POLLUTANT SOURCE IDENTIFICATION IN A CITY DISTRICT BY MEANS OF A STREET NETWORK INVERSE MODEL

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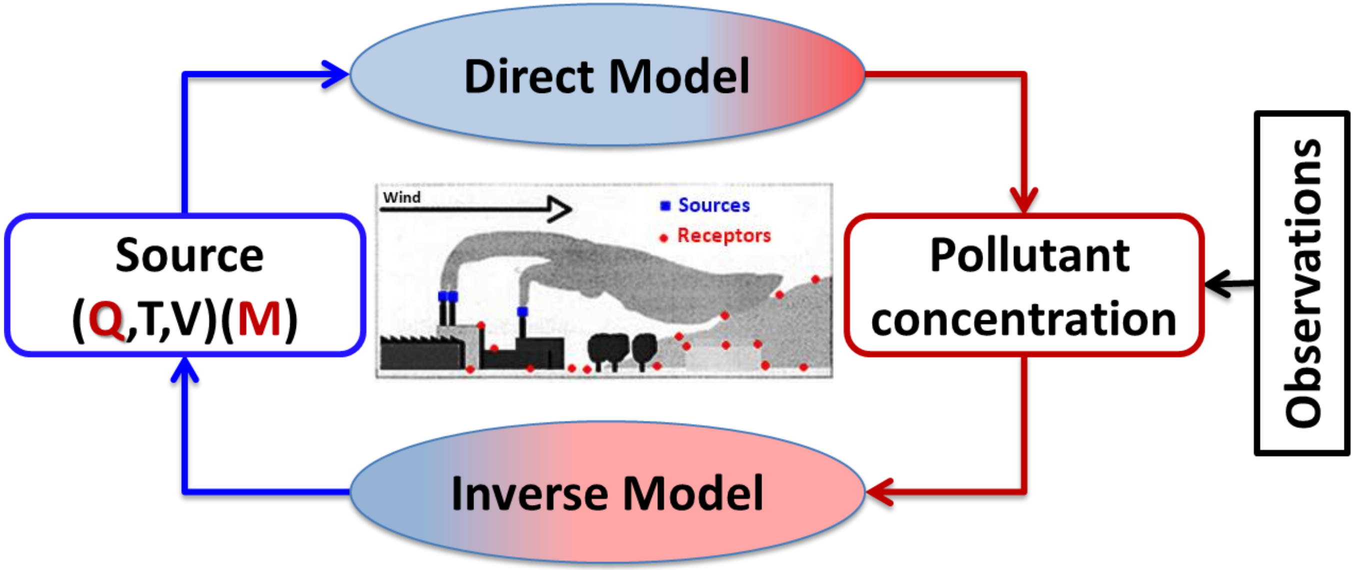

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4. General algorithm

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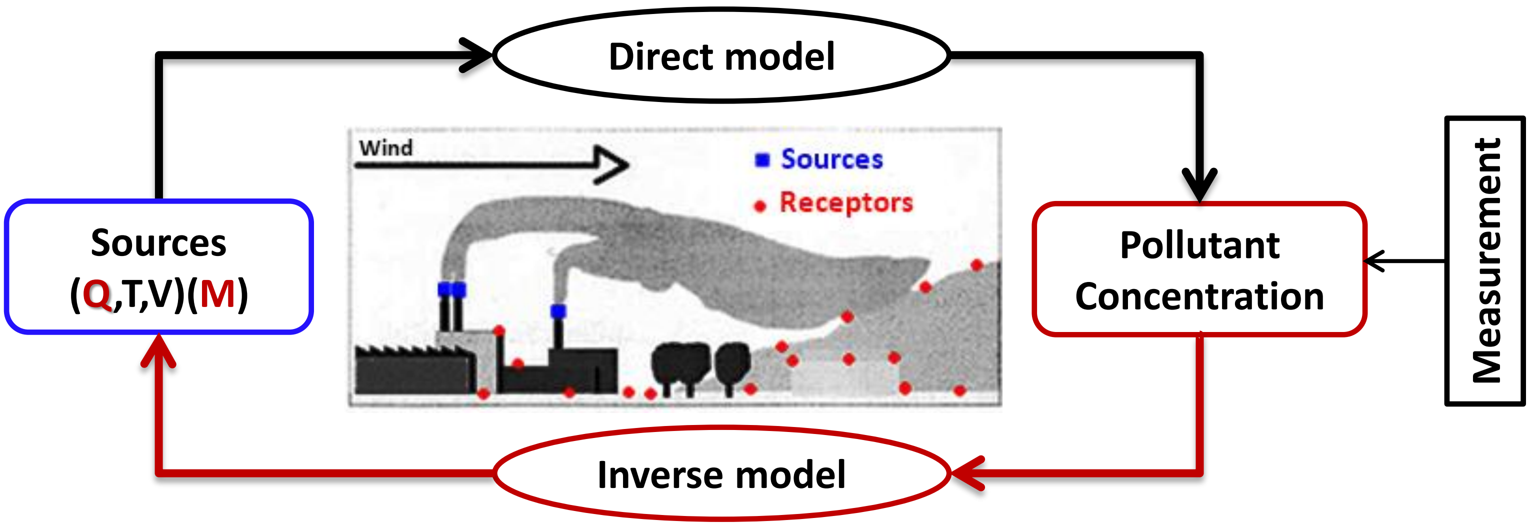
1. Inverse modelling tools
2. Source strength
3. Source location

IV. Conclusions and Perspectives

I. Introduction

I – Introduction

- **Inverse modelling** is used to identify the characteristics of pollutant sources (position and emission rate) using the receptors measurement.



- **The aim** of the study is to identify a single stationary pollution source placed in a city district and whose position and flow rate are unknown.

- To that purpose we use :
  - **Direct model - SIRANE**.
  - An **inverse algorithm**
  - **Observations – wind tunnel experiments**.

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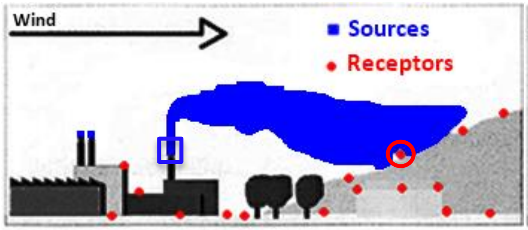
II. Formulation of inverse problem

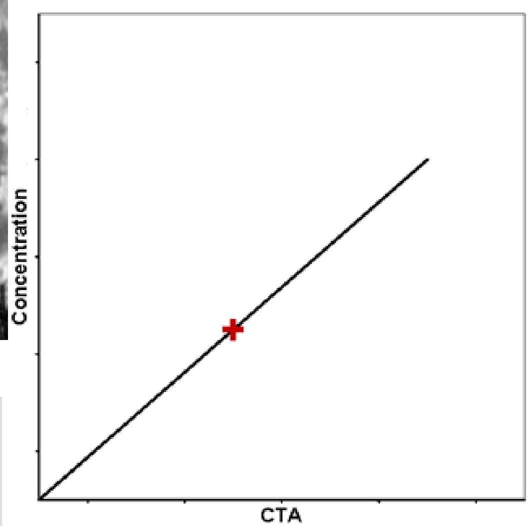
1. Simple cases
2. General cases
3. Philosophy of inverse model
4. General algorithm

