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Basel-Mulhouse Airport and Air Quality - part II: Immission

An analysis of the available data on recent pollution at the Basle-Mulhouse airport

By Beat Freiermuth Ph.D. (ADRA) and Jürgen Fingerle Ph.D. (BISF); June 2018

Introduction

The binational airport Basel Mulhouse is located 3.5 km northwest of the border to the city of Basel and 20 km southeast of Mulhouse. As it is fully located on French territory French aviation regulations apply, among which are the publication of emission inventories and immission measurements to control whether the airports pollution remains within legal limits. The main provider of pollution data is the organization ATMO Grand Est (see list of publications in the reference list of this publication).

While the number of passengers and the number of flights are ever increasing since 2002 it was surprising to see that in the published reports pollution values went down rather than up. This prompted us to have a closer look into the practice of pollution measurement and pollution data interpretation.

Our 2018 airport-pollution-analyses is published as a series of three independent reports covering the emissions (part I), the immissions (this part II report); and our own measurements of ultrafine particles (part III).

Our main conclusion indicates a likely underestimation of pollution at the airport. In comparison to other international airports (e.g. Zürich and Geneva) Basel-Mulhouse falls far behind their standards of pollution data handling. We therefore suggest improvements for future measurements, data evaluation and publications. Reliable emission inventories and immission measurements are essential for decision making to minimize health hazards of the exposed population. We also suggest measures to reduce pollution, like the immediate installation of electricity at the gates to allow jets to stop their auxiliary power units, as it is standard already at most large airports.

Finally we point out on ignored pollutants using the example of ultrafine particles, which are measured on other airports, but until now ignored in Basel-Mulhouse. In our third report we thus provide data from sporadic measurements of our own, compare them to those from other airports and suggest to include those in future official analyses.

Purpose of the measuring campaign performed by ATMO GrandEst in 2016

The legislation requires that the air quality near big pollution sources are investigated regularly to establish prove that immission values stay below the legal limits. The report [ATMO_Q2017] describes how the air quality at and around the airport was monitored during two periodes in 2016, from January 28th to February 25th and from June 28th to July 26th. This corresponded to twice 28 days of data (15% of a year) and is therefore considered sufficient to establish yearly immission values (European Environment Agency Directive 2008/50/CE).

Documentation of pollutants

Unfortunately key pollutants of jet engines were not measured at all:

- No measurements of **Ultra Fine Particles (UFP)** were carried out. Jet engine exhaust contains an enormous number of invisible 10-100 nm (Nanometer) sized particles. UFP´s must be regarded as especially critical for health. Humans are unable to filter these very small particles out of the inhaled air and thus they penetrate the lungs, enter the bloodstream, and even enter living cells. Even though no legal immission limits exist so far for UFP´s, other airports have been aware of this threat and initiated investigations [Keuken_2015], [Zurich_2017], [Hudda_2018], for a review see [ACNUSA_2017].
- No **sulfur dioxide** and no **ozone** data were provided, even though the report claimed that their concentration was measured. At present the concentrations of sulfur oxides and sulfuric acid are no longer a direct environmental problem in our region. As sulphur content is minimal in energy sources of cars and house-heating systems, the concentration of sulfur compounds, however, can be used as reliable tracers for jet engine exhaust. Furthermore several publications indicate that the sulfur content in kerosene correlates with the amount of particle and aerosol matter formed during combustion and hence has a

strong indirect effect both on human health and global climate [Kapadia_2015]. Kerosene supplied in Europe contains about 600-750 ppm of sulfur (Diesel ≤ 10 ppm). Planes arriving from Africa might have considerably more in their fuel, up to 3000 ppm.

Metrological data

Meteorological data used in the ATMO report were taken from a distant station at Village-Neuf. Surprisingly data available from the airport itself or data obtained directly at the position of mobile laboratories were not used. As we show, the meteorological data from the station at Village-Neuf, are NOT representative for the local air flow at the airport. Due to the channel formation between the mountain massifs in the Basel area a rather complex wind flow pattern occurs. This is nicely documented by the day time wind roses of nearby stations, see figure 1 and is well known by meteorological experts [Streicher_2011].

