A customized workflow for indoor BC dispersions analysis in subway stations

Jérémie Tâche*, Fluidian
Laurens Dudragne, Thales C&S

Code_Saturne users meeting
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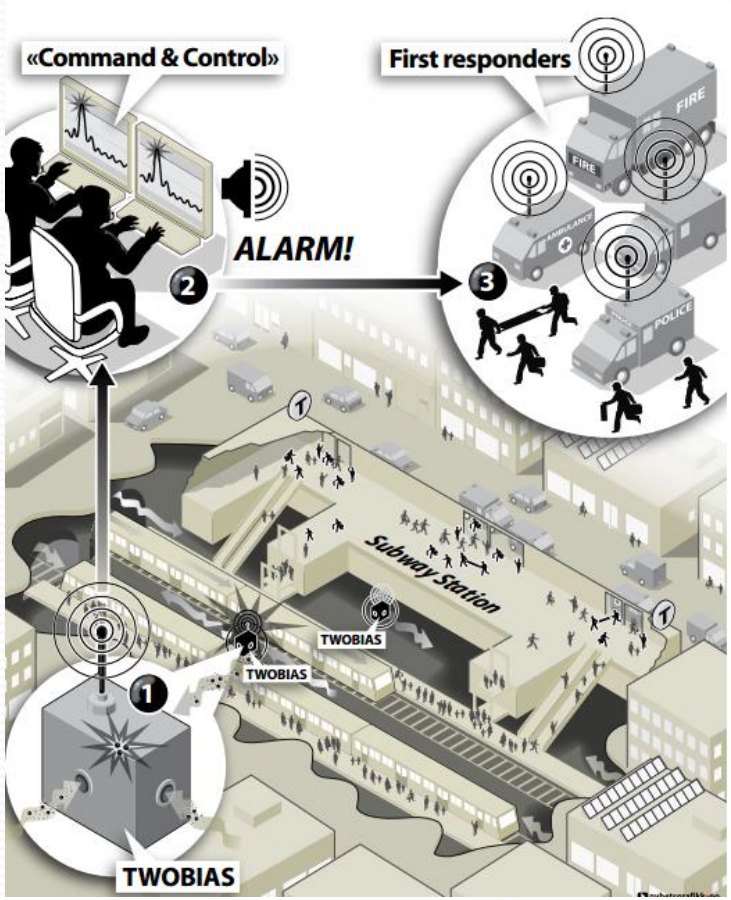
Summary

- Context
- Goal
- Needs
- Design of a solution based on C_S
- Added features
- Demo case

Context

- FP7-security EU-project
- “aims for enhancing security among civilians at public places regarded as targets for a bioterrorist attack by increasing first responders effectiveness as response time is reduced”

→ **CFD tool for “smart” positioning of sensors**



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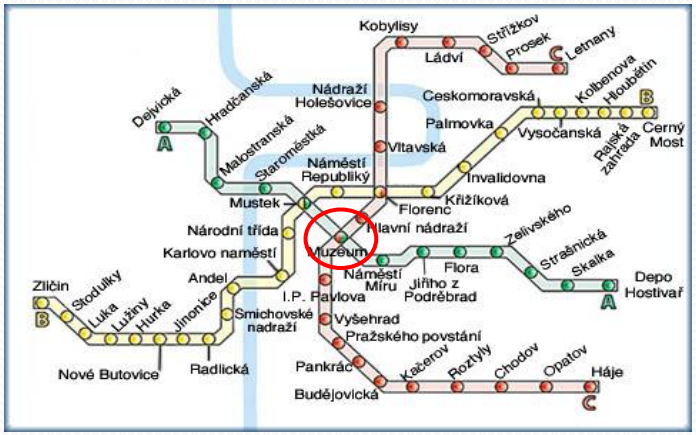
Context

"Museum" subway station (Prague, Czech Rep.)



