Evaluation of Changes in DRIFT Version 3.7.19

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A Report prepared for HSE

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Executive Summary

DRIFT is a gas dispersion model developed by ESR Technology (ESR). As well as being used by ESR in its consultancy work, DRIFT is also used by the Health and Safety Executive (HSE) as a tool to assist it in performing its regulatory duties and in undertaking its research activities. DRIFT software has also been licenced to third parties.

Rather than re-issue all the existing DRIFT 3 published reports every time a new version of DRIFT is released, it is proportionate to document the testing of new or revised aspects of the model and to undertake comparisons of predictions with those from earlier version(s) for a range of selected cases. These checks are mainly for the purpose of verification testing – to ensure that changes to DRIFT software are behaving as intended and have not had an adverse effect on the previous published validation and verification results.

The purpose of this document is to summarise the results of verification testing undertaken by ESR Technology for version 3.7.19 of DRIFT. DRIFT 3.7.19 includes improvements in the modelling of momentum jets, the transition from momentum jet to passive spreading and buoyant lift-off.

DRIFT test cases cover the following aspects are reported:

- Momentum Jets
- URAHFREP Comparisons
- Other Field Trials.

Apart from differences resulting from the specific modelling improvements, DRIFT 3.7.19 is found to perform similarly to DRIFT 3.6.x.

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1.0 Introduction

DRIFT is a gas dispersion model developed by ESR Technology (ESR). As well as being used by ESR in its consultancy work, DRIFT is also used by the Health and Safety Executive (HSE) as a tool to assist it in performing its regulatory duties and in undertaking its research activities. DRIFT software has also been licenced to third parties.

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2.0 Test Cases

2.1 Momentum Jets

One of the main changes in moving from DRIFT 3.6.x to 3.7.x is testing and improvement of the momentum jet modelling in DRIFT. DRIFT 3.6.x already included a momentum jet model, but testing of the jet model was limited, and considered to be less extensive than the testing previously undertaken for the standalone jet model EJECT. Testing relating different aspects of the jet model are summarised below.

2.1.1 Comparison with JINX

JINX is an implementation of the gas jet model of Cleaver and Edwards [1]. Predictions of DRIFT 3.7.19 have been compared with those of JINX Version 2.1.2 (used under licence by ESR Technology) for the following cases:

- 100 bara methane from 50 mm hole
- 10 bara methane from 50 mm hole

The releases are horizontal in a coflowing wind of 5 m/s with neutral stability and comparisons are made using short time averaging in both models. The results from JINX and DRIFT to 2% vol/vol centreline concentration are compared in Table 2-1 and good agreement is found.

Table 2-1 Comparison of methane jet predictions between JINX and DRIFT.

	JINX	DRIFT
100 bara distance (m) to 2% vol/vol	123	120
10 bara distance (m) to 2% vol/vol	41	43

2.1.2 Jet in a Coflow

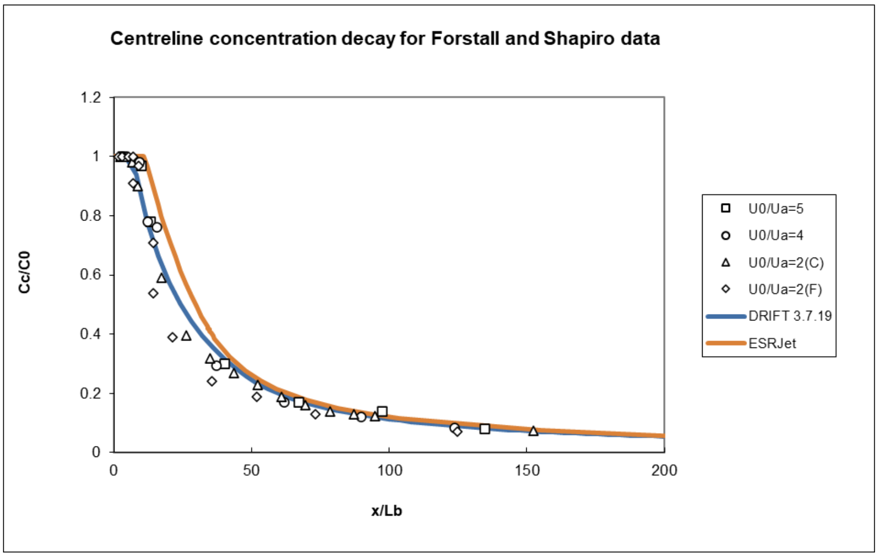

Figure 2-1 Decay of centreline concentration compared with Forstall and Shapiro data [2].

Forstall and Shapirio [2] present data for the decay of centreline concentration in jets of air in a coflowing stream of air. Figure 2-1 shows a comparison of DRIFT 3.7.19 centreline predictions for a jet of air in still air with these data. In Figure 2-1, the centreline concentration, C_c is normalised by the value at the source, C_0 and the distance along the centreline, x is divided by the characteristic length, L_b which is defined in [3] – for a jet in still air it is proportional to the nozzle diameter and for a jet in a co-flow it is based on the conserved excess momentum flux.

DRIFT 3.7.19 includes an empirical delay for the centreline concentration decay to account for the finite length of the so-called zone of flow establishment over which the lateral profiles evolve from those at the exit (approximated as uniform) to those in the established jet (approximated as Gaussian). The empirical delay is set by tuning to Forstall and Shapiro data and so the comparison shows only that this empirical delay is behaving as intended and additionally confirms that the subsequent jet decay is well represented by the jet entrainment coefficient used in DRIFT. Also shown in Figure 2-1 are the predictions from the jet model ESRJet which is an independently coded implementation of the gas jet model of Cleaver and Edwards [1].

Good agreement is also found for comparison with experimental data for the centreline concentration decay in a methane jet issuing into still air. Unfortunately, the comparison cannot be shown here as the experimental data is confidential.

2.1.3 Jet in a Crossflow

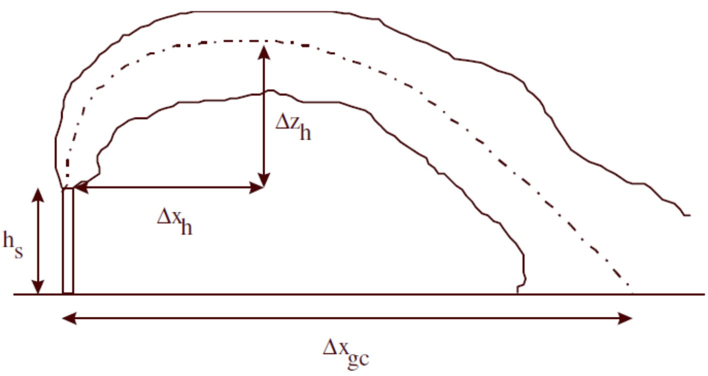

Figure 2-2 Plume rise height and touchdown in the experiments of [4].

Schatzmann et al. [4] conducted wind-tunnel studies on dense jets and plumes from a model stack in both laminar and turbulent crossflows. They presented results for the maximum rise height, concentration and distance at which this occurs, together with the distance to maximum ground-level concentration. The distance definitions are shown schematically in Figure 2-2. Schatzmann et al. varied the momentum and buoyancy flux of the releases as well as the ratio of the jet and crossflow velocities. DRIFT 3.7.19 runs have been undertaken for the turbulent cases only, since they are most relevant to atmospheric dispersion, and the results compared with experimental data are shown in Table 2-2. In this table, Fr_s is the densimetric Froude number of the jet source, D_s is the source diameter, ρ_s/ρ_a is the source density relative to air, U_s/U_a is the source velocity relative to the cross-flow velocity at the source height. The table also includes EJECT model predictions taken from Tickle [3]. The determination of the maximum rise hight and the location of the maximum ground-level concentration are subject to increased uncertainty for very shallow plume trajectories where there is a very slow change in the plume height with distance and in some cases, values are not available from the wind-tunnel measurements. In general, DRIFT compares favourably to these experimental data, especially as there is no tuning of the model parameters to this dataset.

Table 2-2 Comparisons of DRIFT predictions with turbulent cross-flow experiments [4].

run	Fr_s	ρ_s/ρ_a	U_s/U_a	h_s/D_s	$\Delta z_h/D_s$			$\Delta x_h/D_s$			c_h/c_s (%)			$\Delta x_{gc}/D_s$			c_{gc}/c_s (%)		
					EJECT	DRIFT	expt	EJECT	DRIFT	expt	EJECT	DRIFT	expt	EJECT	DRIFT	expt	EJECT	DRIFT	expt
1T	30.6	1.56	20.8	12	40	35	42	43	49	39	3.6	4.6	2.6	211	189	252	0.58	1.09	0.91
2T	30.6	1.56	10.4	12	32	26	29	97	94	94	2	2.7	1.6	613	378	456	0.18	0.32	0.30
3T	30.6	1.56	5.2	12	24	19	19	190	194	158	0.93	1.13	0.57	3340	535	520	0.008	0.10	0.12
4T	766	1.66	33	31.45	246	164	151	26100	25535	3150	0.0012	0.00085	0.016	-	3145		-	0.009	
5T	766	1.66	137	31.45	641	452	401	6651	6270	2520	0.03	0.021	0.088	-	9308	-	-	0.005	-
6T	1313	4.88	33	31.45	425	282	>232	80400	84277	>4095	4.30E-04	9.80E-05	<0.01	-	5031	-	-	0.004	-
7T	1313	4.88	137	31.45	1203	818	>650	21093	19245	>4095	0.01	0.0033	<0.03	-	16981	-	-	0.00155	-
8T	766	4.88	33	31.45	395	268	>228	37740	25786	>4095	0.002	0.0008	<0.01	-	5031	-	-	0.0037	-
9T	766	4.88	137	31.45	949	679	>606	7101	6516	>4095	0.06	0.0143	<0.029	-	12579	-	-	0.0026	-
10T	6.23	2.3	2.54	6.69	5.9	6.1	5.4	12	13	15.75	14	15	6.88	81	75	90.55	1.6	1.9	1.49
11T	6.23	2.3	1.27	6.69	4.6	4.2	3.14	28.3	26	15.75	7.1	8.1	4.65	340	136	150	0.18	0.45	0.33
12T	6.23	2.3	7.51	6.69	7.1	8.8	10.45	2.4	3.2	3.94	32	35	17.83	12.1	14	24.8	7.5	8.0	3.93
13T	9.06	4.8	2.54	6.69	10.8	9.5	9.13	30	27	31.5	9.6	2.8	2.44	178	117	177.2	1.1	0.35	0.61
14T	6.23	4.8	2.54	6.69	7.4	7.5	7.83	11	11	15.75	19.4	5.6	5.57	65	54	66.93	3	0.89	1.66

2.1.4 Gas Jet Pseudo-Source

DRIFT includes an implementation of the pseudo-source model of Birch et al (1987) [5] when modelling dispersion from sonic gas jets. In this model, conditions are calculated corresponding to the jet expanding to ambient pressure by conserving momentum across a simple control volume. Following [5] the temperature is assumed to revert to the upstream stagnation temperature. DRIFT 3.7.19 predictions for the expanded diameter are compared in Table 2-3 with published values for high pressure hydrogen (98.1 bar) from a 1mm nozzle as given by Papanikolaou and Baraldi [6]. DRIFT 3.7.19 pseudo-source diameter agrees with the quoted value from the Birch et al (1987) value.

Table 2-3 Comparison of pseudo-source diameter for 98.1 bar hydrogen from 1mm diameter nozzle.

	Pseudo-source diameter (m)
Birch et al 1987 entry in Table 1 of [6]	5.78×10^{-3}
DRIFT 3.7.19	5.77×10^{-3}

2.1.5 Wall Jets

Rajartnam [7] presents data for the centreline velocity decay of ambient density wall jets resulting from different shaped nozzles. The results are presented as the centreline velocity U_c divided by the exit velocity U_0 plotted as a function of centreline distance, x divided by the square root of the nozzle exit area, A. Figure 2-3 shows a comparison of DRIFT 3.7.19 predictions with these data. Unlike concentration decay, DRIFT does not include an empirical offset for velocity decay and hence centreline velocity predictions decay immediately from the source, whereas the data shows a delay due to the finite length of the zone of flow establishment.

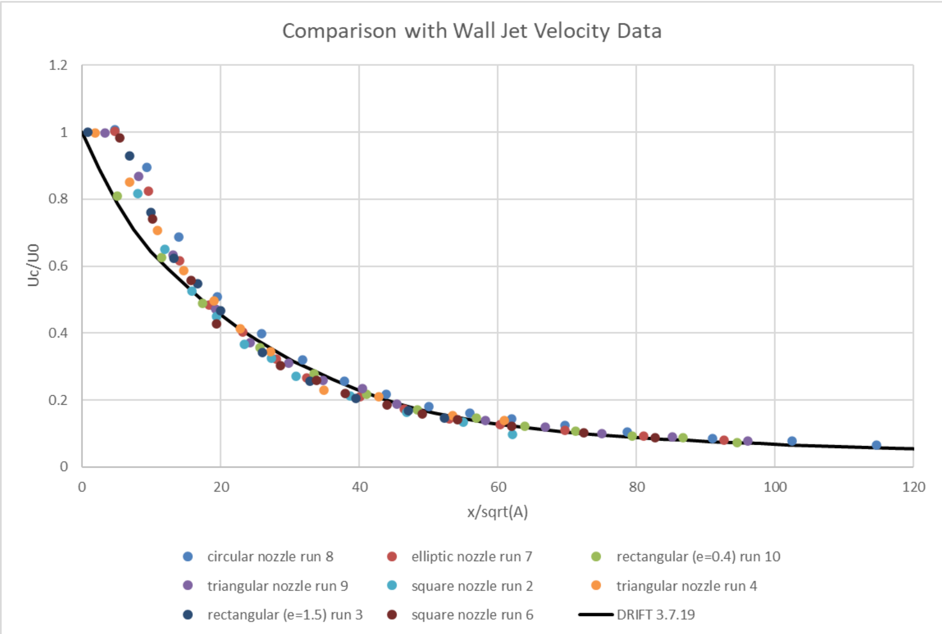

Figure 2-3 Decay of wall jet centreline velocity compared with data from [7].

Davis and Winarto [8] present measurements of the decay of velocity in jets resulting from horizontal jets of air released above a solid surface – these measurements cover the transition from elevated jet to a ground-based wall jet. The two cases available are h/D=4 and h/D=0.5 where h is the centreline release height and D is the nozzle diameter. DRIFT prediction for the centreline velocity

U_c and horizontal L_y and vertical L_z length scales (both to ½ centreline velocity) are given below in Figure 2-4 and Figure 2-5.

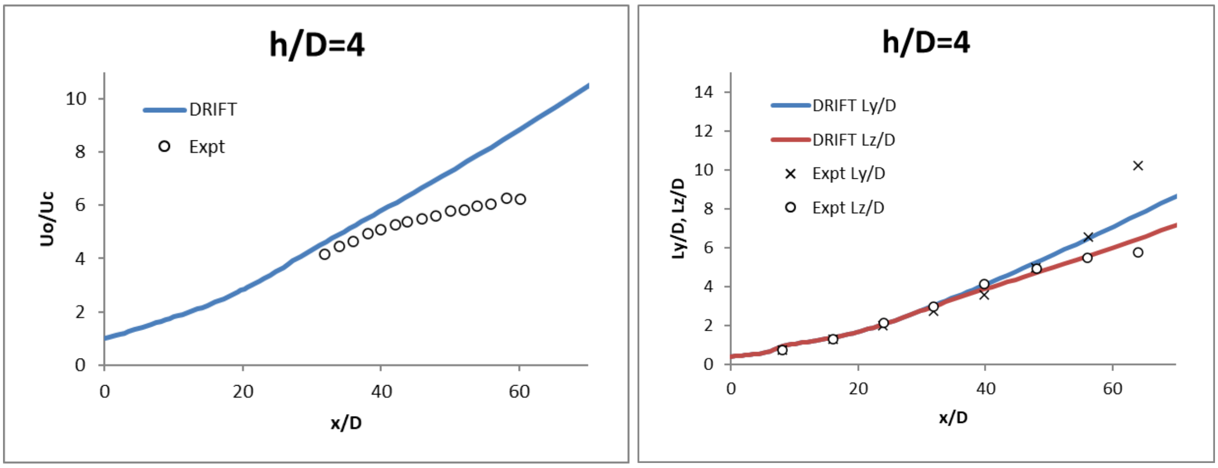

Figure 2-4 Velocity predictions for x/D=4 compared with Davis and Winarto data [8].

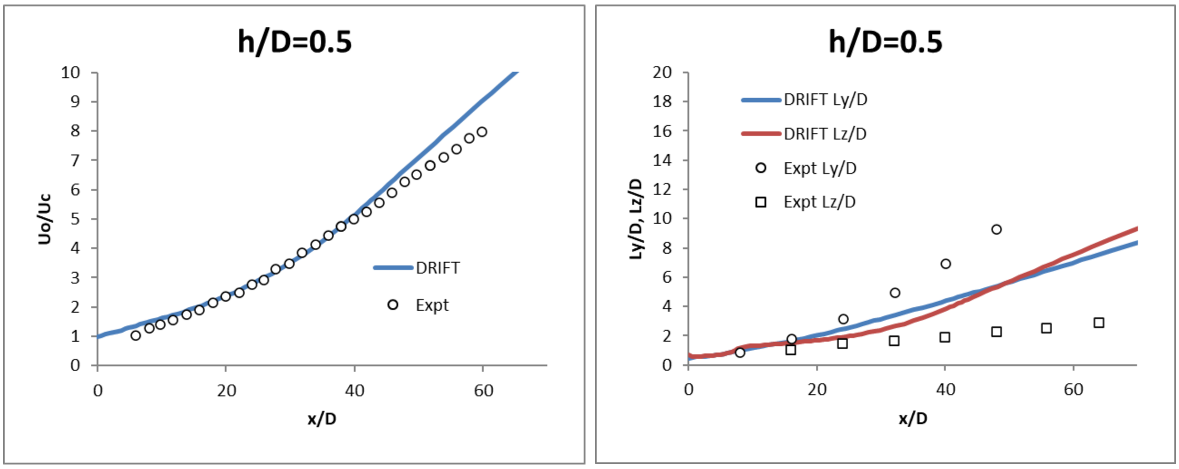

Figure 2-5 Velocity predictions for x/D=0.5 compared with Davis and Winarto data [8].

The predicted centreline decay in DRIFT 3.7.19 for these experiments is similar to that found using EJECT in [9]. The growth of the length scales is also similar to EJECT for h/D=4, although DRIFT shows a smooth transition from elevated to ground wall jet, whereas EJECT shows a discontinuous change. For h/D=0.5 it appears that DRIFT is too slow in transitioning to full wall jet spreading – this is possibly related to its interpolation between elevated and grounded models being tuned to URAHFERP buoyant lift off data (see Section 2.2.1) rather than specifically to the horizontal momentum wall jet.

2.1.6 Transition from Wall Jet to Passive Spreading

DRIFT versions 3.6.x to 3.7.14 transition from wall jet spreading to passive lateral spreading based upon the maximum spreading rate from these two mechanisms. In the circumstance of a very large release rate in low wind conditions it has been found that DRIFT's continuous model can hold onto the wall jet spreading rate far downstream, even when the jet has slowed to very close to the wind speed and the dilution is such that passive behaviour would be expected. For the finite duration model this behaviour tends to be masked by the effects of mixing at the front and back ends of the cloud. DRIFT 3.7.15 and later includes a fix to ensure that passive spreading takes over when the cloud speed and dilution imply passive behaviour. Figure 2-6 shows the effect on centreline concentration for an example case of steady continuous toxic gas jet in F2 weather.

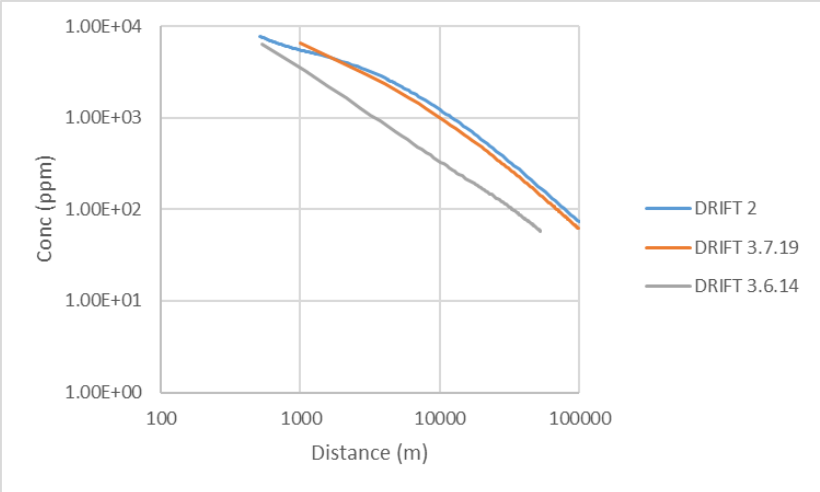

Figure 2-6 Effect of fix to transition from jet to passive spreading for steady continuous releases.

2.1.7 Two-Phase Jet

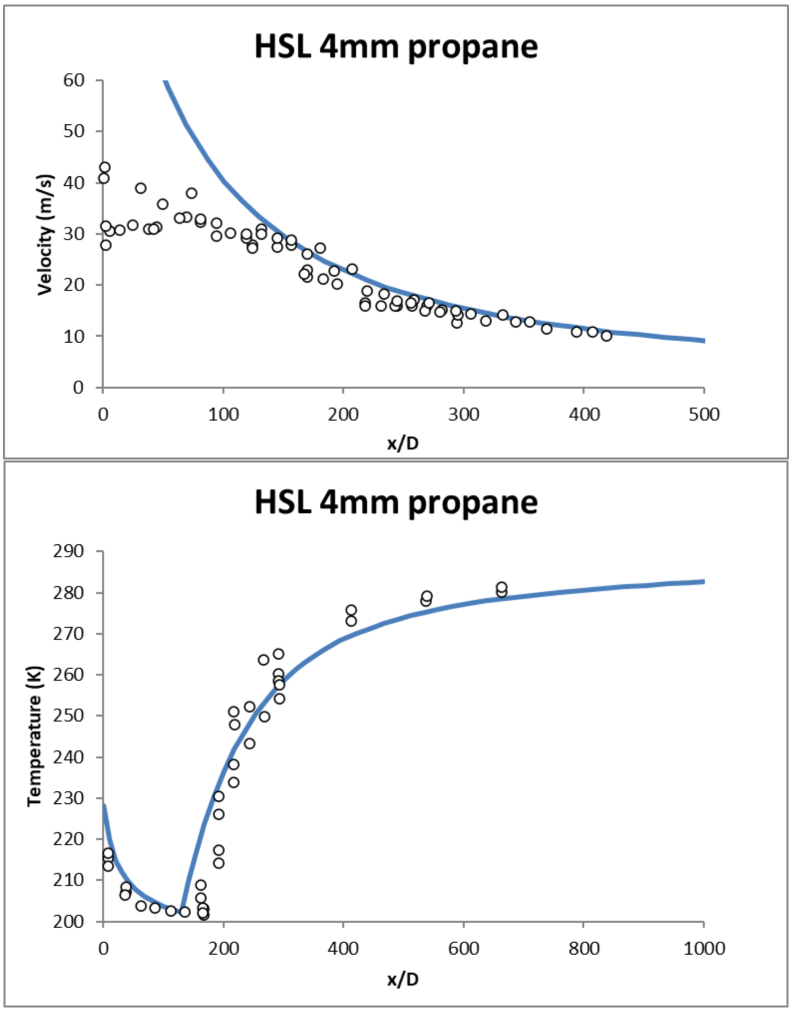

Figure 2-7 DRIFT 3.7.19 comparisons with small-scale two-phase propane jet data.