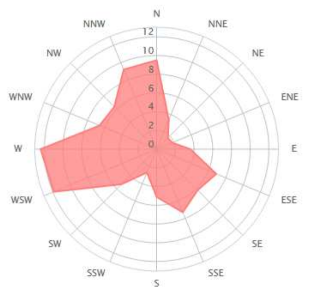
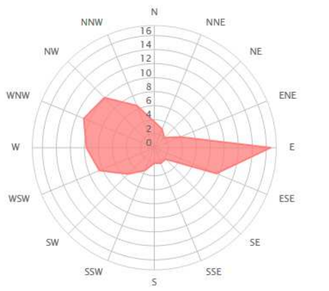
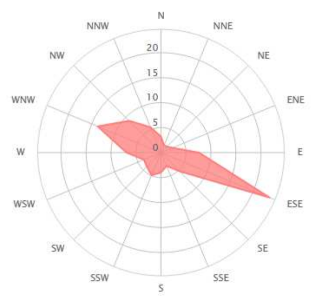
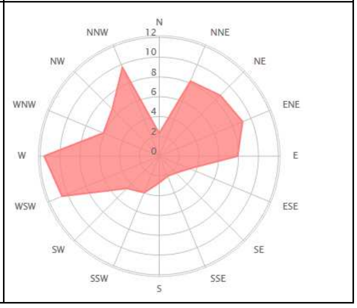
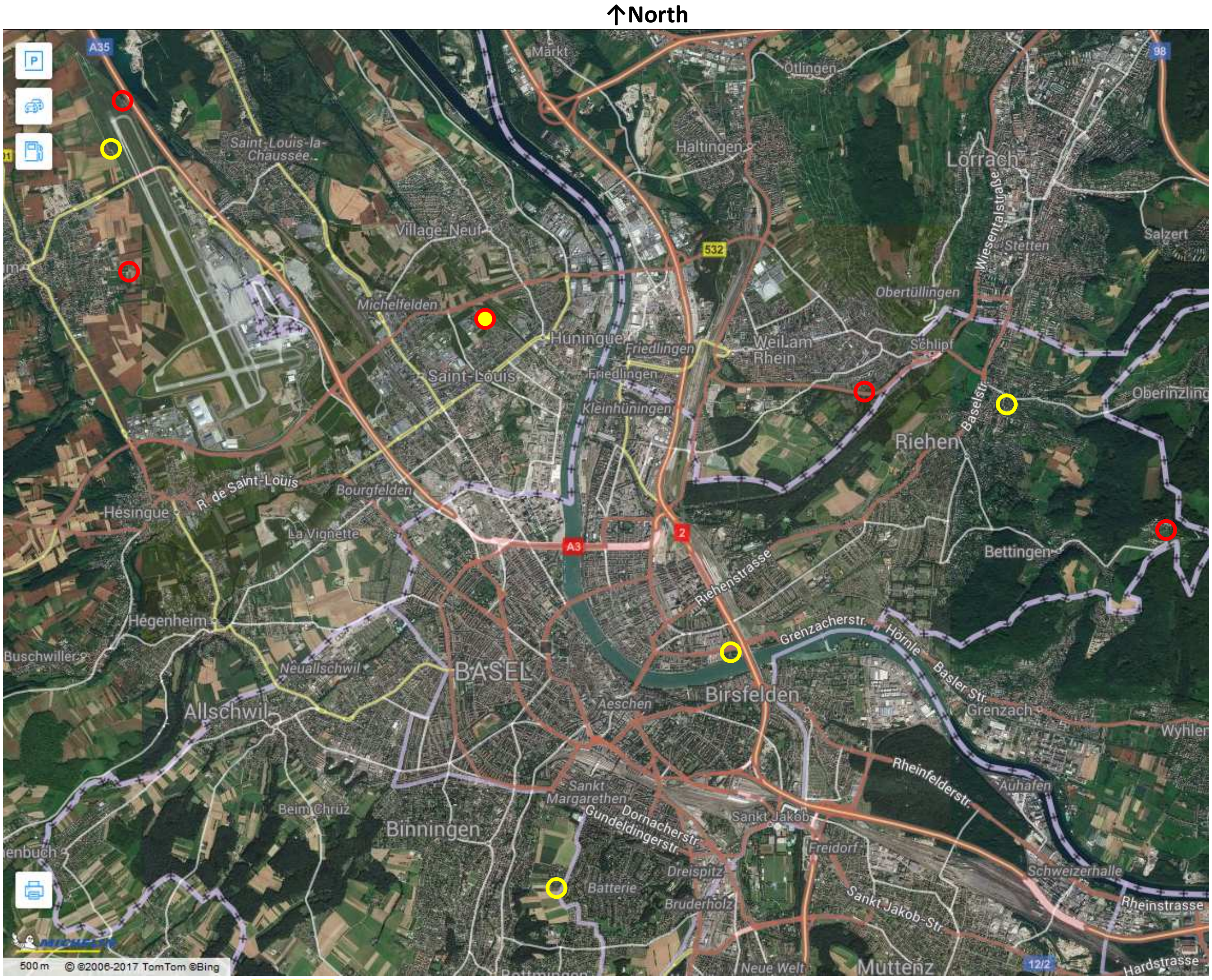
Station EuroAirport; 2 km NNW of gates; Period 2001-2018	Basel/Binningen, 8 km SSE of airport; Period 2009- 2018	Basel/Wettstein; 7 km SE of airport; Period 2013- 2018	Riehen; 9 km E of airport; Period 2013- 2018
			

Figure 1: Day time 7:00-19:00 wind roses accumulated over several years. Source https://de.windfinder.com. No long time data for Village-Neuf was available.

