Air quality and engine emission at Paris CDG airport during AIRPUR field campaigns

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Abstract

Intensive air quality measurements have been organised at Paris Charles de Gaulle airports to characterise source emissions: NO, NO2, speciated VOC, CO, and for aerosols particles including soot and to investigate the influence of emissions on air quality. Chemical samplers, GC and laser techniques have been used to perform gas monitoring by in-situ or by remote sensing at different locations at the airports. Particulate matters have been measured by ELPI, SMPS, TEOM PM1-PM10. Instruments have been deployed at aprons, beside taxiways and runways, at engine test areas, along roads, and at airport landscapes. Samplings performed inside engine plumes for different power settings show a maximum in number of ultra-fine volatile particles (7–10 nm diameter) whereas the concentration of the soot mode (20–40 nm) is at a factor of 100 lower. TEM filter samplings have been continuously operated and show the presence of aggregated soot (20–40 nm) and aerosols containing some proportion of S, Si, Fe, Ca, Mg, and K. VOC emission indices indicate a maximum for ethyne, propene, ethene, benzene, toluene, m-p-xylene, nonane and 1-3butadiene. Results show that NO_2 is highly produced at lower power settings than NO, which dominates the emission at higher thrust setting. Summertime measurements depicting high air temperature lead to a high concentration of ozone. Nevertheless, the airport maximums were lower than observed in the vicinities of the airports and in Paris city at the same period. Air sampling from take-off engine plumes shows a larger concentration of NOx and aerosol particle number concentration. Background values near runways are low, transient variations are strongly dependent on change-over operations of runways (westerly or easterly in CDG).
Key words: NOx, emissions, VOC, PM, engines, airports, directives.

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1 Introduction

The expected continuous increase of air traffic for the next decade may constitute a significant air quality concern at airports and vicinities. Recently, knowledge of airport source emissions having an impact on air quality is improving; however some of them are not precisely identified and quantified.

The Vision for 2020 elaborated by the ACARE Strategic Research Agenda for the Air Transportation includes strategic goals in aeronautical research and development focusing on the improvement of its compatibility to the environment. The SRA is targeting on emission reduction of hazardous air toxics including gaseous exhausts such as NOx (nitrogen oxide) and CO_2 (carbon dioxide). On the other hand, PM (particulate matters) are of the same importance as future European directives focus on new standards for PM2.5 for 2010.

At airports, during landing and take-off phases, aircraft engines are operating at various power settings leading to different quantity of primary pollutants: NOx, CO (carbon monoxide), speciated VOC (Volatile Organic Compounds) and particulate matters playing a significant role on airport air pollution. In the past, European airports have mainly focused on NO_2 (nitrogen dioxide) monitoring a primary pollutant released by aero-engines as recommended by ICAO/CAEP (International Civil Aviation Organization/Committee on Aviation Environmental Protection). However, NO_2 is intimately linked to VOC and ozone chemistry. In order to better quantify the contribution of air traffic on air quality degradation at airports, regarding the European directives, field campaigns have been organized at Paris CDG airports in summer and winter in the frame of the French ONERA project AIRPUR. The objectives of the campaigns consist in continuously measuring air pollutants at different locations including runways and taxiways and quantifying the emission factors of aero-engines and auxiliary power units. Special emphasis has been put on particulate matters characteristics in relation with engine power settings: the size distribution and morphology as well as the emissions indices.

This paper describes preliminary results: the measurement campaign procedures, reports in detail the time-variations of gas pollutants and particulate matters in relation to air traffic density and makes an estimation of engine emission factors with regards to power settings.

2 Campaigns

2.1 Experiments

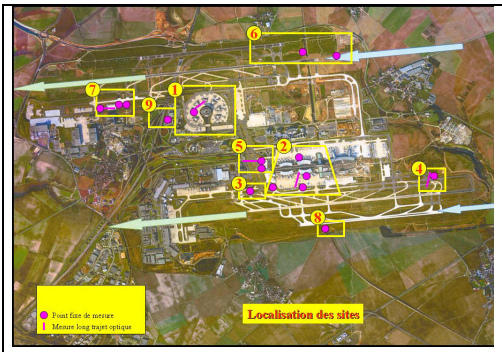
The 2004 field campaign started from October 13th and end on October 28th. The 2005 field campaign started on June 13th and ended on July 22nd divided into periods of observations. Each period (3 days in 2004 and 7 days in 2005) consists in performing measurements for a specific pre-defined objective. Instruments on-board trucks have been deployed at each monitoring site. The first week was devoted to emission measurements at engine test areas, the second week to the taxiways monitoring, the third week to the aprons and terminals

observations, the fourth week to the runways monitoring and finally the fifth week to a spatial coverage of all airport locations over one day for dispersion assessment studies.