II – Formulation of inverse problem

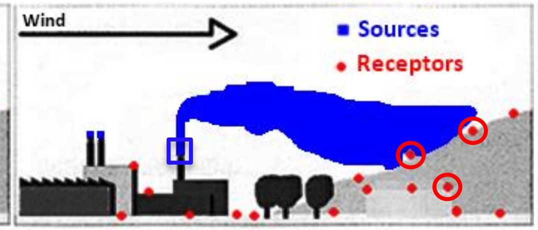
1 – Simple cases



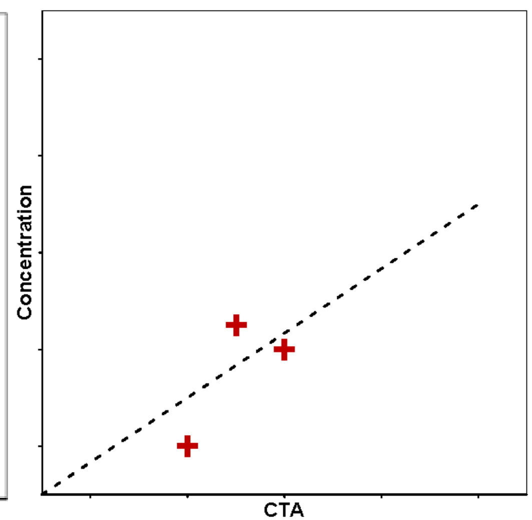
$$C_1^{Obs} = ATC_{1\rightarrow 1} * Q_1$$



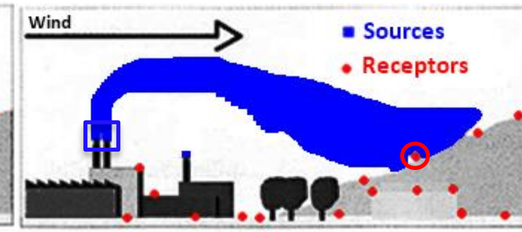
- Single solution.



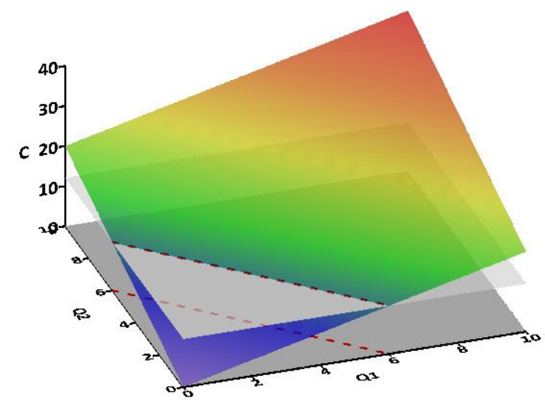
$$\begin{cases} C_1^{Obs} = ATC_{1\rightarrow 1} * Q_1 \\ C_2^{Obs} = ATC_{1\rightarrow 2} * Q_1 \\ C_3^{Obs} = ATC_{1\rightarrow 3} * Q_1 \end{cases}$$

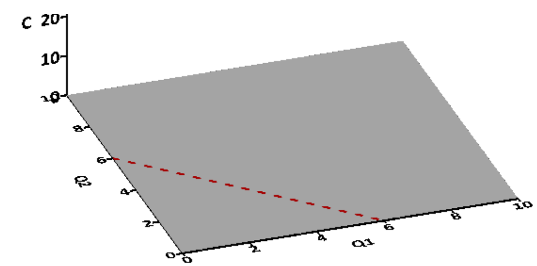


- No exact solution.



$$C_1^{Obs} = ATC_{1\rightarrow 1} * Q_1 + ATC_{2\rightarrow 1} * Q_2$$

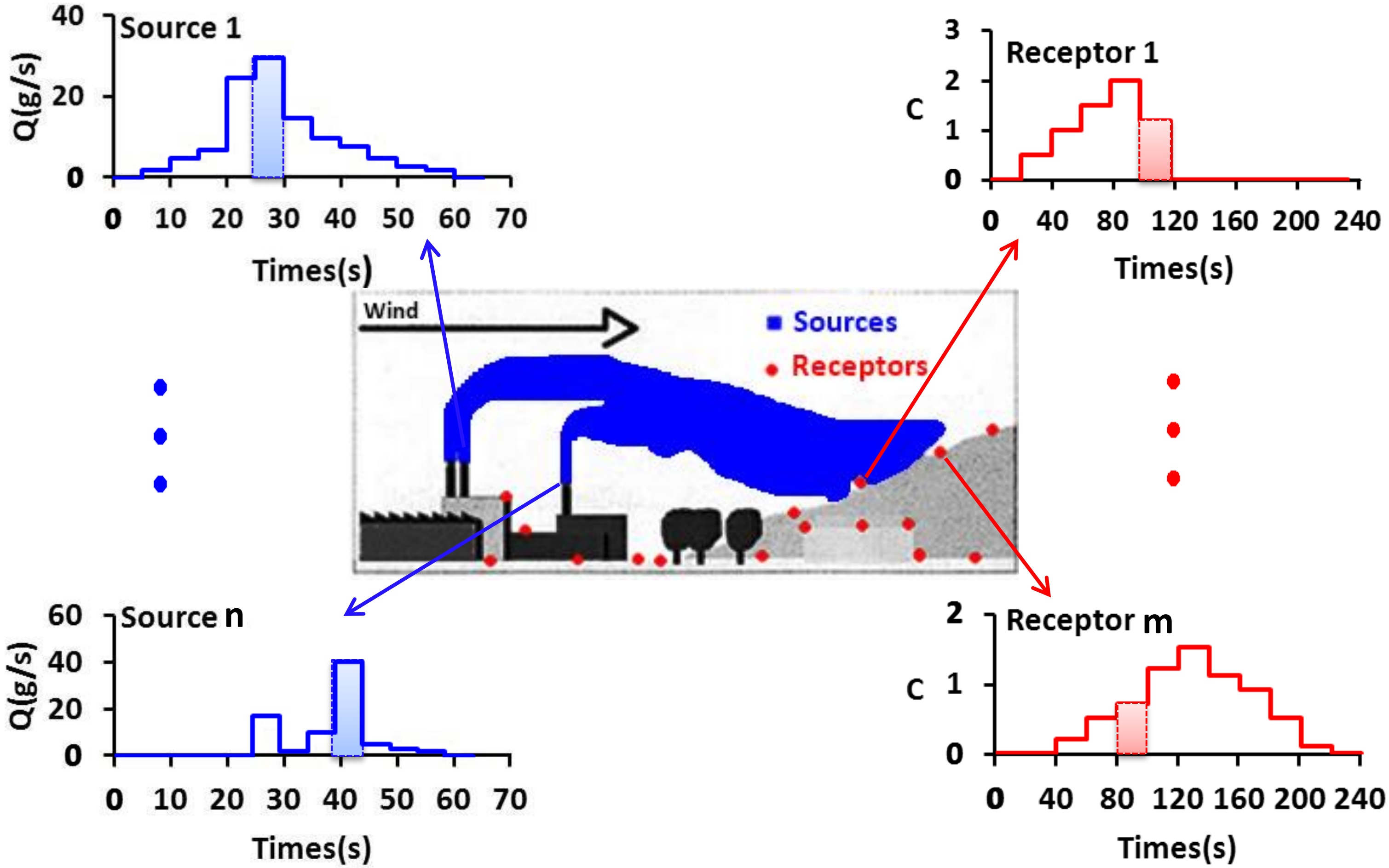




- Infinity of solutions.

