AIRPORTS COUNCIL INTERNATIONAL



Effects of Air Traffic on Air Quality in the Vicinity of European Airports

Local air quality assessments at and around European airports based on the airspace closure in Europe during the volcano eruption in Iceland in April 2010

ACI EUROPE Environmental Strategy Committee
Autumn 2010

The data in this publication is a result of a coordinated effort by the airports represented in the Environmental Strategy Committee of ACI EUROPE (Airports Council International). ACI EUROPE would like to thank all the airports involved in this study for their time and dedication, in particular Zurich Airport's Environmental Department which contributed significantly to the execution and completion of the study.

About ACI EUROPE

ACI EUROPE, the voice of Europe's airports, is the European region of Airports Council International, the only worldwide professional association of airport operators. ACI EUROPE represents over 400 airports in 46 European countries. Member airports handle 90% of commercial air traffic in Europe, welcoming nearly 1.5 billion passengers each year.

For more information, visit **www.aci-europe.org**

Disclaimer

The information published by ACI EUROPE in this report is made available without any warranty of any kind. ACI EUROPE accepts no responsibility or liability whether direct or indirect, as to the currency, accuracy or quality of the information, nor for any consequence of its use. Any data and evidence is as it is at the date of publication and as provided by the specific airport. This document is published by ACI EUROPE for information purposes. It may be copied in whole or in part, provided that ACI EUROPE is mentioned as the source and it is not used for commercial purposes (i.e. for financial gain). The information in this document may not be modified without prior written permission from ACI EUROPE.

For further information, contact:

robert.omeara@aci-europe.org
Copyright ©2010 ACI EUROPE
All rights reserved

Table of Contents

1	Introduction	3
1.1	The volcano eruption in Iceland	3
1.2	The effects on European aviation	4
1.3	Environmental study scope	6
2	Local air quality effects	7
2.1	Budapest Airport	7
2.2	Frankfurt Airport	9
2.3	London-Heathrow Airport	11
2.4	London-Gatwick Airport	13
2.5	Manchester Airport	14
2.6	Paris Airports	15
2.7	Madrid-Barajas Airport	18
2.8	Barcelona Airport	19
2.9	Palma de Mallorca Airport	20
2.10	Geneva International Airport	21
2.11	Vienna Airport	22
2.12	Zurich Airport	23
2.13	Athens International Airport	25
3	Conclusion	26
4	Annex	27
4.1	Sources and References	27

Glossary of Abbreviations

ICAO	International Civil Aviation Organisation, Montreal
IFR	Aircraft traffic under instrument flight rules
MAP	Million annual passenger
NO_2	Nitrogen dioxide
NOx	Nitrogen oxide
PM	Particulate Matter
SO_2	Sulphur dioxide
VEI	Volcanic Explosivity Index
VFR	Aircraft traffic under visual flight rules

1 Introduction

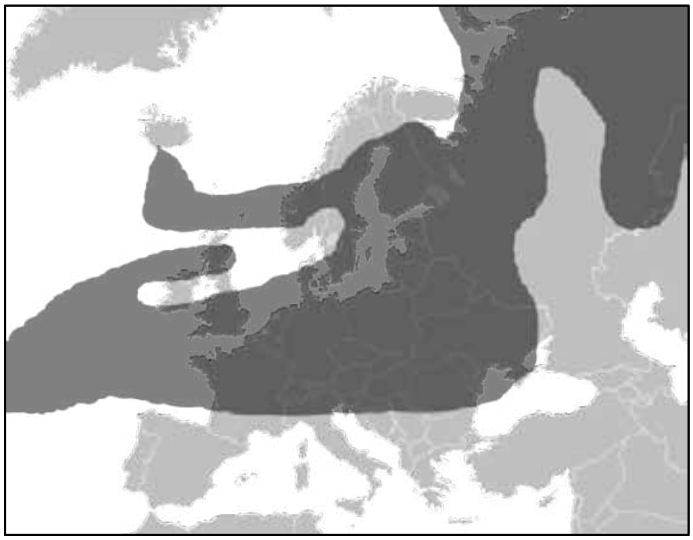
Aviation is an integral part of today's societal mobility. As part of the global transport sector, it contributes significantly to economic and social development of many regions throughout Europe and the world. Increased availability and affordability has turned air travel into a mode of transport that is indispensable for society and one of the primary instruments of cultural exchange and social cohesion in Europe.

Like most other human activities, however, it has environmental impacts. The main environmental aspects are emissions of noise and gaseous substances. There are on-going discussions and also disputes as to the degree that air transportation has an impact on the local air quality and people at and around airports. Many individual airport studies have been conducted, assessing specific situations at selected airports for defined purposes, e.g. environmental impact assessments. All such studies are based on modeling situations and not on real-time conditions. In order to measure the environmental impact of aviation in real-time conditions, it is necessary to measure environmental factors in the absence of aviation, and compare this data with equivalent measurements taken both before and after that period of absence. This, indeed, has happened in the context of the volcano eruption in Iceland in April 2010.

1.1 The volcano eruption in Iceland

Eyjafjallajökull is one of Iceland's smaller ice caps located in the far south of the island. It is situated to the north of Skógar and to the west of the larger ice cap Mýrdalsjökull[i]. The volcanic events starting in March 2010 are considered to be a single eruption divided into different phases. The first eruption phase ejected olivine basaltic andesite lava several hundred metres into the air in what is known as an effusive eruption. Ash ejection from this phase of the eruption is small, rising to no more than 4 km (2.5 mi) into the atmosphere.

On 14th April 2010 however, the eruption entered an explosive phase and ejected fine, glass-rich ash more than 8 km (5.0 mi) into the atmosphere. The second phase is estimated to have been a Volcanic Explosivity Index (VEI) 4 eruption, which is large, but not nearly the most powerful eruption possible by volcanic standards. By way of comparison, the Mount St. Helens eruption of 1980 was rated as 5 on the VEI, and the 1991 eruption of Mount Pinatubo was rated as a 6.

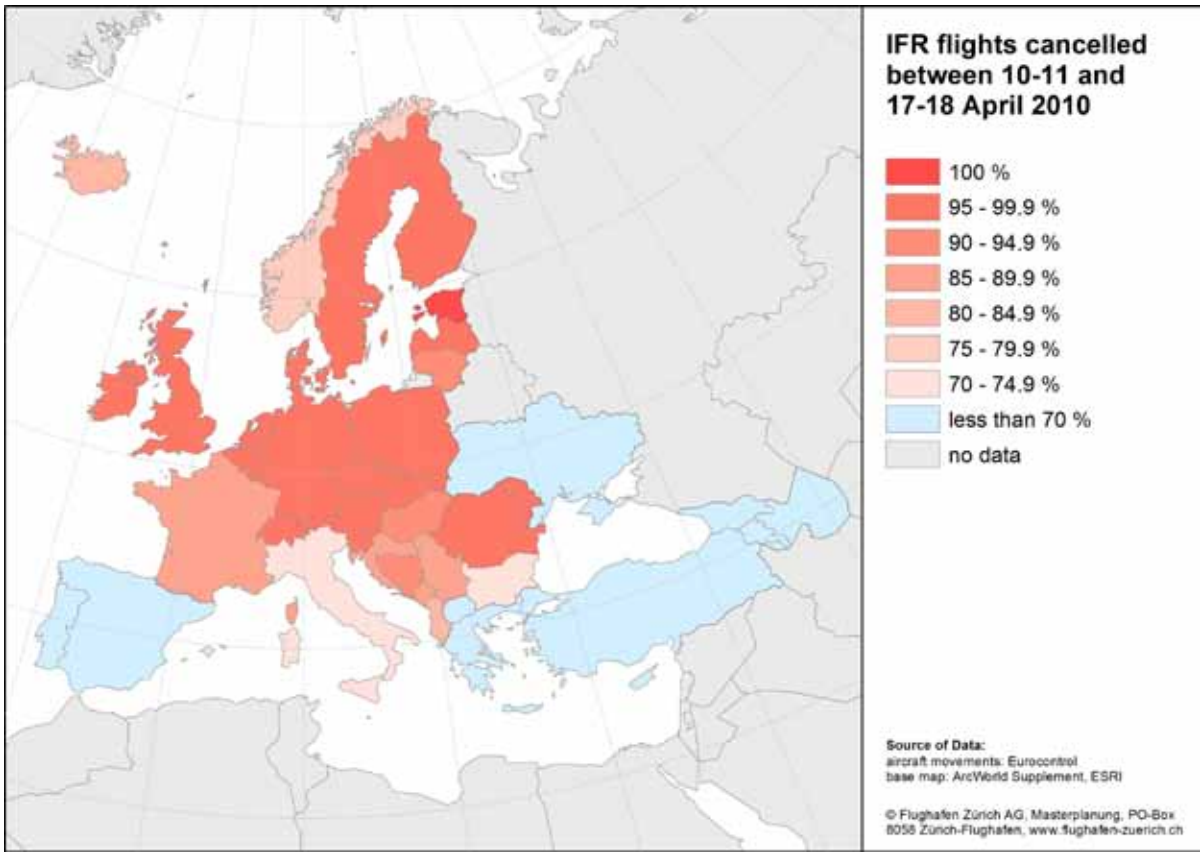


Depiction of the estimated ash cloud at 18:00 UTC on 17th April 2010

1.2 The effects on European aviation

The volcano eruption in Europe had an unexpected and unprecedented large scale effect on commercial aviation in Europe. The diluted ash cloud raised concerns about the safety of air travel and consequently, most European civil aviation authorities closed their national airspaces for commercial instrument flight rules (IFR) flights. The first airports stopped operations on Thursday, 15th April 2010, at noon, and many more followed on Friday, April 16th. At its peak, some 313 airports (about 80% of the European airport network) faced flight operations paralysis. Operations gradually started to resume on Tuesday April 20th[ii]. During the crisis period, the only flights permitted within closed air space were search and rescue or ambulance flights or flights performed under visual flight rules (VFR), depending on the decisions taken by the national authorities.

This event was the first time ever that a significant part or the society's mobility in Europe has been suspended almost simultaneously and disrupted for several days. More than that, the suspension took effect quickly and without any real warning.



Air traffic in Europe during airspace closure

What made this volcanic activity so disruptive to air travel was the combination of a number of factors:

- The volcano's location is directly under the Jet Stream - a specific fast flowing narrow air current in the Earth's atmosphere.
- The direction of the Jet Stream was unusually stable at the time of the eruption's second phase, maintaining a continuous south-easterly heading.
- The explosive phase took place under 200 m (660 ft) of glacial ice. The resulting meltwater flowed back into the erupting volcano which created two specific phenomena:
    - The rapidly vapourising water significantly increased the eruption's explosive power
    - The erupting lava cooled very rapidly which created a cloud of highly abrasive, glass-rich ash
- The volcano's explosive power was sufficient to inject ash directly into the Jet Stream.

The suspension of aircraft movements naturally had a massive impact, with over 10 million passengers affected over the 6 day period. Following information campaigns launched by airports in partnership with their airlines, many passengers stayed at home or where they temporarily resided, rather than travelling to the airport. However many thousands of passengers did find themselves stuck in the middle of the situation - stranded in transfer at major hub airports (Paris-CDG, Frankfurt, Amsterdam-Schiphol, Munich, Zurich, Brussels and others) or landside at significant point-to-point airports such as London-Gatwick. Furthermore, European airports located in open air space (such as Athens and Madrid) had to deal with the ripple effect of significantly restricted intra-European traffic.

The disruption also had a significant effect on the associated airport operations. While certain functions of the airport remained in operation and indeed had to be boosted to accommodate the exceptional circumstances (food and beverage, medical staff, airport information staff), other airport operations were significantly reduced. As a result some of the more technical operations staff normally engaged in airside activities at the airport were staying at home (e.g. airside passenger handling, airline catering and aircraft handling). This led to a distinct change in landside access traffic, most recognizable in road access with vehicles.

1.3 Scope of this Environmental study

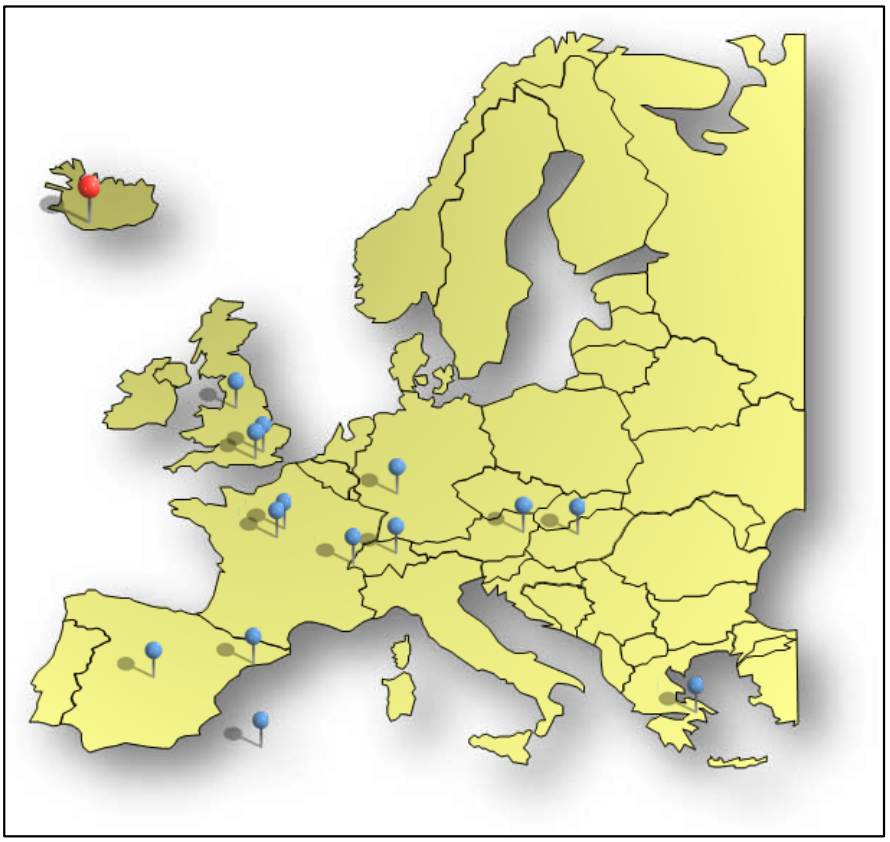
The closure of national airspaces and the suspension of air traffic had the unique effect of one mode of transport in Europe being entirely suspended for a period of time while all other modes of transport or activities in general remained largely unimpacted. The immediate environmental consequences of this stoppage – such as ambiant air quality and noise climate - would be expected to be readily detectable at and around affected airports.

