Effects of COVID-19-related air traffic restrictions on local air quality at Zurich airport

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EMANUEL FLEUTI
Head of Environment, Flughafen Zürich AG, Switzerland

Emanuel Fleuti has been working with Zurich Airport since 1990, heading the Environmental Department. He is responsible for all environmental topics excluding aircraft noise, but is specialised particularly in environmental management, airport air quality and climate change. Zurich airport has held an ISO 14000 certificate for its Environmental Management System since 2001, the Airport Carbon Accreditation Level 3 since 2010 and the Environmental Department also holds an ISO 9001 certificate for Quality Management. Emanuel has participated in numerous international programmes like the Intergovernmental Panel on Climate Change Special Report on Aviation and Global Atmosphere (1999), European Research Programmes (Forum-AE, AVIATOR) and The International Civil Aviation Organization's The Committee on Aviation Environmental Protection process (since 1995). He also represents the airport in the ADV (German Airports Association), and has chaired the environmental committees of Airports Council International (ACI) EUROPE and ACI World while still being an active member. He currently chairs the ACI EUROPE Airport Carbon Accreditation Task Force. Emanuel holds an master of sciences' degree from the University of Berne in physical geography.

P.O. Box, CH-8058 Zurich-Airport, Switzerland
Tel.: +41 43 816 21 81; E-mail: emanuel.fleuti@zurich-airport.com

Abstract

This paper discusses how the efforts of authorities to limit the spread of COVID-19 have led to restrictions in people's mobility with significant impacts on air traffic operations worldwide. Zurich airport has experienced a drop of 91 per cent in aircraft movements from February to April 2020. The decrease in activity has led to a decrease in local emissions of 83 per cent for NOx, while NO_2 concentrations at and around the airport decreased by only 50 per cent. Ultrafine particle numbers show similar values. The analysis further took into account the change in regional road traffic and the meteorology for comparable periods in 2019 and 2020, before and during the crisis.

Keywords

air traffic, airport, local air quality, emissions, impacts, COVID-19

INTRODUCTION AND PROBLEM STATEMENT

The outbreak of COVID-19 and its development into a global pandemic have had unprecedented consequences on people's mobility. While road traffic has declined due to national lockdowns, air traffic has come to an almost complete standstill due to the closure of borders. This development has affected not only personal lives and national economies, but has also had effects on the natural environment. Less activity has led to less environmental impacts.

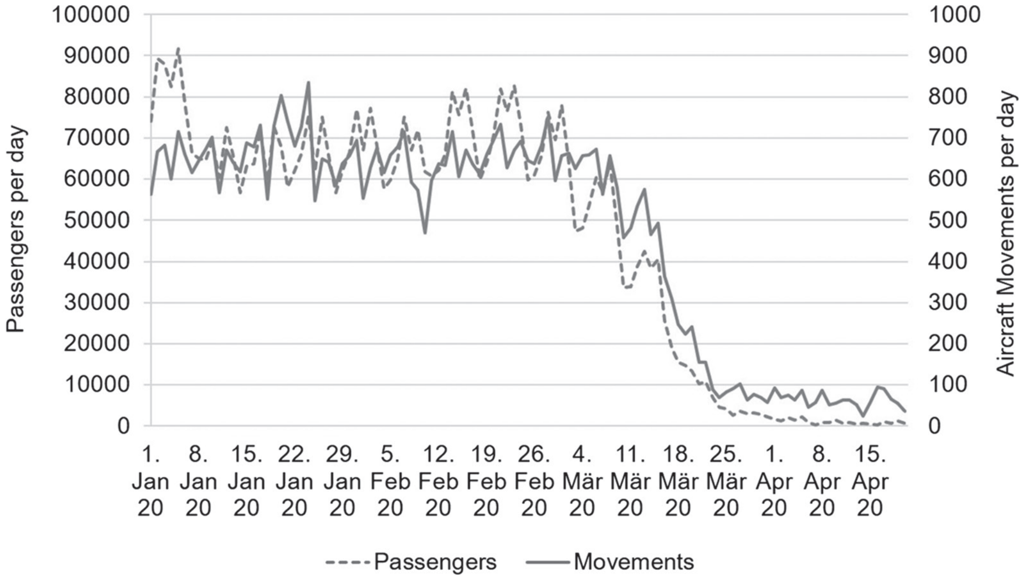

Figure 1 Aircraft movements and passenger numbers — Zurich airport in 2020

The decline in traffic and industrial activities has led to a decrease in emissions and thus ambient concentrations of pollutants. This study analyses the effects that the drop in air traffic, in combination with the reduction in nearby road traffic, have had on emissions and subsequently on the measured ambient concentrations for a comparable period before COVID-19 and during the crisis. Of particular interest to examine was to what degree traffic development, emissions and concentrations cohere for selected critical air pollutants and what role air traffic-related emissions play in the local air quality.

