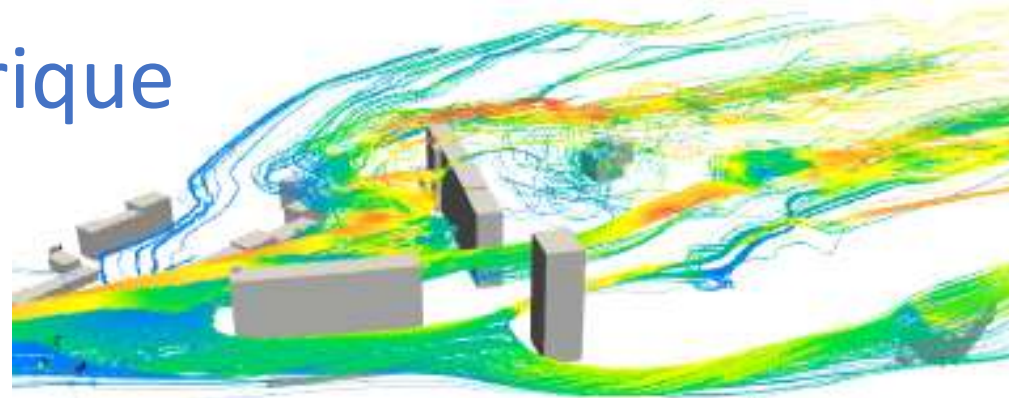


# Approche LBM pour la simulation de la dispersion atmosphérique de polluants



Stéphane JAY, Benjamin BRACONNIER, Augustin NOIRAULT



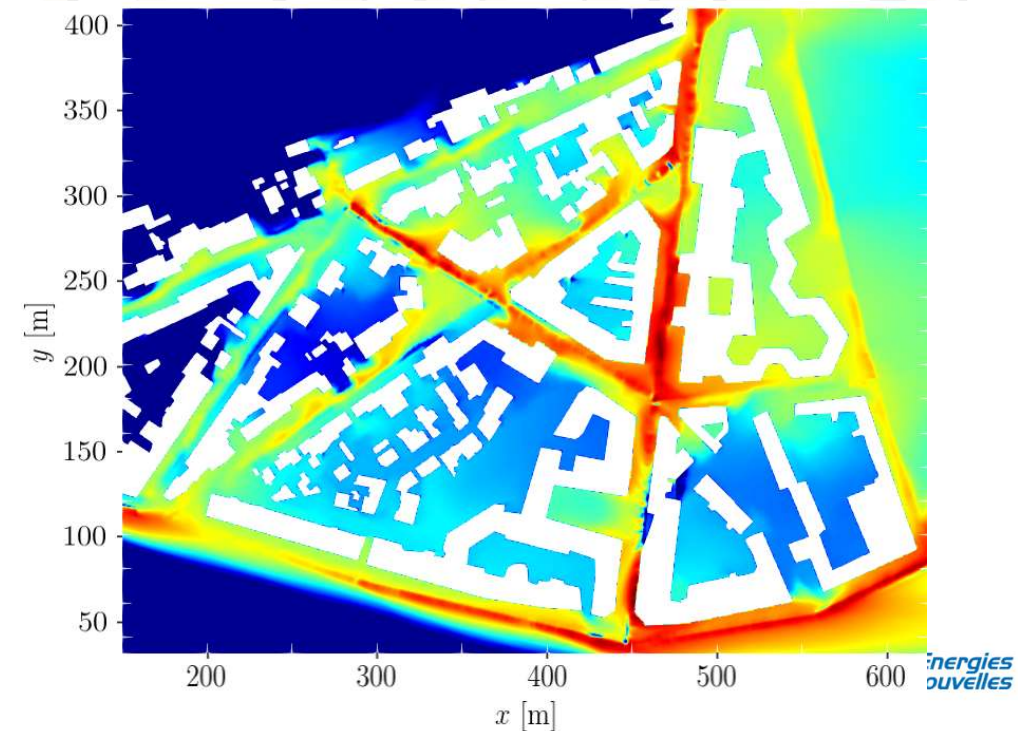
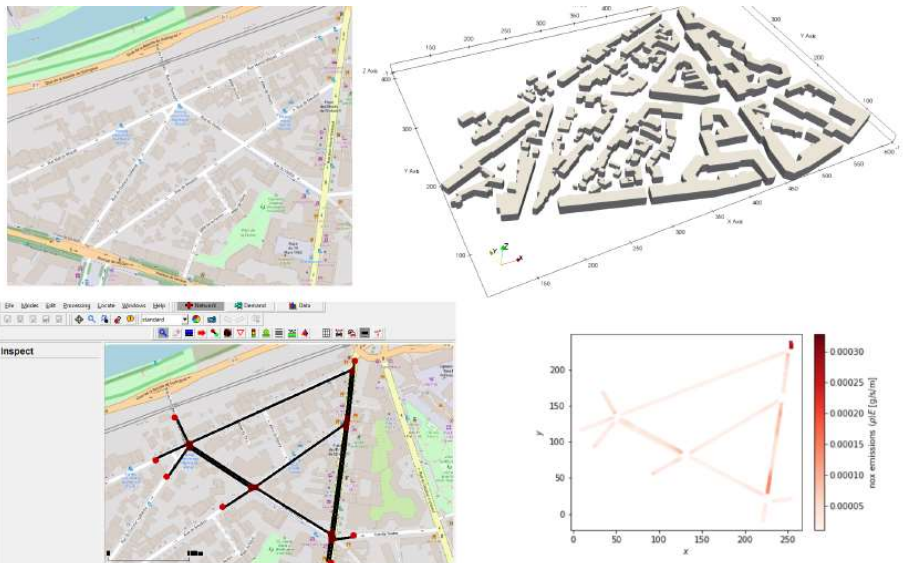
Jeudi 16 octobre 2025

## BACKGROUND

**Mathis PASQUIER** PhD Thesis (2023)

« Quantification d'incertitudes pour la dispersion turbulente de polluants liés au trafic routier à l'échelle micro-urbaine »

Pierre SAGAUT (Univ. d'Aix-Marseille), Stéphane JAY (IFPEN), Delphine SINOQUET (IFPEN)



