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TITLE

Corrective measures for the aircraft noise models NORTIM and GMTIM:

1. **Development of new algorithms for ground attenuation and engine installation effects.**
2. **New noise data for two aircraft families.**

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ABSTRACT

The routines for ground effect and engine installation effect developed in this project improve calculation accuracy for the aircraft noise models NORTIM and GMTIM. For a sample of nearly 70.000 measurements at Gardermoen, the overall improvement is in the order of 1 dB for equivalent noise levels (SEL). Noise data extracted from the measurement program at Gardermoen in 2001 further improves the accuracy by 0.5 dB for SEL.

It is recommended that updated versions of the two programs should be used in noise calculations as an interim solution until a revised recommendation (either from ECAC or SAE) for lateral attenuation appears.

An international co-operative work is needed to supply noise data from normal operations for all aircraft in the database. It is recommended that new noise data be implemented as they occur.

KEYWORDS	ENGLISH	NORWEGIAN
GROUP 1	Acoustics	Akustikk
GROUP 2	Aircraft Noise	Fly støy
SELECTED BY AUTHOR	Lateral Attenuation	Lateral dempning
	Engine Installation Effect	Installasjonseffekt

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1 Introduction

The Norwegian aircraft noise calculation model, NORTIM, is based on the recommendations from ECAC [1], and thereby also on SAE recommendations [2,3]. Investigations made in 1995 [4], when NORTIM was implemented, showed that the model over predicted measurements of equivalent aircraft noise from 1989 with a 0.5 dB mean value and a standard deviation of 1.9 dB. However, measurements from the noise and track monitoring system (NTMS) at Oslo Main Airport, Gardermoen (OSL) from 2000, have shown that the program now under predicts the equivalent noise by 2.7 dB as a mean value [5].

One of the suspected reasons for the shift from over to under prediction has been the routine for computing lateral attenuation, as defined by SAE AIR 1751. This routine was empirically developed in the early 1980s based mainly on measurements from the 1960s and 1970s of chapter 2 type of aircraft, with Boeing 727 as the predominant type. The SAE routine contains no frequency dependency. Lateral attenuation is a combination of source directivity and ground attenuation. The out phasing of older aircraft has lead to quite different source spectra for the dominant sources and may therefore have had an influence on the ground attenuation. While the B-727 has its engines mounted on the rear fuselage, many of the modern types have the engines mounted under the wings. This results in a difference in noise source directivity.

One of the other suspected reasons was the noise data as represented in the database from INM [6]. The data is based on aircraft noise certification measurements performed by the producers, and may be different from what normal, daily operations may represent.

A measurement program was performed at OSL during June 2001 to investigate the possible causes of deviations between calculations and results obtained by NTMS [7, 8]. The main result from this investigation was that the basic assumption of cylindrical symmetry of the aircraft as a noise source is wrong. Correcting this will be a development task for the next generation models. Significant differences were found between observed lateral attenuation and predictions based on SAE AIR 1751. Significant differences were also found between observed noise and the INM database. Other deviations were found in take off procedures, which showed a mix from standard ICAO procedures, to procedures with derated take off thrust and relatively low climb rate. Also, the landing procedures showed that thrust variations were significant, quite different from the standard INM profiles that are used in NORTIM and GMTIM. (GMTIM is a special variant of NORTIM applied at OSL, where the aircraft flight track data is acquired from the ATC radar system.)

The lateral attenuation and noise data were selected as primary objects of further investigation based on the findings from the Gardermoen measurements.

It should be noted that the SAE A-21 Aircraft Noise Committee is undertaking revision of the lateral attenuation routines. Work is also underway by the ANCAT Sub-Group on Aircraft Noise Modelling (ANCAT/AIRMOD) under ECAC, concerning the same. The aim of the current report is to supply an interim solution to be applied in NORTIM and GMTIM until new recommendations are presented by either of the international initiatives. The results from this investigation will be shared with both A-21 and AIRMOD.

Norwegian Air Traffic and Airport Management, Oslo Airport AS, and Norwegian Defence Construction Service funded the investigation, performed by SINTEF with Research Scientist Idar L. N. Granøien as Project Manager, Research Scientists Herold Olsen and Rolf Tore Randeberg as main contributors.

2 New routines for lateral attenuation

The lateral attenuation has been divided into ground effect and a noise source directivity effect. The noise source in this case is the aircraft with engines seen as a whole.

2.1 Ground attenuation

When sound travels from the aeroplane to the receiver, several possible propagation paths are possible: The direct line and sound rays reflected from the ground surface in between. These combine to give a total sound pressure level at the ear of the receiver. Theoretical models have been developed to describe the phenomena. This study uses the NORD2000 [9] model to calculate the effect of the ground as compared to the free field propagation.

2.1.1 Method and Results

A-weighted SEL levels were calculated for a number of virtual flights, for 209 combinations[1] of lateral distance l and elevation angle φ. The ground attenuation for each point of the virtual flights was calculated by means of the NORD2000 method.

NORD2000 calculations require parameter settings that are essential for describing the physical conditions, such as acoustic impedance of the ground. This parameter is defined by the ground flow resistivity, which was set to 250.000 Rayl. This corresponds to soft grass covered ground, and also corresponds to measurements on site [7, 8].

Another important factor is the air turbulence. NORD2000 defines this with two turbulence parameters, for wind and temperature. Results from the Gardermoen test showed best agreement with a setting of 0.5 and 0.0 for these two parameters under the actual meteorological conditions, by comparing the results from two microphone heights at the same position. For standard conditions (used in benchmark testing of NORD2000[10]) the following values were selected:

Wind turbulence parameter:	Cv2 = 0.12 [$m^{4/3}/s^2$]
Temperature turbulence parameter:	Ct2 = 0.008 [K/s^2]

Corresponding A-weighted SEL levels were then calculated for the same slant distance, but with the observer directly below the flight path. In both cases, the source spectre was a mean of the SEL spectra measured at site 1 and 2 (directly below the flight path) during the Gardermoen measurements[7]. Spherical radiation was assumed. The simulated ground attenuation was then calculated as the difference between the level observed below the flight path and the level observed at the given (l, φ) combination. For $\varphi \geq 60$ the attenuation was assumed to be zero.

The simulated ground attenuation can be represented by the surface shown in the figure on the next page. It was assumed that this surface could be represented by formulae similar to the formulae for lateral attenuation in SAE AIR 1751, with some minor modifications, and with all the coefficients fitted to the simulation data.

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[1] The distances were 50, 75, 100, 150, 200, 300, 400, 500, 600, 700 and 1000 m, and the angles were 0, 0.1, 0.5, 1, 2, 3, 4, 5, 6, 8, 10, 15, 20, 25, 30, 40, 50, 80 and 90 degrees.

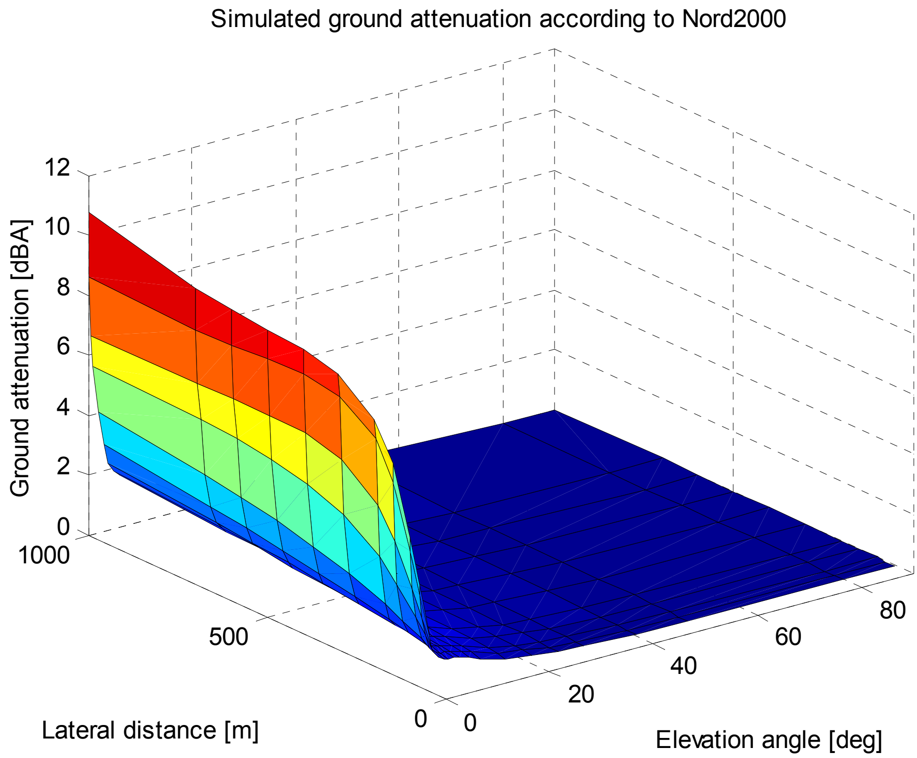

Figure 1 Simulated ground attenuation as a function of lateral distance and elevation angle

The ground attenuation can be written as

$$\mathrm{ATN}\left(l,\varphi\right)=\begin{cases}\dfrac{\left[a_0+a_1\varphi^{a_2}+a_3\exp(a_4\varphi)\right]\cdot\left[a_5 l^{a_6}+\left(1-\exp(a_7 l)\right)\right]}{a_8}, & \varphi<46.6\wedge l\geq 23.4\\ 0 & \varphi\geq 46.6\vee l<23.4\end{cases}$$

The coefficients $a_0..a_8$ were fitted to the simulated ground attenuation by non-linear least squares fitting in MATLAB®. The coefficients are given in the table below.

Table 1 Coefficients for the ATN equation

a_0	a_1	a_2	a_3	a_4	a_5	a_6	a_7	a_8
15.7782	-5.8654	0.2576	31.3516	-0.8068	-0.3597	-0.2063	-0.0089	4.2241

The figures on the next page compare the simulated ground attenuation with predictions from the new formula for ground attenuation, and lateral attenuation as per SAE AIR 1751.

