High resolution numerical study of pollution dispersion in urban neighborhoods in Toulouse

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Outline

- Introduction
- Geometry and mesh generation
- Numerical methods
- Simulation Results
- Conclusion and perspectives

Introduction

- EUREQUA ANR Project (French National Research Agency)
  - Interdisciplinary project: meteorology, sociology, architecture, environment sciences, transport, pyschology...
  - Evaluation objective/subjective environmental quality
  - 5 field measurement campaigns: 3 in Toulouse, 1 in Marseille, 1 in Paris
- Pollutant dispersion in Bordelongue in Toulouse
- CFD open source *Code_Saturne* (www.code-saturne.org)
- Under time-varying meteorological condition from Meso-NH regional simulation with TEB around Toulouse by Météo-France
- Comparison with local measurements made during the campaign between 8th and 10th April, 2014

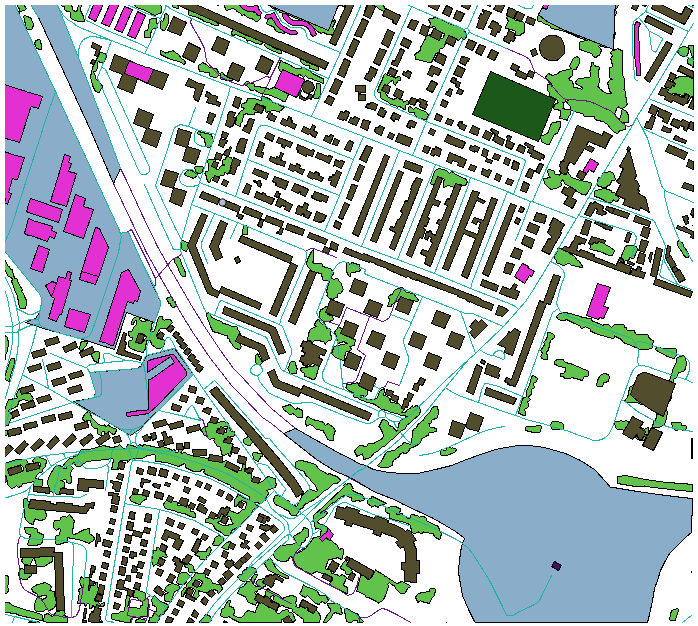
Introduction

- Southwest area of Toulouse
- Urban morphology: various types of buildings and obstacles
  - house districts
  - tower blocks
  - highway, local streets
  - vegetation areas

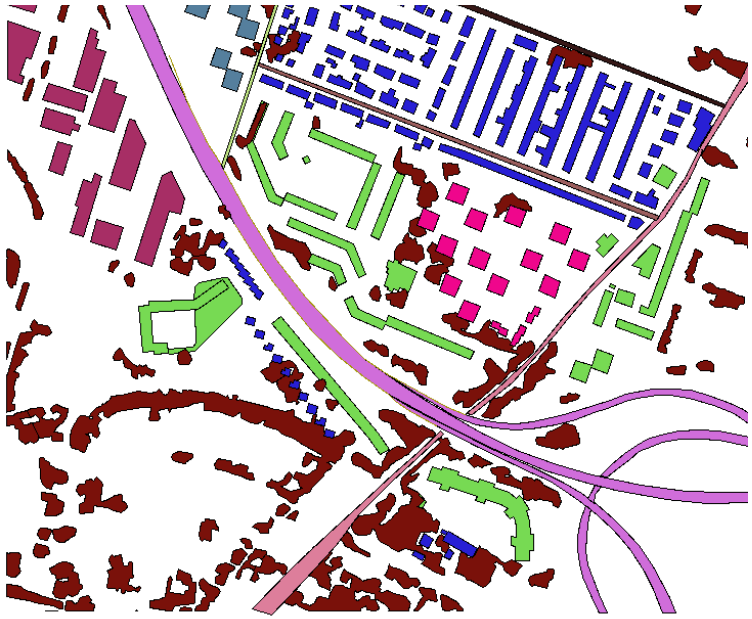
Figure: Urban morphology of Zone Bordelongue

