HSE
Occupational Health and Safety

INSTITUT NATIONAL DES SCIENCES APPLIQUÉES LYON

Evaluation of ground relaxation parametrization over complex terrain and experimental validation for pollutant dispersion: application to the CERN Meyrin site

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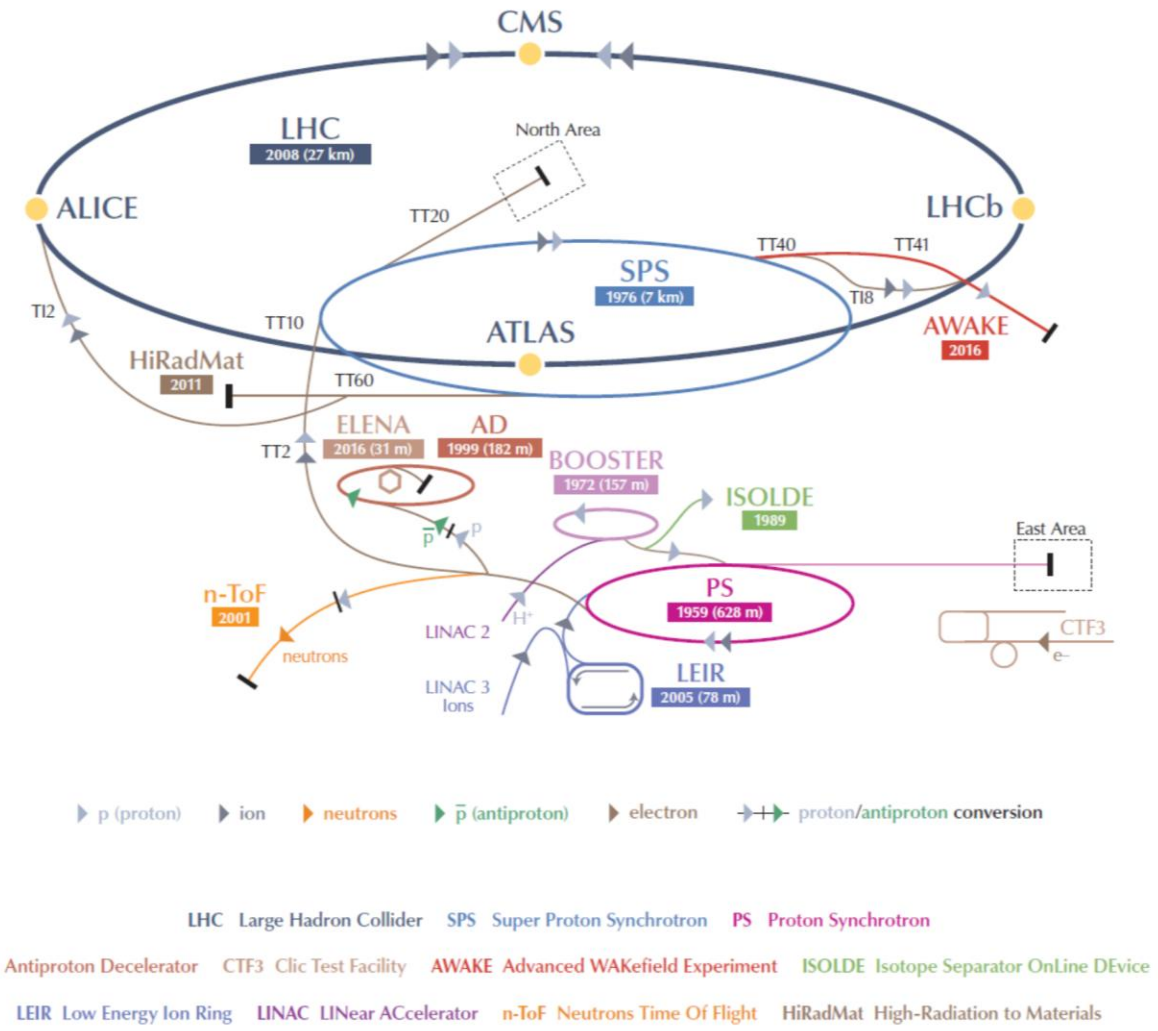
Why study pollution dispersion at CERN?



CERN accelerator complex schematic, CERN

Europe's premier particle-physics lab

- Large underground infrastructure
- Large on-site population

Complex built environment + varied terrain

- >100 experiments, radioactive and chemical laboratories

Fire + radioactive particle-release risk

- Swiss regulations ENSI G-14

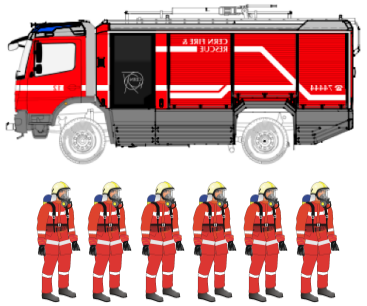
Pollution dispersion challenges:

- Lack of unified methodology
- Lack of real-time, terrain-aware dispersion tools
- Need for accurate near-field (local scale) resolution

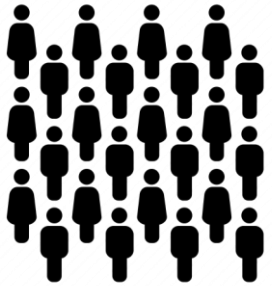
FIRIA: From Concept to Dispersion-Risk Assessment