In parallel, some trucks using FTIR for APU's, DOAS and SODAR have been positioned at specific locations overall the full period. In addition, Aéroports de Paris laboratory performs continuous measurements of air pollutants including particles at 2 different sampling sites (North station and South station). Results are given in Universal Time TU. The following institutions have participated to the AIRPUR campaign: Aéroports de Paris laboratory, CORIA, CERTAM, INERIS, LISA, ONERA from France and FZK from Germany.

2.2 Sampling sites

In order to investigate the impact of air traffic emissions on local air quality, 9 different locations have been selected based on airport and airframe operations as reported on figure 1 (Aéroports de Paris map), constituted by 2 terminals: Charles de Gaulle 1 and 2. The airport is flat extending from 12 km (west-east) to 8 km size (south-north) and is located 30 km away from Paris city.



Sites	Description	Sites	Description
1	Terminal 1	5	Taxiway
2	Terminal 2	6, 8	North and South monitoring station
3	Runway 2 and 4 West	7	Engine test area
4	Runway 2 and 4 East	9	Parking lot

Figure 1: Map of Paris CDG airports and sampling locations at Paris Charles de Gaulle airport during AIRPUR.

2.3 Instrument

Table 1 gives an overview of instruments used during the campaign using remote techniques and in-situ samplers operated on-board trucks or located at non-moving location.

3 Meteorological conditions

On June 26th, the synoptic situation shows an anticyclone lying to the Northwest of France. At this period Paris is at the edge of this anticyclonic area. The wind

direction near the ground thus is in the sector between about 0 and 90 (see figure 2a wind rose). During AIRPUR (summer), the anticyclone has moved eastward leading to a more stable meteorological synoptic situation allowing some daily hot spots as shown in figure 2 (b) where the maximum air temperature increases from 25°C to 30°C. The wind intensity was rather weak, between 2 to maximum 5m/s.

Table 1: Instrument description during AIRPUR campaign (2004, 2005).

Instrument	Parameters	Detection Limit	Site
ELPI	Particle size distribution and concentration measurement	10 nm up to 10 µm.	2,3,4,5,6,7
SMPS (CNC)	Particle size distribution and concentration measurement	7 nm up to 800 nm.	2,3,4,5,7
TEOM PM1	PM1 mass concentration		5
TEM	Morphology		
Thermodenuder	Optimized removal of volatile hydrocarbons		
MILEAGE trucks	CO, NO, NO_2, NOy, HNO_3, PAN O_3, VOC (C3-C9) Wind direction and velocity, Temperature, humidity, pressure, JNO_2	0.1-55 pbbv (CO)	2,3,5,7,9
DOAS	NO_2, SO_2, O_3, NO, benzene, toluene and xylene (BTX)	500 m path: 1-6 µg/m^3	1,2,4,5,7,8
Aéroports de Paris samplers	NO_2, NO, O_3, SO_2 BTEX, PM10 (particles matter)	1 ppbv	6,8
FTIR	H_2O CO_2 N_2O, CO CH4, NO, SO_2 NO_2 ethene HCHO NO, SO_2, NO_2,	100 m path H_2O 0.01 %: 5-100 ppbv (CO_2)	1,2,4,5,7
SODAR and mini SODAR	Vertical turbulence and wind profile of the lower layer of the atmosphere	Vertical range: 1300 m (200 for mini SODAR)	8
Canisters sampling	Speciated VOC (C2-C9)	0.1	7,2

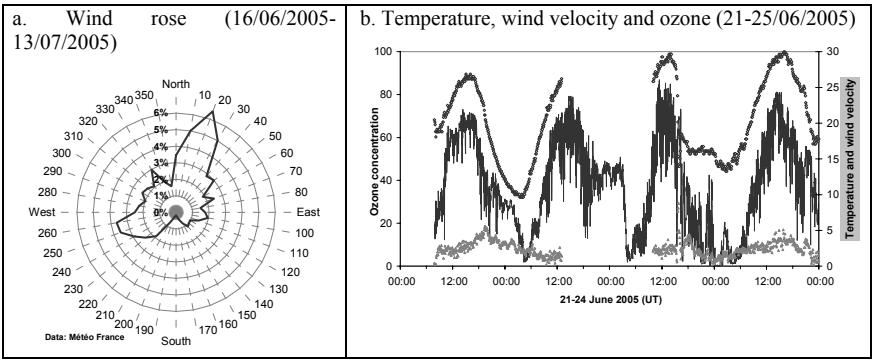


Figure 2: Wind Rose (a) and temperature, wind velocity and ozone concentration (b). Paris Charles de Gaulle airport.

4 Results and discussions

4.1 Engine test emissions

The first objectives at this location consist in measuring the engine emission indices for different gas species and particulate matters when they are operated for different power settings at the ground in a specific area. Instruments have been positioned 25 m behind the aircraft, downstream of the operating engines. During the 2 AIRPUR campaigns (2004 and 2005), measurements of gas-phase species and particles were carried out for different couples aircraft & engines for NO, NO_2, CO, CO_2 and particles. Time-resolution of gas-phase measurements is 1 minute and 1 second to 10seconds for particles. Speciated VOCs have been sampled on-line by using stainless steel canisters for one minute resolution and analysed off-line by using gas chromatographic methodologies (the method is described in Habram et al. [1] and Volz-Thomas et al. [2]).

