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A SENSITIVITY ANALYSIS FOR A LAGRANGIAN PARTICLE DISPERSION MODEL IN EMERGENCY-RESPONSE TEST CASES

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Outline

- *Numerical experiments in the frame of the COST ES1006 action*
- *Class of models and specific model considered*
- *Different setup and applications - results*
- *Conclusions*

COST Action ES1006 (2011-2015)

Evaluation, improvement and guidance for the use of local-scale emergency prediction and response tools for airborne hazards in built environments

Some ideas behind the action

- test different modeling technologies at local scale
- build test cases in order to perform such comparisons

Being the same model technology available from different research groups, a «sensitivity analysis» was conducted in order to evaluate the effects of different configurations of the models and different initial conditions.

How the model setup generated independently by different users can affect output results

The test cases (1)

Wind tunnel experiments (EWTL, Inst. Met., Hamburg University)

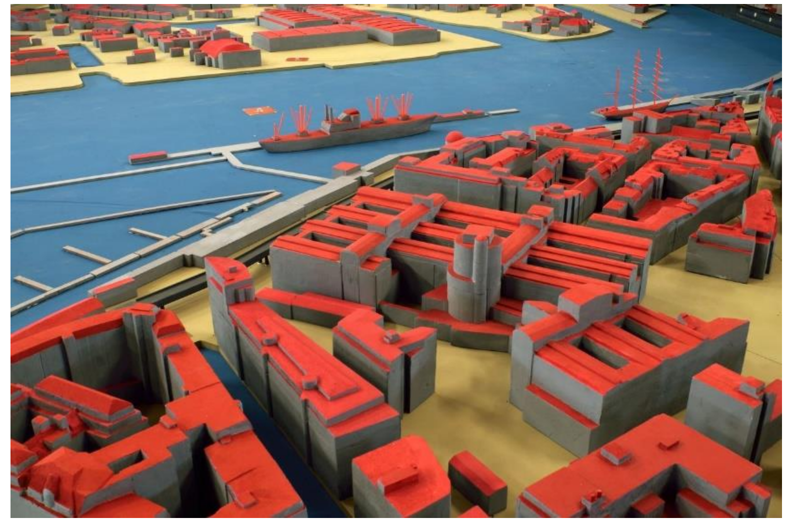
Michelstadt (Wind tunnel)

A **typical** **European urban site** is reproduced.

Several **continuous** and **puff releases** from six different source locations: concentration measured at more than 30 points

Non-blind and **blind** tests

CUTE 3 (Wind Tunnel)



A **real** **European city** is reproduced.

Several **continuous** and **puff releases** from three different source location: concentration measured at more than 30 points

Blind tests

The test cases (2)

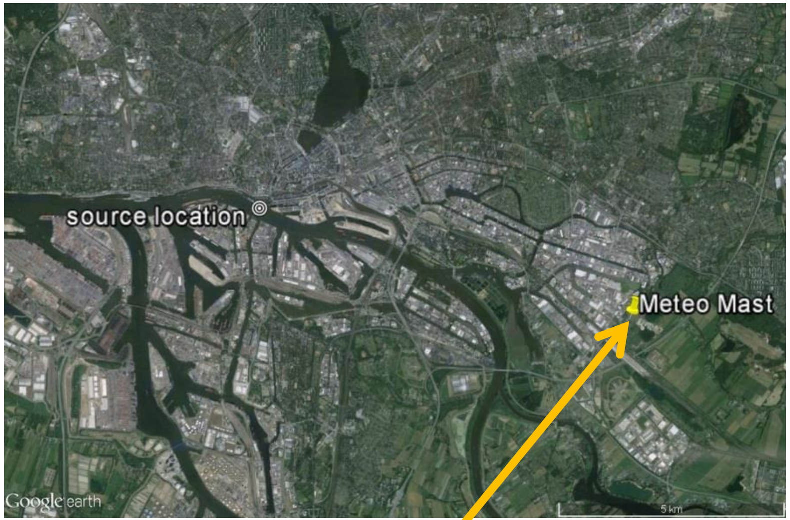
CUTE 1 (real atmosphere)

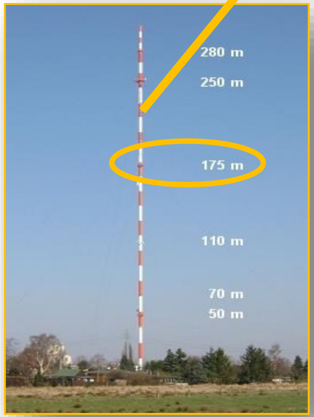
Continuous 45-minutes release of SF6 with a flow rate of 2 g/s, from a boat towards the harbor area.

Concentration detected by 20 measurement stations located at different positions.

Each measurement station had 9 bag samplers. Each bag was filled for 10 minutes => 10-minute average values. Only **Blind** tests

Different meteo data available





10, 50, 110, 175, 250m

The models

COST ES1006 took into account in general three type of models

Model type	Flow modelling approach	Dispersion modelling approach
Type I	models that do not resolve the flow between buildings	Gaussian
Type II	models for which the flow is resolved diagnostically or empirically, although not dynamically resolving the flow between buildings	Lagrangian
Type III	models that resolve the flow between buildings	Eulerian

this particular activity considered only one Lagrangian Particle Dispersion Model driven by a diagnostic flow model

the *SPRAY* stochastic LPDM
in its microscale version with obstacles

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General configuration of sensitivity experiments

1. Michelstadt experiment
   - Different modeling setup given by 3 independent groups
     - ✓ wind speed vertical profiles
     - ✓ background turbulence
     - ✓ horizontal and vertical model resolution
     - ✓ time step for particle advancing
     - ✓ number of particles
2. CUTE 1 experiment
   - One group produced simulations using different entering flow
     - ✓ vertical profile derived from one distributed wind speed and direction
     - ✓ vertical wind profile (speed and direction) measured by a meteorological mast
2. CUTE 1 and CUTE 3 experiments
   - One group produced simulations using different turbulence levels due to a different terrain roughness considered
     - ✓ z_0 = 1 m
     - ✓ z_0 = 0.1 m

