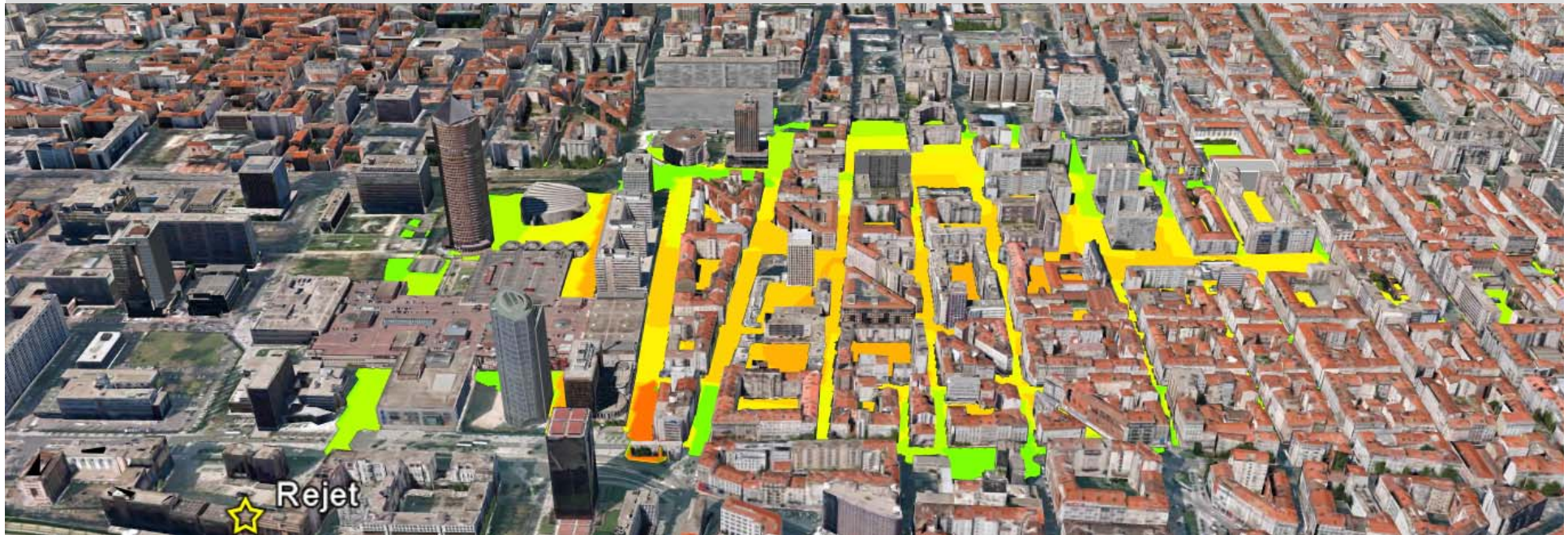


Validation of the SIRANERISK-2.0 operational model against a lagrangian particle dispersion model and a dispersion experiment on an idealized urban geometry

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14th Harmonisation within Atmospheric Dispersion Modelling for Regulatory Purposes Conference

Outline



1. Introduction and motivations
2. Description of SIRANERISK 2.0 model
3. Inter-comparison setup
4. Comparison results over rough and urban area
5. Conclusions and perspectives



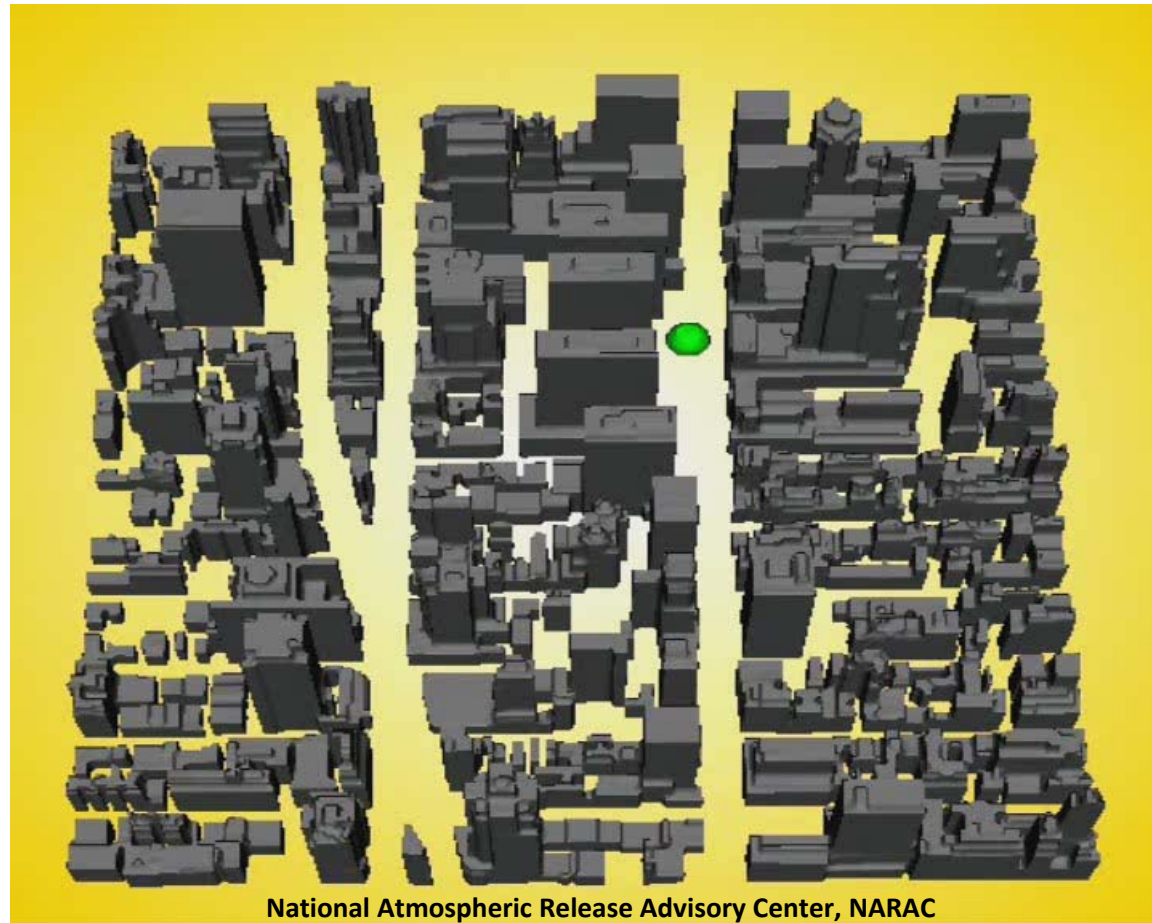


1 – Introduction and motivations

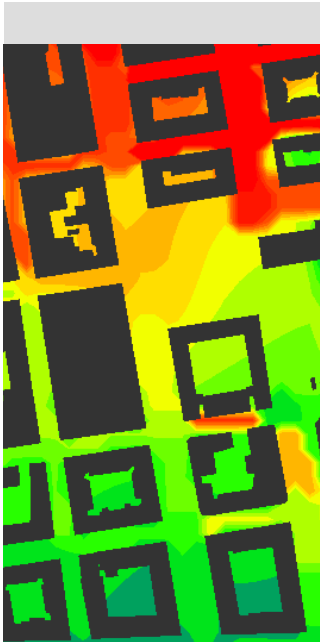
1 – Introduction and motivations

Motivations about modelling of deliberate or accidental releases

A mode of dissemination of RBC agents from deliberate or accidental releases is atmospheric dispersion in urban area



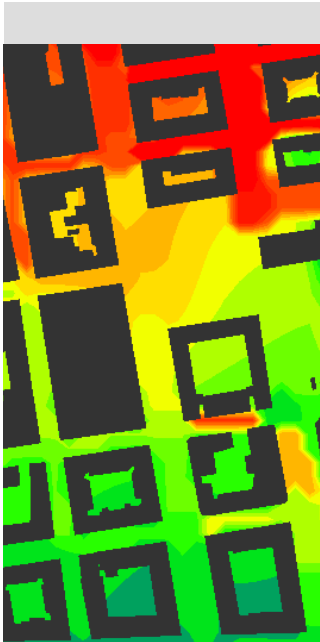
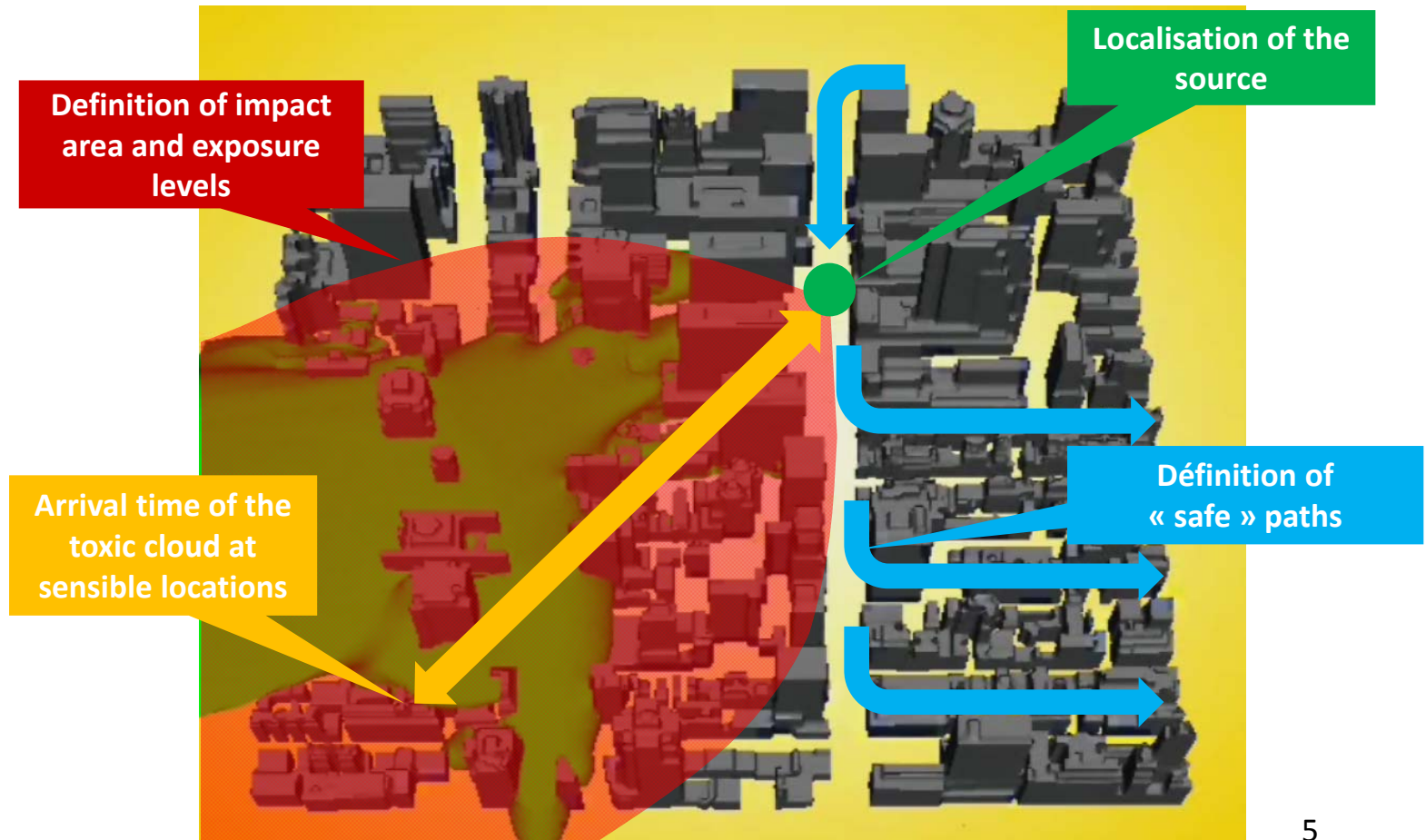
National Atmospheric Release Advisory Center, NARAC



