

Evaluation of Radionuclide Dispersion in Urban Areas – Validation of GRAL within the EXPO-URB Project

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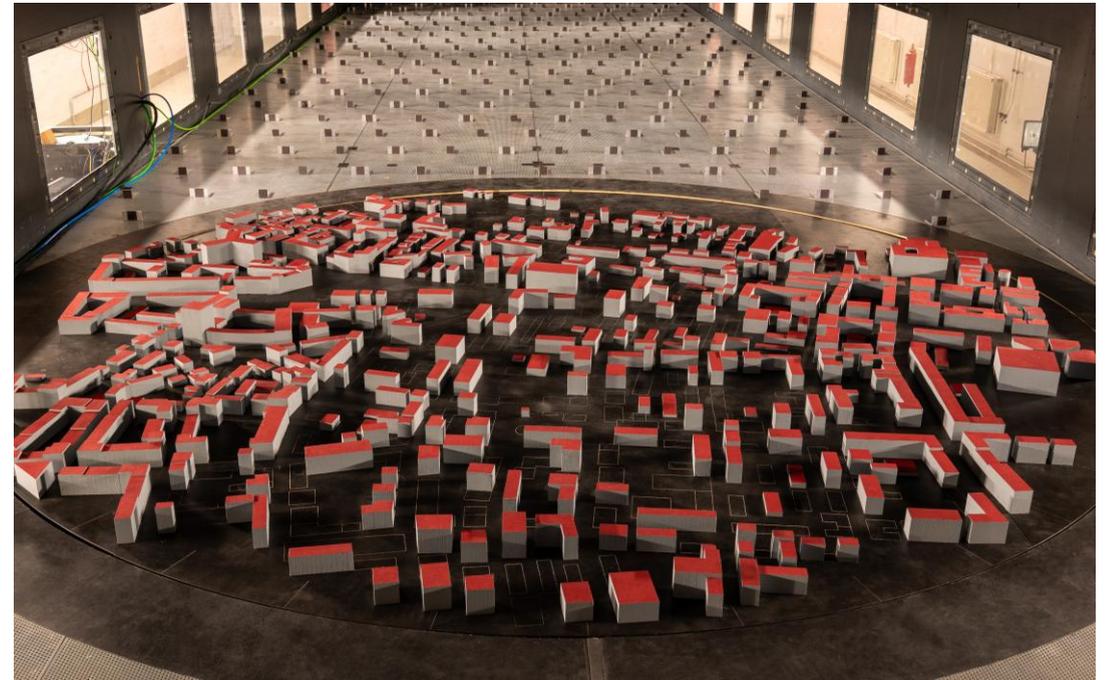
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Introduction/Background EXPO-URB project

- Motivation for the EXPO-URB project is the evaluation of long-term radiation exposure in urban environments from dispersed nuclides
 - Radionuclide sources of interest are characterized by low momentum & no-buoyancy
 - As there is a lack of experimental data to evaluate long term radiation exposure in urban environments a series of wind tunnel tracer release experiments is undertaken at Environmental Wind Tunnel Laboratory at Hamburg University
 - Aim of EXPO-URB project is to evaluate the skill of Lagrangian particle in representing long term radiation exposure in urban environments
- The GRAL model GRAz Lagrangian is one of the Lagrangian Particle models used in EXPO-URB project model intercomparison

Experiments at EWTL & Design

- Boundary Layer Wind Tunnel
- Mock-up of typical European city build
- So far 8 test data sets created for different
 - wind directions (350° , 0° , 10°)
 - Varying building density
 - Source configurations
 - Roof Shape
- Upcoming: move the source to the centre and different wind directions from $18 \times 20^\circ$ sectors will be tested

