ADMS 6 Buildings Validation
Robins and Castro Wind Tunnel Experiments

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1 Introduction

Experiments were conducted in a simulated boundary layer representative of a suburban, or slightly rougher, environment in neutral stability conditions at a model scale of 1/300 of full scale. Concentrations were measured close to a cube-shaped building for emissions above the centre of the building roof. Release heights varying from one to two-and-a-half times the building height were considered for a range of emission velocities. The building was modelled perpendicular to the wind and at 45° to the wind.

Model runs for comparison with the experimental data have been carried out using ADMS 5.2 (version 5.2.0.0) and ADMS 6.0 (version 6.0.0.1). The model runs were performed at full scale.

Section 2 describes the input data used for the model. The results are presented and discussed in Section 3.

2 Input data

2.1 Source parameters

Releases with a range of heights and emission velocities were considered. The range of source heights was such that $1 \leq Hs/Hb \leq 2.5$, where *Hs* is the source height and *Hb* is the building height. The range of emission velocities was $0.5 \leq Ws/Ue \leq 3.1$, where *Ws* is the emission velocity and *Ue* is the 'free-stream' wind speed, equal to 7.4 m/s.

The release was neutrally buoyant, hence the release temperature was set to ambient (15°C). In each case the source was situated directly above the centre of the building.

The source data are listed in **Table 1**.

Location	Height (m)	V (m/s)	T (°C)	D (m)	Q (g/s)
(0,0)	60, 75, 90, 120, 150	3.7, 22.94	15	3	1

Table 1 – Source input parameters. V is the exit velocity, T the exit temperature, D the diameter and Q the emission rate. The location is given relative to the building centre.

2.2 Meteorology

The input meteorology is listed in **Table 2**. In the wind tunnel, a 'free-stream' wind speed of 7.4 m/s was measured. This has been achieved in the model runs by setting the wind speed at the top of the boundary layer (600 m full scale) to 7.4 m/s. A uniform temperature profile with height was defined for ADMS, in order to imitate the wind tunnel conditions more closely.

Wind speed (m/s)	7.4 at 600 m
Wind direction (°)	270
Boundary layer height (m)	600
1/Monin-Obukhov length (m^{-1})	0
Surface roughness (m)	1.3

Table 2 – Meteorological data.

2.3 Buildings

The buildings data are given in **Table 3**. The building was modelled perpendicular to the wind and at 45° to the wind (see **Figure 1**).

Height (m)	Length (m)	Width (m)	Angle (°)
60	60	60	0, 45

Table 3 – Building dimensions.

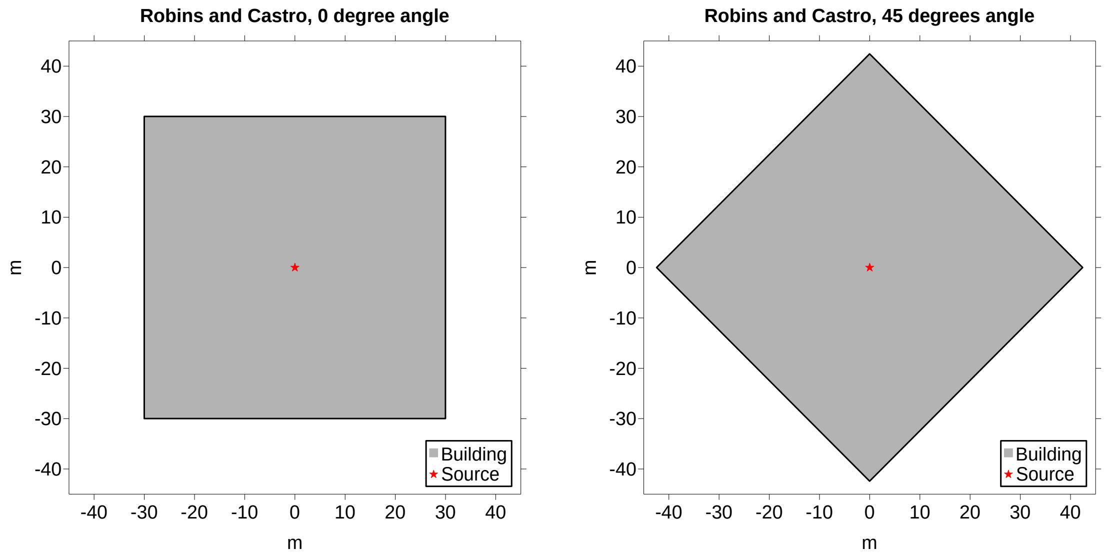

Figure 1 – Building modelled perpendicular to the wind (left) and at 45° to the wind (right).