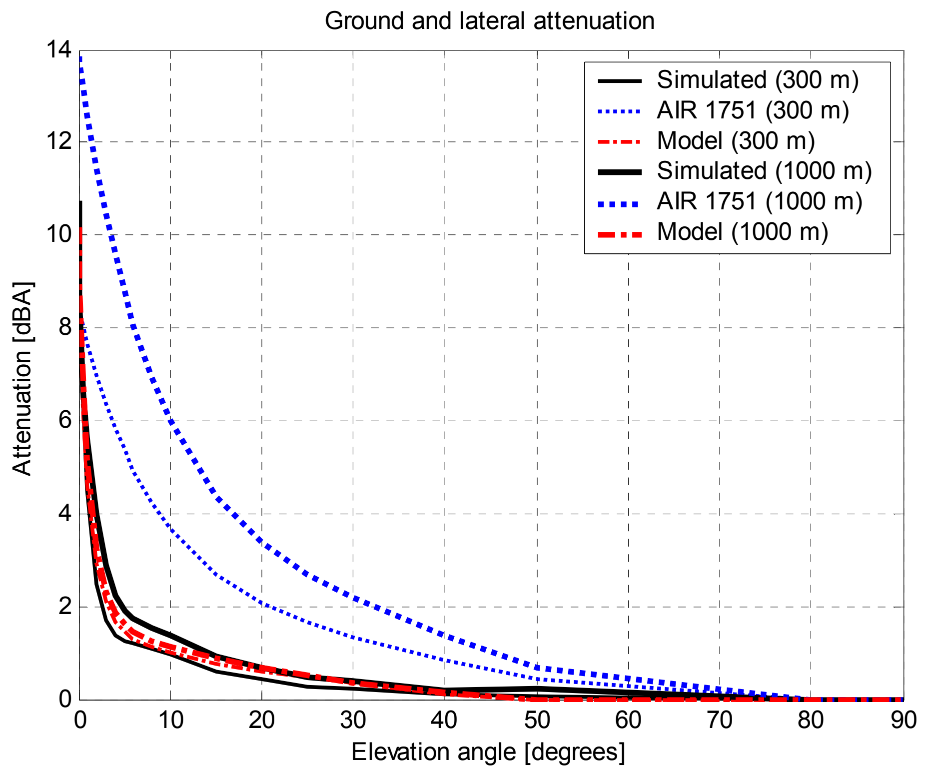

Figure 2 Ground and lateral attenuation as a function of elevation angle

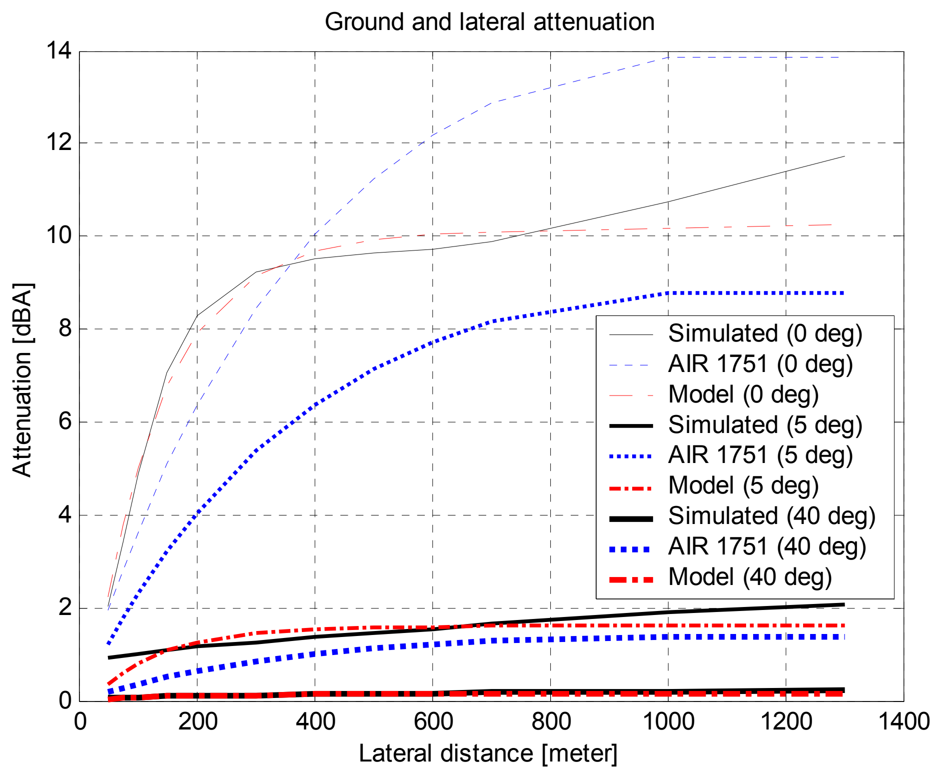

Figure 3 Ground and lateral attenuation as a function of lateral distance

2.2 Installation effects

Installation effect is a term used to incorporate engine noise directivity combined with the influence of the air flow around the airframe, shielding and reflection by the fuselage and the wings, etc. This combines with the fact that sound propagation through the turbulent air in engine exhaust and wing vortexes also have influence on the over all directivity. Several studies (such as [11]) suggest that aeroplanes can be grouped in different classes with common properties, depending on where the engines are installed, the number of engines and engine class.

The Gardermoen data [7,8] consisted of B737's and MD80's. We let B737-600 (B736) and B737-700 (B737) represent engine installation effect for aircraft with engines mounted under wing, and MD81 and MD82 represent aircraft with rear fuselage mounted engines. Propeller aircraft, fighter aircraft and helicopters were not represented in the measurements.

2.2.1 Method and results

The calculations are based on the spectral source directivities obtained during the post processing of the Gardermoen measurement data (2001). The directivities have a horizontal and vertical resolution of 10°.

The source spectra of B736 and B737, likewise, the spectra of MD81 and MD82 were averaged. Both of the averaged spectra were truncated to 50 – 5000 Hz. A-weighted SEL levels were calculated for a number of virtual flights, for 506 combinations [2] of lateral distance l and elevation angle φ. The air absorption for each point of the virtual flights were calculated according to ISO 9613-1, for temperature = 15(C and relative humidity = 70%. Corresponding A-weighted SEL levels were calculated for the same slant distance, but with the observer directly below the flight path. Spherical radiation was assumed. The engine installation effect was then calculated as the difference between the level observed below the flight path and the level observed at the given (l, φ) combination. The calculated engine installation effects thus obtained were then replaced by approximate formulae. The two aircraft types were treated separately.

2.2.2 Under wing mounted engines (B73x)

The engine installation effect was found to be

$$ENG(l,\varphi) = \begin{cases} 1.0032 \cdot GRD(l) - 0.0795 \cdot AIR(l,\varphi) & \varphi \le 64 \\ \text{Linearly interpolated between } \varphi = 64 \text{ and } \varphi = 72 & 64 < \varphi \le 72 \\ 0 & \varphi > 72 \end{cases}$$

where

$$GRD(l) = -15.5120 + 13.7655 \cdot l^{0.0193}$$

and

$$AIR(l,\varphi) = \begin{cases} 48.0678 + A(l,\varphi)\sin(-0.0277 \cdot \varphi - 1.2869) & \varphi \le 29 \\ 4.7395 + 1.8780 \cdot \sin(0.2779 \cdot \varphi + 3.8270) & 29 < \varphi \le 48.5 \\ -8.6393 + 0.2349 \cdot \varphi & 48.5 < \varphi \le 64 \end{cases}$$

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[2] The distances were 75, 100, 150, 200, 300, 400, 500, 600, 800, 1000 and 1200 m, and the angles were every other degree between (and including) 0 and 90 degrees.

The amplitude of the first **sin** function above is given by

$$A(l,\varphi) = 51.2693 + \frac{(29-\varphi)}{29} \cdot \frac{\log(l) - \log(400)}{\log(400)} \cdot \frac{51.2693}{2}$$

The maximum error of this formula compared to the calculated engine installation effect is ±0.3 dBA. The average error is ±0.3 dBA.

2.2.3 Rear fuselage mounted engines (MD8x)

The engine installation effect was found to be

$$ENG(\varphi) = \begin{cases} 2.1853 & \varphi \le 12 \\ 1.3693 - 0.8478 \cdot \sin(-0.1512 \cdot \varphi + 0.0637) & 12 < \varphi \le 32 \\ 0.6716 + 0.3300 \cdot \sin(-0.2990 \cdot \varphi + 2.8287) & 32 < \varphi \le 53.5 \\ -0.9760 + \dfrac{78.1738}{\varphi} & 53.5 < \varphi \le 80 \\ 0 & 80 < \varphi \end{cases}$$

Note that there is no dependence on lateral distance for this aircraft type. The maximum error of this formula compared to the calculated engine installation effect is +0.55 and –0.38 dBA. The average error is ±0.08 dBA.

2.3 Summary

The figures below compare the lateral attenuation of SAE AIR 1751 with the lateral attenuation obtained when the engine installation formulae for the two aircraft types B73x and MD8x is added to the new ground attenuation. The latter formula for ground attenuation is also shown in the figures.