Figure 3 show the results obtained during an engine-test operated for a B747 (equipped by CF6-80C2B1F). Engine test starts at idle conditions by operating 3 engines followed by a peak of maximum power during a short time. Emission measurements results confirm that CO and volatile organic compounds emission factors are higher at low power setting such as when idling or taxiing when the temperature of the air is relatively low and fuel atomization and mixing process least efficient [3]. CO shows a maximum of 7.8 ppmv in concentration. During the test, the engines power has been increased (4 engines operating) producing higher NOx concentration mainly as NO showing a NO/NO_2 ratio of about 2.5. After these warm-up, engines operation have been set to idle conditions during which an increase of CO concentration have been observed up to 4.7 ppmv.

At the same time, measurements of particulate matters have been performed using the ELPI, SMPS and TEOM PM1. The thermodenuder has been operated shortly to demonstrate the volatility characteristics of ultra-fine particles. The SMPS output results are plotted on figure 3b for which a significant increase in particle concentration has been observed at high power settings and idle

conditions with a maximum reaching $2.3x10^6$ particles/cm^3. The TEOM results have been used to estimate the particle density in order to check assumption for mass-calculation from ELPI.

Figure 4 shows the number size distribution of particles obtained from the SMPS measurement system showing a maximum of 10^7particles/cm^3 at around 10 nm size, *i.e*. for ultra-fine particles. The soot mode (centred around 20-40 nm size) number concentration is about a factor of 100 lower than the volatile particles. These results are of the main importance knowing that at the engine nozzle exit (1 m), most of previous existing measurement systems performed by NASA lead to very low ultra-fine particle concentration for 10 nm size (APEX and EXCAVATE [4]) whereas at 30 m downstream, ultra-fine concentration are at their maximum confirming the fact that condensation occurred over hydrophobic particles from the nozzle exit to 25 m downstream in the remote atmosphere as measured during AIRPUR as well. Such results require some consideration for air quality studies for a more precise measurement of effective emission of volatile particles. Particle emissions depend on mode of combustion; kerosene combustion is similar to diesel combustion: when temperature and pressure are higher, the injection of fuel is performed without stequiometry equilibrium bringing a heterogeneous mixture and enhances the particle emissions.

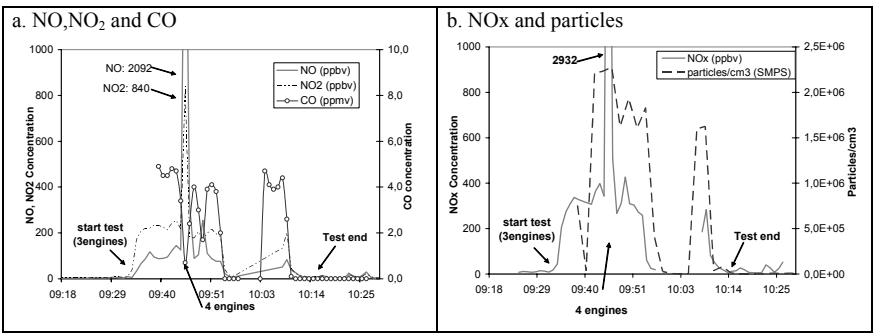


Figure 3: CO, NO, NO_2 measurements (a), NOx and particles (b) measurement during engine test to 17 June 2005.

By using the relationship between of emission index of CO_2, the CO_2 deviations from background and the variations of CO, NO, NO_2 and PM concentration during engine test, engine emission indices can be correctly estimated (using equation (1) Herndon et al. [5]).

$$EI(CO, NO \text{ or } NO_2)=EI(CO_2)\ (c(CO, NO \text{ or } NO_2)_{pl}–c(CO, NO \text{ or } NO_2)_{bg})/(c(CO_2)_{pl}–c(CO_2)_{bg})\ A(CO, NO \text{ or } NO_2) \quad (1)$$

$EI(CO_2, CO, NO \text{ or } NO_2)$ emission index of CO_2 (3.150 g/kg), CO, NO or NO_2, c_{pl} concentration measurement within the aircraft plume, c_{bg} concentrations measurement before the aircraft exhaust plumes were detected and A(CO, NO or

NO_2) the ratio of molecular masses of CO to CO_2 (0.6364), NO to CO_2 (0.6818) or NO_2 to CO_2 (1.0455).

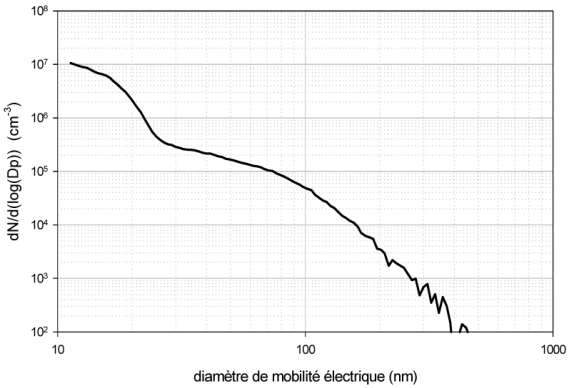


Figure 4: Number size distribution 25 m behind engines (SMPS).