↑North



Map 1(viamichelin.de): Position of referenced meteo stations: EAP Meteo France, Village-Neuf, Wettstein, Riehen

Position of cited pollution measuring sites: North of runway, Blotzheim, Village-Neuf, Weil am Rhein, St.Chrischona

This extreme geographical variability leads to an essential requirement: Wind speed and wind direction must be collected at the site where the immissions are measured. If for some reason this is not possible, solutions must be found to measure as close as possible to the emission sites.

Selection of measurement sites with respect to wind directions

A mobile laboratory was placed at Blotzheim just about 1 km west of the runway and the terminal building, see map1. This location is situated ideally for two reasons, it is the place where the residential homes are closest to the runway and it is perfect to measure the upwind base pollution of the incoming fresh air from the west.

The second mobile laboratory was placed past the north end of the main runway. This location must be regarded as not ideal:

- It is situated closer to the highway A35 than to the runway
- it is furthest away from the densely populated area in the south
- It is again on the upwind side of one of the prevailing wind directions, as shown in figure 1

The ATMO air quality and meteo station Village-Neuf is located 3 km east of the terminal building and is therefore still within the airport pollution zone at least under west wind conditions. But this station is also near busy roads.

In addition to the measurements using the mobile stations, passive tubes were used to measure nitrogen dioxide in residential areas as well directly at the end of the runways. Passive tubes are mainly selective for NO_2 while their sensitivity to determine NO is very low. It needs to be considered, that jet engines, particularly at high takeoff thrust, emit NO mainly. And even in summer the local ozone concentration is not sufficiently high to oxidize NO quickly to NO_2. Furthermore no information is available that clarifies whether such “passive tubes” are able to collect NO_2 correctly in a fast flowing exhaust gas stream from a jet engine. Therefore the tubes at the end of the runways would be better suited to characterize more distant sites (e.g. additional residential zones in St. Louis), where the dominating nitrogen oxide species is NO_2.

MicroVol air samplers were used to determine the amount of PM10 and PM2.5 particles.

Unfortunately the more human health relevant PM2.5 values were only monitored at 4 locations, all on the airport ground except the calibration sampler in Mulhouse. There was no upwind and no downwind reference location. All sites showed values above 10 µg/m^3. While the WHO recommendation and the French air quality objective suggest yearly means below 10 µg/m^3, the EU allows 25 µg/m^3 as the yearly exposure limit.

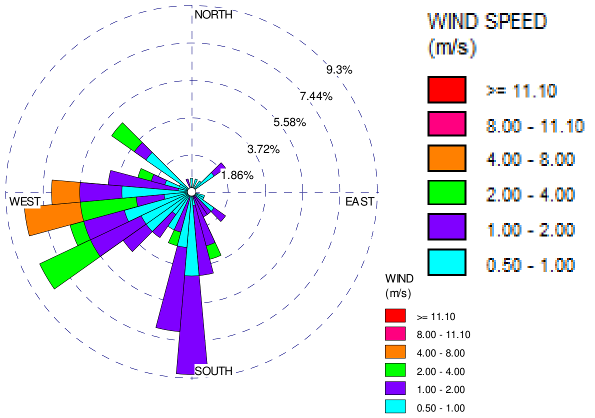
Data Evaluation, General Aspects

In the report [ATMO_Q2017; page 40] the daily distribution in hourly intervals of NO and NO2 immissions are documented for the winter period (28.01-25.02.2016) only. During winter the pollution levels are generally higher, but an in depth analysis of the summer period would have been much more revealing for a judgment on the pollution emitted by the airport for several reasons:

- The flight activity for July 2016 was 9050 movements, in February only 6506 movements
- Due to the higher air temperature on the ground, jet engine performance and buoyancy are reduced, This leads to higher specific kerosene consumption during the start and climb phase.
- The surrounding air is generally cleaner in summer than in winter because pollution due to house heating is minimal and because road diesel engines are running at their optimal temperature.
- Summer periods are associated in general with less wind, which leads to build-up of pollutants near the emission zone. As the daily wind pattern during summer are often quite stable in view of directions and repetitiveness, averaged data make much more sense and can more easily be interpreted.

Thus it is surprising that in contrast to previous immission reports, e.g. [ASPA_Q2012], the report for 2016, did no longer provide the mean values of summer and winter periods separately for all measuring sites. Instead it only showed the extrapolated yearly means. And the evolution of summer and winter data is only discussed insufficiently by comparison of averaged multi-site data. As a direct consequence it becomes impossible to understand the evolution of pollution data over time of respective winter and summer periods as they differ significantly in their meteorological conditions.