Geometry and Mesh generation

- Geographical national database by French geographical institute (IGN).
- Selection of interested obstacles: buildings, houses, highway, etc
- Geometry simplification
  - elimination of excessive points, fusion of nearby points



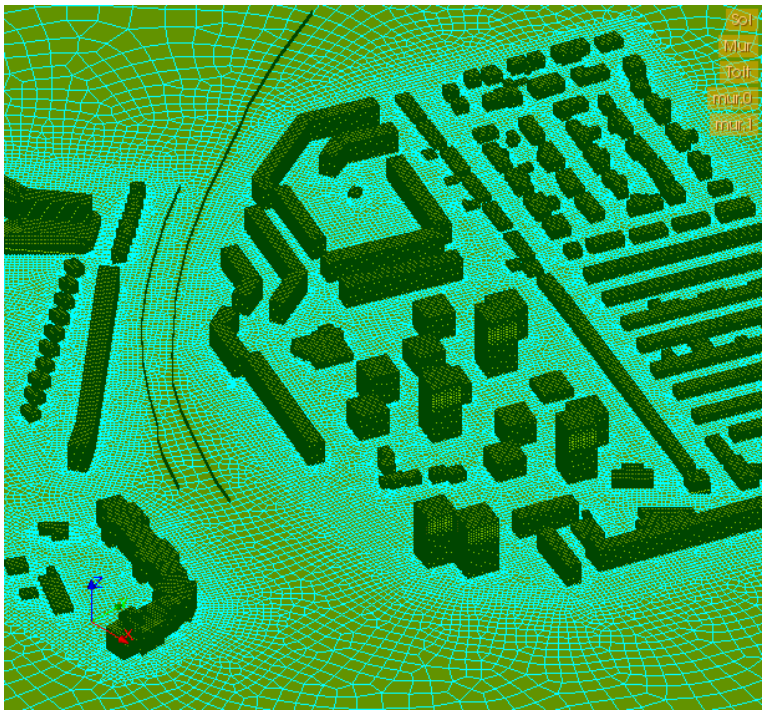
Original data



(b) Simplified shapefiles

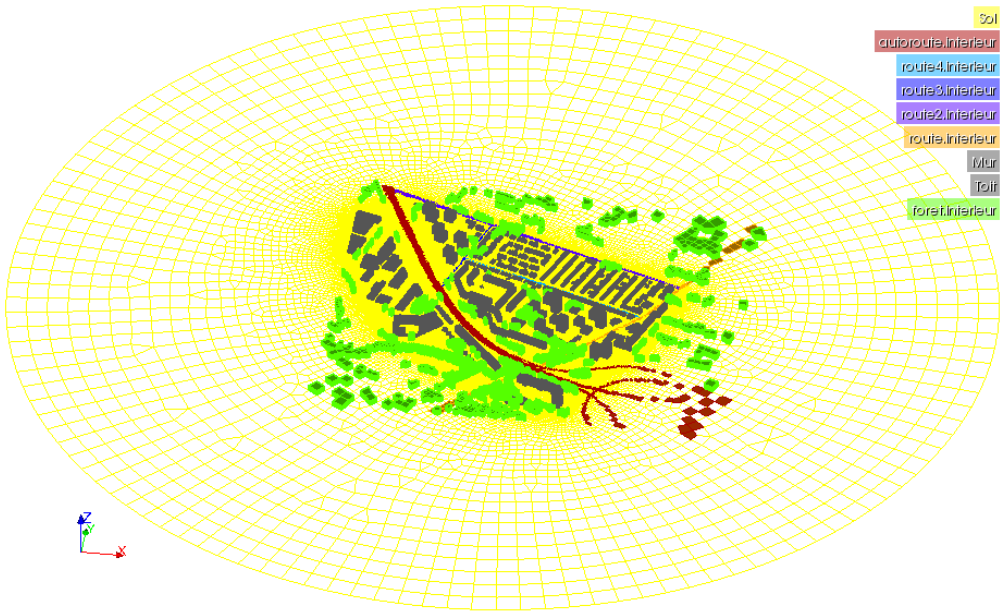
Mesh generation

- Open source Salome_Platform (www.salome-platform.org)
- Python scripts developed by CEREA, Ecole des Ponts ParisTech & EDF
  - 3D extrusion to create 3D mesh for buildings
  - Noise barriers along the highway treated as "Thin Walls"

