VERIFICATION OF ALAQS HOURLY 3D GRID SOURCE APPROACH WITH SMOOTH AND SHIFT PARAMETERS TO ACCOUNT FOR PLUME DYNAMICS

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INTRODUCTION

Aviation is experiencing the fastest growth compared to other transport modes. Despite all the economic benefits that airports bring they have significant environmental impacts on those living nearby. One of the constraints is to comply with the mandatory air quality limit values for NO2 that will become effective in 2010 (as set down in EU Directive 1999/30/EC). As a consequence, accurate air quality studies in Europe are becoming more widespread.

In this context, the ALAQS project was initiated by EUROCONTROL to develop a pan-European methodology and model (ALAQS-AV) to assess aviation's contribution to the degradation of the local air quality surrounding airports. ALAQS-AV is an emission inventory tool specialised in airport air quality used to evaluate the impact of various emission inventory and dispersion calculation methods on the local air quality at airports.

The ALAQS-AV tool intends to provide a general output that can be handled in the same way (at least in principle) by all dispersion models of interest (Gaussian, Lagrangian and Eulerian). After consulting air quality modelling experts, passive three dimension grid sources were found to be the best format to provide data for all types of dispersion models. The Lagrangian random walk model LASAT was the first application coupled with ALAQS-AV using the transformation tool ALAQS-TRANS.

A critical issue was how to deal with source dynamics and in particular how to consider the initial dynamics of the plume after the release of the exhaust gas. Recently, sensitivity studies were performed at Zurich airport in the course of the ALAQS project with ALAQS-AV and LASPORT tools [EUROCONTROL, 2006]. Those studies showed that source dynamics were one of the parameters with the greatest impact on ground concentrations. Therefore, it appeared important to consider source dynamics in the same way in various dispersion models in order to allow for meaningful comparisons.

EU assessment values are based on hourly concentration means. For aircraft applications, source dynamics decay on a time scale of a few minutes. Within this time, they lead to displacement (both horizontally and vertically) and an enhanced dispersion of the emitted plume. On a time scale of one hour and for distances not too close to the emission location, one can account for source dynamics therefore in an approximate way by smoothing and shifting the initial source extent ("smooth and shift" approach). Within the context of ALAQS-AV, this leads to hourly passive grid sources.

The object of this study was to verify the ALAQS grid source output and the applied "smooth and shift" parameters. The parameter values were derived from the source dynamics modelling as implemented in LASPORT 1.6. The Lagrangian particle model LASAT was chosen as the dispersion model. It is used for the dispersion calculation also by LASPORT. The output of the combination ALAQS-AV/LASAT was compared to the output of LASPORT for common test scenarios.

TOOLS

Table 1. List of the models used

Model	Version	Type	Description
ALAQS-AV	May06	Emission inventory	Emissions are calculated over 3D hourly passive grids
ALAQS-TRANS	???	Data manipulation	Creates LASAT input from ALAQS-AV output
LASAT	2.16	Dispersion	Lagrangian particle model
LASPORT	1.6	Emission inventory & dispersion	Includes LASAT; was developed on behalf of the German Airport Association (ADV)

METHODS

In order to verify that the ALAQS hourly grid sources output combined with the "smooth and shift" parameters were implemented correctly, it was necessary to perform some kind of verification. This verification was handled very simply (only one line source representing aircraft at take off) using a LASPORT-like setup, from which the ALAQS "smooth and shift" parameters originated. The same simple scenario was implemented in ALAQS-AV, and the output from this study was formatted using the ALAQS-TRANS programme so that it could also be used directly in the LASAT dispersion model.

The "smooth and shift" concept

The "smooth and shift" parameters for ALAQS-AV were derived from the default parameterization applied in the LASPORT 1.6 for handling source dynamics of aircraft, Auxiliary Power Units (APU), Ground Power Units (GPU), Ground Support Equipment (GSE) and road traffic. In the LASPORT model, aircraft source dynamics were accounted for using dynamic parameters such as exit velocity, decay time, both horizontal and vertical velocity fluctuations, as well as the width, height and vertical shift of the emissions. Details of the derivation are available in the report [Janicke, 2006].

The derivation of "smooth and shift" values from the values of the parameters that describe source dynamics in LASPORT was carried out in an analytic form, so that future refinements or modifications can be easily adopted.

A set of four parameters was obtained to define source dynamics in ALAQS 3D grid sources: width (horizontal extent of the plume), height (vertical extent), vertical shift, and horizontal shift. In the case of aircraft, the parameter set is a function of the ICAO LTO operating mode (idle, take-off, climb-out, and approach). Note that the "smooth and shift" parameters are independent of meteorology; therefore it was not possible to account in detail for the effect of wind direction on directed exit velocity or on plume rise. Instead, mean values were derived.