# VALIDATION

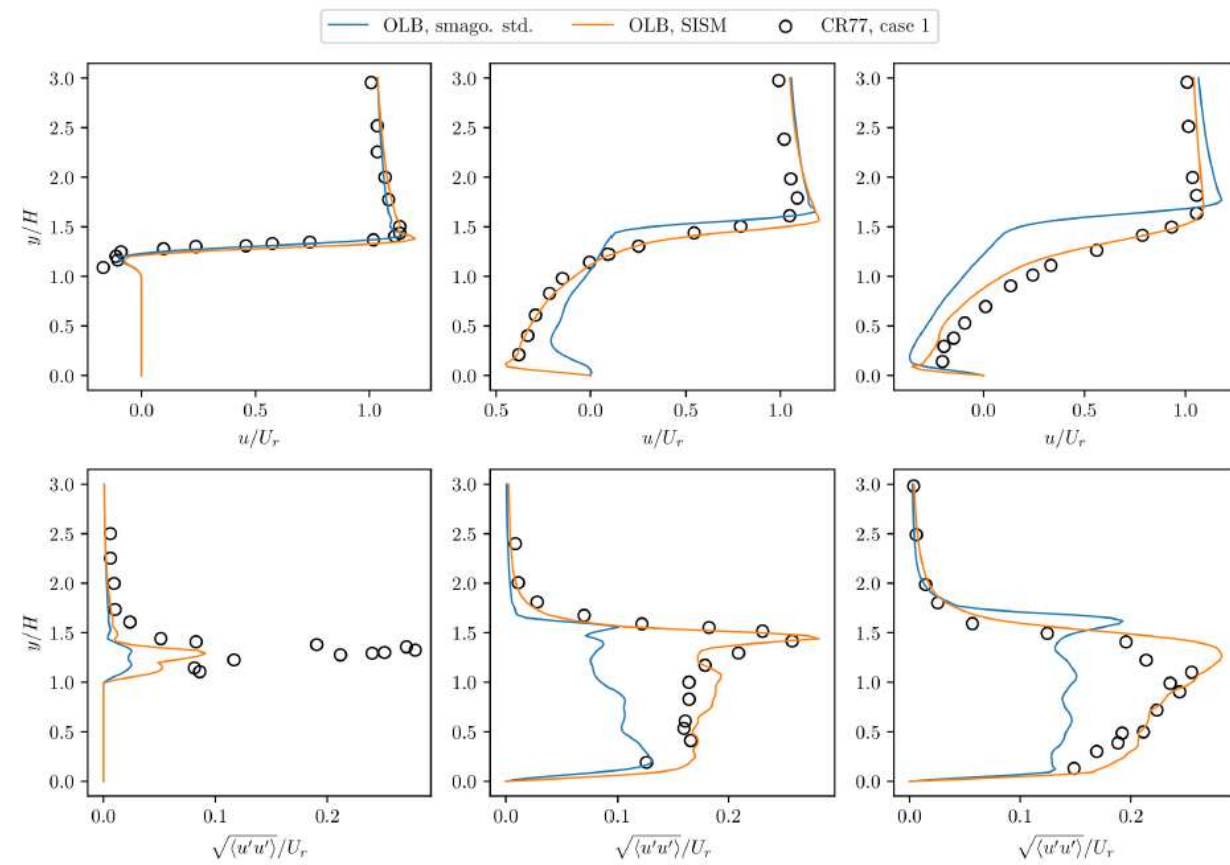
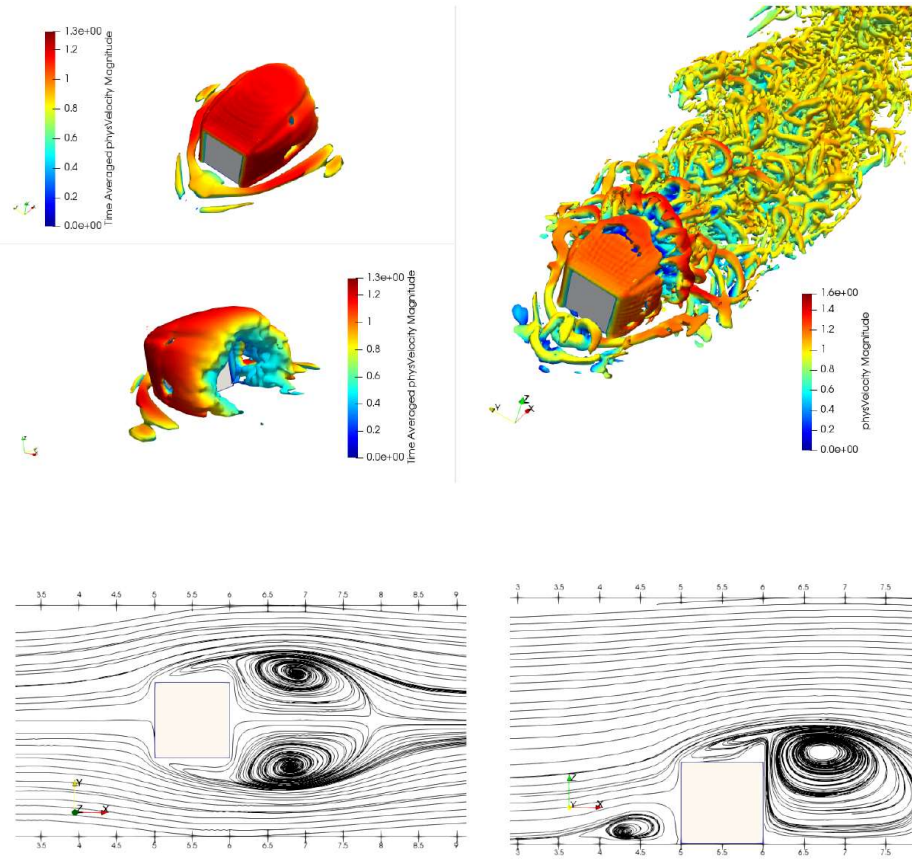


Figure – Average streamlines in horizontal  $z/H = 0.5$  plane (left) and in vertical symmetry plane (right)



## VALIDATION

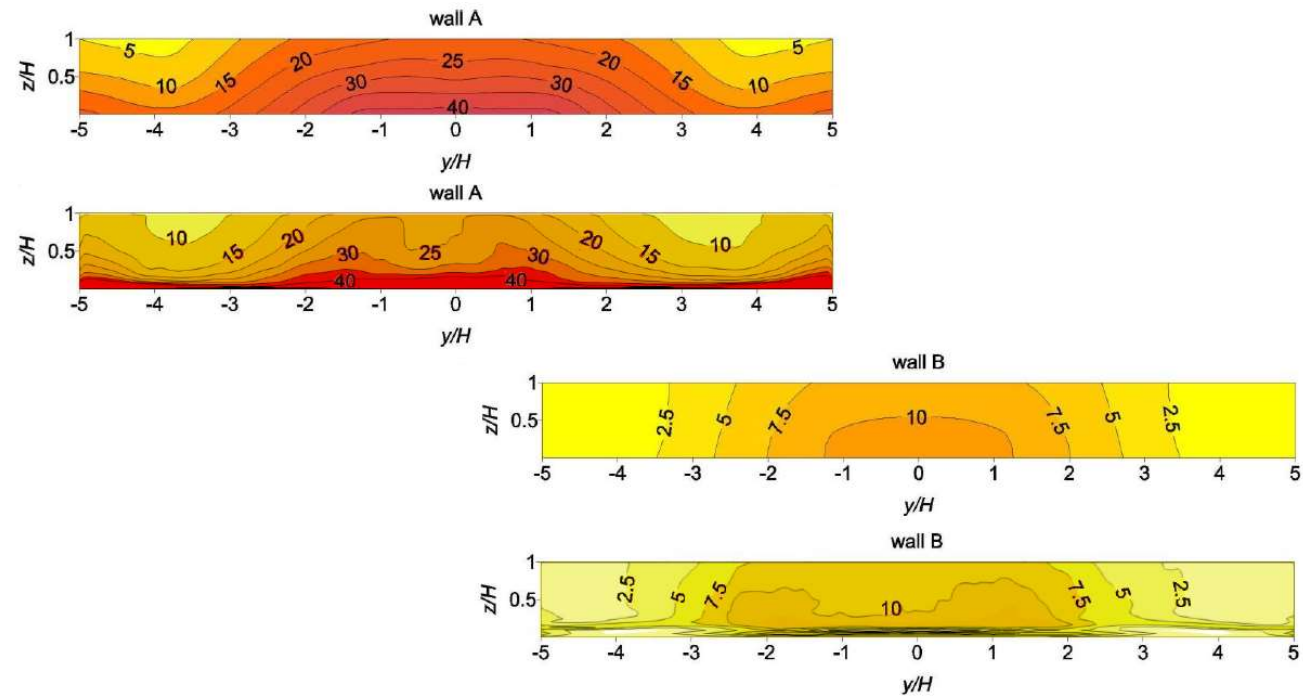
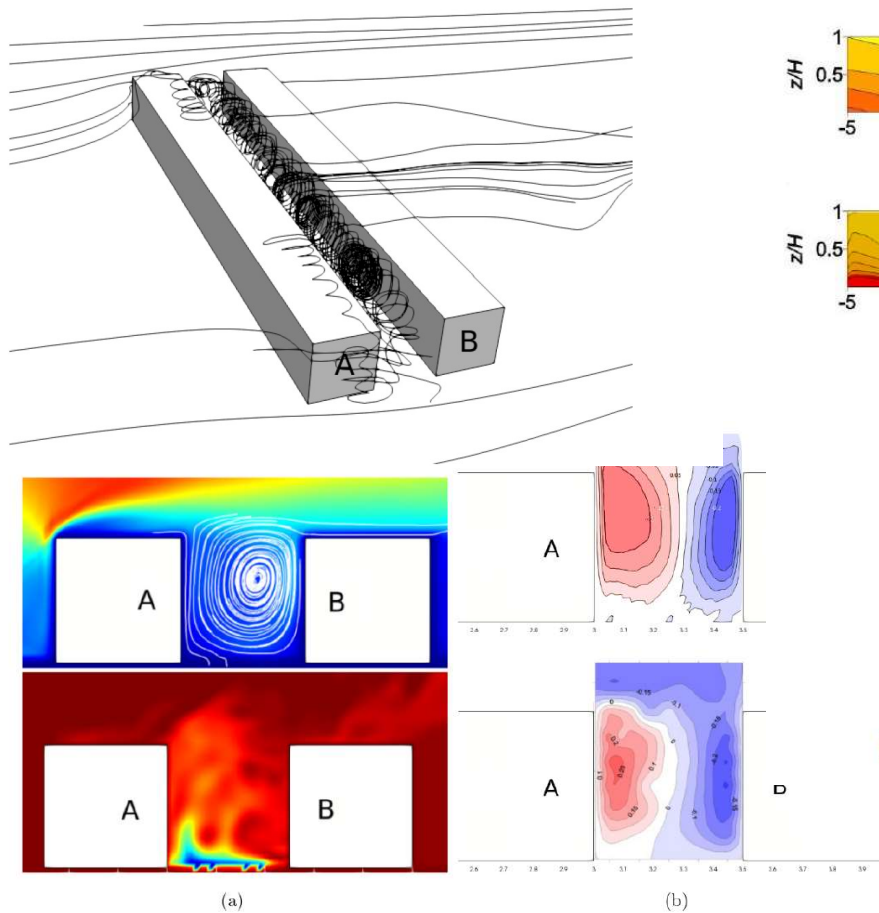