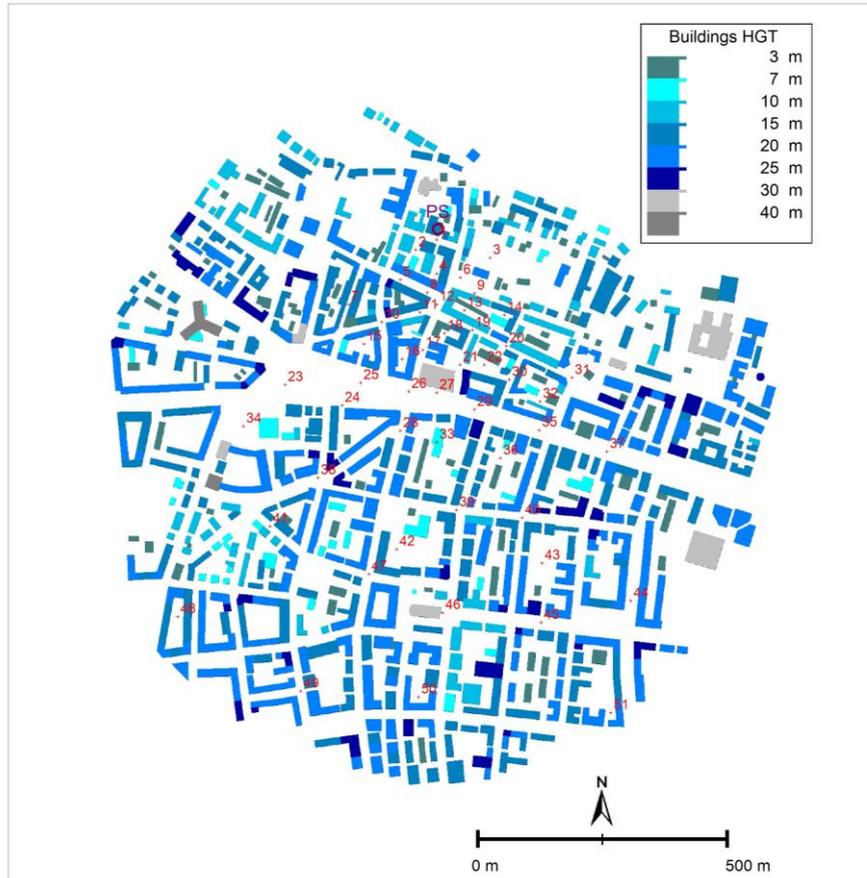


Main Experimental Set-up, Test-Cases, Parameter Variation & GRAL set-up

	Base Settings T1.1	Test-Cases / Parameter Variations	
Flow wind direction	T1.1 0° (360°)	T1.2 10°	T1.3 350°
wind speed	10 m/s @ reference height 100 m		
roughness	z0 = 0.6m		
Stability	neutral		
Buildings & Density	dense block structure	T2 medium block structure	T3 low block structure
Source type	stack	T4.1 stack	T4.2 outlet
emission rate	2 g/s (= kBq/s) (WT)		
exit velocity	2 m/s		
exit temperature	ambient temperature		
diameter/area	2m		2m x 2m
location	x = 430.4m, y=2.4m		x=428.4m, y=7.9m
height over roof / source height:	2m / 20m	T4.1 5m / 23m	T4.2 - / 16.6 m
Roof Shape	T5 Slanted roofs added		

- GRAL-AT 24-04 Version with standard settings used
- GRAL inherent CFD flow solver used to compute obstacle resolved flow (Oettl,2015 complies with VDI Guideline 3783-9)
- Standard power law wind profile used (US-EPA, 2000)
- Plume rise based on Hurley (2005) - stacks
- Sideward ventilation outlet modelled as elevated 2m x 2m tunnel portal with bi-directional traffic

Validation Set-Up



Domain size 1750 m x 1750 m
72 receptor points at 51 locations

- Statistical metrics used:

- $$FB = \frac{\overline{\Phi_o} - \overline{\Phi_p}}{0.5(\overline{\Phi_o} + \overline{\Phi_p})}$$
 Fractional Bias

- $$NMSE = \frac{(\overline{\Phi_o} - \overline{\Phi_p})^2}{\overline{\Phi_o} \cdot \overline{\Phi_p}}$$
 Normalized Mean Square Error

