Assessment of urban air quality using SIRANE dispersion model and a new method for estimating traffic emissions

[a]C.V. Nguyen, [a]L. Soulhac, [a]P. Charvolin and [b]G. Sabiron

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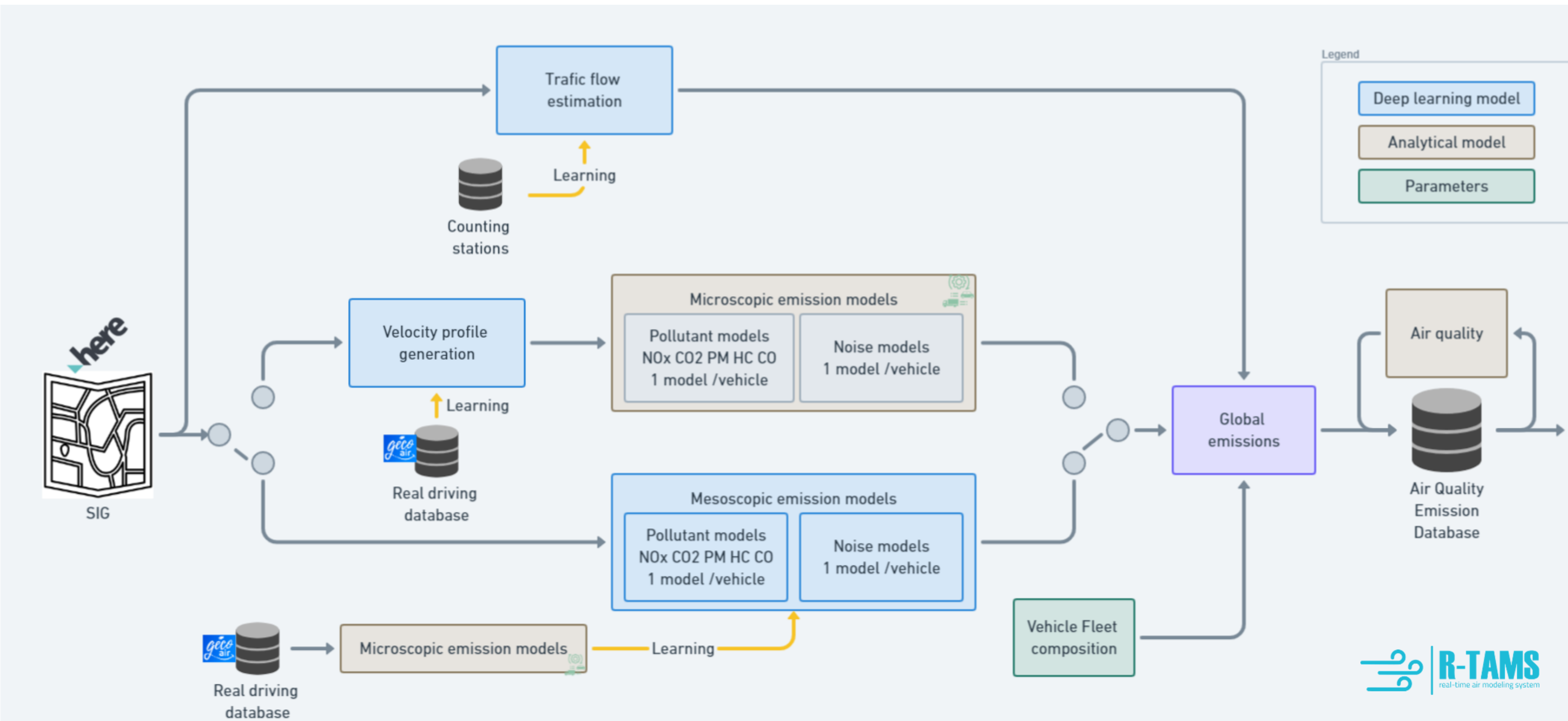
[a] Ecole Centrale de Lyon, CNRS, Université Claude Bernard Lyon I, INSA Lyon, LMFA, UMR 5509, 69130, Ecully, France
[b] Department of Control, Signal and System, IFP Energies Nouvelles, Solaize, France

Urban air quality

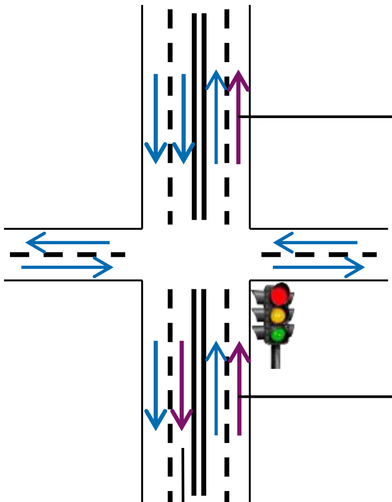
- Outdoor air pollution has caused 4.2 million premature deaths worldwide in 2019 (WHO, 2022)
- High health risks in urban areas due to:
  - High pollution levels
  - Large urban population
- NO_2 pollution mainly due to traffic emissions (Restrepo, 2021)

New method for estimating traffic emissions

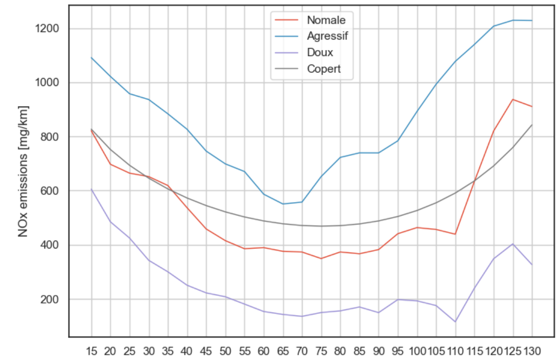
- SAAS implemented **mesoscopic models** → Traffic + Emissions
- Floating car data available for real-time traffic velocity
- Replicability to any territory



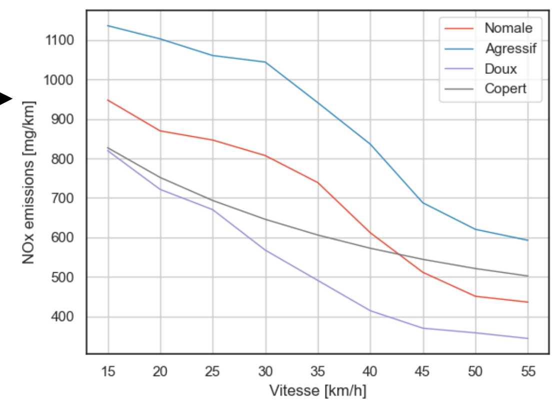
Mesoscopic model vs. COPERT (State-of-the-art)