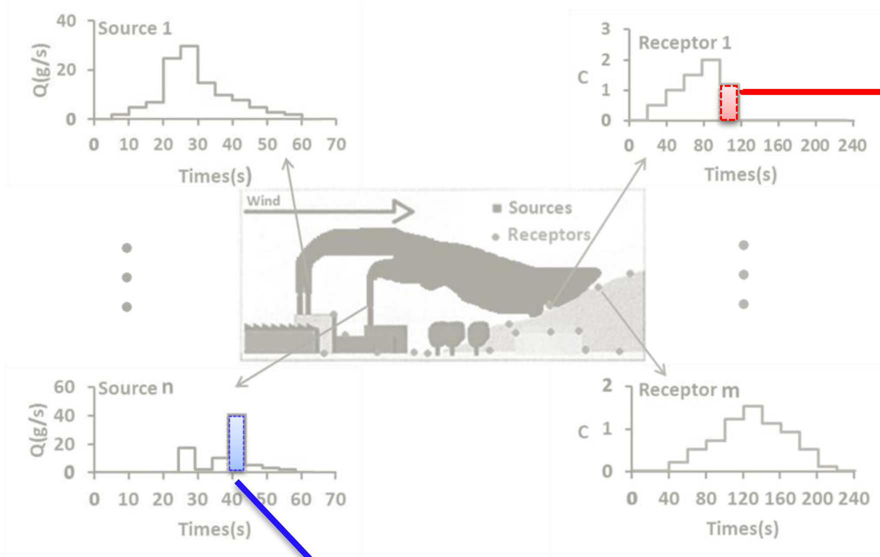
II – Formulation of inverse problem

2 – General cases



II – Formulation of inverse problem

2 – General cases



$$\begin{pmatrix} & \vdots & \\ \cdots & ATC_{T^k_{[Source(i)]} \rightarrow R_j(t_l)} & \cdots \\ & \vdots & \end{pmatrix} * \begin{pmatrix} T^1_{[Source(1)]} \\ \vdots \\ T^k_{[Source(n)]} \\ \vdots \\ T^{n_T}_{[Source(n)]} \end{pmatrix} = \begin{pmatrix} C_{R_1}(t_0) \\ \vdots \\ C_{Rj(t_l)} \\ \vdots \\ C_{R_{n_R}}(t_{n_{ob}}) \end{pmatrix}$$

$$ATC(m*n) \quad * \quad Q(n,1) \quad = \quad C(m,1)$$

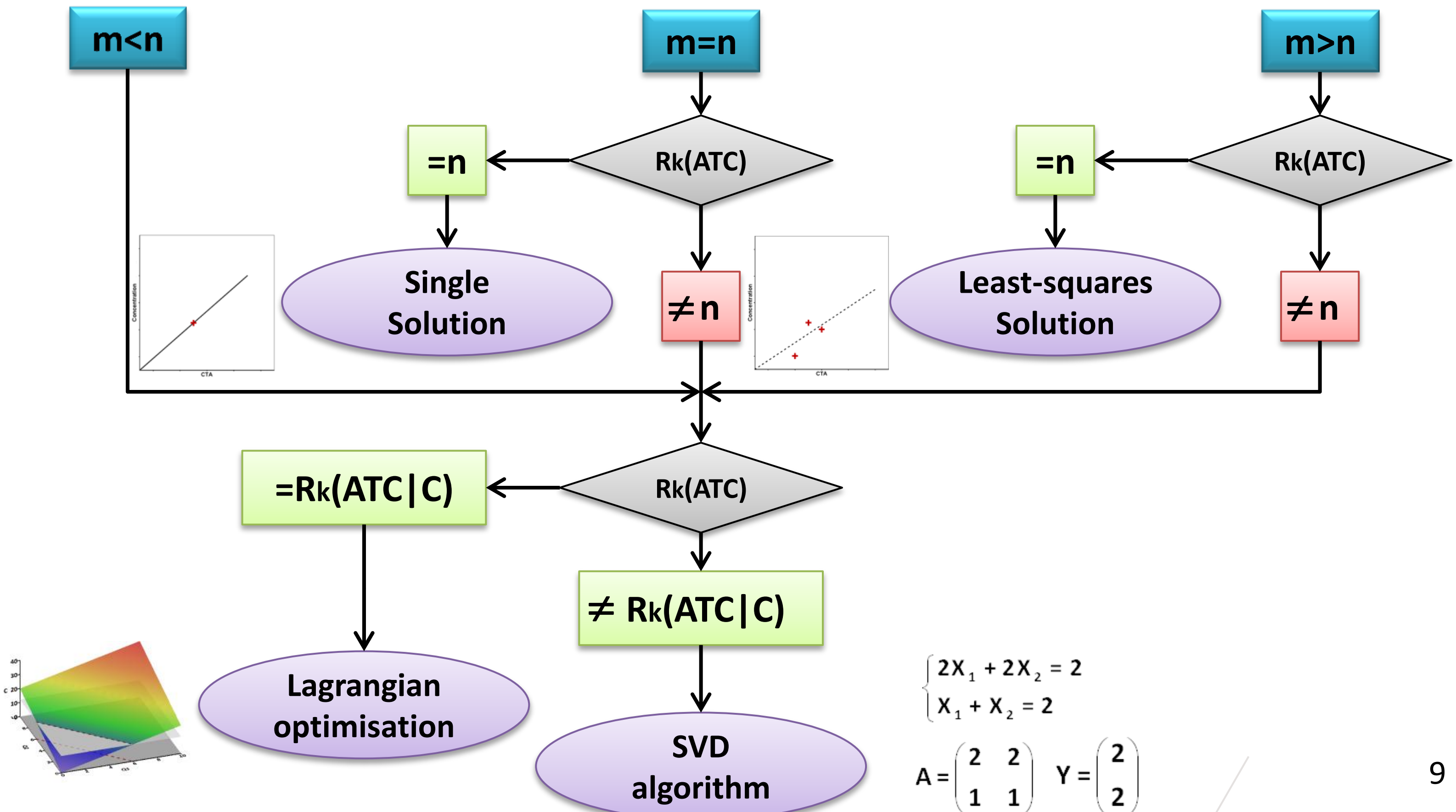
II – Formulation of inverse problem

3 – Philosophy of inverse model

- The actual code solves the problem in the sense of least-squares:

$$J_a = \frac{1}{2}\left\| C - ATC * Q \right\| = \frac{1}{2}\left(C - ATC * Q\right)^t \left(C - ATC * Q\right)$$