- Main inputs
  - Simplified 3D geometry of station
  - Global HVAC flow rates
  - Traffic data
  - Sensors characteristics
- Requested outputs
  - Flow directions and velocity
  - Evolution of bio agent's cloud
  - Concentrations on virtual sensors

Goal

Build a tool with these features :

- Modeling of air flows in infrastructures e.g. airports, subway stations, …
- Simulation of Biological (aerosols) or Chemical (gas) dispersion
- Modeling of BC sensors
- Play “What if” scenarios (efficiency of counter-measures)
- Easy-to-use i.e. automatic handling of geometry, mesh, setup of solver and post-processing of relevant results
- Designed for a (powerful) laptop → need a fast tool

→ Design of an automated CFD workflow dedicated to BC dispersion in critical infrastructures
→ One task / One tool

Needs

What we mainly need :

- An unstructured mesher
- A fast CFD solver for moderate Re incompressible flows
- A post-processing tool

+ Scriptable tools

+ High level of customization

Is there a solution in open-source world ?

Design

Choice of open-source components

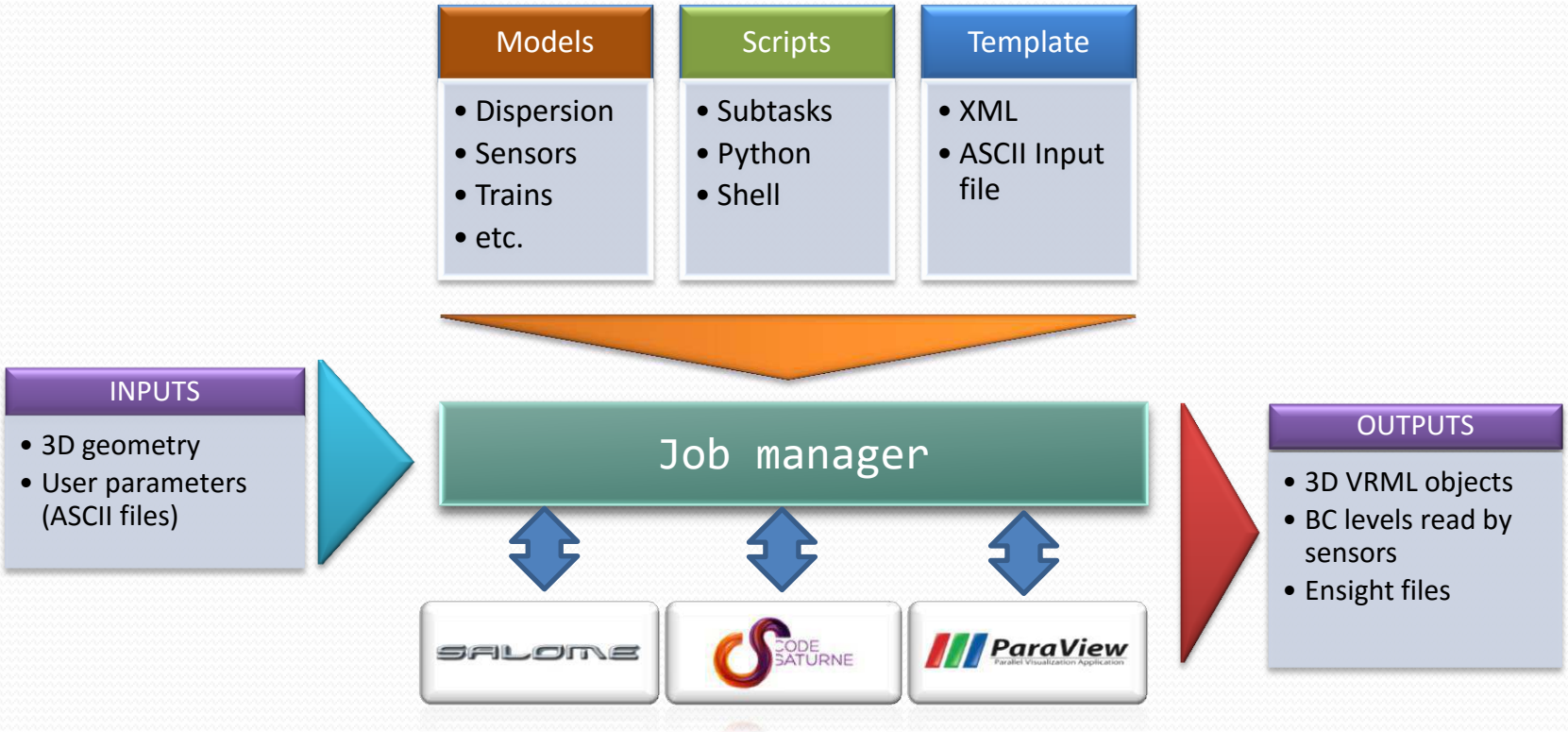
- **Code_Saturne** : implicit unsteady solver is quite robust