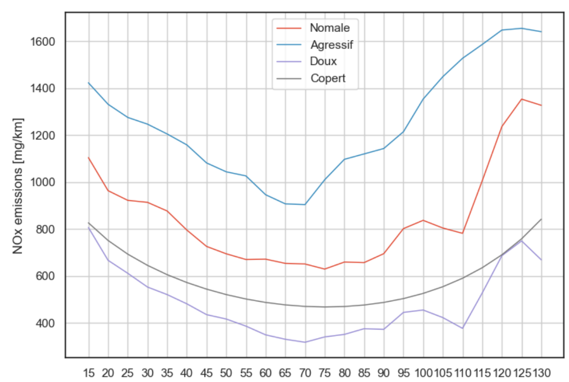
- No signage
- No slope (0%)
- Speed limit 50km/h



- Traffic light
- No slope(0%)
- Speed limit 50km/h



- No signage
- Slope (2.5%)
- Speed limit 50km/h



- Emission dynamics broader than the state of the art
- Impact of driving style
- Recommendations for infrastructure development

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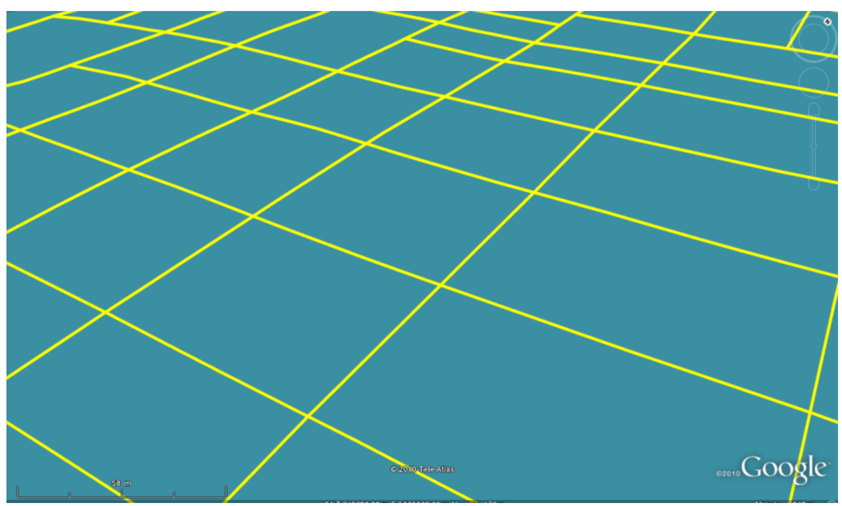
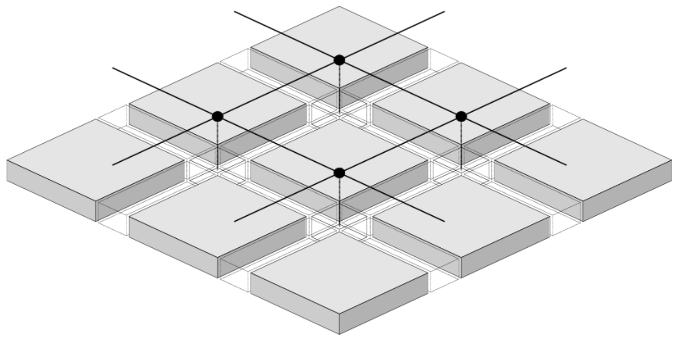
SIRANE

- Urban dispersion model based on street network concept (Soulhac, 2000)
  - Simplified consideration of buildings
  - Point, line, and surface sources
  - Multi-species, taking into account NO-NO_2-O_3 chemical reactions
  - Source apportionment
- Description of urban geometry

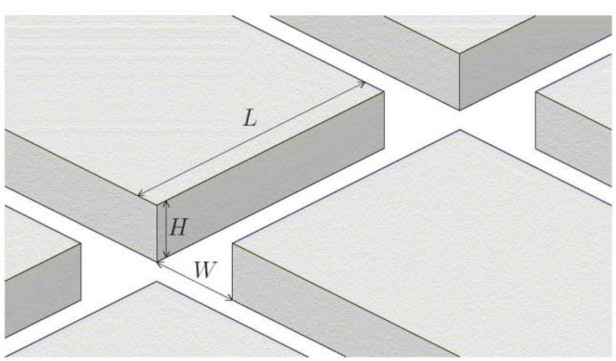
Real geometry → Street volumes → Street canyons → Street network



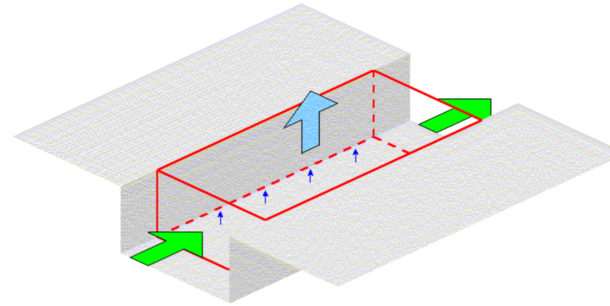
SIRANE
Modelling blocks



Urban canopy represented by a street network

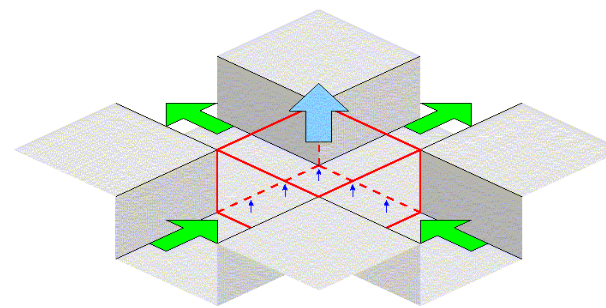


Street canyon modelled by a shoe box

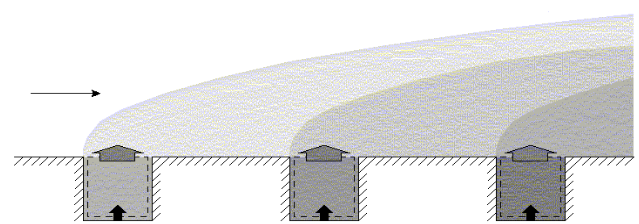


Box model for each street

- Advection along the street axis induced by the parallel component of the wind
- Turbulent diffusion across the interface between the street and the external atmosphere