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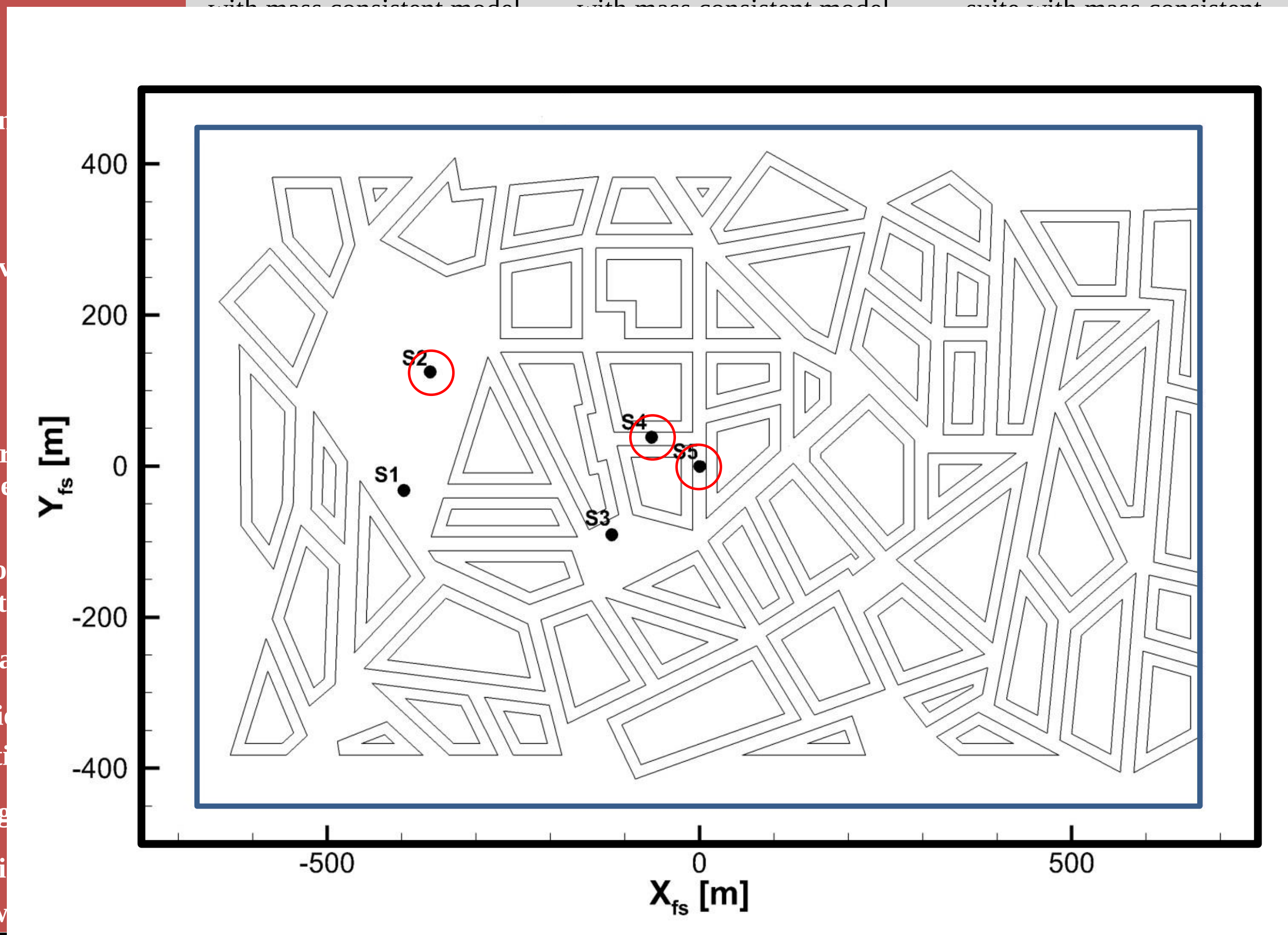
Michelstadt experiment

Three different configurations (1)

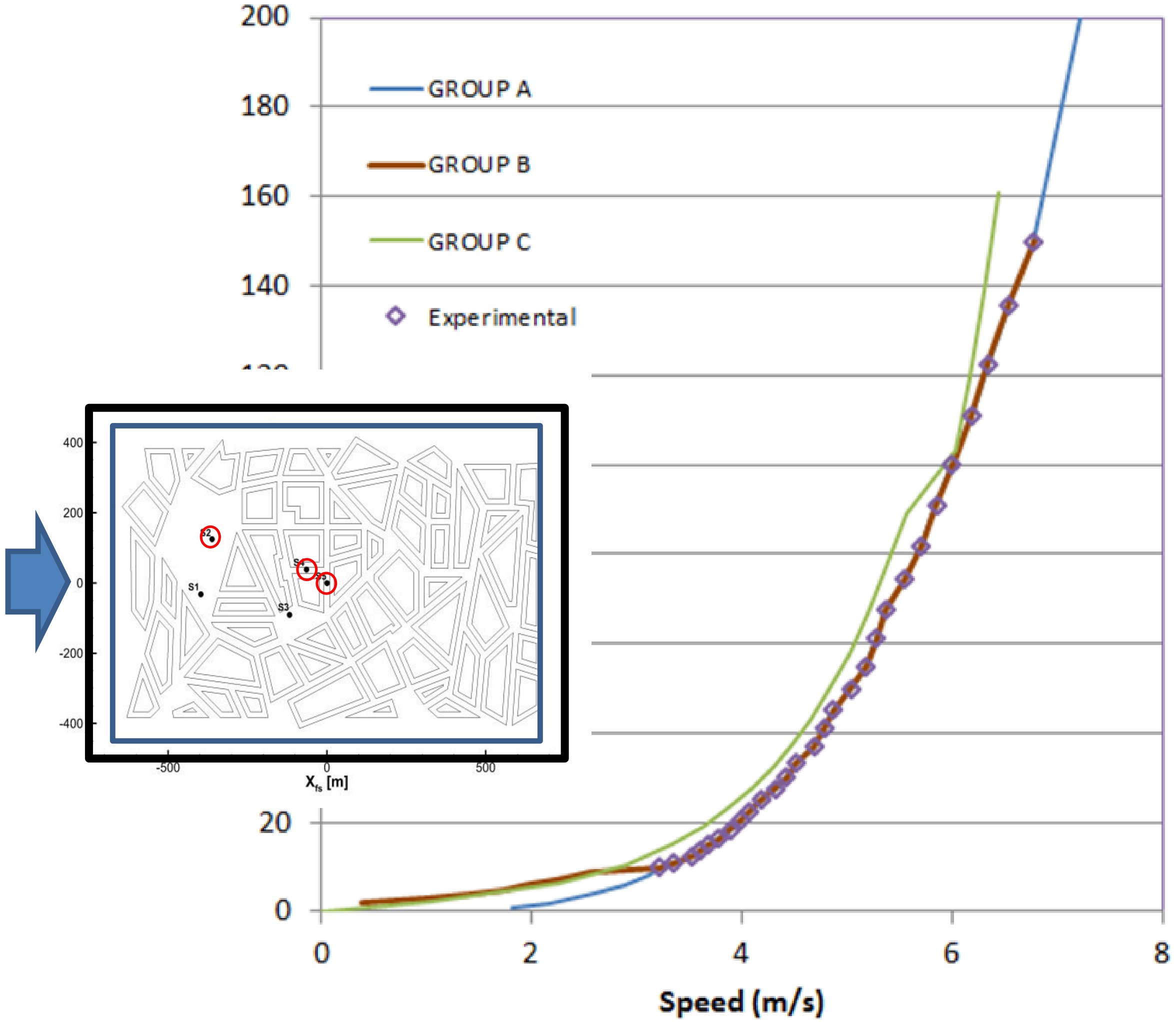
	CONFIGURATION 1	CONFIGURATION 2	CONFIGURATION 3
Model	Parallel Spray stand alone	Scalar Spray standalone	Parallel Spray in a modelling
Scale			
Buildi			
Wind v			
Backg turbule			
Horizo resolut			
Vertica			
Emissi N parti			
Averag			
CPU ti			
Hardw			