The **F**ire **I**nduced **R**adiological **I**ntegrated **A**ssessment Project

Fire Service



Public



Environment

Life

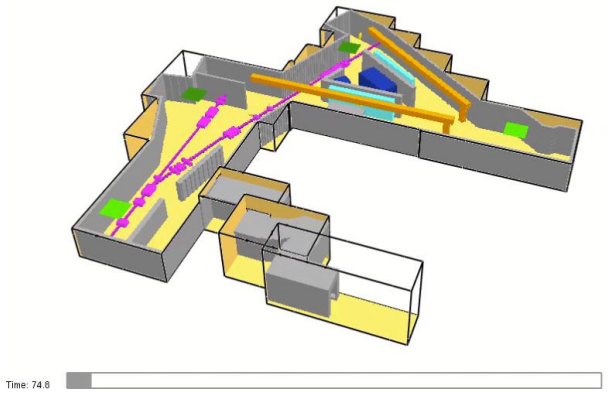
Occupants, neighbors, first responders

Environment

Property

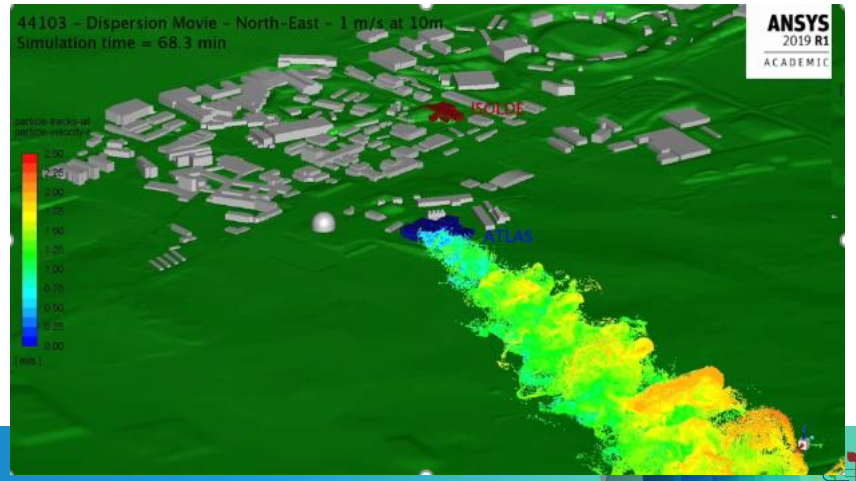
Continuity of operation

Indoor fire dynamics FDS



Soot testing campaign

Pollution dispersion in the ABL



Collaboration CERN fire brigade

What do we need?

Context

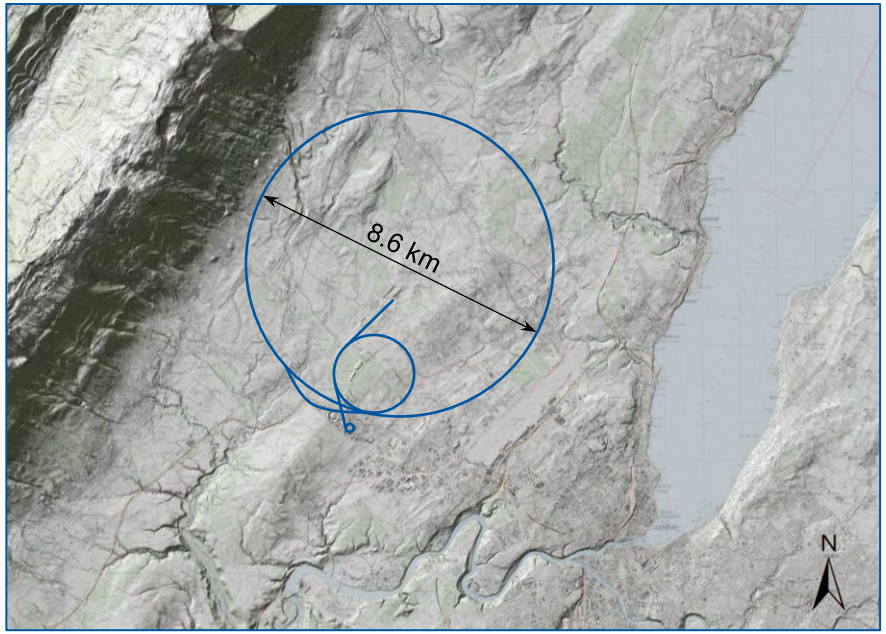
- Large areas around complex terrain
- Local-scale dispersion on several CERN sites

Operational requirements

- Evaluation of multiple scenarios
- Based on worst-case analyses
- Accurate outputs with operational capabilities
- Variable atmospheric conditions

Modelling choice

- CFD for wind fields (ANSYS Fluent)
- Lagrangian dispersion model (SLAM)
- Combined for emergency decision support



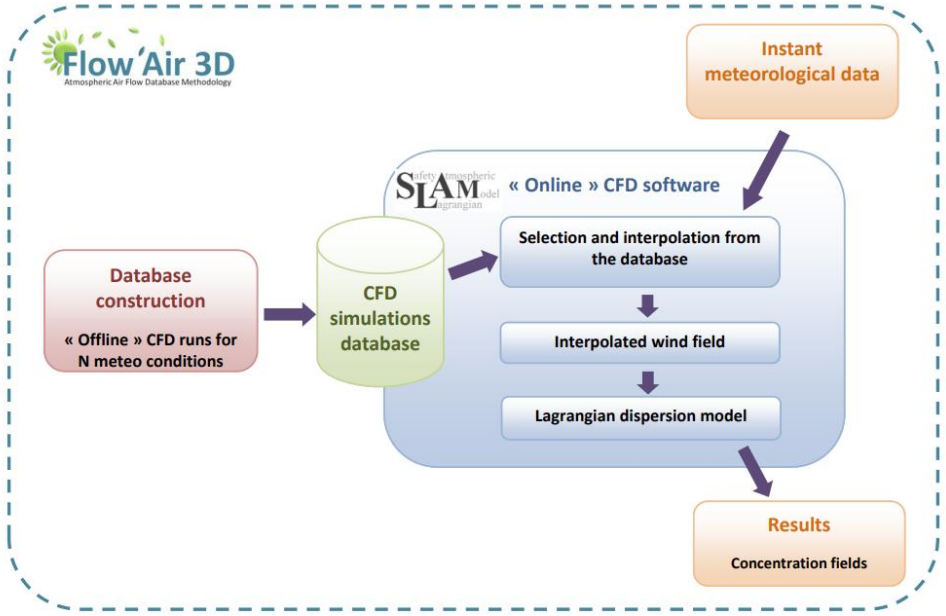
Orography and terrain around CERN (top) and measurement receptor layout at Meyrin (bottom).