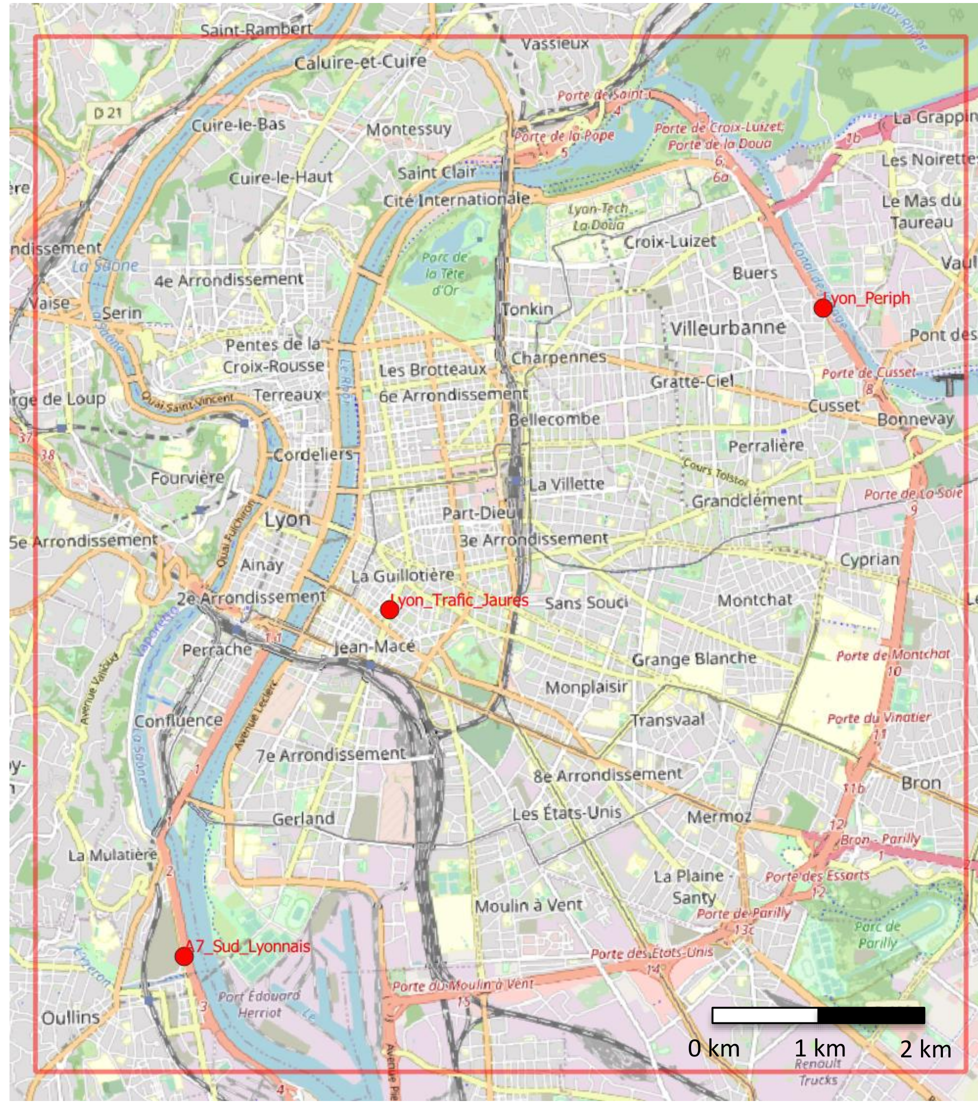
Exchange model at intersections



Gaussian plume model into surface boundary layer

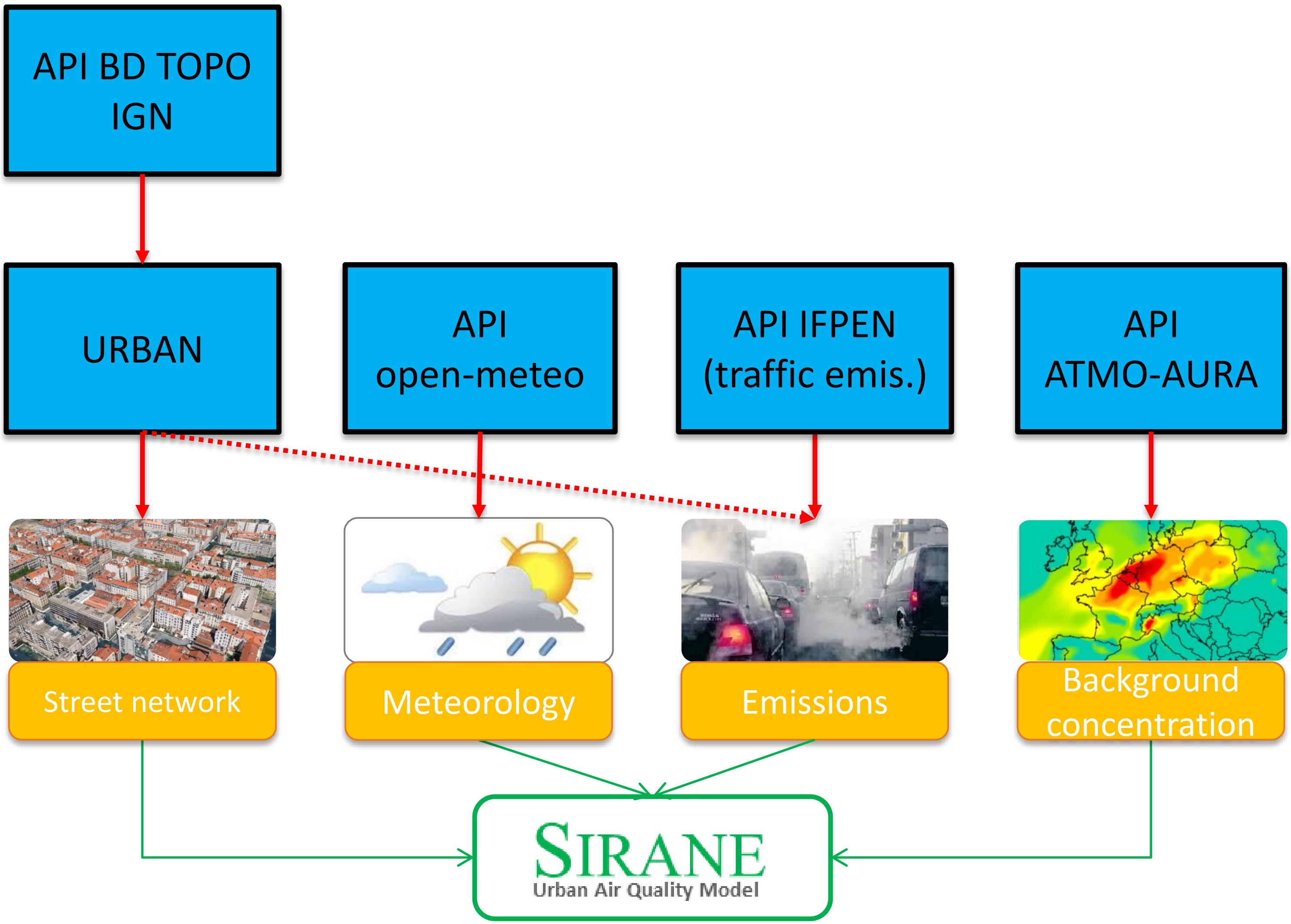
Case study
Description

- Area: Lyon (France)
- Periods (2023):
  - 30th January – 5th February (winter)
  - 21th – 27th May (spring)
  - 19th – 25th June (summer)
- Pollutant: NO_2