Continuous (S2, S4, S5) non-blind releases

Michelstadt experiment

Three different configurations (2)

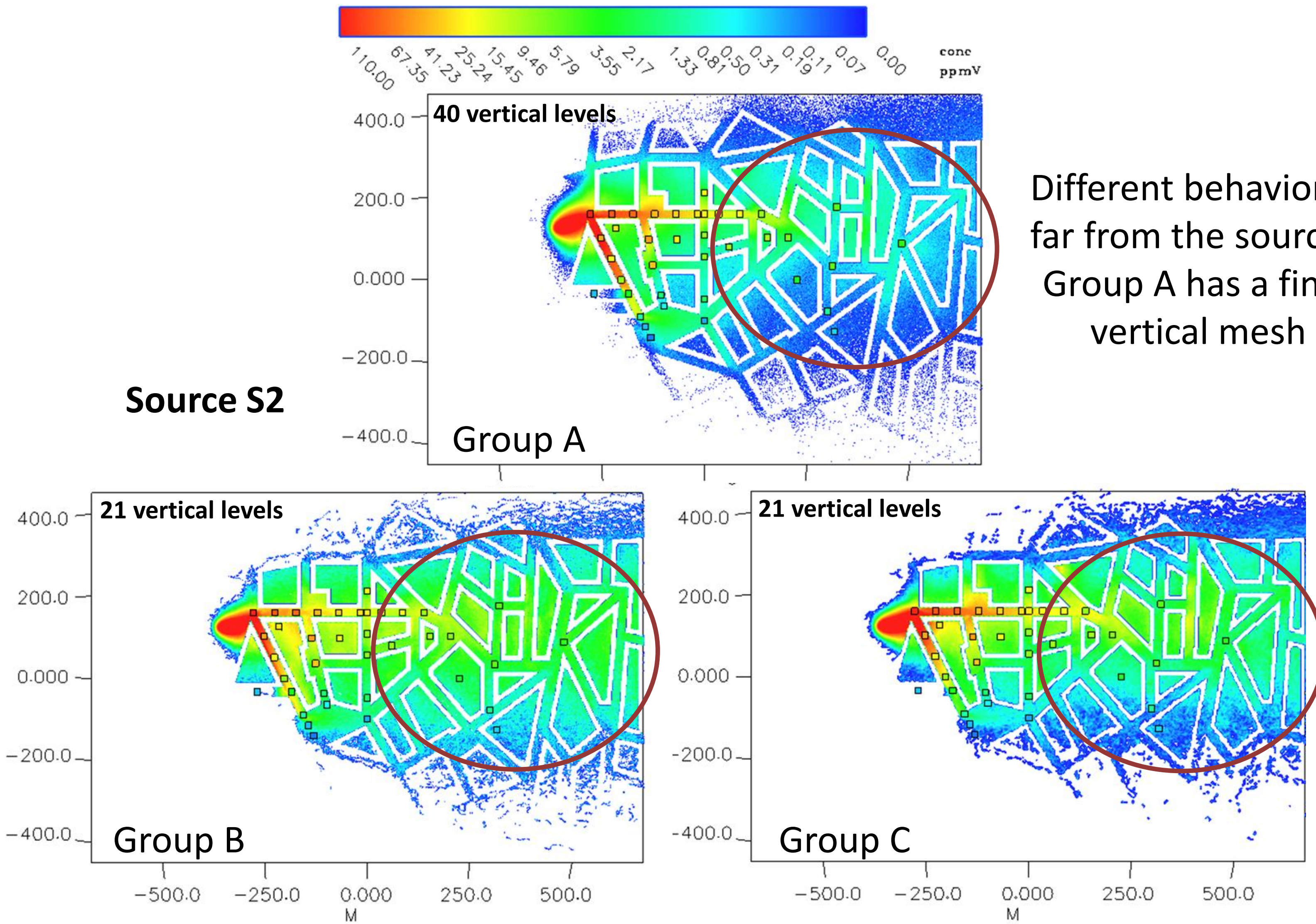


Inlet wind speed profiles

Michelstadt experiment

Results – ground level concentration maps vs experimental data (1)

