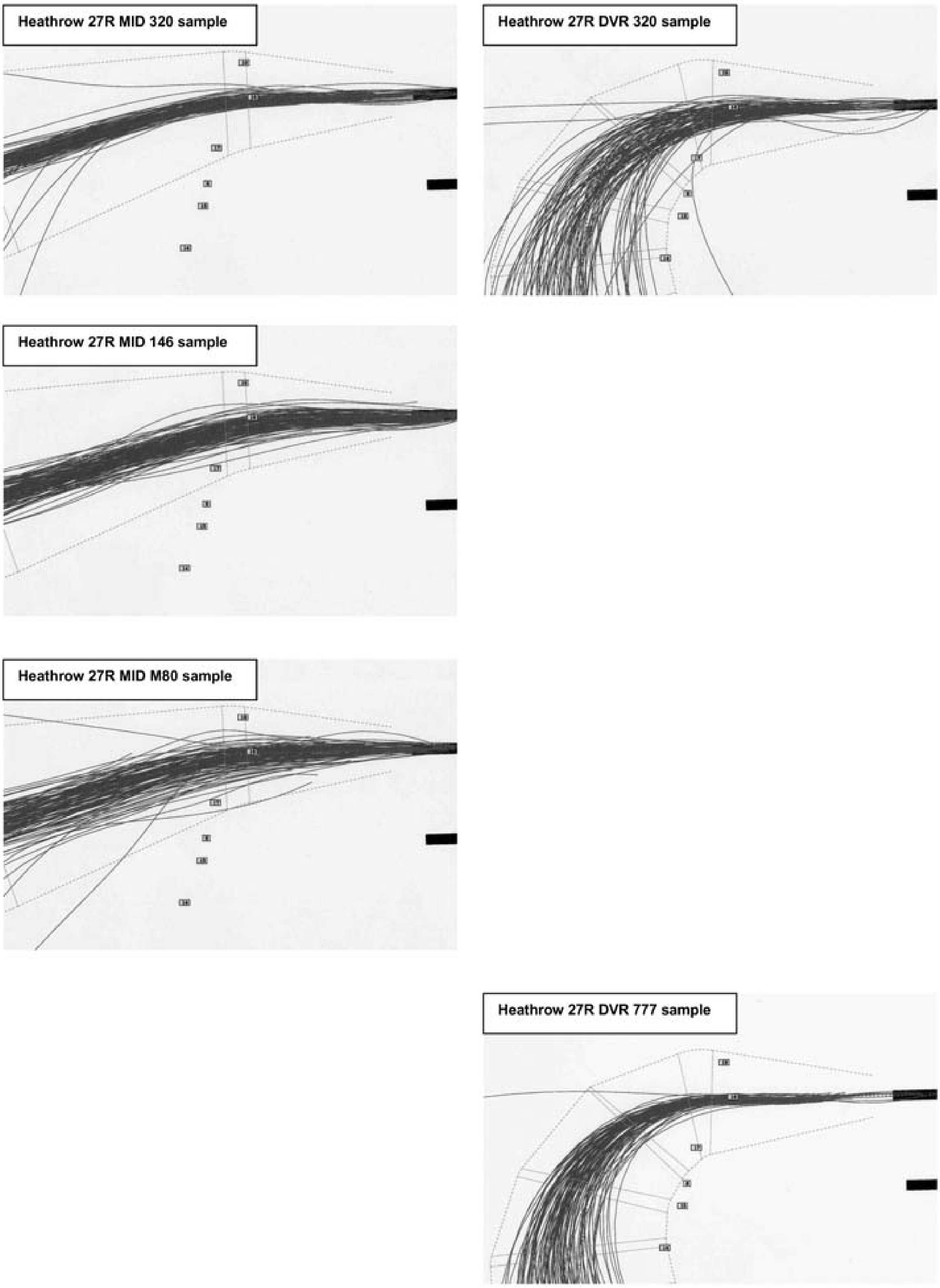


**Figure B3 (a) (ii) Heathrow typical departure tracks relative to noise monitors and NPRs**



### Figure B3 (b) (i) Heathrow typical departure tracks relative to noise monitors and NPRs

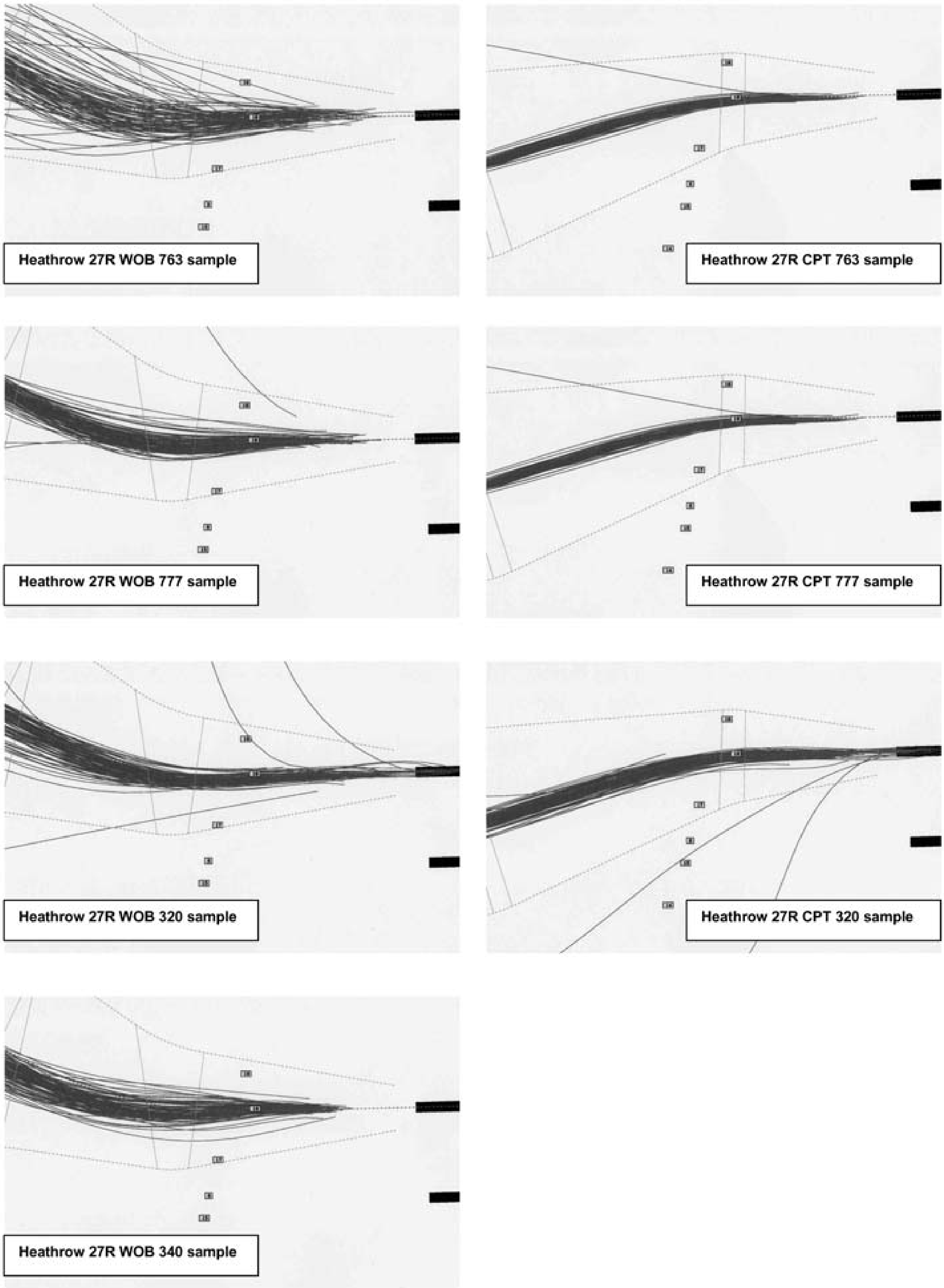
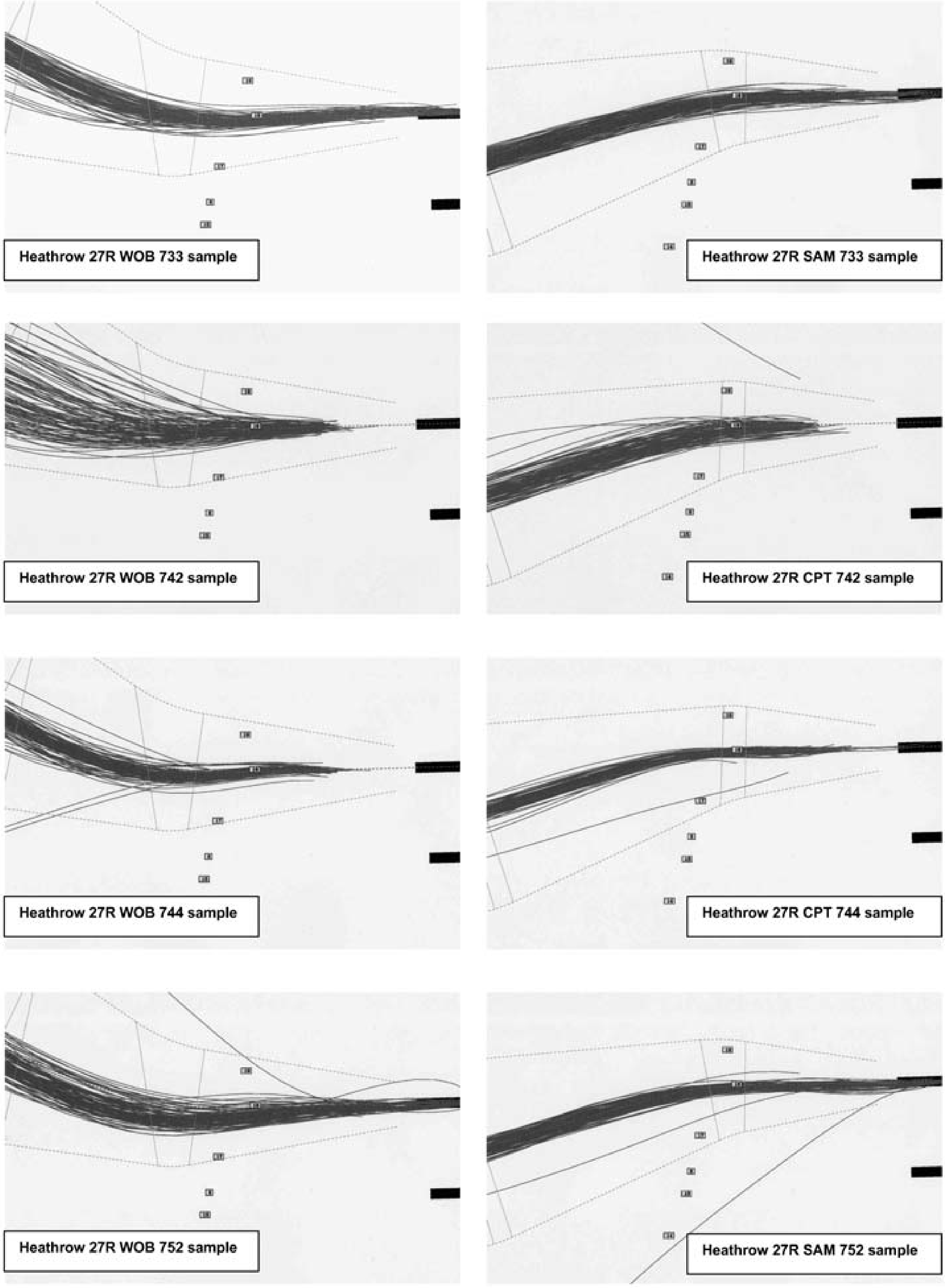


**Figure B3 (b) (ii) Heathrow typical departure tracks relative to noise monitors and NPRs**



Heathrow 27R WOB 733 sample

Heathrow 27R SAM 733 sample

Heathrow 27R WOB 742 sample

Heathrow 27R CPT 742 sample

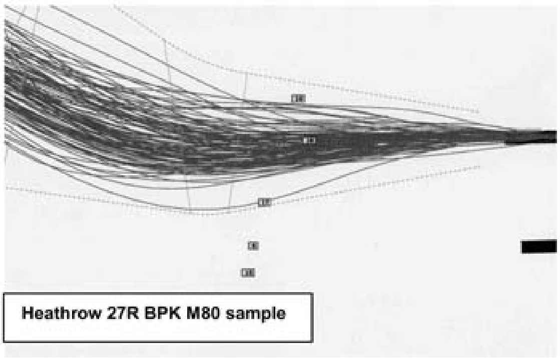
Heathrow 27R WOB 744 sample

Heathrow 27R CPT 744 sample

Heathrow 27R WOB 752 sample

Heathrow 27R SAM 752 sample

### Figure B3 (b) (iii) Heathrow typical departure tracks relative to noise monitors and NPRs



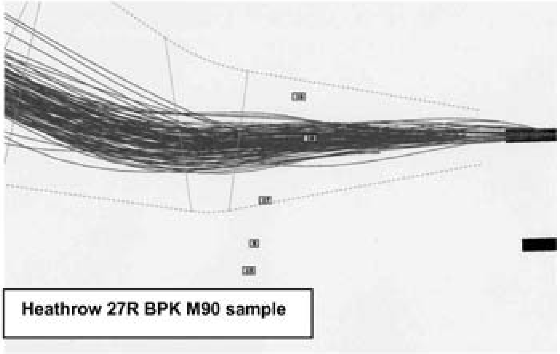


**Figure B4 (a) (i) Heathrow typical departure tracks relative to noise monitors and NPRs**

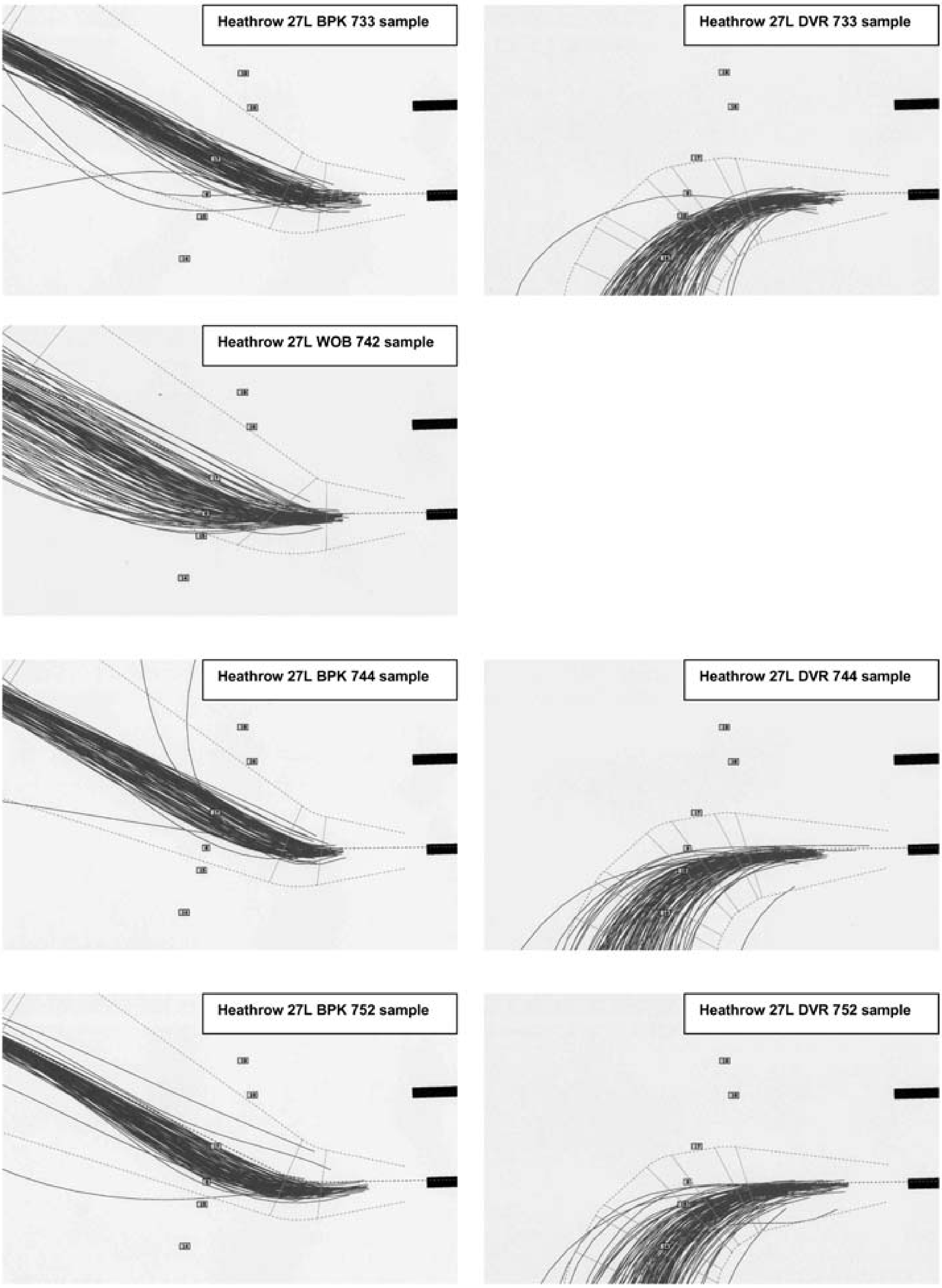
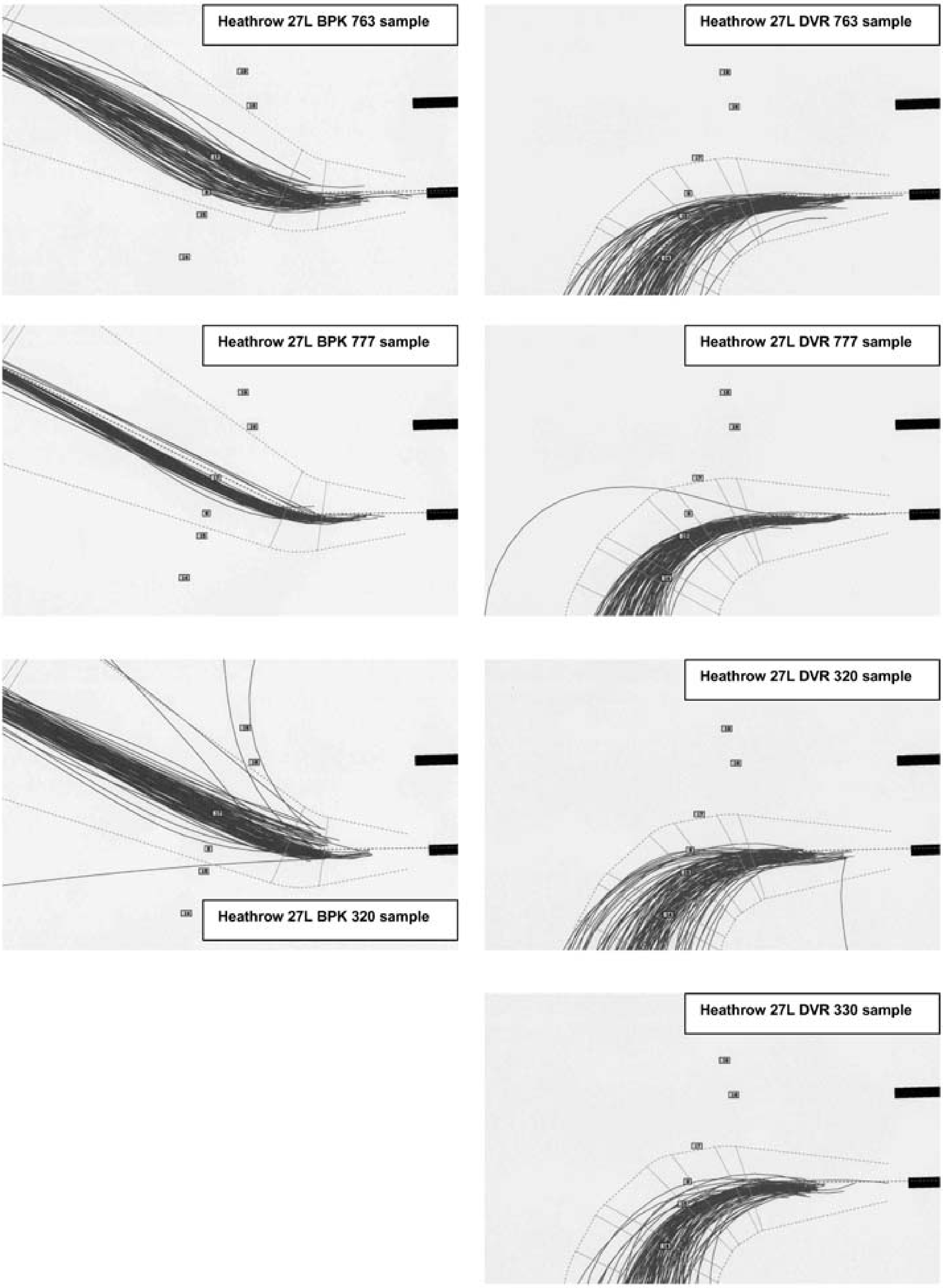
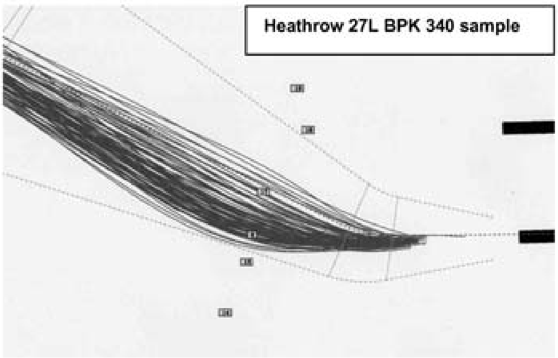
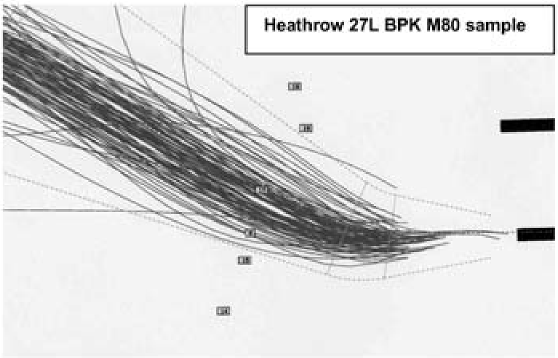


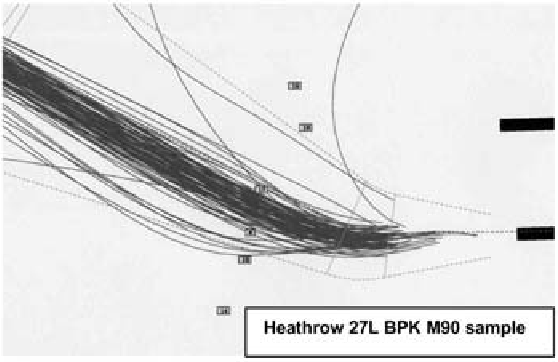
**Figure B4 (a) (ii) Heathrow typical departure tracks relative to noise monitors and NPRs**



## Figure B4 (a) (iii) Heathrow typical departure tracks relative to noise monitors and NPRs







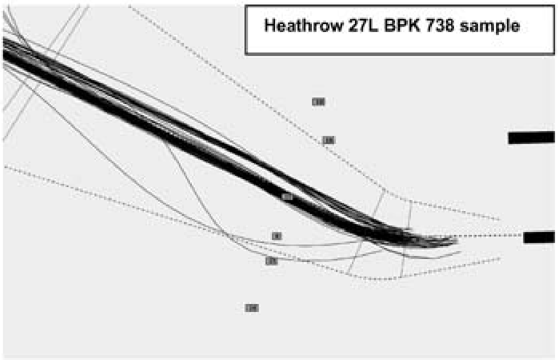


**Figure B4 (b) (i) Heathrow typical departure tracks relative to noise monitors and NPRs**

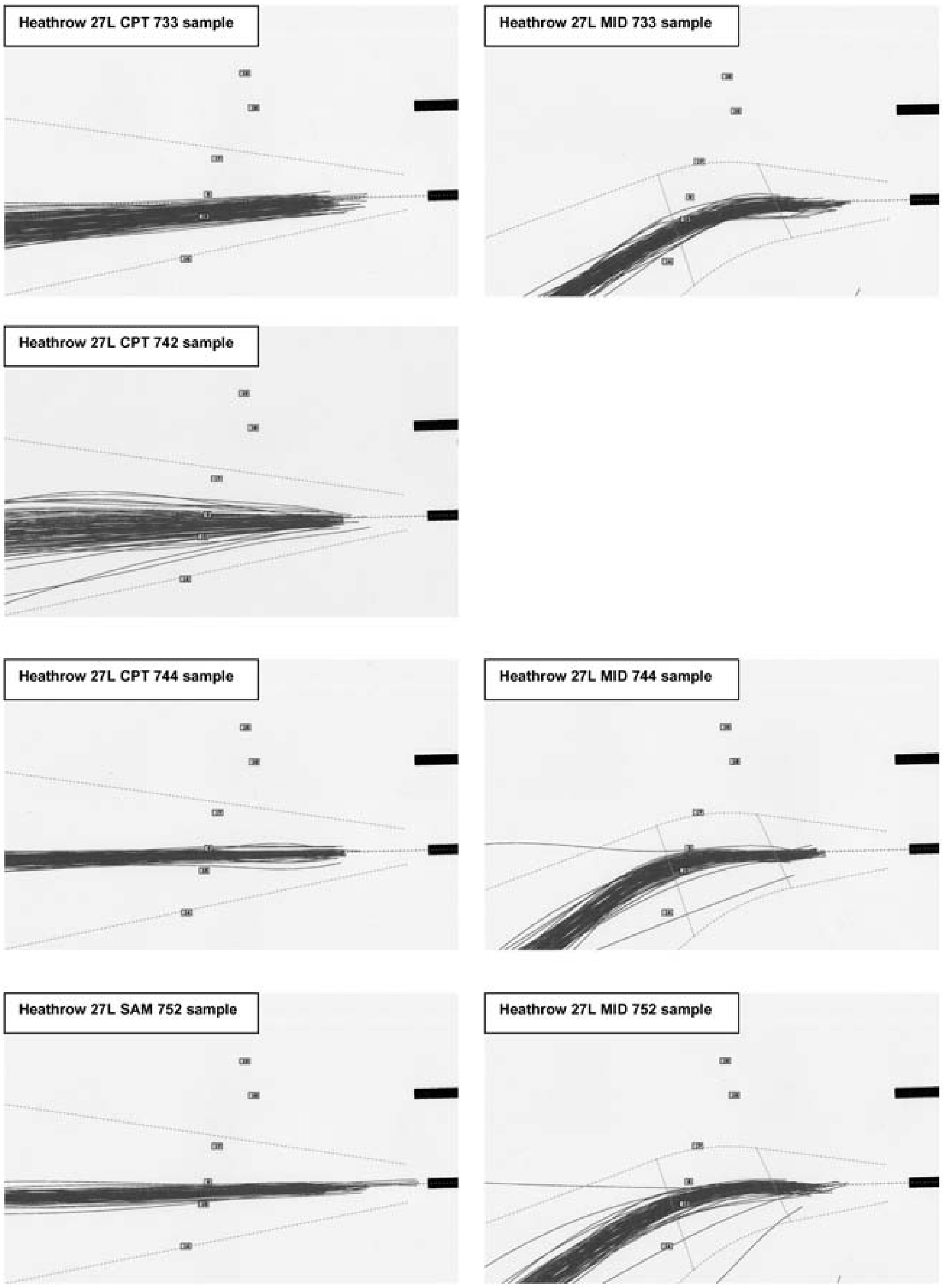


Figure B4 (b) (ii) Heathrow typical departure tracks relative to noise monitors and NPRs

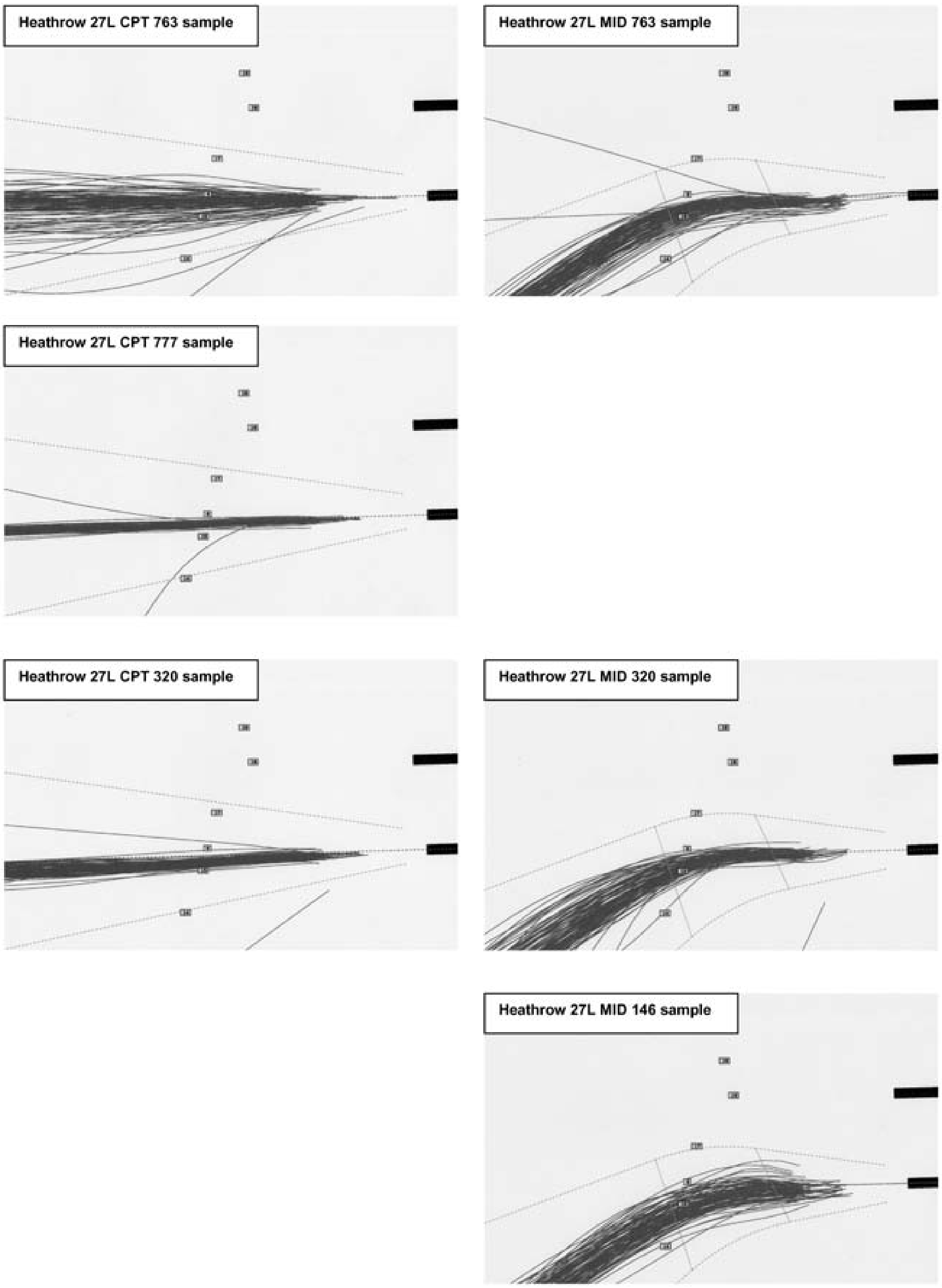


**Figure B4 (b) (iii) Heathrow typical departure tracks relative to noise monitors and NPRs**

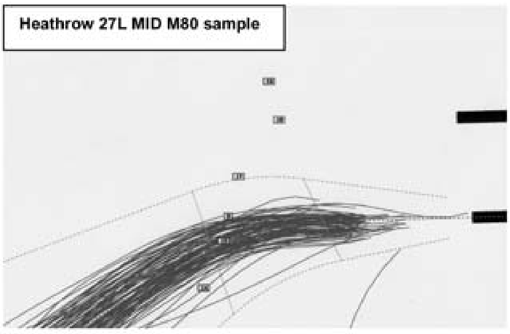


**Figure B5 (a) (i) Stansted typical departure tracks relative to noise monitors and NPRs**

Note: In these figures monitor 10 (the monitor moved on 31/5/01) is shown as monitor 1 (its designation in NTK).

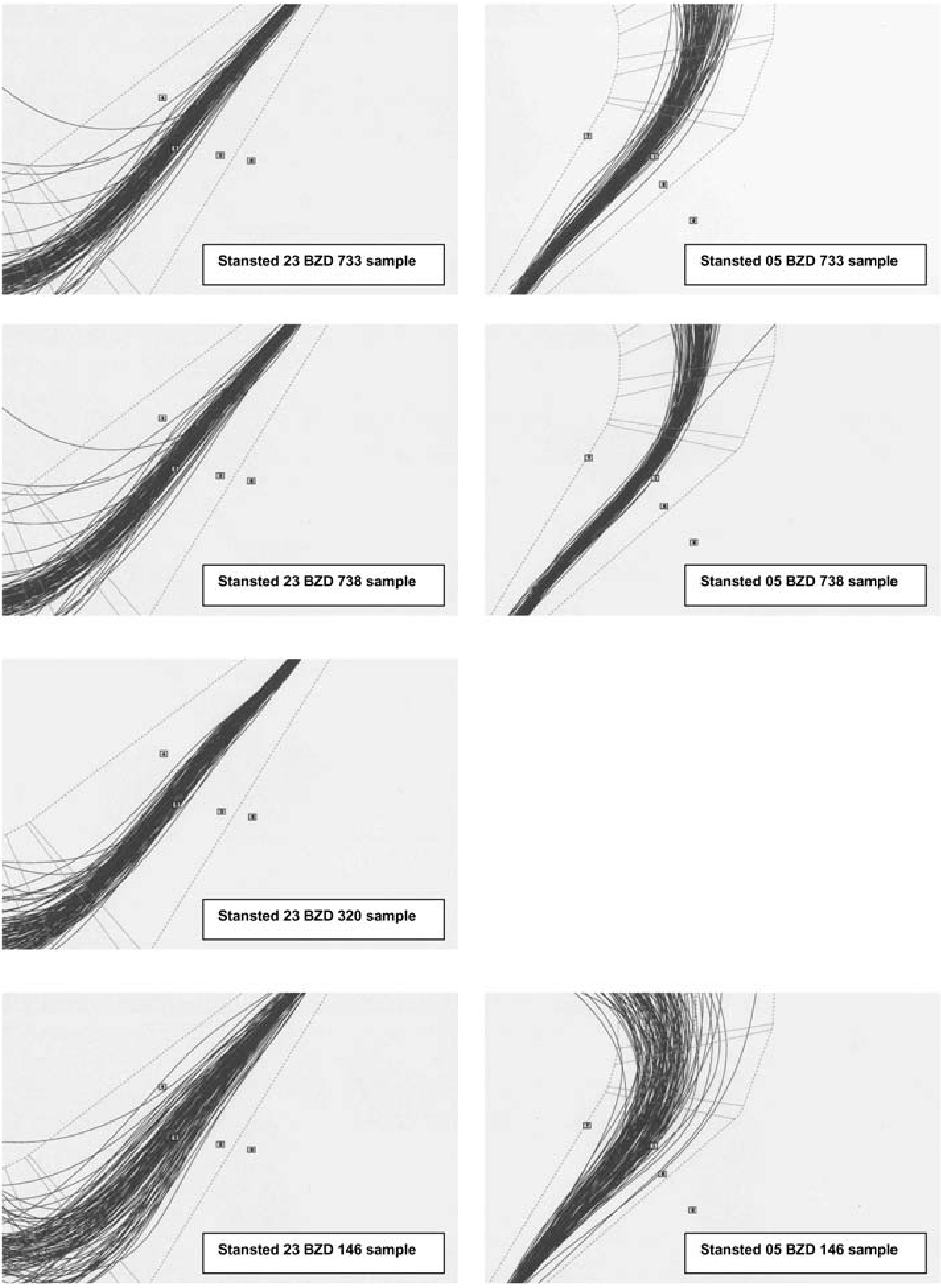


**Figure B5 (a) (ii) Stansted typical departure tracks relative to noise monitors and NPRs**

Note: In these figures monitor 10 (the monitor moved on 31/5/01) is shown as monitor 1 (its designation in NTK).

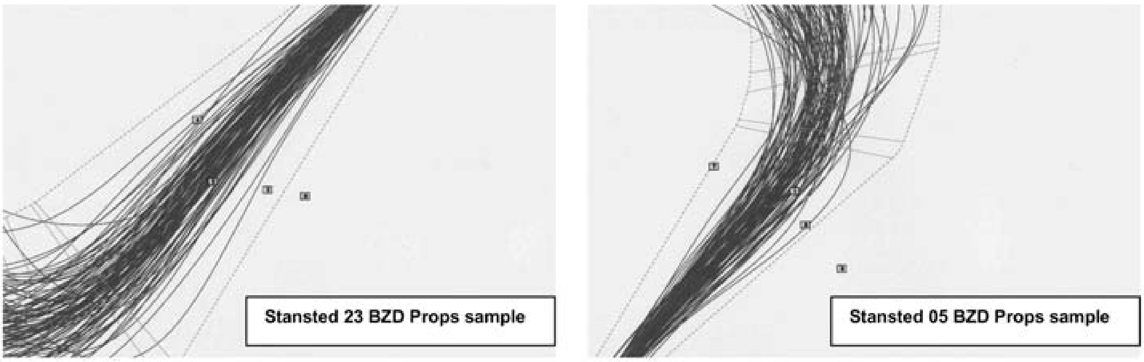


**Figure B5 (b) (i) Stansted typical departure tracks relative to noise monitors and NPRs**

Note: In these figures monitor 10 (the monitor moved on 31/5/01) is shown as monitor 1 (its designation in NTK).

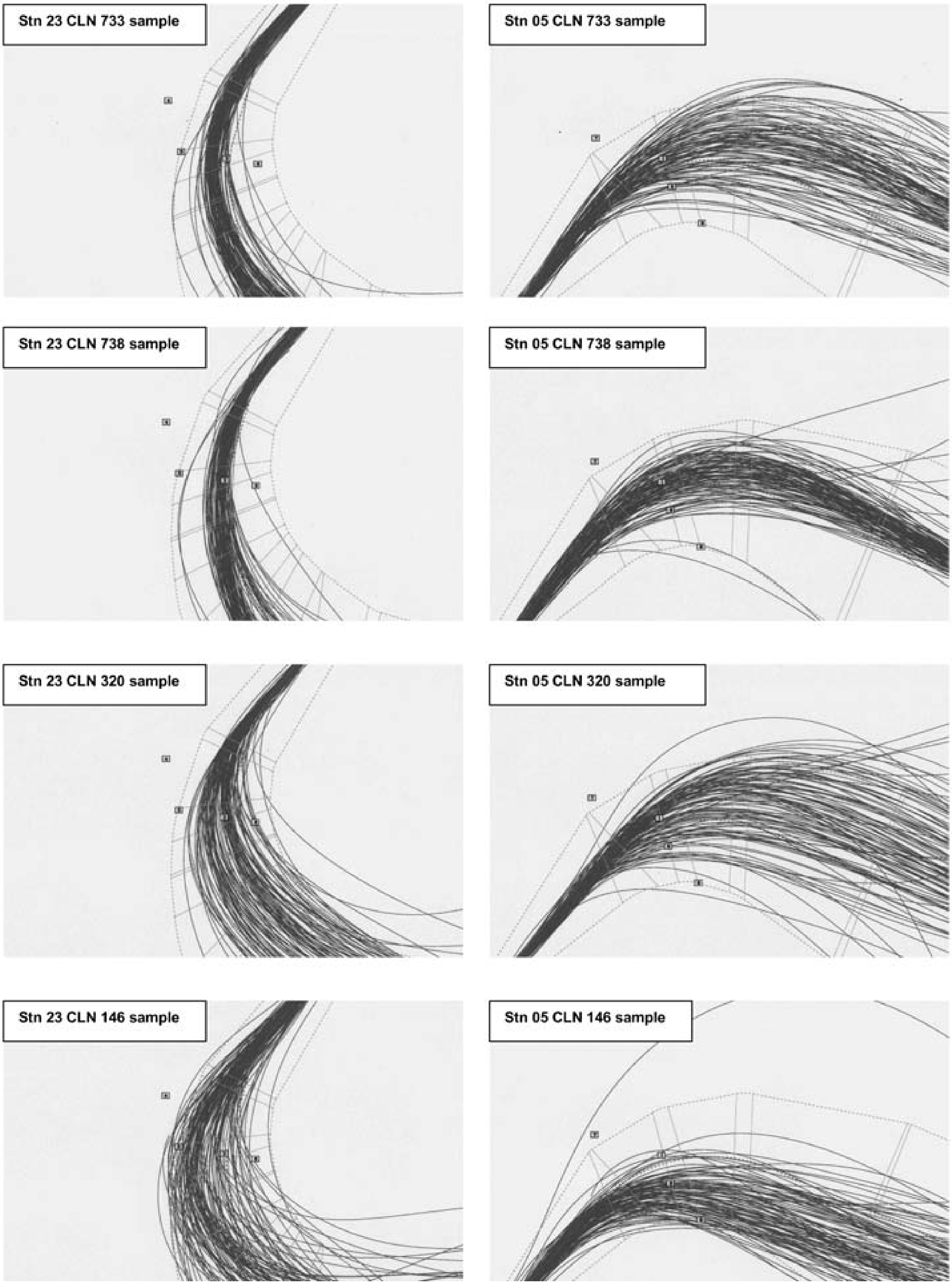
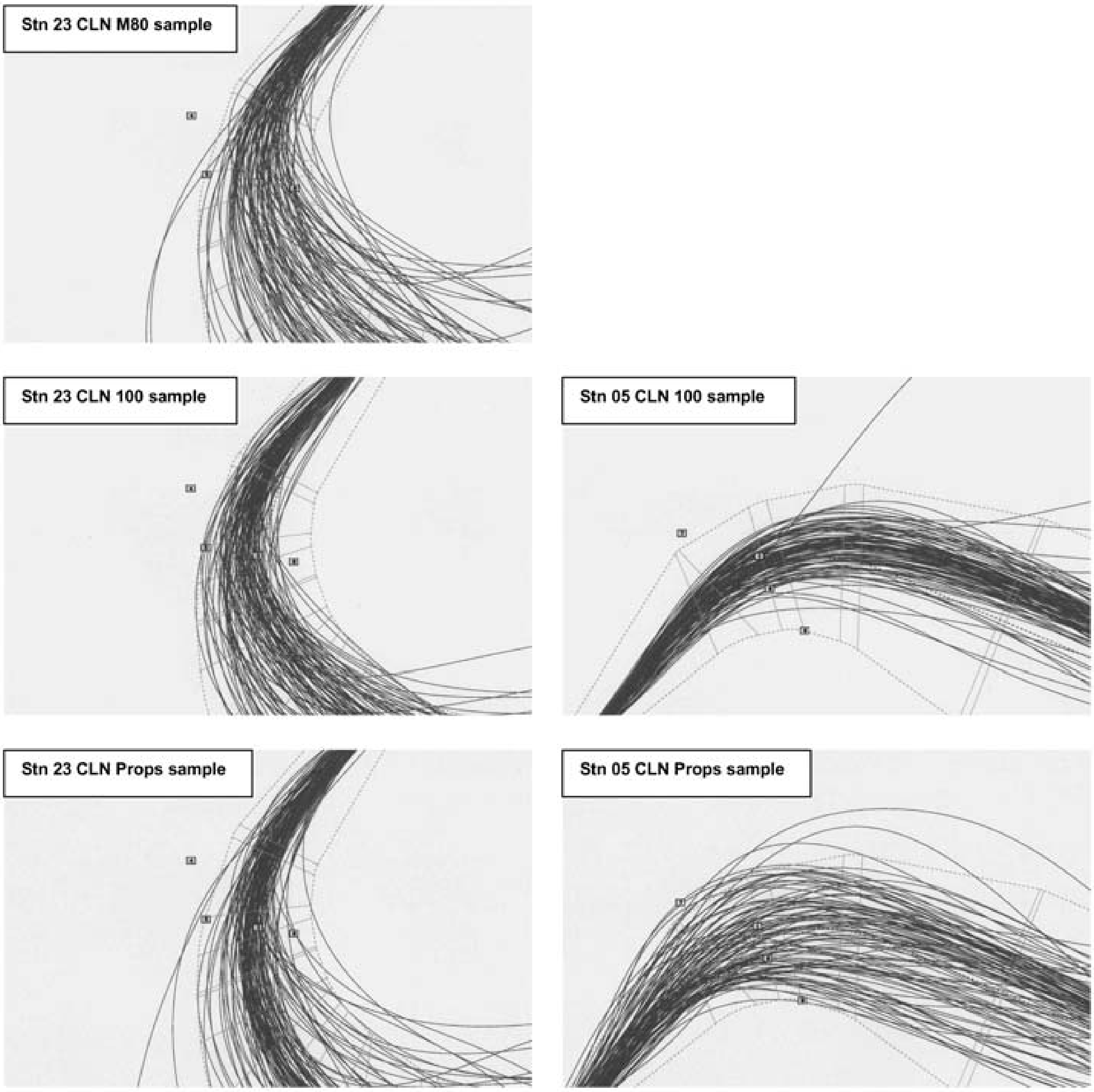


**Figure B5 (b) (ii) Stansted typical departure tracks relative to noise monitors and NPRs**

Note: In these figures monitor 10 (the monitor moved on 31/5/01) is shown as monitor 1 (its designation in NTK).



Stn 23 CLN M80 sample

Stn 23 CLN 100 sample

Stn 05 CLN 100 sample

Stn 23 CLN Props sample

Stn 05 CLN Props sample

**Figure B5 (c) (i) Stansted typical departure tracks relative to noise monitors and NPRs**

Note: In these figures monitor 10 (the monitor moved on 31/5/01) is shown as monitor 1 (its designation in NTK).

