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EVALUATION OF LOCAL-SCALE MODELS FOR ACCIDENTAL RELEASES IN BUILT ENVIRONMENTS – RESULTS OF THE "MICHELSTADT EXERCISE" IN COST ACTION ES1006

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Outline

- Michelstadt Model Evaluation Exercise
- Models applied
- Results
- Conclusions

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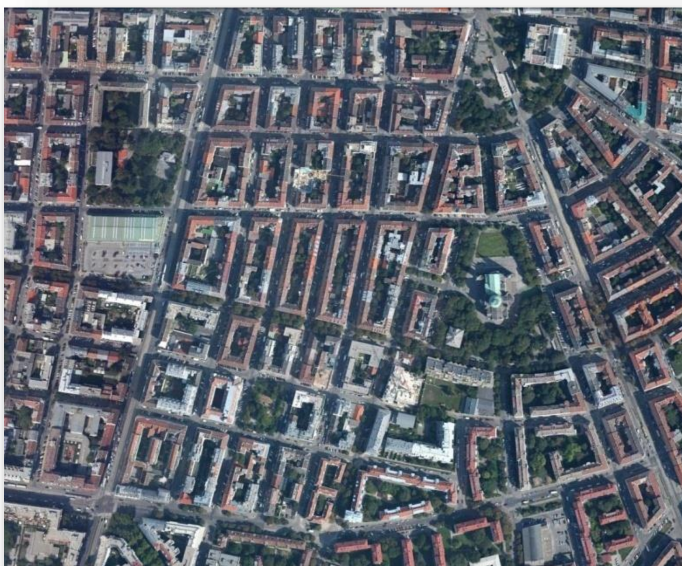
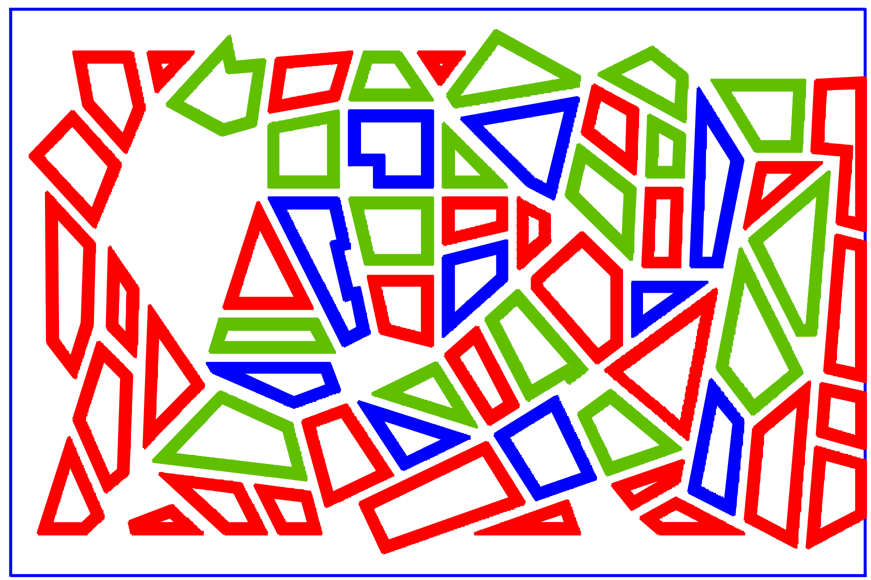
Michelstadt Model Evaluation Exercise

- A virtual town with aspect ratios typical for central European cities
- flat roofs, idealized urban roughness
- building heights: 15 m, 18 m, 24 m
- building width: 15 m
- street width: 18 m, 24 m
- scale: 1:225

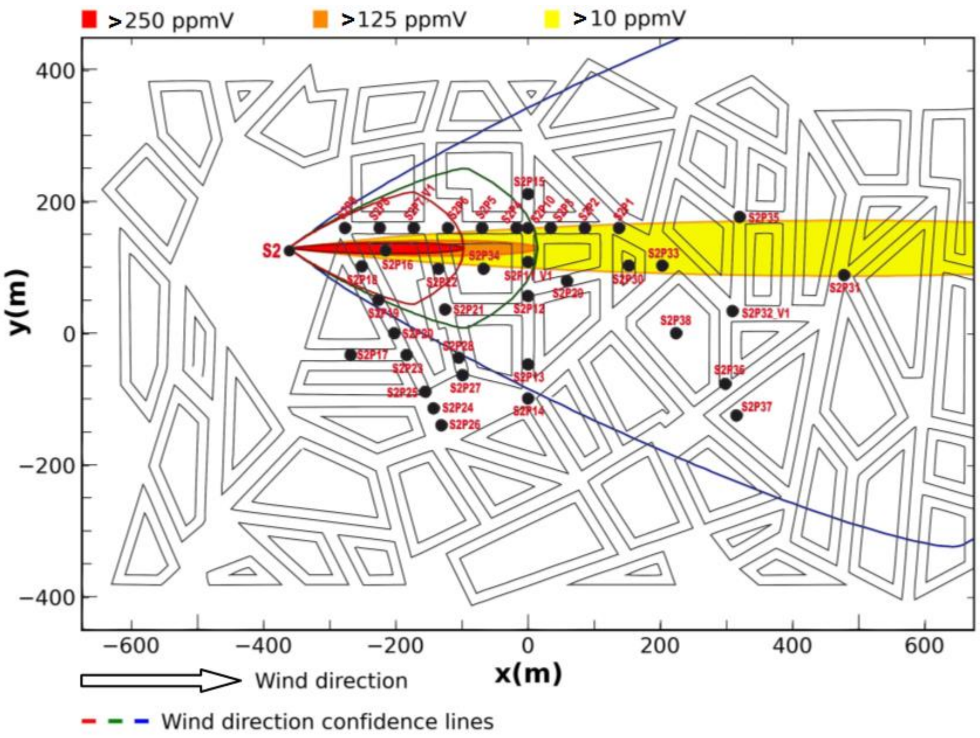




Michelstadt Model Evaluation Exercise

Number of source locations and receptor points in COST ES1006 Michelstadt exercise