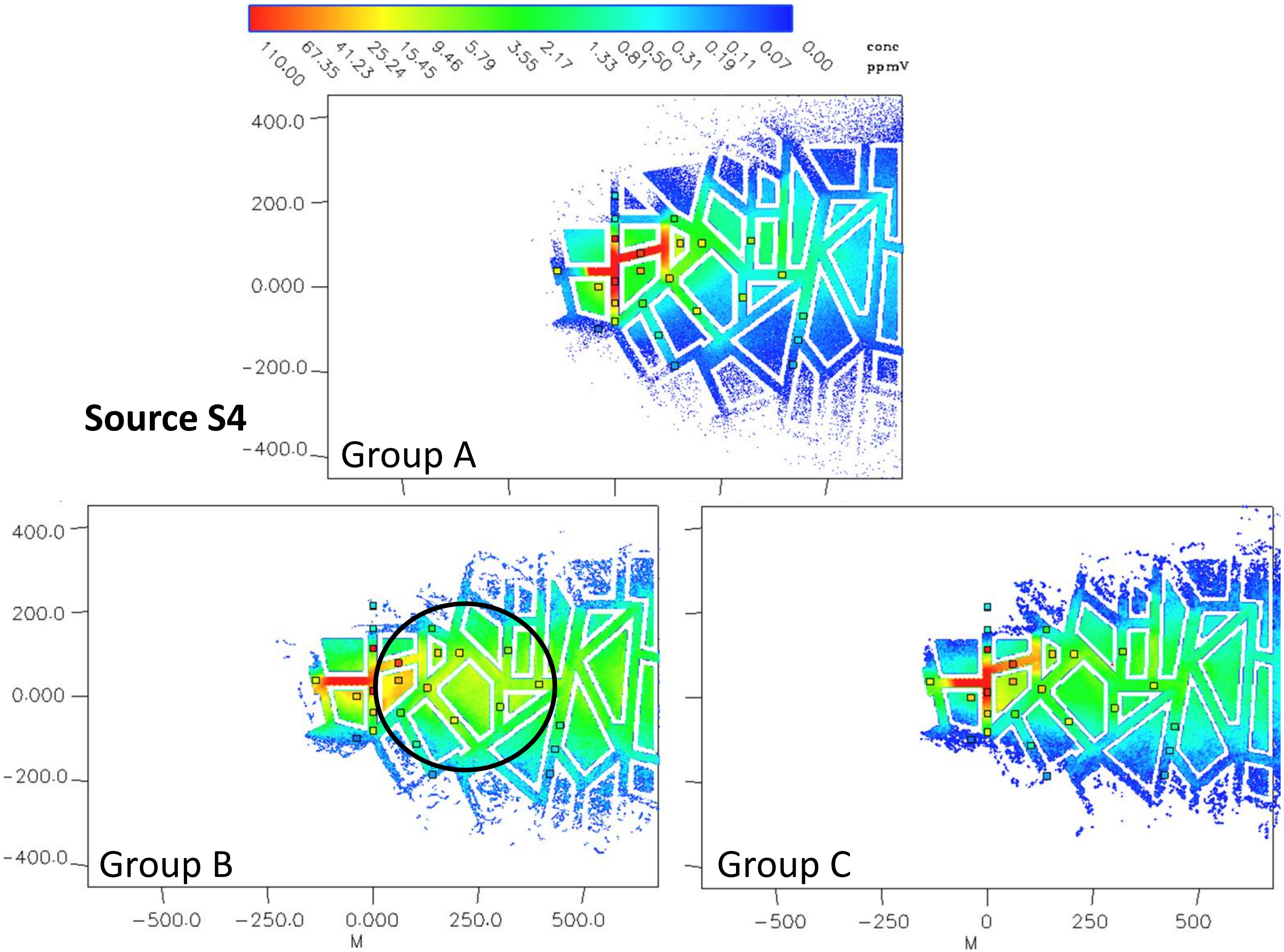
Source S2



Different behaviors far from the source
Group A has a finer vertical mesh

Michelstadt experiment

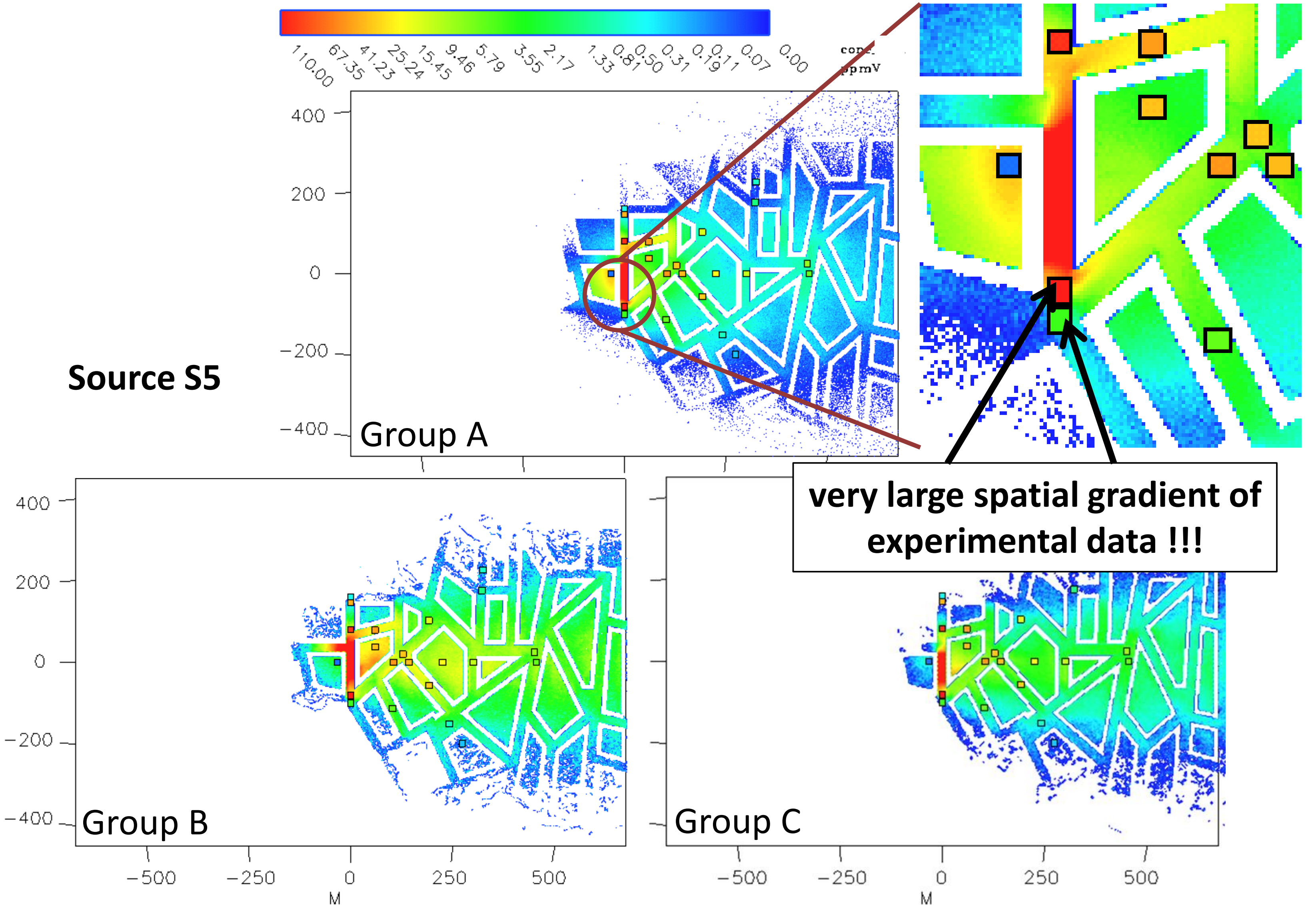
Results – ground level concentration maps vs experimental data (2)



Michelstadt experiment

Results – ground level concentration maps vs experimental data (3)