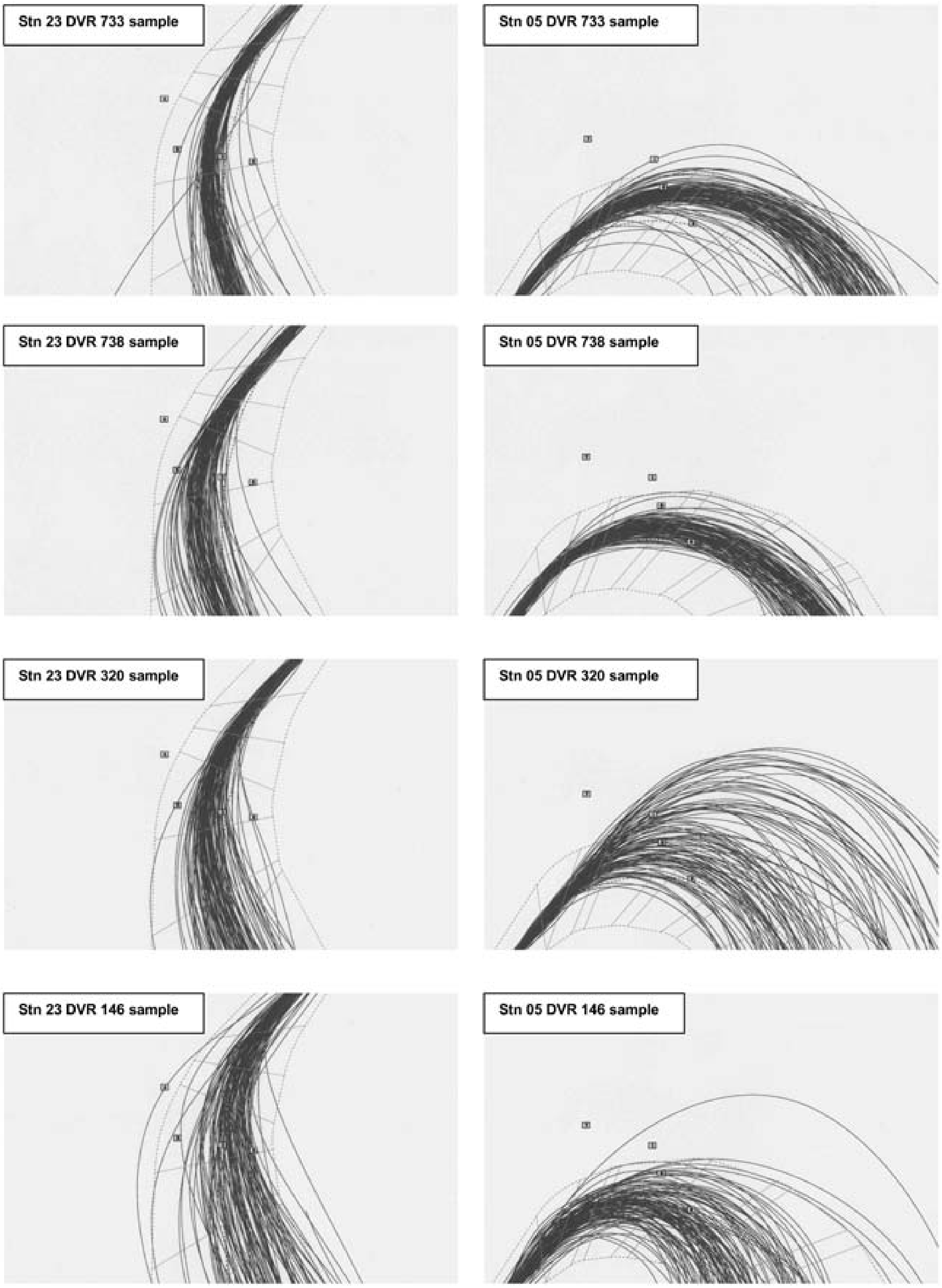
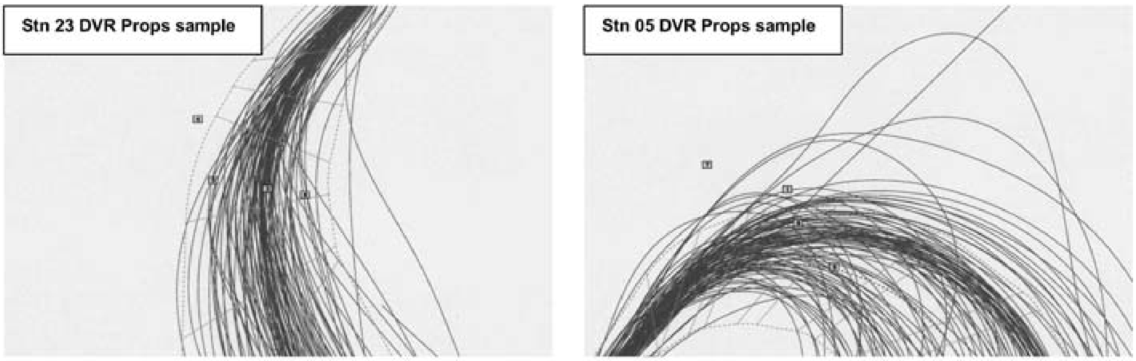


**Figure B5 (c) (ii) Stansted typical departure tracks relative to noise monitors and NPRs**

Note: In these figures monitor 10 (the monitor moved on 31/5/01) is shown as monitor 1 (its designation in NTK).



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## APPENDIX C SCATTERPLOTS

This appendix shows typical scatterplots of tracks relative to each noise monitor "V". Also shown are the appropriate NPR centreline and swathe boundary positions on the gate through the monitor normal to the centreline. Results are shown for a selection of combinations of route and aircraft type.

### List of Figures

*Heathrow 27R MID departures*

| | |
|---|---|
| C4(g) | 733, 744, 763 |
| C4(h) | 320, 146, M80 |

*Heathrow 27R DVR departures*

| | |
|---|---|
| C4(i) | 744, 777 |
| C4(j) | 763, 300 |
| C4(k) | 733, 320 |

*Heathrow 27L WOB/BPK departures*

| | |
|---|---|
| C5(a) | 742Ch3, 744 |
| C5(b) | 340, 777 |
| C5(c) | 763, 757 |
| C5(d) | 733, 738 |
| C5(e) | 320, M80 |

*Heathrow 27L CPT/SAM departures*

| | |
|---|---|
| C5(f) | 742Ch3, 744, 777 |
| C5(g) | 757, 763, 320 |

*Heathrow 27L MID departures*

| | |
|---|---|
| C5(h) | 744, 763 |
| C5(i) | 733, 320 |
| C5(j) | 146, M80 |

*Heathrow 27L DVR departures*

| | |
|---|---|
| C5(k) | 744, 777 |
| C5(l) | 763, 300 |
| C5(m) | 733, 320 |
| C5(n) | 310, 330 |

*Stansted 05 BZD departures*

| | |
|---|---|
| C6(a) | 733, 738 |
| C6(b) | 752, 320 |
| C6(c) | 146, Props |

*Stansted 05 CLN departures*

| | |
|---|---|
| C6(d) | 733, 738 |
| C6(e) | 100, 320 |
| C6(f) | 146, Props |

*Stansted 05 DVR departures*

| | |
|---|---|
| C6(g) | 320, 738, 733 |
| C6(h) | 146, Props |

*Stansted 23 BZD departures*

| | |
|---|---|
| C7(a) | 733, 738 |
| C7(b) | 752, 320 |
| C7(c) | 146, Props |

*Stansted 23 CLN departures*

| | |
|---|---|
| C7(d) | 733, 738 |
| C7(e) | 100, 320 |
| C7(f) | 146, Props |

*Stansted 23 DVR departures*

| | |
|---|---|
| C7(g) | 320, 738 |
| C7(h) | 146, Props |

Figure C1(a) Gatwick April-June 2001 26L departures (all routes) 742Ch3 and 744

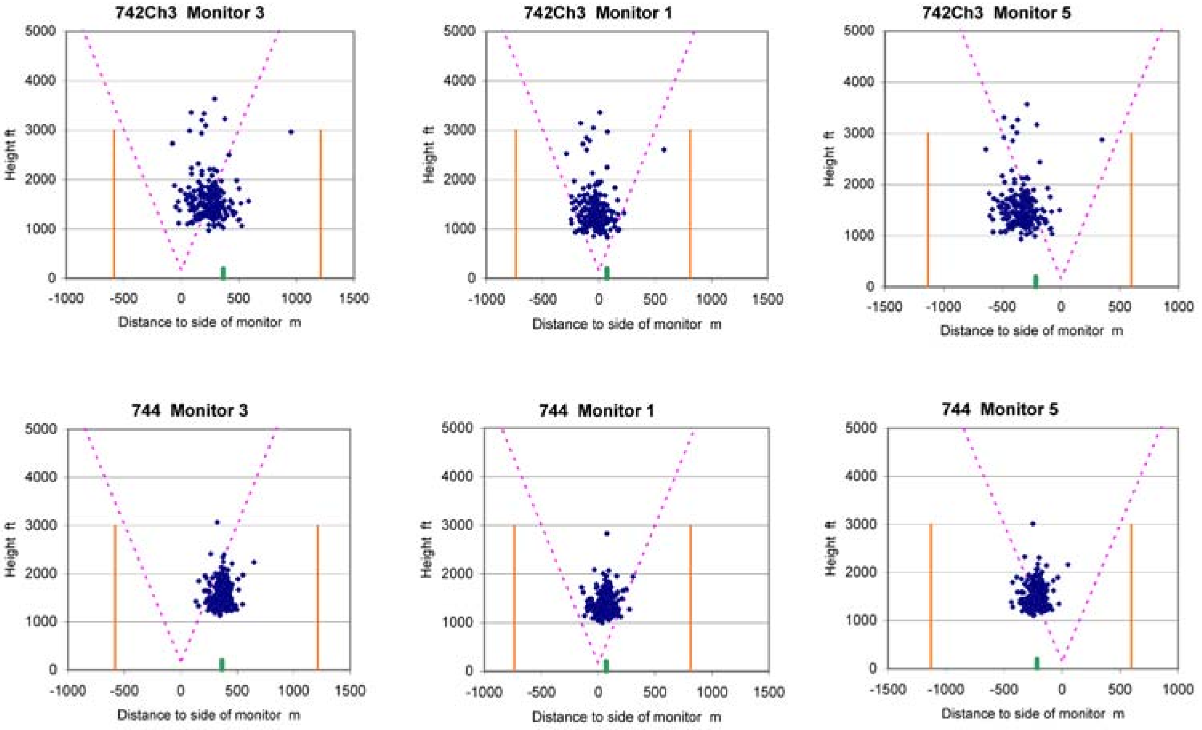


Figure C1(b) Gatwick April-June 2001 26L departures (all routes) 733 and 320

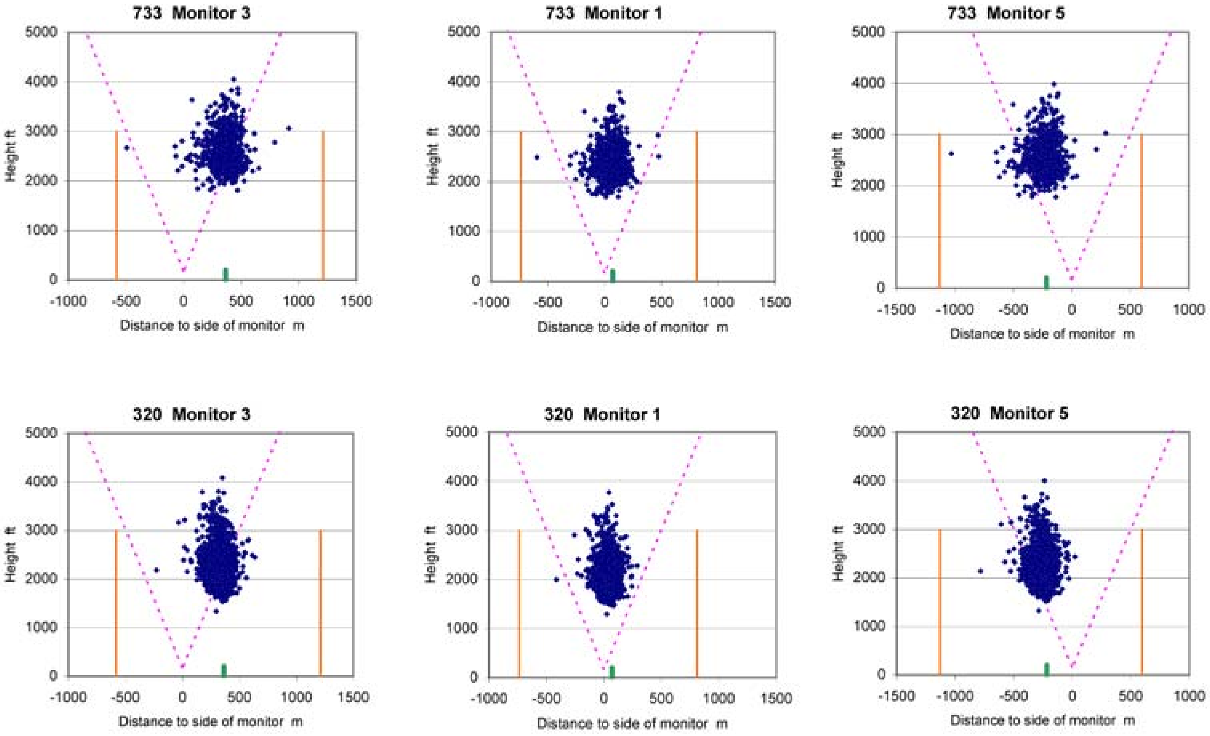


Figure C1(c) Gatwick April-June 2001 26L departures (all routes) 757 and 763

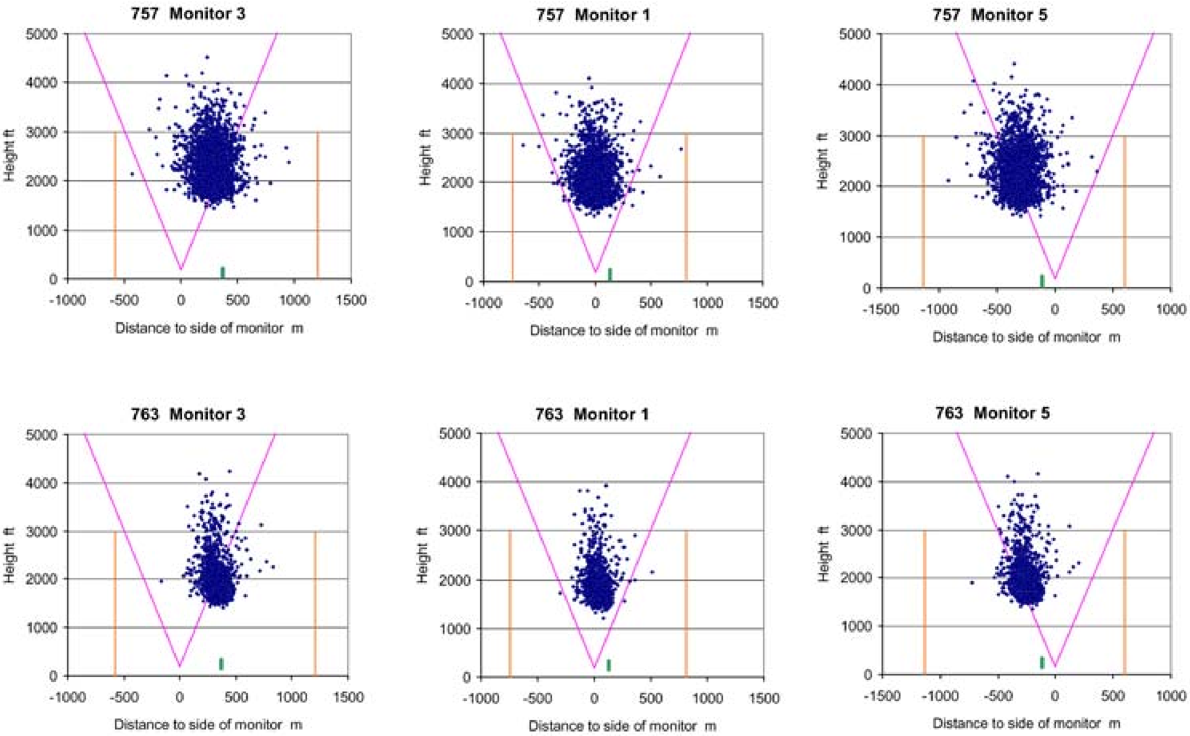


Figure C1(d) Gatwick April-June 2001 26L departures (all routes) 777 and 330

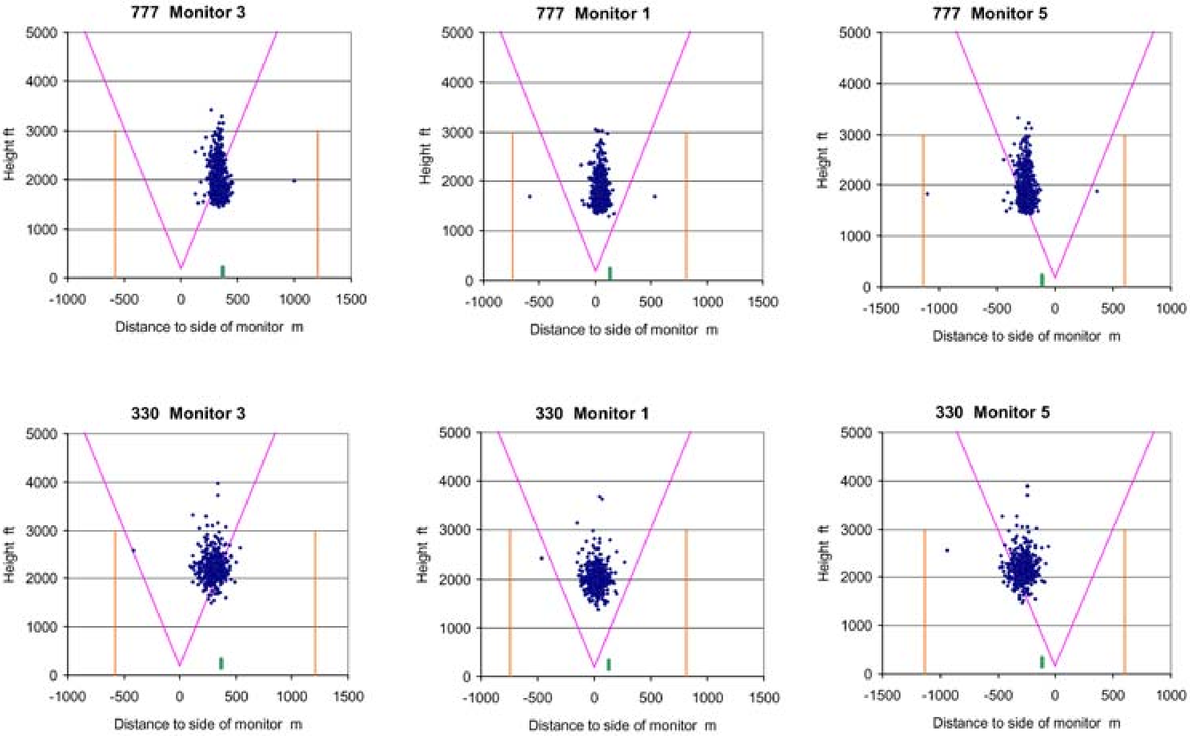


**Figure C1(e) Gatwick April-June 2001 26L departures (all routes) 146 and M80**

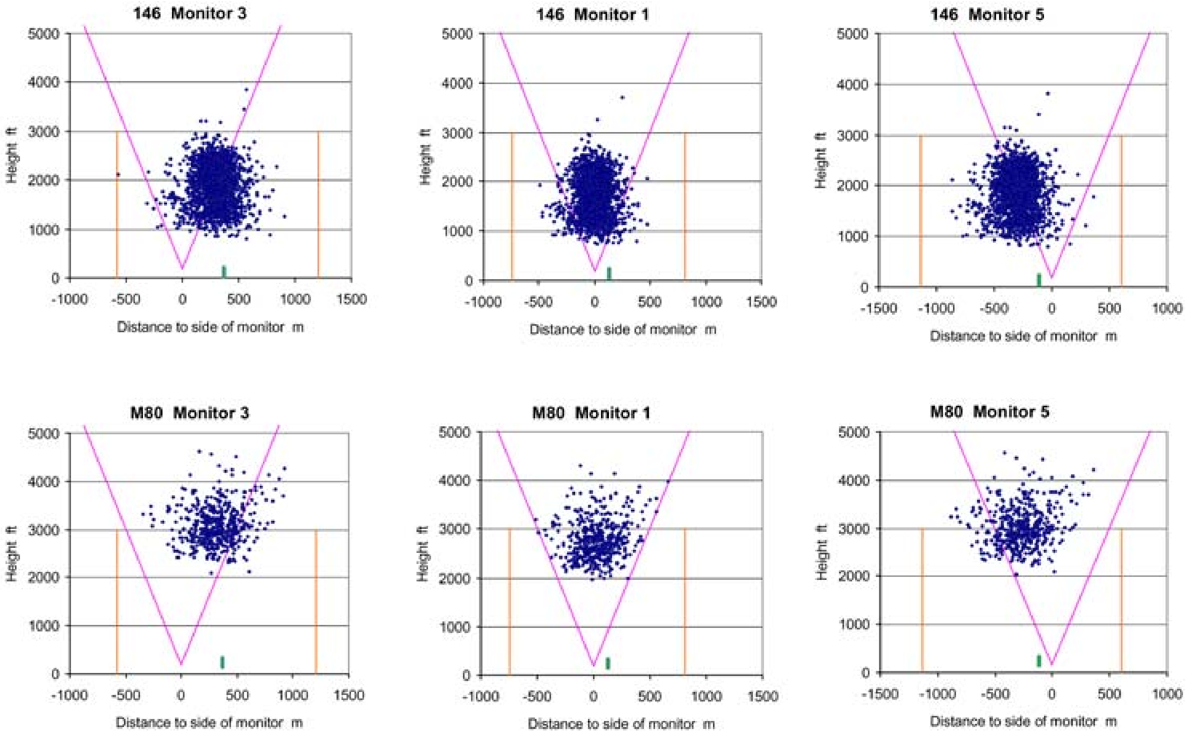


**Figure C1(f) Gatwick April-June 2001 26L departures (all routes) AT7 and DH3**

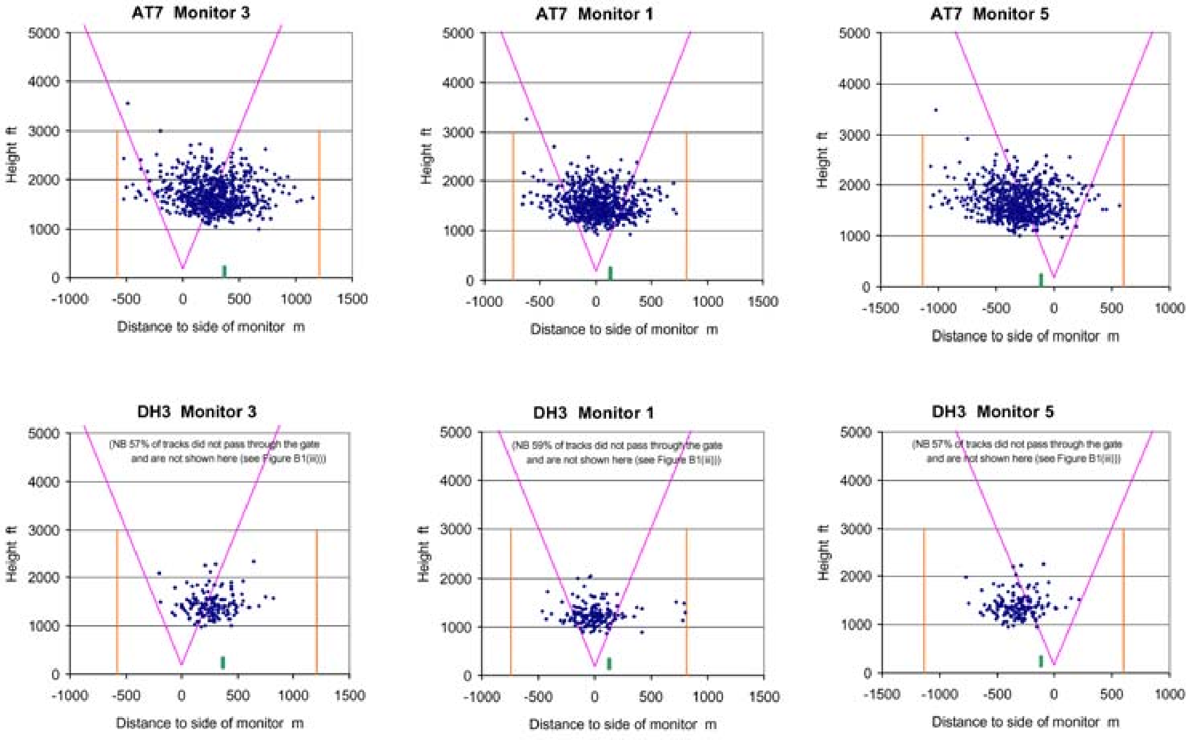
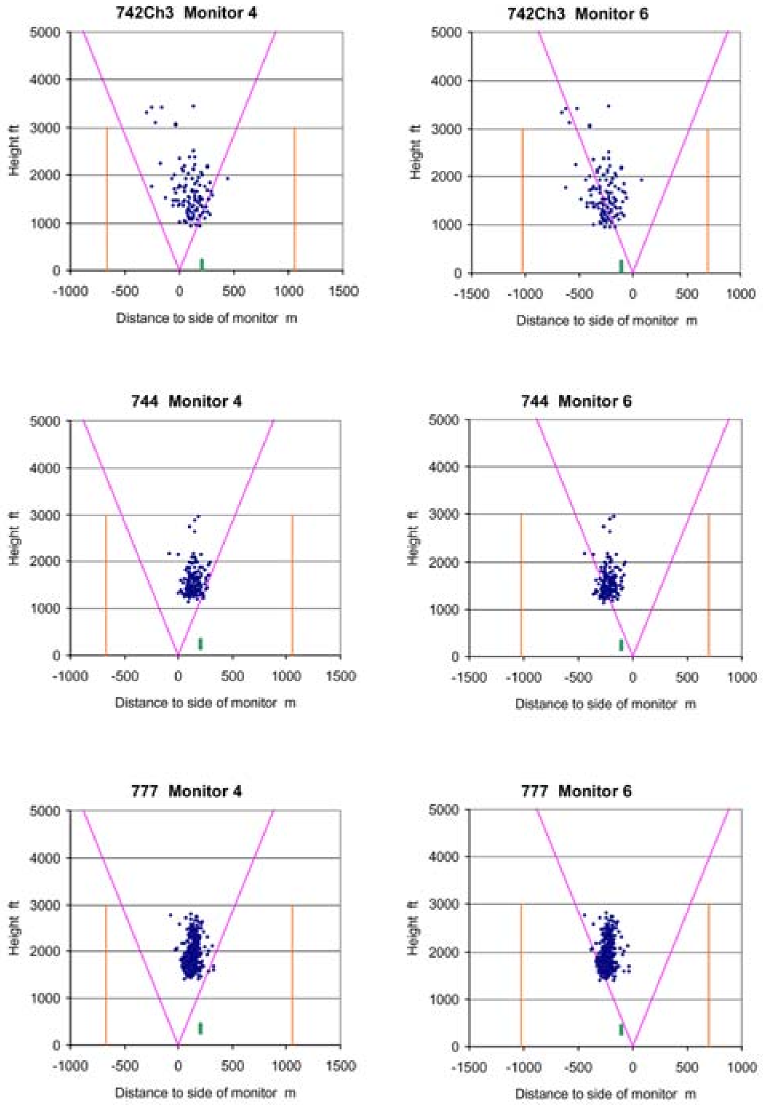


Figure C2(a) Gatwick April-June 2001 08R departures (all routes)
742Ch3, 744 and 777



742Ch3 Monitor 4

742Ch3 Monitor 6

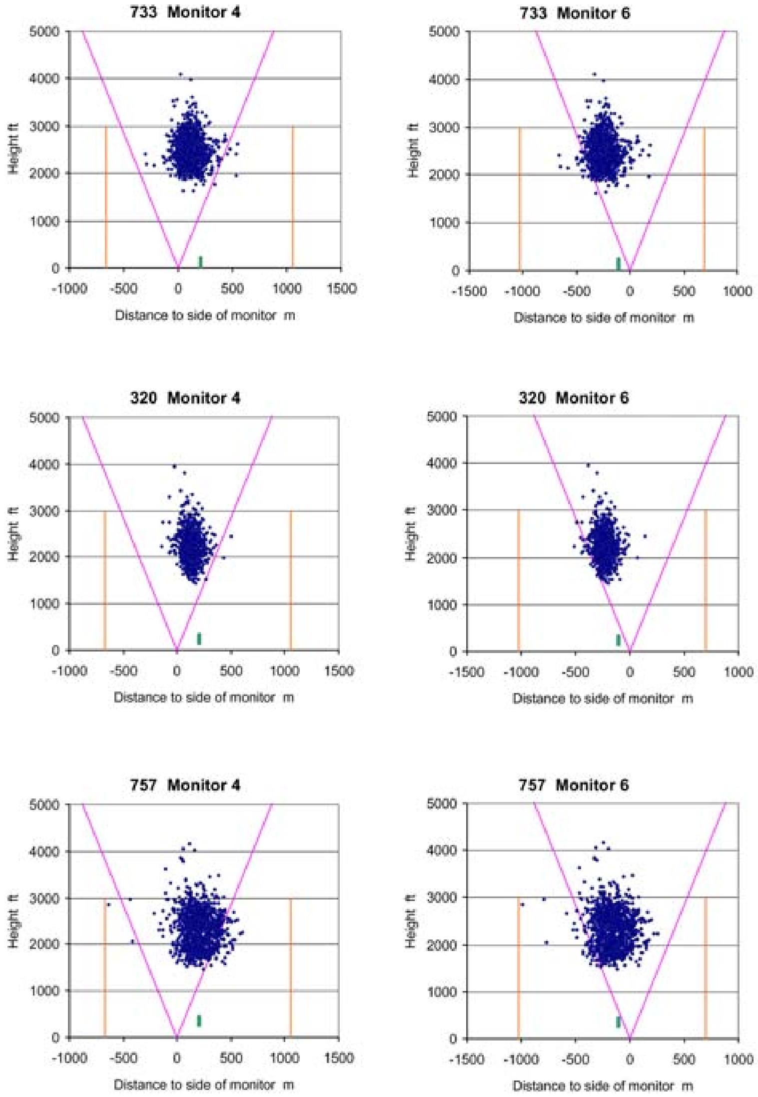
744 Monitor 4

744 Monitor 6

777 Monitor 4

777 Monitor 6

Figure C2(b) Gatwick April-June 2001 08R departures (all routes)
733, 320 and 757



733 Monitor 4

733 Monitor 6

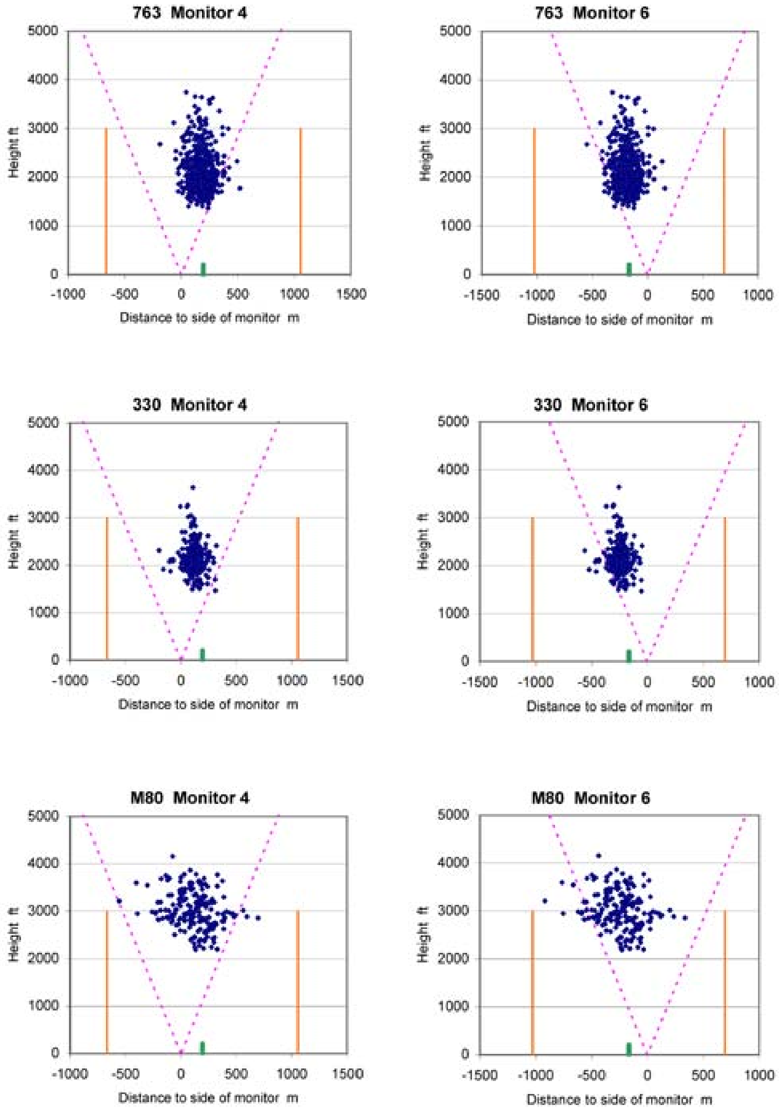
320 Monitor 4

320 Monitor 6

757 Monitor 4

757 Monitor 6

## Figure C2(c) Gatwick April-June 2001 08R departures (all routes)
## 763, 330 and M80



## Figure C2(d) Gatwick April-June 2001 08R departures (all routes)
## 146, AT7 and DH3

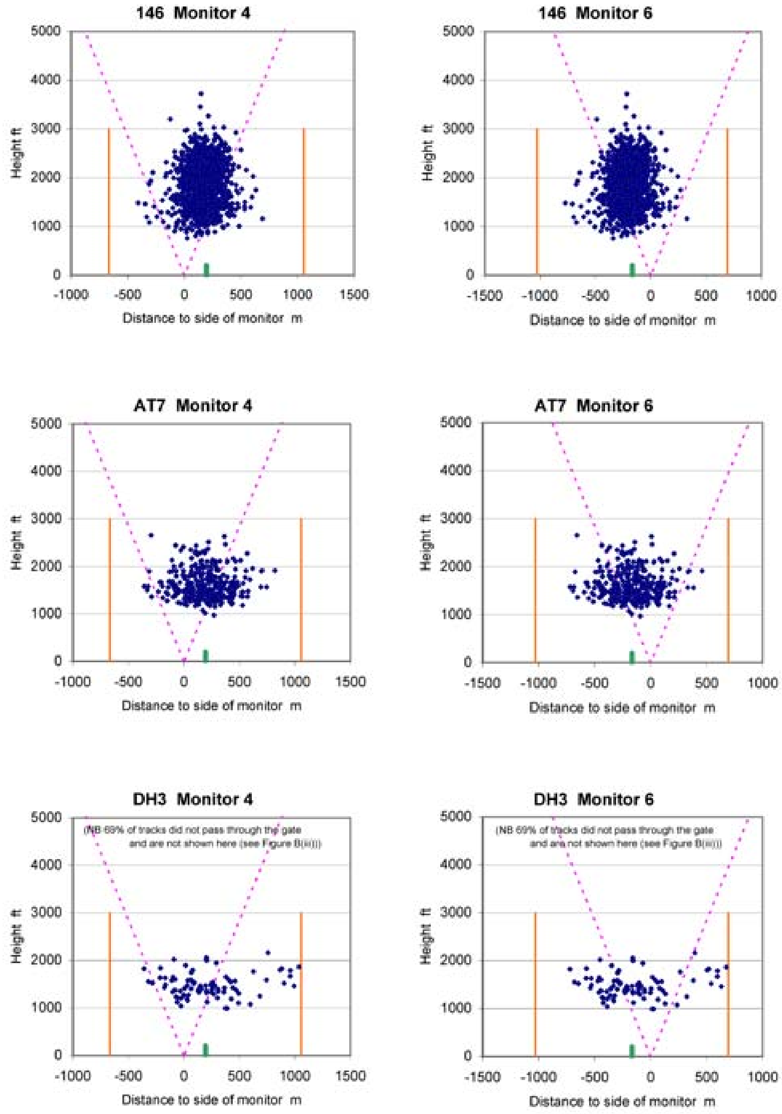


Figure C3(a) Heathrow April-June 2001 09R BUZ/BPK departures
742Ch3, 744 and 340

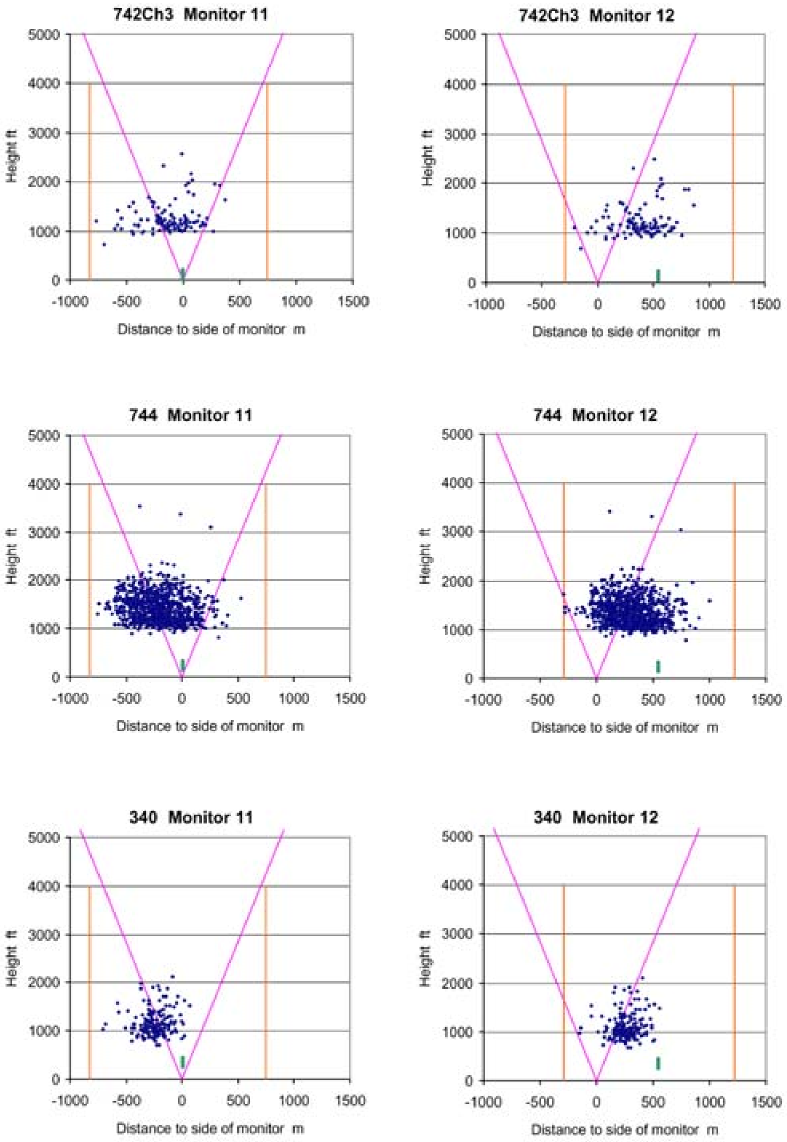
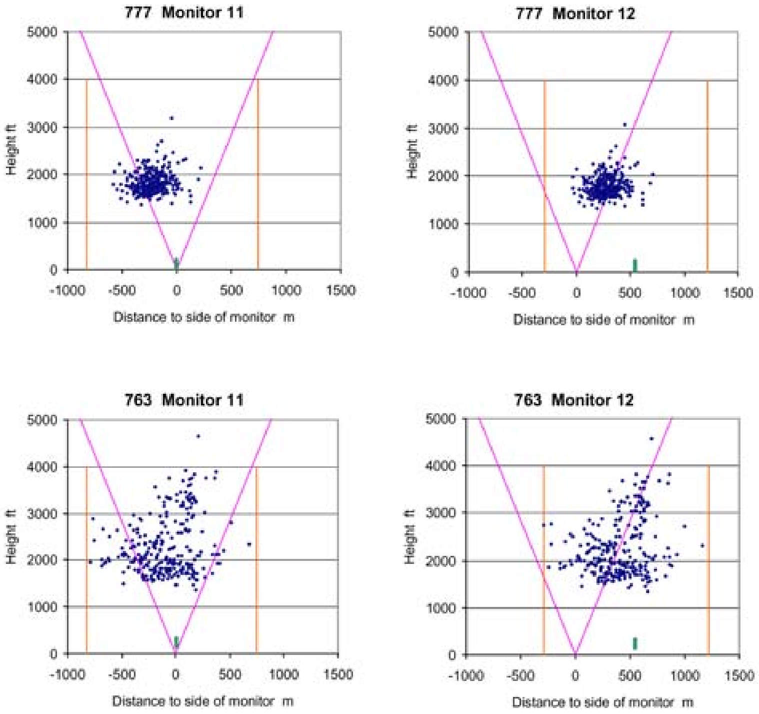
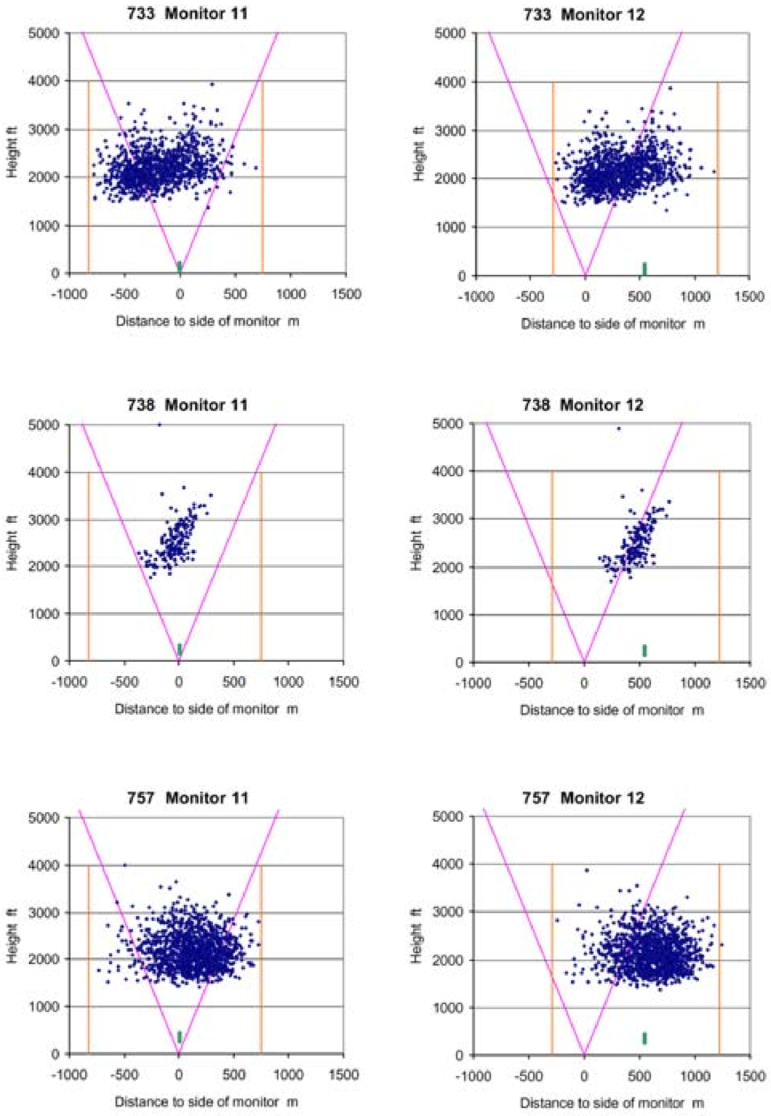