- **Salome platform** : geometry treatments, tetrahedral meshing (MED format)

- **Paraview** : post-processing of Ensight results files, creation of VRML files

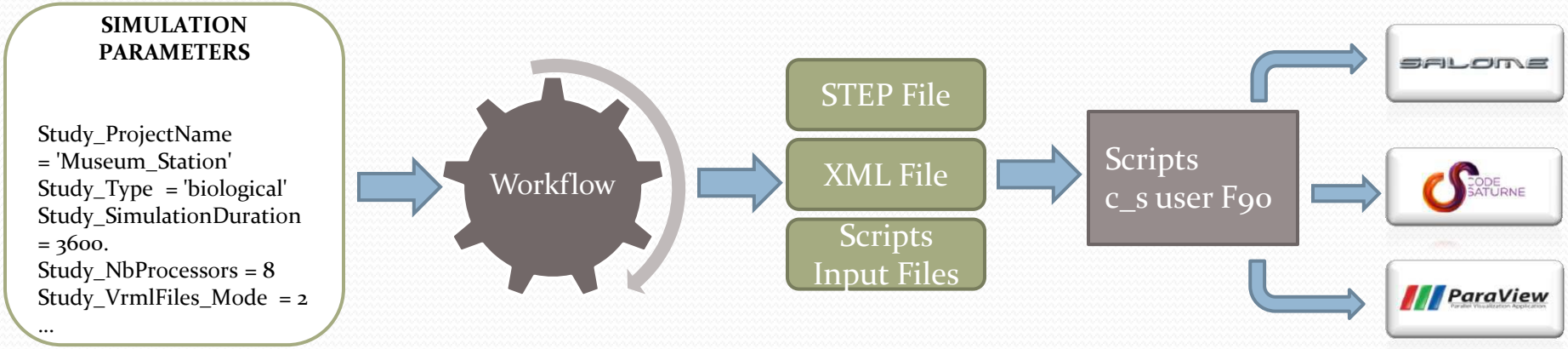
Design

Global workflow architecture



Added features

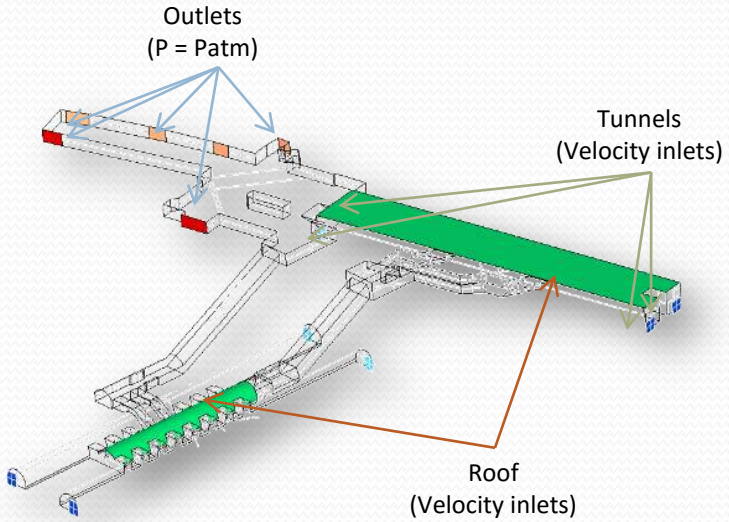
Automated setup of Code_Saturne



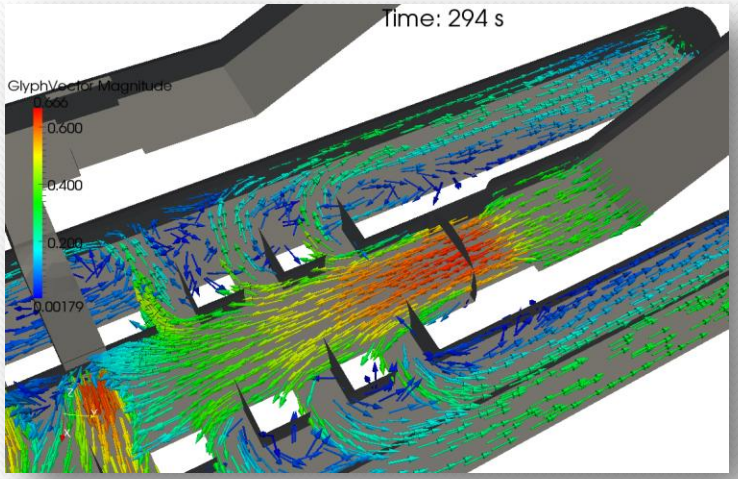
- Main parameters
  - Simulation duration
  - Bio or chemical dispersion
  - NRBC agent(s) properties
  - Sources characteristics
  - Threshold for cloud visualization
- Precision switch
  - Coarse / Fine mesh
  - High / Low CFL
- Some custom options
  - Add HVAC surfaces in the 3D geometry