Source S5



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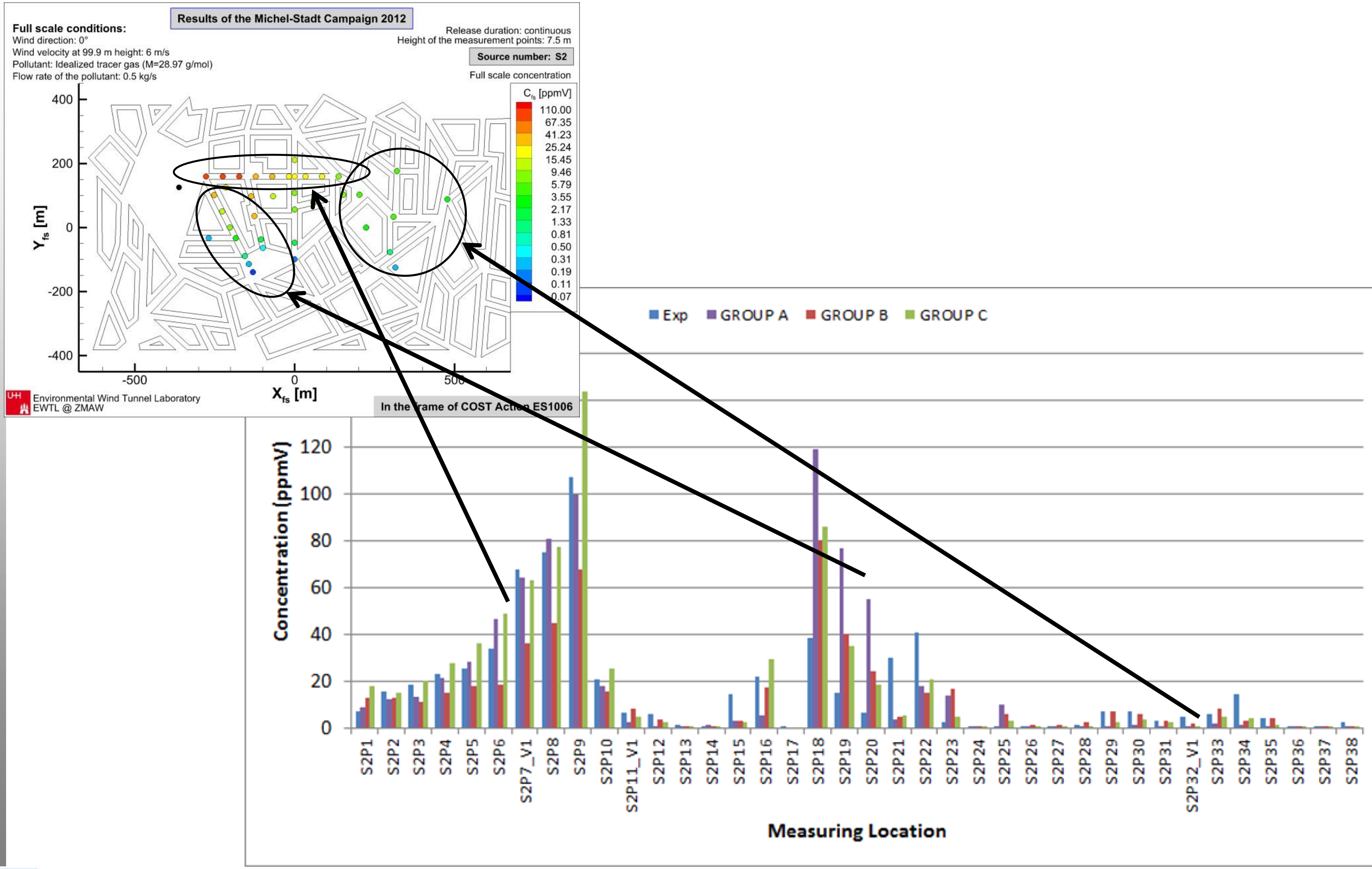
Michelstadt experiment

Results – point to point variability – Source S2 continuous



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Michelstadt experiment

Results – model to model variability

The following Index of Agreement IA has been computed for each pair of models

$$IA = 1 - \left[\frac{\sum_{i=1}^{N} \left(C'_{Gx\_i} - C'_{Gy\_i} \right)^2}{\sum_{i=1}^{N} \left(\left| C'_{Gx\_i} \right| + \left| C'_{Gy\_i} \right| \right)^2} \right]$$

N = Number of concentration pairs

$0 < IA < 1$

Doran, J.E. and T.W. Horst (1985): An evaluation of Gaussian plume-depletion models with dual-tracer field measurements. Atmos. Environ. 19, 939-951

where $C'_{G\_i} = C_{G\_i} - \overline{C_{G\_i}}$ is the deviation of the concentration for each Group x or y

	GROUPS		
IA	A vs B	A vs C	B vs C
Source S2	0.92	0.95	0.90
Source S4	0.40	0.91	0.54
Source S5	0.63	0.74	0.94
All sources	0.69	0.93	0.80

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Michelstadt experiment

Results – Group-to-Group scatter diagrams

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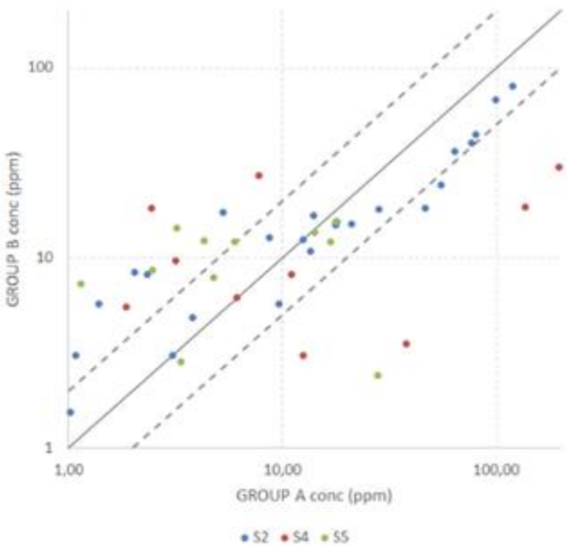
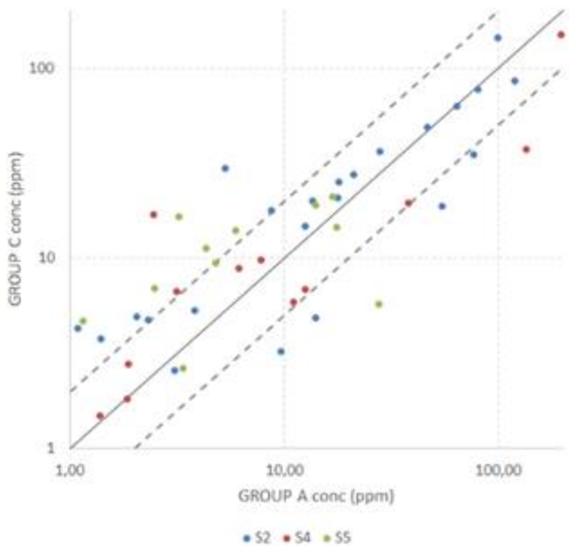
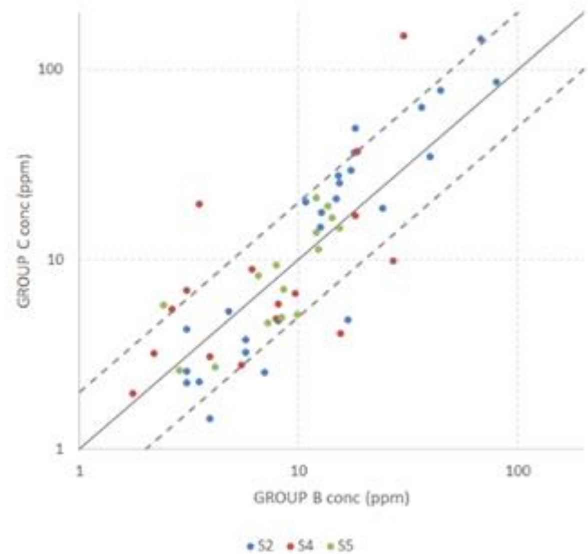
Group A vs Group B