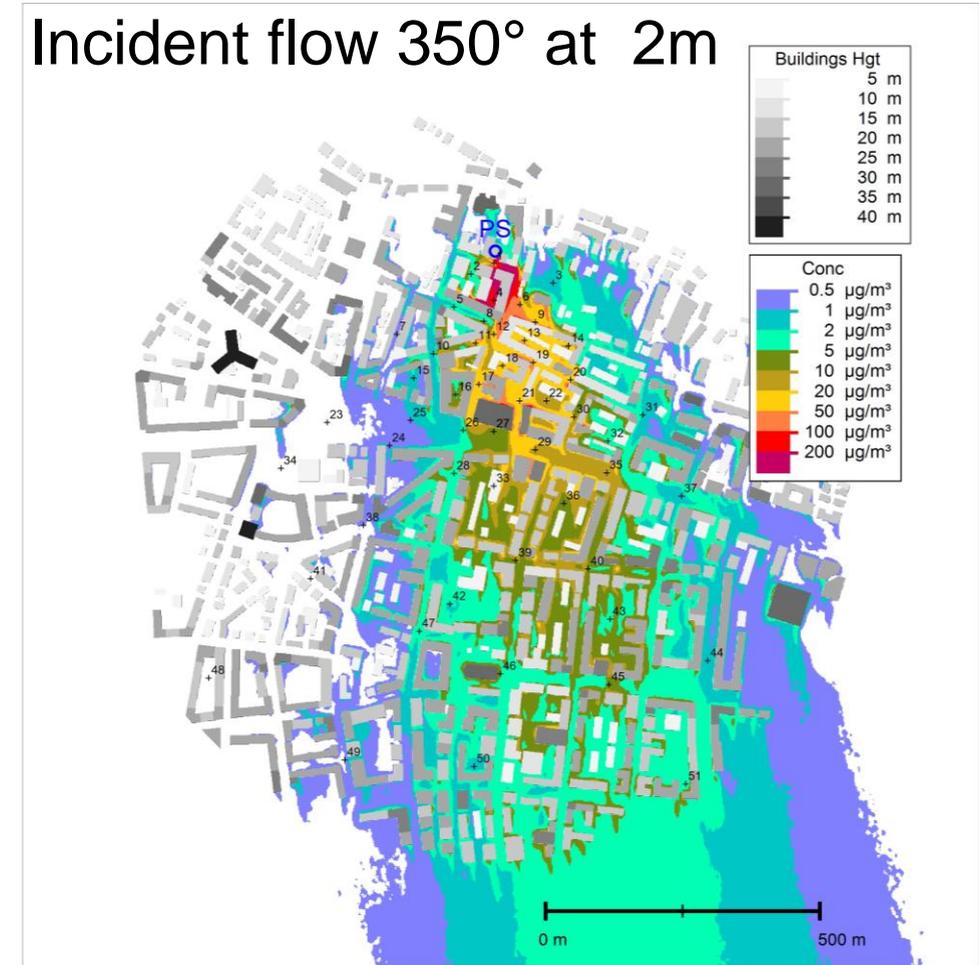
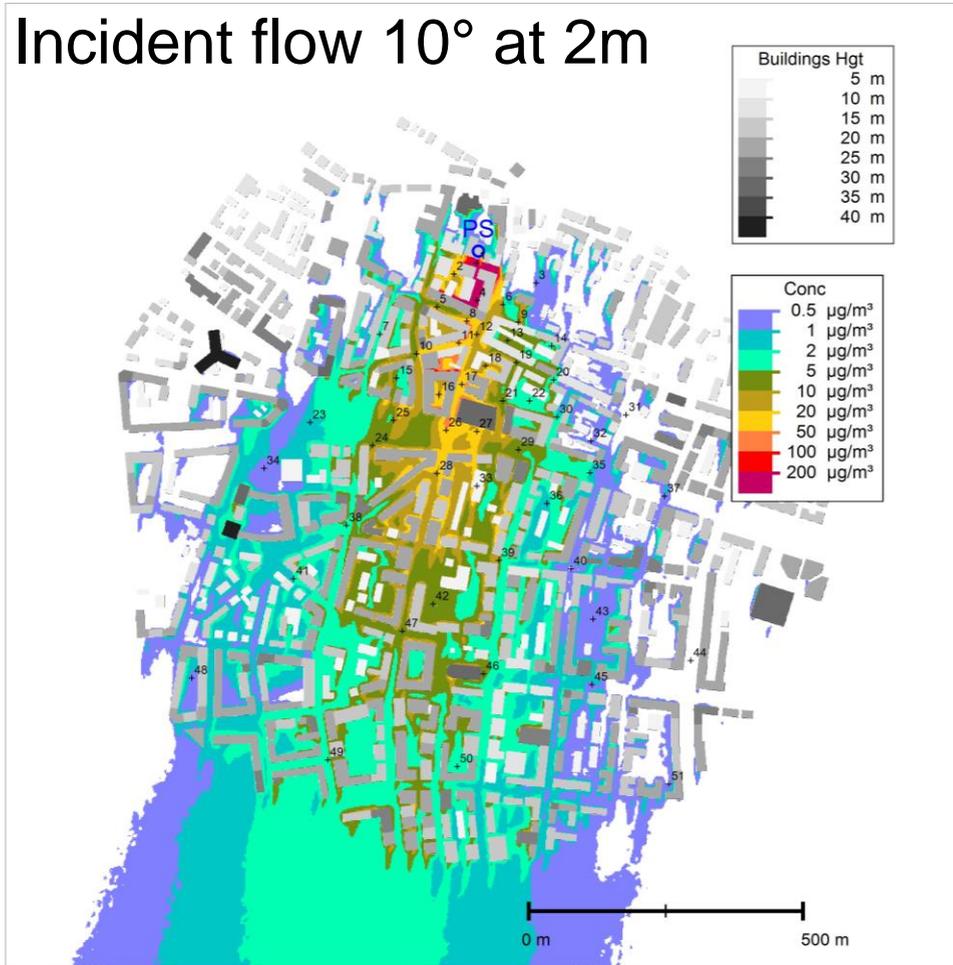
- $$MG = \exp(\overline{\ln \Phi_o} - \overline{\ln \Phi_p})$$
 Geometric Mean Bias

