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Assessment Of A Simplified Environmental Model For Aircraft Noise Prediction

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ABSTRACT

The environmental effects on the noise level on the ground from aircraft near the Arlanda airport are studied by numerical predictions of the acoustic transfer function from the aircraft position to the ground. Sound propagation is modelled by acoustic ray tracing using time-variable 3D atmospheric fields provided by the AROME prognosis model, combined with 2D data on ground topology and ground cover. The acoustic transfer function from selected points on the flight path to the ground is computed as function of range to the ground track at two-hour intervals during a one-year period. The results, aggregated into percentiles of the transfer function, are compared to similarly aggregated results from a simplified model of the atmosphere, the ground and the sound propagation. The simplifications are introduced to reduce the computational demands, are: (i) the ground is flat, (ii) the atmospheric parameters are functions of height only and (iii) rays are not continued beyond their first ground hit.

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1. INTRODUCTION

Modelling of the environmental effects on the propagation of sound from a passing aircraft to the ground is used routinely for investigation and prediction of noise pollution from air traffic. Such sound propagation modelling is a central component in integrated software such as SAFT [1] for simulation of the ground noise levels as function of atmospheric conditions, aircraft type and speed, engine status, flight path geometry, etc. For practical reasons, notably limits on available environmental data and computational resources, modelling of the environment and the sound propagation in such software is necessarily simplified to achieve tolerable computational times. The simplifications however lead to loss of accuracy and thus cause a need to assess the accuracy of the propagation modelling.

In this paper we investigate the effects of such simplifications in the acoustic ray tracing module of the SAFT software by comparing its predictions of the acoustic transfer function to the ground with predictions obtained with XRAY, a raytrace code with more detailed modelling of the atmosphere, the ground geometry, the ground interactions and the sound propagation [2], [3]. The predictions are computed every two hours under a one-year period and the results are presented as percentiles of the transfer function from four aircraft locations on the approach to runway 26 of the Stockholm Arlanda airport to receivers along a 20 km long line perpendicular to the ground track of the aircraft.

2. COMPUTATIONAL STUDY

2.1 Ground geometry and ground properties

A 51 x 62 km rectangular region around the North-East approach to runway 26 of the Stockholm Arlanda airport was considered. The left frame in Figure 1 shows the ground height in this region, with the runway and the ground track of a linear flight path indicated by a magenta strip and a brown dotted line, respectively. Four computational cases denoted A, B, C and D were considered. In each case, the acoustic transfer function was computed from a source point on the flight track to receivers on the ground along a line orthogonal to the ground track and centered vertically under the source as illustrated by the black lines marked A-D in Fig.1. The horizontal ranges from the runway to the source point of the four cases were 1, 3, 10, 30 km and the corresponding source heights, for a flight path with 3^o elevation angle, were 52, 157, 524, 1572 m above the height of the runway.

