Anderson Acoustics

HELIOS

Community Noise Information Report NPL, Teddington

11th August 2015 – 21st March 2016

August 2017

Introduction

This report presents an analysis of operational and noise data for the community around Teddington. At the request of local residents, Heathrow Airport Ltd installed a temporary noise monitor in the grounds of the National Physical Laboratory (NPL), Teddington between 11th August 2015 and 21st March 2016.

The report is structured using a template developed by Anderson Acoustics and Helios working with members of the Heathrow Community Noise Forum (HCNF) Working Group for Monitoring & Verification. It is set out as:

- **Section 2 – Key Findings** are presented.
- **Section 3 – Background & Methodology** provides an overview of how the airport operates, noise and how the data (both operations and noise) has been analysed.
- **Section 4 – Flight track data** presents analysis of the flight tracks and operations around the Teddington area including routes, proximity, spatial distribution, height and aircraft types. As flight track data has been collected for many years in the airport's noise and track-keeping (NTK) system, analysis has compared the noise monitoring period with an equivalent period in 2011/12.
- **Section 5 – Noise Monitor Data** presents an analysis of aircraft noise event and overall community noise levels as measured at the noise monitor. Noise data is analysed only for the monitoring period. Comparison with a historic period is not possible as monitoring has not taken place at the same location previously.
- **Section 6 – Noise Modelling** presents noise levels derived from the verified Heathrow Airport noise model. Average noise levels and noise event statistics have been generated across the wider geographic area for an average day of operations that affect this community (in this case easterly operations) across the summer of 2011 and 2015 to provide a broader understanding of whether there are any differences in noise exposure between the two years. The baseline year of 2011 was agreed as no trials took place in this period and is prior to changes perceived by some members of the community.
- **Section 7 – Appendices** presents large scale versions of all of noise modelling results and provides greater detail on noise terminology around how sound is described, how aircraft noise is measured and how differences of sound level relate to human perception.

It should be noted that this report is intended to describe noise exposure rather than the impact of that exposure - we cannot judge how each individual will respond. The report describes exposure and differences therein (as applicable) of aircraft using a variety of both operations and noise related metrics.

Whilst this report is a comprehensive analysis, it is not intended to be exhaustive. Should there be any questions or comments arsing from the data presented herein, these should be addressed to the HCNF for additional analysis.

Note: Wherever this report refers to "*2015/16*", it should be noted that this is specifically the measurement period from 11th August 2015 to 21st March 2016. Similarly, "*2011/12*" specifically refers to the period from 11th August 2011 to 21st March 2012.

Key Findings

Operations and the community

NPL is overflown by easterly departures only, in particular by aircraft using the GAS and MID routes. During the night, there are no departures scheduled between 23:00 and 06:00, on occasion there are delayed departures after 23:00.

There were more easterly operations in the 2015/16 period than the equivalent 2011/12 period, resulting in 20% more departures over the area (through the NPL gate).

The total number of aircraft using the GAS and MID route is 16% greater in 2015/16 than 2011/12. The proportion of aircraft using the these routes on easterly operations decreased by 1.5%.

Overall, during an average full easterly day there were slightly less aircraft flying in the vicinity of NPL than in 2011/12. The decrease generally occurred before 10am.

Aircraft were on average lower (around 210ft/6%) in 2015/6 than in 2011/12.

Aircraft which were previously concentrated around a single swathe on the MID route are now concentrated around two distinct swathes. The main concentration of departing aircraft following the GAS route moved slightly to the west in 2015/16.

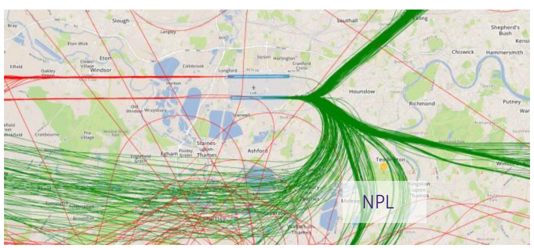
The proportion of A380 aircraft passing through the NPL gate during easterly operations increased from 0% to 1%.

Noise levels in the community based on measurement at NPL	Changes over 5 years in community noise levels based on modelling
At NPL, noise from aircraft makes a substantial contribution to community ambient noise levels during easterly, but not westerly operations.	Daytime average aircraft noise levels (LAeq,16hr, 07:00 to 23:00) have not changed substantially between 2011 and 2015 (<1dB reduction in this area). It should be noted that, all other variables remaining constant, a 26% change in noise events would correspond to about a 1dB increase in $L_{Aeq,16hr}$.
Measured hourly ambient noise levels ($L_{Aeq,1\ hr}$) on an easterly day are 3-13 dB higher than those on a westerly day (during daytime hours).	In this area in 2015, there were up to 7 (~25%) more events per day with an L_{Amax} greater than 65 dB over an average easterly day when compared to 2011.
The highest measured hourly ambient noise levels ($L_{Aeq,1hr}$), greatest number of measured aircraft noise events and the highest average aircraft L_{Amax} occur in the 22:00-23:00 hour. This period has the most larger aircraft types and is a period when non-aircraft noise is reducing.	The night time average aircraft noise level ($L_{Aeq,\ 8hr\ 23:00\ to\ 07:00}$) has increased by ~1dB and number of events ($N_{60,8hr}$) has not changed substantially in the area.
Generally no aircraft noise events were recorded during days of westerly operations.	
The average measured maximum aircraft event noise level on an average easterly day is around 67.4dB L_{Amax}.	
Across the day, small twin-engine aircraft generate the most measured noise events (A320 family generate 53%) followed by the B777 11%, B747 9% and A330 8%.	
The B747 generates the highest average L_{Amax} noise levels in the vicinity of NPL.	

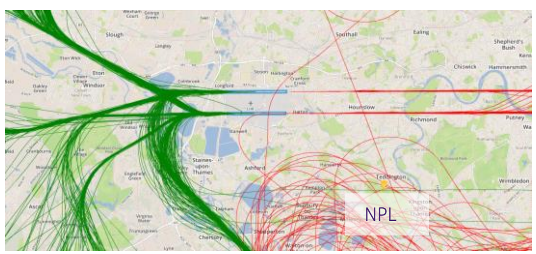
Understanding how wind direction affects aircraft operations.

Wind direction and operating direction

- The direction aircraft land and take-off from Heathrow depends on the direction of the wind. For safety reasons, aircraft take-off and land into the wind.
- When the wind blows from the west, aircraft arrive from the east, over central London, and take off to the west. This is called westerly operations. Conversely, when the wind blows from the east, aircraft arrive from the west over Berkshire and take off to the east. This is called easterly operations.
- The figures below show flight tracks for a typical day of easterly and westerly operations. Arrivals are shown red, departures green.
- NPL/Teddington is predominantly overflown by departing aircraft when the airport is on easterly operations.



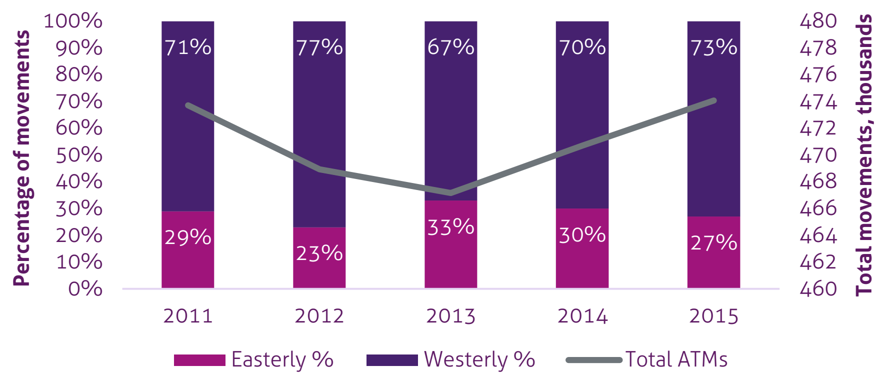
Flight tracks on an easterly day (18th March 2016)



Flight tracks on a westerly day (8th March 2016)

The proportion of easterly operations

- Around Heathrow, the prevailing wind direction is from the west.
- Heathrow also operates what is know as the 'westerly preference'. Aircraft will continue to operate in a westerly direction until there are tail winds consistently of 5kts or more. This was implemented to protect more densely populated areas to the east of the airport.
- As a result, the airport is typically on westerly operations for about 70-75% of the year.
- The figure below presents the **annual** proportion of easterly and westerly operations for the last 5 full years.

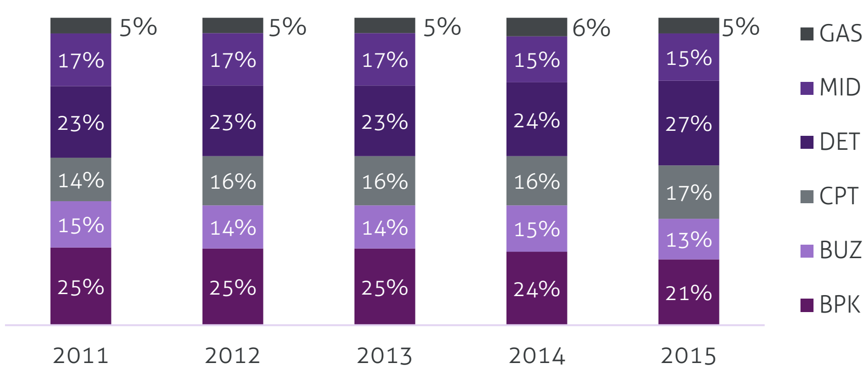


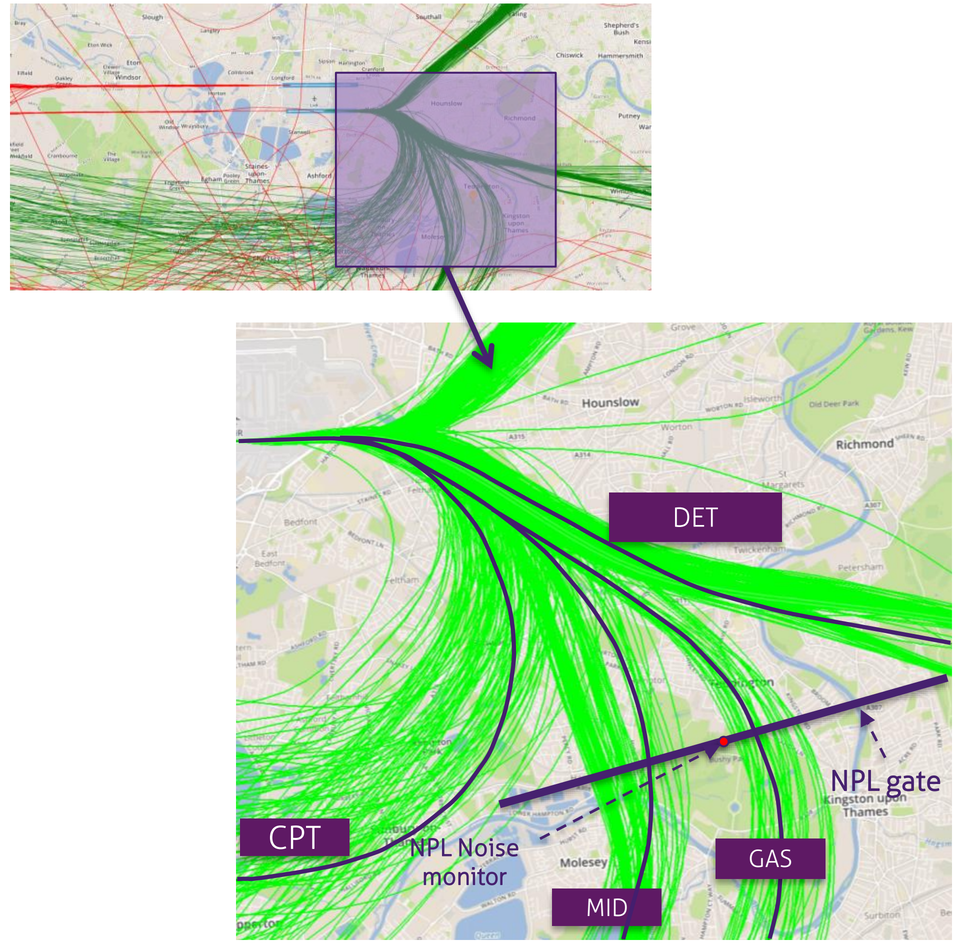
Note: Further information about operations at Heathrow can be found at http://www.heathrow.com/noise/heathrow-operations

Where do aircraft fly on easterly operations?

- Aircraft taking off from Heathrow during easterly operations (towards London) follow one of six pre-defined routes, typically based upon their destination.
- The image to the right shows an example day of tracks for departing during easterly operations.
- NPL is located close to the easterly MID and GAS departure routes. The figure also shows the 'NPL gate' used for analysis of noise events, aircraft heights and concentration in the vicinity of Teddington.
- The figure below shows the proportions of **annual** route usage by easterly operations for each year from 2011-2015. The proportion of aircraft using DET, MID has increased use over this period. GAS has remained similar. Route usage to the north (BPK and BUZ) has decreased.

Annual departure route use on easterly operations





DET and GAS are the new names for the DVR and SAM routes. Throughout this document they are referred to as DET and GAS

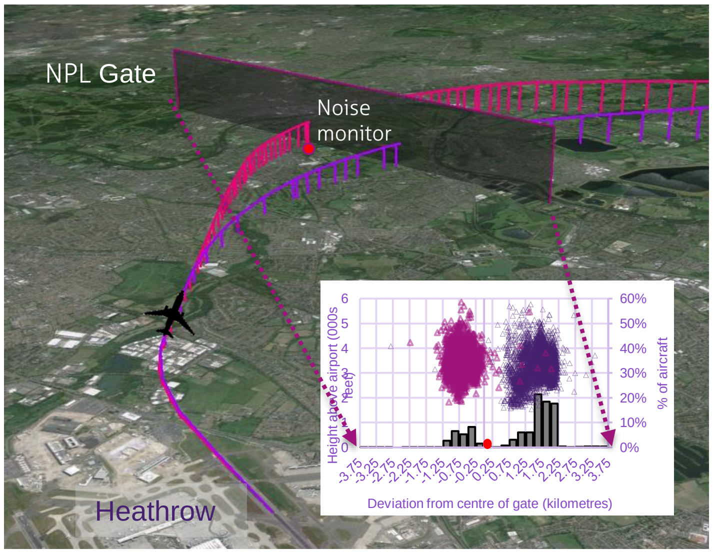
Understanding operational and gate data.

Operational data.

- The following operational data was provided for the period 11th August 2015 – 21st March 2016 and the same period for 2011/12:
  - Easterly/westerly movements - % of movements in easterly/westerly direction.
  - Daily logs - Number of flights operating from Heathrow per day by runway used
  - Heathrow flight-by-flight data - Aircraft type, departure route, runway.

Gate analysis.

- To investigate the heights, distribution and concentration of aircraft, the Noise and Track Keeping (NTK) system's "gate analysis" function was used to provide data on where aircraft have flown relative to the noise monitor.
- A 'gate' was drawn centred above the noise monitor at NPL and incorporates the full width of the MID and GAS NPRs at this point. This is illustrated in the figure below.



- The 'NPL gate' is 7,500m wide and 17,000 feet high.
- The heights and positions of each aircraft passing through the gate were extracted from Heathrow's NTK system (ANOMs). Only Heathrow aircraft departing to the east (easterly operations) were investigated for this report.
- The following data was extracted:
  - Aircraft deviation from the centre of the gate
  - Aircraft height at gate
  - Time that the aircraft penetrated the gate
  - Departure route flown – 'standard instrument departure route' (SID)
  - Aircraft type
  - Runway used

Can the data be trusted?

- Through the Heathrow Community Noise Forum (HCNF), an independent study was carried out, investigating the accuracy of flight track data of Heathrow systems.
- The results confirming the integrity of the data and models are presented in the following report: http://www.heathrow.com/file_source/HeathrowNoise/Static/NLR_HCNF_20160125.pdf

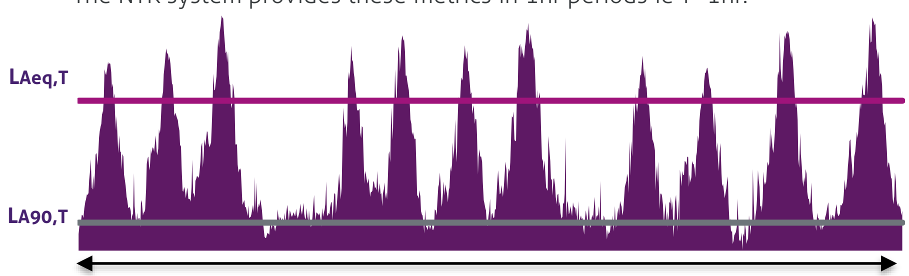
Understanding measured noise data.

Measured noise data:

- A Larson Davis 870, Type 1 integrating sound level meter was set to measure total ambient and background noise levels over hour periods in addition to individual noise events which, where possible, are linked to aircraft operations.
- Measured data is passed into Heathrow's NTK System without modification – no data has been excluded due to adverse weather conditions.
- For this report, noise data has been provided by Heathrow for the period 11th August 2015 – 21st March 2016. Note that a historical comparison is not available since the noise monitor was not installed at this location in previous years.

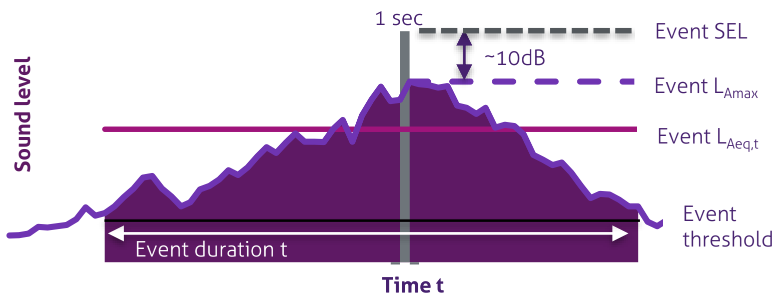
Ambient and background noise levels:

- The figure below illustrates how sound levels can vary over a time period T where aircraft events are experienced. The following metrics are typically used to describe the overall noise environment – $L_{Aeq,T,}$ and $L_{A90,T:.}$ These are described as follows:
  - $L_{Aeq,T}$ – the total sound level across period T from all sources;
  - $L_{A90,T}$ - the sound level exceeded for 90% of the time across period T from all sources, this is often regarded as a measure of the background noise;
  - The NTK system provides these metrics in 1hr periods ie T=1hr.



Noise events:

- For ALL noise events, three descriptors are provided:
  - L_{Amax} - the maximum A-weighted sound pressure level during the event
  - SEL (sound exposure level or singe event level) - the sound level of a one second burst of steady sound level that contains the same A-weighted sound energy as the whole event; and
  - Duration – the length of time (t) in seconds that the event exceeds the event detection threshold set on the sound level meter. The threshold is set dependent on local background noise conditions and can vary between monitor locations.
- For noise events linked to an aircraft operation the following data is also provided :
  - Aircraft type
  - Runway
  - Route
  - Position at time of L_{Amax}
  - Position at point of closest approach.
- The figure below illustrates the sound metrics associated with an aircraft noise event. The difference between L_{Amax} and SEL is typically around 10dB.

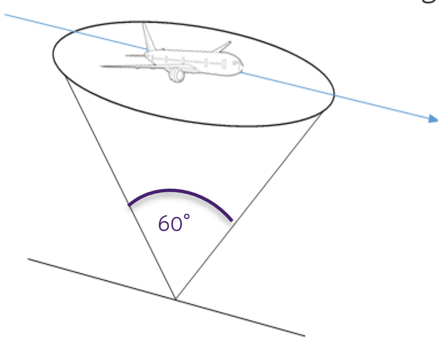


Analysing noise levels from aircraft in this area.

To undertake analysis of measured aircraft noise events, two perspectives are considered.

- Firstly, noise in the community. Aircraft overhead will generally have a higher noise level than those further away. However, noise from aircraft further away still contributes to the noise environment. So when describing noise from aircraft in an area all aircraft noise events should be considered.
- Secondly, if considering relative noise levels of aircraft it is best practice to restrict analysis to aircraft deemed 'overhead' to enable like for like comparison. This ensures that flights that are quieter purely as a result of being further away do not artificially reduce the analysed noise levels from that aircraft type.
- There is no consensus as to what constitutes an overhead flight but one definition involves drawing an imaginary cone with a 60° apex above the noise monitor. This is illustrated in the figure below.