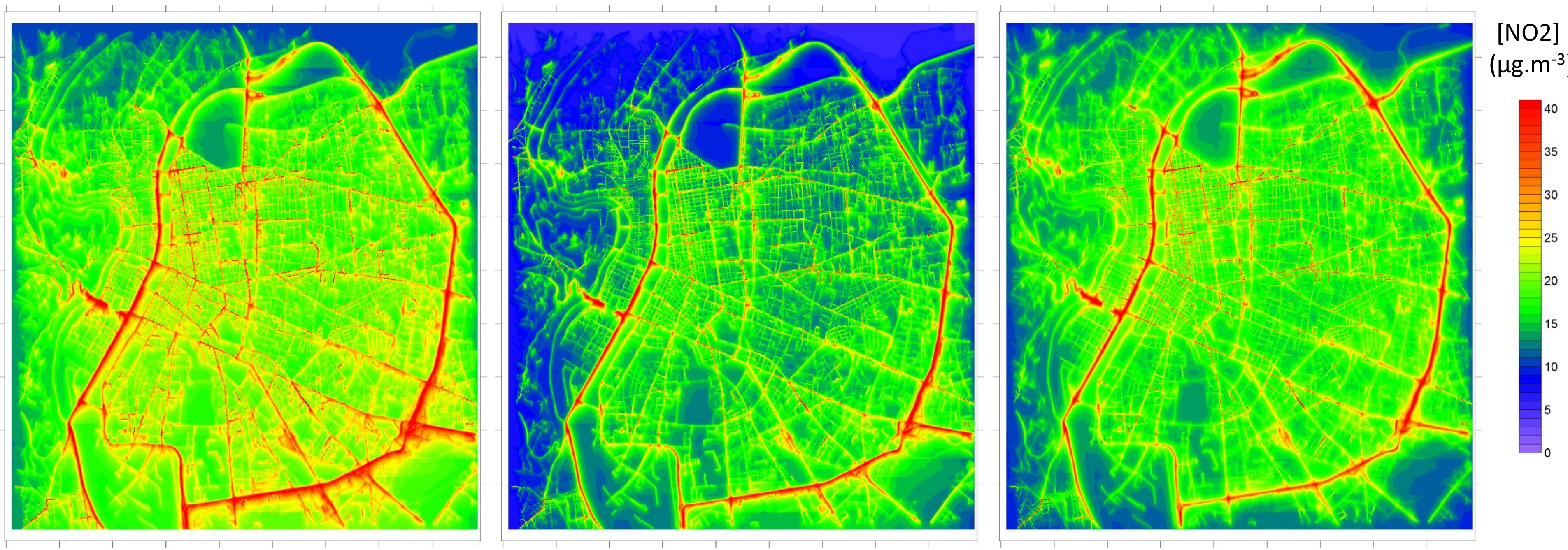
Domain of the case study

Case study
Modelling chain



Case study
Mean weekly concentrations

30th Jan. – 5th Feb. (winter) | 21th – 27th May (spring) | 19th – 25th June (summer)



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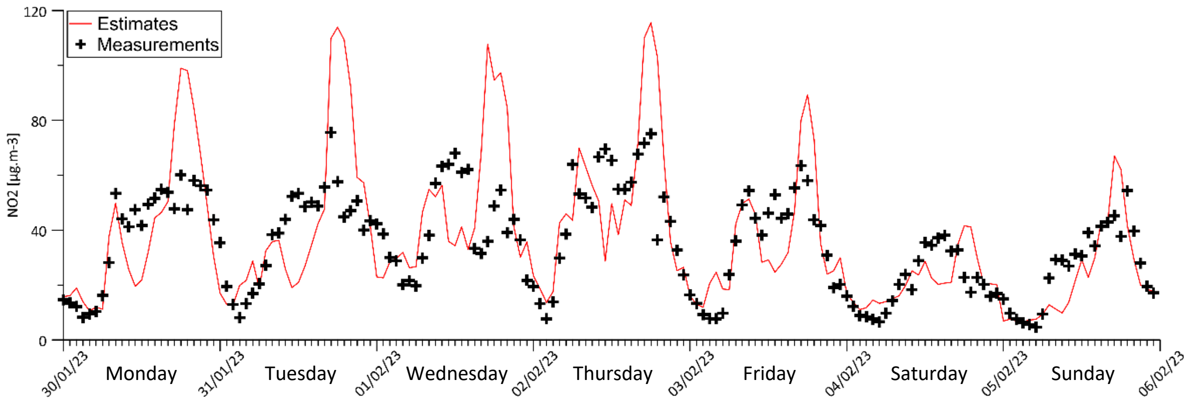
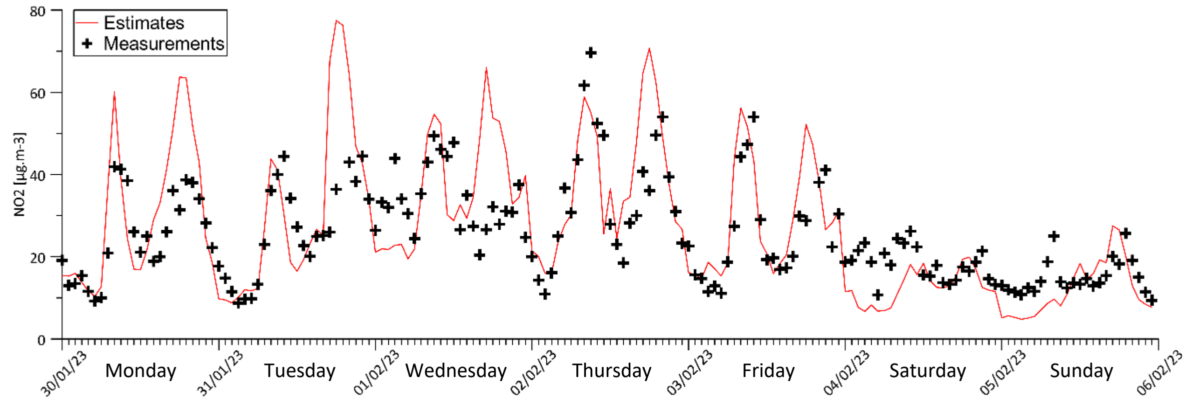
Case study
Mean hourly concentrations