Experiments	Number of	number of receptor points	
	source locations	Continuous	puff releases
non-blind	3	104	10
blind	4	248	31



Horizontal distribution of average near ground concentrations for a continuous release from source S2 simulated with a models of type I (model 101)

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Models applied in the Michelstadt Exercise

Model approaches

Model type	Dispersion modelling method	Computational time
I	Gaussian (without / with building parameterization)	1 -5 minutes
II	Lagrangian dispersion models	2 minutes – 5 hours
III	CFD (RANS; LES; RANS-Lagrangian)	2 hours – 4 days

Number of models and modellers

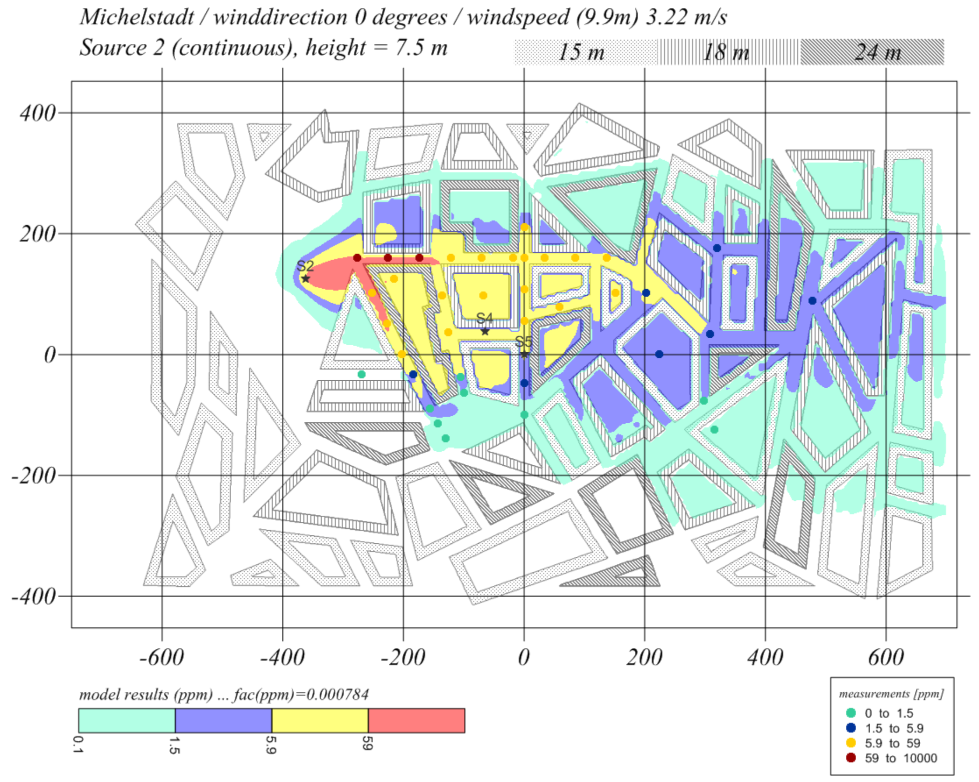
Model Type	Continuous Release		Puff Release	
	number of modellers	number of models	number of modellers	number of models
I	9	7	5	5
II	6	6	4	4
III	12	7	7	5

Results of the Michelstadt Exercise

Note:

Pairing local-scale concentration observations and predictions both in space and in time (for puffs) in statistical comparisons may render worse results than actually obtained because…

- Observed and simulated plumes may be very similar but small differences in the wind direction or in the representation of the buildings can make the plumes' overlap fail resulting in poor statistical paired indices.
- Observations are instantaneous and single-point values. These may significantly differ from the time and space averages produced by a model.
- Observed small-scale gradients between adjacent receptors are hardly captured by models due to spatial averaging.