Flights are considered overhead if the aircraft pass within 60°cone above the noise monitor

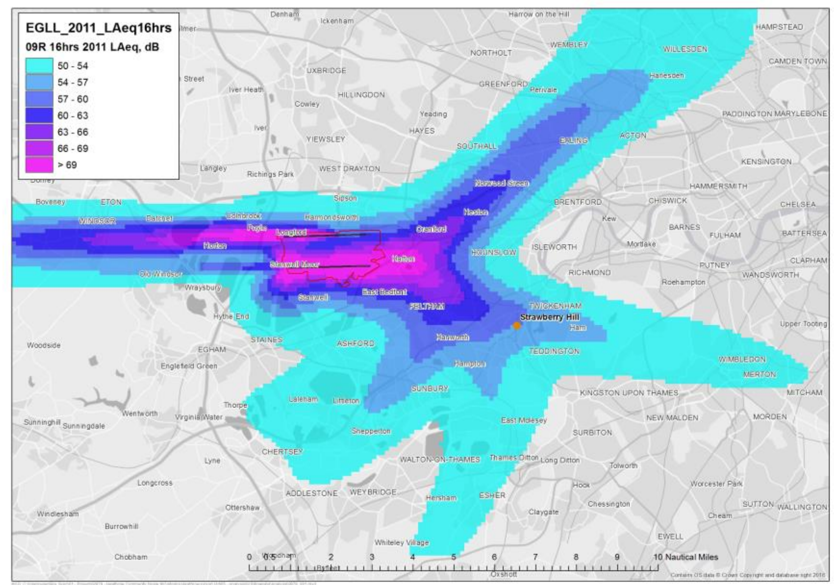


- Although this method has its limitations, this community information report will, where applicable, present results for all overhead flights as well as all registered aircraft noise events.

Noise Modelling

- Aircraft noise modelling has been used to provide an understanding of differences in the noise environment between 2011 and 2015 over the wider geographic area.
- Differences in daytime and night time levels for an **average day and night of easterly operations** across the summer of 2011 and 2015 have been derived using the Heathrow INM model developed for the 2014/15 departure trials and verified recently by NLR.

Example contours generated by aircraft noise modelling



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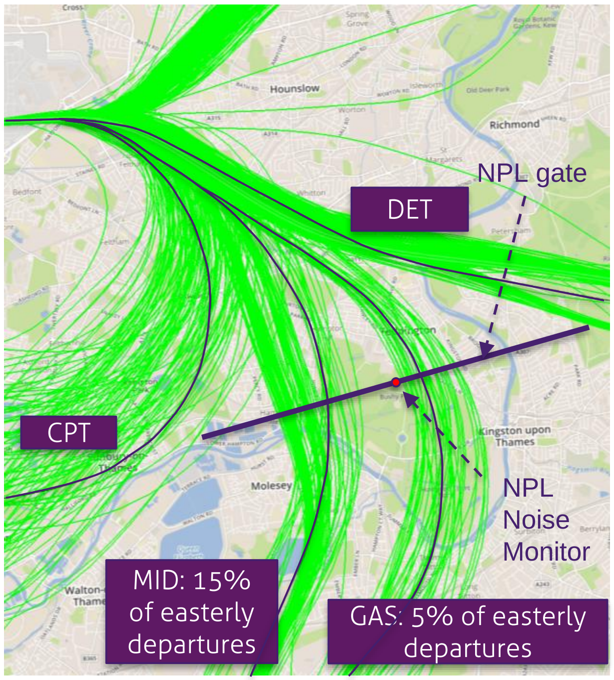
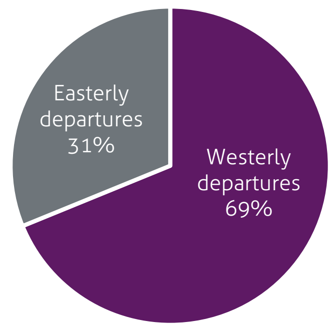
Overview of flight track data

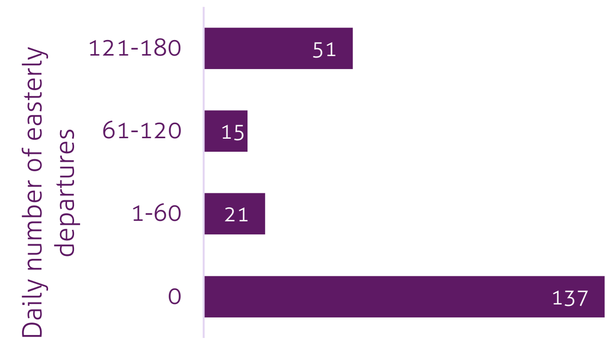
11th August 2015 – 21st March 2016



Example day of departing aircraft tracks in the vicinity of the National Physical Laboratory gate during easterly operations

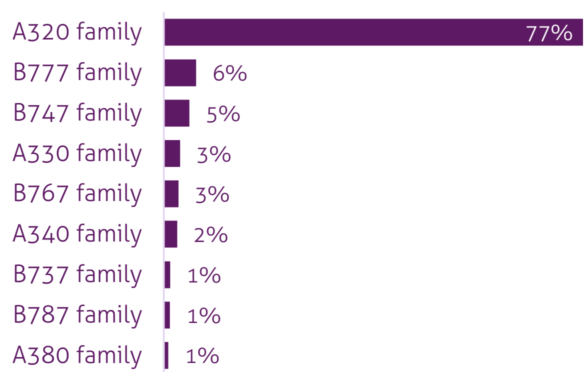
Total 142,274 departures from Heathrow



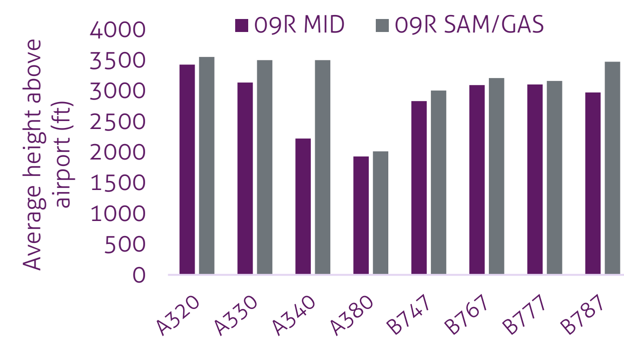


Number of easterly departures per day passing through the NPL gate (224 days in total)

Proportion of departing aircraft types passing through the NPL gate

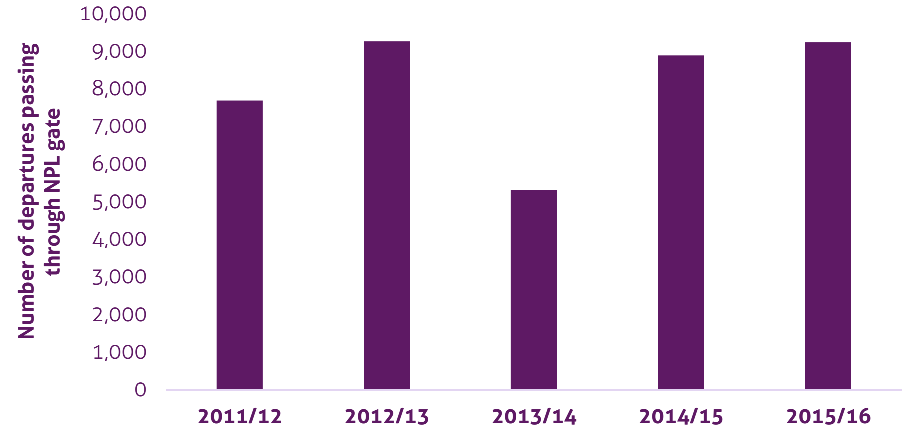


Average height of departing aircraft as they pass through the NPL gate



Is the number of flights over the area different in 2015/16 to 2011/12?

- The figure to the right shows the total number of departures that passed through the NPL gate in the years 2011/12 to 2015/16.
- Over the five year period, between 5,300 and 9,300 departures penetrated the NPL gate with most aircraft being registered during the 2012/13 period closely followed by 2015/16.
- This increase compared to 2011/12 can mostly be attributed to a greater number of easterly operations, the details of which are given in the table in the bottom right.
- **The proportion of easterly operations increased from 24% in 2011/12 to 31% of all movements for 2015/16 monitoring period**.
- During days of easterly operations during the 2015/16 monitoring period approximately one-fifth of aircraft taking-off from Heathrow passed through the NPL gate. This represents **a decrease of around 1% compared to the same period in 2011/12.**
- During days of 100% easterly operations, on average **4% fewer aircraft flew through the NPL gate in 2015/16 than 2011/12 -** 136 departing aircraft in 2015/16, 6 fewer than in 2011/12.
- There were 137 days out of 224 (61%) during which no aircraft passed through the gate.



	2011/12	2015/16	Diff	% change
Proportion of easterly operations (all Heathrow flights)	24%	31%	+7%	N/A
Proportion of easterly departures passing through the NPL gate*	22%	21%	-1%	N/A
Average number of easterly departures passing through the NPL gate per day	142	136	-6	-4%

* Days of 100% easterly operations only.

Note: Wherever this report refers to "*2015/16*", it should be noted that this is specifically the measurement period from 11th August 2015 to 21st March 2016. Similarly, "*2011/12*" specifically refers to the period from 11th August 2011 to 21st March 2012 etc

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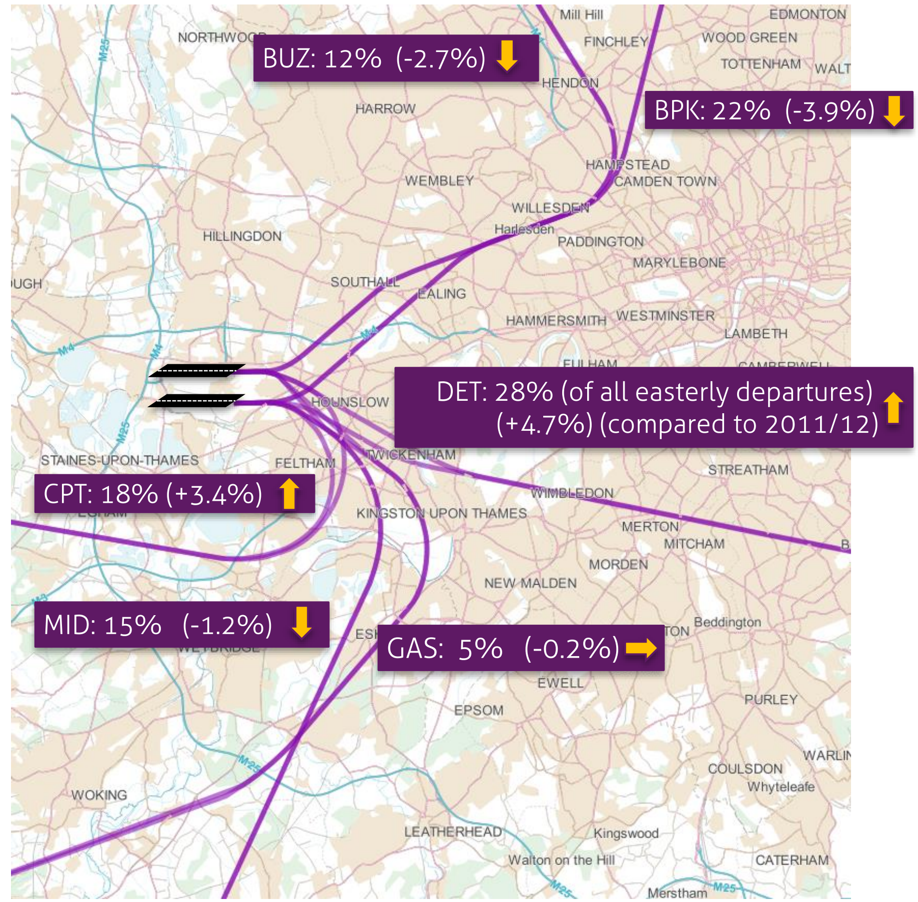
Is the route use different between 2015/16 and 2011/12?

- The figure to the right presents the proportion of flights using each route during a typical full easterly day in the 2015/16 period compared to 2011/12. Aircraft on the MID and GAS route are closest to the noise monitor at NPL although aircraft may still be audible on other routes.
- **In the 2015/16 period, the proportion of all easterly departures using the MID and GAS route combined decreased from 21% to 20% over the same period in 2011/12.** DET was the most commonly used easterly departure route in the 2015/16 period.
- The figures presented reflect a change in the proportion of aircraft using each departure route, and an increase in easterly operations during 2015/16.

Actual numbers of aircraft and percentages of total movements in each time period

Easterly departure route	2011/12	2015/16	Number difference	% difference
BPK	8,895	9,593	698	+8%
BUZ	5,327	5,502	175	+3%
CPT	4,946	7,649	2,703	+55%
DET	8,181	12,133	3,952	+48%
MID	5,797	6,717	920	+16%
GAS	1,900	2,237	337	+18%
TOTAL	35,046	43,831	8,785	+25%

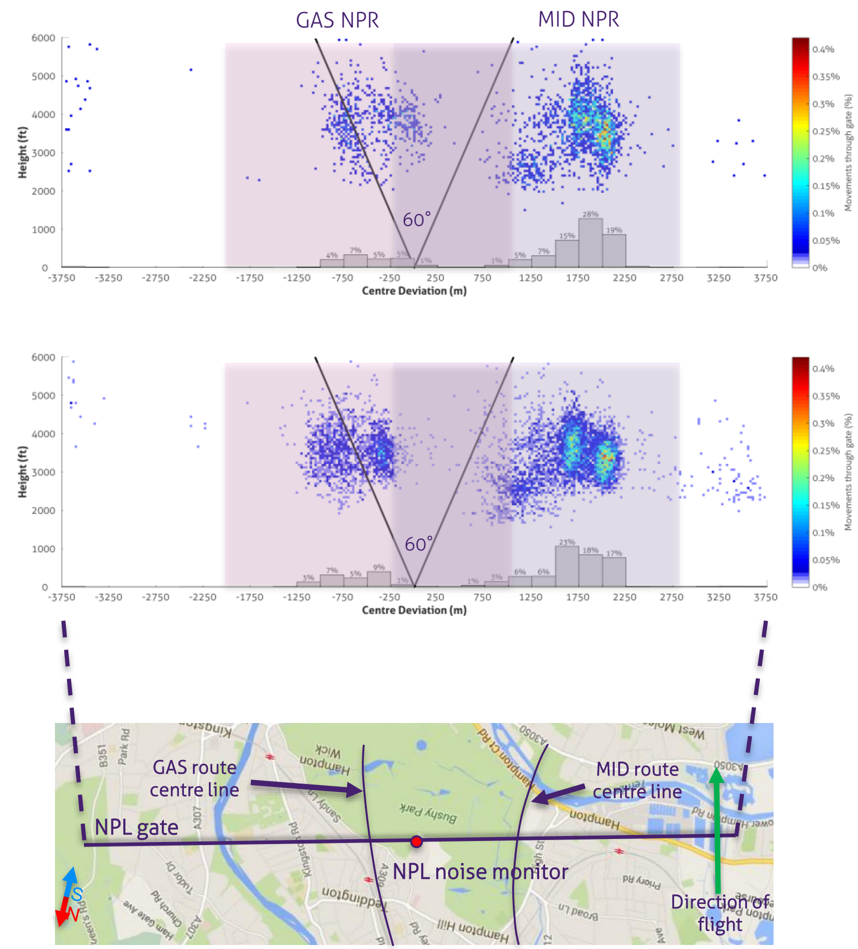
Percentage of route use on fully easterly days in 2015/16 and change since 2011/12



Note: More details of movements trends can be found in Heathrow's Annual Flight Performance Reports and the CAA reports at http://www.heathrow.com/noise/facts,-stats-and-reports/reports and on the ERCD website.

Is the concentration of flights different between 2011/12 and 2015/16?

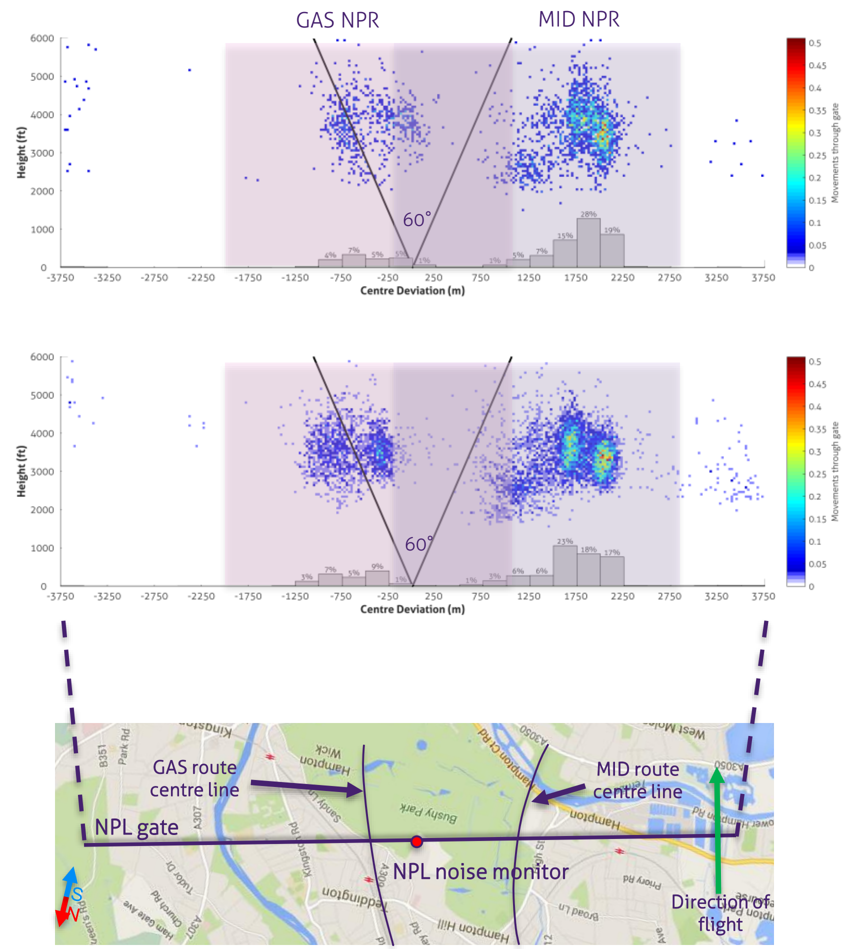
- The figures to the right are 'heat maps' showing the 2D concentrations of easterly departing aircraft as they passed through the NPL gate during the 2011/12 (the upper figure) and 2015/16 (the lower figure) monitoring period.
- These figures have been designed to illustrate the degree of concentration. The scale presents consistent colours for the proportion of aircraft in the grid. For example a "red" indicates 0.4% of the movements passing through a grid square in the gate in both figures.
- The grey bars under the 'heat map' show the actual concentration at different distances from the centre of the gate.
- The figures indicate that the main concentration of departing aircraft following the MID route was spread over a slightly wider distance in 2015/16 with two distinct 'hot spots' being visible within the main concentration. There was also a small shift in the location of the main concentration of departing aircraft following the GAS route in 2015/16 with a distinct concentration closer to the centre of the gate.
- In 2015/16, departing aircraft following the GAS route were concentrated between 250 to the west and 1,250 metres to the east of the NPL noise monitor - in 2011/12 this concentration was between the NPL noise monitor and 1,000 metres to the east.
- Noise events generated by the aircraft movements that fall within the 60° overhead cone (see page 9) shown in the lower heat map have been considered as "overhead" in the noise data analysis.



Note: The "heat maps" have been normalised to account for differences between the number of easterly departures in each of the monitoring periods. This allows the concentrations in each graph to be compared. This method does not account for any changes in daily number of movements passing through the gate - these changes are presented on Page 12. The maps are divided into grid squares, 25m horizontally by 60ft vertically.

Is the number of flights different between 2011/12 and 2015/16?

- The figures to the right are 'heat maps' showing the 2D concentrations of easterly departing aircraft as they passed through the NPL gate during the 2011/12 (the upper figure) and 2015/16 (the lower figure) monitoring period.
- These figures differ from those on the previous page in that they show the average number of movements through the gate on a full day of easterly operations, thus highlighting the change in the number of flights passing through the gate as presented on page 12 (rather than the change in concentration shown on page 14).
- Given that, on a full day of easterly operations, the numbers of aircraft passing through the gate are similar in 2011/12 and 2015/16, these figures are very similar to those on the previous page.

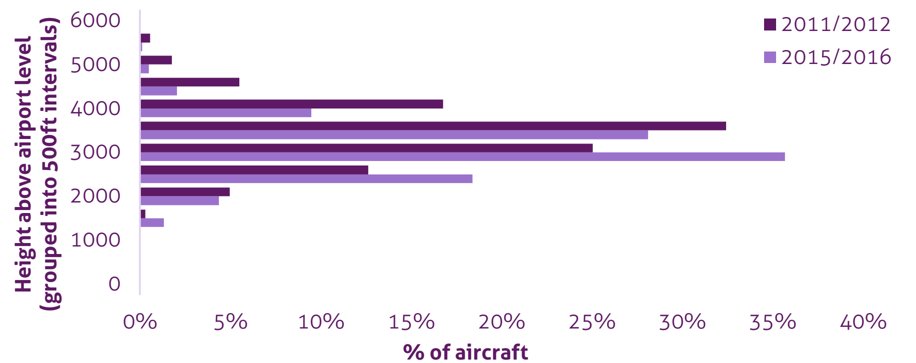


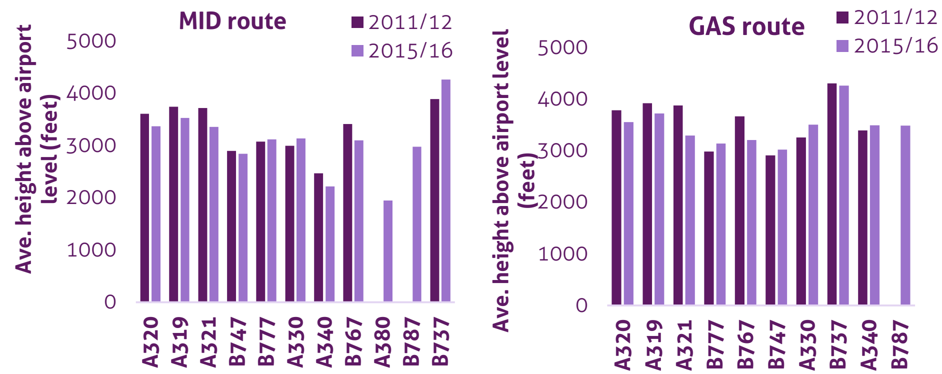
Note: These "heat maps" have not been normalised to account for differences between the number of easterly departures in each of the monitoring periods. This allows the numbers of movements in each year to be compared. The maps are divided into grid squares, 25m horizontally by 60ft vertically.

