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An evaluation of the urban dispersion models SIRANE and ADMS Urban, using field data from Lyon

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Outline of the presentation

- Objectives and motivations
- Description of the models : SIRANE and ADMS Urban
- LYON6 : a field measurement campaign in a district of Lyon
- Comparison between models and data
- Analysis and conclusions

District scale pollution modelling

Agglomeration scale

District scale

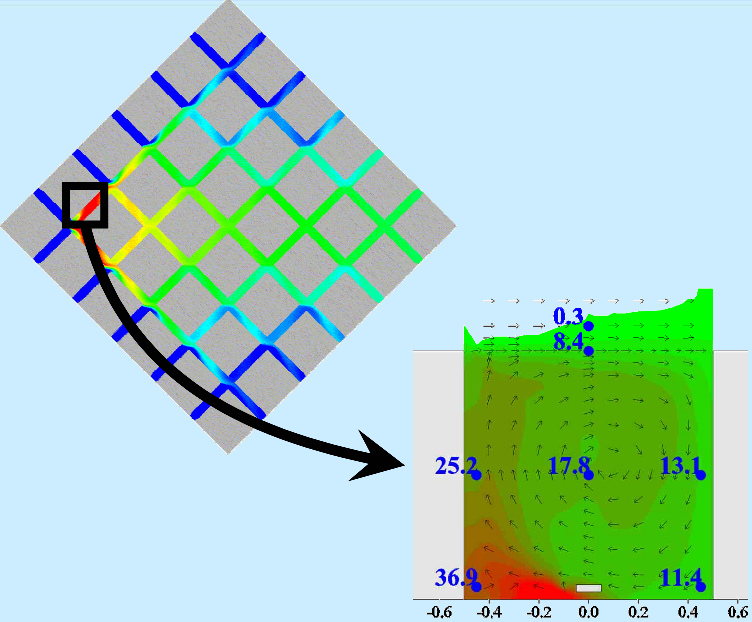
Street scale

State of the knowledge

- District scale less studied than agglomeration and street scales
- Few models and datasets for this scale

Applications related with district scale

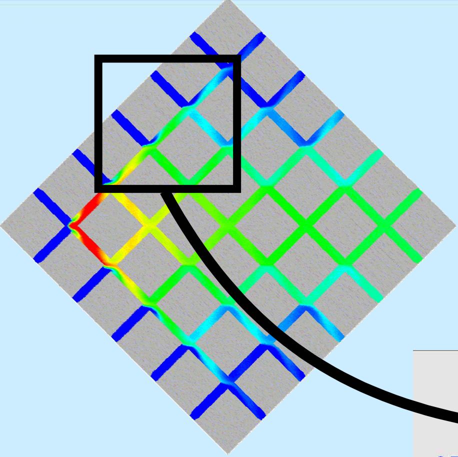
- Urban air quality : cartography of pollution, population exposure, …
- Accidental or terrorist release of hazardous materials



District scale phenomenology

Plume size σ_z / Height of the buildings H

	σ_z << H	σ_z ~ H	σ_z >> H
Main characteristics	The plume is transported by local flows around or between obstacles	The plume is meandering between obstacles and mixed by the topology of the flow (exchange at the intersection)	The plume is mainly transported over the canopy, in the RSL
Processes to reproduce	Microscale flows (recirculating zone, deviations)	Topology of the flow within the district Exchange between recirc. zones and external flow	Flow and turbulence characteristics in RSL or special parameterisation of plume spread (σ_y and σ_z)



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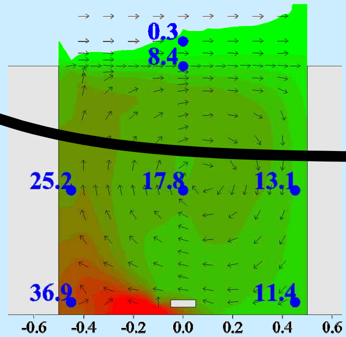