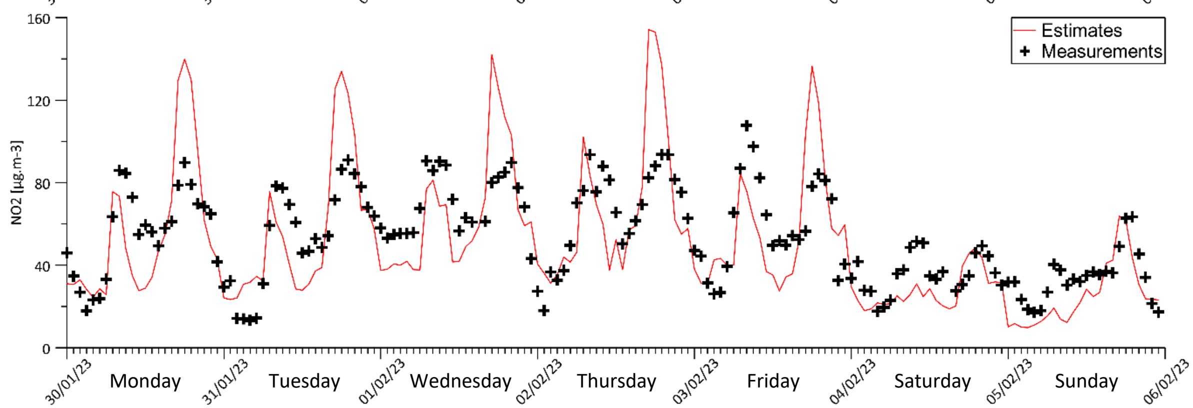
A7 Sud Lyonnais



Trafic Jaurès

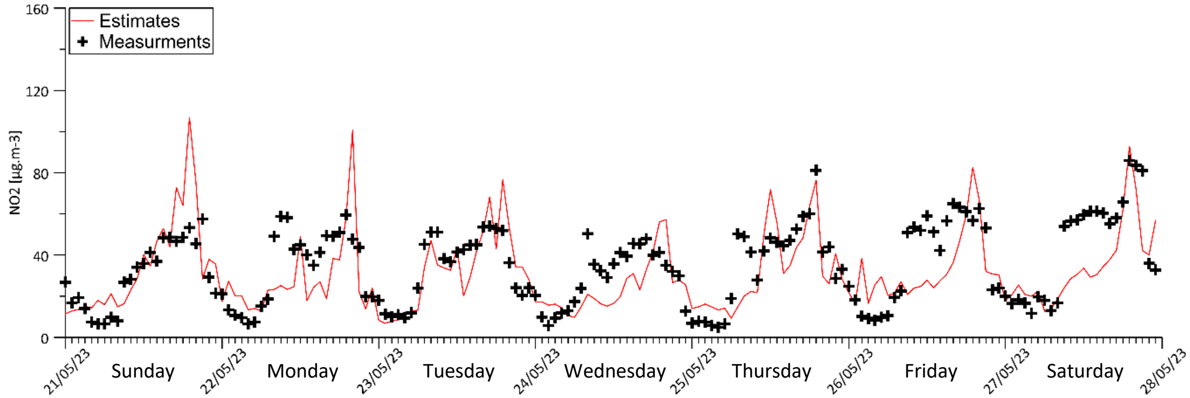


Lyon Périphérique



Case study
Mean hourly concentrations

A7 Sud Lyonnais



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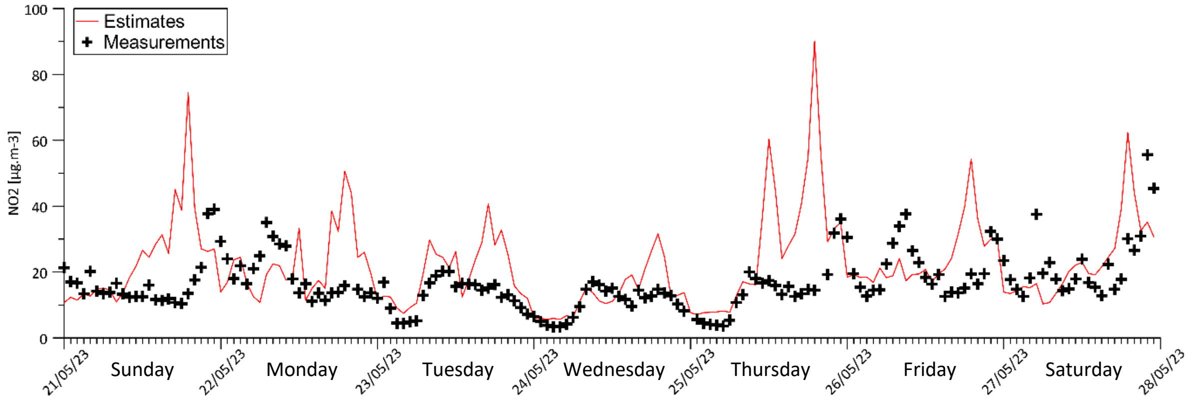

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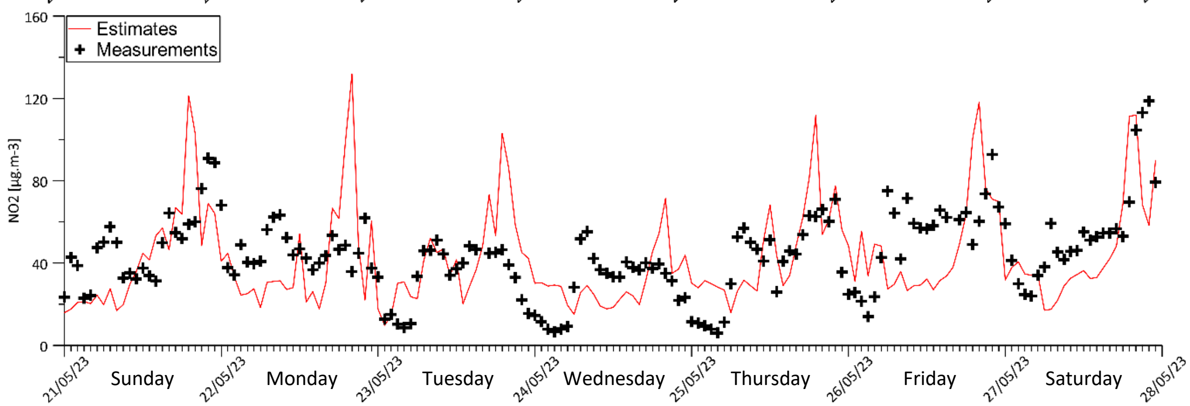
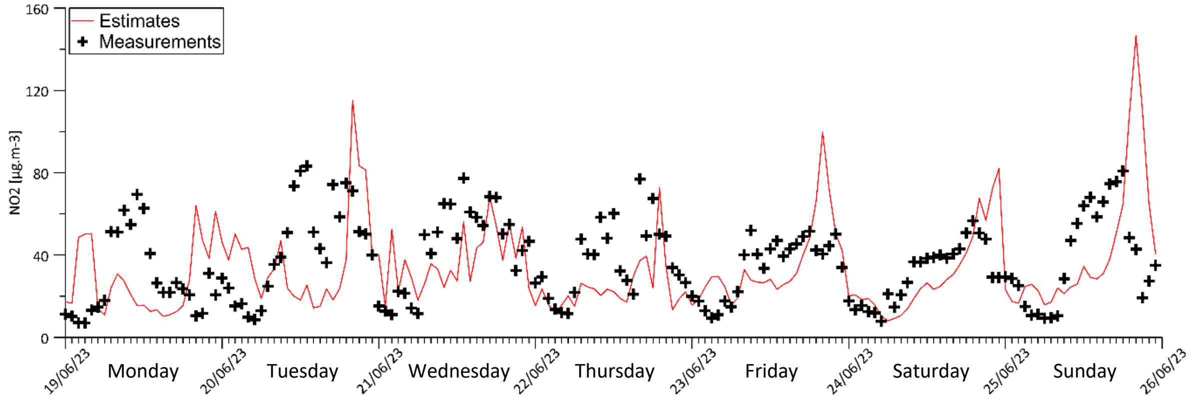