CFD and Lagrangian model coupling

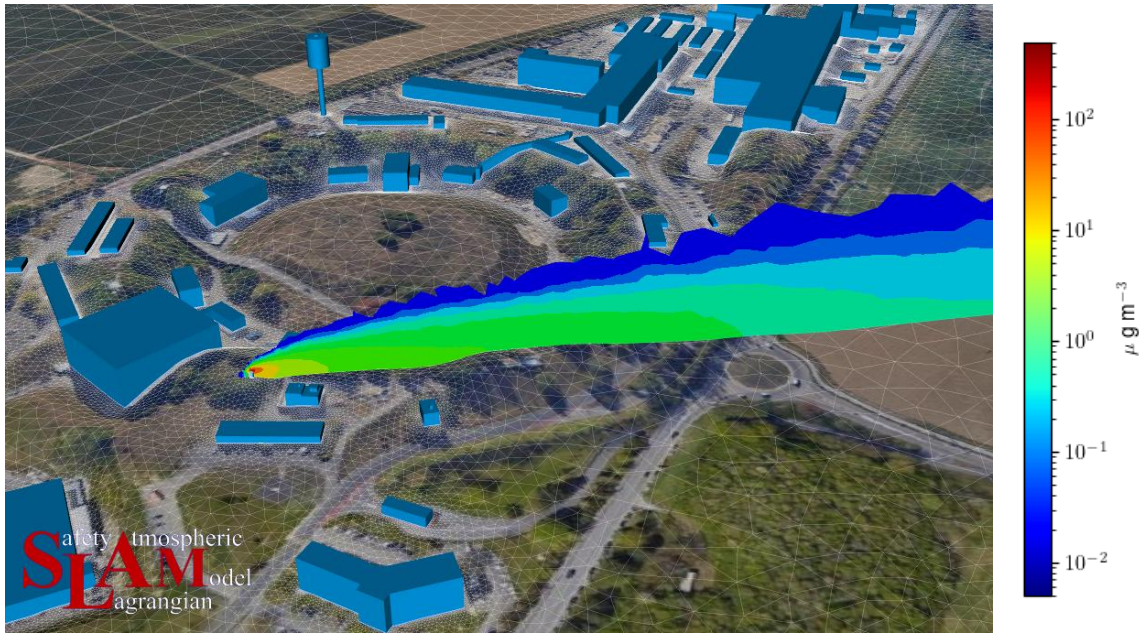
SLAM: Safety Lagrangian Atmospheric Model

- Developed by LMFA
- Lagrangian stochastic particles dispersion model
- Coupled to CFD wind/turbulence database (Generated with Ansys Fluent)

- Validated in ECL's wind tunnel (Vendel et al., 2011, Marro et al., 2014)
- Operational capabilities: Concentration fields in ~minutes



Source: SLAM website, http://air.ec-lyon.fr/SLAM/



Concentration of pollutants over CERN Meyrin site, calculated with SLAM

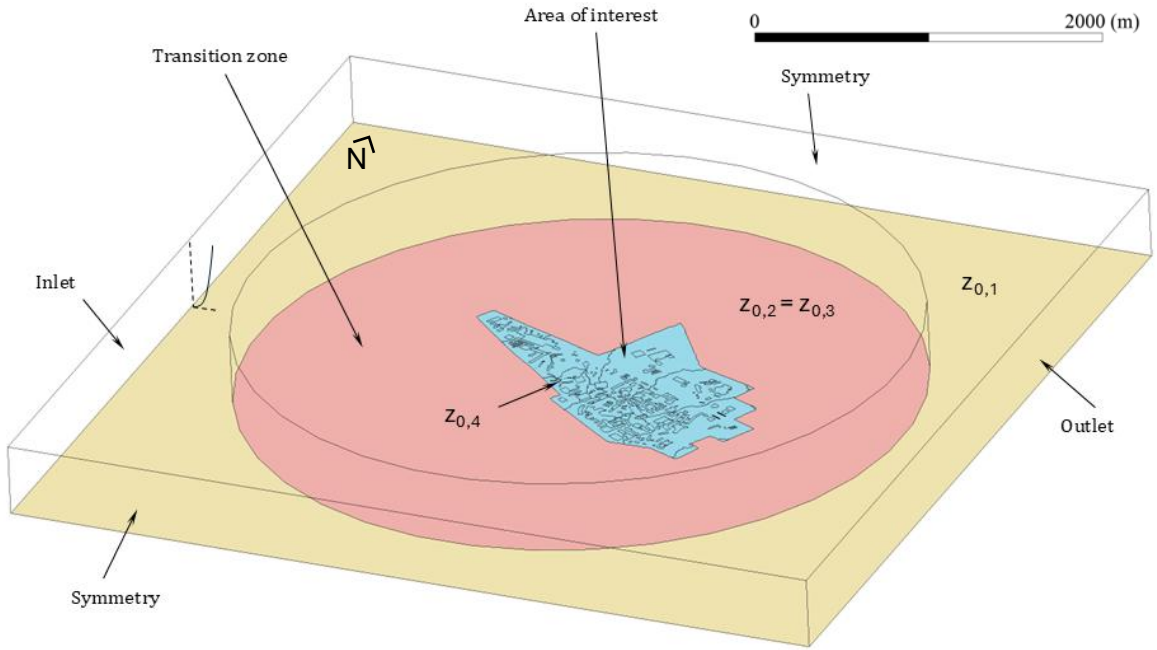
How to specify boundary conditions?