1 – Introduction and motivations

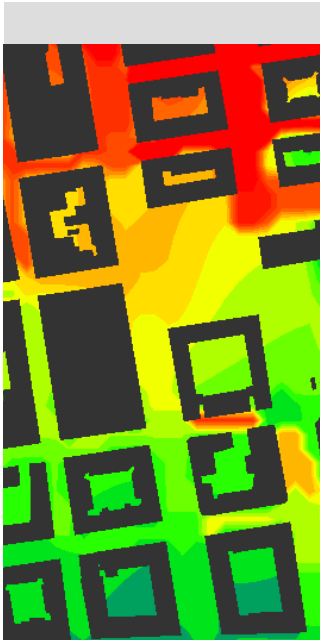
Motivations about modelling of deliberate or accidental releases

Crisis management and decision making require
different kinds of informations

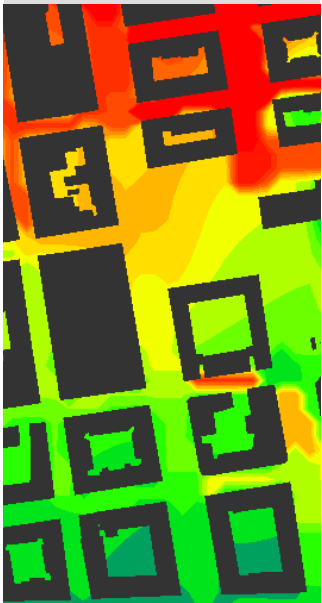


1 – Introduction and motivations

Motivations about modelling of deliberate or accidental releases



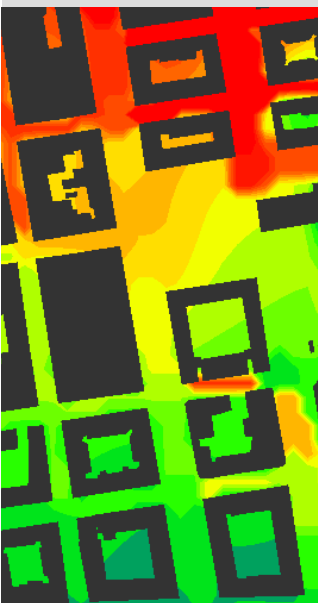
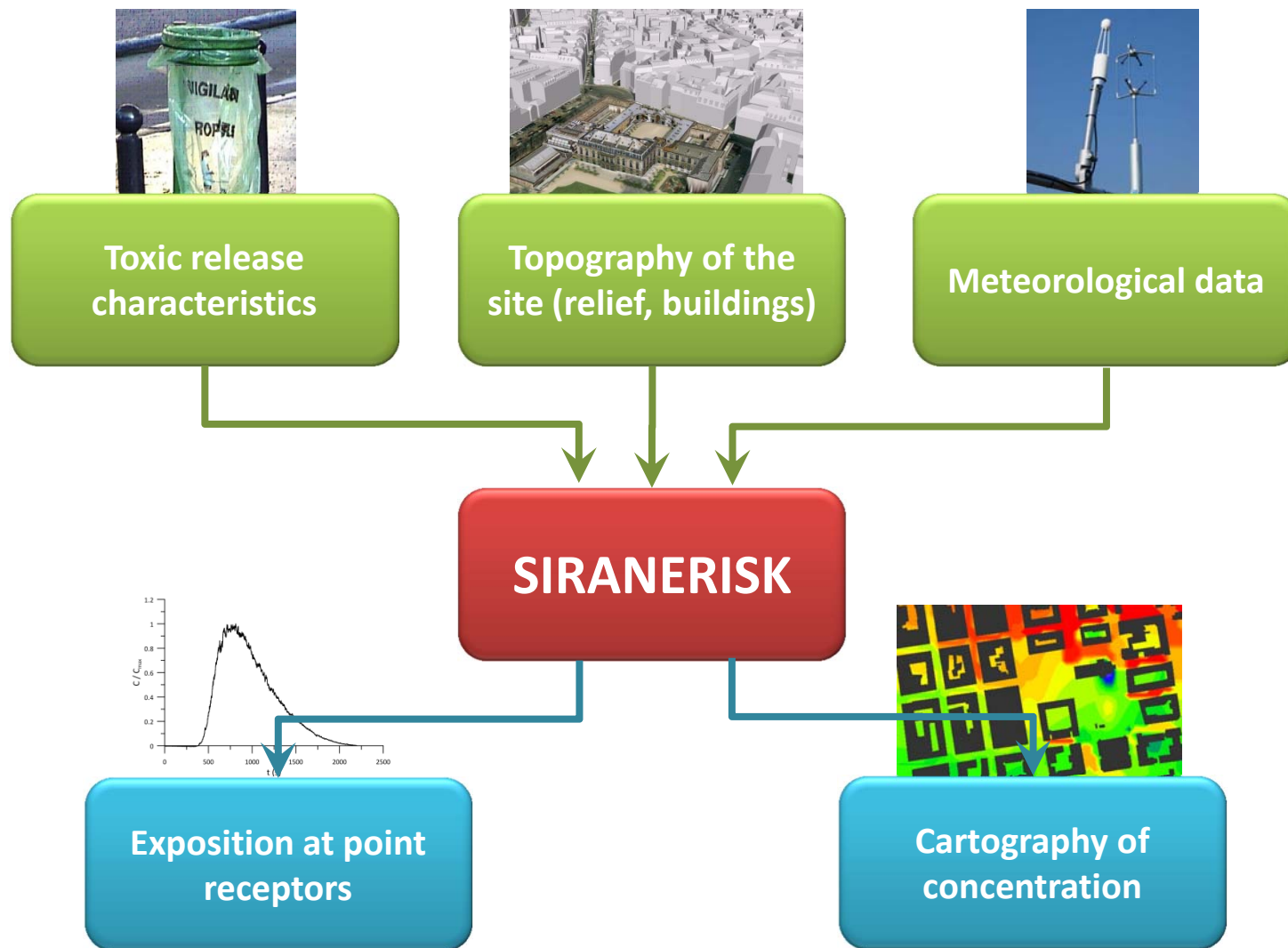
- **To answer these questions, we need fast-response tools**
- **SIRANERISK is a fast-response model adapted to describe dense urban areas**
- **Aim of this work**
 - Propose a parameterization for the wind shear effect
 - Validate the model



2 – Description of SIRANERISK model

2 – Description of SIRANERISK 2.0 model

Overview of SIRANERISK model



2 – Description of SIRANERISK 2.0 model

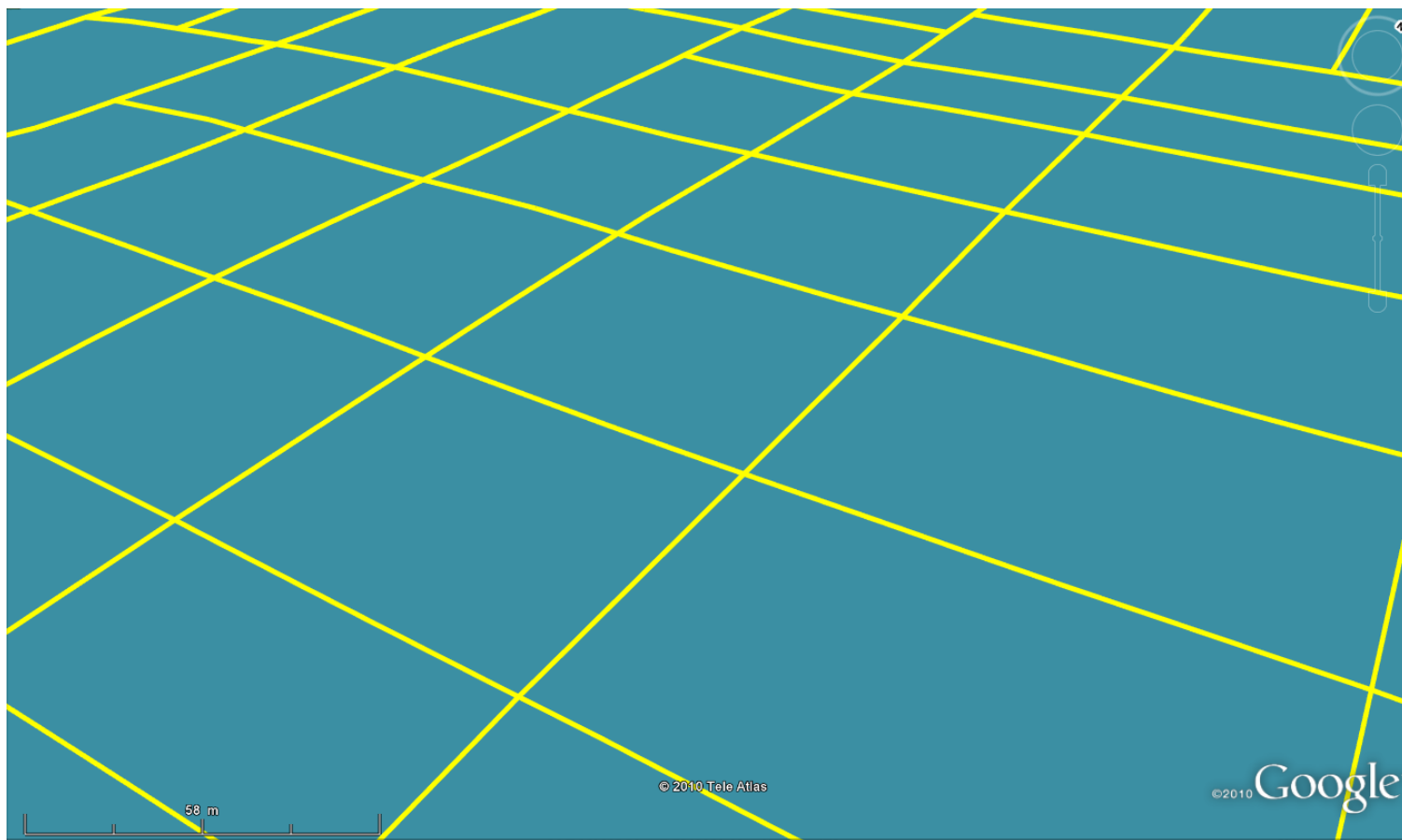
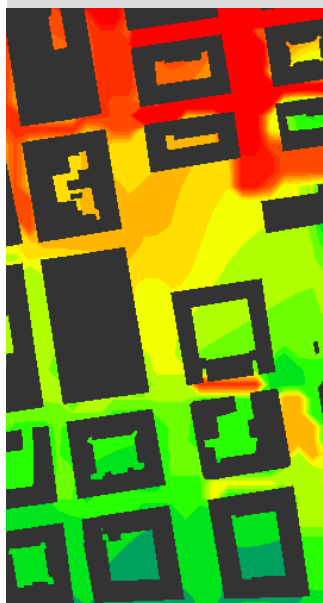
Streets network approach