Traffic and emissions were analysed for the period from 1st to 7th April, 2019, for regular operation and from 1st–7th April, 2020, during the crisis, while the concentrations analyses spanned over a longer period from 18th March to 18th April in 2019 and 2020, respectively.

TRAFFIC DEVELOPMENT

Like many airports worldwide, Zurich has seen a significant drop in aircraft movements and passenger numbers in March 2020, when travel restrictions and national lockdown became effective (Figure 1). Aircraft movements decreased by 91 per cent over only two weeks, leaving minimum traffic of a few scheduled flights, repatriation services, cargo flights, business aviation and air ambulance services.

Not only air traffic operations decreased, but also road traffic slowed down. The imposed stay-home orders have led to an immediate decline in commuter and leisure traffic, and only essential traffic remained. As all activities contributing to emissions have to be analysed, several road traffic-monitoring stations in the vicinity of the airport were evaluated.[1] They showed an overall decrease of 39.3 per cent of traffic between 2019 and 2020, but with some regional disparities as shown in Figure 2. Given the imposed restrictions, the decrease in traffic was different among vehicle categories: personal car traffic decreased the most by 40.5 per cent, light duty vehicles ranked second with

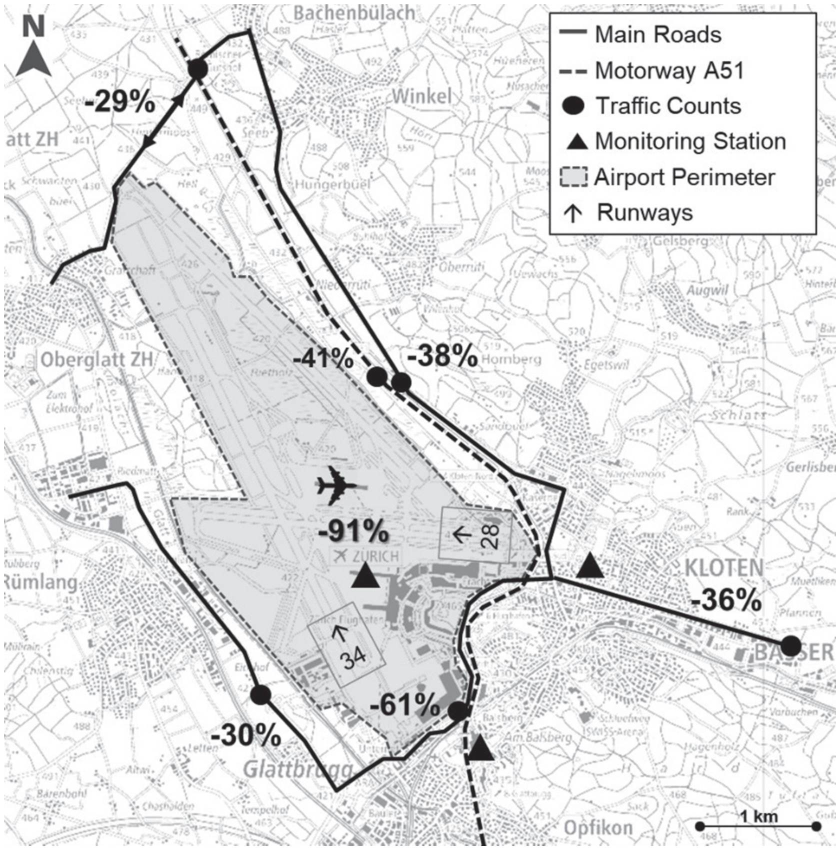

Figure 2 Traffic decrease at and around Zurich airport

35.0 per cent less traffic and heavy duty vehicles only decreased by 16.6 per cent.

CHANGE IN EMISSIONS

The emission amounts for several standard air criteria pollutants have been calculated for the observed periods in 2019 and 2020, considering the emission source groups air traffic, with emissions up to 300m above ground, other airport sources like APUs (auxiliary power units), infrastructure, maintenance and parking and finally the road traffic on the regional road system. Due to lack of data and information, additional sources like regional industry or residential could not be considered. Figure 3 shows the decrease of the pollutants such as nitrogen oxides (NOx: −83 per cent), particulate matter 10 μm (PM10: −80 per cent) and non-volatile particle numbers (nvPN: −93 per cent).

In more detail, air traffic NOx emissions dropped by 91 per cent and particle mass and number by 94 per cent compared to a traffic decline of 91 per cent. As road traffic decreased by 40 per cent, its NOx emissions dropped by 37 per cent and the particle mass and number by 35 and 34 per cent, respectively. There is a good linear correlation between traffic and emissions for both sources.