Figure – Average concentration on interior walls of the canyon vs experiment

Figure – Canyon inner dynamics : average vel. field (top left), instantaneous scalar field (bottom left) and average velocity vertical component vs experiment (right)

# VALIDATION

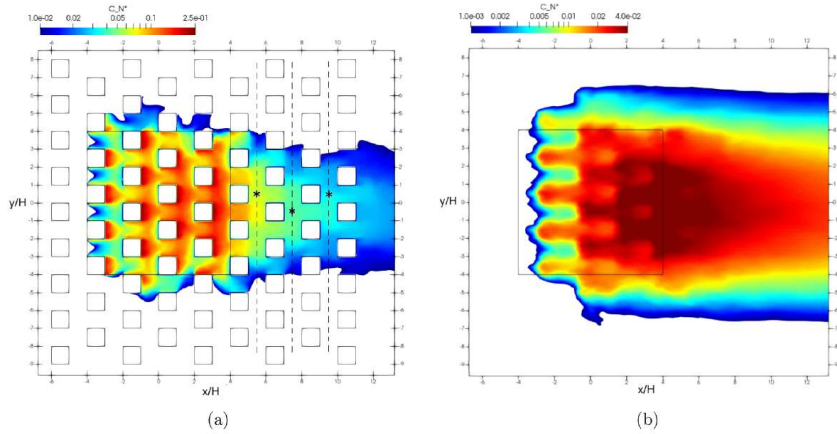
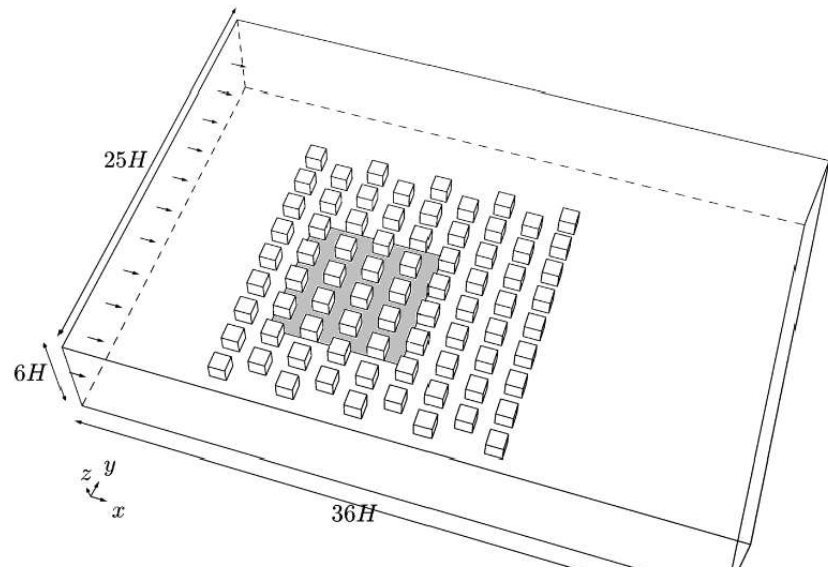


Figure – Average scalar field in horizontal  $z/H = 0.3$  (left) and  $z/H = 1.2$  (right) planes

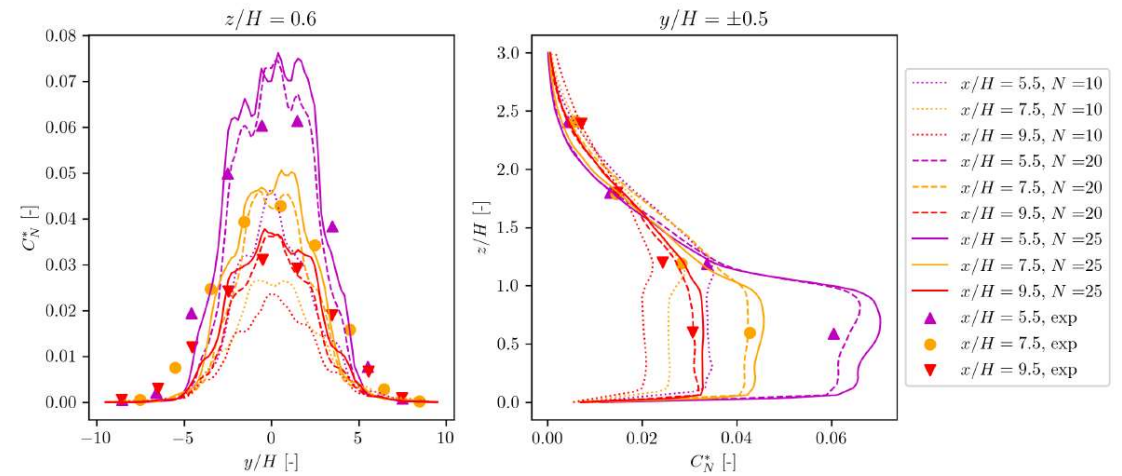


Figure – Average concentration in lateral (left) and vertical (right) cuts downstream of the source

