Note DAPPLE - EnFlo 01
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Initial dispersion experiments in the EnFlo wind tunnel

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1. Introduction

This note describes results of preliminary dispersion experiments using a 1:200 scale model of the Marylebone Road – Gloucester Place site in the EnFlo wind tunnel.

2. Steady emissions

Ground level concentrations have been measured through the street system for ground level sources in York Street for a wind direction of -45˚ in model co-ordinates (i.e. approximately from the SW). Model co-ordinates are defined by:

Origin at centre of Marylebone Rd-Gloucester Pl intersection
x +ve to the East along Marylebone Rd
y +ve to the North along Gloucester Pl
Wind direction 0 degs in direction of +ve x
Wind directions +ve clockwise

The source was located at 5 points along York Street from Gloucester Place (x = 0) to Upper Montagu Street (x = -105m), with the location x = -55m being the junction with Thornton Place. Figure 1 shows the layout of the model and the source and receptor locations used. The colour coding denotes building height ranges. The model was constructed at 1:200 scale from simple, block-shaped buildings with flat roofs.

The approach flow was a nominally 1m deep boundary layer with surface roughness length equivalent to 0.3m at full scale. The reference speed, U, was measured at the boundary layer edge with an ultrasonic anemometer. The majority of runs used a reference speed of about 2.5m/s, though other speeds were used to demonstrate that dispersion behaviour was unaffected by the source conditions.

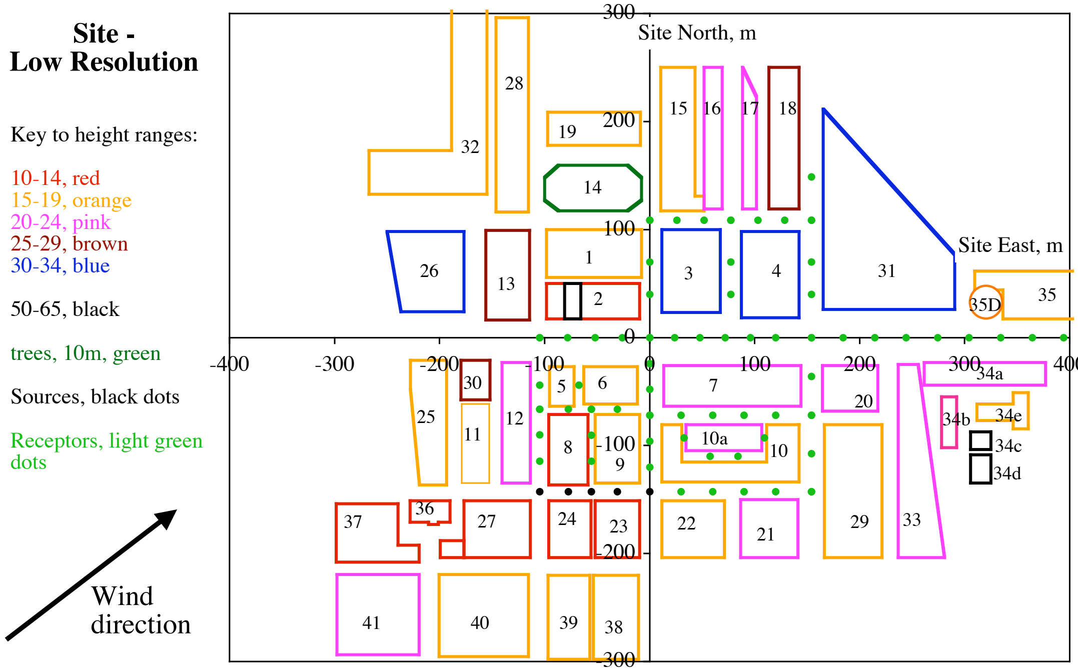

Figure 1. Layout of the 1:200 scale model showing source and receptor locations.

Mean concentrations were made non-dimensional as $C^* = CUH^2/Q$, where C is the measured mean volume concentration of the emission, U the reference wind speed at the boundary layer edge, H a nominal building height of 0.11m (22m at full scale) and Q the volume emission rate. Results are plotted in Figure 2 as a function of straight line distance from source to receptor, R/H.

