AIRPORT AIR QUALITY STUDIES IN ATHENS. FIRST RESULTS OF MEASUREMENT CAMPAIGN

Klaus Schäfer[a], Stefan Emeis[a], Carsten Jahn[a], Herbert-Maria Hoffmann[a], Christine Heyder[a], Costas Helmis[b], George Scouros[b], Helena Flocas[b], Maria Tombrou[b], Dimosthenis Asimakopoulos[b], Christoforos Halios[b], Ralf Kurtenbach[c], Anita Niedojadlo[c], Peter Wiesen[c], Evi Anamaterou[d], Michael O'Connor[d]

[a]Forschungszentrum Karlsruhe (FZK), Institute for Meteorology and Climate Research, Atmospheric Environmental Research, Kreuzeckbahnstr. 19, 82467 Garmisch-Partenkirchen, Germany

[b]National and Kapodistrian University of Athens (NKUA), Department of Applied Physics, Faculty of Physics, Building PHYS-5, University campus, 15784 Athens, Greece

[c]Bergische Universität Wuppertal (BUW), Faculty of Natural Sciences and Mathematics, Department of Chemistry, Laboratory for Physical Chemistry, 42097 Wuppertal, Germany

[d]Athens International Airport S.A., Environmental Services Department, 19019 Spata, Greece

ABSTRACT

Emission inventories of airports are not well known generally because a lot of different emission sources exist. A database is required to characterise real-world emission source strengths as well as air quality and meteorological data at airports that will serve as an input and as validation data for modelling work.

To develop a database of air quality and meteorological data a measurement campaign was carried out at the Athens International Airport (AIA). The campaign from 13 until 25 September 2007 was realised with the aid of existing monitoring equipment at the AIA as well as at the participant partners that was transferred to the AIA, allowing the sharing of knowledge and infrastructure.

The concept of this measurement campaign will be presented. The first results of interpretation of measured data will be discussed such as aircraft emission indices during take-off, influence of aircraft emissions upon airport air quality, possibility of estimation of the airport emission source strengths and influence of airport emissions upon air quality in the surroundings. The future tasks of data use will be discussed as further investigation of aircraft plume processes, modelling of the representative daily course of air quality parameters and meso-scale air pollution studies.

Keywords: *Aircraft emissions, air quality, airport.*

1. INTRODUCTION

The impact of air traffic on the atmosphere was subject to several works in the last years (Rogers et al., 2002; EEA, 2001). But little scientific work has been done concerning airport air quality. Airports themselves often measure concentrations of the main pollutants and use dispersion models to assess the air quality situation.

The objective of this study is to develop a database of air quality and meteorological measurements in an airport that will serve as an input and validation data set for modelling work. For this purpose a measurement campaign was carried out at the Athens International Airport (AIA) investigated from Moussioupolos et al. (2002) by FZK, NKUA and BUW from 13 until 26 September 2007. The campaign was realised with the aid of existing equipment available by the participant partners that was transferred to the AIA, allowing the sharing of knowledge and infrastructure.

The basic characteristics of these investigations are:

- Sample points are spread at different representative locations to collect sufficient data allowing an air quality analysis with respect to European regulation implementation procedures relevant to measurements.
- Different analyzers or remote sensors are placed around the airport, further to background atmosphere and at the edge of the airport domain in order to follow and measure import/export of pollutants and exhaust emissions. This will yield information on different airport activities since they have not equivalent contributions on these specific sites.
- During the experimental period, routine ongoing existing airport air quality measurements were augmented with special measurements provided by additional equipment, according to the needs of the campaign.
- Meteorological stations run continuously at airports and are operated either by the airport authority or the National Meteorological Service to deliver routine observations for management and regulation of air traffic. However, vertical profiles of wind and turbulence are available from radiosonde measurements four times per day only. Sophisticated meteorological equipment (remote sensing and in situ) was installed also to determine continuous information about vertical profiles of wind and turbulence.