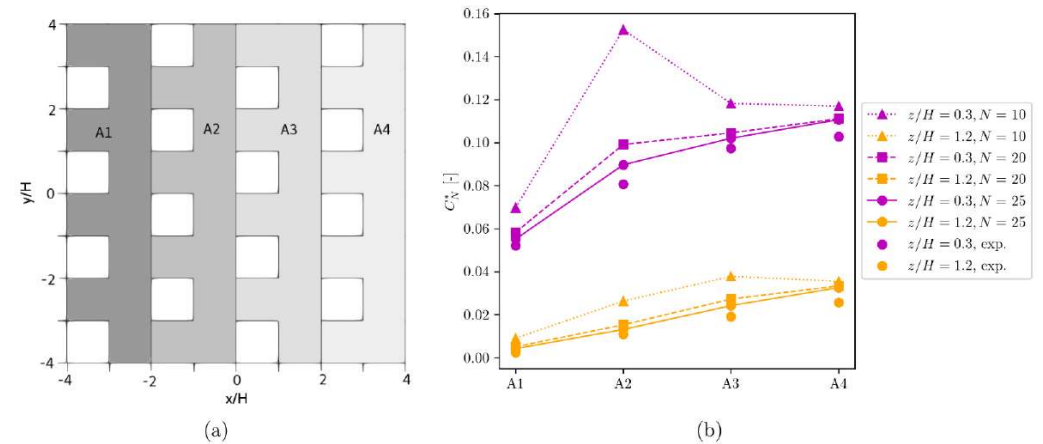
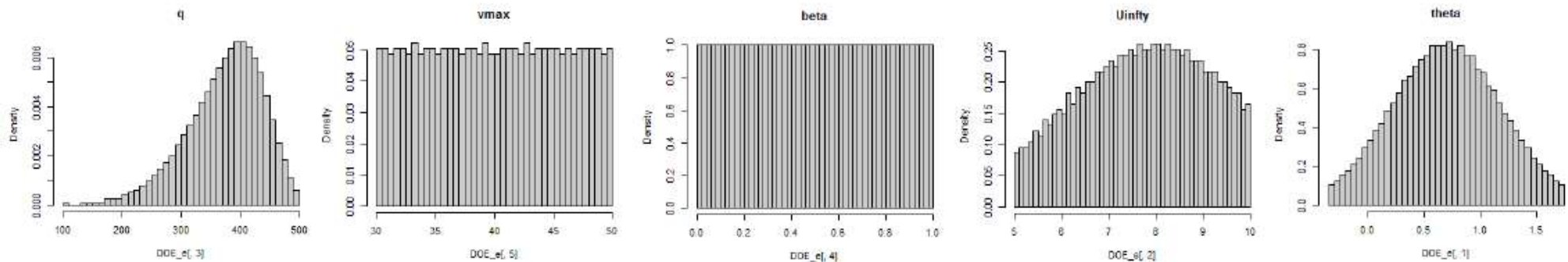
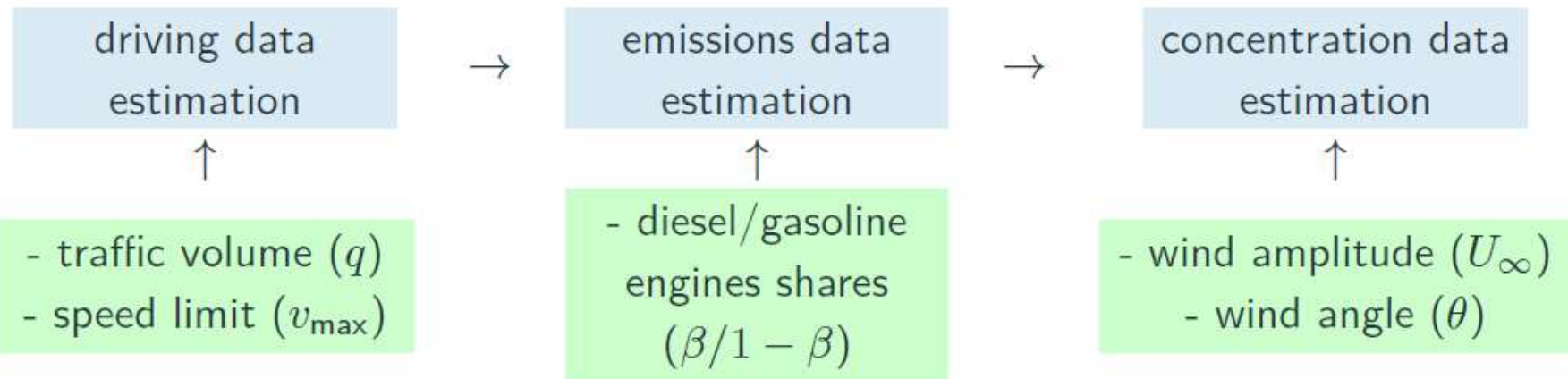


Figure – Surface averaged concentration values above the source (right) for different averaging areas (left)

