Modeling, simulation and analysis of air quality within the perimeter of Basel-Mulhouse Airport

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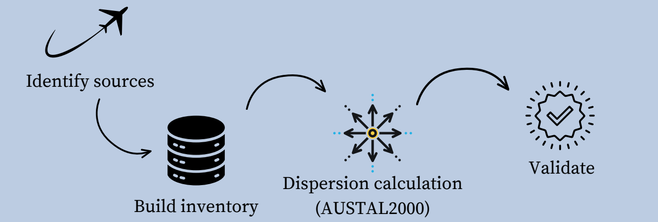
SOURCES :

CONTEXT :

Airports are major local sources of air pollution. Aircraft engines, ground support equipment, auxiliary power units, and road vehicles release a mix of NO_x, PM, and ultrafine particles linked to respiratory and cardiovascular diseases. Inside airport perimeters, particle concentrations can reach **9× urban background levels.**

Basel-Mulhouse Airport (EuroAirport), the **6th busiest in France**, seeks to spatially simulate pollution levels and assess the impact of measures to reduce emissions. Using Open-ALAQS (an open-source QGIS plug-in developed by EUROCONTROL), airport emission sources were spatially digitized and pollutant inventories computed, then dispersion was simulated with AUSTAL.

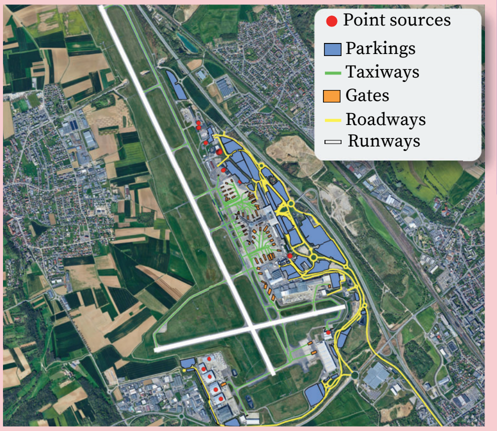
OBJECTIVES:



METHODOLOGY :

① Spatial Setup in QGIS

Map of digitized emission sources :

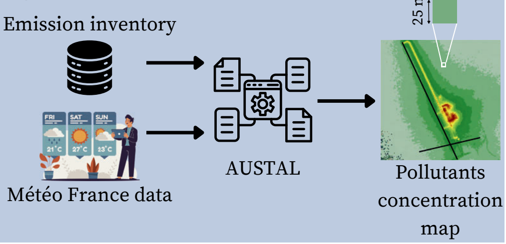


② Emission Inventory with open alaqs

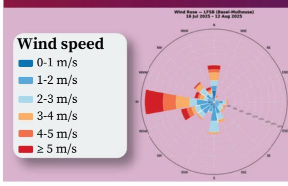
Period	16 Jul - 13 Aug 2025
Movements	7'681 flights
Pollutants	NO_x, CO, HC, PM_{10}, SO_x
Meteo data	Météo France on-site station
Road vehicles	COPERT 5 – EU27

The simulation period matches EuroAirport's in-situ measurement campaign, allowing direct comparison. Open-ALAQS computes hourly emissions from ICAO engine emission factors and the airport's movement records.

③ Dispersion calculations

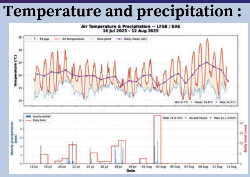


METEOROLOGICAL CONDITIONS DURING THE SIMULATION PERIOD :



Dominant wind from the **west** (30 % of the recorded hours). Light wind from the north (14 % of the recorded hours). Mean wind speed : 2.56 m/s.
⟶ Pollutants transported to the east

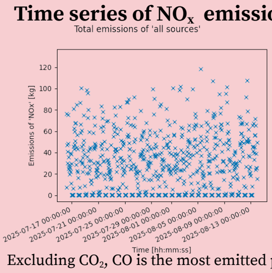
Temperature and precipitation :



Wet first part with 71.6 mm measured. **Heat wave episode** in the last week, with an absolute peak of 34.5 °C.
⟶ Wet deposition in the first part and particle resuspension in the second

RESULTS :

Time series of NO_x emissions :



Hourly NO_x emissions from all sources vary greatly across the period, from zero up to 120 kg/h, with most active hours between 20 and 80 kg/h. The zero points are the night window (00:00–04:00), when the airport is closed. This plot shows the variability of the flight schedule.

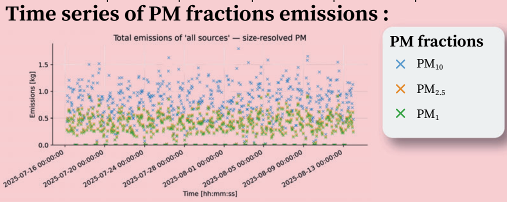
Excluding CO_2, CO is the most emitted pollutant by mass (28,137 kg), followed by NO_x (22,461 kg) and then HC (5,857 kg).

Source contribution to each pollutant :

Aircraft movements dominate the emissions for every pollutant (except SO_x). HC is the only pollutant with a notable secondary source (point sources). Aircraft and point sources emissions of SO_x are not taken into account in the model. Reducing airport air pollution therefore means acting first on aircraft operations (taxiing, APU use), not on parking or road traffic.