For CF6-80C2B1F equipping the B747 using an EI CO_2 of 3150 g/kg the calculated EI at low thrust for other species show a maximum value for CO (76.90 g/Kg) and a minimum for NOx (3.13 g/Kg). At higher thrust EI is lower for CO (4.12 g/Kg), and maximal for NOx (21.3 g/Kg). The results are different to those calculated in ICAO data bank [6]. At low thrust EI of CO is 73.71 g/Kg and at higher thrust 0.52 g/Kg, 4% and 87% respectively of difference. For NOx, at low thrust EI is 3.74 g/Kg and at higher thrust 28.06 g/Kg, or 16% and 24% higher respectively. This is probably related to more incomplete combustion for older engines equipping commercial aircraft.

At the same time, air samples stored in canisters have been analyzed off-line for speciated VOC. A selection of VOC measured is showed in table 2. Results show that higher concentrations are observed during idle condition when efficiency of combustion decreases. At idle conditions light VOC (C2-C4) such as ethane, ethene, ethyne and propene are present in enhanced quantities. Ethene represents 45% of total VOC analysed, Ethyne 21%, Propene 11% and Ethane 2%. Maxima ethane concentration was to 317 ppbv. Aromatics compounds such as benzene and toluene represents 2% and 0.9% of VOC analysed respectively. At the end of the test VOC concentrations decrease between 80 and 90% for almost compounds. The results are comparable with Anderson et al [4] and Spicer et al. [7].

4.2 Taxiway monitoring site

The objectives consist in measuring continuously the chemical composition and physical characteristics of the aircraft plumes under taxi conditions via active and passive FTIR, DOAS and in-situ sampling techniques. Air quality has been monitored at the same location using different time-resolution for gas pollutants and particles. However, as instruments have been deployed beside taxiways and

road activities (Ground Support Equipment GSE, passenger buses) individual plumes and their source emissions have been identified and discriminated

Table 2: Selected analyses results of canister sampling. 17th June 2005.

Compound (ppbv)	Canister 5 (idle)	Canister 1 (take-off)	Canister 10 (take-off)	Canister 9 (background)
Ethane	16.2	2.5	1.5	0.8
Ethene	317.3	67.6	27.8	0.5
Ethyne	144.9	31.7	13.0	0.1
Propene	75.9	11.2	4.8	0.2
1,3-butadiene	14.1	1.8	0.8	Bdl
i-pentane	9.8	1.2	0.3	0.3
benzene	14.4	2.8	1.2	0.2
Toluene	6.4	1.2	0.7	0.2
m,p-xylene	4.2	0.7	0.5	0.1
nonane	4.5	0.3	0.2	0.02

Bdl: below detection limit.

4.2.1 NOx and ozone

Figure 5a shows the time-variations of ozone, NO, NO_2 and NO_2 photolyse constant (JNO_2) at taxiway on 25th and 26th June 2005 showing clear diurnal variations of chemical species. At the beginning, wind direction was blowing from east to south-east, *i.e.* from the airport throughout roads followed by a change in wind direction from the north to north east and an increase in intensity. $J(NO_2)$ is a good indicator of high photochemistry activity [8,9]; its diurnal variation is correlated to the ozone concentration. At 9:00-19:00 enhances quantities of ozone (60-80 ppbv) were measured. The main concentration has been reported at 15:00. A normal shift between ozone profile and $J(NO_2)$ is observed due to ozone is a secondary compound. Atmospheric condition (light wind velocity, stable atmospheric layer and temperature of 25°C during the afternoon) was favourable to ozone production. At the night ozone concentration progressively decreased until 20 ppbv.

Concerning NO and NO_2 a marker of direct combustion source is observed at the beginning of the airport activities (4:00-7:00) with an increase of NO/NO_2 ratio up to 2.4. NO and NO_2 concentration are 146 ppbv and 60 ppbv respectively. Between 9:00 and 19:00 NO and NO_2 concentrations decrease until 4 and 15 ppbv respectively. Nevertheless significant peaks of NO and NO_2 concentration up to 30 ppbv and 60 pbbv respectively, are measured during this period. They probably come from specific taxiway activity. These results were compared with OMS data [10] and show that concentrations in taxiway are lower than OMS values: average hours to NO_2 is 105 ppbv and for ozone average 8 hours is 60.1 ppbv. Figure 5b shows the correlation between particles and NOx indicating that probably these pollutants are emitted at same moment of combustion. In order to conclude more precisely others studies are required, it is

necessary to associate these results with specific location 5 activities: road traffic and aircraft traffic in taxiway area.