  - Auto stop c_s when station is empty of agent
  - Launch workflow through IP network

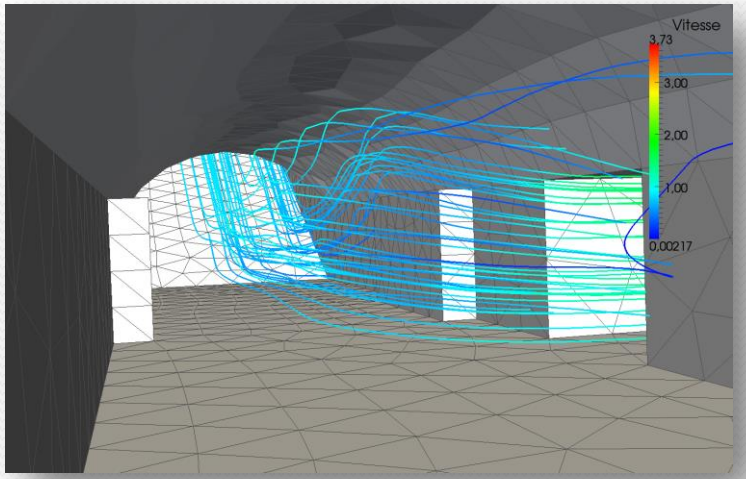
Added features

Automated HVAC simulation



- Turbulence : isothermal unsteady RANS (k-ε model)
- Boundary conditions based on HVAC data (user files)
- Mean mesh size is about 1 m
- Simple definition
- Fast compute

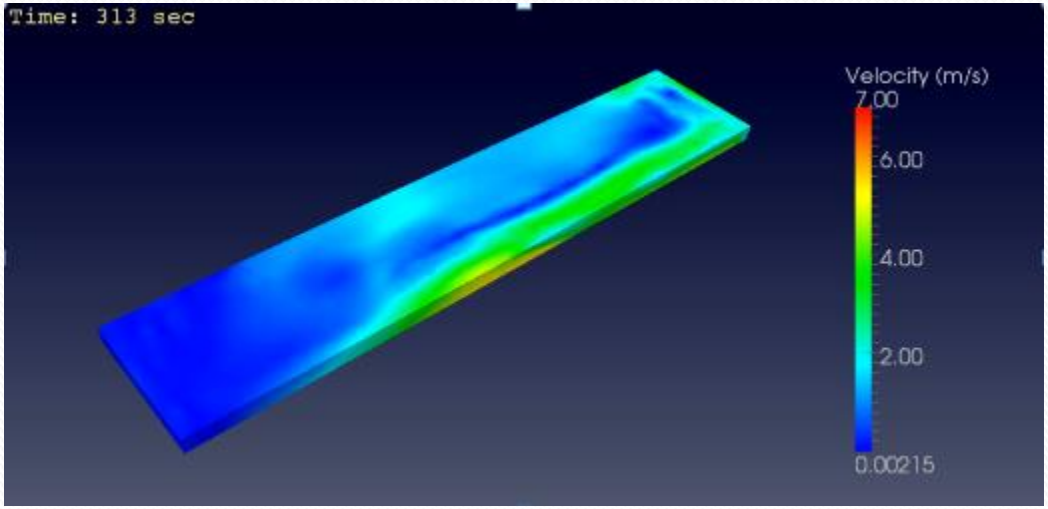




Added features

Perturbations of flow by moving train

- Airflows are strongly affected by moving trains
- Use of a fast “penalization method” through a source term on momentum equations
  - no change in mesh
  - source term is varying in (x,t)
- Implicit C_S solver quite robust on such problems



