VALIDATION OF THE URBAN DISPERSION MODEL (UDM)

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INTRODUCTION

Dstl's Urban Dispersion Model (UDM) is a Gaussian puff model designed to handle dispersion in the urban environment (*Hall et al*, 2001). A substantial verification and validation programme is in progress. This paper provides the results of a comparison between measured and modelled results for selected trials from three field data sets: the Macdonald trials, experiments from the Mock Urban Setting Test (MUST) and the Urban 2000 field campaign at Salt Lake City. These provide a range of scales to test the model.

EXPERIMENTAL DATA

Macdonald

Macdonald's (*Macdonald*, 1996,1997) experiments were conducted at the UMIST Environmental Technology Centre Dispersion Test Site at Altcar, UK, during the summers of 1995 and 1996. The experiments comprised 1/10 scale measurements of flow and dispersion at short range in an urban array made of 1.1m cubical obstacles, placed in layouts of varying width to height ratio in staggered or in-line configurations. Three obstacle area densities of 6.25%, 16% and 44% were used. Releases were at or near the ground or, using propylene tracer gas. This was detected using up to 12 Ultra Violet Ion Collectors (UVIC®s), placed in rows across the array, measuring lateral and vertical concentration profiles separately. Meteorological data were input into the model as a single average value for each experiment (a 10-minute release).

MUST

MUST (*Biltoft*, 2001) was conducted at Dugway Proving Ground, Utah, throughout September 2001. 119 shipping containers were arranged in 12 rows around a 32m tower, which served as a platform for meteorological observations and for samplers to measure the vertical tracer sampling. The obstacle area density was about 13% .Propylene tracer gas was used for 5 puff releases and 63 continuous releases. The source could be positioned at any of 37 different locations, and 6 differing heights over the 68 trials, at the ground or on top of a container. The concentration of the tracer gas was measured within the array using up to 80 photo ionisation detectors, including forty Threshold Ion-pair-Production Spectroscopy detectors (TIPS) placed in four rows to observe the influence of the array on lateral puff and plume spreading. The rows modelled in this validation were located at 41m, 72m, 103m and 134m from the southern edge of the array and are referred to as Lines 1-4 respectively here. Data from these were converted to 15-second averages for the purpose of comparison with the model. Meteorological measurements were obtained from a 32m tower in the middle of the array, with four smaller towers and six Portable Weather and Information Display Systems (PWIDSs) being located in and around the array, with two additional 16m towers were located 30m north and south of the array. Analysis of the data collected by the 16m tower south of the array identified 18 trials as suitable for use in this initial validation study. For these, a combination of the South 16m and Central 16m and 32m meteorological readings were used, depending on their availability. The wind observations were processed into 1-minute average and full trial (15-minute) average periods to produce 36 different data sets. These represented the types of data the model would receive if accepting input from a local meteorological station, or if taking a forecast for local conditions. As experiments were conducted at varying times of the day and night, Pasquill-

Gifford stability categories were determined as Moderately Unstable (B), Slightly Unstable (C), or Slightly Stable (E). For each experiment, comparisons with simulation were made at the point where the tracer release ended. The majority of trials conducted, and all examined here, involve the source being placed upwind of Line 1. For one of the trials, the source was placed outside the array, upwind of the south-eastern container.

