VALIDATION OF LATTICE BOLTZMANN METHOD IN COMPLEX URBAN ENVIRONMENT – HAMBURG & LA DEFENSE

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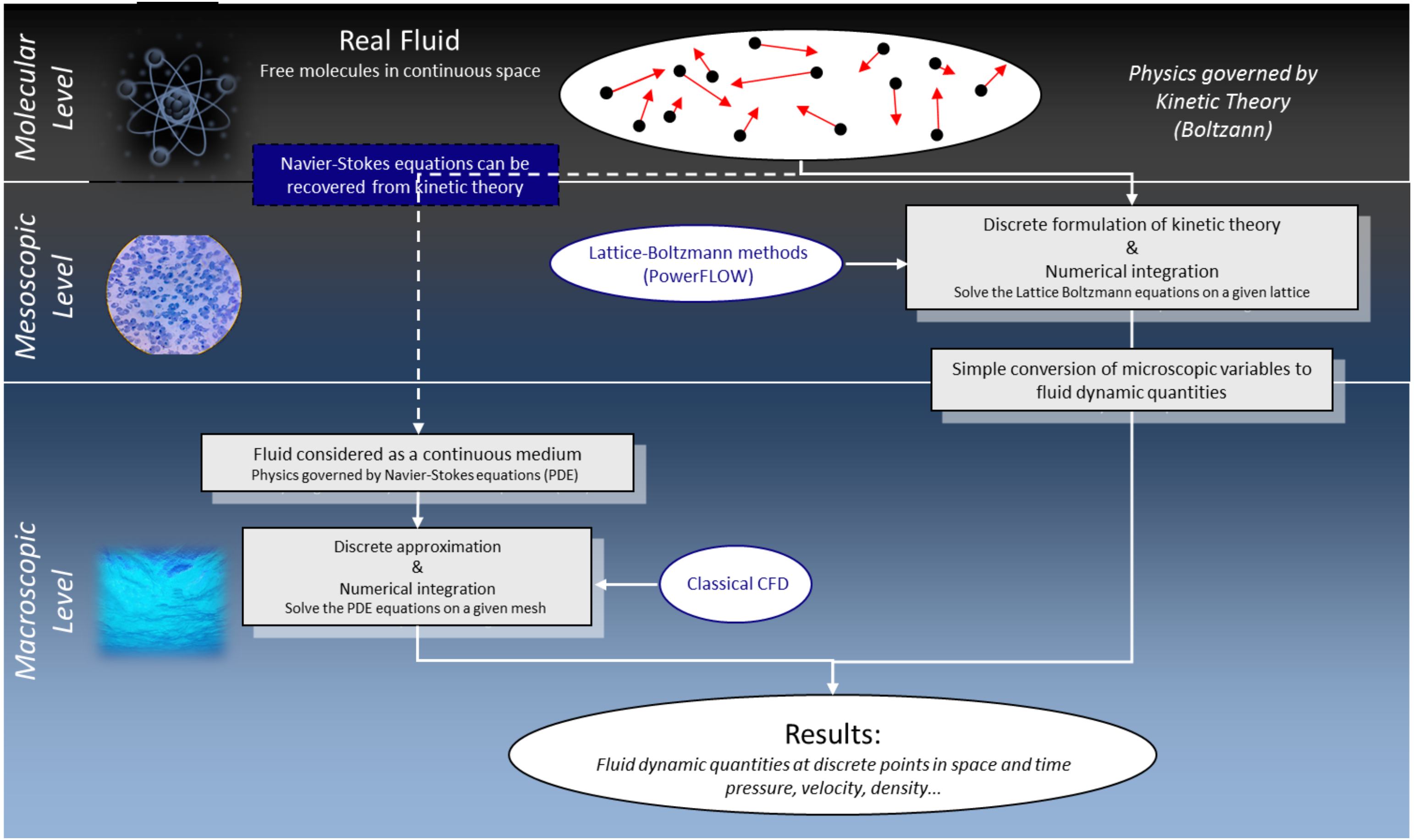
Agenda

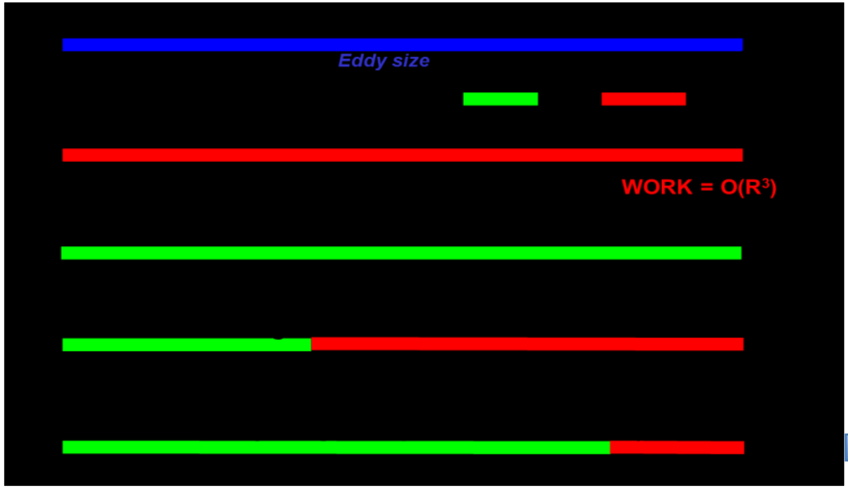
Exa

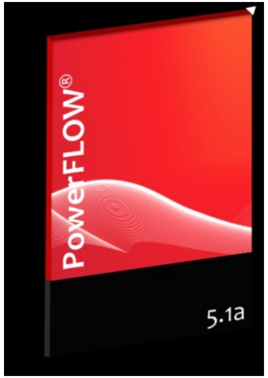
Introduction to LBM Methods and PowerFLOW



Introduction to LBM Methods and PowerFLOW

- Turbulence in PowerFLOW:





Only statically anisotropic eddies outside the Kolmogorov range are computed

- Passive scalar are used to represent small particle field:
  - *Pollutant gases, pathogenic agent, radioactive agent, etc.*
  - *Closed or open environments*
  - *Up to 64 different scalars in the same simulation*
  - *PDE is solved for each scalar in addition of the flow field variables*

Exa

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1 Introduction

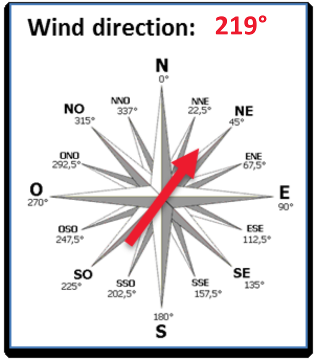
2 Validation Cases: Hamburg

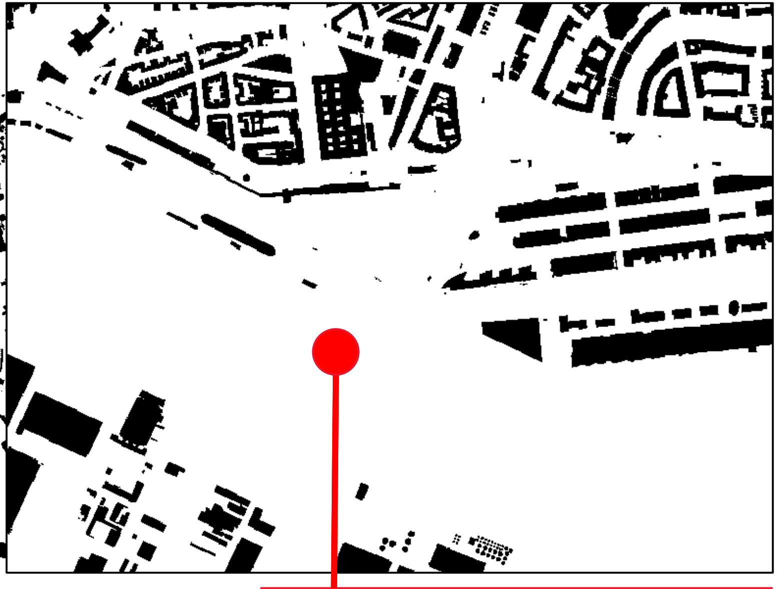
3 Exploration Case: La Défense

Hamburg Validation Cases

- Three different validation cases available from COST ES1006 (see next slides)
- All based on the same Simulation Model and Global Setup
- Surface Mesh:
  - Ground + buildings (4000 x 4000 m)
  - Triangular mesh, 9M elements
- Volume Mesh:
  - Cubic cells
  - Variable resolution (finest: 0.5m)
- Simulation Parameters:
  - Isothermal Simulation
  - Turbulence intensity: 10%
  - Time step: 7ms
  - Physical time simulated: 75min