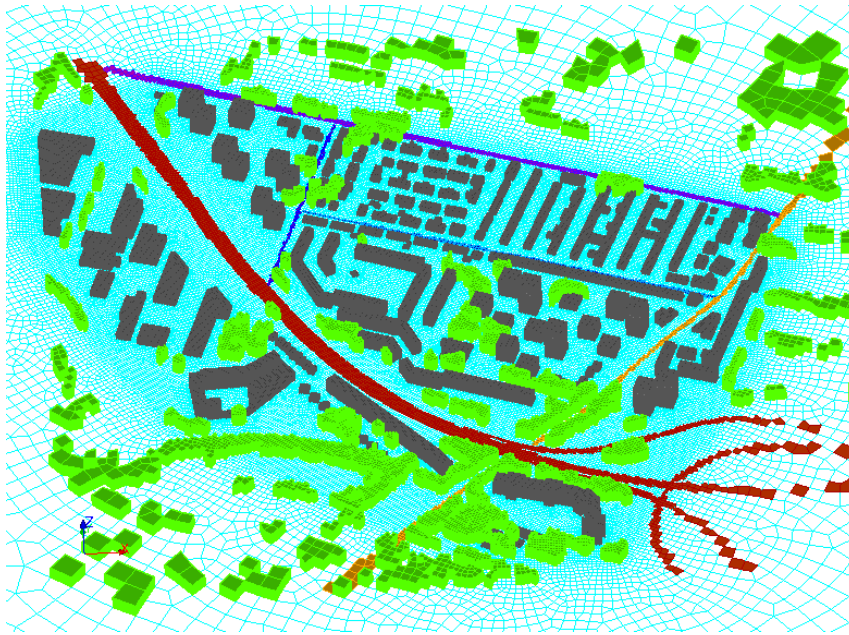


Mesh generation

- Rotating winds (Meso-NH regional simulation with TEB by Météo-France)
- A porous layer to modelizing vegetation canopy (tall trees)
- Pollution emission: cell surfaces selected for highway & local streets