Are aircraft heights different between 2011/12 and 2015/16?

- The table to the right presents the average height of all flights from Heathrow as they passed through the NPL gate on both the MID and GAS routes in 2011/12 and 2015/16.
- **This indicates that aircraft height above NPL were slightly more than 200ft lower in 2015/16 compared to 2011/12.**
- The figures present the distribution of aircraft height through the NPL gate comparing 2011/12 with 2015/16 (upper figure) and the average height by aircraft type on the MID and GAS routes (lower figure).
- The upper figure shows that generally aircraft heights were lower in 2015/16 than in 2011/12.
- It shows that generally aircraft heights were lower in 2015/16 than in 2011/12. Of note there are reductions in the proportions of aircraft passing the gate at heights between 3,500 and 4,000ft, but an increase between 3,000ft and 2,500ft.
- The lower figure indicates that on both routes, the A320 family were more than 200ft lower in 2015/16 when compared to 2011/12 – these aircraft accounted for three quarters of aircraft passing through the gate. Some of the remaining aircraft types were lower while others had increased altitude at NPL.

Average height at NPL gate (feet)	2011/12	2015/16	Difference
MID	3551	3340	-211
GAS	3710	3489	-221





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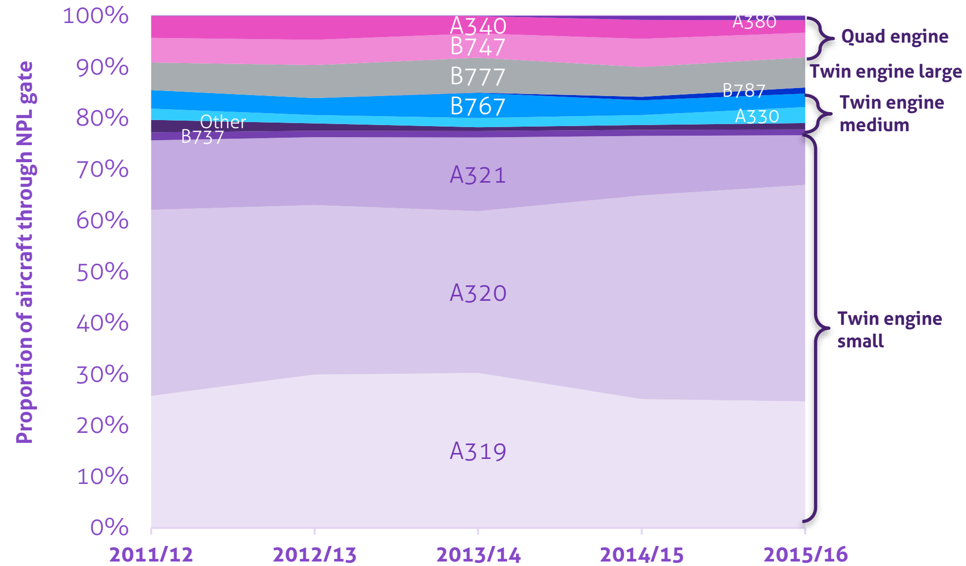
Is the fleet mix different between 2011/12 and 2015/16?

- The table to the right presents the mix of aircraft that passed through the DET gate and overall at Heathrow in 2011/12 and 2015/16.
- For simplicity the fleet mix has been split in to 5 groups:
  - the A380
  - quad (four) engine aircraft (including B747, A340),
  - twin engine large aircraft (B777, A350 (not yet in regular service))
  - twin engine medium aircraft (B767, B787, A330) and
  - twin engine small aircraft (B737, A320 family).
- Previous slides indicated that the number of flights flying through the NPL gate has decreased slightly on an average day of full easterly operations between 2011/12 and 2015/16.
- The analysis on this page indicates that there was a 0.8% increase in the proportion of A380 operations penetrating the NPL gate in 2015/16 compared with 2011/12 - the proportion of the use of the A380 overall at Heathrow increased by 2.5% across the same period.
- The figure provides a more detailed picture of how the fleet mix has changed across the period. The aircraft categories used in this report are distinguished by the different colour schemes.
- The proportion of small twin engine aircraft has remained roughly constant over the five year period at about 80% with the increase in number of A320 being at the expense of the A319 and A321.
- The newest aircraft, the A380 and B787, first flew through the NPL gate in 2013/14 and now represent 2% of movements through the gate.

Fleet mix*

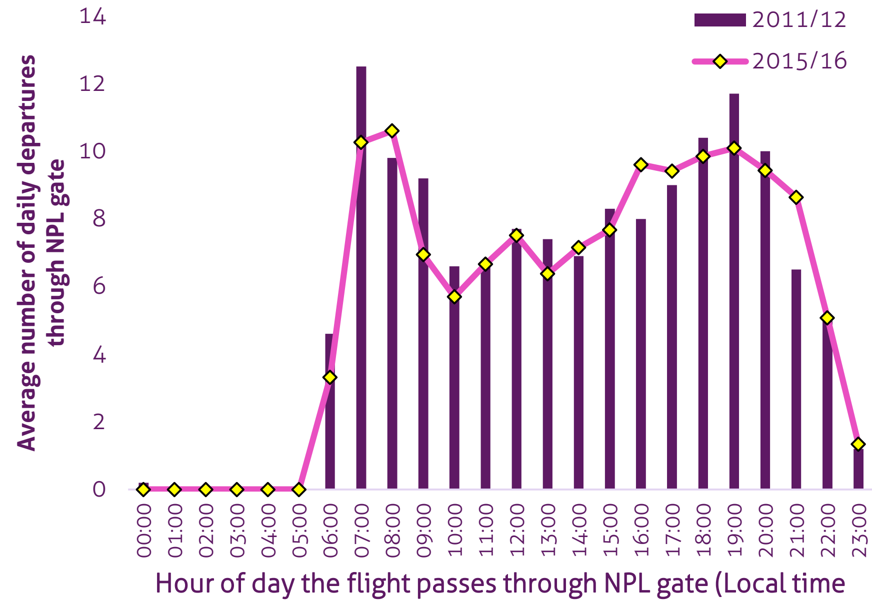
Category	NPL gate		All LHR	
	11/12	15/16	11/12	15/16
A380	0.0%	0.8%	0.9%	3.4%
Quad engine	9.1%	7.4%	11.9%	6.7%
Twin engine large	5.4%	5.2%	11.6%	13.2%
Twin engine medium	6.3%	6.5%	10.1%	14.0%
Twin engine small	79.2%	80.1%	65.6%	62.6%



* Days of 100% easterly operations only

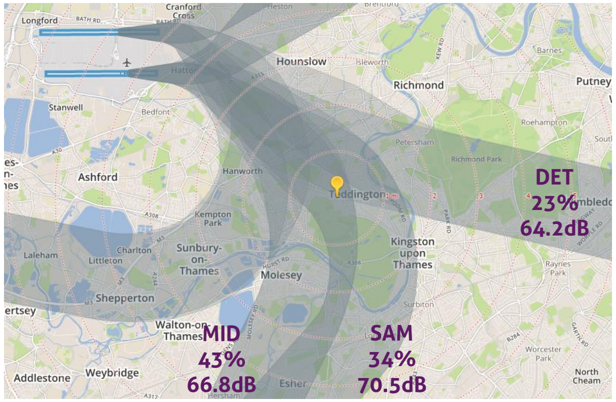
Does the number of flights over the area vary across the day? Is there a difference between between 2011/12 and 2015/16?

- The figure to the right presents the average number of departures through the NPL gate per hour in 2011/12 and 2015/16 during days of 100% easterly operations.
- This shows that there is a broadly consistent cycle of use of this route across the day in both the 2015/16 and the 2011/12 periods. The first peak occurs between around 7-10am and a second increase peaking between 7 and 8pm.
- Over the course of the day, there were 6 less operations passing through the NPL gate in 2015/16 compared to 2011/12. The main reduction occurred in the periods 06:00 - 8:00 and 19:00-20:00 while some other hours experienced an increase.
- As noted previously, there were 4% fewer easterly operations through the DET gate on an average day of full easterly operations in the 2015/16 monitoring period than 2011/12.
- The reduction predominantly occurred on the MID route rather than the GAS route.
- The analysis indicates that on average, on a day of full easterly operations, there was around one delayed departures between 23:00 and 00:00 that pass through the NPL gate. It is noted that the range is between 0 and 4 for this hour.
- Of the total 224 days in the 2015/16 monitoring period, 49 days were 100% easterly operations, there were no delayed departures through the NPL gate on 10 of these days.

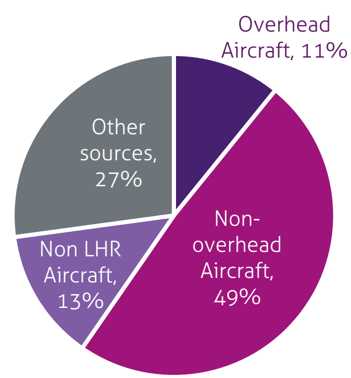


Overview of noise monitor data recorded at NPL

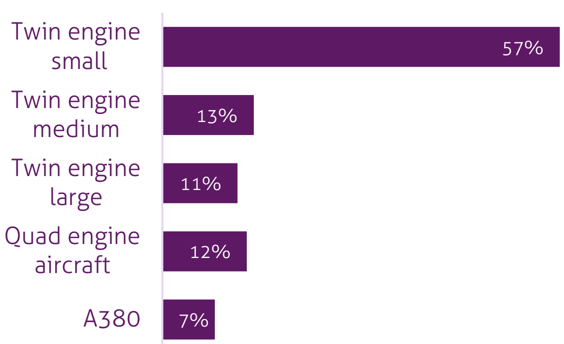
11th August 2015 – 21st March 2016



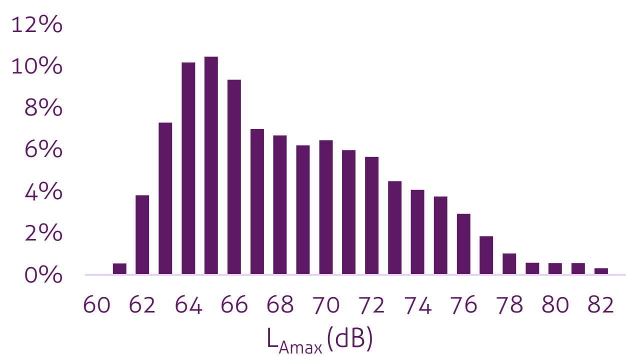
Monitor location, % noise events by route & average L_{Amax}



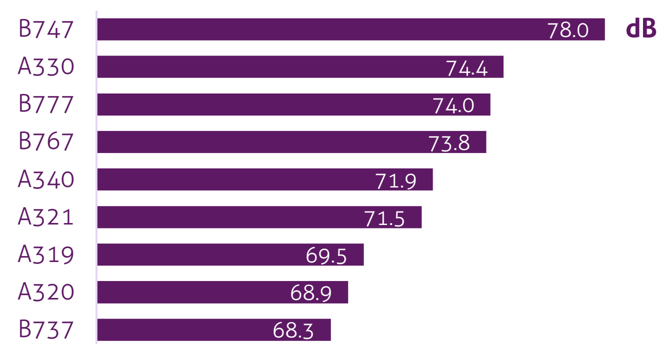
* Flights are considered overhead if aircraft passes within 60° cone above noise monitor



Noise events by aircraft type



Overall distribution of maximum event noise level L_{Amax} - Heathrow aircraft



Average L_{Amax} by Aircraft Type*
*Overhead aircraft only with more than 10 noise events

Noise monitoring overview.

Monitoring location, duration and setup

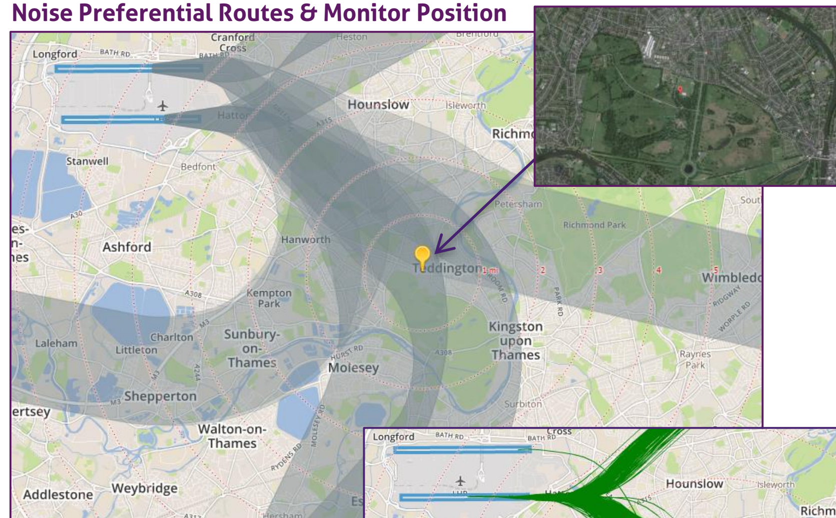
- A temporary noise monitor was installed in the grounds of NPL between 11/08/2015 and 21/03/2016.
- The monitor was set up to record noise events based on a threshold sound pressure level of 60 dBA being exceeded for more than 10 seconds.
- The location of the noise monitor is shown in the figures to the right. It is close to the centre line of the GAS route, and close to the outer edges of the MID and DET noise preferential routes (NPRs).
- It should be noted that since the noise monitor was not set up in this location during the equivalent period of 2011/12 comparison of noise levels relative to those measured in the 2015/16 period is not possible.

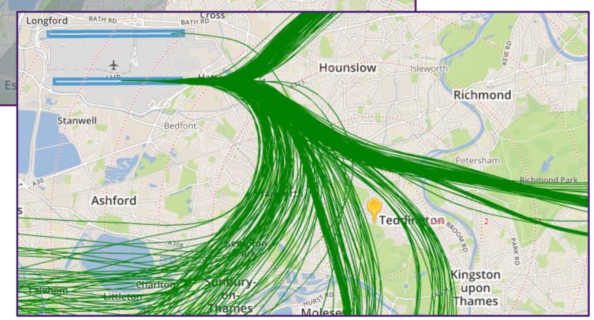
Noise event summary

- A total of 10,058 noise events were measured during the monitoring period. Of these around 60% were from aircraft using Heathrow, 13% were from non-Heathrow aircraft and 27% were from non-aircraft sources.
- Overall, 43% of the aircraft registering noise events at the noise monitor were using the MID route; 18% of aircraft registering noise events were overhead (97% of these were on the GAS route).

Routes (%)			LHR Traffic Overhead (%)
DET	GAS	MID	
23	34	43	18

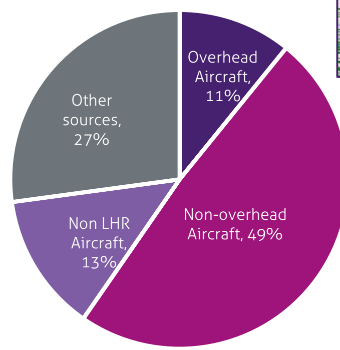
Noise Preferential Routes & Monitor Position





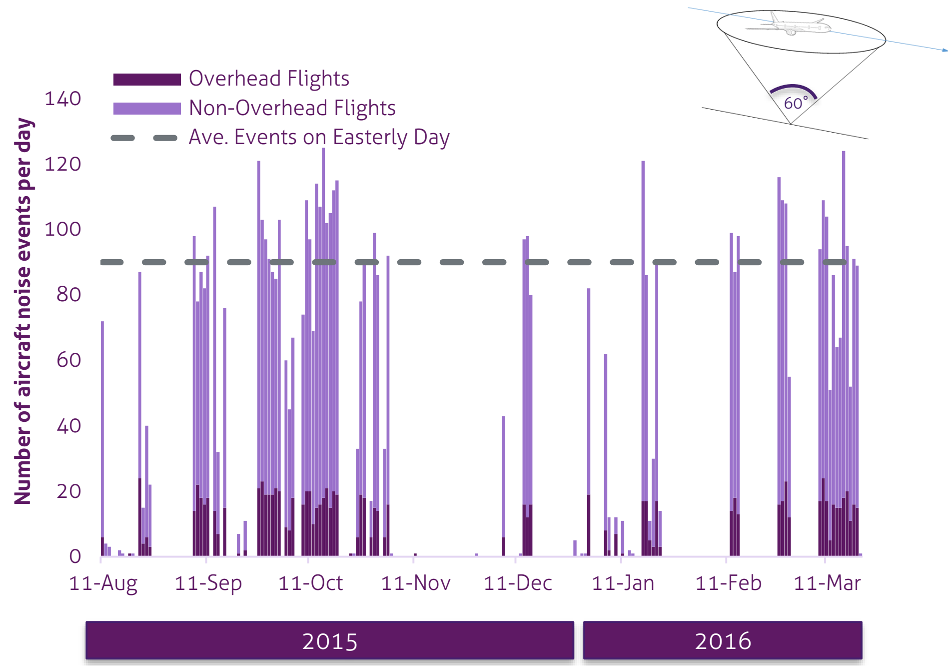
Noise monitor position and flight tracks on a typical Easterly day

Measured Noise Events Summary



How does the direction of operation affect the number of measured aircraft noise events?

- Noise events are captured at NPL mostly during periods of easterly operations and by aircraft using the DET, GAS and MID routes.
- During the monitoring period 49 out of 224 days (22%) related to 100% easterly operations and 128 days (57%) related to 100% westerly operations. On 21% of the days, the airport switched direction of operation during the day resulting in a combination day of easterly and westerly operations.
- During days of full easterly operations, there were, on average, 90 aircraft noise events per day. However, during 100% westerly operations there was an average of less than one aircraft noise event.
- Over the 224 days for which monitoring was taking place, 9% of days experienced 100 or more aircraft events whilst 43% of the days had no aircraft events.
- A prolonged period of easterly winds in October led to many consecutive days of 100+ aircraft noise events.
- It is noted that just because there are no aircraft noise events that aircraft are not audible. There may be aircraft further away that are audible but have not triggered the noise event detection threshold.

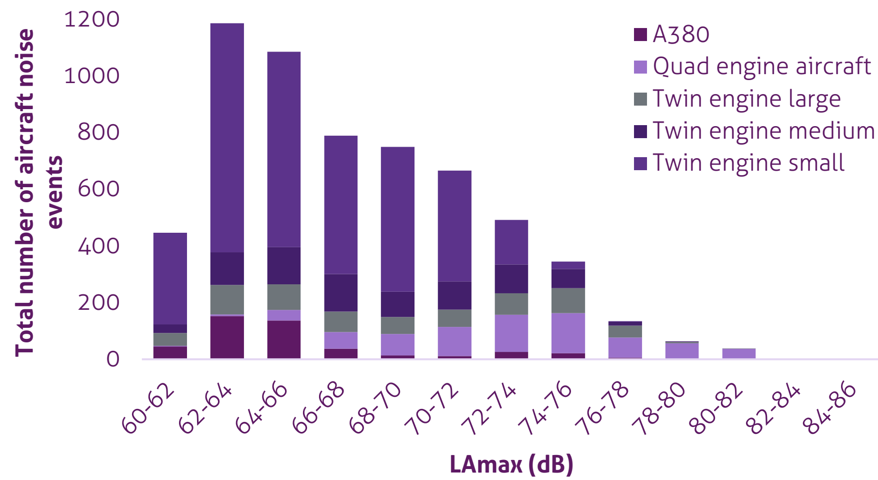


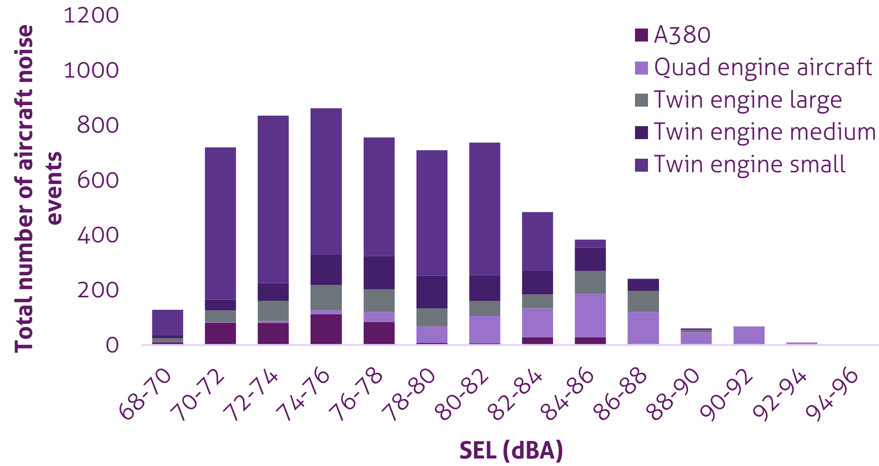
What was the range of L_{Amax} and SEL noise levels from aircraft events?