3 Results

3.1 Output

Concentrations were calculated at a line of points downstream of the source to a distance of 10 building heights from the source. The maximum concentration and the distance downstream at which is occurred were recorded in each case. Non-dimensional concentrations *K* were then calculated as follows:

$$K = \frac{C \ Ue \ l^2}{Q}$$

where *C* is concentration (μg/m^3), *Ue* is the free-stream wind speed (m/s), *l* is the building height (m) and *Q* is the emission rate (μg/s).

The predicted maximum ground level concentrations have been compared with observed values. A statistical analysis of the results is presented in Section 3.2. Section 3.3 shows plots of the variation in maximum concentration with exit velocity and with building orientation.

3.2 Statistics

Statistical analysis of the data has been carried out using the Model Evaluation Toolkit v5.2 [1]. The Model Evaluation Toolkit produces statistics of the data that are useful in assessing model performance. Statistics calculated include mean, standard deviation (Sigma), bias, normalised mean square error (NMSE), fraction of results where the modelled and observed concentrations agree to within a factor of two (Fa2) and fractional bias (Fb).

To avoid giving extra weight to the higher concentrations, observed and modelled concentrations were normalised by the observed value before the statistical analysis was performed. **Table 4** shows the results, where ADMS can be seen to perform well, with high correlation and low bias values.

Data	Mean	Sigma	Bias	NMSE	Fa2	Fb	Cor[1]
Observed	1.00	0.00	0.00	0.00	1.000	0.000	1.000
ADMS 5.2	1.01	0.32	0.01	0.10	0.900	0.008	0.845
ADMS 6.0	1.01	0.31	0.01	0.10	0.900	0.010	0.857

Table 4 − Statistics of the normalised data.

3.3 Graphical results and discussion

Results are presented as graphs showing the variation in magnitude and position of the observed and predicted maximum ground level concentration with source height. **Figures 2** to **5** show results with the building perpendicular to the wind direction ($\theta = 0°$). **Figures 6** to **9** show the results for the building at 45° to the wind direction ($\theta = 45°$). Results are presented for the minimum and maximum momentum emissions, $Ws/Ue = 0.5$ and 3.1.

With the building perpendicular to the wind direction, the model shows over-prediction at lower heights. When the building is at 45° to the wind direction, the model tends to under-predict.

The results of ADMS 5.2 and ADMS 6.0 are very similar. ADMS 6.0 performs slightly better, with small improvements on the standard deviation (Sigma) and correlation (Cor). In ADMS 6.0, the ground-level plume emanating from recirculation region is modelled as a line source rather than a point source, with an initial concentration that is better matched to the uniform concentration of the entrained part of the plume within the well-mixed recirculation region; this is affecting results slightly. The plots below show that the improvements are most pronounced in the cases of minimum momentum emission (Ws/Ue = 0.5) and low source height. A lower and less buoyant release will have a larger entrained fraction within the recirculation region and thus the ground-level plume change will have a larger effect. The new model development relating to how plumes that directly impact a building are modelled does not affect this study as the source is above the building.

[1] Correlation, calculated by the toolkit using un-normalised data in this case, is defined as $\overline{\left(C_o - \overline{C_o}\right)\left(C_p - \overline{C_p}\right)} / \sigma_o \sigma_p$, where C_o and C_p are respectively observed and predicted concentration, and σ_o and σ_p are the standard deviations of the observed and predicted concentrations.