While general airport air quality studies may be affected by local circumstances (location, activities, topography, etc), a pan-European study at the same time would reflect this caveat and the study findings would indicate if there actually are local circumstances to be considered.

ACI EUROPE's Environmental Strategy Committee undertook an environmental study to assess the effects of aircraft traffic on local air quality at a range of European airports.

The specific questions were:

- How large is the impact of the disrupted air traffic on the NOx emission load induced by the airport system and within the aircraft Landing Take Off (LTO) cycle?
- Is there a quantifiable change in NO_2 concentrations at and/or around the airport from before, during and after the event?
- Is it possible to thus quantify the contribution of aircraft traffic to the overall NO_2 concentrations at and/or around the airport?



Study airports in Europe (blue)

In order to obtain a more complete overview, additional information has been compiled. This includes, but is not limited to other pollutant species (PM10, SO_2), the presence of neighbouring infastructure such as motorways, and the primary meteorological determinant of air quality, wind.

Many airports operate monitoring and data management systems that allow the computation of a variety of environmental key performance indicators. In particular, ambient air quality measurement stations at and around airports are operated either by the airport operator itself or on its behalf by a third party. In some cases further organisations are implemented to serve as information or discussion platform for noise relevant issues.

For the purpose of this study, a number of airports in Europe participated by providing computed data and explanations on the air quality situation.

Airport Code	Airport Name	Country	MAP
FRA	Frankfurt	Germany	50.9
ZRH	Zurich	Switzerland	21.9
VIE	Vienna	Austria	18.1
CDG	Paris-Charles de Gaulle	France	57.9
ORY	Paris-Orly	France	25.1
LHR	London-Heathrow	United Kingdom	89.7
LGW	London-Gatwick	United Kingdom	32.0
MAN	Manchester	United Kingdom	22.0
BUD	Budapest	Hungary	8.1
MAD	Madrid-Barajas	Spain	48.4
BCN	Barcelona	Spain	27.4
LPA	Palma de Mallorca	Spain	21.2
ATH	Athens	Greece	16.2
GVA	Geneva	Switzerland	11.3

Table 1-1: Participating Airports in Europe[1]

[1] Million Annual Passengers

2 Local air quality effects

At airports, there are generally four groups of emission sources identified[iii]:

- Aircraft with main engines and auxiliary power unit (APU)
- Aircraft handling with all types of ground support equipment (GSE) and activities (airside traffic)
- Airport infrastructure such as heating/cooling, maintenance, construction, etc
- Landside access traffic

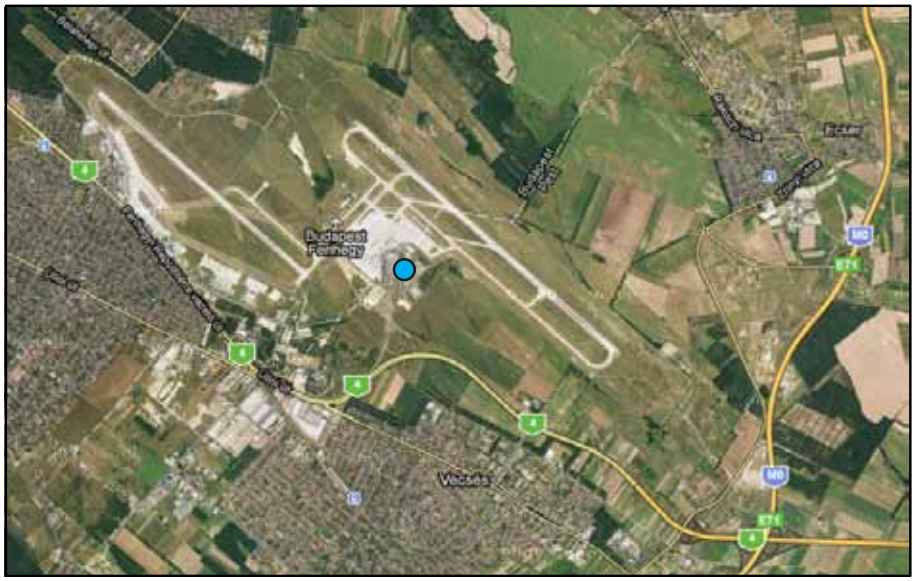
The activities of these sources are interdependent. If one of the source groups is significantly affected in terms of its activities, then the other source groups are affected too. This change in activities leads to changes in emission of the various gaseous substances and subsequently to a change in pollution concentrations.

These effects have been analysed for the airports listed in table 1-1 to the degree that data were available for the period in time. Generally, the month of April 2010 has been analysed.

2.1 Budapest Airport

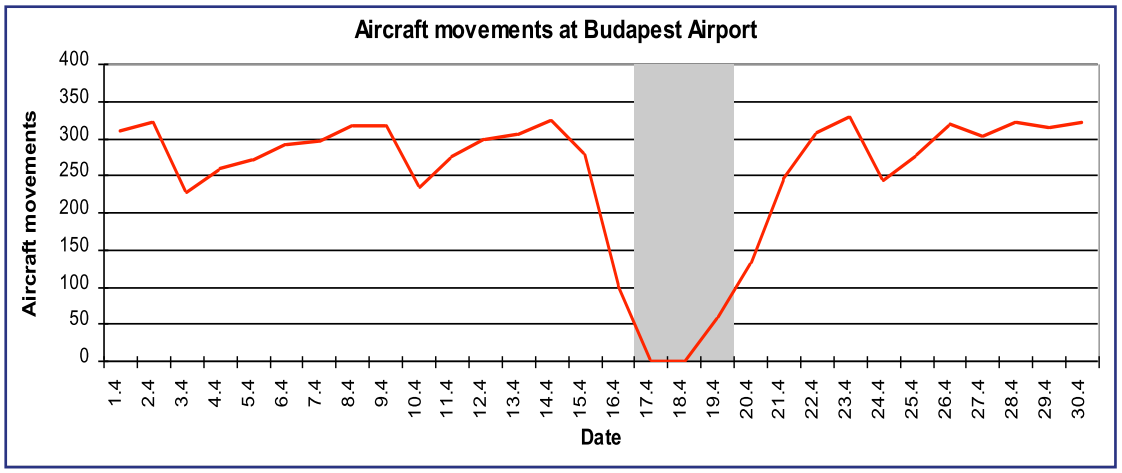
Budapest Airport is the largest airport in Hungary with 109,811 movements and 8.1 million passengers in 2009. It is located 16 km south-east of the city centre. There is a major motorway on the east side of the airport which also serves the airport.

Budapest Airport has an air quality monitoring station that operates on the roof of terminal 2A located in the centre of the airport. NOx, NO_2, O3, CO, SO_2 and PM10 are continuously measured.

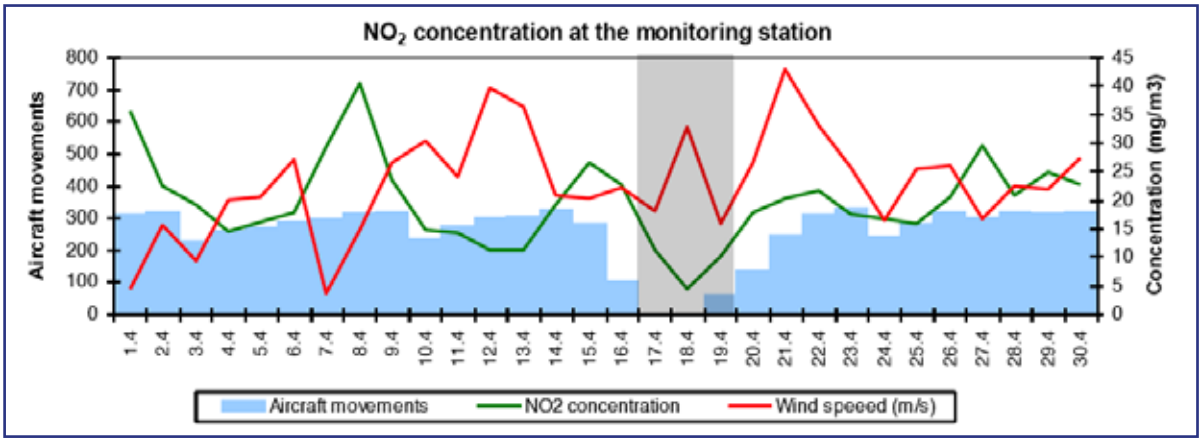


Air quality monitoring station

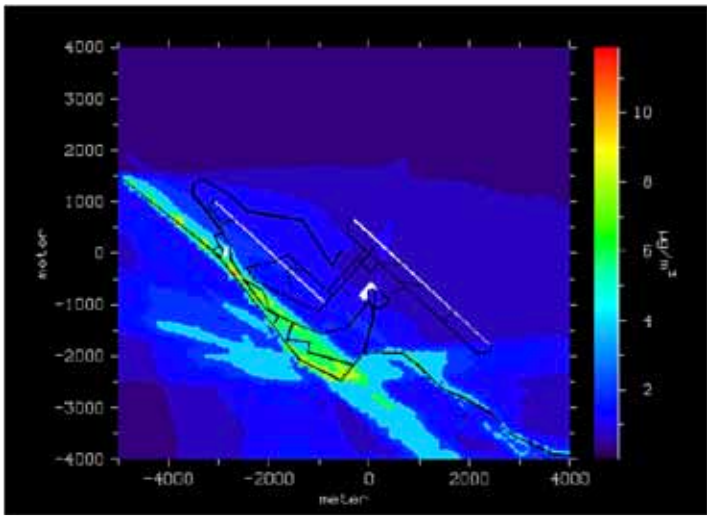
During the airspace closure, aircraft movements dropped from between 250 to 350 movements per day (m/d) to 0 movements per day.



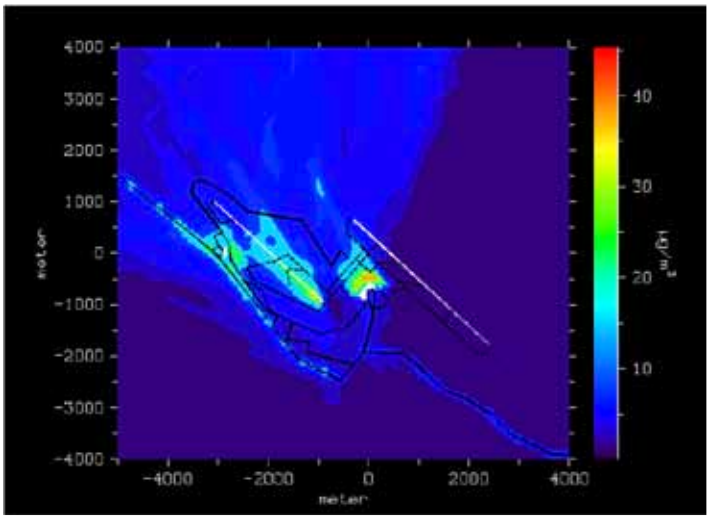
The NO_2 concentration significantly dropped during the airspace closure to 5-10 µg/m3 from a value of 15-30 µg/m3. It can be seen that at low wind speed values the NO_2 concentration is high due to the low advection. At high wind speed the concentration is low due to the high advection and fast dilution in the territory of the airport, which is quite open.



In order to quantify the concentration contribution to the overall ambient situation, the NOx concentrations from air traffic and other sources have been modeled, using the Emissions Dispersal Modeling System (EDMS) version 4.5. For one of the days of airspace closure (April 17th) a day with similar meteorological conditions but full air traffic has also been selected for comparison (April 24th), and for both scenarios the actual daily NOx concentrations have been modeled.



NOx dispersion during airspace closure with remaining handling and airport sources and reduced landside vehicle traffic [17.4.2010]



NOx dispersion of all airport related sources (aircraft (performanced based), handling, other airport sources, landside car traffic) [24.4.2010]

The data analysis shows that the NOx emission related from the landside traffic is below 10 µg/m³ during the airport closure. This value can increase up to 20 µg/m³ during normal operation days. The concentration values drop quickly in the closer vicinity of the airport and in the dwelling area the contribution is smaller than background value.