- Specific algorithms are implemented to treat the cases where the problem is ill-posed and ill-defined.



$$\begin{cases} 2X_1 + 2X_2 = 2 \\ X_1 + X_2 = 2 \end{cases}$$

$$A = \begin{pmatrix} 2 & 2 \\ 1 & 1 \end{pmatrix} \quad Y = \begin{pmatrix} 2 \\ 2 \end{pmatrix}$$

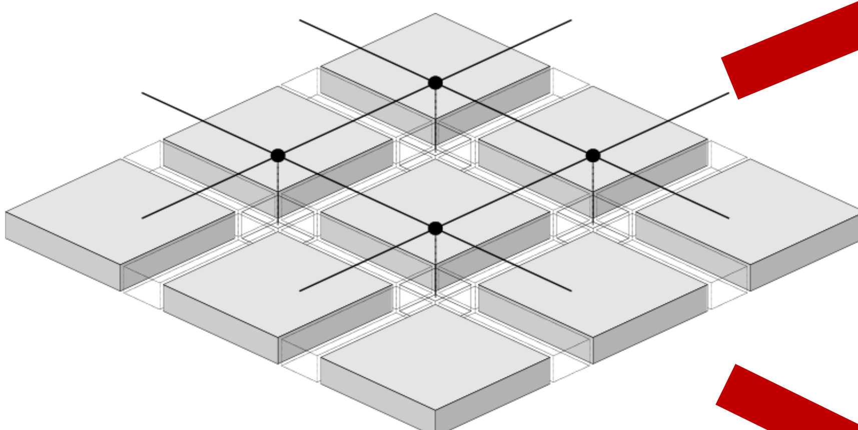
III. Pollutant source identification in a city district

1. Inverse modelling Tools
   a) Direct model : SIRANE
   b) Wind tunnel experiments
2. Source strength
3. Source location
   a) Search algorithm
   b) Test case

1 – Inverse modelling tools

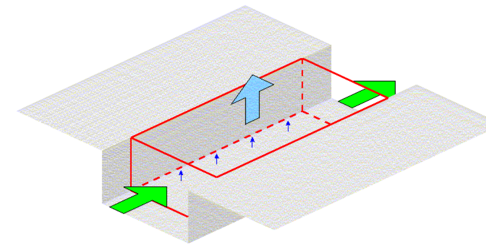
a – Direct model : SIRANE

Network of streets

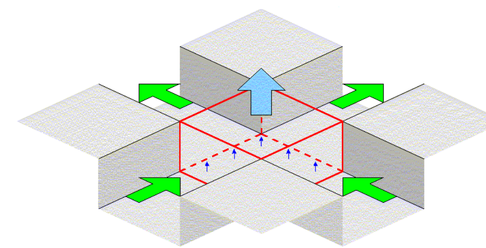


See (Soulhac et al., 2011; 2010)

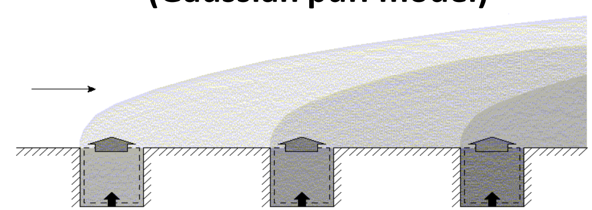
Unsteady pollutant budget in each street



Exchange at intersections



Transport over the roof level (Gaussian puff model)



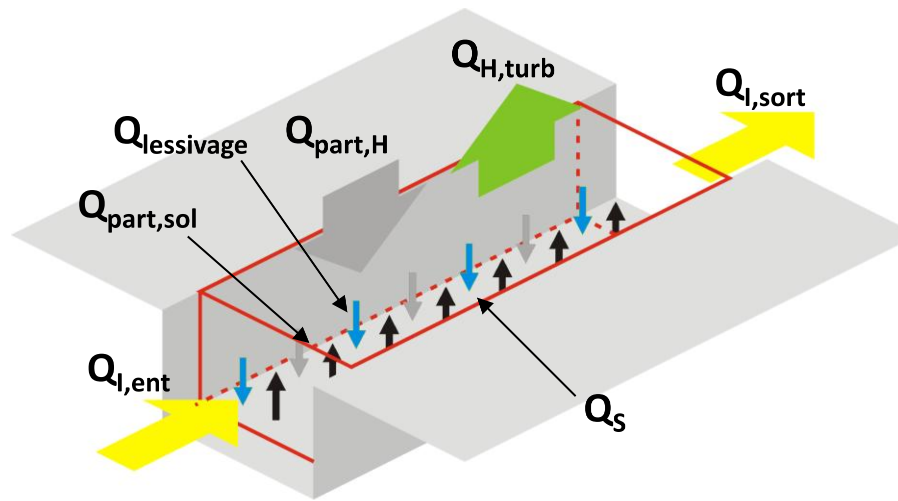
Concentration model for each street

- Budget of pollutant fluxes within the street

$$\underbrace{Q_S + Q_{I,ent} + Q_{part,H}}_{\text{Fluxes in}} - \underbrace{Q_{H,turb} + Q_{I,sort} + Q_{part,sol} + Q_{lessivage}}_{\text{Fluxes out}} = 0$$

- Turbulent exchange at the interface

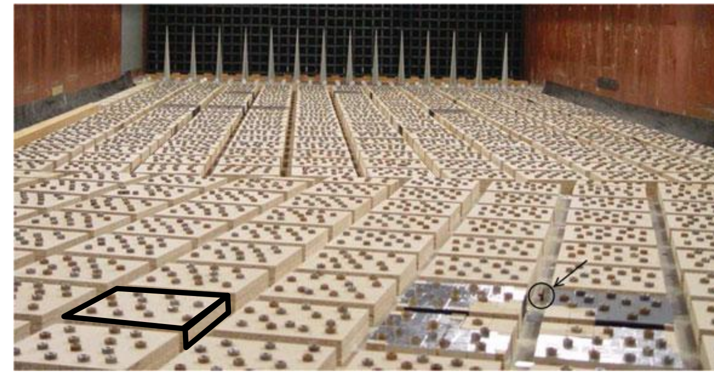
$$Q_{H,turb} = \frac{\sigma_w WL}{\sqrt{2\pi}}\left(C_{rue} - C_{rue,ext}\right)$$