- The figures to the right present the range of L_{Amax} (top) and SEL (bottom) noise levels for **all aircraft noise events measured at NPL**. An explanation of metrics is given on p8.
- The table below presents the average* L_{Amax} and SEL for each aircraft type group.
- The average L_{Amax} of all aircraft events is 67.4dB. There is a relationship between the size of the aircraft and average L_{Amax}. However, since A380s are, on average, further from the noise monitor compared to the other aircraft types, the mean L_{Amax} of the A380 is 0.5dB less than that of the small twin engine aircraft. A similar relationship exists for the SEL.

Aircraft group	Average L_{Amax}	Average SEL, dBA
A380	65.4	75.5
Quad engine	72.9	84.1
Twin engine large	68.7	83.2
Twin engine medium	68.2	82.0
Twin engine small	66.1	76

- As this analysis considers ALL events measured at this monitor regardless of distance or route these results cannot be used to compare the relative noise levels of aircraft types. An analysis of aircraft type noise levels is presented on p25-26.
- As a comparison, the mean L_{Amax} of all non aircraft events is 65.4dB while maximum event levels are similar for aircraft and non-aircraft events.



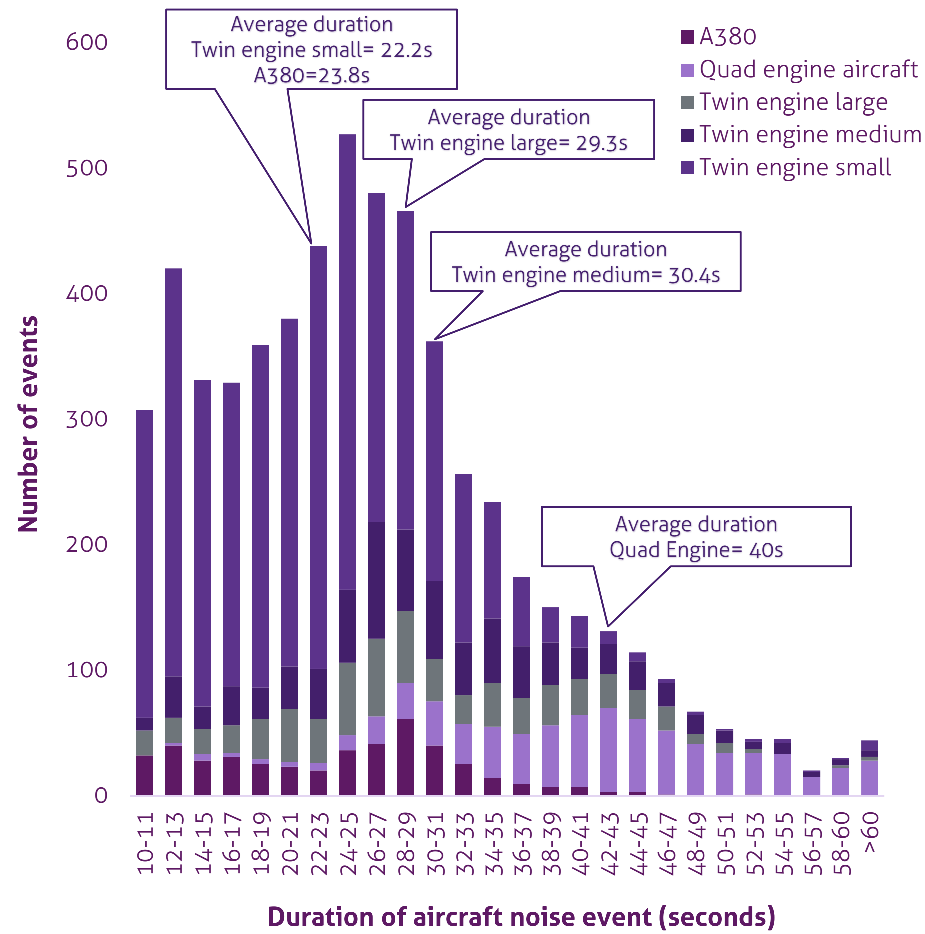


* Note: throughout this report, unless otherwise stated, the arithmetic mean is calculated.

How does the duration of an aircraft event vary?

- The duration of an event is the time for which the noise level exceeds the event threshold level, which, in this case is 60dBA.
- In addition, events are only recorded if the duration is longer than 10s to prevent impulsive sounds which are not characteristic of aircraft noise being recorded or to try and prevent shorter duration transient events such as cars or lorries being captured.
- The average duration of **all measured aircraft events** was 27 seconds. In general, there is a relationship between the size of the aircraft and average event duration. However, since A380s are, on average, further from the noise monitor compared to the other aircraft types, the mean duration of A380 events is similar to that of the small twin engine aircraft.
- The >60 seconds category includes all events with durations more than 60 seconds, which are most likely to be due to one event combining with another (e.g. one of which may not necessarily be an aircraft event)

Aircraft group	Average noise event duration (seconds)
A380	23.8
Quad engine aircraft	42.0
Twin engine - large	29.3
Twin engine - medium	30.4
Twin engine - small	22.2



Which aircraft types account for the measured noise events?

- The table to the right shows the proportion of aircraft noise events recorded for each aircraft type overall, by route and whether the analysis shows it to be overhead at NPL.
- The main aircraft types are shown while the remaining aircraft types are listed under 'Other'.
- As with the Heathrow Airport's traffic in general, the A320 family (A319, A320 & A321) dominate - accounting for 53% of all aircraft noise events detected by the monitor at NPL.
- The B777 series of aircraft account for around 11% of the measured aircraft noise events.
- Around 9% of aircraft noise events were from the B747 and 7% of aircraft noise events were from A380 aircraft,

Aircraft Type	Total*	Route			Overhead**
		DET	GAS	MID	
A320	31%	2%	15%	14%	10%
A319	12%	2%	4%	6%	2%
B777	11%	4%	3%	4%	2%
A321	10%	1%	4%	5%	2%
B747	9%	2%	2%	5%	1%
A330	8%	4%	1%	3%	1%
A380	7%	6%	0%	1%	0%
B767	4%	0%	2%	1%	1%
A340	4%	0%	1%	3%	0%
B737	2%	1%	1%	0%	1%
B787	1%	0%	0%	1%	0%
Other	2%	1%	0%	1%	0%
Total***	**100%**	**23%**	**34%**	**43%**	**18%**

* Percentage based on 5,998 aircraft noise events recorded between 11th August 2015 and 21st March 2016
** Defined as being with the 60 degree cone described on page 9
*** In some cases, the aircraft types do not add up to the totals due to rounding.

Comparison of average maximum noise level (L_{Amax}) for different aircraft.

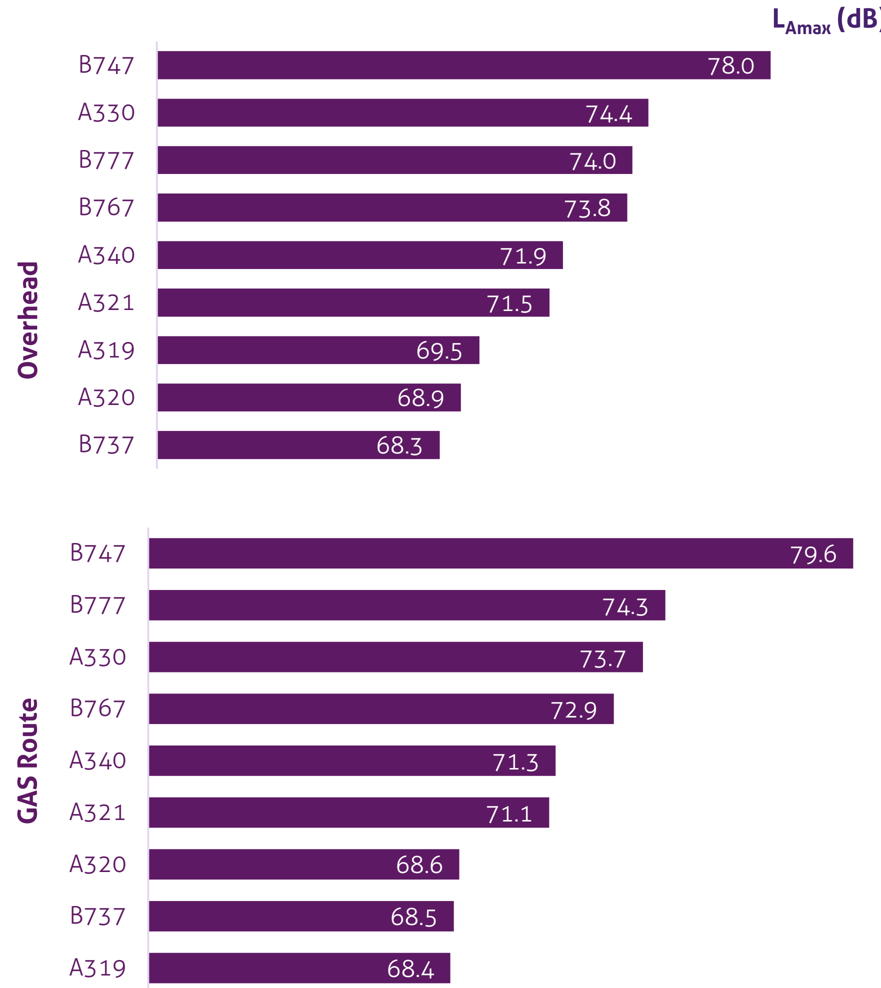
- The plots on the right show the average (arithmetic mean) L_{Amax} of each aircraft type for which at least 10 movements were registered within the **overhead** cone (upper chart) or on the **GAS** route (lower chart).
- Note that some aircraft on the GAS route are not overhead and vice versa (see heat maps on p14 to further understanding).

Overhead aircraft

- The average maximum level of the B747 was 3.6dB greater the next loudest aircraft, the A330. Both the B777 and B767 were within 0.6dB of the A330.
- The A340, a quad engine aircraft, was the next loudest at 71.9 dB while average LAmax of the small twin engine aircraft (A320 family and B737) ranged from 68.3-71.5dB.
- The B787 and A380 were not included in this analysis due to lack of measured noise events.

Aircraft using the GAS route

- When comparing aircraft on the GAS route only, the average L_{Amax} of the B747 was 79.6dB. The A340 (the other 4 engine aircraft in this analysis) was on average around 8.3 dB less.
- The B777, A330 and B767 comprise the next loudest group of aircraft after the B747 with noise levels generally falling between 73-74dB.



HELIOS

Comparison of average Sound Event Level (SEL) for different aircraft.

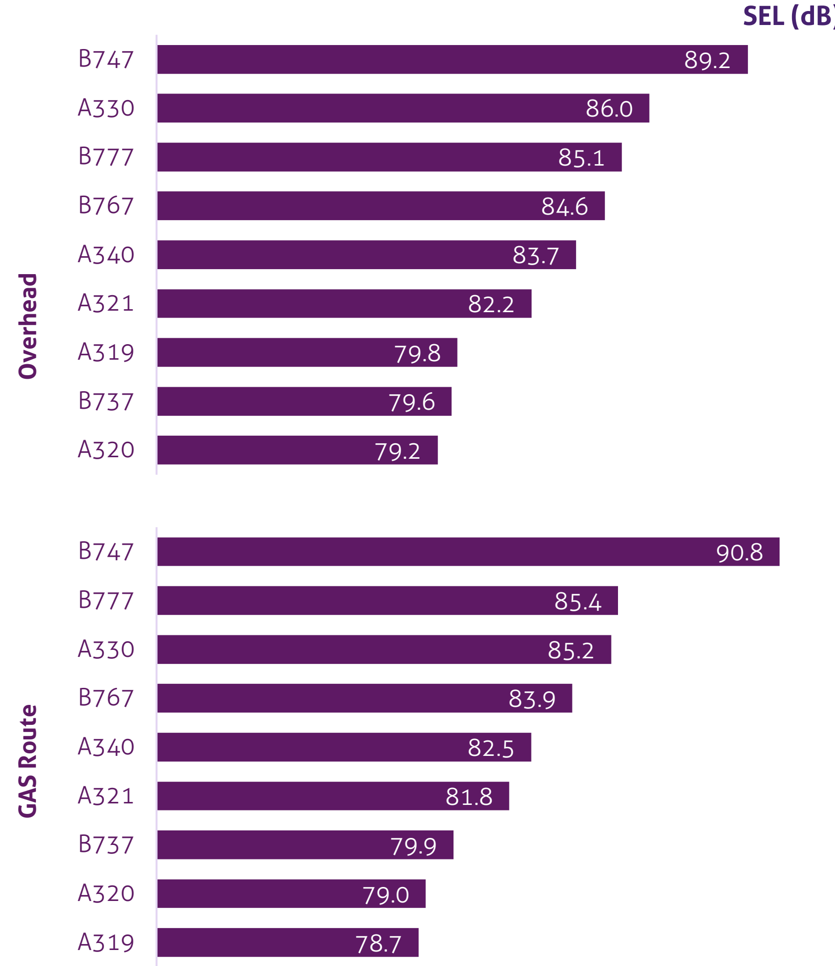
- The plots to the right show the average (arithmetic mean) SEL of each aircraft type for which at least 20 movements were registered within the **overhead** cone (upper chart) and on the **GAS** route (lower chart).

Overhead aircraft

- The highest average SEL noise levels for aircraft considered within the 60˚ cone above the noise monitor is from the B747 at 90.8dBA. Below that the B777 and the A330 (both twin-engine aircraft) generated average SEL values around 5 dB less than the larger B747.
- The small twin engine aircraft form the quietest group of aircraft between 79.2 and 82.2dB.

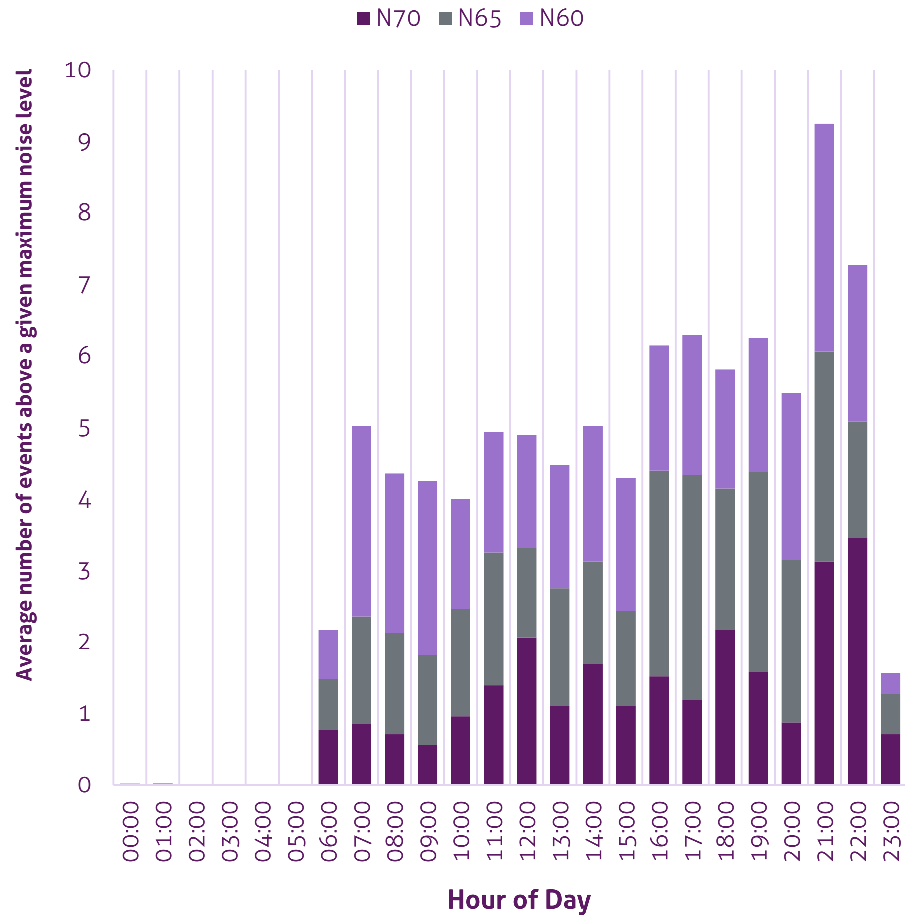
Aircraft using the GAS route

- When comparing aircraft on the GAS route only, the average SEL of the B747 was about 5dB greater than the B777. The A340 (the other 4 engine aircraft) was on average around 8.3 dB less than the B747.
- The A330, B777 and B767 comprise the next loudest group of aircraft generally falling between 83-86dB.



How does the number of noise events above 60, 65 and 70 dB L_{Amax} noise events vary across a day (N60, N65 and N70)?

- It is recognised that the response to aircraft noise is related to more than average noise levels alone. The number of events and their individual levels are becoming increasingly recognised as a useful indicator of community response to aircraft noise.
- The N_{above} set of metrics are used to describe the number of events in a period where the L_{Amax} exceeds a given value. For example, an $N65_{1hr}$ of 10 means that ten aircraft generated a maximum noise level greater than 65dBA in a single hour.
- The figure to the right shows the average hourly N60, N65 and N70 values across an **average 24hr day for days of 100% of easterly operations**. The time refers to the local time that the L_{Amax} was measured.
- The N70 peaks in the evening period between 21:00 and 23:00hrs. This is indicative of the number of aircraft and the noisier aircraft operating in those periods. It is noted that the N65 and N60 also peak during this time period.
- On an average easterly day, the N65 during the 16h day period (07:00-23:00) was over 55; the N60 during the 8h night (23:00-07:00) was less than 5.
- The N60 during the night period on easterly days was less than 5 made up of scheduled departures in the 06:00-07:00 hour and late runners between 23:00 and 00:00.
- On easterly days, there are an average of 1.5 noise events occurring in the hour from 23:00 to 00:00 reaching a maximum of 4 events on one day. On 172 of the 224 days, there were no noise events recorded from late runners.



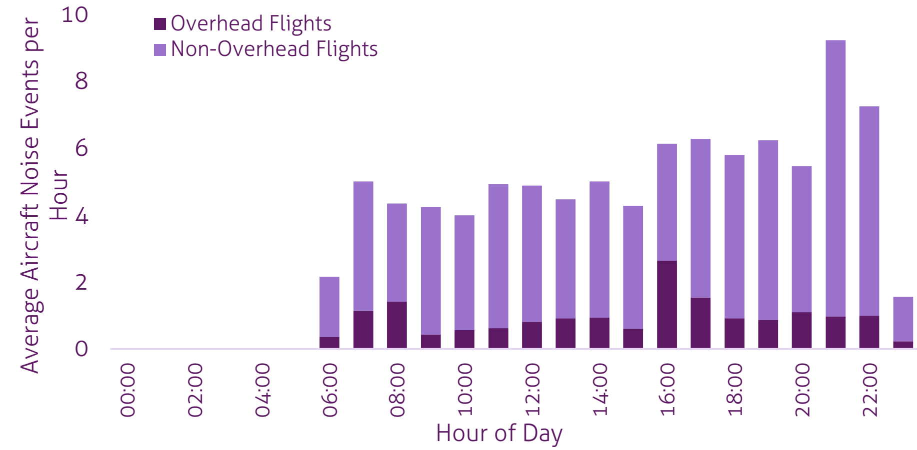
How does the number of aircraft noise events vary across a day?

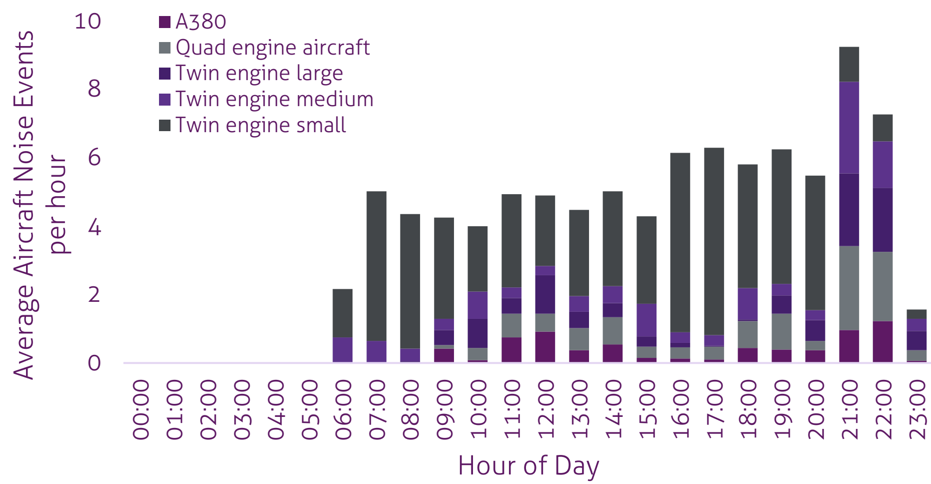
The top right figure shows the average number of noise events during each hour of the day for days of full easterly operations.