The impact of the aircraft movement stoppage on NOx emissions outside of the immediate airport vicinity was therefore negligable.

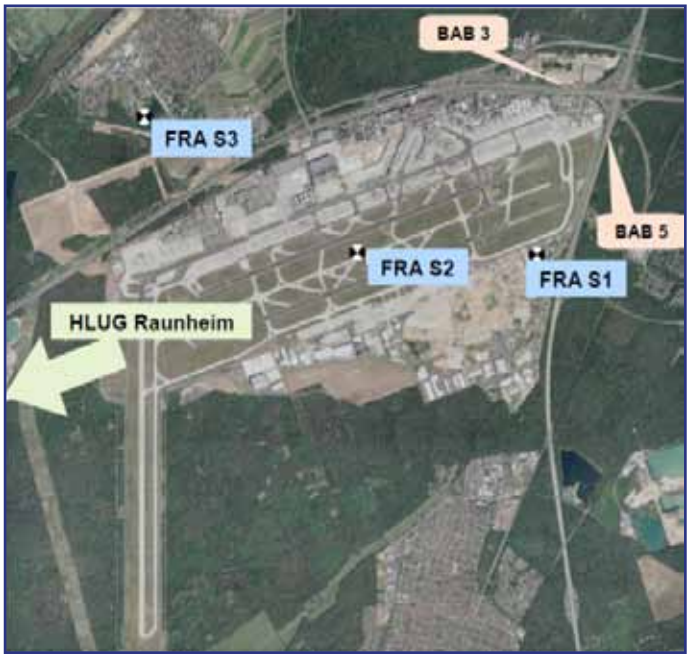
2.2 Frankfurt Airport

Frankfurt Airport is the busiest airport in Germany with 463,110 aircraft movements and 50.9 million passengers in 2009. Two highly frequented federal motorways are located to the north (BAB 3) and to the east (BAB 5). Most of the road traffic is related to transit rather than related airport activities.

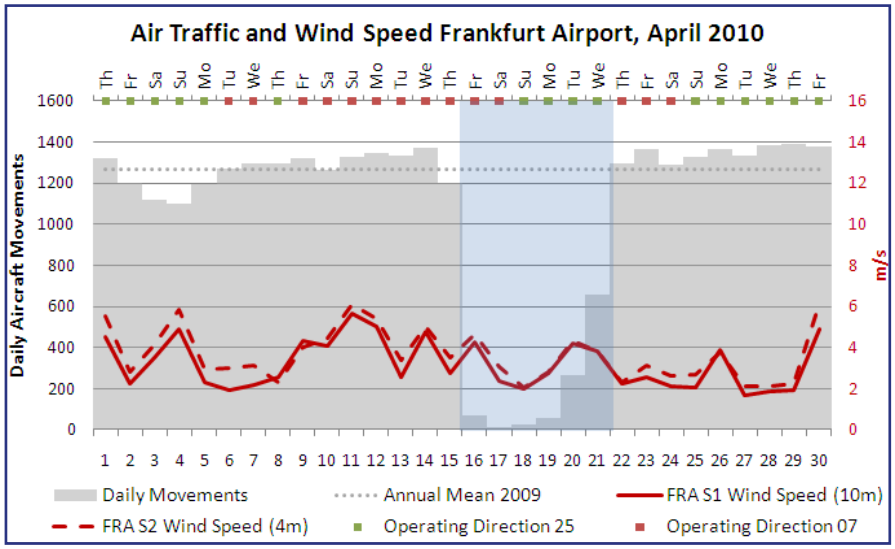
Fraport has been running two continuously operating monitoring stations on site since 2002 (S1 and S2). The range of monitoring covers all relevant components regulated by EU directives concerning protection of human health.

Additionally NOx and PM10 are monitored at the periphery of the nearest residential area (Kelsterbach, S3). To give an impression of the spatial variability the Fraport results are compared to the results of the station Raunheim (Rh), which is part of the public monitoring network (operated by HLUG: (Hesssisches Landesamt für Umwelt und Geologie).

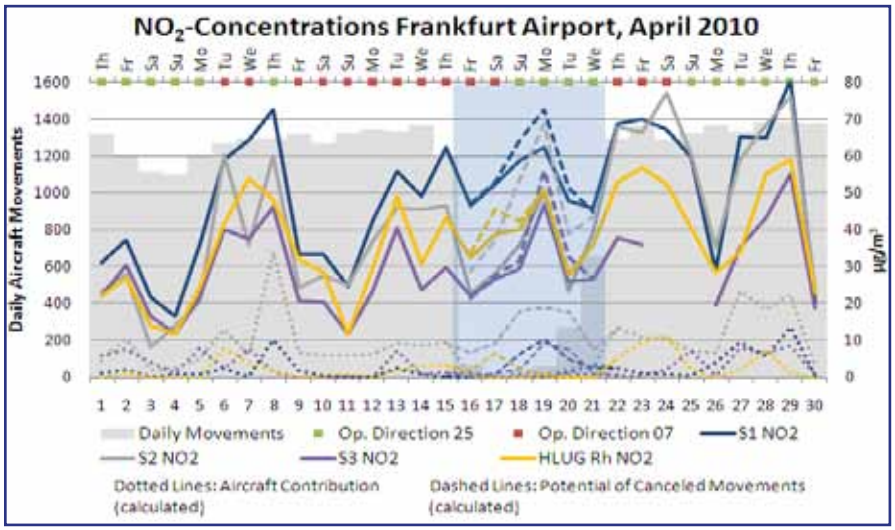
For all four analysed sites the concentration curves look similar and correlate inversely to wind speed. In general concentration values are highest at S1 due to the influence of the near motorway. Lowest concentrations are found at S3. During the episode of extremely reduced air traffic no decrease of air pollution could be observed, although not only aircraft emissions were suspended but ground handling emissions as well.



Location of Fraport stations S1 to S3 and HLUG station Raunheim within about 5 km distance



The contribution of aircraft emissions to the observed NO_2-level was modelled using Lasport 2.0[2]. Dispersion conditions in the calculation area were represented by the meteorological data of S1. As wind speed at given altitude is higher inside the airfield than it is outside, and as concentration values correlate inversely to wind speed, model results for S2 may be overestimated.



The calculated NO_2 contribution of air traffic is smaller than the day to day variation of measured concentrations even in the centre of the airfield. The "missing" contribution of aircraft emissions from April 16th to April 21st was simulated in a second run of Lasport by substituting the air traffic data by the data of one week prior.

Thus a potential concentration could be determined, which would have been expected had air traffic had continued as usual[3]. As a result the concentration at the two Fraport stations on site, S1 and S2, might have temporarily been a little higher than observed. Outside the airport area the difference would have been almost negligible. Finally it may be stated that the impact of meteorology is obviously more important than variation of aircraft emissions.

[2] A programme system for the calculation of airport-related pollutant emissions and concentrations in the lower atmosphere

[3] Except for ground handling emissions being neglected

2.3 London-Heathrow Airport

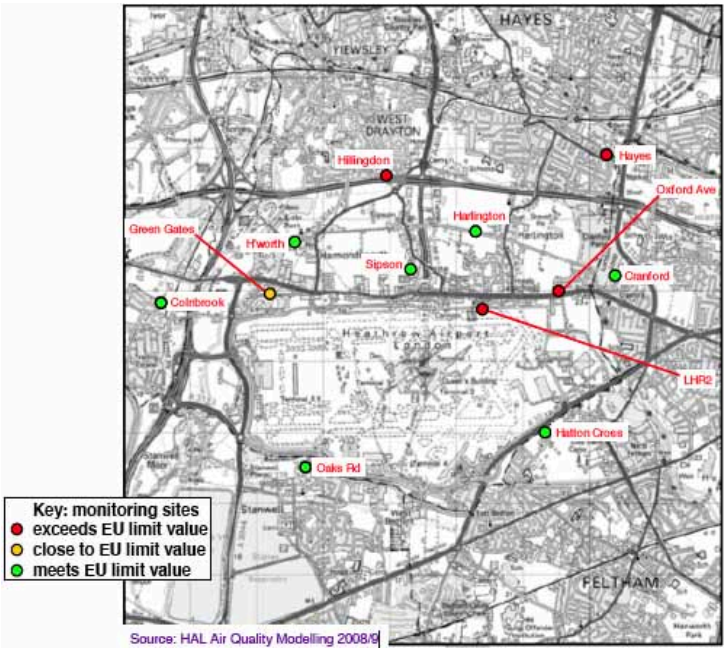
London-Heathrow Airport is the busiest airport in Europe and the only UK airport operating as a hub. It is located 24km west of central London, on the outskirts of the city and is close to two busy motorways; the M4 and M25. In 2009 Heathrow handled 469,026 movements and carried over 66 million passengers.

Heathrow Airport Limited (HAL) operates four continuous air quality monitoring sites. One is on-site, near the northern runway, the others monitor air quality at locations outside of the airport boundary. All measure the pollutants NO, NO_2, PM10 and PM2.5 and one site also measures O3.

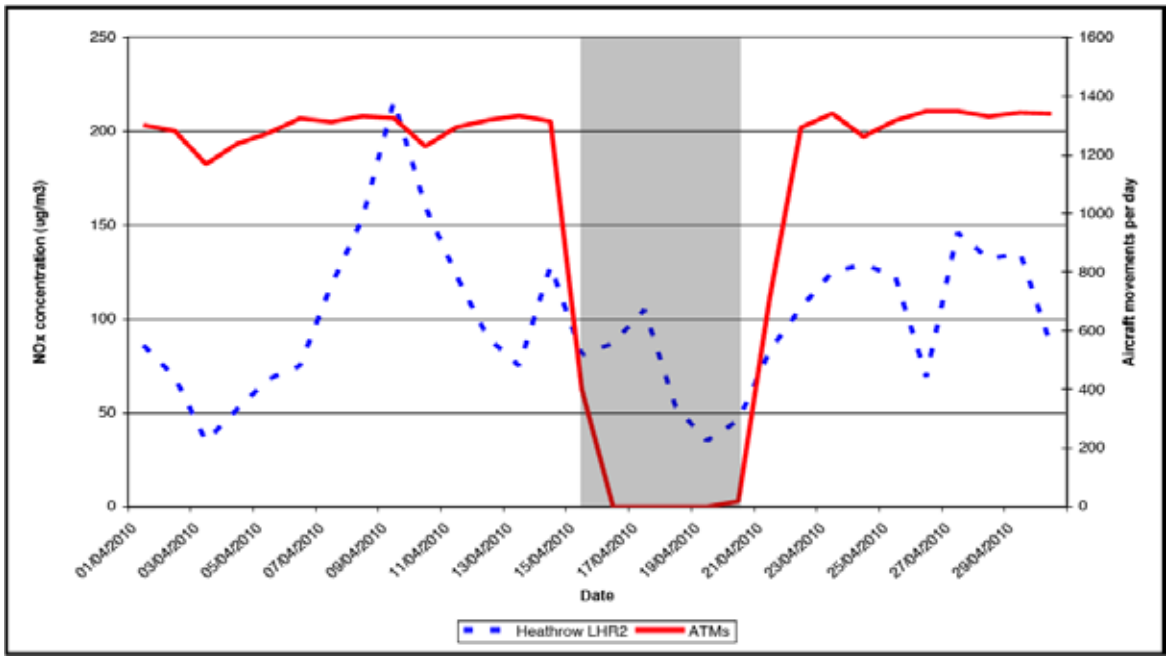
Local authorities and central government carry out additional air quality monitoring in neighbouring areas. HAL uses air quality measurements from all of these sites to assess local air quality and data is available from the following website: *heathrowairwatch.org.uk.*

On a day-to-day basis, measured concentrations vary widely, reflecting the complex mix of emissions (from housing, major roads and industry as well as emissions from London and other local areas) in addition to changes to meteorology; wind speed, for example. In general, the south westerly prevailing wind blows airport emissions towards the Oxford Avenue monitoring site, the closest housing to the airport boundary. Studies suggest direct Heathrow emissions contribute approximately 20% of measured concentrations there.

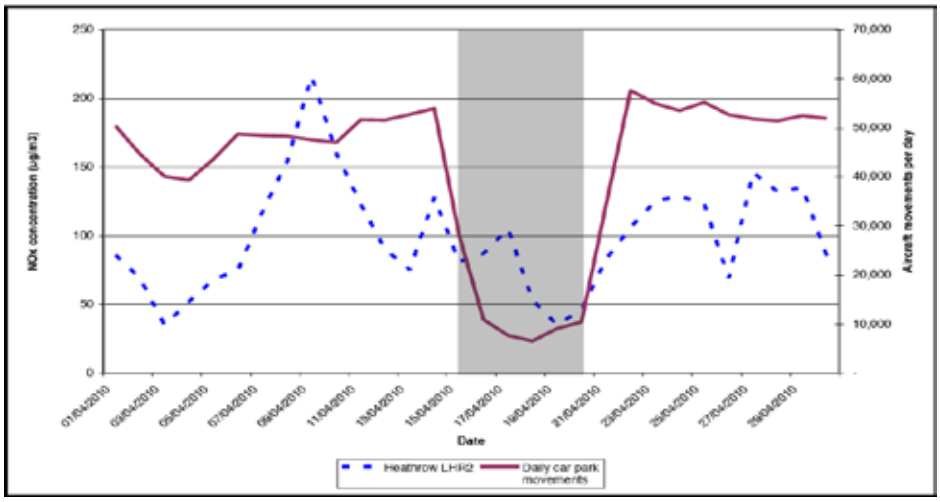
During the closure of UK airspace from Thursday April 15th to Tuesday 20th April 2010, air traffic movements (ATMs) fell from an average of 1,307 movements per day to zero. UK airspace reopened in the evening of April 20th, when 19 flights landed - all but one of which were long-haul. Closed airspace also had an affect on passenger car travel to the airport. Average daily car park movements (entry and exit) fell from approximately 50,500 to a lowest level of 6,500 on Sunday 18th.