- $$VG = \exp \left[\overline{(\ln \Phi_o - \ln \Phi_p)^2} \right]$$
 Geometric mean Variance

- $$IA = 1 - \left[\frac{\sum_{i=1,N} (\Phi_{pi} - \Phi_{oi})^2}{\sum_{i=1,N} (|\Phi_{pi} - \overline{\Phi_o}| + |\Phi_{oi} - \overline{\Phi_o}|)^2} \right]$$
 Index of Agreement

Acceptance criteria by Hanna and Chang (2012):
 $|FB| < 0.67$; $NMSE < 6$, i.e.; $0.5 < MG < 2.0$; $VG < 75$

Results



Statistical results

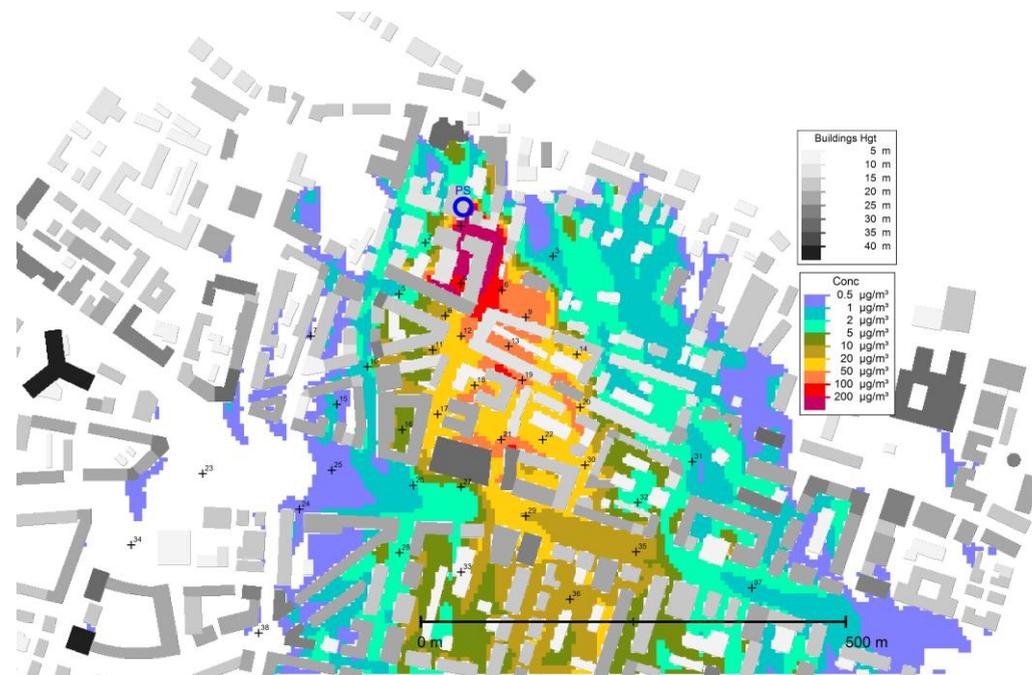
$|FB| < 0.67$; $NMSE < 6$, i.e.; $0.5 < MG < 2.0$; $VG < 75$

Test Case	FB 5 m	NMSE 5 m	MG 5 m	VG 5 m	IA 5 m	FB 2 m	NMSE 2 m	MG 2 m	VG 2 m	IA 2 m
T1.1 0°	-0.22	4.34	0.74	6.86	0.93	0.03	2.05	0.85	6.89	0.97
