University of Salford MANCHESTER

Acoustics Research Centre

A.J.TorijaMartinez@salford.ac.uk

https://hub.salford.ac.uk/sirc-acoustics/

USAL-SoNA2: Technical Review of Phase 2 of the Survey of Noise Attitudes (SoNA) studies.

Gethin Manuel & Antonio J. Torija Martinez

University of Salford, UK.

Client:	Department for Transport
Address:	Great Minster House
	33 Horseferry Road
	Westminster
	London
	SW1P 4dR
Report reference	USAL-SoNA2
Report Issue Date:	April 26th, 2021

Signed: ………………………………………………………….

Mr. Gethin Manuel

Approved: ……………………………………………….

Dr. Antonio J Torija Martinez

Executive Summary

Scope

- This report includes the technical review of the analysis carried out by the Civil Aviation Authority (CAA) for the Survey of Noise Attitudes (SoNA) studies.
- The CAA's Environmental Research and Consultancy Department (ERCD) has analysed social survey data in conjunction with noise modelling to draw conclusions on attitudes to aircraft noise.
- The Department for Transport (DfT), the client, intend to use these conclusions to help their management of noise at the designated airports, and for developing policies relating to aircraft noise.
- This technical review covers the **Phase 2: SoNA2 Annoyance and Sleep**.
- This report presents the findings of the technical peer review of the calculations which underpin the analysis presented in Phase 2: SoNA2 Annoyance and Sleep studies.

Objectives

- Assure DfT, the client, that the analysis has been undertaken accurately and meet relevant standards.
- Assure the studies' audience, which comprises academics, community, industry and other government stakeholders, that the conclusions drawn are reliable and based on robust analysis.

Conclusions

- These reviewers have investigated the integrity and robustness of the respite categorisation at Heathrow Airport, the calculation of change in noise dose in consecutive years (i.e. 2013 and 2014) and the procedure to calculate additional awakenings at Heathrow Airport.
- These reviewers have inspected the calculations and master datasets used in Phase 2: SoNA2 Annoyance and Sleep studies.
- **These reviewers are confident that the calculations and analyses undertaken are accurate, reliable and robust**, and meet standard practice in the field.
- Some recommendations are included to expand the analysis of departure operations in the noise respite studies at Heathrow, and to analyse the relationship between number of events (e.g. Number Above a given L_{Amax}) and the number of additional awakenings.

Table of Contents

1. Review of respite categorisation at Heathrow Airport

This task is performed according to Appendix C in the SoNA Peer Review scope document (attached). This appendix presents the methodology to quantify the amount of respite experienced by respondents around Heathrow airport during westerly operations. The SoNA Peer Review scope document specifically mentions *"westerly arrival and departure operations"* to be included in the analysis. Westerly departure operations were included in the respite analysis but given that the routes from the 27L and 27R runways converge soon after take-off, CAA found that there was no statistical association between departure respite and annoyance responses.

During the review process, the colleagues of the CAA explained the different steps for the calculation of sound levels at respondent locations under morning and afternoon westerly alternation patters. CAA also described the procedure of quantifying respite.

1.1 Calculation of sound levels at respondent locations

$L_{Aeq,8h}$ and L_{Amax} sound levels were calculated using ANCON at each of the respondent locations using an MNX file, as a list of points. For four westerly runway alternation patterns described according to which runway (27L or 27R) are designated for arrivals during either the morning (06:00-15:00) or afternoon (from 15:00 until the last departure of the day) period.

i. Morning period when 27R is the designated runway for arrivals
ii. Afternoon period when 27R is the designated runway for arrivals
iii. Morning period when 27L is the designated runway for arrivals
iv. Afternoon period when 27L is the designated runway for arrivals

Within the relevant Microsoft Excel Spreadsheet for noise dose differences (e.g. LHR14_Westerky_MNX_results_ARR.xlsx), are separate tabs containing the sound levels calculated by ANCON at each receiver location. As said above, only the data from arrivals was carried through to the spreadsheet. During this technical review, CAA offered to share the respite noise calculations for departure operations, but these reviewers were content to use the arrivals review as representative of the approach taken.

Sound levels calculated by ANCON (i.e. $L_{Aeq,8h}$ and L_{Amax}) were split into runway 27L and 27R. The sound levels were also separated into the corresponding morning and afternoon periods.