Urban 2000
Urban 2000 (*Allwine et al,* 2002), conducted in Salt Lake City, Utah, during October 2000, was a full scale experiment to examine meteorology and atmospheric dispersion within an urban area, containing over 60,000 buildings. Three different scales of dispersion were investigated: an individual building area, located adjacent to the source; a 'downtown area' of 6 blocks and the whole urban domain. During six of the ten overnight 'Intensive Operating Periods' (IOPs), sulphur hexaflouride tracer (SF_6) was released for three 1-hour periods, each followed by a 1-hour gap. This release was from a ground level source, approximately 30m south of the Heber Wells Building (400S 200E). Over 115 samplers were deployed throughout the area to measure the dispersion of the tracer, 32 of them taking readings within the urban domain on arcs at 2, 4 and 6km north-west of the release, identified as Arc1, Arc2, and Arc3 respectively here. Extensive meteorological measurements were taken throughout the campaign. Two meteorological stations were of particular importance to this validation study, a rooftop Sound Detection and Ranging instrument, SODAR, on the Bennett Federal Building on the north-eastern side of the Downtown Area and two instruments located at Raging Waters, approx. 4km south-west of the release, at which were a 10m tower and a Doppler SODAR. At each location, a vertical wind profile was derived by curve fitting the SODAR data to produce measurements at 3 or 4 heights at each location, for runs with two averaging times of 5-minute (raw) and 1-hour updates, for the same reasons as with the MUST comparison. The Pasquill-Gifford stability criterion was taken as slightly stable (E). The results here are concerned with IOP Nos 5, 9, 10. IOP 5 experienced very light and variable wind speeds, whereas IOP 9 and 10 experienced high wind speeds and less variability, to such a degree that the release rate was doubled during IOP 9.

RESULTS
The summary statistics used here are: Fractional Bias (FB), Normalised Mean Square Error (NMSE), and the proportion of model predictions within a factor of 2 or 3 of the experimental values (FA2 and FA3).

Macdonald
Table 1. *Macdonald Results for Plume Width & Peak Concentration*

	Plume Width			Peak Concentration		
Area Density	FA2	FB	NMSE	FA2	FB	NMSE
Unobstructed	0.92	0.37	0.24	0.40	-0.45	0.55
6.25%	0.92	-0.11	0.15	0.88	0.42	0.89
16%	0.74	0.45	0.48	0.71	0.45	1.19
44%	1.00	0.18	0.04	0.86	-0.05	0.15

Peak concentrations and plume widths were obtained from a Gaussian fit to both sets of concentration data (observed and modelled) for comparison**.** Table 1 shows the comparisons between observed and predicted values of these, recorded on each run. The plume width measurements show that 84% are within FA2 and all of the predictions are within a factor of 3. The 44% area density comparison is particularly close, with all the data points within FA2 and very similar values of both the fractional bias, NMSE and peak concentration. The peak concentration estimates at 6.25% area density also have a high proportion, 71%, within FA2.

MUST
It was also possible to fit Gaussian distributions to the measured concentrations here, but only to each line where the plume is deemed to be sufficiently captured (i.e. the profile has enough data to be able to estimate its shape and peak parameters). 29 crosswind profiles were obtained for each type of meteorological input out of a possible 72 (18 trials with four lines).

Table 2. MUST Results for Plume Width & Peak Concentration

	Plume Width				*Peak Concentration*			
	FA2	FA3	FB	NMSE	FA2	FA3	FB	NMSE
15 Min	0.79	0.90	-0.04	0.37	0.50	0.60	0.02	1.85
1 Min	0.93	0.96	-0.04	0.13	0.75	0.82	0.17	1.54

Table 2 shows the comparison between the model predictions and the experimental results. It can be seem that the 1-minute averaged meteorological data provides better predictions, as a higher proportion of these are with the FA2 and FA3 bounds. The model performs well again on fractional bias and NMSE, although it is clear that the error in the predictions, indicated by the NMSE, is greater for the peak concentration results than for the predictions of plume width, consistent with other results presented here.

Urban 2000
The sampler arcs were used to provide cross wind profiles for 1-hour average periods which was the maximum sampling time of some samplers. While three arcs were modelled, Arc3 failed to capture the plume in the majority of cases, so these results were not used.