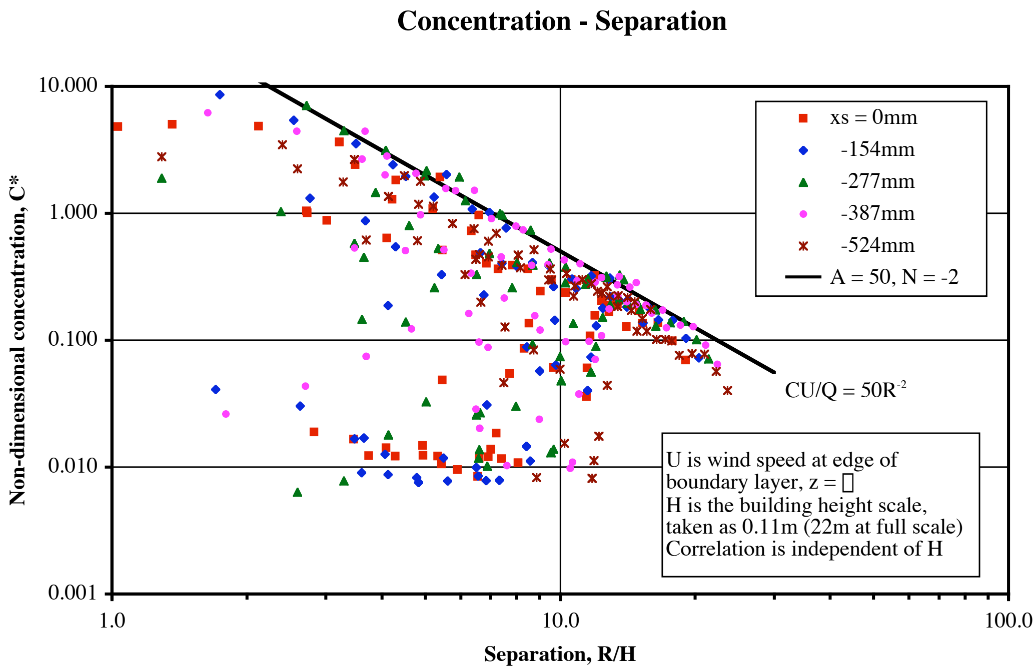

Figure 2. Non-dimensional concentrations as a function of separation, R/H.

The upper bound to the data is reasonably well fitted by the line:

$$CUH^2/Q = 50(R/H)^{-2}$$

and if we assume that the wind speed just above roof level, U_H, is about 0.5U then this becomes:

$$CU_H/Q = 25R^{-2}.$$

Some additional runs treated the detailed effects of source position across York Street. In the main body of experiments the source was in the street centre and some sensitivity to location was found at short fetches.

3. Transient emissions

The source was positioned in York Street x = -308m, y = -143m (origin centre of Marylebone Road, Gloucester Place intersection) and was held on for 10 seconds. Measurements were made at ground level in Gloucester Place, Marylebone Road, Baker Street and Bickenhall Street, using a fast flame ionisation detector (FFID), frequency response about 100Hz. Approximately 70 repeat emissions were used to create ensemble averaged concentration records. This was done separately for the rising edge and the falling edge of the signal, rather than for the whole signal. A sample ensemble averaged trace is shown below, in Figure 3, together with the source state (on/off).