Effects of two moving objects in a simple box

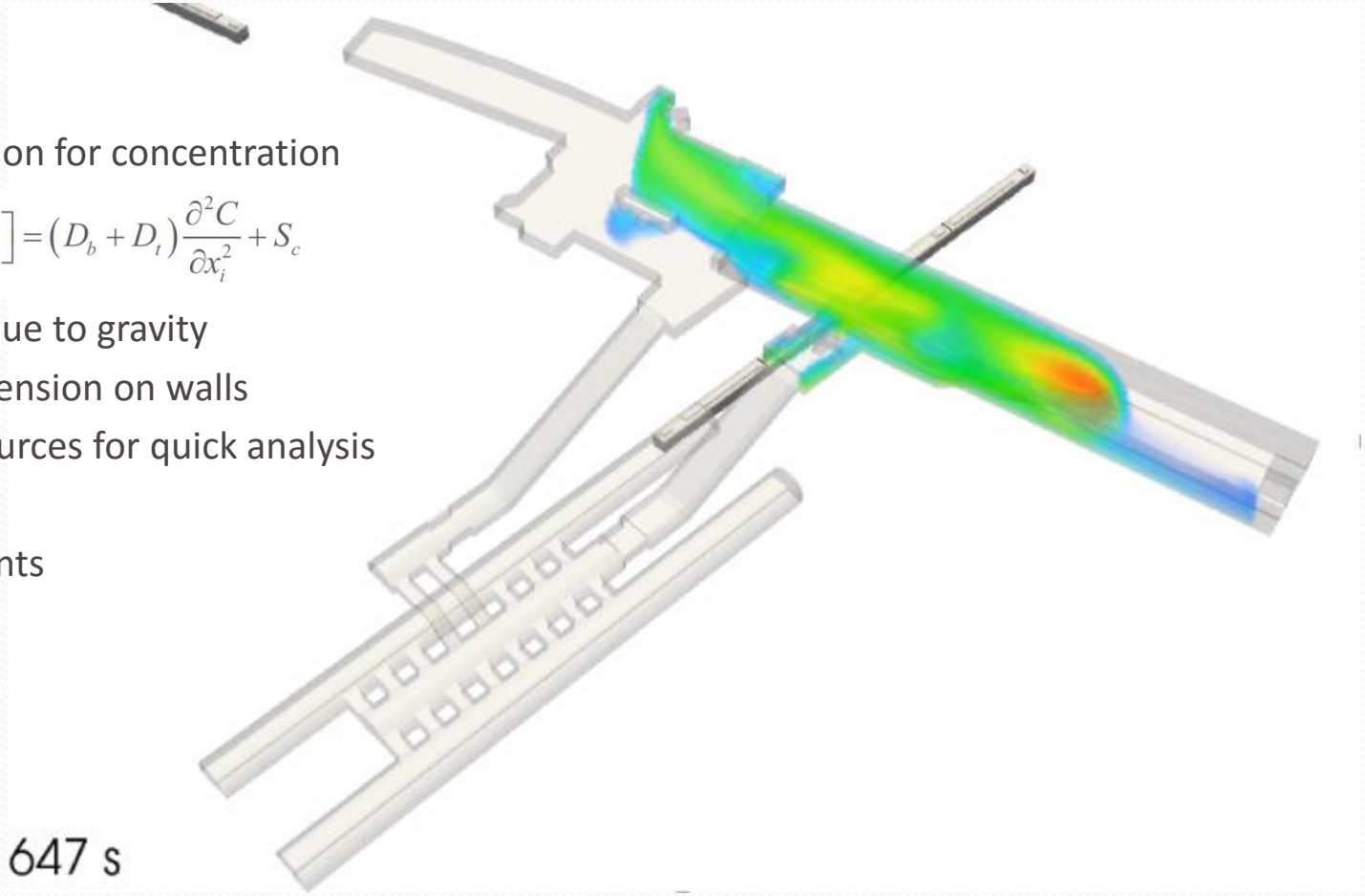
Added features

Dispersion of biological agent

- Scalar transport equation for concentration

$$\frac{\partial C}{\partial t}+\frac{\partial}{\partial x_i}\left[\left(U_i+V_{s,i}\right)C\right]=\left(D_b+D_t\right)\frac{\partial^2 C}{\partial x_i^2}+S_c$$