Figure C3(b) Heathrow April-June 2001 09R BUZ/BPK departures
777 and 763



## Figure C3(c) Heathrow April-June 2001 09R BUZ/BPK departures 733, 738 and 757



## Figure C3(d) Heathrow April-June 2001 09R BUZ/BPK departures 320, M80 and M90

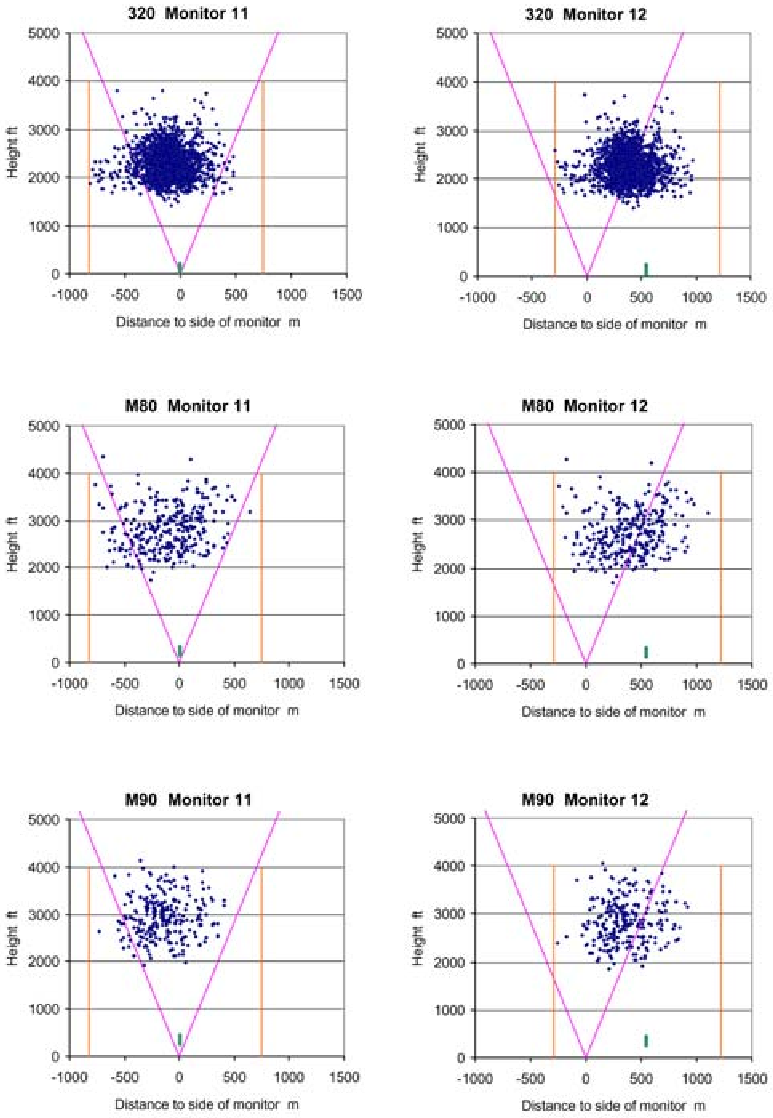


Figure C3(e) Heathrow April-June 2001 09R DVR departures 744 and 777

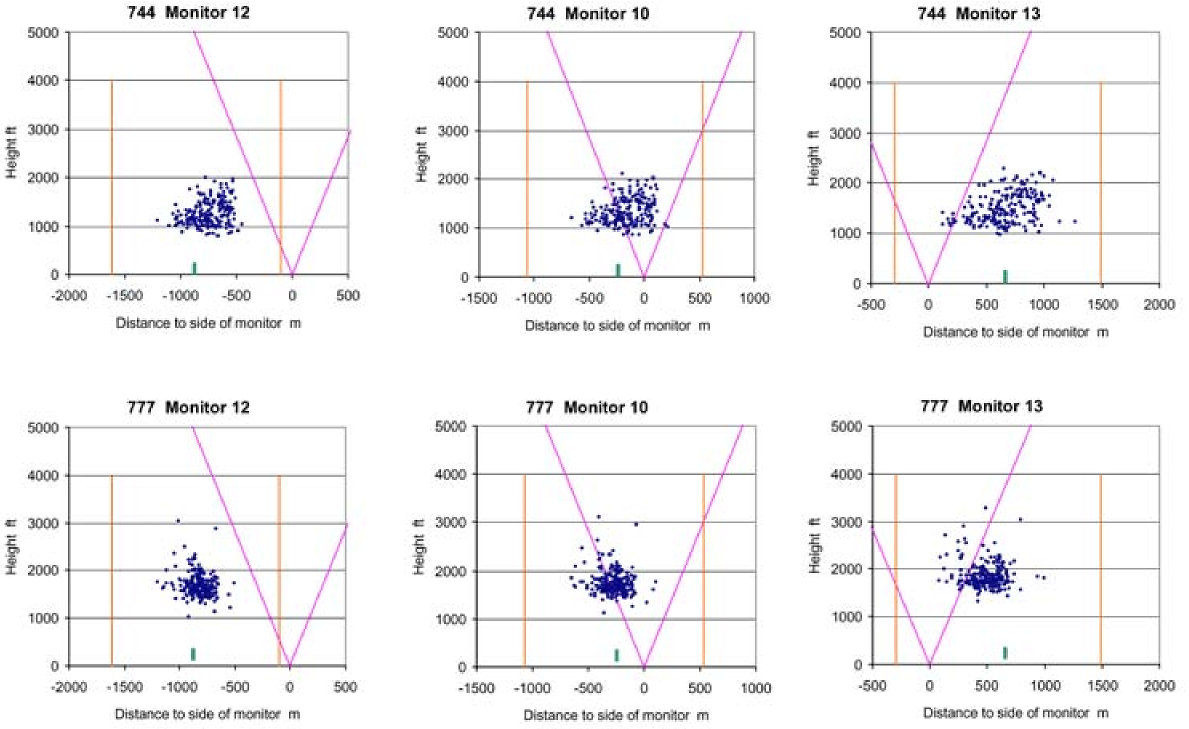


Figure C3(f) Heathrow April-June 2001 09R DVR departures 330 and 763

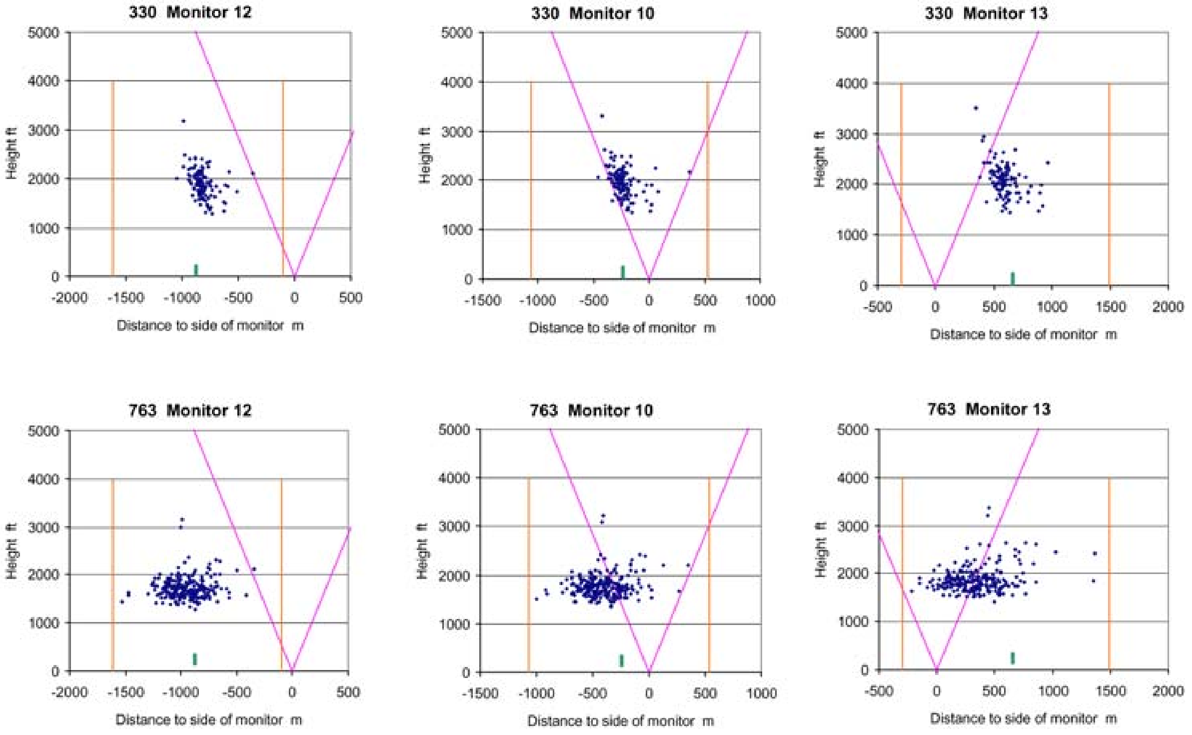


Figure C3(g) Heathrow April-June 2001 09R DVR departures 300 and 320

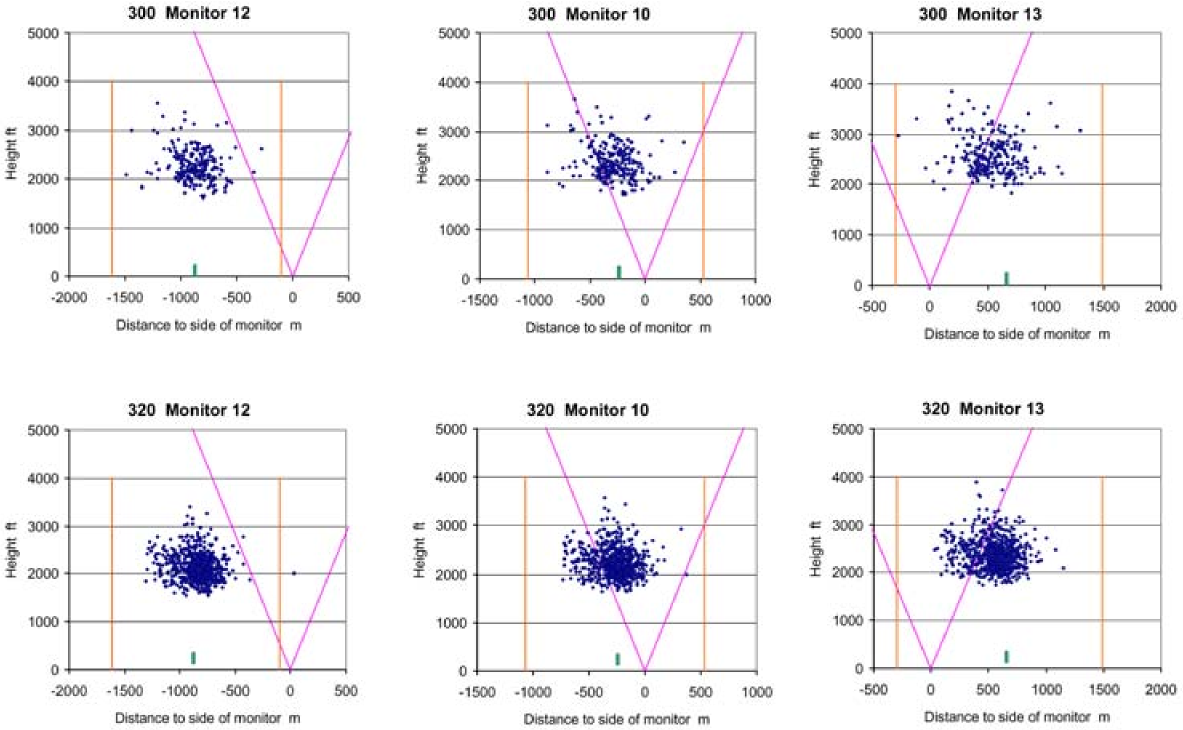


Figure C3(h) Heathrow April-June 2001 09R DVR departures 733 and 757

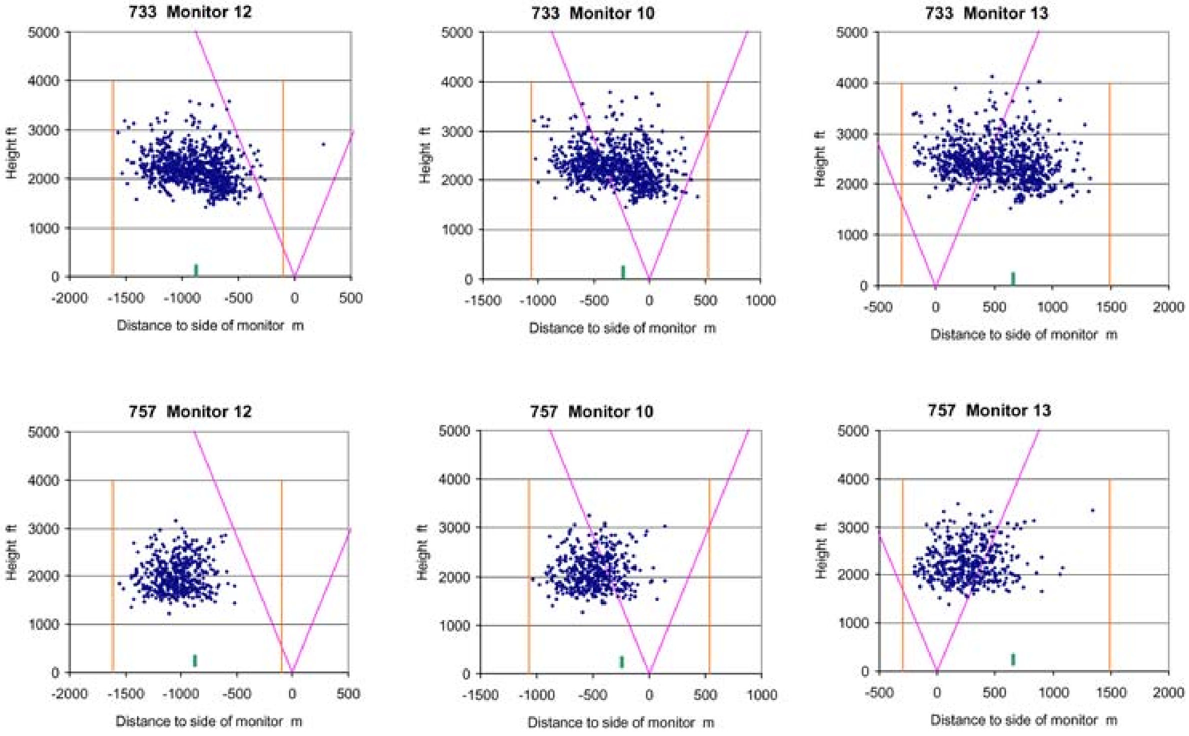


Figure C3(i) Heathrow April-June 2001 09R MID departures
744, 757, 763

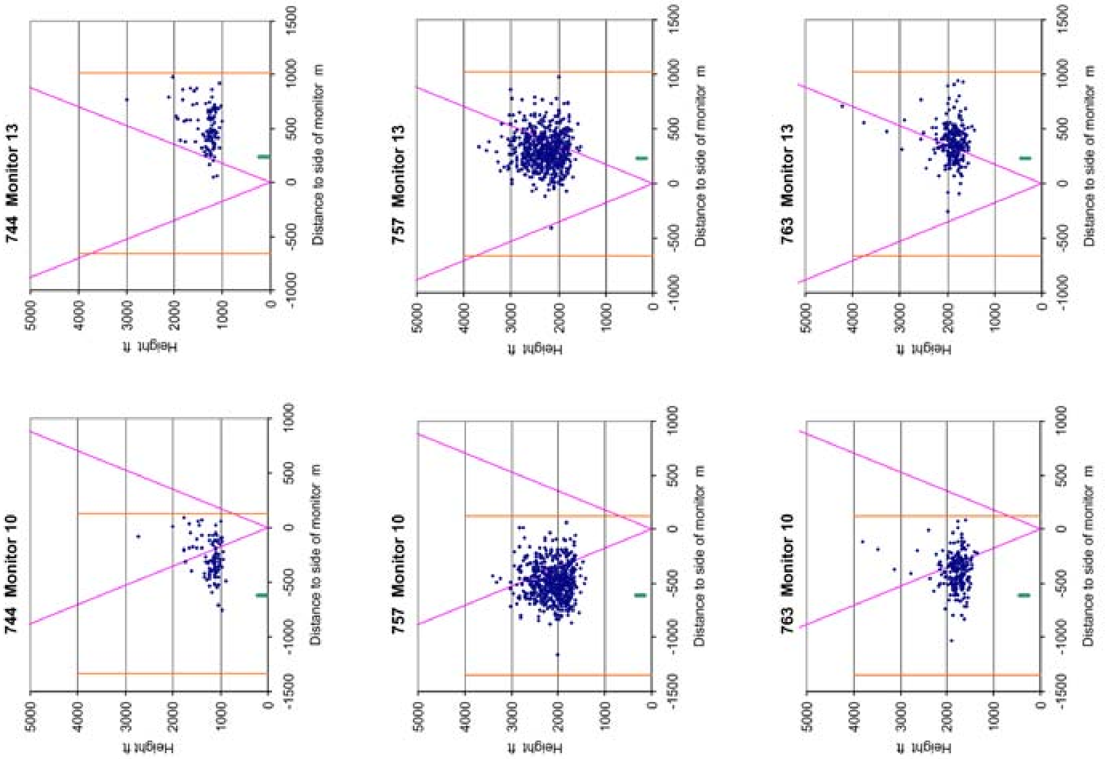
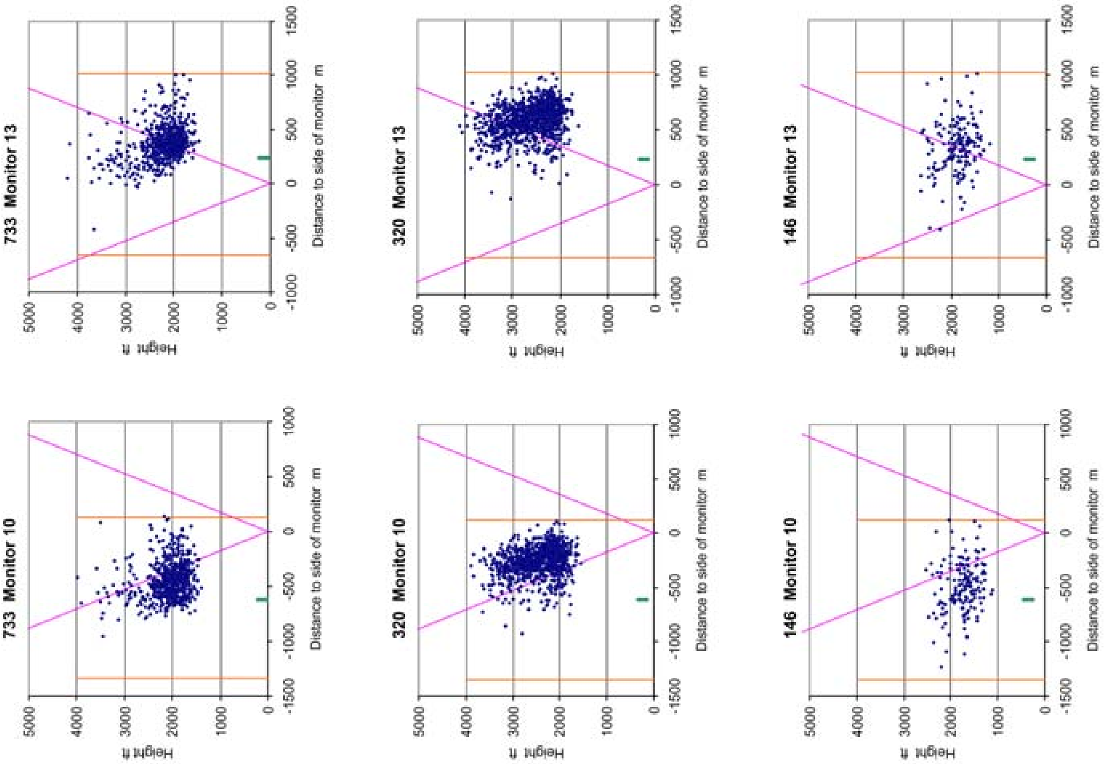
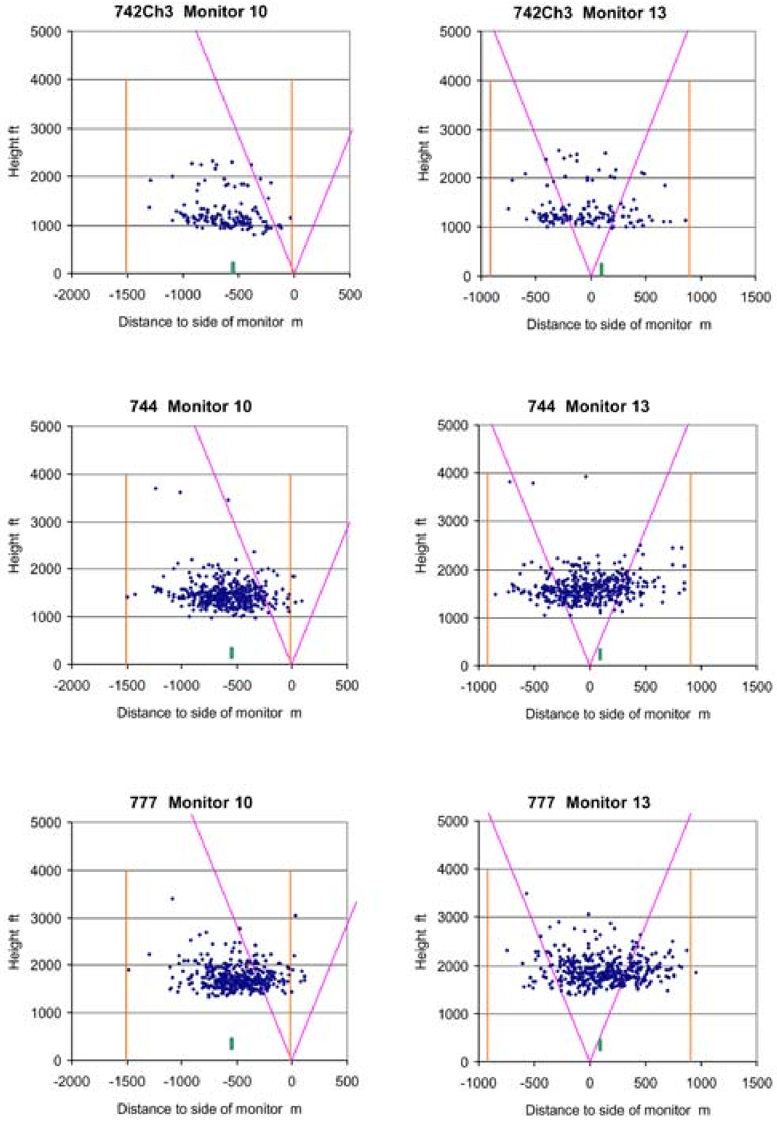


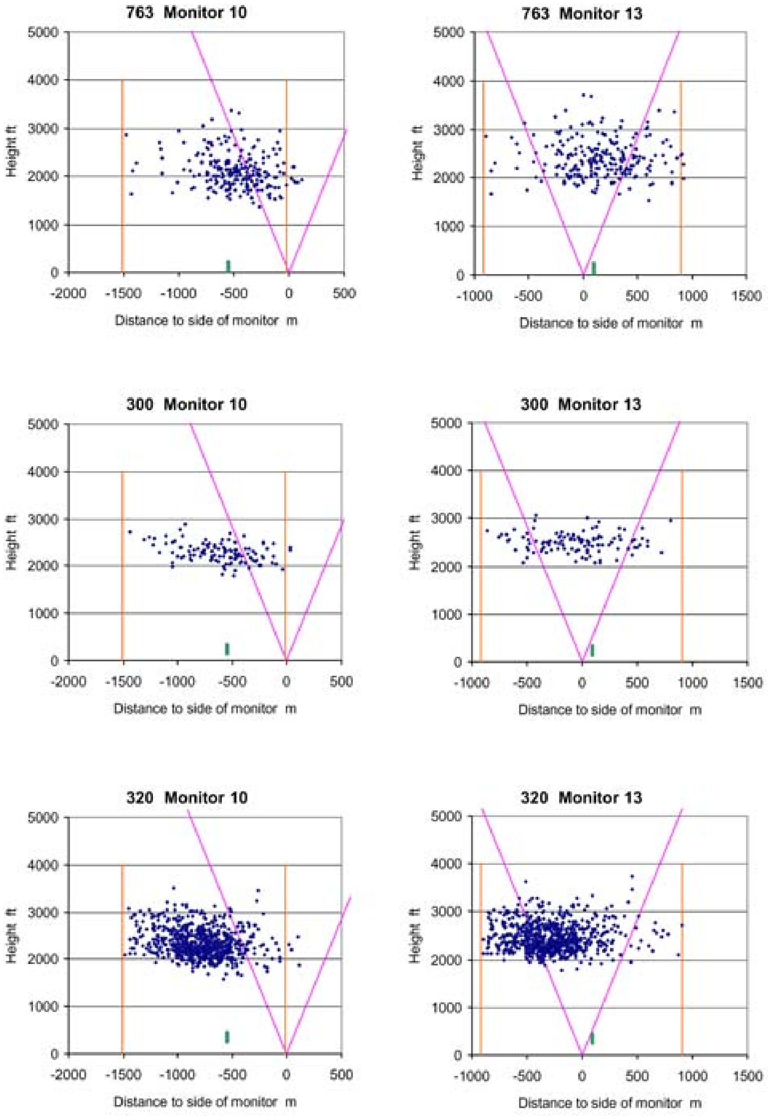
Figure C3(j) Heathrow April-June 2001 09R MID departures
733, 320, 146



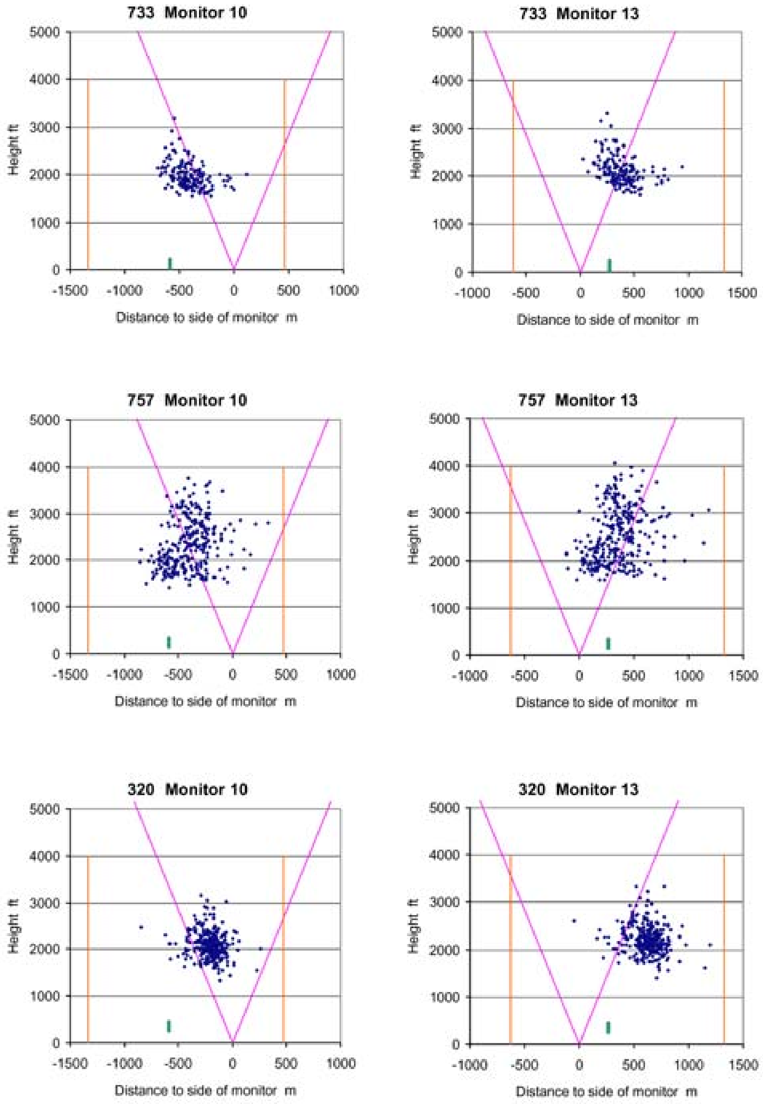
## Figure C3(k) Heathrow April-June 2001 09R CPT departures
## 742Ch3, 744, 777