## 3D BASED SENSITIVITY ANALYSIS

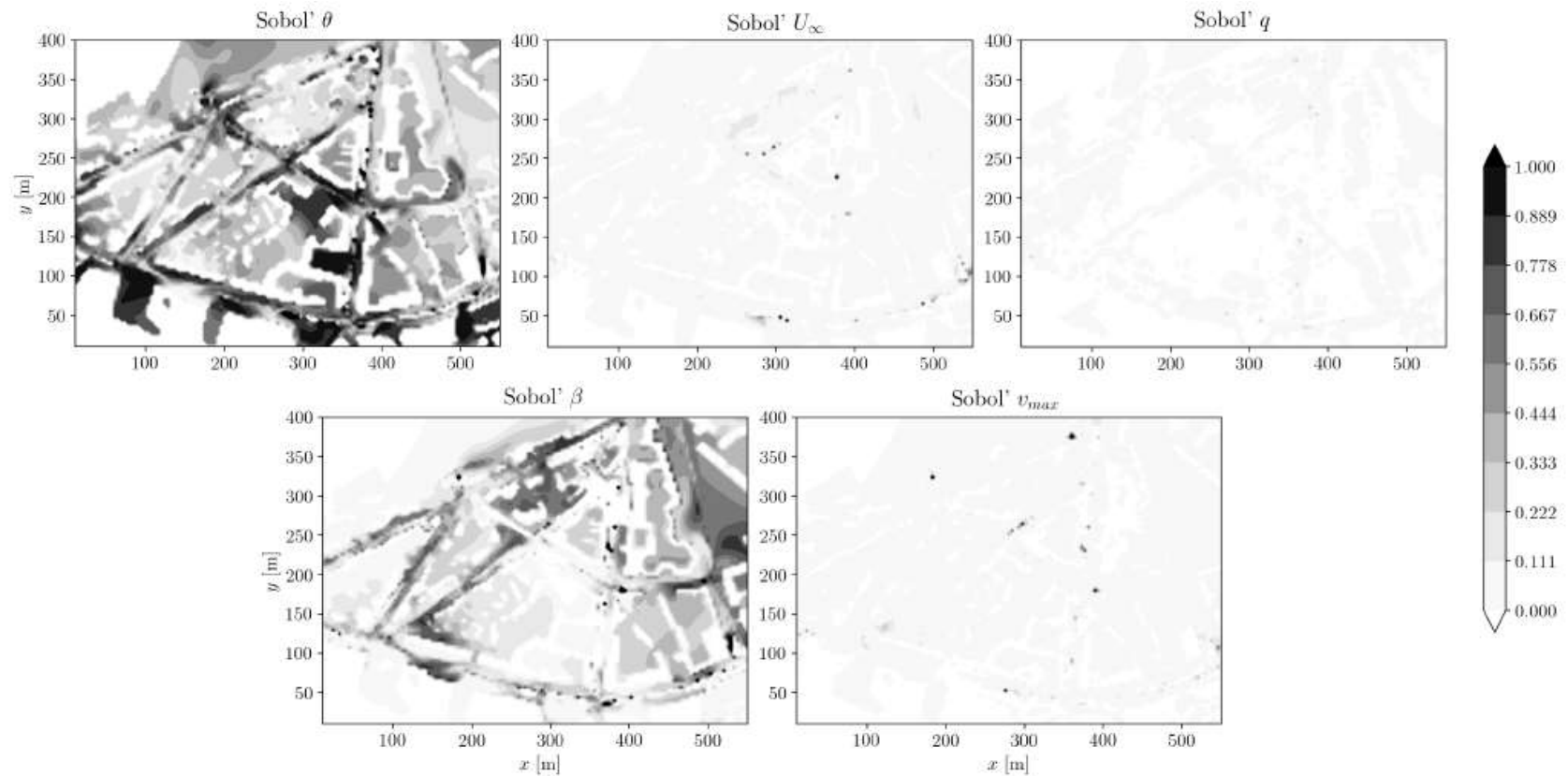
SUSTAINABLE MOBILITY



**Assumption:** independent variables

## 3D BASED SENSITIVITY ANALYSIS

SUSTAINABLE MOBILITY

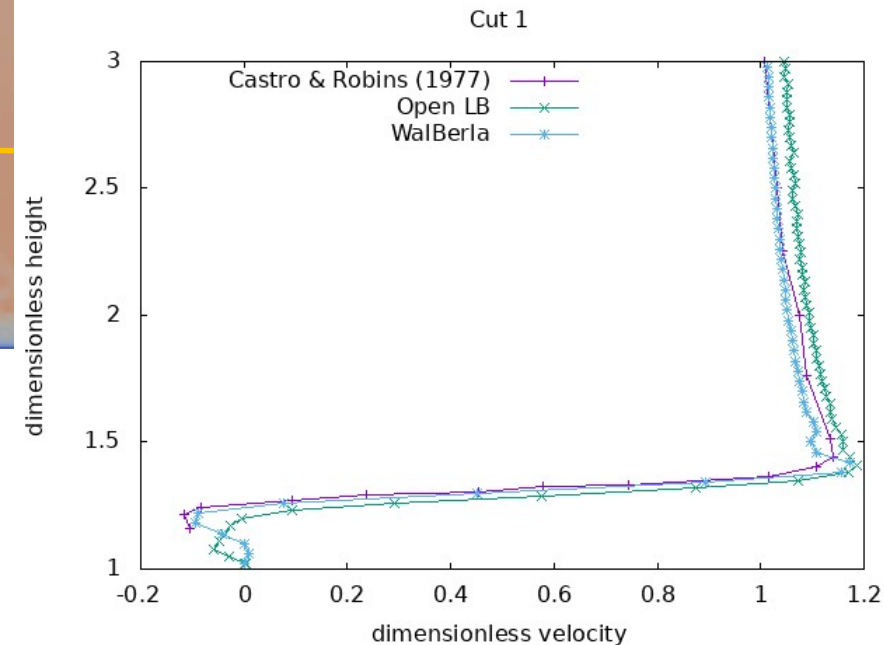
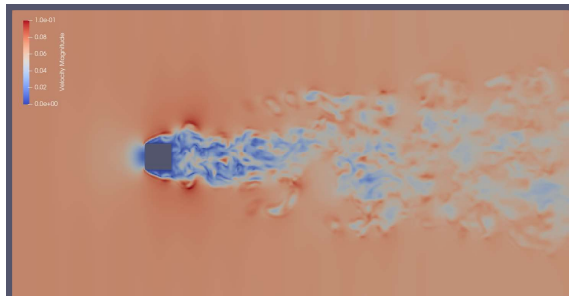
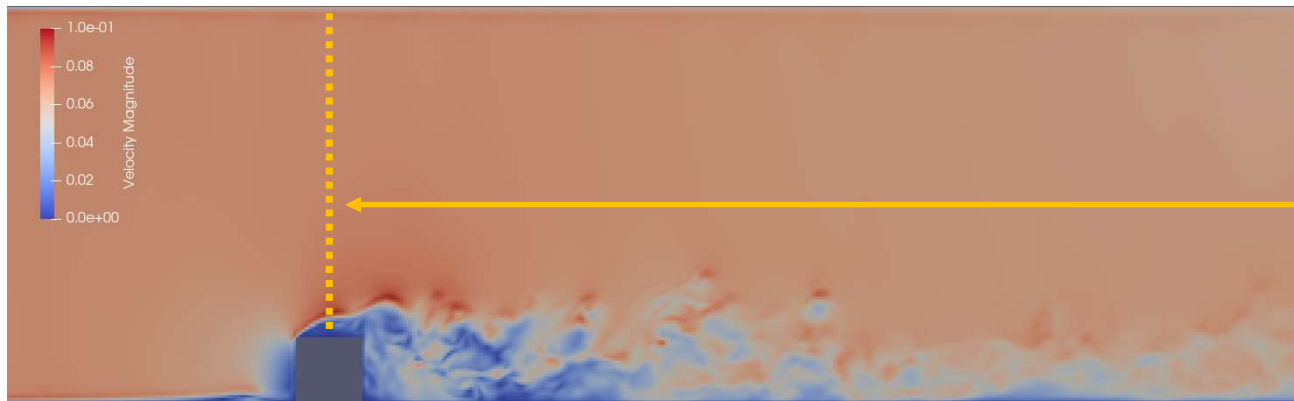


**Figure 19:** First-order Sobol' indices of the concentration LCP for the three traffic-related and meteorological uncertain inputs, using the POD-GPR metamodel.



# OPENLB VS WALBERLA VS EXPÉRIENCE CASTRO & ROBINS (1977), 20M NOEUDS

- **OpenLB:** D3Q19, collision « recursive regularized », BC + sponge zones, turbulence: modèle Samgorinski model, physical units
  - 360 cœurs (CPU) : 6.8h
- **walBerla:** D3Q27, collision « cumulant », lattice units, CPU/GPU with lbmpy
  - 375 cœurs (CPU) : 63min





# ATMOSPHERIC DISPERSION USING LBM: WORKFLOW & ANALYSIS

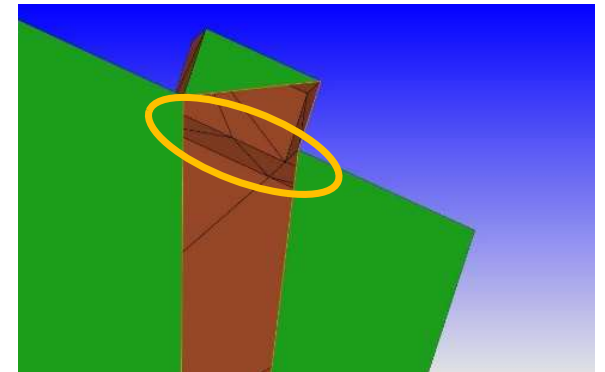
## ● Set-up and preparation of geometries

- Use of QGIS to select a specific area in the BDD TOPO IGN
- Use of Blender (opensource python/C++) for 3D geometries preparation
  - GIS add-on to import geolocalised database