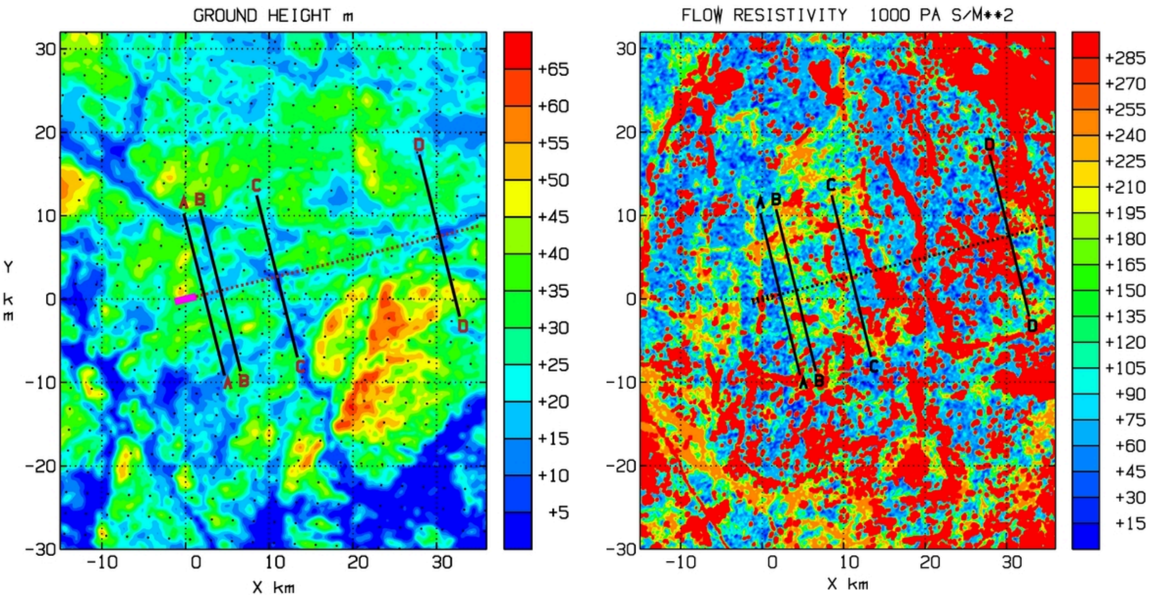


Figure 1: *The computational region at runway 26 of the Stockholm Arlanda airport. Left: Ground height, with the runway and ground track indicated by the magenta strip and the dotted line. The black transects marked A-D show the receiver lines on the ground in the four computational cases. The black dots indicate gridpoints of the AROME prognosis model providing the atmospheric data. Right: Flow resistivity of the ground.*

In the XRAY code, the ground height is modelled as a smooth function *h(x,y)* of the horizontal coodinates, with the *x a*nd *y* axes pointing east and north, respectively. *h(x,y)* is represented by a B-spline expansion fitted to ground height data from Lantmäteriet [8]. The ground is an impedance boundary of the acoustic field, with impedance as function of frequency and flow resistivity given by the Delaney-Bazley model [6]. The flow resistivity of the ground, shown in the right frame of Fig. 1, is obtained by combining Table I in Embleton et.al. [5] with data on the ground cover type from Swedish Environmental Protection Agency [4].

In the SAFT code the ground height was modelled as independent of *(x,y)* and the ground material is modelled as acoustically rigid. The ground reflection was represented by a constant multiple of the incident acoustic intensity at the ground.

2.2 Atmospheric data

The atmospheric data were given as snapshots of the atmospheric field at two hour intervals throughout year 2017. Each of the 4319 snapshots consisted of data from the AROME prognosis model on a 3D grid with 65 vertical levels and 2.5 x 2.5 km horizontal resolution available from archives at the Norwegian Meteorological Institute [7]. The black dots in Fig. 1 show the positions of the AROME gridpoints in our computational region.

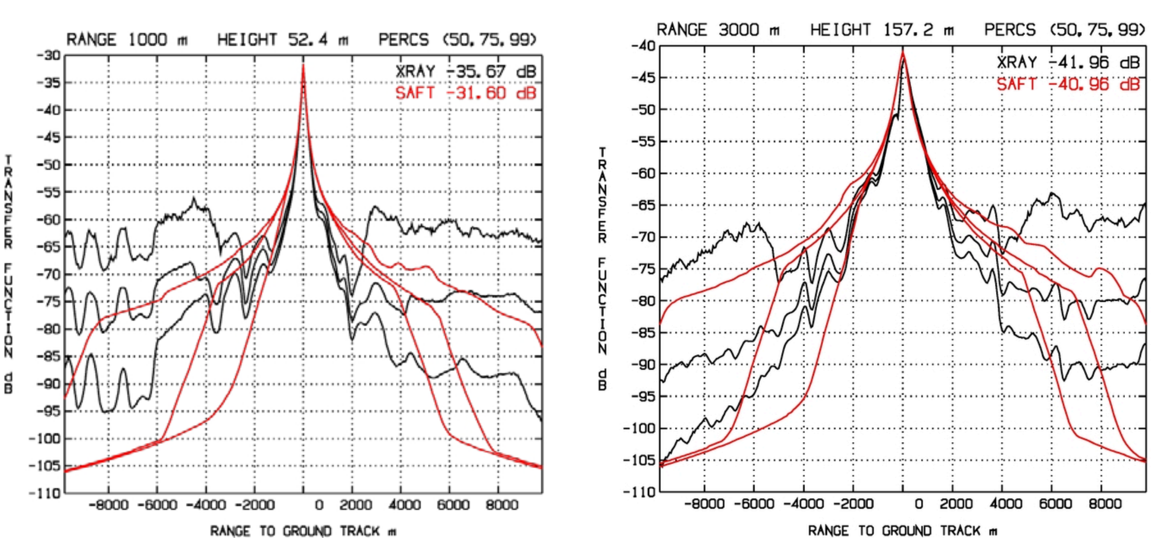
In XRAY the data on the AROME gridpoints were processed by smoothing and interpolation combined with variance-reducing B-splines [9, ch.11] to obtain smooth representations of the atmospheric fields air pressure *p(x,y,z)*, temperature *T(x,y,z)*, the *x* and *y* components *u(x,y,z)* and *v(x,y,z)* of the wind velocity, relative humidity *RH(x,y,z)* and sound speed *c(x,y,z).*

In the SAFT code the atmospheric data were simplified to be functions of height z only, defined by the AROME data at the gridpoint closest to the midpoint of the runway.

