COMPARISON OF MEASURED AND MODELLED NO2 VALUES AT ZURICH AIRPORT, SENSITIVITY OF AIRCRAFT NOX EMISSIONS INVENTORY AND NO2 DISPERSION PARAMETERS

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INTRODUCTION

It is acknowledged that the aviation industry is experiencing the fastest growth compared with other transport modes (EEA 2003 & 2004). Despite all the economic benefits that airports bring they have significant environmental impacts on those living nearby. One of their constraints is to comply with the mandatory air quality limit values for NO2 that will apply from 2010 (as set down in EU Directive 1999/30/EC) (DfT, 2003). As a consequence, accurate air quality studies are becoming more widespread in Europe.

In this context, the ALAQS project was initiated by EUROCONTROL to develop a pan-European methodology to assess aviation's contribution to the degradation of the local air quality surrounding airports. This paper reports on two studies which are part of the ALAQS project. The full reports (EUROCONTROL 2005 and 2006) can be consulted on the EUROCONTROL website or by contacting the authors.

Within the ALAQS project, a complete assessment of the regional air quality around Zurich airport was completed for the year 2004: it began with an emission inventory of the airport activities for the year 2004, and was followed by dispersion calculations of those emissions, taking into consideration the meteorology for the year 2004. The results from this dispersion study were combined with a regional emission inventory in order to calculate the total ambient regional pollution concentrations. Finally, measurements were taken at a number of locations in and around the airport and the measured values were compared with the modelled values at given locations.

The sensitivity study considered the impact of operational and program parameters on aircraft emissions inventory and dispersion for NO2 annual mean concentrations.

METHODOLOGY AND TOOLS

Measurements

Zurich airport air quality has been monitored for many years. The 21 monitoring sites used in the study were selected following a monitoring concept developed in collaboration with the Zurich local authorities which was last updated in 2005. The location and type of the monitoring stations is shown in figure 1. Three types of measuring equipment were used:
Passive NO2 sampling tubes for the regional stations (stations 1 to 18 in figure 1);
A standard NOx / NO / NO2 analyser located between the three runways of the airport (station 19 on figure 1);

Automated continuous monitoring stations using DOAS methodology (differential optical absorption spectroscopy - stations 20 and 21 on figure 1).

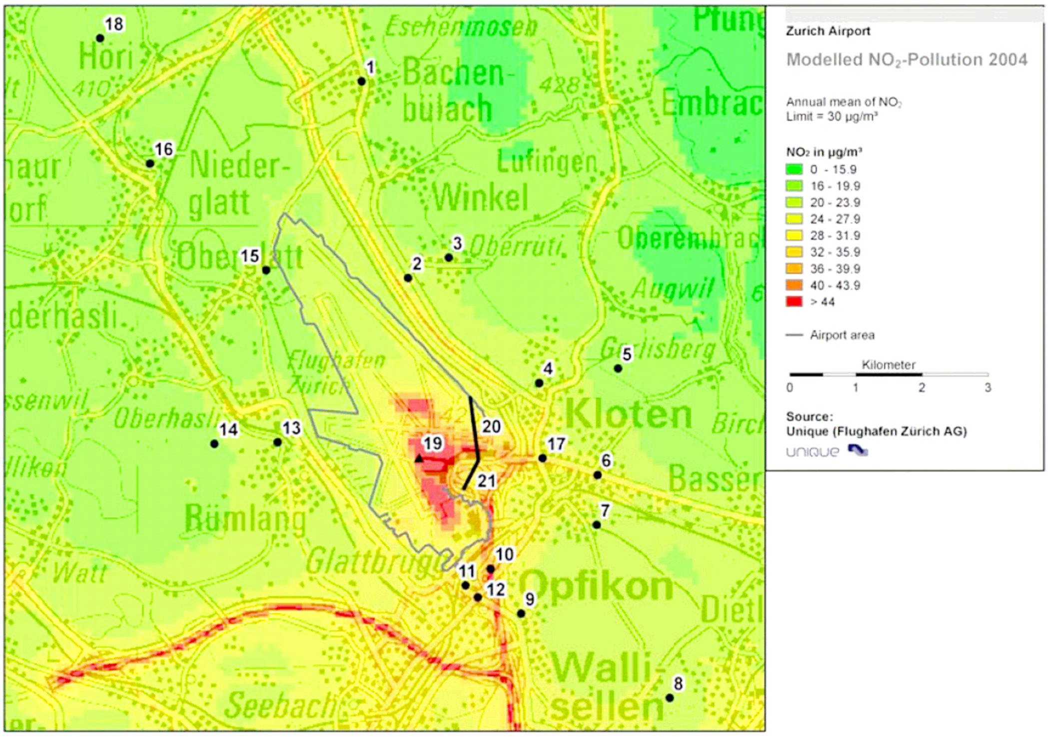

Fig. 1: Description and location of measurement points at and around Zurich airport.