- During daytime hours, there were typically between 5 and 9 flights per hour of which between 0 and 3 were (passing within the 60° cone above the noise monitor).
- The two busiest hours of the day in terms noise events fell between 21:00 and 23:00, with 7-9 flights per hour. The busiest hour for overhead aircraft was 16:00-17:00.

The lower figure shows the same data broken down by aircraft size.

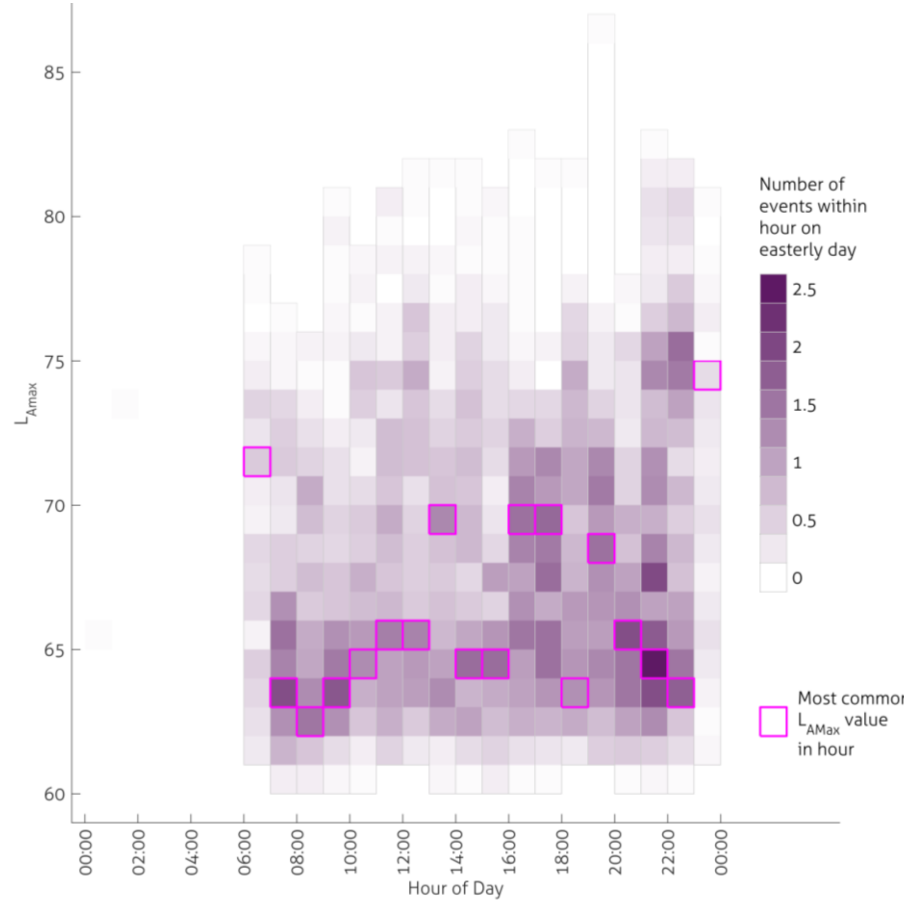
- Before 09:00, 84% of noise events were from small twin engine aircraft – predominantly the A320 family. Although there is some variation, the aircraft mix between 09:00 and 21:00 is fairly constant.
- Before 21:00 smaller twin-engine aircraft dominate. This drops to 11% between 21:00 and midnight when the proportion and number of the larger aircraft increases when compared with the rest of the day.
- On easterly days, three aircraft noise events were registered between the hours of midnight and 06:00 over the monitoring period. In the hours 06:00-07:00 and 23:00-24:00 there were approximately 2 and 1.5 noise events per easterly day respectively.
- The number of the noisier, larger wide body aircraft increasing in the evening hours is reflected in the N_{above} plots on the previous slide (p27).





How does the L_{Amax} vary across a day?

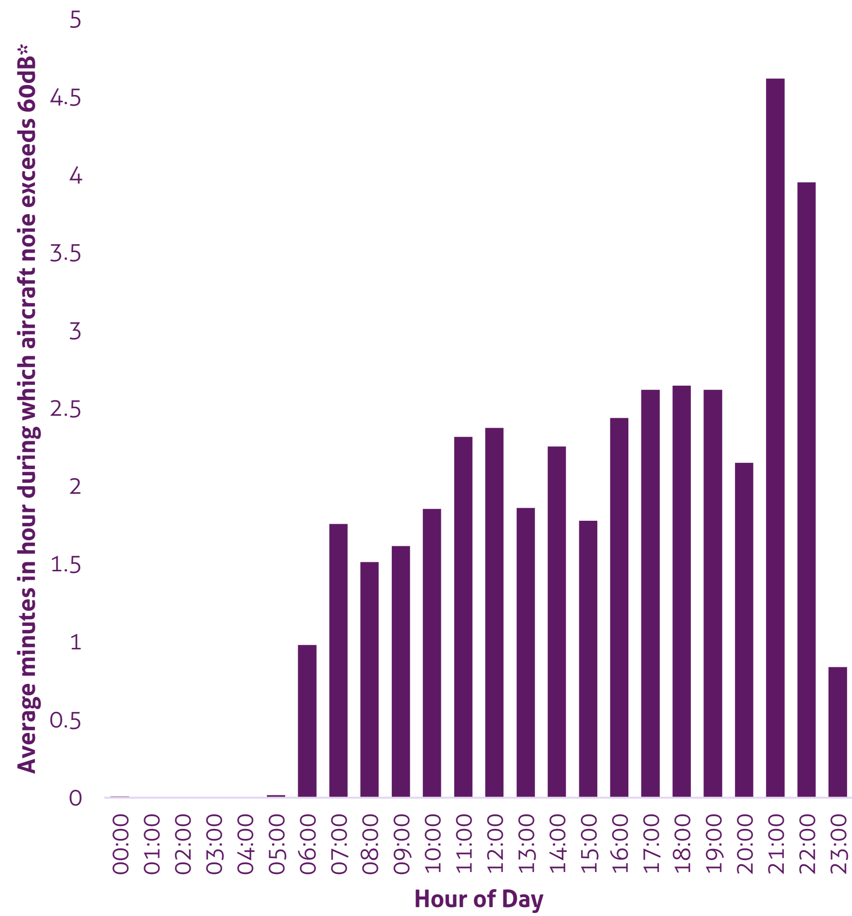
- The figure to the right shows the range of L_{Amax} values of aircraft noise events for each hour of the day. The average number of aircraft events in each decibel interval and hour on a typical easterly day is shown by the colour of each square; the darker the square, the more aircraft events occurred during that hour at a given level.
- The L_{Amax} value which occurred most often in each hour is highlighted by the pink border.
- During daytime hours, typical L_{Amax} values ranged between 63 and 66dB. The lowest average L_{Amax} occured between 08:00 and 09:00 when movements are dominated by smaller aircraft - 84% of the noise events are caused by smaller twin engine aircraft.
- There a larger number of louder event sin the hours 21:00-23:00, however, in these hours, the most common level is 63-65dB.



HELIOS

Average minutes in an hour during which aircraft noise exceeded monitor threshold.

- The figure to the right shows the average number of minutes in each hour when the sound level within an aircraft noise event exceeding the measured noise event threshold - in this case 60dBA – on a day of full easterly operations. At this location this could be described as the amount of time (in minutes) that the aircraft noise level exceeds 60 dBA.
- It should be noted that individual aircraft events may be audible when the level is below that of the monitor threshold and therefore the total time the events are audible may be greater than given in the figure. This would be particularly the case during the night when background noise is lowest.
- The figure shows that on 100% easterly days aircraft noise exceeded the monitor threshold for a total of between 1.5 and 2.6 minutes in each hour (2.5-4.3% of the hour) between the hours of 7am and 9pm.
- Between 9pm and 11pm this increased to 4-5minutes. As with other analysis, this increase is because of the B777 and B747 movements, which generate longer events.

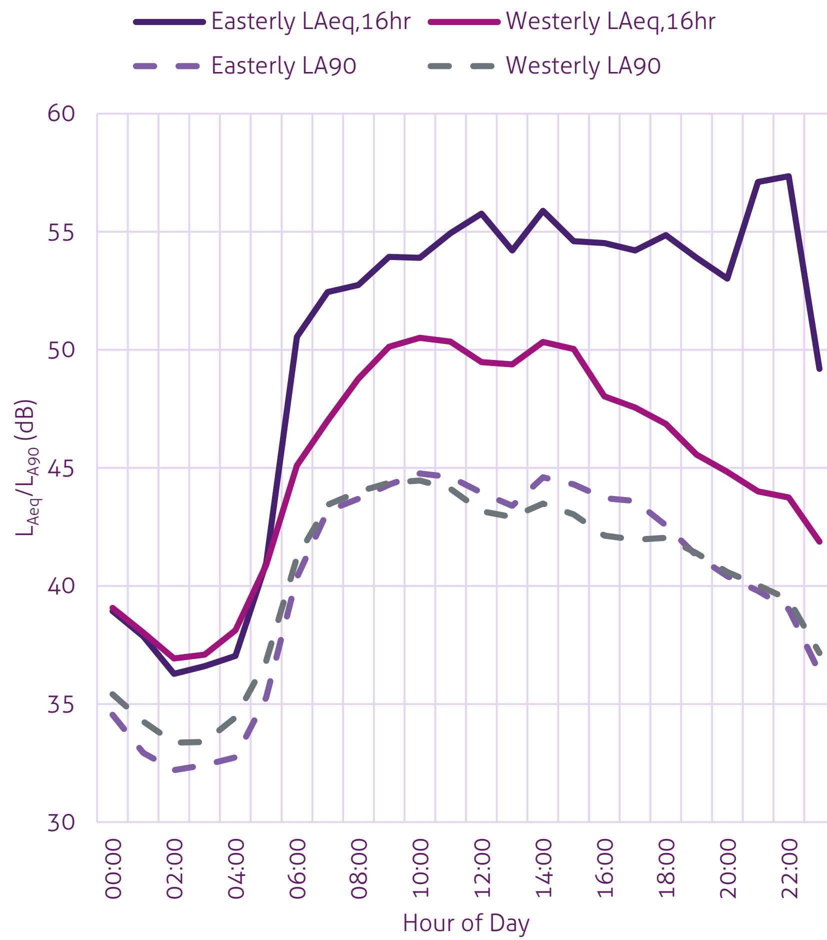


Note: It is important not to compare the results on this page with other sites since the individual threshold can vary from monitor to monitor. The same noise event would register a longer duration if a lower threshold were to be used.

Do aircraft contribute to overall ambient noise levels on days of easterly operations?

- The figure to the right shows the average (arithmetic mean) hourly $L_{Aeq,1hr}$ and $L_{A90,1hr}$ on days where 100% of operations were either westerly or easterly. It should be noted that these metrics describe the overall noise environment including all noise sources, not just aircraft noise.
- During days of full easterly operations daytime $L_{Aeq,1hr}$ values were between 3dB and 14dB higher when compared with the same hour during a full westerly day. This indicates that the overall noise environment for each hour is governed by aircraft noise when on easterly operations.
- During the period the monitor was in place, the average daytime $L_{Aeq,16hr,1hr\ average}$ between 07:00 and 23:00 was 48dB on westerly and 55dB on easterly operations from all noise sources*.
- During the night, the average $L_{Aeq,8hr,1hr\ average}$ between 23:00 and 07:00 was 41dB on westerly operations and 45dB on easterly operations.
- The contribution of aircraft noise to the noise environment is most discernible during the period 21:00 and 23:00. This is shown by a difference of more than 13dB between easterly and westerly $L_{Aeq,1hr}$ values. The $L_{Aeq,1hr}$ peaks between 21:00-23:00 reaching 57dB on easterly operations. The ambient noise levels are highest at this time during easterly operations but (across the day period) are the lowest at this time during westerly operations.
- The background noise ($L_{A90,1hr}$) across the day is similar on easterly and westerly operations.

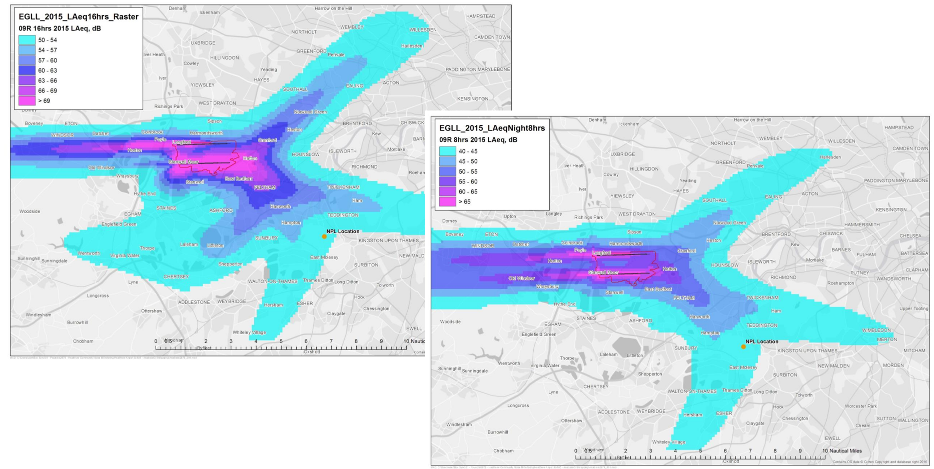
*Note: The $L_{Aeq,16hr,1hr\ average}$ has been derived by taking the logarithmic average of the 16 daytime hours where each day is an (arithmetic) average of each hour the in the day when the airport is on westerly or easterly operations. A similar calculation has been performed for the $L_{Aeq,8hr,1hr\ average}$

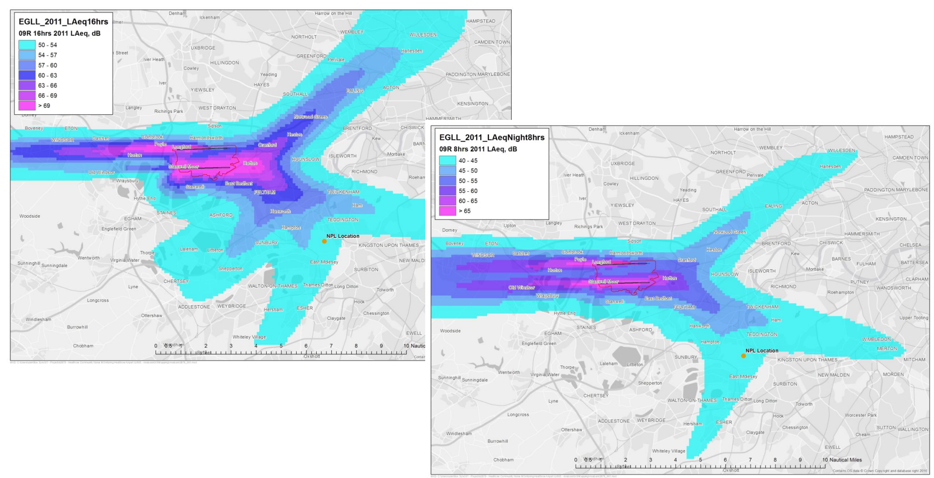


Please note the y-axis on the above plot does not start at 0dB

Comparing longer term average daytime ($L_{Aeq, 16hr}$ /N65) and night-time ($L_{Aeq, 8hr}$ /N60) aircraft noise levels around the airport using modelling.

- While a noise monitor can provide an in-depth picture of the noise environment at a specific location, the data cannot be used to provide an understanding of the noise environment over a wider geographical area.
- The Heathrow INM model has been run using flight track data for **2011 and 2015** to investigate whether there are any differences in daytime ($L_{Aeq, 16hr}$ /N65) and nighttime ($L_{Aeq, 8hr}$ /N60) for an **average day and night of easterly operations** across the summer in each of these years.
- Note that these contours are specific to easterly operations and are not the same as the traditional annual contours which derive an overall average for the summer that combines westerly and easterly operations. They only use days when there were full easterly operations across that day.
- Daytime $L_{Aeq, 16hr}$ values are presented in bands >50 dB, > 54dB and then in 3 dB increments to 69 dB.
- Night-time $L_{Aeq, 8hr}$ values are presented in 5dB bands starting at >40 dB to 65 dB.
- These are longer terms metrics averaged over 16 and 8hrs and do not directly reflect the shorter term fluctuations between individual events.
- It should be noted that aircraft noise modelling to levels around 50 dB carries increasing uncertainty in the result. In areas where aircraft noise levels are in this range it should be noted that many non aircraft noise sources may be of similar (or even higher) levels. Interpretation of the modelled results at this noise level should bear this mind.





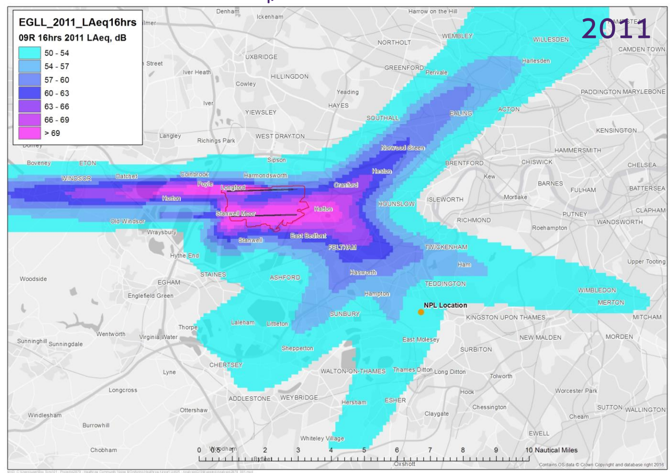
Modelled average **daytime** $L_{Aeq, 16\,hour}$ and N65 aircraft noise levels

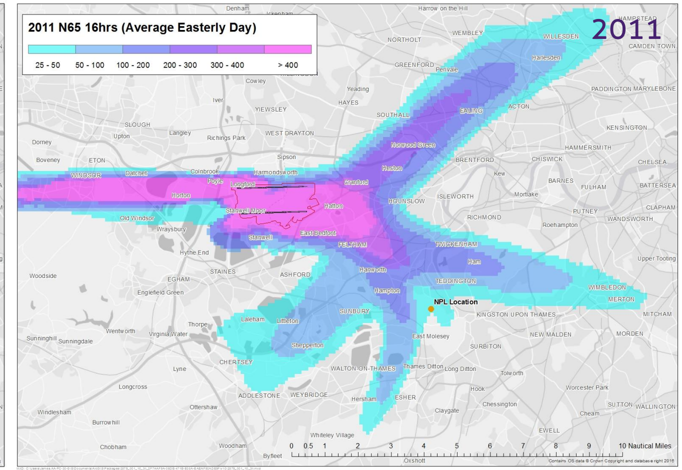
- The figures to the right show the 2011 and 2015 daytime $L_{Aeq, 16hr}$ bands in the left column and N65 bands in the right column for **an average easterly summer day when the airport is on 100% easterly operations**.
- The position of the noise monitor is marked by the orange dot.
- The N65 is defined as the number of aircraft noise events where the L_{Amax} exceeds 65dBA over the 16 hour day period between 7am and 11pm.

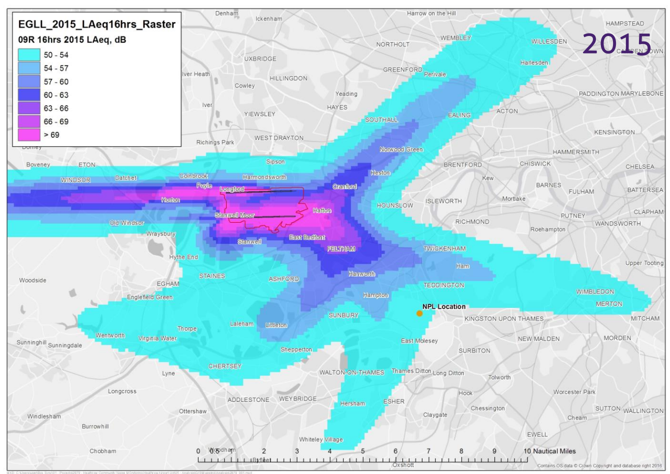
- Larger figures are shown in Appendix A.