Table 2. Aircraft "smooth & shift parameters" derived from LASPORT 1.6 default settings

Parameter	Unit	Idle	Approach	Climb-out	Take-off
Width	m	81.0	165.0	278.0	301.0
Height	m	49.0	100.0	167.0	181.0
Vertical shift	m	0.0	-137.5	-171.0	0.0
Horizontal shift	m	0.0	0.0	360.0	360.0

Study plan

The verification of ALAQS-AV 3D grid sources and the "smooth and shift" approach was performed by comparing the concentrations from ALAQS-AV and from LASAT at various altitudes.

The three modelled cases are reported in table 3. Note that the ALAQS-AV results were compared against two cases from LASAT: LASAT with passive sources ("smooth and shift", case B) and LASAT with LASPORT source dynamics (case C). The comparison of A against B showed the difference was due to the use of 3D grids while the comparison of A (or B) with C highlighted the variation between "smooth and shift" approach and explicit (time-dependent) plume dynamics.

Table 3. Summary of the three cases modelled and their comparisons

	Model used	Plume dynamics description	Comparisons
Case A	ALAQS May06 LASAT	"smooth and shift" parameters applied onto ALAQS-AV 3D passive grid source	● ●
Case B	LASAT	"smooth and shift" parameters for passive line sources	● ●
Case C	LASAT	sources with LASPORT dynamics	● ●

Case Study

A comparable scenario was built in both ALAQS-AV and LASAT. One runway over flat terrain was considered with 10 aircraft per hour and take-off roll emissions (passive NO_x) only. The runway length was 1800 m. The direction of the aircraft was from east to west. The grid mesh was 50m and the calculation area of 6000m x 4000m centred on the runway. Flat terrain was assumed. Twenty vertical layers between 0 and 200m were considered for the analysis of concentrations.

Dispersion was calculated over an isotropic wind rose, the wind direction changing by 10º clockwise every hour. Other parameters were fixed: wind speed 3 m/s, Monin-Obukhov length 300m, roughness length 0.3m, displacement height 1.8m, and anemometer height 12m. The split of the take-off segment into grid source cells (for ALAQS-AV) and into line sources (for LASAT) was the same.

The statistical uncertainty of the concentrations, inherent in calculations with a Lagrangian particle model, was in the range of <1% (at the locations of high concentrations) to about 10% (at the locations of low concentrations).

RESULTS AND DISCUSSION

The maps presented in figure 1 show the ground concentration maps obtained in case A and case C. The map corresponding to case B is not shown because it is very similar to the map in case A. As expected, the major differences between passive, "smoothed and shifted" sources and sources with explicit dynamics occur in the near field at the runway level, the former causing an underestimation of the concentrations (darkest area in the middle of the map). With explicit source dynamics, the effect of (in particular vertical) concentration dilution takes some time and it is thus fully developed only at some distance from the runway. In contrast, for the passive sources the dilution takes effect from the beginning. However, in all cases A, B, and C, the pollution peak is located at the beginning of the runway, i.e. where the take-off roll starts. For locations further away from the runway, the difference between the cases is much smaller, indicating that the "smooth and shift" approach is feasible at some distance from the sources, in practice e.g. outside the direct airport terrain.