Location of air quality monitoring sites near Heathrow Aiport, colour coded to show compliance with the EU annual average NO_2 limit value

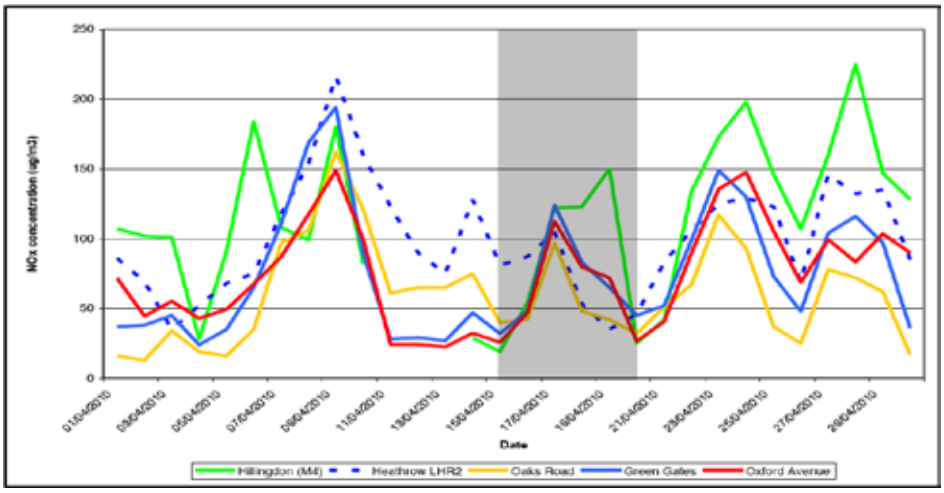


UK airspace closure April 2010 - daily average NOx concentrations measured at Heathrow Airport compared to daily aircraft movements



UK airspace closure April 2010 - daily average NOx concentrations measured at Heathrow Airport compared to total daily car park movements

Heathrow's 2008/2009 Emissions Inventory suggests daily average aircraft NOx emissions from ground operations are typically 4.5 tonnes. Airborne aircraft emissions (up to 1,000m), which have less impact on local air quality, are typically 7.5 tonnes per day on average. Emissions from both sources fell to zero for 4 days. No data relating to changes to the use of airside vehicles is available.



UK airspace closure April 2010 - daily average NOx concentrations measured at selected sites on and around Heathrow

Measured NOx concentrations at all sites typically show a wide variation from day to day, though peak concentrations measured at one site are usually reflected at others in the area, suggesting a common cause. However, significantly different concentrations are sometimes measured which are not detected at other monitors, particularly at the Hillingdon (M4) and on-airport (LHR2) sites.

Measured NOx concentrations increased on 17th April when there was no aircraft movements, but whether this was due to an increase in emissions from local sources, or to background levels is not known at present.

Comparing NOx concentrations measured at Heathrow's on-airport monitoring site with concentrations before and after airspace closure showed a drop of about one third. Source apportionment studies estimate direct airport emissions contribute approximately this proportion to measured concentrations - 75% of this airport source is from aircraft engines.

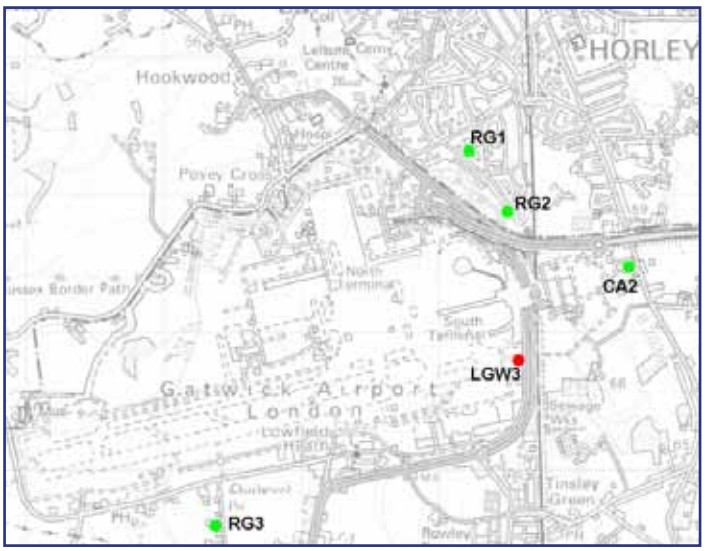
No significant difference in measured NOx concentrations was found at locations outside of the airport boundary, even those within a couple of hundred metres of it. Heathrow's source apportionment work indicated a measurable difference would take place - from 20% at Oxford Avenue down to 7% at Green Gates. The comparison study is continuing.

2.4 London-Gatwick Airport

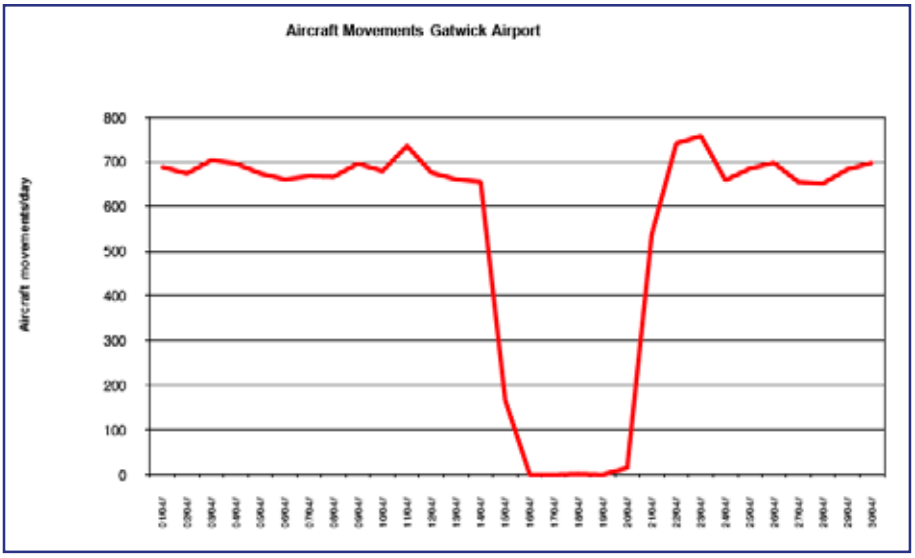
Gatwick Airport is the 2nd largest airport in the UK with over 250,000 movements and 32 million passengers in 2009. It is also the world's busiest single-runway airport, 6th busiest airport in Europe and the 10th busiest airport internationally. The airport is located 28 miles south of London and is located on the M23 motorway.

Gatwick airport has one air quality monitoring station (LGW3), but there are four further monitoring stations owned by the adjacent local authorities (Reigate and Banstead Borough Council (RG1, 2 and 3) and Crawley Borough Council (CA2)).

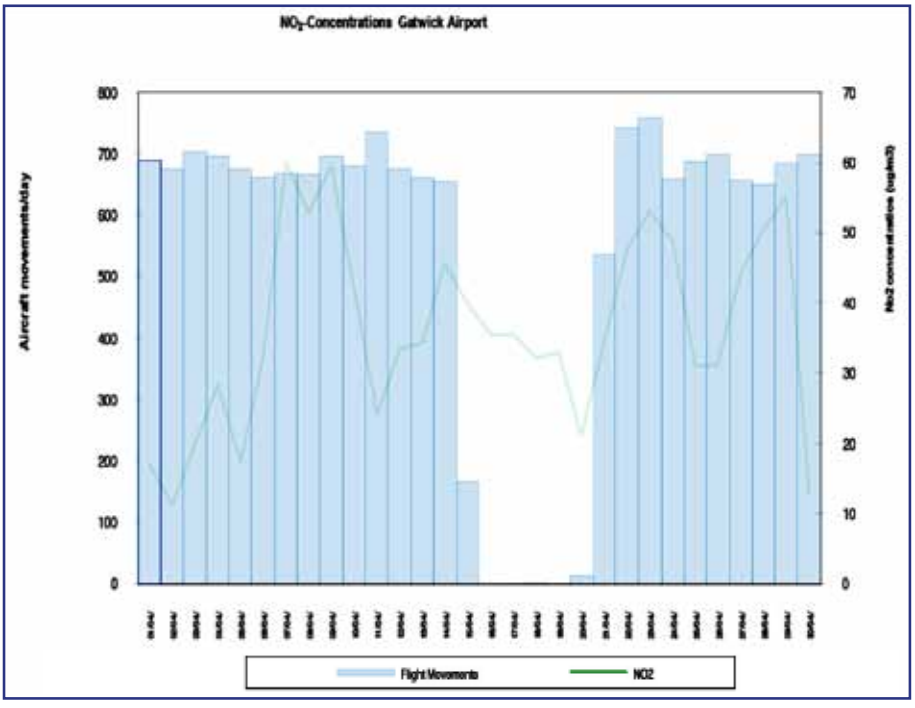
During the airspace closure, the aircraft movements dropped from between 600 and 700 m/d to 0 m/d.



Air Quality Monitoring Stations



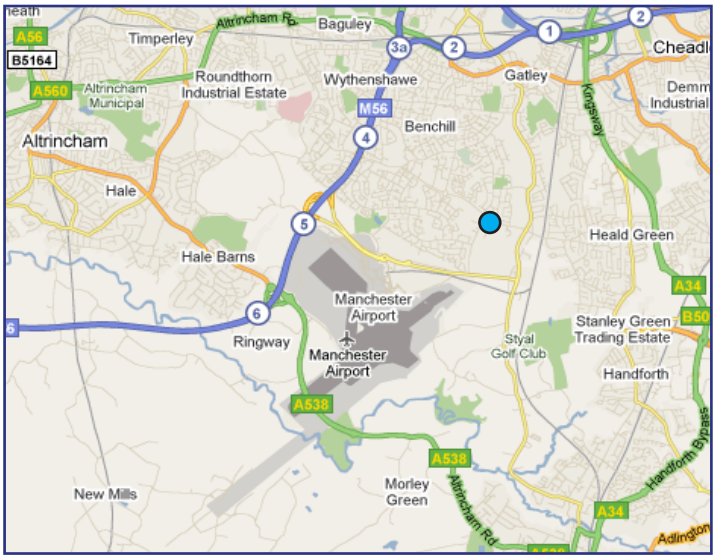
The NO_2 concentrations seem to correlate with the aircraft movements during the airspace closure. However, high variability in concentrations can be observed even more so earlier and later in April with regular air traffic.



2.5 Manchester Airport

Manchester Airport is located just south of the city of Manchester. A major motorway, M56, is located along the north-western side of the airport. The airport accommodates more than 22 million passengers with over 200,000 annual aircraft movements.

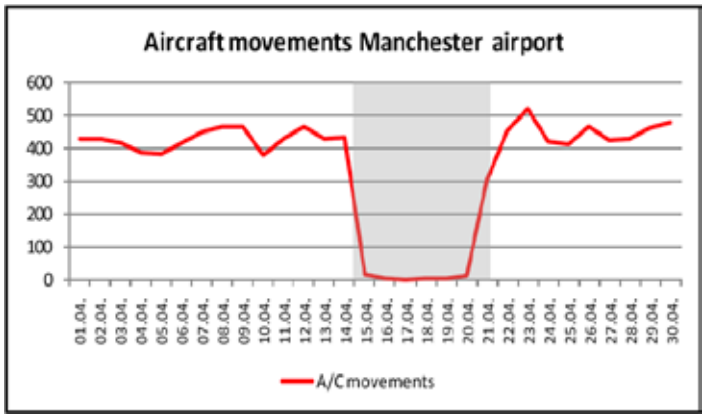
An air quality monitoring station is located north-east of the airport premises, in Heald Green.



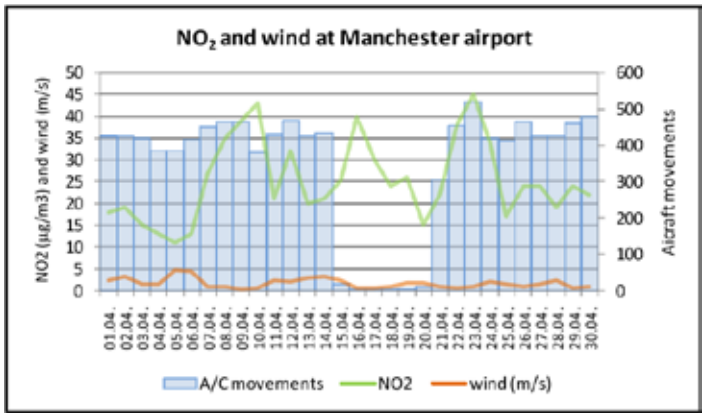
Manchester South Monitoring Station

The daily traffic volume is approximately 450 aircraft movements. During the airspace closure from April 15th-20th, this number dropped to 1-11 movements per day (-99%).