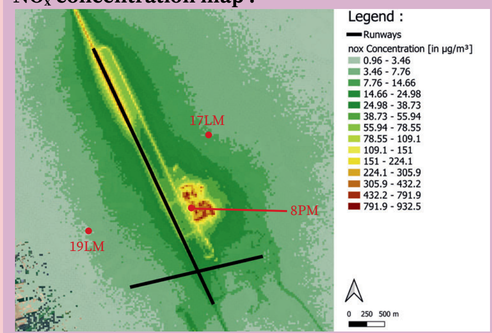
Source	NO_x	CO	HC	PM_{10}	SO_x
Aircraft movements	98.0 %	98.6 %	84.7 %	97.0 %	0 %
Parking lots	0.2 %	0.1 %	0.0 %	0.3 %	12 %
Point sources	0.1 %	0.0 %	14.7 %	0.1 %	0 %
Roadways	1.7 %	1.3 %	0.6 %	2.5 %	88 %

Time series of PM fractions emissions :



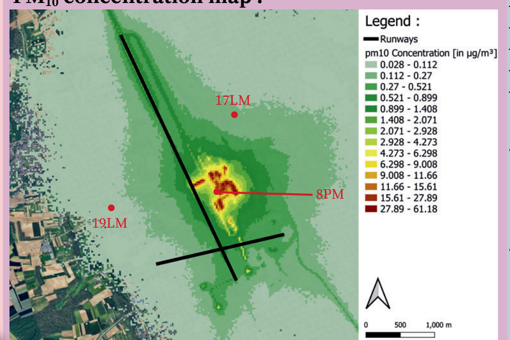
Splitting PM emissions by size shows $PM_{2.5}/PM_{10} \approx 0.53$ and $PM_1/PM_{2.5} \approx 0.95$ (daytime means). Fine particles are known to dominate aircraft emissions and reach deeper into the lungs than coarser PM.

NO_x concentration map :



The modeled NO_x map shows a sharp hotspot over the terminal, with peak concentrations above 790 µg/m³, and a second hotspot on the runway. The plume orientation matches the dominant westerly wind. The background concentrations are in the range : 3–25 µg/m³.

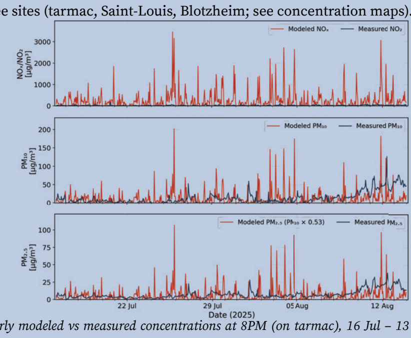
PM_{10} concentration map :



PM_{10}, CO, HC and SO_x follow roughly the same spatial pattern as NO_x.

Comparison with EuroAirport measurements :

Modeled concentrations were compared to EuroAirport measurements at three sites (tarmac, Saint-Louis, Blotzheim; see concentration maps).



Hourly modeled vs measured concentrations at 8PM (on tarmac), 16 Jul – 13 Aug 2025. Modeled $PM_{2.5}$ is derived as $PM_{10} \times 0.53$ (see PM fractions).

Site	Pollutant	Measured mean (µg/m³)	Modeled mean (µg/m³)
8PM	NO_2 vs NO_x	19.91 (NO_2)	251.19 (NO_x)
8PM	PM_{10}	12.82	11.81
17LM	NO_x	10.94	7.41
17LM	PM_{10}	12.58	0.15
19LM	NO_x	7.86	3.41
19LM	PM_{10}	12.70	0.07

Summary table of the measured vs modeled mean concentrations over the period for NO_x (NO_2) and PM_{10}. Values shown in red exceed the annual mean limits for France (40 µg/m³) and Switzerland (30 µg/m³).

Key findings :

- At the 8PM tarmac site, modeled NO_x exceeds measured NO_2 by roughly an order of magnitude, which is partly an expected $NO_x \neq NO_2$ difference, partly a real over-prediction near the source. In the surrounding municipalities, mean values are of the same order of magnitude (but under-predicted) : absolute bias of −3.53 µg/m³ at 17LM and −4.45 µg/m³ at 19LM.
- For PM_{10}, at 8PM site concentrations are roughly matching with an absolute bias of −1.01 µg/m³ (Normalized Mean Bias = −7.9 %). However, outside of airport domain there is a strong under-estimation (NMB = −99%), since the model takes only into account airport-related emissions whereas measured values also include urban background and especially the highway (close to the airport).

CONCLUSION :

Aircraft movements account for 97–99% of NO_x, CO, and PM_{10} emissions at EuroAirport, producing two clear concentration hotspots (terminal and runway). Comparison with on-site measurements confirms the model is realistic where airport emissions dominate, while outside of airport domain the under-prediction reflects the absence of urban background and highway sources rather than a model default. Because aircraft operations dominate emissions of nearly all pollutants, reduction strategies should prioritize operational measures over measures on parking or roadways, for example reduced taxiing, single-engine taxi, electrified ground support or limited APU use. As for the limitations, the study covers only the summer period, the absence of aircraft and point-source SO_x in the model, and the modeling of only a selected set of pollutants (NO_x, CO, HC, PM_{10}, SO_x). With careful interpretation of values (especially for NO_x), the model can serve as a baseline for testing such scenarios.