(a) Mesh for buildings



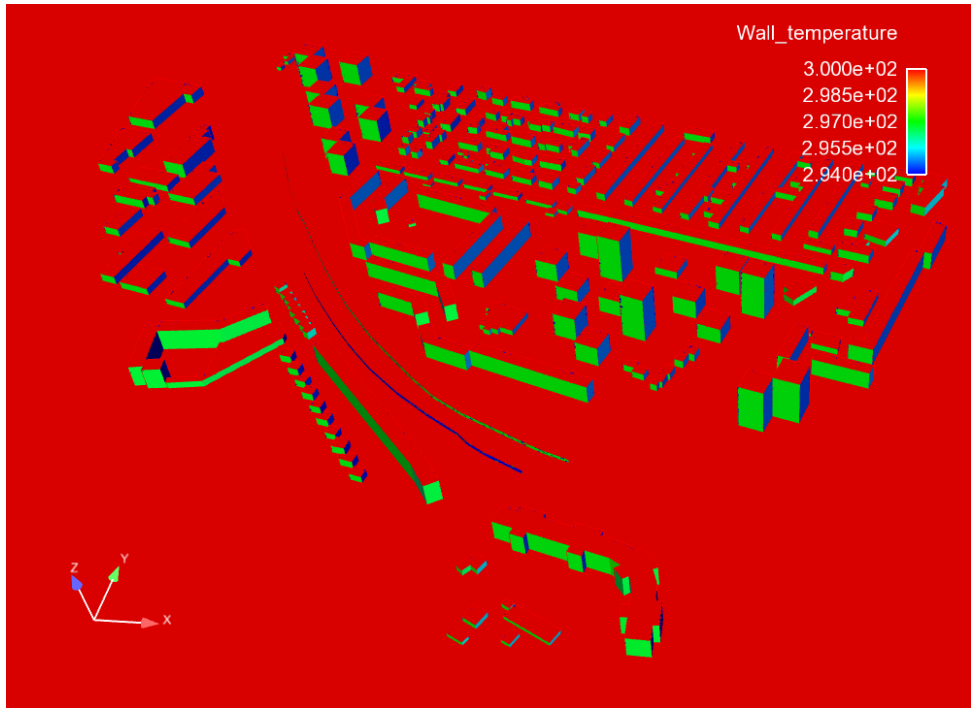
(b) plant area

Numerical Methods

- Dry Atmosphere option in *Code_Saturne* (www.code-saturne.org)
  - Navier-Stokes equation
  - Transport equation for potential temperature
  - k-ϵ model adapted for atmosphere
  - Six scalars for pollutants
    - Five scalars for each of the highway and four local streets
    - Sixth scalar for the background pollution of surrounding areas
  - Porous layer model for vegetation areas (Katul *et al.* 2004 BLM)
  - Running with 384 processors on EDF HPC Cluster
    - 5 millions cells mesh
    - 24h to simulate 72h meteo

Boundary conditions

- Surrounding edges and top of the domain using meteorological profile obtained from Meso-NH regional simulations around Toulouse by Météo-France
- Zero velocity at the solid surfaces (of buildings, roads, *et al.*) using one scale rough wall law
- Wall temperature of buildings given by an interpolation in time and in angular direction of the temperature deduced from infrared images in N.S.E.W. directions
- Ceillings and ground temperature deduced from infrared images