Station 68297001, EAP Meteo France	Station ATMO, Village-Neuf



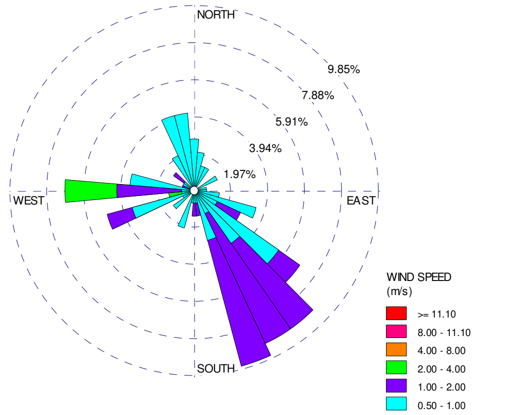
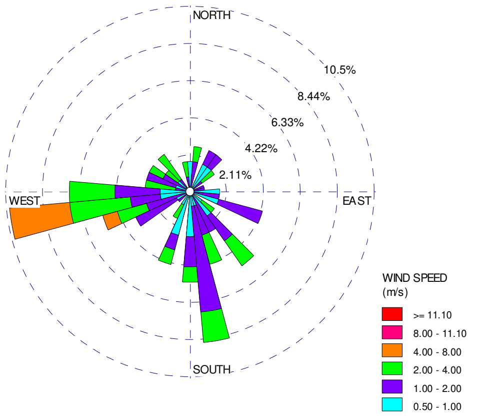


Fig. 2a: Late night period, 2-6 h local time; Calms 10.5 %

Calms 9.7 %



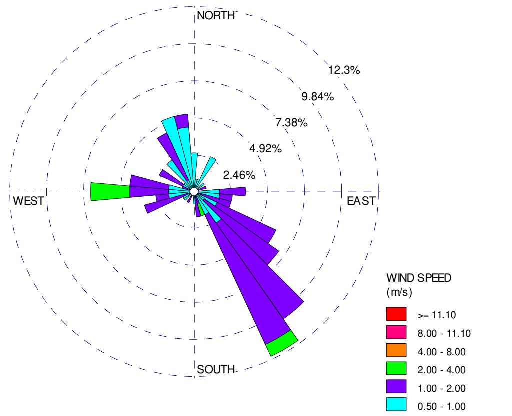
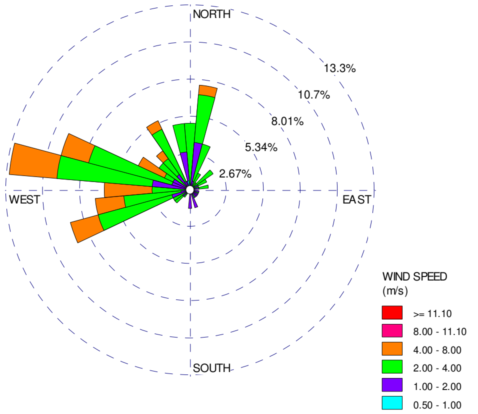


Fig. 2b:. Morning period 7-10 h, Calms 5.2 %

Calms 1.7 %



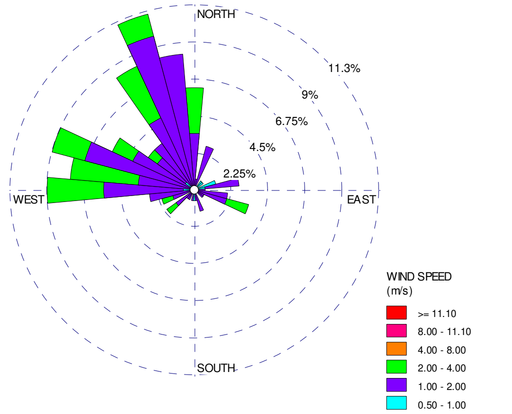
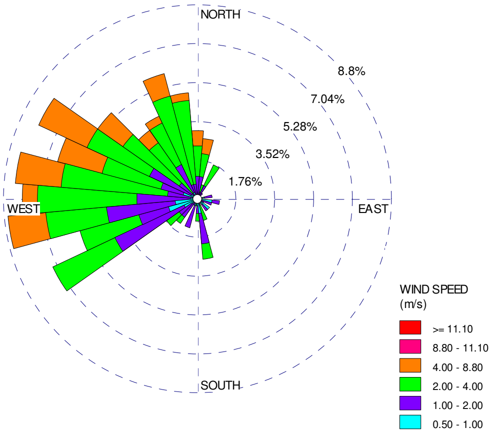


Fig. 2c; Midday period 11-15 Uhr; Calms 0.0 %

Calms 0.0 %



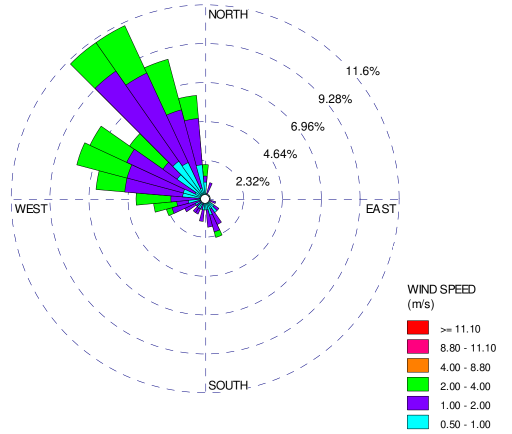


Fig. 2d; Afternoon & night period 16-01 h; Calms 1.0 %

Calms 4.5 %

Figure 2a-2d: Wind Roses for the period 28.6.2016- 26-7.2016 accumulated for different day times.
Calms with wind < 0.5 m/s are not included as colored area

New analysis based on the summer data from the ATMO report

The following part of this report does focus on our own evaluation of the nitrogen oxide data provided by ATMO GrandEst for the summer period 2016. ATMO supplied the primary raw data for the pollutants and the wind data from the Village-Neuf station. Further pollution data was received from the Landesanstalt für Umwelt Baden-Württemberg and the Lufthygieneamt beider Basel. The airport supplied the data for the flight departure times and the local wind data from the EAP Meteo France station.