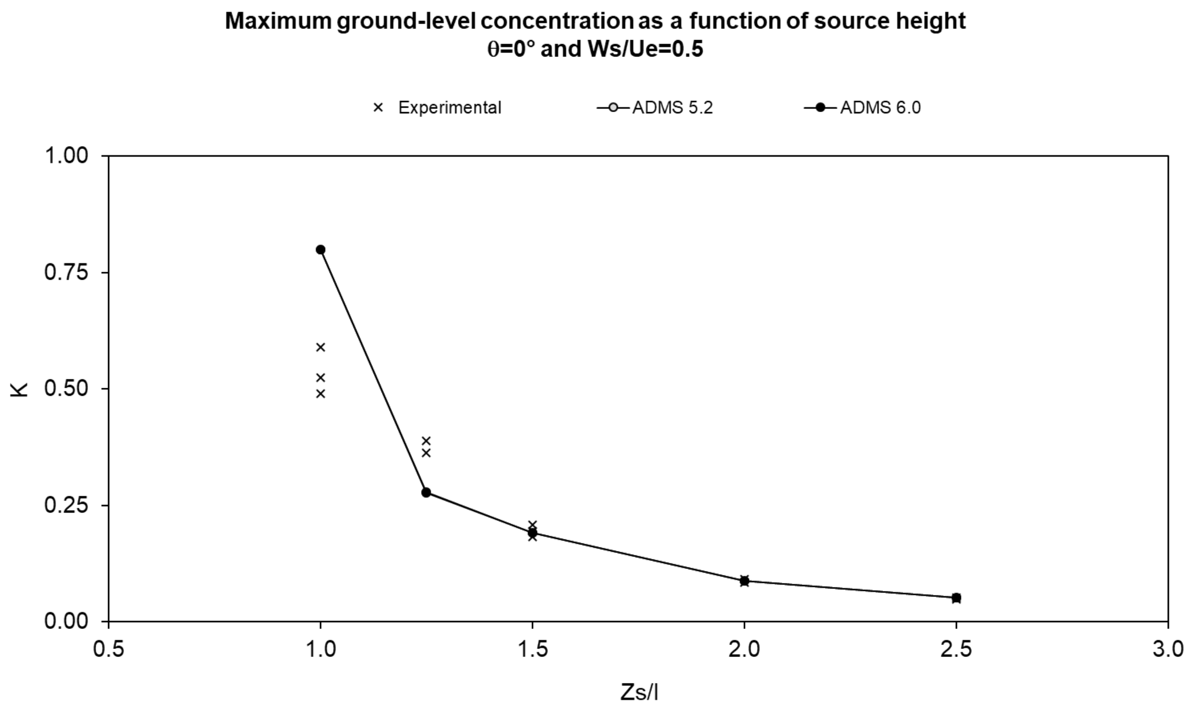

Figure 2 − Maximum ground-level concentration as a function of source height ($\theta = 0°$ and *Ws*/*Ue* = 0.5).