Airport air quality model

LASPORT version 1.5 was used to carry out both the emission inventory and the study of the dispersion of the pollution at Zurich airport in 2004. LASPORT is a program package specialised in the prediction of air pollutant emission and dispersion at and around airports. The sources considered include the aircraft main engines and Auxiliary Power Units, Ground Power Units, Ground Support Equipment, airside and landside road traffic and other stationary source at an airport. A Lagrangian dispersion model, LASAT, is integrated in the LASPORT package.

The chemical conversion of NO to NO2 was modelled by means of linear conversion rates dependent on the atmospheric stability according to the German Guideline VDI 3872 Part 1 (VDI, 2001). An initial fraction of NO2 in NOx of 15% was assumed.

Aircraft emission calculations

When dealing with aircraft engine emissions within the LTO cycle, LASPORT version 1.5 makes it possible to use different methodologies: either using default aircraft flight profiles or the times-in-mode from the ICAO certification LTO cycle [ICAO, 1995]. The effect of various cut-off altitudes was evaluated using different height limits for the calculations - between 305m and 914m (ICAO limit altitude). Modified thrust, fuel flow and emission factors were adjusted manually outside LASPORT according to the Boeing fuel flow curve fitting method (ICAO CAEP, 2004.

In view of the comparison of modelled and measured concentrations, aircraft emissions were calculated using LASPORT default profiles, Zurich specific taxiing times, and a cut-off altitude of 600m derived from the German Clean Air Act in a conservative approach. Operational procedures such as reverse thrust, de-rated thrust or reduced thrust were not accounted for in the comparison with the monitored data. However a complete sensitivity analysis, on both emission and dispersion modelling, which considers those operational procedures, is available upon request.

Total ambient concentrations in the airport region

Besides the contributions of the airport, a large number of other emission sources have an effect on air quality, such as roads, rails, domestic heating, trade and industries, construction and industrial machinery, forestry and off-road activities. In order to obtain modelled airport-related concentrations that are comparable with the monitored values, it is necessary to consider those additional sources which contribute to the total concentration. This was achieved by the Swiss national and regional authorities, and in particular the canton of Zurich, which have developed an emission inventory and a dispersion model which take into consideration the relevant sources as listed above. Given that detailed emissions were calculated in 2000 and 2005, the emissions of the year 2004 were linearly derived for this study, except for road emissions, where the traffic from 2000 was taken. The NOx concentrations were calculated using a Gaussian plume model with a meteorological pre-processor, resulting in annual mean values on a hectare grid (100 x 100 m).

The regional NOx concentration grid was combined with the airport NOx concentration grid and transformed into the final NO2 concentration map. In addition to the region emission sources, background NOx was also accounted for in the model (19 µg/m3 in 2005). The background concentration is a function of reference of the actual terrain elevation, regional NOx production and import from further away. The resulting NOx was calculated into NO2 using an empirical approach: annual mean values for NOx and NO2 were taken from all measurement stations throughout Switzerland and a correlation (via a x-y-best fit curve) was used. This yielded good values for annual mean values - however this approach would not be suitable for short term considerations of very high NOx exposure.

MEASURED-MODELLED RESULTS

The modelled and measured concentrations were compared for the stations indicated in figure 1. The results are shown in figure 2 (bars correspond to modelled values, points to measured values). While some locations show a good correlation, others seem to be less correlated. The stations have been grouped in figure 1 according to their potential main contributor specified in the airport's ambient air quality monitoring concept (UNIQUE, 2004):
Monitoring stations most likely dominated by road traffic;
Monitoring stations most likely dominated by airport activities;
Monitoring stations most likely dominated by other sources;
Background monitoring stations.

The monitoring stations dominated by road traffic (stations 1, 2, 6, 10, 12, 17) showed higher measured concentrations than modelled concentrations. In the particular case of Zurich airport this was believed to be due to some underestimations in vehicle traffic. Considering the stations located close to the airport - and in particular the ones which are closest to the runways and the aircraft (i.e. stations 19, 20, and 21), the modelled concentrations were found to overestimate the monitored concentrations. This seems to confirm the thesis that the emission factors for aircraft in real operations are actually lower than the ICAO LTO defined ones for certification purposes. This thesis is also supported by, among others, Farias et al. (2006) and Schurman et al. (2007). There is also strong belief within the local air quality modellers' community that some other parameters (e.g. APU heat flux of initial vehicle plume dispersion) have considerable effects. Measurement stations dominated by other sources (as well as background stations) showed a good correlation between measured and modelled values.