## Figure C3(l) Heathrow April-June 2001 09R CPT departures
## 763, 300 and 320



# Figure C3(m) Heathrow April-June 2001 09R SAM departures
733, 752, 320



733 Monitor 10

733 Monitor 13

757 Monitor 10

757 Monitor 13

320 Monitor 10

320 Monitor 13

Figure C4(a) Heathrow April-June 2001 27R WOB/BPK departures 742Ch3, 744

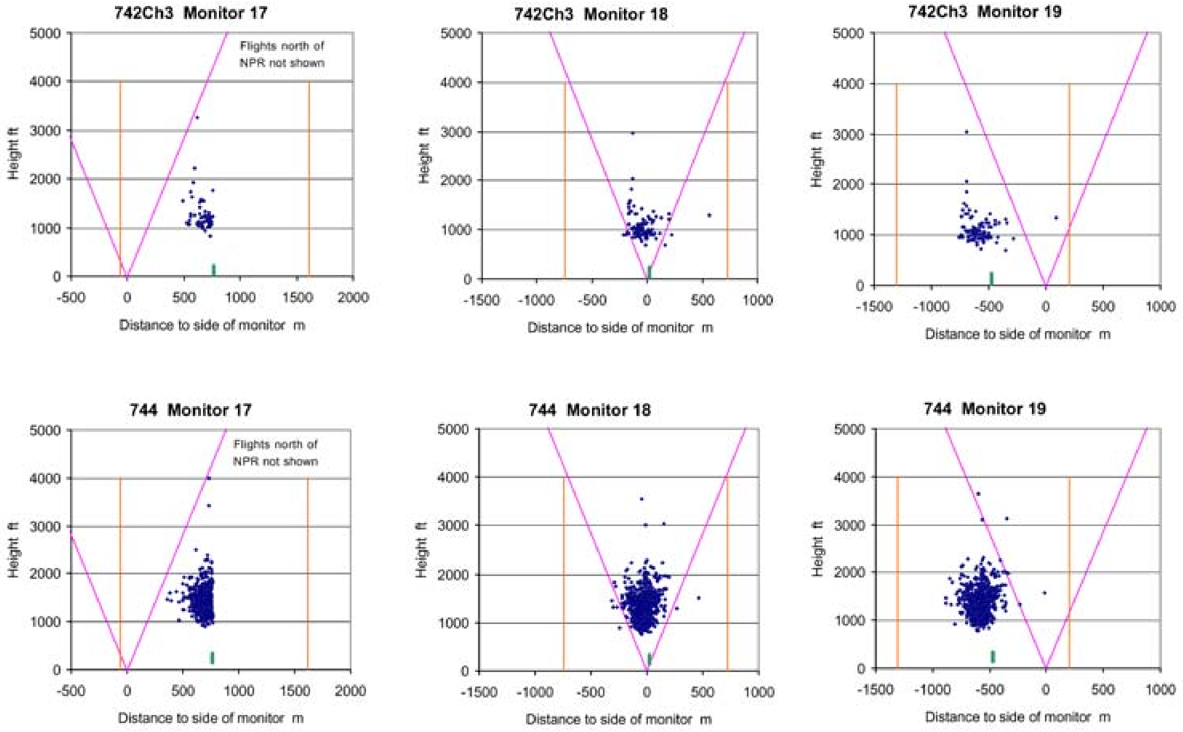


Figure C4(b) Heathrow April-June 2001 27R WOB/BPK departures 340, 777

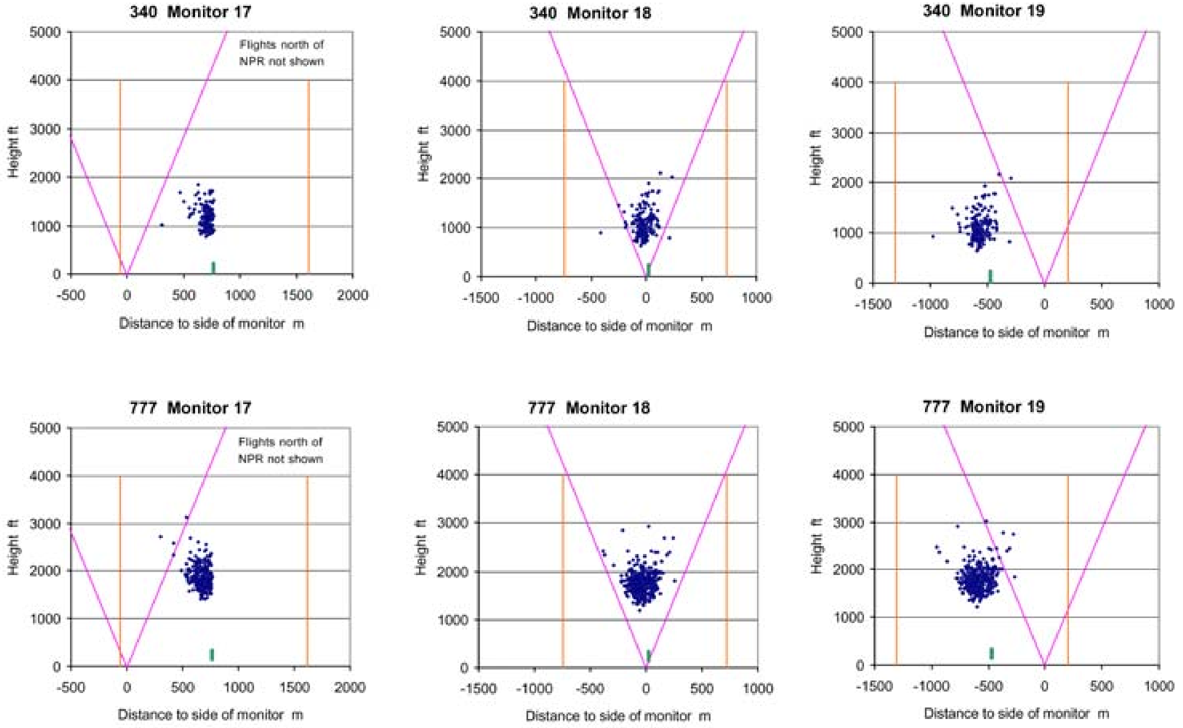


**Figure C4(c) Heathrow April-June 2001 27R WOB/BPK departures 763, 757**

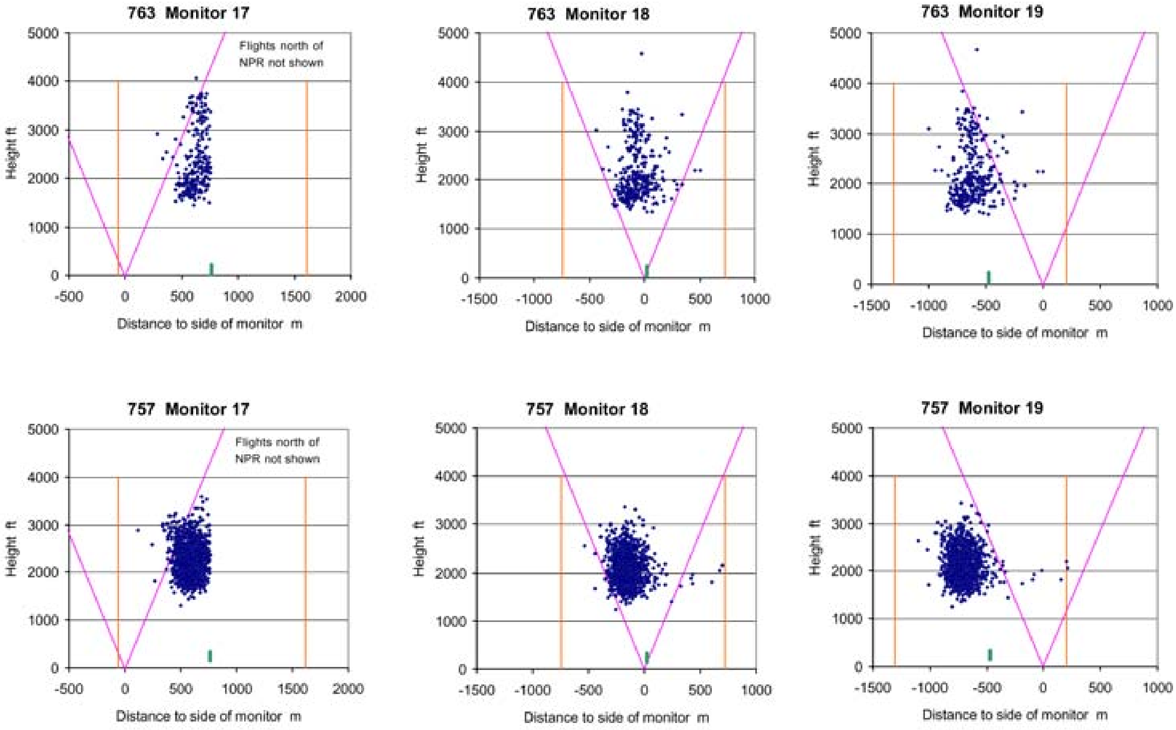


**Figure C4(d) Heathrow April-June 2001 27R WOB/BPK departures 733, 738**

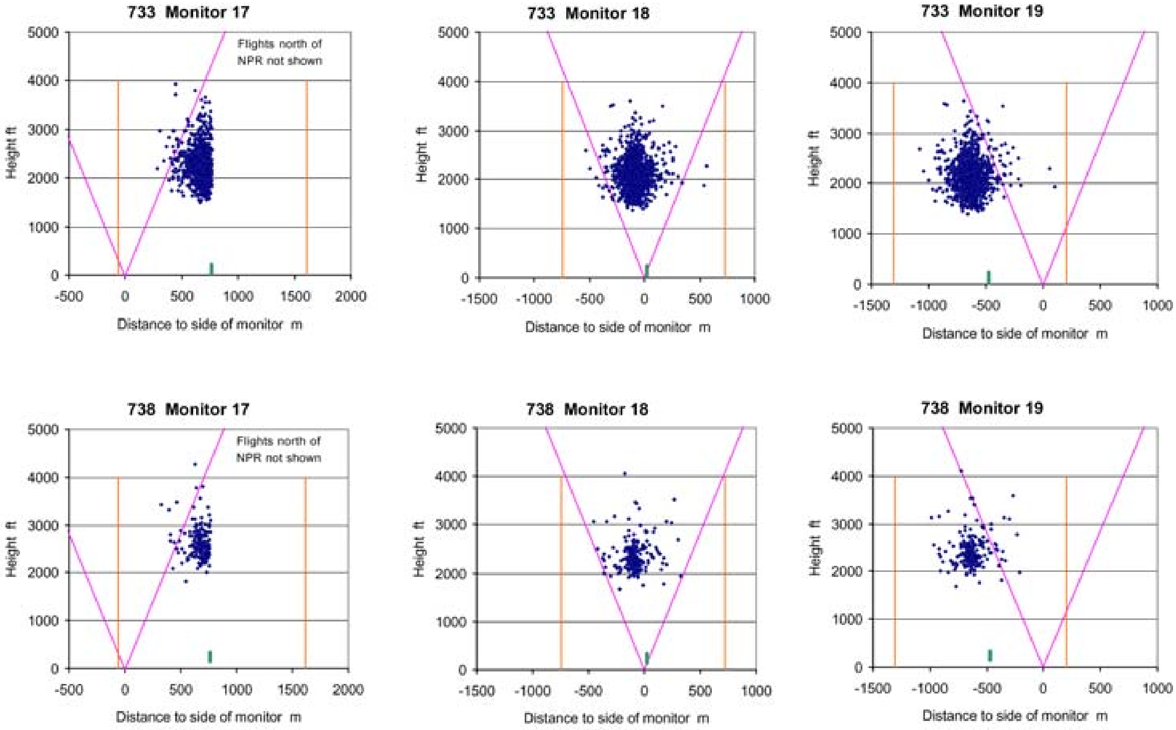


**Figure C4(e) Heathrow April-June 2001 27R WOB/BPK departures 320, M80**

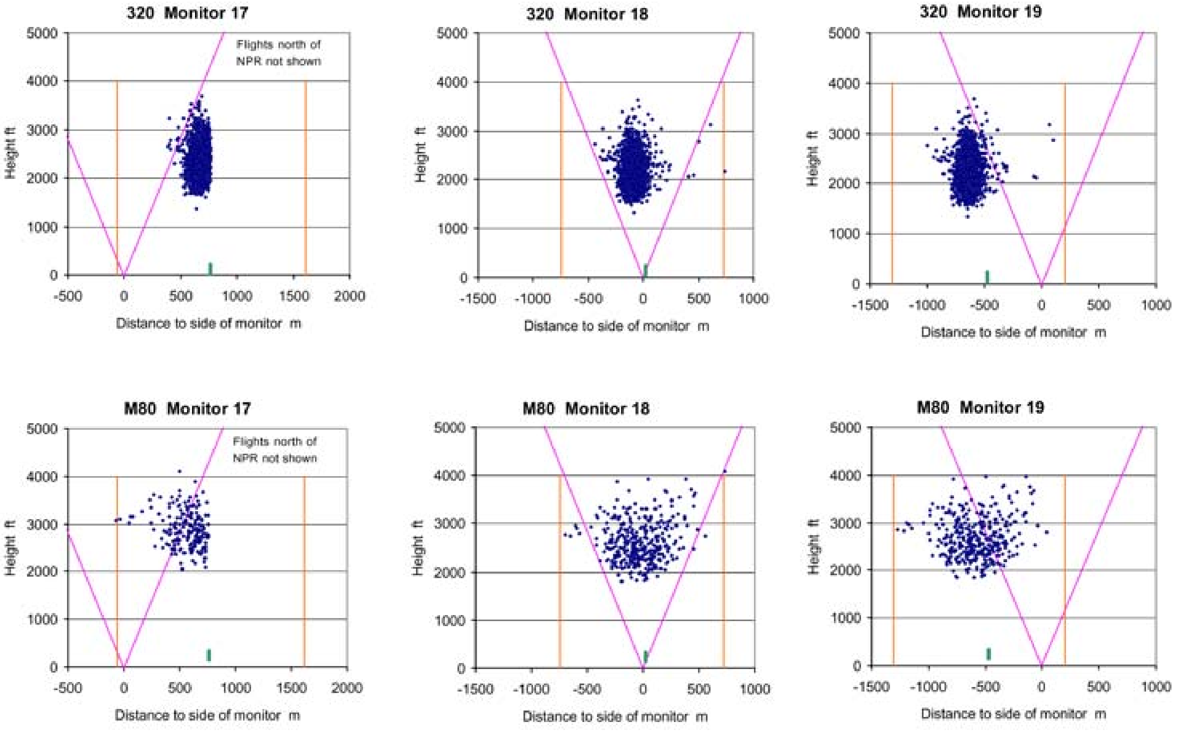


**Figure C4(f) Heathrow April-June 2001 27R CPT/SAM departures Monitor 18 742Ch3, 744, 752, 763, 777, 320**

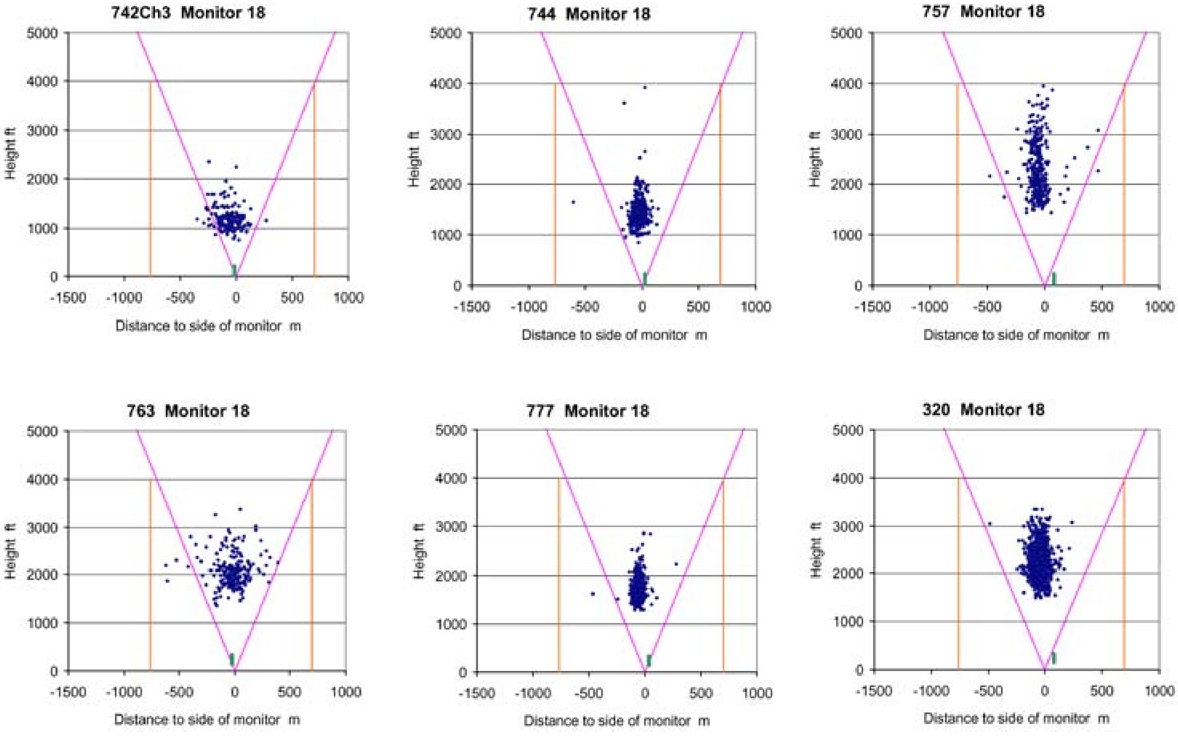


**Figure C4(g) Heathrow April-June 2001 27R MID departures**
**733, 744, 763**

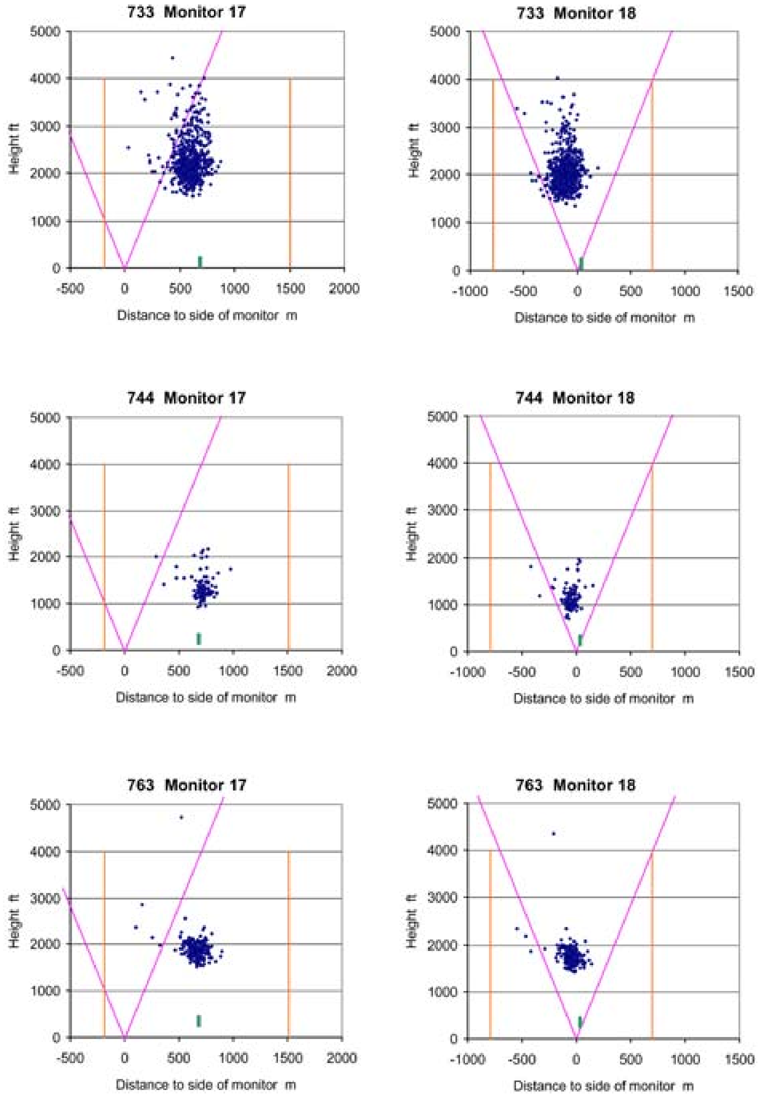


**Figure C4(h) Heathrow April-June 2001 27R MID departures**
**320, 146, M80**

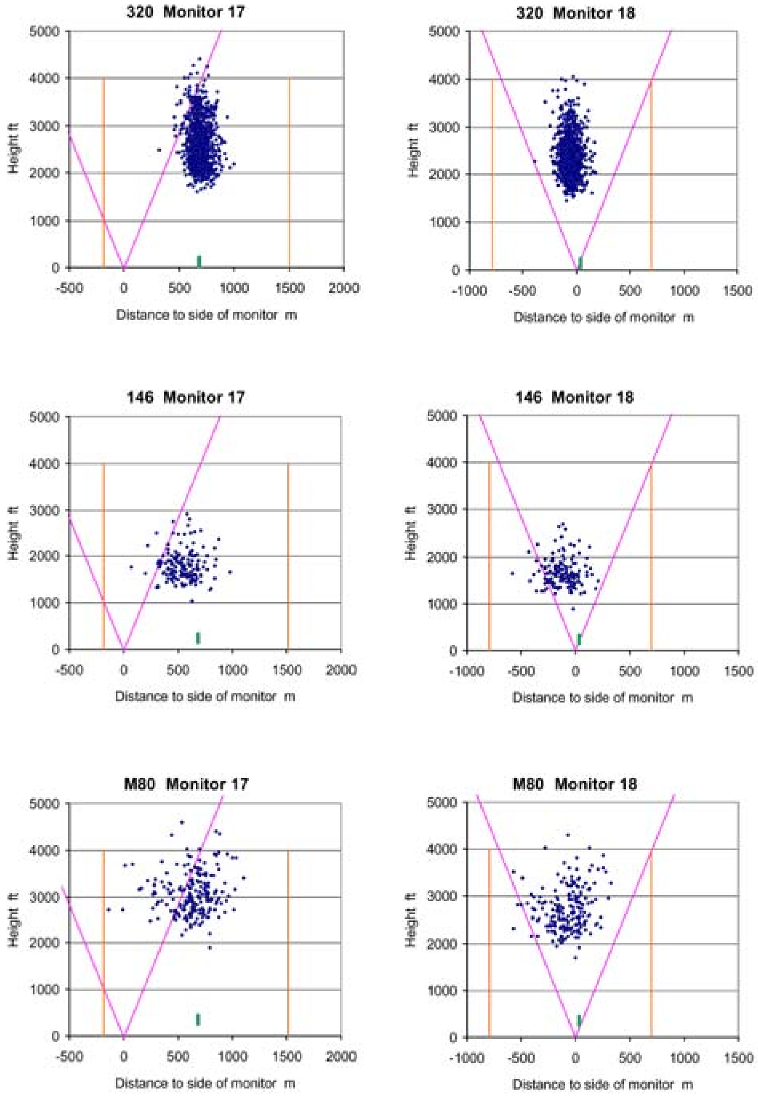


**Figure C4(i) Heathrow April-June 2001 27R DVR departures 744, 777**

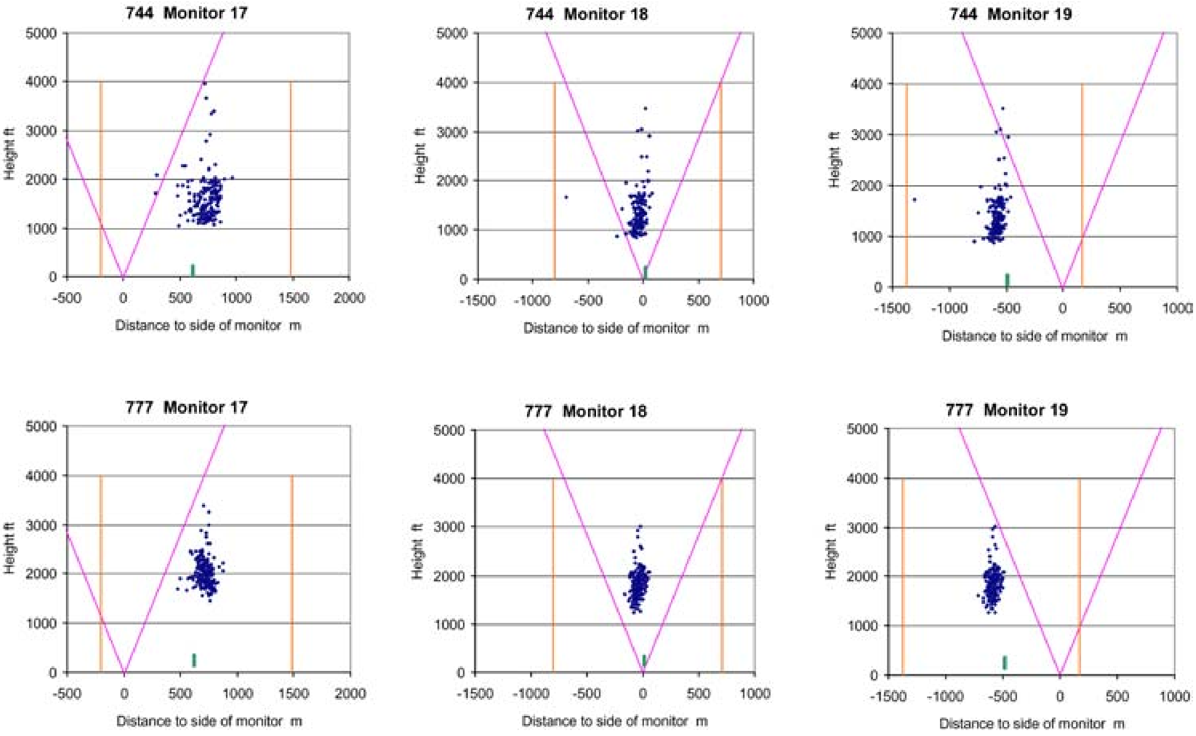


**Figure C4(j) Heathrow April-June 2001 27R DVR departures 763, 300**

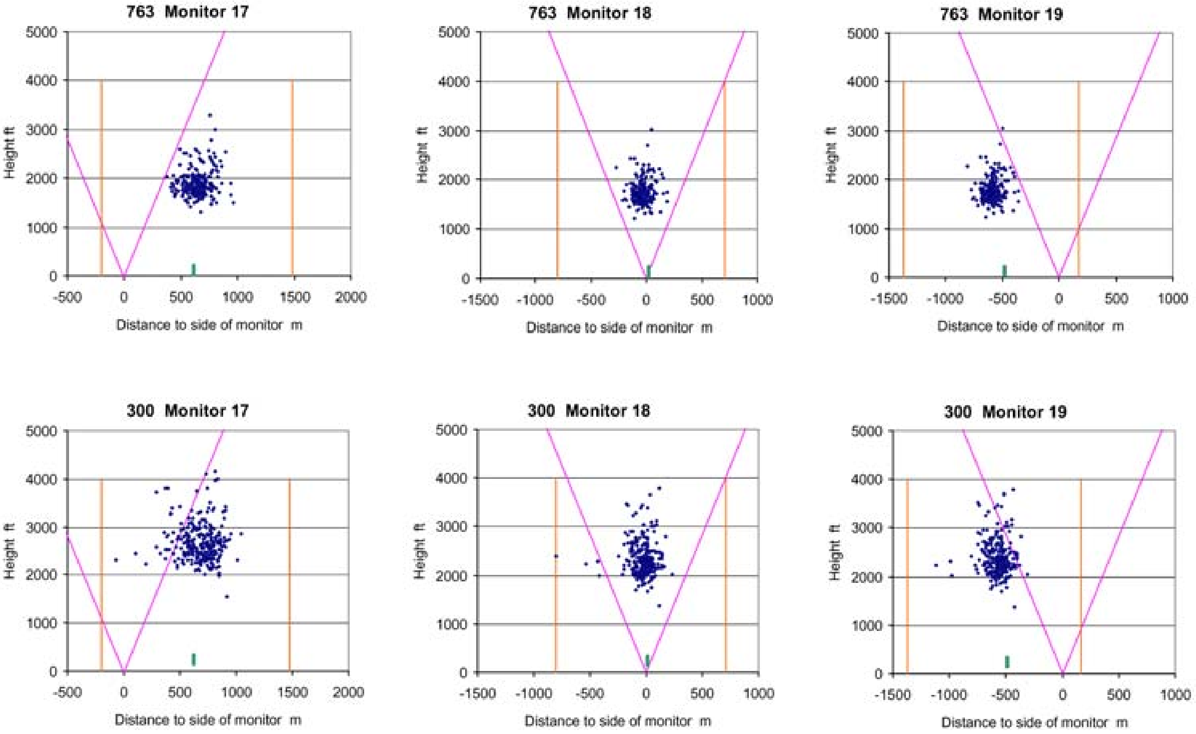


**Figure C4(k) Heathrow April-June 2001 27R DVR departures 733, 320**

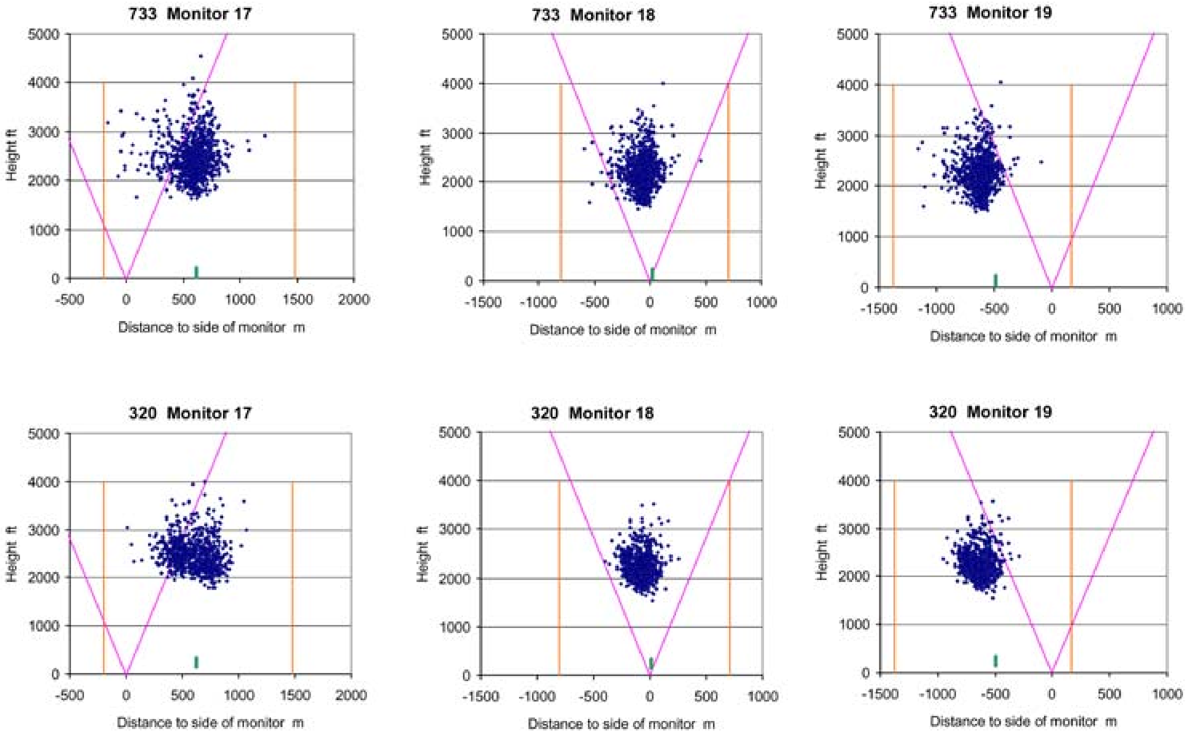


Figure C5(a) Heathrow April-June 2001 27L WOB/BPK departures 742Ch3, 744

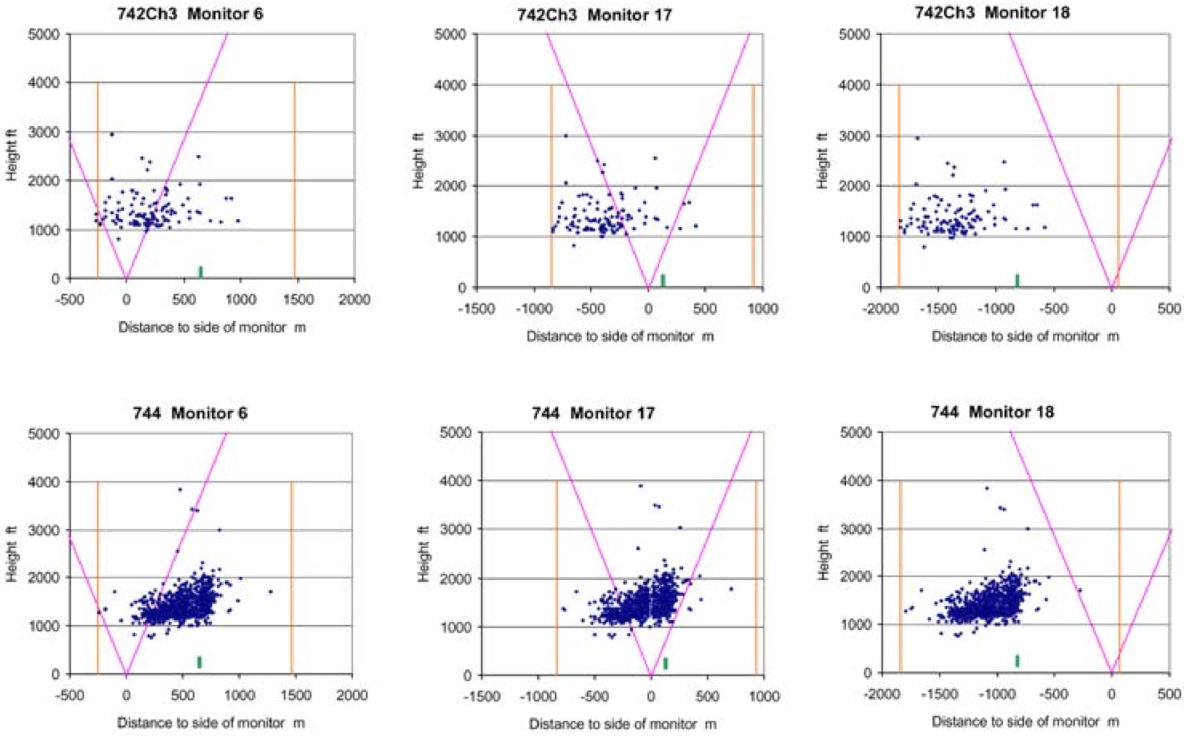


Figure C5(b) Heathrow April-June 2001 27L WOB/BPK departures 340, 777

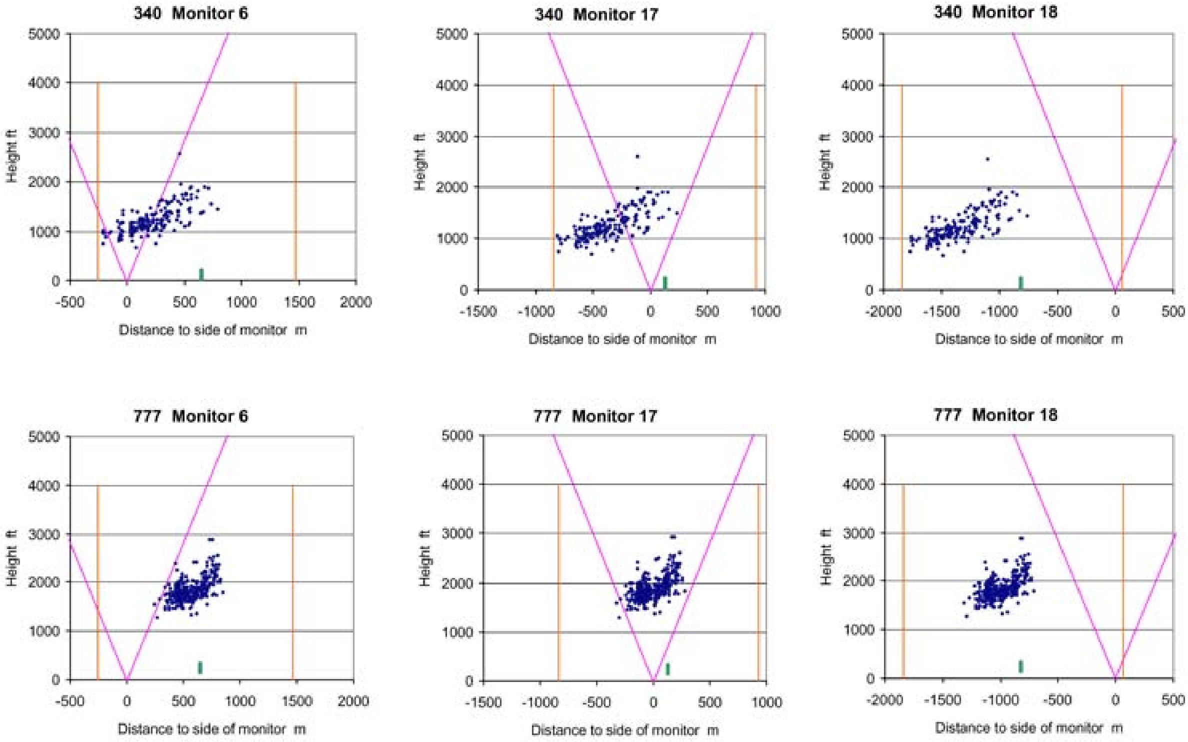


Figure C5(c) Heathrow April-June 2001 27L WOB/BPK departures 763, 757

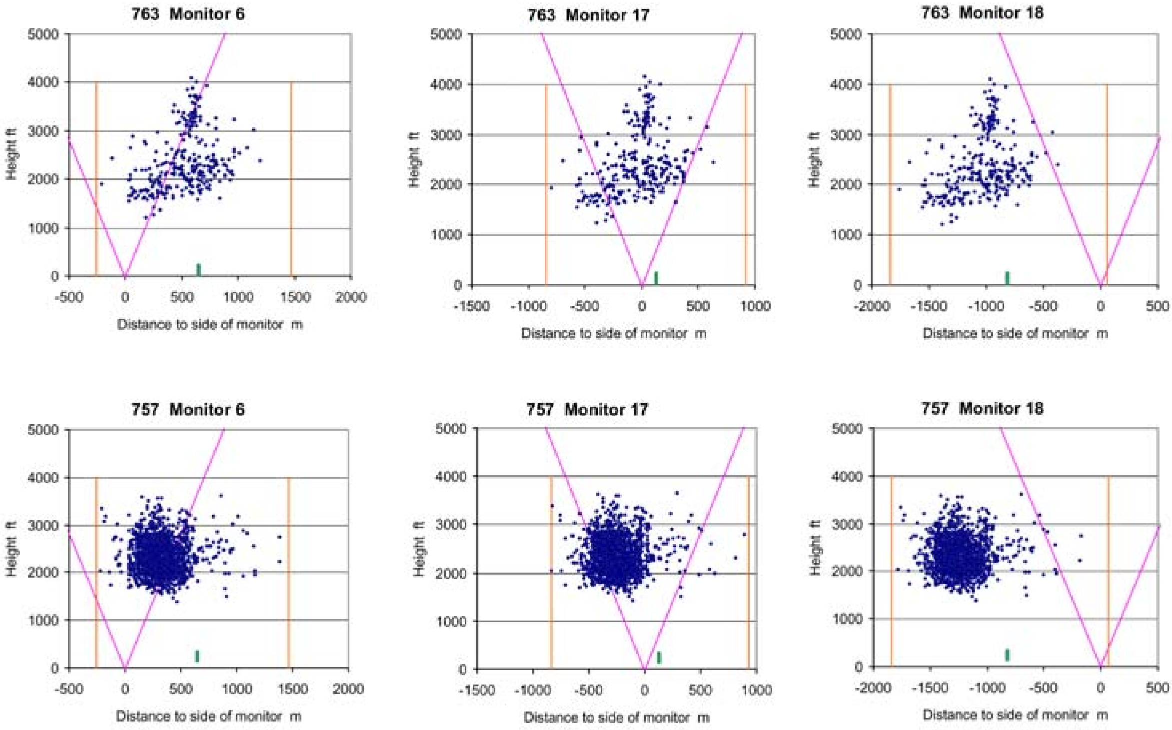
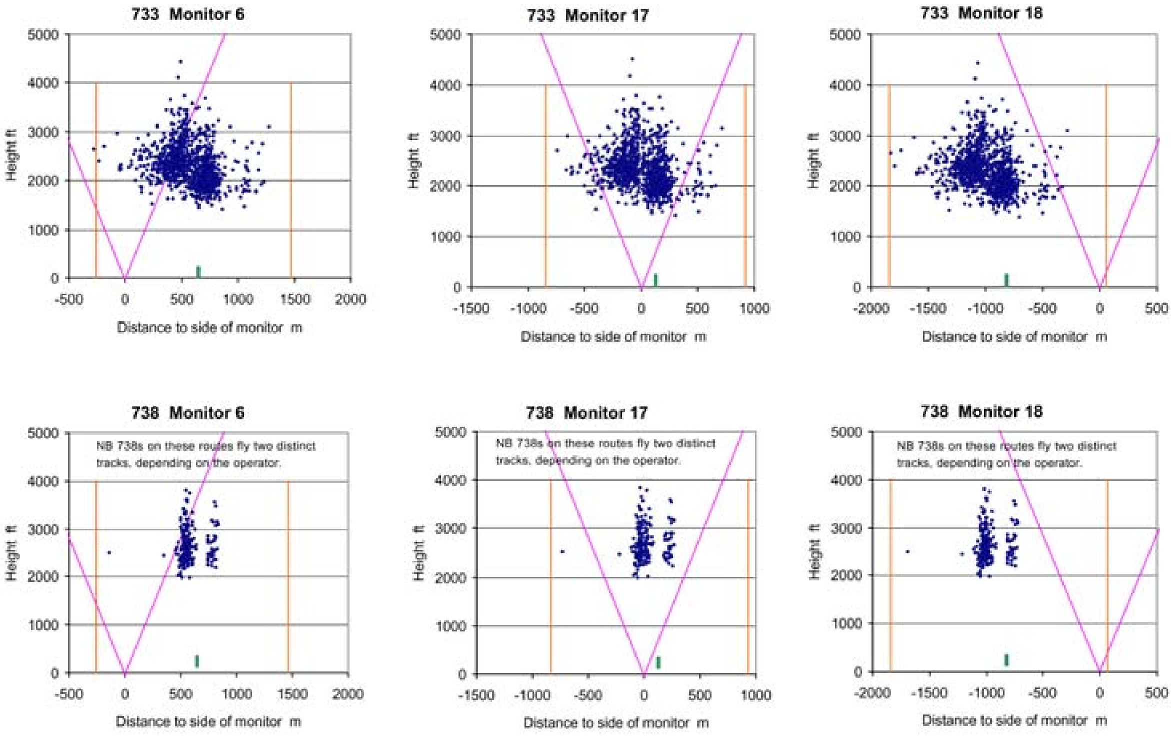
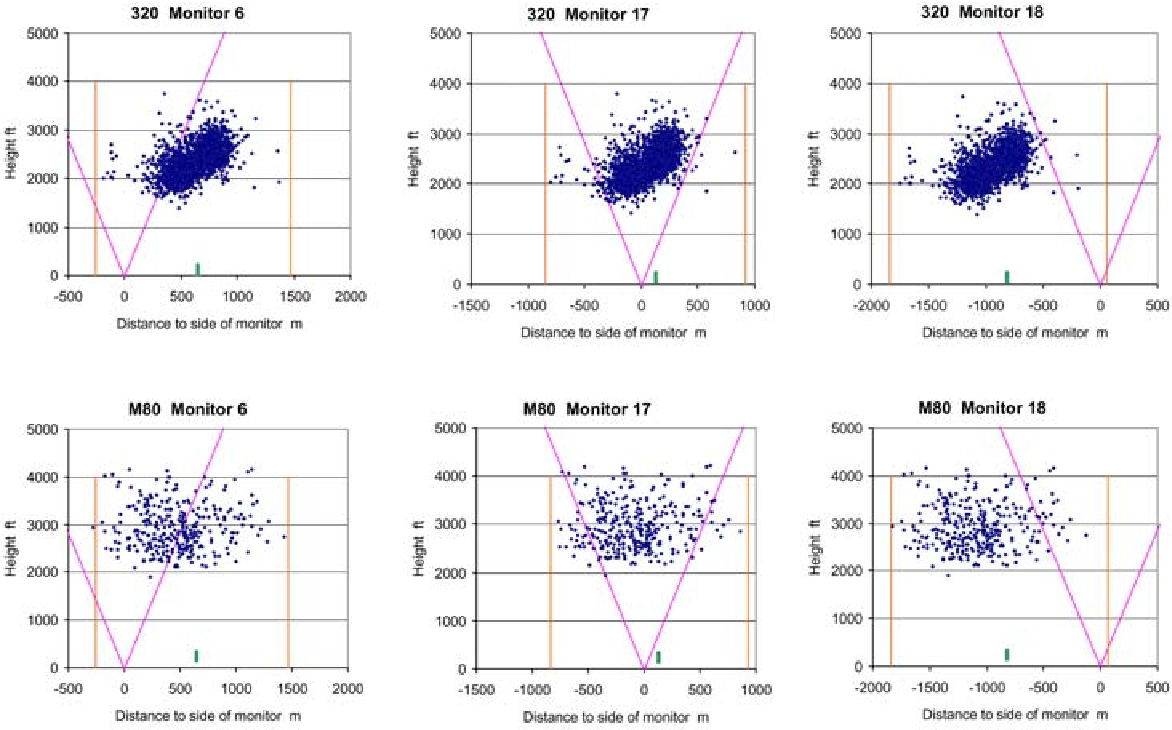


Figure C5(d) Heathrow April-June 2001 27L WOB/BPK departures 733, 738

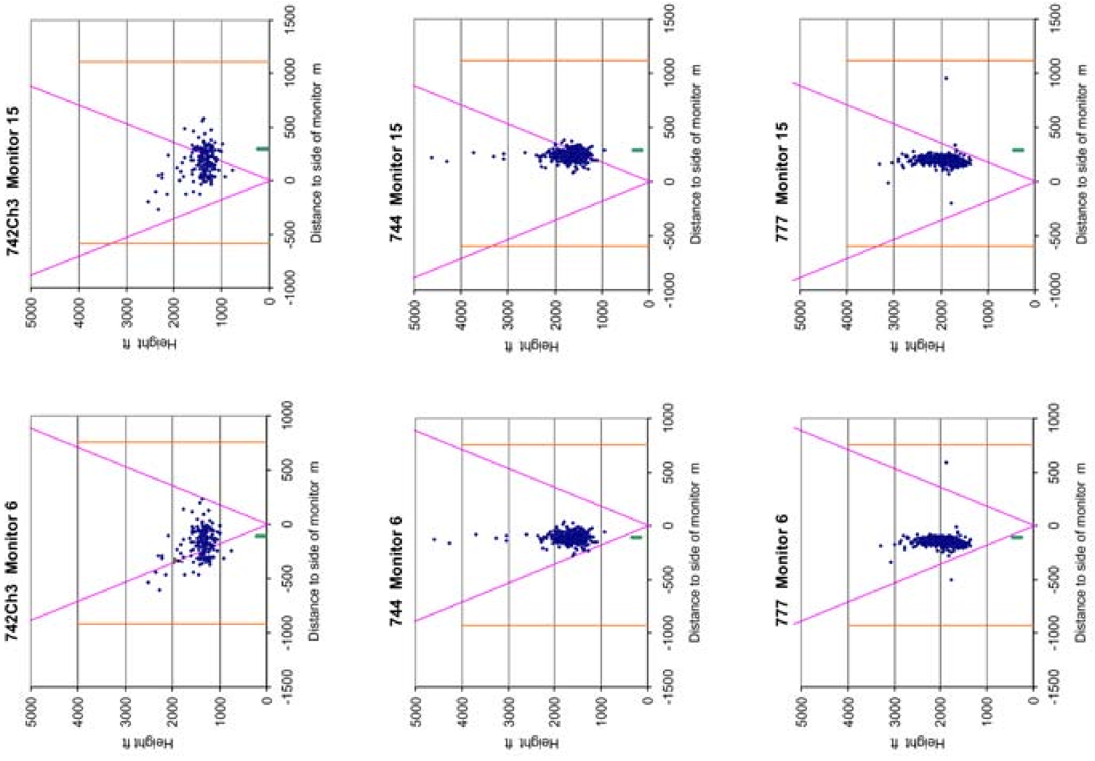


NB 738s on these routes fly two distinct tracks, depending on the operator.

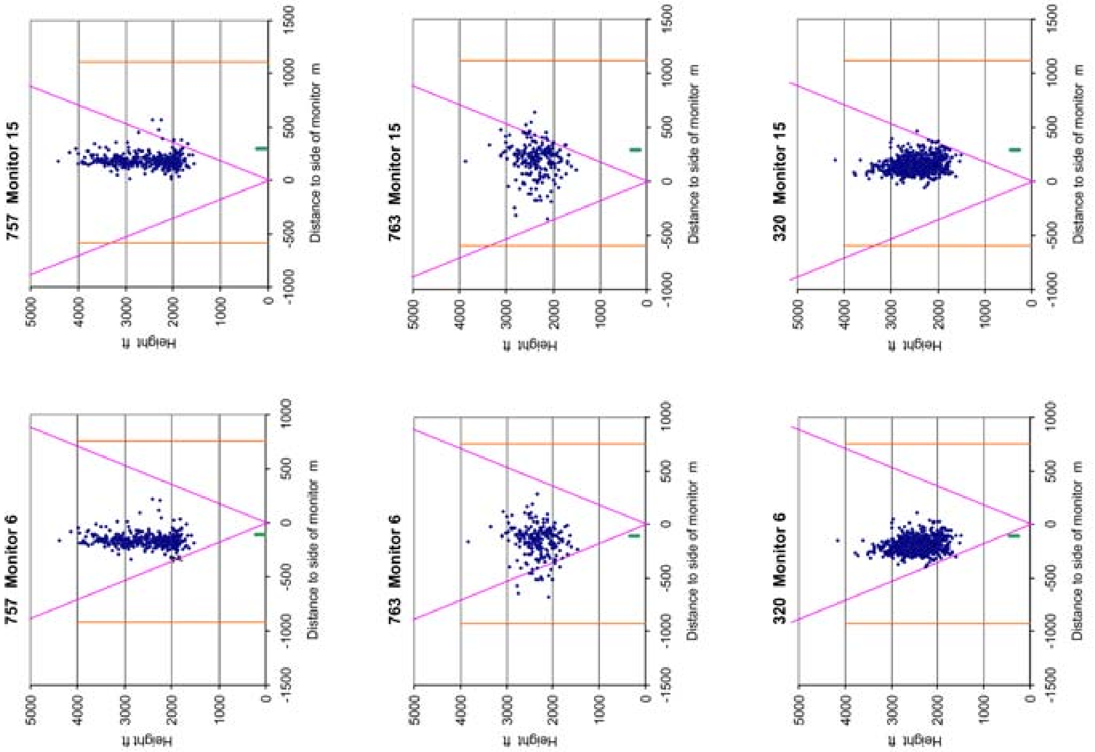
Figure C5(e) Heathrow April-June 2001 27L WOB/BPK departures 320, M80



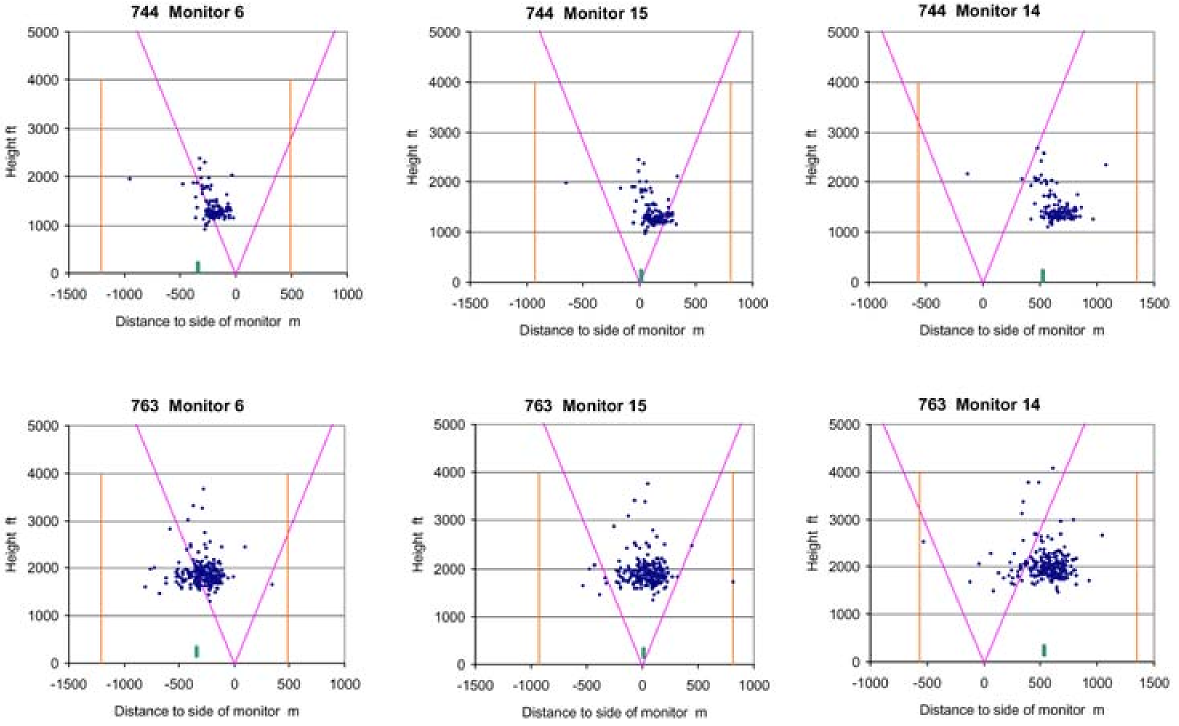
## Figure C5(f) Heathrow April-June 2001 27L CPT/SAM departures 742Ch3, 744, 777