This sound levels data is organised within Microsoft Excel by respondent location using a serial number, along with grid coordinates. Terrain is accounted for using heights of the respondent ID's relative to Heathrow airport. As the objective is to calculate an overall noise dose, a logarithmic average of sound levels is carried out.

'Out of alternation arrival' flights as a result of Tactically Enhanced Arrival Measures are accounted for.

By taking into account all possible alternation patterns, weekly (e.g. Difference A27R – A27L Morning) and daily (e.g. Difference A27R Morning – A27L Evening) differences in level are calculated for the parameters shown in Table 1.

Table 1: Parameters calculated for each respondent location, for the determination of the minimum difference in $L_{Aeq,8h}$ and L_{Amax} for each respite scenario.

<table>
<tr><th>Receiver Locations</th><th colspan="2">Weekly Differences</th><th colspan="2">Daily Differences</th></tr>
<tr><td rowspan="7">e.g. Location 1</td><td>Morning Right (27R) – Morning Left (27L)</td><td>Evening Right (27R) – Evening Left (27L)</td><td>Morning Right (27R) – Evening Left (27L)</td><td>Morning Left (27L) – Evening Right (27R)</td></tr>
<tr><td colspan="2">$L_{Aeq,8h}$</td><td colspan="2">$L_{Aeq,8h}$</td></tr>
<tr><td colspan="2">L_{Amax}</td><td colspan="2">L_{Amax}</td></tr>
<tr><td colspan="2">SEL</td><td colspan="2">SEL</td></tr>
<tr><td colspan="4">Overall Minimum differences</td></tr>
<tr><td colspan="2">$L_{Aeq,8h}$</td><td colspan="2">L_{Amax}</td></tr>
</table>

Note 1: SEL differences were set to zero as they are not carried through in the analysis. $L_{Aeq,8h}$ is also a first order indication of the magnitude of SEL.
Note 2: Only arrival operations are considered.

1.2 Respite methodology

Once the minima of all respite combinations for both $L_{Aeq,8h}$ and L_{Amax} were determined, respondent locations which were subject to an $L_{Aeq,8h}$ of below 45dB were filtered. The effect of the filter cut-off was rigorously examined, and it was shown that a value of 45dB was appropriate, where any values below were discounted. This pre-processing was performed in order to avoid potential artifacts happening at very low sound levels. Indexing was used to encode further information on the quantity of respite at respondent locations from the filter output. CAA used an Excel formula to categorise each respondent location according to the following criteria:

i. Category 0: minimum difference is less than 4 dB
ii. Category 1: minimum difference is at least 4 dB and above but less than 9 dB
iii. Category 2: minimum difference is greater than at least 9 dB

These noise respite categories were used within SPSS for further statistical analysis. This was done separately for $L_{Aeq,8h}$ and average L_{Amax}.

Threshold of respondent respite was analysed within the main Master Data file (i.e. 2020_SoNA_Further Annoyance Analysis – Master Data 210224.xlsx). A respite threshold analysis was carried out. The question was *'what is the lowest Lmax threshold to give significant respite, and more importantly, what is the equivalent Leq level for this?'* Two conditions were investigated (see Fig. 1):

i. Analysis using Respite thresholds of a difference of >=4dB and <9dB 'some respite' and >=9dB 'much respite'
ii. Analysis using Respite thresholds of a difference of >=4dB and <8dB 'some respite' and >=8dB 'much respite'