The identified scientific objectives for the measurement campaign were:

- Determination of the influence of airport emissions upon air quality in the surroundings (Yu etal., 2004; Unal et al., 2005),
- Estimation of the airport emission source strengths for numerical simulation of airport air quality (Schürmann et al., 2007),
- Determination of the influence of aircraft emissions upon airport air quality (Spicer et al., 1994),
- Determination of the aircraft emission indices during take-off (ICAO, 1993; Popp et al., 1999; Schäfer et al., 2003; Herndon et al., 2004),
- Investigation of the representativeness of airport air quality monitoring sites for the characterisation of airport air quality.

2. STATE OF THE ART

The routine measurements at AIA include (see Figure 1):

1. One continuous air quality monitoring mobile station at the airport (NO_x, NO_2, NO, SO_2, CO, O_3, PM10, total hydrocarbons)
2. Five stations (SPA, PAL, MAR, GLY, KOR) consisting the Air Quality Monitoring Network (AQMN) of the AIA monitoring the air pollution levels in the neighbouring area around the airport (NO_x, NO_2, NO, SO_2, CO, O_3, PM10, total hydrocarbons), along with the prevailing wind direction and wind speed. Four of these stations record BTX (benzene, toluene, xylene) as well.
3. One meteorological station at the airport providing continuous observations of wind speed and direction, air temperature, relative humidity. Rainfall is recorded at the above mentioned 5 AQMN stations in the periphery of the airport, solar radiation at two of them (MAR and PAL) while atmospheric pressure data are collected at one AQMN station (SPA).

4. One SODAR/RASS system for continuous, remote measurements of the three-dimensional wind and temperature profile as well as turbulence characteristics in the lower atmosphere. The SODAR/RASS is located next to the meteorological station.
5. One DOAS System is located at the beginning of a runway (next to the current position of the AQMN mobile station) to contribute not only to the assessment of air quality on the Airport premises, but also to the monitoring of aircraft emissions.

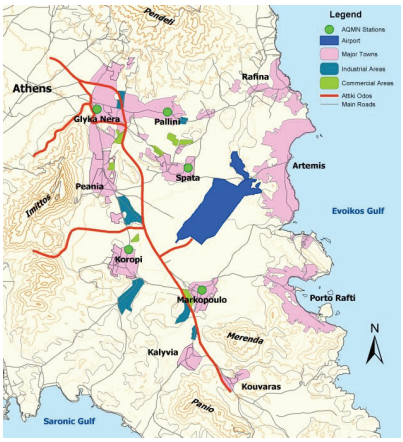

Figure 1: Air Quality Monitoring Network (AQMN) of the Athens International Airport (AIA)

3. METHODOLOGY

In order to get detailed insight in airport air quality at the airport, all available information are analysed together. The measurement sites were chosen in such a way that the influence of runways can be identified in the concentration measurements. This implies an upwind and downwind measurement with respect to the taxiways and runways. Due to the careful choice of the measurement locations according to the main wind directions, it was guaranteed, that for all main wind directions the influence of the airport or parts of the airport can be derived from the measurements. To get insight in chemical processes, detailed measurements of chemical species at different distances downwind of the runway were performed.

The following special measurements were performed according to the needs of the development of a data base for airport air quality within the frame of this measurement campaign by FZK and BUW at site A; see Figure 2a:

- In situ instruments for CO (Al5001, Aerolaser), NO_x (TE42CL, Thermo Electron and CLD AL, ECO-Physics), O_3 (APOA-350E, Horiba), total hydrocarbons (APHA-350-E, Horiba) CO_2 (Carbondio 1000 ppmV, Pewatron), HCHO (Al4001, Aerolaser), particlenumber size distribution (SMPS, TSI) and an automatic VOC sample system (VOC C_2-C_{10}) within a measurement van,
- A PM10 instrument (FH62I-R, Thermo Electron), stand alone,
- A ceilometer for mixing layer height (LD40, Vaisala), stand alone,
- Ultrasonic anemometer for wind and temperature (USA-1, Metek), stand alone,
- An open-path DOAS system for NO and NO_2 (emitter/receiver unit ER130, analysator AR500, OPSIS) with one retro-reflector (RR090, OPSIS), stand alone (see Figure 2b),
- An open-path FTIR system for CO and CO_2 (spectrometer K300, Kayser-Threde) with globar in parallel to the DOAS (Kayser-Threde), stand alone (see Figure 2b).