Real geometry

Street volumes

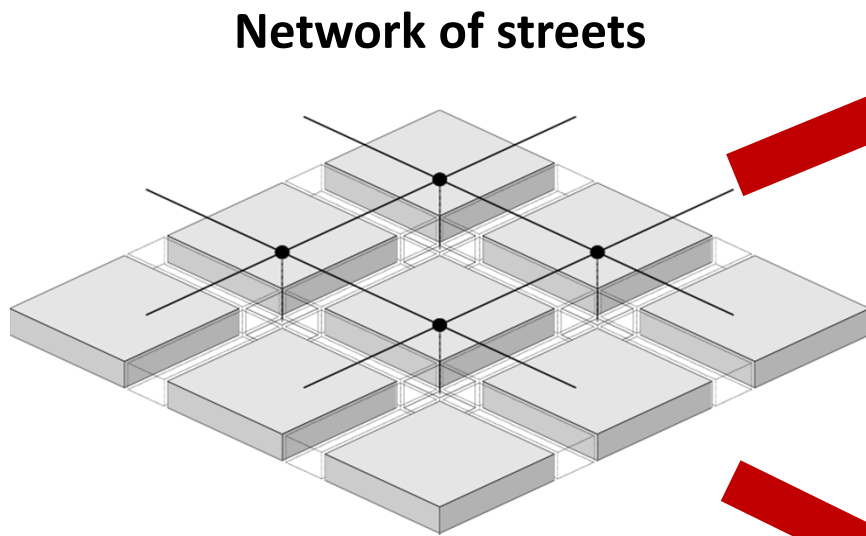
Street-canyons

Network of streets

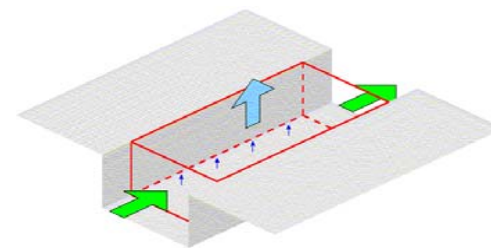


2 – Description of SIRANERISK 2.0 model

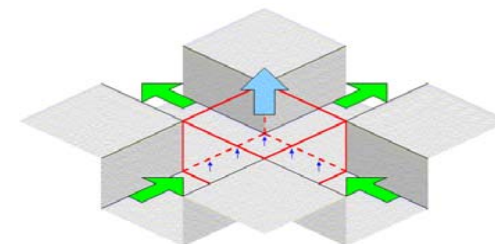
Different model parts



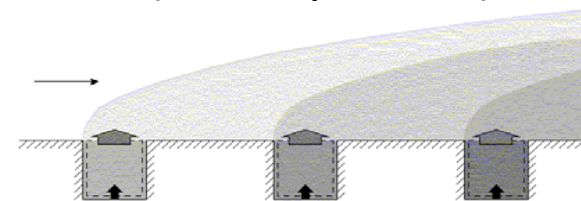
Unsteady pollutant budget in each street



Exchange at intersections

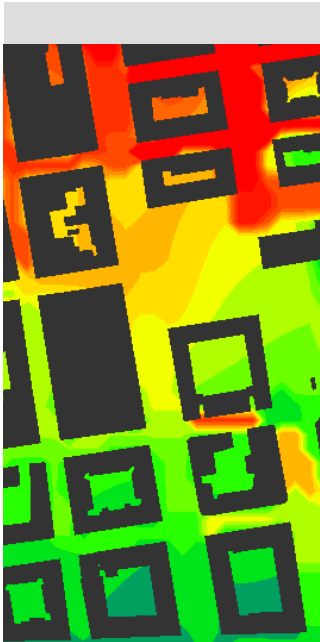


**Transport over the roof level
(Gaussian puff model)**

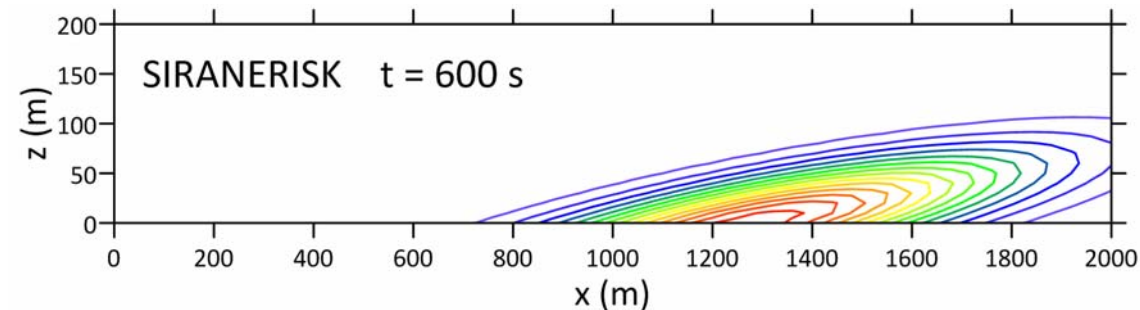


2 – Description of SIRANERISK 2.0 model

Modelling wind shear in the Gaussian puff model



- **The wind shear induces**
 - A longitudinal spreading of the cloud in the flow direction (σ_x can be one order of magnitude greater than σ_y or σ_z)
 - Enhanced dilution induces a reduction of maximum concentrations
- **It is necessary to take into account this effect in the SIRANERISK model**



2 – Description of SIRANERISK 2.0 model

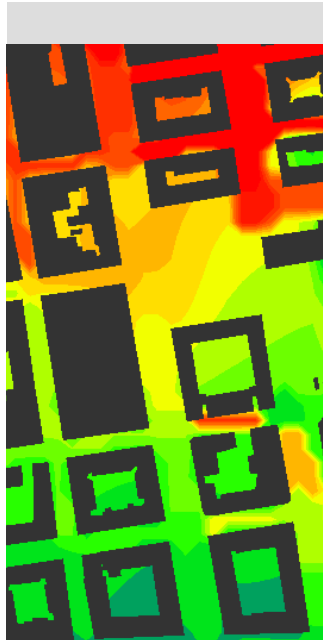
Modelling wind shear in the Gaussian puff model

- A sheared puff can be represented by a generalized gaussian distribution :

$$C = \frac{M}{(2\pi)^{3/2} \sqrt{\det(\Sigma)}} \exp\left(-\frac{1}{2} \Delta^2\right) \text{ avec } \Delta^2 = (\mathbf{x} - \boldsymbol{\mu})^T \cdot \Sigma^{-1} \cdot (\mathbf{x} - \boldsymbol{\mu})$$

- Δ is called the Mahalanobis distance
- \mathbf{x} is the location vector of the receptor
- $\boldsymbol{\mu}$ is the location vector of the puff center
- Σ^{-1} is the inverse of the variances-covariances tensor Σ , defined by :

$$\Sigma = \begin{pmatrix} \sigma_x^2 & \sigma_{xy} & \sigma_{xz} \\ \sigma_{xy} & \sigma_y^2 & \sigma_{yz} \\ \sigma_{xz} & \sigma_{yz} & \sigma_z^2 \end{pmatrix}$$



2 – Description of SIRANERISK 2.0 model

Modelling wind shear in the Gaussian puff model

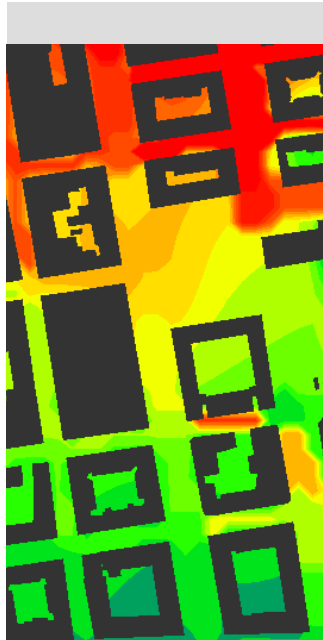
- Sykes and Henn (1995) have shown that :

$$\left. \frac{d\sigma_{ij}}{dt} \right|_{\text{shear}} = \sigma_{ik} \frac{\partial U_j}{\partial x_k} + \sigma_{jk} \frac{\partial U_i}{\partial x_k}$$

- This term can be added to the turbulent term in the evolution of the variances (standard deviations) of the puff :

$$\left. \frac{d\sigma_{ij}}{dt} \right|_{\text{tot}} = \left. \frac{d\sigma_{ij}}{dt} \right|_{\text{turb}} + \left. \frac{d\sigma_{ij}}{dt} \right|_{\text{shear}} \quad \text{with} \quad \left. \frac{d\sigma_{ij}}{dt} \right|_{\text{turb}} = 0 \quad \text{if} \quad i \neq j$$

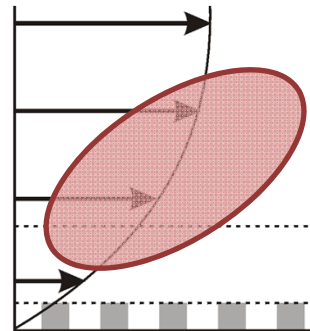
- The evolution of the variances/covariances is calculated at each time step with this formula



2 – Description of SIRANERISK 2.0 model

Modelling wind shear in the Gaussian puff model

- The problem is that the shear is not constant over the height of the puff !!