$$u_z = \frac{u_*}{\kappa}\left[\ln\left(\frac{z-d}{z_0}\right)\right]$$

Flat terrain allows to define homogeneous ABL at domain boundaries

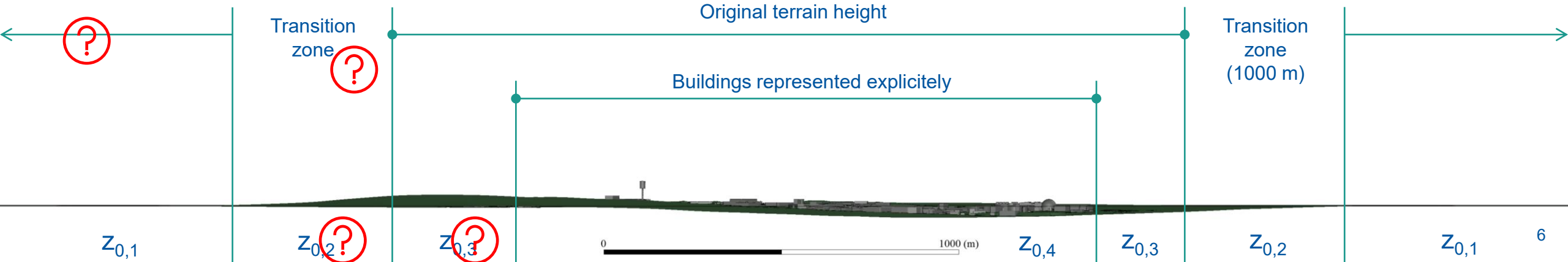
Open questions

- How long must relaxation be?
- How should we blend z_0 and height?
- Which is the impact on concentration profiles?



Domain & boundary conditions of the CERN Meyrin case

Goal: maximize SLAM versatility while limiting relaxation-induced effects at the area of interest



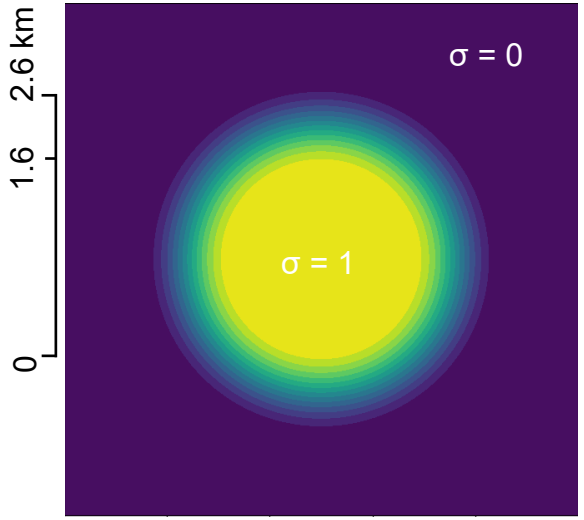
Terrain manipulations

Optimal relaxation unknown → Reference case → Reproducible and comparable

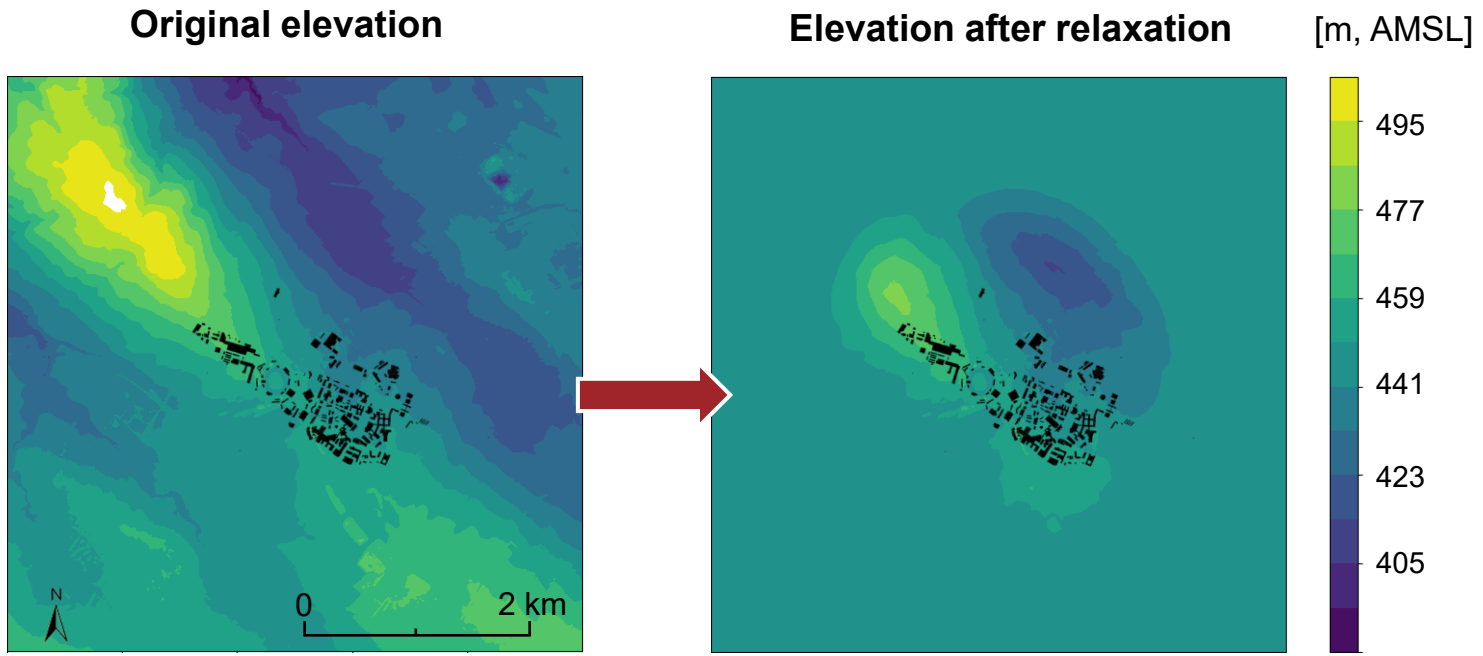
- Terrain relaxed with a smooth cosine function based on Balogh & Kristóf 's (2009) method