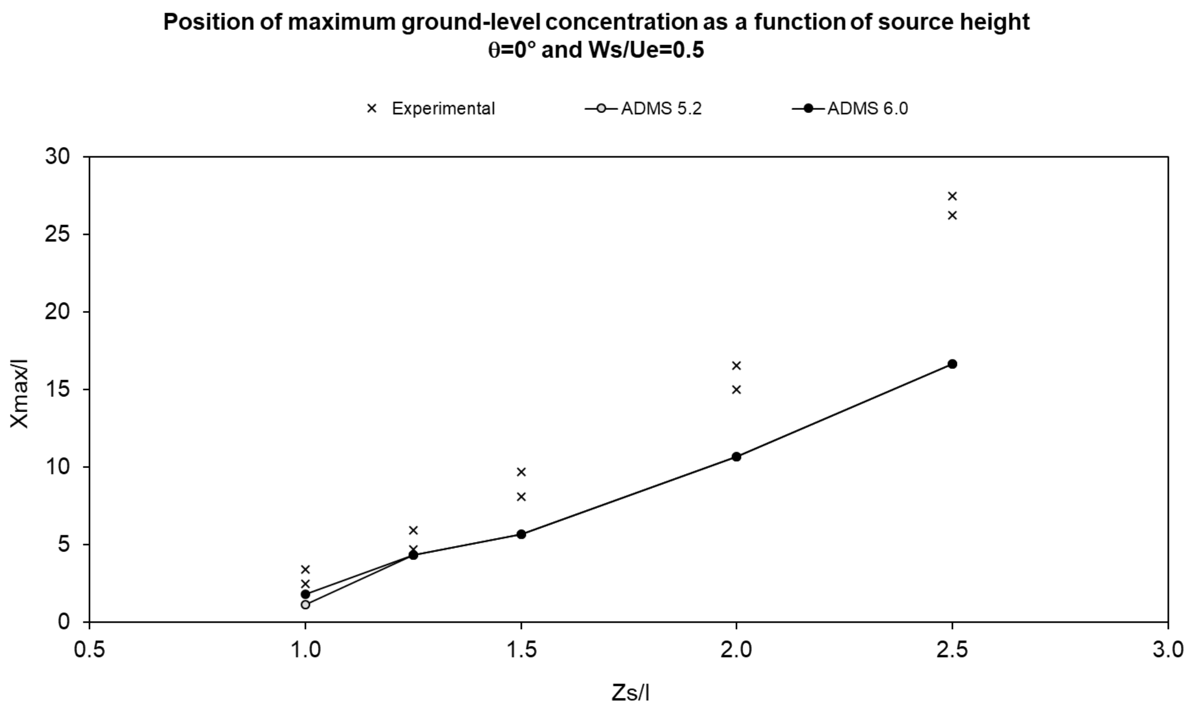

Figure 3 − Position of maximum ground-level concentration as a function of source height ($\theta = 0°$ and *Ws*/*Ue* = 0.5).