Coldrick [10] presents comparisons of jet model predictions with temperature and velocity measurements of small-scale two-phase propane jets. One of the models Coldrick compared against was DRIFT 3.7.2. Figure 2-7 compares DRIFT 3.7.19 with these data (release condition and data taken from Tickle et al. (1997) [3]) which confirms that DRIFT 3.7.19 still provides a good representation of these experiments.

2.2 URAHFREP Comparisons

The European Union (EU) URAHFREP research project included laboratory, wind-tunnel and field trials to investigate the thermodynamics, buoyant lift-off from ground-level sources and atmospheric dispersion of hydrogen fluoride (HF) clouds.

2.2.1 Buoyant Lift-Off

The interpolation parameter controlling the transition from ground-based to elevated cloud in DRIFT has been further tuned in DRIFT 3.7.x to optimise plume lift-off predictions compared with the wind-tunnel results of Hall and Walker [11]. Wind-tunnel data is also available for the lift-off behaviour of buoyant puffs as presented in Hall, Walker and Tily [12]. Comparisons with earlier versions of DRIFT are presented elsewhere in Tickle (2012) [13] for Version 3.6.1 and in Tickle (2014) [14] for version 3.6.15. These comparisons have been repeated for the purposes of DRIFT 3.7.19 verification. Figure 2-8 and Figure 2-9 show a comparison between DRIFT results from 3.6.15 and 3.7.19 for plume and puff releases at the two vertical sampling array positions at horizontal distances x/L=15 and x/L=29.8. In these plots K and Kmax refer to the ground level centreline and maximum concentration for plume cases, non-dimensionalised as described in [11], F/u^3L is the non-dimensional buoyancy flux also described in [11]. C and Cmax refer to the puff concentrations non-dimensionalised as described in [12]; on the x-axis the first letter indicates the puff release duration and the second the buoyancy flux (see [13]). In general, the retuning in DRIFT 3.7.19 has improved the agreement with the plume data, but there is little change for the puff predictions. Results using 3.7.19 for all cases are given in Appendix 1.

3.6.15 3.7.19

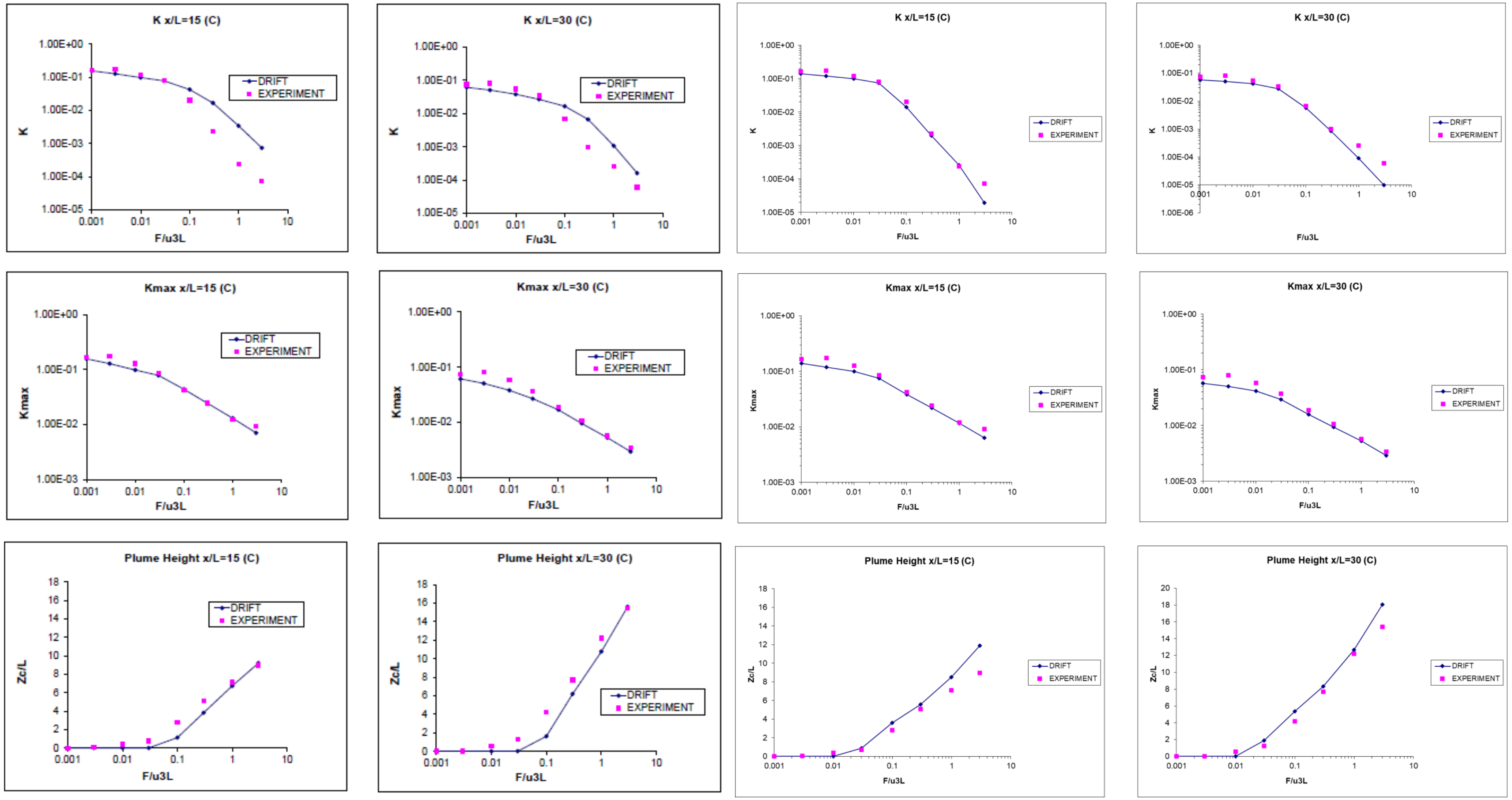

Figure 2-8 Comparison of buoyant lift-off from DRIFT 3.6.15 (left) and DRIFT 3.7.19 (right) for URAHFREP wind-tunnel plume source C.

3.6.15 3.7.19

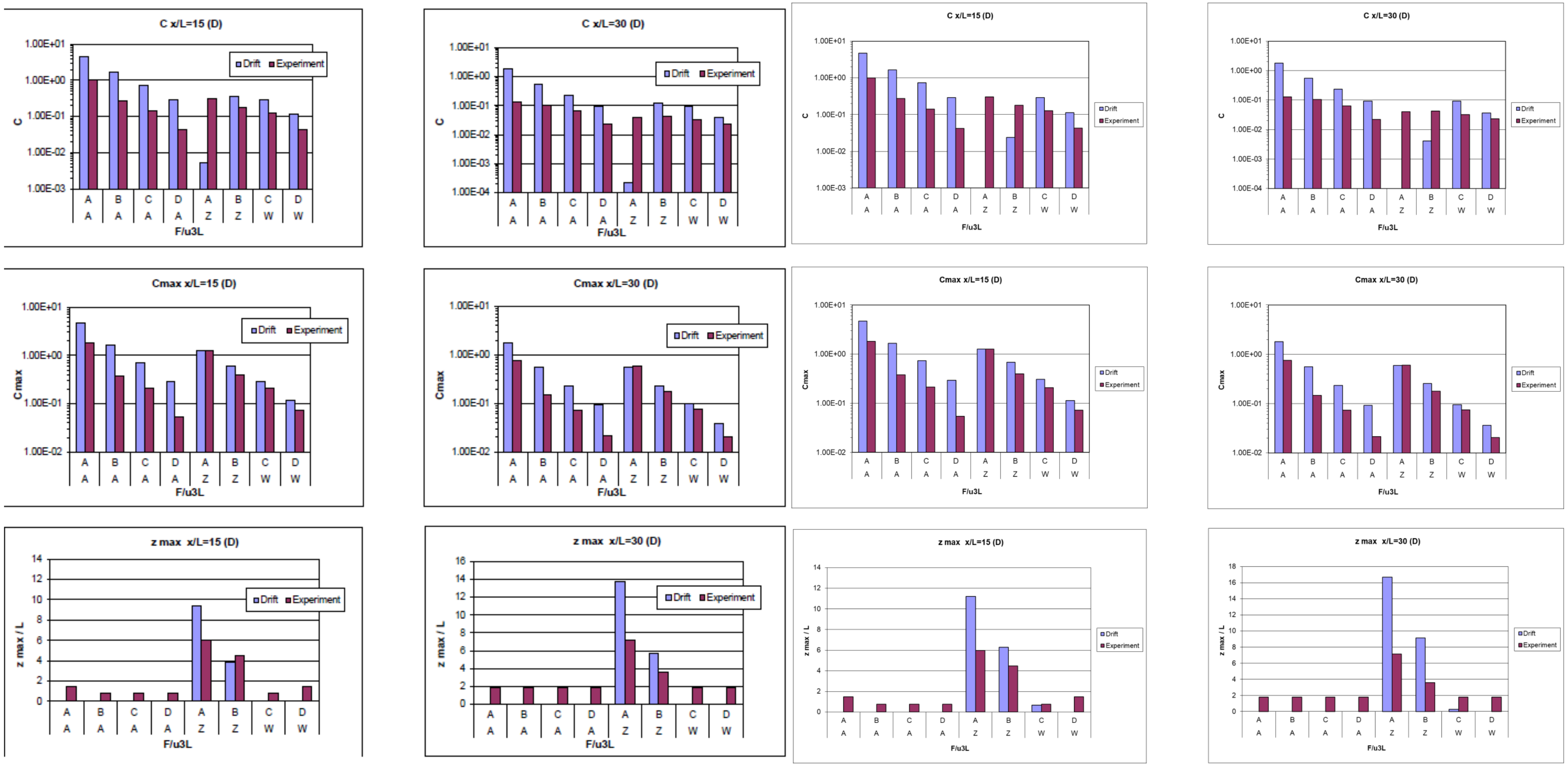

Figure 2-9 Comparison of buoyant lift-off from DRIFT 3.6.15 (left) and DRIFT 3.7.19 (right) using instantaneous release option for URAHFREP wind-tunnel puff source D.

2.2.2 HF Thermodynamics

DRIFT includes a model for the thermodynamics of mixing hydrogen fluoride with moist air. The HF thermodynamics model is unchanged between DRIFT 3.6.x and DRIFT 3.7.19. This is confirmed in Figure 2-10 which shows predictions of the temperature change on mixing HF with moist air for different relative humidities.

2.2.3 HF Field Trials

Despite there being no change in the HF thermodynamics, changes to the jet model and interpolation between elevated and grounded models between DRIFT versions 3.6.x and 3.7.19 merit checking that the agreement seen for 3.6.15 remains valid for 3.7.19 comparisons with URAFREP Campaign 2 field trial data. Figure 2-11 compares the predictions of both versions with the field trial data. This figure shows concentration predictions for two averaging times:

- Averaging over the duration of the discharge (appropriate for CEA filters)
- Averaging over 1s (appropriate for other measurements)

Further details of the field trials are reported in [13] and references within.

Figure 2-11 shows that DRIFT 3.7.19 performs comparably to DRIFT 3.6.15 for these trials.

3.6.15

3.7.19

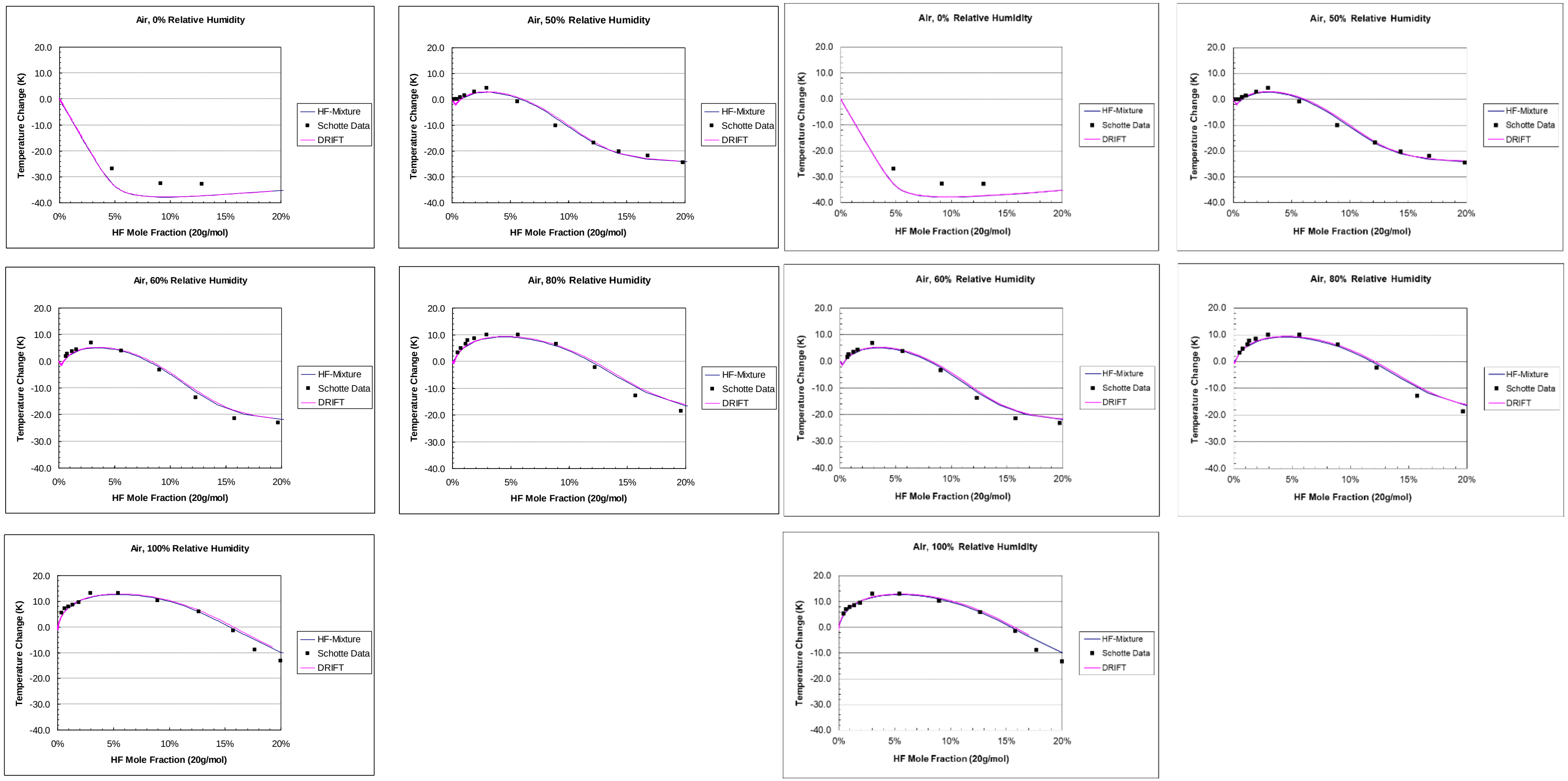

Figure 2-10 Temperature change on mixing HF with moist air at 299K. Comparisons using DRIFT 3.61.5 on the left and DRIFT 3.7.19 on the right.

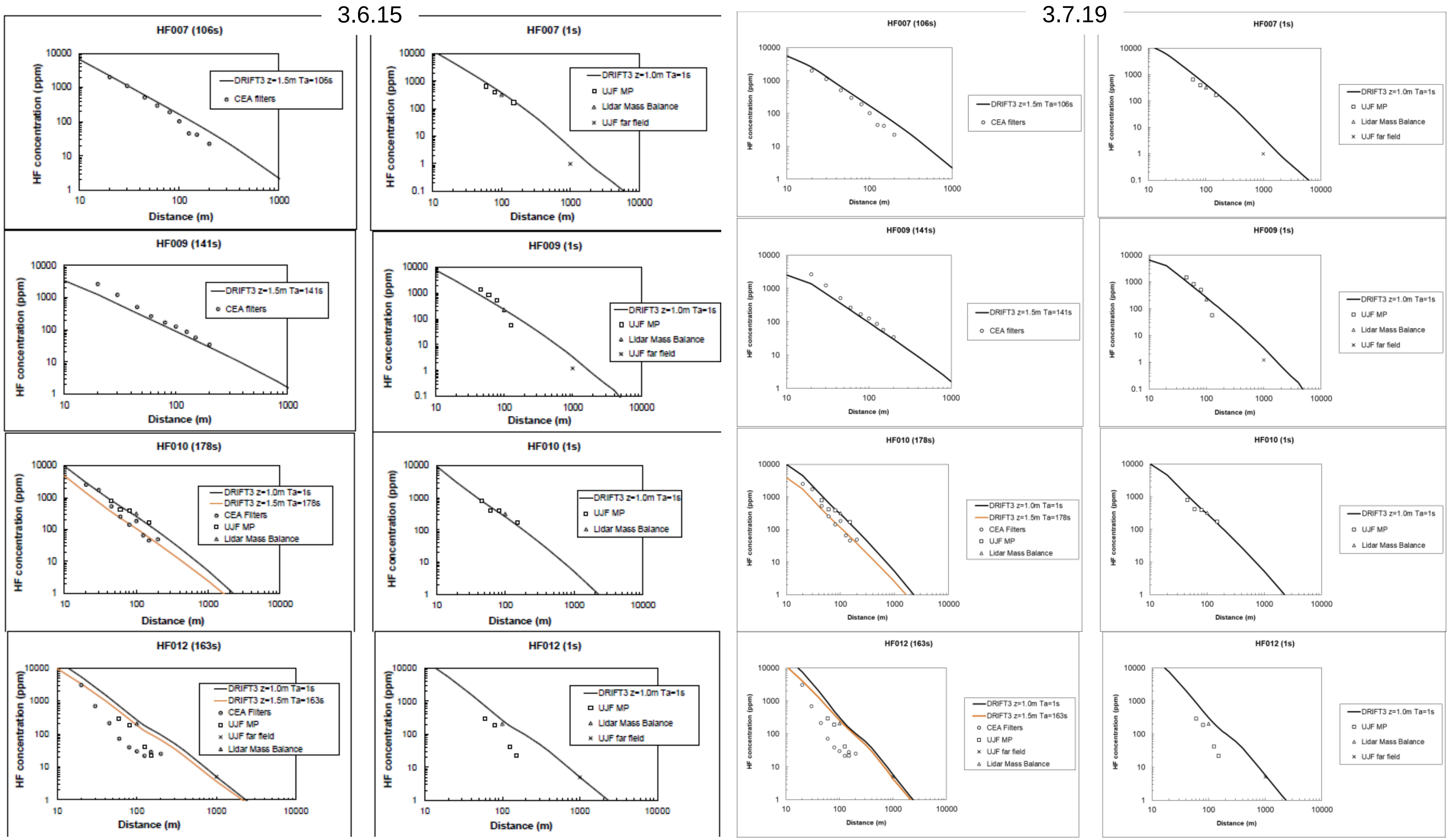

Figure 2-11 DRIFT comparisons with URAHFREP Campaign 2 field trial data. DRIFT 3.6.15 on left and DRIFT 3.7.19 on the right.

2.3 Other Field Trials

[15] reported comparisons between predictions of DRIFT 3.6.1 and the following gas dispersion datasets:

- Thorney Island: Freon 12/nitrogen mixture
- Burro: Liquefied natural gas (LNG) spill and dispersion
- Desert Tortoise: Two-phase ammonia dispersion
- Goldfish: Two-phase hydrogen fluoride dispersion
- Prairie Grass: Passive tracer dispersion.

These datasets cover releases involving dense and passive gas dispersion in a range of atmospheric conditions. Appendix 2 provides results from DRIFT 3.7.19 runs for all the cases given in [15]. Selected cases are compared with DRIFT 3.6.1 predictions in the following sub-sections.

2.3.1 Thorney Island

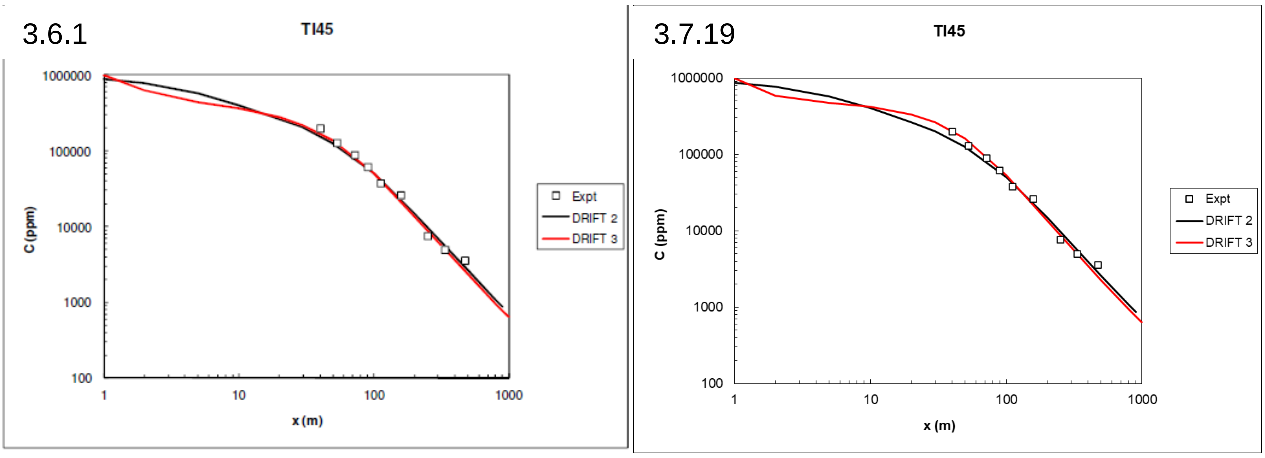

Figure 2-12 Centreline concentration predictions for Thorney Island Trial 45. Note DRIFT was originally tuned against this trial. Using DRIFT 3.6.1 on the left and DRIFT 3.7.19 on the right.