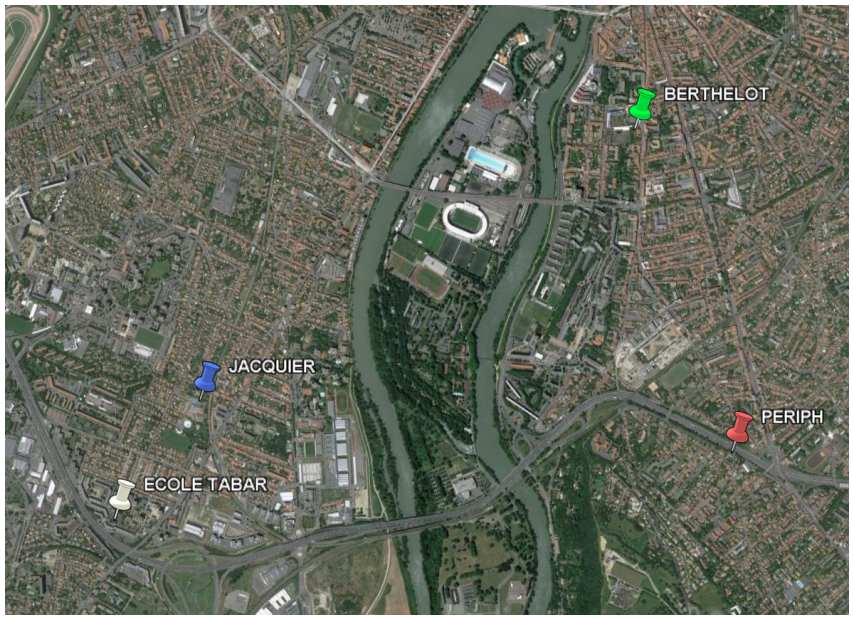


Imposed wall temperature at 39h

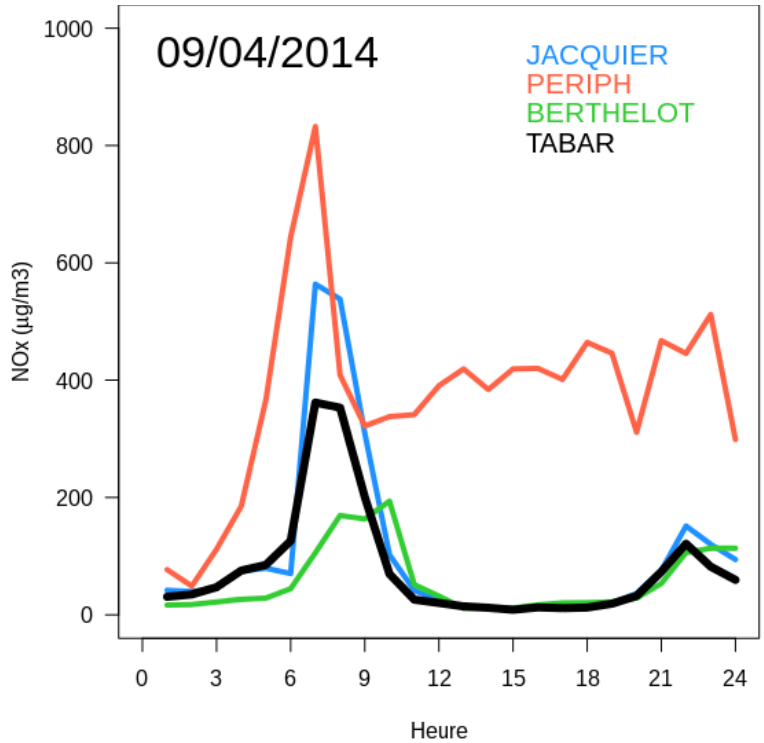
Scalars for pollutants

- Source terms: the 1st layer of cells next to surfaces of highway/streets
- Surrounding edges: Dirichlet condition for inlet flow (Jacquier)
- Zero-flux at the solid surfaces for all the passive scalars
- Data from measurements averaged for each hour during 72 hours

Pollution data from ORAMIP



(a) Location of sensors

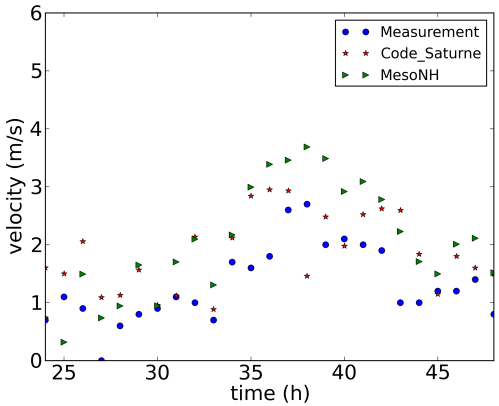


(b) 24 hour evolution

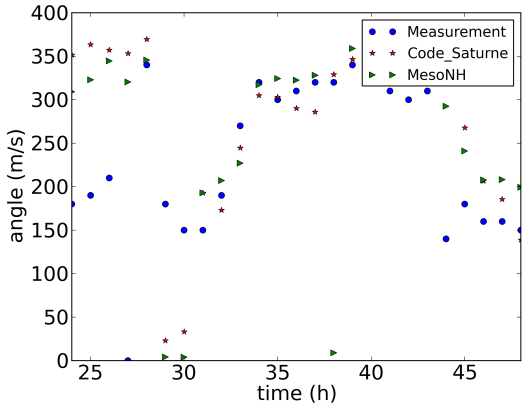
Simulation Results

- Simulation v.s. Measurement for 24h (9th April 2014)
- Meteorological station installed on the top Residence Enzo Goreas