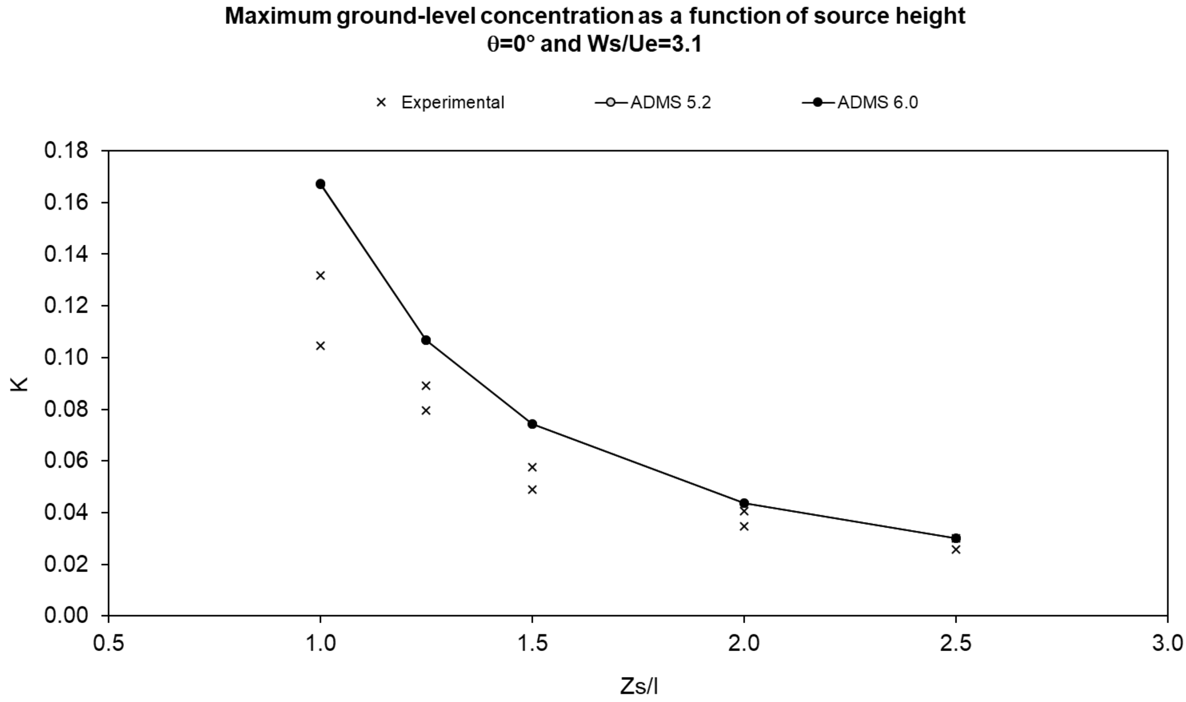

Figure 4 − Maximum ground-level concentration as a function of source height ($\theta = 0°$ and *Ws/Ue* = 3.1).

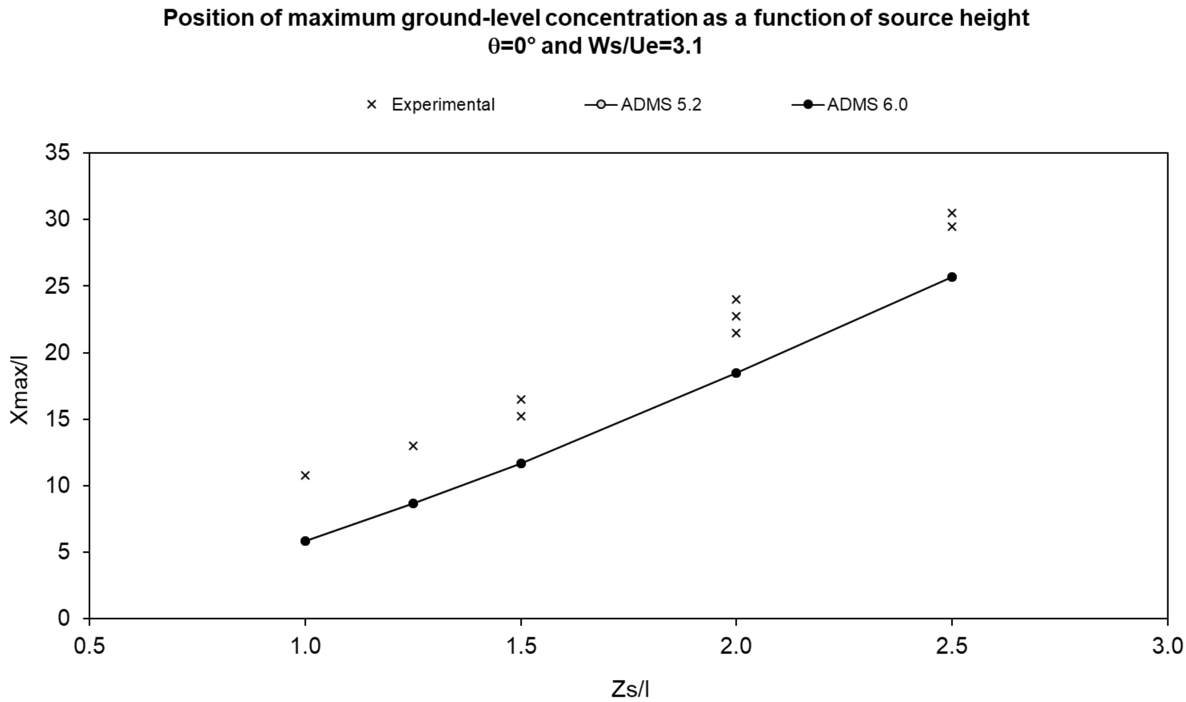

Figure 5 − Position of maximum ground-level concentration as a function of source height ($\theta = 0°$ and *Ws/Ue* = 3.1).