REGIONAL AIR QUALITY CONCENTRATIONS

The local air quality at and around Zurich airport is monitored using

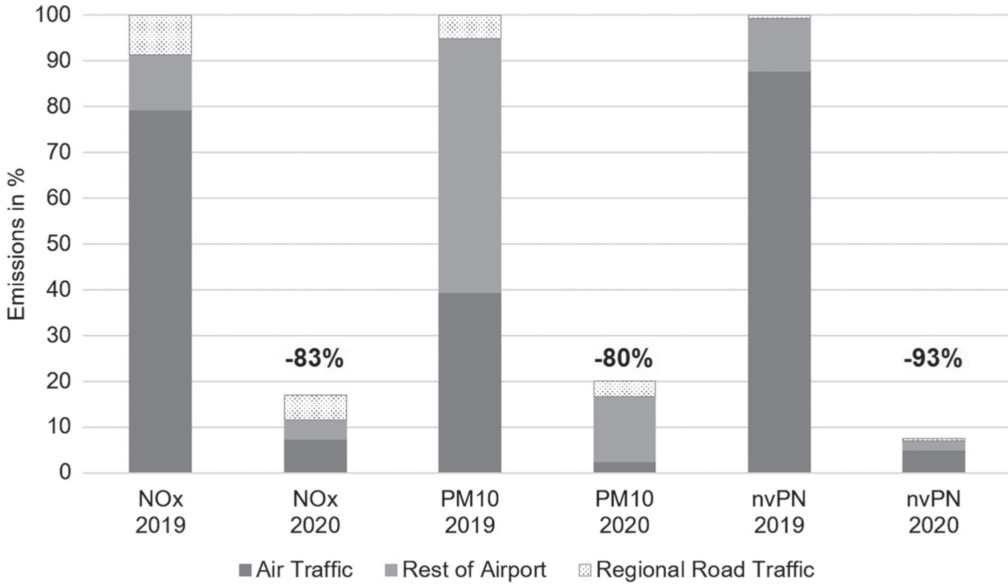

Figure 3 Changes in the emissions from airport and road traffic

various stations. Zurich airport operates its own monitoring station, located on the roof of Pier A at the centre of the airport (Figure 2). It is equipped with an NOx/NO_2-analyser (Horiba APNA-370) an ozone-analyser (Horiba APOA-370), a particle matter analyser (Fidas 200 in the range 0.18–18 μm) and an ultrafine particle system (Envi-SMPS 2100X in the range 7–1200 nm with an added catalytic stripper). The monitoring is supported by a weather station. The system runs automatically, and monitoring data is available for both periods in 2019 and 2020. Two neighbouring stations are operated by Ostluft,[2] the cross-cantonal authority for air quality in eastern Switzerland. Both stations that are considered in this analysis monitored NO_2 and PM10. They are located close enough to the airport to be potentially impacted by emissions sourcing from the airport with station Opfikon being 2.2 km distant and station Kloten-Gerlisberg 2.1 km from the airport station (Figure 2).

When analysing and eventually comparing data from various stations and time periods, there are two significant challenges that must be addressed:

1. Comparable meteorological situations: Experience from previous measurement campaigns at Zurich airport has shown that the meteorological conditions often have a higher impact on the results than the actual emissions. This is mostly due to wind velocity and direction, but also due to precipitation or atmospheric turbulence. As such, this analysis takes into consideration not only specific periods of calm wind ($\leq$ 2 m/s) but also periods with prevailing wind directions like North-Easterly wind (0°–90°) and West wind (240°–300°).
2. Contributing emission sources: At any monitoring station, a blend of emissions from all sources in the vicinity is captured. Often, there is a dominant source like a road or an industrial plant close to the station. In this regard, the