Group A vs Group C

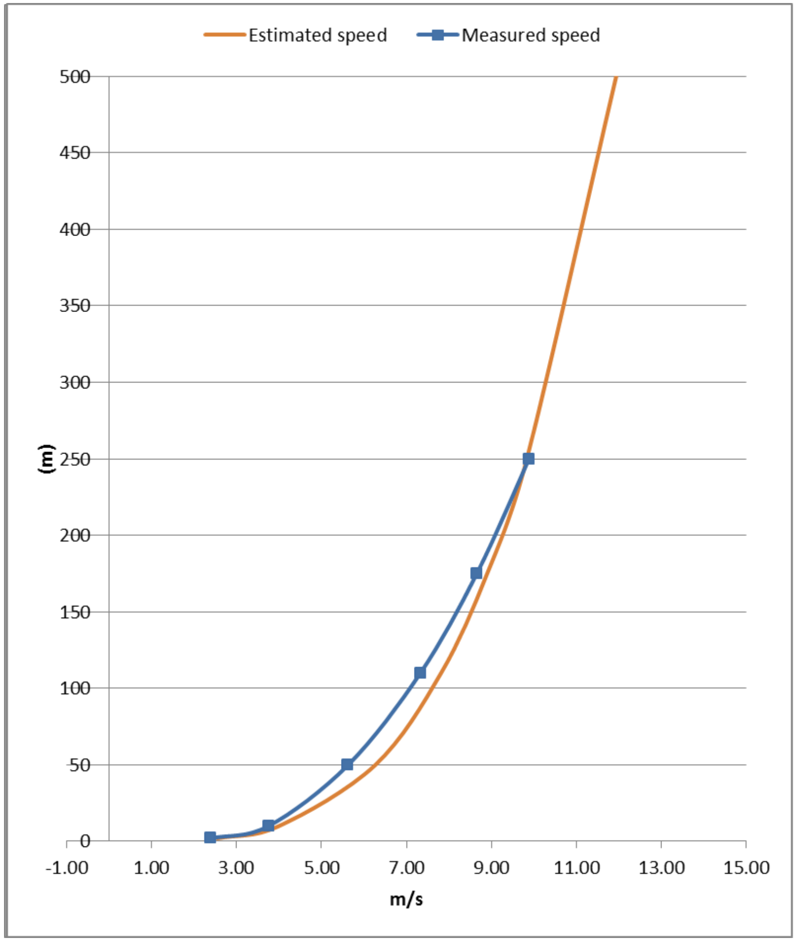


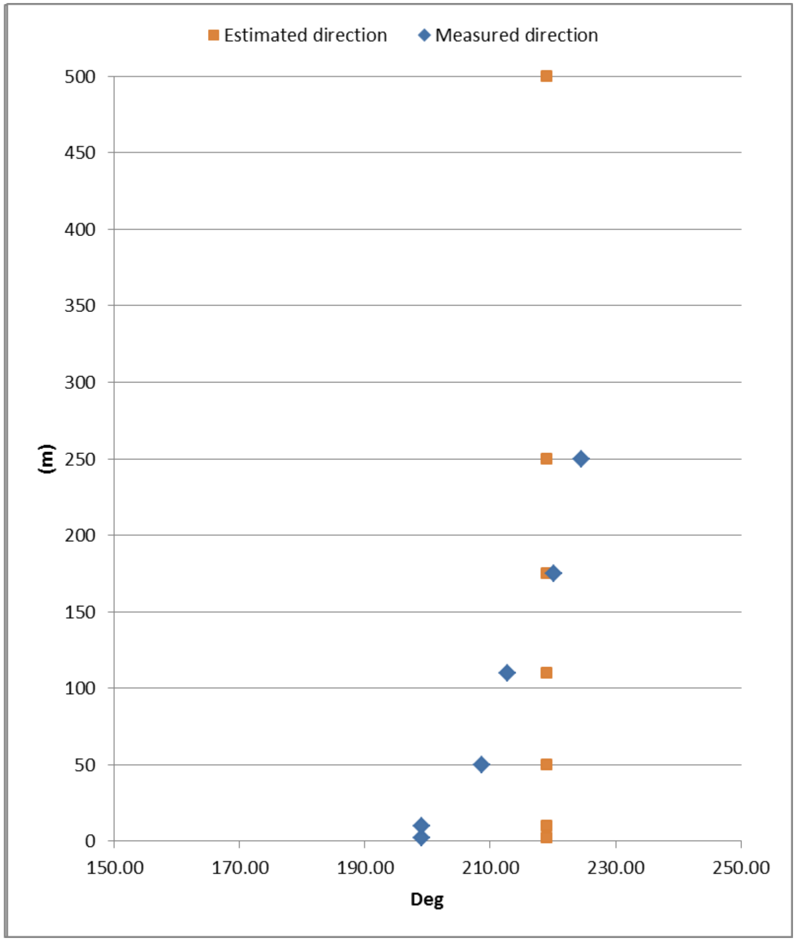
Group B vs Group C



CUTE 1 experiment

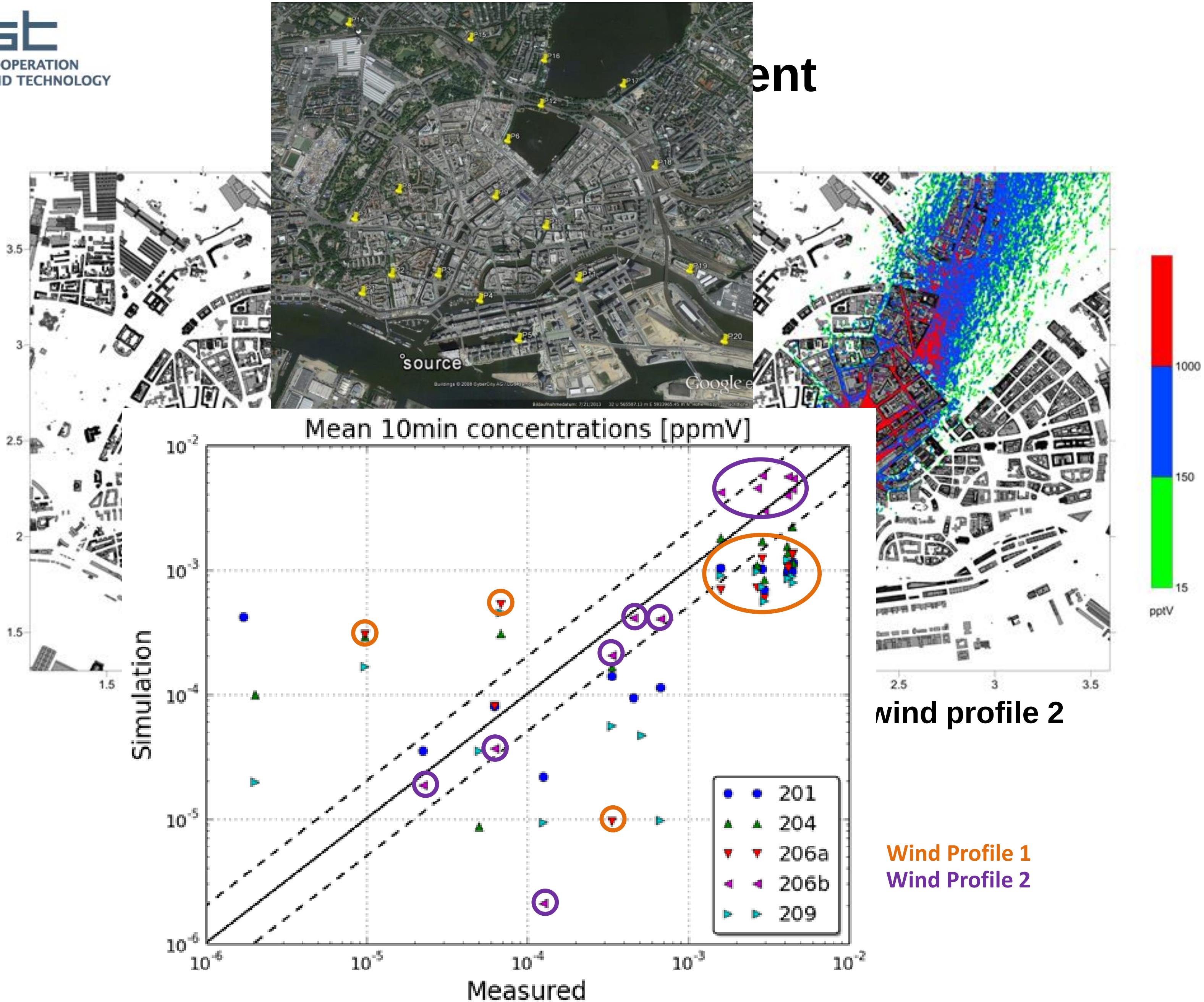
Two different inlet wind profiles





Wind direction given at 175 m above ground= 219 ° profile 1

Wind direction measured by the mast = from 199 ° to 224 ° profile 2



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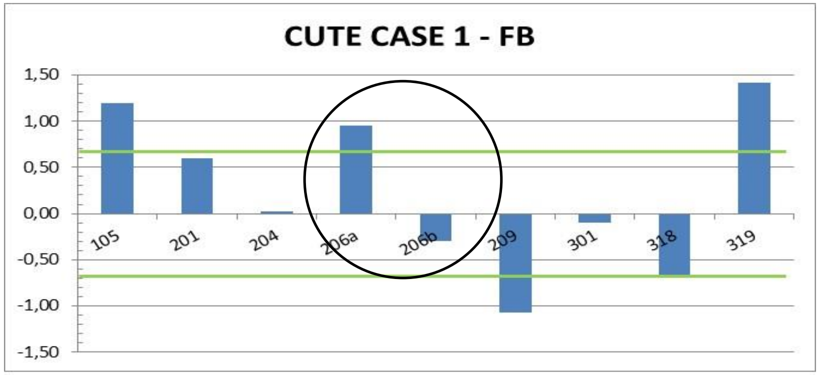
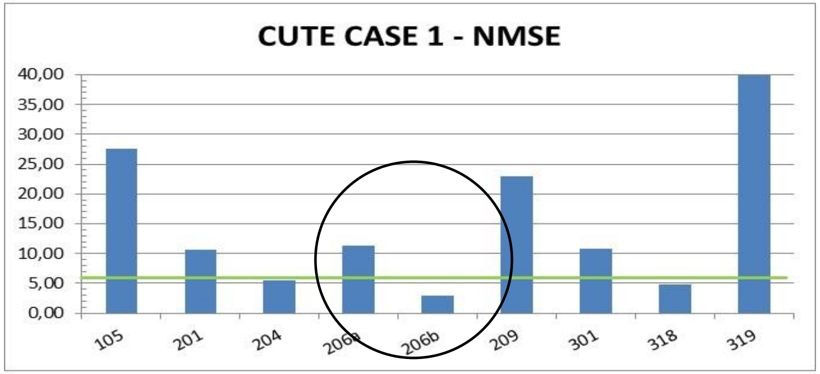
CUTE 1 experiment

Results – statistical indexes

$$FB = \frac{\overline{\Phi_o} - \overline{\Phi_p}}{0.5\left(\overline{\Phi_o} + \overline{\Phi_p}\right)} = \frac{\overline{\Phi_o - \Phi_p}}{0.5\left(\overline{\Phi_o} + \overline{\Phi_p}\right)}$$