Hamburg Case 1





Wind direction and intensity are constant in time

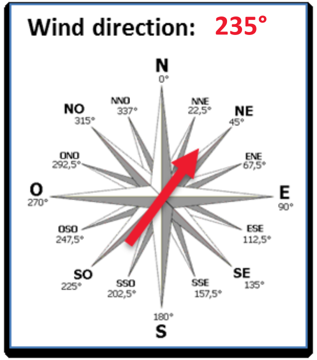
Velocity profile reconstructed based on the Velocity 8.9 m/s at z=175m

Neutral atmospheric stability

Gaz :

- Punctual source; from a boat on the river
- Q = 2g/sec (45min)
- Gas: SF6; $C_d=1.5^{e}$-05 m^2/sec

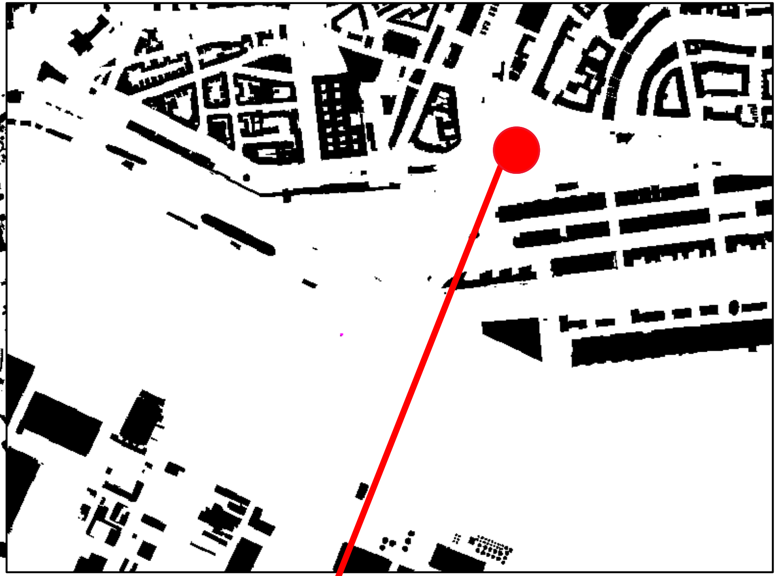
Hamburg Case 3 Continuous



Wind direction and intensity are constant in time

Velocity profile reconstructed based on the Velocity 6 m/s at z=49m

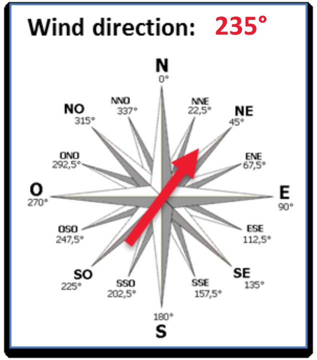
Neutral atmospheric stability



Gaz :

- Punctual source (1m diameter cylinder)
- Q = 0.5 kg/sec (60min)
- Gas: SF6; C_d=1.5^e-05 m²/sec

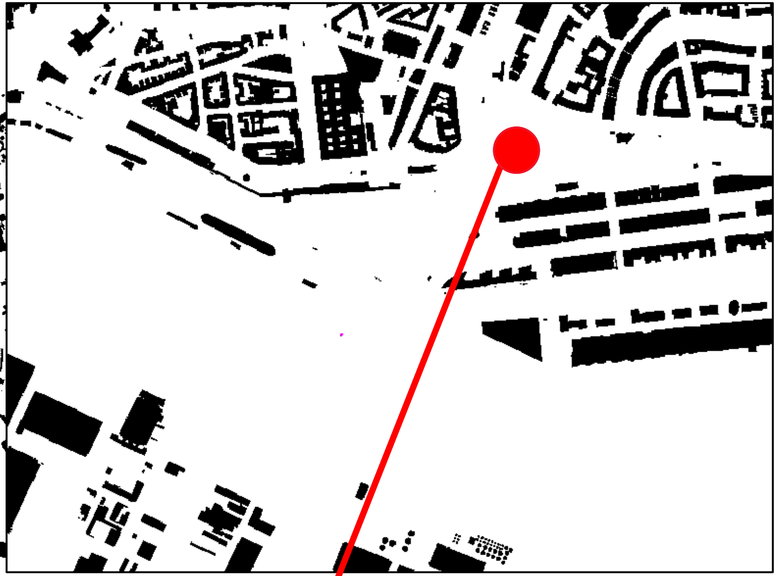
Hamburg Case 3 Puff



Wind direction and intensity are constant in time

Velocity profile reconstructed based on the Velocity 6 m/s at z=49m

Neutral atmospheric stability



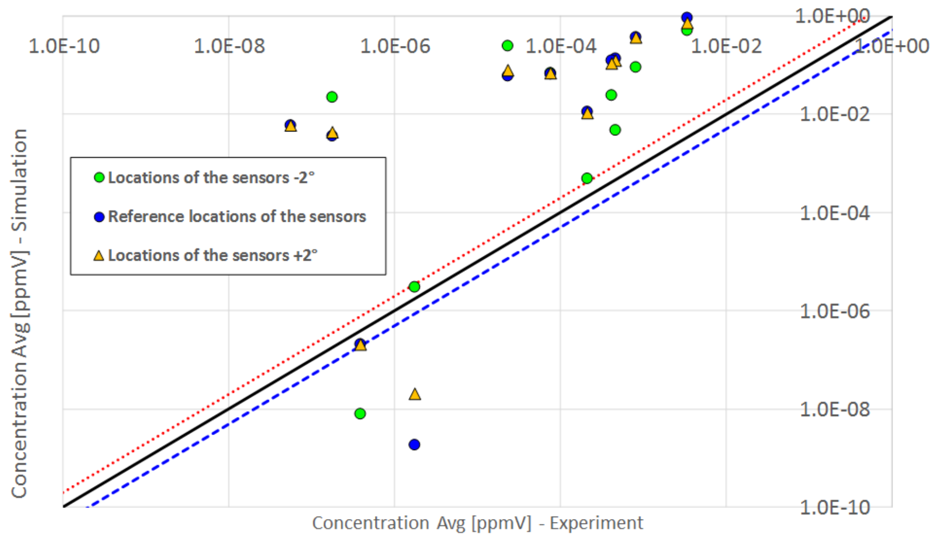
Gaz :

- Punctual source (1m diameter cylinder)
- Initial release 50 kg in 31 sec
- Gas: SF6; C_d=1.5^e-05 m²/sec

Validation Criteria

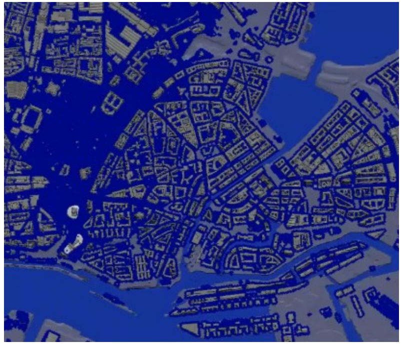
- CASE 1 and CASE 3 Continuous: time averaged gas concentration
- CASE 3 Puff: dosage (integral of the concentration over time)
- As mean of statistical correlation, we calculate the usual metrics: fractional bias (FB), geometric mean bias (MG), normalized mean square error (NMSE) and fraction of predictions within a factor of 2 of observations (FAC2).
- We used the reference acceptance criteria for atmospheric dispersion modelling of accidental releases in built environments defined by **Hanna & Chang**, which are:
    - $| FB | \leq 0.67$
    - $NMSE \leq 6$
    - $FAC2 \geq 0.3$