Figure 2: (a) Location of all air pollution and meteorological measurement equipment at AIA together with site A and B for additional equipment by FZK, BUW and NKUA (left) and (b) location of open-path measurements by FTIR and DOAS at site A (right)

A picture of the actual installation at site A is given in Figure 3.

Figure 3: Measurement site A with all installations

The following instrumentation of NKUA was operated at site B (where the AIA SODAR system is operating, see Figure 2a):

- 10 m mast equipped with sonic anemometers and fast hydrometers at 2 levels,
- Air quality monitoring mobile station equipped with NO_x, SO_2, O_3, PM10, PM2.5 in situ analyzers,
- 1 in situ instruments for NO_x (TE42CL, Thermo Electron), for intercomparison,
- PM10, PM2.5, PM1 airborne particle monitors.

4. RESULTS

The NO and NO_2 concentrations at site A and B as well as movements of aircraft at both runways are shown in Figure 4 and together with wind speed and wind direction in Figure 5. There is no clear correlation between the air pollution and the aircraft movements at the runway nearby. During the afternoon hours with aircraft departures at the runway the NO and NO_2 concentrations are enhanced in comparison to the time periods before and after. It is obvious that the change from westerly wind direction to easterly ones during the day is followed by the pollution concentrations at both sites. During easterly winds site A is

downwind of the airport and correspondingly the NO_2 concentrations at site A are higher than at site B. The same relation holds for most of the time periods with westerly winds so that emission sources westerly of the airport seem to be important. The pronounced peak concentration of NO and NO_2 in the morning can be caused by road traffic. The influence of the mixing layer height can be important also.

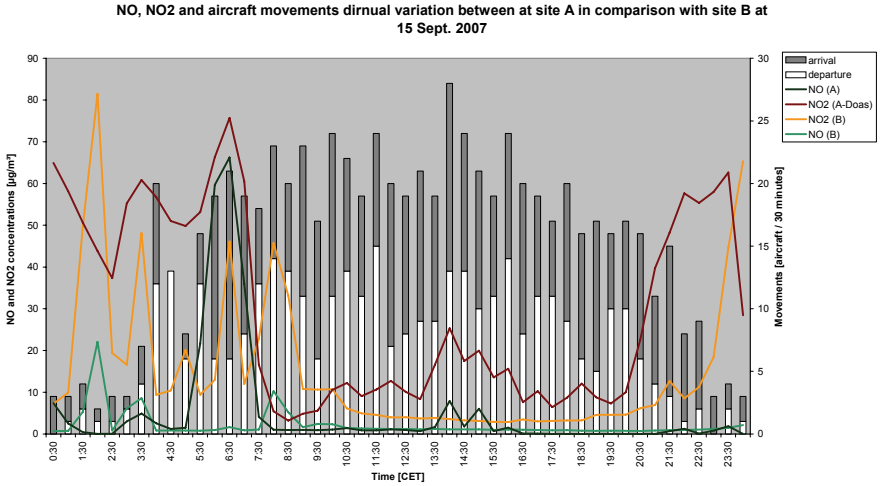

Figure 4: NO and NO_2 concentrations at site A and B as well as movements of aircraft at both runways on 15 September 2007