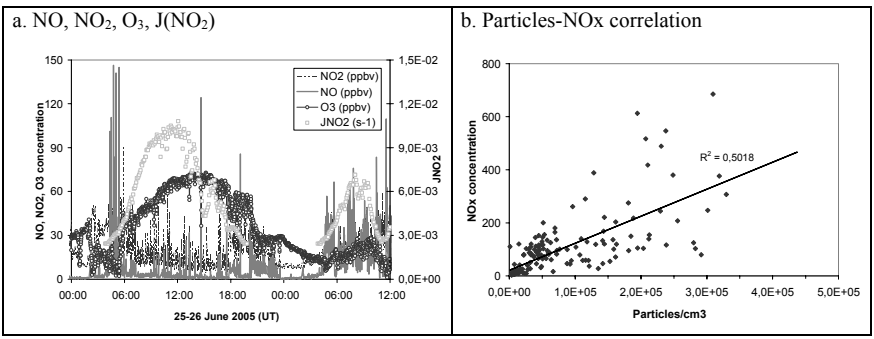


Figure 5: Temporal variation of ozone, NO_2 and $J(NO_2)$ (a) and correlation particles-NOx (b) at taxiway. 25th-26th June 2005. Paris Charles de Gaulle airport.

4.2.2 Particulate matters

After July 14th, specific measurements methodologies have been organised to investigate the impact of dispersion or physical transformation of particulate matters throughout the airport domain and downwind for plume processes. ELPI measurements show that the hourly-averaged number size distributions of particles at all locations are still dominated by ultra-fine diameter. Maximum ($6x10^4$ particles/cm^3) is observed near aprons at terminal D and C where emissions from GSE, buses and rotating flights (50 mn frequency) are mixed). At terminal A and C devoted for long-haul flights, particle concentrations are lower (10^4 particles/cm^3). Near runways 1 km downwind to the terminal C, the soot mode still have the same concentration, whereas ultra-fine particle concentration is lower ($3x10^3$ particles/cm^3) indicating coagulation processes.

Near runways, sample filters have been collected and analysed off-line by using a TEM. The morphology of aerosol particles is shown as an example on Figures 6 a and b respectively for 72000 and 10000 enhancement factors. The diameter of filter-holes (white color) is 800 nm. On the left figure, population of agglomerated soot is observed at airports (in the accumulation mode) beside volatile particles likely composed by sulphate and condensed organic compounds (spherical and opaque on the filters), but at very low concentration compared to ultra-fine. On the right figure, population of fine to ultra-fine particles (individual spherical particles) is observed as confirmed by measurements obtained with SMPS and ELPI. Chemical analyses has been performed confirming that carbon soot are mostly observed at the airports mixed with a small portion of Fe, Si, Ca, K and sulphate (heavy organic compounds have not been measured)

4.2.3 Volatile Organic Compounds (VOC)

Ambient air quality measurement of 35 VOCs (C3-C9) and 22 VOCs (C3-C7) were conducted during the AIRPUR 2004 and 2005 campaigns respectively.

Primarily, VOCs play an important role in the formation of ozone with a sparse chemical reactivity in the atmosphere introducing non-linear chemical effects in presence of NOx. On the other hand, according to concentration level of different compounds, VOC may have important health effects, *e.g.* benzene witch was classified by EPA (Environmental Protection Agency) to generate human cancer [11]. The third contribution of VOC or semi-VOC to the air quality degradation is the formation of secondary organic aerosols (SOA) from gas to particle conversion.

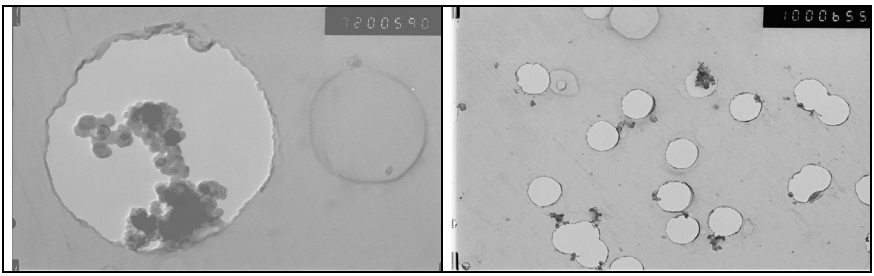


Figure 6: (a) and (b): Morphology of airborne aerosol particles near runways.

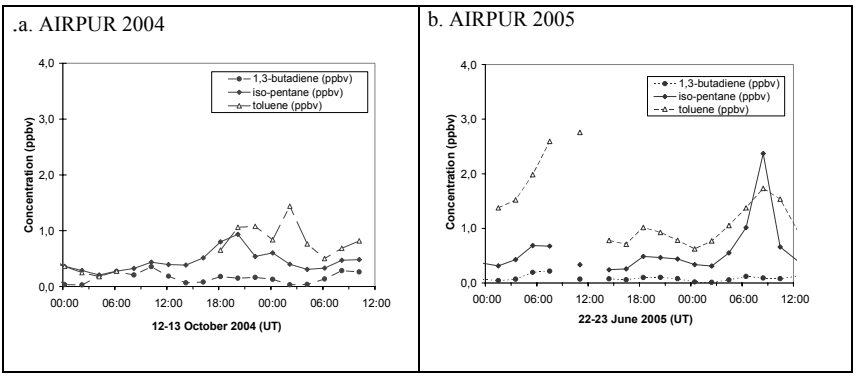


Figure 7: Diurnal variation of selected VOC at taxiway on 12th -13th October 2004 (a) and on 22th-23th June 2005 (b).