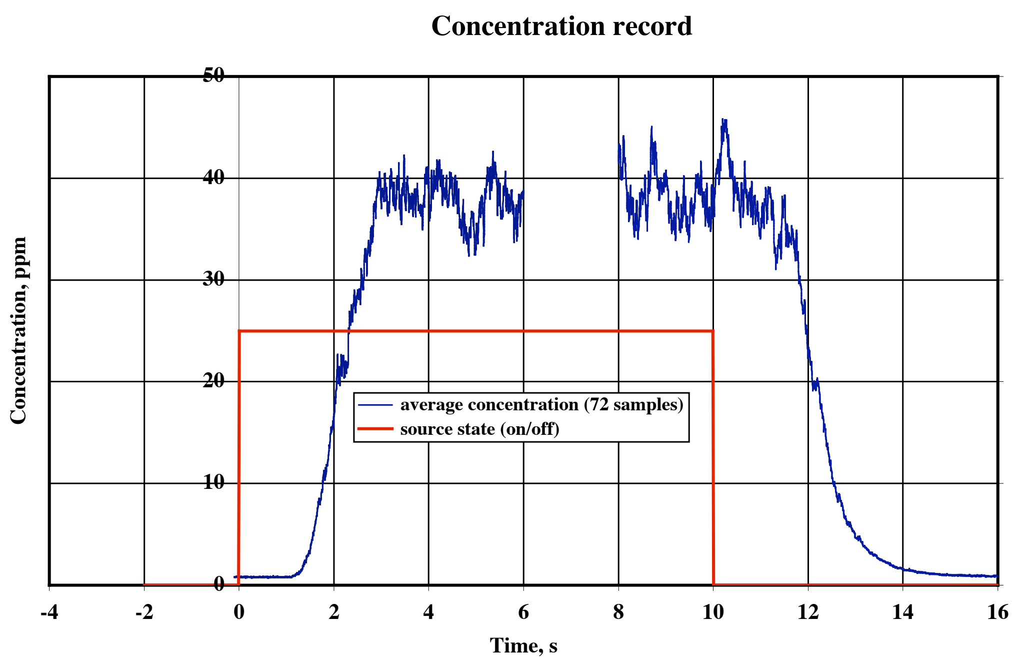

Figure 3. Example ensemble average concentration signal and source state.

A time of flight was obtained for both the leading and trailing edge, together with the characteristic rise and fall time scales. The travel time, T_{50}, was measured from the time of source switching to the concentration becoming 50% of its average central value (approximately that between 3 and 11 seconds in the trace above). The rise time, ΔT_{50}, was measured between the times at which the concentration attained 25% and 75% of the central value and vice-versa for the fall time. Results were made non-dimensional as, for example, UT_{50}/H, where U is the tunnel reference speed (at the edge of the boundary layer) and H a characteristic building height (taken to be 22m).

A set of runs was included in which the reference speed was changed, demonstrating that the time scales were controlled solely by the tunnel speed and were not significantly affected by the source operation. These results are shown below in Figure 4.