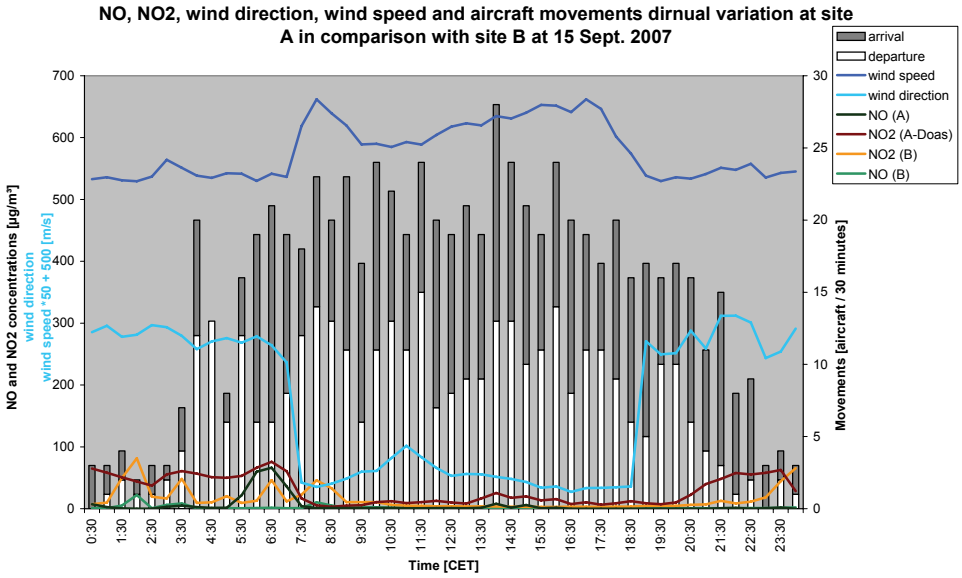

Figure 5: NO and NO_2 concentrations at site A and B as well as movements of aircraft at both runways together with wind speed and wind direction on 15 September 2007

The influence of departing aircraft at the runway nearby site A in the afternoon upon NO_2 concentrations (see Figure 2, 4 and 5 also) is shown in Figure 6. A lot of peak concentrations are clearly correlated with aircraft plumes.

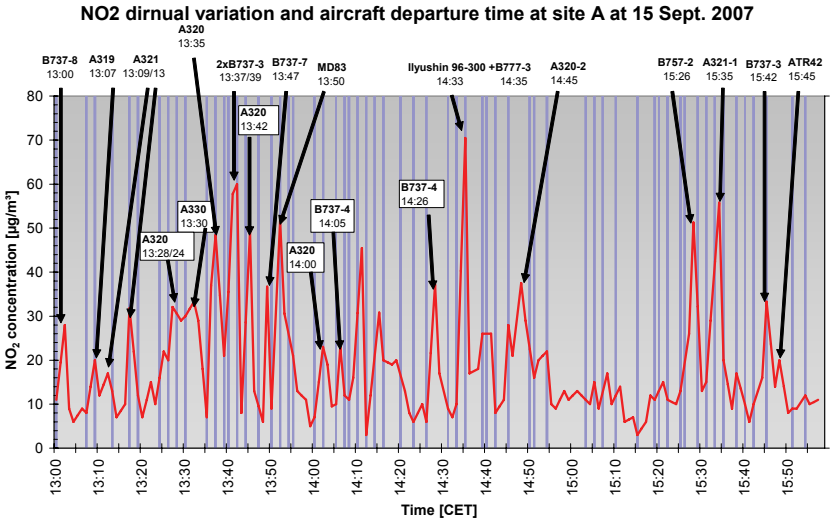

Figure 6: NO_2 concentrations measured by DOAS and departing aircraft at the runway nearby site A on 15 September 2007

Unfortunately, only some CO_2 peak concentrations are correlated with aircraft departures at the runway nearby.

The particle number size distribution in a single aircraft plume is shown in Figure 7. It peaks at particle diameters of 22 nm. Exactly the sizes up to about 30 nm are not present in ambient air so that these are originated by the aircraft engines.