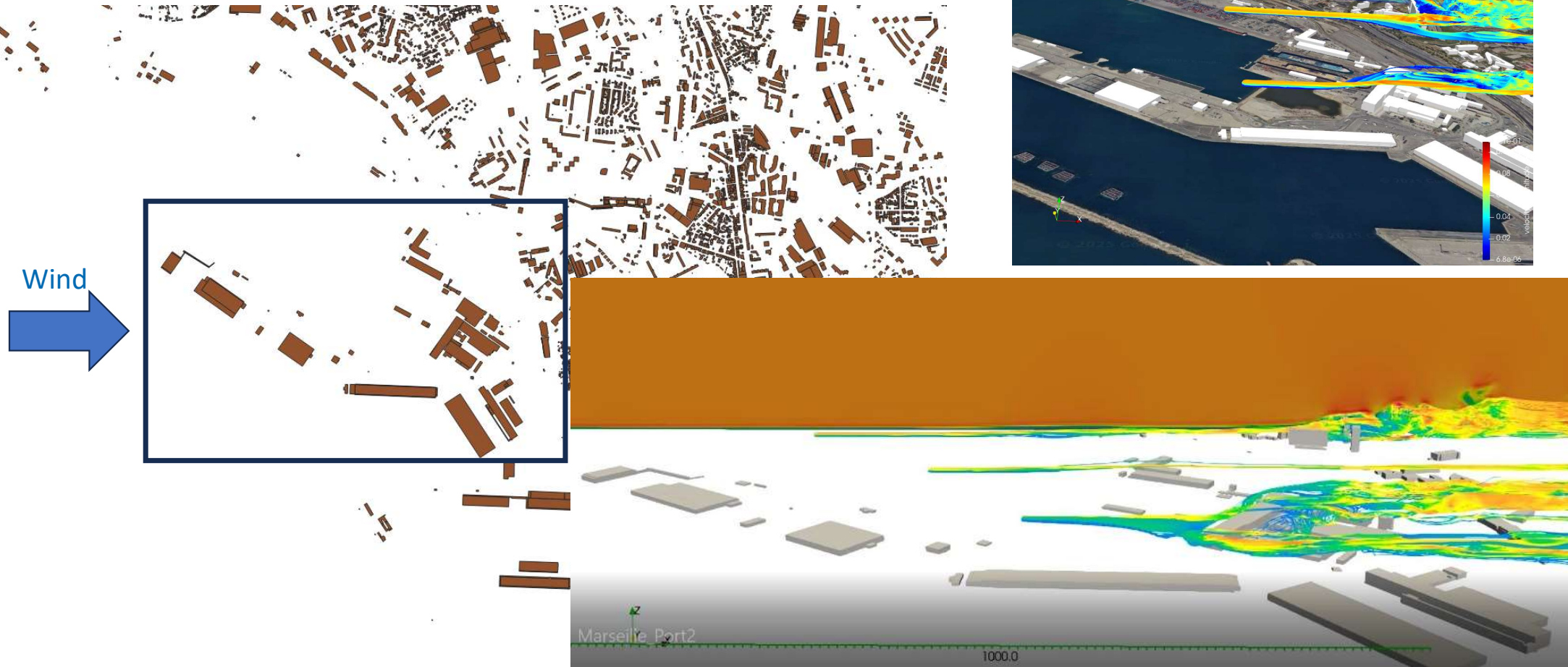


- Geometry cleaning and conversion methodology
  - Removal of multiple surfaces, geometry filling, removal of holes
  - Conversion .shp to .stl => OK

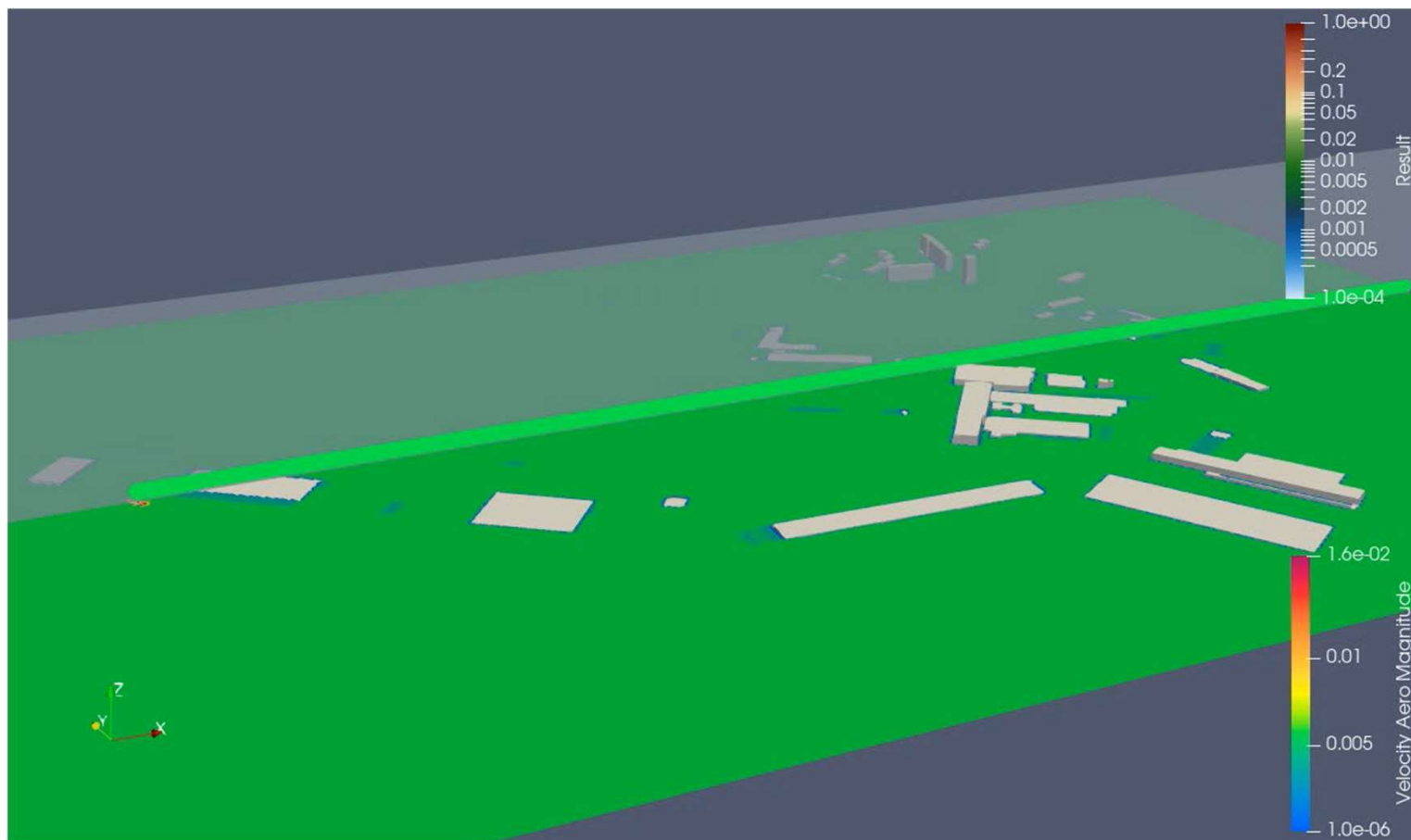
- Use of real heights from BDD TOPO IGN => OK