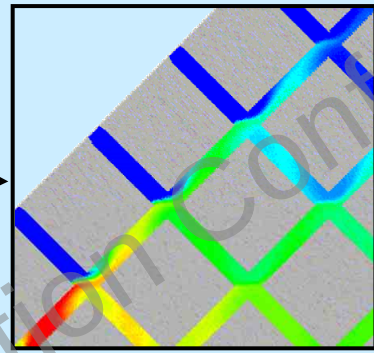

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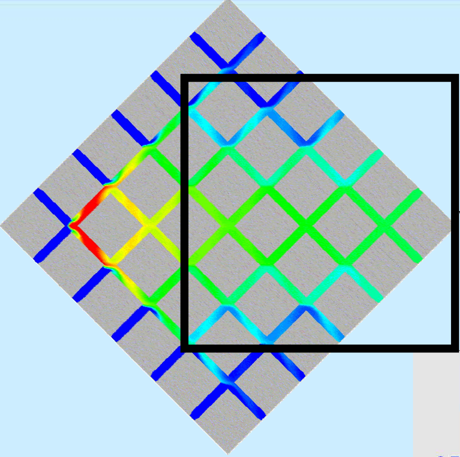

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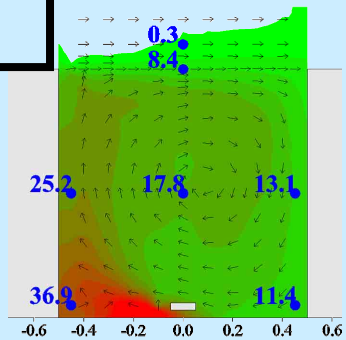

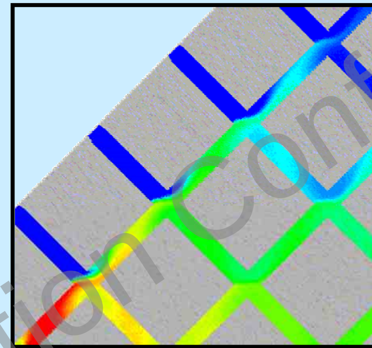

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Difficulties in modelling district scale

- Many buildings to model :
  - Cannot be replaced by roughness nor modelled in detail
  - Which geometrical model or simplifications to use ?
- Meteorological preprocessing :
  - What are the relevant meteorological parameters at district scale ?
  - How to estimate them from measurements near the ground or outside the district ?
  - Which modifications are needed from existing "rural" preprocessors ?
- Validation datasets :
  - Few datasets available (field or wind tunnel experiments)
  - Need of a variety of experiments, from simple cases to real complex configurations

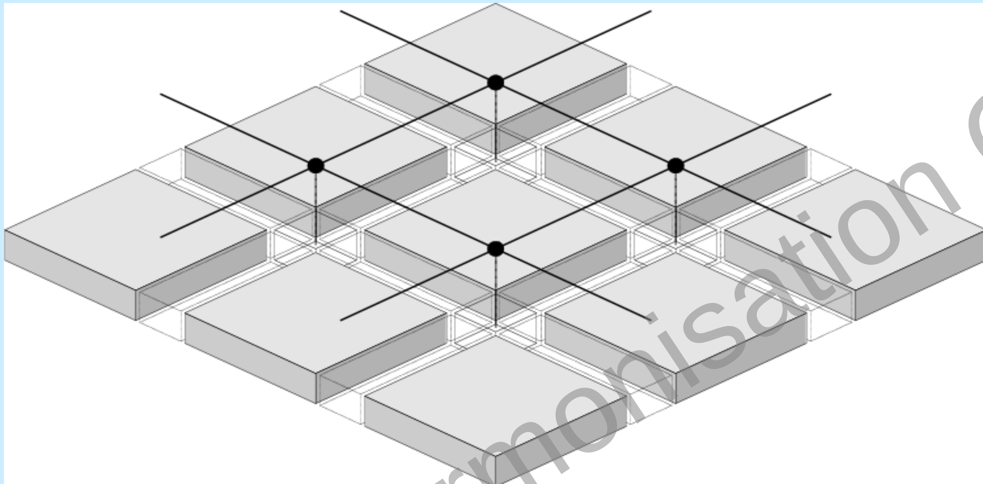
Methodology

- Use of two models designed for the district scale : SIRANE and ADMS Urban
- Coupling with traffic and emission modelling
- Application in a real case where detailed traffic, meteorological and concentration measurements were performed
- Comparisons and discussion