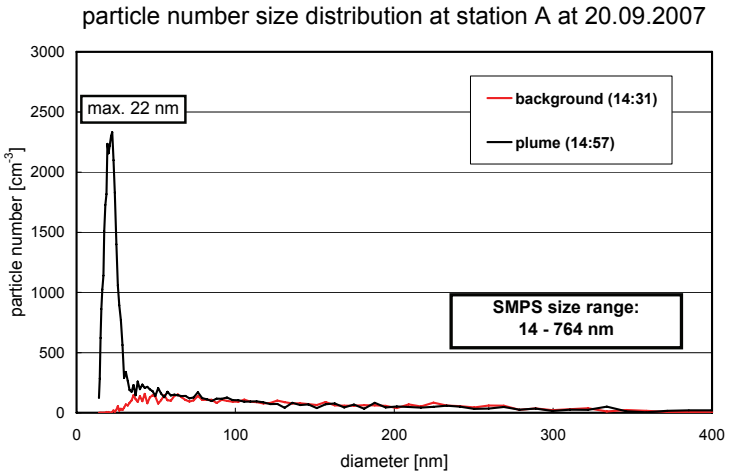

Figure 7: Particle number density distribution in an aircraft exhaust plume as well as in ambient air some minutes earlier on 20 September 2007

The temporal variation of NO_2, O_3 and NMHC concentrations at site A on 20 September 2007 is shown in Figure 8. The clear anti-correlation between NO_2 and O_3 is giving information about NO_x chemistry within aircraft exhaust plumes, i.e. the formation of NO_2 by means of O_3. Some enhanced NMHC concentrations in exhaust plumes can be observed also.

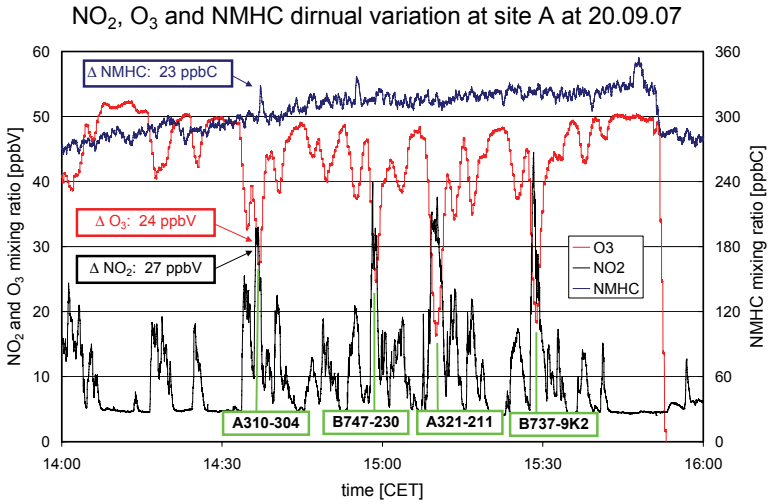

Figure 8: Temporal variation of NO2, O3 and NMHC concentrations at site A on 20 September 2007

In Figure 9 the O_x (O_3 + NO_2) mixing ratio in dependence from NO_x (NO + NO_2) mixing ratio on 14 September from 13:00 until 16:00 is given. Using the determined linear relationship of O_x from NO_x the primary NO_2/NO_x ratio (0.22 ± 0.06) and the O_3 background mixing ratio (53 ± 3 ppbV) are calculated.

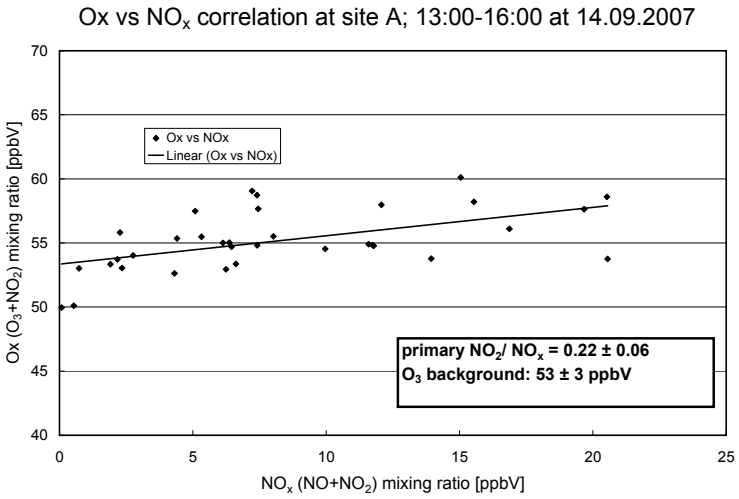

Figure 9: Ox (O3 + NO2) mixing ratio in dependence from NOx (NO + NO_2) mixing ratio on 14 September from 13:00 until 16:00. The primary NO2/NOx ratio and the O3 background mixing ratio are given also

5. CONCLUSIONS

Site A is representative for an airport area of about 1 km x 1 km. But during certain meteorological conditions short-time aircraft emissions as well as enhanced mean air pollution concentrations (NO_2, NO, NMHC, PM) from the nearby runway can be detected also.