# ATMOSPHERIC DISPERSION USING LBM: WORKFLOW & ANALYSIS



## ATMOSPHERIC DISPERSION USING LBM: WORKFLOW & ANALYSIS



# ACCOUNTING FOR ATMOSPHERIC STABILITY EFFECTS

## What does it represent ?

- Subgrid scale model
- Effects of the smallest scale

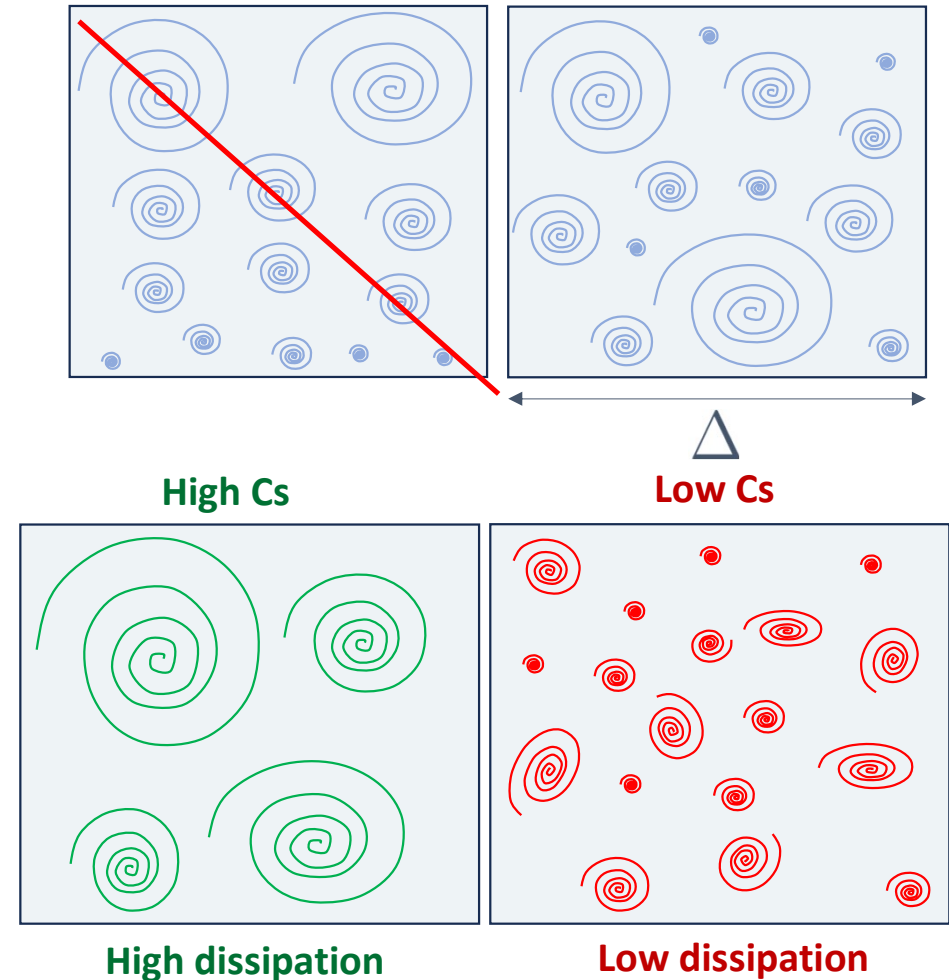
## Hypothesis

- Isotropic turbulence

## Limit

- Not valid close to walls
- Same constant in the domain

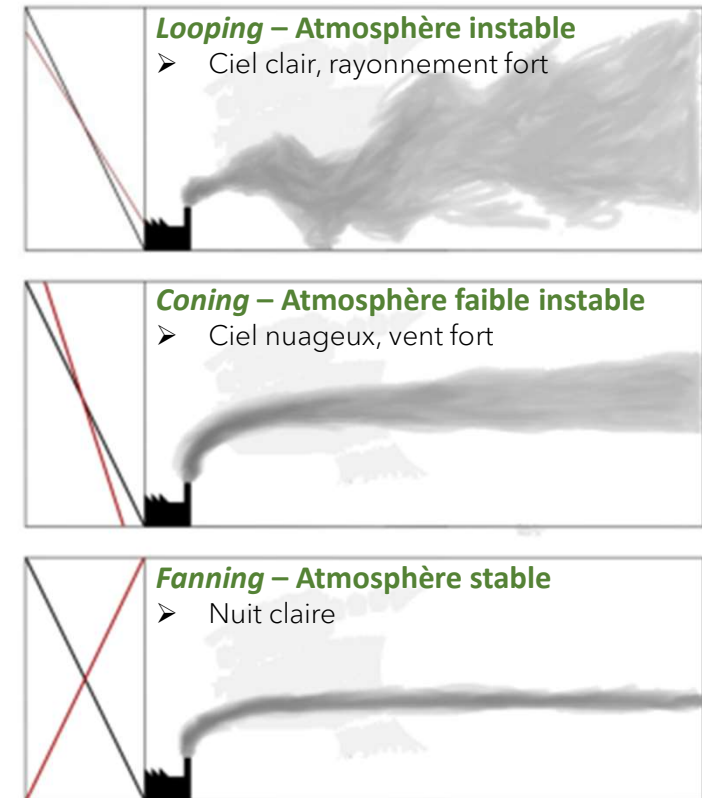
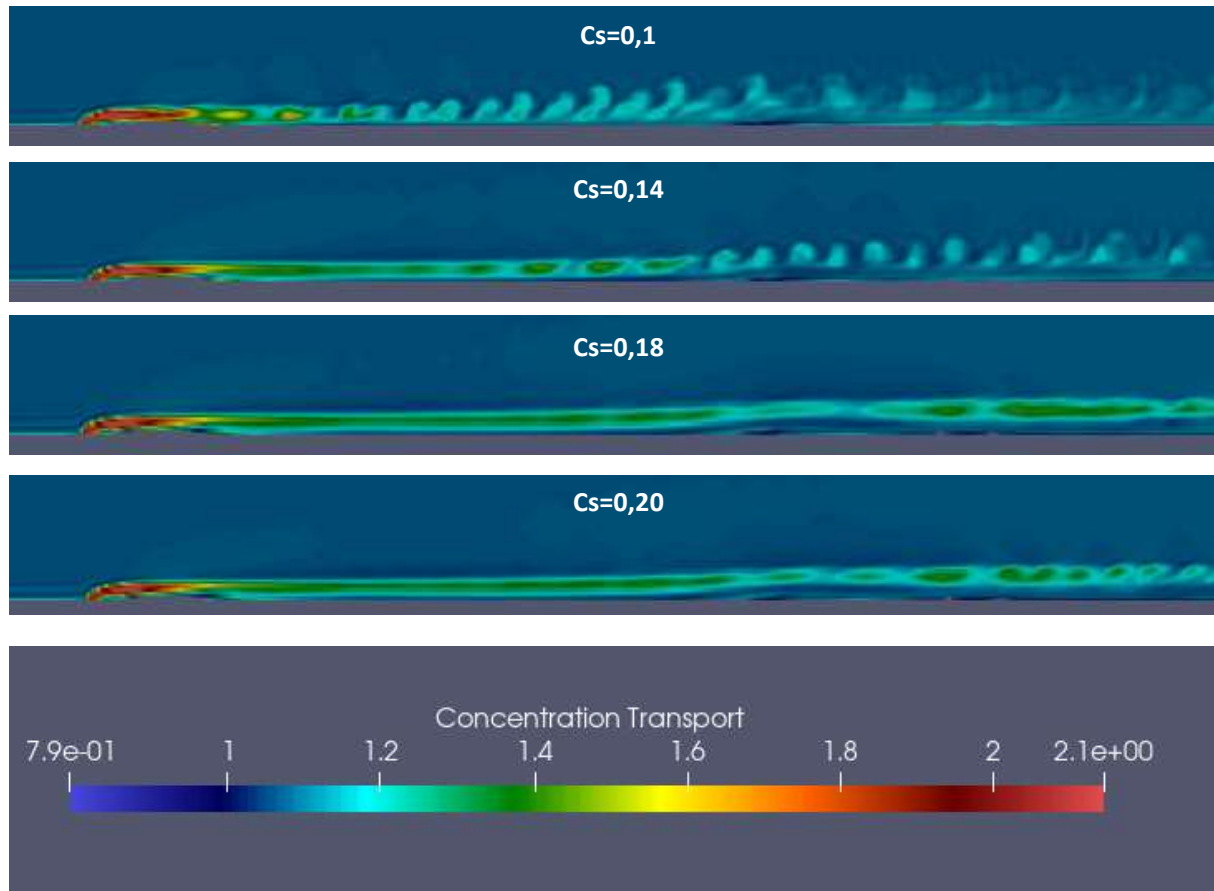
Smagorinsky constant range:  $0,1 < C_s < 0,2$