Hamburg Case 1

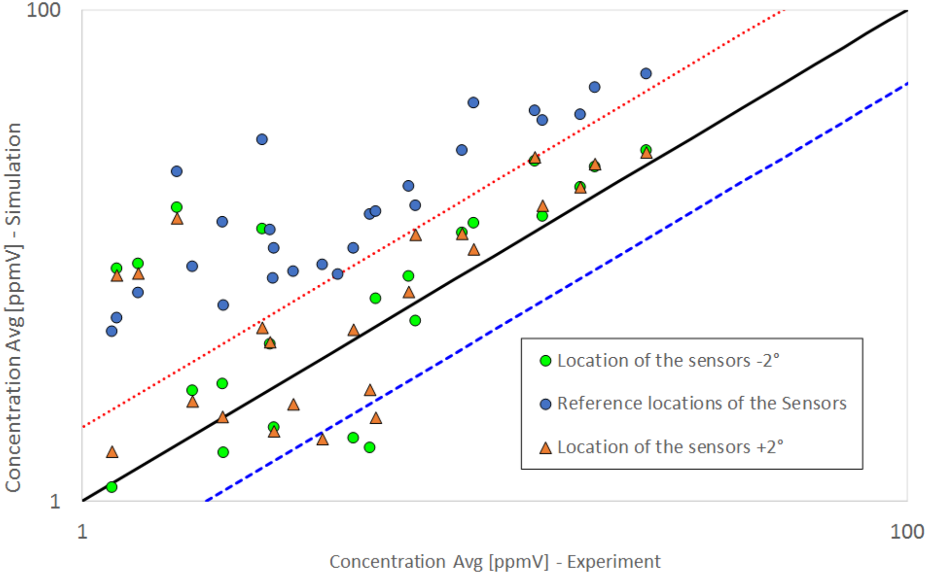


(*) Typically, a 4m variation compared to the reference location

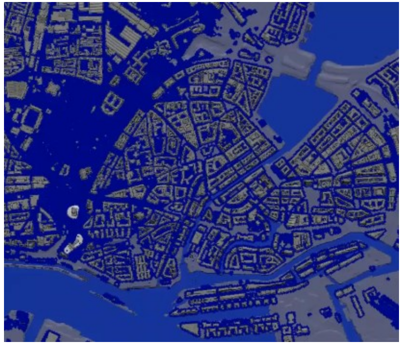
- The results for this case are disappointing as no Probe lies within the acceptance range (materialized by the 2 dotted lines)
- We conducted a sensibility test to Probe location; we also recorded data for a Model rotated by -2 and +2° (*)
  - These tests also gave almost no correlated Probe
- There are disputable reasons for this poor match:
  - Geometry delta between our WT Model and the actual city
  - Hypothesis of constant meteorological conditions during the experiment



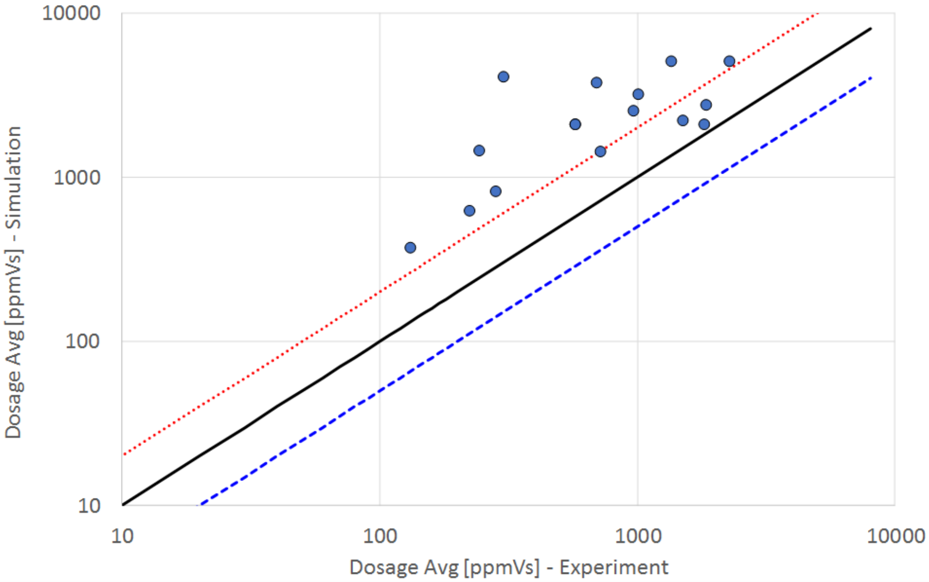
Hamburg Case 3 Continuous



- The results for this case are also disappointing as no Probe lies within the acceptance range
- We can note though a clear trend for the Simulation to over-predict the Experiment measurements
- The sensibility test to the Probe location show much improved results:
  - The FAC2 jumps to 0.53 for the +2° test
  - The FAC2 jumps to 0.50 for the -2° test



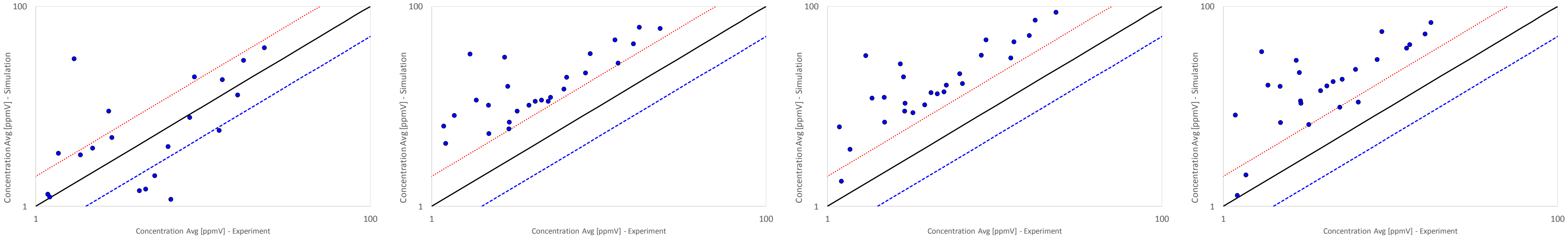
Hamburg Case 3 Puff



- The results for Puff case are better as the FAC2 is 0.25
- We note the same clear trend of overpredicting the Experiment measurements
- The sensibility test to the Probe location does not show any improvement:
  - FAC2 is 0.25 for the -2° test
  - FAC2 is 0.19 for the +2° test

Hamburg Case 3 Continuous – Comments

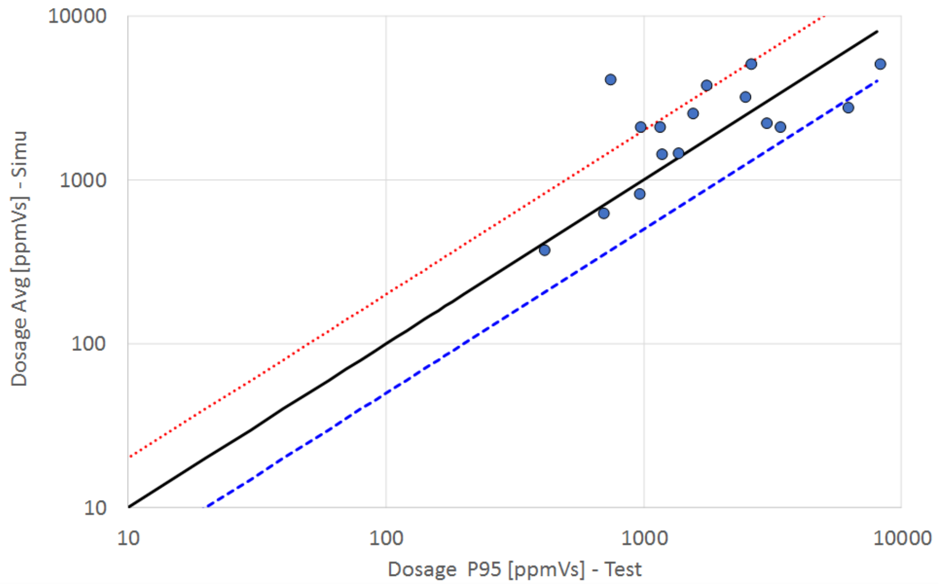
- In our validation exercise, we averaged the concentration over the whole length of the simulated gas release (60 minutes)
- In this slide, we look at sliding averages over 10 minutes



0 – 10 minutes   10 – 20 minutes   20 – 30 minutes   30 – 40 minutes

- Originally, our predictions are OK (FAC2 is 0.38 for 0-10 minutes) but very quickly, we overpredict the Experiment concentrations
- Is there a gas build-up in our Simulations, are we still under resolved?