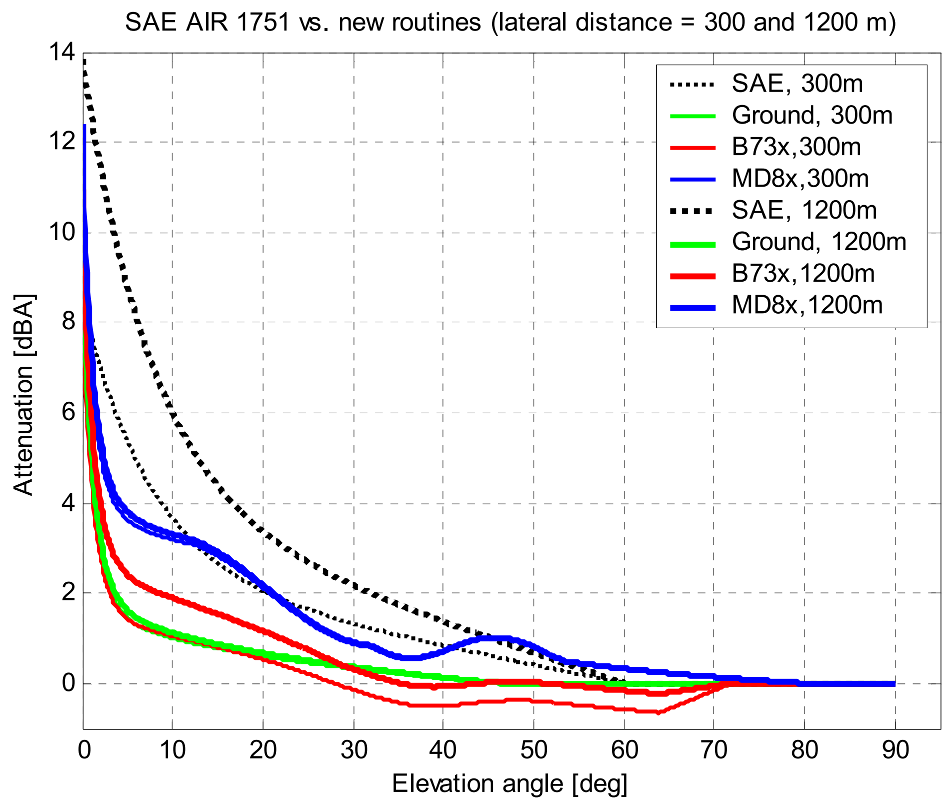

Figure 4 Comparison of new routines with SAE AIR 1751, per elevation angle

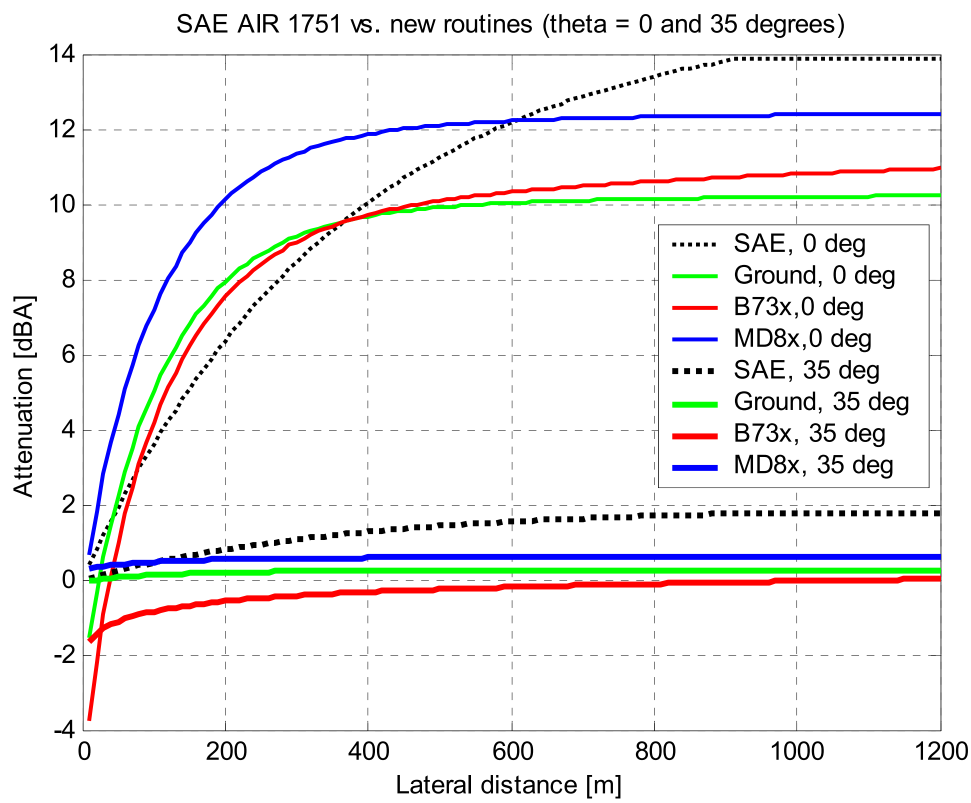

Figure 5 Comparison of new routines with SAE AIR 1751, per lateral distance

3 Adjustment of noise data

The analysis of the Gardermoen measurement data indicated that the Noise-Power-Distance (NPD) data for some aircraft types should be adjusted. This chapter describes the methods that have been used to calculate the necessary adjustments.

3.1 SAE Integrated Method

SAE AIR 1845 describes several methods to obtain NPD data sets from measurements, of which the “integrated method” should be the most accurate. The measured sound level corresponding to a given position, velocity and thrust level of the aircraft is adjusted to a number of different aircraft–observer distances. Air absorption differences are accounted for, and the effective time interval between the samples is adjusted according to mean velocity of the aircraft and the aircraft–observer distance.

The integrated procedure assumes that the engine power setting and airspeed of the aircraft is kept constant during the measurements. This is unfortunately not the case for many of the flights observed during the Gardermoen measurements. The procedure also requires 24 1/3 octave band samples to be available for the entire time period used to calculate SEL, *i.e.* the time interval where the A-weighted sound level is not more than 10 dBA below the maximum level. All in all, the requirements are too stringent for the present data sets, and other methods were therefore chosen.

3.2 Alternative method – Simulations

This method uses the noise source directivity data obtained during the Gardermoen measurements to calculate noise from simulated flights. The source directivity spheres are generated using data from the three microphones at measurement positions 1 and 2. The directivity spheres for B73x are based on data for B736 and B737. The spheres for MD8x are based on data for MD81 and MD82. The thrust levels are normalised to the thrust levels used in the NPD table of NORTIM. The resulting directivity spheres are not completely filled for all thrust levels. Therefore, the simulations can only be done for a limited number of thrust levels.

For the simulations, Nord2000 is used to calculated the ground attenuation (with turbulence parameters 0.12 and 0.008). The air attenuation is calculated using the tabulated coefficients in Table B1 in SAE AIR 1845. Only the frequency range 50–4000 Hz is considered.

3.2.1 Departure thrust levels

For each of the aircraft categories B73x and MD8x, only one thrust level had a directivity sphere complete enough to allow calculations of SEL and MAX levels. The following figures compare the tabulated NPD level[3] with the simulated levels.

[3] NORTIM database MD80 NPD curve for takeoff is already 1.5 dB higher than INM database.