The NO_2 concentrations show little correlation with the aircraft movements and there is no pattern in relation to the airspace closure. The regular significant drops in NO_2 concentrations (April 4th, 11th, 18th, 25th) even without evident wind are all on Sundays which tend to point to other emission sources, i.e. vehicle traffic.



The NO_2 concentrations show little correlation with the aircraft movements and there is no pattern in relation to the airspace closure. The regular significant drops in NO_2 concentrations (April 4th, 11th, 18th, 25th) even without evident wind are all on Sundays which tend to point to other emission sources, i.e. vehicle traffic.



2.6 Paris Airports

Paris-Charles de Gaulle

Located 20 km north-east of Paris, Paris-Charles de Gaulle Airport dealt with 518,000 movements and 57.9 million passengers in 2009.

Along the 4 runways airfield, highway A1 on the Western side (the most important in France) and heavy traffic RN2 on the southern side concentrate most of the road traffic nearby.

In addition to the two automatic stations specific to the airport air quality monitoring network, two stations, Gonesse and Tremblay from the association Airparif managing the regional network around Paris are used for comparison.

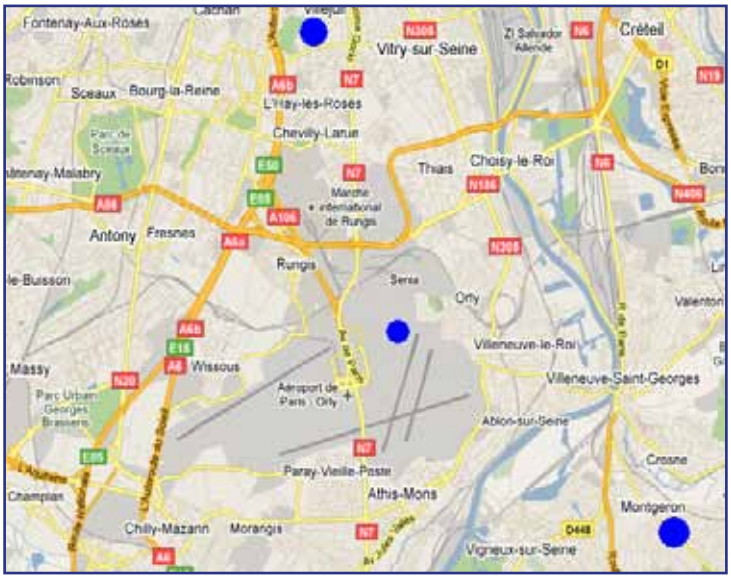


Monitoring Station

Paris-Orly

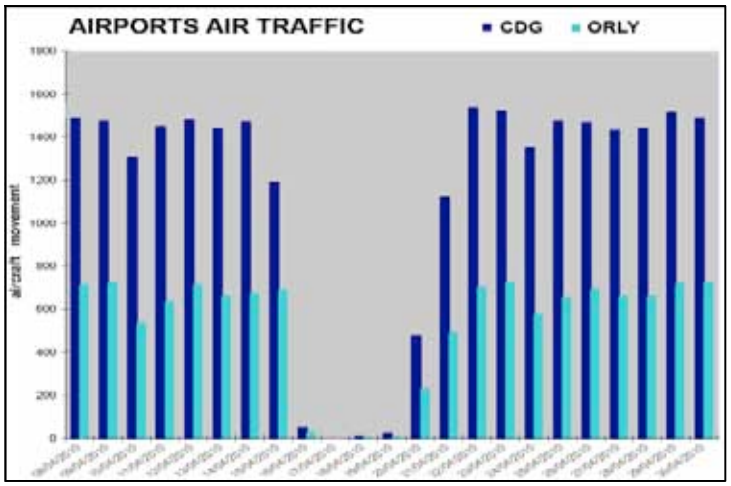
Located 10 km south of Paris within a quite dense urban environment, Paris-Orly Airport's 221,000 movements on the 2 runways in 2009 traffic accommodated 25.1 million passengers.

Two main road cross nearby - the A6 highway on the Western side and the RN7 crossing the platform in the middle in the South-North direction. As with Paris-Charles de Gaulle, the data from the automatic station specific to the airport air quality monitoring network are compared to those from the two Airparif stations, Montgeron and Vitry-sur-Seine.

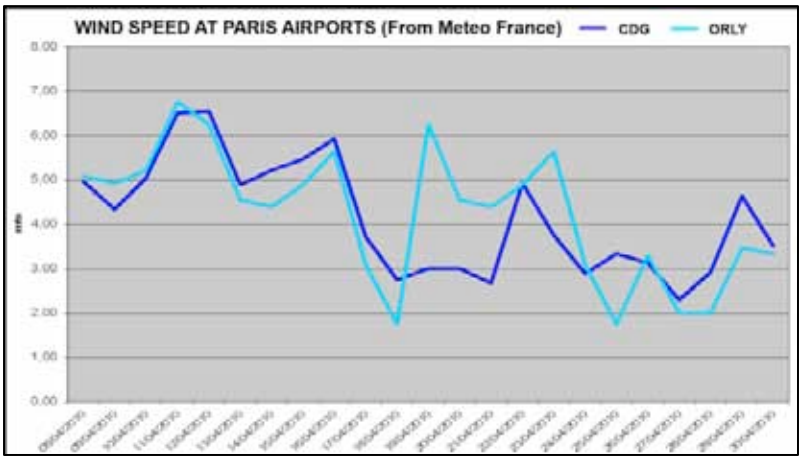


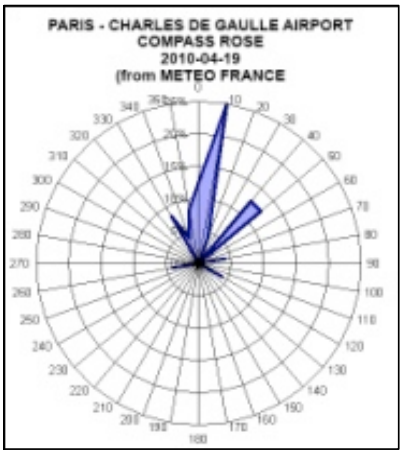
Monitoring Station

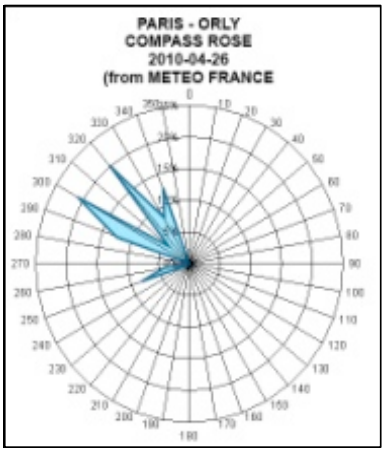
For both airports, traffic was completely interrupted from Thursday April 15th, 11pm, to Tuesday April 20th, growing smoothly to reach again its normal level on Thursday April 22nd.



For both sites, the meteorological conditions were similar with a moderate wind averaging daily 2 to 6.5 m/s coming from north/north-east from April 8th to 23th (8th to 25th for Paris-Orly), then east to north-west the following days.



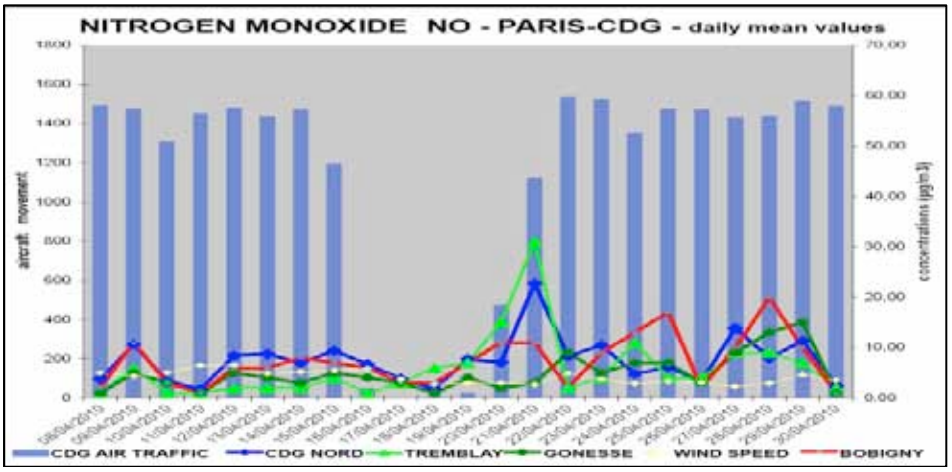


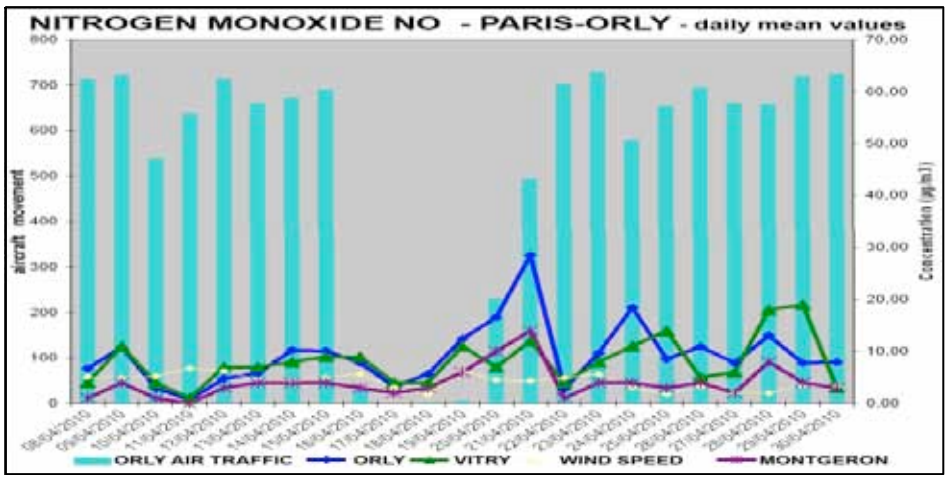


Wind Directions at Paris CGD & Paris Orly

Nitrogen Monoxide (NO)

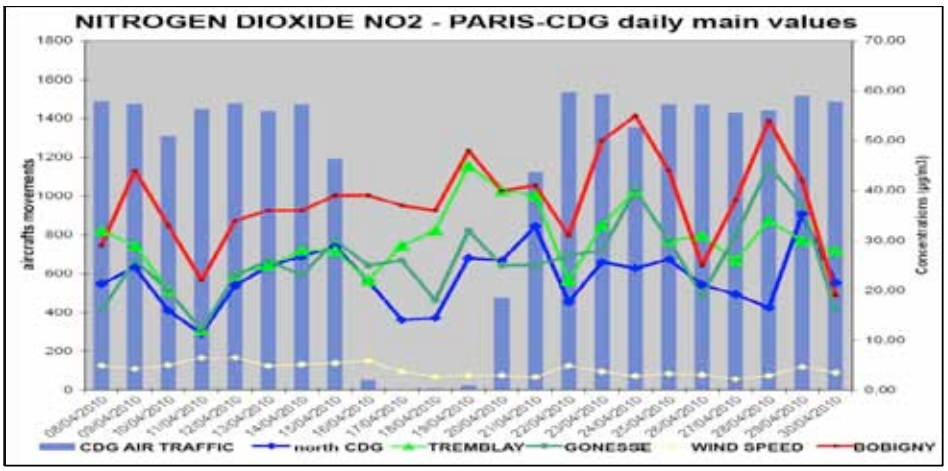
This pollutant, produced directly in the atmosphere by transport activities, characterises proximity pollution. An increase in concentration is observed when the traffic starts again; the decrease in the following days under consolidated aircraft traffic may be caused by a range of other meteorological changes (wind speed, limit layer thickness, sunshine duration impact etc.).

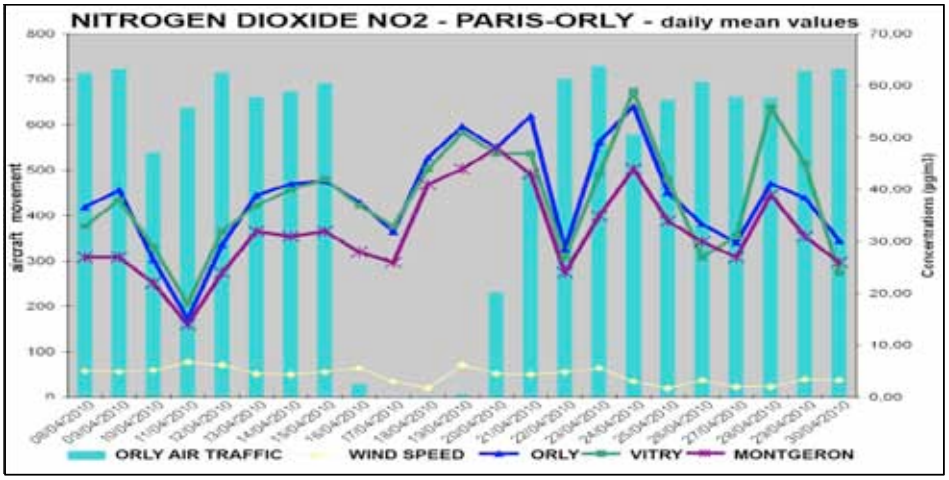




Nitrogen Dioxide (NO_2)

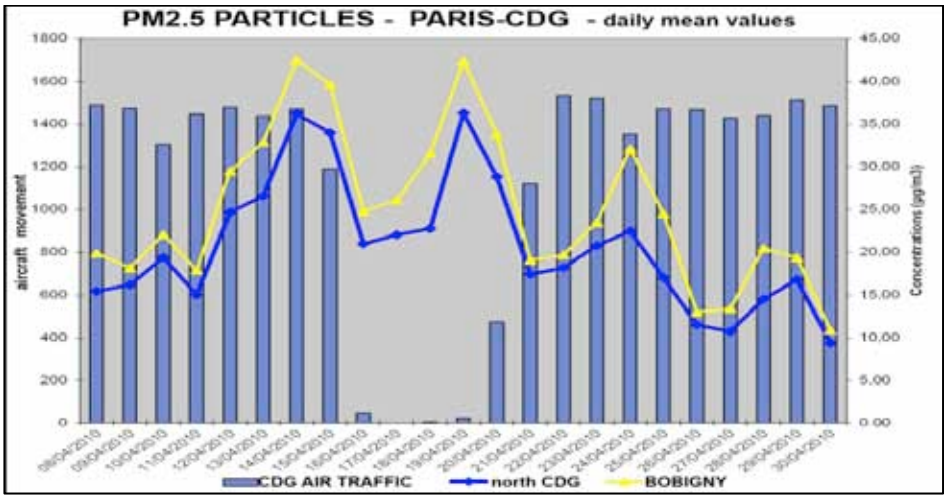
Also issued directly from transport activities but also from reaction between ozone and nitrogen monoxide, this pollutant characterises both proximity and background pollution, as observed during the no flight period where the pollutant concentrations stay about at the same level as before. Therefore it is not possible to measure the air traffic impact, as it is hardy observable when traffic returns.