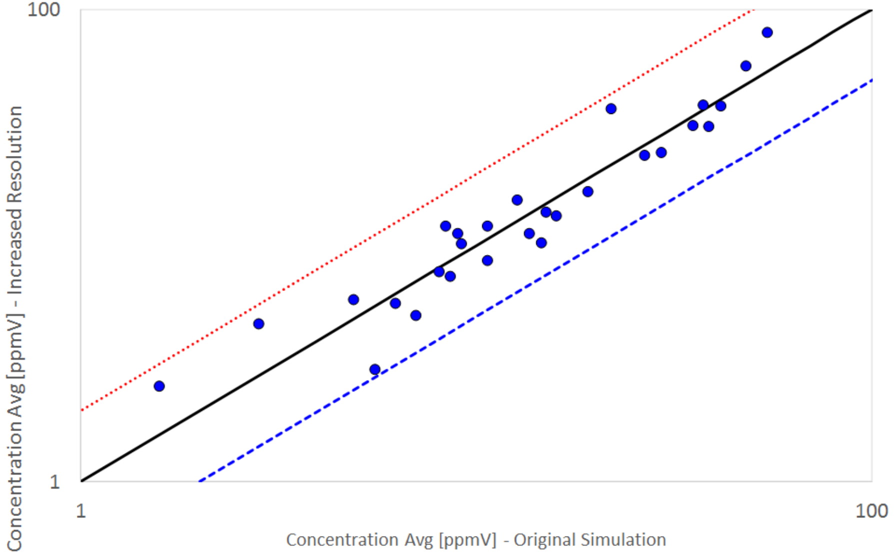
Hamburg Case 3 Puff – Comments



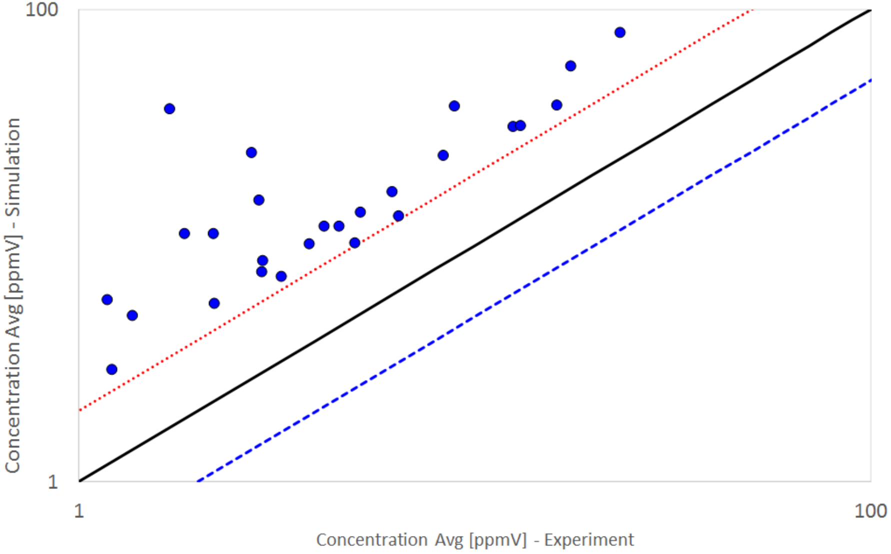
- As the mean Dosage comparison showed, the Simulation overpredicts consistently the Experiments
- This is reinforced by the scatter plot of the 95 percentile Dosage for which the FAC2 is 0.75
- This could also denote a too coarse resolution so we refined the Grid around the city centre

Hamburg Case 3 Continuous – Increased Resolution

Average Concentration Scatter Plot – Original Simulation vs. Increased Resolution



Average Concentration Scatter Plot – Experiment vs. Increased Resolution

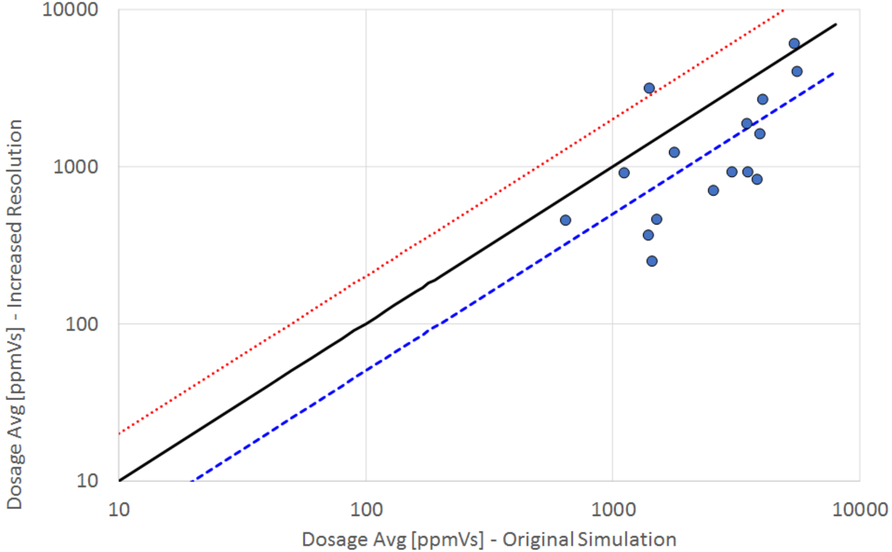


- Increasing the resolution has no impact on the averaged Concentration as all the Probes lie close to the slope 1 curve on the left scatter plot
- As a result, the correlation for the Continuous case remains poor, as shown by the right plot