Case study
Mean hourly concentrations

A7 Sud Lyonnais



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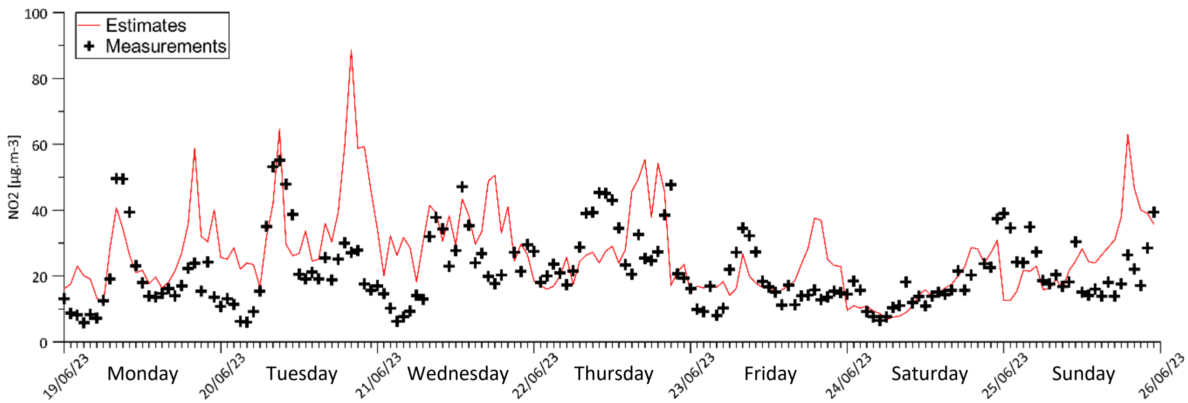

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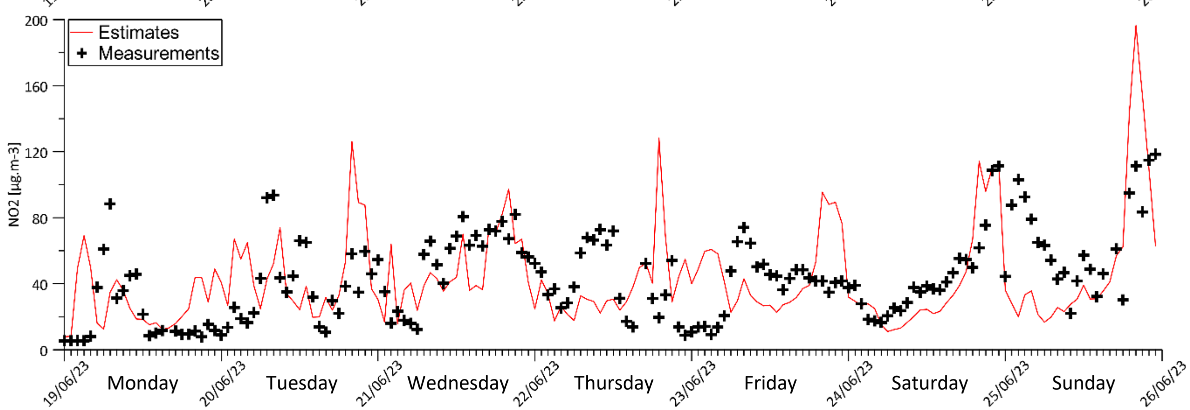
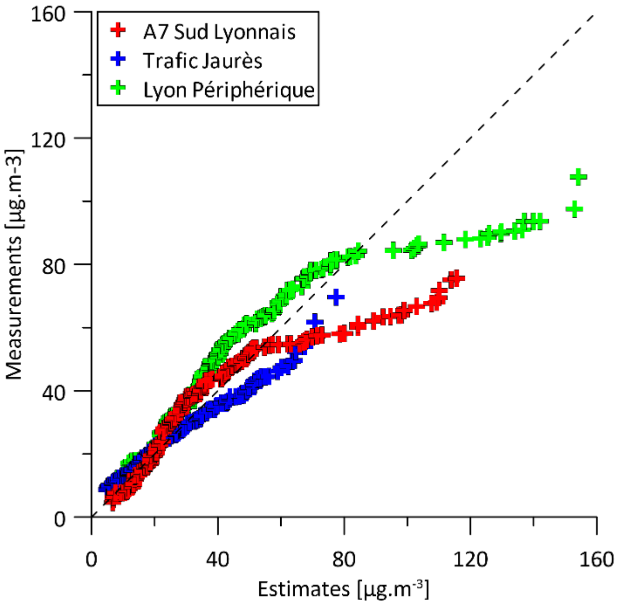
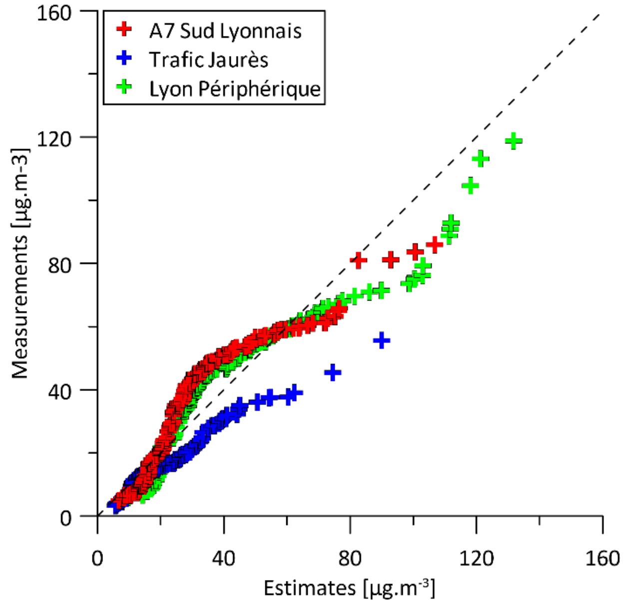