## Figure C5(g) Heathrow April-June 2001 27L CPT/SAM departures 757, 763, 320



### Figure C5(h) Heathrow April-June 2001 27L MID departures 744, 763



### Figure C5(i) Heathrow April-June 2001 27L MID departures 733, 320

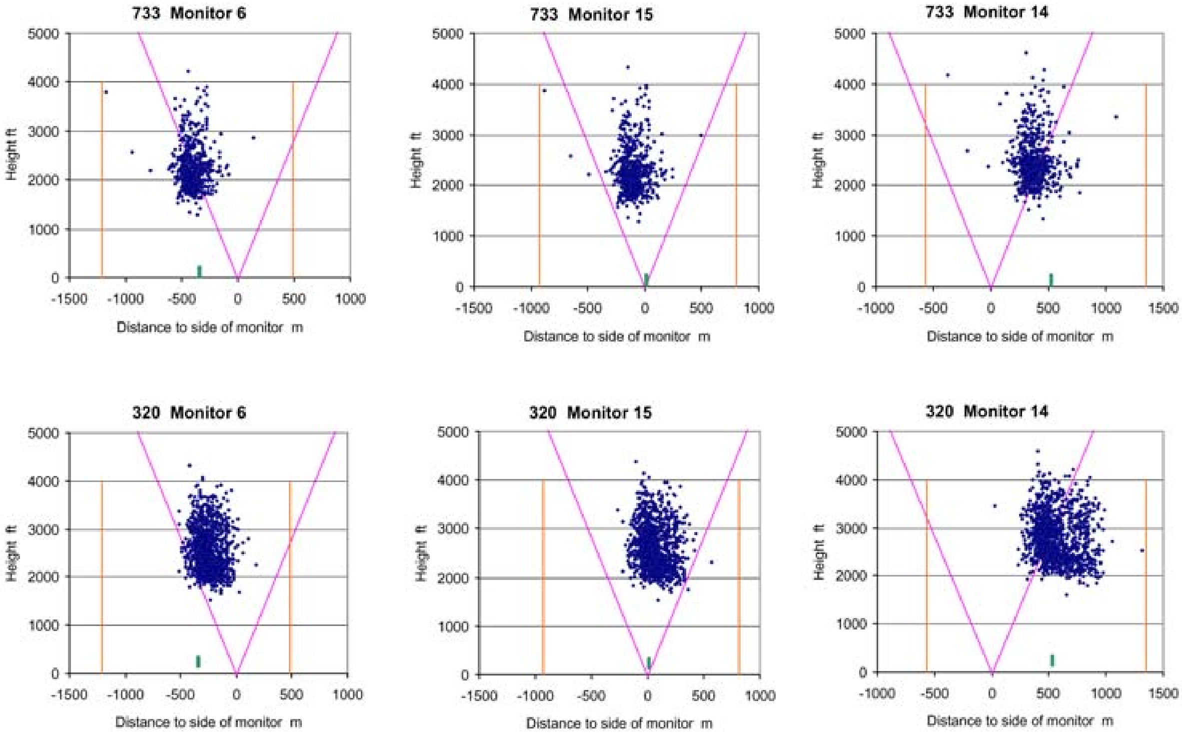


Figure C5(j) Heathrow April-June 2001 27L MID departures 146, M80

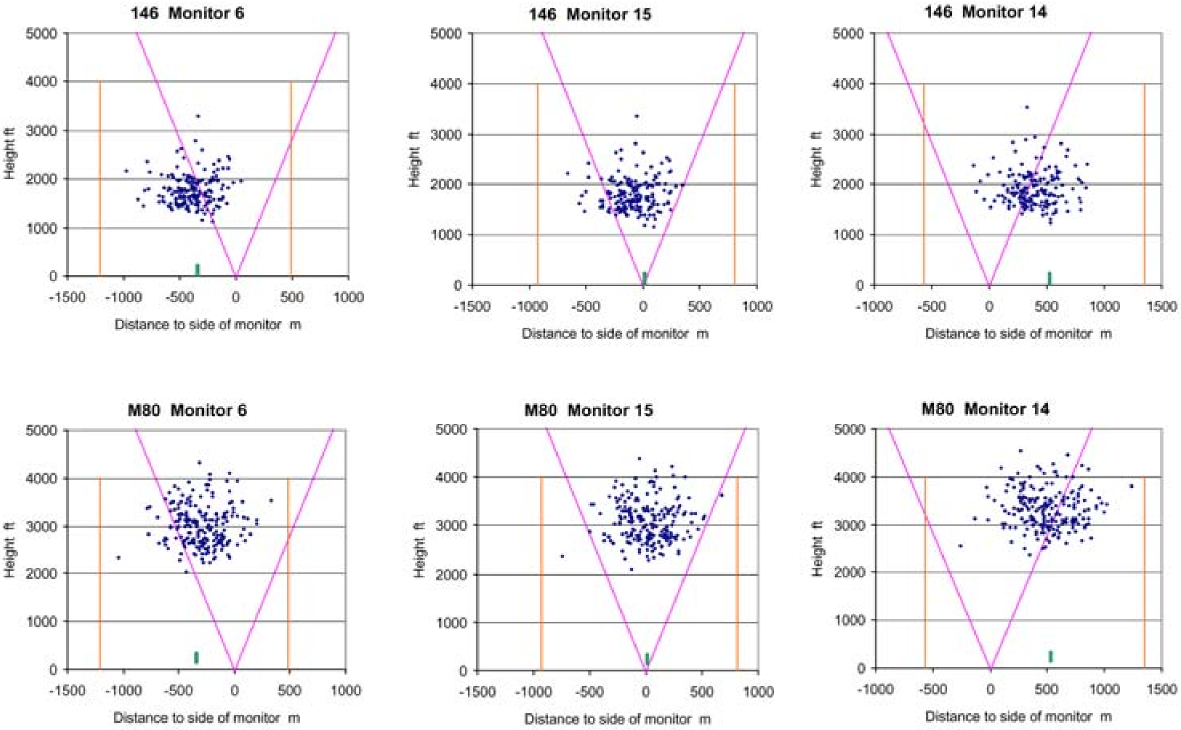


Figure C5(k) Heathrow April-June 2001 27L DVR departures 744, 777

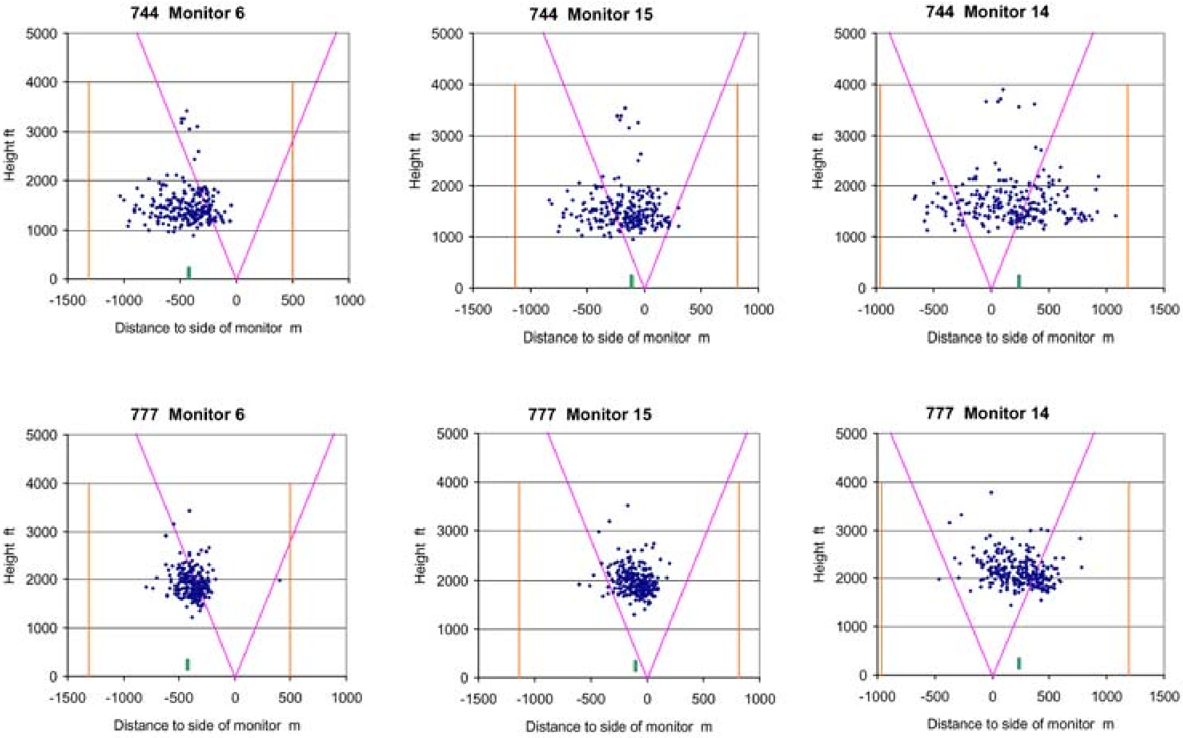


Figure C5(l) Heathrow April-June 2001 27L DVR departures 763, 300

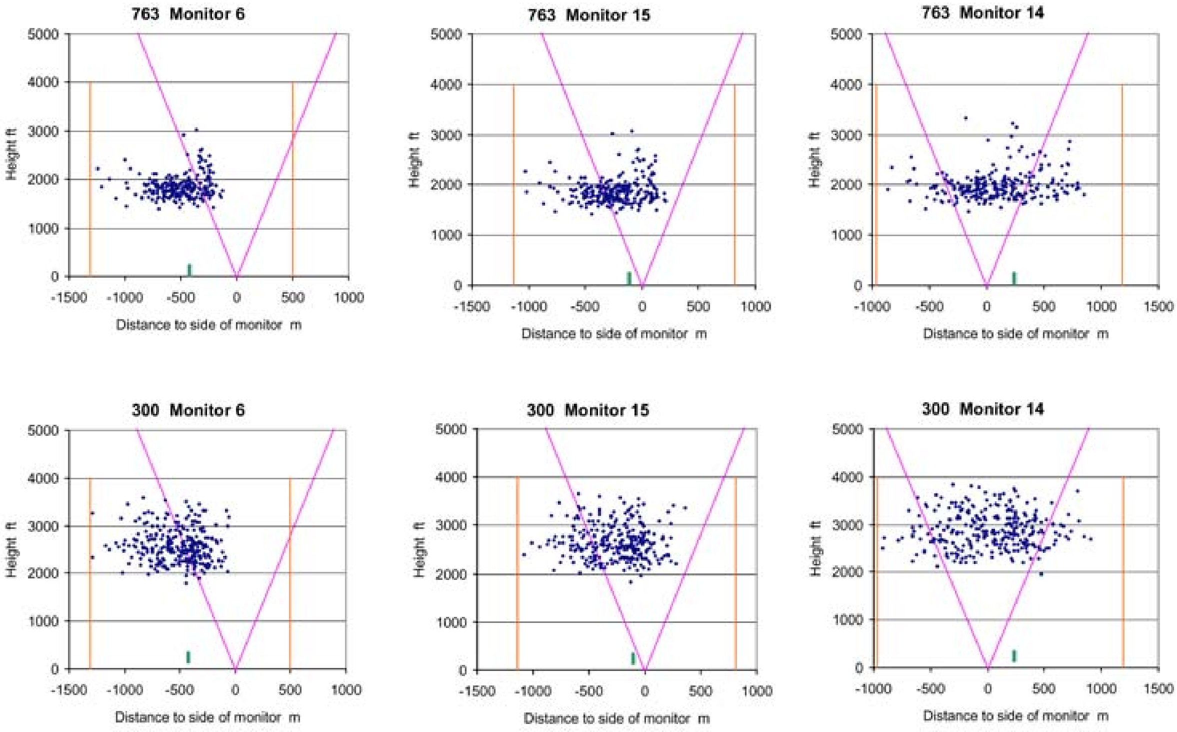


Figure C5(m) Heathrow April-June 2001 27L DVR departures 733, 320

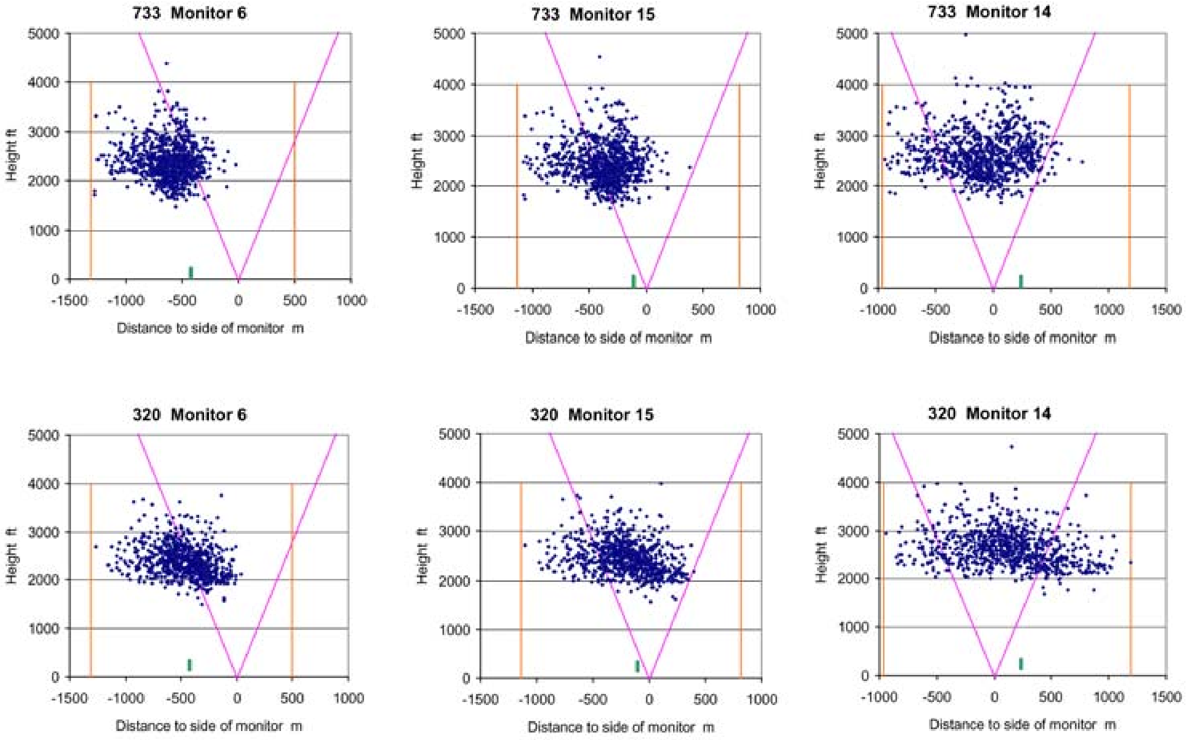


**Figure C5(n) Heathrow April-June 2001 27L DVR departures 310, 330**

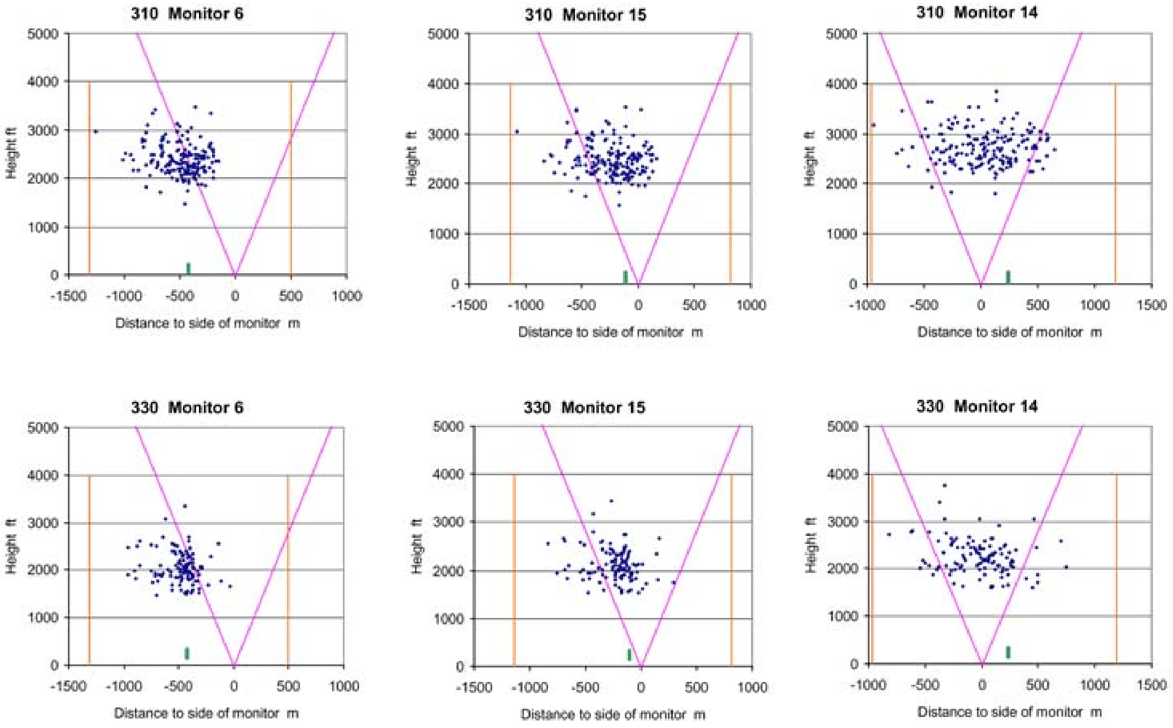


**Figure C6(a) Stansted April-June 2001 05 BZD departures 733, 738**

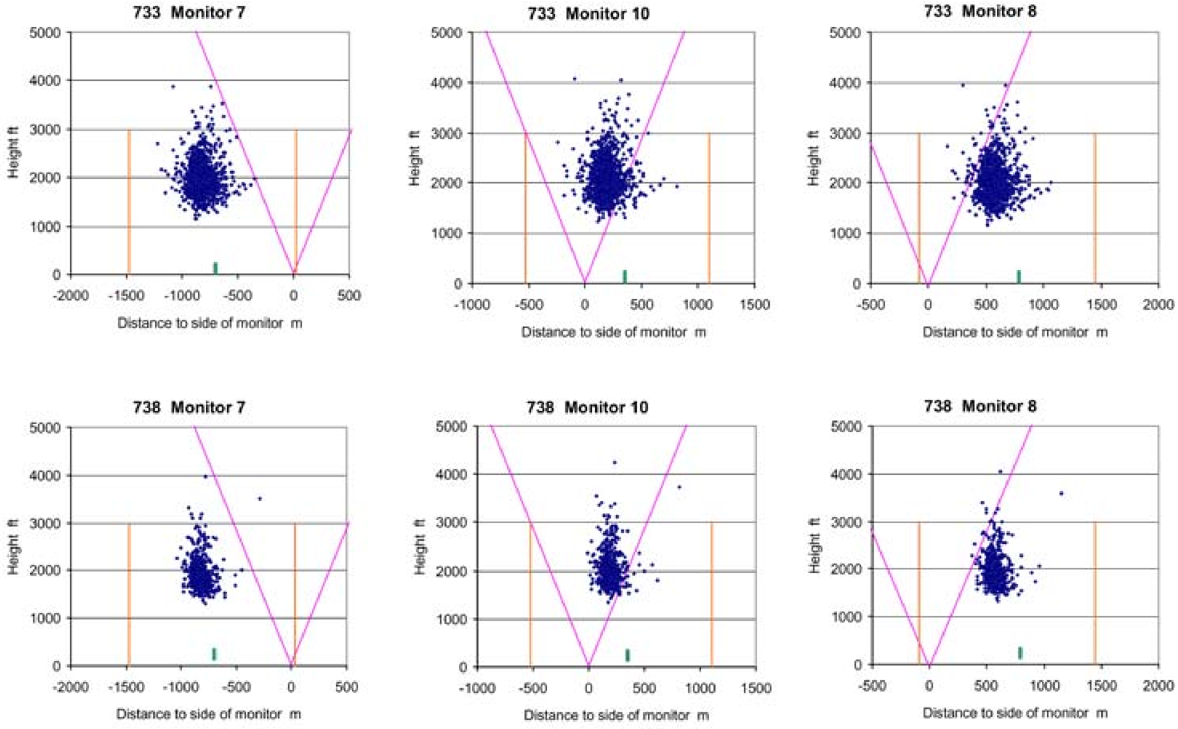


**Figure C6(b) Stansted April-June 2001 05 BZD departures 757, 320**

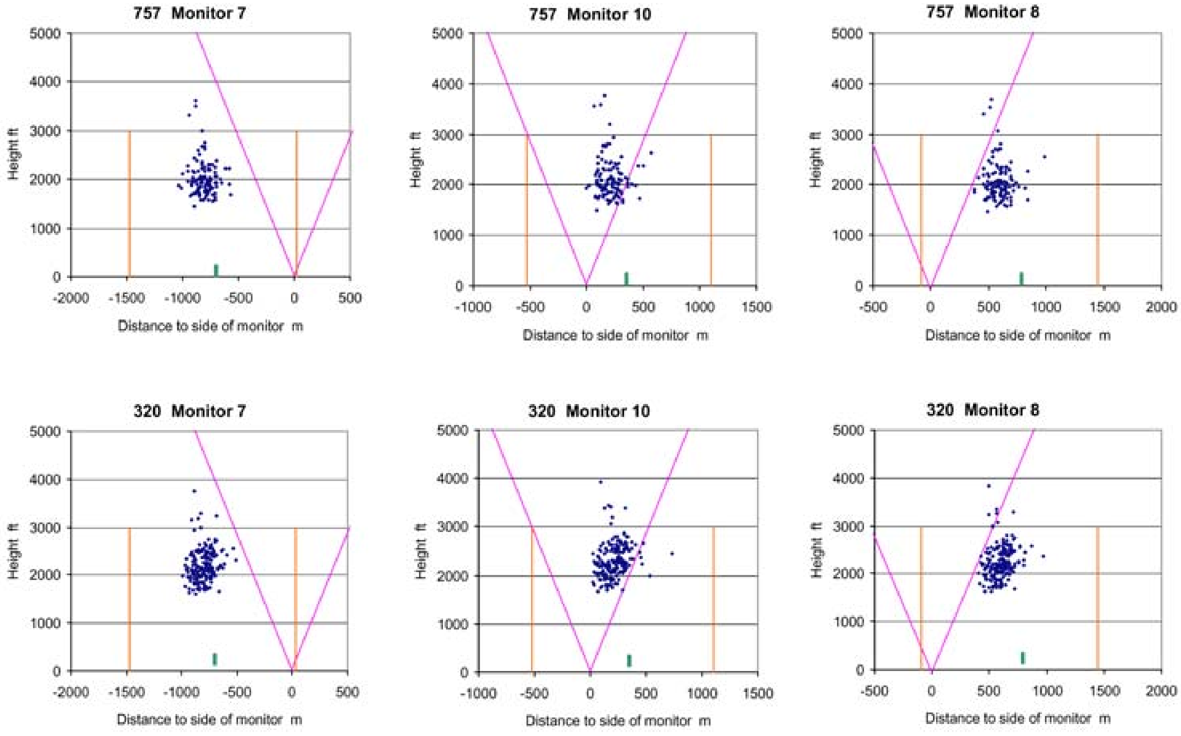


Figure C6(c) Stansted April-June 2001 05 BZD departures 146, Props

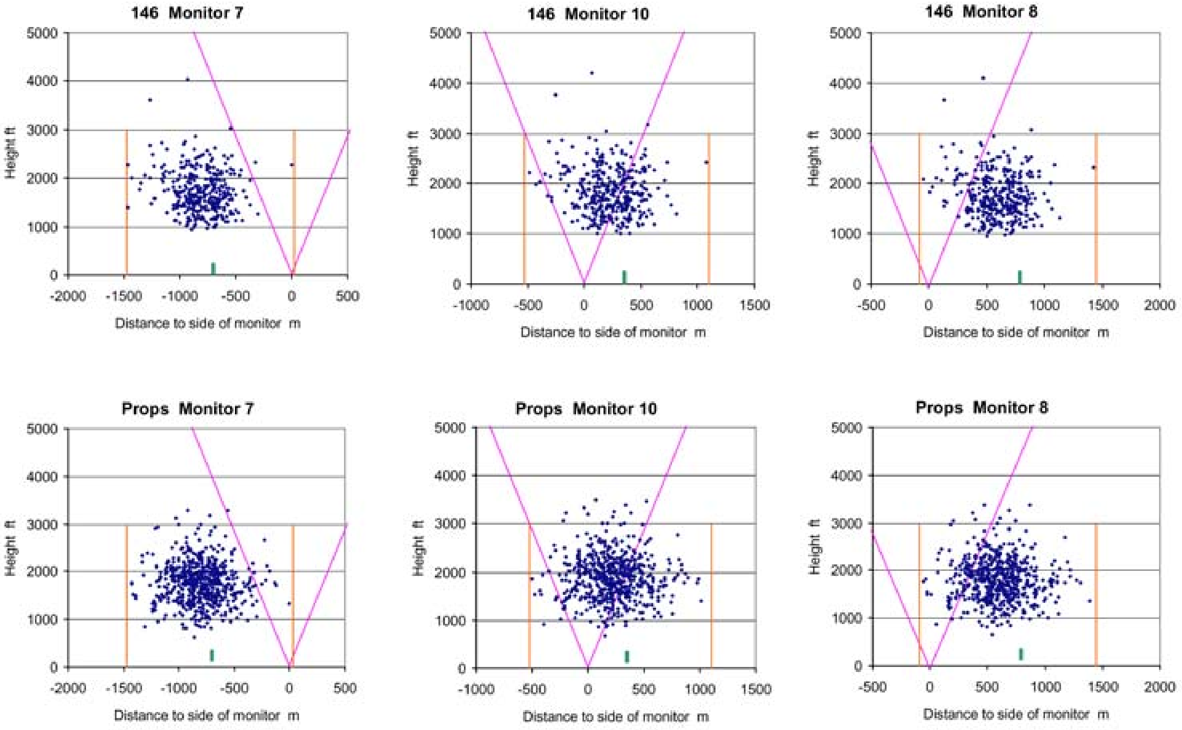


Figure C6(d) Stansted April-June 2001 05 CLN departures 733, 738

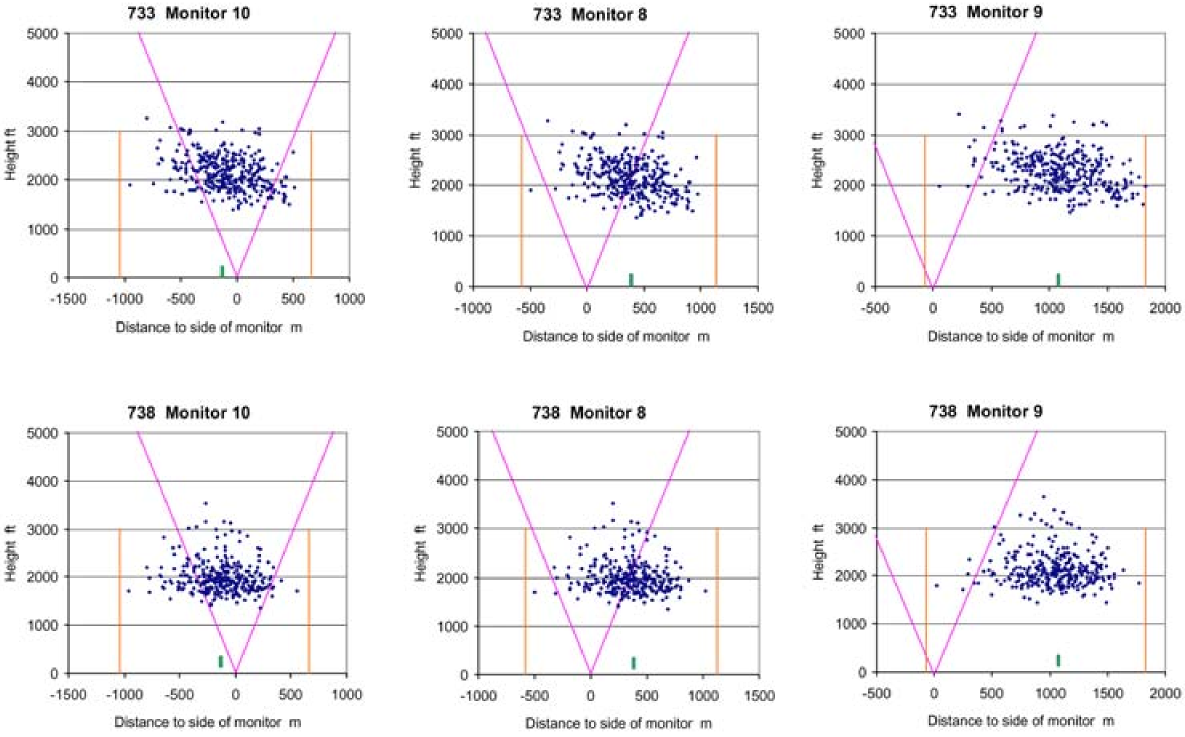


**Figure C6(e) Stansted April-June 2001 05 CLN departures 100, 320**

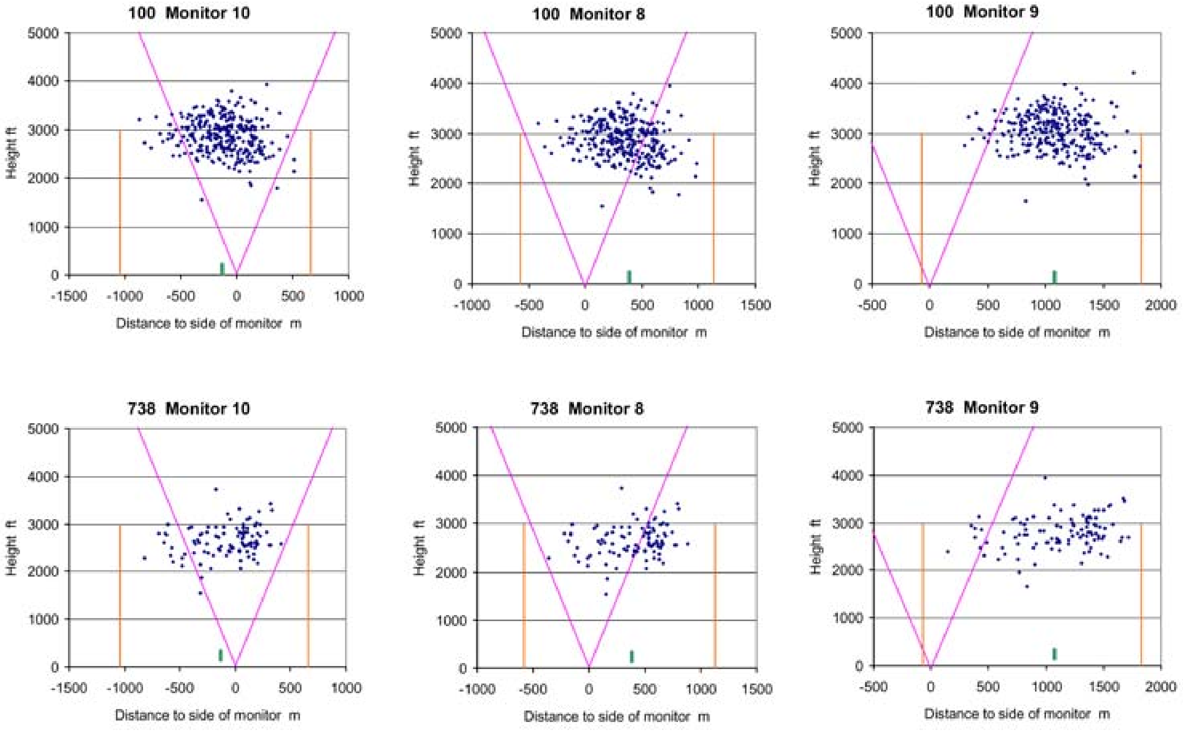


**Figure C6(f) Stansted April-June 2001 05 CLN departures 146, Props**

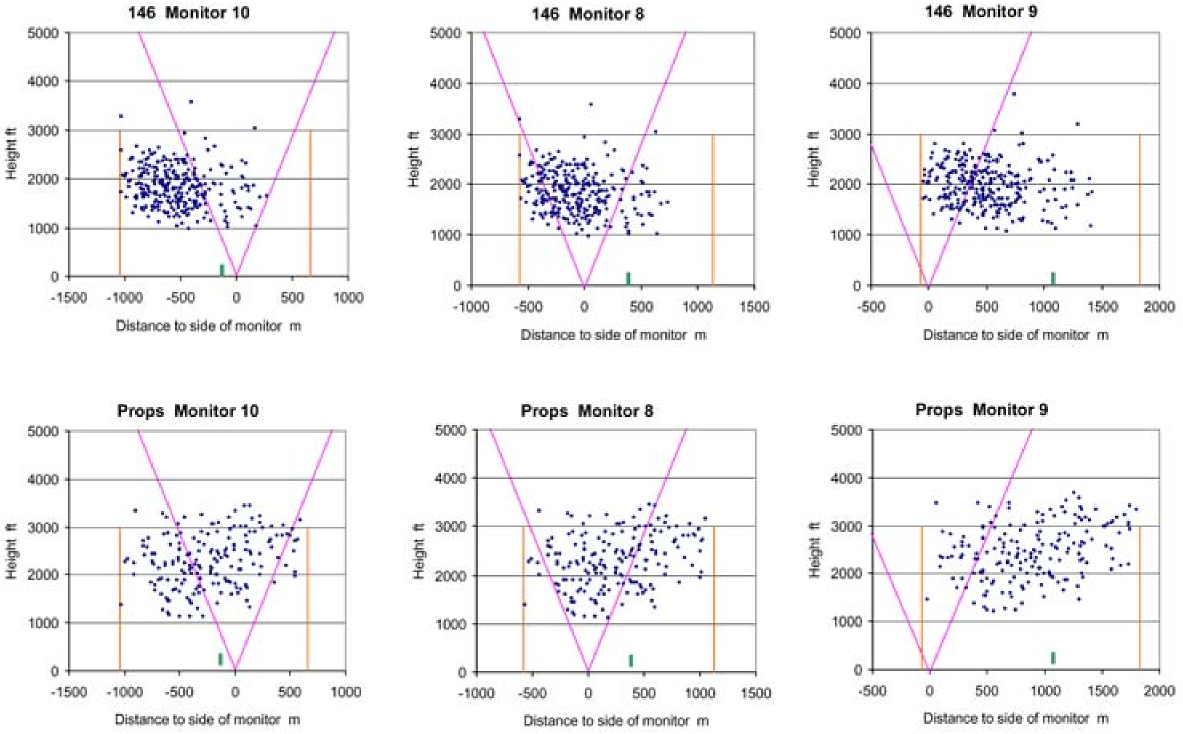


Figure C6(g) Stansted April-June 2001 05 DVR departures 320, 738, 733

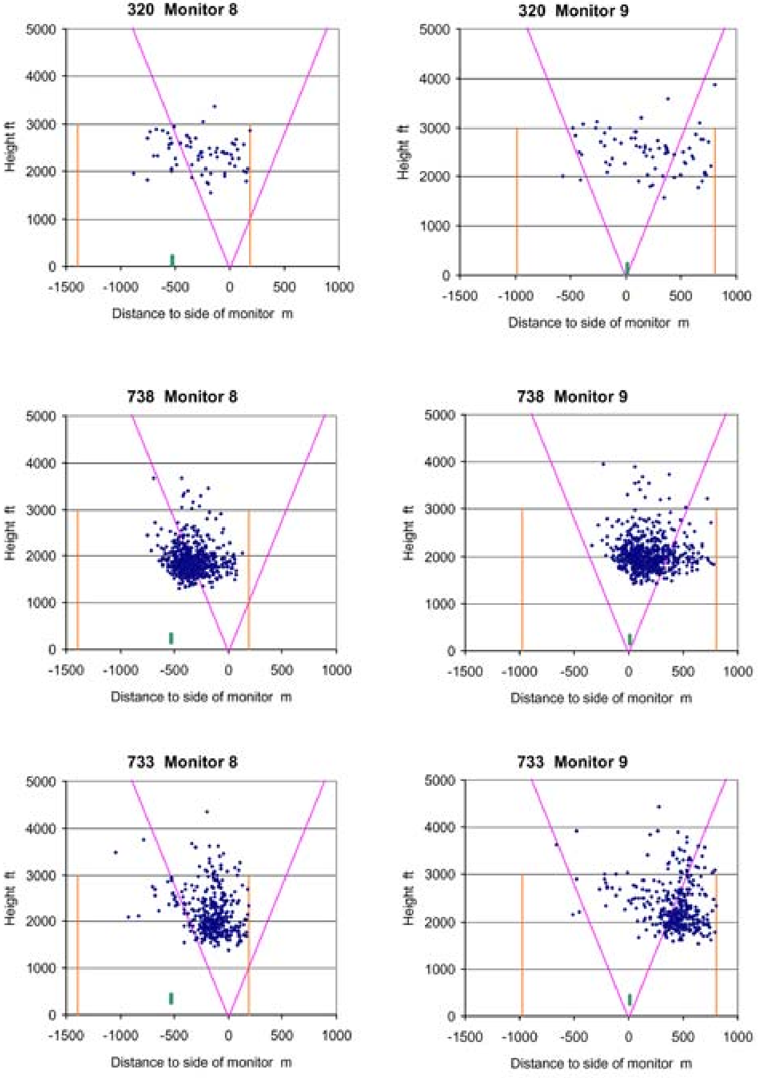


Figure C6(h) Stansted April-June 2001 05 DVR departures 146, Props

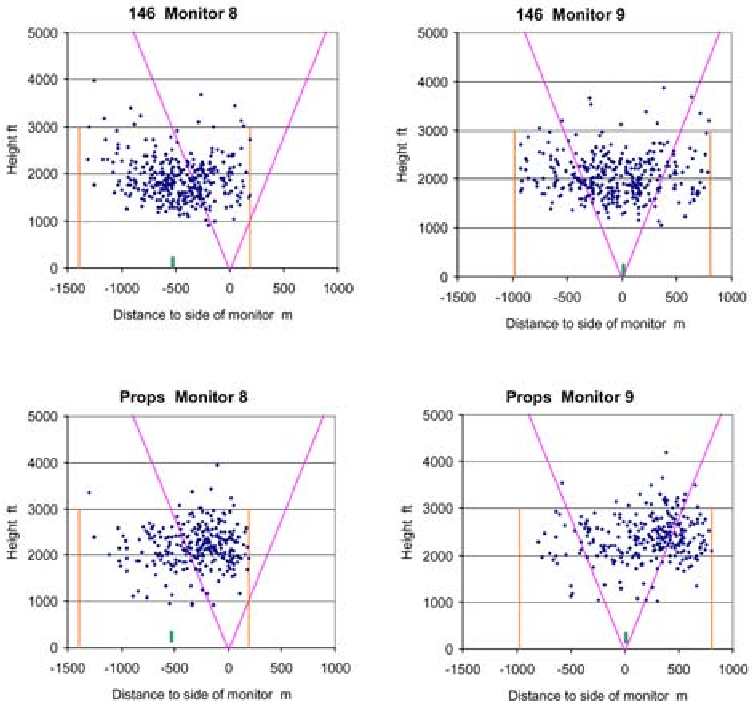


Figure C7(a) Stansted April-June 2001 23 BZD departures 733, 738

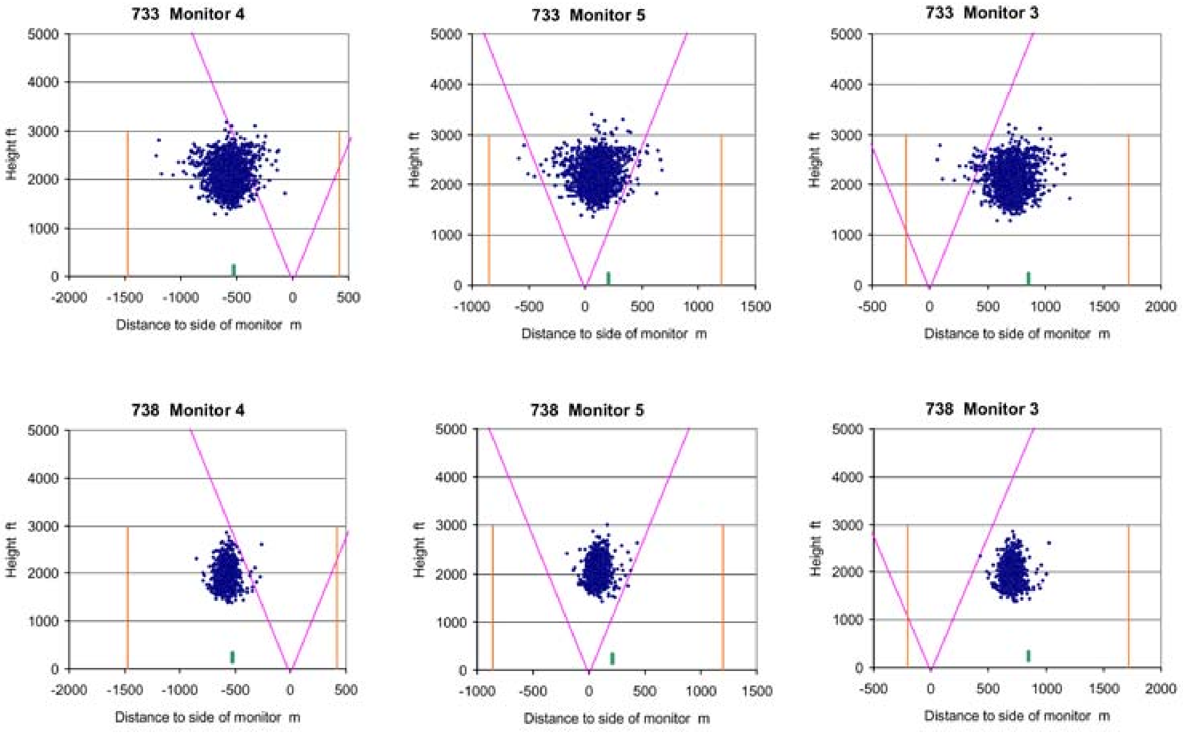


Figure C7(b) Stansted April-June 2001 23 BZD departures 757, 320

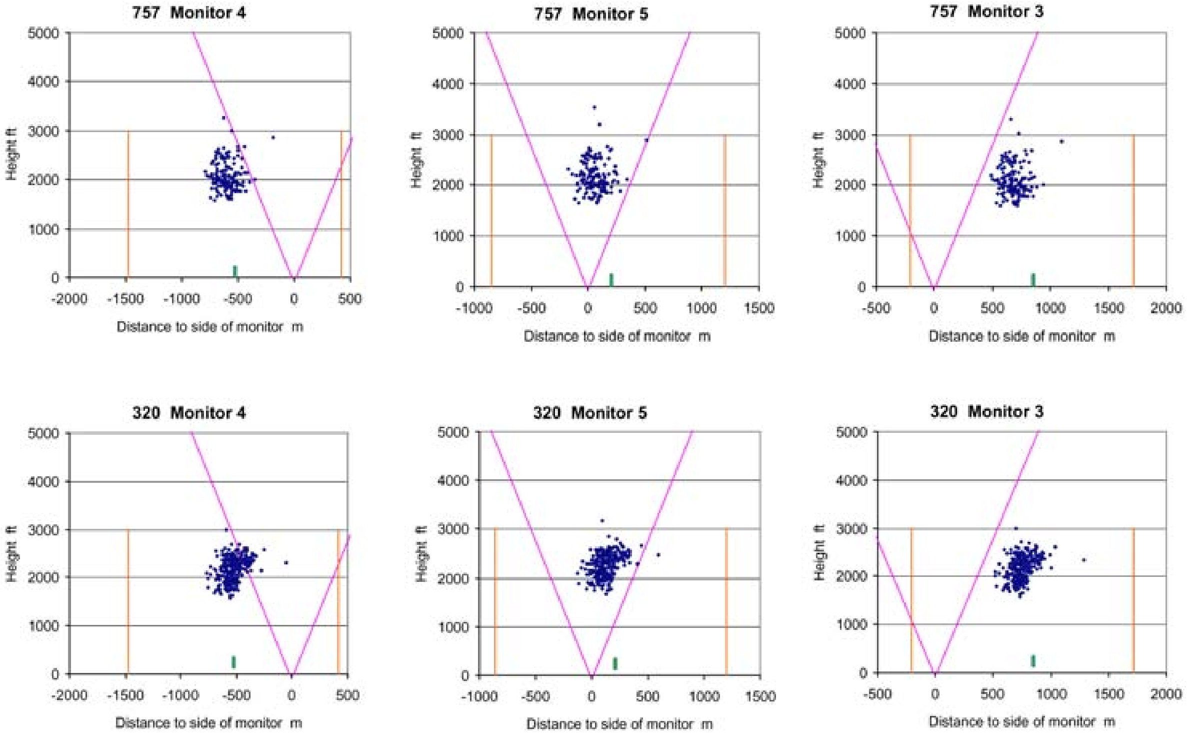


**Figure C7(c) Stansted April-June 2001 23 BZD departures 146, Props**

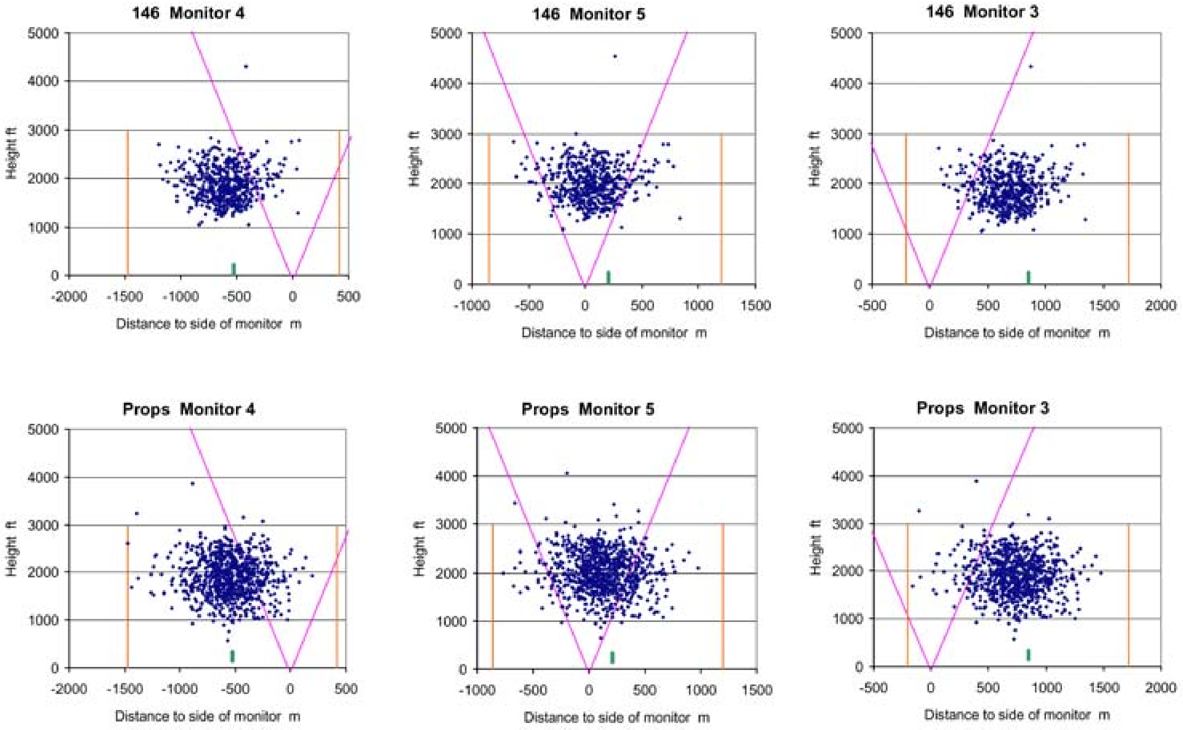


**Figure C7(d) Stansted April-June 2001 23 CLN departures 733, 738**

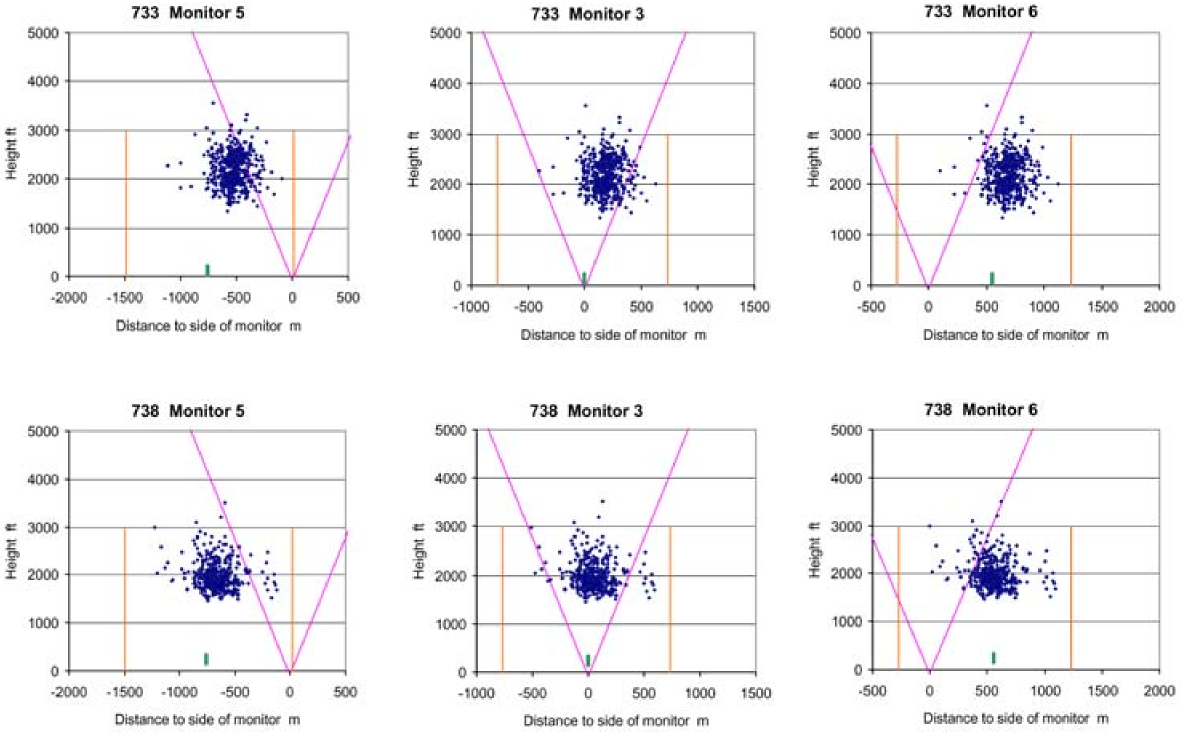


**Figure C7(e) Stansted April-June 2001 23 CLN departures 733, 738**

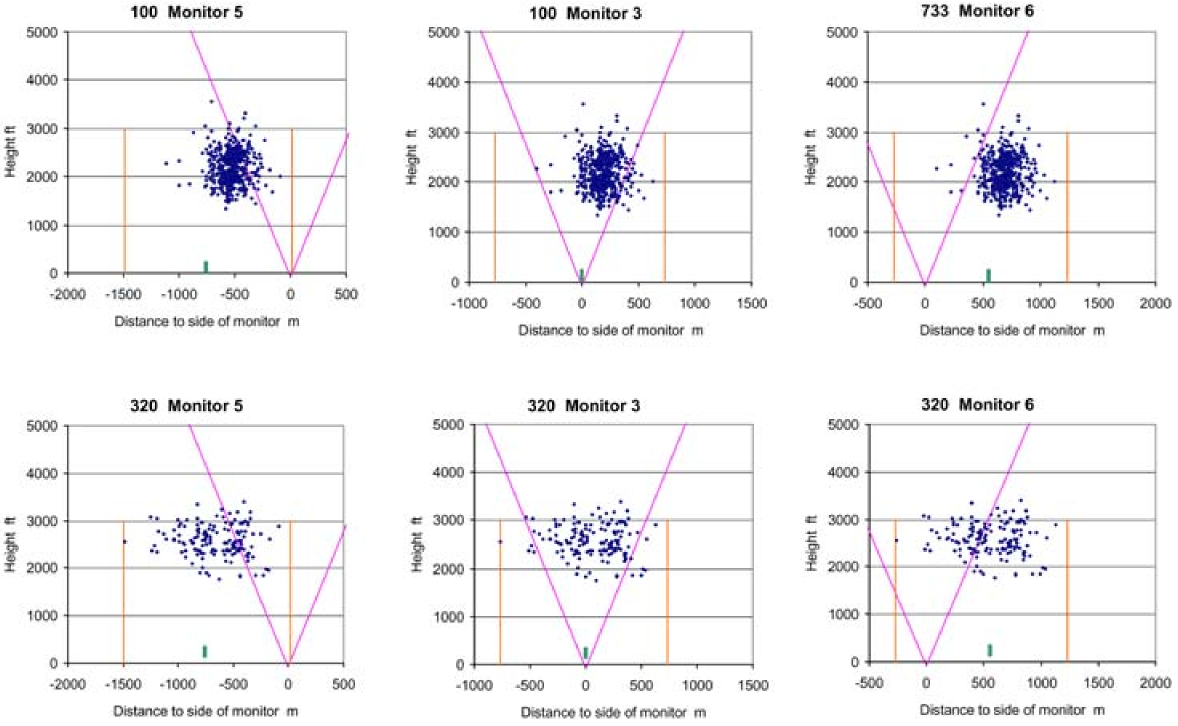


**Figure C7(f) Stansted April-June 2001 23 CLN departures 146, Props**

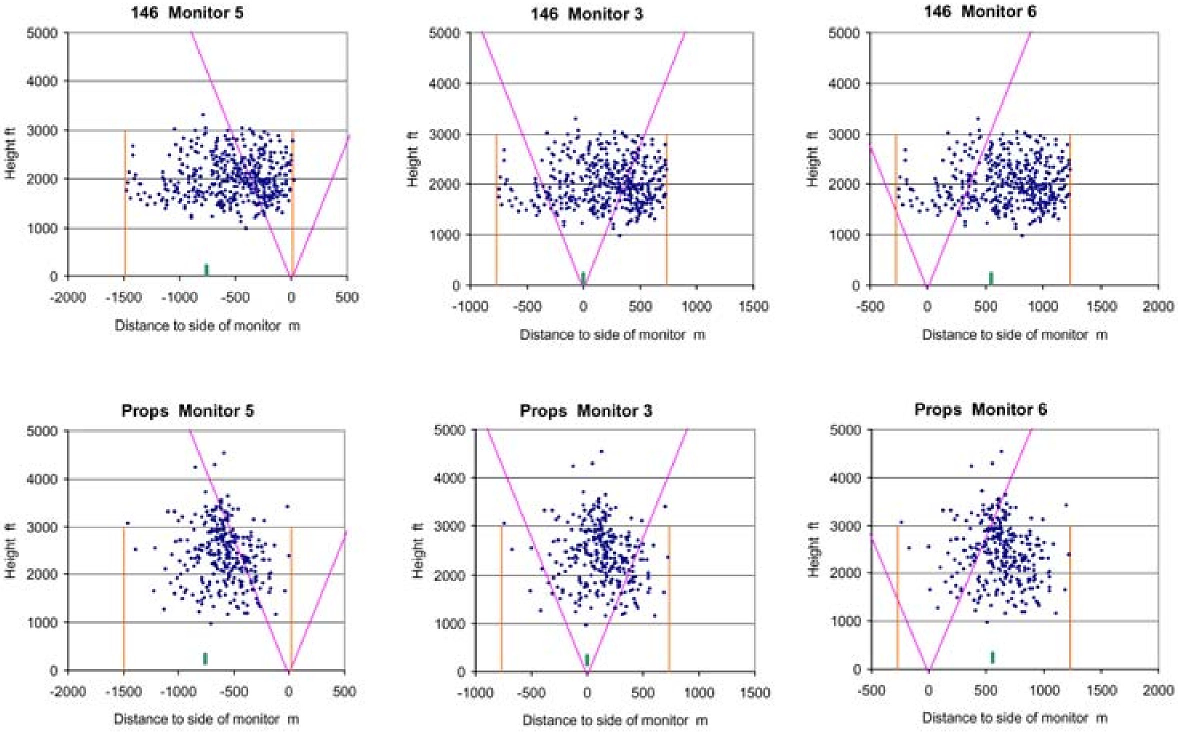
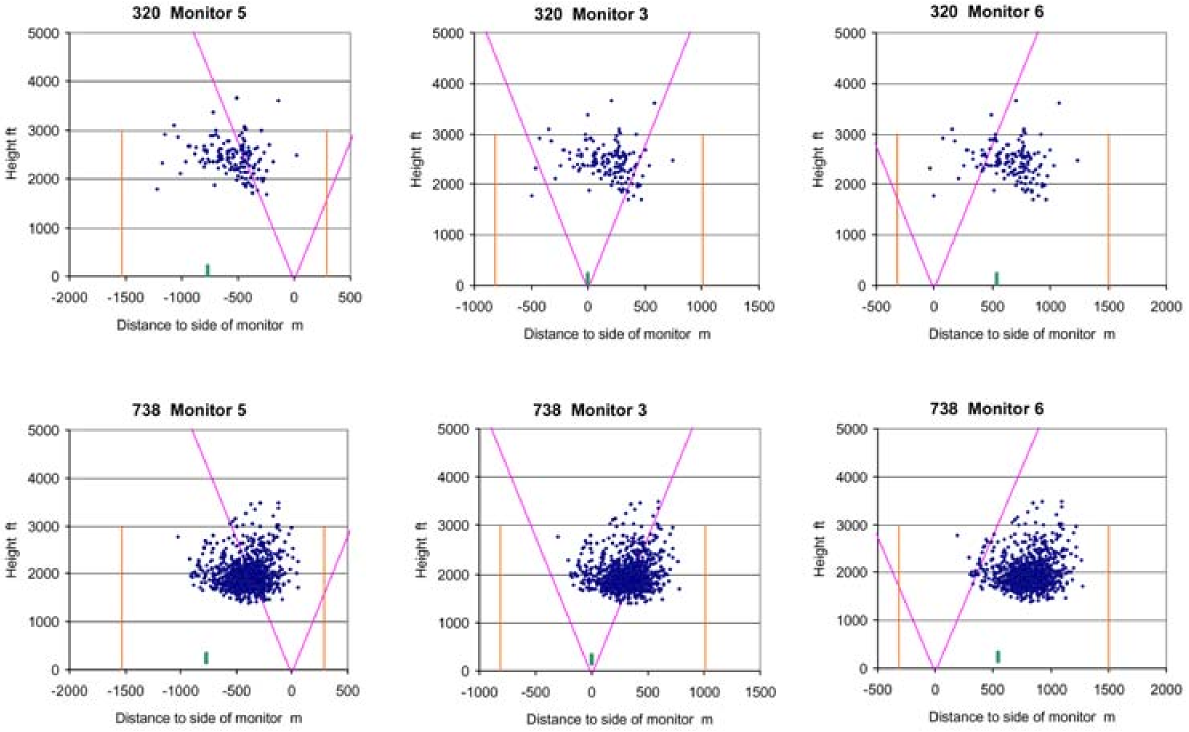


Figure C7(g) Stansted April-June 2001 23 DVR departures 320, 738



320 Monitor 5

320 Monitor 3

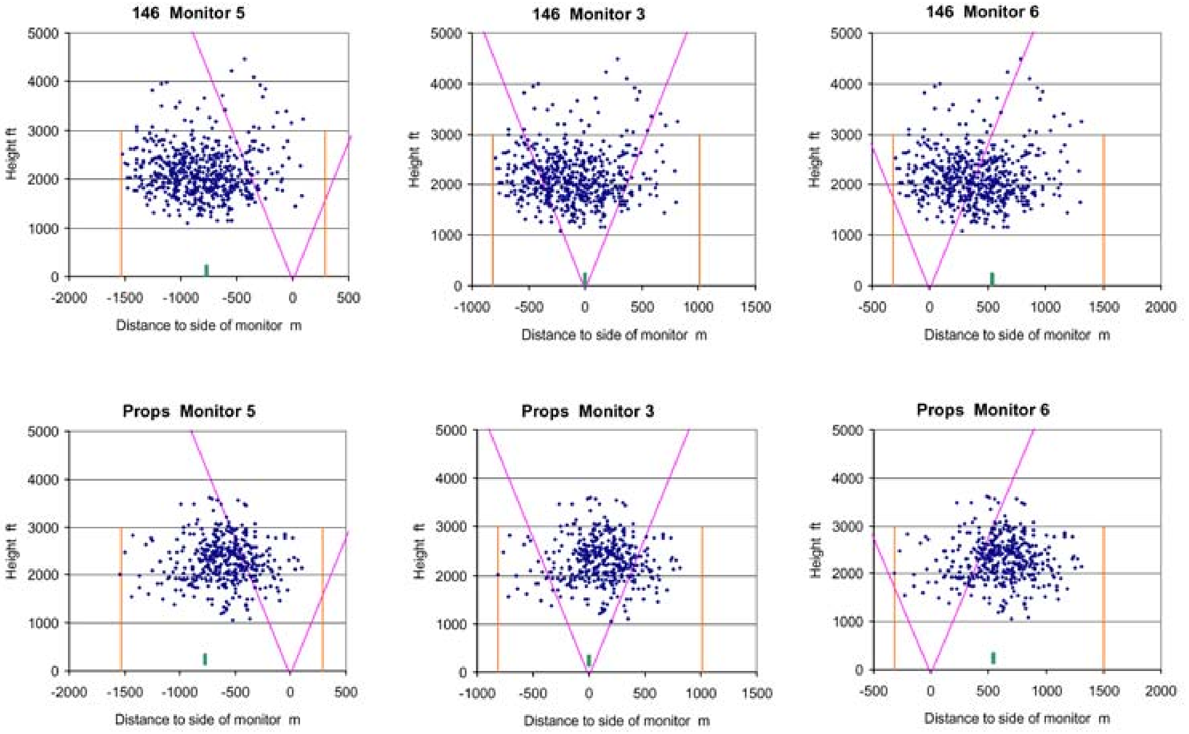
320 Monitor 6

738 Monitor 5

738 Monitor 3

738 Monitor 6

Figure C7(h) Stansted April-June 2001 23 DVR departures 146, Props



146 Monitor 5

146 Monitor 3

146 Monitor 6

Props Monitor 5

Props Monitor 3

Props Monitor 6

# APPENDIX D PRACTICAL FACTORS FOR PROPOSED NEW MONITOR LOCATIONS

## D1 Introduction

D1.1 Seven scenarios for improvements to the current monitor arrays were initially considered (an additional scenario, numbered 7, related to track-keeping improvements). The findings from the site visits and subsequent work related to these scenarios are given below. The figures referred to are in the maps in the main body of the report.