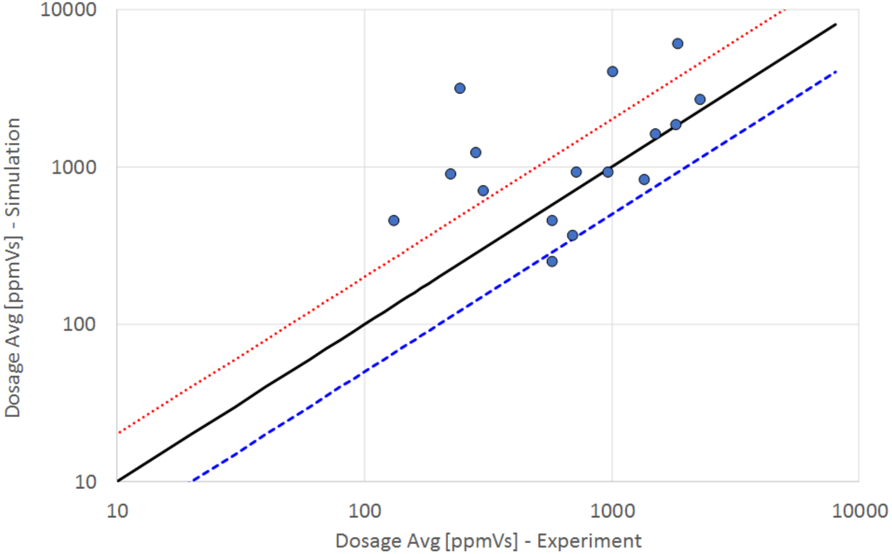
Exa

Hamburg Case 3 Puff – Increased Resolution

Mean Dosage Scatter Plot – Original Simulation vs. Increased Resolution

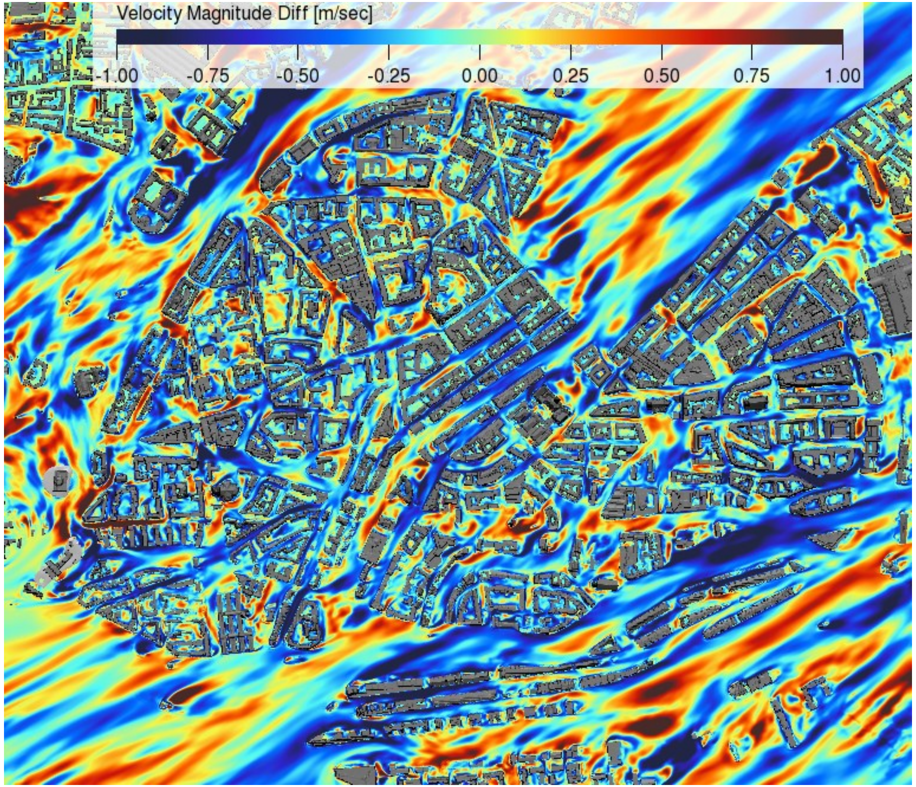


Mean Dosage Scatter Plot – Experiment vs. Increased Resolution



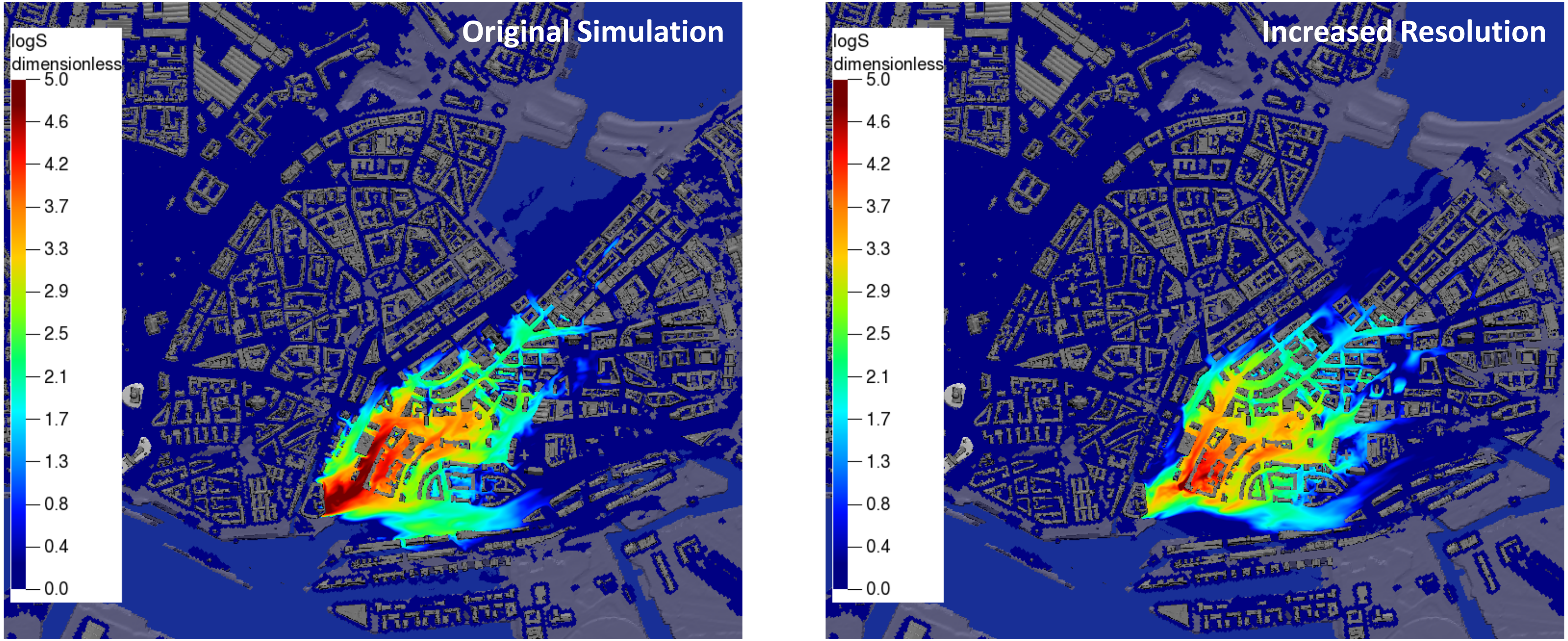
- The concentration levels are reduced for the increased resolution case
- The FAC2 is 0.5, in the acceptance range defined by **Hanna & Chang**

Hamburg Case 3 Puff – Increased Resolution



- Shown left is the difference of the averaged Velocity fields for the original and the increased resolution Simulations
- We see here that the Velocity increases in the centre of the model
- Velocity decreases in the more open areas, around the densely built area

Hamburg Case 3 Puff – Increased Resolution



0 to 5 minutes Gas Averaged Concentration Fields

Hamburg Cases – Next Steps

- Finalizing the setup in terms of Resolution
  - Puff case is OK, but not the Continuous case
  - Results seem to improve though
  - Test finer resolution scheme(s)

		Baseline	Scheme 1	Scheme 2
CONTINUOUS	FB			
	NMSE			
	FAC2			
PUFF	FB			
	NMSE			
	FAC2			

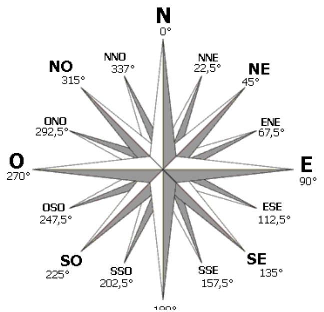
- Investigate on better matching the boundary conditions and possibly the fidelity of our Simulation Model

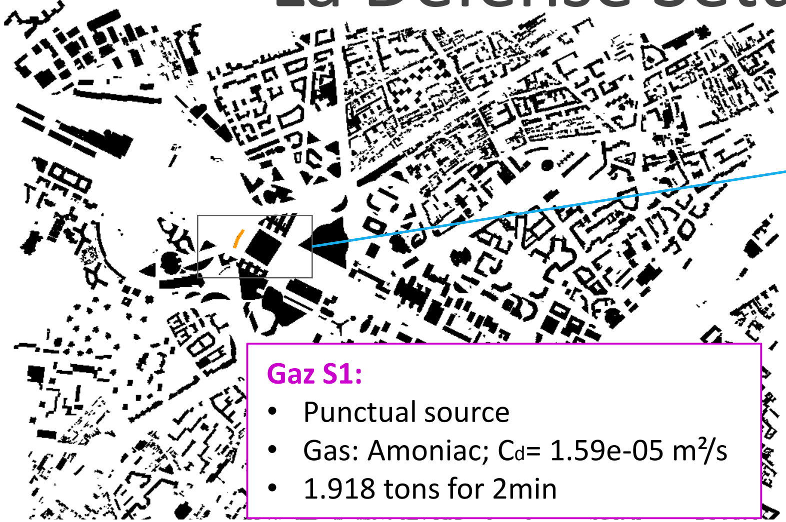
- Test proof our future BP vs. another Experiment / City ?