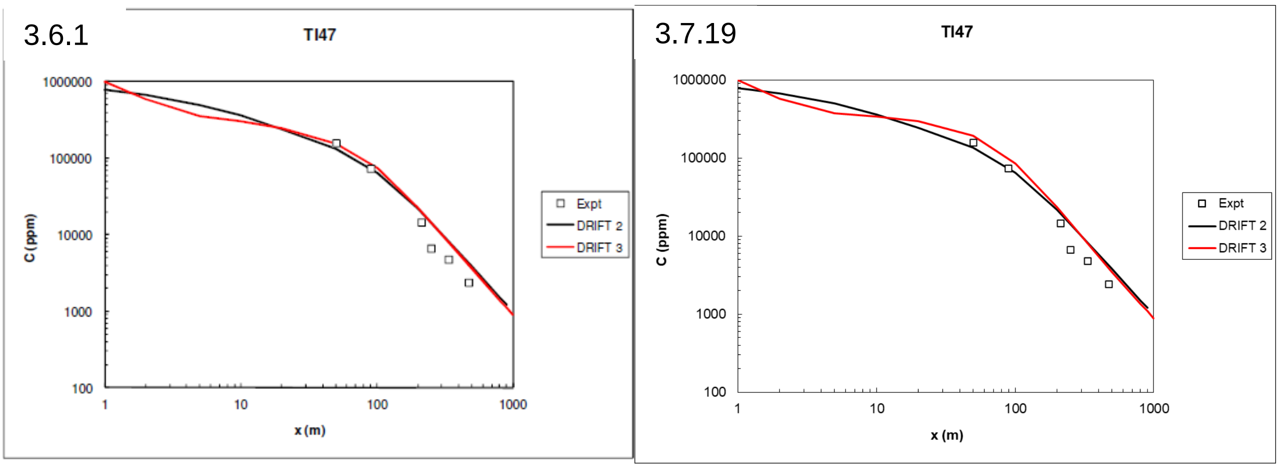

Figure 2-13 Centreline concentration predictions for Thorney Island Trial 47. Using DRIFT 3.6.1 on the left and DRIFT 3.7.19 on the right.

Figure 2-12 and Figure 2-13 show a comparison of DRIFT 3.6.1 predictions and DRIFT 3.7.19 predictions for the two continuous Thorney Island trials reported in [15]. These two versions of DRIFT show comparable agreement with the experimental data.

2.3.2 Burro

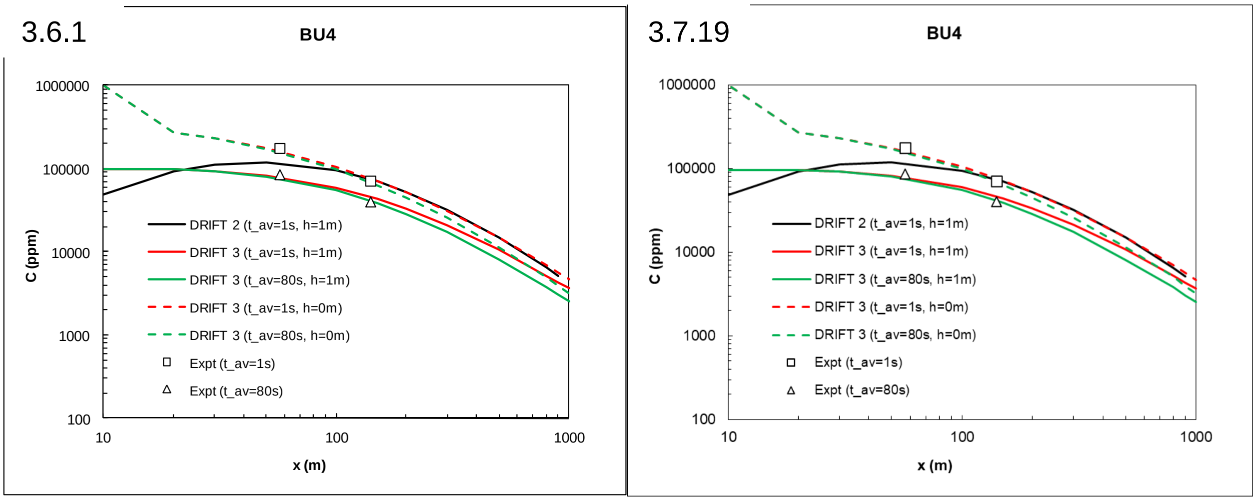

Figure 2-14 Centreline concentration predictions for Burro Trial 4. Using DRIFT 3.6.1 on the left and DRIFT 3.7.19 on the right.

Figure 2-14 shows that DRIFT 3.7.19 produces almost identical predictions to DRIFT 3.6.1 for Burro Trial 4. DRIFT 3.7.19 predictions for all the Burro trials reported in [15] are given in Appendix 2.

2.3.3 Desert Tortoise

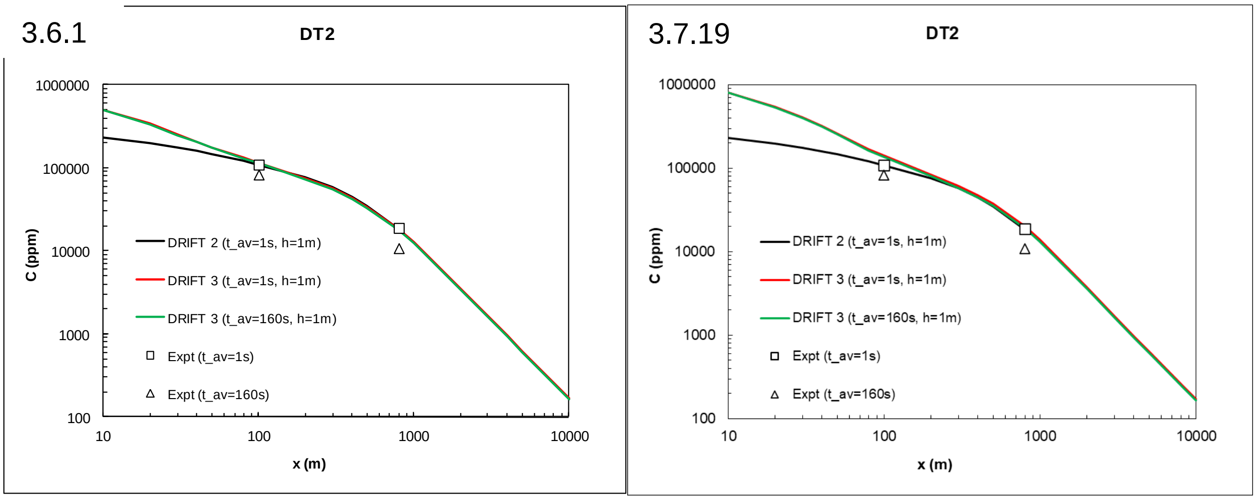

Figure 2-15 Centreline concentration predictions for Desert Tortoise Trial 2. Using DRIFT 3.6.1 on the left and DRIFT 3.7.19 on the right.

Figure 2-15 shows DRIFT predictions for Desert Tortoise Trial 2. Very similar agreement with the field trial measurements is observed. Compared with DRIFT 3.6.1, DRIFT 3.7.19 predicts slightly higher concentrations at 10 m distance, presumably this relates to changes in the jet model, however there is no experimental data to corroborate the predictions at this distance. DRIFT 3.7.19 predictions for all the Desert Tortoise trials reported in [15] are given in Appendix 2.

2.3.4 Goldfish

Figure 2-16 shows DRIFT predictions for Goldfish Trial 1. DRIFT 3.7.19 shows very similar agreement with the experimental data compared with earlier DRIFT versions. Again, there is a slight difference between DRIFT 3.7.19 and 3.6.1 at 10m distance which is likely related to changes in the jet model. DRIFT 3.7.19 predictions for all the Goldfish trials reported in [15] are given in Appendix 2.

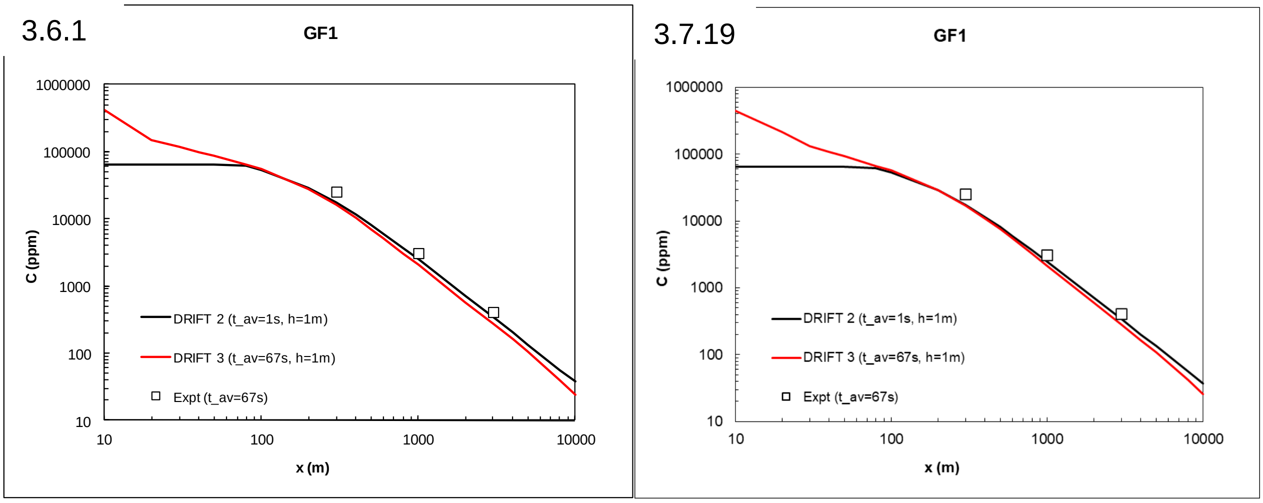

Figure 2-16 Centreline concentration predictions for Goldfish Trial 1. Using DRIFT 3.6.1 on the left and DRIFT 3.7.19 on the right.

2.3.5 Prairie Grass

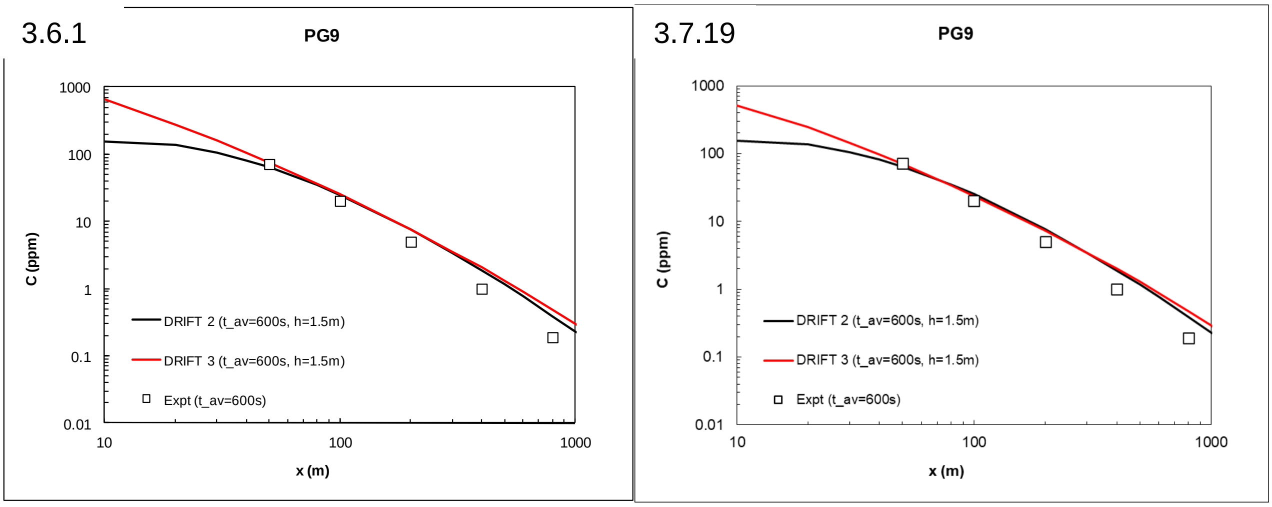

Figure 2-17 Centreline concentration predictions for Prairie Grass Trial 9. Using DRIFT 3.6.1 on the left and DRIFT 3.7.19 on the right.

Figure 2-17 shows DRIFT predictions for Prairie Grass Trial 9. DRIFT 3.7.19 produces indistinguishable results from DRIFT 3.6.1 for this trial. DRIFT 3.7.19 predictions for all the Prairie Grass trials reported in [15] are given in Appendix 2.

3.0 Conclusions

This document summarises the results of verification testing undertaken by ESR Technology on DRIFT 3.7.19. Apart from differences resulting from improvements in the modelling of momentum jets, transition from jet to passive spreading and buoyant lift-off, DRIFT 3.7.19 is found to perform similarly to DRIFT 3.6.x.

4.0 References

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[12] D. J. Hall, S. Walker and P. J. Tily, "Puff rise from buoyant area sources at the ground," BRE Report No. 202614, 2001.

[13] G. A. Tickle, "Comparisons of predictions of the gas dispersion model DRIFT (version 3) against URAHFREP data," ESR Technology Report ESR/D1000976/001/Issue 4, 29 June 2012.

[14] G. A. Tickle, "Comparison of predictions from the gas dispersion model DRIFT (Version 3) against URAHFREP data," in *IChemE Symposium Series No. 159, Hazards 24*, 2014.

[15] G. A. Tickle, "Comparisons of DRIFT version 3 predictions with DRIFT version 2 and experimental data," ESR Technology Report ESR/D1000846/STR01/Issue 3, 25th June 2012.

Appendix 1 Comparisons against URAHFREP wind-tunnel data

A1.1 Plume Data

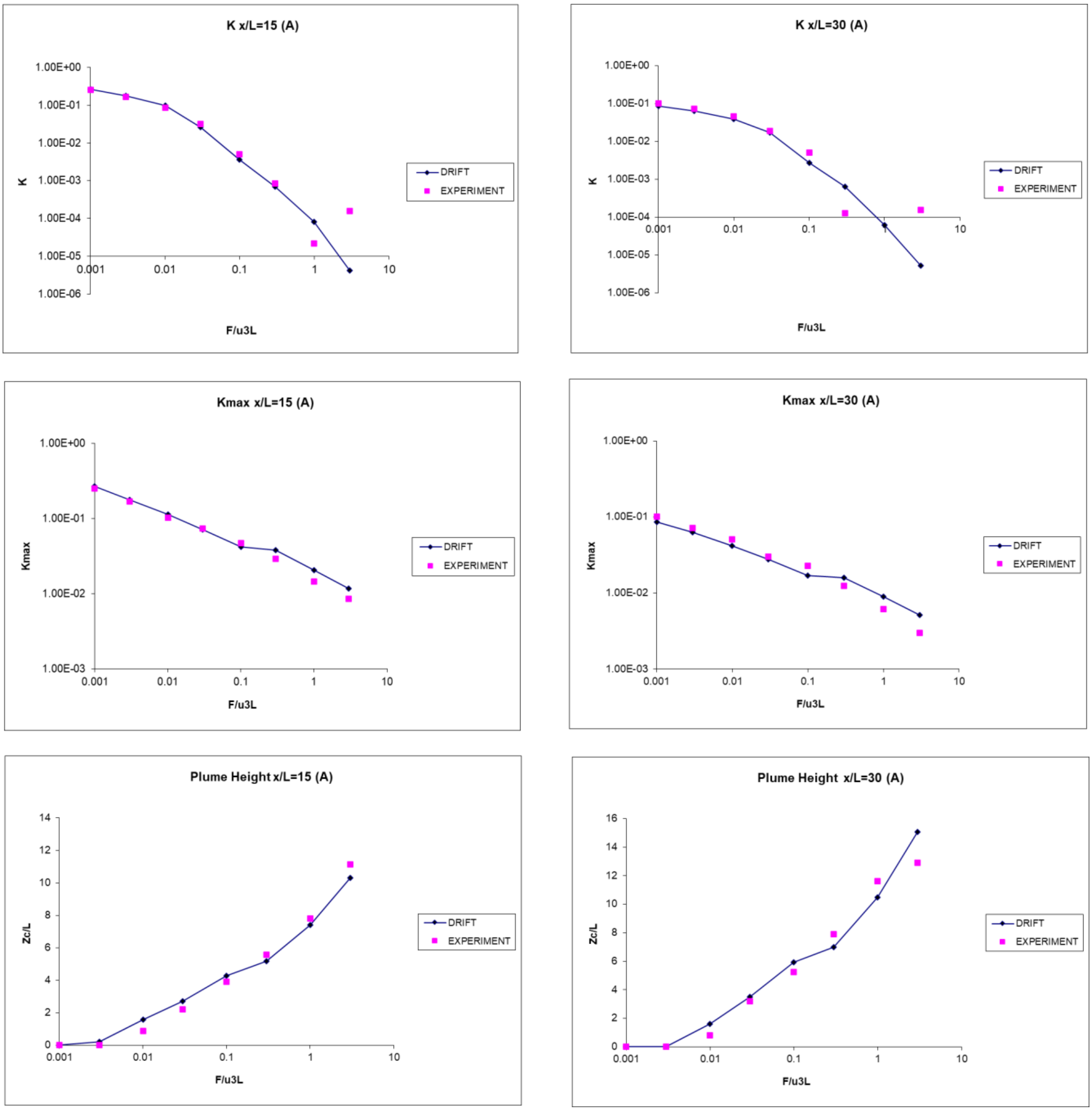

Figure A1- 1 DRIFT model predictions for plume source A.

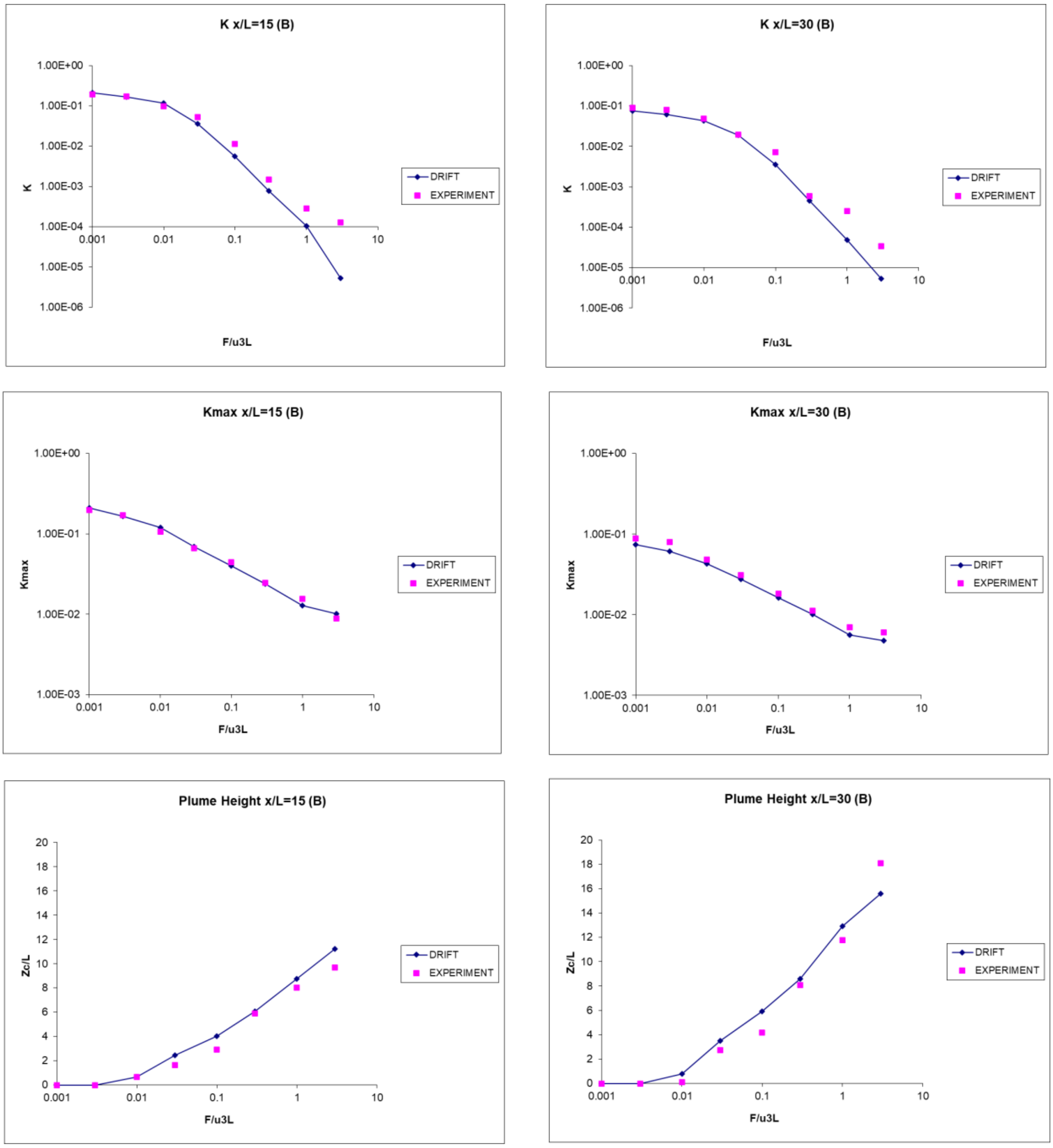

Figure A1- 2 DRIFT model predictions for plume source B.