$$\sigma(x,y) = \frac{1+\cos(\tilde{R}(x,y))}{2}$$

$$H_{\text{relaxed}}(x,y) = (H(x,y) - H_c) \cdot \sigma(x,y) + H_c$$



Representaion of the applied relaxation mask



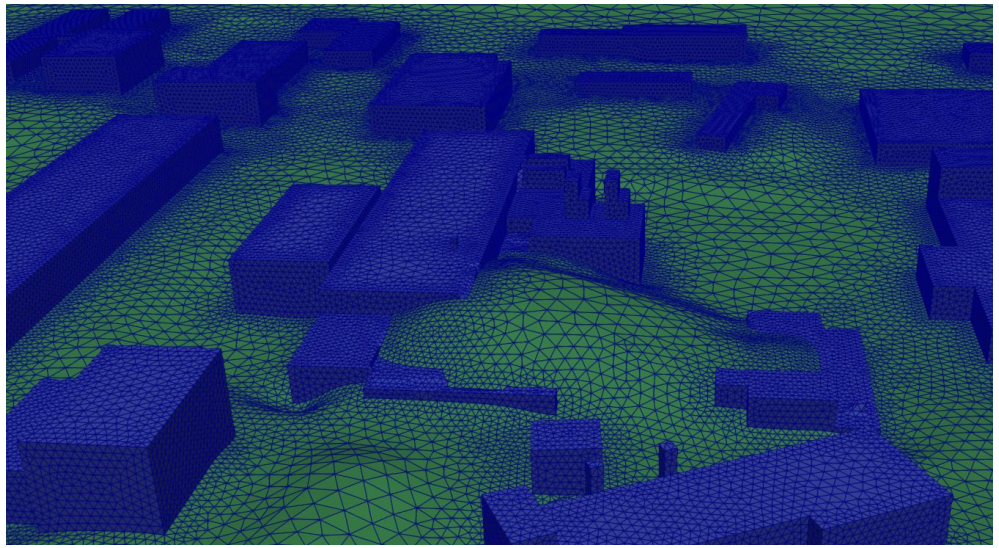
Elevation plots of the domain used for the modelling of the CERN Meyrin site, before and after relaxation, with buildings

Meshing and flow field database

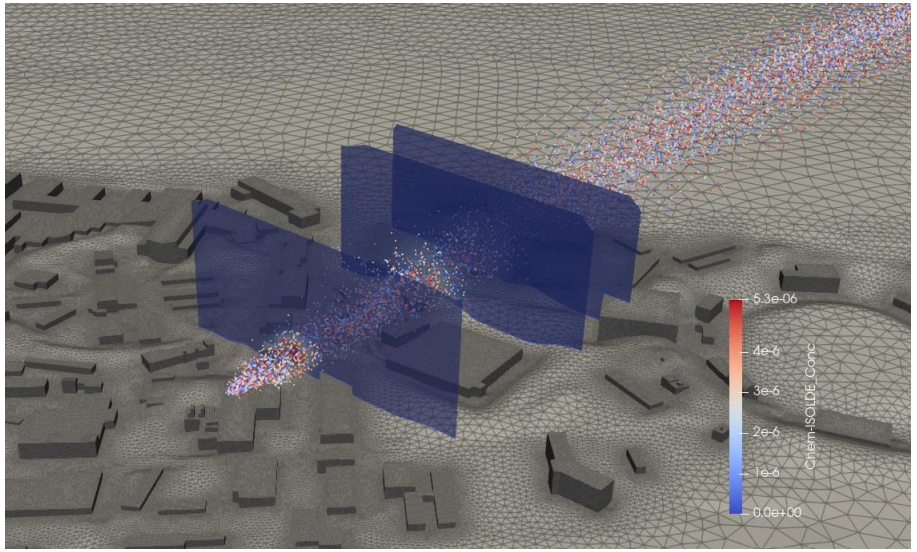
Meshing
- Poly-hex unstructured mesh, 4-cell inflation layer
- Cell and mesh size: 0.3 – 50 m, 7M cells

Boundary conditions
- 30-m top entrainment layer
- Inlet log wind profile, neutral stability
- Chimney release (10 m a.g.l.):
  - Inert, no chemical reactions
  - Nombre de particules → 50000

Database
- RANS k-ε, SIMPLE algorithm and 2nd order schemes
- 18 wind directions in neutral stability



Screenshots from the numerical model and mesh used in the SLAM tool



Pollutants particle release and concentration over CERN Meyrin site, calculated with SLAM

Experimental wind-tunnel campaign

Mock-up
- Mock-up built by EWTL Hamburg
- 1:250 scale, 3.5 m diameter
- 2 wind directions, 2 source points