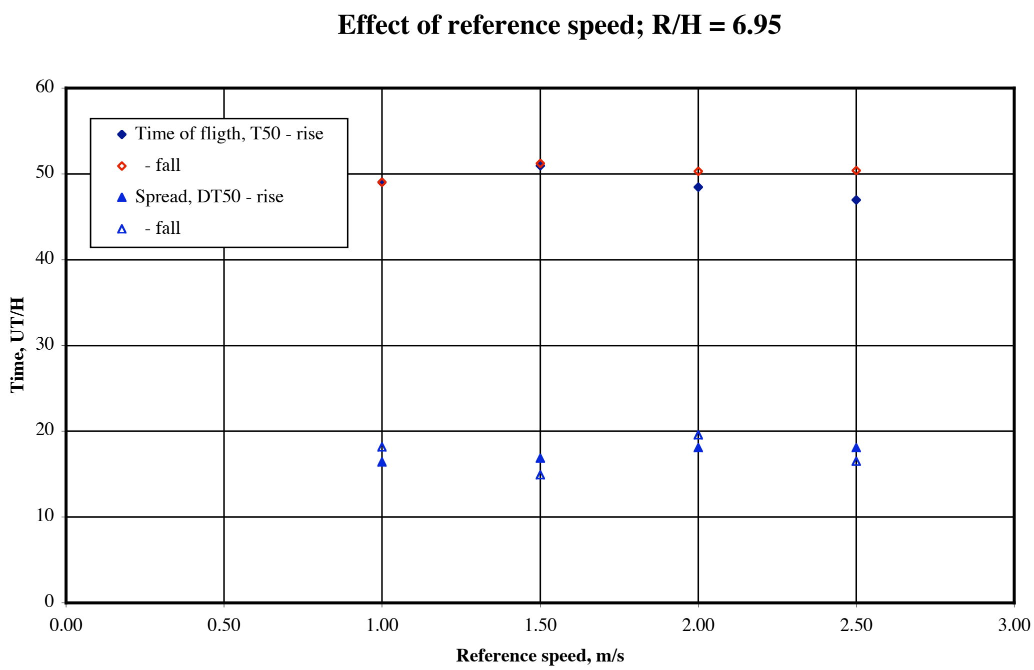

Figure 4. Non-dimensional travel time, rise time and fall time at a fixed receptor as a function of tunnel speed.

In the caption, R is the straight-line distance from the source to the receptor – the receptor was in Marylebone Road. The full data from all sources is shown below, in Figure 5, as a function of R/H. The figure shows that the travel time steadily increases with increasing fetch, with UT_{50}/H typically in the range from 6R/H to 9R/H. Taking U/2 as an estimate of the wind speed just above roof level, U_H, leads to a travel time estimator of:

$$T_{50} \approx 3.5R/U_H$$

At full scale with an above-roof wind speed of 7m/s this implies that T_{50} is 50s at 100m,100s at 200m and, assuming the relationship remains valid, 250s at 500m.

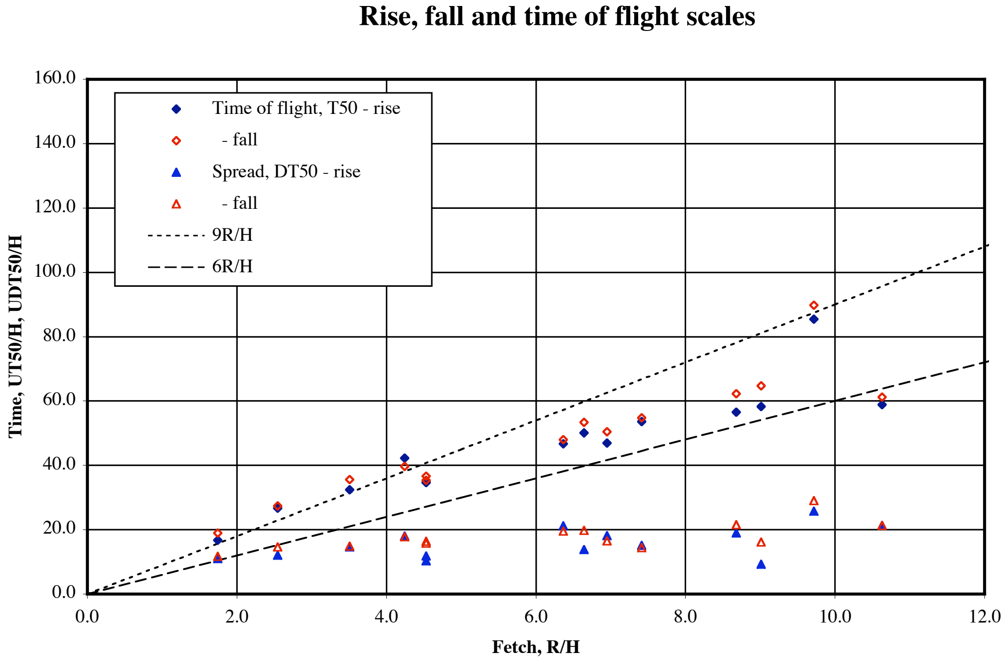

Figure 5. Non-dimensional travel time, rise time and fall time as a function of separation between source and receptor, R/H.

The rise and fall times increase rapidly at short range (R/H < 2) and more slowly thereafter. In general, the fall time is somewhat longer than the rise time. Some of the initial rapid growth may be due to the experimental set-up as the source control valve was placed in the road, leading to some blockage there. In future, a better arrangement will be used, perhaps with the valve inside one of the buildings, but that was not possible for these initial experiments. On the other hand, the effects seen may solely reflect rapid mixing of the emission in the 'source' street. The non-dimensional rise and fall times lay in the range from 10 to 20, for R/H between about 2 and 11. At full scale, with an above-roof wind speed of 7m/s, this implies time constants between 15 and 30s.