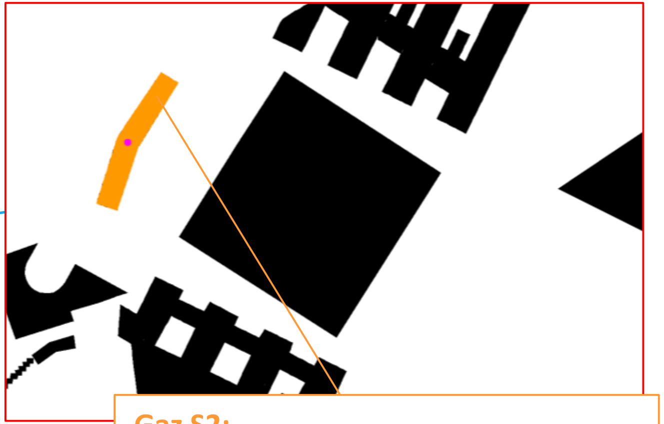
Agenda

La Défense Setup

Wind direction varies in time







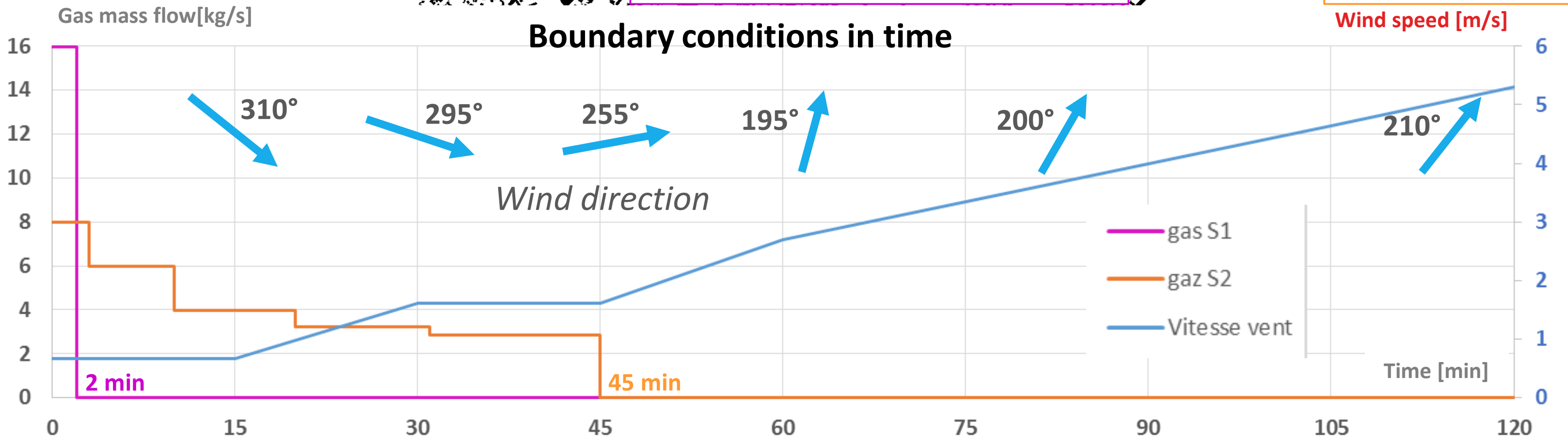
Gaz S1:

- Punctual source
- Gas: Amoniac; C_d= 1.59e-05 m²/s
- 1.918 tons for 2min

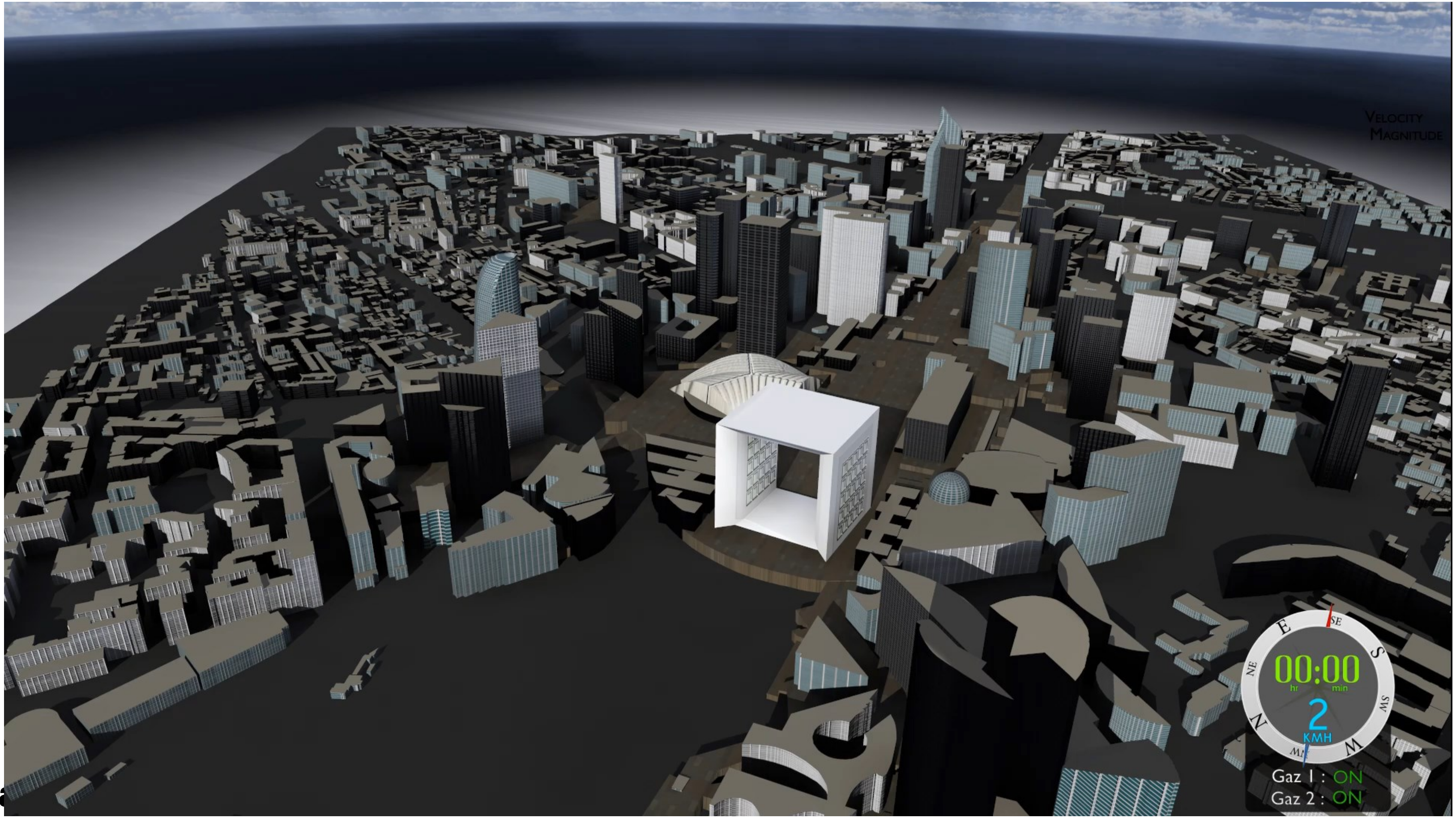
Gaz S2:

- Surface source (puddle)
- Gas: Amoniac; C_d= 1.59e-05 m²/s
- Decreases by steps over 45min