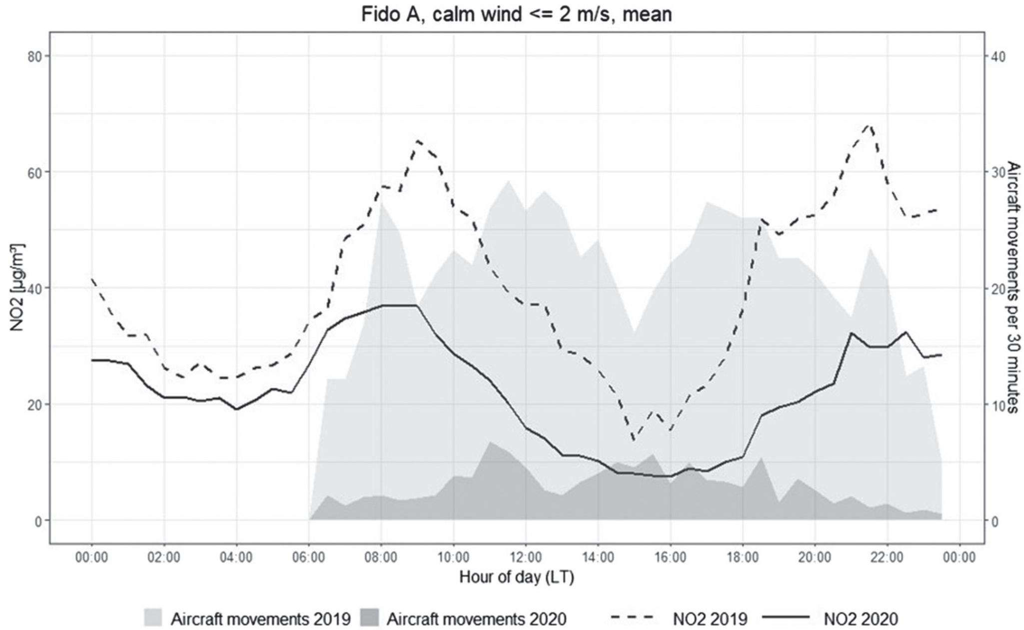

Figure 4 Diurnal variations in mean NO_2 in 2019 and 2020 at the airport station

location of the station has to be analysed for close and dominant emission sources and their development of activities.

DECREASE IN NITROGEN DIOXIDE (NO_2) CONCENTRATIONS

The main criteria substance is still nitrogen dioxide (NO_2), regulated through national ambient air quality standards where the Swiss national standard is 30 µg/m^3 annual mean value (contrary to the EU [European Union] standard of 40 µg/m^3). The analysis covered daily mean concentrations during calm wind conditions at all three stations. The airport station showed NO_2 average day levels decreasing by 18.7 µg/m^3 from 42.1 µg/m^3 to 23.4 µg/m^3 (−44 per cent) compared to the drop in traffic by 91 per cent. This station is mainly dominated by activities at the airport, primarily aircraft operations.

Figure 4 shows the diurnal NO_2 analysis at the airport, again for calm wind conditions. While for 2019, a certain correlation between aircraft movements and NO_2 concentrations seems visible, this pattern is missing for 2020. Despite the significant decrease of traffic and other associated airport activities particularly in the morning and the evenings, there is still a distinct morning peak from 06:30–09:00 and an evening peak from 20:30–23:00 that do not correlate with the actual aircraft traffic.

Apparently, emissions from the surrounding road traffic and other sources — primarily residential — seem to still markedly influence the measured concentrations at the airport itself, and aviation activities seem to have only a limited impact. The key question would then be if it is possible to detect some airport contribution at the nearby monitoring stations. If air traffic were to have a significant impact on the regional concentrations of emissions, then the

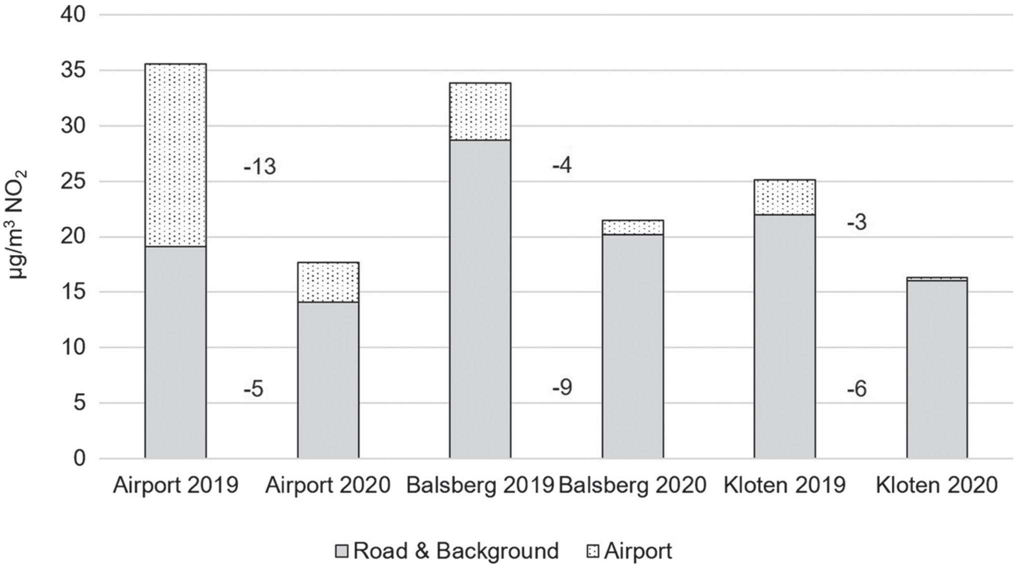

Figure 5 NO_2 concentration changes at the airport and in the region

concentration values would now have decreased far more than suggested by the decrease in road traffic alone. To evaluate this, the two neighbouring stations in Opfikon (Balsberg) and Kloten (Gerlisberstrasse) are analysed (Figure 2).