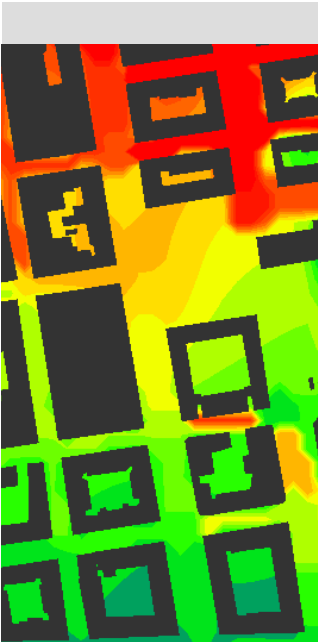
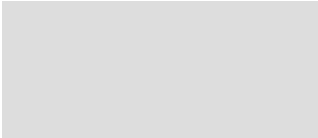
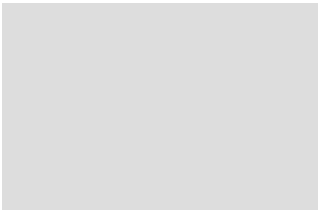
- The same problem occurs for the advection velocity. McDonald (2000) proposed a parameterization for the height of evaluation of the advection velocity (for a ground source) :

$$z_{\text{advection}} = \max(z_{\text{center}}, 0.55\sigma_z)$$

- This height is not pertinent for the shear but by analogy, we have observed that the behavior of the puff is well reproduced if the shear is calculated at :

$$z_{\text{shear}} = \max(z_{\text{center}}, 0.65\sigma_z)$$



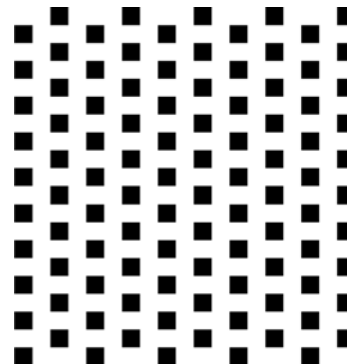
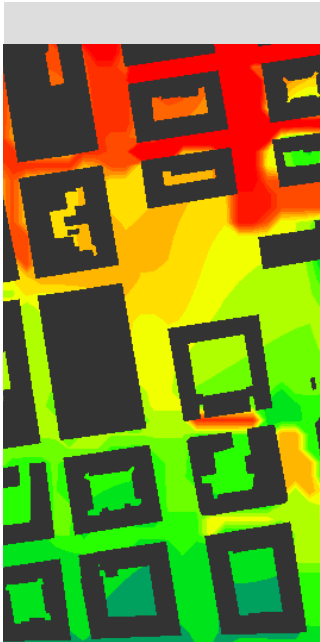


3 – Inter-comparison setup

3 – Inter-comparison setup

Lagrangian dispersion model on a sub-urban rough terrain

- In a Lagrangian dispersion model, each particle is influenced by the local velocity
- So the Lagrangian model is adequate to describe the effect of wind shear on the dispersion
- We used a Lagrangian dispersion model to study dispersion from a ground source over a rough flat terrain

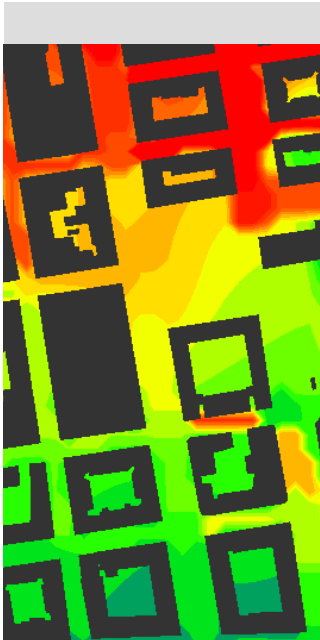


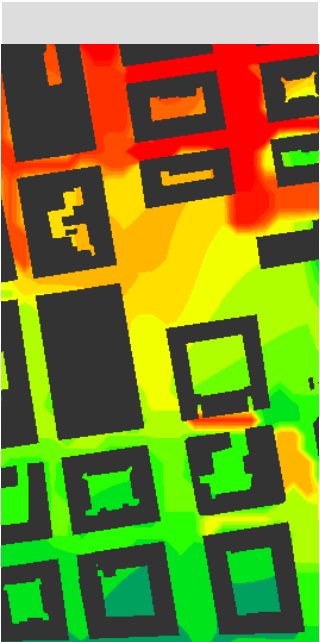
Flat terrain with
roughness $z_0 = 0.64$ m

3 – Inter-comparison setup

Wind tunnel experiments of an urban district

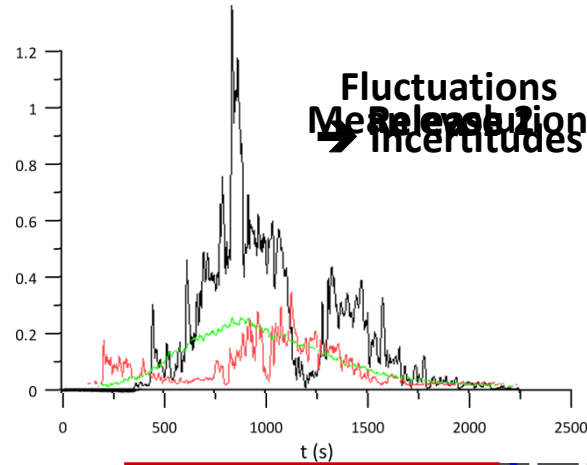
- 2 urban-type geometrical configurations
 - B30 : Street of $H = W = 50 \text{ mm}$; $L = 5H$; wind direction = 30°
 - B45 : Street of $H = W = 50 \text{ mm}$; $L = 5H$; wind direction = 45°





3 – Inter-comparison setup

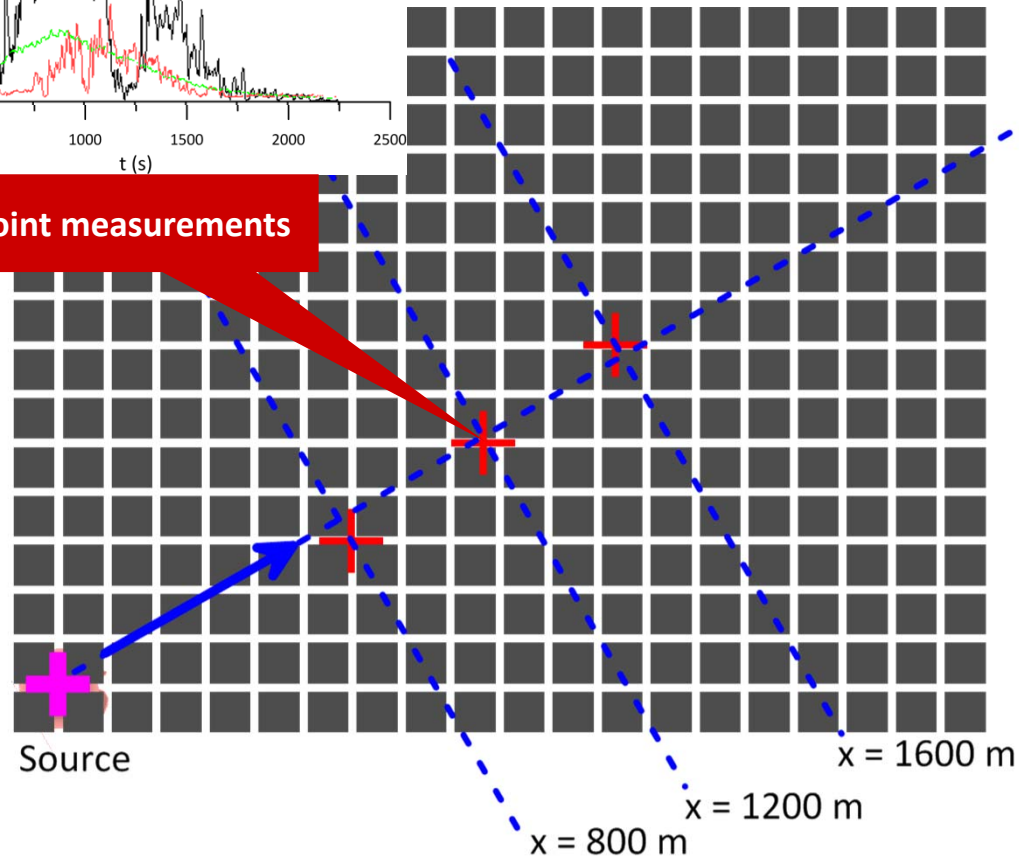
Wind tunnel experiments of an urban district



• Experimental methodology

- We performed 100 instantaneous releases
- We average measurements at each location

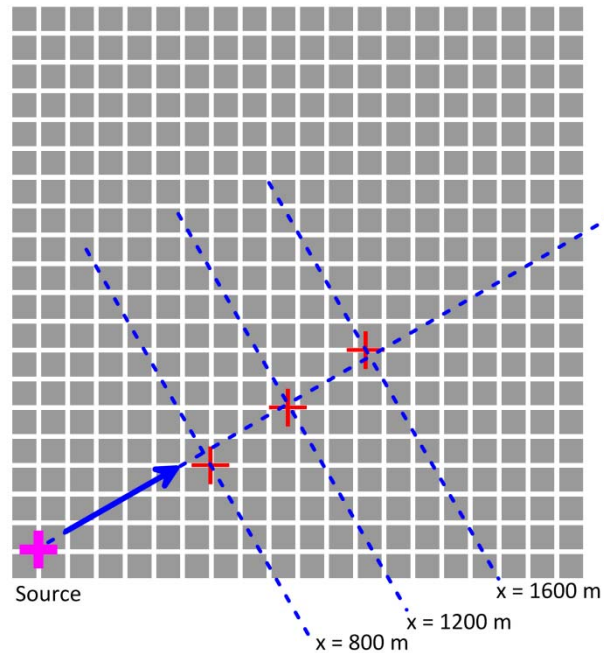
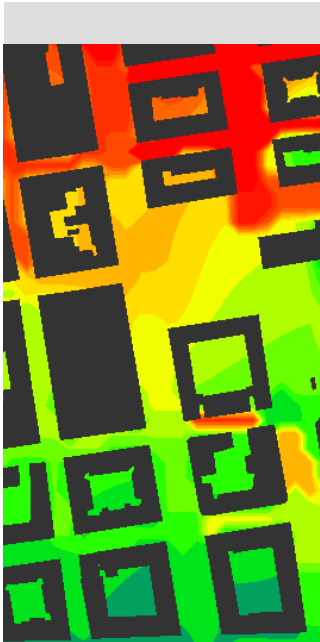
Point measurements