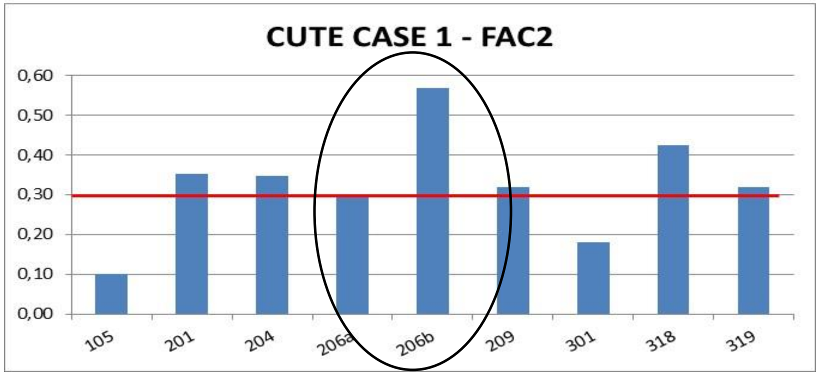


$$NMSE = \frac{\overline{\left(\Phi_o - \Phi_p\right)^2}}{\overline{\Phi_o} \cdot \overline{\Phi_p}}$$



206b (Wind Profile 2) shows the best performance

fraction of data that satisfy $0.5 \leq \frac{\Phi_p}{\Phi_o} \leq 2$



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CUTE 1 and CUTE 3 experiments

Two different inlet turbulence profiles

For both case Neutral Atmosphere – two different roughness values

Turbulence profile 1 - z0=1m :

CUTE 1 (Field case) u_*=1.31 m/s ; TKE(z=10 m)=6.4 m²/s²
CUTE 3 (Wind tunnel case) u_*=1.26 m/s ; TKE(z=10 m)=5.9 m²/s²

Turbulence profile 2 - z0=0.1m :

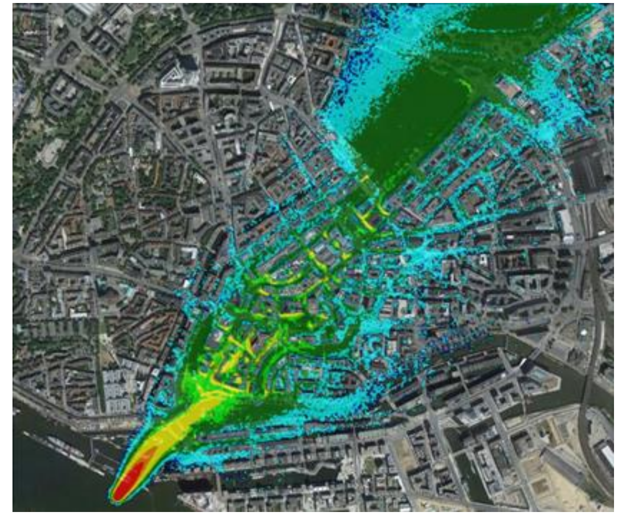
CUTE 1 u_*=0.33 m/s ; TKE(z=10 m)=0.4 m²/s²
CUTE 3 u_*=0.31 m/s ; TKE(z=10 m)=0.39 m²/s²