T1.2 10°	-0.13	0.92	0.71	9.38	0.98	0.25	0.38	0.78	9.99	0.99
T1.3 350°	-0.21	6.27	0.49	20.82	0.90	-0.08	5.36	0.51	26.65	0.92
T2 0° low dens	0.19	0.36	0.80	7.91	1.00	0.29	0.46	0.91	7.55	0.99
T3 0° medium dens	-0.15	2.47	0.97	6.15	0.95	0.13	1.85	1.14	5.01	0.97
T4.1 stack H=23m	-0.23	4.74	0.72	7.74	0.93	0.03	2.25	0.82	7.61	0.97
T4.2 outlet H=16.6m	0.97	13.86	1.45	11.85	0.64	0.62	5.51	1.01	7.57	0.83
T5 roof shapes	-0.35	3.62	0.68	9.02	0.94	-0.28	5.70	0.85	4.33	0.91

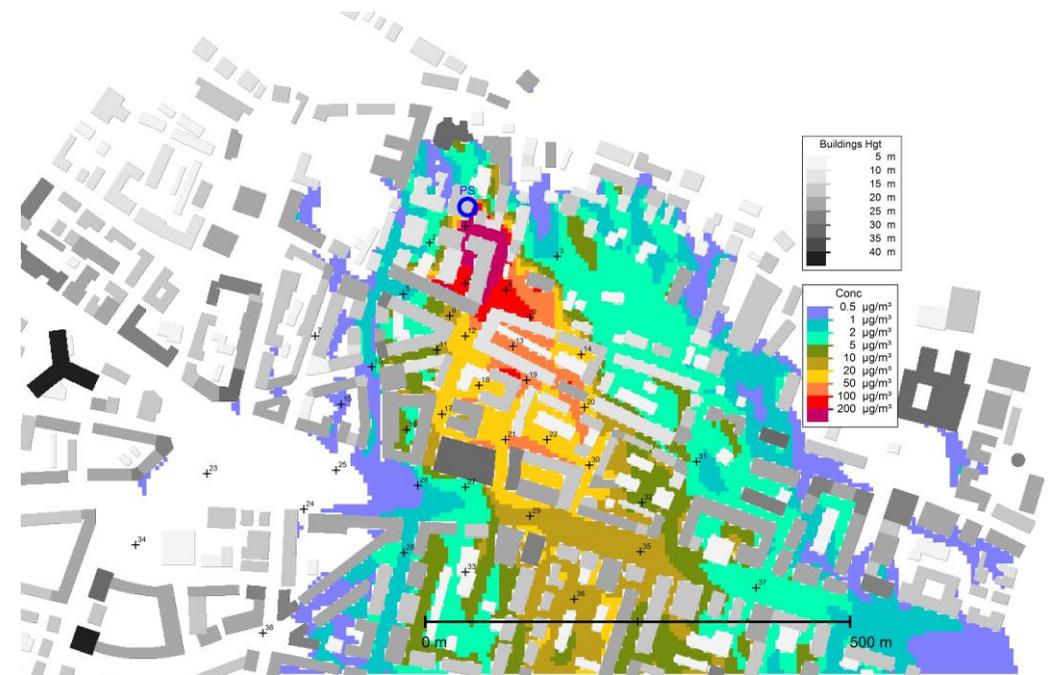
FB Fraction bias NMSE Normalized Mean Square error MG Geometric Mean bias / VG Geometric mean Variance