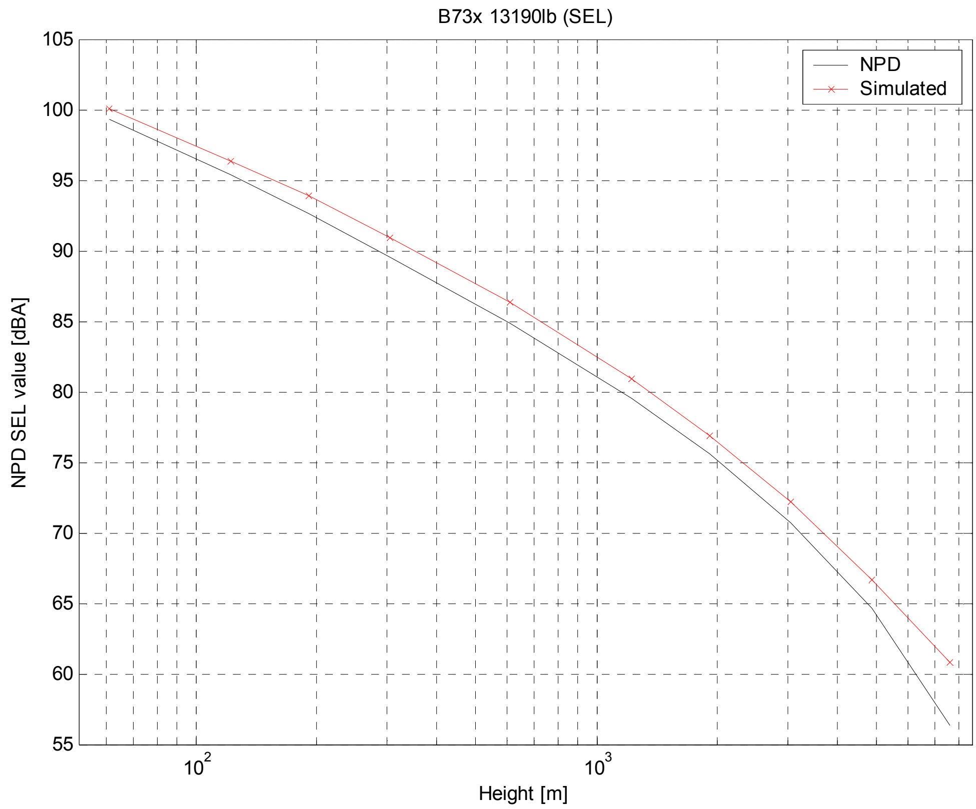

Figure 6 NPD curves for take off thrust for B737, SEL

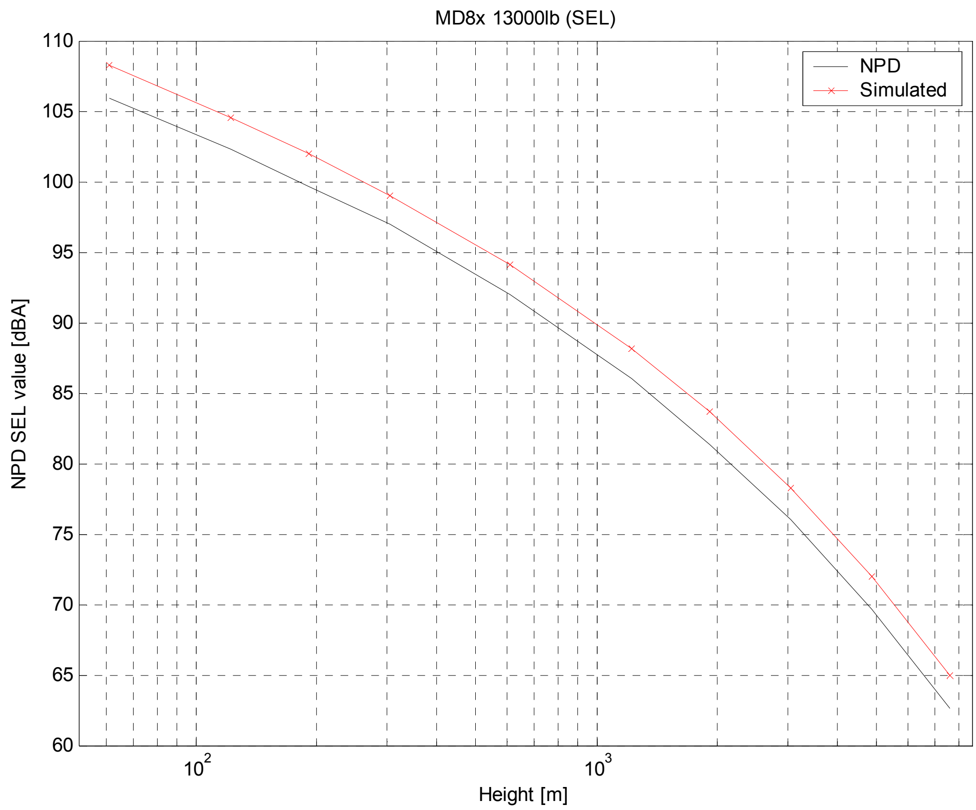

Figure 7 NPD curves for take off thrust for MD80, SEL

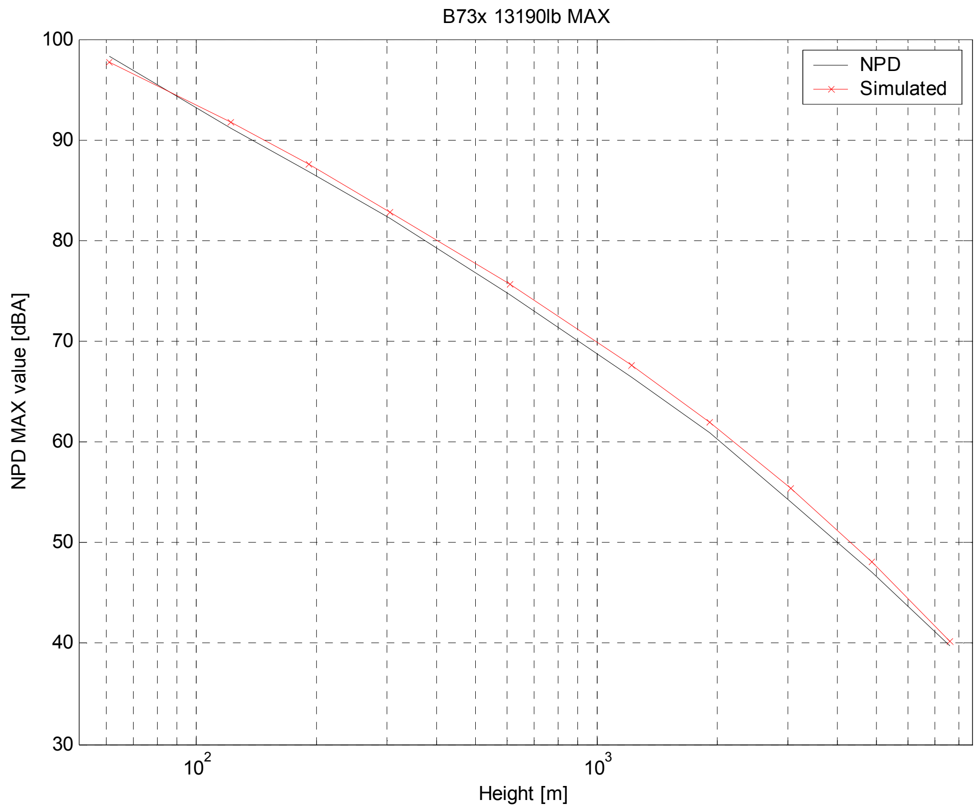

Figure 8 NPD curves for take off thrust for B737, LAMAX

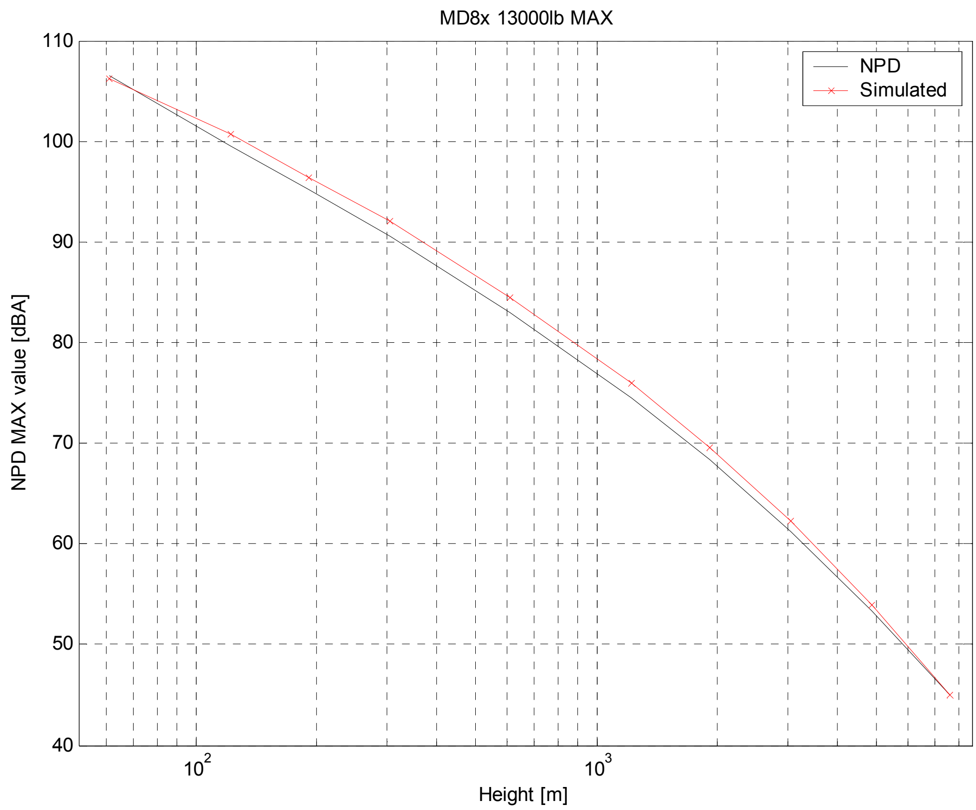

Figure 9 NPD curves for take off thrust for MD80, LAMAX

3.2.2 Approach thrust levels

The directivity sphere for B73x was too incomplete to calculate NPD data of acceptable quality. A constraint on thrust variation similar to take off also excludes this method for acquiring results for the MD80 family.

3.3 Alternative method – Measurements

For approaches, the A-weighted data at the lower microphone at measurement position 2 were used. The data were adjusted by subtracting the air attenuation according to ISO9613-1 for the ambient temperature and relative humidity, and adding the air attenuation given in SAE AIR 1845. SEL and MAX values were calculated for each flight. The measured SEL and MAX values were compared to interpolated values from the current NPD table. For the interpolation, the distance was taken from the measurement data, while the thrust levels were taken from the database standard profile for a 3-degree glide path.

The tables below show the deviation between NPD and measurements, similar to Tables 4.3 and 4.4 in the Gardermoen report. Note that B736 and B737 are compared to NPD data for 737700.

Table 2 Statistical analysis of SEL value differences

Type	Operation	No of Obs	Mean	St.dev	CI_low	CI_high
B736	LA	7	3.7	1.1	2.6	4.7
B737	LA	8	2.0	1.0	1.2	2.9
MD81	LA	6	-3.9	0.8	-4.8	-3.0
MD82	LA	9	-4.2	2.2	-5.9	-2.5

Table 3 Statistical analysis of MAX value differences

Type	Operation	No of Obs	Mean	St.dev	CI_low	CI_high
B736	LA	7	2.7	1.1	1.7	3.7
B737	LA	8	1.0	0.9	0.2	1.8
MD81	LA	6	-3.5	0.9	-4.5	-2.5
MD82	LA	9	-4.5	3.0	-6.8	-2.2

3.4 Summary - Adjustment of database NPD values

This investigation has shown that measured noise levels from the two aircraft families differ from the INM noise database. The INM noise data are based on measurements taken under noise certification tests. The conditions during those tests may not be representative to the normal conditions in daily operations. The Gardermoen measurements were taken at normal operations and justify a replacement of data with the ones obtained during the study.

3.4.1 Departures

The NPD SEL and MAX data for departures with 737700 are adjusted according to the deviation for B73x shown in section 3.2.1. Similarly, the NPD data for MD81, MD82 and MD83 are adjusted according to the deviation for MD8x. The adjustments are distance dependent, and for any given distance, the same adjustment is applied to all (departure) thrust levels. The tables below show the adjustments as function of distance (in feet).