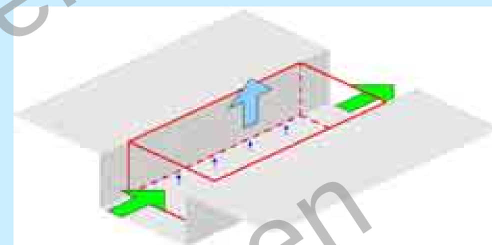
SIRANE Model

(Soulhac, 2000)

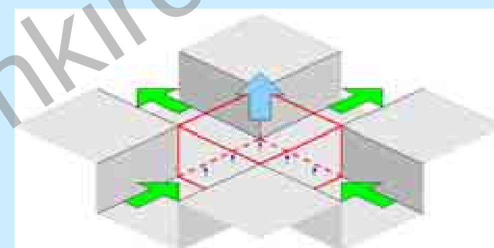
Street network model



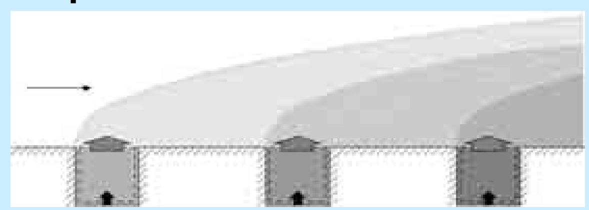
Pollutant budget in each street



Exchange at the intersections



Dispersion over the roof level



Model characteristics

- Meteorological preprocessor, based on Monin-Obukhov theory
- Gaussian plume model with spread parameters derived from similarity theory
- Simple chemical scheme for NO-NO_2-O_3

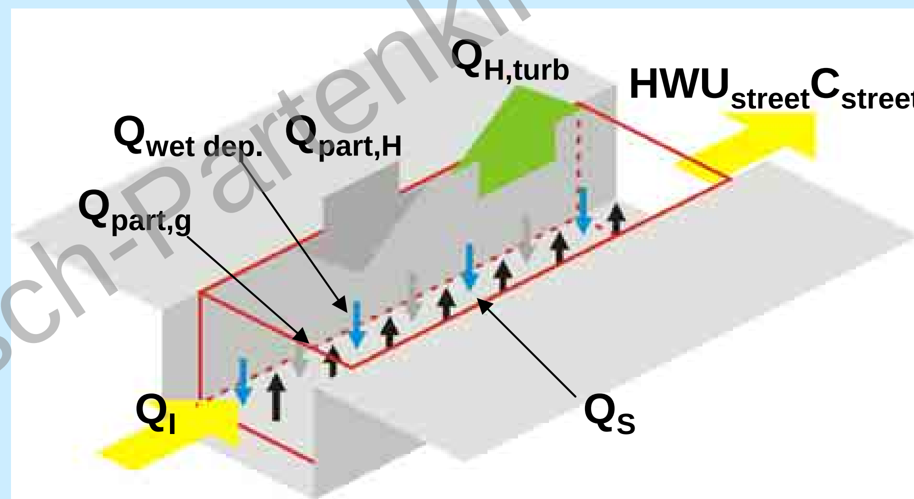
SIRANE Model : street modelling

- Model for the flow along the street
- Pollutant budget in the street

$$\underbrace{Q_S + Q_I + Q_{part,H}}_{\text{Ingoing flux}} = \underbrace{Q_{H,turb} + HWU_{street}C_{street} + Q_{part,g} + Q_{wet\,dep.}}_{\text{Outgoing flux}}$$

- Turbulent echange at the interface

$$Q_{H,turb} = \frac{\sigma_w WL}{\sqrt{2\pi}}\left(C_{street} - C_{ext}\right)$$