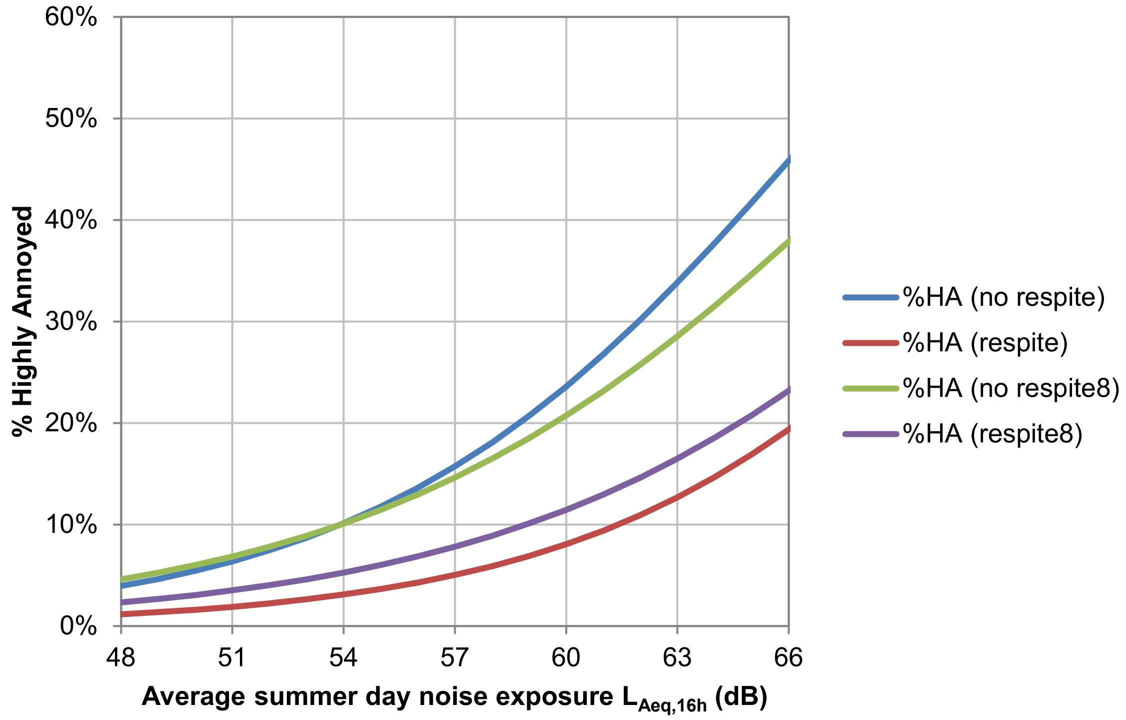

Figure 1: Percentage of highly annoyed as a function of average summer day noise exposure $L_{Aeq,16h}$ with and without noise respite, for the >=8dB 'much respite' and >=9dB 'much respite' conditions.

Logistic functions were created for each of these conditions, plotted in Figure 1. Table 2 shows a summary of the outcome on annoyance for each of the conditions analysed.

Table 2 : Relationship between $L_{Aeq,8h}$ and L_{Amax} and outcome on annoyance.

$L_{Aeq,8h}$ (dB)	L_{Amax} (dB)	Outcome
9.0	11.3	Has a significant effect on annoyance
8.0	10.2	Does not have a significant effect on annoyance
7.0	**9.0**	Does not have a significant effect on annoyance
6.1	**8.0**	Does not have a significant effect on annoyance

The details of the statistical analysis are not within the scope of this technical review. However, these reviewers have checked that the filtering of respite from the previous spreadsheet is carried through to the master data, where for respondent locations with $L_{Aeq,8h}$ that pass through the 45dB are banded in 3dB bins from 45dB to a maximum of 69dB. The reviewers have also checked the respite threshold analysis.

During peer review knowledge transfer meetings, these reviewers were presented with figures, such as the graphic included in Figure 2, which aided the explanation of how respite can be interpreted spatially. Such observations also served as a 'sanity check' on the respite categories.

Figure 2 shows how survey respondent locations are situated within respect to Heathrow airport, with their respective colours representing the degree of respite that they encounter. Overlaid on to the figured is the 60dB and 63dB $L_{Aeq,8h\ morning}$ noise contours.

These reviewers have observed Figure 2 and other associated figures, which visualise the number of respondents within respite categories and are confident that the diagrams are representative of the data shown within the master data files.

The effect of 'out of alternation' operations apparent within Figure 2 was observed and discussed within meetings with the CAA during the peer review process. Consequently, the reviewers are confident that the slight asymmetry in respite contours is representative of the data.