Description of the Wind-tunnel
- Wind-tunnel facility of LMFA
- 14 m x 3.7 m x 2 m, test section

Wind field measurements
- Hot-wire anemometry (HWA)
- Verification of the results with Nironi (2015)

Concentration measurements
- Flame ionization detector (FID)
- ~600 measurement points per scenario

Visualization campaign performed in the LMFA wind-tunnel, with the CERN Meyrin mock-up

Experimental wind-tunnel campaign

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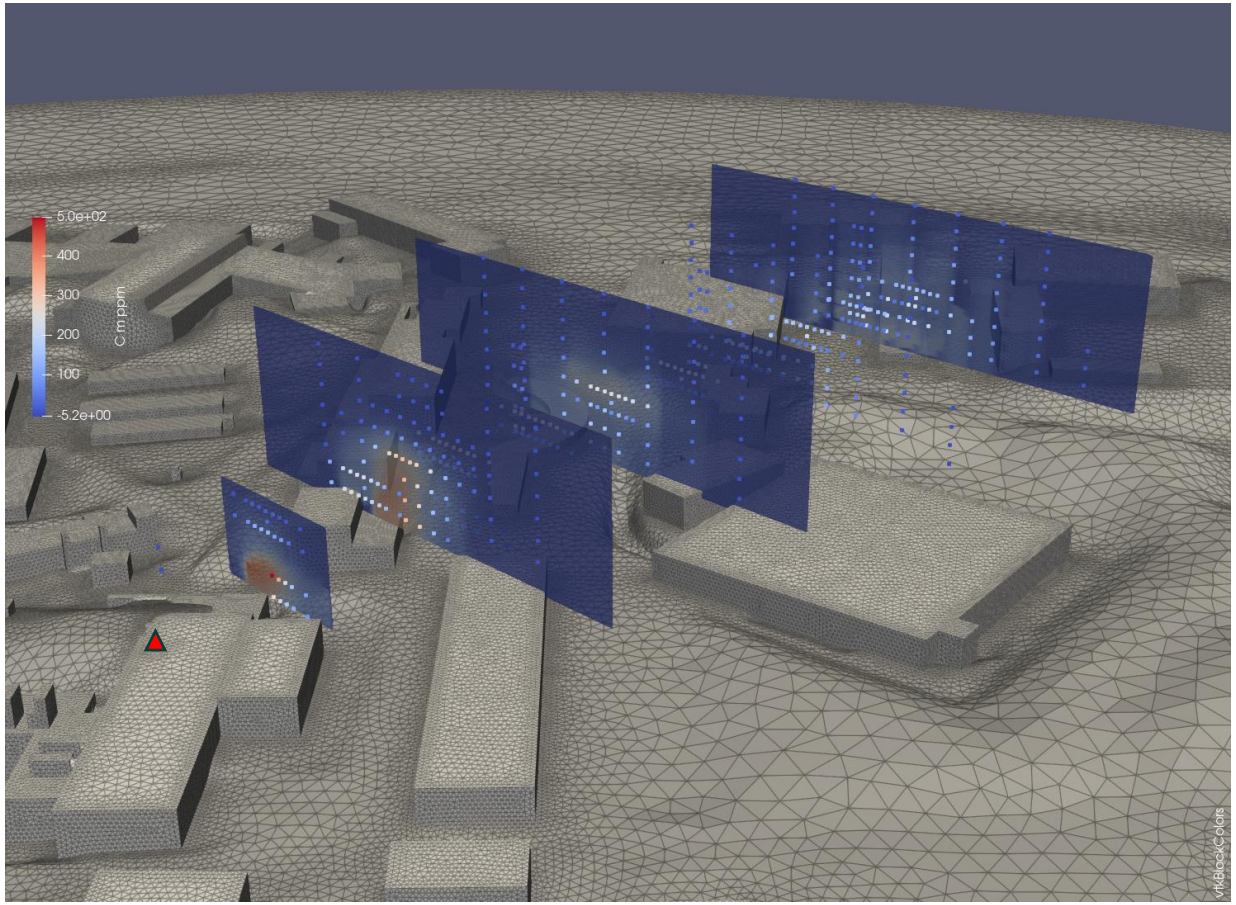
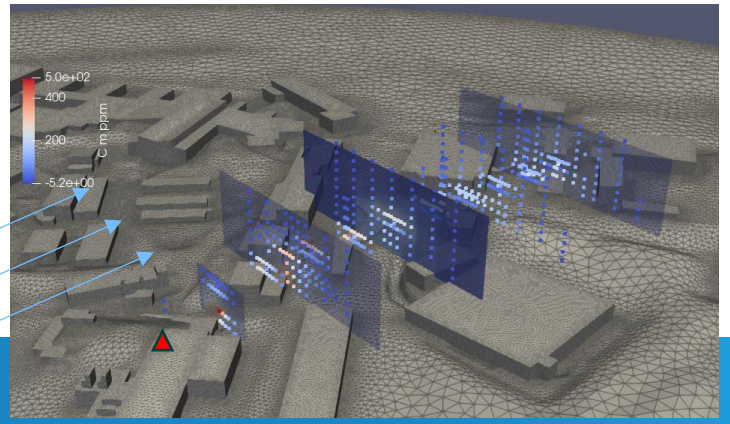