Case A: ALAQS-AV "smooth & shift" Case C: LASPORT source dynamics

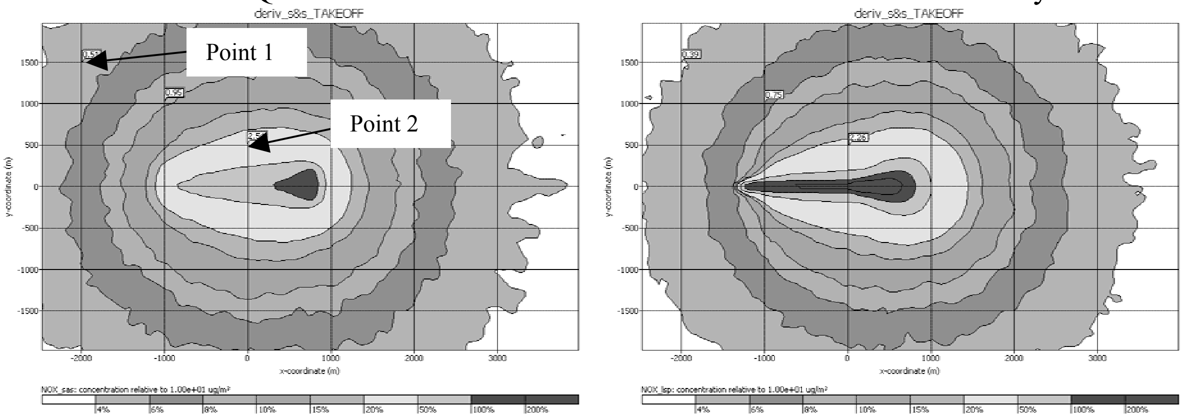
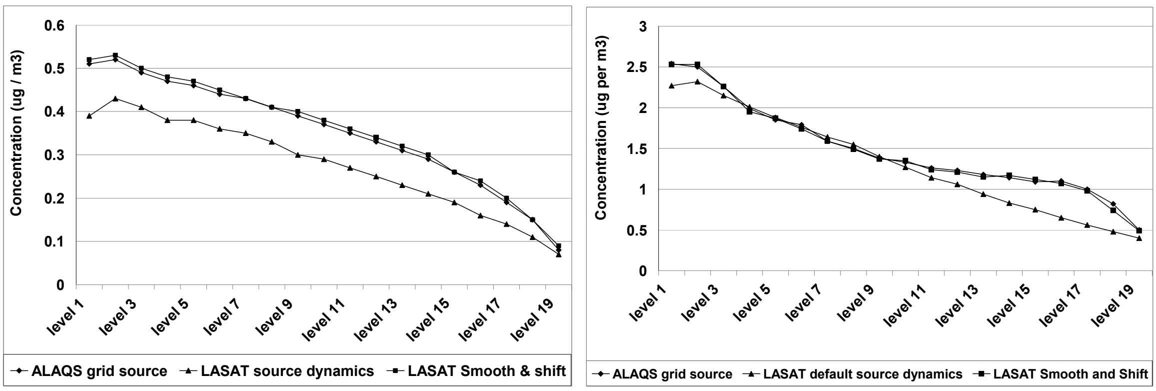


Fig.1; Ground concentrations results from ALAQS-AV and LASAT.

The next step of the analysis focused on the evolution of the vertical concentrations. Two sample locations were chosen, located at various distances from the runway but not in the runway axis (see figure 1). The results are shown in figure 2. Point 1 was at approximately 3300m from the origin of the runway, point 2 was 1100m away. A more detailed analysis is available in the full report [EUROCONTROL, 2006].



Point 1 (3300m) Point 2 (1100m)

Fig. 2; Vertical evolution of the concentrations resulting from the three cases modelled.

As expected, the ALAQS-AV concentrations are very similar to the concentrations obtained with LASAT "smoothed and shifted" line sources. This shows that the 3D grid source approach and the "smooth and shift" parameters were correctly implemented in ALAQS-AV. Considering point 1 far away from the main emission location, a small systematic difference (about 0.1 $\mu g/m^3$) was observed when comparing the vertical distribution of the "smooth and shift" cases with the ones with explicit source dynamics. When observing point 2 in the near field, discrepancies appeared especially for ground level concentrations and levels above 100m. This can be regarded as a consequence of the simplified handling of the additional near field dispersion in the "smooth and shift" approach. Here, the concentrations calculated using explicit source dynamics were slightly lower than for the two other cases with absolute differences between 0.5 and 1 $\mu g/m^3$. This could be due to the effect of directed exit velocity on the concentration distribution which depends on the direction of the ambient wind in the explicit source dynamics approach, whereas in the "smooth and shift" approaches it is modelled independently of wind direction using a fixed horizontal shift. As the same shift is used for all aircraft within the time interval of the study, the highest concentrations always occur in the same area in the "smooth and shift" approach while with explicit source dynamics the peak concentration areas also depend on the wind direction which changes every hour, leading thus to smoothed concentrations around the runway.

However, it is worth noticing that some other tests have been run using a simplified airport [EUROCONTROL 2005, 2006] and realistic meteorology parameters and it was shown that ALAQS "smooth and shift" concentrations at the runway are generally lower than the LASPORT results (by a few $\mu g/m^3$).

CONLUSIONS AND RECOMMENDATIONS

The 3D hourly grid source approach developed in ALAQS-AV has proven to be adequate to handle emission calculations combined with "smoothed and shifted" sources. Close to near-ground sources, the simplified approach with passive sources yields variations in concentrations, further away (e.g. outside the airport terrain), both approaches yield very similar results.

The ALAQS-AV "smooth & shift" parameters are transparently derived and thus easy to modify. They have been implemented for all airport-related sources, in particular aircraft, GSE, APU, and motor vehicles. Therefore ALAQS-AV can be used as a tool to evaluate the most appropriate values to consider for those parameters for each specific type of source. In addition, further sensitivity studies will be undertaken to fully reveal the importance and impact of source dynamics on ambient concentrations.

Another upcoming objective of the ALAQS project is to develop ALAQS-TRANS so that it can prepare other dispersion models' inputs. Presently, an interface for ALAQS-AV and the Gaussian dispersion model AERMOD is being developed.

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