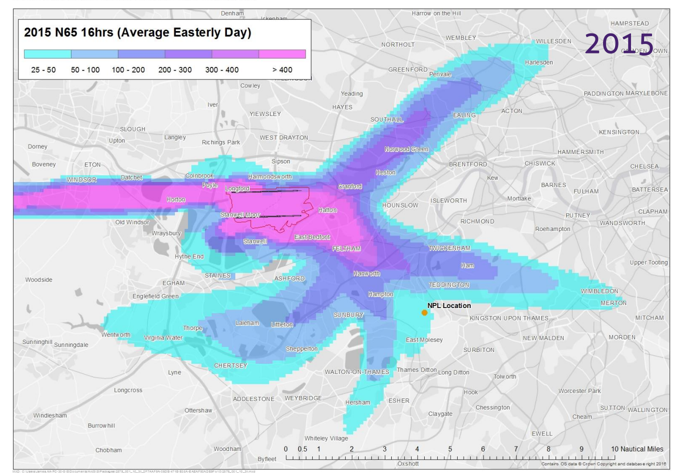
$L_{Aeq,16hr}$

N65, Daytime





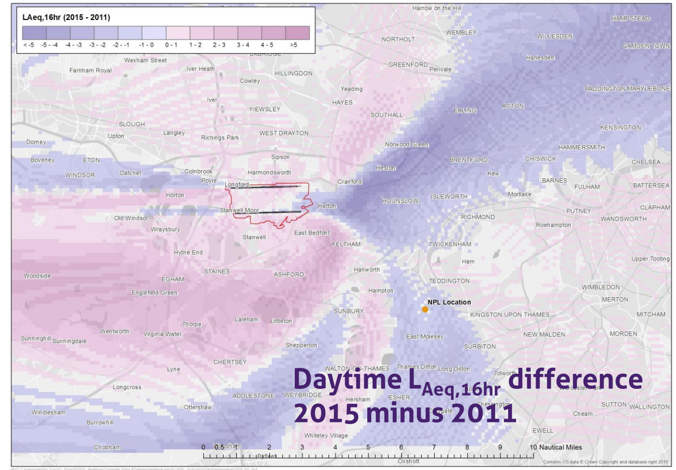


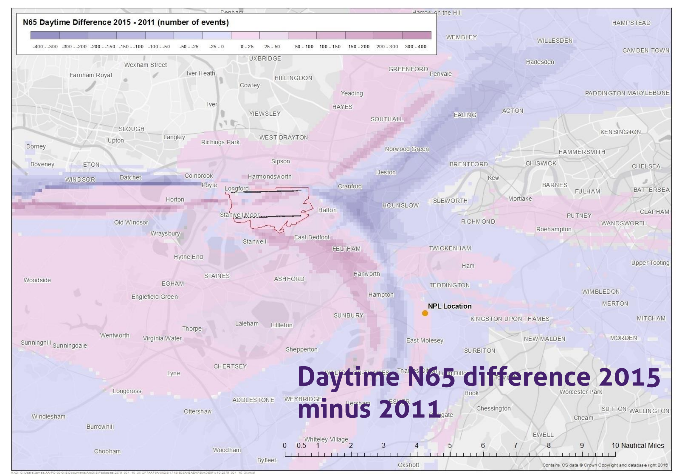


Modelled **daytime** $L_{Aeq,\,16\,hour}$ and $N65_{(16\,hour)}$ differences - 2011 to 2015

- The difference in the modelled average $L_{Aeq,\,16hr}$ and $N65_{16\,hr}$ contours around Heathrow between 2011 and 2015 are shown in the figures to the right. This is for **an average easterly summer day when the airport is on 100% easterly operations**
- The upper image shows the change in daytime $L_{Aeq,16hr}$ and the bottom image shows the change in daytime $N65_{16hr}$. Areas with a decrease in average exposure are shown in blue and those areas with an increase in average exposure shown in pink.
- At NPL there was less than a 1dB difference in average modelled daytime noise level $L_{Aeq,16hr}$ between 2011 and 2015 at 52dB.
- The modelling indicates an increase of up to around 7 (+25%) daytime N65 events.
- It should be noted that, all other variables remaining constant, a difference in 26% of noise events, would correspond to about a 1dB increase/decrease in $L_{Aeq,16hr}$.

- Larger figures are shown in Appendix A.



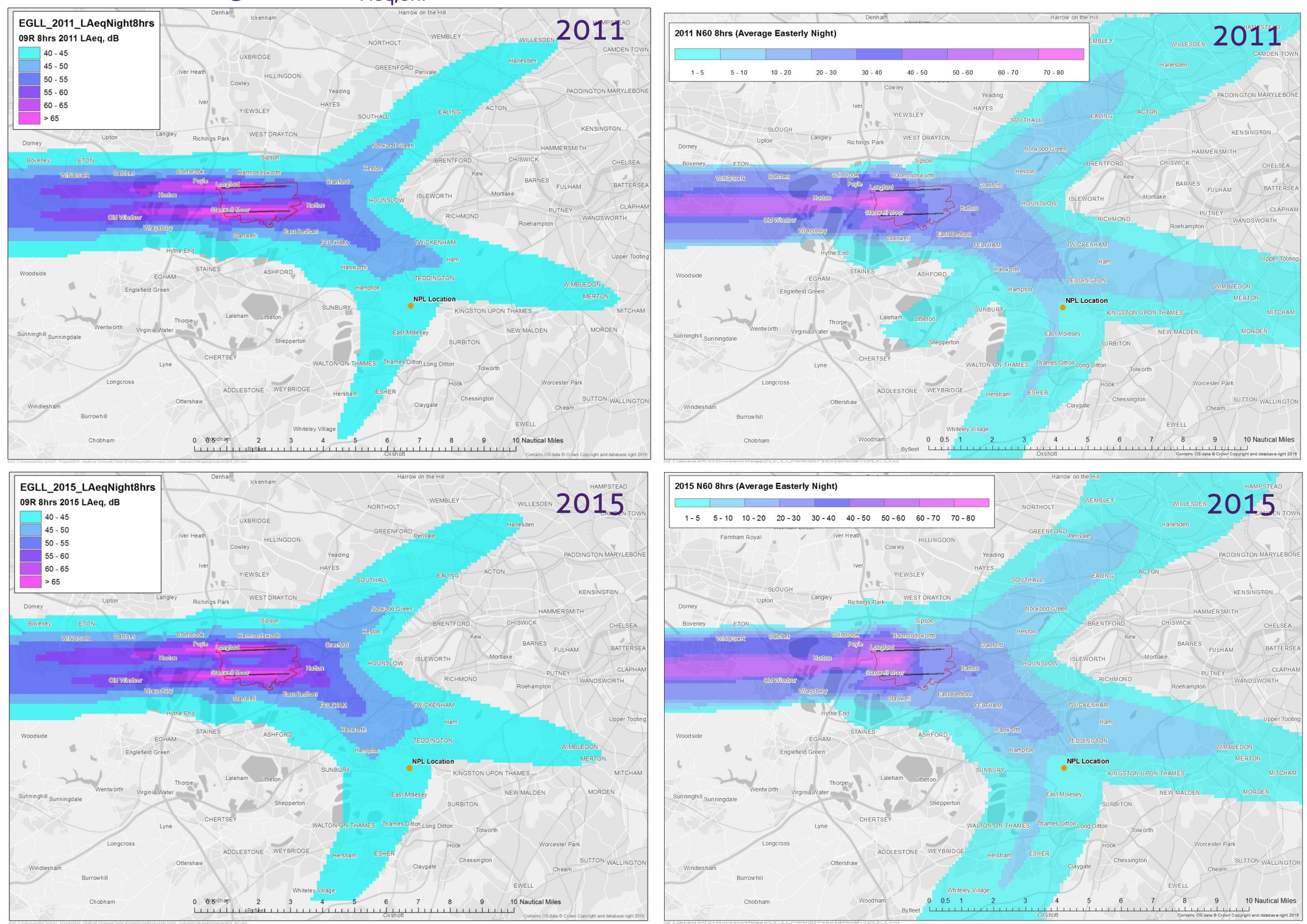


HELIOS

Modelled average **night time** $L_{Aeq,\,8hr}$ and N60 aircraft noise levels.

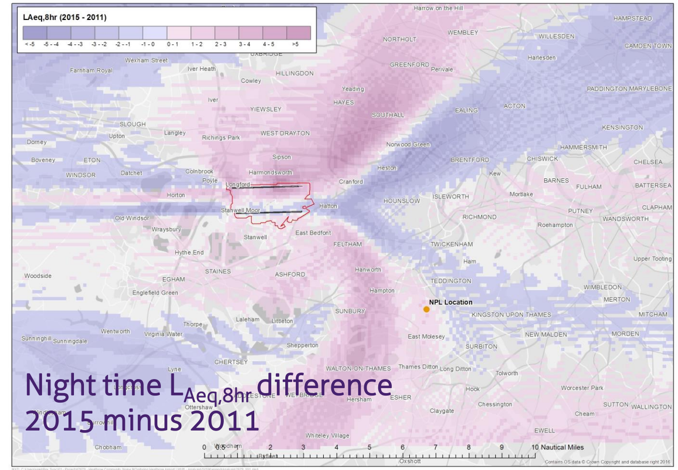
- The figures to the right show the 2011 and 2015 night-time $L_{Aeq,\,8hr}$ bands in the left column and N60 bands in the right column. This is an average noise level on an average easterly summer night between 11pm and 7am when there are 100% easterly operations. Generated from **an average easterly summer day when the airport is on 100% easterly operations**
- The $L_{Aeq,8hr}$ contours are presented in 5dB intervals from >40 to > 65dB.
- The N60 is defined here as the number of aircraft noise events that exceed 60dBA over the 8 hour night period between 11pm and 7am.
- The figures to the right shows the average $N60_{8hr}$ values for 2011 and 2015 from 1 up to greater than 80 when the airport is on easterly operations.
- Larger figures are shown in Appendix A.

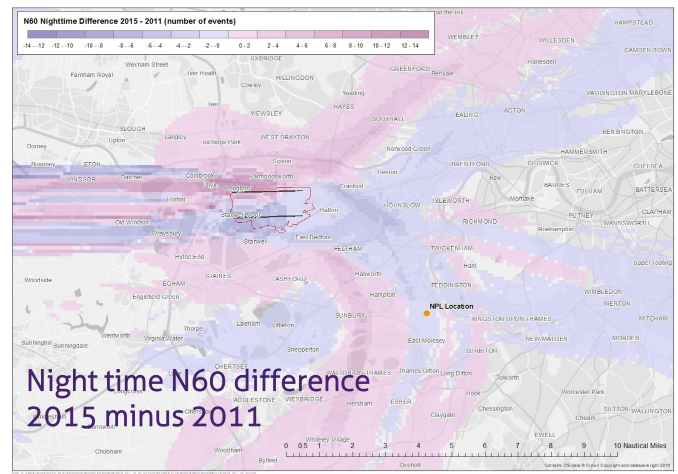
Night-time $L_{Aeq,8hr}$ | N60, night-time



Modelled average **night-time** $L_{Aeq,\,8hr}$ and N65 differences - 2011 to 2015

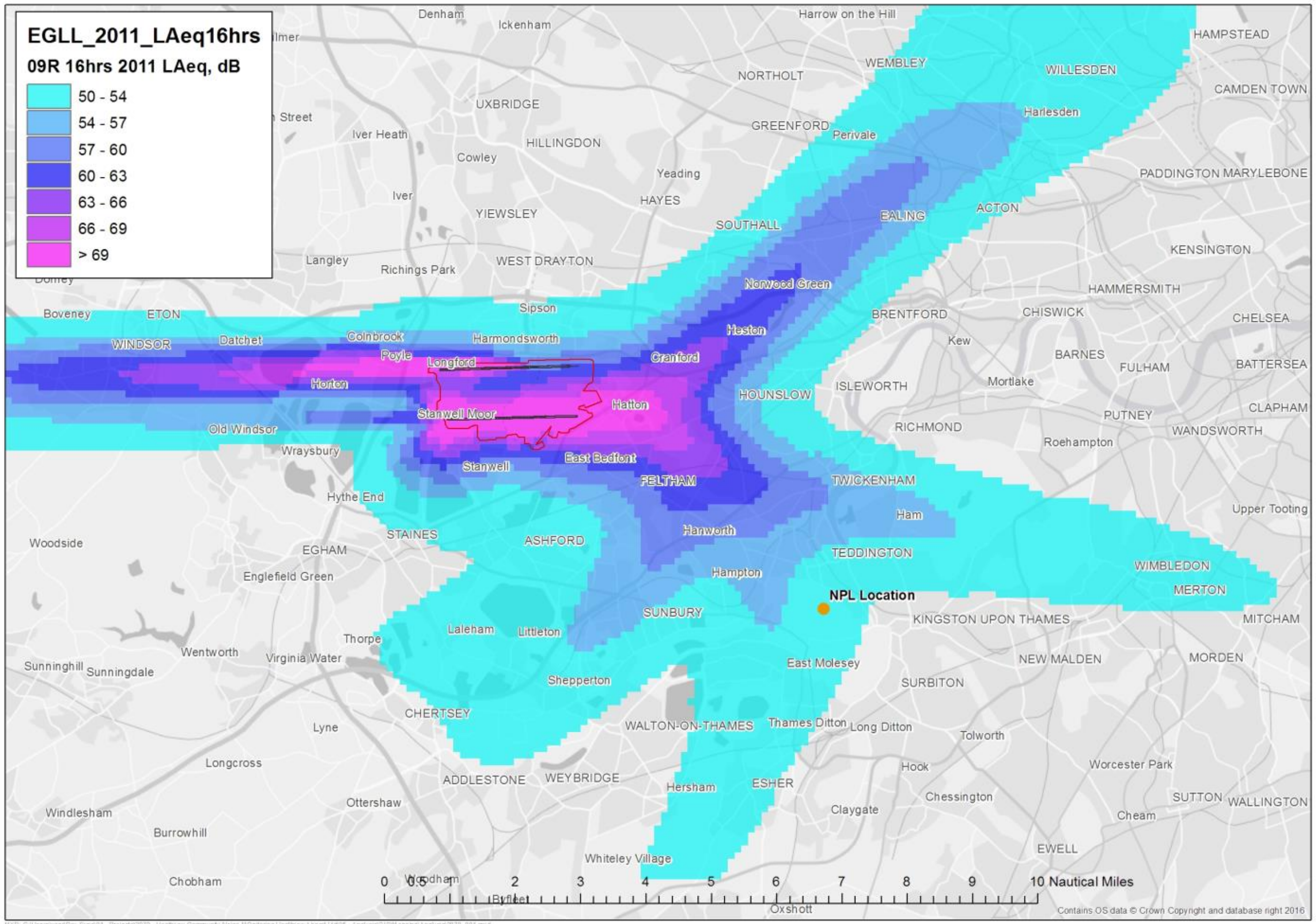
- The difference in the modelled average $L_{Aeq,\,8hr}$ (upper figure) and $N60_{(8\ hr)}$ (lower figure) values around Heathrow between 2011 and 2015 are shown in the figures to the right.
- Areas with an average decrease are shown in blue and those areas with an average increase in pink.
- The results indicate an increase in $L_{Aeq,8hr}$ of 1dB and a marginal reduction in N60 at NPL from 2011 to 2015.
- Larger figures are shown in Appendix A.



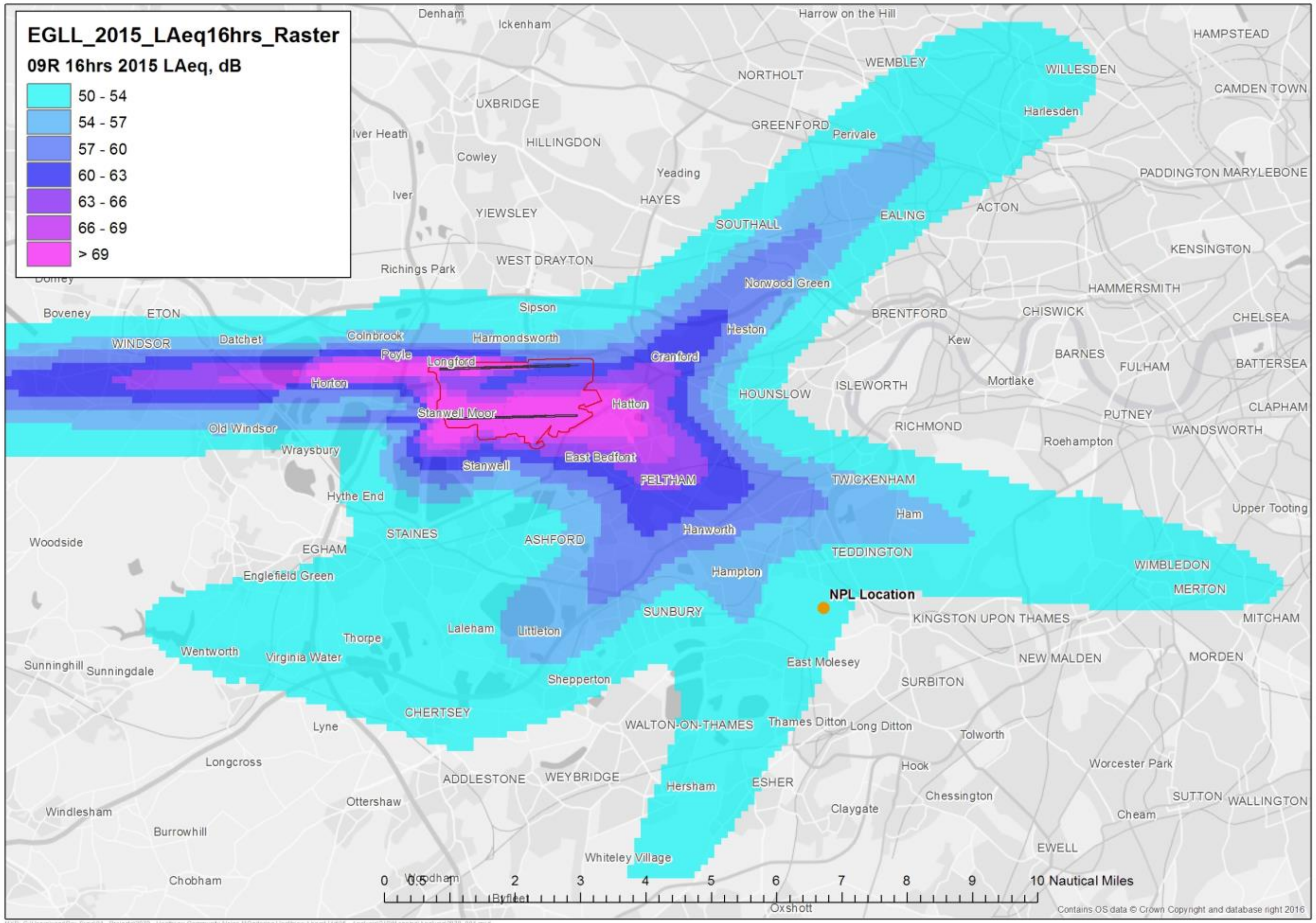


HELIOS

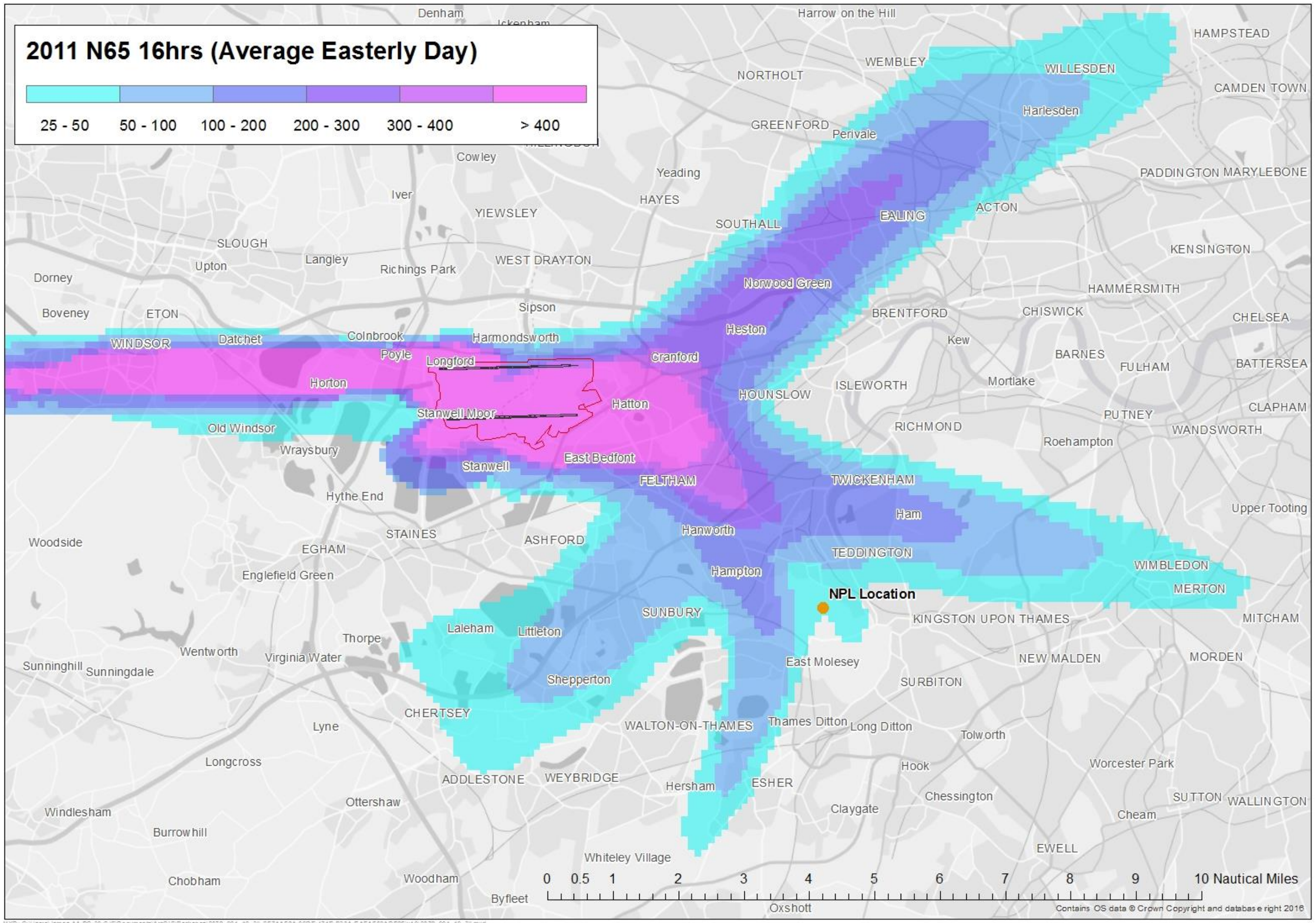
Appendix A: $L_{Aeq,\ 16hr}$ contours (2011)