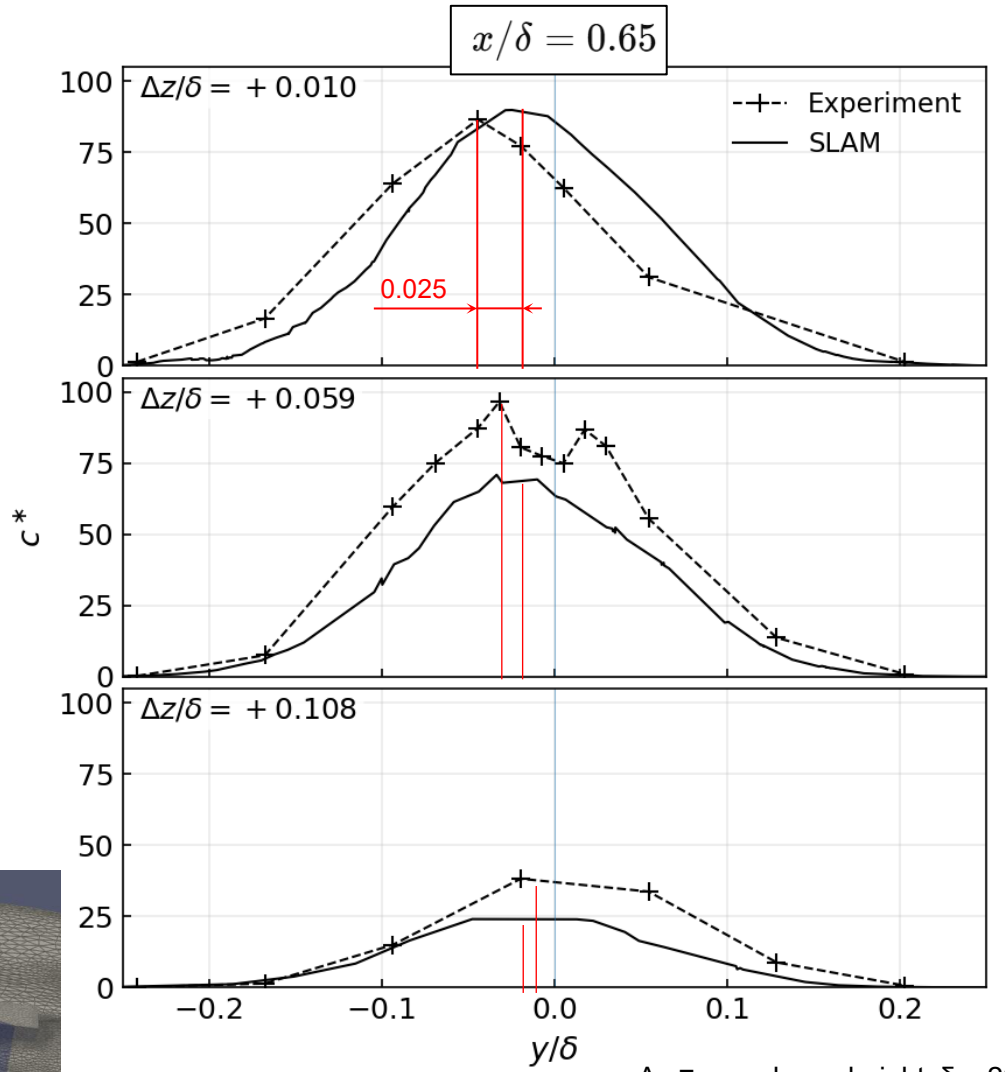
Wind-tunnel concentration measurements (dots) and interpolation on vertical contour plots located at y/δ = 0.26, 0.32, 0.64 and 1.25. The red triangle marks the release point.

Comparison of concentration measurements

Transversal plane

- Adimensionalized concentrations : $C^* = \frac{C\,U_\infty\,\delta^2}{Q}$
- Good agreement between numerical and experimental results on max. values and plume size
- Slight lateral deviation, decreasing with height
  - Max. deviation = 0.025 y/δ → ~2.2°
  - Wind-tunnel flow direction uncertainty: ± 2.5° (Ben Salem et al., 2015)





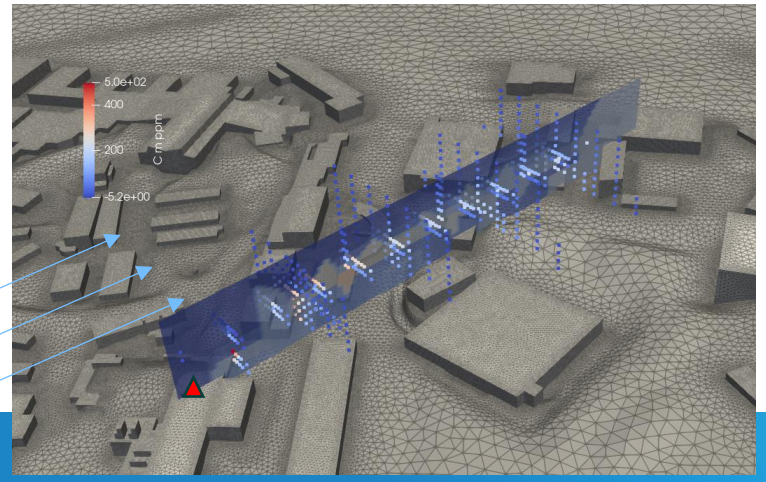
Δz ≡ z − release height, δ = 204 m,
Comparison of adimensionalized concentration profiles at different heights, measured at x/ δ = 0.65 from the source