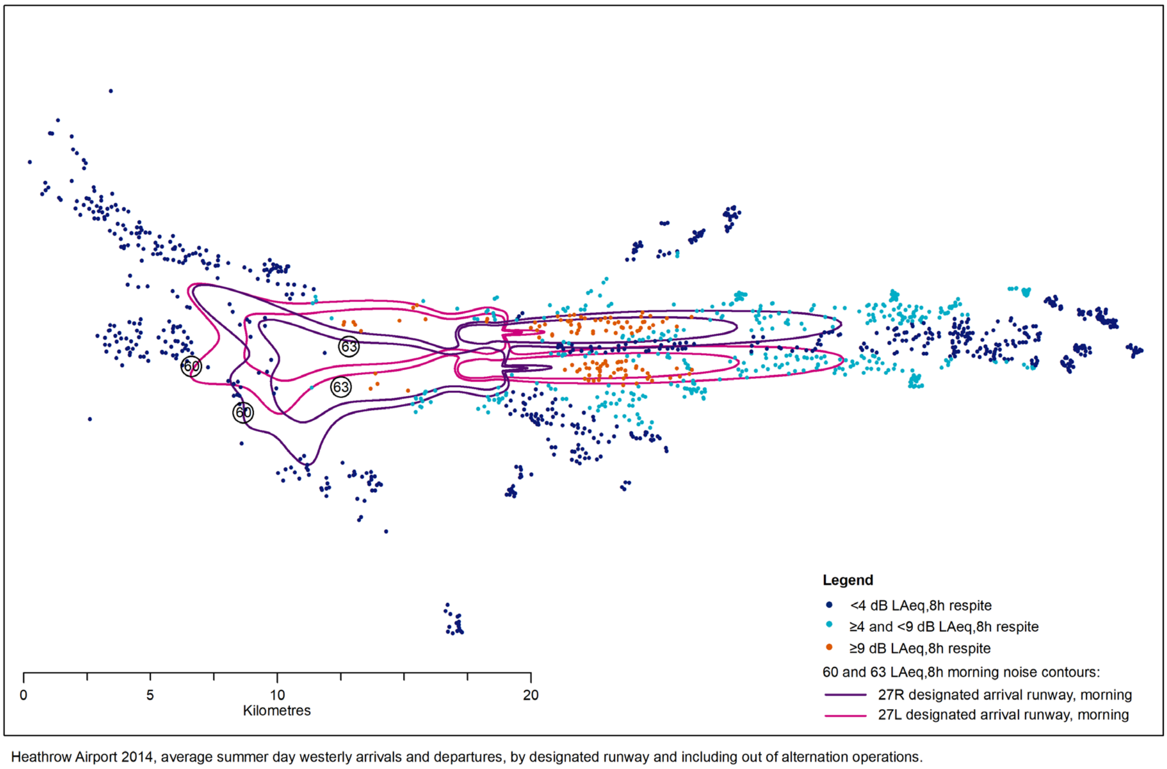

Figure 2: Spatial visualisation of respite data for Heathrow Airport 2014, average summer day and departures $L_{Aeq,8h}$ data, by designated runway and including out of alternation operations.

2. Review of calculation of change in noise dose since previous year

The aim of this study was to investigate whether respondents had received an increase in aircraft noise dose since the year preceding the study (i.e. year 2013). Only 5 airports (Birmingham, Gatwick, Heathrow, Manchester and Stansted) were considered for analysis within this study where ANCON data was available, although some other airports were considered during the initial survey.

In this study, these reviewers have checked the calculation of summer average sound levels in 2013 and correction for 2014 modal split. Also, CAA described the methodology for the quantification of differences in sound level between 2013 and 2014 at each receptor. The procedure is detailed in 'Appendix D: Previous year methodology' in the SoNA Peer Review scope document (attached).

2.1 Modal split

The proportion of runway use is accounted for during the calculation of modal split, where aircraft operations can occur in either runway.

The distribution of runway operations varies year to year due to variation in prevailing wind directions. In order to control for the variation in the distribution of runway operations in the analysis, a simulated 2013 exposure was computed as though it had the same modal split as 2014, where the distribution in airport operational direction and number of flights were captured.

2.2 Calculation of summer average sound levels in 2013

$L_{Aeq,16h}$ were calculated at each respondent using summer traffic for 2013 (rather than 2014), following the methodology described in steps 1-5 of Appendix B: 'Noise dose methodology' in the SoNA Peer Review scope document (attached). This methodology was reviewed in USAL-SoNA1 report.

2.3 Correction for 2014 modal split

Within the relevant spreadsheet (i.e. LAeq16h_2013_all_airports_mnx.xlsx) is a tab which contains the standard table of respondent location (identified by respondent serial number), along with which airport it belonged to, and its eastings and northings. The noise dose (i.e. $L_{Aeq,16h}$) under easterly arrival and departure, and westerly arrival and departure conditions is listed for respondent locations along, followed by logarithmic averages of the yearly noise dose metric using either the 2014 or 2013 modal splits respectively. An example of how the layout of this data may be visualised is found in Table 3.