The influence of airport emissions upon air quality in the surroundings is important in relation to other sources as road traffic. Other sources can be more important as e.g. in the morning the road traffic peak.

The estimation of the airport emission source strengths can be detected due to different wind directions and the determination of mixing layer height. The upwind and downwind situations for site A and B can be analyzed.

The influence of aircraft emissions upon airport air quality is detected (NO_2, NO, CO, VOC, PM) by taking into account the chemistry. These are short-time influences in the order of 1 minute.

The future tasks of data interpretation are further investigation of aircraft plume processes, modelling of representative daily curse of air quality and meso-scale air pollution studies.

6. REFERENCES

EEA (European Environmental Agency), 2001. Emission inventory Guidebook, Air Traffic, SNAP Codes 080501 -080504. Kopenhagen, Denmark (http://reports.eea.eu.int/EMEPCORINAIR4/en/B851vs2.4.pdf).

Herndon, S.C., Shorter, J.H., Zahniser, M.S., Nelson, D.D., Jayne, J., Brown, R.C., Miake-Lye, R.C., Waitz, I., Silva, P., Lanni, T., Demerjian, K., Kolb, C.E., 2004. NO and NO2 Emission Ratios measured from in-use commercial aircraft during taxi and takeoff. Environmental Science & Technology 38, 6078 - 6084.

ICAO - International Civil Aviation Organization, 1993. Environmental Protection, Annex 16 Vol II, Aircraft Engine Emissions, 2nd edition. ICAO Document sales unit, 1000 Sherbrooke Street West, Suite 400, Montreal, Quebec H3A 2R2, Canada (http://www.caa.co.uk/default.aspx?categoryid=702&pagetype=90).

Moussiopoulos, N., Sahm, P., Karatzas, K., Papalexiou, S., Karagiannidis, A., 1997. Assessing the impact of the new Athens airport to urban air quality with contemporary air pollution models. Atmospheric Environment 31, 1497 - 1511.

Popp, P.J., Bishop, G.A., Stedman, D.H., 1999. Method for commercial aircraft nitric oxide emission measurements. Environmental Science & Technology 33, 1542 - 1544.

Rogers, H.L., Lee, D.S., Raper, D.W., Foster, P.M.d.F., Wilson, C.W., Newton, P.J., 2002. The impact of aviation on the atmosphere. The Aeronautical Jounal 106, 521 - 546.

Schäfer, K., Jahn, C., Sturm, P., Lechner, B., Bacher, M., 2003. Aircraft emission measurements by remote sensing methodologies at airports. Atmospheric Environment 37, 5261 - 5271.

Schürmann, G., Schäfer, K., Jahn, C., Hoffmann, H., Bauerfeind, M., Fleuti, E., Rappenglück, B, 2007: The impact of NO_x, CO and VOC emissions on the air quality of the airport Zurich. Atmospheric Environment 41, 103-118, doi:10.1016/j.atmosenv.2006.07.030.

Spicer, C.W., Holdren, M.W., Riggin, R.M., Lyon, T.F., 1994. Chemical composition and photochemical reactivity of exhaust from aircraft turbine engines. Annales Geophysicae 12, 944 - 955.

Unal, A., Yongtao, H., Chang, M.E., Odman, M.T., Russell, A.G., 2005. Airport related emissions and impacts on air quality: Application to the Atlanta International Airport. Atmospheric Environment 39, 5787 - 5798.

Yu, K.N., Cheung, Y.P., Cheung, T., Henry, R.C., 2004. Identifying the impact of large urban airports on local air quality by nonparametric regression. Atmospheric Environment 38, 4501 - 4507.