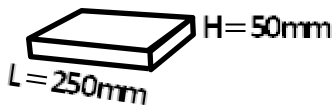
1 – Inverse modelling tools

b – Wind tunnel experiments and direct model validation

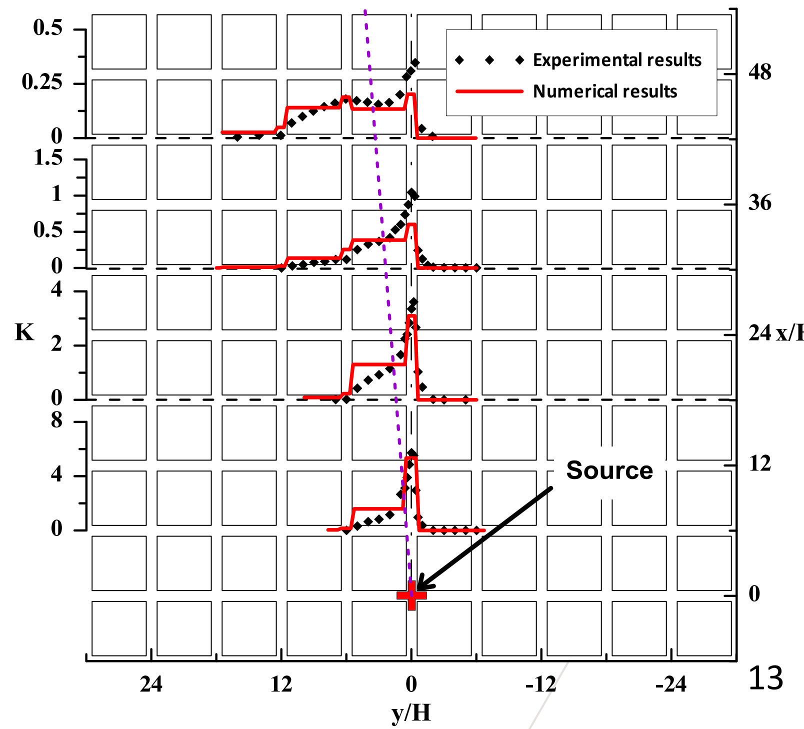
- The experimental measurements used are those presented by ***Garbero et al. (2010)***.



- The idealised city district is made up by blocks with squared section.



- A stationary source of a passive scalar ***Q*** used.



- The mean concentrations are expressed in a standard dimensionless :

$$K(x,y,z)=\frac{CU_H LH}{Q}*10^{-6}$$

where

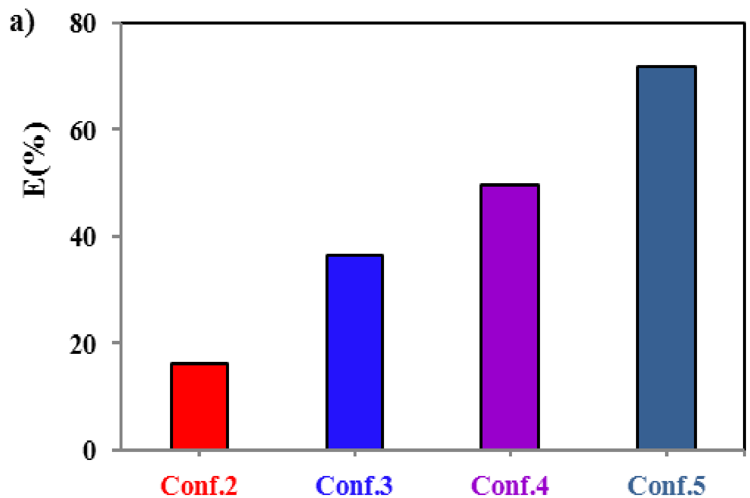
C : is the measured mean concentration (ppm)

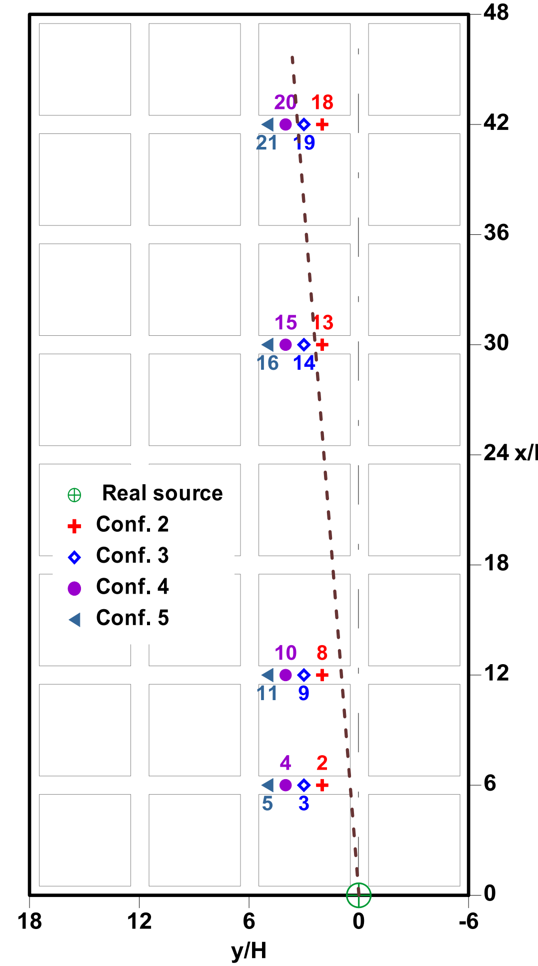
U_H : is the velocity at roof height ***(Garbero et al, 2010)***.

2 – Source strength

Sensitivity of the position of the receptors

- **a) The receptors locate in four different streets :**
  - Conf.2={2;8;13;18}
  - Conf.3={3;9;14;19}
  - Conf.4= {4;10;15;20}
  - Conf.5={5;11;16;21}