## D2 Scenario 1 (Heathrow 09R – Figure 16)

D2.1 An additional monitor located midway between monitors 10 and 13 would improve current monitoring performance for 09R departures. The 6.5km reference arc for 09R departures crosses the Hounslow Heath nature reserve, where the visual intrusion of a 6m high mast would probably not be acceptable and vehicular access and provision of services are unlikely to be possible. A privately-owned site just to the north of the heath (marked “X” on Figure 16) was initially identified for a monitor; although it is significantly closer to 10 than to 13, it would still represent an improvement in filling the gap between these monitors. This location, a former garden centre, is probably close enough to an existing building to permit use of fixed power and telephone connections. However the building is disused and the site is (or will be) subject to development proposals, which make suitable positioning of a monitor uncertain until the future of the site is known and any new building work completed. The location is in an area likely to be prone to vandalism.

D2.2 A more suitable site, slightly closer in, was subsequently identified (“Y” on Figure 16). This site is adjacent to a golf course car park, and more adequately closes the gap between monitors 10 and 13. It is at a distance of 6.3km from SOR, slightly closer in than the optimum 6.5km, but because of the difficulties of access on Hounslow Heath there would appear to be no other suitable options.

## D3 Scenario 2 (Heathrow 27L/27R – Figure 15)

D3.1 The 6.5km reference arcs for 27L and 27R departures between monitors 17 and 18 cross a large fairly inaccessible area close to the Colne Brook consisting at present largely of gravel workings, some of which have been reclaimed and others are currently being converted into a lake. Vehicular access is difficult anywhere in this area. There may be a limited possibility of a site at the northern tip of the Arthur Jacob Nature Reserve. Being adjacent to a river the area is sometimes subject to flooding, and site security would be a problem. The visual intrusion of the mast may also not be acceptable within a nature reserve. An alternative could be to access the area via Manor Farm on Poyle Road, where there is an existing track used for the gravel workings, although in its current condition this would not be accessible in bad weather. Other possible access points are via Berkyn Manor Farm. Background noise from the gravel workings and other activities in the area could be a potential difficulty in the short term. It is unlikely that power or telephone connections would be feasible at any site in this area.

## D4 Scenario 3 (Stansted 05 – Figure 17*)*

D4.1 Few if any jet aircraft currently fly near monitor 7. Moving monitor 7 closer to monitor 10 would ensure that tracks currently outside (to the north-west) of the V for monitor 10 would then be within a V. The area east of monitor 7 comprises parts of four large unfenced open arable fields, none of which allow suitable vehicular access for servicing a monitor, and all of which would pose a security risk because of the clear visibility of a monitor from adjacent roads and nearby footpaths. There is a possibility of a site close to a suitable road-side parking place, where a monitor would be less visible beside a hedge: this is marked on Figure 17 as site "A". It is unlikely that power or telephone connections would be feasible at such a site. An alternative possibility is shown as site "B", in or adjacent to a private garden; although at a greater distance from SOR (approximately 7.0km), this would be more practicable for provision of services, access and security, and STAL are pursuing this possibility with the relevant land owners with a view to deploying a mobile monitor initially to assess the site's feasibility.

## D5 Scenario 4 (Heathrow 27L – Figure 15)

D5.1 The deployment of monitors for runway 27L DVR departures is not ideal, especially monitor 14, but this is because of the constraint of the Wraysbury Reservoir[65]. Figure 11(d) (and Appendix C Figures C5(k)-(n)) show that a significant number of aircraft fly south-east of the V for monitor 14. To monitor these sharp-turning departures, it is likely that a suitable site could be located on Thames Water property close to the reservoir (as are monitors 6 and 14). Security and accessibility would be excellent. Such a site would be at a distance from SOR similar to the 7.2km of monitor 14, and also similarly placed relative to the reservoir embankment. Background noise from the adjacent (lightly used) railway and from the nearby M25 motorway could potentially be a slight problem but only in monitoring quieter aircraft types.

## D6 Scenario 5 (Heathrow 09R – Figure 16)

D6.1 For 09R departures on the BPK/BUZ routes, Table 3 shows that the 340 has a particularly low percentage of flights passing through a V. The gap between monitors 11 and 12, about 500m, is wider than the 350m optimum needed for effective monitoring of slow-climbing aircraft types such as this. The area between 11 and 12 is almost completely built-up, and filling the gap would necessitate finding a suitable rear garden for the noise monitor placement. Selected houses in Ivanhoe Road and Manor Avenue would provide the best opportunities, but all the gardens in this neighbourhood are quite small, and it would require a door-to-door search to find a suitable property where the owner was willing to have a permanent monitor installed.

## D7 Scenario 6 (Heathrow 09R – Figure 16)

D7.1 In order to effectively monitor departures turning north of 11, an additional monitor location could be installed near the A4/A30 roundabout, such as at the rear of the Safeway/BP petrol station. Access would be straightforward, but noise from nearby vehicles, the car wash and from the A4 could possibly be a problem for monitoring quieter aircraft types at this location. It would also require the removal of a number of recently planted trees. Alternatively a rear garden of a house at the southern end of Burns Way (which have disused allotments to the rear) could be suitable.

## D8 Scenario 8 (Stansted 05 – Figure 17)

D8.1 With current track-keeping, a small improvement in monitoring performance could theoretically be achieved by an additional monitor south of monitor 9. Access from Moor End Farm to a suitable location appears not to be possible due to the nature of

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[65] It is not feasible to consider noise monitors on floating structures on the reservoir.

the land and the farm tracks; only one possible suitable location has been identified and is shown as site “C” on Figure 17 (accessible via a private track from Brown’s End Road). It is unlikely that power or telephone connections would be feasible at such a site. The spacings between monitors 8 and 9, and between 9 and the suggested new location if required, are both larger than ideal (about 750m in each case), but there do not appear to be any other practical locations for noise monitors in this area.

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# APPENDIX E MONITOR ARRAYS: SPECIAL CONSIDERATIONS FOR DIFFERENTIAL MONITORING

## E1 Introduction

E1.1 The current arrays were designed for effective monitoring of infringements of the overall limits for the day, night and shoulder periods. These limits only have an impact on the noisiest aircraft types. However as the terms of reference of the Review included an assessment of the possibility of differential monitoring, it is important to consider what (if any) changes to the arrays would be needed if differential monitoring were to be introduced. The main differences between aircraft types that must be considered are in the departure routes used by each type, their track patterns, their height distributions and their noise characteristics. These aspects are considered in detail below.

## E2 Departure routes and track and height distributions

E2.1 The current arrays are to a large extent ‘optimised’ to monitor departures by slower-climbing types (currently at Heathrow and Gatwick primarily the 744 and 742Ch3), which are also the heaviest and probably the noisiest types[66]. Faster-climbing and/or quieter aircraft types may in some cases use departure routes that are not commonly used by the heavier aircraft. The current arrays for all the Heathrow and Gatwick routes were assessed in this study for 742 and/or 744 departures as well as for other types (see Tables 2 and 3). The Stansted array assessments were made primarily for the 733, 738, 146, 320 and ‘Props’ aircraft types, because there are insufficient numbers of departures of heavier types.

E2.2 If the track patterns of lighter aircraft are different from those of the heavier types on a given route, some arrays may need reconsidering if differential monitoring were to be introduced. However, the arrays will all still need to effectively monitor departures of the heavier types, so the assessments of array improvement proposals considered in this paper are equally valid for overall limits and for differential monitoring, unless large numbers of aircraft were to fly on routes significantly different from those currently flown. The V-analyses were undertaken for all aircraft type groups for which sufficient data was available. Heavy 4-engined jets tend to have the lowest heights over the monitors: aircraft that are higher are generally more likely to fly within a V, so differences in height distributions between aircraft types are unlikely to be as important in assessing arrays as differences in track distributions.

## E3 Noise characteristics

E3.1 The noise characteristics of each aircraft type must also be considered. The main issue is that of event detection for quieter types, where the noise levels of some events are more likely to be close to the background noise level. Selection of quiet locations for the noise monitors is thus more crucial if differential monitoring were to be introduced for the quietest groups of types, in order to ensure that automatic detection and matching of aircraft noise events function reliably in NTK. Ideally sites should be away from any known major sources of noise, including motorways and roads, but this can conflict with the other requirements for access and security. Schools can provide suitable secure locations, but the noise of children in

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[66] Since the 1995 review the 340 has come into operation; its heights at 6.5km are often lower than those of B747s, so the arrays are not necessarily optimised for that type.

playgrounds may be an issue. Even 'dawn chorus' bird song has been shown to be a potential problem on occasions at sites near trees.

E3.2 As a guideline, the average measured $L_{Amax}$ levels for the quieter aircraft type groups are shown in Table E1, where they are compared with typical background noise levels[67] at each of the fixed monitor locations. Although the average aircraft noise levels all well exceed the $L_{90}$ values, it should nevertheless be remembered that 90% of the time the noise at the monitor exceeds the $L_{90}$ level, while around half the departures have a lower noise level than the average value shown. However for determining infringements of course it is only the noisiest events for each aircraft type group that are of interest, so it is concluded that background noise should not be a major problem for differential monitoring at any of the existing monitor locations at any time of day or night.

E3.3 It is likely that many of the aircraft most effectively monitored by some of the additional monitors suggested in the proposals in this report would be the quieter aircraft types, especially those at Stansted. There is unlikely to be a background noise issue with any of the Stansted scenarios[68].

## E4 Specific issues

E4.1 The results given in Table 3 indicate that the current arrays at Gatwick achieve very good detection rates, with 99% or more of all jet aircraft types on either runway flying through a V. **Propeller aircraft** however generally tend to climb more slowly than most jets, and some, which are exempt from the requirement to follow NPRs, are routinely vectored onto departure paths away from the NPRs (i.e. the extended runway centreline at Gatwick) before passing the noise monitors, so for some propeller types smaller proportions of departures fly through a V (e.g. 84% of DH3s on 08R). If any differential monitoring scheme were to include propeller aircraft such as the DH3, additional noise monitors might be needed purely for that purpose (probably two at each end of the airport with their current track patterns) – but such monitors would make a negligible difference to the detection rates for almost all jet aircraft. It may be considered that the small benefits of including propeller aircraft in any scheme for differential noise monitoring would not be sufficient to justify the expense and complication of the additional monitors that would be needed at Gatwick (and possibly also at Stansted, where additional monitors might also be required because of different track patterns and lower heights for propeller aircraft).

E4.2 Apart from propeller aircraft, the aircraft types with a consistently lower proportion of departures passing through a V are all the common 4-engined jets. The monitoring performance for the **146** from the V-analysis results was affected by its lower heights at the noise monitors compared with most other small/medium jet types. 146s in particular may be affected to some extent by the number of departures not using the full runway length for their take-off roll, and by more dispersed track-keeping on certain turning routes. Improvements suggested to the arrays for the monitoring of the overall limits would also improve the monitoring of 146s.

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[67] Background noise is indicated here by typical values of L90 - the level exceeded 90% of the time, as far as possible during selected periods when aircraft were not in the vicinity.

[68] although background noise could possibly be a problem for monitoring quieter aircraft types at some of the existing runway 23 monitors close to the M11 motorway.

## TABLE E1 Typical background noise levels L90 and average aircraft levels at each fixed monitor

| | | Background noise ($L_{90}$ dBA) | | | Average measured noise level dBA (for aircraft on nearest route(s) to monitor) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Airport | Monitor | Day | Shoulder | Night | 100 | 146 | 319 | 320 | 321 | 738 | AT7 | CRJ | DH3 | M90 | Props |
| Heathrow | 6 | 46 | 44 | 39 | 74.4 | 75.1 | 73.3 | 75.0 | 75.0 | 73.8 | 70.7 | - | - | 73.1 | - |
| | H/10 | 49 | 44 | 40 | 76.1 | 74.5 | 73.2 | 74.2 | 74.8 | 74.3 | - | - | - | 72.7 | - |
| | F/11 | 48 | 46 | 41 | 76.5 | 77.3 | 76.1 | 76.5 | 76.2 | 76.1 | 70.7 | - | - | 74.9 | - |
| | G/12 | 50 | 47 | 40 | 75.4 | 74.6 | 74.4 | 74.4 | 74.9 | 75.5 | 73.1 | - | - | 75.0 | - |
| | I/13 | 46 | 44 | 39 | 73.6 | 75.1 | 72.6 | 73.5 | 75.2 | 74.4 | - | - | - | - | - |
| | E/14 | 48 | 48 | 39 | 74.1 | 73.6 | 72.4 | 73.8 | 74.2 | 74.2 | - | - | - | - | - |
| | D/15 | 45 | 38 | 37 | 76.2 | 74.7 | 72.7 | 74.5 | 74.5 | 73.9 | 75.0 | - | - | 72.5 | - |
| | C/17 | 48 | 48 | 44 | 76.6 | 76.6 | 74.7 | 75.6 | 75.1 | 74.3 | 71.9 | - | - | 74.3 | - |
| | B/18 | 51 | 47 | 41 | 77.9 | 78.1 | 75.9 | 76.5 | 77.3 | 76.3 | 72.9 | - | - | 75.5 | - |
| | A/19 | 54 | 53 | 43 | 71.9 | 77.8 | 74.2 | 74.8 | 75.3 | 76.5 | 74.2 | - | - | 75.6 | - |
| Gatwick | 1 | 36 | 34 | 30 | 76.9 | 76.0 | 75.2 | 76.5 | 78.5 | 78.5 | 73.0 | 67.7 | 69.9 | - | - |
| | 3 | 40 | 35 | 28 | 73.5 | 74.0 | 73.6 | 74.0 | 75.3 | 76.2 | 71.5 | 64.5 | 68.3 | - | - |
| | 4 | 44 | 46 | 41 | 73.9 | 74.3 | 73.5 | 74.9 | 77.0 | 76.7 | 71.5 | 65.4 | 66.8 | - | - |
| | 5 | 48 | 38 | 36 | 75.4 | 74.9 | 74.3 | 75.0 | 77.2 | 76.4 | 71.4 | 66.1 | 67.6 | - | - |
| | 6 | 47 | 49 | 40 | 74.0 | 73.7 | 72.2 | 73.2 | 75.3 | 75.1 | 70.5 | 65.1 | 66.0 | - | - |
| Stansted | 1 | 45 | 47 | 40 | 72.8 | 74.2 | 73.0 | 73.6 | 75.5 | 74.0 | - | 66.9 | - | - | 69.8 |
| | 3 | 53 | 51 | 45 | 73.9 | 75.2 | 73.8 | 74.9 | 75.4 | 76.1 | - | 73.1 | - | - | 71.3 |
| | 4 | 50 | 52 | 46 | 72.3 | 74.4 | 72.1 | 72.6 | 72.4 | 71.7 | - | 72.9 | - | - | 71.9 |
| | 5 | 49 | 48 | 45 | 72.4 | 74.5 | 71.8 | 74.2 | 75.3 | 74.6 | - | 68.4 | - | - | 72.7 |
| | 6 | 49 | 44 | 41 | 71.9 | 74.2 | 72.0 | 72.7 | 74.0 | 73.1 | - | 71.9 | - | - | 72.3 |
| | 7 | 37 | 39 | 29 | 74.2 | 72.9 | - | 73.8 | 75.5 | 74.3 | - | 68.5 | - | - | 72.7 |
| | 8 | 44 | 44 | 43 | 72.2 | 74.2 | 72.3 | 73.6 | 74.4 | 74.7 | - | 73.2 | - | - | 71.5 |
| | 9 | 44 | 40 | 29 | 72.8 | 74.1 | 71.1 | 73.6 | 74.5 | 76.2 | - | 72.7 | - | - | 73.3 |
| | 10 | 42 | 39 | 35 | 72.5 | 72.9 | 72.1 | 73.4 | 74.8 | 75.1 | - | 66.0 | - | - | 68.6 |

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# APPENDIX F ACCURACY OF NTK HEIGHT AND TRACK DATA

## F1 Introduction

F1.1 There are no current British or international standards that relate directly to the accuracy of the height or positional data in an NTK system. The NTK system does not in itself add any inaccuracy to the data input to it. The system was specified to use SSR (Secondary Surveillance Radar) for its source of height and position data, and it is the accuracy of this which is discussed here.

F1.2 This Appendix summarises the results from Ref 12, which provides a technical assessment comparing NTK data at all three airports against height and positional information recorded on board aircraft, using (i) flight calibration aircraft data and (ii) flight recorder information from commercial jet aircraft.

## F2 Accuracy of height data

F2.1 The height data output by NTK is derived from SSR 'Mode C' transmissions of pressure altimeter readings from the aircraft. This Flight Level data (which is referenced to a reference atmospheric pressure of 1013.25 hPa) is in units of 100ft. Below Flight Level 60 (corresponding to an altitude of approximately 6000ft), the Flight Level is adjusted by the NATS radar data processing system to 'QNH', i.e. the altitude relative to mean sea level at the London Area local atmospheric pressure. The altitude data is then transferred to the airports' NTK systems, which apply the appropriate airfield elevation adjustment, so the data stored in NTK is the aircraft height above airfield level.

F2.2 Ref 12 indicates that a broadly-based estimate of the probable overall error in the NTK height data is ±75ft. The individual height readings (values typically every 4 sec) are 'splined' (smoothed) by NTK, so much of the impact of the coarse resolution is removed before height data is used in any study, improving the overall accuracy of NTK height data.

## F3 Accuracy of positional data

F3.1 The accuracy in aircraft position as indicated by NTK is dependent on the aircraft's location relative to the appropriate radar head. In the direction along the line between the radar head and the aircraft, the data has a resolution of 116m, thus resolution errors in this direction could be of the order of ±60m. At $90^0$ to this direction, the accuracy decreases with distance from the radar head; at 6.5km radius of the radar head (a typical distance for the noise monitors), resolution in this direction is better than 10m.

F3.2 As with the height data, when these individual position readings (values typically every 4 sec) are splined by NTK, much of the uncertainty associated with the coarse resolution is removed and the overall accuracy of NTK data is significantly better than the worst case.

## F4 Accuracy checks

F4.1 Ref 12 gives the results of direct checks of the NTK (SSR-derived data) against independently derived precision data obtained from height and positional information recorded on board aircraft, including data from flight calibration aircraft, which are used to check navigational aids such as the Instrument Landing Systems at each airport, and flight recorder data from airlines.

F4.2 The results from the study indicate that the accuracy of NTK data is, on average, no worse than ±20ft in aircraft height and no worse than 40m error in position. The typical range of individual point errors at each airport was within ±100ft for height and the average positional error for individual points was less than 100m. There was no clear evidence of a consistent bias in the height or position data at any of the airports.

F4.3 Note that for the purposes of this study the relevant data is relatively close to the airport, so the positional errors would tend to be smaller than those seen in the more general comparisons given here. It is concluded that NTK data is of ample accuracy for this assessment of departure noise limits, especially as the data used in the study is of the same standard as that used for routine monitoring.

# APPENDIX G FACTORS AFFECTING REFERENCE LEVELS

## G1 Introduction

G1.1 This Appendix contains detailed results of the statistical analyses conducted on NTK data from Heathrow, Gatwick and Stansted for the year September 2000 to August 2001. Simplified explanations of some of the statistical terms used in these results are given below.

G1.2 **Slope** gives the rate of change of noise level (laterally adjusted Reference level $L_{RU}$) with the selected variable.

G1.3 A perfect **linear relationship** exists between two variables if, when plotted on a graph, all points fall on a diagonal straight line.

G1.4 The **correlation coefficient** is an indication of the strength of the relationship between two variables. It is calculated using the 'least squares' criterion, summing a standardised version of the discrepancies between actual values and predicted values for each data point. Values of correlation coefficient lie between -1 (indicating a perfect negative linear relationship between the two variables) and +1 (indicating a perfect positive relationship). However, in the real world perfect correlation is extremely unlikely. Generally a coefficient of at least +/- 0.3 is considered large enough to indicate that a relationship exists. If the correlation coefficient is zero there is no linear relationship between the two variables.

G1.5 Depending on how stringently we wish to test for a relationship, we can test for **significance**, at for example the 5% level, or better the 1% level. Generally speaking, this means that for a relationship which is significant at the 1% level the expected relationship holds true 99% of the time. Ideally, for significance at the 1% level values of the significance (e.g. in Tables G4, G5 and G6) would be less than 0.01.

## G2 List of Tables

## G3 List of Figures

# TABLE G1 Reference level statistics for all aircraft types at each airport

| | | | | Percentiles | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **Code** | **Mean** | **SD** | **5%** | **10%** | **90%** | **95%** | **Maximum** | **Range** | **Count** |
| **Heathrow** | | | | | | | | | | |
| | **100** | 75.5 | 2.6 | 70.7 | 71.8 | 78.5 | 78.9 | 81.5 | 15.4 | 498 |
| | **146** | 75.6 | 2.4 | 71.9 | 72.6 | 78.8 | 79.4 | 82.9 | 16.3 | 1423 |
| | **300** | 79.0 | 2.9 | 74.3 | 75.2 | 82.7 | 83.7 | 91.6 | 21.4 | 3160 |
| | **310** | 78.1 | 3.0 | 72.8 | 74.1 | 81.9 | 82.7 | 87.8 | 20.6 | 1804 |
| | **319** | 74.0 | 2.3 | 69.9 | 70.9 | 76.6 | 77.3 | 88.6 | 23.3 | 7876 |
| | **320** | 74.8 | 3.1 | 69.6 | 70.7 | 79.0 | 80.1 | 90.4 | 27.1 | 15182 |
| | **321** | 75.0 | 2.2 | 71.1 | 72.0 | 77.6 | 78.3 | 92.1 | 26.3 | 13259 |
| | **330** | 80.0 | 2.8 | 75.0 | 76.0 | 83.0 | 83.6 | 87.3 | 17.2 | 1299 |
| | **340** | 85.8 | 3.1 | 79.4 | 81.8 | 89.4 | 90.1 | 93.4 | 20.9 | 2052 |
| | **733** | 76.6 | 2.5 | 72.1 | 73.1 | 79.6 | 80.4 | 92.4 | 26.5 | 22914 |
| | **736** | 73.1 | 2.2 | 69.4 | 70.1 | 75.6 | 76.1 | 90.9 | 25.2 | 550 |
| | **738** | 74.4 | 2.3 | 70.3 | 71.3 | 77.2 | 78.0 | 83.7 | 15.8 | 2017 |
| | **742** | 90.3 | 3.2 | 84.7 | 86.4 | 93.7 | 94.7 | 99.1 | 28.0 | 2481 |
| | **743** | 90.2 | 3.9 | 82.8 | 85.5 | 94.6 | 95.7 | 98.8 | 24.0 | 416 |
| | **744** | 88.4 | 2.8 | 83.7 | 85.0 | 91.7 | 92.5 | 98.6 | 28.3 | 11739 |
| | **757** | 74.9 | 2.7 | 70.3 | 71.3 | 78.2 | 78.9 | 92.6 | 29.9 | 22531 |
| | **762** | 80.7 | 2.9 | 75.7 | 76.7 | 83.9 | 85.0 | 90.2 | 21.9 | 830 |
| | **763** | 80.2 | 3.1 | 74.3 | 76.0 | 83.7 | 84.4 | 91.9 | 25.8 | 7873 |
| | **777** | 80.4 | 2.8 | 75.1 | 76.4 | 83.6 | 84.5 | 91.6 | 24.4 | 8809 |
| | **D10** | 82.4 | 4.7 | 75.3 | 76.6 | 88.7 | 90.2 | 94.0 | 22.0 | 311 |
| | **ERJ** | 69.7 | 2.3 | 64.9 | 66.5 | 72.6 | 73.7 | 75.0 | 10.7 | 87 |
| | **EXE3** | 72.8 | 3.8 | 67.2 | 68.0 | 78.0 | 80.2 | 83.3 | 17.7 | 299 |
| | **M11** | 82.6 | 4.1 | 75.7 | 77.2 | 87.7 | 89.6 | 95.3 | 25.5 | 486 |
| | **M80** | 82.9 | 2.6 | 78.4 | 79.5 | 85.9 | 86.7 | 93.1 | 22.7 | 5465 |
| | **M90** | 74.0 | 2.5 | 69.4 | 70.5 | 76.9 | 77.6 | 82.9 | 18.4 | 2304 |
| | **Props1** | 70.3 | 2.9 | 65.7 | 66.7 | 74.1 | 75.4 | 82.1 | 18.6 | 716 |
| **Gatwick** | | | | | | | | | | |
| | **100** | 73.4 | 2.8 | 68.3 | 70.1 | 76.7 | 77.7 | 81.8 | 21.2 | 1294 |
| | **146** | 73.3 | 3.1 | 68.6 | 69.6 | 77.5 | 78.9 | 89.6 | 30.6 | 19004 |
| | **300** | 77.5 | 2.5 | 72.8 | 74.5 | 80.4 | 81.1 | 85.3 | 20.3 | 1458 |
| | **319** | 72.2 | 2.2 | 68.1 | 69.3 | 75.0 | 75.6 | 77.8 | 13.6 | 482 |
| | **320** | 73.0 | 2.4 | 69.1 | 70.1 | 75.9 | 76.8 | 81.1 | 20.1 | 5716 |
| | **321** | 75.1 | 2.5 | 71.0 | 72.3 | 78.1 | 78.9 | 82.5 | 22.8 | 2188 |
| | **330** | 78.6 | 2.5 | 74.8 | 75.7 | 81.4 | 82.3 | 88.1 | 24.5 | 2378 |
| | **733** | 75.3 | 2.4 | 71.2 | 72.3 | 78.2 | 79.0 | 90.9 | 31.4 | 35903 |
| | **736** | 72.1 | 2.5 | 67.9 | 68.8 | 75.1 | 75.8 | 78.1 | 16.4 | 343 |
| | **738** | 75.0 | 3.0 | 69.6 | 71.1 | 78.4 | 79.2 | 81.7 | 28.0 | 1584 |
| | **742** | 88.9 | 4.0 | 80.1 | 84.2 | 93.2 | 94.3 | 97.5 | 25.1 | 1271 |
| | **744** | 86.5 | 2.3 | 82.6 | 83.8 | 88.9 | 89.4 | 91.9 | 23.9 | 2772 |
| | **757** | 74.1 | 3.1 | 69.0 | 70.4 | 77.9 | 78.9 | 92.4 | 38.5 | 11391 |
| | **762** | 76.8 | 3.6 | 70.1 | 72.3 | 80.6 | 81.8 | 86.9 | 29.0 | 2106 |
| | **763** | 78.0 | 3.6 | 71.7 | 73.6 | 82.0 | 83.0 | 88.4 | 30.2 | 5564 |
| | **777** | 78.3 | 2.6 | 74.1 | 75.2 | 81.8 | 82.6 | 87.8 | 25.1 | 5425 |
| | **CRJ** | 64.3 | 2.5 | 60.4 | 61.2 | 67.2 | 68.2 | 81.9 | 28.4 | 1780 |
| | **D10** | 83.6 | 3.8 | 77.4 | 79.3 | 88.3 | 89.5 | 94.1 | 26.3 | 1734 |
| | **ERJ** | 67.4 | 2.1 | 63.9 | 64.7 | 69.9 | 70.4 | 75.7 | 16.0 | 339 |
| | **EXE3** | 70.3 | 5.3 | 61.9 | 63.4 | 77.2 | 79.1 | 81.8 | 29.1 | 347 |
| | **M80** | 81.5 | 2.7 | 76.6 | 78.1 | 84.8 | 85.4 | 89.4 | 22.6 | 2839 |
| | **Props1** | 69.1 | 2.9 | 64.2 | 65.3 | 72.8 | 73.6 | 79.7 | 23.1 | 6128 |
| | **Props2** | 73.2 | 2.4 | 69.2 | 70.1 | 76.2 | 77.3 | 80.3 | 13.8 | 527 |

## TABLE G1 continued Reference level statistics for all aircraft types at each airport

**Stansted**

| | Code | Mean | SD | 5% | 10% | 90% | 95% | Maximum | Range | Count |
|---|---|---|---|---|---|---|---|---|---|---|
| | **100** | 74.3 | 2.0 | 70.9 | 71.7 | 76.8 | 77.4 | 82.8 | 18.3 | 2878 |
| | **146** | 76.0 | 2.6 | 71.6 | 72.7 | 79.2 | 80.1 | 86.0 | 19.8 | 6374 |
| | **300** | 79.2 | 2.7 | 74.2 | 75.6 | 82.2 | 83.1 | 86.9 | 19.3 | 501 |
| | **310** | 78.2 | 3.6 | 72.8 | 73.7 | 83.0 | 83.5 | 86.0 | 17.6 | 544 |
| | **319** | 74.2 | 1.8 | 71.3 | 71.8 | 76.5 | 76.9 | 77.7 | 9.3 | 72 |
| | **320** | 75.4 | 2.0 | 71.7 | 72.9 | 77.7 | 78.3 | 82.3 | 15.2 | 1852 |
| | **321** | 76.6 | 2.2 | 72.9 | 74.0 | 79.5 | 80.2 | 83.1 | 16.4 | 1575 |
| | **733** | 78.4 | 2.7 | 73.2 | 74.8 | 81.5 | 82.2 | 86.5 | 21.4 | 14888 |
| | **736** | 74.5 | 2.2 | 70.7 | 71.7 | 77.2 | 77.9 | 83.0 | 16.0 | 916 |
| | **738** | 76.4 | 2.3 | 72.3 | 73.5 | 79.0 | 79.6 | 90.0 | 28.1 | 10212 |
| | **744** | 81.4 | 4.4 | 74.6 | 75.8 | 87.3 | 88.3 | 92.9 | 23.9 | 446 |
| | **757** | 76.3 | 2.7 | 71.0 | 72.8 | 79.4 | 80.2 | 85.1 | 21.1 | 874 |
| | **763** | 78.3 | 3.1 | 73.4 | 74.3 | 82.0 | 83.0 | 86.9 | 17.3 | 247 |
| | **CRJ** | 68.2 | 2.0 | 64.9 | 65.4 | 70.5 | 71.4 | 78.9 | 17.4 | 310 |
| | **D10** | 78.0 | 3.6 | 73.0 | 74.1 | 81.7 | 84.2 | 92.1 | 24.0 | 267 |
| | **ERJ** | 69.4 | 2.2 | 65.7 | 66.7 | 72.2 | 72.8 | 78.8 | 15.8 | 388 |
| | **EXE2** | 82.9 | 3.7 | 76.4 | 78.3 | 87.3 | 87.9 | 91.1 | 21.3 | 193 |
| | **EXE3** | 72.8 | 3.6 | 67.4 | 68.5 | 77.4 | 79.0 | 86.2 | 25.0 | 841 |
| | **M11** | 80.9 | 4.0 | 74.0 | 75.9 | 85.5 | 86.4 | 93.4 | 27.7 | 869 |
| | **M80** | 82.1 | 2.8 | 77.2 | 78.8 | 85.4 | 86.5 | 90.9 | 19.5 | 489 |
| | **Props1** | 70.6 | 2.6 | 66.5 | 67.5 | 73.9 | 75.0 | 81.6 | 20.6 | 1756 |
| | **Props2** | 76.5 | 2.7 | 72.2 | 73.2 | 80.1 | 80.7 | 84.8 | 17.3 | 559 |
| | **Props3** | 81.9 | 2.1 | 78.2 | 79.0 | 84.4 | 84.9 | 89.0 | 13.8 | 256 |

## TABLE G2 Laterally adjusted Reference level statistics for all aircraft types at each airport

| | | | | Percentiles | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **Code** | **Mean** | **S.D.** | **5%** | **10%** | **90%** | **95%** | **Maximum** | **Range** | **Count** |
| **HEATHROW** | | | | | | | | | | |
| | **100** | 75.9 | 2.5 | 71.0 | 72.4 | 78.7 | 79.4 | 81.8 | 15.3 | 498 |
| | **146** | 76.2 | 2.4 | 72.3 | 73.0 | 79.3 | 80.0 | 83.3 | 16.3 | 1423 |
| | **300** | 79.5 | 2.9 | 74.6 | 75.7 | 83.3 | 84.3 | 93.1 | 22.8 | 3160 |
| | **310** | 78.6 | 3.0 | 73.2 | 74.6 | 82.4 | 83.2 | 87.9 | 20.2 | 1804 |
| | **319** | 74.4 | 2.3 | 70.4 | 71.2 | 77.0 | 77.7 | 89.5 | 23.0 | 7876 |
| | **320** | 75.2 | 3.2 | 69.9 | 71.1 | 79.4 | 80.5 | 90.7 | 27.2 | 15182 |
| | **321** | 75.5 | 2.3 | 71.4 | 72.3 | 78.1 | 78.8 | 92.4 | 26.4 | 13259 |
| | **330** | 80.4 | 2.7 | 75.4 | 76.5 | 83.4 | 84.1 | 88.5 | 17.4 | 1299 |
| | **340** | 86.4 | 3.2 | 80.0 | 82.2 | 90.0 | 90.8 | 93.7 | 20.8 | 2052 |
| | **733** | 77.1 | 2.6 | 72.6 | 73.6 | 80.2 | 81.0 | 93.9 | 27.6 | 22914 |
| | **736** | 73.5 | 2.3 | 69.8 | 70.3 | 76.1 | 76.5 | 91.0 | 25.3 | 550 |
| | **738** | 74.8 | 2.3 | 70.8 | 71.6 | 77.7 | 78.6 | 83.9 | 15.8 | 2017 |
| | **742** | 90.8 | 3.2 | 85.3 | 87.0 | 94.3 | 95.3 | 99.9 | 28.5 | 2481 |
| | **743** | 90.7 | 3.9 | 83.6 | 85.9 | 95.1 | 96.1 | 99.0 | 22.9 | 416 |
| | **744** | 88.9 | 2.9 | 84.1 | 85.4 | 92.2 | 93.0 | 98.6 | 27.9 | 11739 |
| | **757** | 75.4 | 2.7 | 70.8 | 71.9 | 78.7 | 79.5 | 92.8 | 29.9 | 22531 |
| | **762** | 81.2 | 2.9 | 76.0 | 77.4 | 84.5 | 85.5 | 91.1 | 22.6 | 830 |
| | **763** | 80.7 | 3.1 | 74.7 | 76.4 | 84.2 | 85.0 | 93.0 | 26.7 | 7873 |
| | **777** | 80.8 | 2.8 | 75.4 | 76.8 | 84.1 | 84.9 | 91.9 | 23.9 | 8809 |
| | **D10** | 83.0 | 4.6 | 75.7 | 77.3 | 89.1 | 90.8 | 94.3 | 22.0 | 311 |
| | **ERJ** | 70.2 | 2.4 | 65.3 | 67.1 | 73.1 | 74.4 | 75.4 | 10.6 | 87 |
| | **EXE3** | 73.3 | 3.8 | 67.5 | 68.7 | 78.2 | 80.6 | 83.3 | 17.2 | 299 |
| | **M11** | 83.1 | 4.1 | 76.2 | 77.6 | 88.2 | 89.9 | 95.4 | 25.2 | 486 |
| | **M80** | 83.5 | 2.5 | 79.0 | 80.1 | 86.5 | 87.3 | 93.2 | 21.6 | 5465 |
| | **M90** | 74.5 | 2.5 | 69.7 | 71.0 | 77.5 | 78.2 | 83.8 | 18.4 | 2304 |
| | **Props1** | 70.8 | 2.9 | 66.0 | 67.1 | 74.7 | 75.9 | 82.2 | 18.3 | 716 |
| **GATWICK** | | | | | | | | | | |
| | **100** | 73.8 | 2.8 | 68.6 | 70.4 | 77.1 | 78.0 | 82.4 | 21.5 | 1294 |
| | **146** | 73.7 | 3.2 | 68.8 | 69.8 | 78.0 | 79.4 | 90.4 | 31.0 | 19004 |
| | **300** | 77.9 | 2.6 | 73.2 | 74.8 | 80.9 | 81.6 | 85.4 | 20.2 | 1458 |
| | **319** | 72.6 | 2.3 | 68.5 | 69.6 | 75.4 | 76.1 | 78.6 | 14.3 | 482 |
| | **320** | 73.3 | 2.5 | 69.3 | 70.3 | 76.4 | 77.2 | 81.8 | 20.7 | 5716 |
| | **321** | 75.4 | 2.6 | 71.1 | 72.5 | 78.5 | 79.3 | 82.9 | 23.1 | 2188 |
| | **330** | 79.0 | 2.6 | 75.0 | 75.9 | 81.9 | 82.8 | 88.8 | 25.2 | 2378 |
| | **733** | 75.6 | 2.5 | 71.4 | 72.5 | 78.6 | 79.4 | 91.3 | 31.5 | 35903 |
| | **736** | 72.4 | 2.6 | 68.1 | 69.1 | 75.6 | 76.3 | 78.5 | 15.6 | 343 |
| | **738** | 75.3 | 3.1 | 69.9 | 71.4 | 78.8 | 79.6 | 82.6 | 28.9 | 1584 |
| | **742** | 89.3 | 4.1 | 80.3 | 84.5 | 93.7 | 94.7 | 97.6 | 25.0 | 1271 |
| | **744** | 86.9 | 2.4 | 82.9 | 84.1 | 89.5 | 90.0 | 93.0 | 24.9 | 2772 |
| | **757** | 74.4 | 3.1 | 69.2 | 70.6 | 78.3 | 79.4 | 92.9 | 39.0 | 11391 |
| | **762** | 77.1 | 3.7 | 70.4 | 72.6 | 81.1 | 82.2 | 87.2 | 29.3 | 2106 |
| | **763** | 78.4 | 3.7 | 71.9 | 73.7 | 82.6 | 83.6 | 88.7 | 30.5 | 5564 |
| | **777** | 78.7 | 2.7 | 74.3 | 75.4 | 82.4 | 83.3 | 89.0 | 26.3 | 5425 |
| | **CRJ** | 64.6 | 2.6 | 60.6 | 61.5 | 67.6 | 68.6 | 82.4 | 28.8 | 1780 |
| | **D10** | 83.9 | 3.8 | 77.8 | 79.5 | 88.7 | 89.9 | 94.9 | 26.6 | 1734 |
| | **ERJ** | 67.7 | 2.1 | 64.2 | 64.9 | 70.3 | 70.8 | 75.8 | 15.7 | 339 |
| | **EXE3** | 70.7 | 5.3 | 62.3 | 63.6 | 77.5 | 79.5 | 81.9 | 29.1 | 347 |
| | **M80** | 81.9 | 2.7 | 77.1 | 78.6 | 85.1 | 85.8 | 89.5 | 22.6 | 2839 |
| | **Props1** | 69.5 | 2.9 | 64.5 | 65.7 | 73.2 | 74.0 | 80.5 | 22.8 | 6128 |
| | **Props2** | 73.7 | 2.5 | 69.4 | 70.6 | 77.0 | 77.9 | 81.5 | 14.7 | 527 |

## TABLE G2 continued — Laterally adjusted Reference level statistics for all aircraft types at each airport

### STANSTED

| | Code | Mean | S.D. | 5% | 10% | 90% | 95% | Maximum | Range | Count |
|---|---|---|---|---|---|---|---|---|---|---|
| | **100** | 74.8 | 2.1 | 71.3 | 72.1 | 77.4 | 78.0 | 83.3 | 18.7 | 2878 |
| | **146** | 76.5 | 2.6 | 72.1 | 73.2 | 79.8 | 80.7 | 87.1 | 20.3 | 6374 |
| | **300** | 79.6 | 2.7 | 74.5 | 76.0 | 82.7 | 83.5 | 87.9 | 20.0 | 501 |
| | **310** | 78.7 | 3.7 | 73.3 | 74.0 | 83.6 | 84.2 | 86.8 | 18.1 | 544 |
| | **319** | 74.7 | 1.7 | 71.6 | 72.2 | 77.0 | 77.5 | 78.3 | 9.2 | 72 |
| | **320** | 75.9 | 1.9 | 72.4 | 73.5 | 78.1 | 78.7 | 83.3 | 15.7 | 1852 |
| | **321** | 77.2 | 2.2 | 73.3 | 74.5 | 80.0 | 80.7 | 83.3 | 16.4 | 1575 |
| | **733** | 78.9 | 2.7 | 73.7 | 75.3 | 82.0 | 82.7 | 87.7 | 22.0 | 14888 |
| | **736** | 75.0 | 2.2 | 71.2 | 72.1 | 77.7 | 78.5 | 83.1 | 15.6 | 916 |
| | **738** | 77.0 | 2.3 | 72.8 | 74.2 | 79.5 | 80.1 | 90.4 | 27.6 | 10212 |
| | **744** | 82.0 | 4.5 | 75.0 | 76.3 | 88.0 | 89.1 | 93.2 | 23.7 | 446 |
| | **757** | 76.7 | 2.7 | 71.7 | 73.1 | 79.8 | 80.5 | 85.2 | 20.3 | 874 |
| | **763** | 78.8 | 3.1 | 73.8 | 74.5 | 82.3 | 83.5 | 87.7 | 17.9 | 247 |
| | **CRJ** | 68.8 | 1.9 | 65.7 | 66.5 | 70.9 | 71.6 | 79.3 | 17.2 | 310 |
| | **D10** | 78.5 | 3.5 | 73.9 | 74.5 | 82.0 | 84.7 | 92.8 | 23.6 | 267 |
| | **ERJ** | 70.1 | 2.1 | 66.6 | 67.3 | 72.6 | 73.2 | 79.1 | 15.0 | 388 |
| | **EXE2** | 83.3 | 3.7 | 76.6 | 78.7 | 87.8 | 88.4 | 91.8 | 22.0 | 193 |
| | **EXE3** | 73.4 | 3.6 | 68.0 | 69.2 | 78.0 | 79.5 | 86.5 | 24.5 | 841 |
| | **M11** | 81.4 | 4.0 | 74.4 | 76.5 | 85.8 | 86.7 | 93.8 | 26.8 | 869 |
| | **M80** | 82.6 | 2.8 | 78.0 | 79.2 | 85.8 | 86.8 | 91.4 | 20.0 | 489 |
| | **Props1** | 71.2 | 2.6 | 67.2 | 68.0 | 74.6 | 75.6 | 82.3 | 20.7 | 1756 |
| | **Props2** | 77.0 | 2.7 | 72.5 | 73.5 | 80.6 | 81.1 | 84.9 | 16.7 | 559 |
| | **Props3** | 82.4 | 2.1 | 78.6 | 79.7 | 84.9 | 85.7 | 89.3 | 13.2 | 256 |

## TABLE G3 Slopes of graphs of Laterally adjusted Reference level vs other variables at each airport

### HEATHROW

| | Stage length | Ground Speed | Height | Temperature | Headwind | Pressure | RH |
|---|---|---|---|---|---|---|---|
| **Aircraft Type** | **dB/1000nm** | **dB/10kt** | **dB/100ft** | **dB/10 degC** | **dB/10kt** | **dB/1000MB** | **dB/10%** |
| **100** | 1.19 | -0.26 | -2.61 | -0.48 | -0.11 | -0.02 | 0.18 |
| **146** | -2.22 | 0.45 | -2.45 | 0.04 | -0.29 | -0.01 | 0.11 |
| **300** | 1.04 | -0.56 | -1.27 | -0.85 | -0.36 | -0.02 | 0.16 |
| **310** | 1.53 | -1.38 | -1.55 | -0.46 | -0.64 | -0.01 | 0.06 |
| **319** | 0.53 | 2.48 | -1.03 | -0.68 | 0.06 | -0.02 | 0.12 |
| **320** | 1.02 | 2.63 | -2.48 | -1.05 | 0.18 | -0.03 | 0.17 |
| **321** | 1.44 | 0.52 | -1.38 | -0.47 | -0.30 | -0.01 | 0.09 |
| **330** | 1.63 | 2.74 | -3.03 | 0.14 | -0.84 | 0.01 | -0.16 |
| **340** | 1.80 | 2.82 | -4.47 | -0.45 | -1.39 | -0.01 | 0.22 |
| **733** | 1.50 | 2.12 | -1.40 | -0.73 | -0.12 | -0.01 | 0.08 |
| **736** | 0.97 | 0.98 | -0.02 | -0.53 | -0.33 | 0.00 | 0.18 |
| **738** | 1.21 | 2.06 | -0.83 | -0.67 | -0.43 | -0.03 | 0.21 |
| **742** | 1.56 | 3.22 | -4.80 | -0.17 | -0.82 | -0.03 | 0.18 |
| **743** | 2.17 | 6.40 | -5.52 | 0.16 | -1.65 | 0.04 | 0.38 |
| **744** | 1.25 | 4.36 | -4.52 | -0.32 | -1.18 | -0.01 | 0.29 |
| **757** | 0.42 | 0.56 | -3.20 | -0.44 | -0.34 | -0.02 | 0.17 |
| **762** | 1.15 | 2.12 | -3.01 | -0.06 | -0.36 | -0.02 | -0.03 |
| **763** | 0.15 | 3.38 | -3.79 | -0.28 | -0.61 | -0.01 | 0.09 |
| **777** | 1.42 | 2.17 | -2.61 | -0.86 | -0.63 | -0.02 | 0.39 |
| **D10** | 2.56 | 4.38 | -5.18 | -0.50 | -0.86 | 0.05 | 0.64 |
| **EXE3** | 1.62 | 0.56 | -2.08 | -0.98 | 0.30 | -0.02 | 0.24 |
| **M11** | 1.46 | 4.96 | -4.49 | -0.54 | -3.07 | 0.01 | 0.77 |
| **M80** | 1.39 | 0.73 | -1.66 | -0.51 | -0.85 | -0.01 | 0.00 |
| **M90** | 1.66 | 0.89 | -1.74 | -0.52 | -0.38 | -0.02 | 0.18 |
| **Props 1** | 56.67 | 2.15 | -2.14 | -1.07 | -0.55 | -0.02 | 0.33 |