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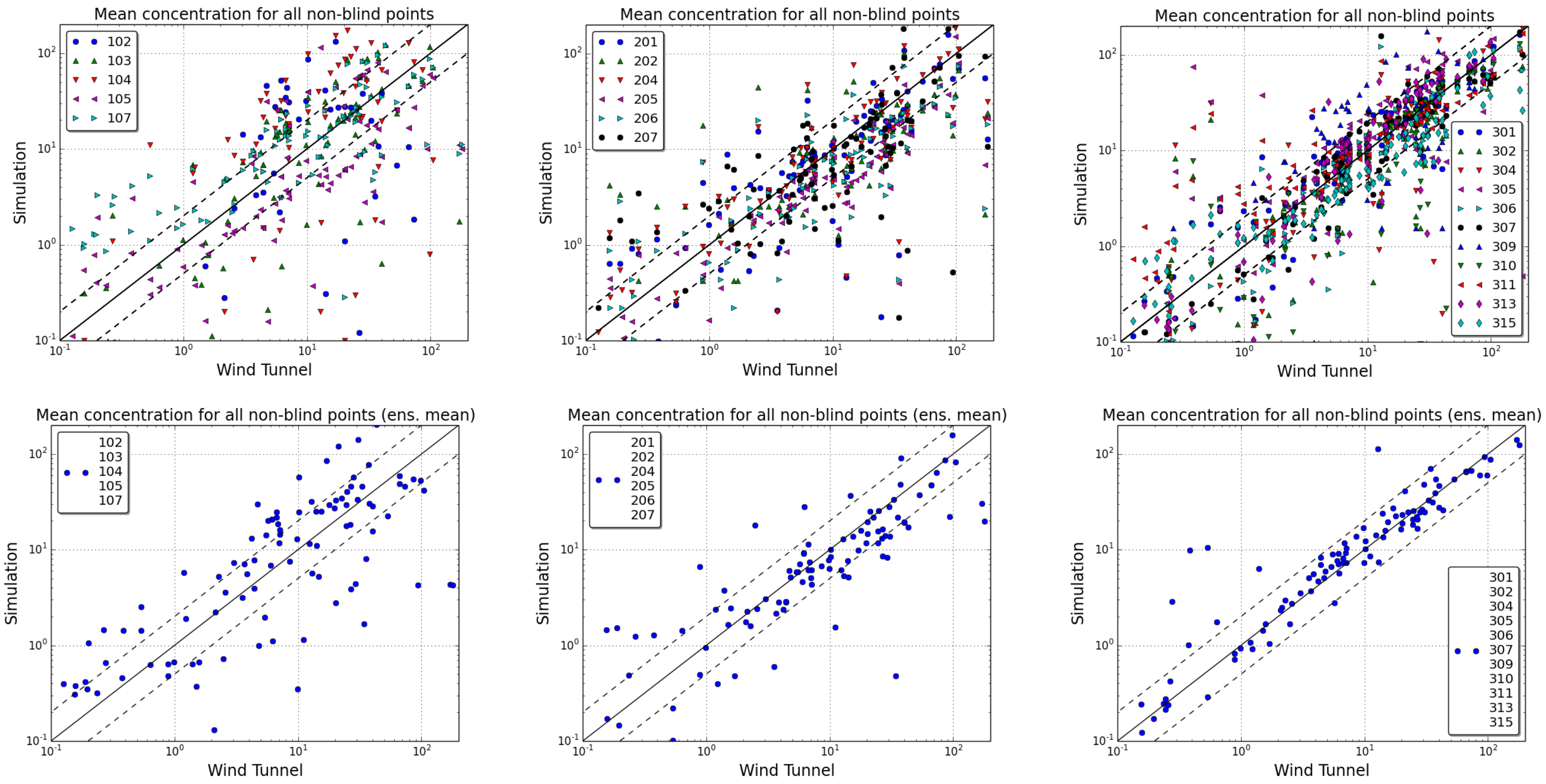
Results of the Michelstadt Exercise – non-blind test for continuous releases

Model type I (Gaussian) | Model type II (Lagrangian) | Model type III (CFD)



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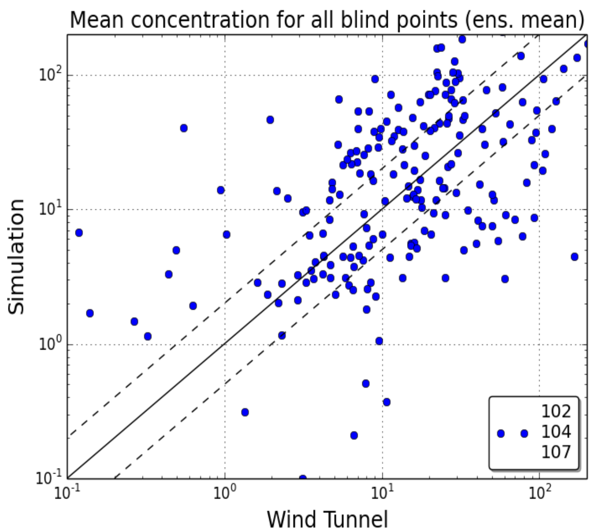
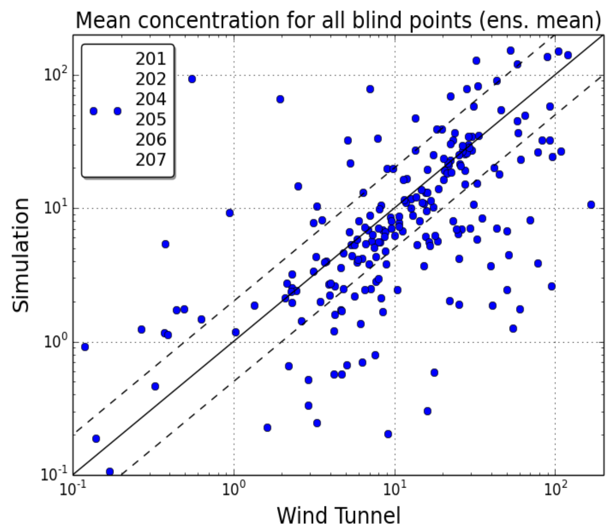
Results of the Michelstadt Exercise – blind test for continuous releases

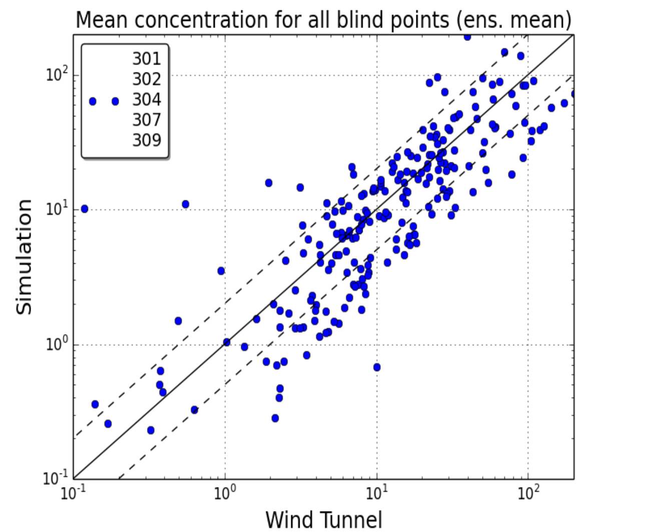
Model type I (Gaussian)