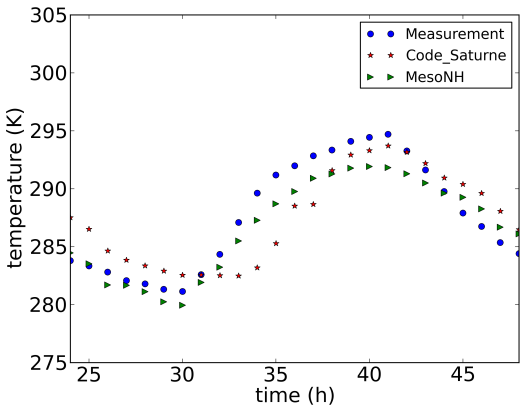
Wind speed



Wind direction



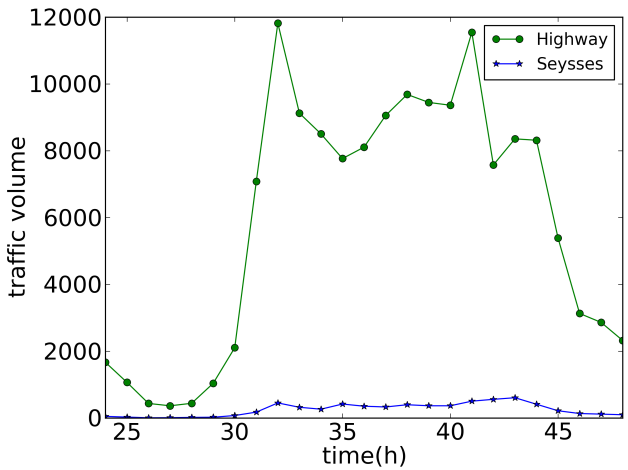
Potential Temperature



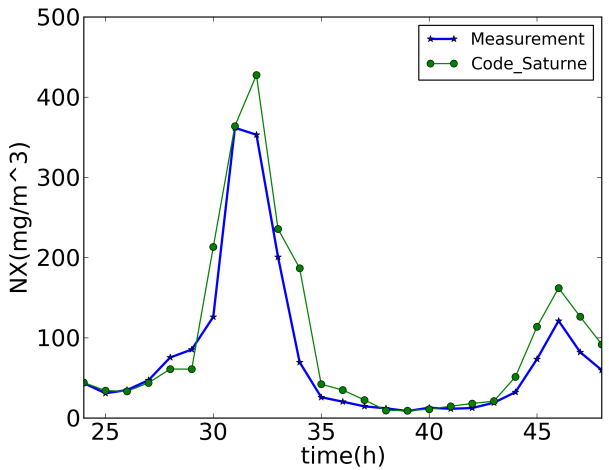
Simulation Results

- Simulation v.s. Measurement for 24h (9th April 2014)
- Air quality sensor installed at "Ecole Tabar"

Traffic

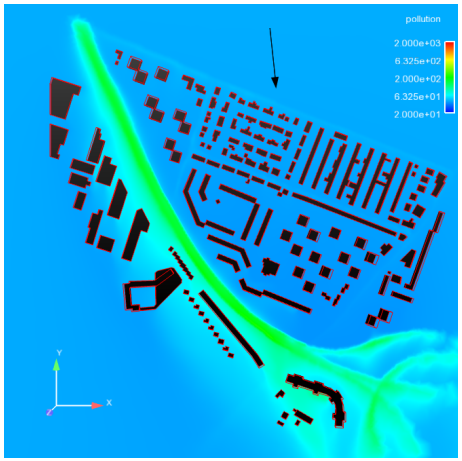


Pollutant concentration

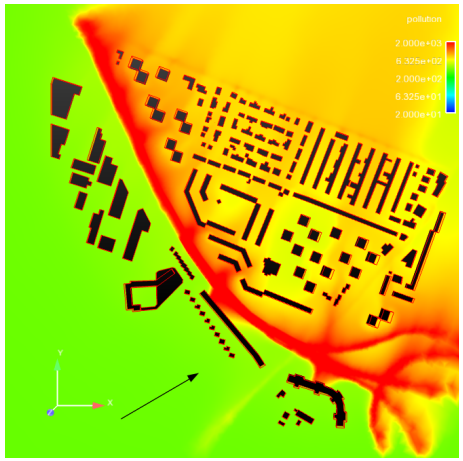


Simulation Results

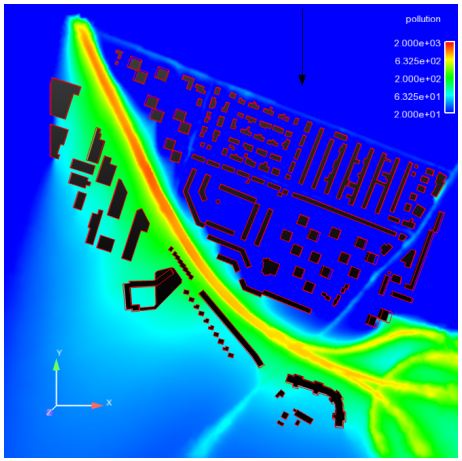
Concentration distributions at 2m above the ground