The station Opfikon is located directly alongside Motorway A51, a high-frequency access motorway to the airport and to the north of the canton. Consequently, road traffic is the dominating source for the emission concentrations. Contribution from the airport is potentially limited to the approaches to Runway 34 early in the morning from 06:00–07:00 and at a distance of 1.3 km. Other activities at the airport in general are also contributors. The concentration values for NO_2 dropped from 37.4 μg/m^3 in 2019 to 24.3 μg/m^3 in 2020. This is a reduction by 13.2 μg/m^3 or 35 per cent. As the traffic drop right beside the station was 41 per cent from 41,000 vehicles per day to 25,000 vehicles per day, it can be assumed that the decrease in emission concentrations is mainly due to the change in road traffic activity.

The station Kloten-Gerlisbergstrasse is further away from the main road to Bassersdorf (150 m) and closer to the approach path runway 28 (960 m distance to touchdown). This runway takes up all landings after 9 pm, while serving as the main take-off runway for all short-haul flights during the day. The general NO_2 concentration stood at 31.8 μg/m^3 in 2019, dropping to 22.2 μg/m^3 in 2020. This reduction of 9.6 μg/m^3 equals 30 per cent. The NO_2 levels here are generally at a lower level than in Opfikon, given the road traffic with 20,000 vehicles per day in 2019, decreasing to 13,000 vehicles per day in 2020 (–36 per cent). In this case, the emission concentrations decrease is slightly higher than the traffic decrease.

A source apportionment has been done with the air quality dispersion model, LASPORT, including all meteorological conditions and not only calm winds (Figure 5). At the airport, concentrations from the airport sources decreased by 13 μg/m^3, but only by 3 and 4 μg/m^3 at the other stations. For road traffic,

Table 1 PM mean concentrations for various wind conditions

Wind Condition	*2019 (µg/m³)*	*2020 (µg/m³)*	*Difference (µg/m³)*	*Percentage*
Calm (≤2 m/s)	19.3	23.4	+4.1	+21%
East ('Bise', >2 m/s, 0°–90°)	20.2	14.8	−5.4	−27%
West (>2 m/s, 240°–300°)	10.9	17.4	+6.5	+60%

concentrations dropped by 5 µg/m³ at the airport, but by 6 and 9 µg/m³ in the region. As such, the reduction in road traffic has had a more significant impact on the NO_2 concentrations than the reduction in air traffic.

The relatively low levels of NO_2 contribution from aviation to the closer vicinity of the airport is also due to the fact that only emissions up to approximately 300 m directly contribute to the ground level concentrations. This altitude is quickly reached by departing aircraft and is often still within the airport property.

The analysis also shows the effect of meteorological conditions. During 'no wind' situations, the concentrations at the airport were found to be at 42.1 µg/m³ in 2019. Considering all meteorological conditions (predominantly West wind), the concentrations were only at 35.6 µg/m³ during the same time period, demonstrating the dilution effect.

SURPRISES ON PARTICULATE MATTER

Particulate matter is another pollutant regulated by Swiss clean air legislation. Annual mean limits are at 10 µg/m³ for PM2.5 and 20 µg/m³ for PM10. The analysis of the situations in 2019 and 2020 covered PM10 at the airport station only, as there was only limited information available from the other two stations used for comparisons. The measurements at the airport were performed using a Fidas 200 monitoring device in the range of 0.18–18 µm.

Again focusing on calm wind situations, the comparison from 2019 with full air traffic and 2020 with almost no air traffic showed an unexpected increase in concentrations from 19.3 µg/m³ to 23.4 µg/m³ or 21 per cent (Table 1). Further analysis was deemed necessary and as the next step, other prevailing wind situations were analysed. At wind situations from the East (the Swiss 'Bise'), the concentrations indeed showed a decrease as would be expected from the decreased activities. Values dropped from 20.2 µg/m³ to 14.8 µg/m³ or −27 per cent. When looking at the wind from the West, however, an even higher increase in concentrations can be observed (Table 1) where values spiked from 10.9 µg/m³ to 17.4 µg/m³ or +60 per cent.

Apparently, the changes bear no causality with air traffic activities and as such, different emission sources trigger the increase. A phenomenon, often observed in Southwestern and Central Europe, is the effect of the so-called 'Sahara Dust'. In this situation, wind is picking up dust over Morocco and Algeria and transports it towards the Alps. Such a specific situation occurred on 18th April, 2020 (Figure 6).