### GATWICK

| | Stage length | Ground Speed | Height | Temperature | Headwind* | Pressure | RH |
|---|---|---|---|---|---|---|---|
| **Aircraft Type** | **dB/1000nm** | **dB/10kt** | **dB/100ft** | **dB/10 degC** | **dB/10kt** | **dB/1000MB** | **dB/10%** |
| **100** | 1.13 | 2.97 | -2.77 | 0.41 | -1.36 | 0.01 | -0.29 |
| **146** | 1.78 | 3.74 | -4.73 | -0.16 | -0.21 | 0.00 | -0.03 |
| **300** | 0.65 | 2.72 | -3.71 | 0.13 | -0.40 | 0.00 | -0.12 |
| **319** | 0.24 | 2.09 | -1.31 | -0.36 | 0.25 | 0.00 | -0.02 |
| **320** | 1.23 | 2.87 | -2.96 | -0.03 | -0.18 | 0.00 | -0.13 |
| **321** | 1.37 | 3.00 | -4.21 | -0.48 | -0.56 | 0.00 | -0.03 |
| **330** | 0.91 | 2.59 | -3.50 | 0.00 | -1.11 | 0.02 | -0.14 |
| **733** | 2.46 | 2.80 | -3.34 | -0.09 | -0.87 | 0.01 | -0.10 |
| **736** | 1.50 | 3.13 | -2.48 | 0.22 | -1.96 | 0.04 | -0.22 |
| **738** | 2.93 | 3.40 | -4.33 | 0.52 | -0.88 | 0.01 | -0.12 |
| **742** | 2.90 | 6.06 | -7.81 | -0.18 | -1.34 | 0.01 | -0.06 |
| **744** | 0.72 | 3.37 | -6.37 | -0.68 | -1.00 | 0.01 | 0.29 |
| **757** | 1.24 | 3.18 | -4.00 | -0.14 | -0.92 | 0.01 | -0.13 |
| **762** | 1.35 | -0.28 | -5.15 | 0.60 | -0.56 | 0.01 | -0.32 |
| **763** | 1.96 | 2.51 | -6.01 | -0.04 | 0.11 | 0.00 | -0.27 |
| **777** | 0.91 | 4.44 | -3.52 | 0.00 | -0.71 | 0.03 | -0.23 |
| **CRJ** | 1.68 | 1.87 | -1.64 | -0.01 | -0.41 | 0.00 | -0.18 |
| **D10** | 2.47 | 5.41 | -6.90 | -0.07 | -1.64 | -0.01 | 0.22 |
| **ERJ** | 0.10 | 1.43 | -2.01 | 0.07 | -0.81 | 0.03 | -0.09 |
| **EXE3** | 0.97 | 1.62 | -3.95 | -0.86 | -0.44 | -0.03 | 0.24 |
| **M80** | 2.53 | 2.32 | -2.28 | 0.12 | -1.16 | 0.02 | -0.28 |
| **Props 1** | 5.51 | 3.22 | -2.86 | -0.17 | -0.77 | 0.01 | -0.05 |
| **Props 2** | -6.97 | 3.10 | -2.64 | -1.28 | -0.77 | 0.02 | 0.16 |

## TABLE G3 continued Slopes of graphs of Laterally adjusted Reference level vs other variables at each airport

### STANSTED

| | Stage length | Ground Speed | Height | Temperature | Headwind* | Pressure | RH |
|---|---|---|---|---|---|---|---|
| **Aircraft Type** | **dB/1000nm** | **dB/10kt** | **dB/100ft** | **dB/10 degC** | **dB/10kt** | **dB/1000MB** | **dB/10%** |
| **100** | 2.08 | 0.07 | -2.50 | 0.00 | -0.82 | -0.01 | 0.00 |
| **146** | 3.34 | 1.24 | -4.52 | 0.33 | -0.72 | -0.01 | 0.00 |
| **300** | 2.43 | 0.85 | -3.84 | 0.25 | -1.18 | -0.01 | 0.01 |
| **310** | 3.14 | -0.91 | -4.17 | 1.83 | -0.42 | 0.02 | -0.82 |
| **320** | 0.68 | 0.56 | -3.06 | 0.02 | -0.41 | -0.01 | -0.04 |
| **321** | 3.21 | 0.46 | -4.17 | 0.14 | -0.88 | 0.00 | 0.02 |
| **733** | 3.20 | 2.20 | -4.83 | 0.24 | -1.45 | 0.01 | -0.15 |
| **736** | 0.26 | 1.18 | -2.78 | -0.07 | -1.34 | 0.01 | -0.09 |
| **738** | 2.21 | 2.84 | -4.52 | 0.40 | -1.39 | 0.01 | -0.14 |
| **744** | 1.32 | -0.26 | -5.75 | -0.49 | 0.04 | -0.04 | 0.48 |
| **757** | 0.90 | 0.66 | -4.51 | 0.13 | -1.00 | -0.01 | -0.07 |
| **763** | 0.73 | 2.56 | -4.18 | 0.17 | -1.16 | 0.01 | 0.09 |
| **CRJ** | 2.03 | 1.74 | -1.59 | -0.06 | -0.31 | -0.01 | 0.10 |
| **D10** | 3.15 | 0.46 | -3.69 | -0.18 | -1.58 | 0.02 | 0.17 |
| **ERJ** | 8.49 | 1.37 | -3.06 | -0.37 | -0.40 | -0.03 | 0.41 |
| **EXE2** | 1.09 | 1.97 | -3.86 | 0.23 | -1.11 | 0.01 | -0.56 |
| **EXE3** | 0.30 | 0.28 | -2.85 | 0.01 | -0.03 | -0.03 | 0.12 |
| **M11** | 1.92 | -2.84 | -4.30 | -0.87 | -1.36 | -0.03 | 0.46 |
| **M80** | 1.04 | -0.68 | -2.73 | -0.10 | -0.72 | -0.03 | -0.11 |
| **Props 1** | 2.07 | 0.85 | -1.96 | -0.39 | -0.53 | -0.03 | 0.12 |
| **Props 2** | 3.64 | 0.34 | -1.84 | -1.37 | -0.64 | -0.02 | 0.16 |
| **Props 3** | 1.84 | 2.09 | -3.85 | -0.18 | -1.00 | -0.01 | -0.50 |

* Hourly averages of Headwind

## TABLE G4 Correlations between laterally adjusted Reference level and other variables for Heathrow

| Aircraft Type | Correlation | Stage Length | Ground Speed | Height | Temperature | Headwind | Pressure | Rel. Humidity |
|---|---|---|---|---|---|---|---|---|
| **100** | Coefficient | **0.07** | **-0.04** | **-0.37** | **-0.13** | **-0.02** | **-0.09** | **0.10** |
| | Significance | 0.12 | 0.37 | 0.00 | 0.00 | 0.74 | 0.05 | 0.03 |
| **146** | Coefficient | **-0.10** | **0.08** | **-0.42** | **0.01** | **-0.06** | **-0.03** | **0.06** |
| | Significance | 0.00 | 0.00 | 0.00 | 0.69 | 0.14 | 0.31 | 0.03 |
| **300** | Coefficient | **0.41** | **-0.09** | **-0.18** | **-0.19** | **-0.06** | **-0.06** | **0.07** |
| | Significance | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.00 | 0.00 |
| **310** | Coefficient | **0.45** | **-0.19** | **-0.23** | **-0.10** | **-0.09** | **-0.04** | **0.02** |
| | Significance | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.08 | 0.33 |
| **319** | Coefficient | **0.05** | **0.40** | **-0.20** | **-0.20** | **0.01** | **-0.09** | **0.06** |
| | Significance | 0.00 | 0.00 | 0.00 | 0.00 | 0.40 | 0.00 | 0.00 |
| **320** | Coefficient | **0.13** | **0.36** | **-0.33** | **-0.22** | **0.03** | **-0.11** | **0.07** |
| | Significance | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.00 | 0.00 |
| **321** | Coefficient | **0.16** | **0.09** | **-0.24** | **-0.14** | **-0.06** | **-0.05** | **0.05** |
| | Significance | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **330** | Coefficient | **0.57** | **0.39** | **-0.53** | **0.04** | **-0.14** | **0.04** | **-0.07** |
| | Significance | 0.00 | 0.00 | 0.00 | 0.20 | 0.00 | 0.14 | 0.02 |
| **340** | Coefficient | **0.66** | **0.27** | **-0.55** | **-0.09** | **-0.22** | **-0.02** | **0.08** |
| | Significance | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.41 | 0.00 |
| **733** | Coefficient | **0.17** | **0.34** | **-0.23** | **-0.18** | **-0.02** | **-0.05** | **0.04** |
| | Significance | 0.00 | 0.00 | 0.00 | 0.00 | 0.02 | 0.00 | 0.00 |
| **736** | Coefficient | **0.22** | **0.19** | **0.00** | **-0.17** | **-0.07** | **-0.02** | **0.10** |
| | Significance | 0.00 | 0.00 | 0.93 | 0.00 | 0.18 | 0.68 | 0.02 |
| **738** | Coefficient | **0.27** | **0.31** | **-0.16** | **-0.20** | **-0.09** | **-0.12** | **0.11** |
| | Significance | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.00 | 0.00 |
| **742** | Coefficient | **0.47** | **0.30** | **-0.54** | **-0.04** | **-0.12** | **-0.08** | **0.07** |
| | Significance | 0.00 | 0.00 | 0.00 | 0.08 | 0.00 | 0.00 | 0.00 |
| **743** | Coefficient | **0.70** | **0.64** | **-0.74** | **0.03** | **-0.23** | **0.10** | **0.12** |
| | Significance | 0.00 | 0.00 | 0.00 | 0.57 | 0.00 | 0.04 | 0.02 |
| **744** | Coefficient | **0.49** | **0.40** | **-0.51** | **-0.07** | **-0.19** | **-0.05** | **0.12** |
| | Significance | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **757** | Coefficient | **0.05** | **0.07** | **-0.49** | **-0.11** | **-0.06** | **-0.10** | **0.08** |
| | Significance | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **762** | Coefficient | **0.39** | **0.28** | **-0.50** | **-0.01** | **-0.06** | **-0.07** | **-0.01** |
| | Significance | 0.00 | 0.00 | 0.00 | 0.69 | 0.26 | 0.06 | 0.71 |
| **763** | Coefficient | **0.06** | **0.39** | **-0.59** | **-0.06** | **-0.09** | **-0.03** | **0.03** |
| | Significance | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.00 |
| **777** | Coefficient | **0.39** | **0.25** | **-0.32** | **-0.17** | **-0.10** | **-0.08** | **0.09** |
| | Significance | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **D10** | Coefficient | **0.68** | **0.56** | **-0.82** | **-0.07** | **-0.08** | **0.12** | **0.17** |
| | Significance | 0.00 | 0.00 | 0.00 | 0.21 | 0.33 | 0.04 | 0.00 |
| **EXE3** | Coefficient | **0.34** | **0.09** | **-0.34** | **-0.16** | **0.04** | **-0.05** | **0.08** |
| | Significance | 0.00 | 0.13 | 0.00 | 0.00 | 0.67 | 0.43 | 0.18 |
| **M11** | Coefficient | **0.73** | **0.56** | **-0.75** | **-0.08** | **-0.33** | **0.03** | **0.21** |
| | Significance | 0.00 | 0.00 | 0.00 | 0.07 | 0.00 | 0.58 | 0.00 |
| **M80** | Coefficient | **0.11** | **0.11** | **-0.33** | **-0.13** | **-0.15** | **-0.06** | **0.00** |
| | Significance | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.87 |
| **M90** | Coefficient | **0.07** | **0.11** | **-0.31** | **-0.14** | **-0.07** | **-0.07** | **0.08** |
| | Significance | 0.00 | 0.00 | 0.00 | 0.00 | 0.02 | 0.00 | 0.00 |
| **Props 1** | Coefficient | **0.34** | **0.24** | **-0.27** | **-0.25** | **-0.08** | **-0.08** | **0.14** |
| | Significance | 0.00 | 0.00 | 0.00 | 0.00 | 0.11 | 0.04 | 0.00 |

## TABLE G5 Correlations between laterally adjusted Reference level and other variables for Gatwick

| Aircraft Type | Correlation | Stage Length | Ground Speed | Height | Temperature | Headwind* | Pressure | Rel. Humidity |
|---|---|---|---|---|---|---|---|---|
| **100** | Coefficient | **0.06** | **0.42** | **-0.50** | **0.09** | **-0.19** | **0.03** | **-0.15** |
| | Significance | 0.03 | 0.00 | 0.00 | 0.00 | 0.00 | 0.21 | 0.00 |
| **146** | Coefficient | **0.06** | **0.42** | **-0.50** | **0.09** | **-0.02** | **0.03** | **-0.15** |
| | Significance | 0.03 | 0.00 | 0.00 | 0.00 | 0.00 | 0.21 | 0.00 |
| **300** | Coefficient | **0.25** | **0.36** | **-0.47** | **0.03** | **-0.05** | **0.01** | **-0.07** |
| | Significance | 0.00 | 0.00 | 0.00 | 0.29 | 0.05 | 0.64 | 0.01 |
| **319** | Coefficient | **0.03** | **0.28** | **-0.19** | **-0.10** | **0.04** | **0.00** | **-0.01** |
| | Significance | 0.55 | 0.00 | 0.00 | 0.03 | 0.40 | 0.94 | 0.79 |
| **320** | Coefficient | **0.20** | **0.37** | **-0.38** | **-0.01** | **-0.03** | **0.02** | **-0.09** |
| | Significance | 0.00 | 0.00 | 0.00 | 0.58 | 0.07 | 0.13 | 0.00 |
| **321** | Coefficient | **0.21** | **0.30** | **-0.53** | **-0.11** | **-0.08** | **0.00** | **-0.02** |
| | Significance | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.00 | 0.36 |
| **330** | Coefficient | **0.29** | **0.32** | **-0.42** | **0.00** | **-0.17** | **0.07** | **-0.08** |
| | Significance | 0.00 | 0.00 | 0.00 | 0.95 | 0.00 | 0.00 | 0.00 |
| **733** | Coefficient | **0.29** | **0.36** | **-0.42** | **-0.02** | **-0.13** | **0.04** | **-0.06** |
| | Significance | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **736** | Coefficient | **0.25** | **0.43** | **-0.38** | **0.05** | **-0.27** | **0.17** | **-0.14** |
| | Significance | 0.00 | 0.00 | 0.00 | 0.32 | 0.00 | 0.00 | 0.01 |
| **738** | Coefficient | **0.51** | **0.37** | **-0.57** | **0.10** | **-0.10** | **0.03** | **-0.07** |
| | Significance | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.23 | 0.01 |
| **742** | Coefficient | **0.71** | **0.49** | **-0.83** | **-0.03** | **-0.12** | **0.02** | **-0.02** |
| | Significance | 0.00 | 0.00 | 0.00 | 0.34 | 0.00 | 0.42 | 0.42 |
| **744** | Coefficient | **0.28** | **0.36** | **-0.62** | **-0.18** | **-0.16** | **0.05** | **0.18** |
| | Significance | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.00 |
| **757** | Coefficient | **0.24** | **0.46** | **-0.54** | **-0.03** | **-0.11** | **0.04** | **-0.06** |
| | Significance | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **762** | Coefficient | **0.50** | **-0.03** | **-0.62** | **0.10** | **-0.06** | **0.02** | **-0.14** |
| | Significance | 0.00 | 0.16 | 0.00 | 0.00 | 0.01 | 0.27 | 0.00 |
| **763** | Coefficient | **0.63** | **0.23** | **-0.64** | **-0.01** | **0.01** | **-0.01** | **-0.12** |
| | Significance | 0.00 | 0.00 | 0.00 | 0.66 | 0.41 | 0.71 | 0.00 |
| **777** | Coefficient | **0.21** | **0.47** | **-0.38** | **0.00** | **-0.10** | **0.11** | **-0.13** |
| | Significance | 0.00 | 0.00 | 0.00 | 0.95 | 0.00 | 0.00 | 0.00 |
| **CRJ** | Coefficient | **0.06** | **0.35** | **-0.29** | **0.00** | **-0.06** | **-0.01** | **-0.11** |
| | Significance | 0.01 | 0.00 | 0.00 | 0.89 | 0.02 | 0.60 | 0.00 |
| **D10** | Coefficient | **0.58** | **0.48** | **-0.73** | **-0.01** | **-0.17** | **-0.01** | **0.09** |
| | Significance | 0.00 | 0.00 | 0.00 | 0.63 | 0.00 | 0.54 | 0.00 |
| **ERJ** | Coefficient | **0.00** | **0.25** | **-0.40** | **0.02** | **-0.13** | **0.11** | **-0.06** |
| | Significance | 0.99 | 0.00 | 0.00 | 0.77 | 0.02 | 0.05 | 0.24 |
| **EXE3** | Coefficient | **0.14** | **0.17** | **-0.45** | **-0.09** | **-0.03** | **-0.06** | **0.07** |
| | Significance | 0.01 | 0.00 | 0.00 | 0.09 | 0.57 | 0.24 | 0.20 |
| **M80** | Coefficient | **0.15** | **0.30** | **-0.41** | **0.03** | **-0.16** | **0.08** | **-0.17** |
| | Significance | 0.00 | 0.00 | 0.00 | 0.14 | 0.00 | 0.00 | 0.00 |
| **Props 1** | Coefficient | **0.14** | **0.40** | **-0.37** | **-0.04** | **-0.10** | **0.04** | **-0.03** |
| | Significance | 0.00 | 0.00 | 0.00 | 0.01 | 0.00 | 0.00 | 0.03 |
| **Props 2** | Coefficient | **-0.05** | **0.44** | **-0.36** | **-0.28** | **-0.11** | **0.07** | **0.07** |
| | Significance | 0.25 | 0.00 | 0.00 | 0.00 | 0.01 | 0.11 | 0.13 |

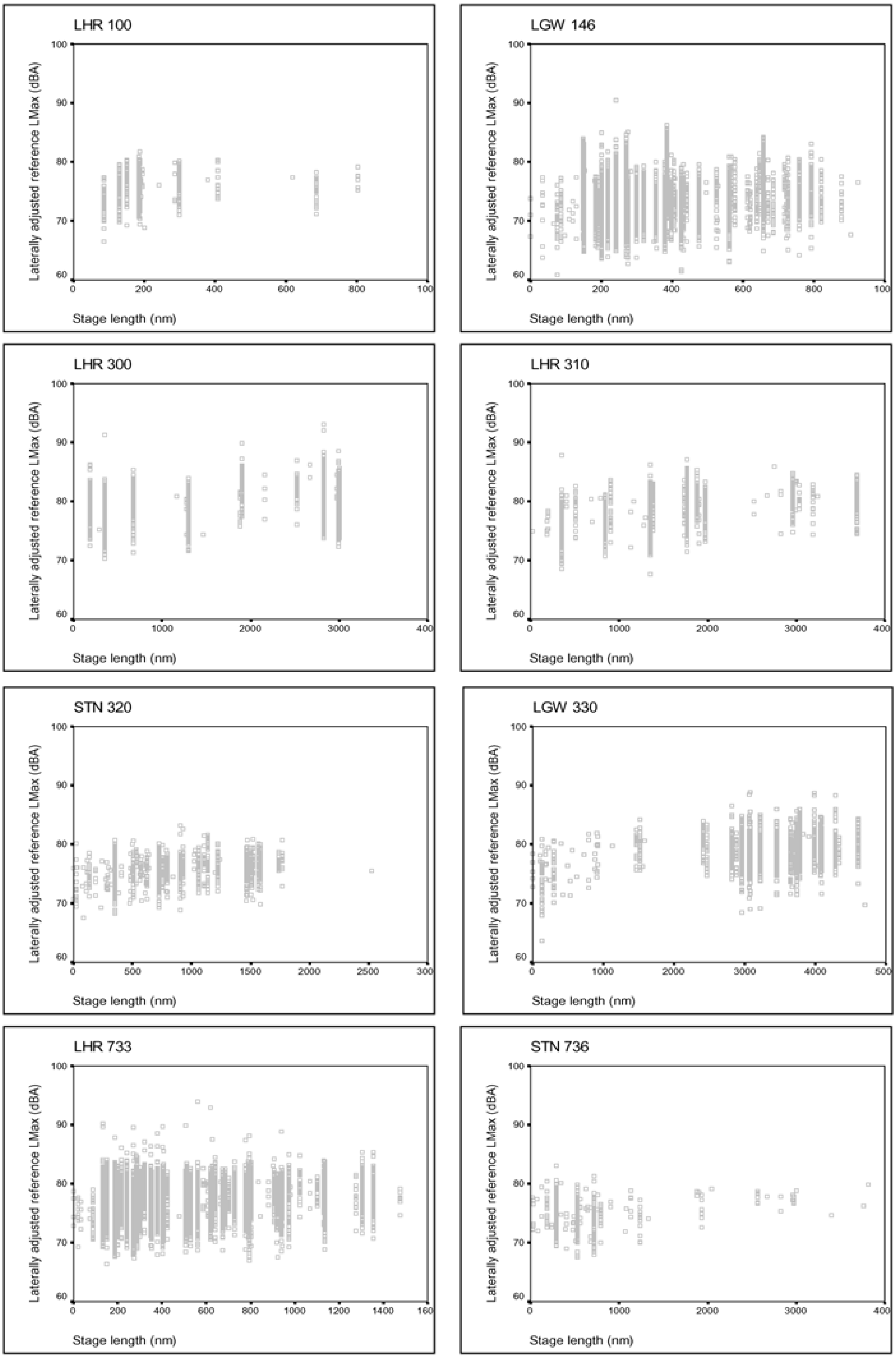
* Hourly averages of Headwind

## TABLE G6 Correlations between laterally adjusted Reference level and other variables for Stansted

| Aircraft Type | Correlation | Stage Length | Ground Speed | Height | Temperature | Headwind* | Pressure | Rel. Humidity |
|---|---|---|---|---|---|---|---|---|
| **100** | Coefficient | **0.05** | **0.02** | **-0.43** | **0.00** | **-0.18** | **-0.07** | **0.00** |
| | Significance | 0.02 | 0.34 | 0.00 | 0.97 | 0.00 | 0.00 | 0.99 |
| **146** | Coefficient | **0.19** | **0.24** | **-0.72** | **0.07** | **-0.13** | **-0.04** | **0.00** |
| | Significance | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.95 |
| **300** | Coefficient | **0.22** | **0.14** | **-0.66** | **0.05** | **-0.20** | **-0.05** | **0.00** |
| | Significance | 0.00 | 0.00 | 0.00 | 0.24 | 0.00 | 0.32 | 0.96 |
| **310** | Coefficient | **0.66** | **-0.11** | **-0.80** | **0.33** | **-0.05** | **0.05** | **-0.35** |
| | Significance | 0.00 | 0.01 | 0.00 | 0.00 | 0.21 | 0.24 | 0.00 |
| **319** | Coefficient | **0.18** | **0.47** | **-0.52** | **0.25** | **-0.21** | **0.04** | **0.08** |
| | Significance | 0.13 | 0.00 | 0.00 | 0.03 | 0.07 | 0.73 | 0.50 |
| **320** | Coefficient | **0.17** | **0.10** | **-0.46** | **0.01** | **-0.10** | **-0.05** | **-0.04** |
| | Significance | 0.00 | 0.00 | 0.00 | 0.78 | 0.00 | 0.02 | 0.11 |
| **321** | Coefficient | **0.54** | **0.06** | **-0.70** | **0.04** | **-0.19** | **0.02** | **0.01** |
| | Significance | 0.00 | 0.01 | 0.00 | 0.10 | 0.00 | 0.50 | 0.57 |
| **733** | Coefficient | **0.30** | **0.29** | **-0.63** | **0.06** | **-0.25** | **0.06** | **-0.09** |
| | Significance | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **736** | Coefficient | **0.05** | **0.21** | **-0.48** | **-0.02** | **-0.29** | **0.06** | **-0.07** |
| | Significance | 0.13 | 0.00 | 0.00 | 0.48 | 0.00 | 0.08 | 0.04 |
| **738** | Coefficient | **0.21** | **0.36** | **-0.63** | **0.12** | **-0.29** | **0.07** | **-0.10** |
| | Significance | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **744** | Coefficient | **0.66** | **-0.03** | **-0.89** | **-0.07** | **0.00** | **-0.10** | **0.17** |
| | Significance | 0.00 | 0.59 | 0.00 | 0.15 | 0.93 | 0.05 | 0.00 |
| **757** | Coefficient | **0.27** | **0.09** | **-0.68** | **0.03** | **-0.18** | **-0.03** | **-0.04** |
| | Significance | 0.00 | 0.01 | 0.00 | 0.41 | 0.00 | 0.35 | 0.24 |
| **763** | Coefficient | **0.31** | **0.34** | **-0.51** | **0.04** | **-0.17** | **0.04** | **0.04** |
| | Significance | 0.00 | 0.00 | 0.00 | 0.58 | 0.01 | 0.51 | 0.53 |
| **CRJ** | Coefficient | **0.06** | **0.27** | **-0.33** | **-0.02** | **-0.07** | **-0.07** | **0.09** |
| | Significance | 0.33 | 0.00 | 0.00 | 0.69 | 0.25 | 0.25 | 0.11 |
| **D10** | Coefficient | **0.71** | **0.07** | **-0.71** | **-0.03** | **-0.20** | **0.05** | **0.07** |
| | Significance | 0.00 | 0.26 | 0.00 | 0.60 | 0.00 | 0.38 | 0.29 |
| **ERJ** | Coefficient | **0.34** | **0.23** | **-0.60** | **-0.12** | **-0.07** | **-0.16** | **0.29** |
| | Significance | 0.00 | 0.00 | 0.00 | 0.02 | 0.16 | 0.00 | 0.00 |
| **EXE2** | Coefficient | **0.15** | **0.19** | **-0.36** | **0.04** | **-0.16** | **0.02** | **-0.19** |
| | Significance | 0.04 | 0.01 | 0.00 | 0.60 | 0.03 | 0.74 | 0.01 |
| **EXE3** | Coefficient | **0.08** | **0.04** | **-0.38** | **0.00** | **0.00** | **-0.11** | **0.05** |
| | Significance | 0.02 | 0.22 | 0.00 | 0.95 | 0.90 | 0.00 | 0.13 |
| **M11** | Coefficient | **0.78** | **-0.36** | **-0.77** | **-0.14** | **-0.17** | **-0.07** | **0.18** |
| | Significance | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.03 | 0.00 |
| **M80** | Coefficient | **0.11** | **-0.12** | **-0.44** | **-0.02** | **-0.12** | **-0.13** | **-0.06** |
| | Significance | 0.02 | 0.01 | 0.00 | 0.69 | 0.01 | 0.00 | 0.18 |
| **Props 1** | Coefficient | **0.08** | **0.16** | **-0.32** | **-0.10** | **-0.10** | **-0.12** | **0.07** |
| | Significance | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **Props 2** | Coefficient | **0.09** | **0.07** | **-0.23** | **-0.27** | **-0.11** | **-0.08** | **0.07** |
| | Significance | 0.03 | 0.11 | 0.00 | 0.00 | 0.01 | 0.06 | 0.11 |
| **Props 3** | Coefficient | **0.24** | **0.36** | **-0.67** | **-0.05** | **-0.20** | **-0.04** | **-0.22** |
| | Significance | 0.00 | 0.00 | 0.00 | 0.49 | 0.00 | 0.50 | 0.00 |

* Hourly averages of Headwind

**FIGURE G1. Laterally Adjusted Reference Level vs Stage Length**



## FIGURE G1 (continued). Laterally Adjusted Reference Level vs Stage Length

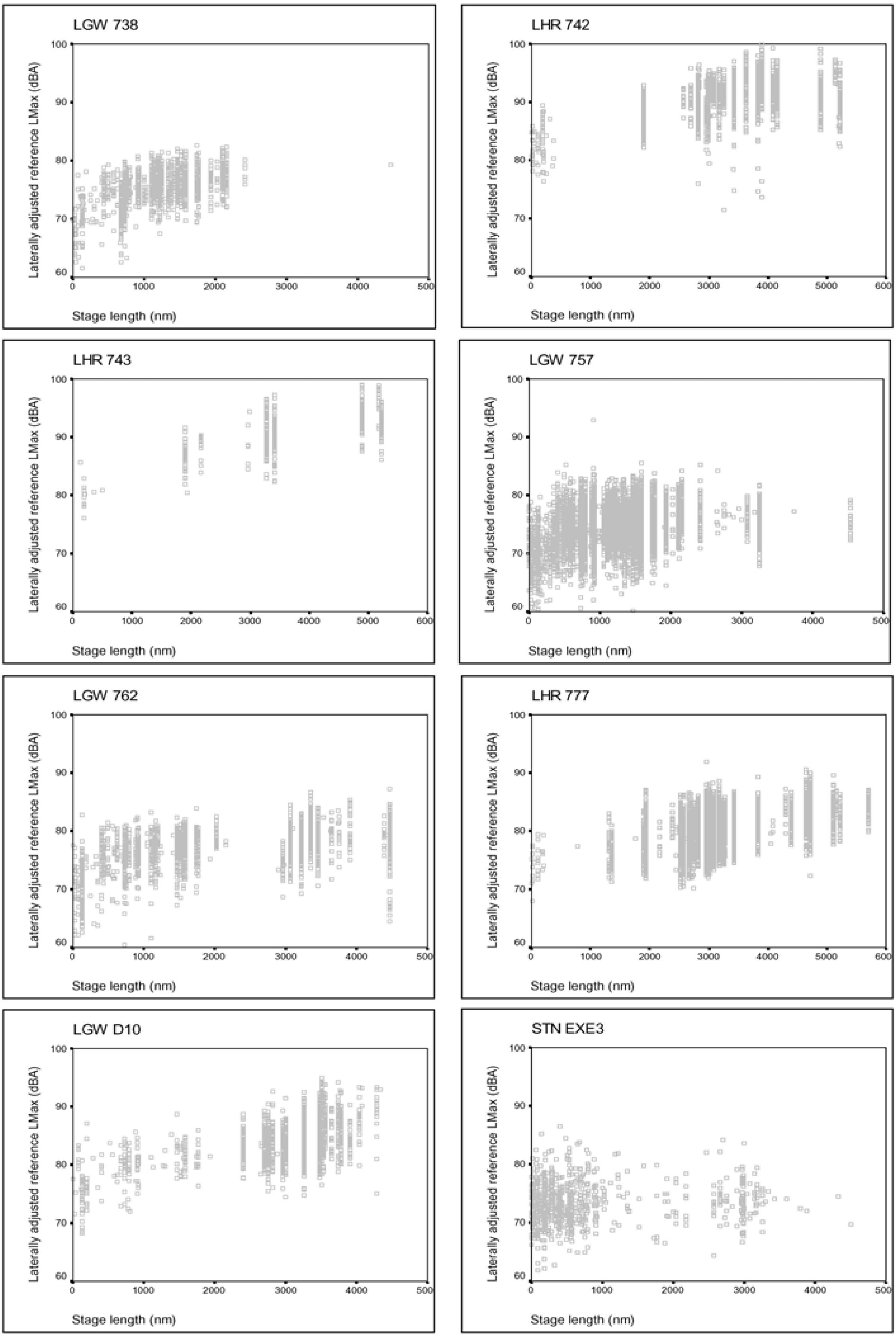
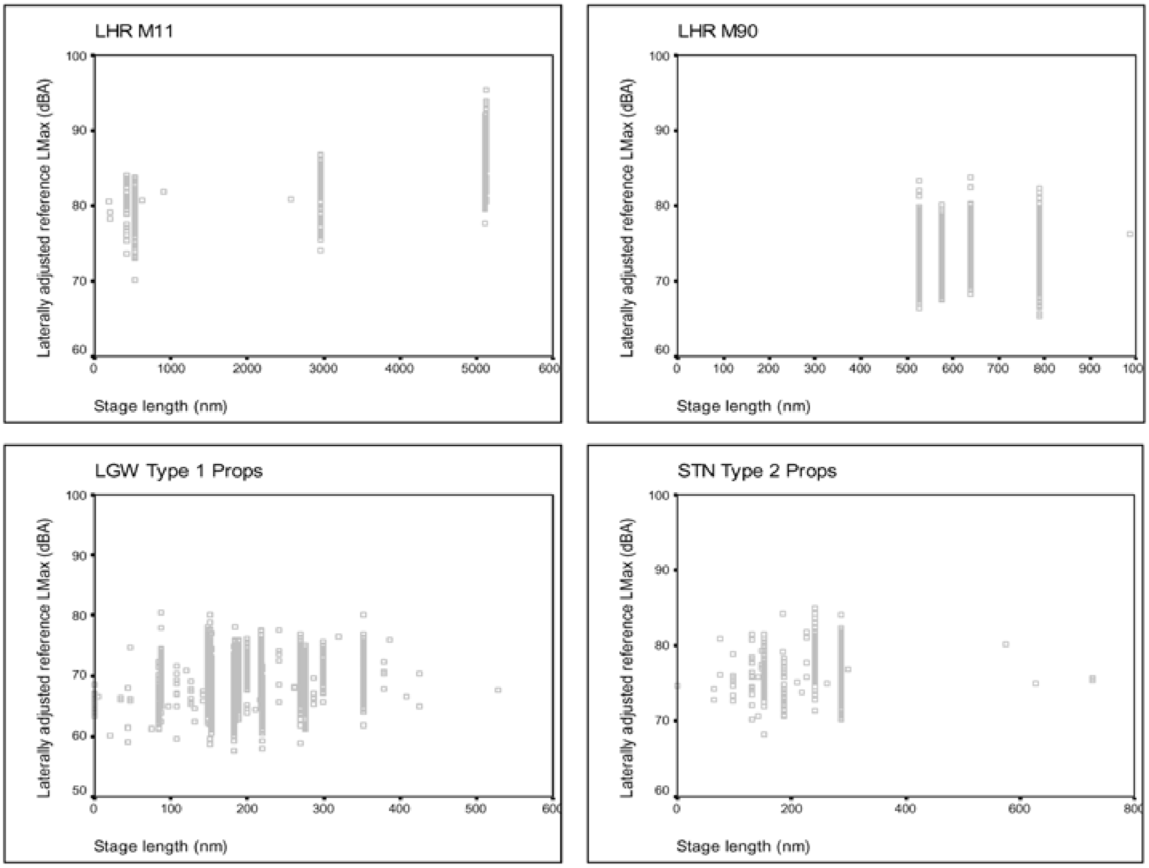
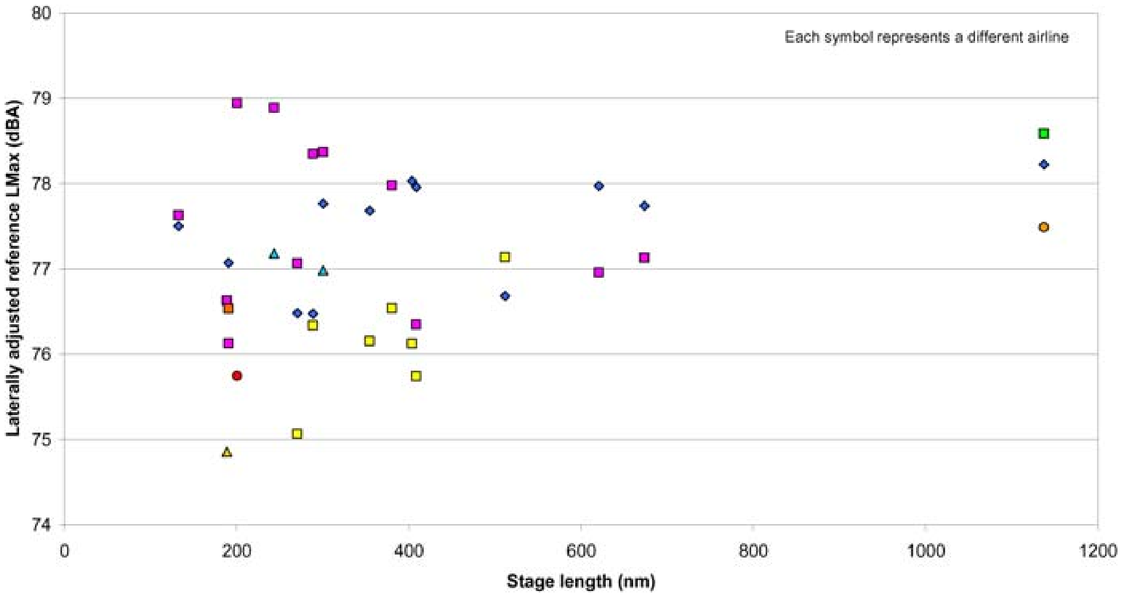


**FIGURE G1 (continued). Laterally Adjusted Reference Level vs Stage Length**



## FIGURE G2(a) Comparison of mean laterally adjusted Reference level between airlines for Heathrow 733s



## FIGURE G2(b) Comparison of mean laterally adjusted Reference level between airlines for Heathrow 763s

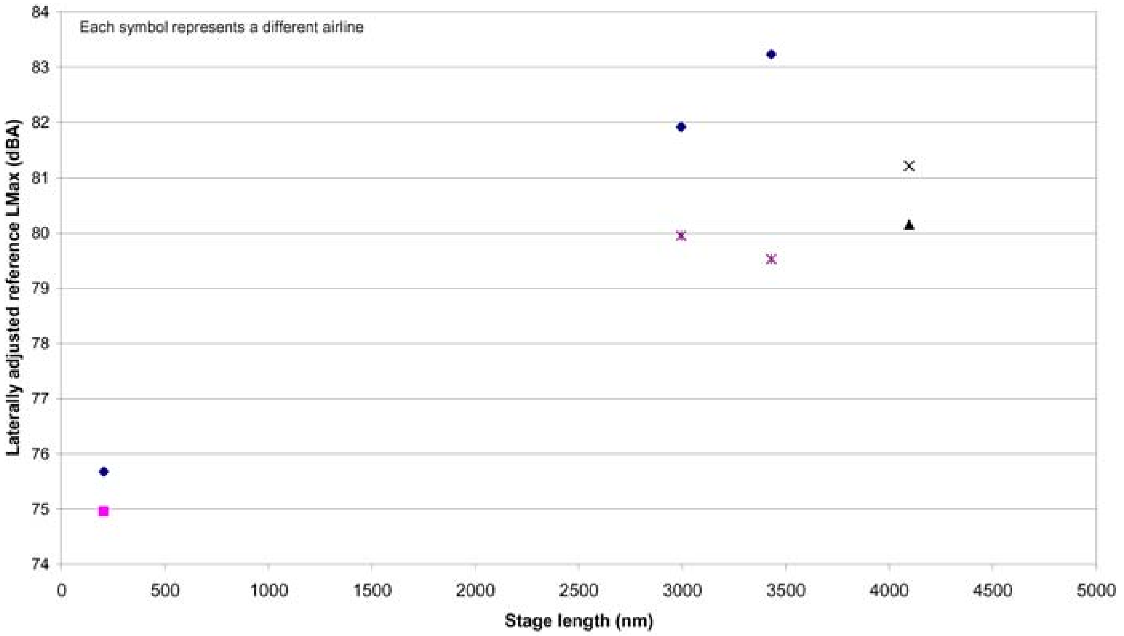


**FIGURE G3. Effect of Temperature on Laterally Adjusted Reference Level**

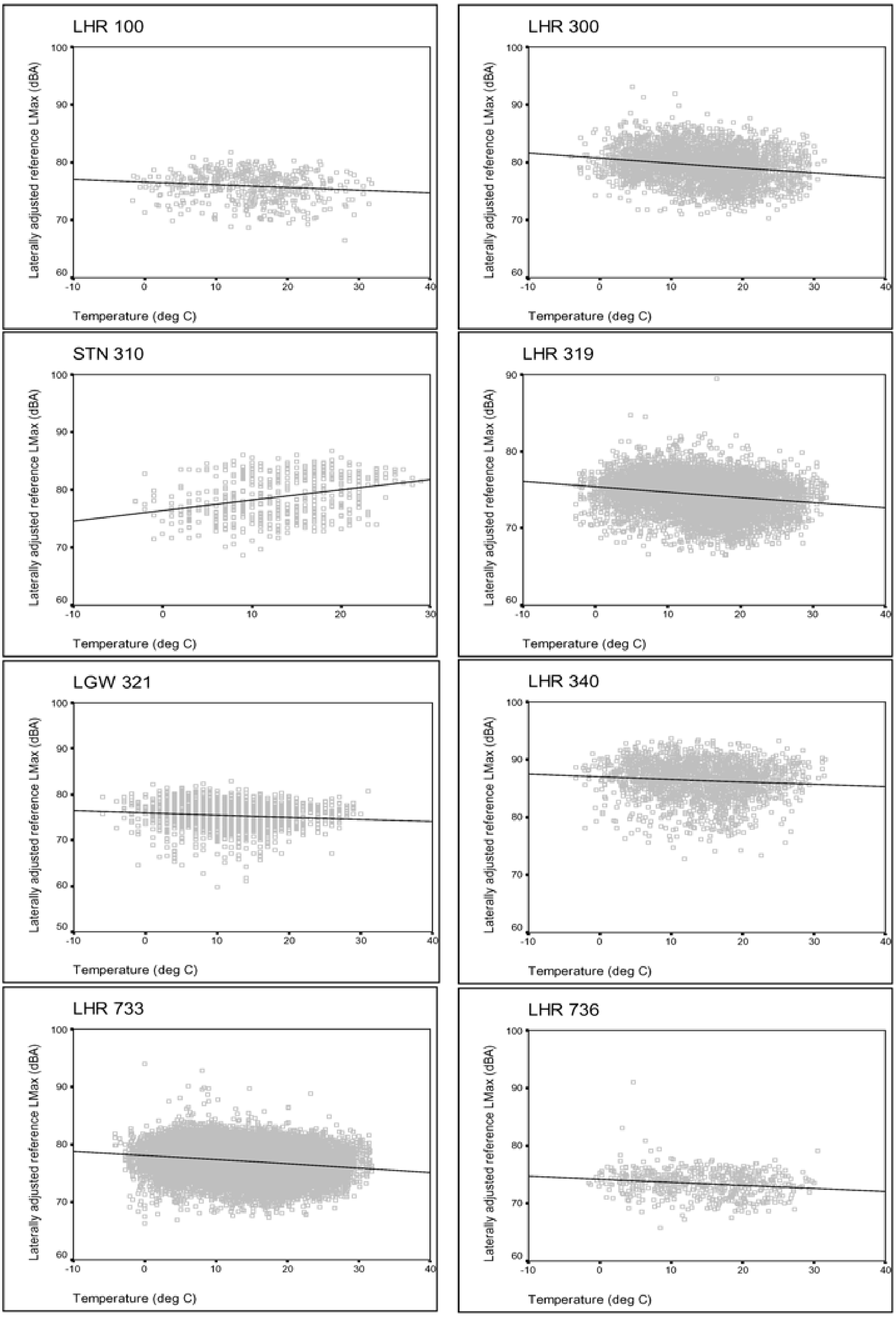
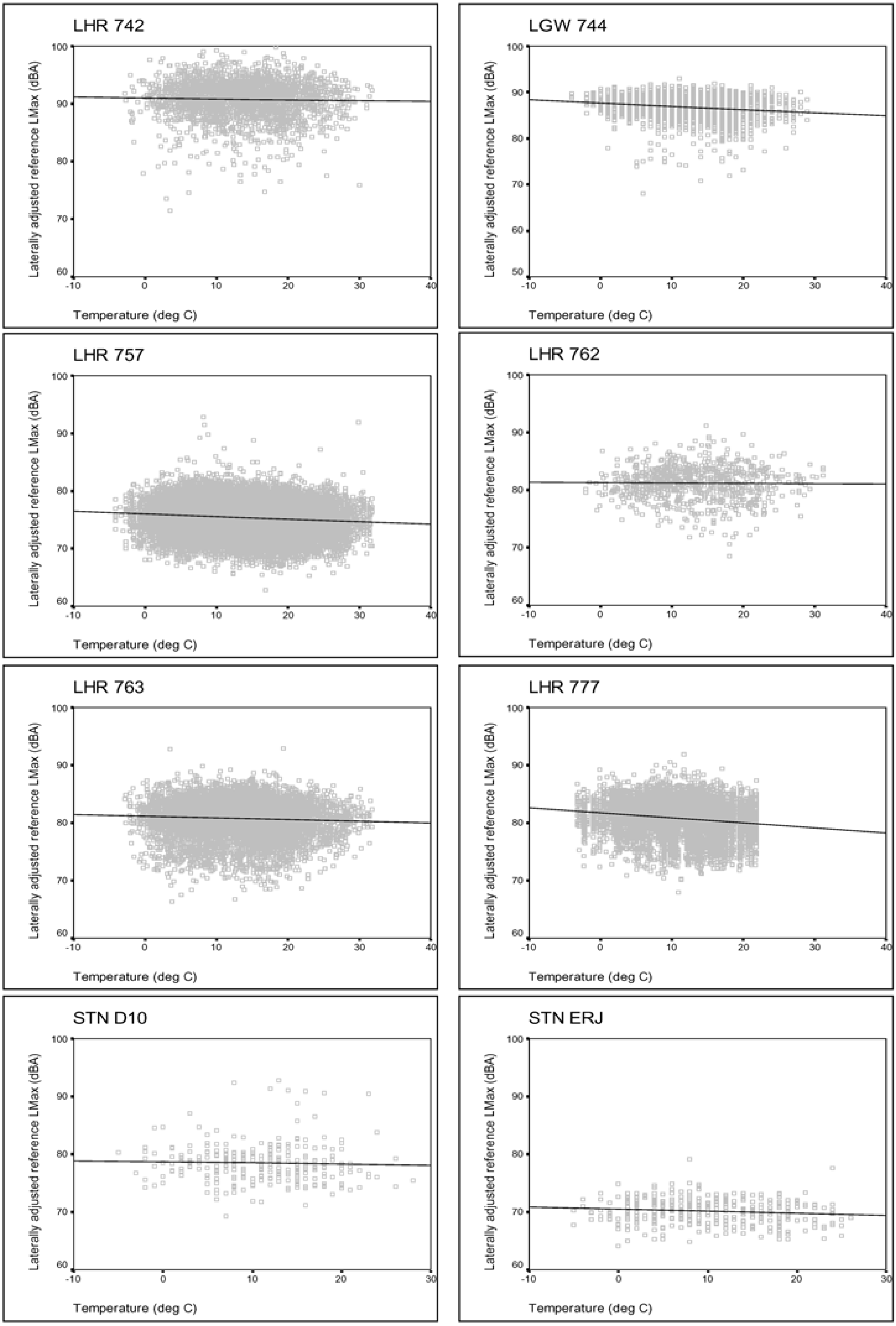
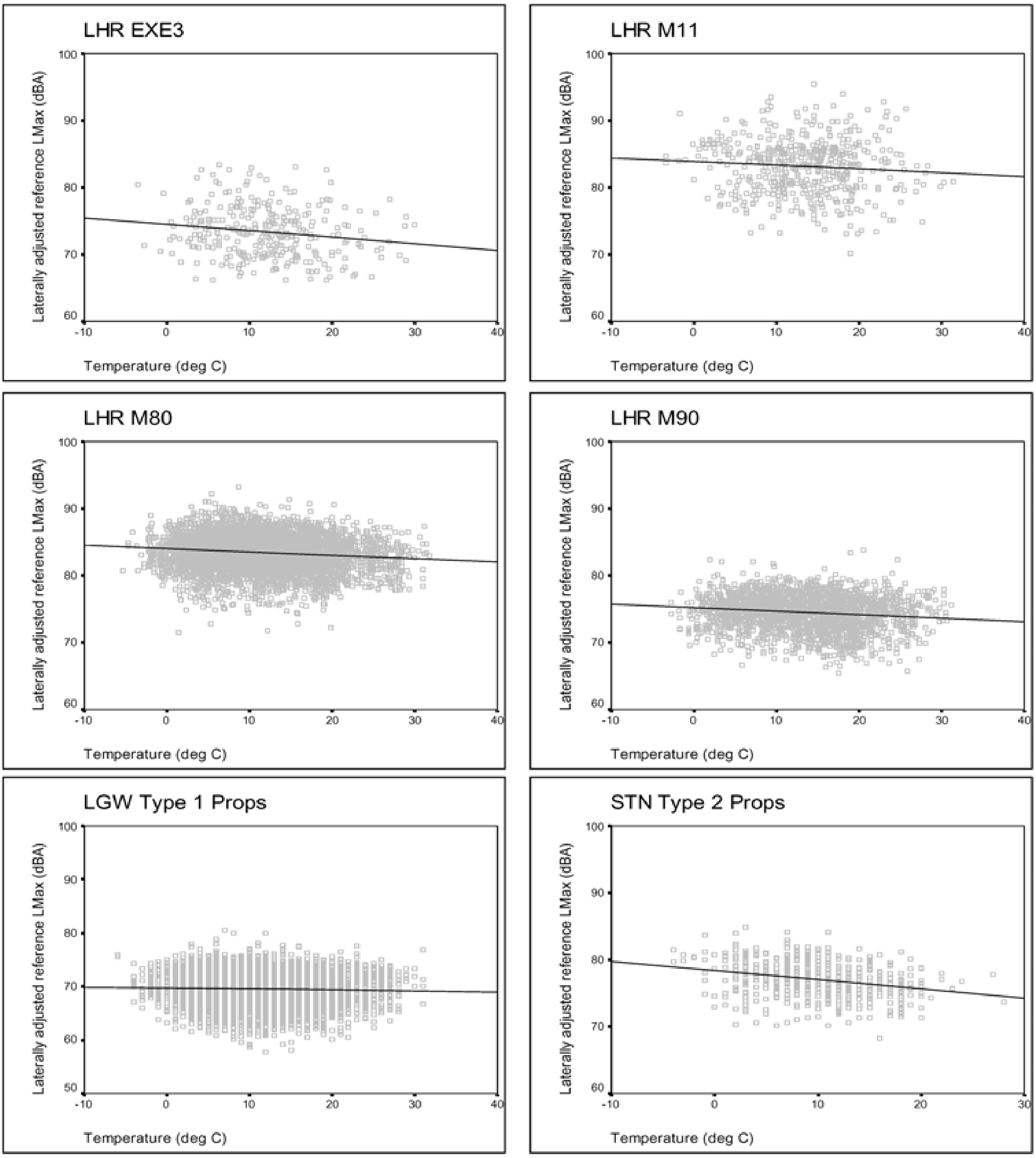