Model type II (Lagrangian)



Model type III (CFD)



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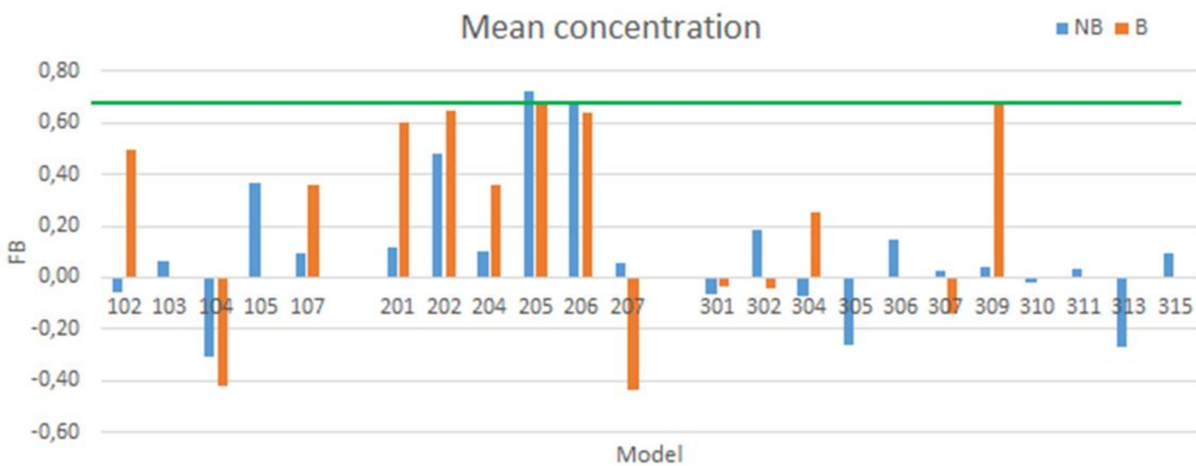
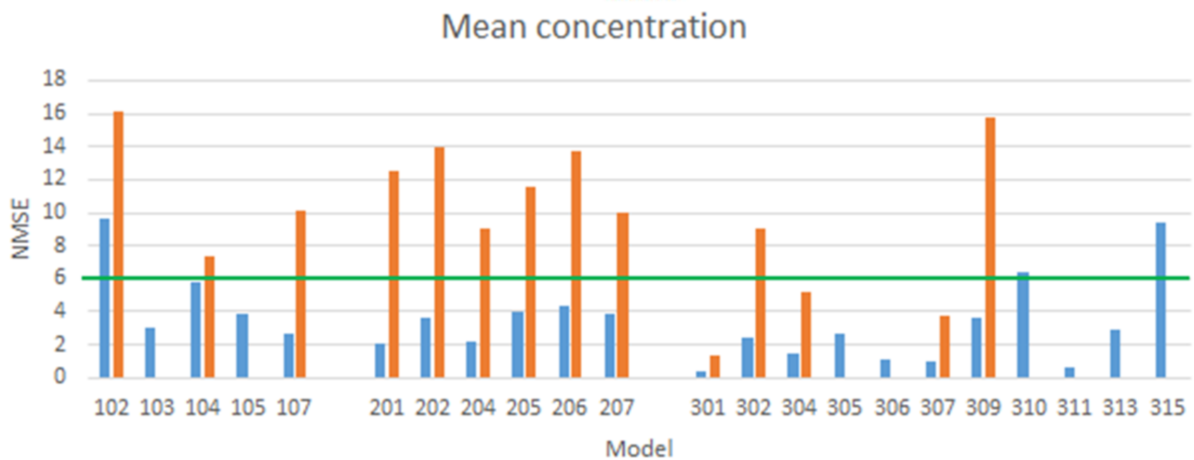
Results of the Michelstadt Exercise – non-blind / blind tests

continuous releases

$$FB = 2\frac{\overline{c_0} - \overline{c_p}}{\overline{c_0} + \overline{c_p}}$$



$$NMSE = \frac{\overline{(c_0 - c_p)^2}}{\left(\overline{c_0}\,\overline{c_p}\right)}$$



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Results of the Michelstadt Exercise - Puff parameters included

- ✓**dosage** [ppmVs]: the total amount of tracer gas reaching the measurement location during the measurement period,
- ✓**peak concentration** (ppmV): the highest concentration occurring at the measurement location during the measurement period,
- ✓**arrival time** ([s]): the time between the beginning of the puff release and when 5% of the total dosage of the puff reaches the measurement location,
- ✓**peak time** ([s]): the time between the beginning of the puff release and when the peak concentration occurs at the measurement location,
- ✓**leaving time** ([s]): the time between the beginning of the puff release and when 95% of the total dosage of the puff leaves the measurement location,
- ✓**ascent time** ([s]): the time between the arrival time and the peak time,
- ✓**descent time** ([s]): the time between the peak time and the leaving time,
- ✓**duration** ([s]): the time between the arrival time and the leaving time.