In this paper, selected speciated VOC are presented according to their chemical reactivity and their role on public health [12,13]. In October 2004, ethyne, toluene and propene have been found to be the main compounds (generally lower than 1.5 ppbv). During the AIRPUR 2005 campaign, average VOC concentrations are also lower than 1.5 ppbv. Nevertheless minimum and maximum concentrations are very different due to the variability of airport activities. Daily VOC variation was probably more significant during the AIRPUR 2005 rather than AIRPUR 2004 campaigns (Figure 7). Highest concentrations were found during the early morning hours (7:00-11:00), especially toluene. In the nocturnal boundary layer the vertical air exchange is reduced and the dilution of morning rush hours VOC emissions is obstructed

[14]. Additionally between 17:00 and 20:00 hours high values are registered while lower concentrations are monitored between 13:00-16:00 hours and 22:00-00:00. Level concentrations also depend on life time of each VOC; the most reactive compound of the selected list is 1,3-butadiene (2.6 hours), explaining its lower concentration. Iso-pentane and toluene have a lower reactivity with a lifetime of 2 days and 1.2 day respectively; toluene is emitted in enhance quantities explaining its dominance. Both results AIRPUR 2004 and AIRPUR 2005 indicate lower concentration than typical urban values.

4.3 Upwind/downwind assessment study

One of the main objectives of the AIRPUR campaigns consists in quantifying the influence and contribution of airport emissions, including the air traffic, on air pollutants concentration at airports and their vicinities. Such an assessment study has been conducted at O'Hare airport [15] leading to similar conclusion than stated in this paper.

To achieve these objectives, instruments have been positioned at different locations where the signature of regional emissions or rural cleaner air (or from vicinities) imported to the airport domains and the contribution of the airports could be tackled and monitored continuously. For this reason, measurement compiled from 3 monitoring sites (and in addition 1 far- neighbouring station located in Tremblay city, south of Paris CDG airports), have been explored and analysed. This includes: the north-east site (NES), measurement trucks located in the centre of the airport near taxiways and terminals and the south sampling site (see figure 1). Northern areas of Paris CDG domain are mainly landscapes and small cities (considered as rural sites). As a consequence, when northern wind prevails, the NE will measure rural emissions. The south sampling site (SS) is located beside runways downstream when wind is blowing from the north, measurements includes younger emission. In case of southern wind, measurements at the northern stations can be considered as containing some of the airport emissions knowing that south-westerly winds could bring regional emissions from Paris town or surrounding cities. In this paper, we discuss one configuration when the wind is mostly in sector north-east (direction: 0 to 45°) for which the averaged wind intensity is between 5 and 8 m/s.

On Figure 8 diurnal variations of NOx and O_3 continuously measured at NES and SS on Sunday 10th July 2005 are plotted. On figure 8a, NOx variations are flat at NES reflecting the fact that rural background emission are observed by the stations whereas SS NOx show some fresh signatures of aircraft on take-off and landing phases (maximum around 20 to 40 ppbv) in good correlation with the air traffic volume varying with time starting to increase at 4:00 a.m. UT. The ozone concentration is plotted on figure 8b. Summertime conditions and high insolation and air temperature are good factors for ozone local formation (maximum at mid-afternoon qualitatively easily explained by classical photo chemistry). However, ozone at SS is lower (by a small factor) than observed at NES, this is due to the presence of higher concentration of NOx freshly emitted continuously by running aircraft consuming ozone molecules (or producing lower ozone molecules) than is the case in NES (background NOx). Under northern wind

conditions, ozone and NOx measurements in Tremblay show lower concentration for NOx and greater level for ozone, due to "downwind ozone formation processes" and to a continuous and dispersion of NOx. A more precise quantification of NOx-O_3 concentration at airports and vicinities require a detailed analysis of the relationship between speciated VOC emitted at airports and NOx but also nitrogen reservoir (such as PAN) and termination species (such HNO_3).