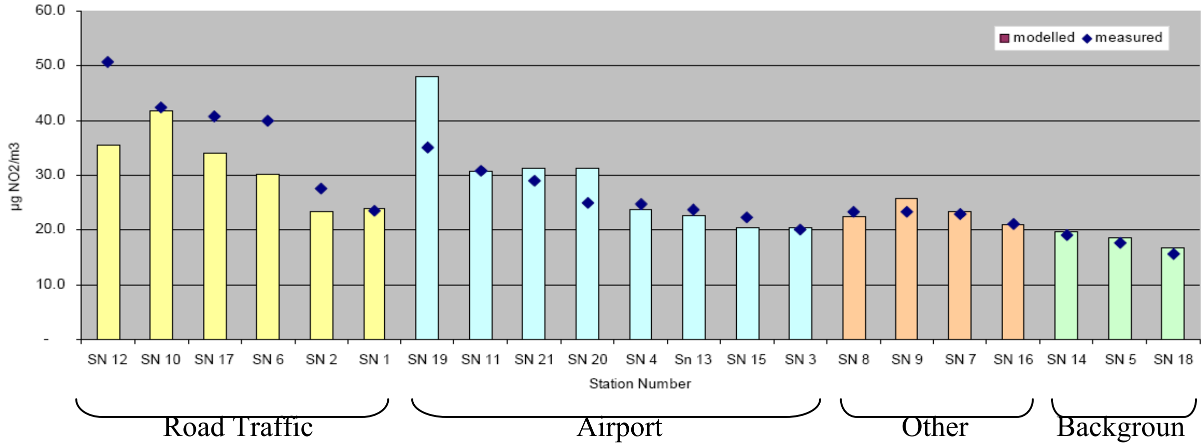

Fig. 2: Modelled vs. measured NO2 concentration values (2004)

In addition, the modelled NO2 concentrations show that the contribution of the airport activities to the degradation of the local air quality fall below 1 µg of NO2/m3 for a dispersion distance greater than 3 kilometres.

A full version of this study - including all results and conclusions for non-aircraft sources - can be consulted on the Eurocontrol website or by contacting the authors.

SENSITIVITY ANALYSIS RESULTS

In the sensitivity study operational and program parameters for emissions and dispersion were varied to determine their influence on the final concentrations and therefore the airport's contribution to local air quality. The study focused on aircraft sources because previous emission inventories for Zürich airport showed that aircraft main engines were the main source of NOx, other sources (aircraft handling, road traffic and infrastructure) accounted for less than 10% of total NOx emissions

Table 1: Operational variations in aircraft emissions calculation.

Scenario	Thrust in Mode	Time-in-mode	Tonnes NOx
0	ICAO default thrust in mode for all engine types and modes with respective ICAO fuel flow and NO_x indices.	ICAO default times-in-mode for all modes and all engines.	1 038.0
6	Modified thrust, expressed as modified fuel flow and NO_x indices for all jets using original fuel flow and NO_x data with Boeing fuel flow curve fitting method. [Dubois D., Painter G., 2006]),	Actual LTO times as calculated with LASPORT default profiles and ZRH taxiing times.	757.0

The results of the sensitivity study on a complete year of aircraft movements, where the ICAO LTO certification parameters were replaced with observed fuel flow and emission factors at Zürich, showed that modelled emissions were greater than measured values for aircraft dominated sources. The differences highlighted the sensitivity to careful choice of the times-in-mode, fuel flow and emission factors. The results in Table 1 show 2 of the 7 scenarios studied, these confirm the findings of Unique [Unique 2004] where individual modelled LTO cycles using the ICAO LTO overestimated the NOx emissions by between 4% (Airbus A340) and 47% (Boeing 767).

The dispersion sensitivity parameter study compared NO_2 annual mean concentration maps at Zürich for different parameters. Care was taken when combining different emission layers into one total pollution concentration layer to allow for NO to NO_2 conversion.

Complex terrain effects were found to contribute 1 to 3 µg/m3 NO_2. Mesh size can reduce computation time without impact on statistical uncertainty. Increasing the Cut-off altitude limit from 305m to 914m gave a marginal increment of maximum +0.75 µg/m3, in particular at locations in the centre of the airport where the concentrations were already high. Changing the Atmospheric stability by varying the Monin-Obukhov length from 2 to 20 showed less than ±0.3µg/m3 variation in NO_2. Changing the Source dynamics varied the height from 2m to 8m indicated variations of 9.5 µg/m3.

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