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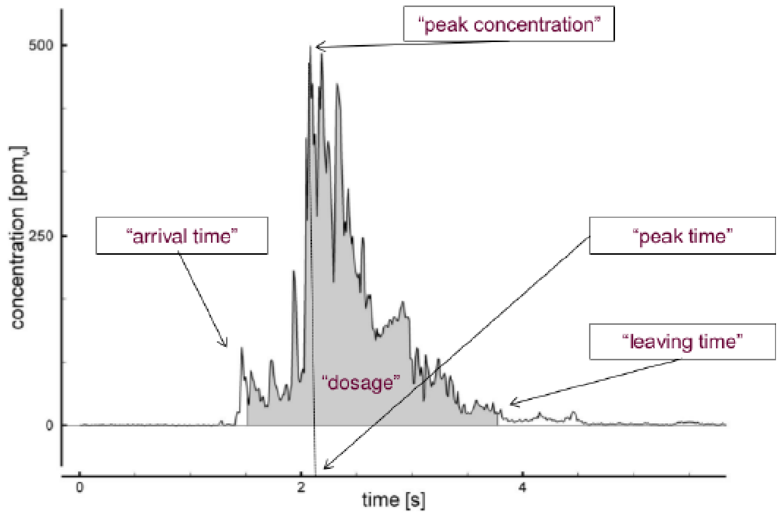
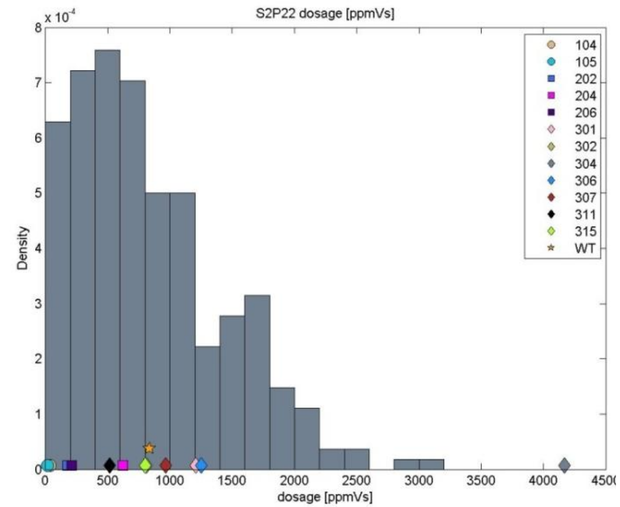
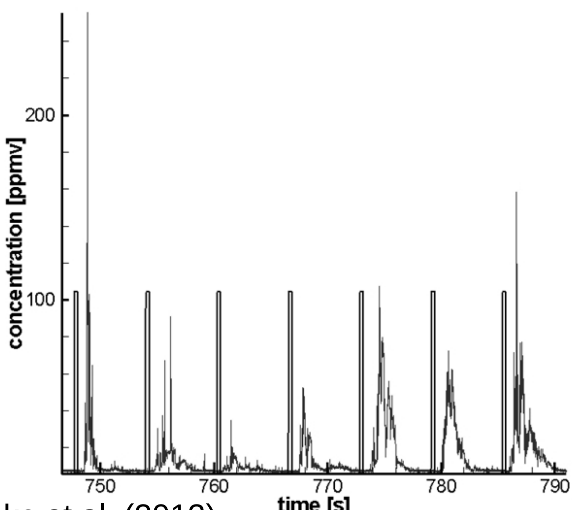
Results of the Michelstadt Exercise – puff releases

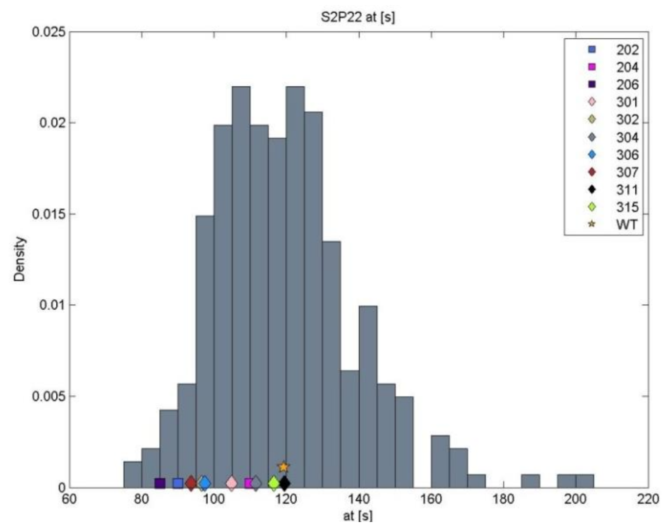




modelled and measured dosages at P22 for source S2



Lübcke et al. (2013)