Table 3: *Urban 2000 Results for Plume Width & Peak Concentration*

	Plume Width			Peak Concentration			
5 Min - 2km	FA2	FB	NMSE	FA2	FA3	FB	NMSE
5 Min - 4km	1.00	0.07	0.08	0.55	0.89	0.65	0.83
1 Hr. - 2km	0.96	0.27	0.12	0.41	0.77	0.58	0.80
1 Hr. - 4km	1.00	0.33	0.16	0.61	0.94	0.21	0.47
	0.96	0.47	0.31	0.59	0.76	0.27	0.52

Table 3, above, shows the comparison between the model's predictions and the experimental results. The same trend as observed in the MUST comparison is seen here, with the error being larger for the peak concentration than for the plume width. The majority of peaks are within FA3. IOP 5's light and variable wind speeds had a significant effect on the proportion of data within these limits, as this variability in the wind is very large for a sampling time of 1 hour. It is interesting to note that in some of the measures the average meteorological input gives a better comparison than the more accurate 5-minute updates.

Summary
It is useful to see all the comparison data plotted. This is done so for the plume width in Figure 1, showing the observed width versus the ratio of observed to predicted width.
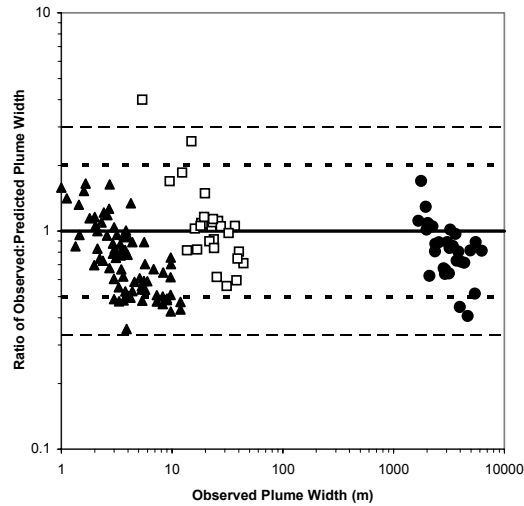
● Urban 2000 □ MUST ▲ Macdonald ——Ideal - - -FA2 − − −FA3

Figure 1. Comparisons of observed versus predicted data for plume width.

There appears to be no bias with source distance in the comparison; the observed/predicted ratio is mostly within FA2 and equally spread for MUST and Urban 2000. Comparison with Macdonald's data is also mostly within FA2, but shows a bias towards under-prediction by the UDM.
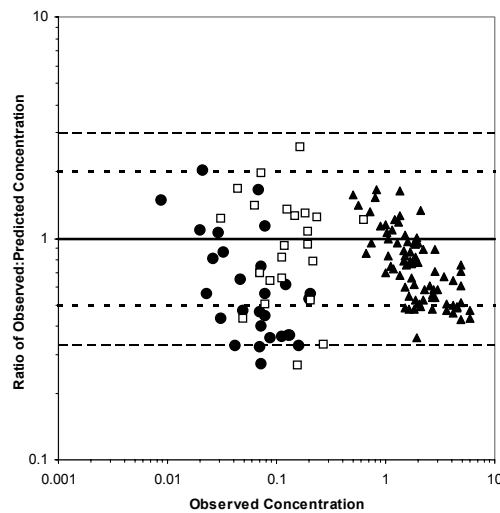
● Urban 2000 □ MUST ▲ Macdonald ——Ideal - - -FA2 − − −FA3

Figure 2. Comparisons of observed versus predicted data for peak concentration.

Figure 2 shows a similar plot for the dimensionless peak concentration. Here, most of the comparisons remain within FA2 for all three data sets, but there is an overall bias towards the model under predicting, so that the major fraction of the data outside FA2 is low. This is at least

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partly due to the scale of the releases. There is a greater spread of data about the centreline in this plot, with more of the points being further from the centreline than for the plume width predictions. This is to be expected from the results shown earlier, as the values of NMSE and fractional bias for peak concentration were larger than those for plume width: both plume width and peak concentration comparisons are generally very good.

CONCLUSIONS AND FUTURE WORK

The results show that the UDM has performed well against these examples of short, medium and long-range field studies, accurately recreating experimental observations. Validation of the UDM will continue against further trials from both the MUST and the Macdonald data sets to compare vertical plume measurements, and perform further analysis of the Urban 2000 data.

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