Individual realisations differ greatly from the ensemble mean, as is clear from comparison of Figure 6 below with the ensemble mean previously shown (these both refer to the same source and receptor). The central value for the ensemble average is approximately 40ppm and the peak in the realisation shown is five times greater. The travel times are also different. Results for locations near the plume edge can be even more variable.

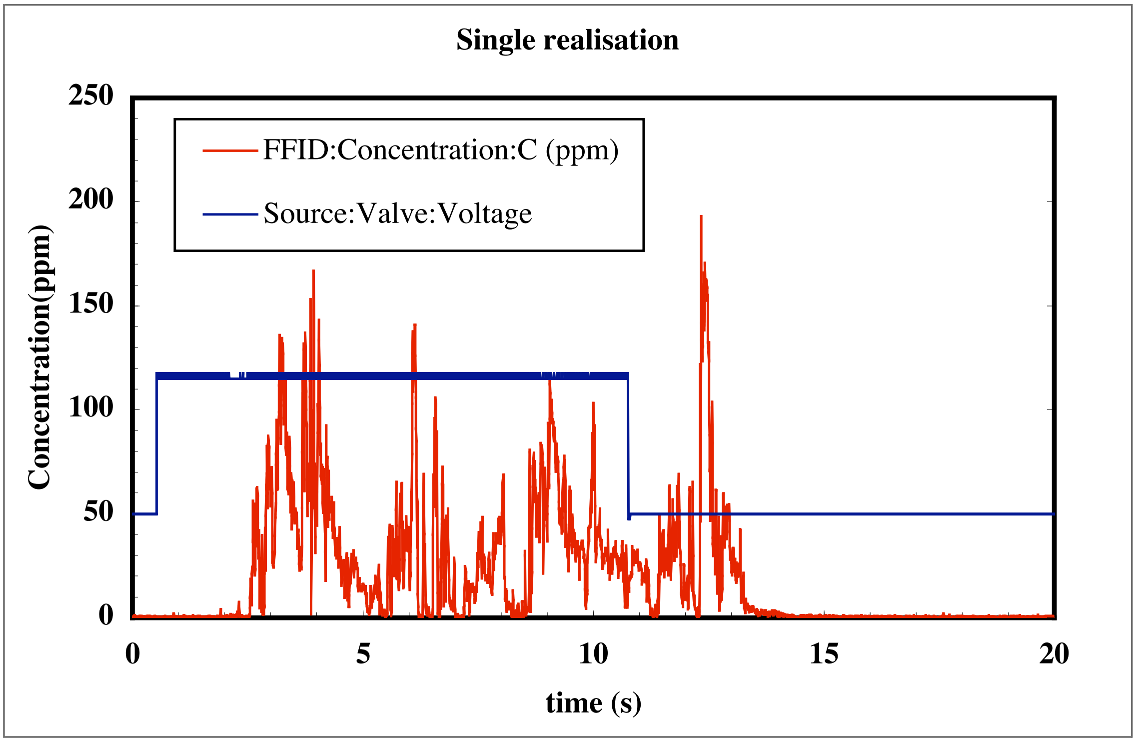

Figure 6. Example concentration signal and source state for a single release.

4. Comments

These are preliminary results, undertaken to demonstrate the capabilities of the wind tunnel simulations and to provide data of use in planning field tracer studies. Some further results of this sort will treat wind direction effects for continuous emissions, concentration fluctuations and the dispersion of short duration emissions. Three release durations, □, will be used, one larger than the typical times of flight, one of similar magnitude and one shorter (say, □= 4, 2, 1s). Attention then will focus on obtaining a more appropriate upstream boundary layer, with roughness length equivalent to about 1m and zero plane displacement equivalent to about 22m, and investigating the effects of the extent of the model, especially the upstream fetch.