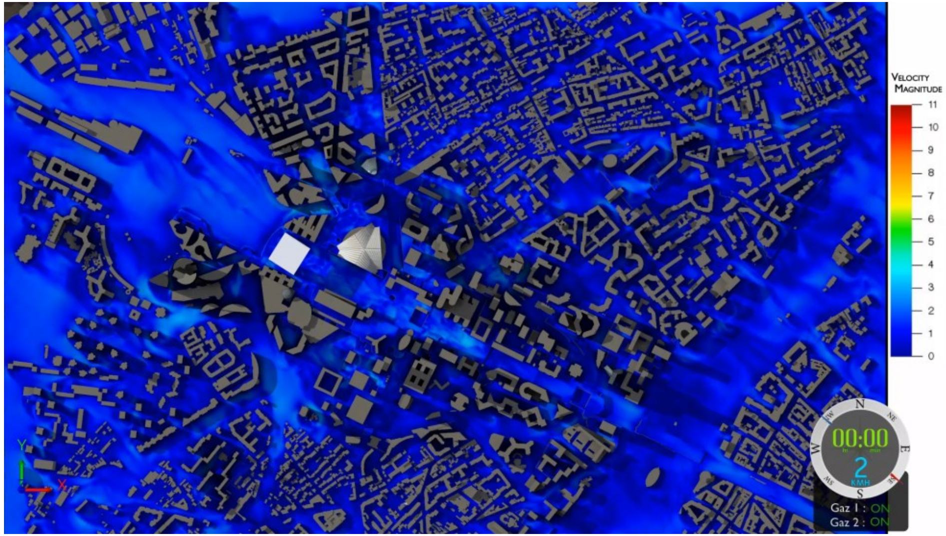
Boundary conditions in time

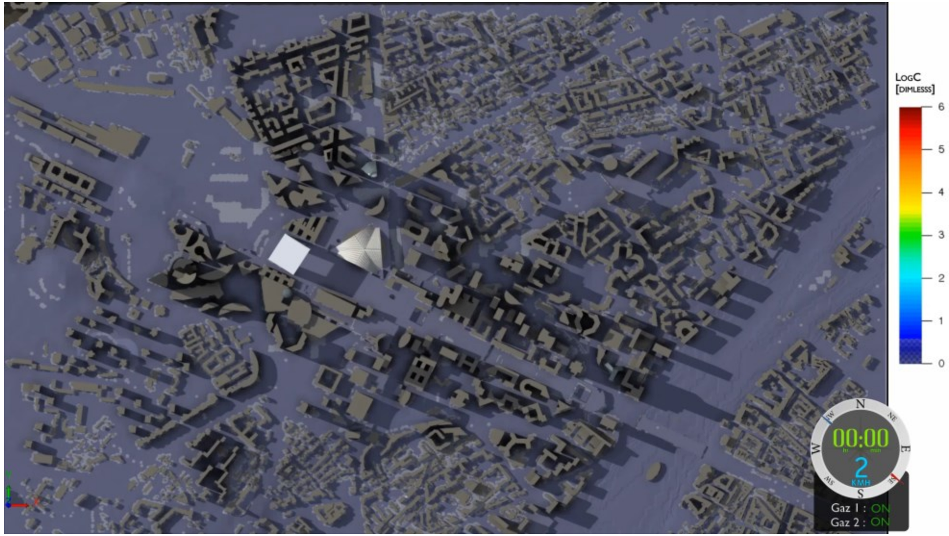


Gas S1 Concentration Volume Visualization

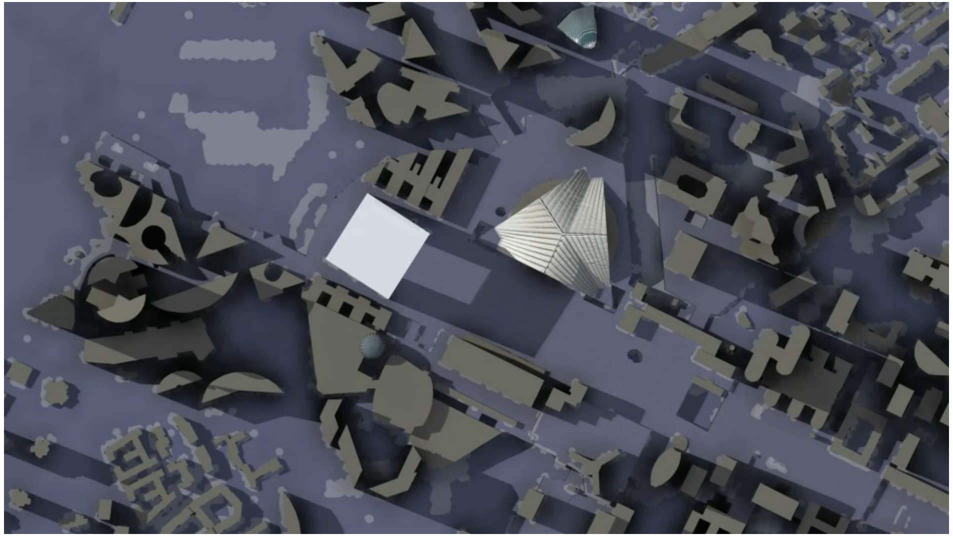


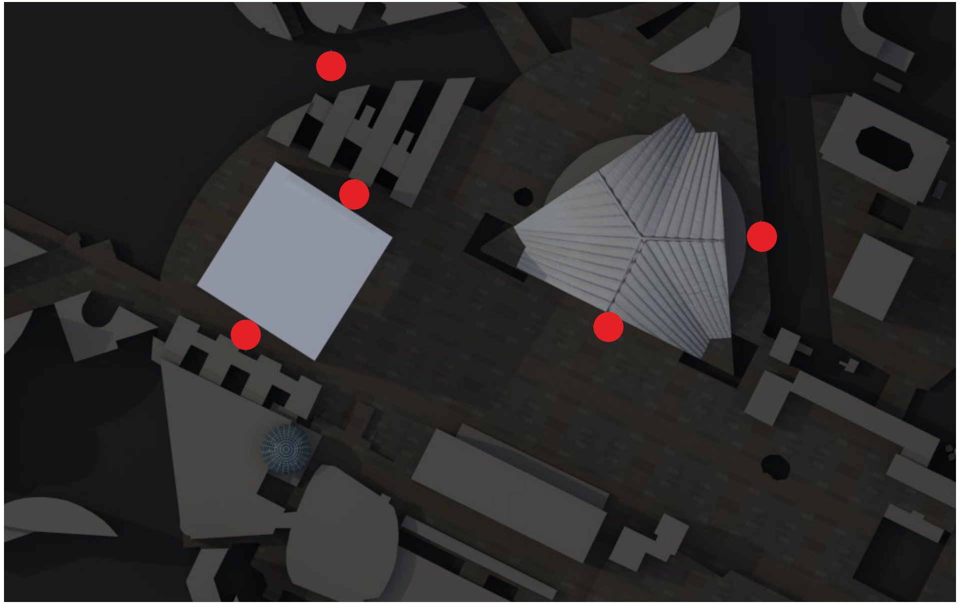
Velocity & S1 Concentration Histories in Z plane (Ground +2m)