The effect of that and several other events is displayed in Figure 7, which shows the period from mid-March to approximately mid-April for both 2019 and 2020, at the Swiss Alpine Monitoring Station, Jungfraujoch. The

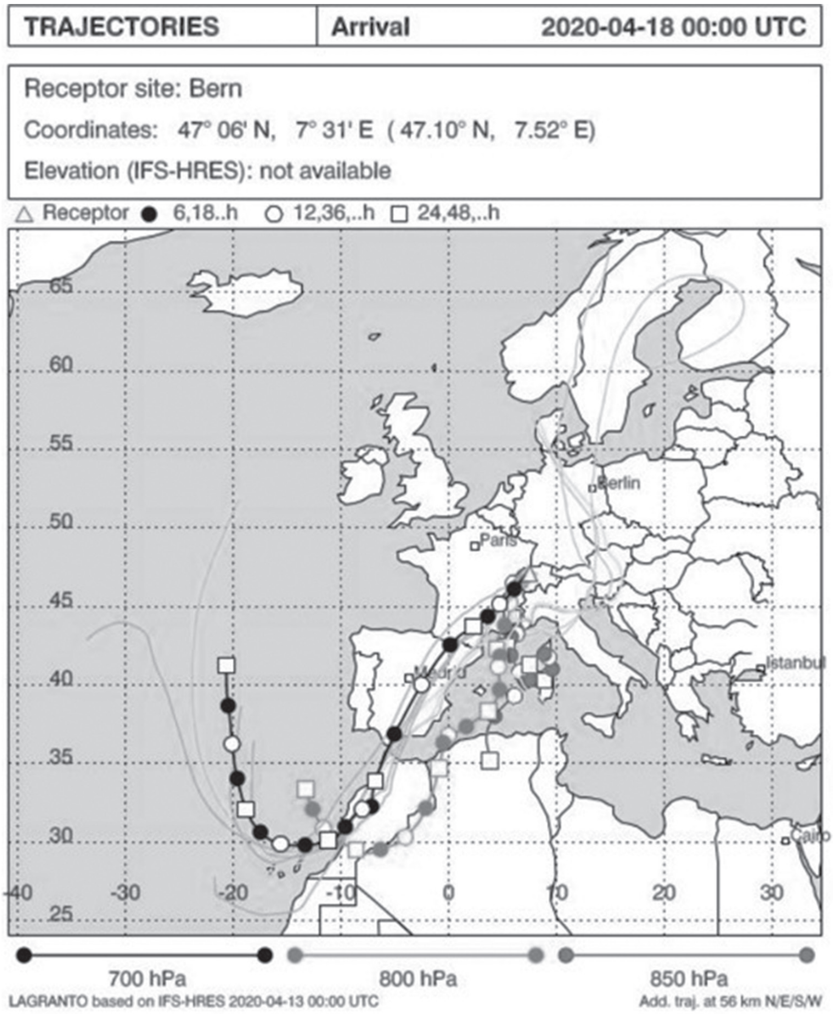

Figure 6 Wind trajectories, 18th April, 2020[3]

high elevation of 3,466 m above sea level provides undisturbed ambient atmospheric measurement results. Spring 2020 has been a very active Sahara dust season in this respect, and several high peaks could be observed on 17th , 21st, 29th March and 13th and 18th April. Daily PM10 concentrations were >5 µg/m³ (with peaks up to 15 µg/m³), whereas the background is usually <1 µg/m³.

In conclusion, evaluation of the COVID-19-related effects on the particulate matter concentrations is not possible.

DECREASE OF ULTRAFINE PARTICLES

Ultrafine particles (UFPs) from aviation have gained a lot of attention over the past few years, as aircraft engines tend to emit high numbers of particles that are ultrafine (<100 nm).[5] While UFPs are not regulated in terms of ambient concentrations, they are frequently measured at airports in order to provide better understanding of their dynamics and relevance. Zurich airport operates an UFP-monitoring station (Figure 2) that includes an SMPS (scanning mobility particle sizer) in the range of