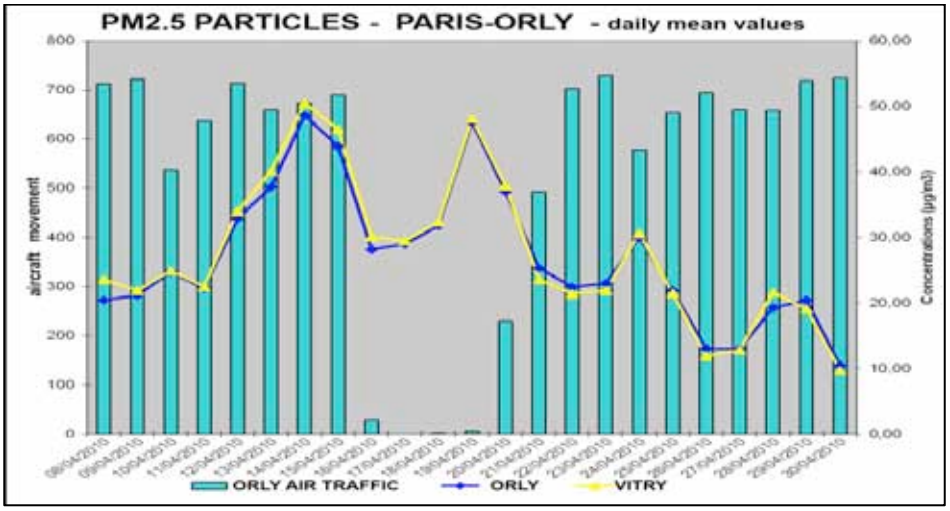




Particle Matter (PM2.5)

Compared to those measured outside the airports in areas without aviation activity, at Bobigny (south of Paris-CDG) and Vitry, (north of Paris-Orly) concentrations in PM2.5 are strictly equivalent in quantity and variations, even decreasing when flights returned. This shows the predominance of meteorological conditions on pollutant dispersion. The air traffic impact on particles concentration is not detectable.





2.7 Madrid-Barajas Airport

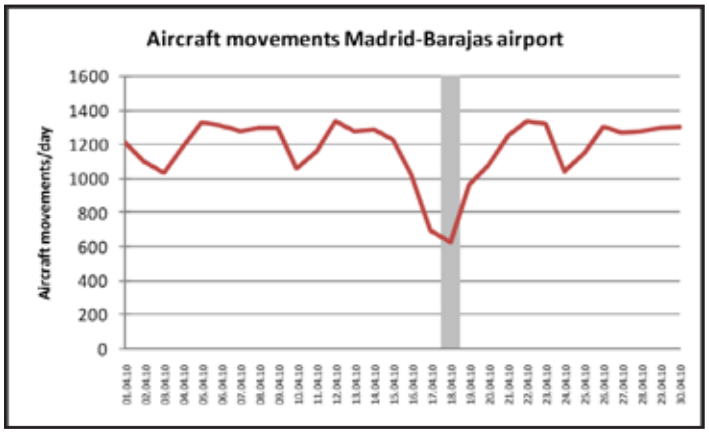
Madrid-Barajas Airport is the largest airport in Spain with 435,187 movements and 48.4 million passengers in 2009, and one of the ten largest airports in Europe. It is located 12 km north-east of the city center. Adjacent to the airport there are three major motorways.

Madrid-Barajas has an air quality monitoring network (REDAIR) composed of three fixed stations. The stations are located at the departure points of runways 36L, 15 and 18L, close to the middle area of runway 18R/36L, and on the southern boundary of the airport. These stations are continuously measuring NO_2 among other pollutants and meteorological parameters. A mobile station is also available for specific measurements. The reported values refer to the station located between the runways.

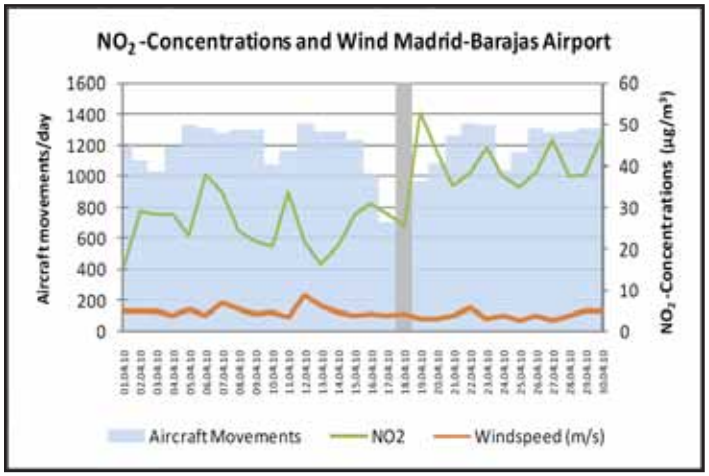


Air Quality Monitoring Stations

Unlike the large majority of airports in northern Europe, the Spanish airports remained partially closed to air traffic only from 08:54 UTC to 18:00 UTC on April 18th. During the closure of the Spanish airspace, aircraft movements in Madrid-Barajas dropped from an average of 1,100-1,200 m/d to 629 m/d (-47%). Also, many flights with origin or destination to Northern Europe airports were cancelled during the days before and after the event.



The NO_2 concentration dropped during the airspace closure but did also to a significant degree during the weekends before and after the event. As such, the lack of aircraft emission cannot be said to affect the daily NO_2 concentrations. Indeed, the nearby motorways seems to have a much larger influence, as the drop in NO_2 concentrations seems correlated with the absence of heavy duty traffic on weekends.



2.8 Barcelona Airport

Barcelona Airport is the 2nd busiest airport in Spain with 278,981 movements and 27.4 million passengers in 2009. It is located approximately 10 km south-west of the city of Barcelona, by the sea and within the Delta del Llobregat. There are two motorways close by that also serve the airport.

Barcelona Airport has an air quality monitoring network composed of four fixed stations. NO, NO_2, O3 and PM10 among other pollutants are continuously measured. The stations are located in the airport and in strategic points in the surrounding area (in Gava, El Prat and Viladecans). The data refer to the "AEROPUERTO" monitoring station.

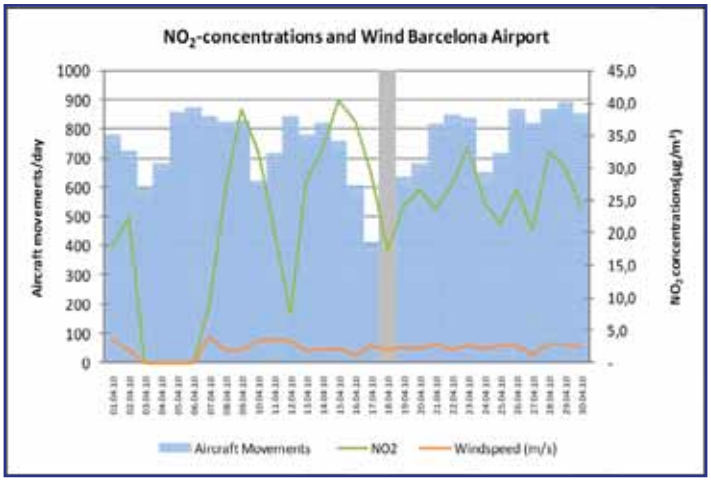
During the partial closure of the Spanish airspace on April 18th, aircraft movements dropped from an average of 700-800 m/d to 173 m/d (-77%). Also, many flights with origin or destination to northern European airports were cancelled during the days before and after the event.

The NO_2 concentrations seem to correlate with the aircraft movements during the airspace closure. However high variability in concentrations can be observed even more so earlier and later in April, with regular air traffic volumes. An impact contribution from air traffic emissions (or the lack thereof) on the pollution concentrations can thus not directly directly be quantified.



Air Quality Monitoring Stations





2.9 Palma de Mallorca Airport

Palma de Mallorca Airport is the 3rd largest airport in Spain with 177,502 movements and 21.2 million passengers in 2009, reaching the top of the traffic charts during the summer season. Palma de Mallorca is among the 20 busiest airports in Europe.

The airport is located within the municipality of Palma de Mallorca, 8 km west to the city center and less than 1 km away from Coll d'en Rabassa, Can Pastilla and S'Arenal. There is a motorway located south of the airport.

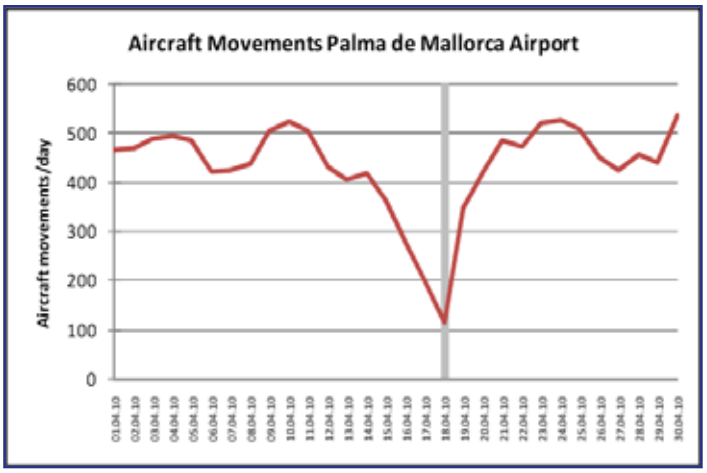
Palma de Mallorca Airport has an air quality monitoring station. NO, NO_2, O3 and PM10 among other pollutants are continuously measured.

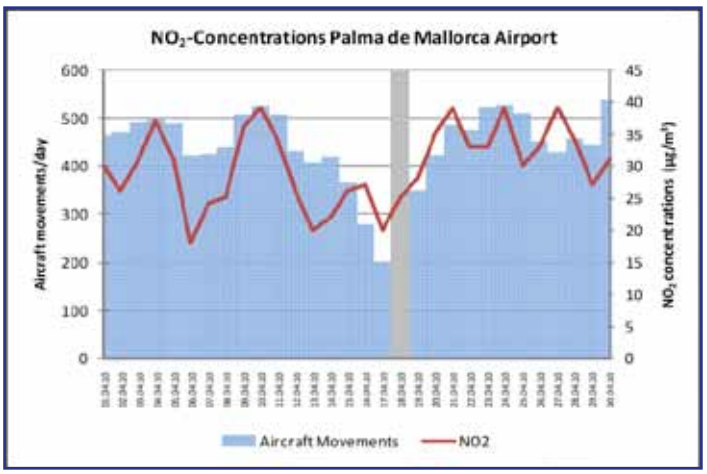
During the partial closure of the Spanish airspace on 18/04, aircraft movements dropped from an average of 430-440 m/d to 114 m/d (-74%). Also, many flights with origin or destination from/to northern European airports were cancelled during the days before and after the event.

The NO_2 concentrations seem to correlate with the aircraft movements during the airspace closure. However a drop in concentrations can be observed to at least the same degree earlier in April while there is no correlation later in April with regular air traffic.



Air Quality Monitoring Stations





2.10 Geneva International Airport

Geneva International Airport is largest airport in western Switzerland with more than 11.3 million passengers in 2009. Located just north of the city and close to the French border, it is served by a busy motorway alongside the southern airport premises.