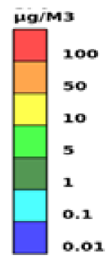
Variation is quite large

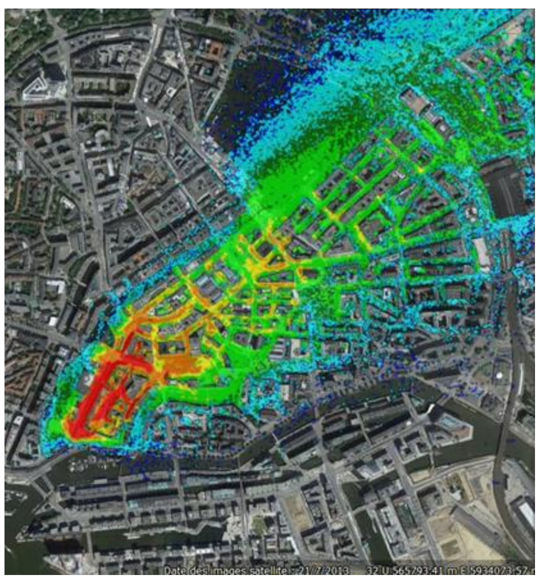
CUTE 1 and CUTE 3 experiments

Results – concentration maps

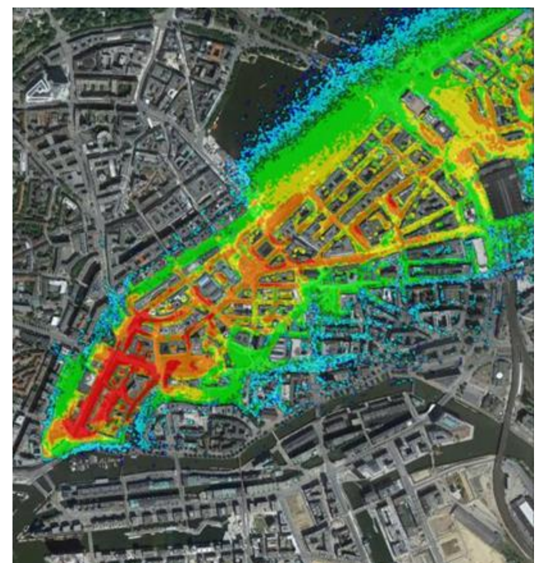
CUTE 1







CUTE 3

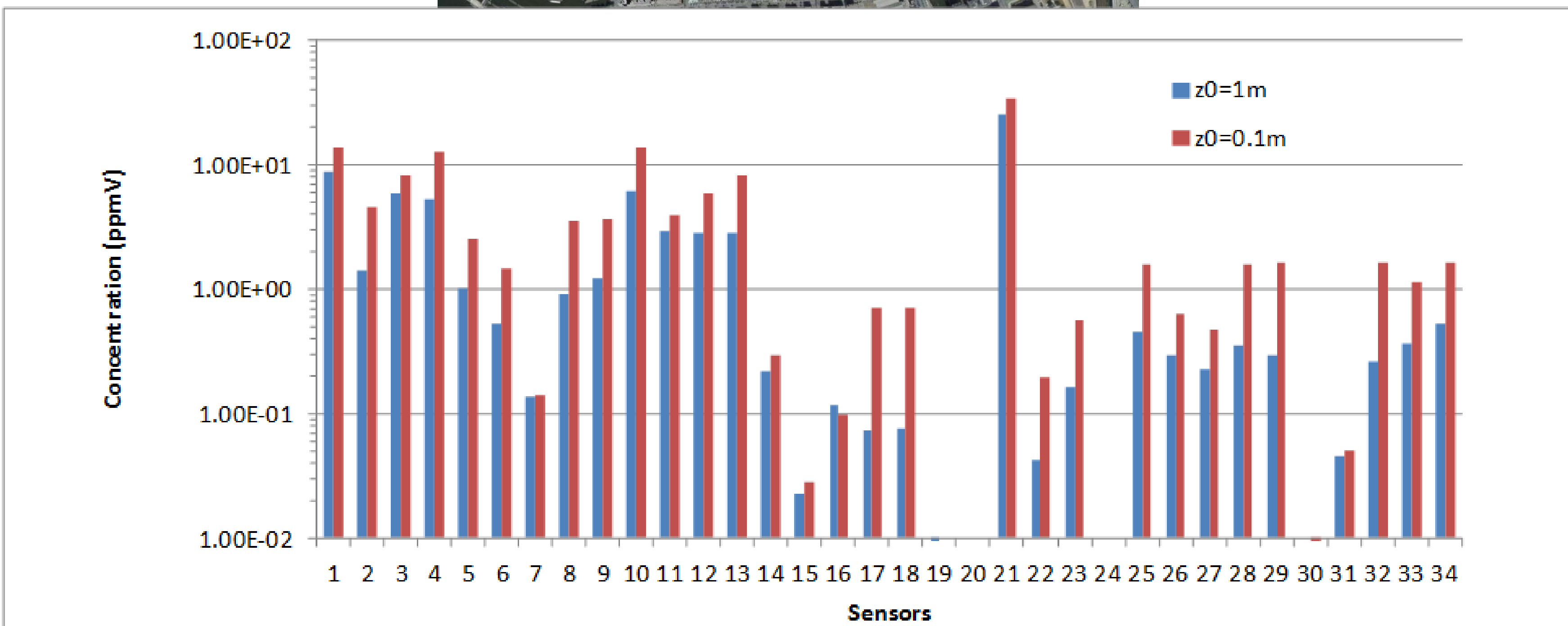


Inlet turbulence profile 1

Inlet turbulence profile 2

Cute 3 experiment

Results – Concentrations at sampler positions



maximum variation of the order of 25/30 %, but not for larger concentration values

SOME CONCLUSIONS

This cannot be a 'conclusive' work, but even with such a small number of analyzed cases, some useful tips can be taken

- besides the physical quantities, there are key quantities handled by the users changing and improving the performances, such as the number of particles, horizontal and vertical grid resolutions
- a parallel configuration allows for substantial reduction of the computational time allowing the use of more refined parameters or faster simulations
- the availability of more precise or sophisticated data (wind profiles, turbulence characterization) can also improve simulation results, but sometimes not in a decisive manner.

In spite of the highlighted differences, the tested dispersion models show at the end to be robust. Even using independent different configurations, the quality of the results is comparable and the simulations provide overall consistent output