ADRA/BISF Wind Flow Analysis

With proper knowledge of the true local air movements it becomes possible to understand why only at some locations, but not at others, at particular day-times pollutants can be measured.
We found, that during the summer period from June 28th to July 26th a stable weather condition was responsible that most of the time 2 characteristic local wind patterns could build up:

- A night time and early morning flow pattern with no winds or up to a light breeze often from the south or south-east
- A day and evening pattern with winds from the west to north, but rarely from the south or east.

Switch over times occur quite regularly around 2am at night and 10am in the morning, see figures 2a-d for explanation. The percentage of calms (wind less than 0.5m/s) and weak winds at night and in the morning hours are clearly lower than during the rest of the day. As expected from the special topology of the Basel area and as explanted earlier in this report, the Meteo France station at the airport shows wind roses quite different to those seen at the ATMO station at Village-Neuf.

From the daily wind pattern the following conclusions can be drawn for the summer period 2016:

- During the night and early morning hours due to the low wind speeds high pollutant concentrations are to be expected in the north of the airport rather than in the south.
- During the late morning hours the frequent wind flow from the south stops. As the wind then comes from the west or north, it transports the pollutions from the airport to Saint Louis and Basel into the upper Rhine valley and into the outskirts of the Black Forest.
- During summer day time hours, airplanes do start mostly in southerly direction followed by the so called ELBEG-turn. Thus the highest consumption of kerosene and production of its combustion pollution takes place during the climbing phase in the west and north-west of Basel at relative low altitude. Pollutants are thus unfortunately just produced at the prevailing upwind side of the center of the trinational agglomeration.
- As expected the wind speeds at the airport, which is mostly open country, are considerably higher than at the station ATMO in Village-Neuf, which is located in a built up area and is located at lower altitude.

ADRA/BISF Analysis of the daily variations of nitrogen oxide concentrations in Summer 2016

The nitrogen monoxide and dioxide values over the entire measurement period in summer 2016 were available to us as means collected for 15 min for the French sites and for 1 hour intervals for German and Swiss sites. A summary of the accumulated intervals for the entire measurement period in summer 2016 is plotted in figure 3a and 3b. Please consult map 1 for the location of the airport near measurement sites. As indicated on the right y-axis of the plots, only the takeoffs at the airport are listed as number of departures per 15 min. We focused on departing airplanes to correlate NOx immission with airport activity. During takeoff and climb the engines are at 80-100% of thrust and emit much more pollutants as compared to landings (30% thrust).

After 6am a steep rise in NO and NO_2 is observed at the north end of the runway 33. It normally takes an aircraft 10 to 20 minutes from the moment it leaves the gate (official departure time) till the "Takeoff clearance". Therefore the pollution rise must occur slightly shifted on the time axis and this is exactly what is observed. With the knowledge of the wind directions from figures 2a-d, it becomes clear, why only in the morning hours very high peaks both for NO and NO_2 are observed at this location. Later during the day (fig 2c and d) when the wind changes directions, the westerly to northerly winds clear away the pollution. The pollution levels only grow again at the end of the day, when the wind speed slows down.

A further explanation for the nitrogen monoxide accumulation with high values just in the morning and at night is the low ozone concentration. In the absence of ultra-violet rich sunlight ozone production and thus conversion from NO to NO_2 is low.