Table 3: Example layout of data for the calculation of 2013 $L_{Aeq,16h}$ accounting for a 2014 or 2013 modal split.

Respondent number	**Airport**	**Easting**	**Northing**	**$L_{Aeq\,16h}$ Easterly Op.**		**$L_{Aeq\,16h}$ Westerly Op.**		**$L_{Aeq\,16h}$, 2013 (2014 split)**	**$L_{Aeq\,16h}$, 2013 (2013 split)**
				Arr.	Dep.	Arr.	Dep.		
				Total		Total			
Location 1	Heathrow	…	…	…		…		X dB	Y dB
.	.	.	.	.		.		.	.
Location N	.	.	.	.		.		.	.

The principle of the logarithmic averaging is outlined below.

$$Noise\ Dose = 10\log\left(10^{Easterly\ Dose \times Fraction\ of\ Easterly\ op.} + 10^{Easterly\ Dose \times Fraction\ of\ Easterly\ op.}\right) \quad (1)$$

This process has been scrutinised and validated with hand calculations within the same Excel spreadsheet, and was performed within Excel by converting the total easterly and westerly noise data to acoustic energies and converting the easterly and westerly modal splits to percentages. The proportion of easterly and westerly acoustic energies are then obtained through multiplication with their respective modal split and are finally converted back to decibels. These reviewers are satisfied that all calculations were performed correctly with the respective data.

3. Review of processing to calculate additional awakenings at Heathrow Airport

The aim of this study was to estimate the number of additional awakenings experienced by respondents around Heathrow airport during the summer of 2014. This calculation of additional awakenings was based on the methodology proposed by Basner et al. (2006)[1]. This methodology is described in detail in Appendix E: 'Additional awakenings methodology' in the SoNA Peer Review scope document (attached).

The basis of the additional awakenings methodology is the calculation of maximum sound pressure levels (L_{Amax}) for each combination of aircraft type and flight track in arrival and departure operations and survey respondent locations. These were calculated for mean flight-tracks at the closest point of approach to the receptor and generally represented the best estimate for L_{Amax} levels which may arise from each operational combination. All L_{Amax} levels were calculated using the validated ANCON model.

The estimated attenuation of 15dB from each L_{Amax} level was discussed within knowledge transfer meetings with the CAA, who explained that 15dB was justified to represent the average sound transmission loss through a partially open window, representative of the summer-time.

These L_{Amax} levels were then input into the quadratic function proposed by Basner et al. (2006) (see eq. 2), which then determined the probability of additional awakenings.

$$P_{AWR} = 1.894 \times 10^{-3} {L_{Amax}}^2 + 4.008 \times 10^{-2} {L_{Amax}}^2 - 3.3243 \qquad (2)$$

The probability of additional awakenings, calculated with eq. 2, reaches a value of zero with L_{Amax} = 33 dBA (equivalent to 48 dBA L_{Amax} outdoors). This creates an artifact in the calculation of the probabilities of additional awakenings. For each combination of aircraft type / flight track, there is an associated standard deviation (which is based on noise monitoring data). Therefore, mean L_{Amax} noise levels at the cut-off value in Basner et al.'s model might lead to underestimation of the probability of additional awakenings.

---

[1] Basner M, Samel A and Isermann U, "Aircraft noise effects on sleep: Application of the results of a large polysomnographic field study", Journal of Acoustical Society of America, 119 (5), May 2006.

In order to address this issue, CAA developed a procedure where the average L_{Amax} was re-distributed across a normal distribution using bins, each 0.2 dB in width, and a standard deviation of 2.5 dB. These reviewers have gone through this calculation using a VBA script provided in the spreadsheet 'Probabilities of Awakening_PastedValues_Darren Normal Distribution added.xlsx'. The standard deviation of 2.5dB was considered and based upon measured noise levels from the study. This re-distribution process, based on a Normal distribution, becomes critical at levels below 55 dBA L_{Amax} (outdoors). These reviewers agree that this process is appropriate and robust. The number of additional awakening was then calculated using the eq. 3:

$$N_{AWR} = \sum_i P_{AWR}(L_{Amax,i})n(L_{Amax,i}) \qquad (3)$$

These reviewers have checked this calculation performed using a VBA script. The number of additional awakenings were calculated by multiplying the probability of additional awakenings to the respective average numbers of summer night operations for each aircraft type along each route. These numbers of additional awakenings were evaluated at respondent locations in order to correlate with attitudes of sleep disturbance. Plot contours of additional awakenings were produced and showed to these reviewers (see for instance Figure 3).