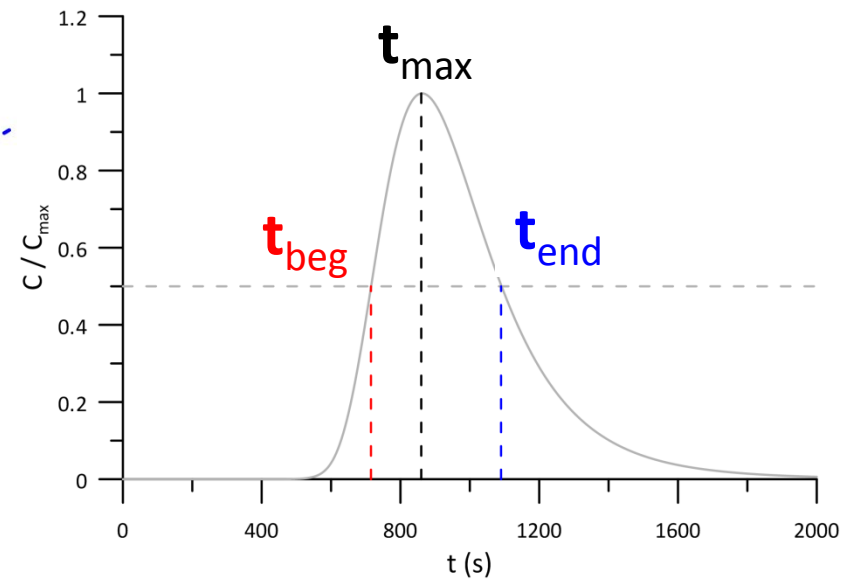
3 – Inter-comparison setup

Wind tunnel experiments of an urban district

- Analysis of the temporal evolution of the concentration at several measurement points



Localisation of point receptors downwind of the source



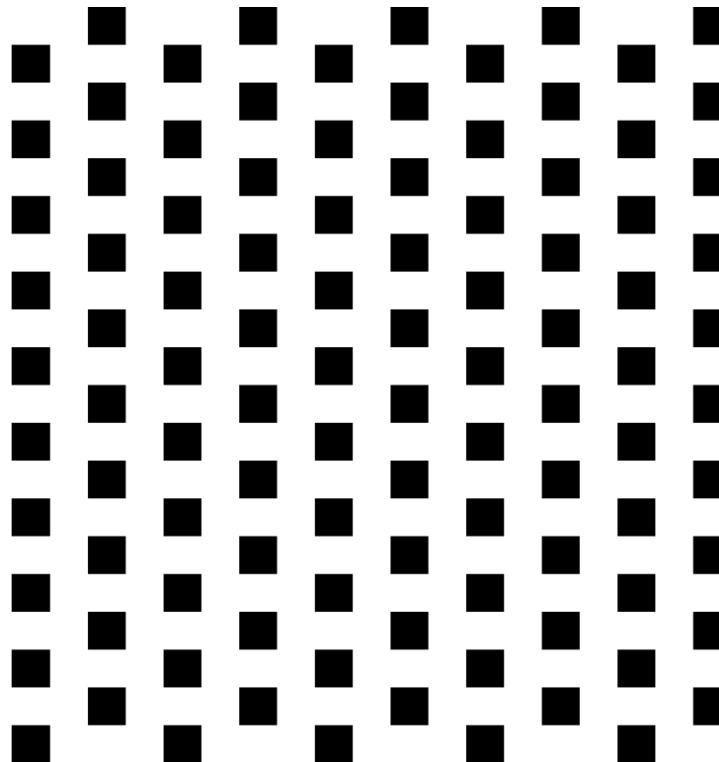
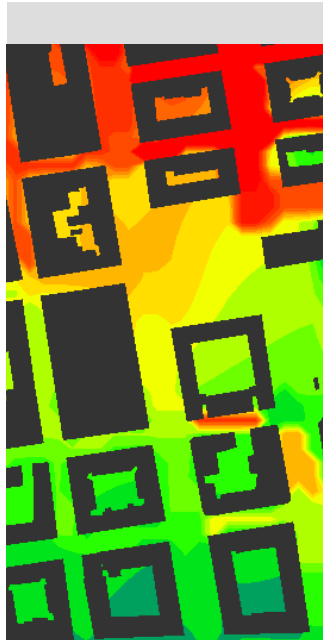
Definition of cloud arrival times



4 – Comparison results over rough and urban area

4 – Comparison results over rough and urban area Sub-urban rough terrain

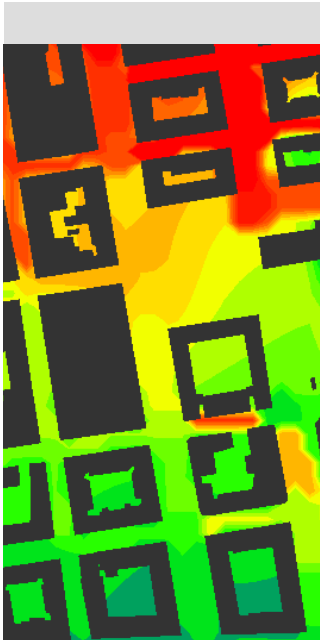
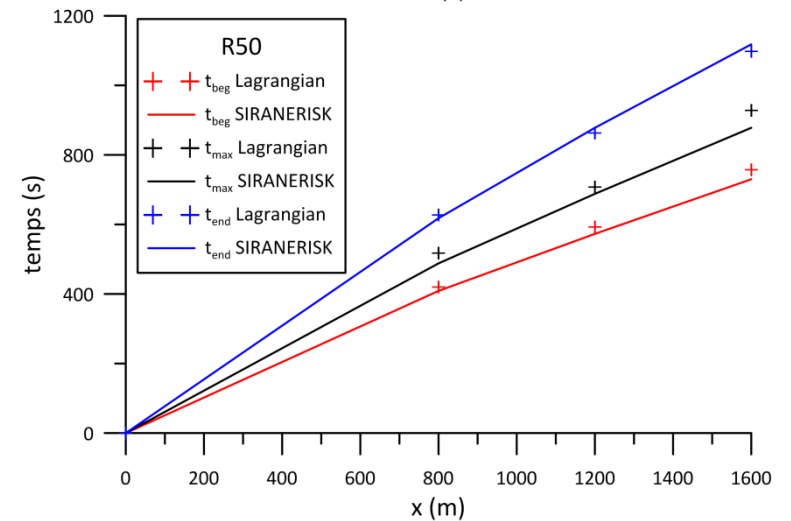
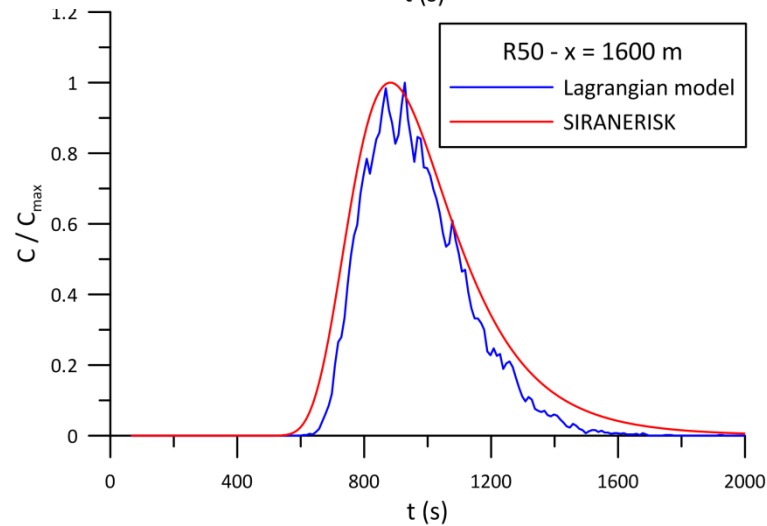
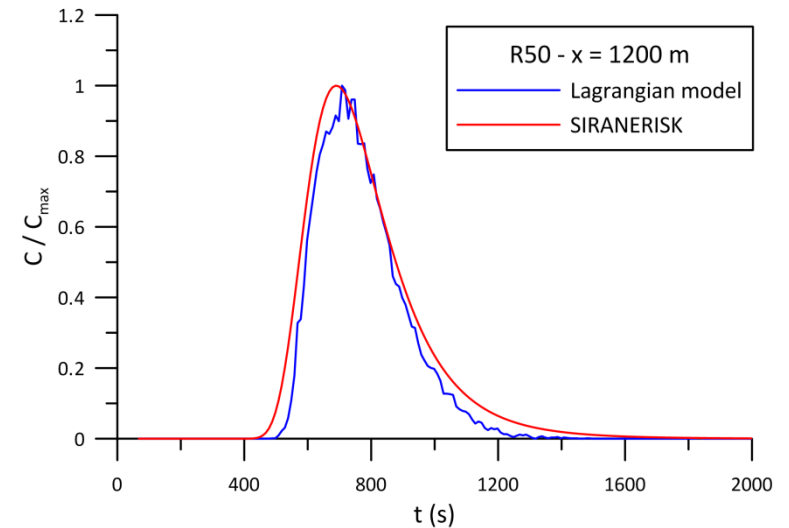
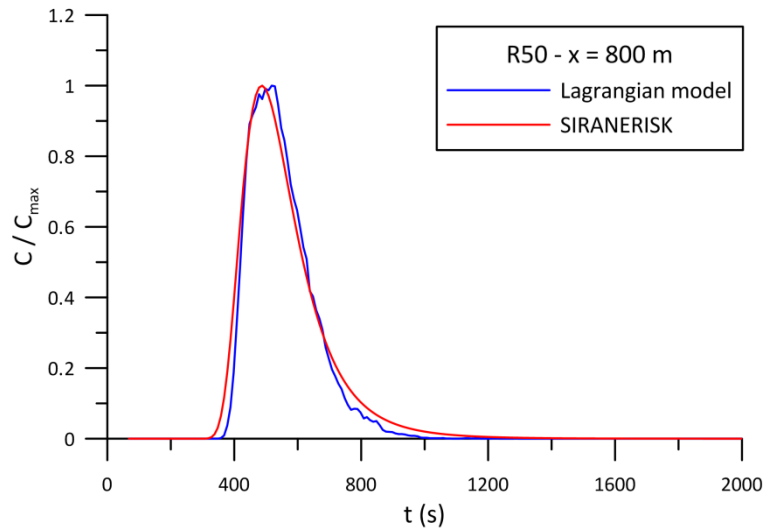
Sub-urban rough terrain (R50)