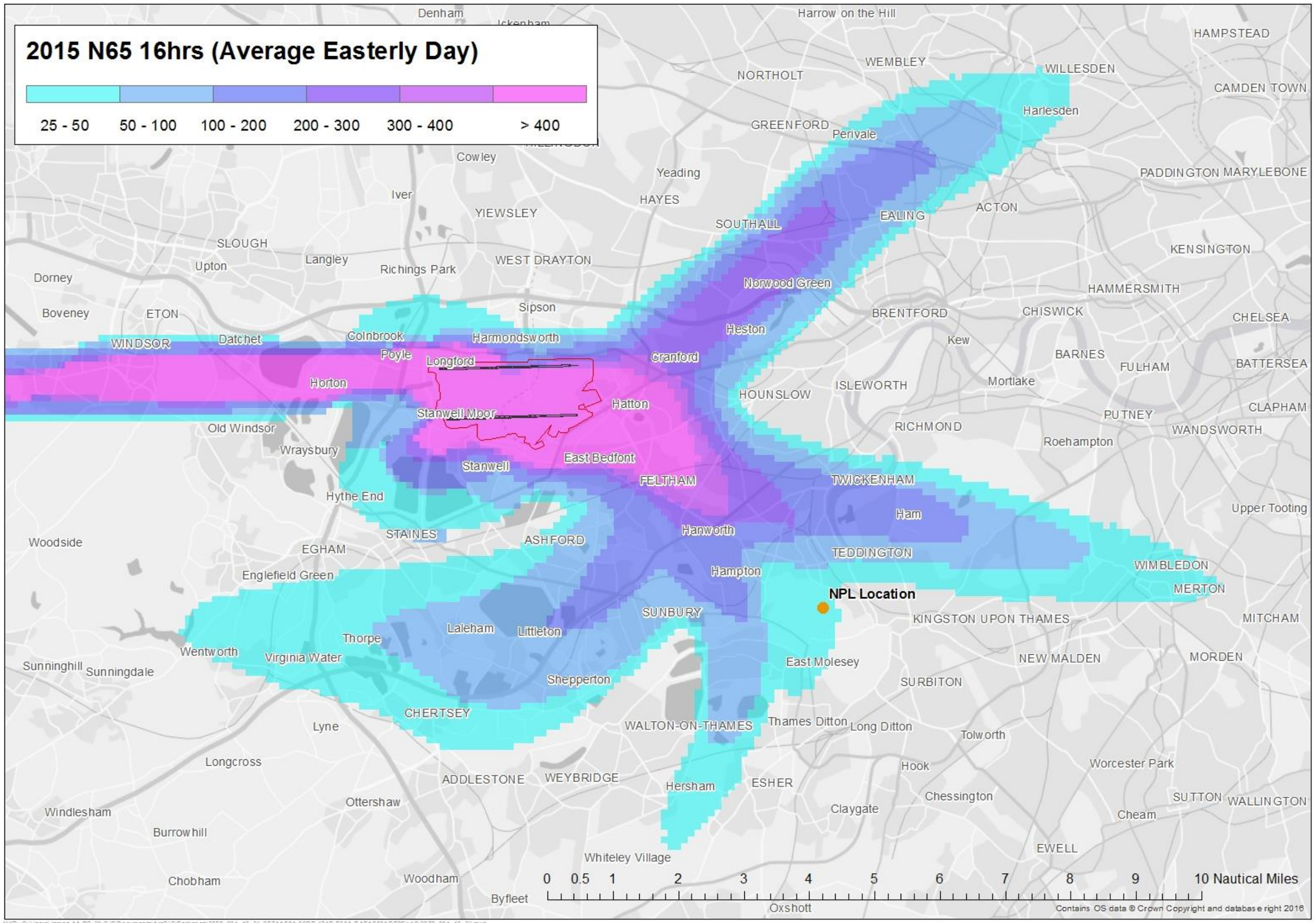
Appendix A: $L_{Aeq, 16hr}$ contours (2015)



Appendix A: $N65_{16hr}$ contours (2011)

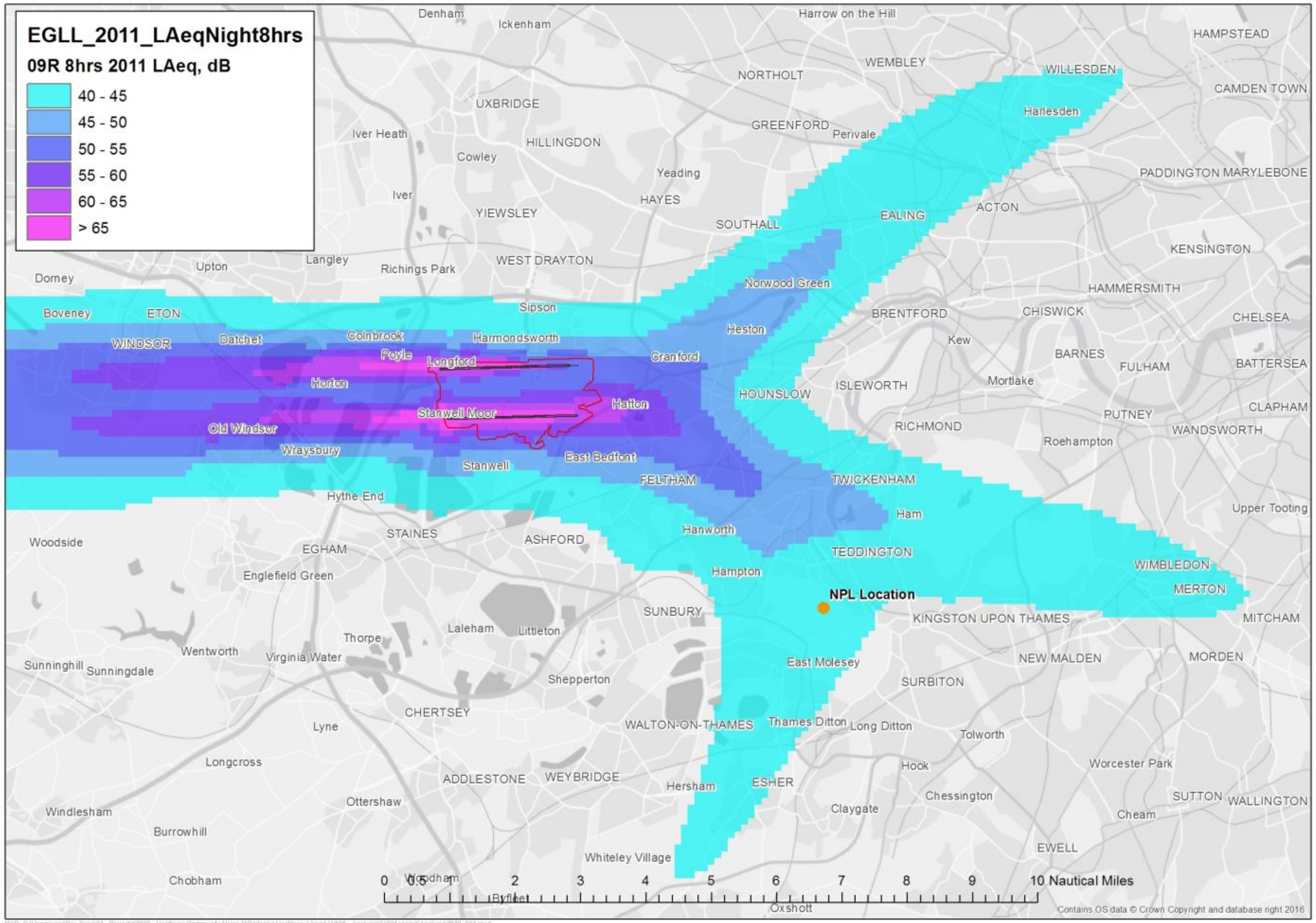


Appendix A: $N65_{16hr}$ contours (2015)

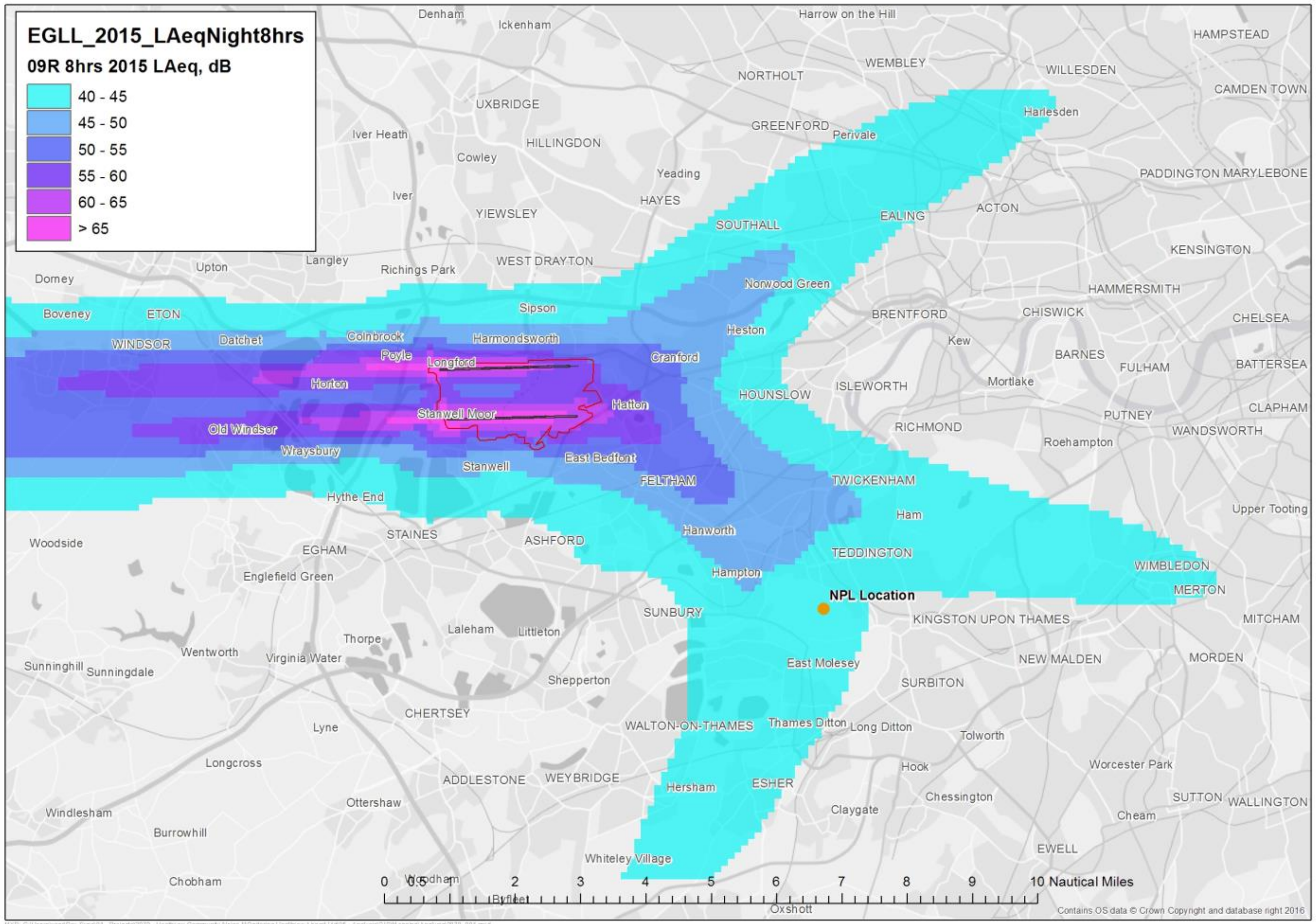


HELIOS

Appendix A: $L_{Aeq, 8hr}$ contours (2011)

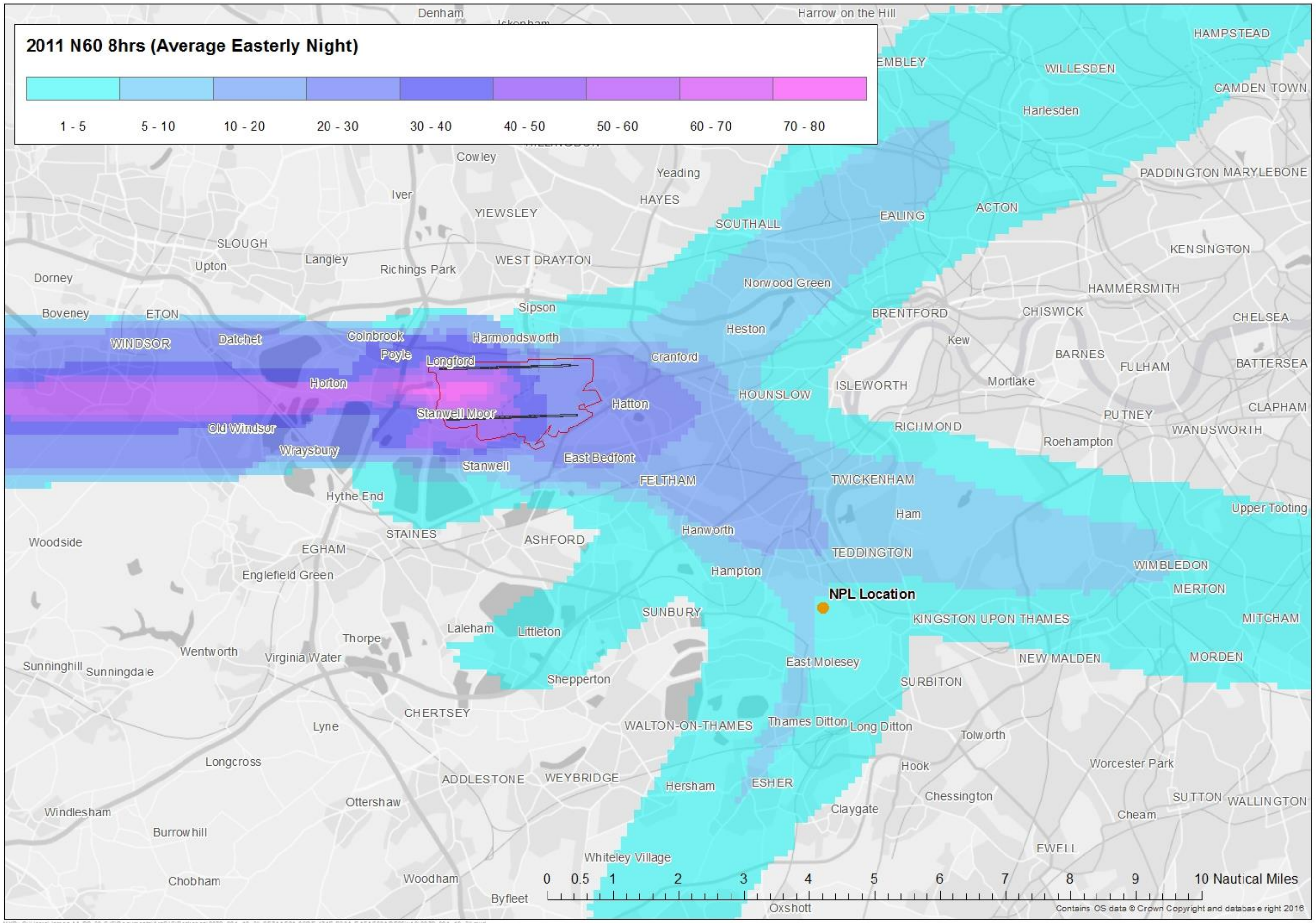


Appendix A: $L_{Aeq, 8hr}$ contours (2015)

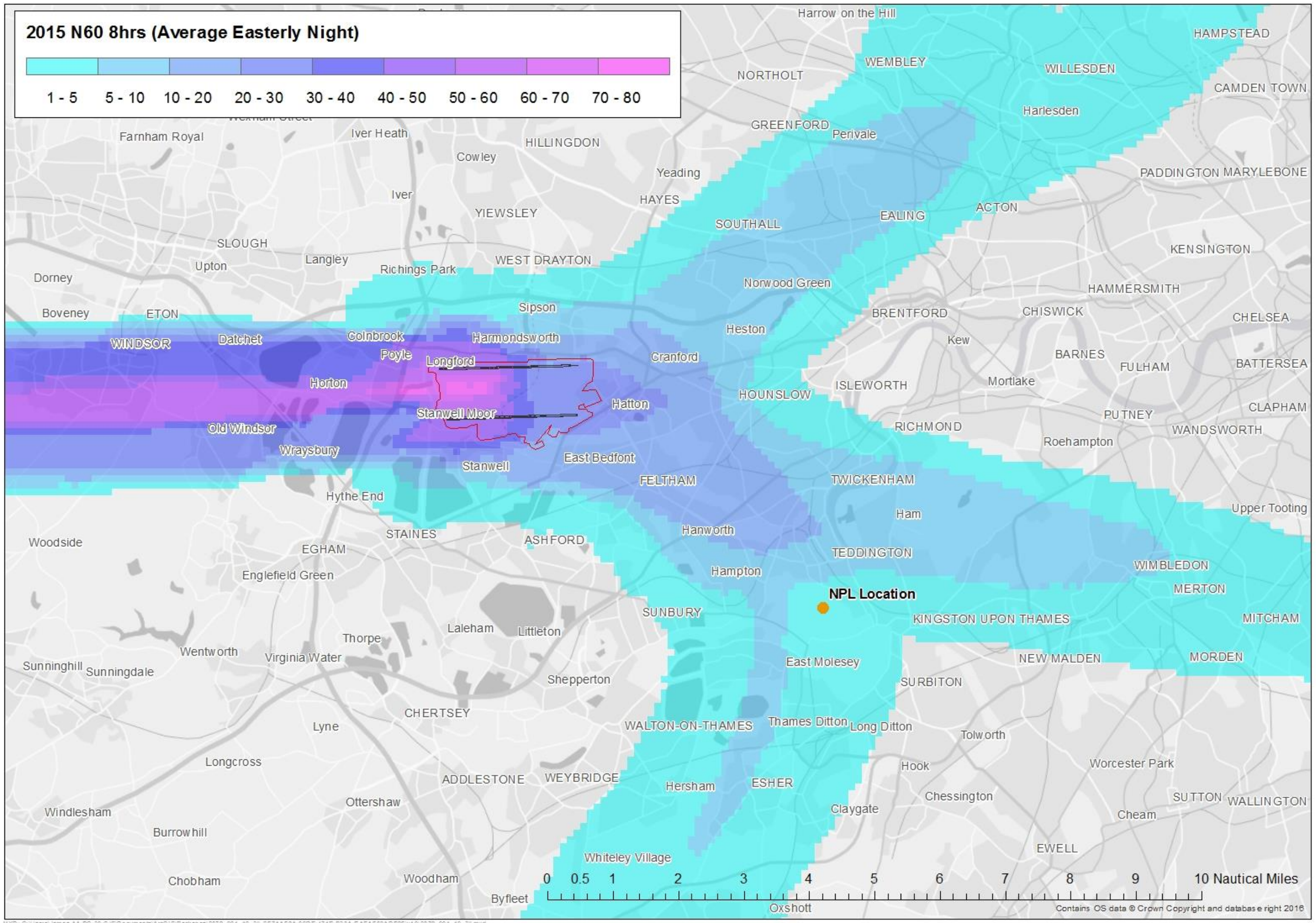


HELIOS

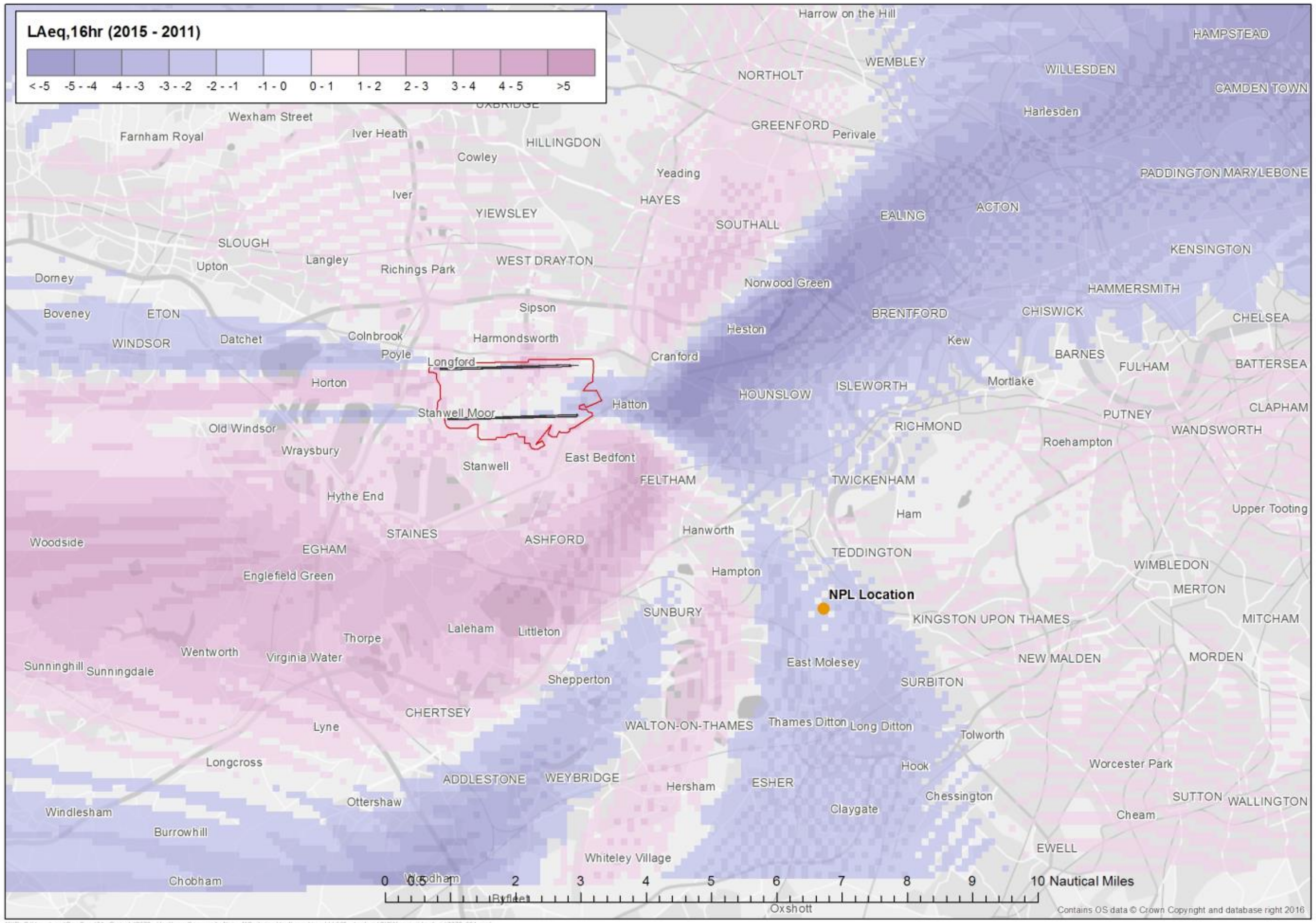
Appendix A: $N60_{8hr}$ contours (2011)