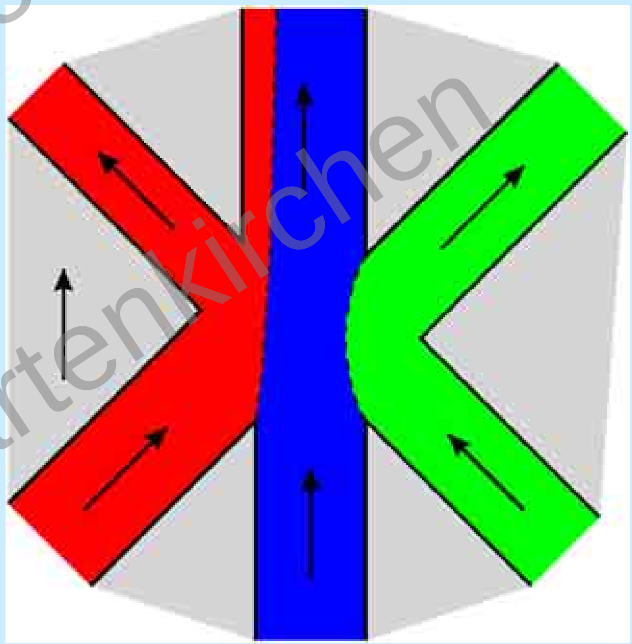
SIRANE Model : intersection modelling

- Calculation of the exchange flux as a function of wind direction

$$Q_{i,j}(\theta)$$

- Averaging on wind direction distribution

$$\overline{Q_{i,j}}(\theta_0) = \int P(\theta - \theta_0) Q_{i,j}(\theta) d\theta$$



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CNRS

CENTRALE LYON

LMFA

ADMS Urban model

(McHugh et al, 1997)

- Modification of the ADMS3 model for urban areas
- Gaussian plume model with spread parameters derived from similarity theory
- Meteorological preprocessor based on Monin Obukhov theory
- Street-canyon effects reproduced using the OSPM street canyon model (Berkowicz et al, 1997)
- Chemical reactions for NO-NO_2-O_3 modelled with Derwent-Middleton correlation or GRS scheme

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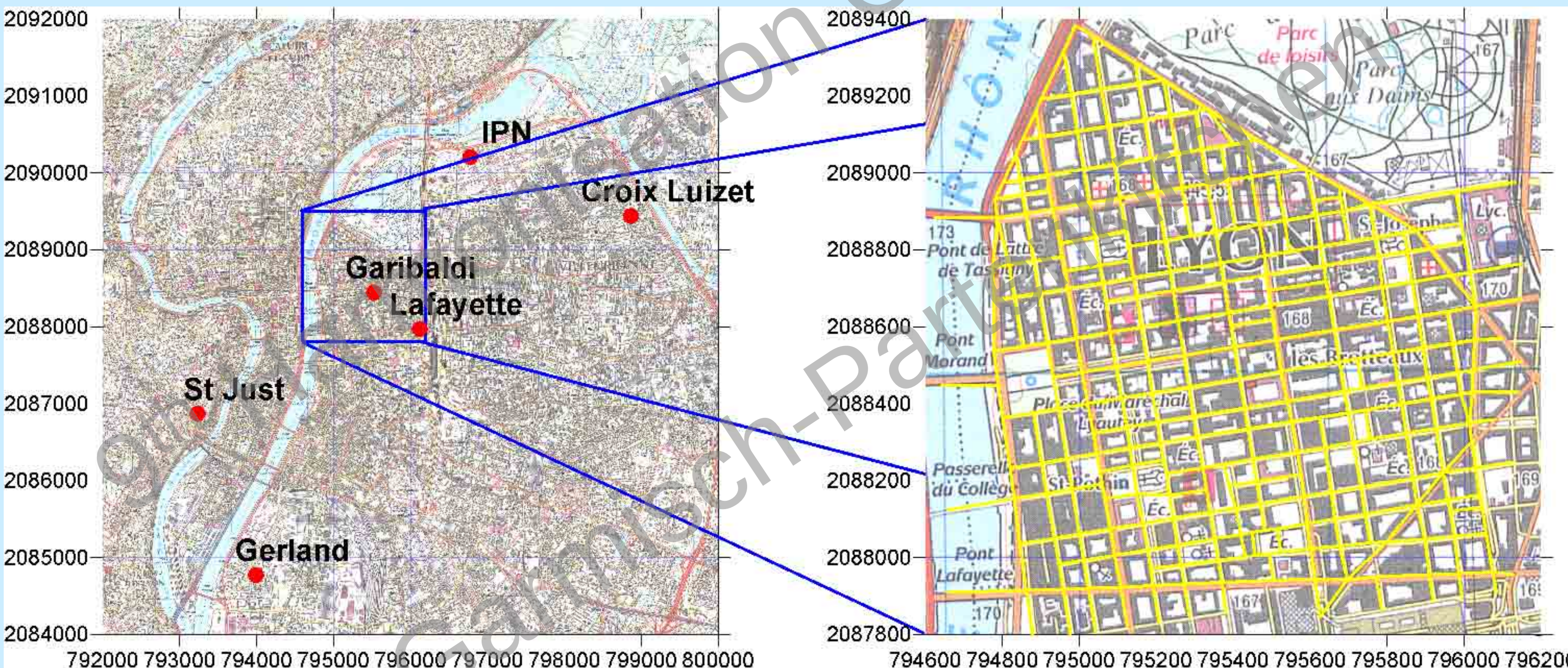
Main differences between the models