Sensitivity Wind Direction

Incident flow 350°



Incident flow 345°

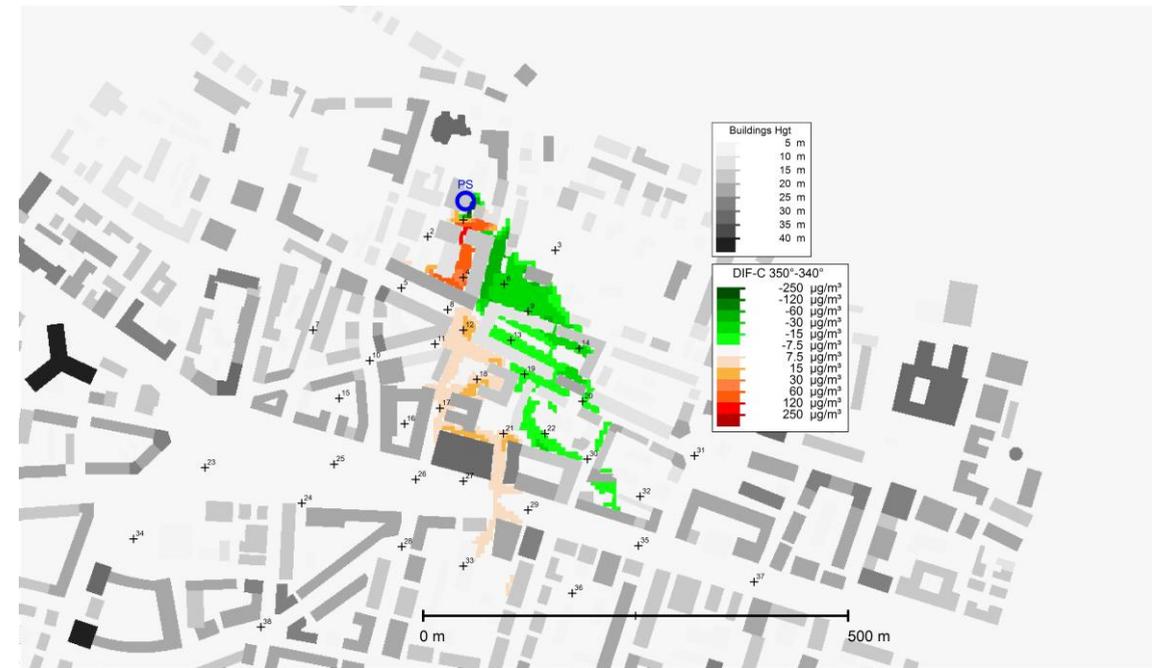


Sensitivity Wind Direction

Conc incident flow 350°

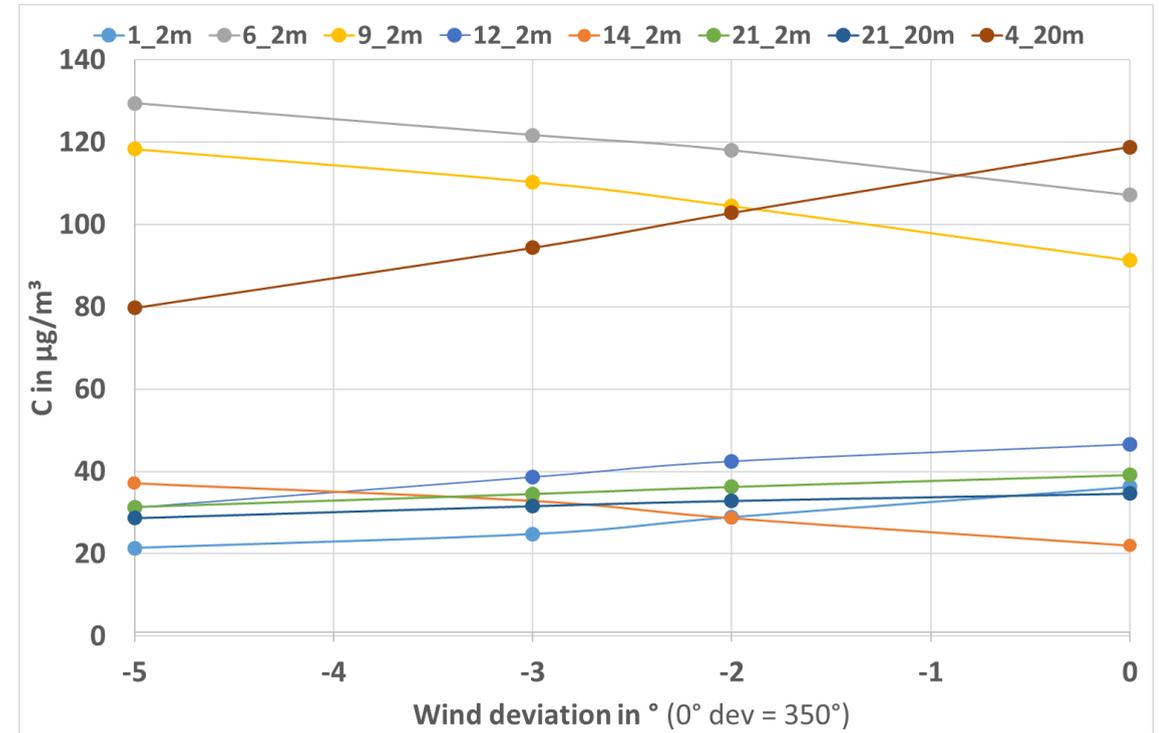


Diff incident flow Conc 350° - Conc 345°



Sensitivity Wind Direction 5 m grid

- Incident flow varied
 - WD = 345°/347°/348°/350°
 - 350° -5° / -3° / -2° / 0°
- Strong sensitivity but No erratic concentration jumps due to changes in flow
- Statistical parameters change steadily
- 2° change acceptance criteria are fulfilled!



	345°	347°	348°	350°
FB	0.00	-0.08	-0.13	-0.21
NMSE	2.49	3.76	4.54	6.27
MG	0.63	0.56	0.53	0.49
VG	18.41	17.67	18.81	20.82
IA	0.96	0.93	0.92	0.90

Summary

- In URB-EXPO wind tunnel passive tracer release experiments are conducted using a mock-up of a EU city centre
 - tracer measurements for 8 experimental configurations at 72 receptor points are available
- GRAL simulations were run for these 8 experiments on grids 5 m & 2 m
- Statistical analysis was performed & GRAL simulations evaluated on grids 5 m & 2 m
 - Acceptance criteria **|FB| < 0.67; NMSE < 6, i.e.; 0.5 < MG < 2.0; VG < 75**
 - 5 m grid acceptance criteria fulfilled for six cases
 - 2 m grid acceptance criteria fulfilled for all 8 cases, overall improvement
 - Sensitivity study for changing wind indicates strong sensitivity of small changes in wind direction

Acknowledgements

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