Table 4 Adjustment of NPD data as function of distance (ft) for B737700 at departure

	200	400	630	1000	2000	4000	6300	10000	16000	25000
SEL	0.66	1.03	1.33	1.34	1.41	1.46	1.31	1.47	2.01	4.41
MAX	-0.63	0.60	0.65	0.58	0.99	1.16	1.09	1.37	0.98	0.40

Table 5 Adjustment of NPD data as function of distance (ft) for MD80s at departure

	200	400	630	1000	2000	4000	6300	10000	16000	25000
SEL	2.30	2.27	2.35	1.96	2.06	2.14	2.36	2.25	2.33	2.37
MAX	-0.31	1.25	1.23	1.55	1.44	1.54	1.10	1.03	0.66	0.02

3.4.2 Arrivals

The NPD SEL and MAX data for arrivals with B737700 are adjusted according to the mean of the deviation for B736 and B737 shown in section 3.3. Similarly, the NPD data for MD81, MD82 and MD83 are adjusted according to the mean of the deviation for MD81 and MD82. The adjustments are independent of distance, and are applied to all (arrival) thrust levels. The table below show the adjustments.

Table 6 Adjustment of NPD data for arrival thrust levels

NPD Aircraft type	Noise type	Adjustment
737700	SEL	-2.85
MD81/MD82/MD83	SEL	4.05
737700	MAX	-1.85
MD81/MD82/MD83	MAX	4.00

4 Implementation of new routines and noise data into NORTIM and GMTIM

The new formulae for ground attenuation and engine installation effects, described in chapter 2, will replace the SAE AIR 1751 formulae for the lateral attenuation. This chapter describes how the new formulae will be implemented in GMTIM and NORTIM. The new noise data will also be described.

4.1 Implementing a Ground Attenuation Routine

In NORTIM, the aircraft noise data from the database is modified by adding or subtracting corrections due to velocity, directivity, topography, lateral attenuation, etc. All formulae associated with lateral attenuation according to SAE AIR 1751 are replaced with the new ground attenuation formulae.

If the topography option is turned off, the new ground attenuation for the given lateral distance and elevation angle is calculated, and subtracted from the tabulated noise level. If the topography option is turned on, the new ground attenuation formula is used in the topography routine in several places:

- The gradient weighting is calculated according to the derivative of the distance dependent part of the ground attenuation formula[4].
- For soft ground, both the lateral distance part and the elevation angle part of the ground attenuation formula are used. However, the distance used is the source-receiver distance, and the angle used is an "equivalent" aircraft to ground elevation angle.
- For the hard ground correction, only the angle dependent part is used. For small elevation angles, the correction should be –3 dB. Therefore, the denominator of the ground attenuation formula is replaced with a value so that the correction becomes -3 dB for small elevation angles.

The resulting ground attenuation is compared to the attenuation due to natural and artificial screens. The higher of these two values for attenuation is subtracted from the tabulated noise level.

4.2 Implementing Engine Installation Effects

The engine installation effects represent the other part of the lateral attenuation of SAE AIR 1751. The effects are dependent on aircraft type. The aircraft types are grouped in a number of families:

- Aircraft with under wing mounted engines (W)
- Aircraft with rear fuselage mounted engines (R)
- Turboprop aircraft (T)
- Propeller aircraft (P)
- Fighter aircraft (F)
- Helicopter (H)

Adding a column in the ACcat table in the NORTIM master database takes care of the grouping (Assignment to group is shown Appendix 1). The user interface outputs the engine installation category as an extra field in the FOR18.DAT file. The calculation kernel reads this field and selects the appropriate formulae. The installation effect for the given aircraft family is calculated for the given lateral distance and elevation angle, and is subtracted from the tabulated noise level.

Currently, the installation effects are only calculated for aircraft with engines mounted under the wing and aircraft with engines mounted on the rear fuselage. The Wallops Study[11] concludes that there is no evident installation effect for two engine turboprops. The installation effects of the other aircraft families are not known. For these aircraft families, there are no installation effects implemented so far.

4.3 Adjusted Noise Data

The data in noise curve CF567B in the database have been adjusted according to the results obtained for B737-600 and -700. Likewise, the noise curve 2JT8D2 has been adjusted according to the MD80 results as described in section 3.4. The following tables show noise as a function of power (thrust) and distance (feet) for the two aircraft families.

Table 7 New NPD for CF567B (B737700)

THRUST		200 ft	400	630	1000	2000	4000	6300	10000	16000	25000
3000	MAX	91.2	84.1	79.3	74.3	66.2	57.4	50.7	43.8	35.7	27.5
4000		91.8	84.7	79.9	74.8	66.9	58.1	51.6	44.8	36.0	27.9
5000		92.3	85.2	80.4	75.4	67.4	58.7	52.3	45.6	37.2	29.3
6000		92.8	85.7	80.9	75.8	67.9	59.3	52.9	46.3	38.6	31.1
7000		93.2	86.1	81.2	76.2	68.3	59.7	53.4	46.9	40.0	32.7
10000		94.6	88.5	84.3	79.4	72.3	64.2	58.4	51.8	45.2	37.3
13000		97.5	91.6	87.4	82.6	75.5	67.5	61.8	55.3	47.9	40.0
16000		99.9	94.3	90.0	85.2	78.3	70.4	64.6	58.2	50.4	42.5
19000		102.1	96.6	92.4	87.7	80.7	72.9	67.2	60.9	53.2	45.3
23500		106.6	101.5	97.2	92.5	85.7	78.0	72.5	66.0	58.7	50.8
3000	SEL	92.7	88.5	85.4	82.1	76.7	70.5	65.5	60.4	53.1	46.8
4000		93.4	89.1	86.0	82.8	77.4	71.3	66.6	61.5	54.0	47.9
5000		93.9	89.7	86.6	83.3	78.0	72.0	67.3	62.4	55.2	49.6
6000		94.4	90.2	87.1	83.9	78.6	72.7	68.1	63.2	56.6	51.5
7000		94.9	90.6	87.6	84.3	79.1	73.2	68.7	63.9	58.0	52.8
10000		97.0	93.1	90.7	87.6	82.8	77.4	73.3	68.5	63.3	56.3
13000		99.9	96.2	93.7	90.7	86.1	80.8	76.7	72.0	66.5	60.5
16000		102.4	98.6	96.3	93.4	88.8	83.6	79.6	75.0	69.3	64.4
19000		104.6	100.9	98.6	95.8	91.3	86.2	82.3	77.7	72.3	68.1
23500		109.1	105.5	103.3	100.6	96.4	91.4	87.7	83.0	77.5	73.9

Table 8 New NPD for 2JT8D2 (MD80)

THRUST		200 ft	400	630	1000	2000	4000	6300	10000	16000	25000
4000	MAX	92.5	85.7	81.3	76.5	69.0	60.4	54.6	47.7	39.6	31.1
6000		95.6	88.8	84.2	79.5	72.0	63.7	57.4	50.5	42.3	33.6
7000		99.1	92.6	88.1	83.5	76.2	67.8	61.7	55.1	47.4	39.0
10000		99.9	95.3	90.7	86.4	78.8	70.4	63.9	57.0	48.9	39.8
13000		106.2	100.8	96.4	92.1	84.4	76.0	69.5	62.2	54.0	45.0
19000		112.1	107.0	102.3	97.9	90.1	81.7	74.9	67.7	59.3	50.1
4000	SEL	94.6	91.1	88.6	85.8	81.1	75.1	70.4	65.0	58.6	51.5
6000		97.8	93.7	91.4	88.6	83.9	78.0	73.1	67.9	61.4	54.1
7000		99.7	96.1	93.6	90.7	86.4	80.5	76.0	70.8	64.5	57.6
10000		102.8	99.3	96.8	93.7	88.9	83.1	78.8	73.1	67.0	60.2
13000		108.2	104.6	102.0	99.0	94.1	88.1	83.7	78.3	71.9	65.0
19000		114.3	110.6	108.0	105.0	100.3	94.3	89.8	84.2	77.8	70.9

5 Computation examples with new models

This chapter will present results from recalculations of noise contours at two airports with NORTIM. For OSL recalculations with GMTIM with comparison to measurements from the Noise and Track Monitoring System (NTMS) will be presented. The latter use the same flight data as described in [5].

5.1 Consequences of new lateral attenuation models at Bodø airport

The noise contour maps are based on real traffic data from Bodø 1998. The traffic is a mix of narrow body airliners and military fighters, the latter being the dominant source. The following figures compare the original model (SAE AIR 1751, black) with the new model (pink).