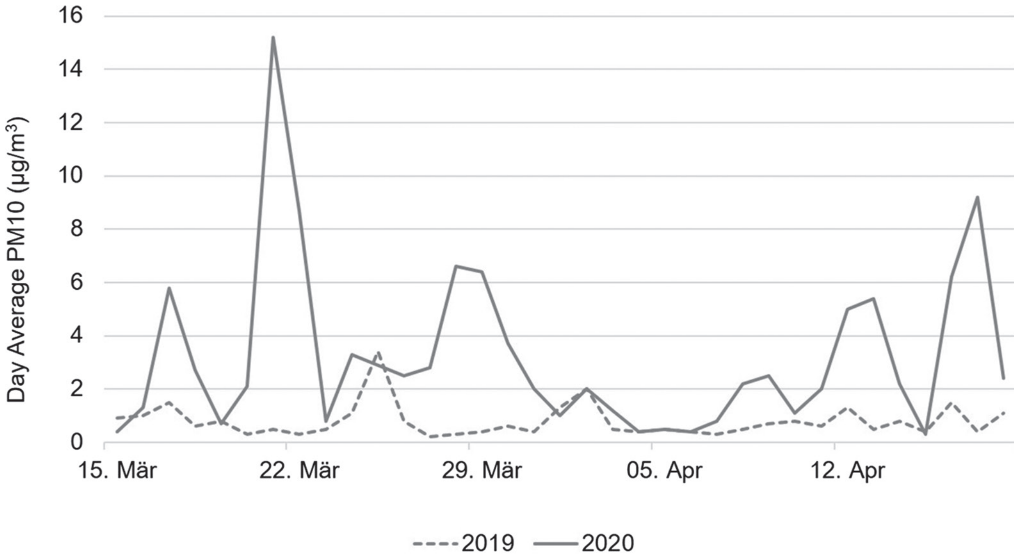

Figure 7 PM10 concentrations at Jungfraujoch station, 2019 and 2020[4]

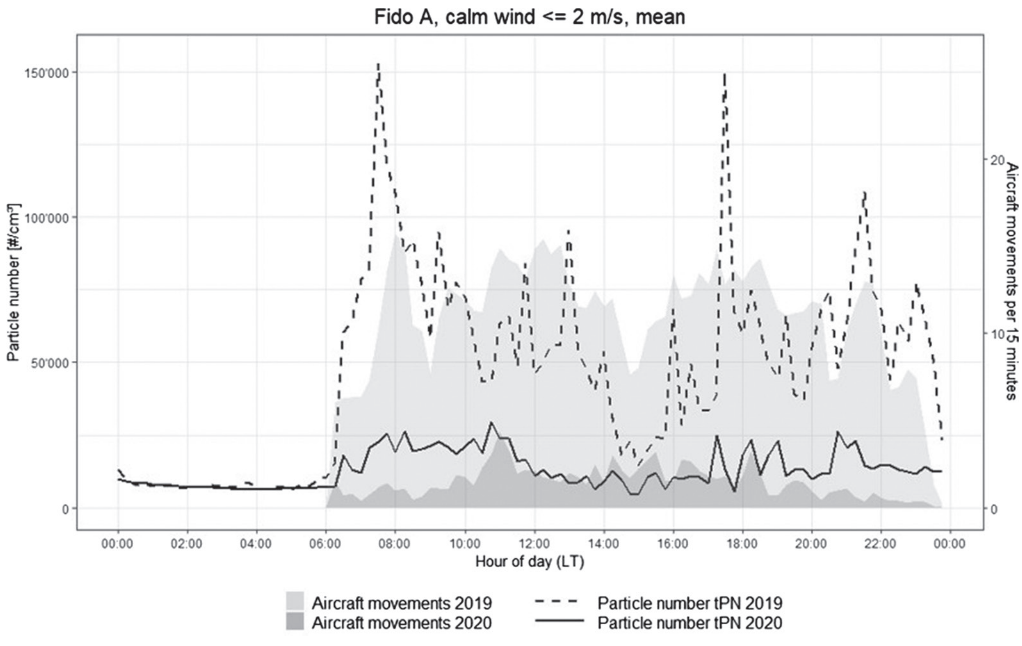

Figure 8 Diurnal variation of particle numbers at Zurich airport, 2019 and 2020

7–470 nm with an upfront catalytic stripper that heats the sample to 350°C and thus removes any volatile particles. In combination with an automatic switch, it is possible to measure size-classified total and nonvolatile specified particles approximately every 3 minutes.

The diurnal variation of UFP compared to the aircraft activity is displayed in Figure 8 (PN — particle number). While not only air traffic activities decreased, also the UFP concentrations were much lower in 2020, during the hours of activity. The 2019 and 2020 data are similar between midnight and

Table 2 Total and nonvolatile particle numbers and diameters for various time periods, 2019 and 2020

Calm Wind (≤2m/s)		2019	2020	Difference	
Mean particle number during all hours (7–470 nm)					
nvPN and vPN	#/cm³	41,141	12,725	−28,417	−69%
nvPN	#/cm³	10,747	5,982	−4,765	−44%
Share of volatile particles	%	74%	53%		
Mean 07:00–21:00					
nvPN and vPN	#/cm³	59,518	16,014	−43,504	−73%
nvPN	#/cm³	14,069	6,521	−7,548	−54%
Share of volatile particles	%	76%	59%		
Mean 00:00–05:00					
nvPN and vPN	#/cm³	7,023	7,283	260	4%
nvPN	#/cm³	4,011	5,055	1,044	26%
Share of volatile particles	%	43%	31%		
Mean particle diameter during all hours (7 to 470 nm)					
nvPN and vPN	nm	29	48	19	
nvPN	nm	35	43	8	
Mean diameter 07:00–21:00					
nvPN and vPN	nm	27	40	13	
nvPN	nm	32	40	8	
Mean diameter 00:00–05:00					
nvPN and vPN	nm	70	74	4	
nvPN	nm	55	49	−6	