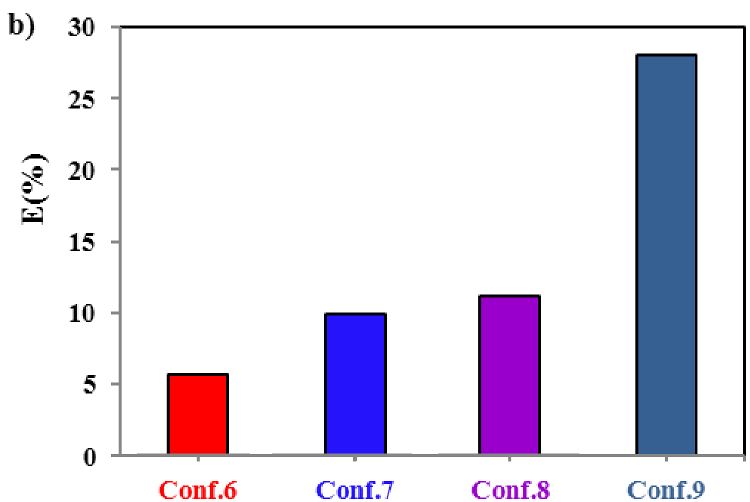


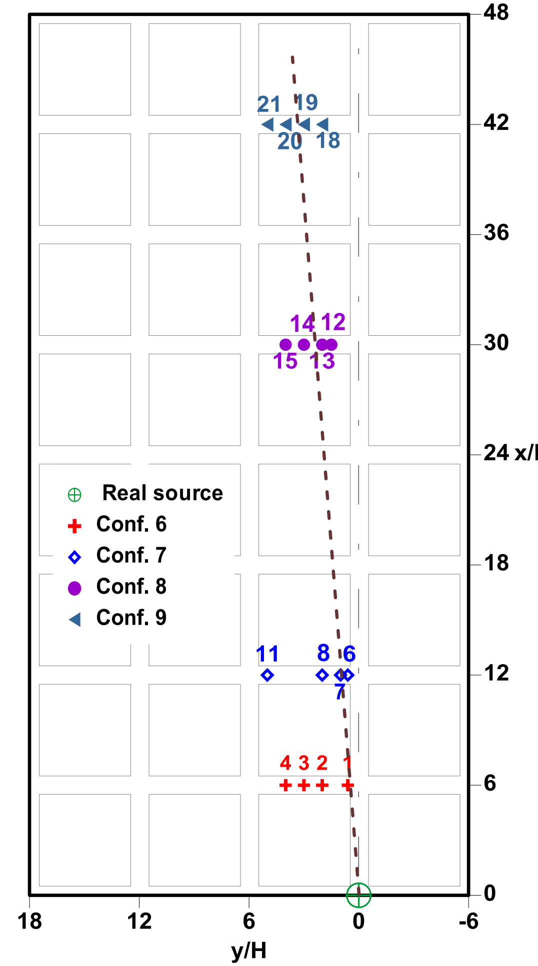
- The relative error between the inversion results and the real strength increases as we move laterally away from the center of masse of the plume.

2 – Source strength

Sensitivity of the position of the receptors

- **b) The receptors placed in a same street:**
  - Conf.6={1;2;3;4}
  - Conf.7={6;7;8;11}
  - Conf.8={12;13;14;15}
  - Conf.9={18;19;20;21}.



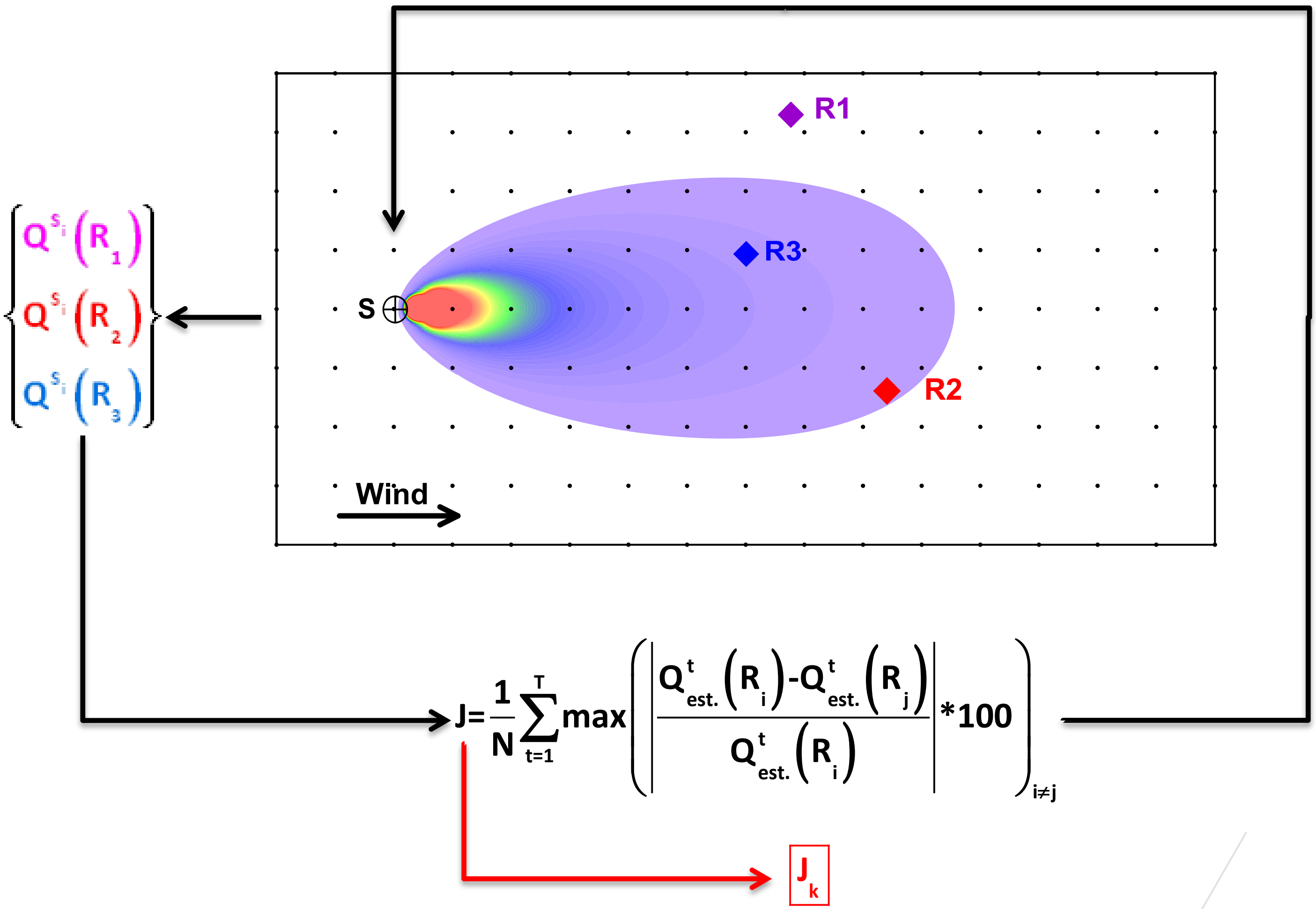


- The relative error between the inversion results and the real strength of the source pollution increases for increasing distances from the source.