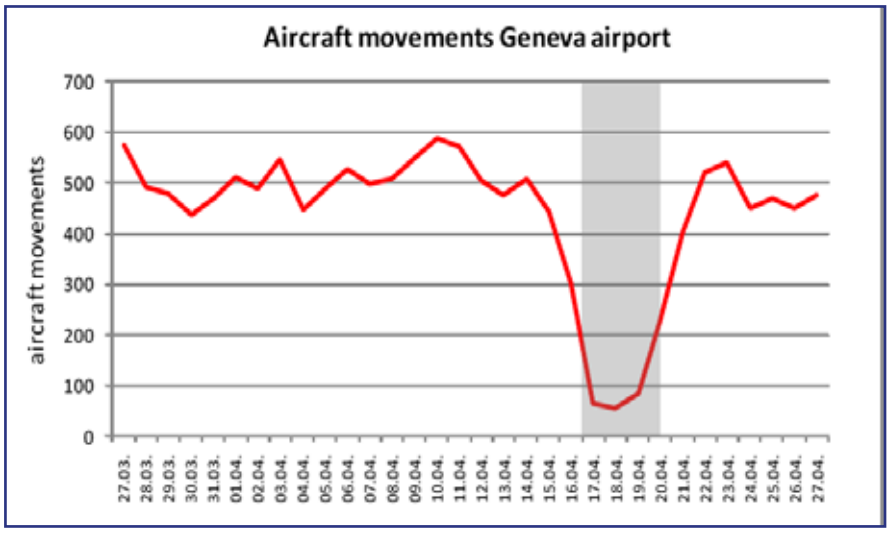
Geneva airport operates an air quality station at the airport while the authorities operate additional stations for NO_2 in the closer airport vicinity, in Meyrin and Ferney-Voltaire.

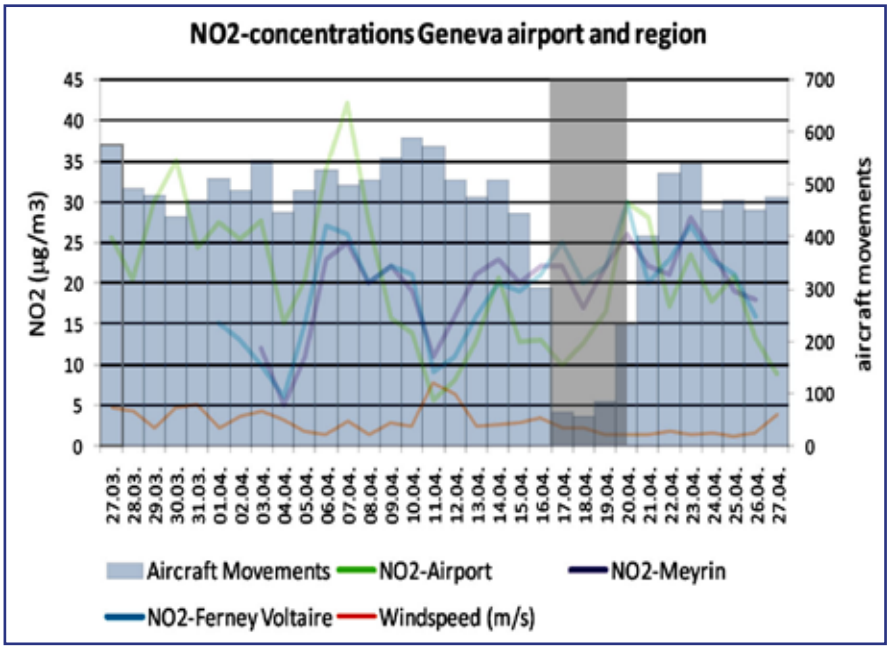
The airport had only limited aircraft operations from 0000 hours April 17th, until 0800 hours April 20th, with movements dropping from a daily average of 500 to approximately 80 (-84%) which were only light aircraft (general aviation). The meteorological conditions were not significant with respect to wind speed.

The measured concentrations show a reasonable correlation for the studied period (March 27th to April 27th) between the three measurement stations. During the airspace closure, a drop in NO_2 concentration at the airport station could be observed that can be explained by the reduction in emissions. The neighboring stations show a reduction only during one day of the reduced air traffic (Sunday 18th) and show similar reduction for previous Sundays (April 4th and 11th). As such, there is no indication that the air traffic significantly impacts the concentrations in the vicinity of the airport.



Airport air quality monitoring station
Regional monitoring stations





2.11 Vienna Airport

Vienna Airport is the largest airport in Austria with 243,430 movements and 18.1 million passengers in 2009. It is located 12 km south east of the city center. Adjacent to the airport, passing on the north side is a busy motorway.

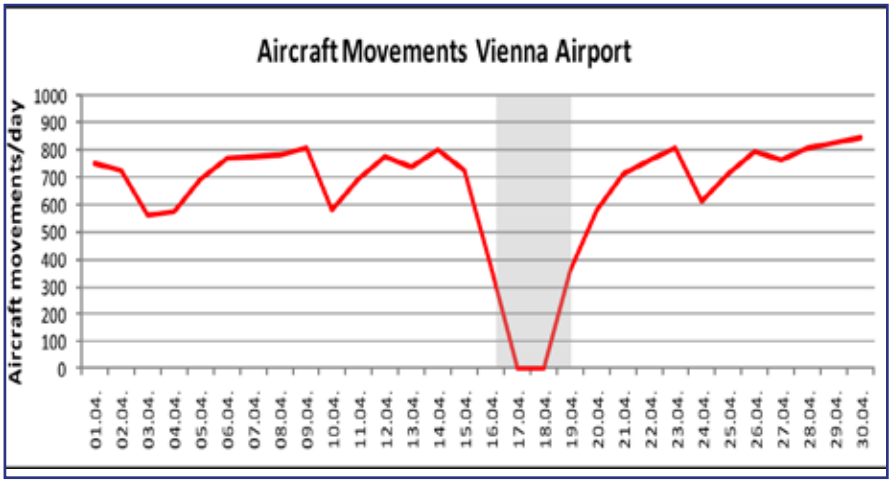
In the proximity of the runways, an air quality monitoring station is located, continuously measuring among other species NO_2 and meteorological parameters.

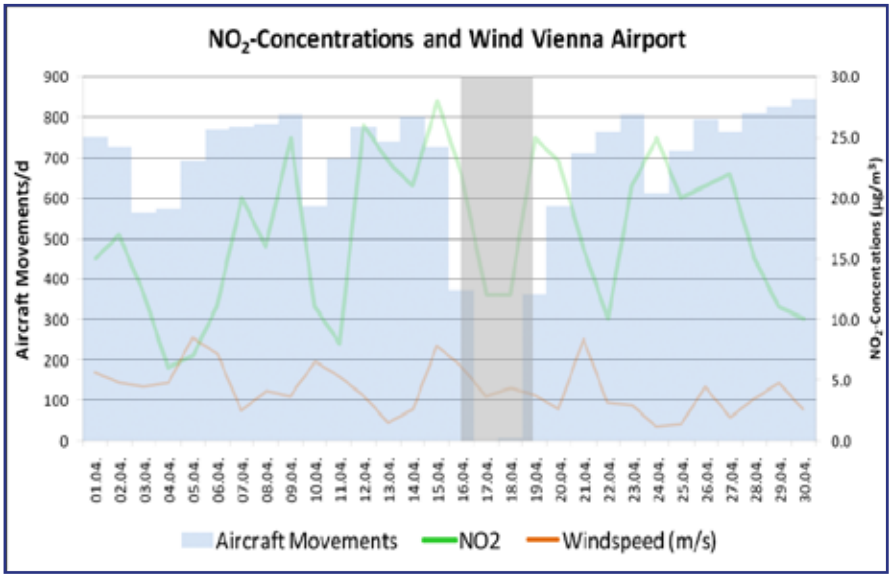
During the airspace closure, aircraft movements dropped from between 600 to 800 m/d to 0 movements (-100%).



Air Quality Monitoring Station

The NO_2 concentrations drop during the airspace closure, but do so to an even more significant degree during the weekends before and after the event. As such, the lack of aircraft emissions do not seem to affect the daily NO_2 concentrations. Indeed, the nearby motorway has a much larger influence, as the heavy duty traffic that is absent during the weekends causes the drop in NO_2 concentrations.

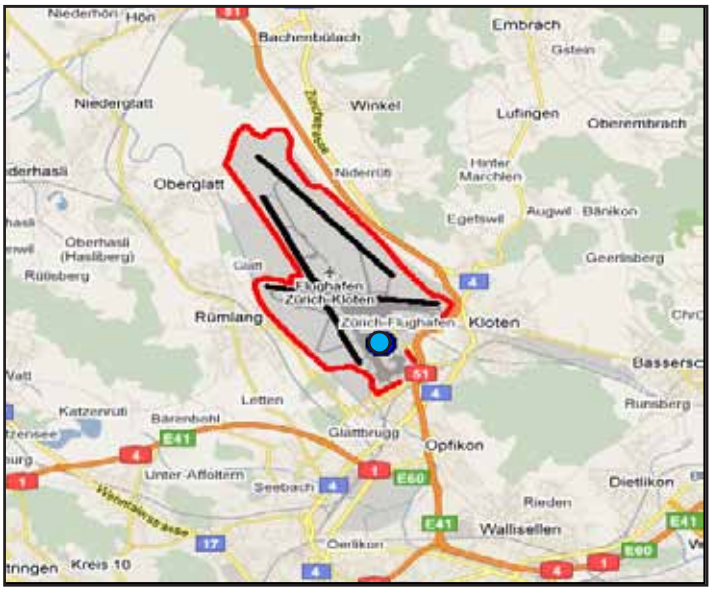




2.12 Zurich Airport

Zurich Airport is the busiest airport in Switzerland with 262,100 movements and 21.9 million passengers in 2009. It is located approximately 5 km north of the city of Zurich in an area with a dense population but little industry. There are two major motorways close by that also serve the airport.

Zurich airport has (among others) an air quality monitoring station operated on the roof of the pier A in the centre of the airport. NOx, NO_2, O3 and PM10 are continuously measured.



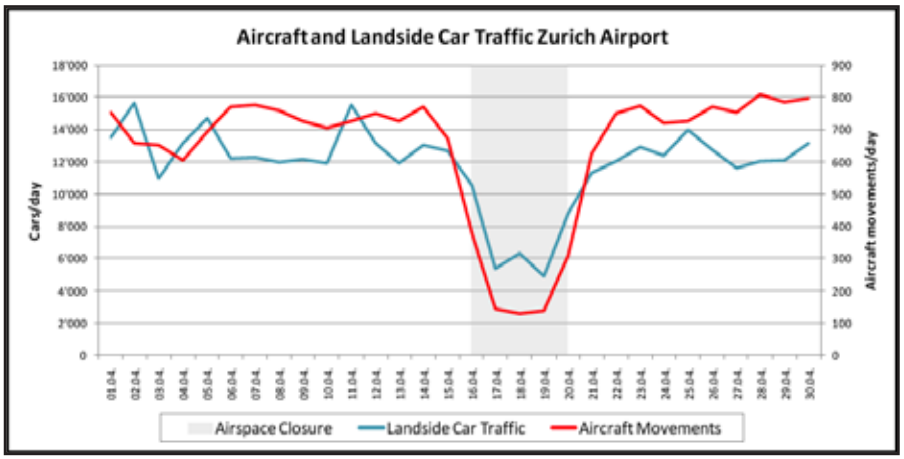
Air Quality Monitoring Station

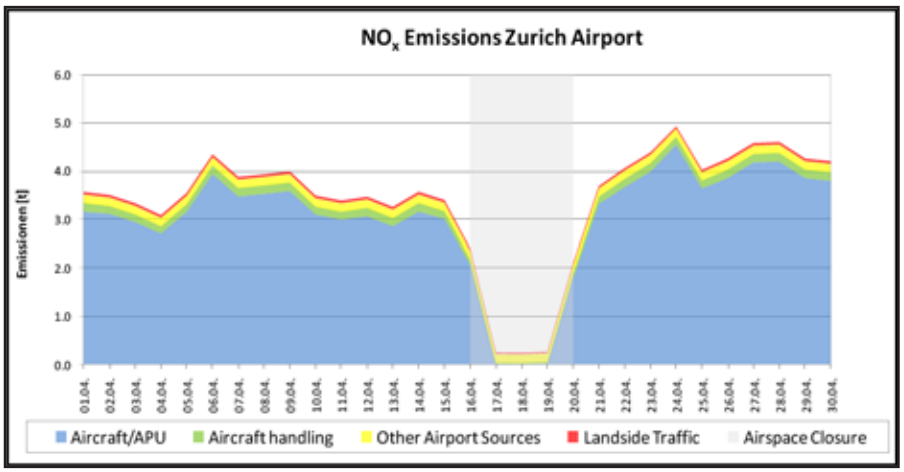
During the Swiss airspace closure from April 16th to April 20th, the aircraft traffic dropped from an average of 750 m/d to 150 m/d, which was mainly VFR traffic (-80%).

This also affected the landside access traffic with a drop from 13,000 cars/d to 6,000 cars/d (-54%). The variations in the car traffic depicts the weekend situations.