- Sedimentation effect due to gravity
- Deposition and resuspension on walls
- Multiple uncoupled sources for quick analysis
  - different agents
  - different start instants
  - different quantities
  - different locations



Added features

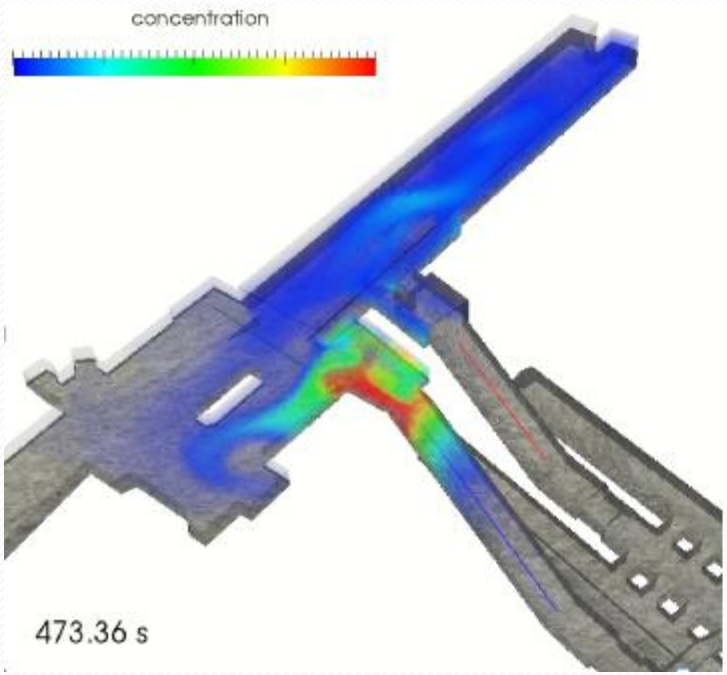
Dispersion of chemical agent

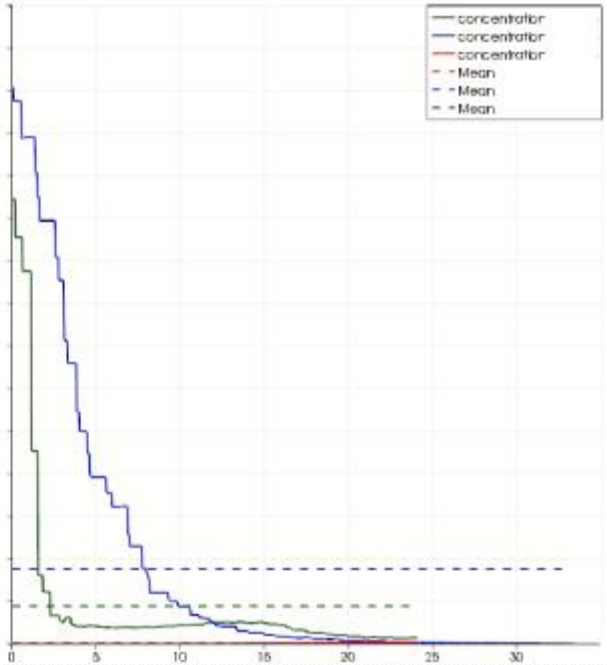
- Scalar transport equation for concentration
- Light or heavy gases : buoyancy effect through modification of mixing density
- Evaporating puddle
  - gas flux computed from local conditions (u*, T)
- Multiple coupled sources
  - single agent
  - different start instant
  - different quantities
  - different locations

Added features

Sensors

- Different type of sensors
  - Concentration Probes
  - IR or UV barrier
  - FTIR camera
- Sensor parameters
  - Location
  - Type
  - Activation threshold
  - H/V angles





Example : IR barriers in Museum station (Prague, Czech Rep.)