4 – Comparison results over rough and urban area

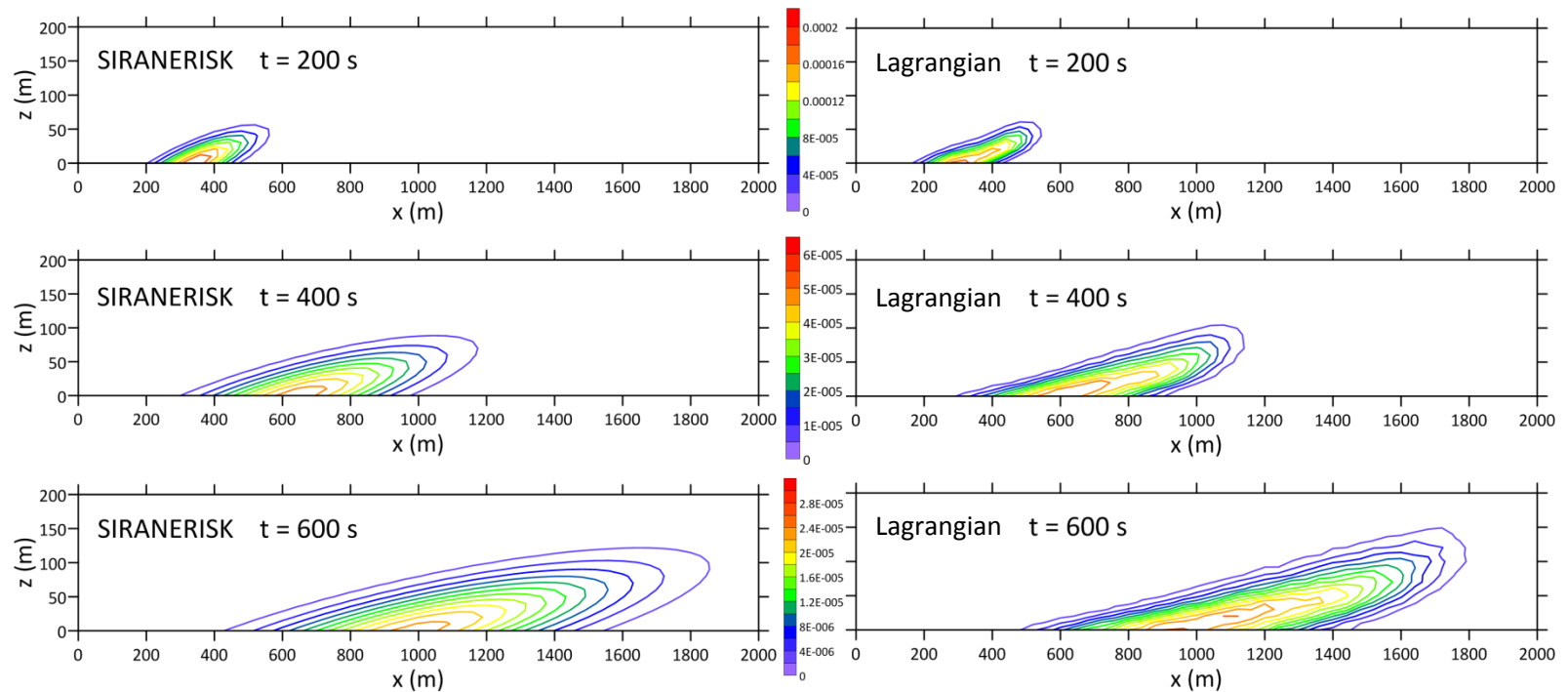
Sub-urban rough terrain

• **Temporal evolution at 3 point receptors**

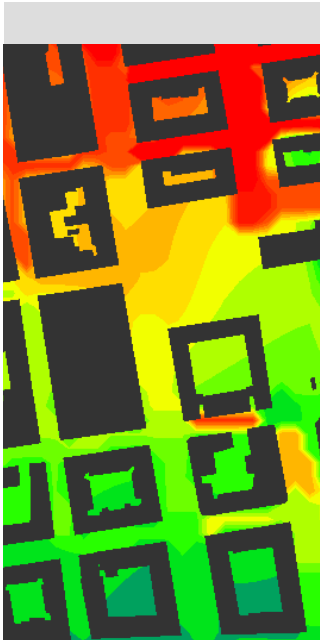


4 – Comparison results over rough and urban area Sub-urban rough terrain

- Vertical cross section of concentration

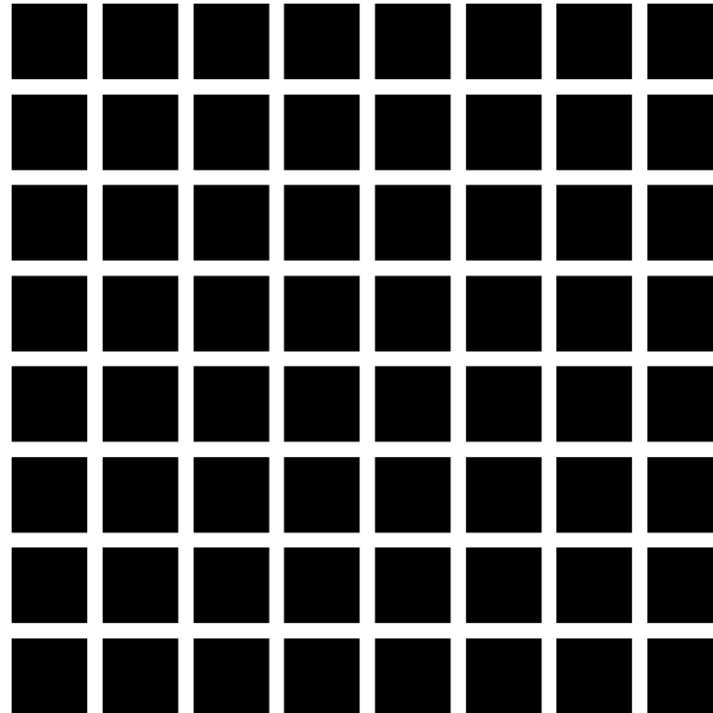
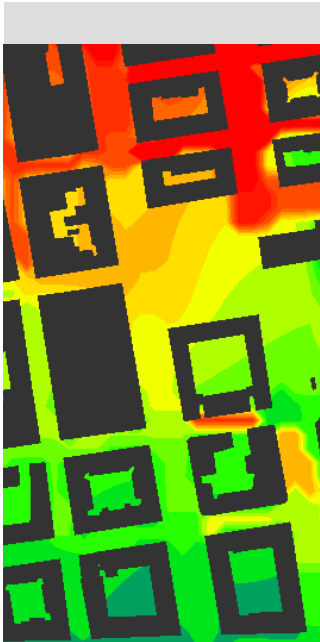


- SIRANERISK reproduces correctly the general behavior of the pollutant cloud
- The shear effect is well described



4 – Comparison results over rough and urban area Urban district 30°

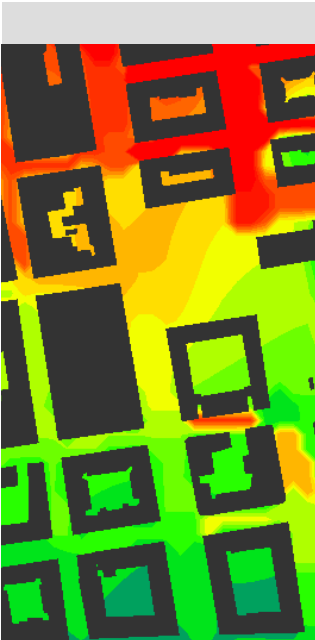
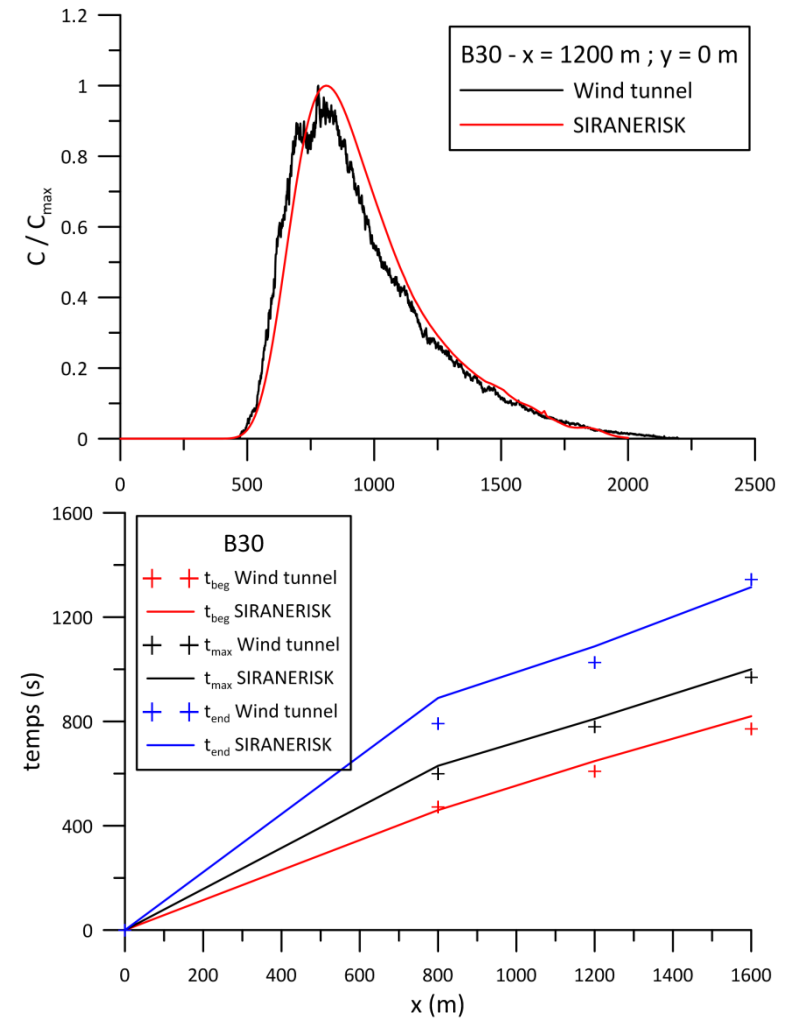
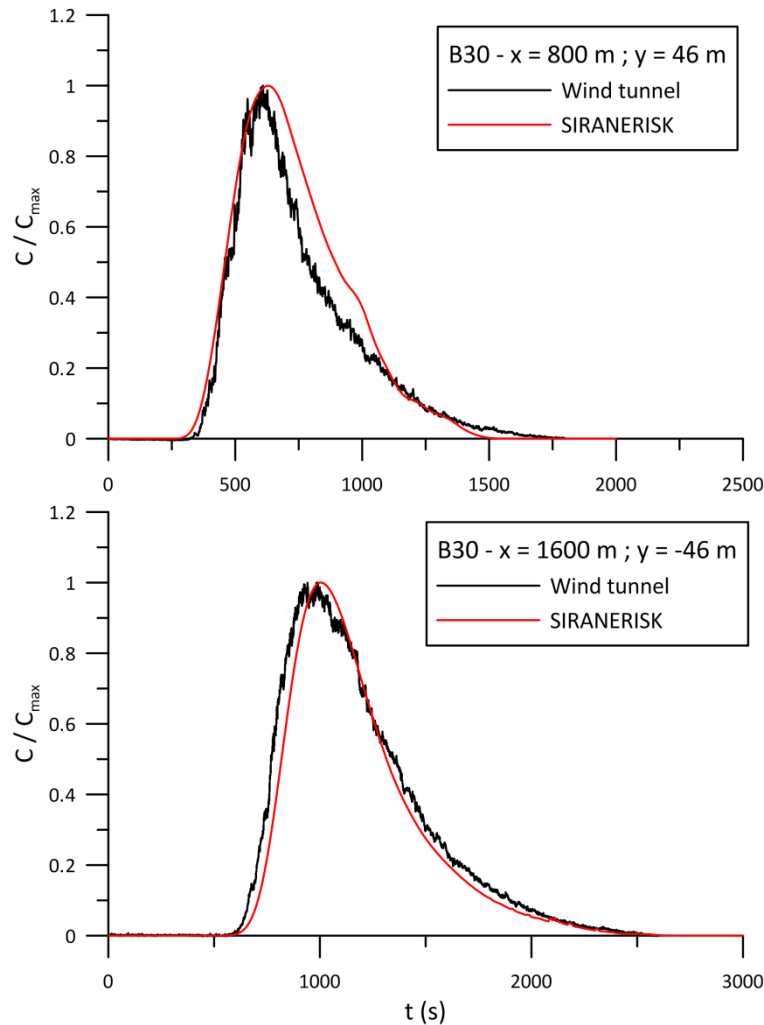
Urban district (30°)