3. RESULTS

Fig. 2 shows a summary of the results of the four computational cases in the form of the 50 %, 75% and 99% percentiles of the squared average transfer function

over a frequency band with center frequency fc = 100 Hz and 1/3 octave bandwidth B = 23 Hz. *r* and *f* denote, respectively, the coordinate along one of the the lines A-D on the ground in Fig. 1 and frequency. *p(r,f)* is the complex pressure excited at r, -10000 <= r <= 10000, by a non-directive point source at the source position above *r = 0* on the transect. $p_0(f)$ denotes the complex pressure 1m away from the point source. The black and the red curves show percentiles of *TF(r)* computed by XRAY and SAFT, respectively.



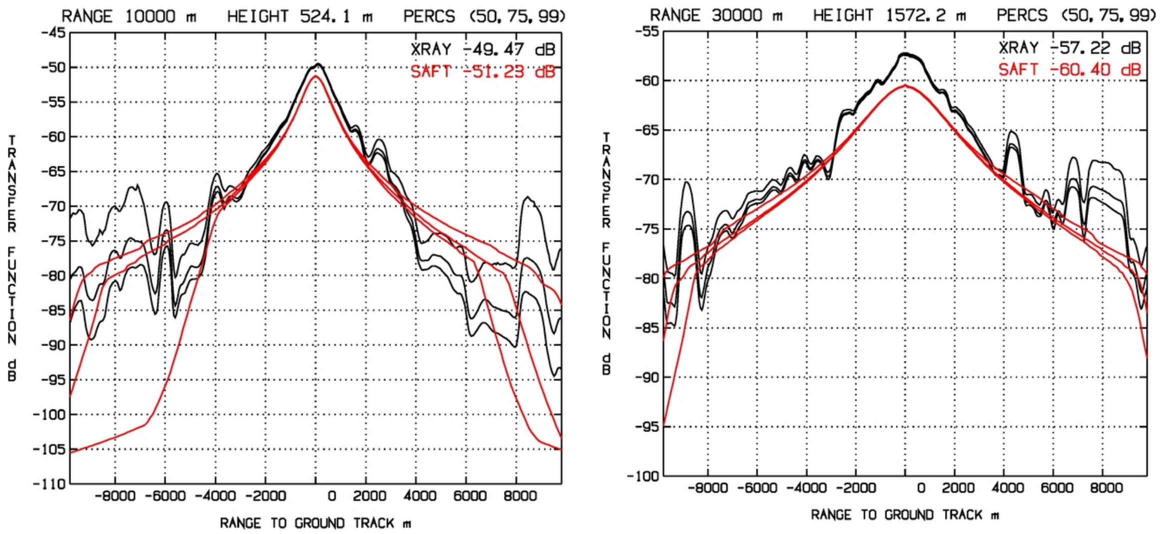


Figure 2: *50%, 75% and 99% percentiles of the transfer function from the source point to the receivers on the ground in the four cases A (top left, B (top right), C (bottom left) and D (bottom right) computed with XRAY (black) and SAFT (red).*

As seen in Fig. 2 the differences between the percentiles computed SAFT (red curves) and those computed with XRAY (black curves) are quite significant for all values of *r.*

In particular, large differences emerge in source-receiver configurations in which the elevation angles of the sound propagation paths are small and consequently the influence of ground interactions and horizontal variations of the ground height and the atmospheric fields is large. Such far-field differences of the 99% percentiles of the transfer function *TF(r)* are up to 30 dB, (case A), 18 dB (case B), 13 dB (case C) and 9 dB (case D).

Differences are seen to occur also for small values of i.e. near the ground track where the sound propagation paths are steep. Predominant causes of such near-field differences are the simplified modelling of ground interactions in SAFT and differences in the sound absorption model of the two codes.

5. ACKNOWLEDGEMENTS
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