3 – Source location

a – Search algorithm

- We apply a direct method algorithm to identify rapidly **the position** and **the emission rate** (strength) of **the source**. The algorithm tests different source locations, distributed over a regular mesh. It selects the source location that minimizes the cost function J.



$$J=\frac{1}{N}\sum_{t=1}^{T}\max\left(\left|\frac{Q^t_{est.}(R_i)-Q^t_{est.}(R_j)}{Q^t_{est.}(R_i)}\right|*100\right)_{i\neq j}$$

3 – Source location

a – Search algorithm

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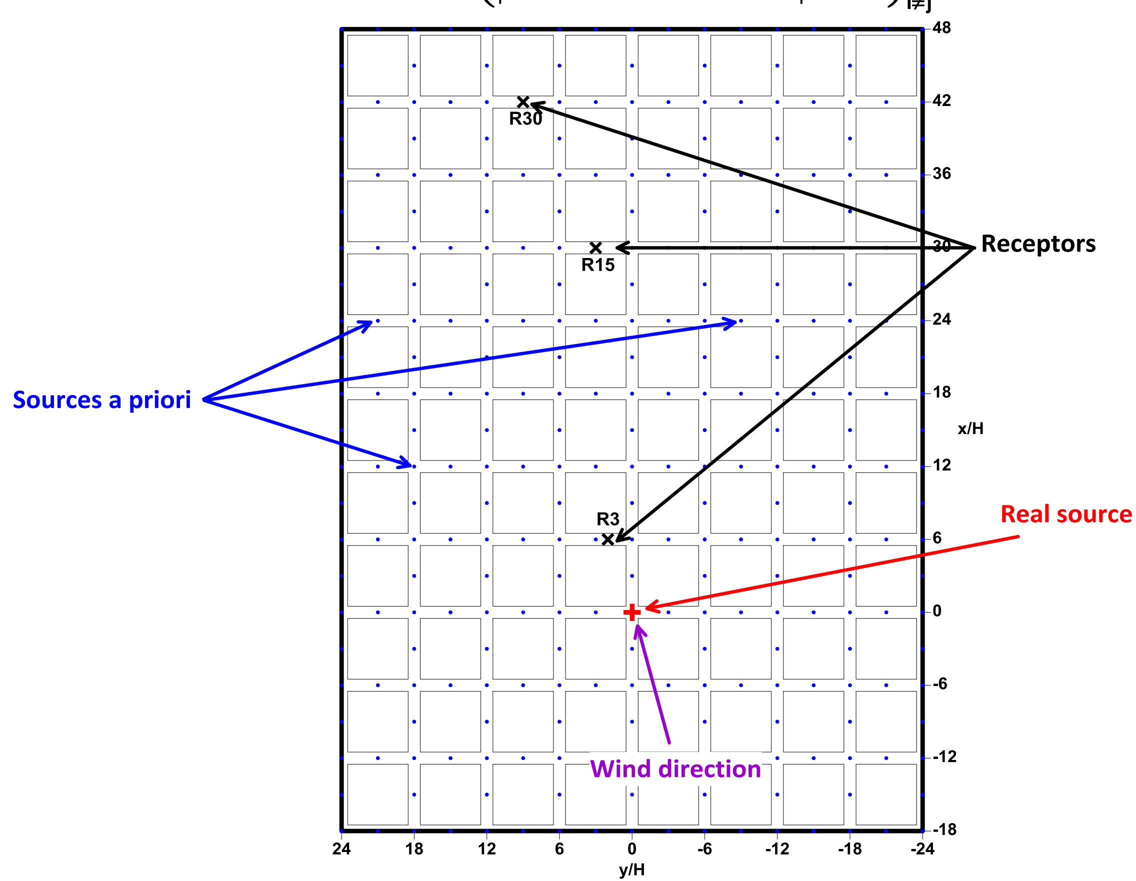
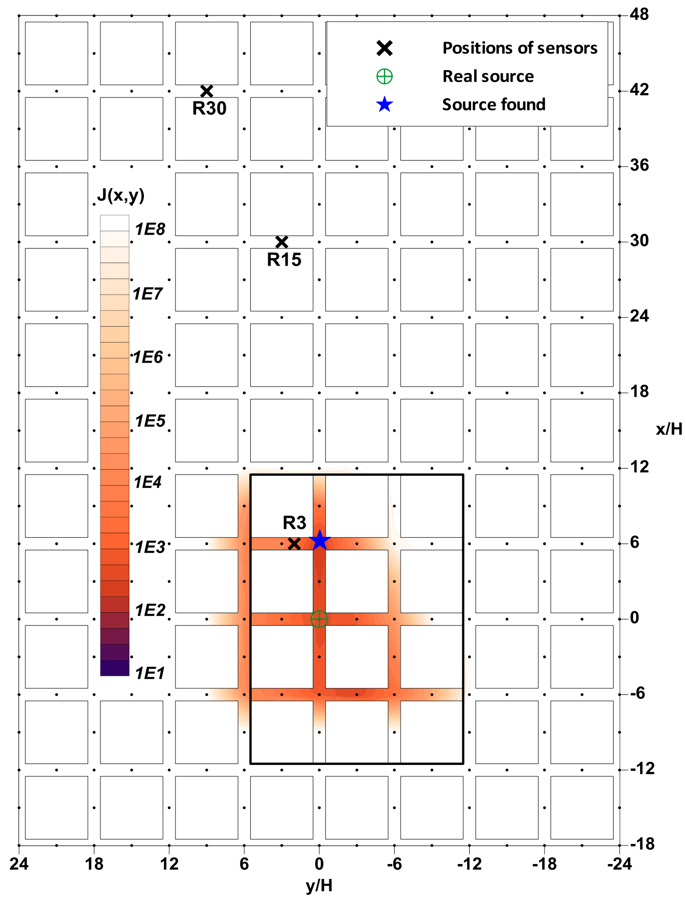