modelled and measured arrival times at P22 for source S2

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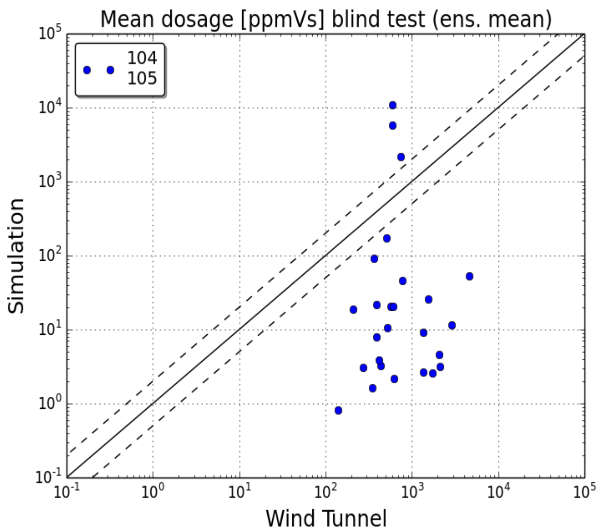
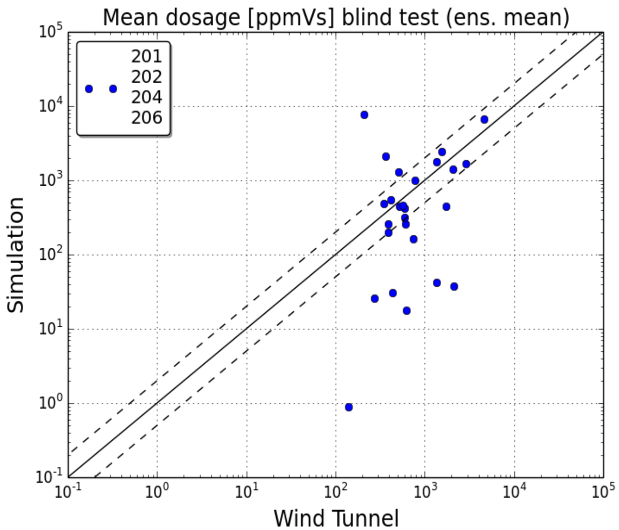
Results of the Michelstadt Exercise – blind test for puff releases

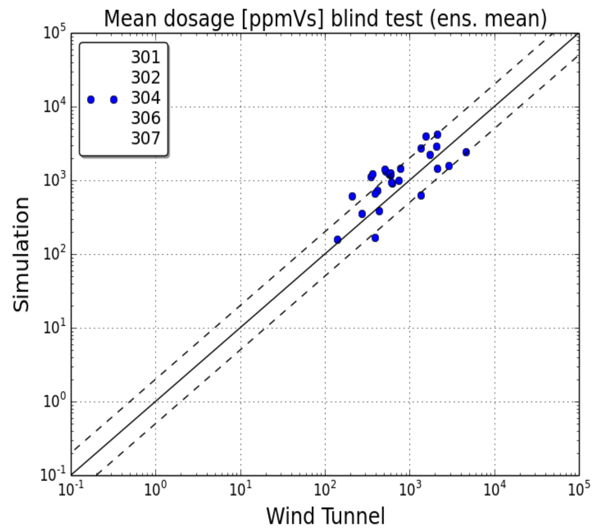
Model type I (Gaussian)



Model type II (Lagrangian)

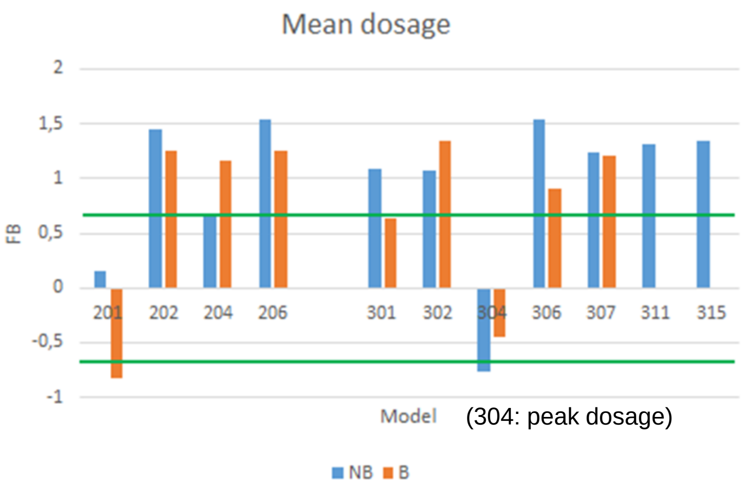


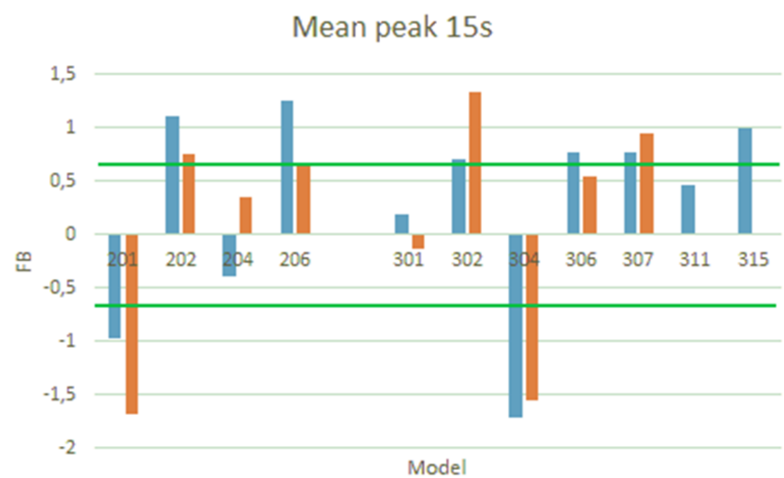
Model type III (CFD)