To confirm these hypotheses and conclusions, the same variations are plotted on figure 9 for another day. Nevertheless, NOx concentration at North station increase at 4:30 on 11th and 12th July until 28 ppbv; the difference between figure 8 and 9 can be explained by exploring the impact of road-traffic emissions. 10th July is a Sunday and the 11th and 12th Monday and Tuesday. Ground traffic flow is more important during the week than during the weekend. On a yearly-averaged basis, the road traffic decreases 41% during weekend; additionally during weekend the airport activity is 17% higher than during the week [16]. The decrease in road traffic flow during the weekend is performed at the same proportion than NOx concentration at the north station. These assumptions can be confirmed by using another time-series of the same species (figure 10) for another day at another location near apron (location 5-taxiway November and Fox–Apron Golf Area). NOx concentration increases at 03:30 a.m. UT at location 5 and at SS. At location 5, concentrations are between 30 and 76 ppbv while at south station concentration are between 25 and 65 ppbv (figure 10). 26th July is a Sunday where airport activities are important. A significant decrease (8-12 ppbv) is observed at 22:30 when the air traffic is less important. 27th June at 03:30 NOx concentration increases again. During the night (22:00-3:45) when airport activities are reduced, NOx concentration is low (<10 ppbv) but is similar at the three locations. NOx concentration at location 5 is more important than south station in most case because aircraft are closer. Ozone profile concentration and values are similar at 3 sites; concentrations are between 10 and 50 ppbv with a significant decrease of ozone at 12:00 when NOx concentration reaches a maximum

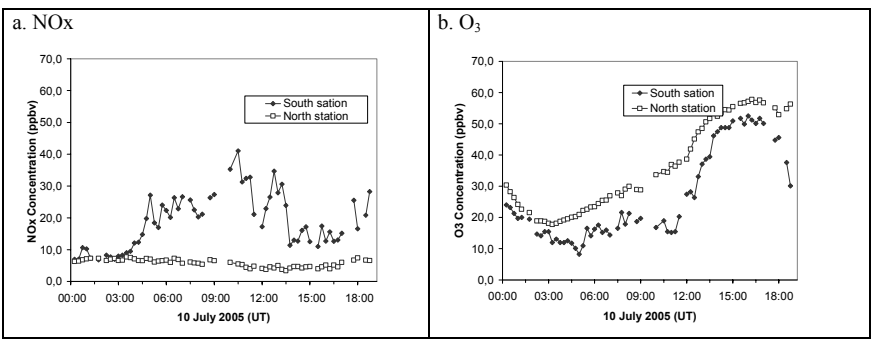


Figure 8: Diurnal variation of NOx (a) and ozone (b) north station and south station. Charles de Gaulle airport. AIRPUR campaign (10th July 2005)

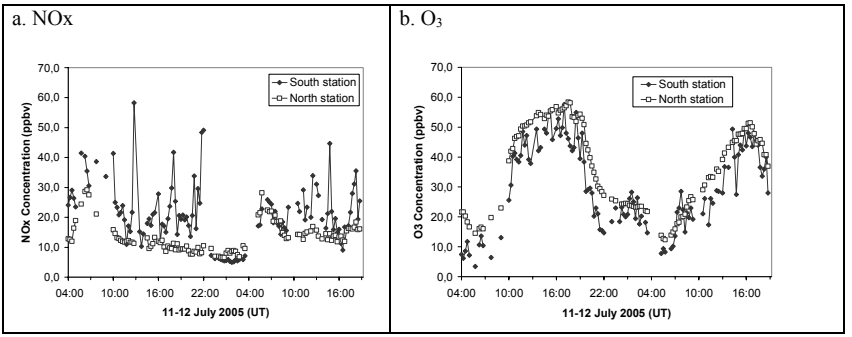


Figure 9: Diurnal variation of NOx (a) and ozone (b) at north station and south station. Charles de Gaulle airport. AIRPUR campaign (10th - 12th July 2005).

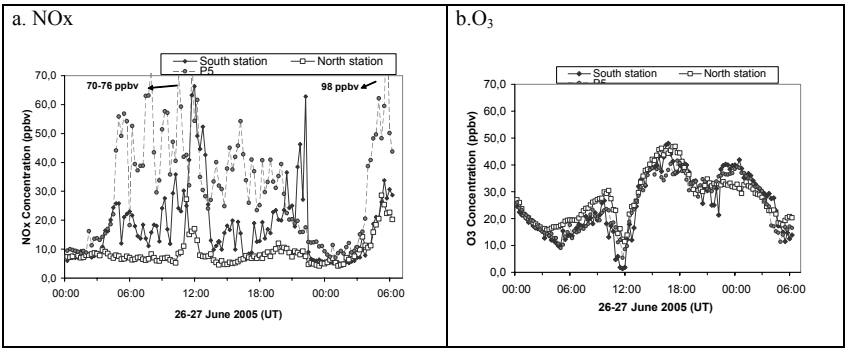


Figure 10: Diurnal variation of NOx (a) and ozone (b) at north and south station and P 5 (Golf area). Charles de Gaulle airport. AIRPUR campaign (26th-27th July 2005).

4.3.1 Location 6 (North between runways)

The objectives of the study at this location, is to follow continuously over a "long-term basis" the impact of runways emissions (landing and take off), potential importation of non-airport emissions and "internal dispersion" of airport emission down to the runaways areas.