SIRANE	ADMS Urban
• Box model for the concentration within the streets	• Description of the concentration field within the streets
• Modelling of the exchanges at the intersection between streets	• No exchanges at the intersections
• Simple chemical scheme based on photostationarity	• 2 chemical schemes (DM and GRS)

LYON6 field experiment

(in collaboration with COPARLY)

Objectives : Measurement of traffic, meteorology and NO_X concentrations at the scale of a district, to validate air quality models



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CENTRALE LYON

LYON6 measurements

- Traffic :
  - 10 counting stations in the district
- Meteorology :
  - Meteorological ground station
  - SODAR + sonic anemometer placed on a roof

  All located outside the district
- Pollutant concentration :
  - 60 NO_2 passive samplers (concentration integrated over 2 weeks) at 33 different positions
  - 3 NO_X analysers within the district + 3 others around which provide the background concentration

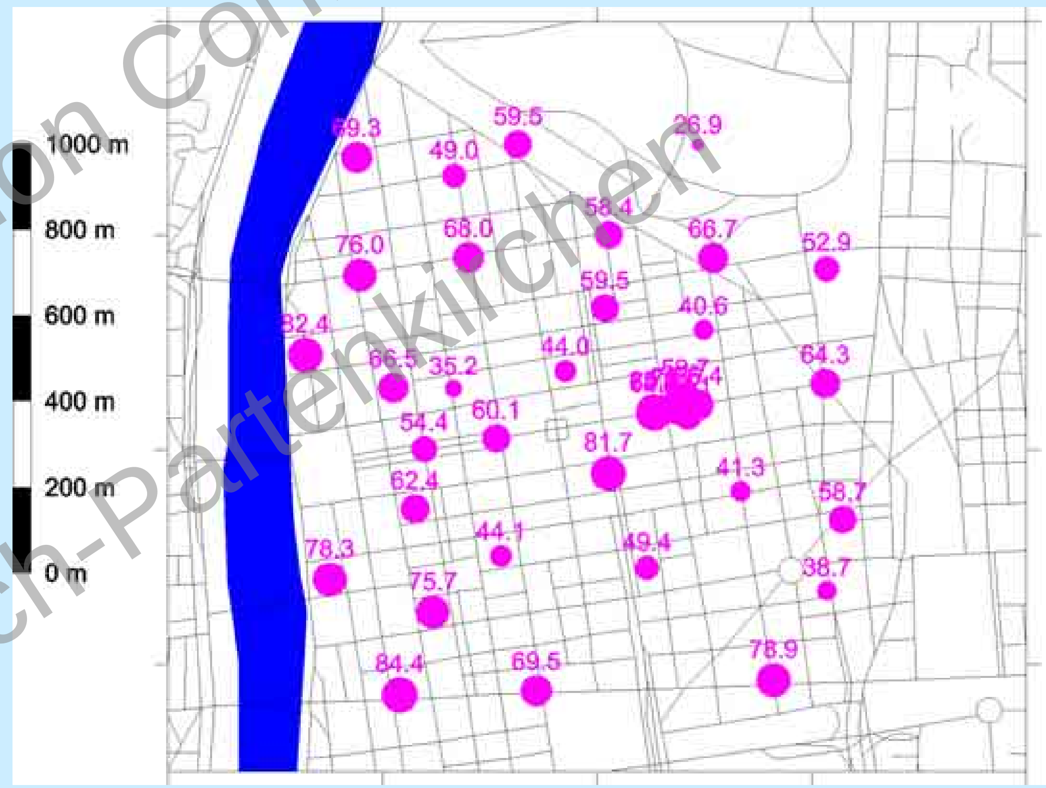
LYON6 field experiment

- 15 days of measurements during July 2001

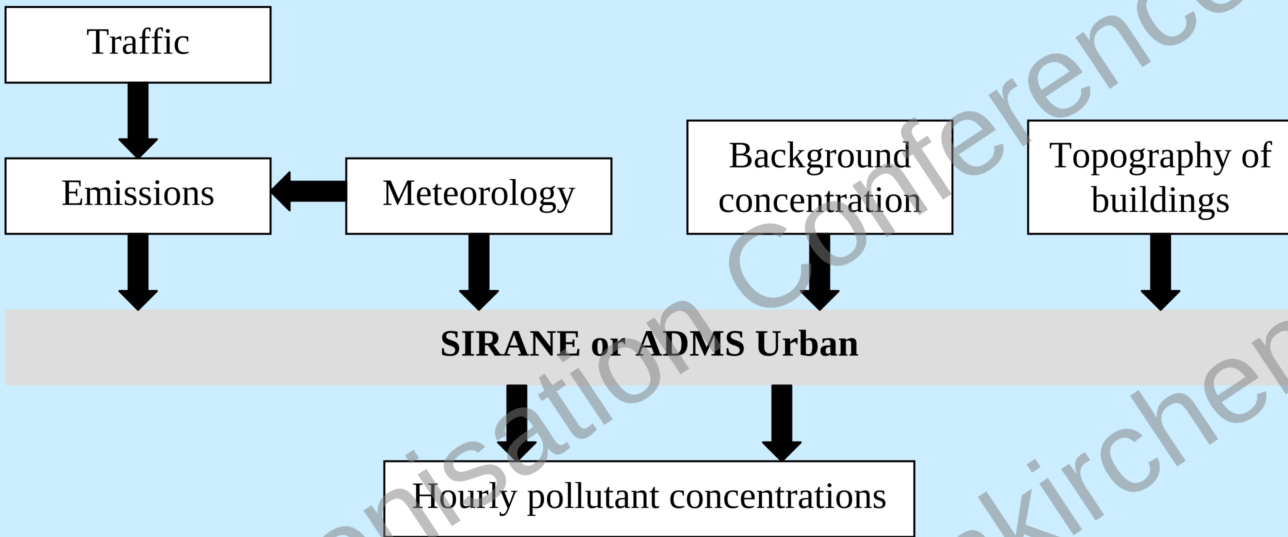
- NO_2 passive samplers corrected by analysers measurements

- Dataset available for people how want to use it

Passive samplers NO_2 concentration (µg/m^3)



Simulation with the models



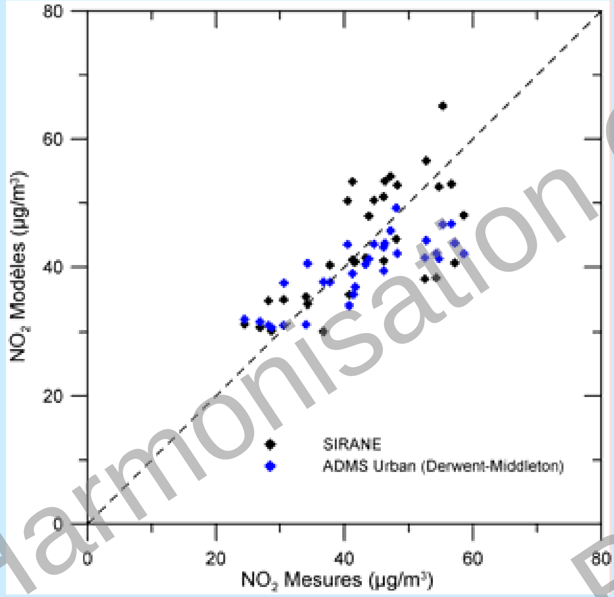
- **Traffic** : coupling between counting and traffic simulations for rush hours
  - Smallest streets are not taken into account
  - Error of 15 % due to the use of traffic simulation
- **Emissions calculation with COPERT III**
  - Large variability (factor of 2 or more) depending on the assumptions used (vehicle fleet composition, …) but no adjustment
- **Topography of buildings** : development of a program to calculate automatically width and height of the streets from GIS buildings maps