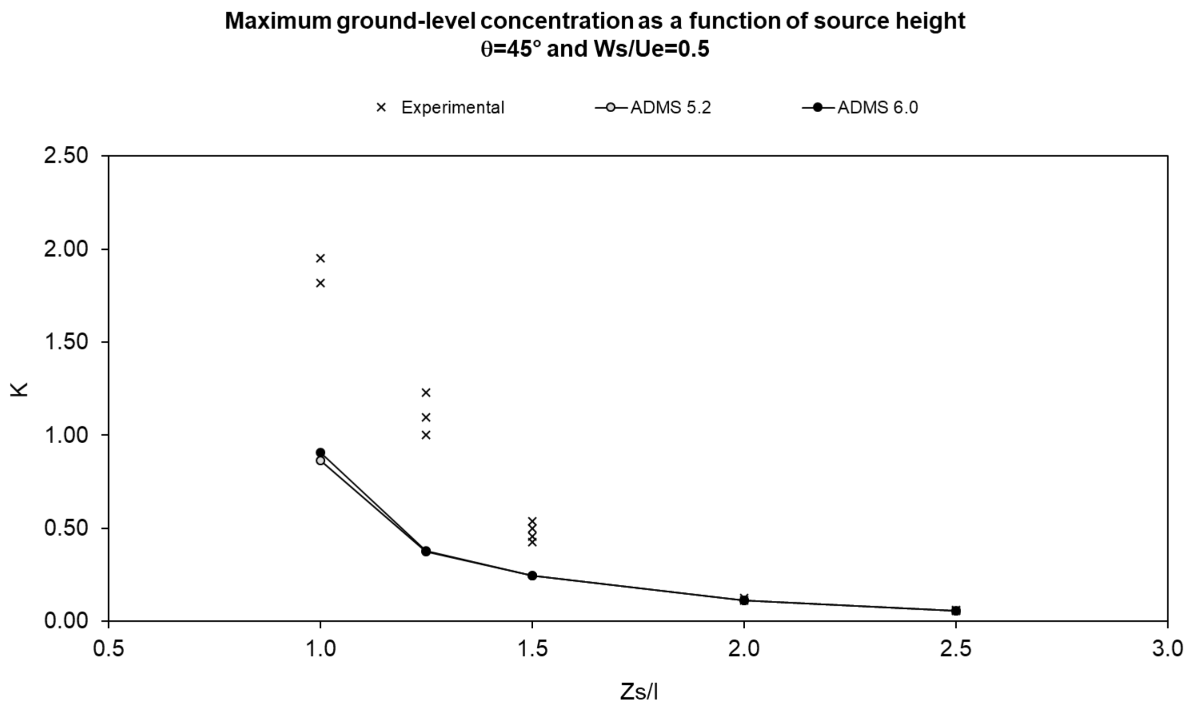

Figure 6 − Maximum ground-level concentration as a function of source height ($\theta = 45°$ and *Ws*/*Ue* = 0.5).