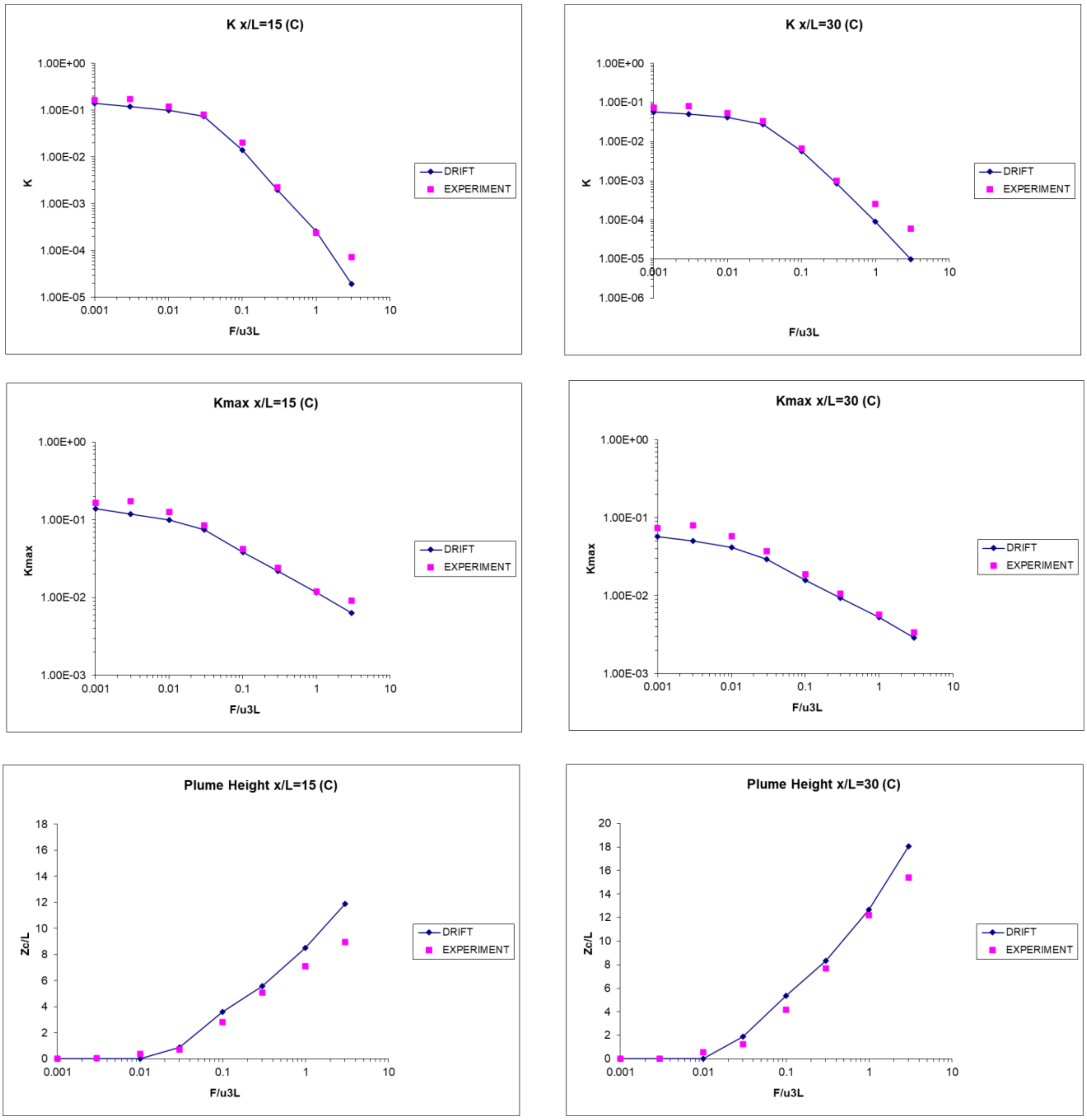

Figure A1- 3 DRIFT model predictions for plume source C.

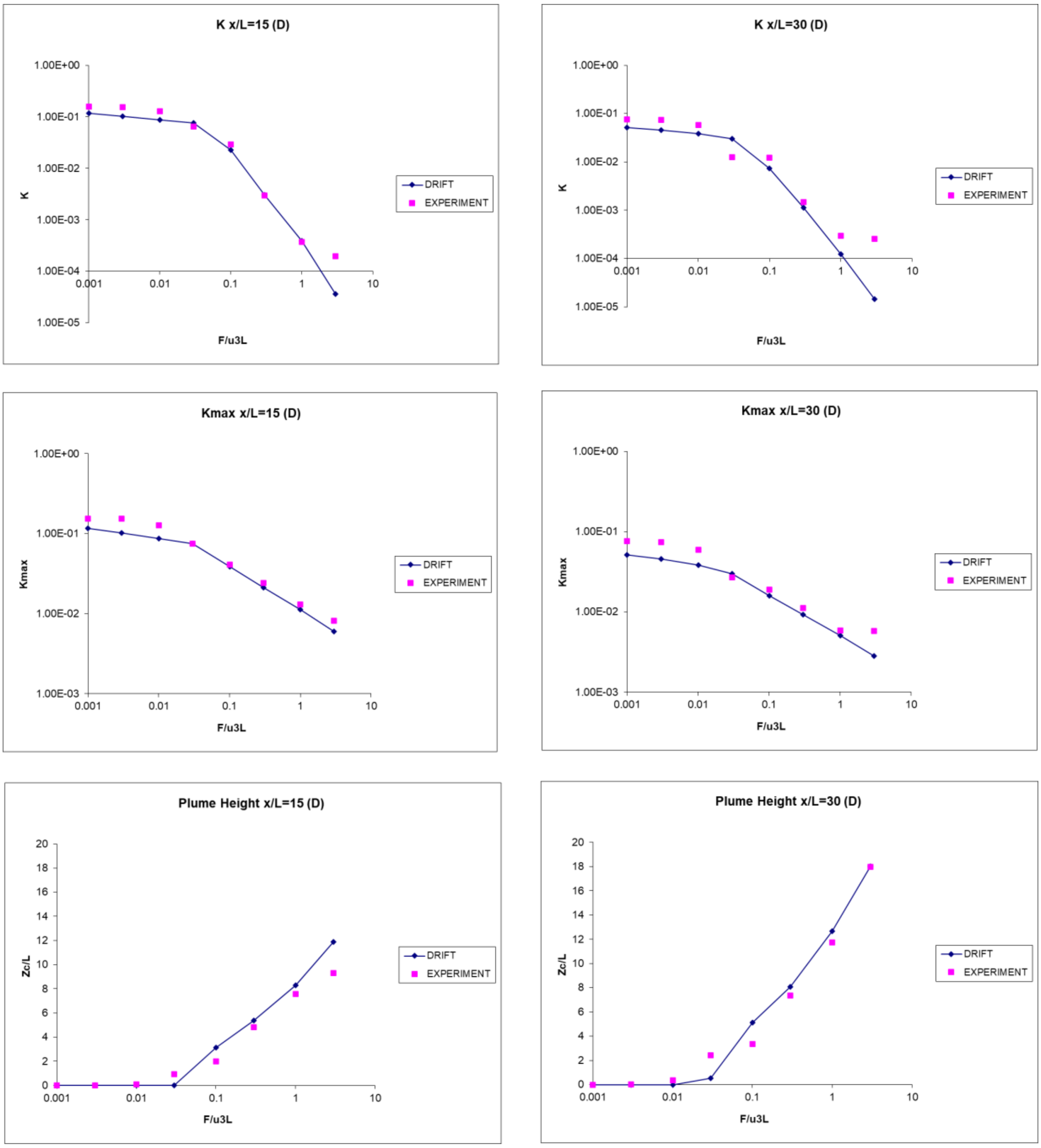

Figure A1- 4 DRIFT model predictions for plume source D.

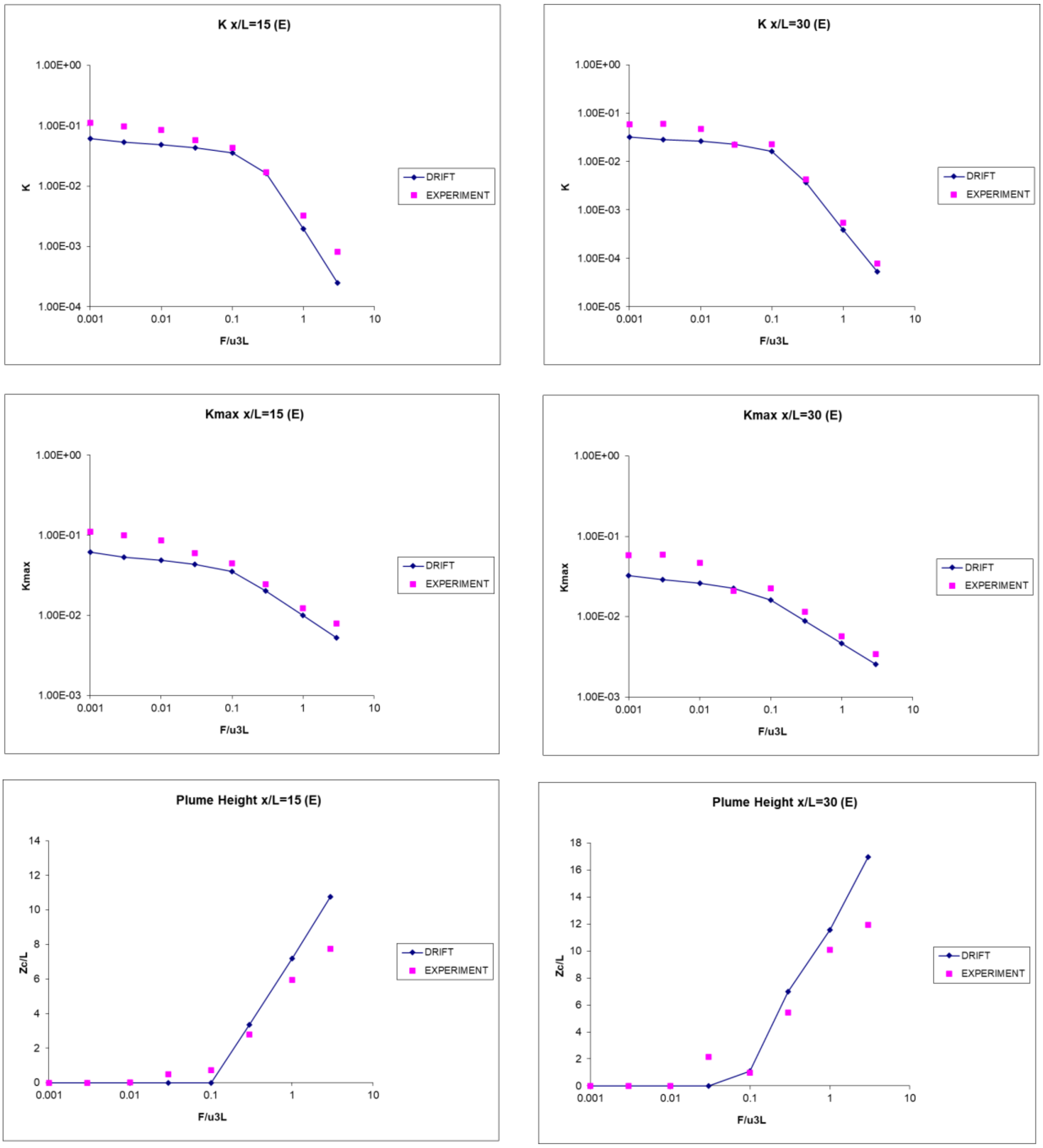

Figure A1- 5 DRIFT model predictions for plume source E.

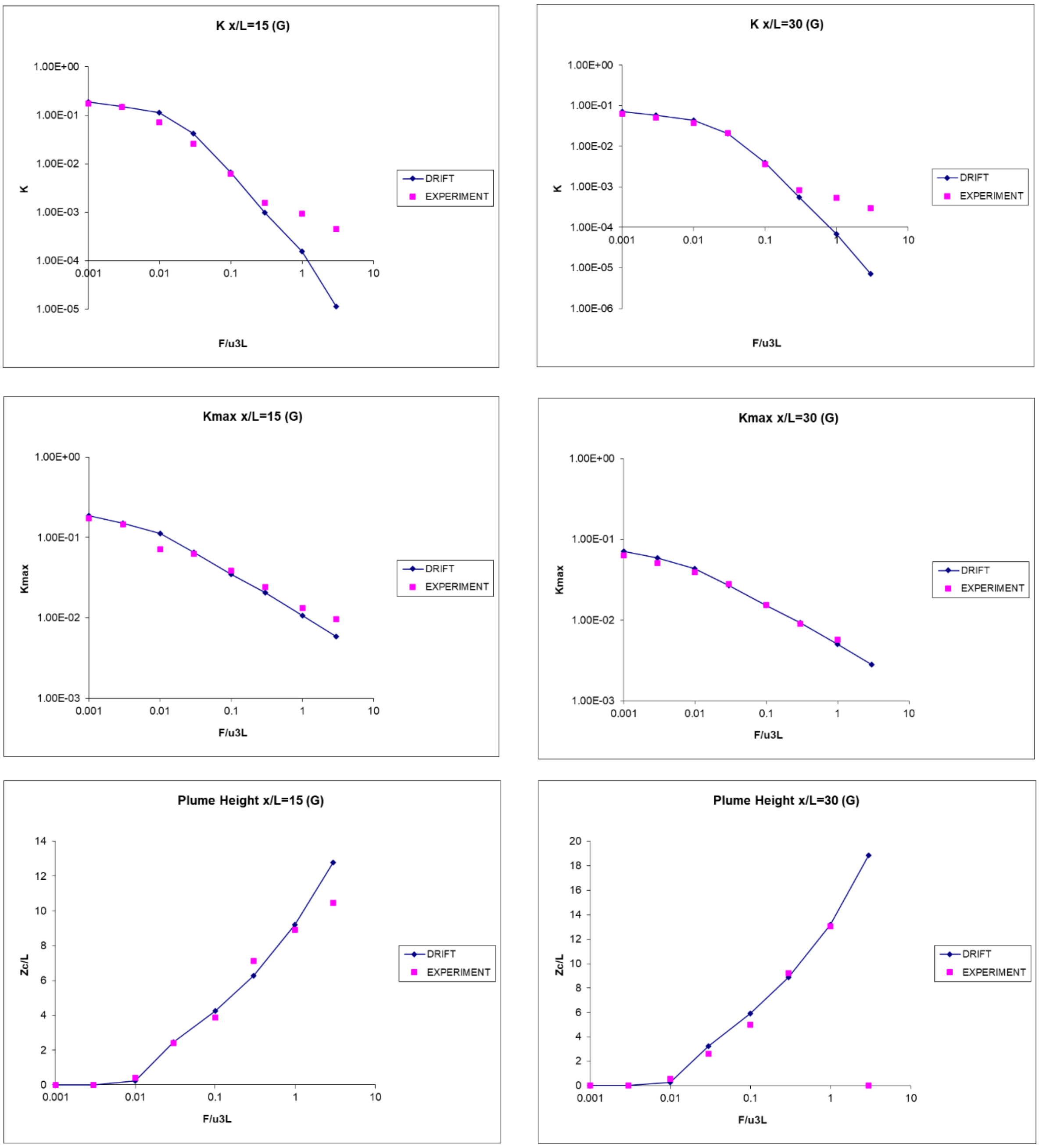

Figure A1- 6 DRIFT model predictions for plume source G.

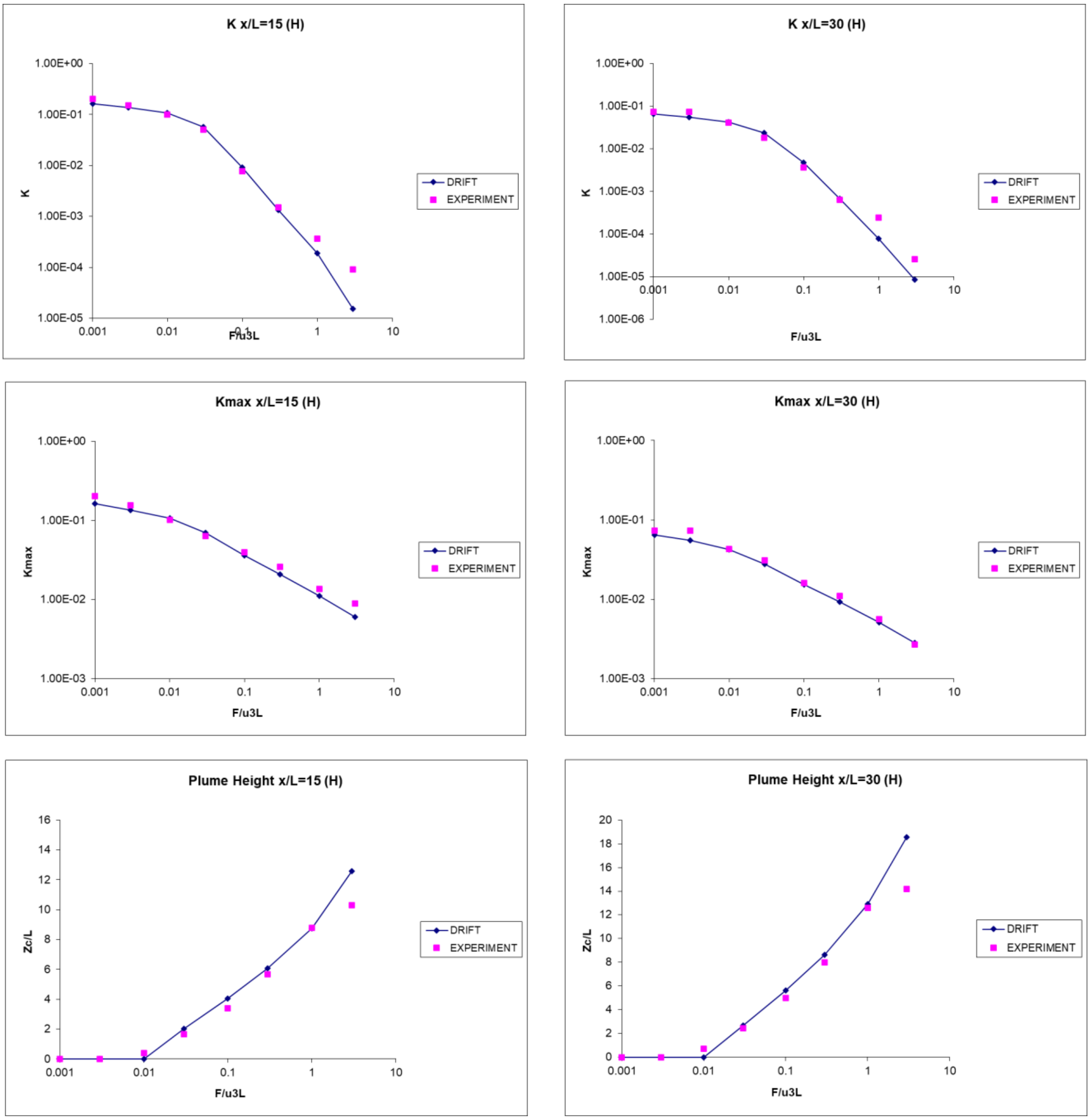

Figure A1- 7 DRIFT model predictions for plume source H.

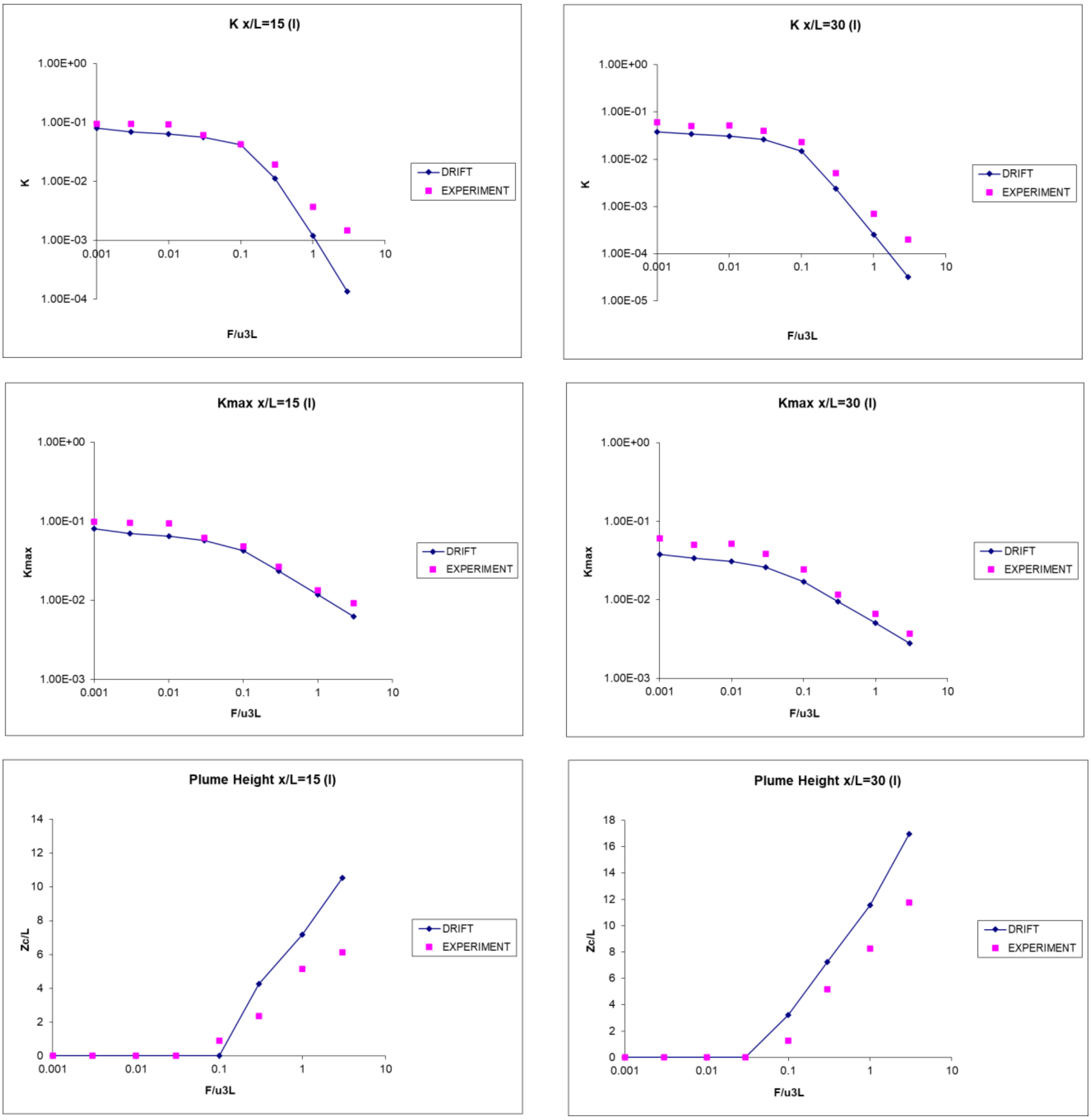

Figure A1- 8 DRIFT model predictions for plume source I.