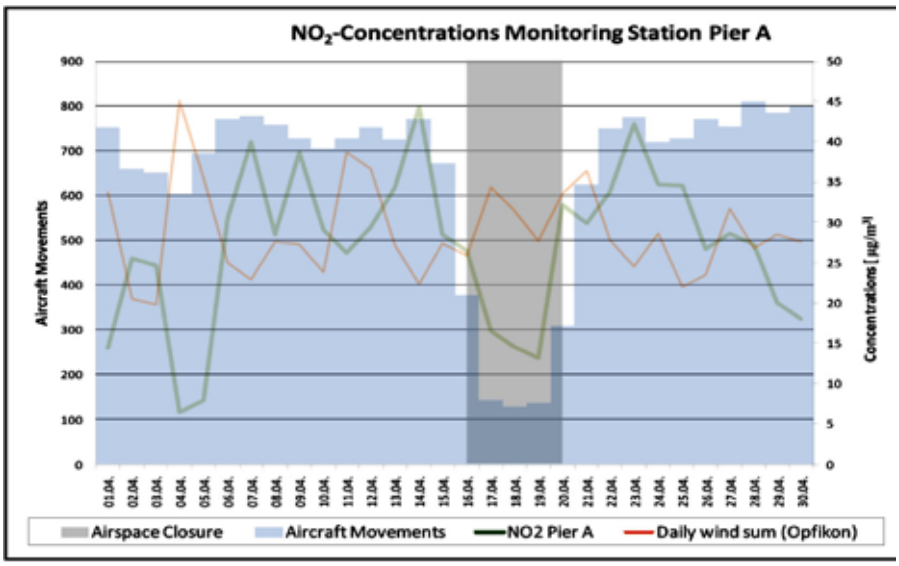
The NOx emissions from aircraft, aircraft handling and landside car traffic sources drop significantly, while other airport sources (mainly stationary sources) and some landside traffic emissions still remain. The NOx emissions dropped from 3.5 t/d to 0.25 t/d (-93%).

The NOx concentrations seem to significantly correlate with the aircraft movements during the airspace closure. However, a drop in concentrations can be observed even more so earlier and later in April with regular air traffic. When considering the wind situation (of a wind station approximately 2 km south of the monitoring station) it can be seen that the higher the winds, the lower the concentrations are (known correlation). An impact contribution from air traffic emissions (or the lack thereof) on the pollution concentrations can thus not directly be quantified.

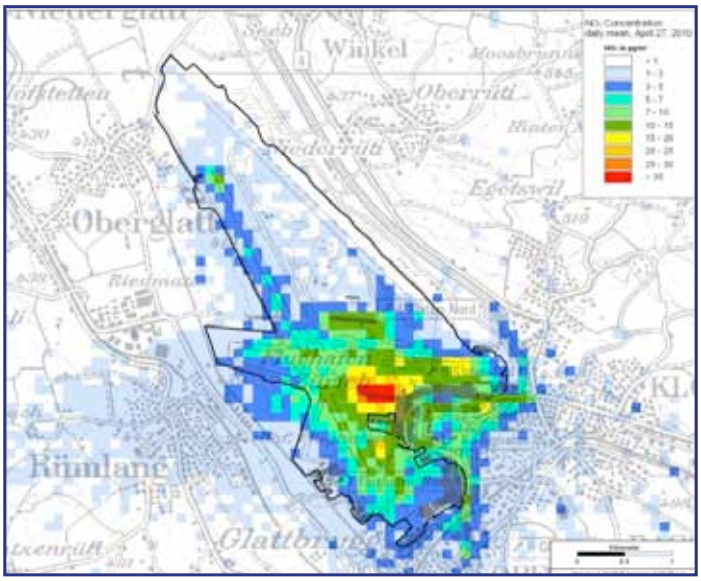




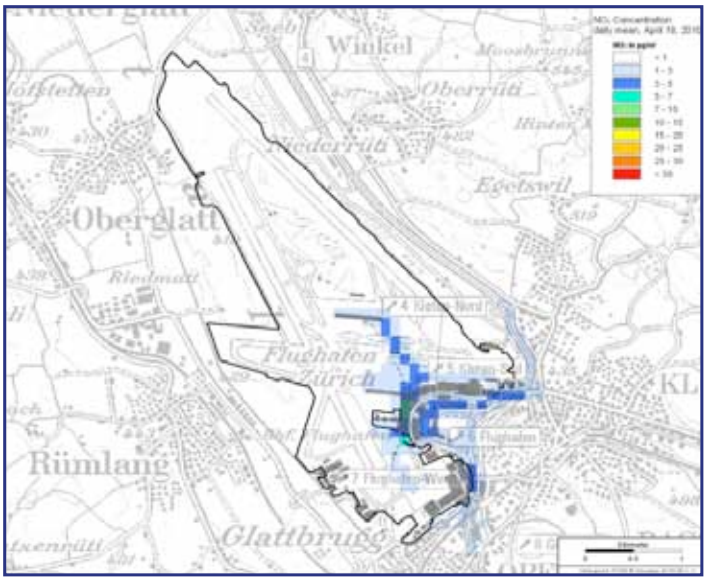
In order to quantify the concentration contribution to the overall ambient situation, the NO_2 concentrations from air traffic and other sources have been modeled using the model LASPORT 2.0. For one of the days of airspace closure (April 18th) a day with similar meteorological conditions but full air traffic has been selected for comparison (April 28th) and for both scenarios the actual daily NO_2 concentrations have been modeled.



The data analysis shows that the difference in concentrations is largest within the airport perimeter, but quickly drops in the closer vicinity of the airport. In the nearby residential areas of Kloten or Rümlang (1 km east and west of the airport perimeter respectively), the difference of NO_2 concentrations ranges from 1-3 µg/m3 where the total 2009 annual mean concentrations range from 19-23 µg/m3. The contribution of air traffic to the overall concentration thus is approximately 2 µg/m3 in residential areas, which is about 10% of the total concentration.



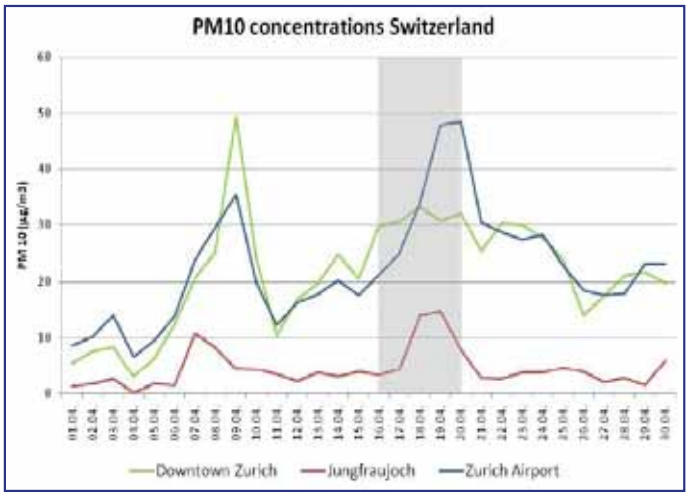
NO_2 dispersion of all airport related sources (aircraft (performanced based), handling, other airport sources, landside car traffic) [27.4.2010]



NO_2 dispersion during airspace closure with remaining handling and airport sources and reduced landside car traffic [18.4.2010]

Effects on fine particle concentrations

The event of the volcano eruption had effects not only in relation to air traffic emissions, but also had a direct impact upon Europe's air quality. The eruption triggered the emission of huge amounts of particles that then were dispersed all over Europe. As particles are also an exhaust product of aircraft, the development of PM10 concentration is monitored as well. A typical example is presented in the graph below with three stations in Switzerland: downtown Zurich, Zurich Airport and the mountain station Jungfraujoch (which, at 3,475 metres is solely influenced by background concentrations)[v].



PM concentrations in Switzerland[iv]

The PM10 concentration rose at all stations, with the Zurich airport and Jungfraujoch stations in particular experiencing higher concentratations after the ash cloud had reached Switzerland. Several days later, the concentrations dropped again. This picture suggests that there is little to no influence visible from the aircraft particle matter emissions; otherwise one would expect that the raise in concentration would be compensated by the decline due to the closure of the airspace.

2.13 Athens International Airport

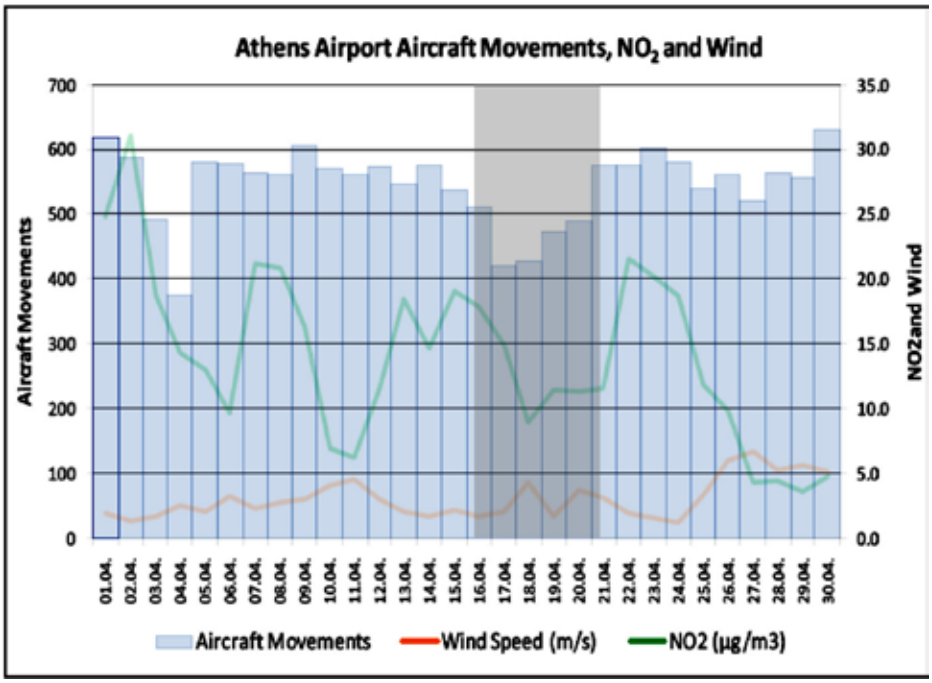
Athens International Airport is the largest airport in Greece, situated approximately 40 km east of the city of Athens. In 2009, it accommodated 210,000 aircraft movements and 16.2 million passengers. The airport is served by a dedicated motorway that also serves other areas in the vicinity of the airport, such as the near by retail park.



The air quality monitoring station is located on the airport premises and measures NOx, NO_2, O3, PM10, SO_2 and HC.

Athens airport, while not closed for traffic, encountered cancelled flights to other European destinations from during the affected period, starting with 22 cancelled flights, increasing to a maximum of 165 on April 17th and ending with 35 cancelled flights on April 21st.

The NO_2 concentrations, when viewed over the month of April show no correlation with air traffic, but more so with the wind speed (an inverse correlation). The effect of reduced air traffic is not visible in the concentrations.



3 Conclusion

This study by necessity focused on one narrow element of local air quality at and around airports. The scope of the study is constrained by a number of complicating factors.

Firstly, the closure of airspace will have varying impacts on different elements of airport operations. While some groups, such as passengers and staff will not come to the airport at all, other user groups, such as shoppers and visitors, will continue to come, albeit at a much reduced rate. There is considerable interdependancy and is not immediately obvious when considering a singled out effect of suspended aircraft operations. As such, airports have to be looked at a system, where the various activities (air, airside, landside) interact.

Secondly, the change in recorded NOx levels can be subject to a number of factors, such as the methodology used, the number of sources included or not included, or the ability to measure short term emissions. As such the resulting change in emissions does not give sufficient information on the actual air quality impact of aircraft operational changes. As has been observed before, the calculated emission load is not an adequate metric to describe the air quality effects at and around an airport[v].

Notwithstanding these provisos, the clear conclusion which emerges from the study is that the significant disruption and reduction of flight activity did not significantly affect air quality concentrations of NO_2, confirming that the contribution of air traffic to local air quality in the vicinity of airports is very small.

While it may seem that the concentrations are somewhat correlated with the traffic during the airspace closure, across wider observations the correlation is weak. There are many other periods in the month of April where the patterns of air activity and concentrations vary considerably. In several instances the correlation observed is actually as a result of the main airspace closure occuring on a weekend, with subsequent lower traffic levels on nearby main road arteries.

Indeed, the analysis shows that the meteorological conditions like wind speed (Budapest, Frankfurt, Zurich) or nearby larger emission sources (Vienna) have a more significant influence on the measured concentration than the number of aircraft movements or calculated emissions.

In addition, where there are several stations close by (such as Geneva), while the airport stations may show lower concentrations the effect is leveled out at the neighboring stations, indicating the very local effect of emission changes (in may cases limited to the airport perimeter itself). This observation is supported by the modeling of aircraft emission dispersion (as occurred at Zurich and Budapest) where results show the neglibile impact of the airspace closure on NOx concentrations outside of the airport perimeter.

Finally, the results of PM10 measurement in Switzerland indicate that the impact of aviation on fine particle concentration in the air is extremely small.

In spite of these conclusions, there remains an ongoing need for setting and further developing aircraft engine NOx standards as is currently being done through the competent international

bodies. Although aircraft have a small contribution, the general demand for air mobility triggers continuous growth of air traffic. If engine technology does not continue to improve at a smiliar growth rate, then the industry will experience a further growth of emissions as well. As these emissions occur in areas of high activities with other sources of emissions there may be areas of conflict with national air quality standards that could present bottlenecks for airport to develop their infrastructure as deemed necessary.

4 Annex

4.1 Sources and References

i www.wikipedia.org, visited 21.05.2010
ii EUROCONTROL, personal information , May 2010
iii ICAO: Airport Air Quality Guidance Manual. Document 9889, 1st edition, 2007
iv Swiss Federal Office for Environment (FOEN): www.bafu.admin.ch, last visited 18.6.2010 (NABEL data query)
v Zurich Airport, 2009: Air Quality Assessment Sensitivities - Zurich Airport Case Study, Zurich, December 2009