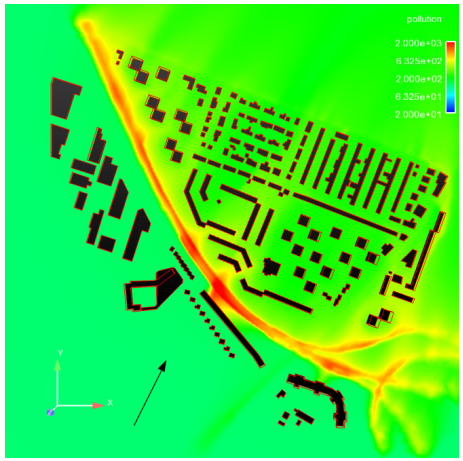
26h



32h



39h

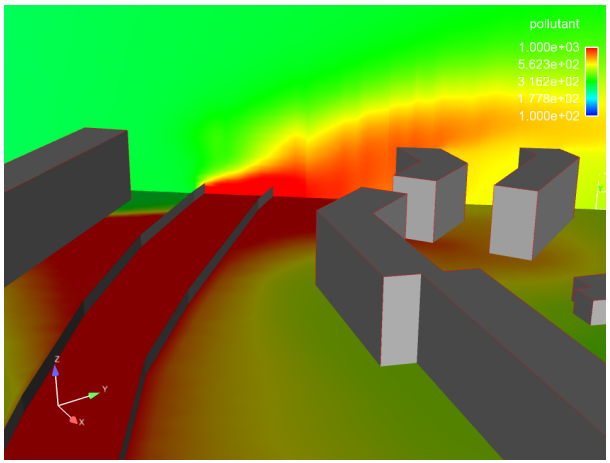


46h

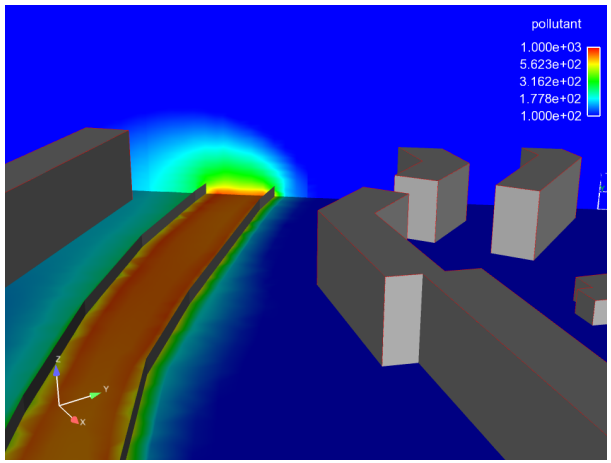
Simulation Results

Effects of noise barriers (height of 3m)

32h



39h



Pollutant concentration distributions in two planes: one is at 2m above the ground, the other is vertical and perpendicular to the noise barriers around the location "Point Tabar"

Conclusion and perspectives

- HPC simulation of the urban area Bordelongue in Toulouse
  - Mesh Generation
    - Simplification of SIG data
    - Python scripts with *Salome* to generate the 3D mesh
  - *Code_Saturne* simulation
    - Atmospheric option with $k - \epsilon$ turbulent model
    - Time evolving meteorological boundary conditions imposed from Meso-NH regional simulations (Météo-France)
    - Wall temperatures using measurement data in situ
    - Pollution: background and traffic emission
  - Numerical results with respect to measurements
    - A good agreement at "Ecole Tabar" air quality station
    - Local traffic emission is the main pollution source in the area for this period
    - Noise barriers has a small effect stopping the pollution dispersion
- Future works
  - Further validation with measurements
  - Computation of UTCI or other comfort indices
  - Urban renewal scenario studies (e.g. higher noise barriers...)

Thank you for your attention!