4 – Comparison results over rough and urban area

Urban district 30°

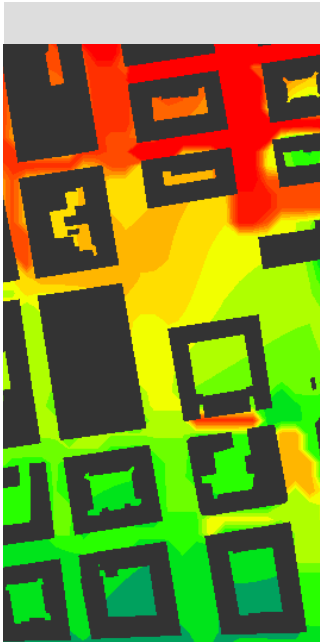
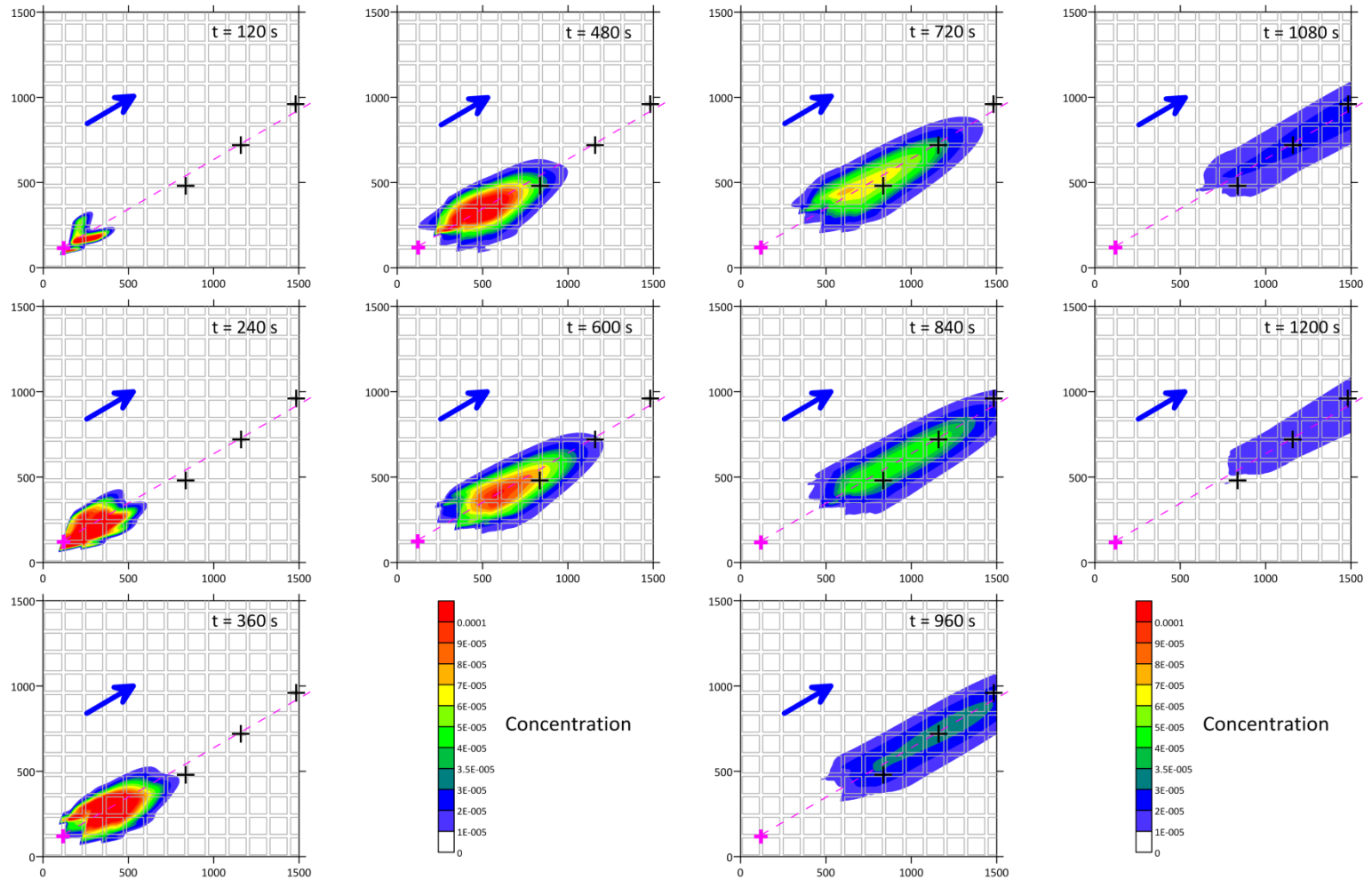
- Temporal evolution at 3 point receptors



4 – Comparison results over rough and urban area

Urban district 30°

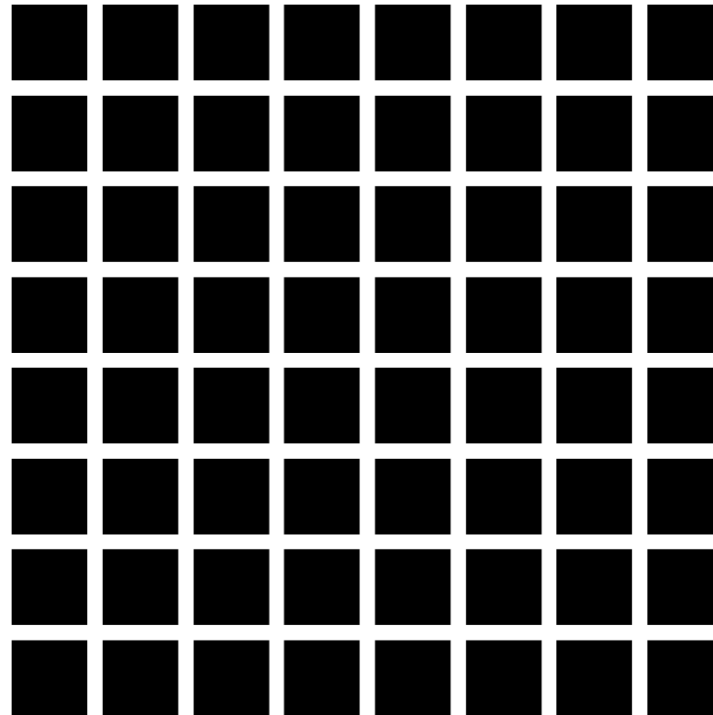
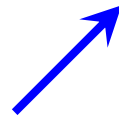
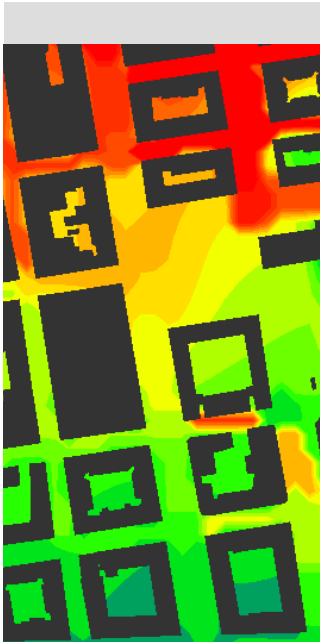
- Cartographies de concentration