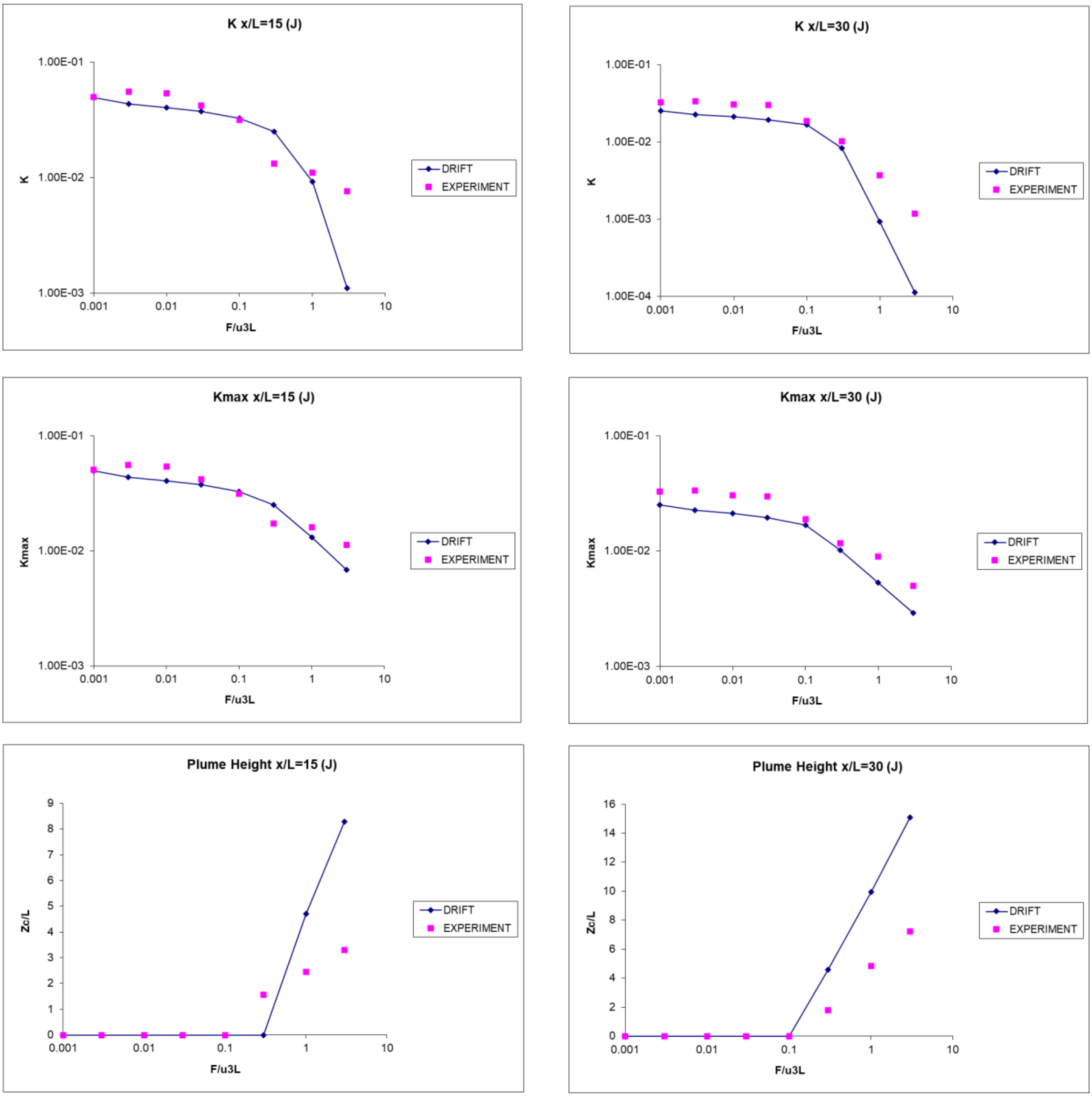

Figure A1- 9 DRIFT model predictions for plume source J.

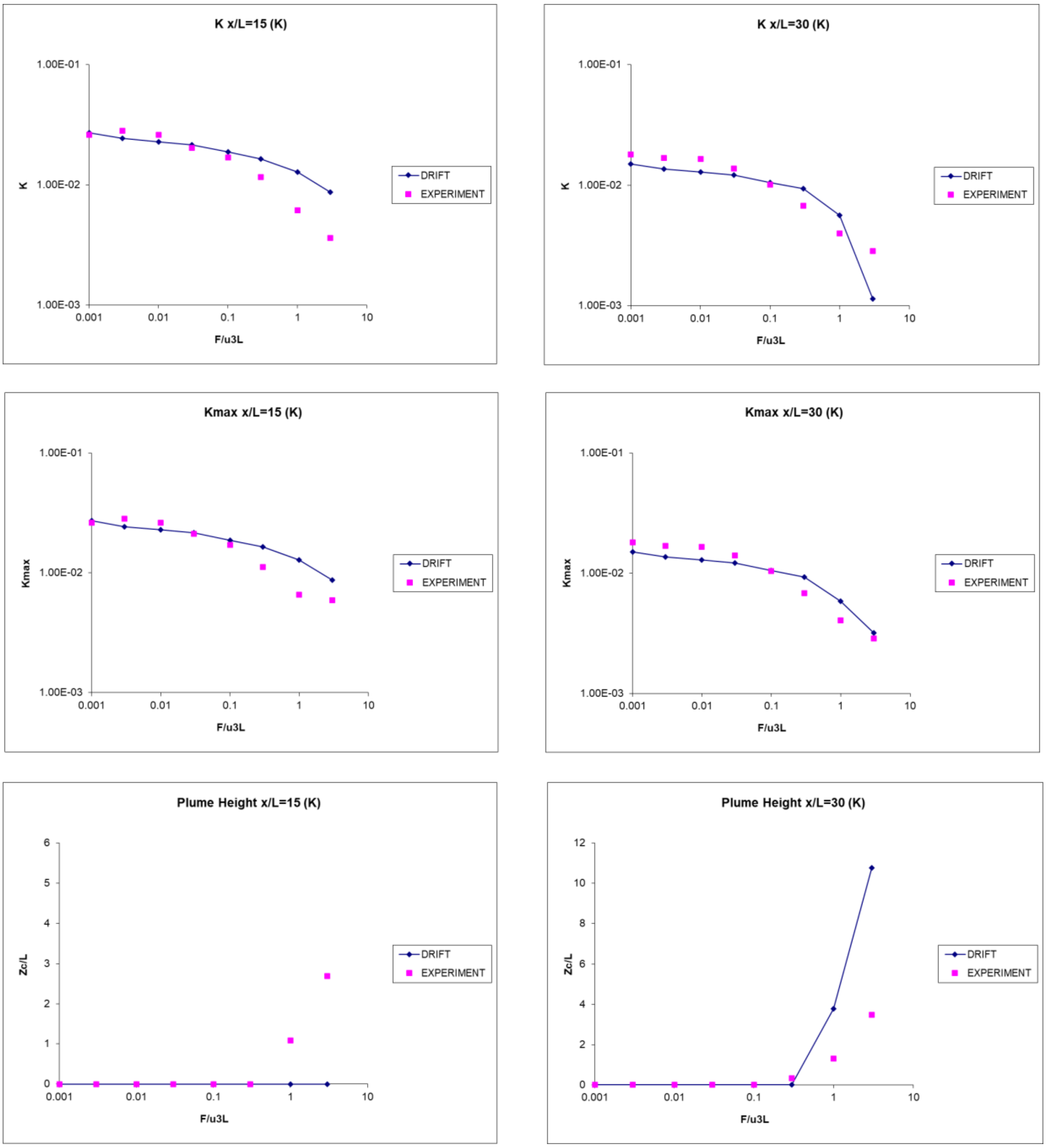

Figure A1- 10 DRIFT model predictions for plume source K.

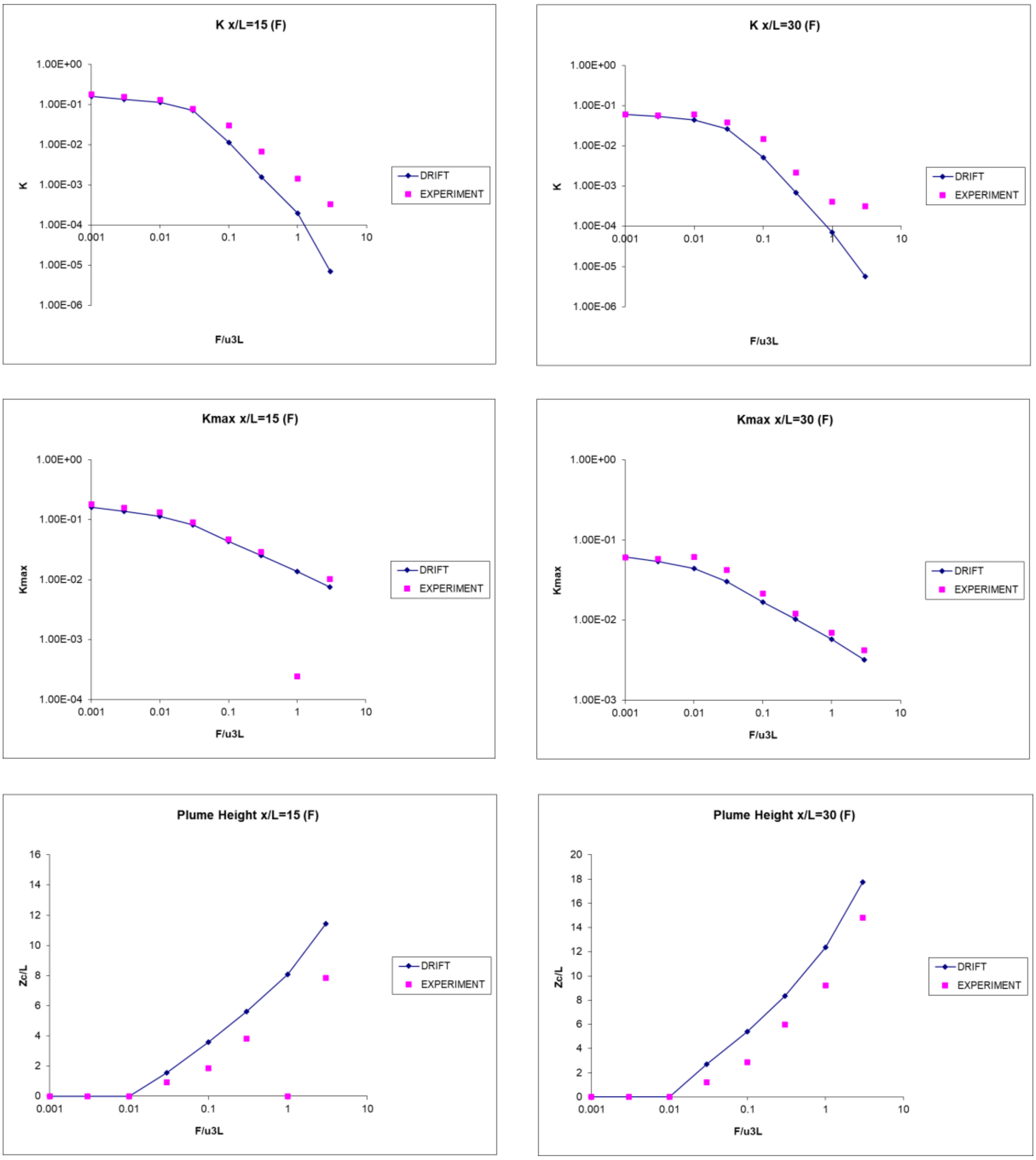

Figure A1- 11 DRIFT model predictions for plume source F.

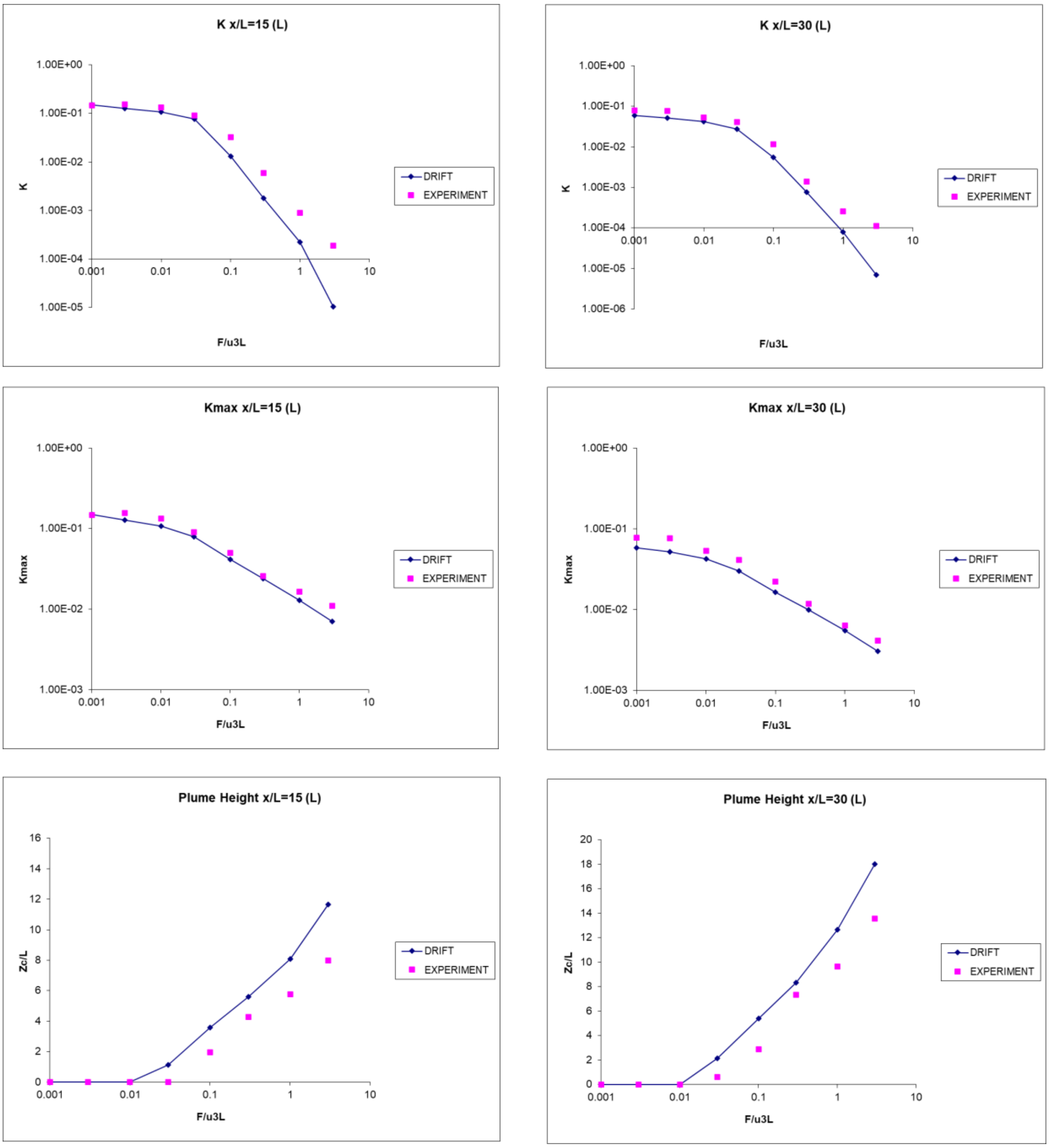

Figure A1- 12 DRIFT model predictions for plume source L.

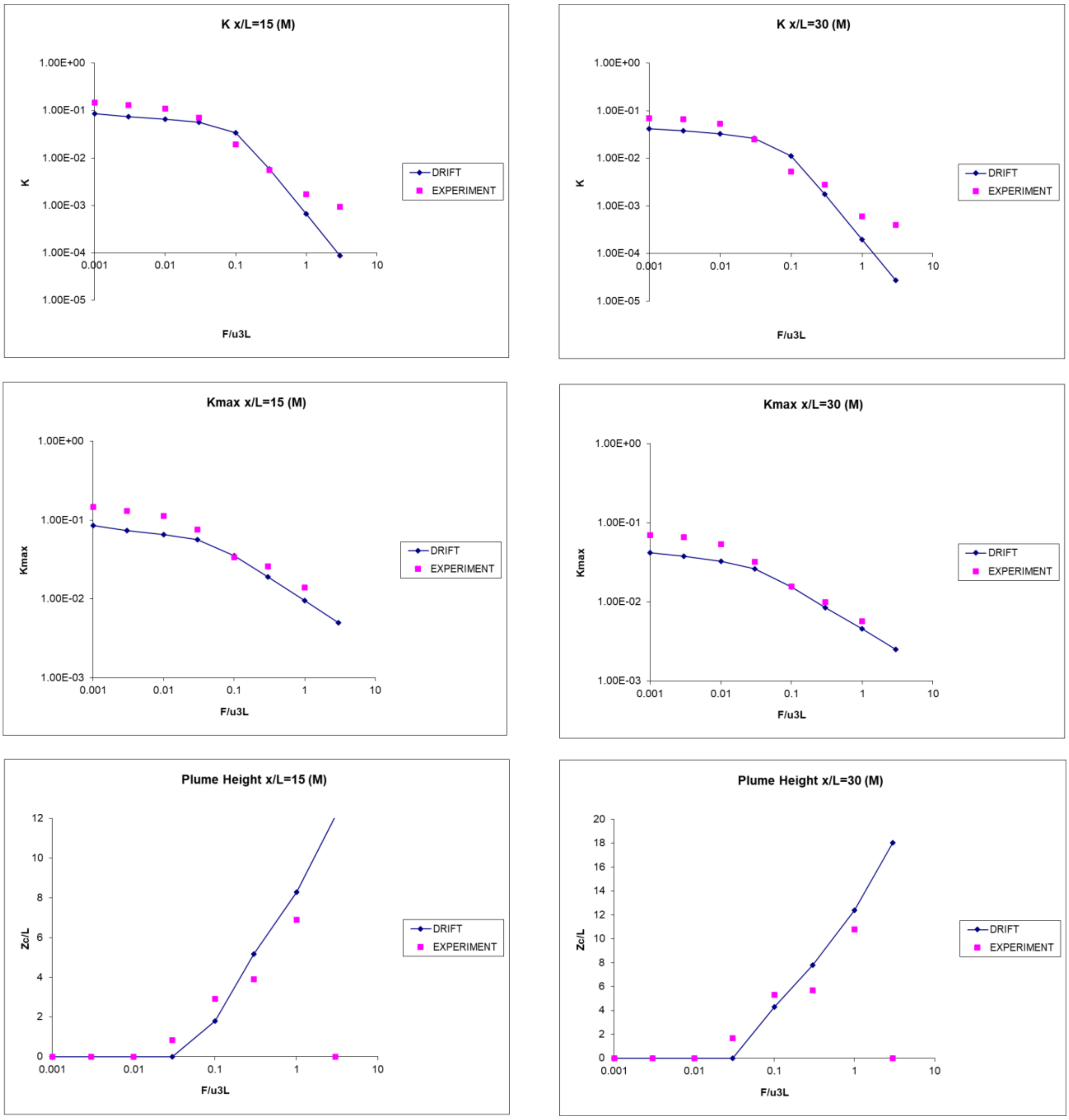

Figure A1- 13 DRIFT model predictions for plume source M.

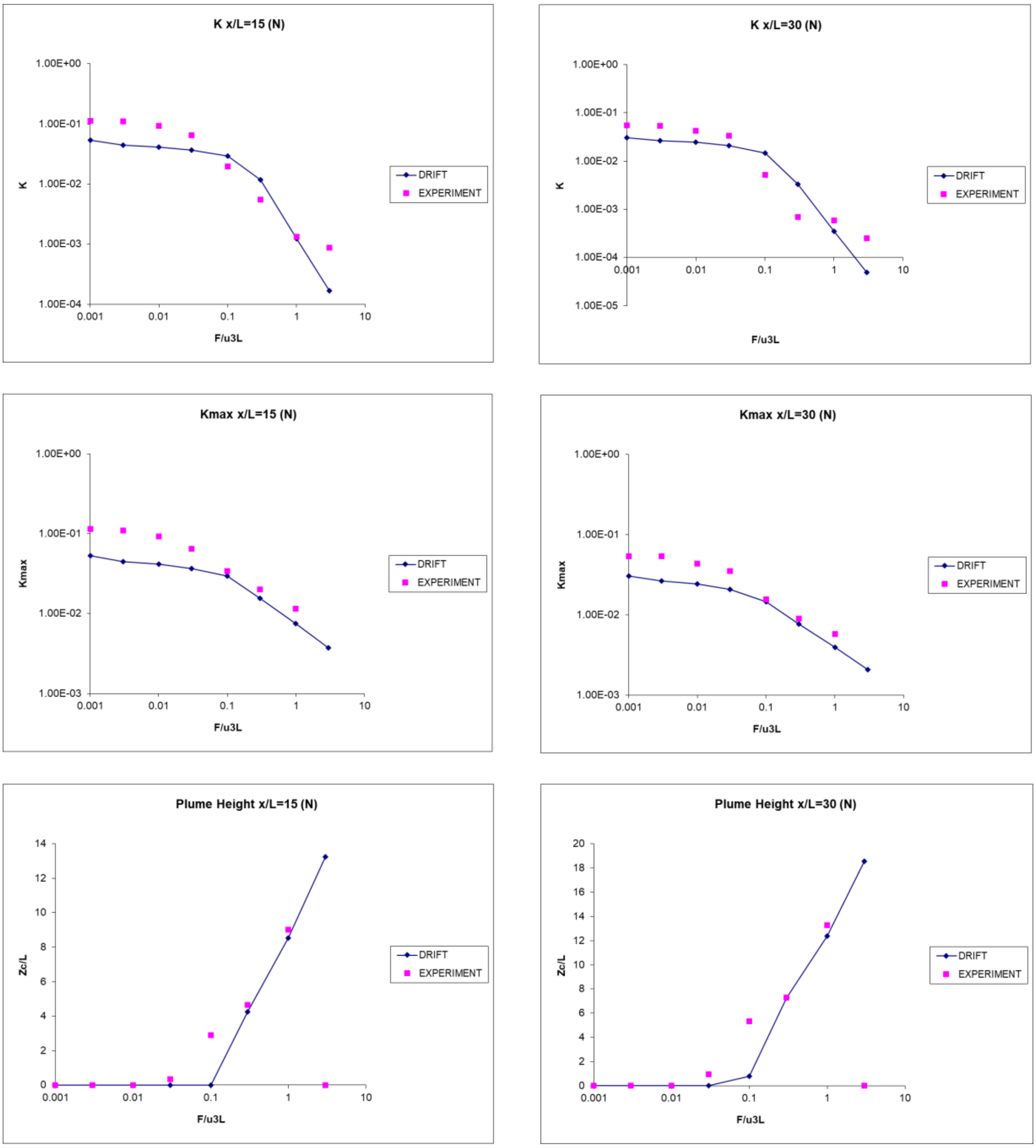

Figure A1- 14 DRIFT model predictions for plume source N.