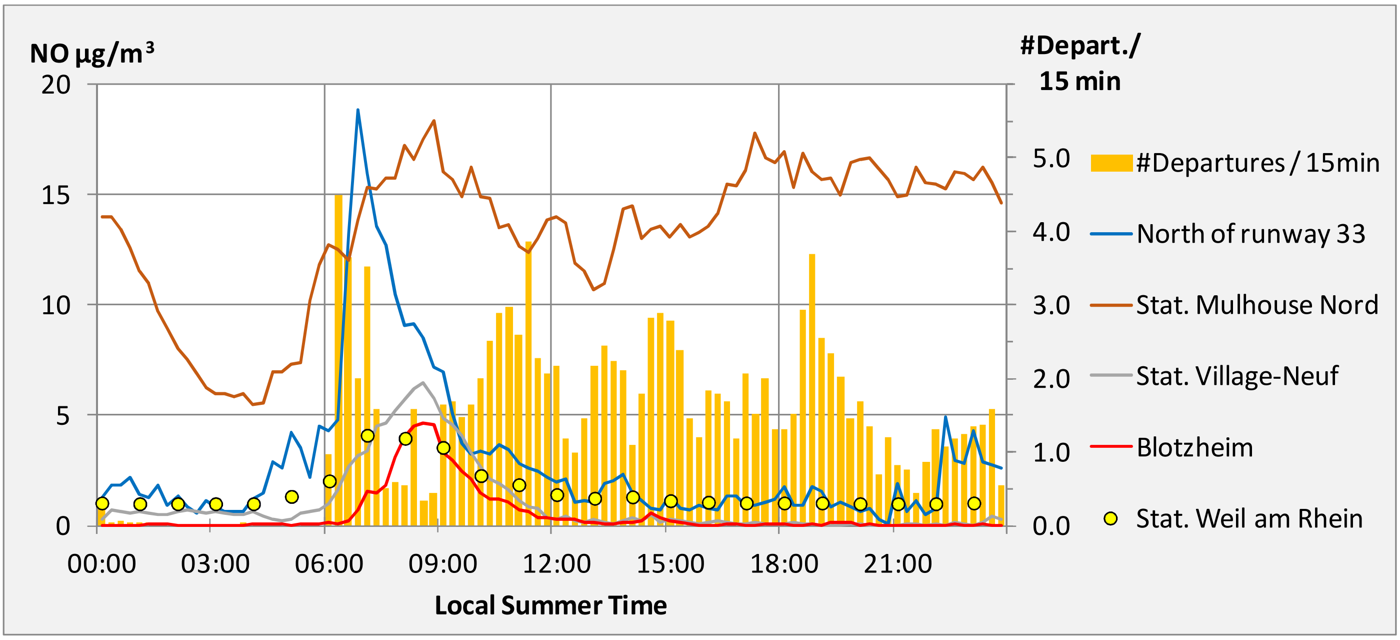


Fig. 3a: 28.June-26.July, mean daily NO concentration and flight departures

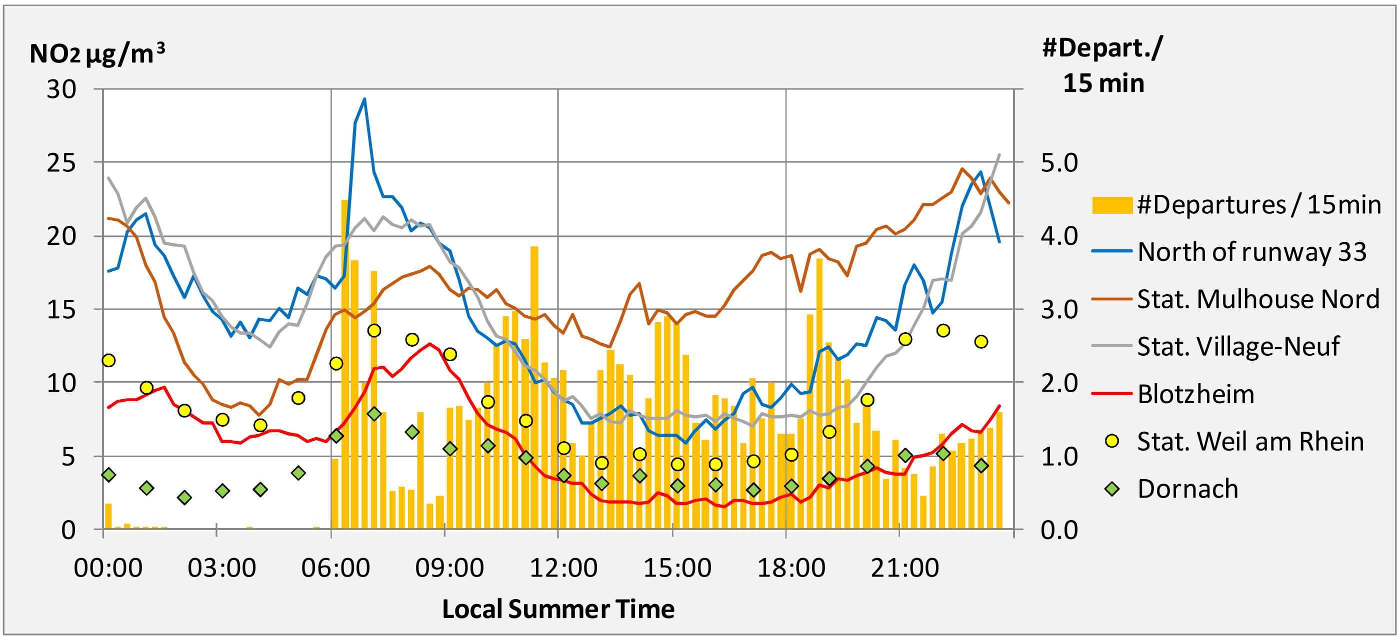


Fig. 3b: 28.June-26.July, mean daily NO_2 concentration and flight departures

At first glance the pollution curve for the other two locations near the airport, Blotzheim and Village-Neuf, with peak maximums between 7 and 9 hours could be induced by pollution from road traffic. A correlation with flight activity seems to be absent. For the evening hours however there is a distinct difference with the sites where pollution is dominated by road traffic, e.g. Mulhouse North, Dornach or Weil am Rhein. At these locations, distant from the airport, the NO_2 concentration only shows a moderate increase between 6pm and midnight or even levels off before midnight. In contrast at the airport near sites, from 6pm onwards, the pollution values continuously rise until midnight and only drop significantly after 1am. This does correlate very well with the last flight departure waves between 6pm and midnight and is enhanced by the gradually slowdown of wind activity.