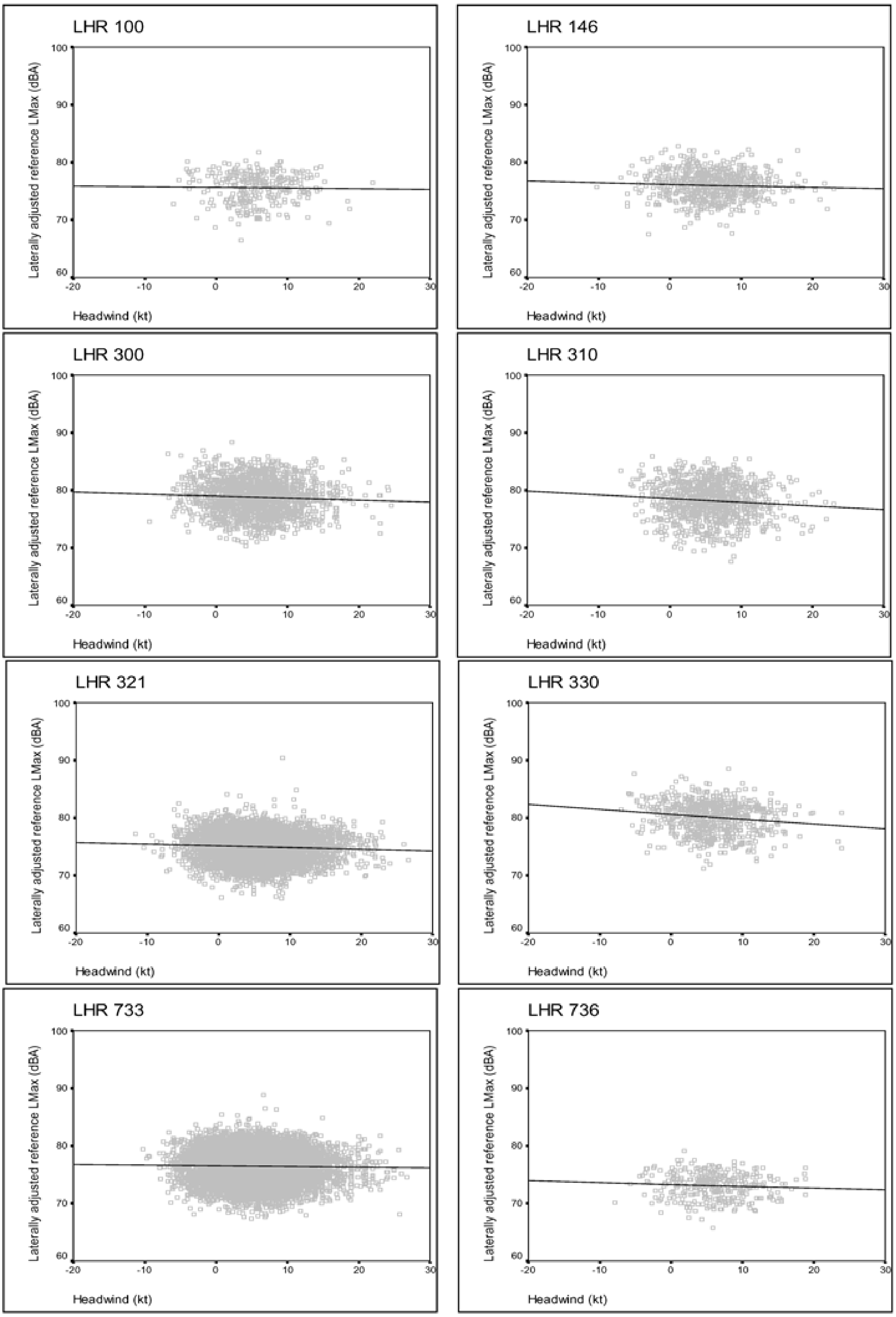
**FIGURE G3 (continued). Effect of Temperature on Laterally Adjusted Reference Level**



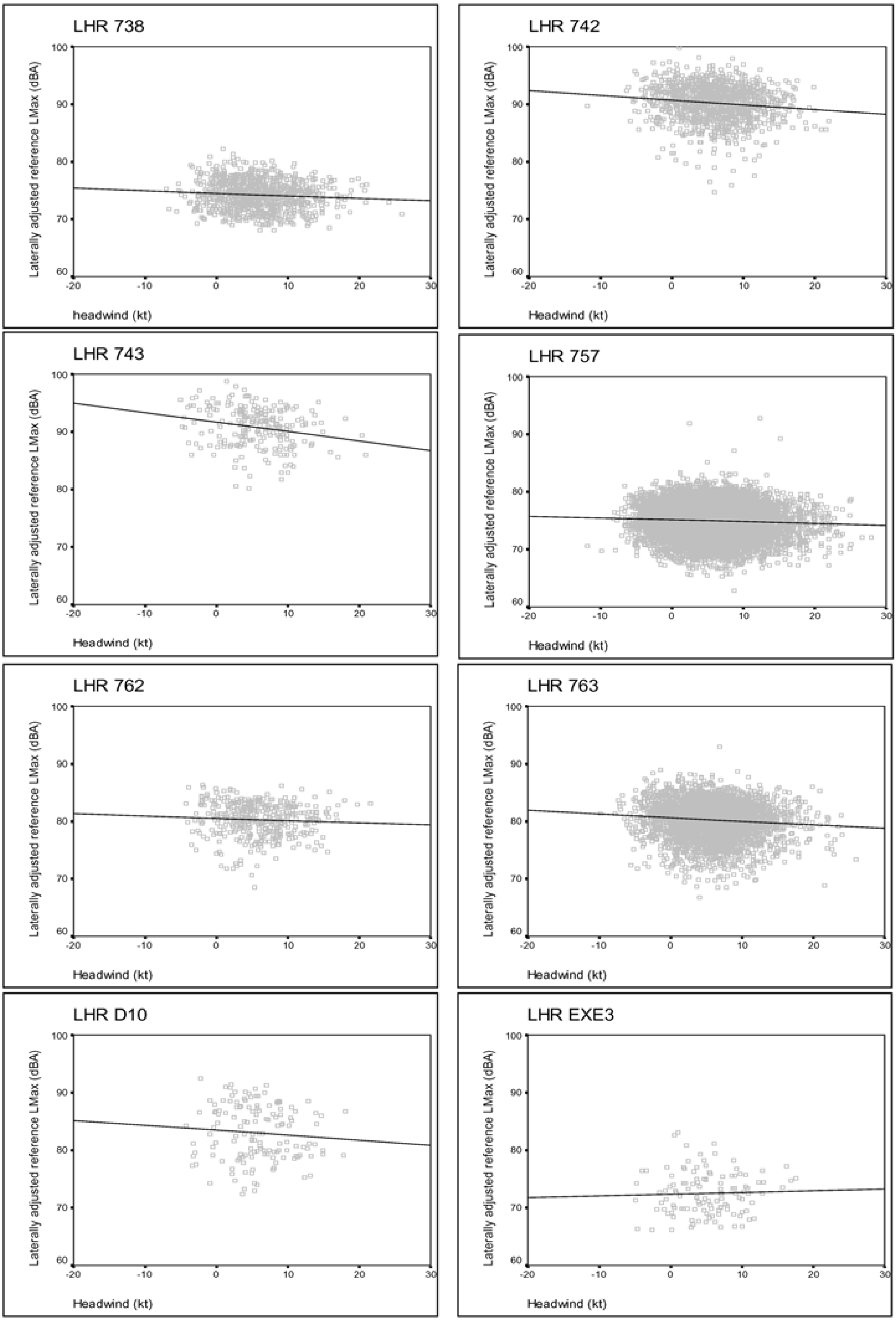
## FIGURE G3 (continued). Effect of Temperature on Laterally Adjusted Reference Level



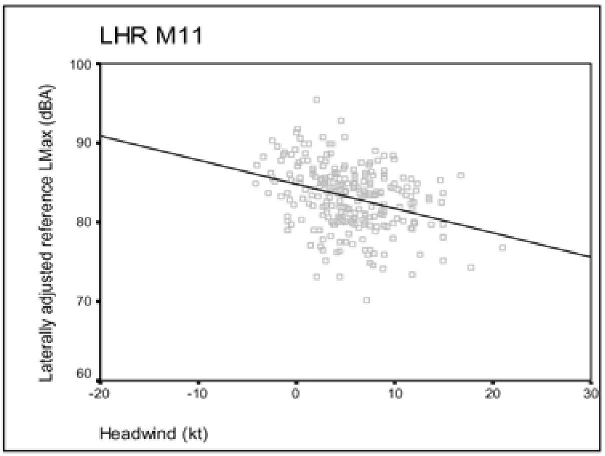
## FIGURE G4. Effect of Headwind on Laterally Adjusted Reference Level

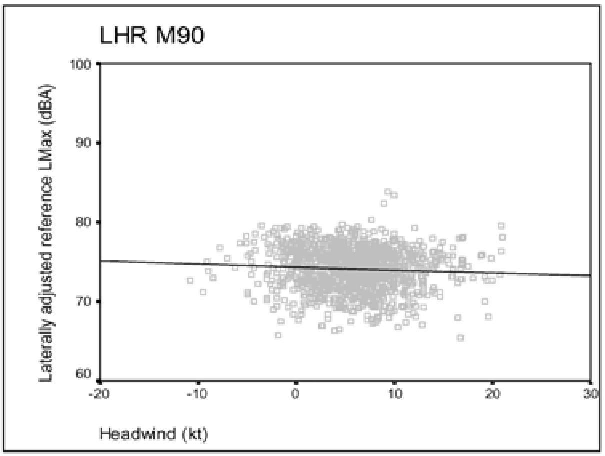


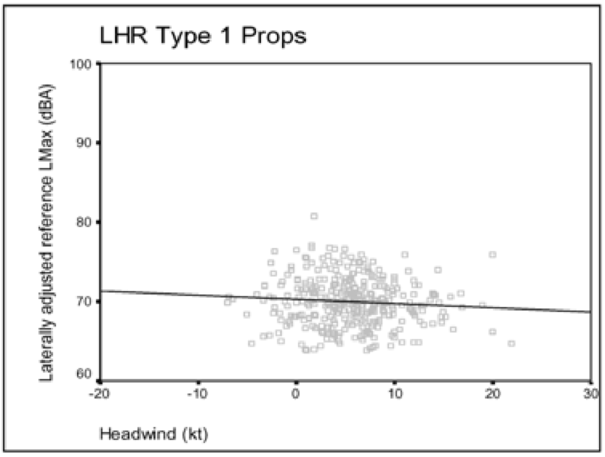
## FIGURE G4 (continued). Effect of Headwind on Laterally Adjusted Reference Level



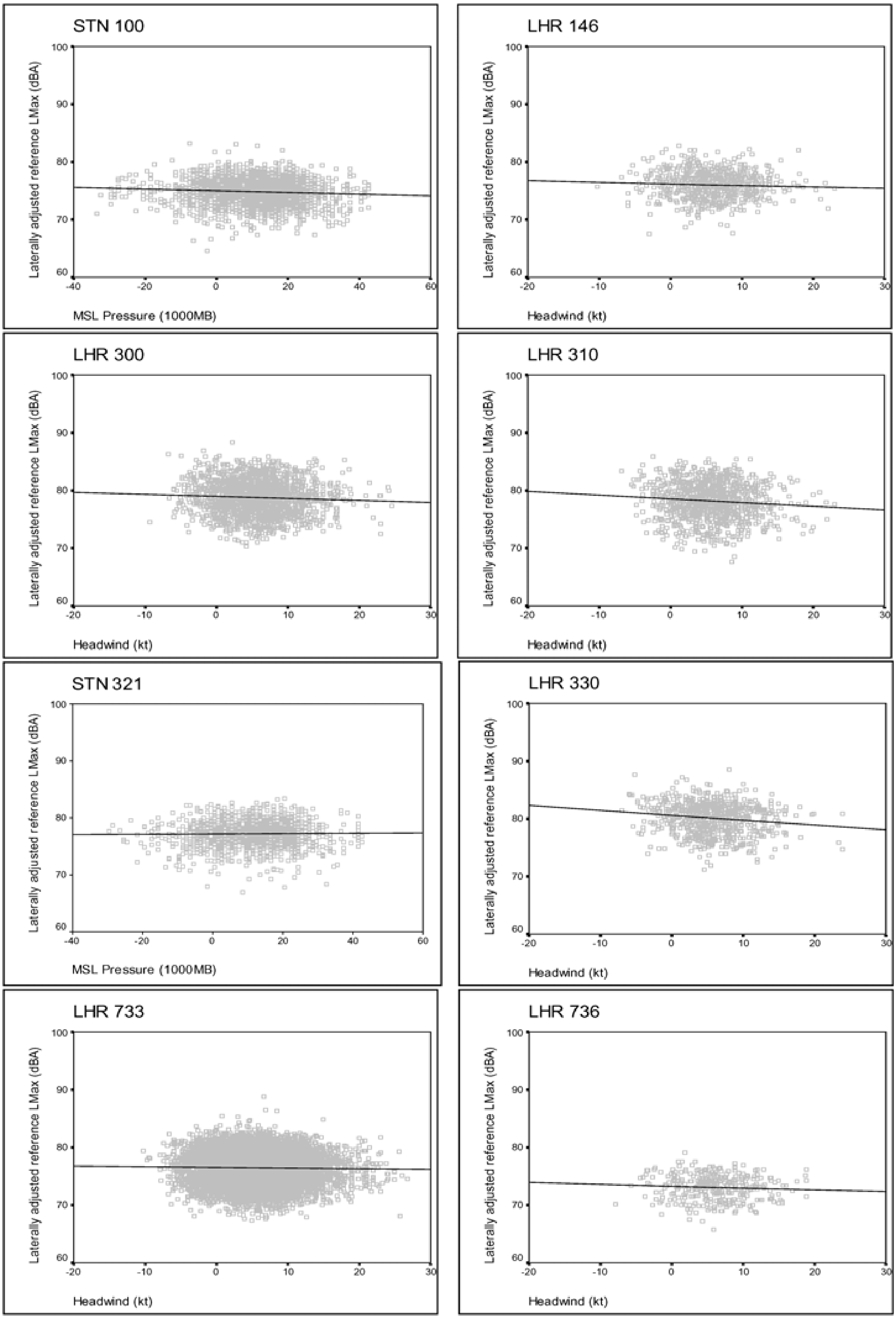
## FIGURE G4 (continued). Effect of Headwind on Laterally Adjusted Reference Level



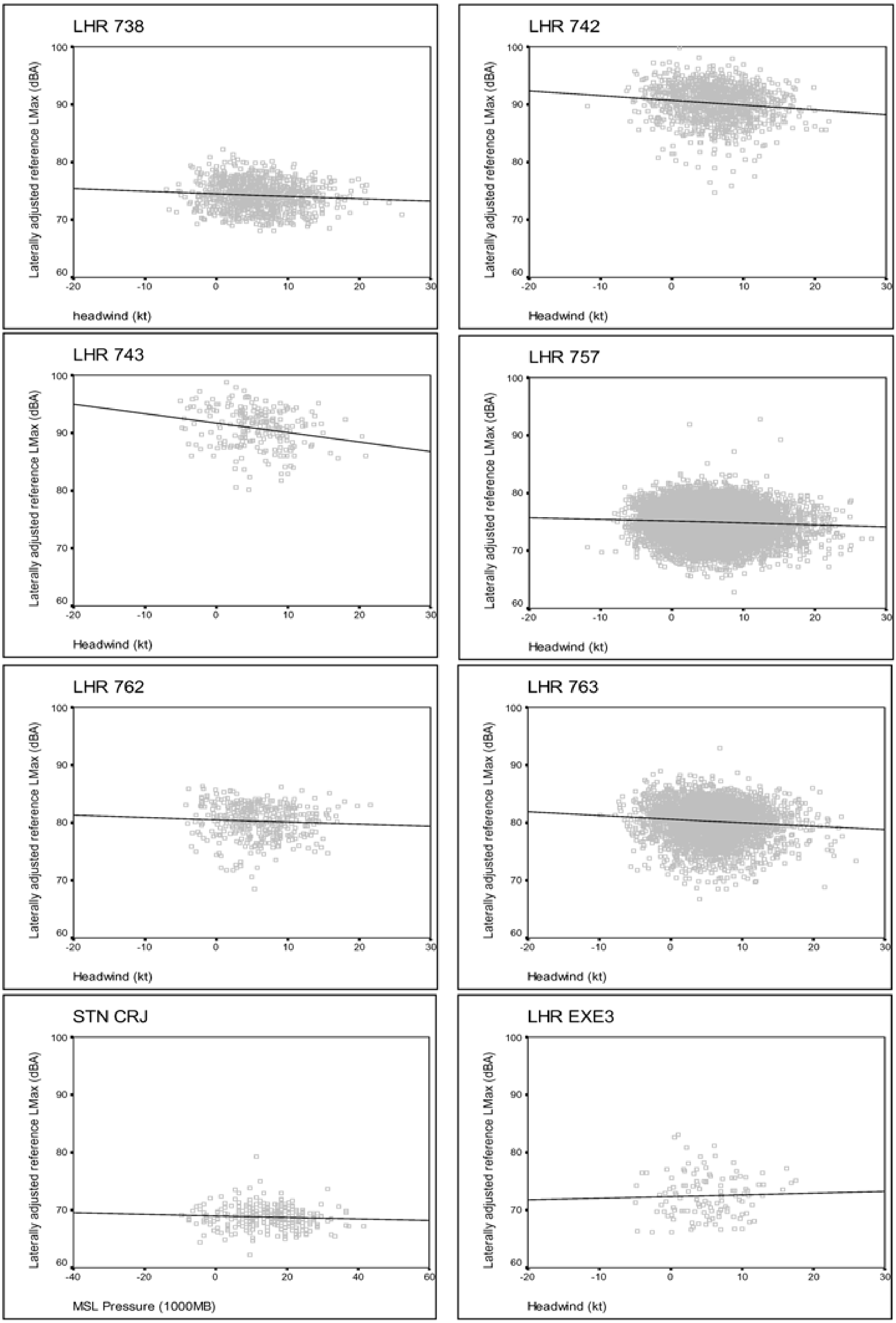




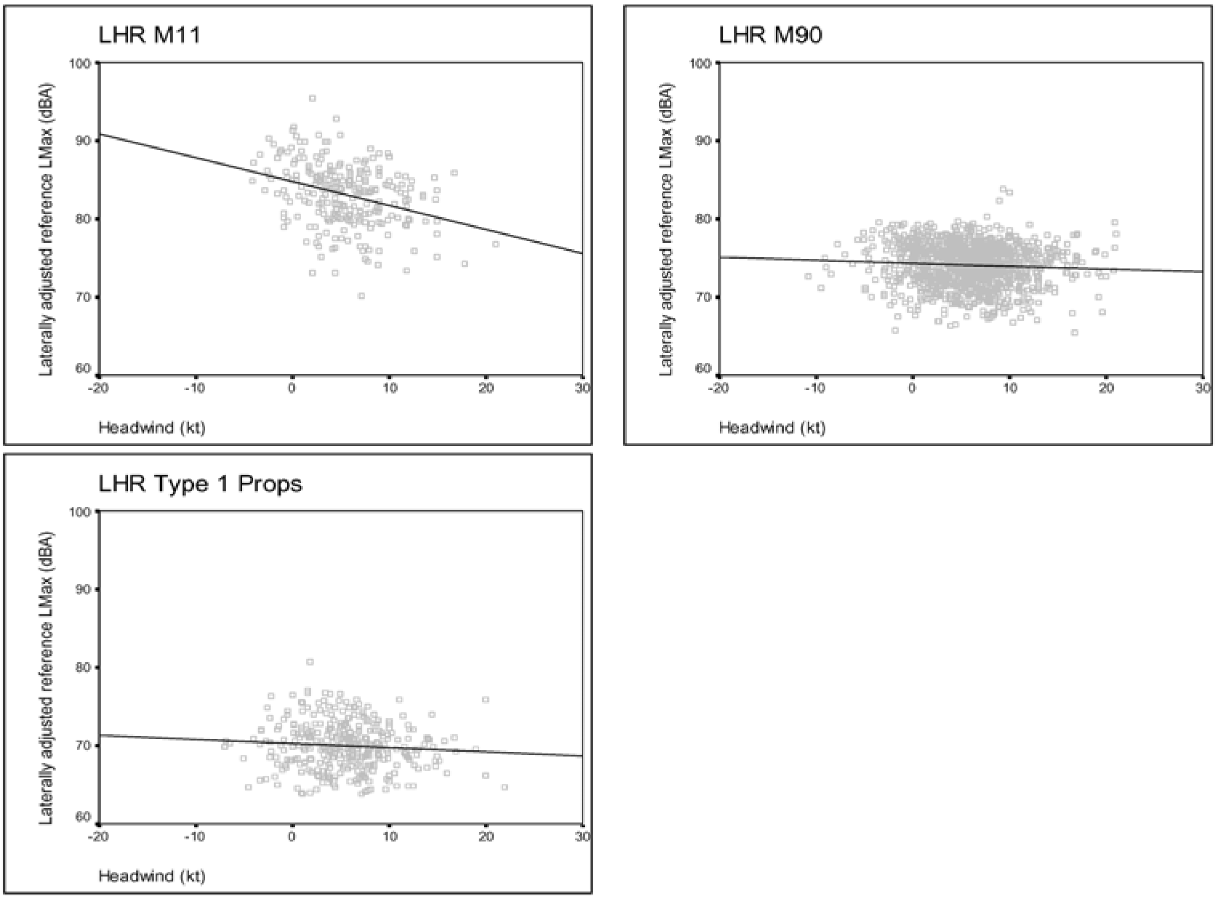
# FIGURE G5. Effect of Pressure on Laterally Adjusted Reference Level



## FIGURE G5 (continued). Effect of Pressure on Laterally Adjusted Reference Level



## FIGURE G5 (continued). Effect of Pressure on Laterally Adjusted Reference Level



## FIGURE G6. Effect of Relative Humidity on Laterally Adjusted Reference Level

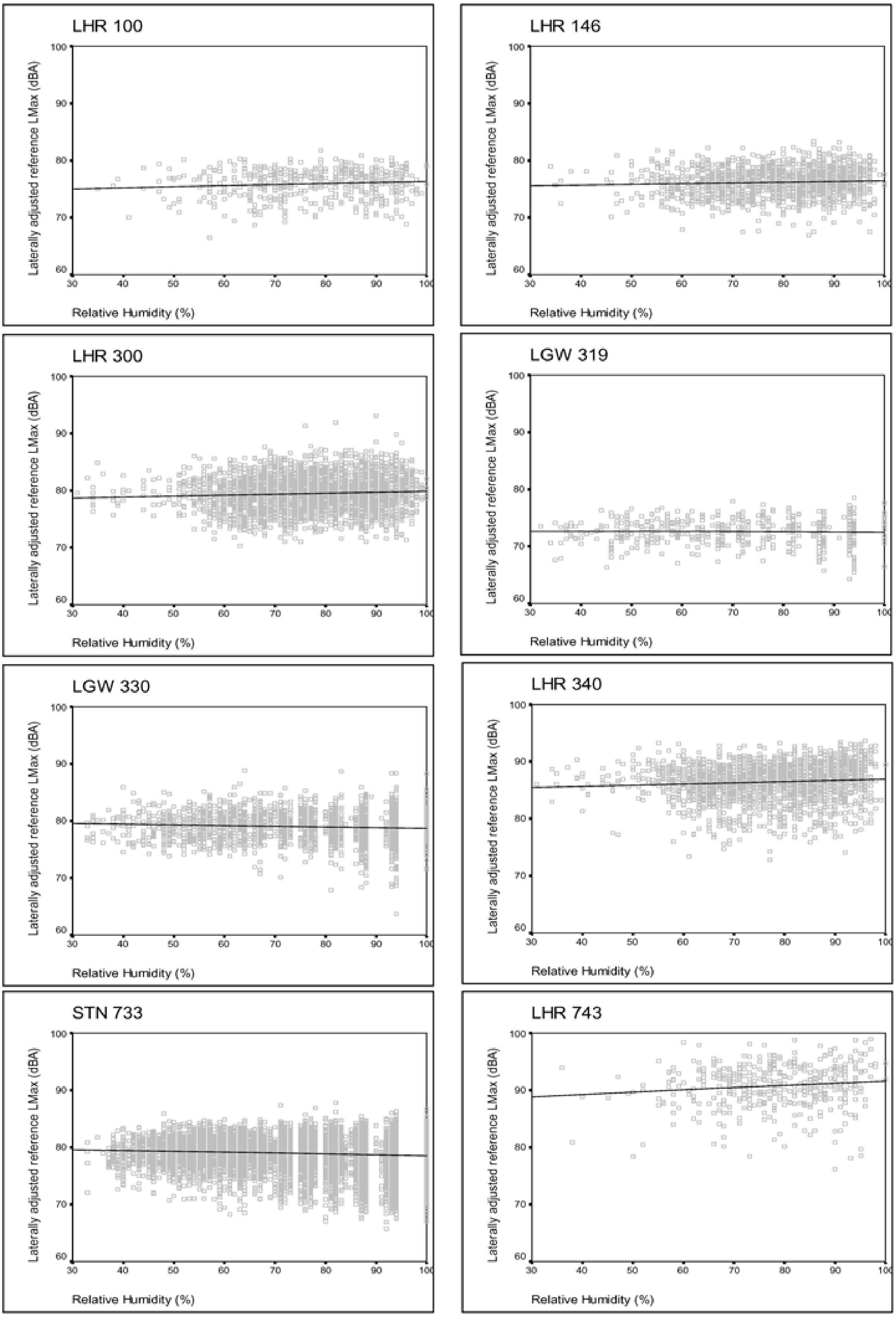
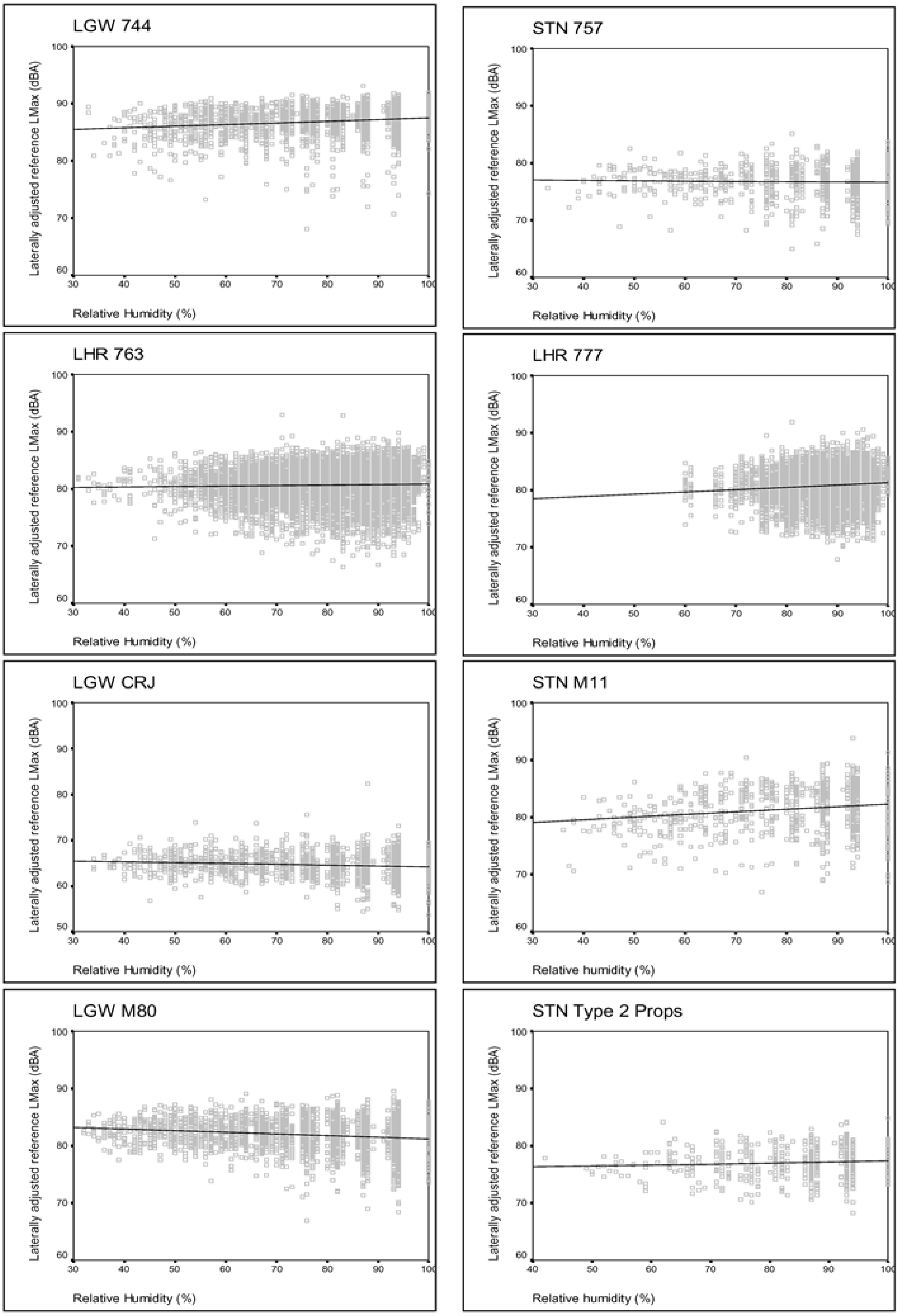


**FIGURE G6 (continued). Effect of Relative Humidity on Laterally Adjusted Reference Level**



LGW 744

STN 757

LHR 763

LHR 777

LGW CRJ

STN M11

LGW M80

STN Type 2 Props

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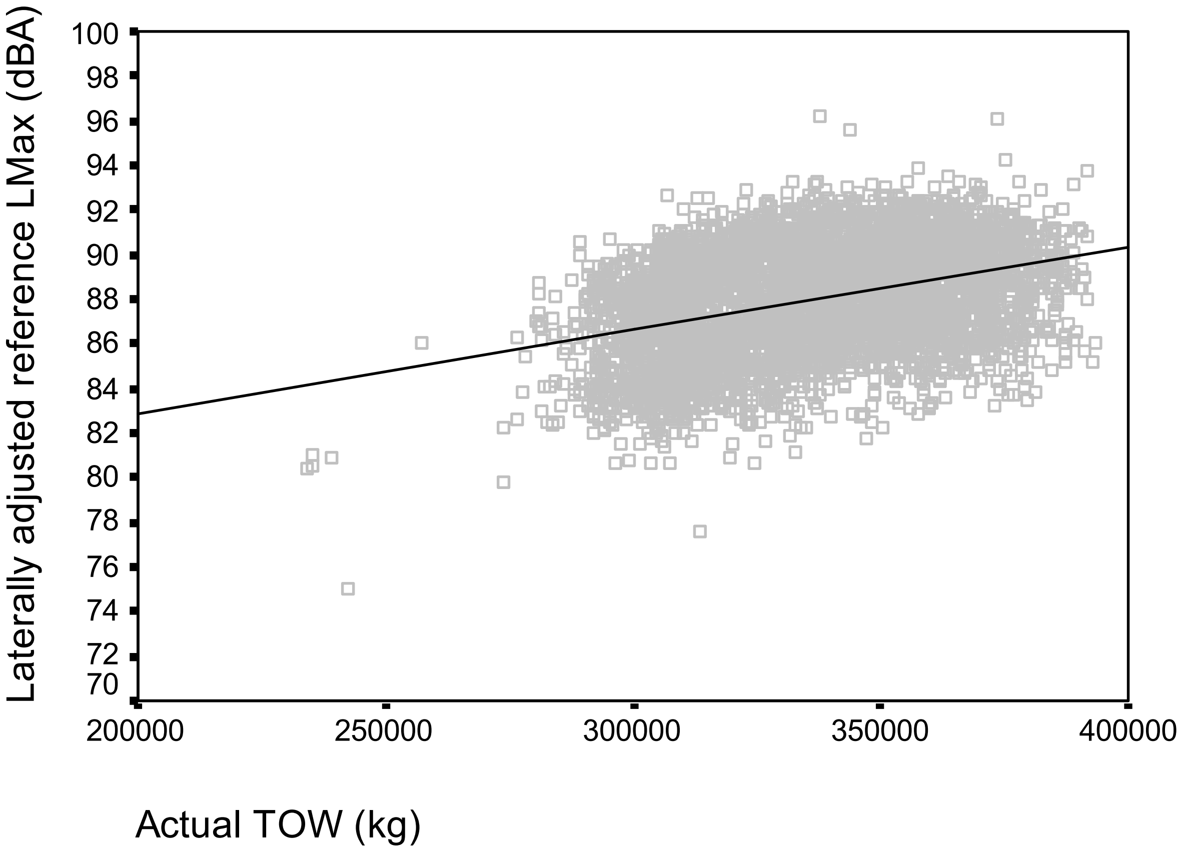
## APPENDIX H ANALYSIS OF TAKE-OFF WEIGHT DATA

H1 This Appendix gives the results of preliminary analysis of TOW data provided for this study by one operator of 744s at Heathrow. The data supplied covers the period January to June 2002. Each flight was matched against the corresponding event in NTK and Figure H1 plots the highest $L_{RU}$ for each flight against TOW. A best fit straight line has been drawn through the data, although the true relationship (especially at lighter weights) is unlikely to be linear. The line has a slope of 3.8dBA per 100,000kg, which agrees well with the slope of 3.7dBA per 100,000kg from the measured data summarised in paragraph 4.25 of Ref 2.

**FIGURE H1 Effect of TOW on laterally adjusted Reference level: Heathrow 744**



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## APPENDIX I SUGGESTED OUTLINE FOR A TRIAL OF DIFFERENTIAL LIMITS

I1 This Appendix provides some initial suggestions for a trial that could be conducted either at ERCD or at one of the airports' Flight Evaluation Units. The details are subject to discussion between DfT, BAA and ERCD and to consideration by ANMAC. The main points to consider are listed below:

1. *Trial airport*: Gatwick would be the preferred location, as the airport handles a wide variety of aircraft types and has monitors positioned such that nearly all departures fly through a monitor V. The analysis could either be undertaken by the Gatwick Flight Evaluation Unit (which would result in a better appreciation of any difficulties that might arise at an airport site, and of the resources required), or by ERCD using their NTK system which is linked to Gatwick's (and to the other London airports).

2. *Trial duration*: A 2 month period would provide reasonably large but manageable sample sizes for a range of aircraft types. A longer trial period might have an adverse impact on the timescale for implementing changes to the monitoring regime as a result of this review; a shorter period may not give sufficiently representative results.

3. *Aircraft types*: For the initial trial, only aircraft that are QC/1 and above for departure will be considered.

4. *Additional data sources required*: For each individual aircraft (defined by its registration), the departure QC rating and also the certificated flyover noise level are required. For aircraft that currently operate at night, BAA already have this information; for other aircraft ERCD are generally able to provide it (for many aircraft it has already been determined as part of the QC monitoring study, Ref 9). This information will be needed in a suitable database that can be linked to the NTK databases.

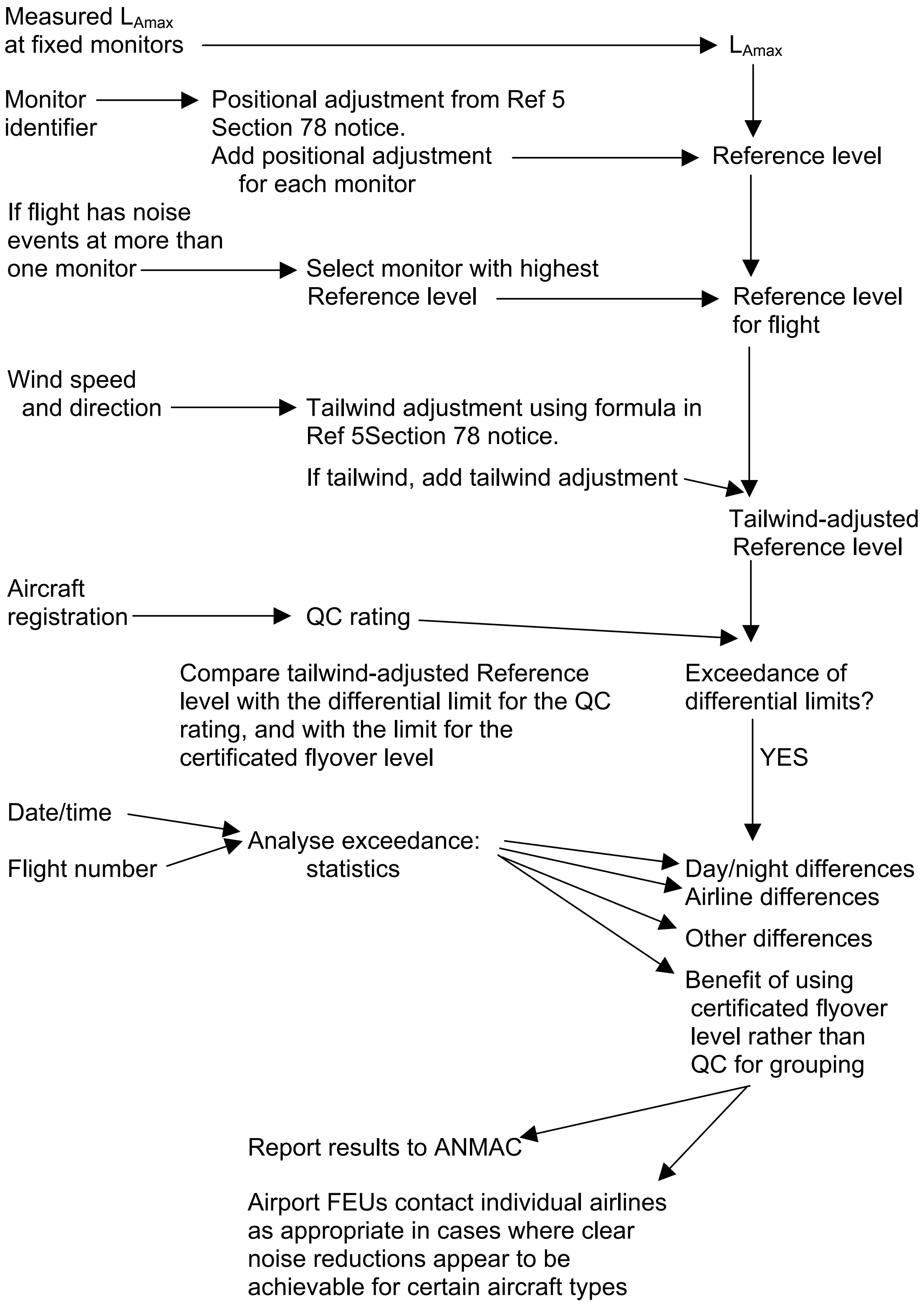
5. *Application of adjustments to measured levels at fixed monitors*: It is proposed that, as with the overall limits, measured levels are effectively adjusted to Reference levels (6.5km distance, airfield elevation) in the same way. Thus the positional adjustments and the allowances for tailwind need to be applied to each measured noise level. The NTK software at present is not designed to show Reference level, so it is suggested that for this trial the analysis is handled using standard PC software.

6. *Mobile monitors*: In addition to the fixed monitors at a nominal 6.5km distance, mobile monitors would be deployed so that any changes in noise levels closer-in or further-out could be determined.

7. *Analysis of data*: It is relatively straightforward to create a file from NTK containing aircraft registration, date/time, flight number, runway, monitor identifier, $L_{Amax}$ noise level and wind conditions for each noise event at each fixed monitor. Only the data at the monitor giving the highest Reference level for each flight requires further analysis, as shown in the flow chart in Figure I1. Figure I2 shows a template for spreadsheet analysis of the results. The results can be used to determine any day/night, airline or other differences. They should also illustrate whether it would be more beneficial to use the certificated flyover noise level rather than the QC rating for grouping aircraft for differential limits.

8. *Use of results from trial*: The trial would indicate whether the suggested QC-based limits are set at a level that would give an unmanageable number of infringements (or alternatively if they are set at so low a level as to produce only a very small number of infringements). It is proposed that in the first instance the results would be reported to ANMAC, who would assess them and subsequently advise whether they consider that formal differential noise monitoring should or should not be instigated. However, irrespective of ANMAC's considerations, the airport Flight Evaluation Units could contact individual airlines as appropriate in cases where clear noise reductions appear to be achievable for certain aircraft types (for example where one airline is producing consistently higher noise levels than another operating the same type over a similar route). Those airlines should be asked to amend their take-off procedures if possible (at least for the duration of the trial) to enable "before and after" noise measurements to be made to determine any benefits in terms of noise reductions.

## FIGURE I1 TRIAL OF DIFFERENTIAL LIMITS: DATA PROCESSING FLOW CHART FOR RESULTS FROM FIXED MONITORS



## FIGURE I2 TRIAL OF DIFFERENTIAL LIMITS: SPREADSHEET TEMPLATE

| Field | Date | Time | Flight no. | Aircraft Regis-tration | QC rating (Exempt =0) | Certificated flyover noise level EPNdB | Noise monitor | $L_{Amax}$ dBA | Wind direction at time of $L_{Amax}$ (deg) | Wind speed at time of $L_{Amax}$ (kt) | Runway | Runway heading (deg) | Positional adjust-ment (dBA) | Tailwind compo-nent (kt) | Tailwind adjust-ment dBA | Tailwind-adjusted Reference level dBA | Day/ Night/ Shoulder period | Differential limit for QC rating dBA (max 94 dBA) | Infringement of differential limit? |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Source | NTK | NTK | NTK | NTK | ERCD database | ERCD database | NTK | NTK | NTK | NTK | NTK | ERCD | (from Ref 5 Section 78 notice) | | Ref 8 | | Day 0700-2300, Shoulder 2300-2330 & 0600-0700, Night 2330-0600 | | |
| Expression | | | | | QC | | NMT | L | $W_D$ | $W_S$ | | $R_U$ | A | $W_T=W_S \cos(R_U-W_D)$ | T | R=L+A-T | | D=79+10*(0.6+log(QC)) | R>D ? |