$$\nu_t = (C_s \Delta)^2 |\bar{S}|$$

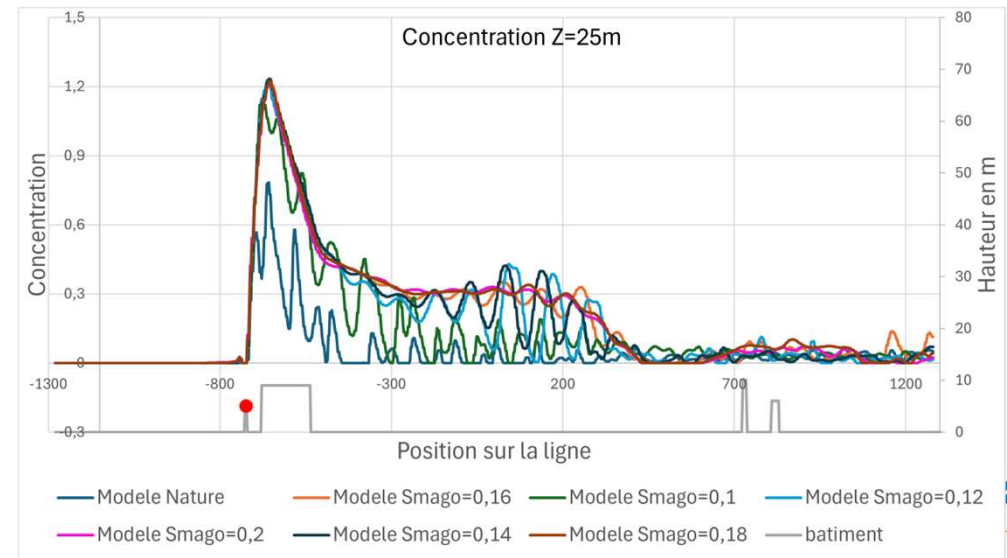
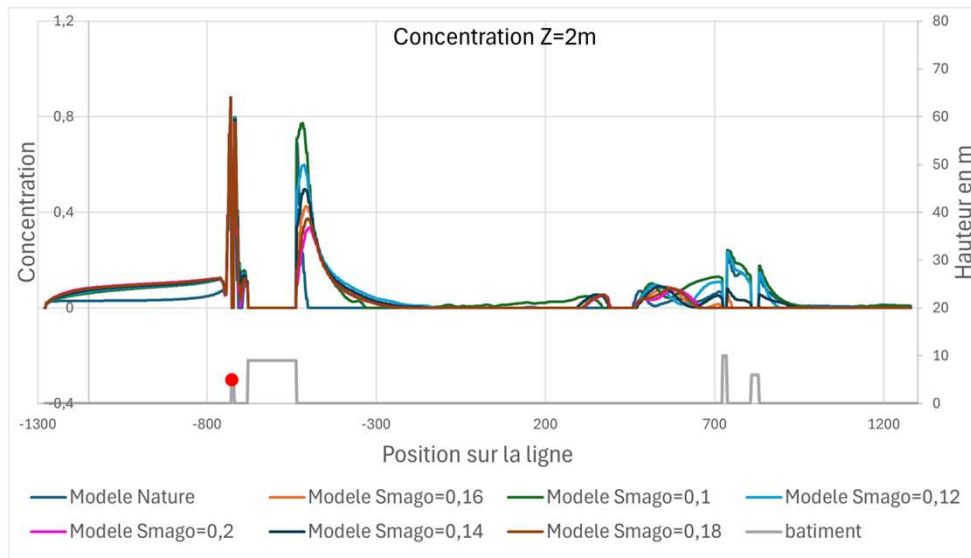
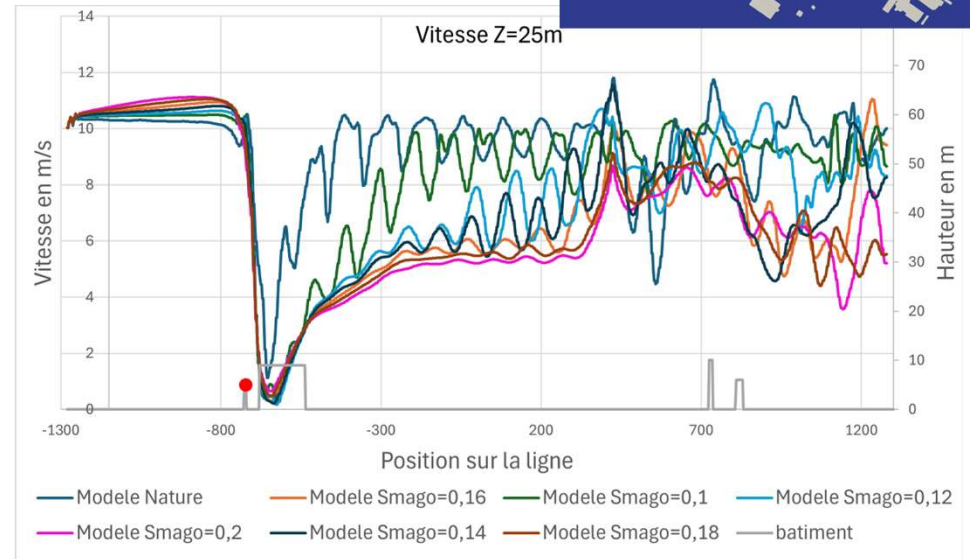
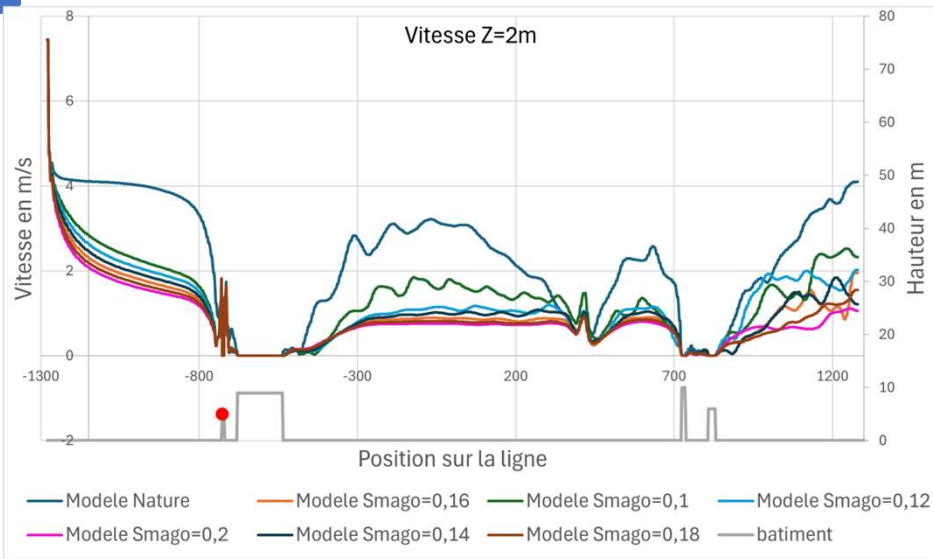
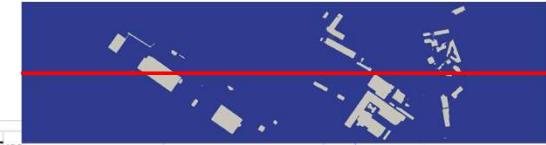


## ACCOUNTING FOR ATMOSPHERIC STABILITY EFFECTS



J. Kleissl, V. Kumar, and C. Meneveau, "Numerical study of dynamic smagorinsky models in large-eddy simulation of the atmospheric boundary layer : Validation in stable and unstable conditions," Boundary-Layer Meteorology, vol. 118, no. 1, pp. 1–31, 2006

# ACCOUNTING FOR ATMOSPHERIC STABILITY EFFECTS



## SUMMARY AND FUTURE WORK

### Digital twin for pollutant dispersion

#### Recent progress on modelling

- Precision, stability and computational time ++ (large range of Reynolds and Péclet numbers)
- Complex and realistic geometry operational with IGN data base
- Effect of atmospheric stability conditions
- Variable instantaneous conditions

#### Limits

- Thermal and buoyancy effects not accounted for
- Chemical effects are not accounted for

#### In progress

- Improvement of the subgrid scale model and boundary conditions (turbulence)
- Application / comparison with field measurements data (CROISI'Air Project, N°2262D0127)