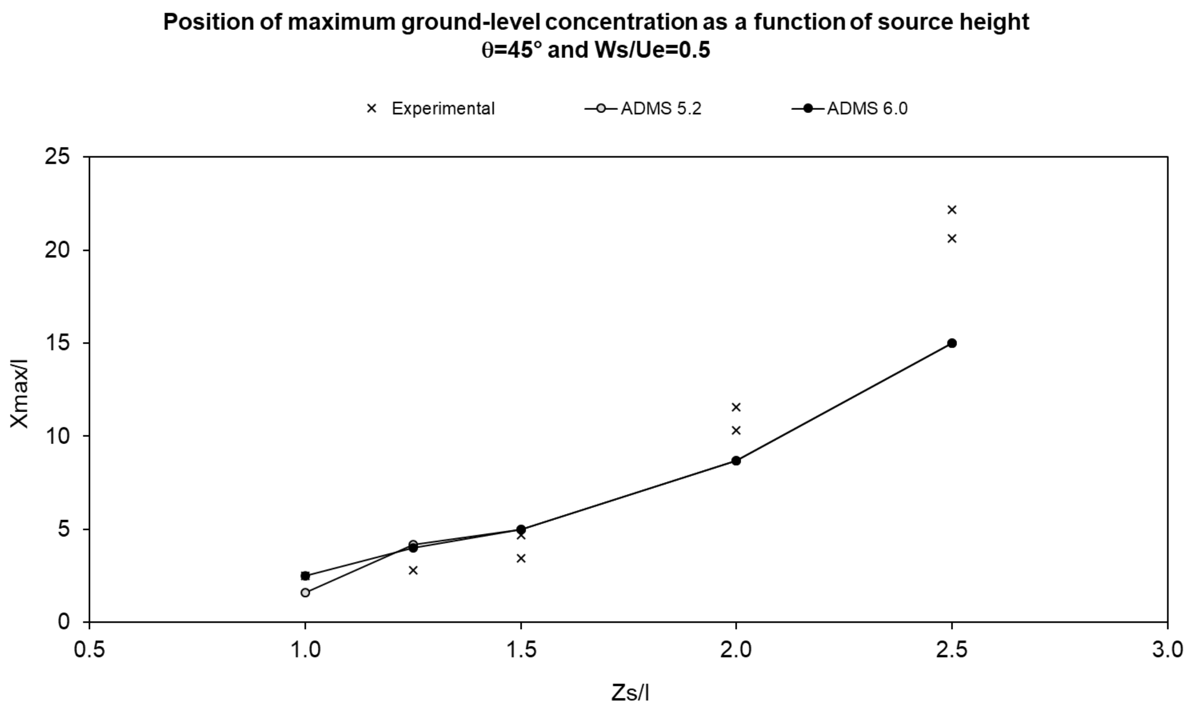

Figure 7 − Position of maximum ground-level concentration as a function of source height ($\theta = 45°$ and *Ws*/*Ue* = 0.5).

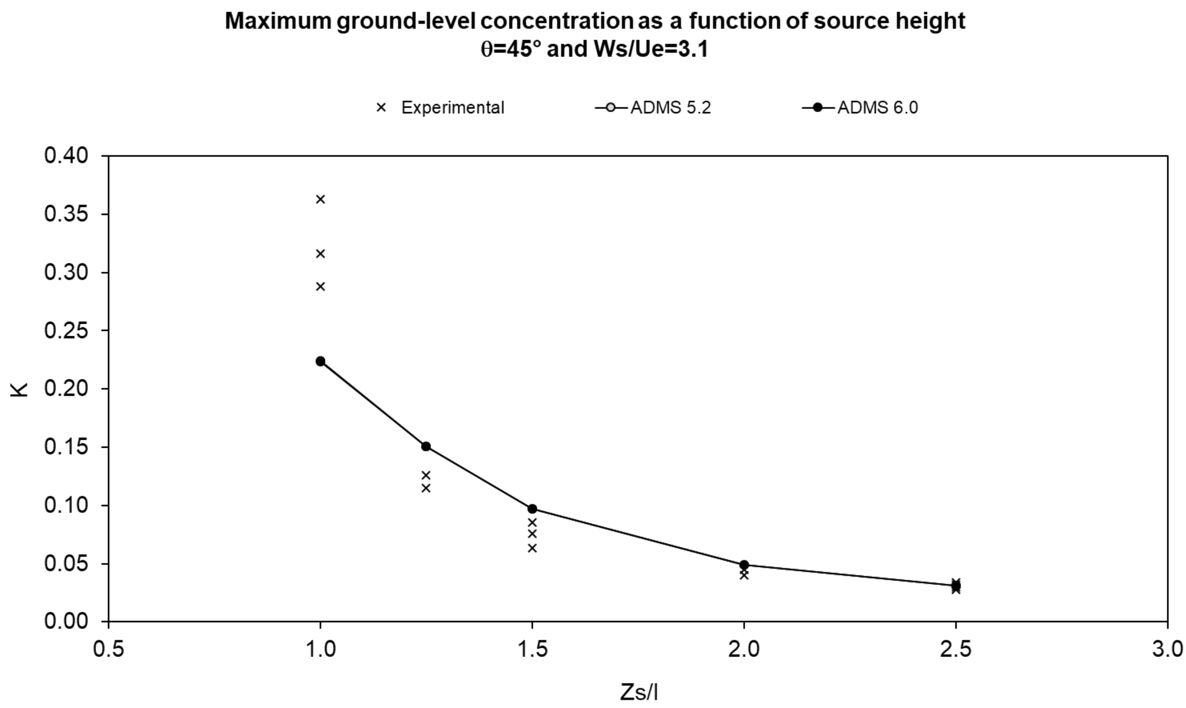

Figure 8 − Maximum ground-level concentration as a function of source height ($\theta = 45°$ and *Ws*/*Ue* = 3.1).