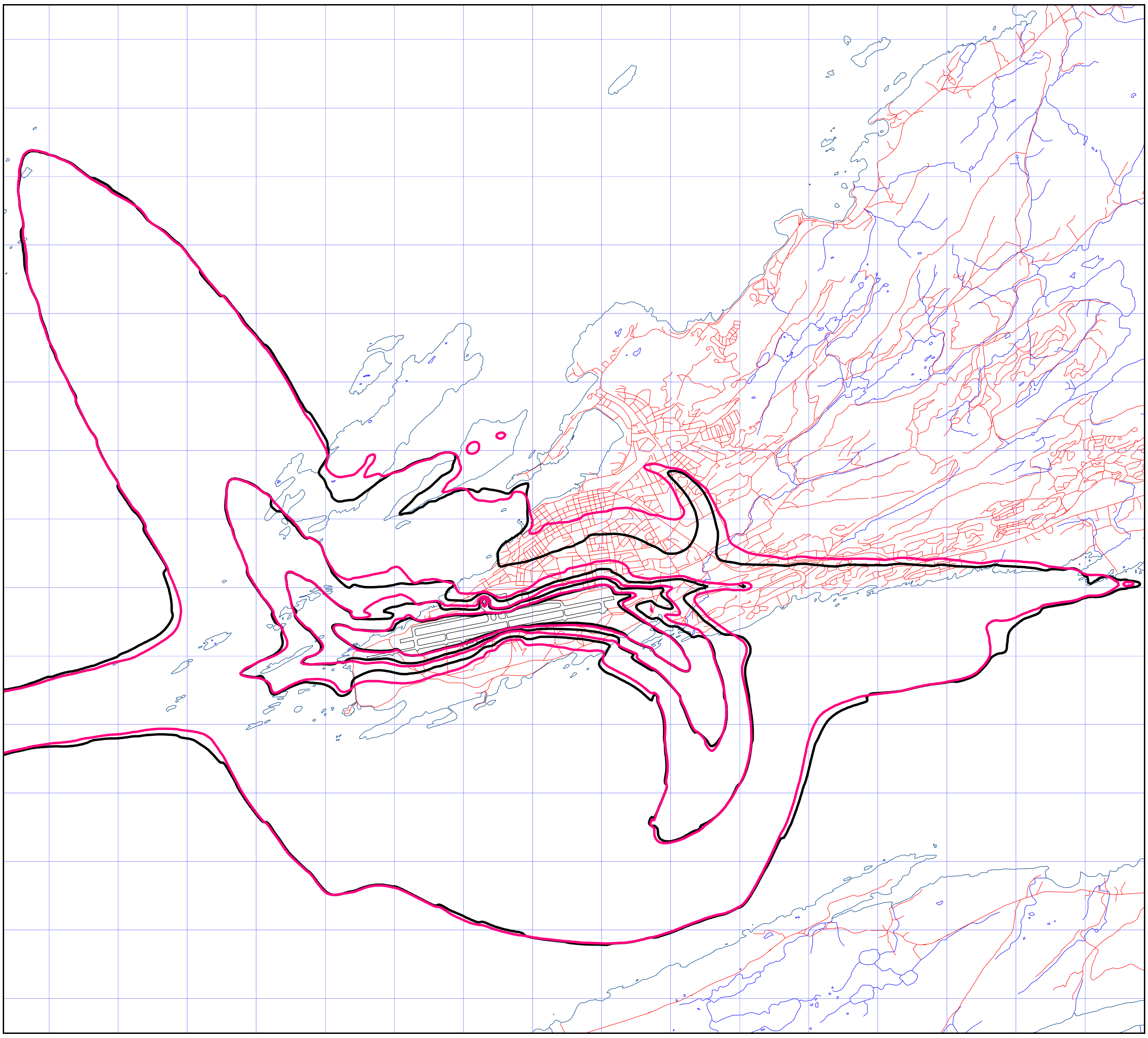

Figure 10 Equivalent aircraft noise at Bodø Airport. Contours showing EFN 50, 60, 65 and 70 dBA. Pink curves: new model, black curves: according to SAE AIR 1751

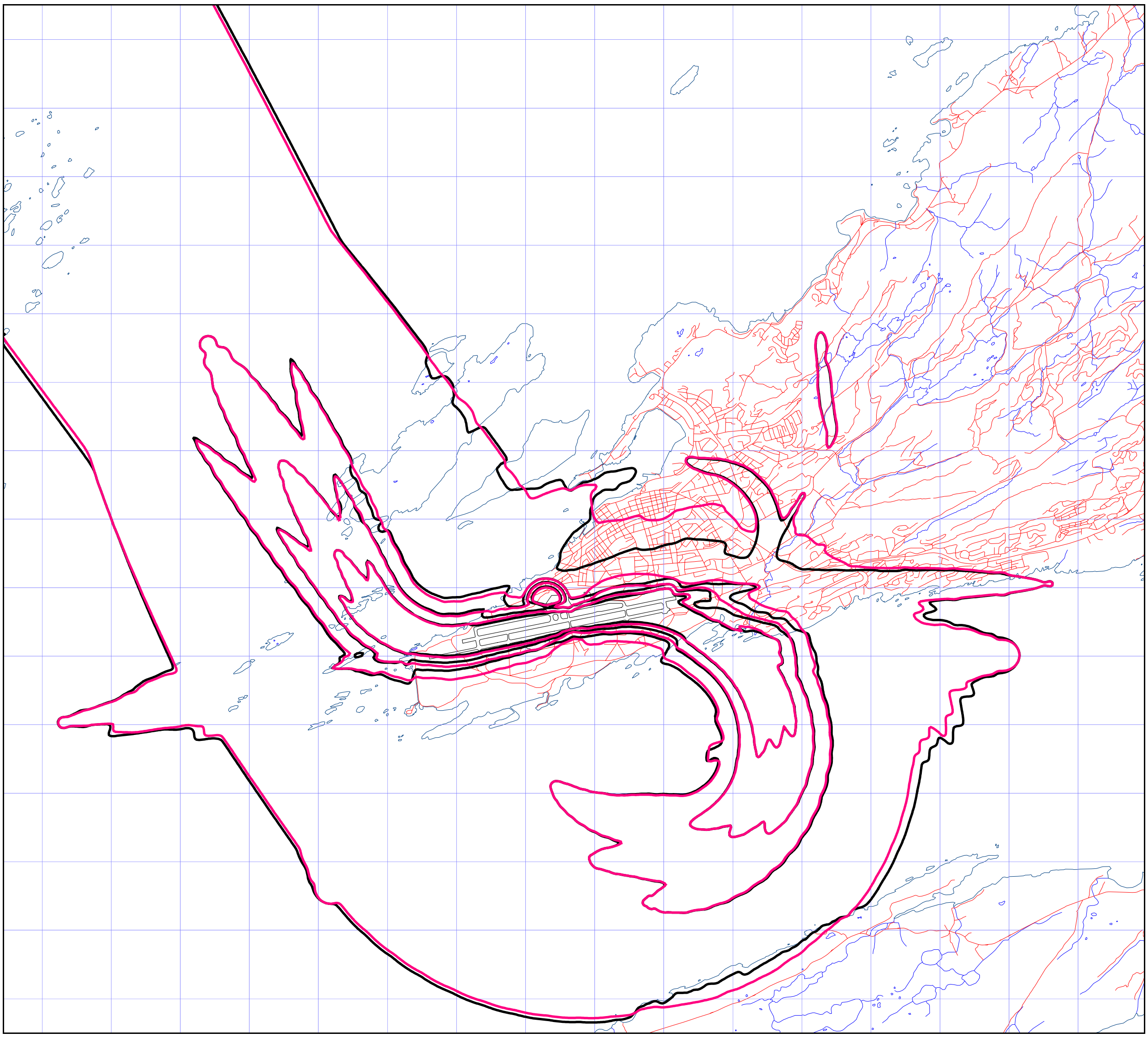

Figure 11 Maximum aircraft noise at Bodø Airport. Contours are MFN 80, 95, 100 and 105 dBA. Pink curves: new model, black curves: according to SAE AIR 1751

5.2 Consequences of new lateral attenuation models at Florø airport

The noise contour maps are based on traffic data from Florø (1999). The traffic mainly consists of turboprop (DHC-8) and off shore helicopters (AS332). The following figures compare the original model (SAE AIR 1751, black) with the new model (pink). (Note that the runway has been extended to the west without the map being updated.)

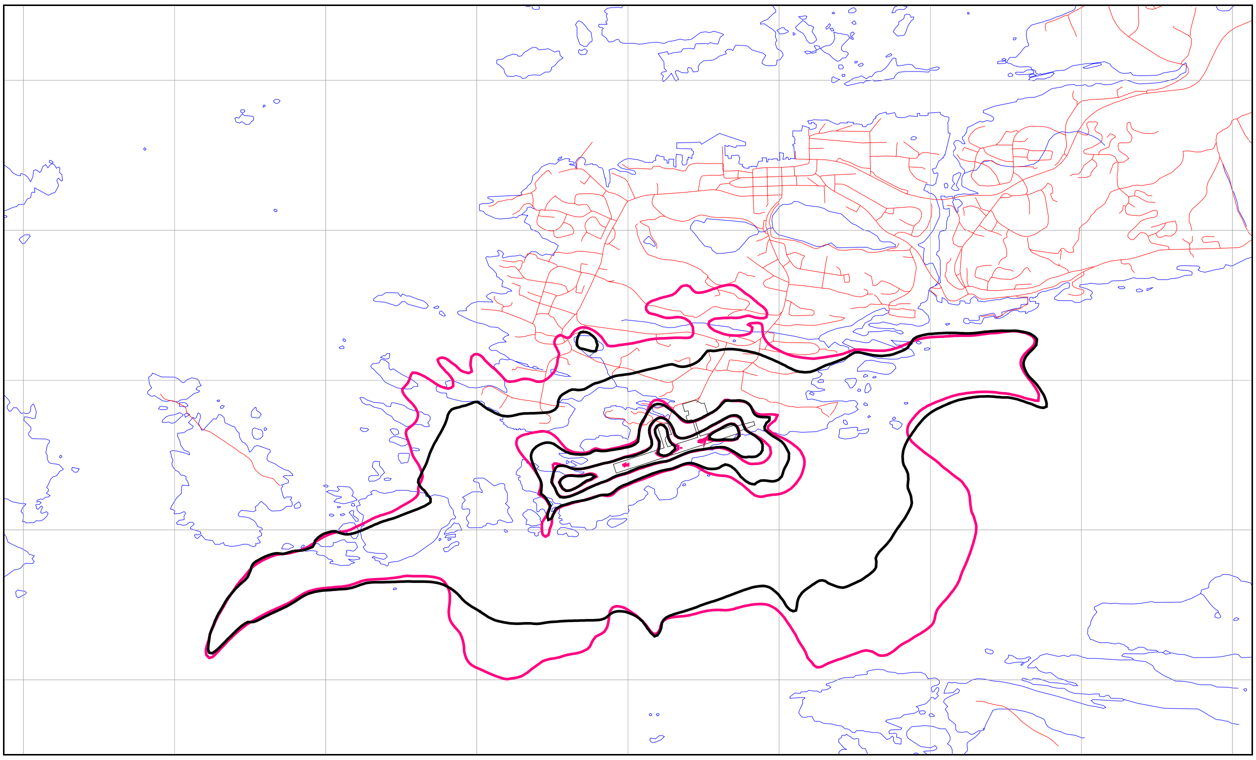

Figure 12 Equivalent aircraft noise at Florø Airport. Contours showing EFN 50, 60, 65 and 70 dBA. Pink curves: new model, black curves: according to SAE AIR 1751