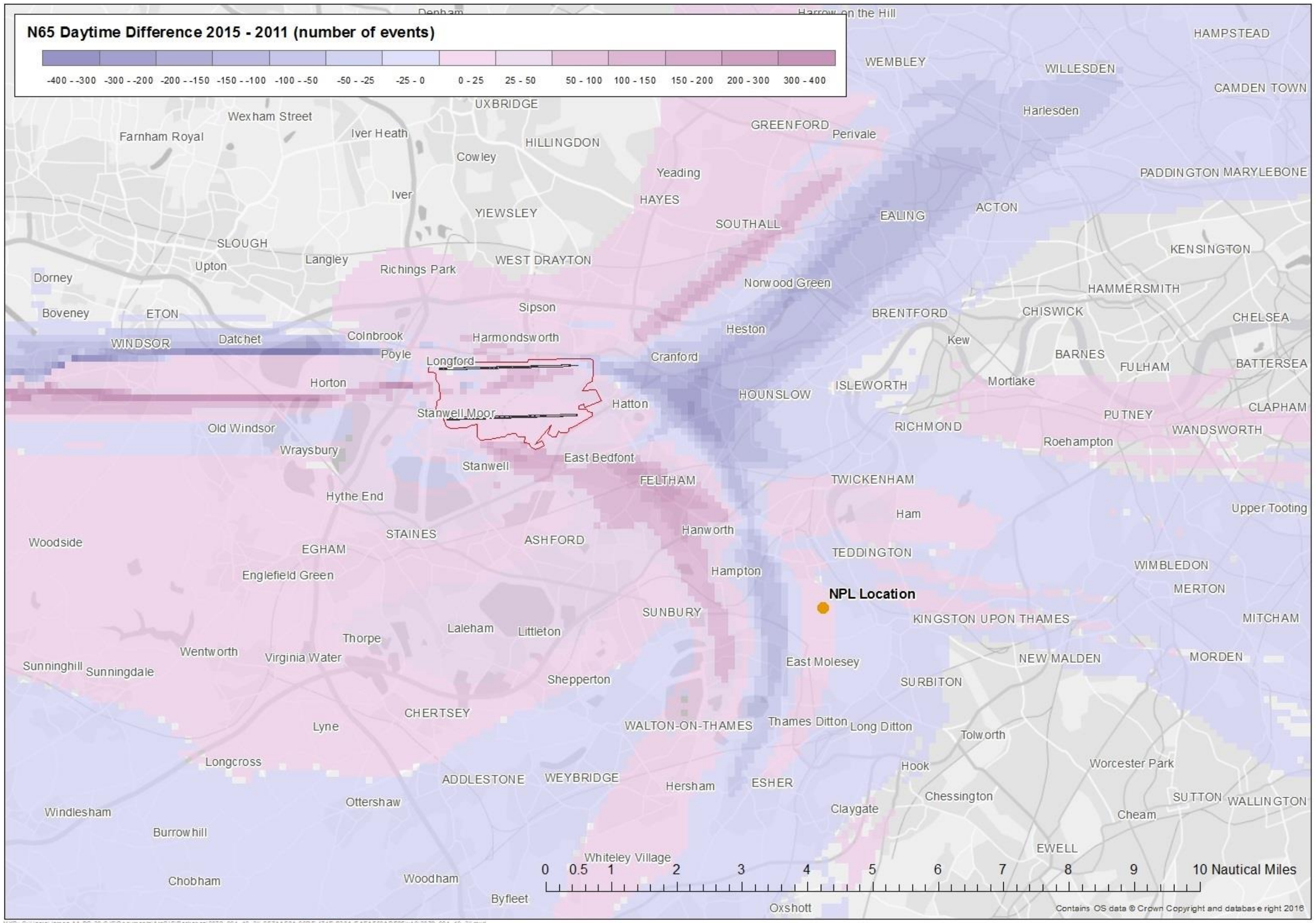
Appendix A: $N60_{8hr}$ contours (2015)



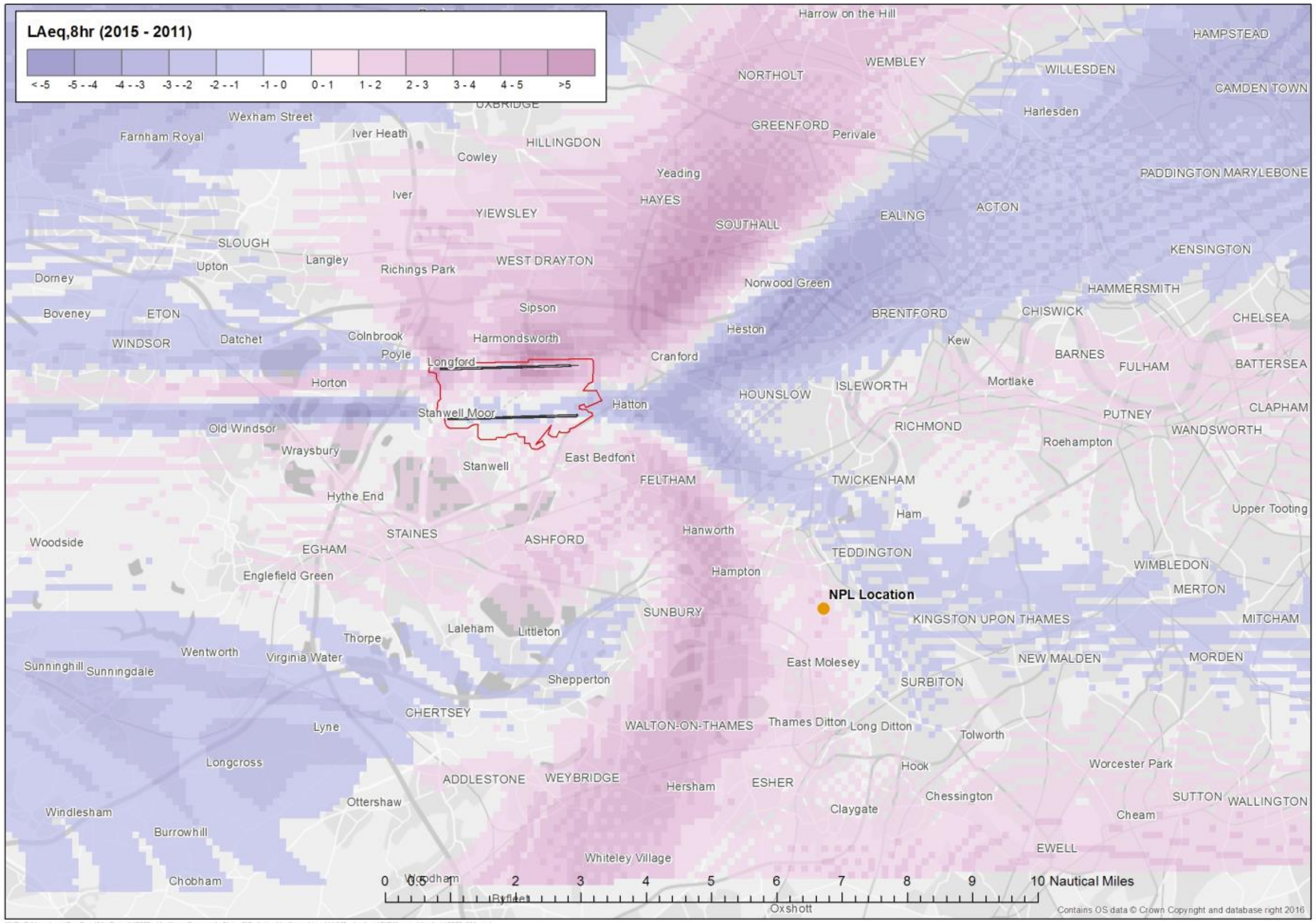
Appendix A: $L_{Aeq, 16hr}$ difference (2015 minus 2011)



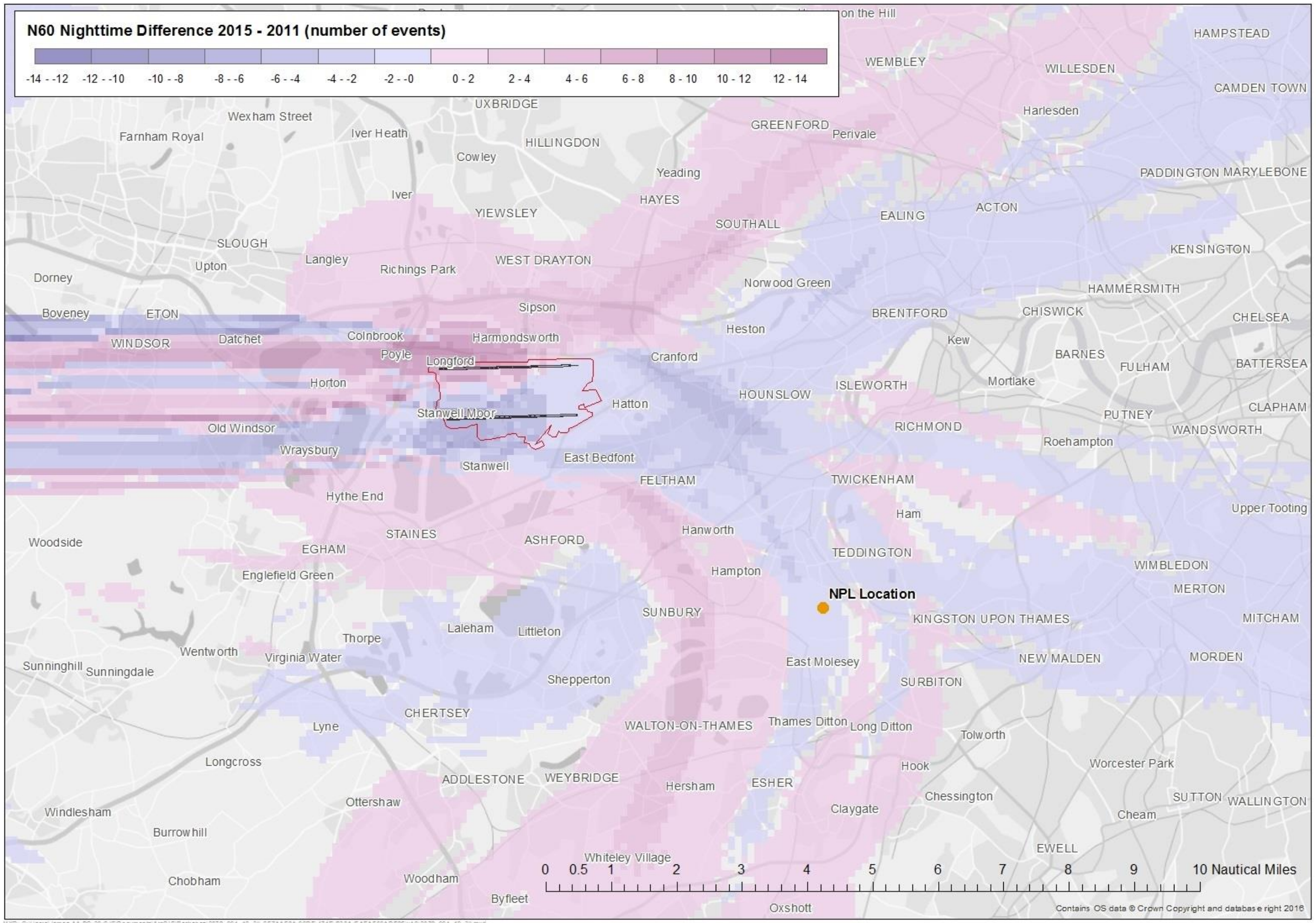
Appendix A: $N65_{16hr}$ difference (2015 minus 2011)



Appendix A: $L_{Aeq, 8hr}$ difference (2015 minus 2011)



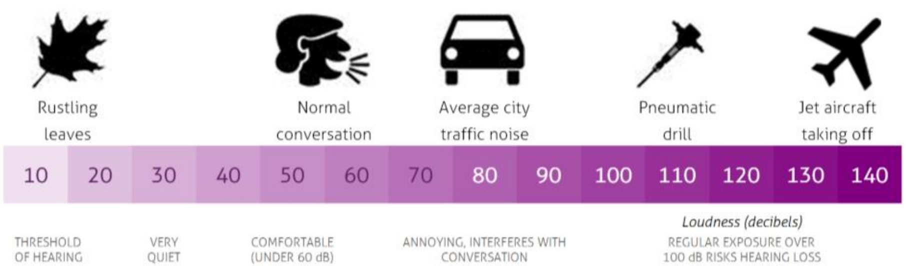
Appendix A: $N60_{8hr}$ difference (2015 minus 2011)



Appendix B: Noise Terminology

How is noise measured?

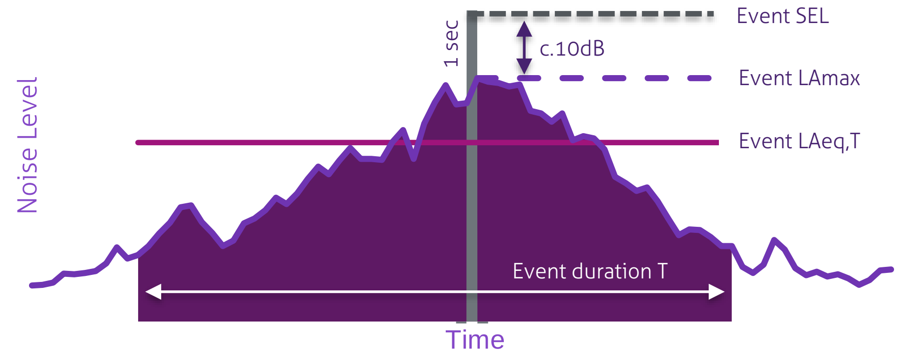
There is a million to one ratio between the threshold of hearing and the highest tolerable sound pressure. Noise is therefore measured using a logarithmic scale, to account for this wide range, called the decibel (dB). Typical noise levels of everyday sounds are shown in the figure below.



The human ear is capable of detecting sound over a range of frequencies from around 20 Hz to 20 kHz, however its response varies depending on the frequency and is most sensitive to sounds in the mid frequency range of 1 kHz to 5 kHz. Instrumentation used to measure noise is therefore weighted across the frequency bands to represent the sensitivity of the ear. This is called 'A weighting' and is represented as dB(A). All units in this report use this A-weighting.

How is aircraft noise measured?

As an aircraft passes over a location, noise levels slowly increase from ambient levels, reach a maximum and decrease back down to ambient levels. An example flyover is shown below.



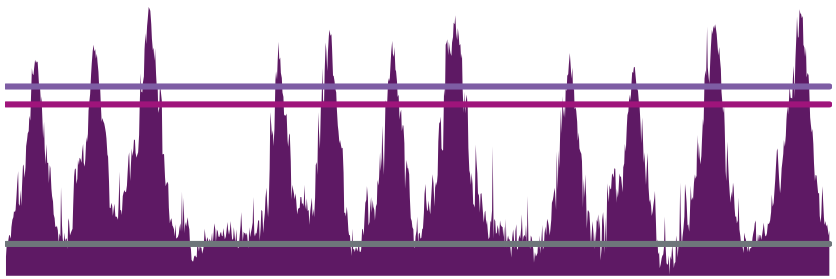
There are a number of metrics that can then be used to characterise a noise event all of which can be derived from modelling:

- The L_{Amax} is the highest sound pressure level during the event, it is an instant value, this is used typically with noise limits;
- The $L_{Aeq,t}$ is the continuous sound pressure level that would generate the same energy as that of the fluctuating noise level during the event of period T. It is in effect the average noise level over the time of the event;
- The SEL (sound exposure level or single event level), is the sound pressure that would arise for if all the energy of the event were to be delivered in 1 second.

Appendix B: Noise Terminology

How is long term noise exposure measured?

The L_{Amax} and SEL are useful at describing the noise level of individual events but how is aircraft noise exposure measured over time? The standard approach is based on long term averages such as the L_{Aeq} in the UK. The L_{Aeq} for a period of aircraft overflights is demonstrated in the figure below.



Although the L_{Aeq} plays a role in policy and planning assessment it does not adequately describe community experience. Supplementary noise metrics have been developed to better reflect community experience in simpler language. For example, the N65 describes the number of events which exceed 65dB which, in the above example, would be 11 over the period displayed.

The L_{A90} is a useful indicator of background noise in the absence of aircraft or other distinctive noise events. The L_{A90} is defined as the noise level which is exceeded for more 90% of monitored period and is demonstrated by the grey line in the figure above.

How does noise vary with distance?

As we move away from a sound source, the level we hear reduces since the sound energy is spread over a larger and larger area. If we assume a source emits sound equally in all directions, we can generate some rules regarding sound levels at different distances. For example, if the distance between a source and the receiver is doubled, the sound level will reduce by 6dB or if it is increase by a factor of 10 the level will reduce by 20dB.

Ratio of Distances	Level difference
1	0dB
1.25	2dB
1.5	3.5dB
2	6dB
5	14dB
10	20dB

Appendix B: Noise Terminology

How is noise level related to loudness?

Loudness is a subjective measure that describes the perceived strength of a sound. It is related to sound level but also related to other parameters such as frequency and duration. The table below provides an indication of the how the perceived loudness of a sound changes with an increase or decrease in sound level. For example, an increase of 10dB corresponds to a doubling of perceived loudness. It should be noted that the table below should only act as a guide to the relationship between level and perceived loudness – since loudness is a subjective measure, the same sound will not create the same loudness perception by all individuals

Level difference (dB)	Loudness Perception
+20dB	x 4
+10dB	x 2
+6dB	x 1.5
+3dB	x 1.2
±0dB	0
-3dB	÷ 1.2
-6dB	÷ 1.5
-10dB	÷ 2
-20dB	÷ 4

How does average noise level relate to number of events?

Average noise levels ($L_{Aeq,T}$) are determined by not only the level of individual aircraft events but also the frequency of which they occur. Due to the logarithmic nature in which noise is measured, a doubling of noise energy relates to a 3dB increase in average noise level. Therefore, if the number of events is doubled over a given time period (assuming the levels of individual events are the same), the $L_{Aeq, T}$ will increase by 3dB. Likewise, a 26% increase in events will raise the $L_{Aeq, T}$ by 1dB. Further factors are shown in the table below.

Number of Events	Noise level difference
x4	+6dB
x2	+3dB
x1.58	+2dB
x1.26	+1dB
0	0
÷1.26	-1dB
÷1.58	-2dB
÷2	-3dB
÷4	-6dB