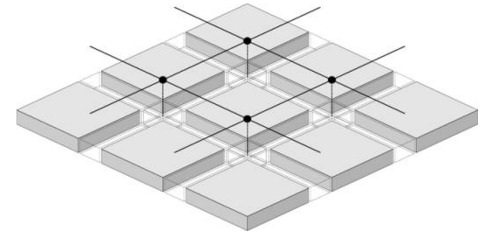
3 – Source location
b – Test case

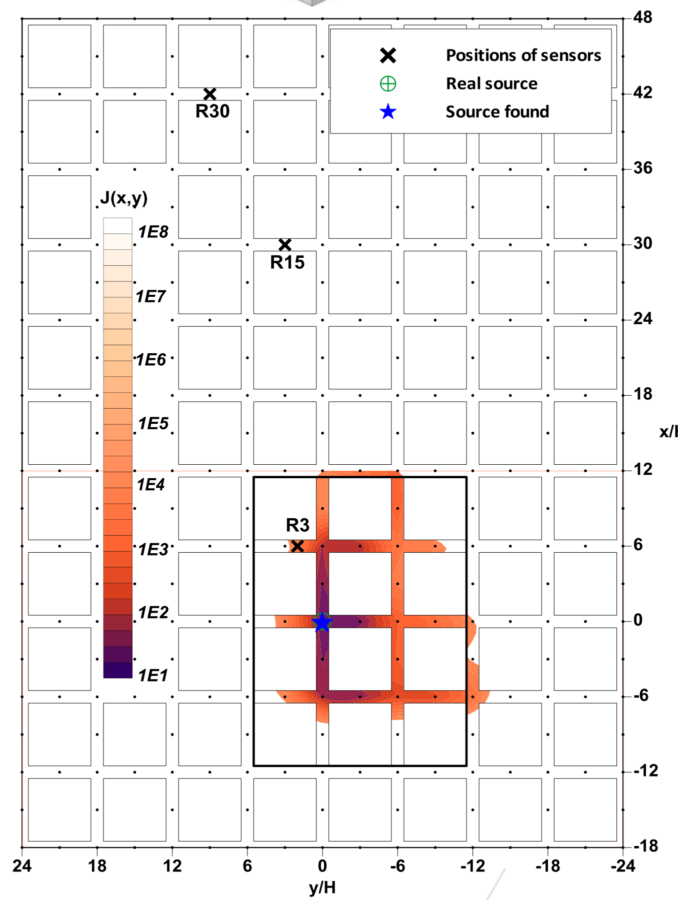
Gaussian puff model

$$C = \frac{M}{8\left[\pi\left(t-t_0\right)\right]^{3/2}\sqrt{K_x K_y K_z}} \exp\left[-\frac{1}{4\left(t-t_0\right)}\left(\frac{\left(x-x_0\right)^2}{K_x}+\frac{\left(y-y_0\right)^2}{K_y}+\frac{\left(z-z_0\right)^2}{K_z}\right)\right]$$



SIRANE model





Plot contours of the cost function J

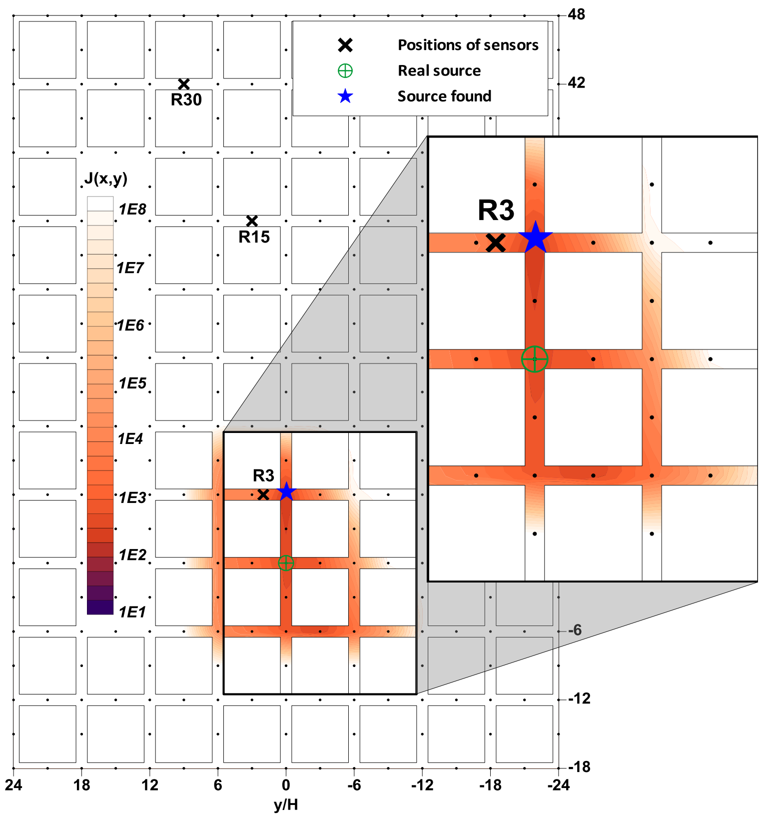
3 – Source location

b – Test case

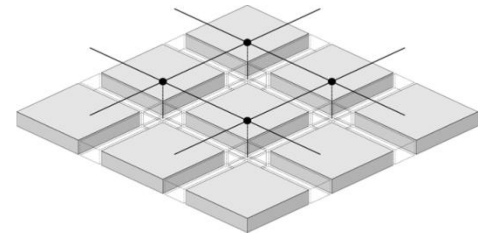
Gaussian puff model

$$C = \frac{M}{8\left[\pi\left(t-t_0\right)\right]^{3/2}\sqrt{K_x K_y K_z}} \exp\left[-\frac{1}{4\left(t-t_0\right)}\left(\frac{\left(x-x_0\right)^2}{K_x}+\frac{\left(y-y_0\right)^2}{K_y}+\frac{\left(z-z_0\right)^2}{K_z}\right)\right]$$

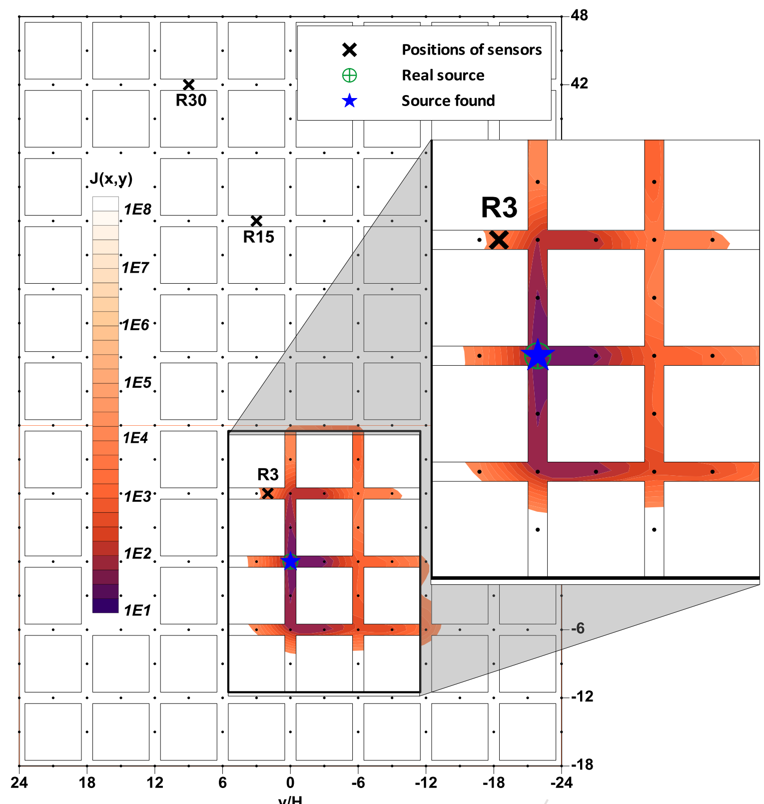
- Relative error of strength = 200%



SIRANE model



- Relative error of strength = 30,5%



Plot contours of the cost function J

IV. Conclusions and Perspectives

Conclusions and Perspectives

- **Conclusions**
  - We presented a few tests of inversion to identify position and emissions rate of a pollutant source located within a city district.
  - The inverse made by combining the street network dispersion model **SIRANE** and wind tunnel measurements.
  - The use of the model **SIRANE** is more efficient than using the Gaussian puff model with the inverse algorithm to identify position and emissions rate.

- **Perspectives**
  - Future work will concern the extension of this analysis to different wind directions, obstacle layout, and time-dependent pollutant emissions.

We study the consistency of the inverse model to invert the unsteady emission rate

(see poster section T7)

THANK YOU
for your attention !