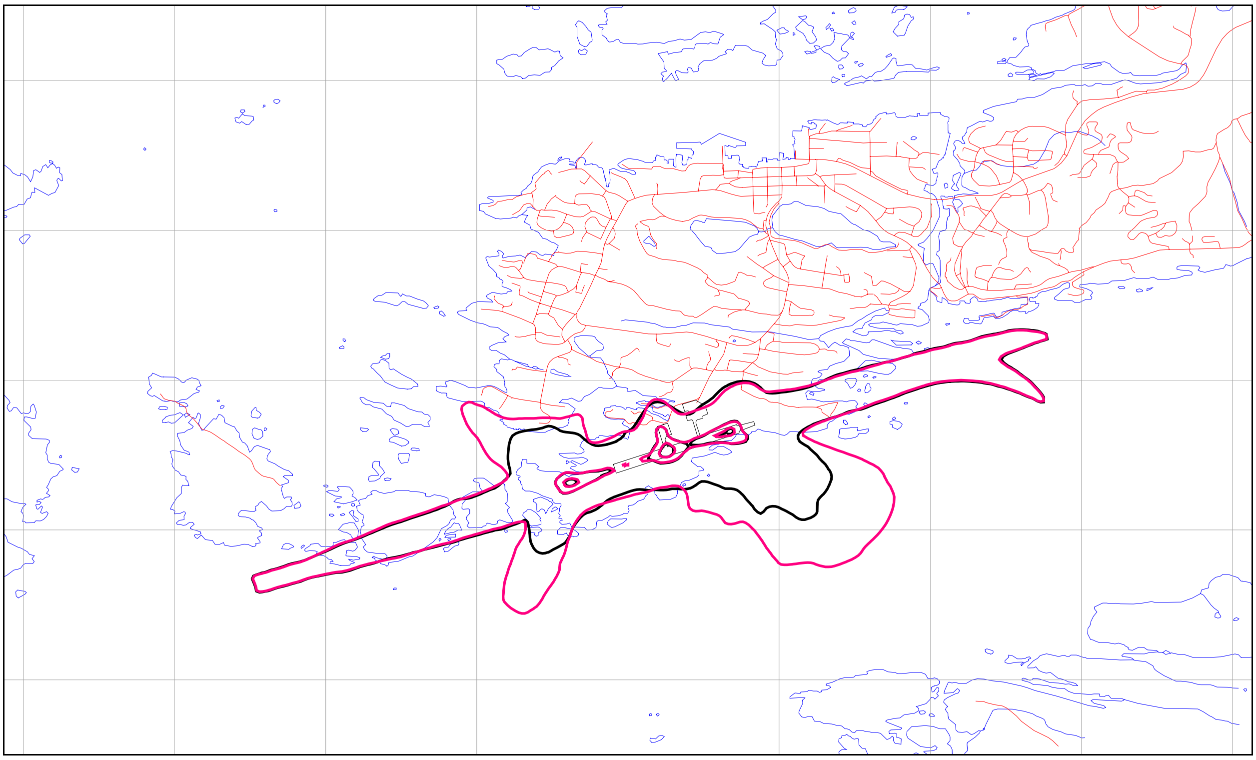

Figure 13 Maximum aircraft noise at Florø Airport. Contours are MFN 80, 95 and 100 dBA. Pink curves: new model, black curves: according to SAE AIR 1751

5.3 Consequences at OSL Gardermoen

Collections of close to 70.000 aircraft movements have been measured at the different microphone locations of the NTMS. Microphone height at the NMTS is approximately 8 meters, while GMTIM and NORTIM calculations are done for the standard 1.5 meters height. It has been shown in previous work that the height difference gives on average 0.5 dB higher measurement results at the NMTS than 1.5 m would have given.

The figures show the deviation between measured and calculated sound levels. Comparison has been made first with only new lateral routines implemented, and secondly with the noise data revision included.

In the figures, the average deviation is marked with crosses. ***Red crosses*** represent the original model, while ***green crosses*** represent the new model for lateral attenuation and ***blue crosses*** also include adjusted NPD data for 737700 and MD81/MD82/MD83.

The results are shown both for SEL and LAMAX, for all movements and for approach (A) and departures (D) separately. The number of observations is indicated in each sample. (The 95% confidence interval is so small in these figures that the bars are not visible beyond the crosses.)

The results show an improvement in calculation accuracy for this test sample for both the new lateral attenuation model and the adjusted NPD data, with one exception: SEL for approaches. The new version of the programs reduces the deviation between measurements and calculations to –1.5 dB for SEL and –2.2 dB for LAMAX for the test samples (of which microphone height accounts for approximately –0.5 dB).