Comparisons with passive samplers

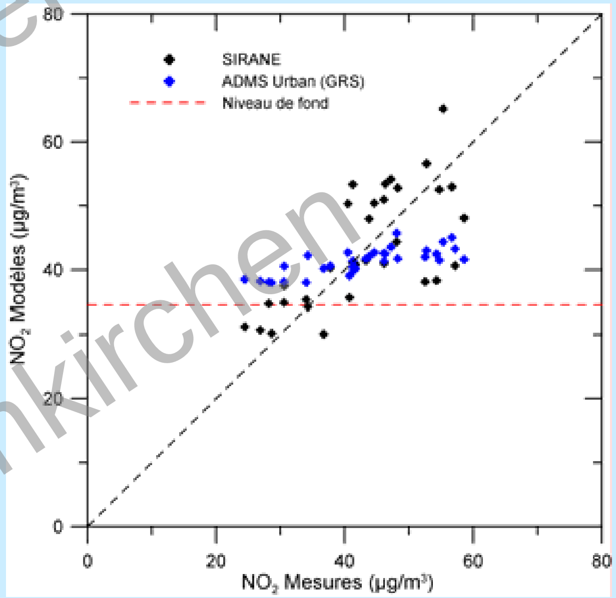
Passive samplers NO_2 concentration (µg/m³)

Concentration average over 2 weeks

SIRANE & ADMS DM



SIRANE & ADMS GRS



- Relatively good agreement for SIRANE and ADMS DM
- Low variability for ADMS GRS :

  Tests done by Numtech show that the adjustment of the NO_X concentrations with the measurements improve the GRS chemical modelling of NO_2 which becomes better than DM

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Comparisons hourly

	Analyser 1					
	NOX		NO2			
	SIRANE	ADMS	SIRANE	ADMS DM	ADMS GRS	
FB	-21 %	-45 %	-4.9 %	-17 %	-21 %	19.8
√NMSE	57.9 %	63.9 %	34.3 %	39.5 %	50.9 %	45.8
ER	53.4 %	52.1 %	30.1 %	31.1 %	45.9 %	33.2
R	0.66	0.83	0.76	0.79	0.55	0.
MG	0.90	0.75	1.00	0.94	0.86	1.
VG	1.61	1.53	1.18	1.20	1.46	1.
FAC2	67.8 %	67.5 %	91.6 %	90.5 %	72.5 %	90.4