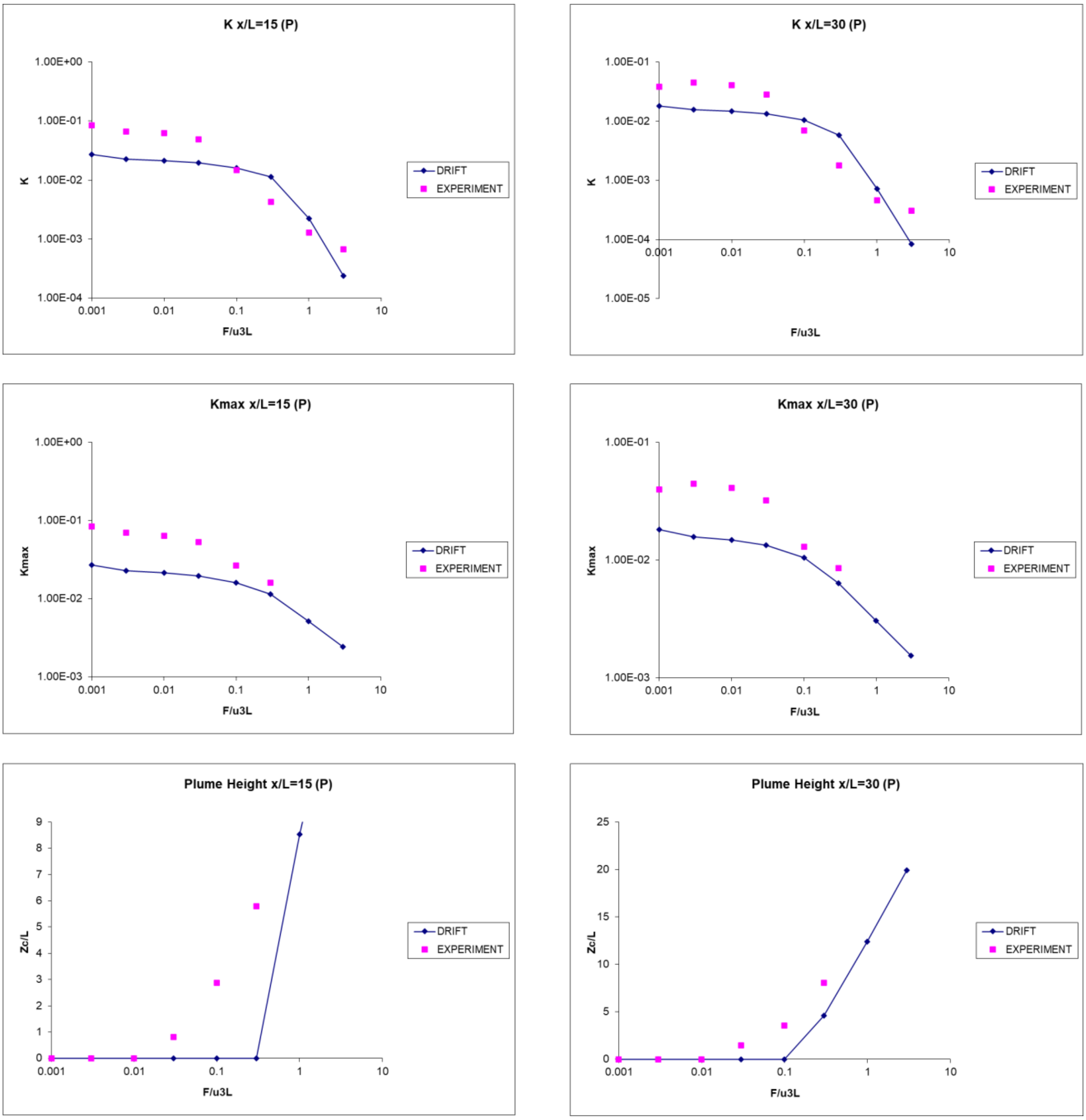

Figure A1- 15 DRIFT model predictions for plume source P.

A1.2 Puff Data

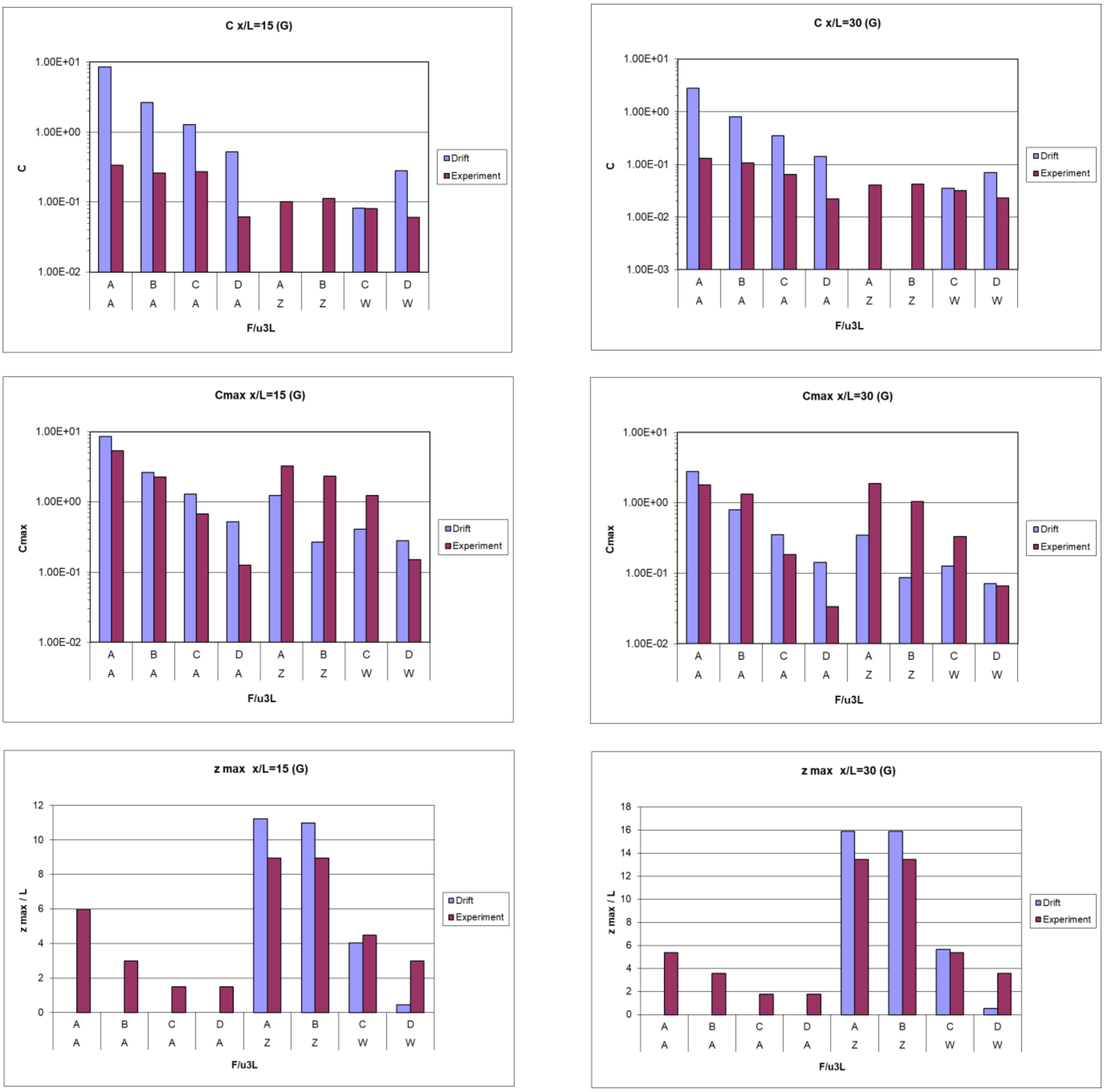

Figure A1- 16 DRIFT finite duration model predictions for puff source G.

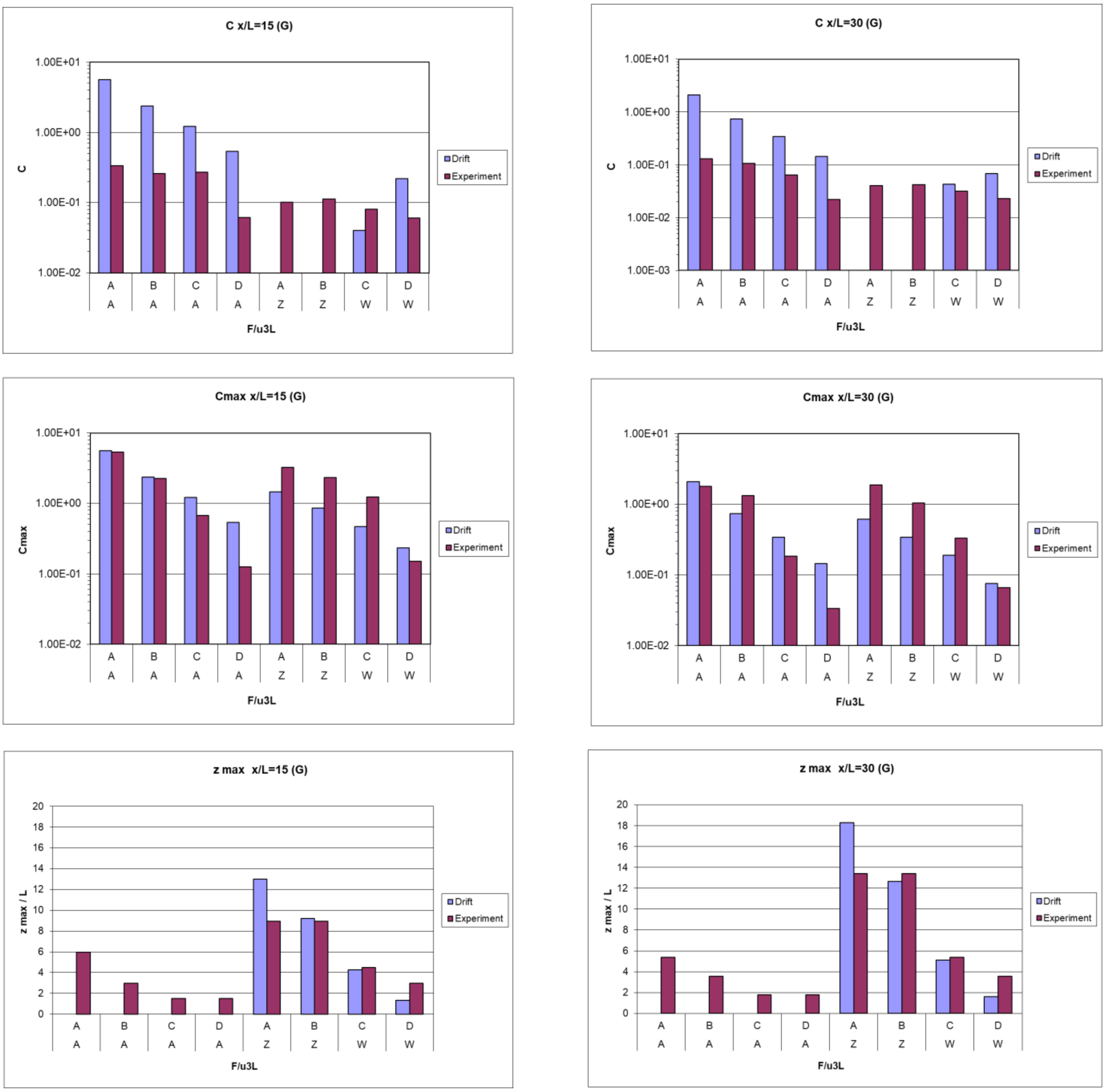

Figure A1- 17 DRIFT instantaneous model predictions for puff source G.

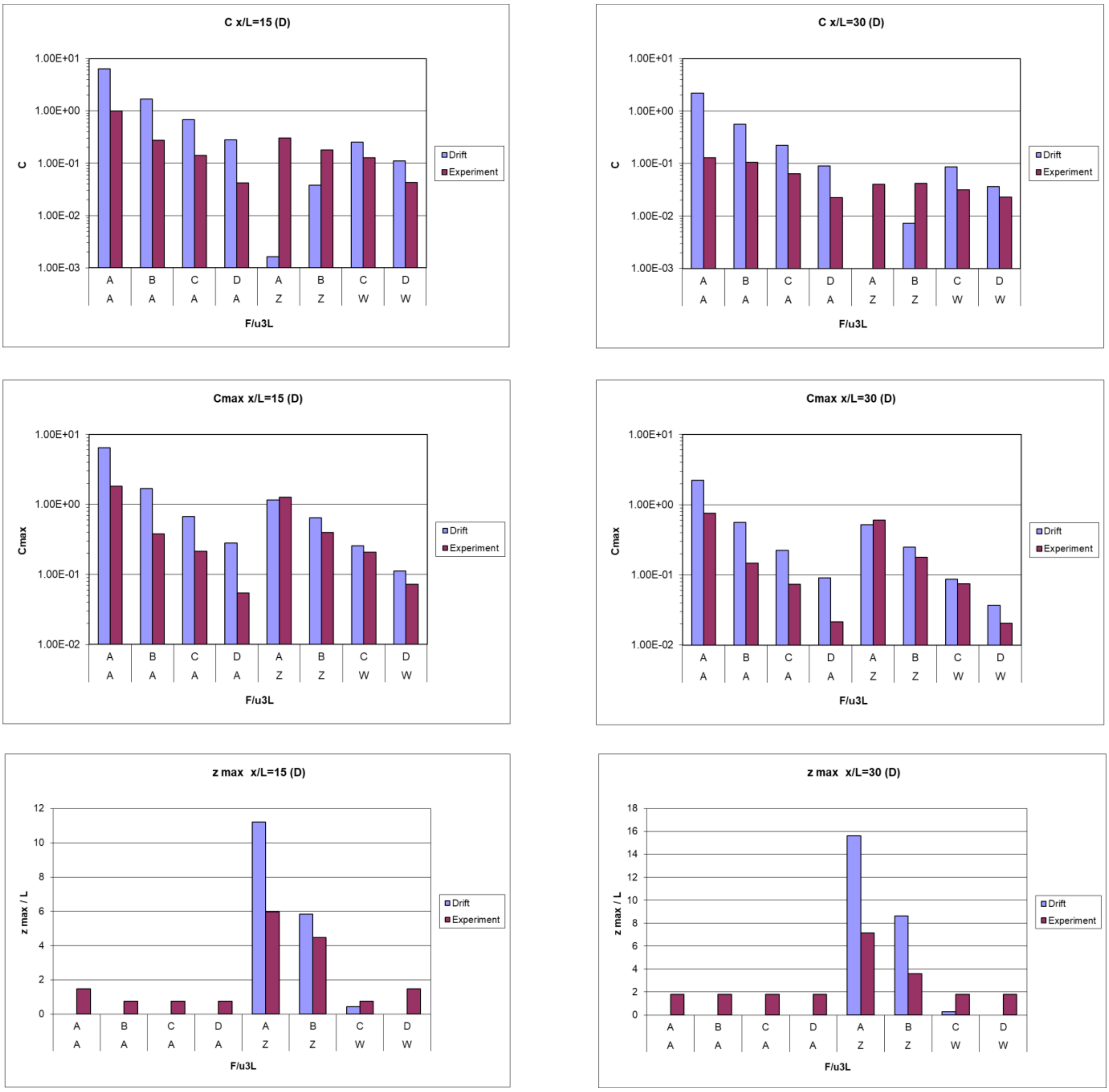

Figure A1- 18 DRIFT finite duration model predictions for puff source D.

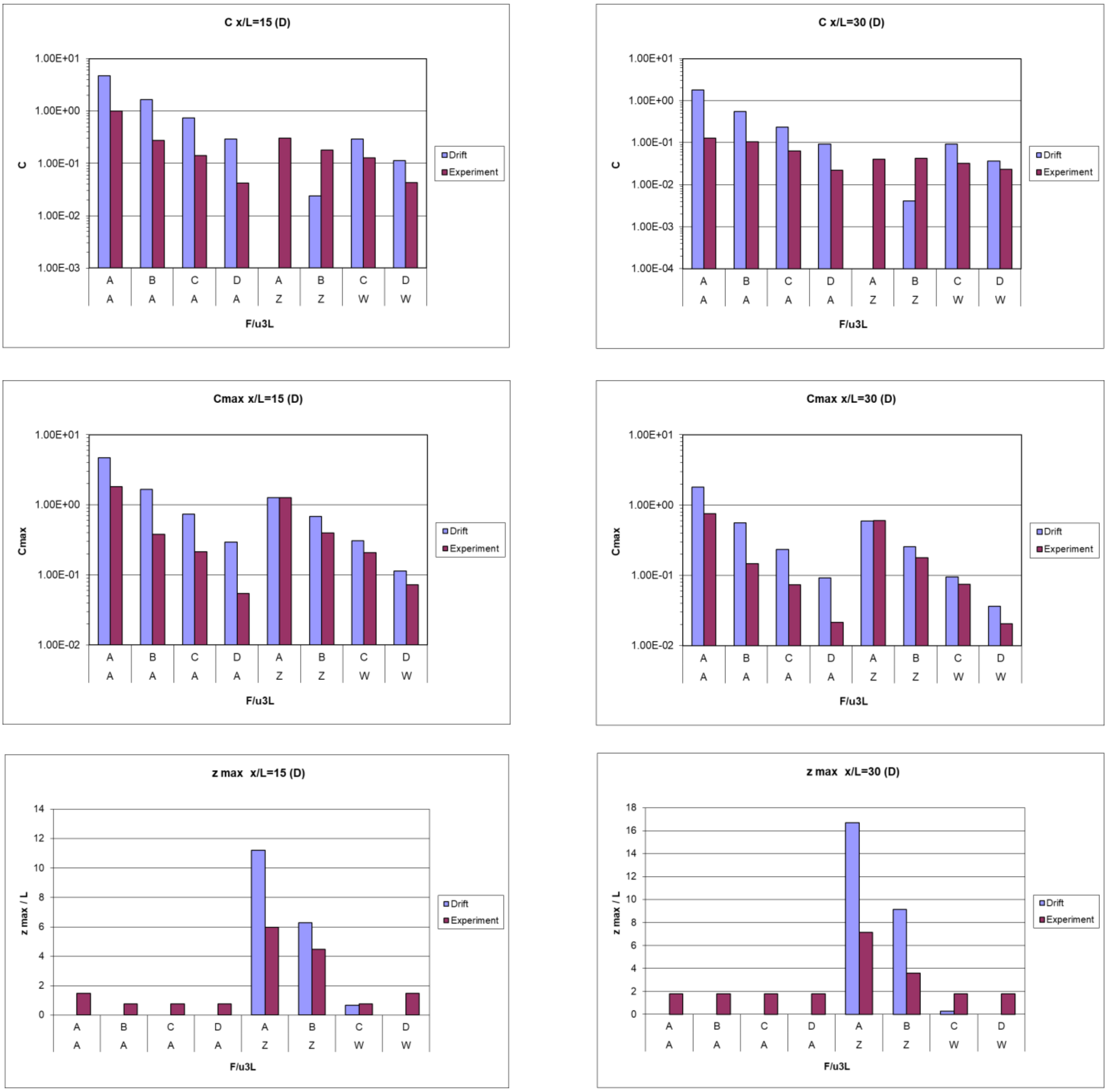

Figure A1- 19 DRIFT instantaneous model predictions for puff source D.

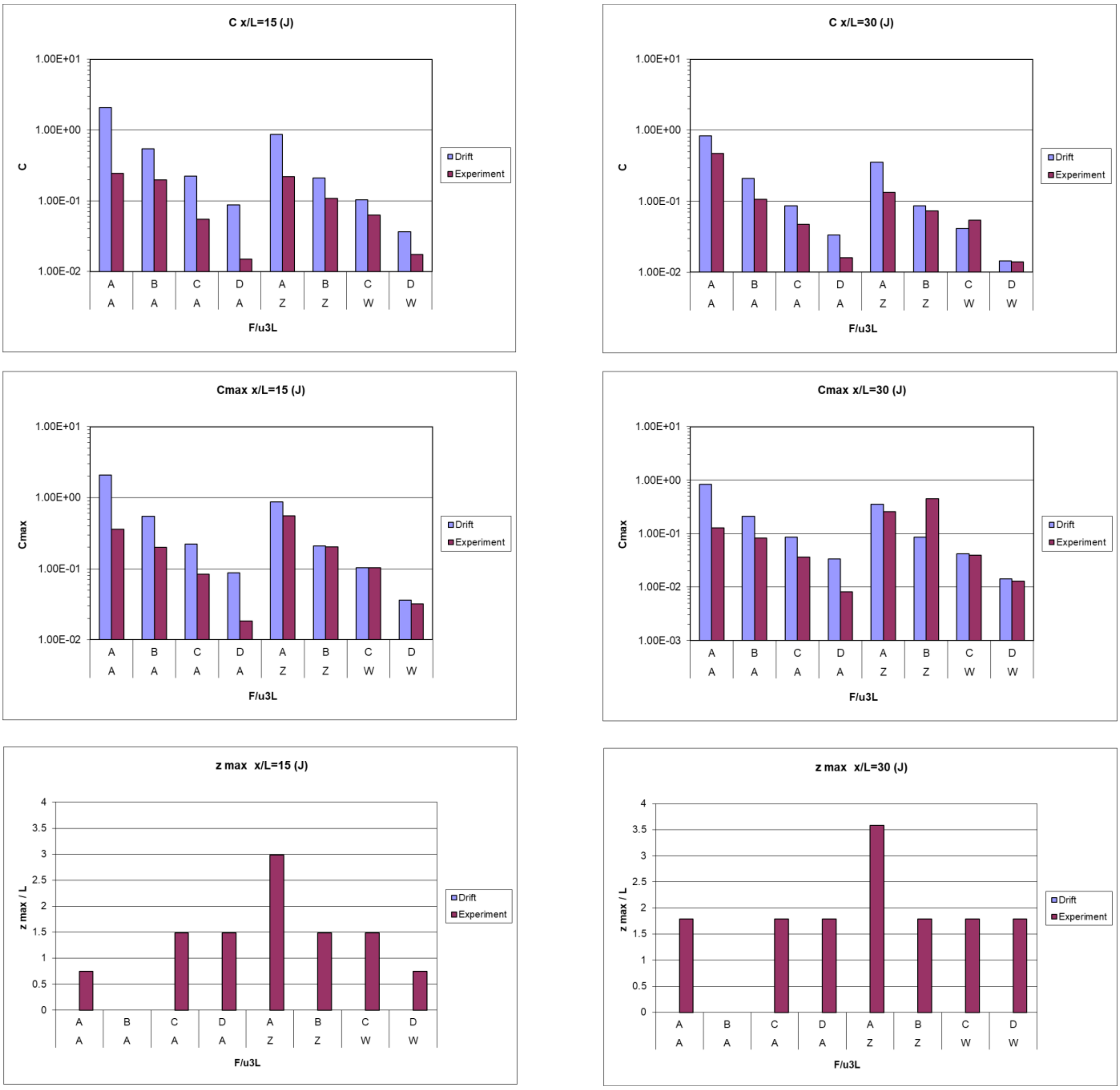

Figure A1- 20 DRIFT finite duration model predictions for puff source J.