Between 22nd June and 1st July 2005 continuous measurements of NO, NO_2 and particulate matters (ELPI) were carried out at location 6. Results have been analysed with regards to averaged wind direction. Median values are representative of background level and include all emissions from to south of the airport. Median concentration is up to 47 ppbv for NOx and up to $7.1x10^3$ for particules/cm^3. Maximal values compiled from the database within aircraft or "other non-identified" small-scale plumes (figure 11) for NOx (500-700 ppbv) as well as for particles ($4\text{-}5x10^4$ particles/cm^3) are characteristic of a proximity source, takeoff of the north runway indicate that their contribution mainly come from of northern runway (positioned at south of location 6).

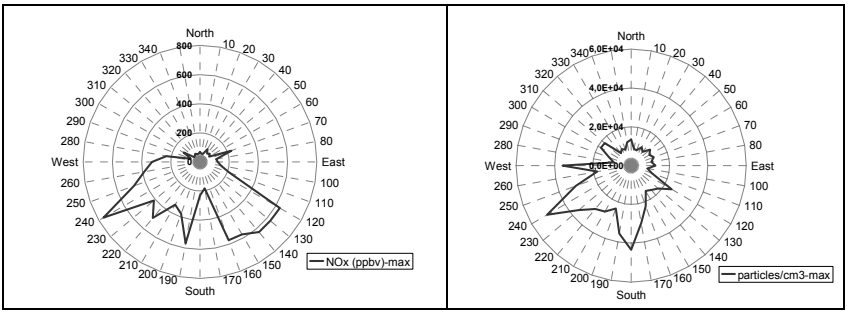


Figure 11: NOx (a) and particles (b) roses pollution at location 6. 22nd June-1st July 2005. Paris-Charles de Gaulle airport.

5 Conclusions

Sampling performed in engine test area shows a maximum of NOx concentration (2932 ppbv) at high power setting whereas CO concentration is highest (7.8 ppmv) at low power setting when the efficiency of the combustion decreases. VOC are in increasing quantity at lower power setting. Measurement of VOC indicates that light VOC are the main compounds, e.g. ethane represents 45% of total VOC and ethyne 21%. Actual researches are focused to the finding of VOC marker for aircraft combustion. It is important to find a marker for VOC aircraft emissions in order to obtain a distinction between road traffic and aircraft emissions.

SMPS measurement system showed a maximum of 10^7 particles/cm^3 at around 10 nm size (ultra-fine particles). The soot mode (20-40 nm size) number concentration is about a factor of 100 lower than the volatile particles. This observation confirms the fact that condensation occurred over hydrophobic particles from the nozzle exit to a 25 m downstream distance in the remote atmosphere. Results are comparable with those given by APEX and EXCAVATE researches.

On June 2005 meteorological conditions (high temperature, light wind velocity…) were favourable to formation of ozone. Concentration up to 80 ppbv was observed at taxiway area. Early in the morning when airport activity start, NO/NO_2 ratio increase to 2.5-3.0 which is representative to the proximity of a combustion source, characteristic of this area. During the rest of day NO_2 concentration is higher to NO concentration (NO/NO_2 ratio 0.2-0.5) indicating some distance to the direct source.

Relevant values of VOC were found during the morning (7:00-11:00); meteorogical conditions and air traffic could explain this result. Among VOC measured (C3-C7), toluene presented a higher concentration. However these results remain within "typical urban range" or even lower. Same observation for NO,NO_2 and ozone measurements.

Near aprons $6x10^4$ particles/cm^3 were observed where the emission from ground support equipment, buses, rotating flights are mixed. ELPI measurements

show that the hourly-averaged number size distribution of particles at this location is still dominated by ultra-fine particles.

Under northern conditions NOx NES (north-east site) measured concentration equivalent to rural background emission. Nevertheless evidence of road-traffic impact is observed during the working days. In SS (south sampling site), some fresh signatures of aircraft on take-off and landing phases (maximum around 40 ppbv) are in good correlation with air traffic. Therefore ozone concentration at SS is lower than observed at NES. A more precise quantification of NOx and ozone concentration with analysis of speciated VOC emitted at airports will be conducted.

The objective of two AIRPUR campaigns was to develop knowledge about pollutants emitted on airport plate-form (taxiway monitoring site - upwind/downwind study). Specific gas compounds measurement, analyses of their interaction and assessment of particles size distribution and morphology of aerosol have been performed. It is probably one of the most complete field campaigns in airports witch have ever been organised recentely. However the results require some consideration for air quality studies, especially for a more precise measurement of effective emission of volatile particles and VOC compounds. It is important to continue to evaluate VOC emissions at airports in order to increase our knowledge regarding these compounds and their implication in events such as tropospheric ozone formation and SOA (secondary organic aerosol) formation. Results will permit to develop and consolidate modelisation tools. Furthers works will involve performing a box model assessment study using a set of photochemical mechanisms to evaluate the importance when VOC coupled to NOx emissions to secondary air pollutant formation. The box model will include VOC, NOx, and particles data. At the same time, it is also relevant to continue to conduct field measurement campaigns.

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