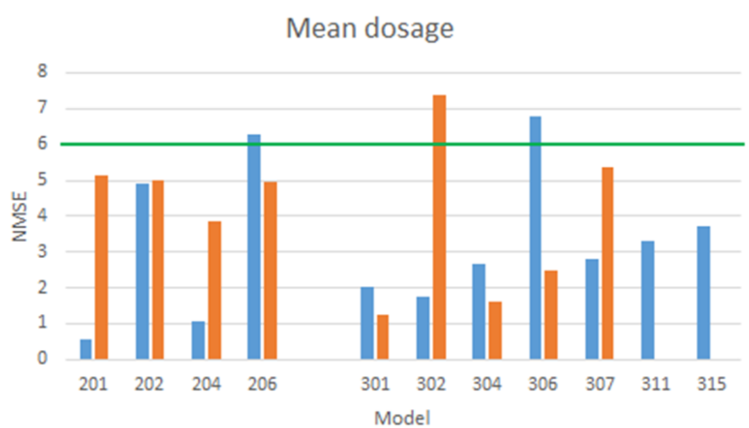


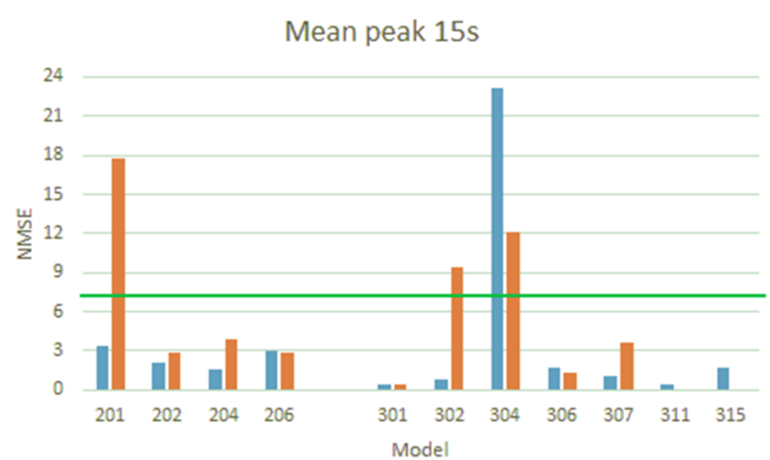
Results of the Michelstadt Exercise – non-blind / blind tests

Puff releases









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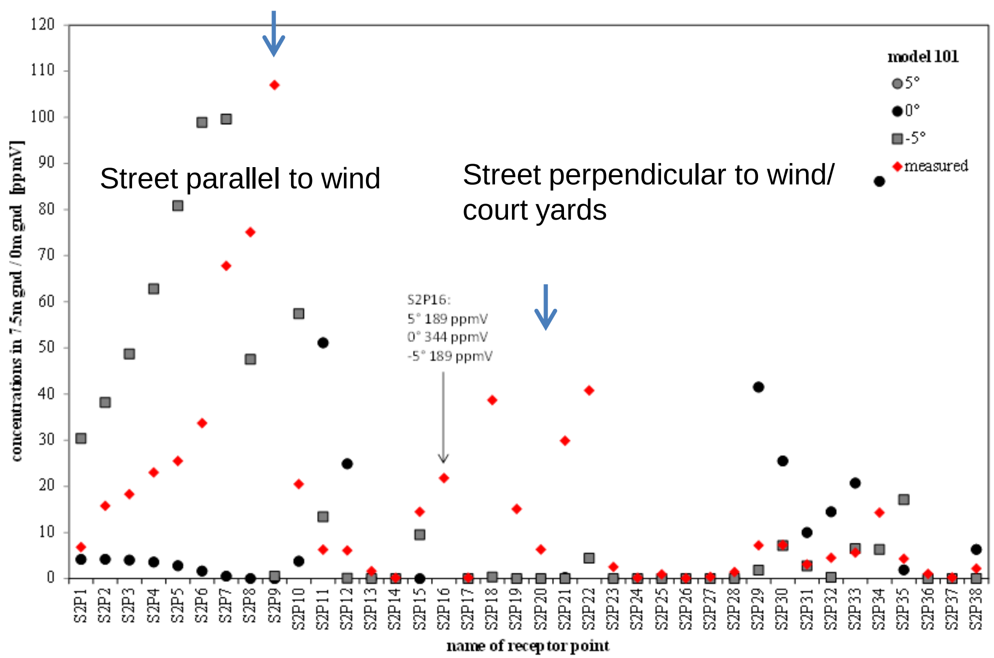
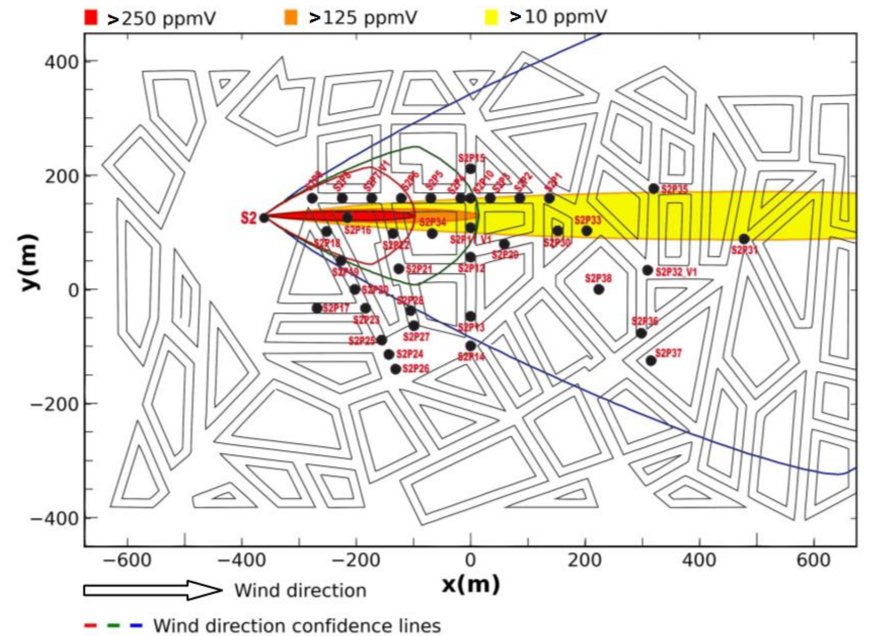
Results of the Michelstadt Exercise – sensitivity to input

In crisis management, type I models are often applied with „wind direction confidence lines“ to take into account variations in flow direction not explicitly simulated.