	Analyser 1				
	NOX		NO2		
	SIRANE	ADMS	SIRANE	ADMS DM	ADMS GRS
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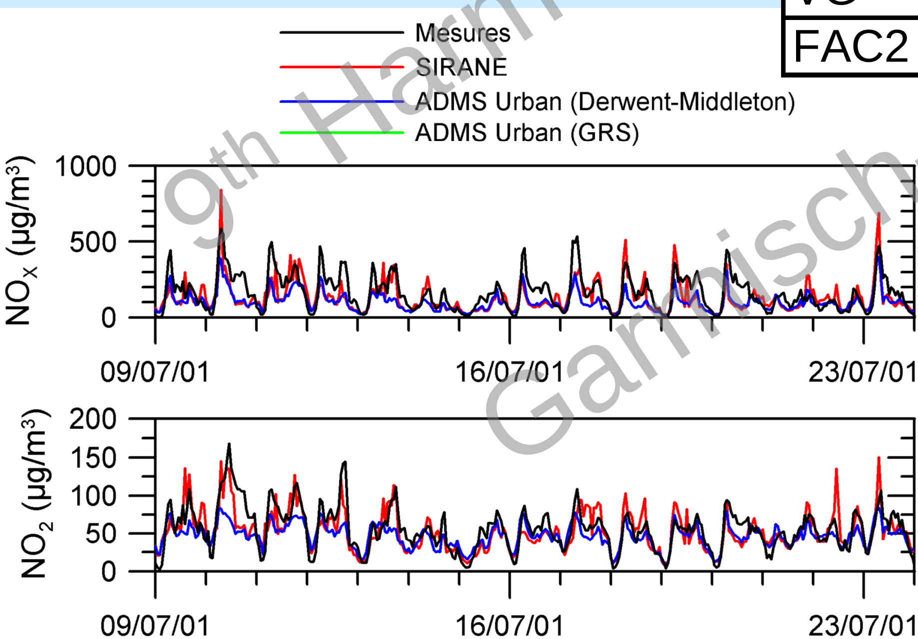

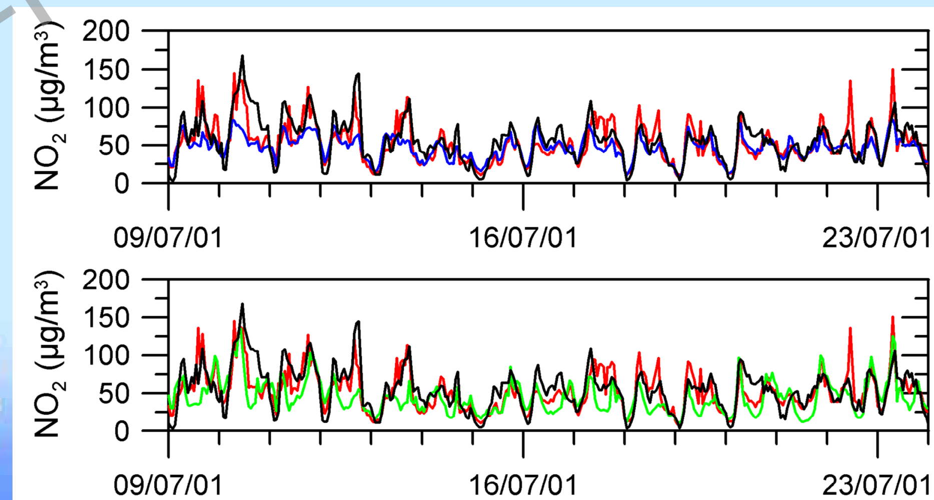

Discussion

NO$_X$ concentration field (µg/m³)
Calculated with the SIRANE model

- It is an evaluation of a chain of models and not only of the dispersion models
- Good agreement for 2 weeks averaged concentrations in different locations for SIRANE and ADMS Urban DM
- Comparison for hourly concentrations
  - The order of magnitude is reproduced
  - The time variability is generally realistic
  - Hourly concentration are more difficult to reproduce, because of :
    - The stochastic nature of atmospheric dispersion
    - The simplifications in the dispersion models
    - Incertitude in the input data (modelled and measured)

It will not change ! → The stochastic nature of atmospheric dispersion

That is our work in the future → The simplifications in the dispersion models

Traffic and emission models can improve but an important "random" variability will remain → Incertitude in the input data

Conclusions and perspectives

Conclusions

- Realisation of a field measurement campaign for the evaluation of air quality models at the district scale
- Comparison between SIRANE, ADMS Urban and the measurements :
  - "Correct" agreement for the two models (order of magnitude and variability)
  - More difficulties to reproduce hourly concentrations
  - Differences between the models :
    - Differences observed between the chemical schemes
    - With such real case, it is more difficult to identify the differences between the dynamical formulations

Perspectives

- Need of wind tunnel experiments to improve our knowledge on dispersion processes at this scale and to provide simple cases for model evaluation ; some experiments are in preparation at the Ecole Centrale de Lyon
- Need of field tracer experiments in a dense network of streets (not a group of obstacles)