Case study
QQ plots

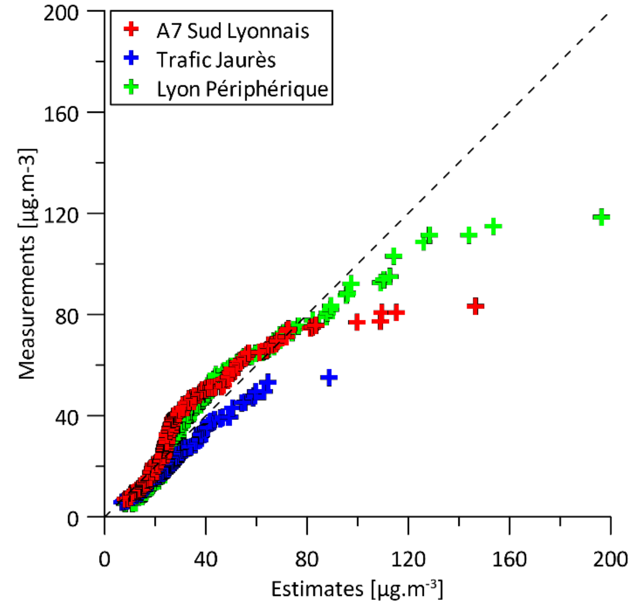
30th Jan – 5th Feb (winter)



21th – 27th May (spring)



19th – 25th June (summer)



Modelled concentrations tend to overestimate measured concentration peaks

Case study
Statistical indices

	Expression	Optimal value	Criteria (Chang et Hanna, 2004)
FB	$\dfrac{\overline{C_p} - \overline{C_m}}{0.5(\overline{C_p} + \overline{C_m})}$	0	$-0.3 \leq FB \leq 0.3$
ER	$\overline{\left(\dfrac{\lvert C_p - C_m \rvert}{0.5(\overline{C_p} + \overline{C_m})}\right)}$	0	
NMSE	$\dfrac{\overline{(C_p - C_m)^2}}{\overline{C_p}\,\overline{C_m}}$	0	$\sqrt{NMSE} \leq 2$
R	$\dfrac{\overline{(C_p - \overline{C_p})(C_m - \overline{C_m})}}{\sqrt{\overline{(C_p - \overline{C_p})^2}\ \overline{(C_m - \overline{C_m})^2}}}$	1	
MG	$\exp\left(\overline{\ln(C_m)} - \overline{\ln(C_p)}\right)$	1	$0.7 \leq MG \leq 1.3$
VG	$\exp\left(\overline{\left(\ln(C_m) - \ln(C_p)\right)^2}\right)$	1	$VG \leq 1.6$
FAC2	Proportion of estimates that check $0.5 < C_p/C_m < 2$	1	$FAC2 \geq 0.5$

C_m: measured concentration
C_p: modelled concentration

Case study
Statistics

30th January 2023 – 5th February 2023 (winter)

Station	FB	ER	NMSE	R	MG	VG	FAC2
A7 Sud Lyonnais	-0.059	0.352	0.280	0.670	0.978	1.227	0.881
Trafic Jaurès	-0.047	0.320	0.192	0.737	1.050	1.196	0.886
Lyon Périphérique	0.048	0.339	0.174	0.749	1.131	1.191	0.910

21th – 27th May 2023 (spring)

Station	FB	ER	NMSE	R	MG	VG	FAC2
A7 Sud Lyonnais	0.109	0.430	0.253	0.637	1.063	1.329	0.756
Trafic Jaurès	-0.273	0.438	0.563	0.260	0.774	1.394	0.764
Lyon Périphérique	0.036	0.488	0.311	0.417	1.036	1.456	0.711

19th – 25th June 2023 (summer)

Station	FB	ER	NMSE	R	MG	VG	FAC2
A7 Sud Lyonnais	0.092	0.553	0.560	0.222	1.080	1.688	0.673
Trafic Jaurès	-0.222	0.427	0.357	0.384	0.789	1.376	0.765
Lyon Périphérique	0.008	0.577	0.497	0.393	0.968	1.855	0.648

Generally the statistics meet Chang and Hanna (2004) quality criteria.
Nevertheless, there is a poor correlation in spring and summer.

Conclusion

- Assessment of urban air quality using a new method for estimating traffic emissions:
  - Quality of estimates varies according to time period and geographical area
    - Worse results in summer
    - Poorer results for A7 Sud Lyonnais station
  - Globally the statistics meet Chang and Hanna (2004) quality criteria

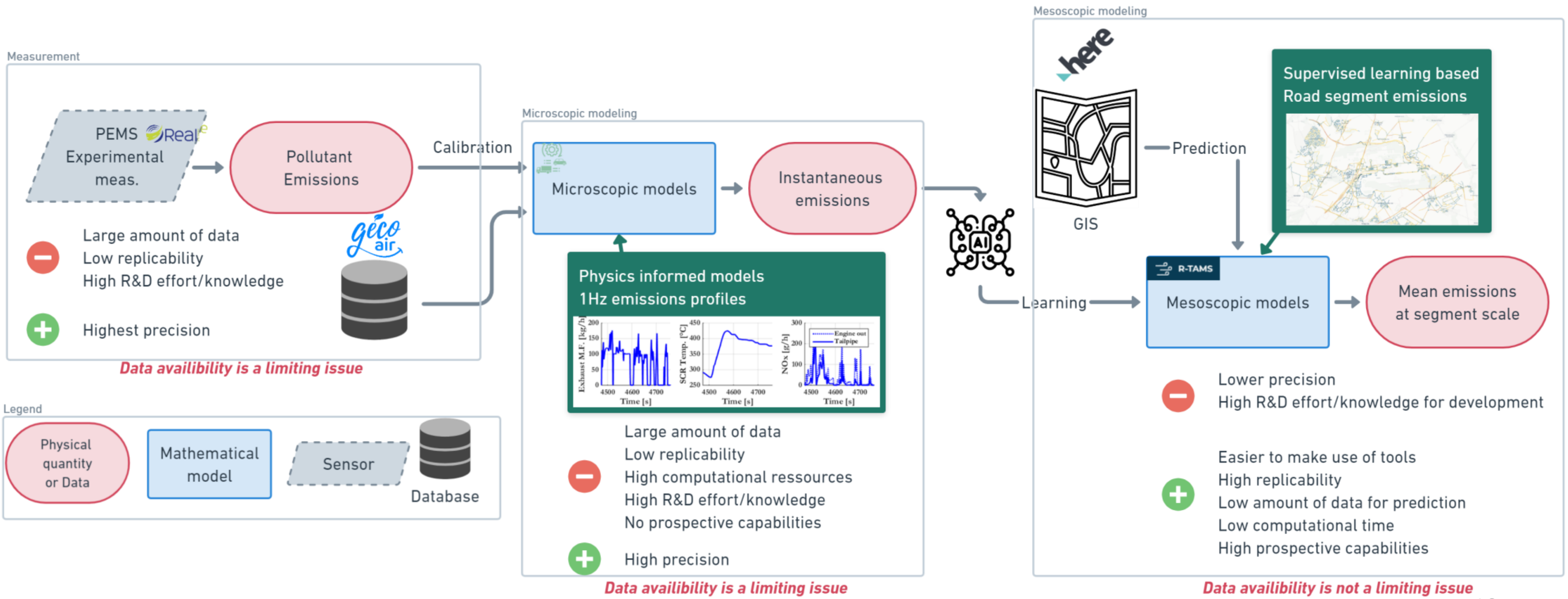
- Outlook:
  - Compare traffic emissions with COPERT method
  - Takes into account low traffic neighbourhoods, car classification/restriction, etc.
  - Consider emissions from industries, heating, residential-tertiary activities etc.