Note: nvPN , nonvolatile particle numbers; vPN, volatile particle numbers

early morning, showing a minimum background scatter, while the period between 06:00 and 24:00 is significantly different both in variability and in absolute number of particles. The 2019 data indicates some qualitative correlation with the aircraft activity (number of movements per 15-minutes interval). The 2020 data, however, already shows high concentrations with very little aircraft activity between 06:00 and 10:00 and between 21:00 and 24:00. This again indicates that the typical road traffic rush hours — despite the decrease in those activities — may have some significant contribution to the particle concentrations even at the airport.

The differentiation between volatile and nonvolatile particles from aviation is of special interest as both types of particles have different properties that may be relevant to potential health impacts. In Table 2, the total and nonvolatile UFP size and number analysis are displayed for conditions of calm wind, both in 2019 and 2020, and for different time periods that cover daytime with activities and the nighttime without activities.

The measurement results in Table 2 show a decrease in total particle numbers from 2019 to 2020 of 69 per cent over the whole day and even 73 per cent during the hours of activity. This may be even higher if the Sahara dust effect had not influenced the results. For NO_2, the decrease was only 44 per cent, mainly because of influences from other sources. This would indicate that for UFPs, there are few other sources and the aircraft is the dominating one.

Looking at the share of volatile particles of the total numbers gives values in 2019, of approximately 75 per cent. This is well in line with previous findings.[6] In 2020, with the lack of air traffic during the day, this share drops to 53–59 per cent. The absence of aircraft-engine emissions also reduces the number of volatile particles. This indicates that the aircraft engines emit a high amount of volatile particles.

An analysis for the nighttime with no activities is not viable as the Sahara dust effect in 2020, has led to an increase in particle numbers that is not activity related.

Particle diameters are inversely proportional to the numbers. While particle numbers are generally decreasing, the diameters are increasing (Table 2). This is more pronounced during the time of activities than during the night and more significant for all particles and just to the nonvolatile ones.

OUTLOOK

The current study reveals the opportunities to gain experience and further insight into airport-related pollution concentrations and their assessment. The analysis is also with limitations. If many measurement stations had been available, then that would have allowed for the assessment of several substances in parallel. There is a need to improve the measurement capabilities, particularly for the low-cost sensor technology. This would allow setting up a larger number of stations whose results could be compared among them. This would allow for better spatial and temporal resolution of data and thus for a better interpretation as to the role and impact of aircraft emissions. The current project AVIATOR (Assessing aViaton emission Impact on local Air quality at airports: TOwards Regulation), a European Union Horizon 2020 research and innovation programme aims at filling such gaps until mid of 2022.[7]

While the COVID-19 effects have reduced environmental impacts, they are likely to be of temporary nature only. One of the key elements in the recovery phase of aviation is to thus monitor the longer-term correlation of emissions and resulting concentrations. Gradual but low increase of emissions in the past have still not led to an increase in concentrations, both for NO_2 and PM10. At the same time, previous measures taken to reduce emissions will still be continued, duly reflecting the 'build back better' approach. It is assumed that airlines will resume and build operations relying on more fuel-efficient aircraft with lower emissions. It is expected that the lower level of concentrations will last while aviation is recovering, albeit not as significant as during the acute phase of the crisis.

CONCLUSIONS

The imposed travel restrictions amid the COVID-19 crisis have led to an unprecedented drop in air traffic at Zurich airport. The analysis of traffic, emissions and measured concentrations of various pollutants for a period in 2019 compared to a period in 2020 led to several conclusions:

- There is no equivalent correlation between change in traffic, change in emissions and change in concentrations. The air traffic drop of 91 per cent led to −87 per cent in NOx-emissions at the airport, but only to a −44 per cent NO_2-reduction. This scenario is also due to influences from other-than-aircraft sources, such as regional road traffic, that also contribute to the emissions concentrations at the airport.

- The effects of emissions from airport sources significantly decrease over short distances from the airport and a decrease in concentrations at the airport is not carried over into the region at the same rate. This confirms previous modelling that shows a rapidly decreasing influence of the airport outside the perimeter.
- Meteorological conditions or anomalies may have a significantly higher impact on concentrations than the emissions themselves. Correlations thus have to be always cross-checked with causality.

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