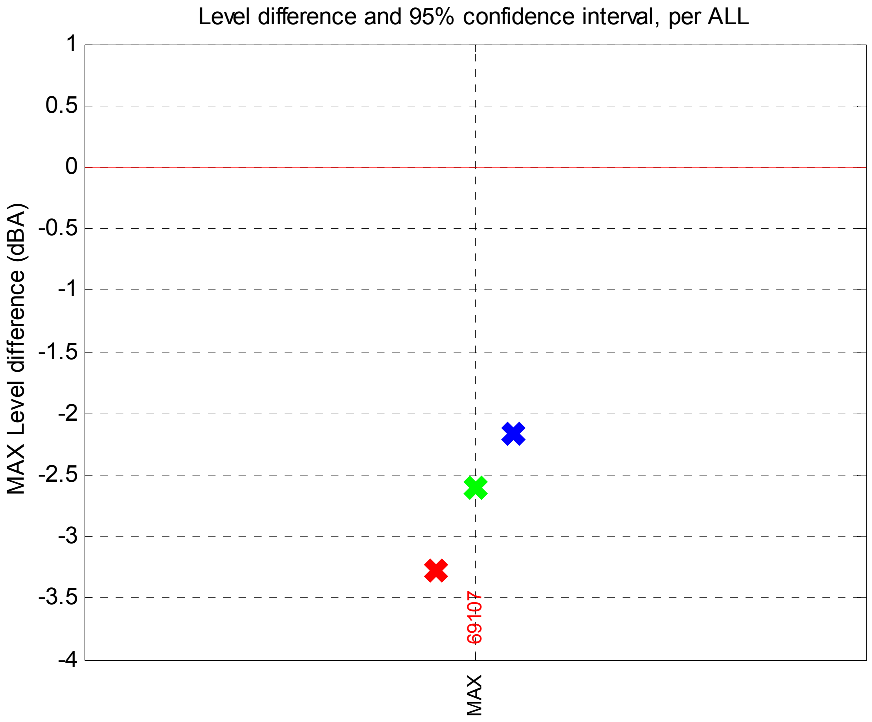

Figure 14 Simulated minus measured level for all samples, LAMAX

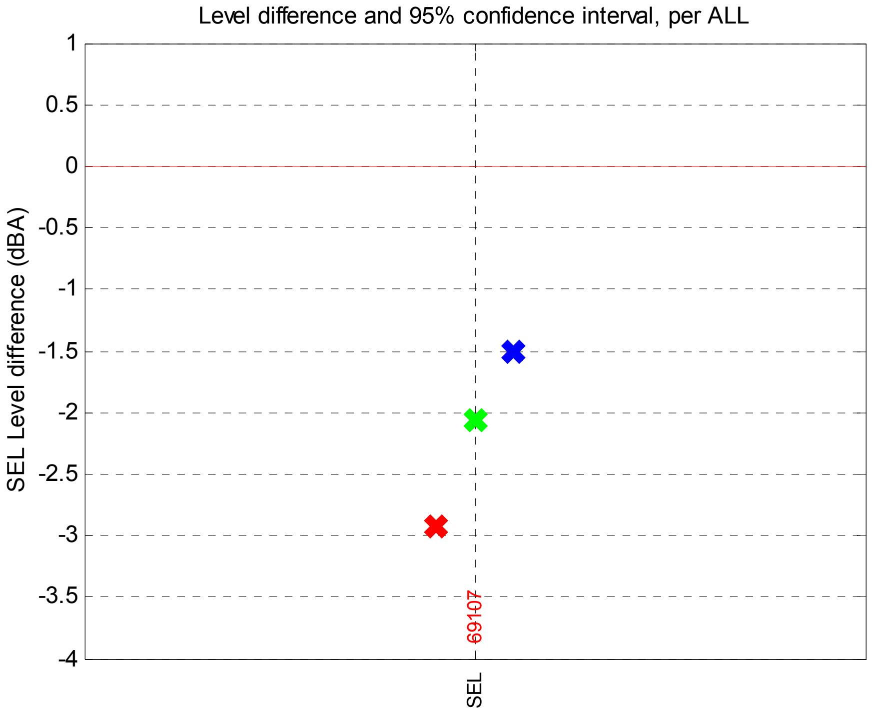

Figure 15 Simulated minus measured level for all samples, SEL

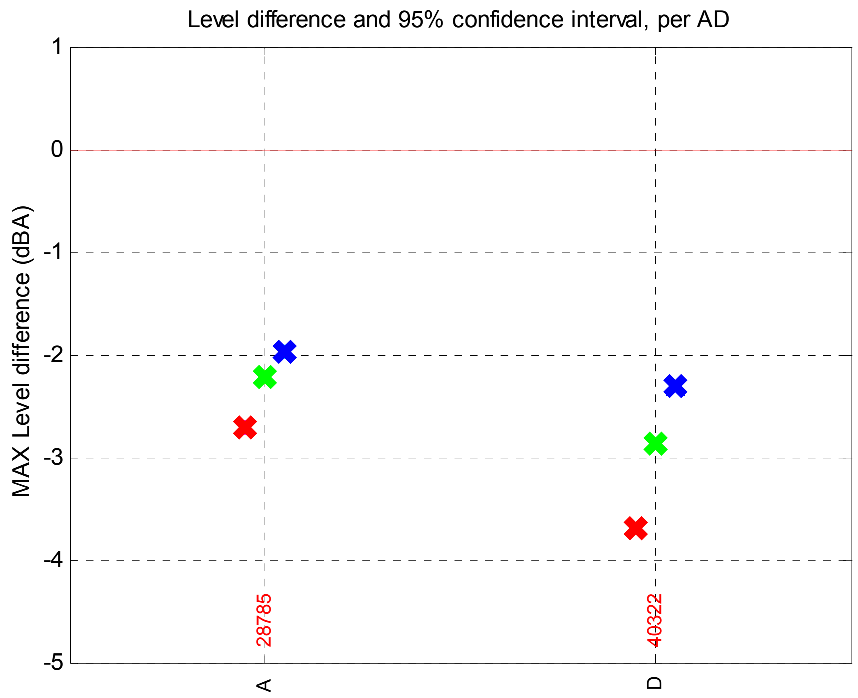

Figure 16 Simulated minus measured level for arrival and departure, LAMAX

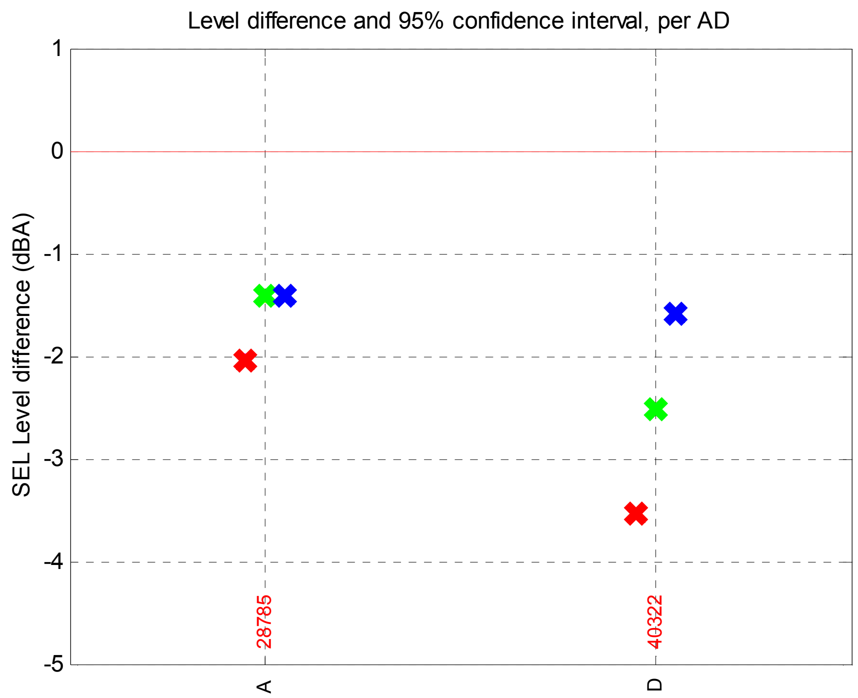

Figure 17 Simulated minus measured level for arrival and departure, SEL

6 Conclusions

The routines for ground effect and engine installation effect developed in this project improve calculation accuracy for the aircraft noise models NORTIM and GMTIM. For a sample of nearly 70.000 measurements at Gardermoen, the overall improvement is in the order of 1 dB for equivalent noise levels (SEL). Noise data extracted from the measurement program at Gardermoen in 2001 further improves the accuracy by 0.5 dB for SEL.

One can expect that a future revised recommendation from the SAE A-21 group will suggest a routine that may differ from the equations suggested here. However, the deviation is expected to be small. It is therefore recommended that updated versions of the two programs should be used in noise calculations as an interim solution until a revised recommendation for lateral attenuation appears.

An international co-operative work is needed to supply noise data from normal operations for all aircraft in the database. It is recommended that new noise data be implemented as they occur.

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Appendix: Engine installation – aircraft classes

- Aircraft with under wing mounted engines (W)
- Aircraft with rear fuselage mounted engines (R)
- Turboprop aircraft (T)
- Propeller aircraft (P)
- Fighter aircraft (F)
- Helicopter (H)

AC type	AC cat	Engine Install
707	J1	W
707120	J1	W
707320	J1	W
707QN	J2	W
720	J1	W
720B	J1	W
727100	J1	R
727200	J1	R
727D15	J1	R
727D17	J2	R
727EM1	J3	R
727EM2	J3	R
727Q15	J2	R
727Q7	J2	R
727Q9	J2	R
727QF	J3	R
737	J1	W
737300	J3	W
7373B2	J3	W
737400	J3	W
737500	J3	W
737700	J3	W
737D17	J2	W
737N17	J3	W
737N9	J3	W
737QN	J2	W
747100	J2	W
74710Q	J3	W
747200	J3	W
74720A	J3	W
74720B	J3	W
747400	J3	W
747SP	J3	W
757PW	J3	W
757RR	J3	W
767300	J3	W
767CF6	J3	W
767JT9	J3	W
777200	J3	W

AC type	AC cat	Engine Install
A10A	J0	R
A3	J0	R
A300	J3	W
A310	J3	W
A319	J3	W
A320	J3	W
A32023	J3	W
A330	J3	W
A340	J3	W
A37	J0	R
A4C	J0	F
A5C	J0	F
A6A	J0	F
A7D	J0	F
A7E	J0	F
AV8A	J0	F
AV8B	J0	F
B1	J0	W
B2A	J0	W
B52BDE	J0	W
B52G	J0	W
B52H	J0	W
B57E	J0	F
BAC111	J2	R
BAE146	J3	W
BAE300	J3	W
BEC58P	P0	P
BUCCAN	J0	F
C-130E	T0	T
C-20	J0	R
C118	P0	P
C119L	P0	P
C12	T0	T
C121	J0	F
C123K	P0	P
C130	T3	T
C130AD	T0	T
C130E	T0	T
C130HP	T0	T

AC type	AC cat	Engine Install
C131B	J0	R
C135A	J0	W
C135B	J0	W
C137	J0	W
C140	J0	W
C141A	J0	W
C17	J0	W
C18A	J0	W
C21A	J0	R
C22	J0	R
C23	J0	R
C5A	J0	R
C7A	P0	P
C9A	J0	R
CANBER	J0	F
CIT3	J3	R
CL600	J3	R
CL601	J3	R
CNA172	P0	P
CNA206	P0	P
CNA20T	P0	P
CNA441	T0	T
CNA500	J3	R
CNA55B	J0	R
COMJET	J1	R
COMSEP	P0	P
CONCRD	J0	W
CVR580	T0	T
DC1010	J3	W
DC1030	J3	W
DC1040	J3	W
DC3	P0	P
DC6	P0	P
DC820	J1	W
DC850	J1	W
DC860	J1	W
DC870	J3	W
DC8QN	J2	W
DC910	J1	R

AC type	AC cat	Engine Install
DC930	J1	R
DC93LW	J3	R
DC950	J2	R
DC95HW	J3	R
DC9Q7	J2	R
DC9Q9	J2	R
DHC6	T0	T
DHC6QP	T0	T
DHC7	T3	T
DHC8	T3	T
DHC830	T3	T
DOMIN	J0	F
E3A	J0	W
E4	J0	W
E8A	J0	W
EA6B	J0	F
EMB120	T3	T
EMB145	J3	R
EMB14L	J3	R
F-111F	J0	W
F-18	J0	F
F-4C	J0	F
F10062	J3	R
F10065	J3	R
F100D	J0	F
F101B	J0	F
F102	J0	F
F104G	J0	F
F105D	J0	F
F106	J0	F
F111AE	J0	F
F111D	J0	F
F117A	J0	F
F14A	J0	F
F14B	J0	F
F15A	J0	F
F15E20	J0	F
F15E29	J0	F
F16A	J0	F
F16GE	J0	F
F16N	J0	F
F16PW0	J0	F
F16PW9	J0	F

AC type	AC cat	Engine Install
F18EF	J0	F
F28MK2	J2	R
F28MK4	J2	R
F4C	J0	F
F5AB	J0	F
F5E	J0	F
F8	J0	F
FAL20	J2	R
FB111A	J0	F
GASEPF	P0	P
GASEPV	P0	P
GII	J2	R
GIIB	J2	R
GIV	J3	R
GV	J3	R
HARRIE	J0	F
HAWK	J0	F
HS748	J0	T
HS748A	T2	T
HUNTER	J0	F
IA1125	J3	R
JAGUAR	J0	F
JPATS	T0	T
KC-135	J0	W
KC10A	J0	W
KC135	J0	W
KC135B	J0	W
KC135R	J0	W
KC97L	P0	P
L1011	J3	W
L10115	J3	W
L188	T0	T
LEAR25	J2	R
LEAR35	J3	R
LHEL	H	H
LIGHTN	J0	F
MD11GE	J3	W
MD11PW	J3	W
MD81	J3	R
MD82	J3	R
MD83	J3	R
MD9025	J3	R
MD9028	J3	R

AC type	AC cat	Engine Install
MHEL	H	H
MU3001	J3	R
NIMROD	J0	W
OV10A	T0	T
P3A	T0	T
P3C	T0	T
PHANTO	J0	F
PROVOS	J0	F
S3A&B	J0	W
SABR80	J2	R
SD330	T3	T
SF340	T3	T
SR71	J0	R
T-2C	J0	F
T-38A	J0	F
T-43A	J0	W
T1	J0	F
T29	P0	P
T3	J0	F
T33A	J0	F
T34	P0	T
T37B	J0	R
T39A	J0	R
T41	P0	P
T42	P0	P
T44	J0	F
T45	J0	F
THEL	H	H
TORNAD	J0	F
TR1	J0	F
U2	J0	F
U21	T0	T
U4B	P0	P
U6	P0	P
U8F	P0	P
VC10	J0	R
VICTOR	J0	W
VULCAN	J0	W
YC14	J0	W
YC15	J0	W