Thank you for your attention

Questions ?

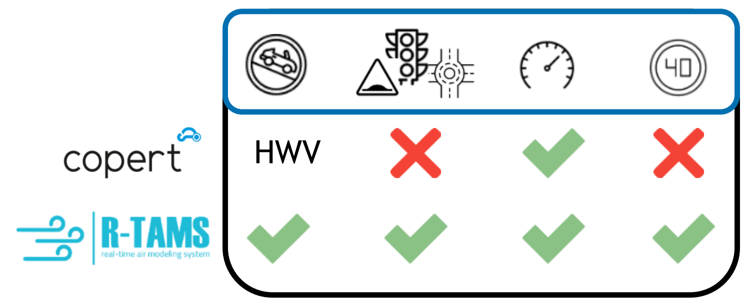
From measurement to mesoscopic model

- Starting point : sensor measurements (PEMS)
- Microscopic step for accurate estimation
- Mesoscopic step for replicability and limited comp. cost.



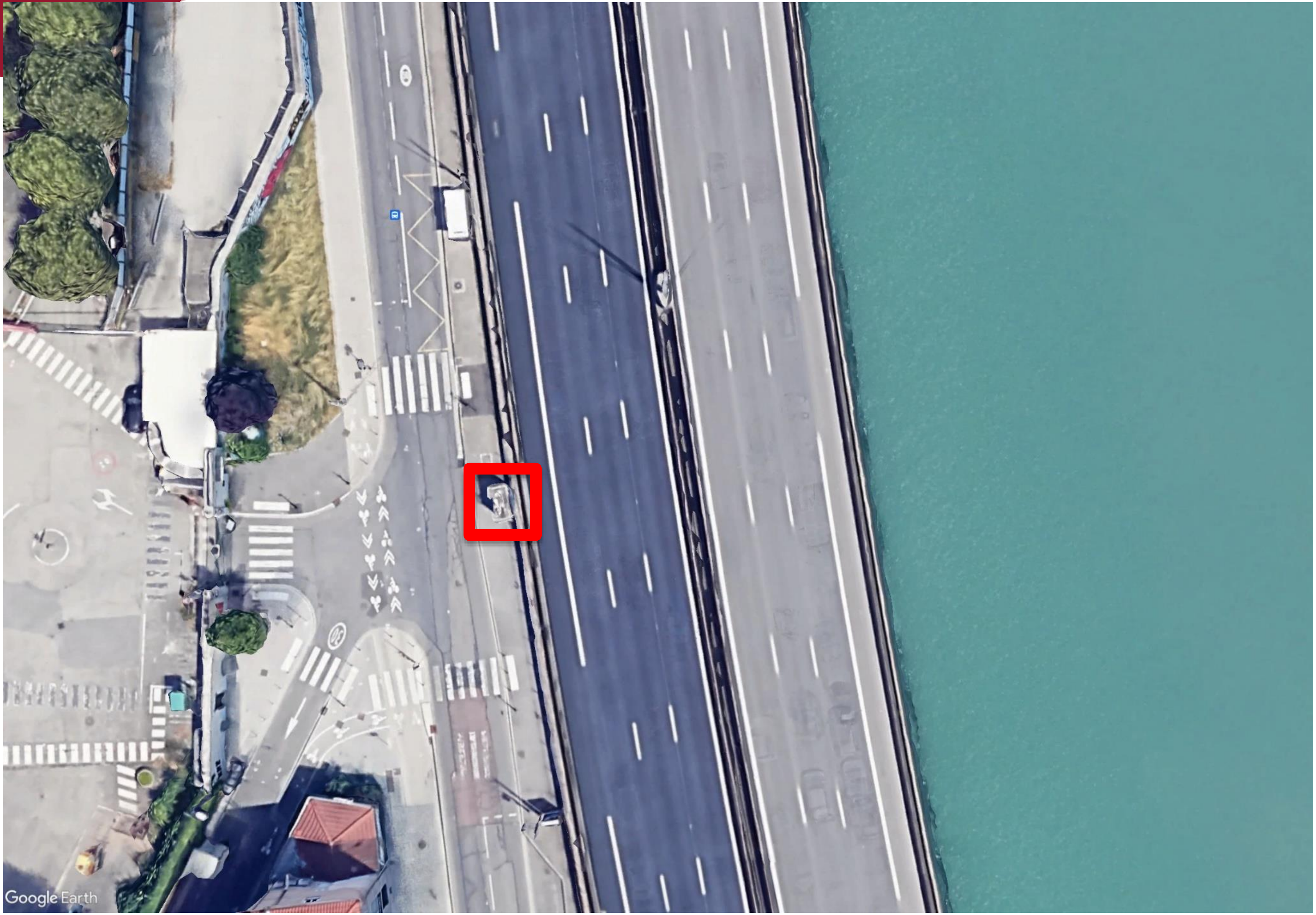
Road Traffic Emissions Estimation

- State of the art: copert
  - European Standard for the Calculation of Vehicle Emissions
  - Combination of laboratory test data, on-road measurements and modelling
  - Macroscopic Emission Model
  - Rely only of traffic speed
- Model (developed by IFPEN): R-TAMS
  - Mesoscopic Emission Model
  - Rely on infrastructure, slope, speed limit and traffic speed here
  - Learned from data from microscopic modelling



	Microscopic	Mesoscopic	Macroscopic
Data	Instant. (1 Hz)	Aggregated	Aggregated
Accuracy	Very high	High	Low
Comp. cost	High	Low	Low
Model		R-TAMS	copert

A7 Sud Lyonnais



École Centrale Lyon

Trafic Jaurès

Lyon Périphérique