In urban environment, high concentration values may be encountered even outside these confidence lines.





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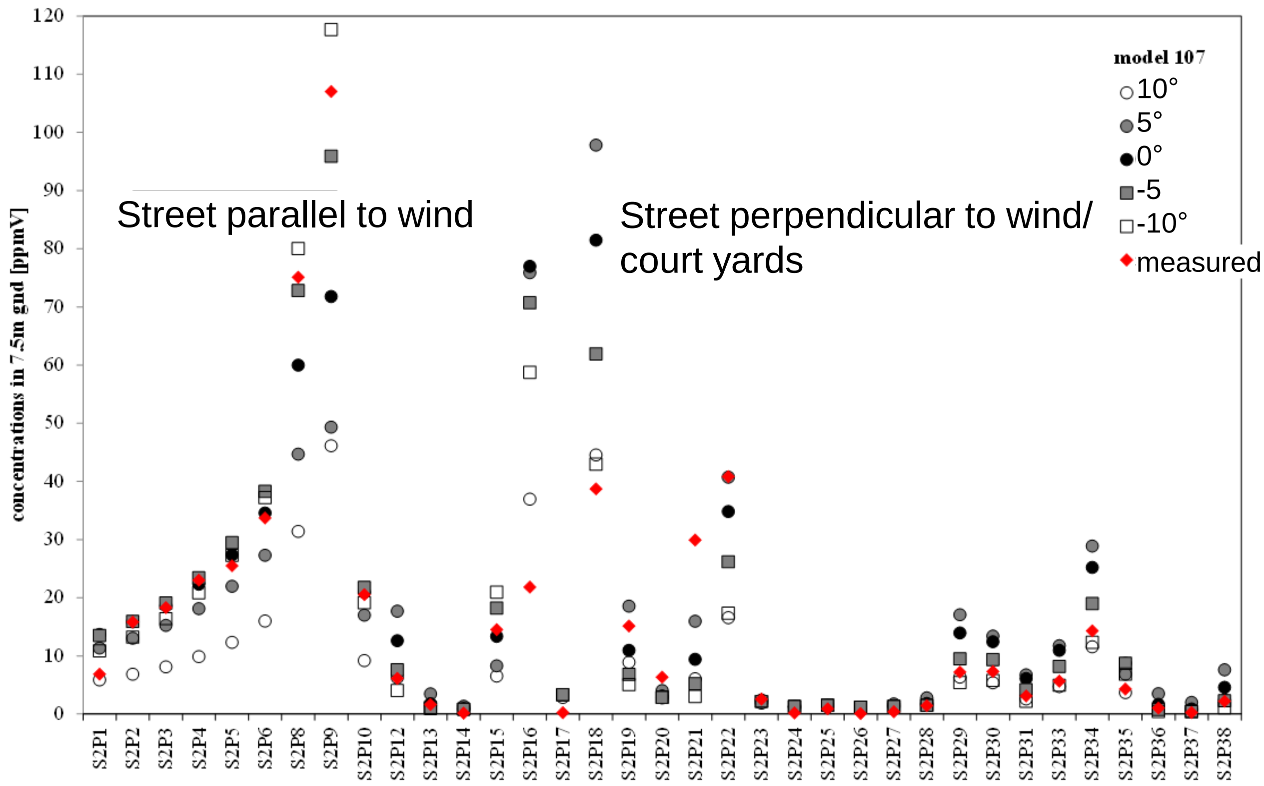
Results of the Michelstadt Exercise – sensitivity to input

Model type I sensitivity to roughness length and wind direction

	$u_* = 0.4$ (71% u_{*0})	
z_0	FB	NMSE
0.50	-0.06	1.01
0.80	0.01	0.88
1.00	0.05	0.85
1.25	0.11	0.84
1.50	0.14	0.85



Source2 release – receptor points

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Conclusions

What is essential for hazmat model evaluation?

- test data for continuous and puff releases
- appropriate statistical measures
- spatial coverage with receptor points (estimation of „affected area“)

What did we learn from the Michelstadt experiment of COST ES1006?

- model performance is depending on source location and location of receptor points (complexity of scenario)
- model evaluation for puff releases - by far more complex:
  - various parameters
  - puff to puff variations!
- Model performance increases with increasing model complexity.
- CFD models (“type III”) in general superior to Lagrangian dispersion models (“type II”) and Gaussian models (“type I”)
- “Type II” models render quite satisfying agreement with measurements and are significantly faster than “type III” models

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Conclusions

Non-blind / blind tests

- The quality of the results is not always better for the non-blind case than for the blind one.
- The performance of the models is well established, few errors in input or model set-up.
- The uncertainty in the mean dosage simulation is linked to the complexity of puff releases.
- The quality of the results of type II and III models improves for the 15-s-mean peak concentration.

Sensitivity tests

- Uncertainty / variability of wind direction: use of wind direction confidence lines is not sufficient in complex urban building structures
- choice of roughness length essential for model type I applications
- Increase of grid resolution in cases significantly improve model performance for model type II and III (sensitivity studies not presented here)

Outlook: Model evaluation exercises based on data from a real accidental release and from a field experiment are under preparation.

COST is supported by the EU RTD Framework Programme

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