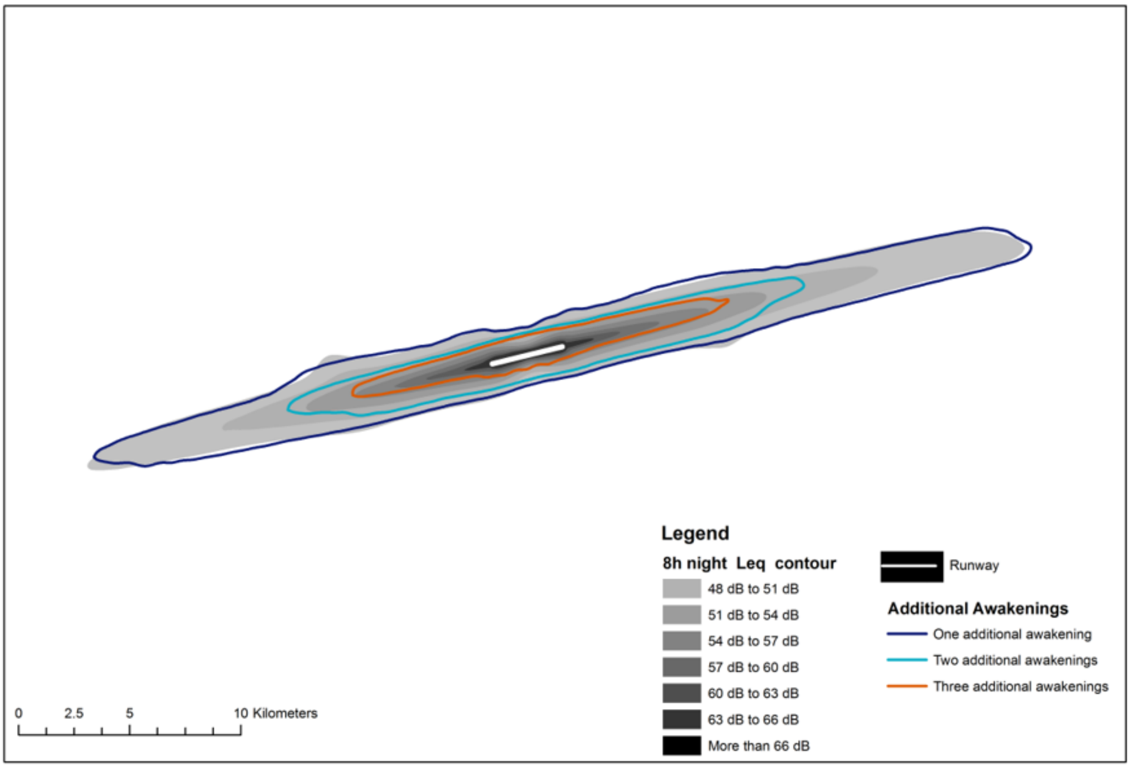

Figure 3: Additional average summer night awakenings versus LAeq,8h contours for Gatwick Airport.

Furthermore, Figure 3 shows how the boundaries of one, two and three additional awakenings are related spatially to the average summer night-time (8-hour) L_{Aeq} contours of noise from Gatwick Airport. Figure 3 shows that for Gatwick airport, the 1, 2 and 3 additional awakening thresholds to some degree resemble the shapes of three lowest $L_{Aeq, 8hr}$ contours.

4. Recommendations

This reviewing team makes the following recommendations for future work:

- Expand the analysis of departure operations in the noise respite studies at Heathrow. In the study under review, CAA included westerly departure operations in the respite analysis. However, departure routes converged soon after take-off, and therefore CAA found no statistical association between departure respite and annoyance responses. An extended analysis on departure operations will contribute to a better understanding of the overall effects of noise respite on communities.
- Analyse the relationship between number of events (e.g. Number Above a given L_{Amax}) and the number of additional awakenings. Basner et al.'s model is a well-established methodology for quantifying additional awakenings, but the consideration of other metrics such as number of events above a given threshold might be relevant from a policy-making perspective.
- State the uncertainty associated with the sound level calculations for the noise respite and additional awakenings studies. Although the reviewers have no question about the validity and robustness of the calculations performed, a study on uncertainties is highly advisable.