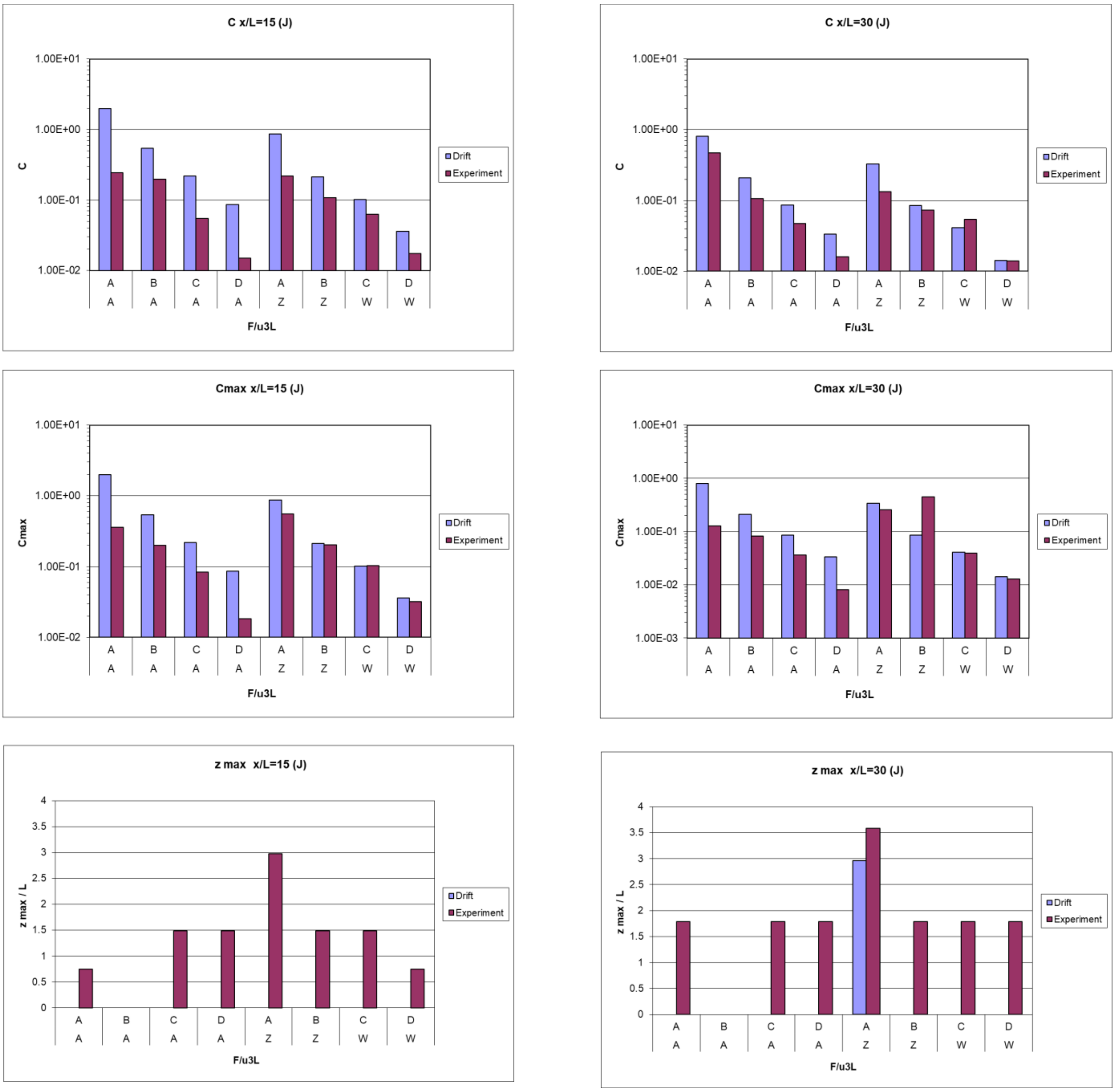

Figure A1- 21 DRIFT instantaneous model predictions for puff source J.

Appendix 2 Comparisons with other field trials

A2.1 Thorney Island

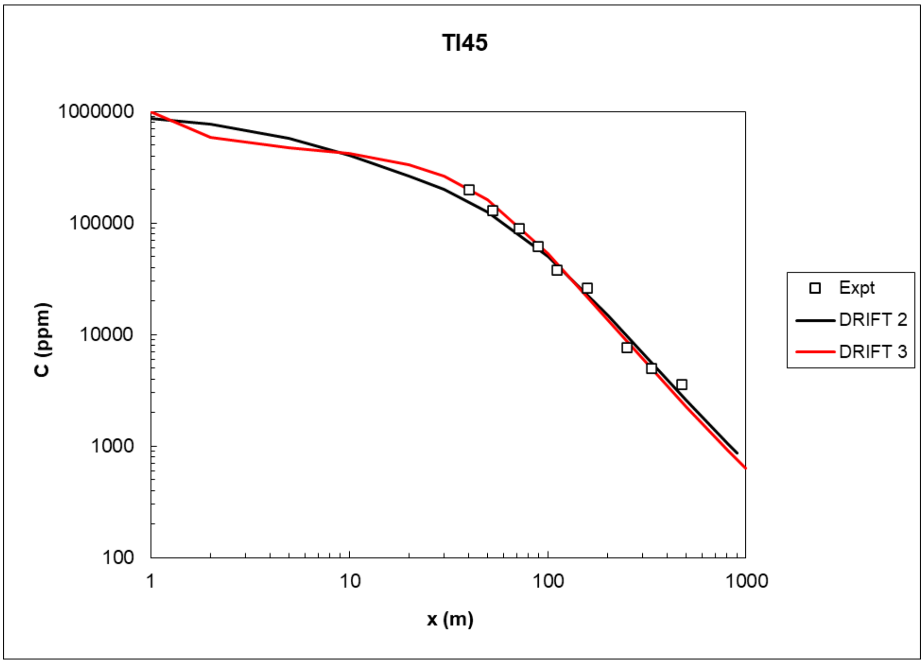

Figure A2- 1 Centreline concentration predictions for Thorney Island Trial 45. DRIFT was originally tuned using this trial.

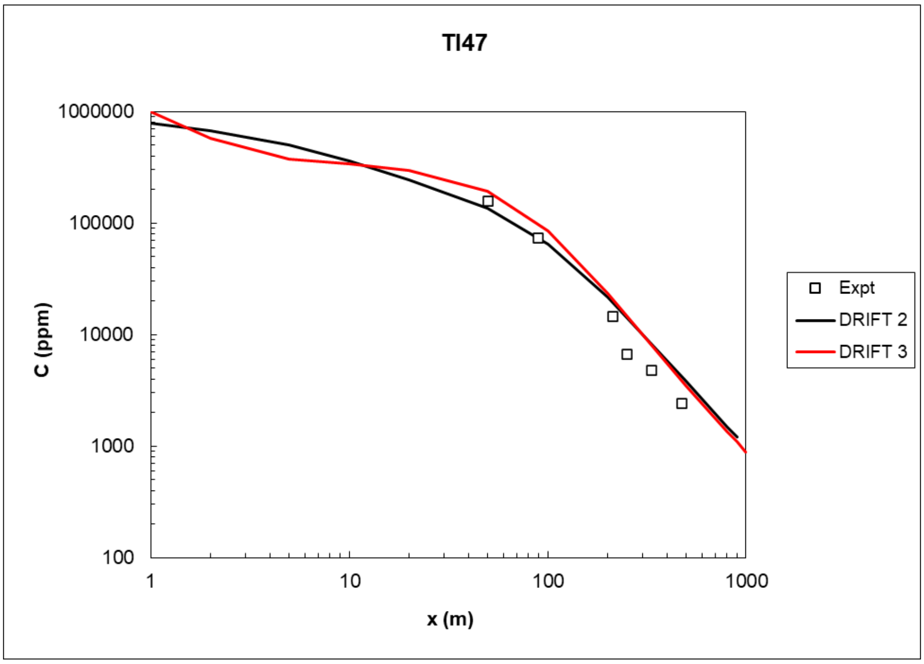

Figure A2- 2 Centreline concentration predictions for Thorney Island Trial 47.

A2.2 Burro

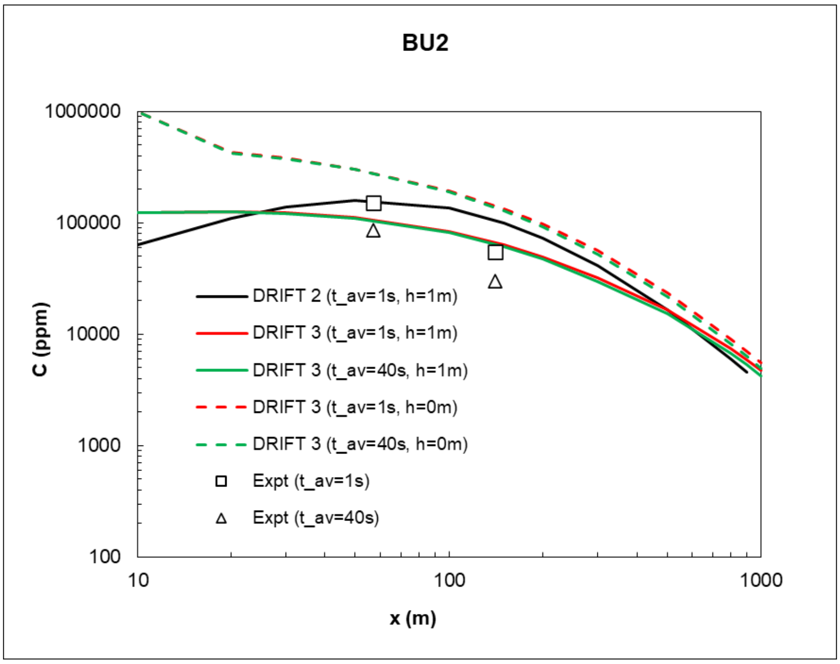

Figure A2- 3 Centreline concentration predictions for Burro Trial 2.

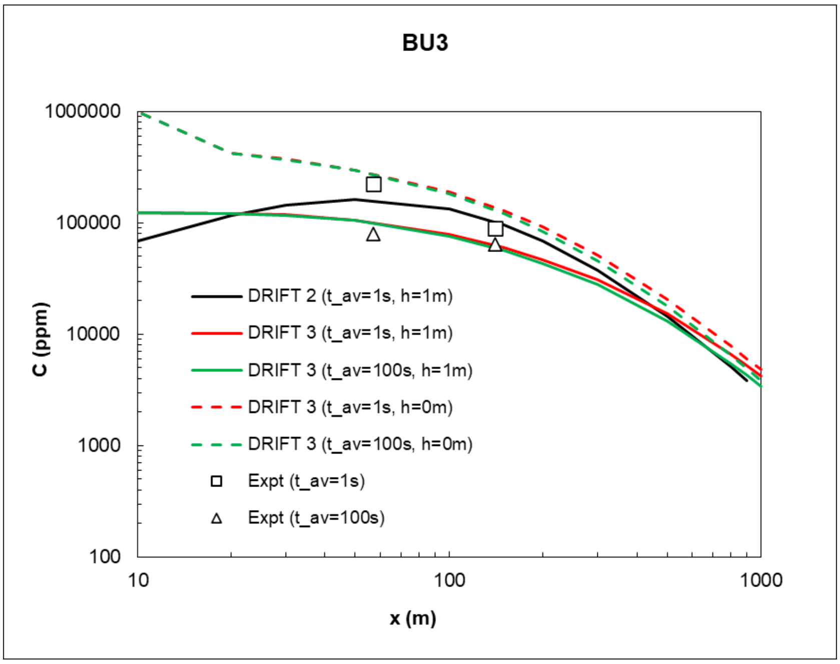

Figure A2- 4 Centreline concentration predictions for Burro Trial 3.

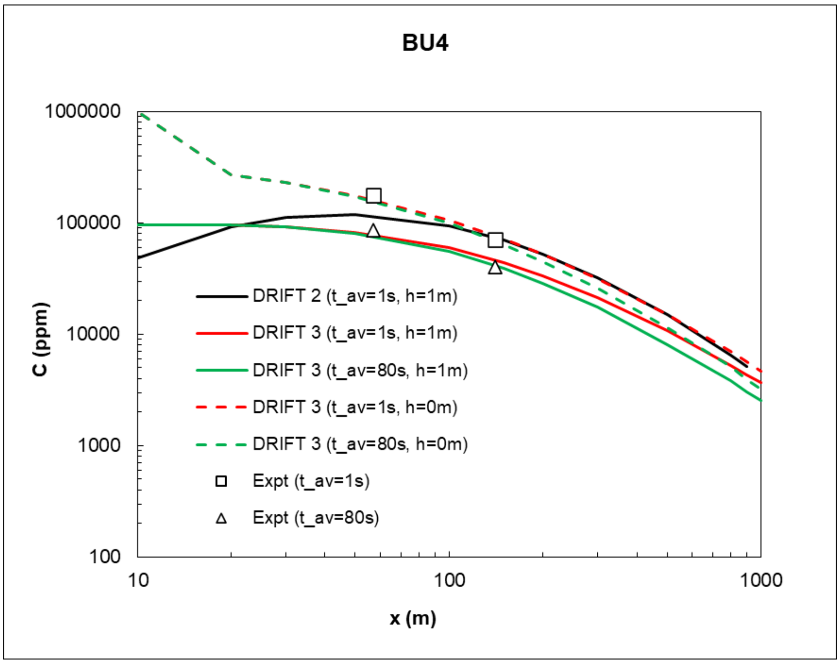

Figure A2- 5 Centreline concentration predictions for Burro Trial 4.

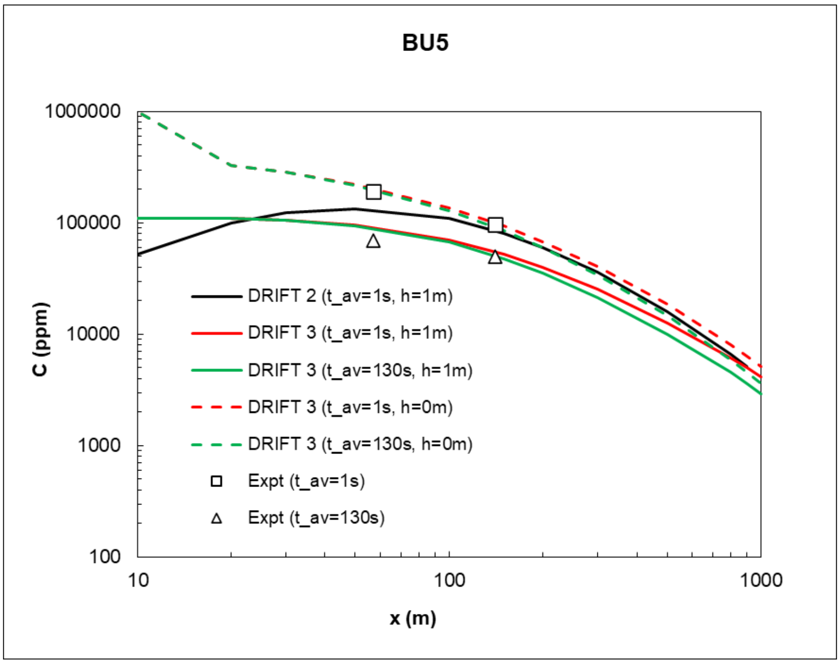

Figure A2- 6 Centreline concentration predictions for Burro Trial 5.

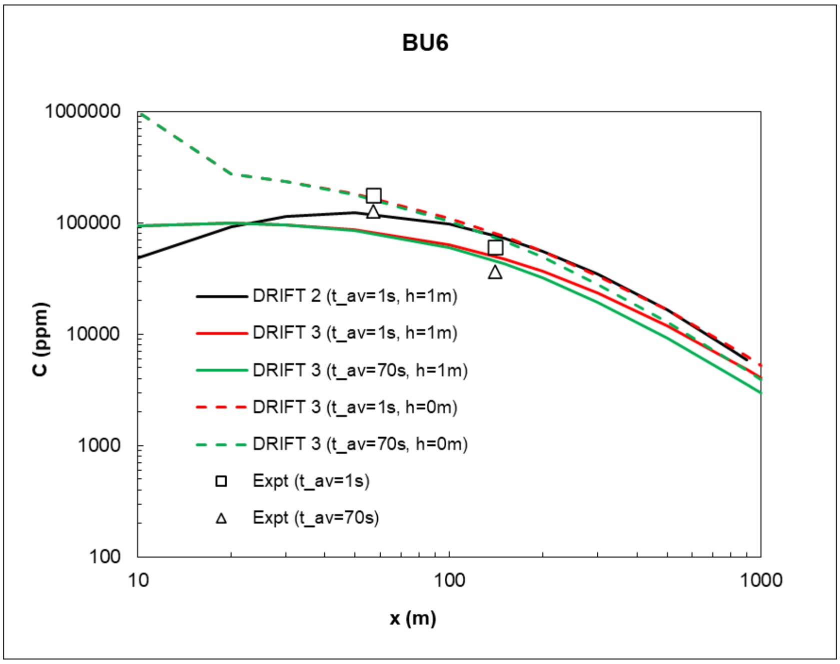

Figure A2- 7 Centreline concentration predictions for Burro Trial 6.

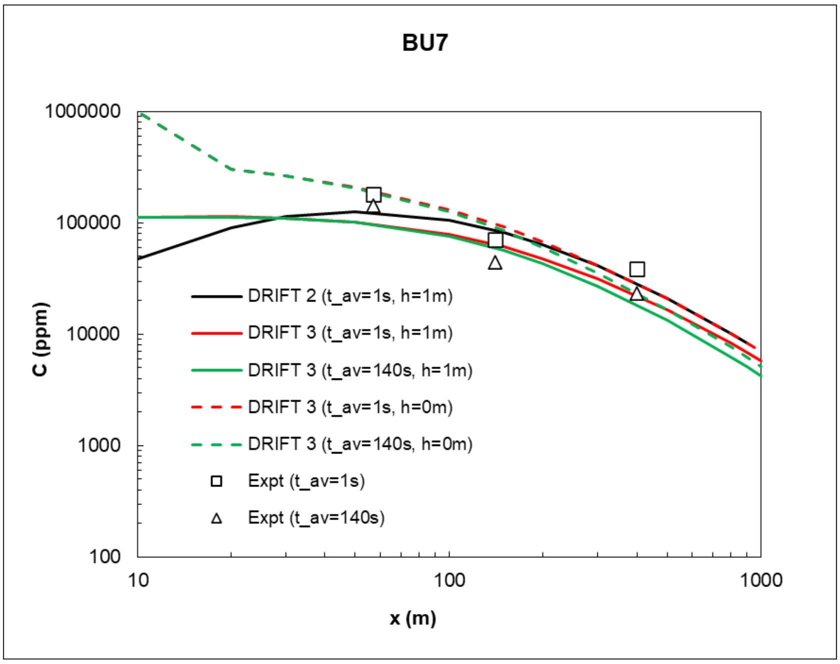

Figure A2- 8 Centreline concentration predictions for Burro Trial 7.

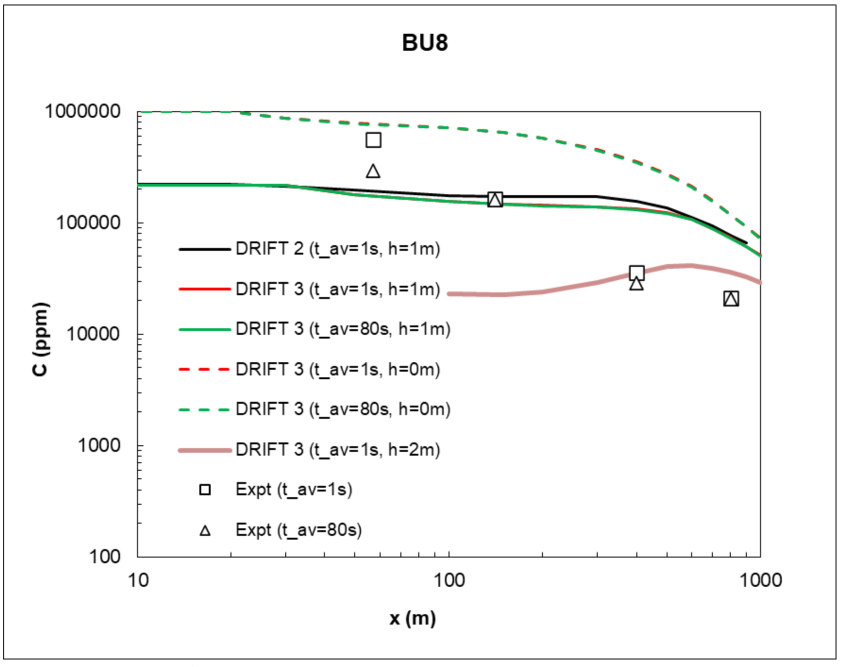

Figure A2- 9 Centreline concentration predictions for Burro Trial 8.

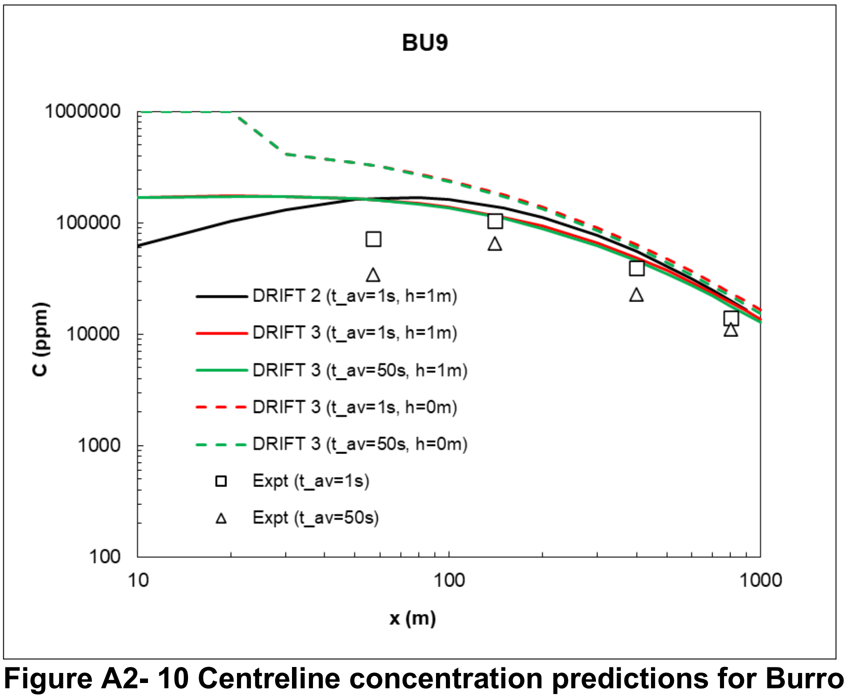

Figure A2- 10 Centreline concentration predictions for Burro Trial 9.