Figure 4 represents a plot based on non-averaged NO_2 data obtained for several sites for the period from June 28th to July 10th.

Figure 4 is able to further explain the rather continuously changing NO_2 exposure shown in figure 3b:

- High concentrations of NO_2 are only present for some hours per day at Blotzheim but peak values are much higher compared to Dornach. As noticed above high values often occur just after midnight, when at other stations already a reduced level is observed
- Pollution peaks at Blotzheim occur not every day at the same hour, but depend very much on the actual wind situation. High concentrations are observed with winds from the east or south and if wind speed is low.
- Under conditions of west wind exposure, the values of NO_2 drop to very low levels (0-3 µg/m^3). The site of Weil am Rhein and to smaller extent Dornach show a clearly higher base level.

If the data from ATMO are shown as in figure 4, it becomes evident that Blotzheim is a site, heavily impacted by the airport activity. Especially if the wind arrives from the east or south-east Blotzheim is suffering from airport pollution. Without the nearby airport the average pollution level in Blotzheim would certainly be lower as compared to e.g. Dornach, a densely populated semi-urban location 9 km south of Basel.

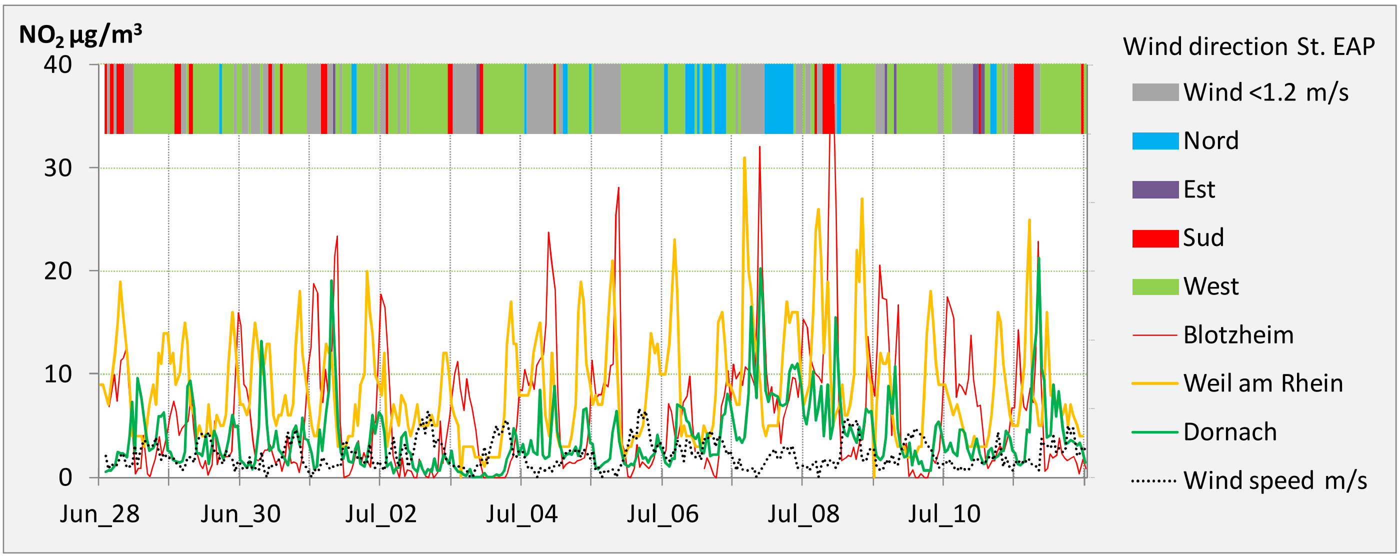


Fig. 4: NO_2 concentration (hourly aggregated values) and wind directions EAP Meteo France during June 28th till July 14th