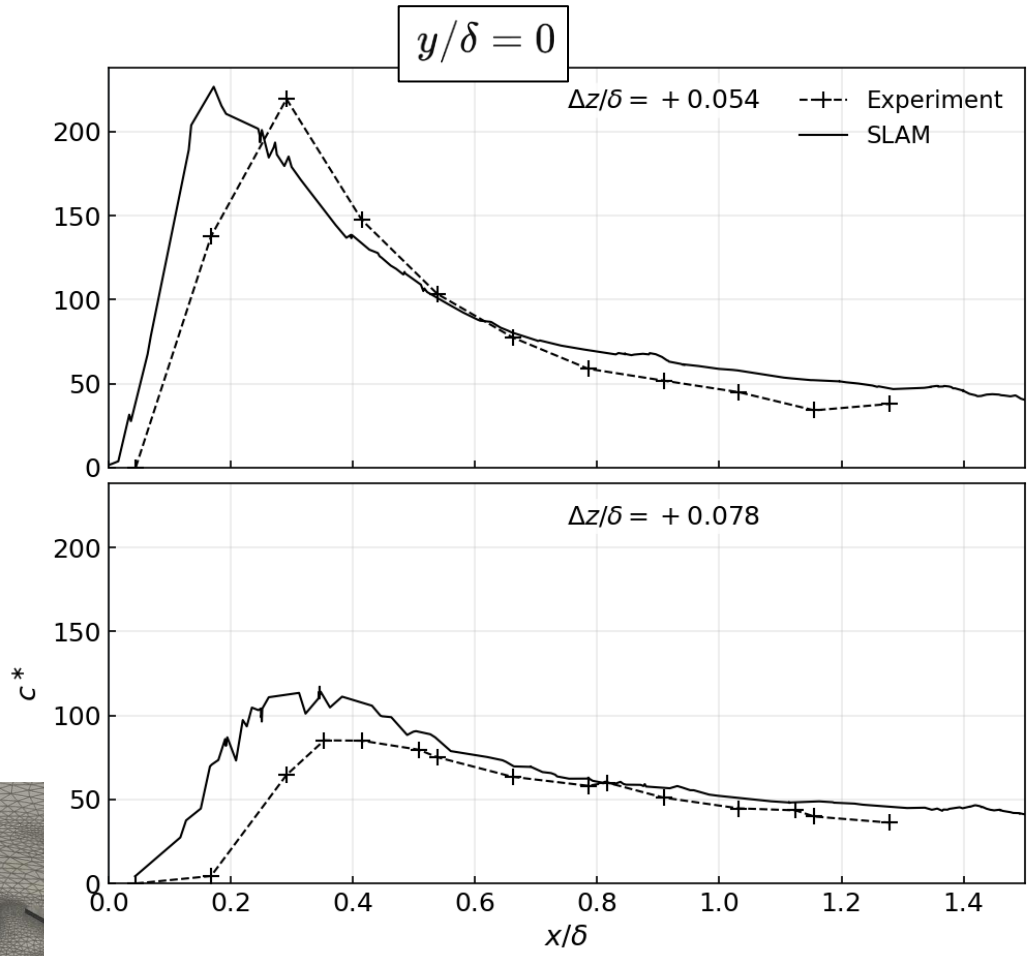
Comparison of concentration measurements

Longitudinal plane

- Adimensionalized concentrations : $C^* = \frac{C\,U_\infty\,\delta^2}{Q}$
- Good agreement between numerical and experimental results on max. values and plume behaviour after a certain distance

- Slight longitudinal delay in the plume centerline
  - Tuning of release characteristics





Δz ≡ z − release height, δ = 204 m,
Comparison of adimensionalized concentration profiles at different heights, measured over the y=0 axis

Future work

Schematic of different types of land use around CERN Meyrin, extracted and simplified from CORINE Land Cover

Study of remaining wind directions:

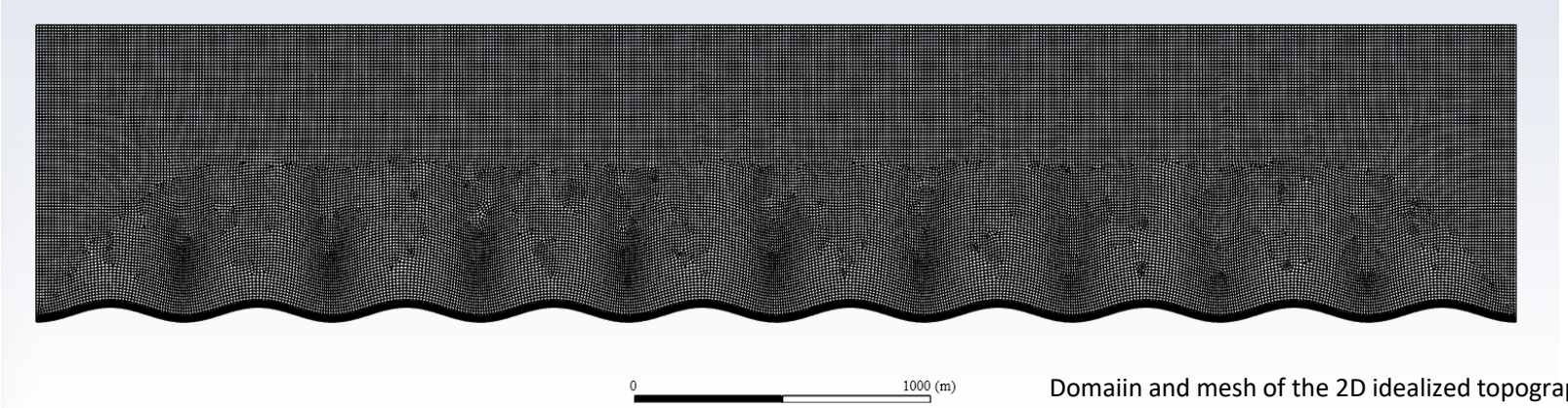
- Compare remaining experimental results

Domain simplification:

- Study on idealized topography (2D, 2.5D and 3D)
- Building representation methodology

Ground use analysis:

- Improve roughness length definition by ground-use analysis and relaxation of these parameters



Domaiin and mesh of the 2D idealized topography for future work

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Fire Safety Engineering Team

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Thank you for your attention

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