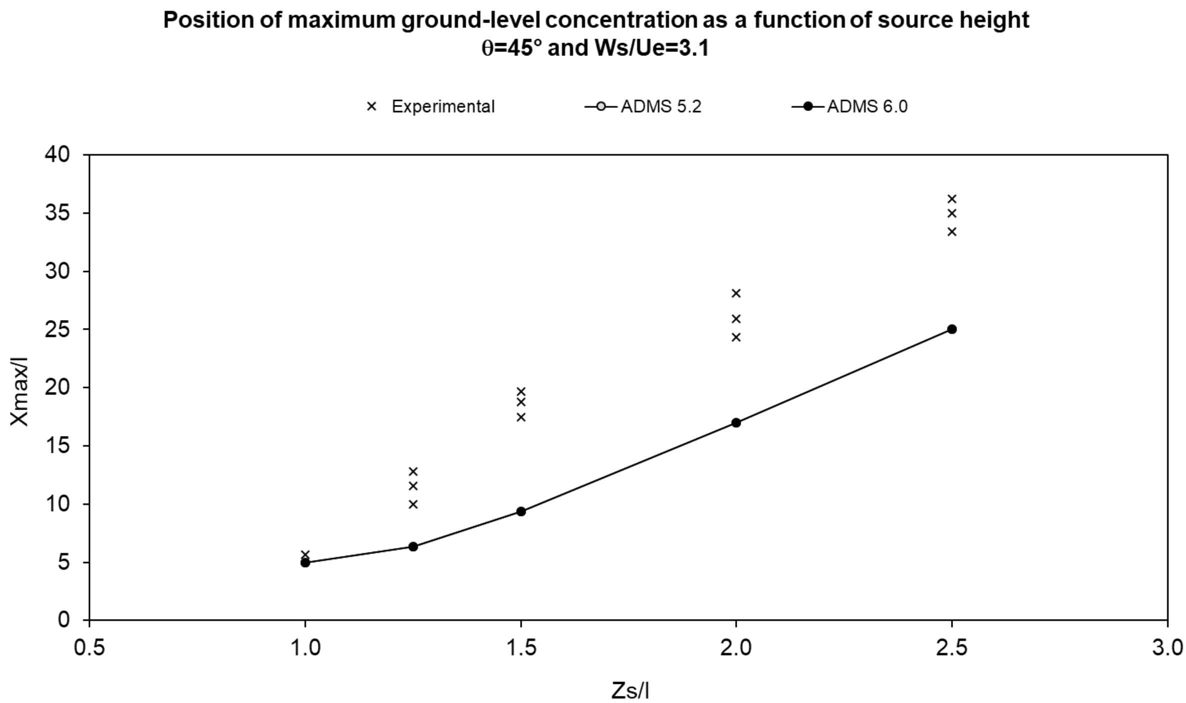

Figure 9 − Position of maximum ground-level concentration as a function of source height ($\theta = 45°$ and *Ws*/*Ue* = 3.1).

4 References

[1] Stidworthy A, Carruthers D, Stocker J, Balis D, Katragkou E, and Kukkonen J, 2013: *MyAir Toolkit for Model Evaluation*. 15th International Conference on Harmonisation, Madrid, Spain, May 2013.

[2] Thunis P., E. Georgieva, S. Galmarini, 2010: *A procedure for air quality models benchmarking*. https://fairmode.jrc.ec.europa.eu/document/fairmode/WG1/WG2_SG4_benchmarking_V2.pdf

[3] David Carslaw and Karl Ropkins (2011). *openair: Open-source tools for the analysis of air pollution data*. R package version 0.4-7. http://www.openair-project.org/

[4] Chang, J. and Hanna, S, 2004: *Air quality model performance evaluation*. Meteorol. Atmos. Phys. **87**, 167-196.