Added features

Alerts & Countermeasures

- Complex logic condition for a set of sensors

Condition = (Probe1 **OR** Barrier2) **AND** (Barrier1 **OR** Camera3)

- Condition == TRUE → launch of countermeasures during calculation
  - Stop train traffic
  - Change HVAC boundary conditions e.g.
    - inverse flow directions (extract)
    - increase or decrease flow rates
  - Open more outlets
  - Open/Close internal walls

→ **Possibility to compare effectiveness of different set of countermeasures**

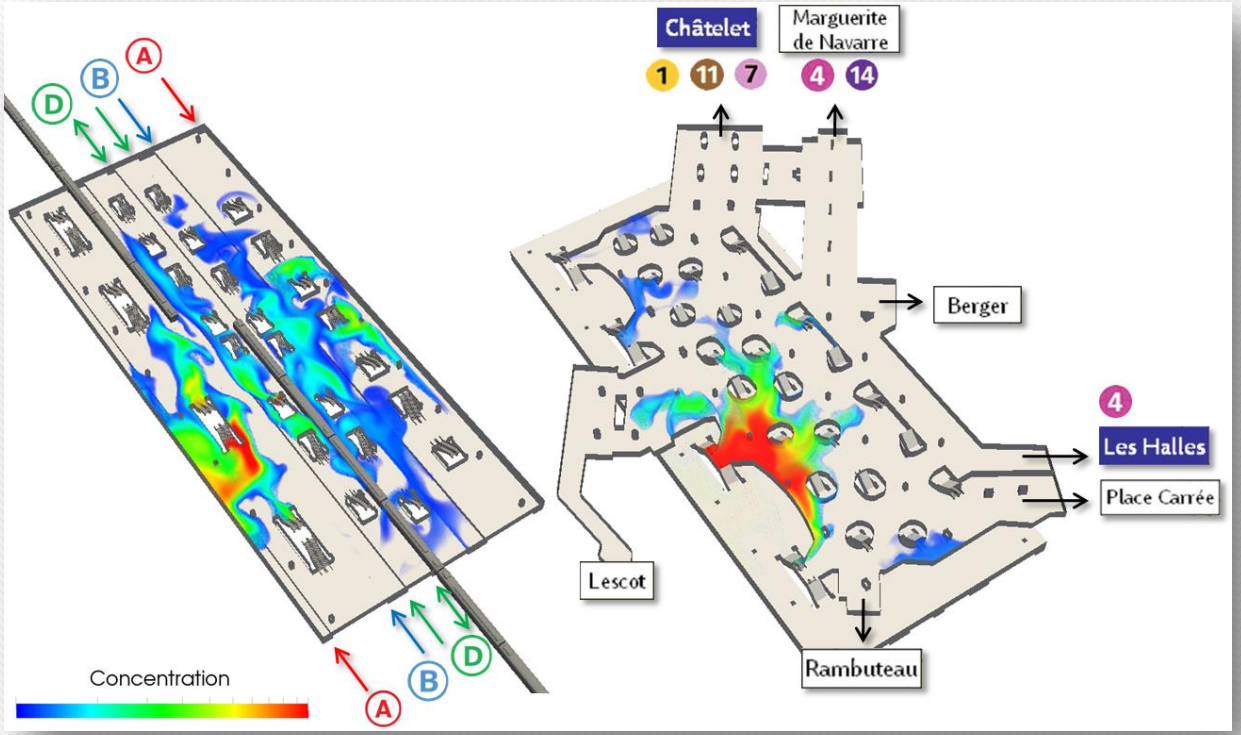
Demo case

RER station «Chatelet-les-halles », Paris, Fr.

- In-house demo case « for play »
- Test of robustness on a larger infrastructure
- Use of realistic data for
  - geometry,
  - HVAC,
  - Trains.

- Play “what if scenarios” by easy changes of parameters

- **Example** : transfer of a bio agent between levels



Fluidian	Thales Communications & Security
12 rue des 3 cèdres 95000 Cergy	20 rue Grange Dame Rose 78141 Vélizy
www.fluidian.com	www.thalesgroup.com