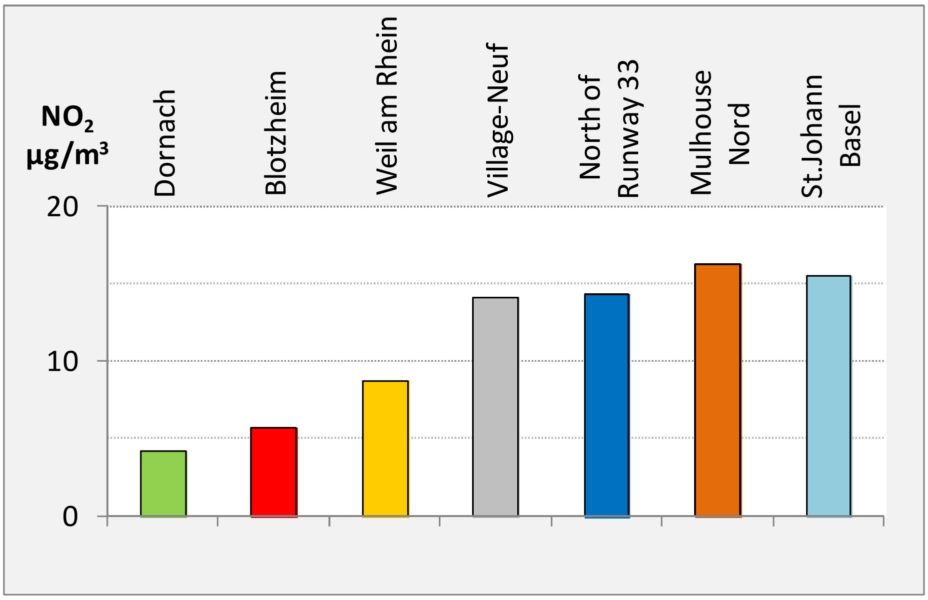


Fig. 5: Average NO_2 concentration from June 28th till July 26th

As can be seen in figure 5 the average NO_2 concentrations at the north of runway 33 and Village-Neuf displayed a similar level as seen at the station Mulhouse North or in downtown Basel St. Johann during the summer period 2016. Unfortunately without any data for sulfur dioxide or ultrafine particles, (UFP) it cannot be estimated to what extent this high values were due to the airport or the nearby busy roads. The wind flow analysis shows that Village-Neuf and certainly also Saint Louis often receive the inflow of contaminated air from downtown Basel mainly at night time and in the morning.

Conclusions from our data evaluation and considerations of the local meteorological situation

One of the conclusions of the report [ATMO_Q2017] was:
"Les niveaux de pollution enregistrés par les deux camions laboratoires présentent les caractéristiques d'un site de fond, distant avec les sources d'émissions polluantes, à Blotzheim tout comme en bout de piste en seuil 15 (LM Unimog)".
This is simply wrong, as we can show that a daily averaging of the pollution values leads to false interpretations of permanently low exposure. As soon as the data are analyzed on the basis of hourly or better 15 min resolutions plus if the wind conditions are factored in, the signature of the pollution caused by the airport activity becomes obvious. The enormous spikes in NO_2 concentration, occurring just for some hours, rise up to more than 10 fold over the low background level. This pattern strongly suggests that a nearby pollution source must be present.
For the site of Blotzheim this means that prolonged high pollution levels must be feared if persistent slow east to south-east winds occur.

Beyond this main finding, we had to discover that further important findings are missing in the conclusion section of report [ATMO_Q2017].

- If the conclusions of the ATMO report were correct, which they are unfortunately not, it remains unclear, why the report did not propose alternative locations for their mobile laboratories – e.g. moving them to one of the main downwind location for future measuring campaigns, or to look for a pair wise comparison of parallel up- and downwind measurements. From literature e.g. [Hudda_2014] it is known that at downwind locations the characteristic pollution can be detected still in several km distance from the airport.
- Ozone reaches often a critical level only at a certain distance from the pollution sources. Ozone is a photochemical secondary pollutant and is not emitted directly by the airport. But the airport is next to road traffic a main source of precursor substances for ozone, NO_x and volatile organic compounds. According to the report ozone was measured, but no data and no discussion of its values is presented anywhere in the report.

  A look at the data of nearby stations where ozone is measured would have indicated to ATMO that during the summer period multiple surpasses of the limits and air quality levels occurred:

  - At the station Sankt Chrischona the Swiss hourly limit of 120 $\mu g/m^3$ (1 hour mean) was surpassed during 10 days.
  - At the station Weil am Rhein in July 2016 the German air quality target value of 120 ug/m^3 (8 hour moving average) was surpassed during 6 days in July 2016.

  Both stations are in the east of the airport and are therefore downwind for the dominating day time wind flow pattern.

It is our main conclusion that the pollution data from the Basel-Mulhouse airport are suffering from several deficits on several levels of analysis. This includes the location of the measurement stations, the limited measurement of specific species of pollutants, the superficial analysis, and the lack of comparability over time.

We urge the airport, their contractors and the supervising authorities to consider these issues and install improvements.

References

The ASPA and ATMO reports can be downloaded from:
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Data Sources

ATMO GrandEst Raw Data for pollutants, and wind; WK-ADM-COE-17-1177 and WK-ADM-COE-18-0257

EuroAirport RELEVES HORAIRES DE LA DIRECTION ET DE LA FORCE DU VENT MOYEN A BALE-MULHOUSE; Station Meteo de France Nr. 68297001

Flight arrival and departure times for the period 28.6.2016- 26.7.2016

Further Data https://udo.lubw.baden-wuerttemberg.de/public/pages/selector/index.xhtml

https://luftqualitaet.ch/messdaten, and Lufthygieneamt beider Basel

https://de.windfinder.com/

Special Software

For wind roses: WRPLOT View , https://www.weblakes.com