A2.3 Desert Tortoise

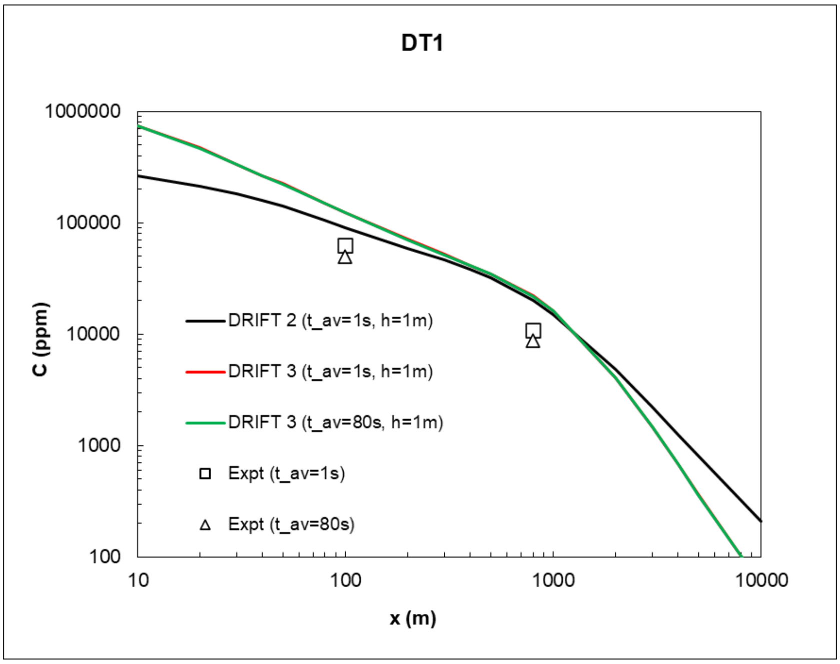

Figure A2- 11 Centreline concentration predictions for Desert Tortoise Trial 1.

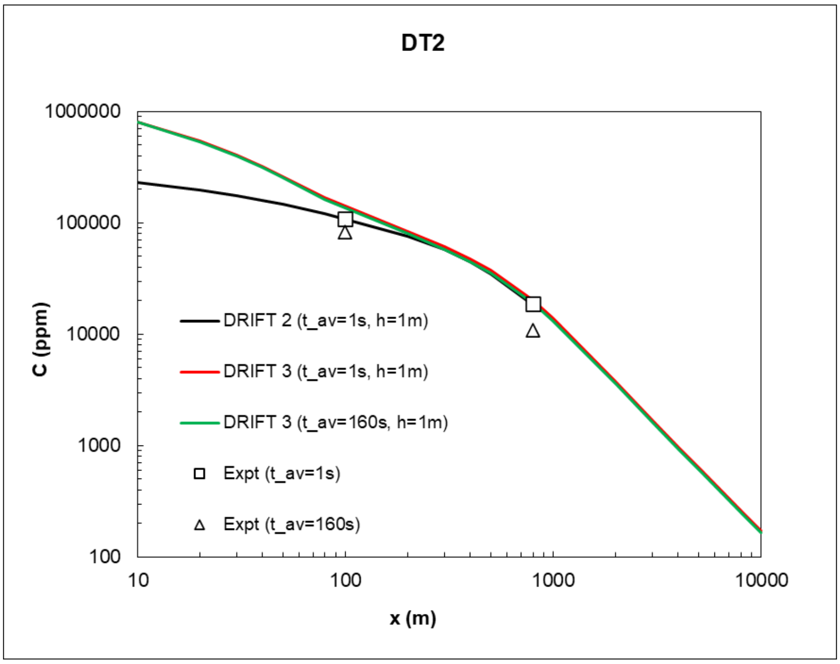

Figure A2- 12 Centreline concentration predictions for Desert Tortoise Trial 2.

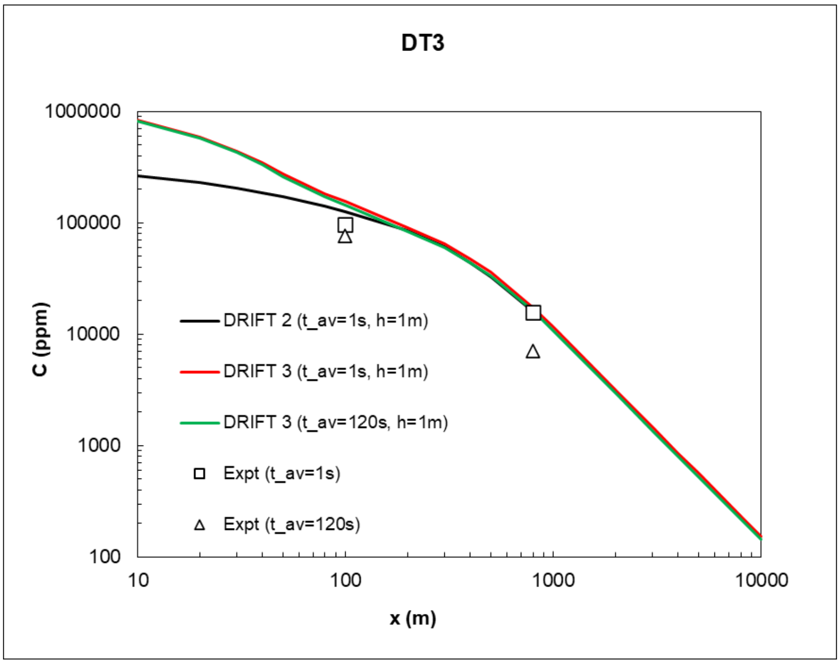

Figure A2- 13 Centreline concentration predictions for Desert Tortoise Trial 3.

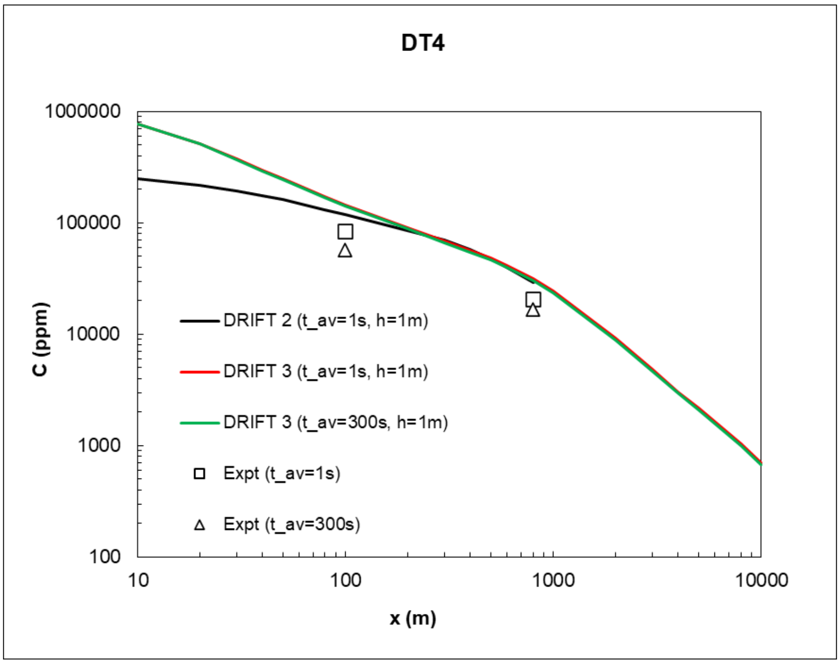

Figure A2- 14 Centreline concentration predictions for Desert Tortoise Trial 4.

A2.4 Goldfish

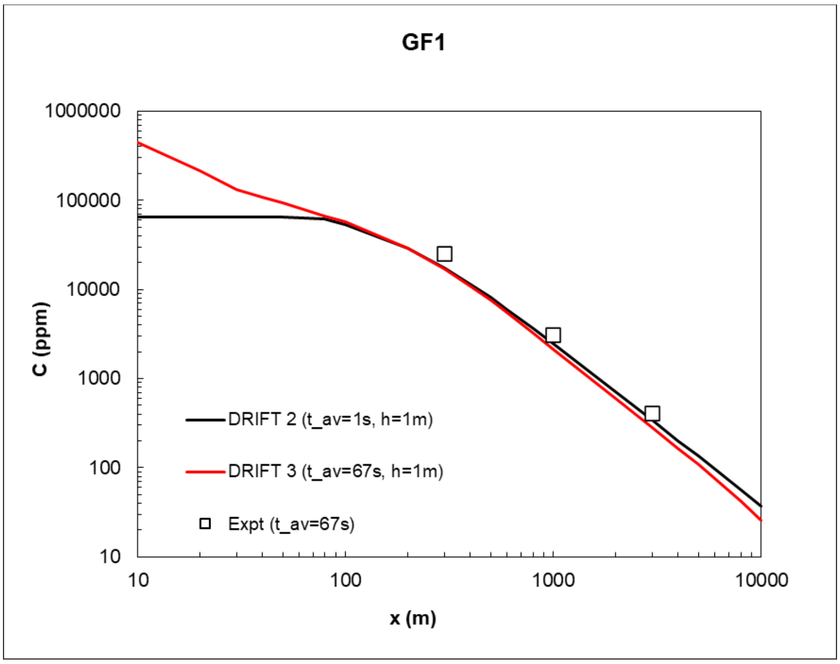

Figure A2- 15 Centreline concentration predictions for Goldfish Trial 1.

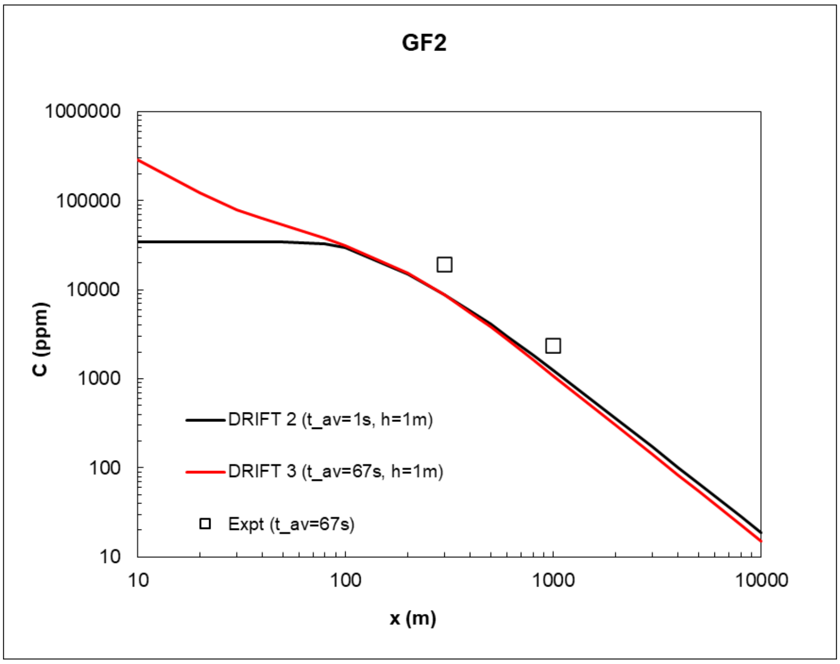

Figure A2- 16 Centreline concentration predictions for Goldfish Trial 2.

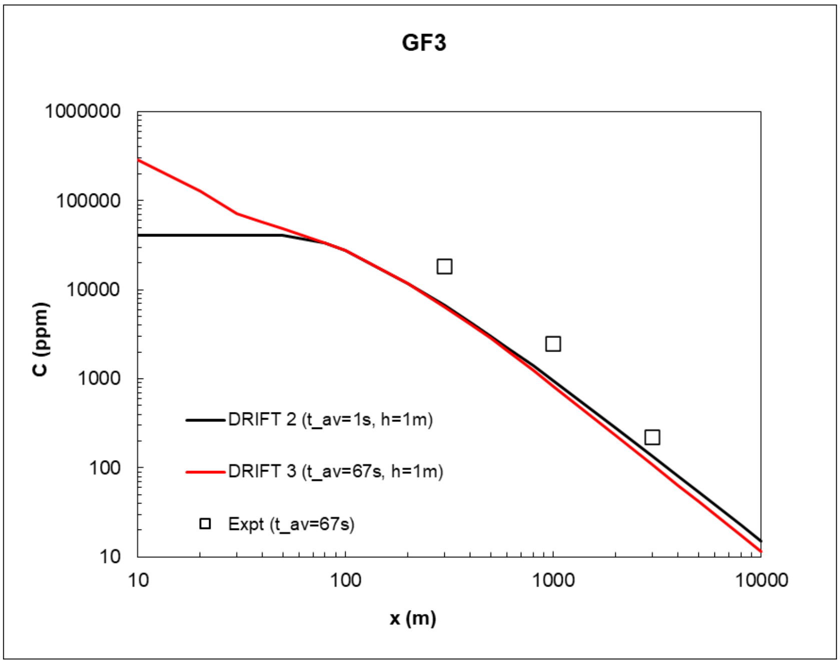

Figure A2- 17 Centreline concentration predictions for Goldfish Trial 3.

A2.5 Prairie Grass

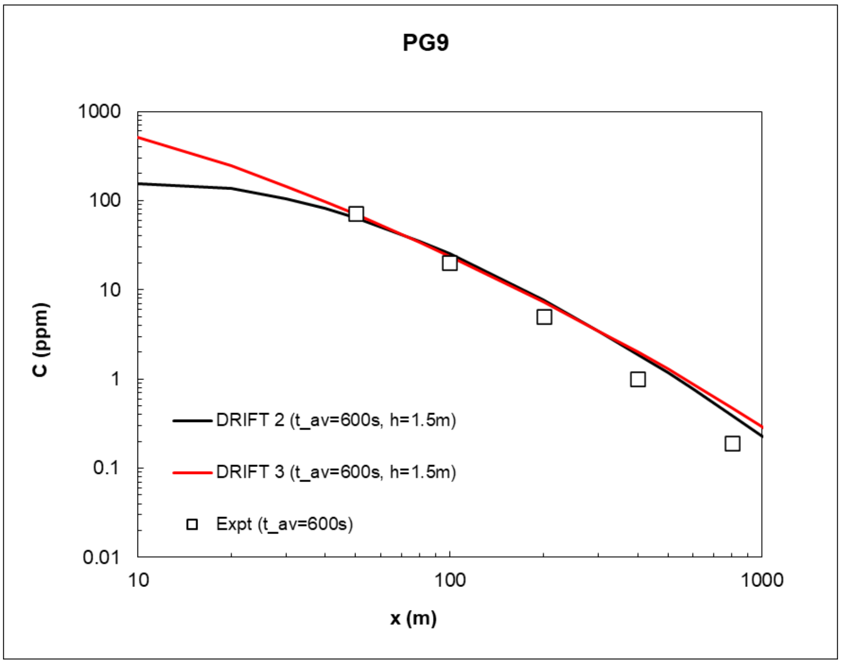

Figure A2- 18 Centreline concentration predictions for Prairie Grass Trial 9.

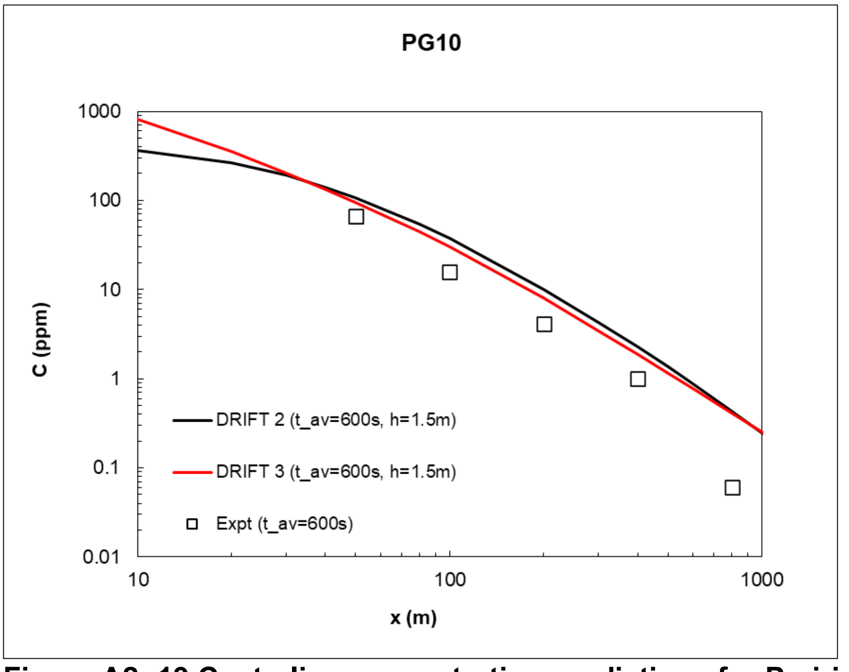

Figure A2- 19 Centreline concentration predictions for Prairie Grass Trial 10.

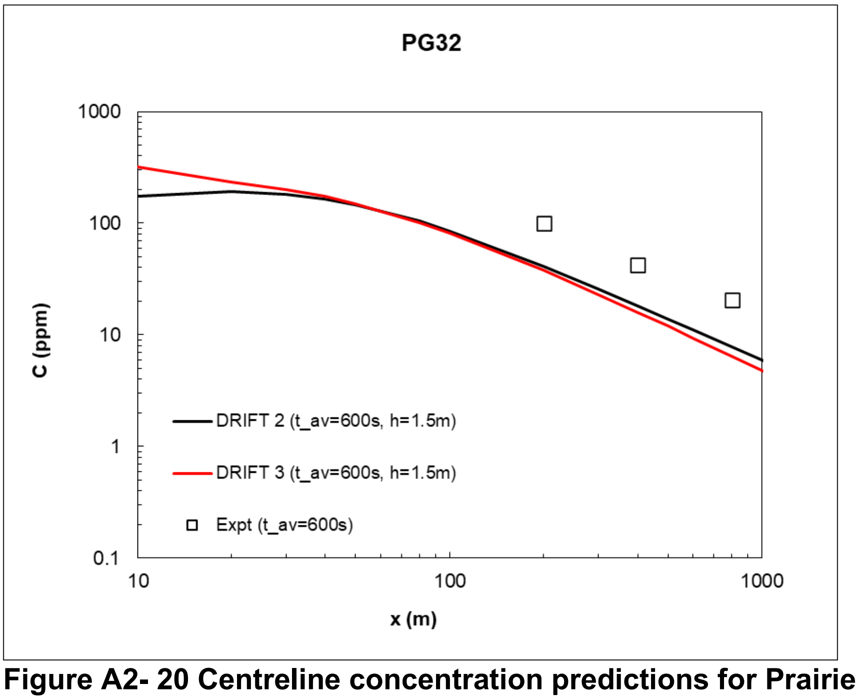

Figure A2- 20 Centreline concentration predictions for Prairie Grass Trial 11.

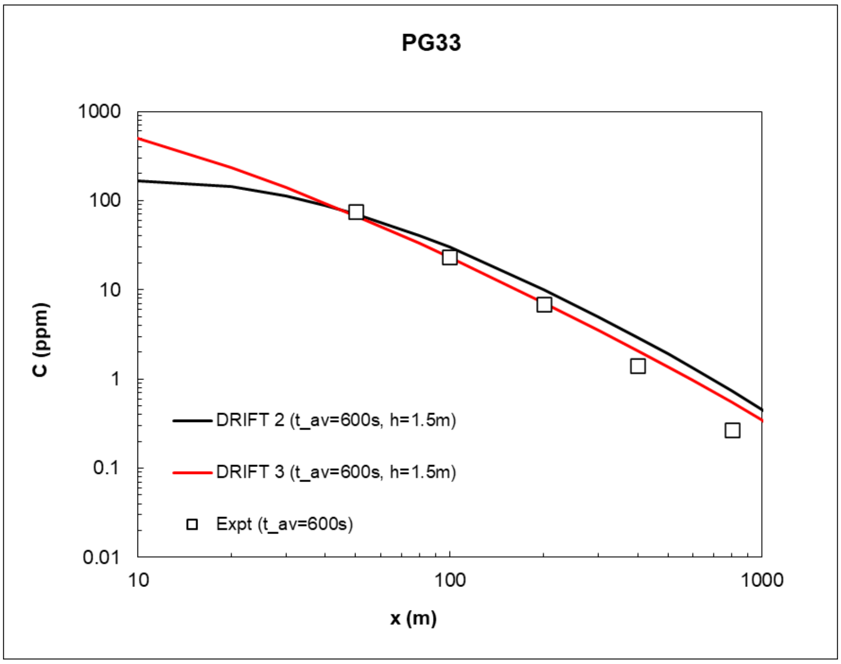

Figure A2- 21 Centreline concentration predictions for Prairie Grass Trial 33.

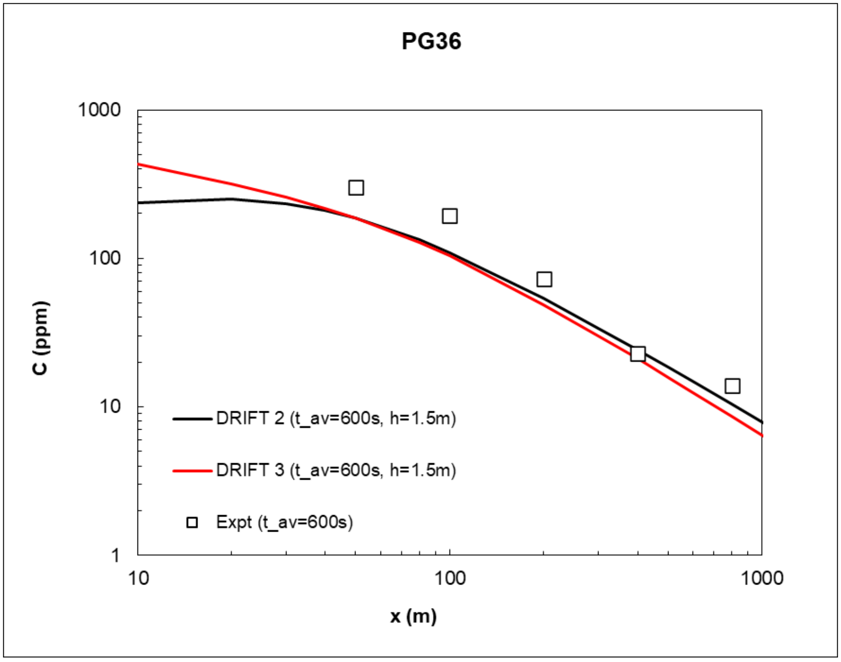

Figure A2- 22 Centreline concentration predictions for Prairie Grass Trial 36.

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