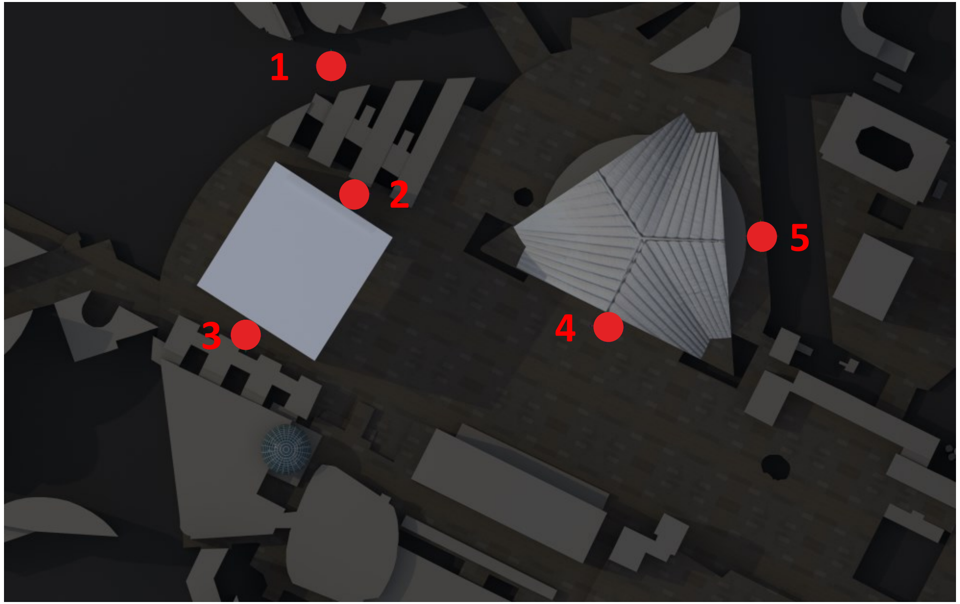
Dangerous Areas Mapping



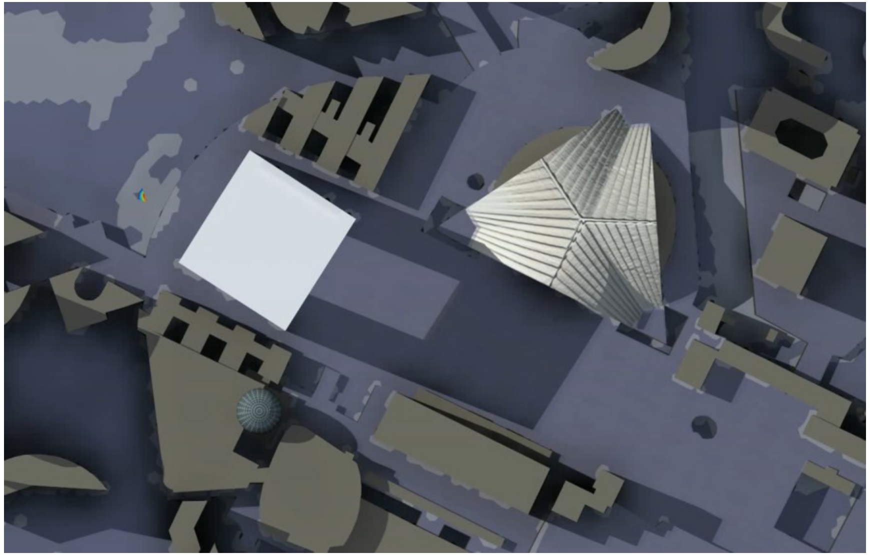


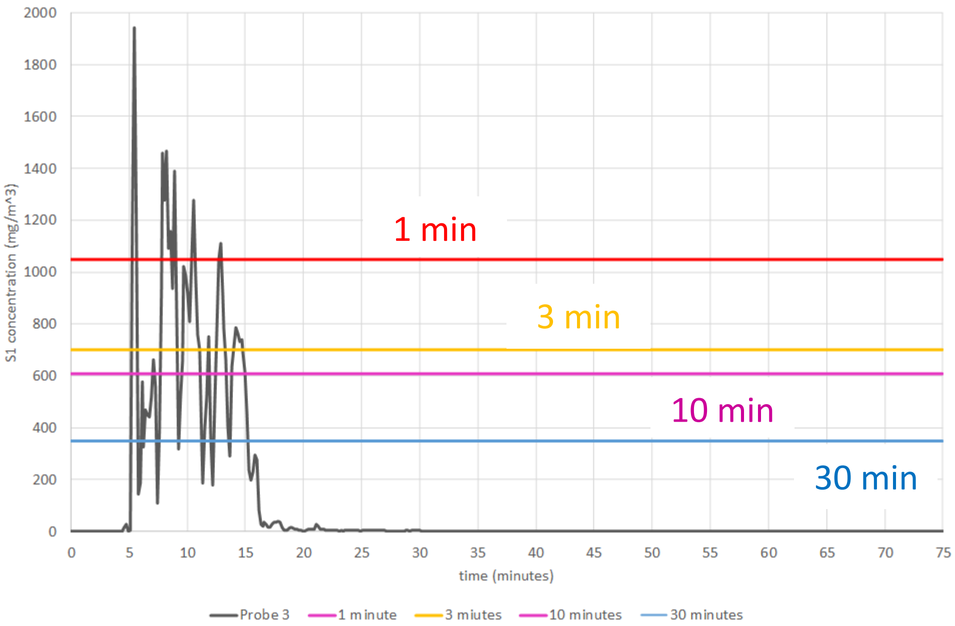
Probe Time Metrics

Probe	1	2	3	4	5
Mean Dosage (mg/m^3)	376	802		9489	2971
Concentration Peak (mg/m^3)	1.6	2.0		85.6	12.2
Arrival Time	1840	1740	330	1050	2410
Peak Time	1960	3690	330	1050	3050
Leaving Time	5220	5180	920	3420	3650
Ascent Time	120	1950	0	0	640
Descent Time	3260	1490	590	2370	600
Duration Time	3380	3440	590	2370	1240



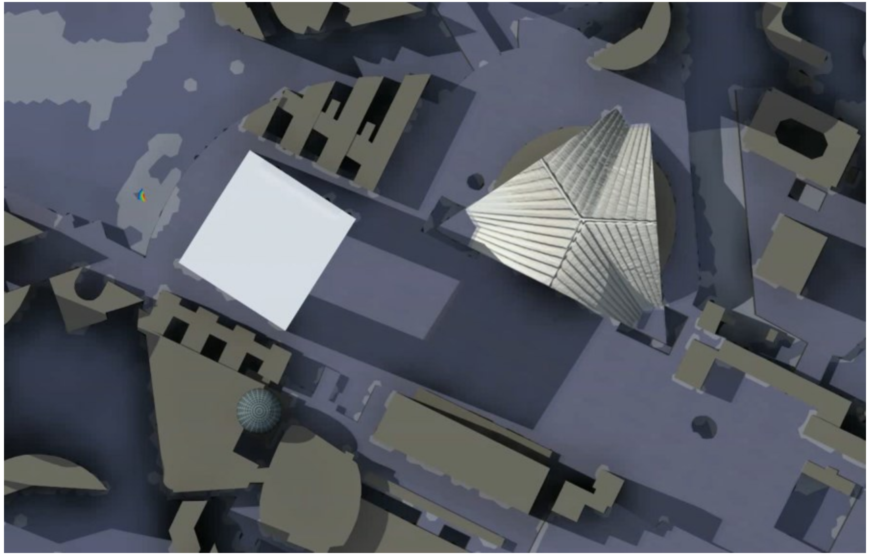
Probe 3 Location – Health Risks Management – S1

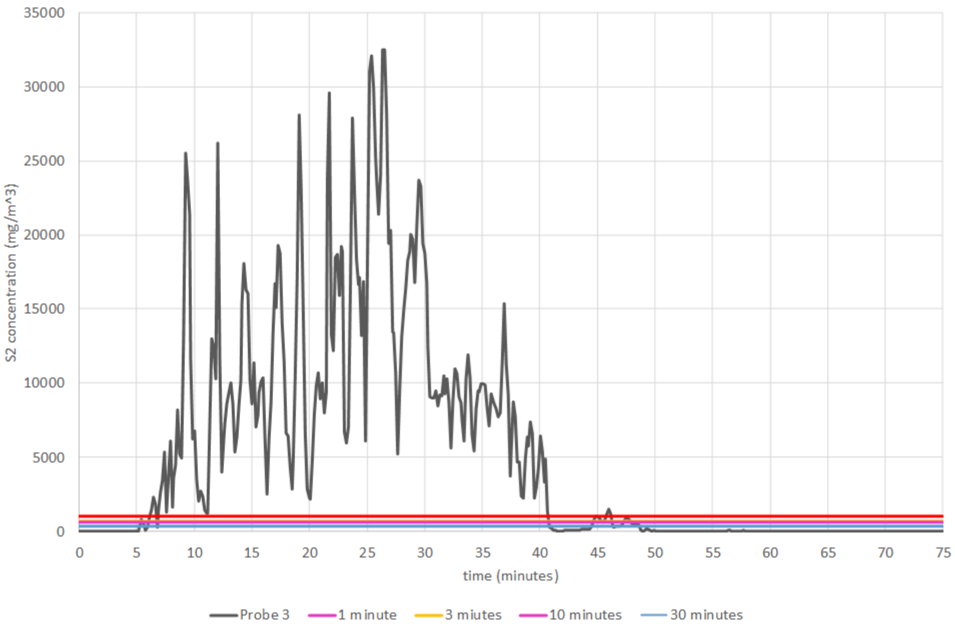




Exa

Probe 3 Location – Health Risks Management – S2





Thank you for your attention

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