4 – Comparison results over rough and urban area

Urban district 45°

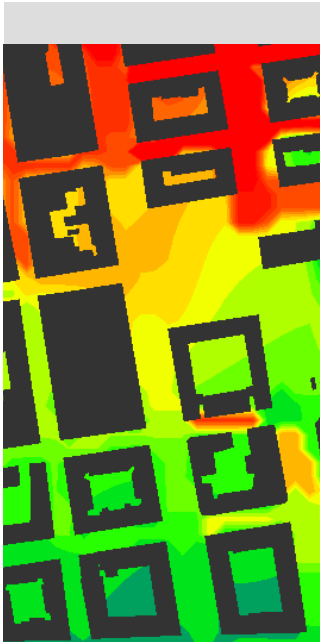
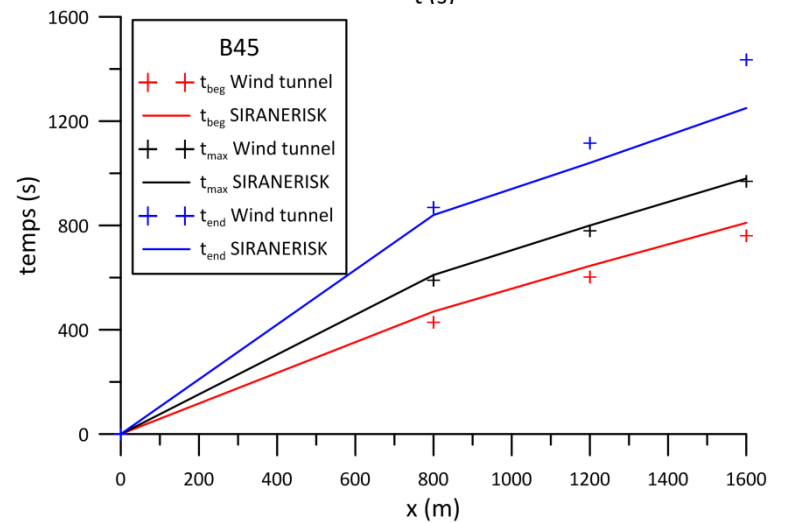
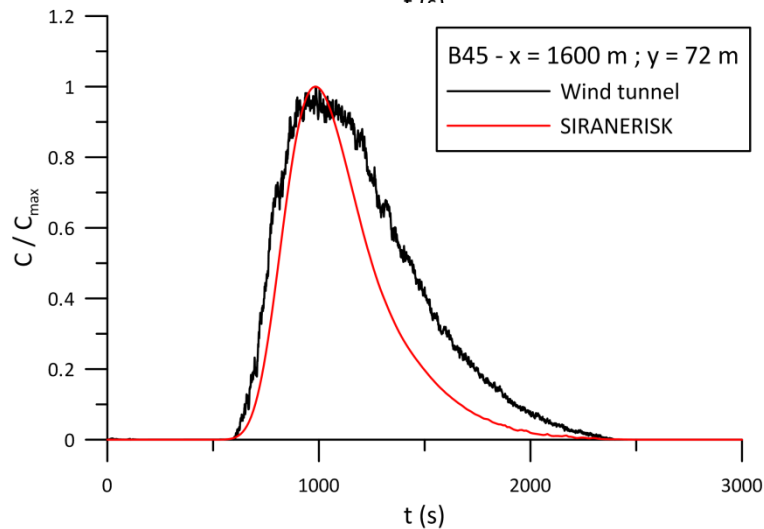
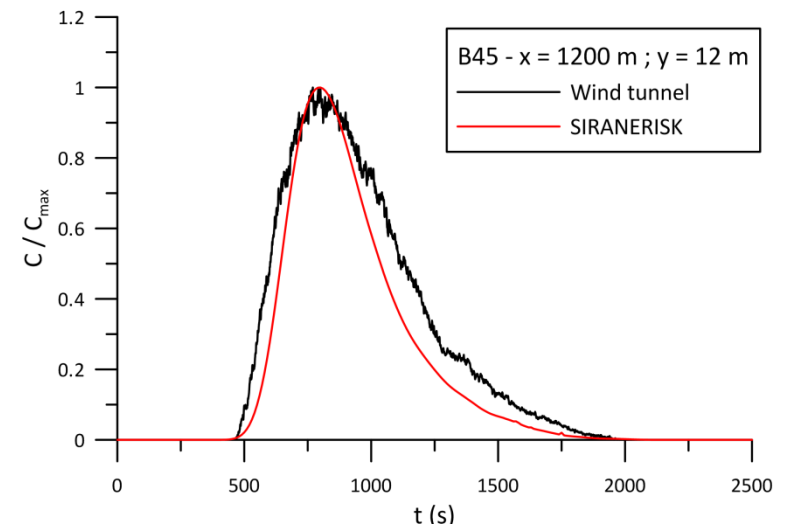
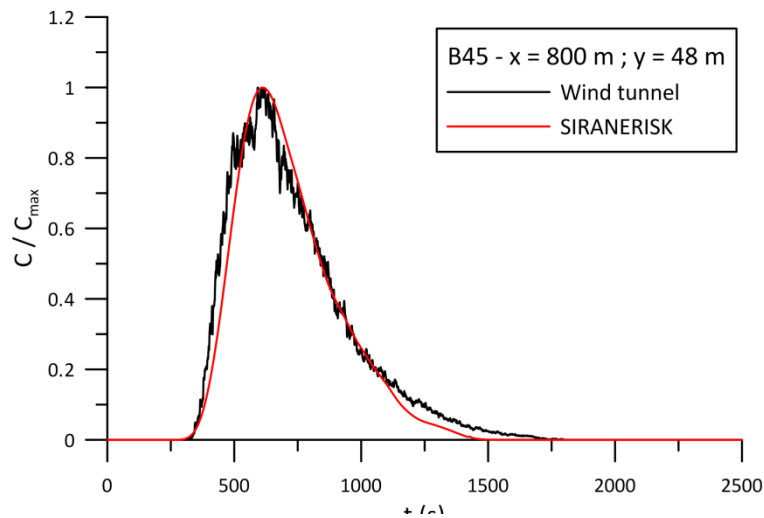
Site urbain (45°)



4 – Comparison results over rough and urban area

Urban district 45°

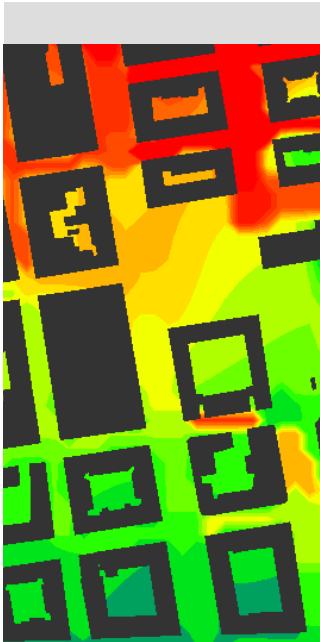
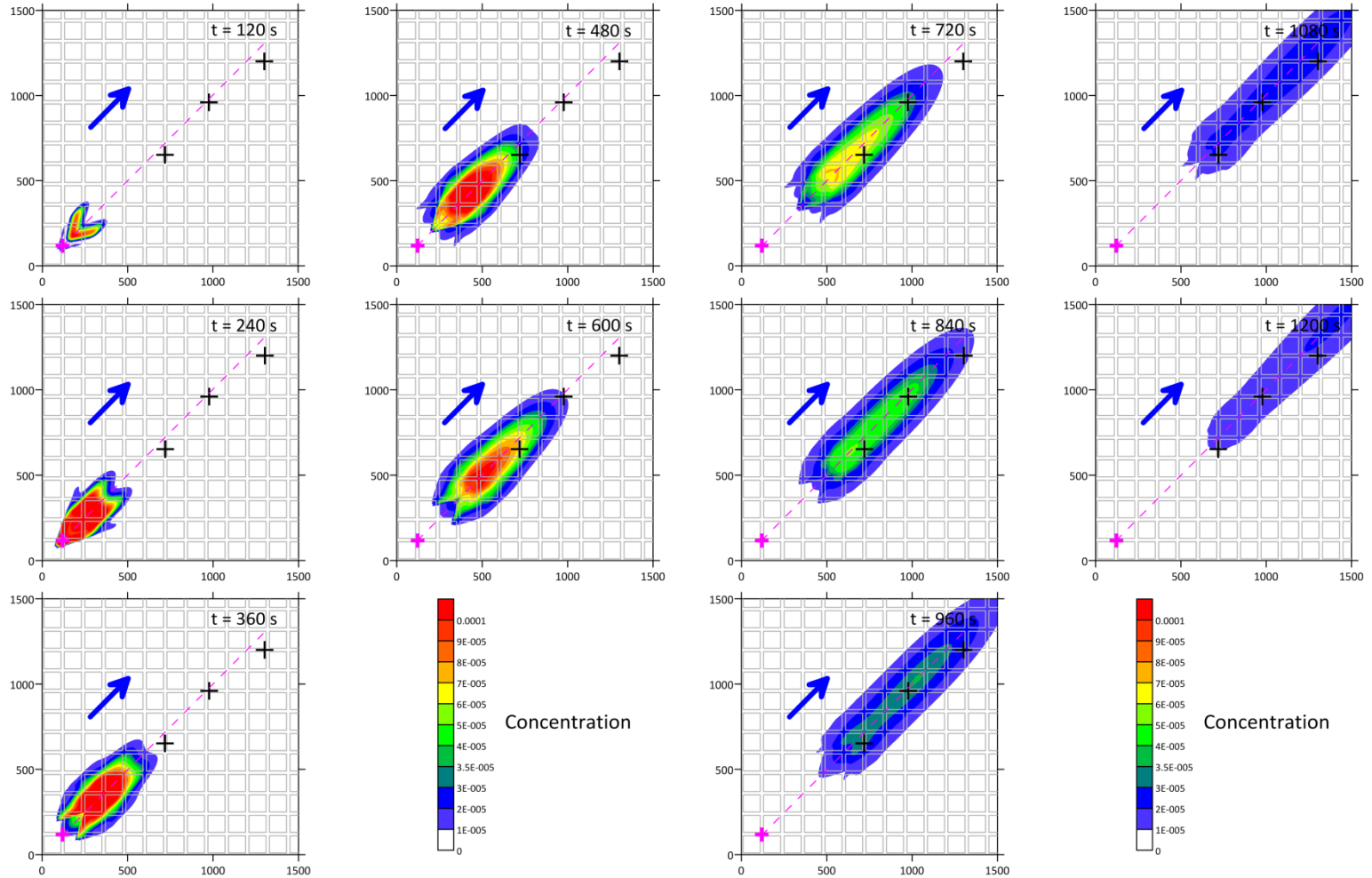
- Temporal evolution at 3 point receptors



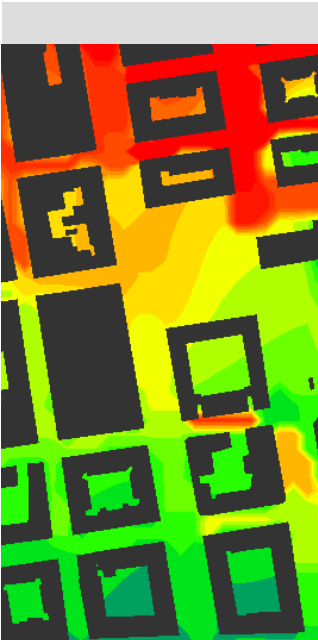
4 – Comparison results over rough and urban area

Urban district 45°

- Cartographies de concentration



5 – Conclusions and perspectives



5 - Conclusions and perspectives

Conclusions



- **SIRANERISK 2.0 is an operational urban dispersion model for short releases**
 - Based on the street network approach
 - Canopy parameterization
 - Puff dispersion model
 - **Specific parameterization of the wind shear effects**
- **Validation against Lagrangian model and wind tunnel**
 - Good agreement for :
 - The mean arrival time of the cloud
 - The longitudinal spreading of the plume

5 - Conclusions and perspectives

Some perspectives directions



- **Calculation of concentration PDF in order to provide ensemble statistics**
- **Inverse dispersion modelling to identify the sources from observations**
- **Interaction with buildings :**
 - **3D deposition distribution**
 - **Indoor/outdoor transfer**

Thank you for your attention 😊

Questions ?

