Decay of Maximum Concentrations in an Urban Area

Alan Robins
EnFlo, November, 2003

1. Introduction

In our first DAPPLE note, Robins and Cheng (2003), we showed that wind tunnel, ground level concentration data, C(x, y, 0), obtained with the site model and using a point emission in York Street had an upper bound that could be expressed by:

$$C_{\max} U_{ref} H^2 = 50(R/H)^{-2} \qquad (1)$$

where U_{ref} is the reference speed at the edge of the boundary layer, H the building height, Q the (steady) emission rate and R the straight line distance between source and receptor. We now test this result against two other data sets, one from the wind tunnel and one from Salt Lake City (Hanna et al, 2003).

2. Results

2.1 DAPPLE experiments, Figure 1

This is taken directly from Robins and Cheng (2003) and shows $C^*=CU_{ref}H^2/Q$ as a function of R/H.

2.2 Regular array, Figure 2

This is a similar presentation of ground level concentration data measured in regular arrays of blocks (Martinie, private communication) in the EnFlo wind tunnel. The source and receptors were all within the arrays.

Block height: 125mm
Block plan: 250 x 500mm
Number of blocks in array: 16 or 20
Spacing between blocks: 125mm
Orientations: 30, 45, 60 degs (90 degs is normal to the longer face)

Other experimental details are as in by Robins and Cheng (2003). The figure shows $C^*=CU_{ref}H^2/Q$ as a function of R/H.

2.3 Salt Lake City, Figure 3

Figure 3 is based on data from Salt Lake City (Hanna et al, 2003). There were 6 periods of measurements (designated IOP 2, 4, 5, 7, 9, 10), providing the 18 sets of maximum, hourly averaged, ground level concentrations that are tabulated in the paper as a function of radius from the source. The experiments were all undertaken at night in light wind conditions; each emission lasted for one hour. The paper gives a table containing C_{max}/Q as a function of radius, R, for each of the 18 data sets. The figure shows $C^*=C_{max}U_H H^2/Q$ as a function of R/H. The mean building height is assumed to be 15m (though, as we see later, this is unimportant) and the wind speed at 23m is used as the reference, U_H.

3. Discussion

Both sets of wind tunnel data are well fitted by equation (1). In the wind tunnel, the wind speed just above roof level, U_H, is approximately 50% of U_{ref} so (1) can be rewritten as:

$$C_{\max} U_H H^2 \approx 25 (R/H)^{-2} \qquad (2)$$

which is a good fit to the upper bound of the Salt Lake City data, which is remarkable in that the field experiments were undertaken in light wind, night time conditions, not the neutral flow of the wind tunnel work. This result can be more simply expressed as:

$$C_{\max} U_H R^2 = 25 \qquad (3)$$

in which the building height no longer appears. We now need to test (3) against further experimental data, in particular to discover how universal it might be. For example, does it hold when the wind is aligned with the street network? We also need to understand the dominant processes leading to the concentration decay law.

The Salt Lake City data suggests that the limit of application of equation (3) is about R/H < 250 – standard dispersion behaviour must appear further downwind when the plume becomes deep compared with the building heights. This is probably an upper limit as the field work was carried at night when wind speeds were low and vertical plume spread will be more rapid in most other wind and stability conditions.

Results from Los Angeles, included in Hanna et al (2003), have not been used as the data given is for an averaging time of 2.5 minutes with the release duration being 5 minutes. This is not consistent with the other data sets, though use may later be made of this work once more comprehensive reports become available.

4. References

Robins, A G and Cheng, H, 2003. Initial dispersion experiments in the EnFlo wind tunnel. Note DAPPLE - EnFlo 01, University of Surrey, May, 2003.

Hanna, S R, Britter, R and Franzese, P, 2003. A baseline urban dispersion model evaluated with Salt Lake City and Los Angeles tracer data. Atmos. Environ., 37, 36, 5069 – 5096.

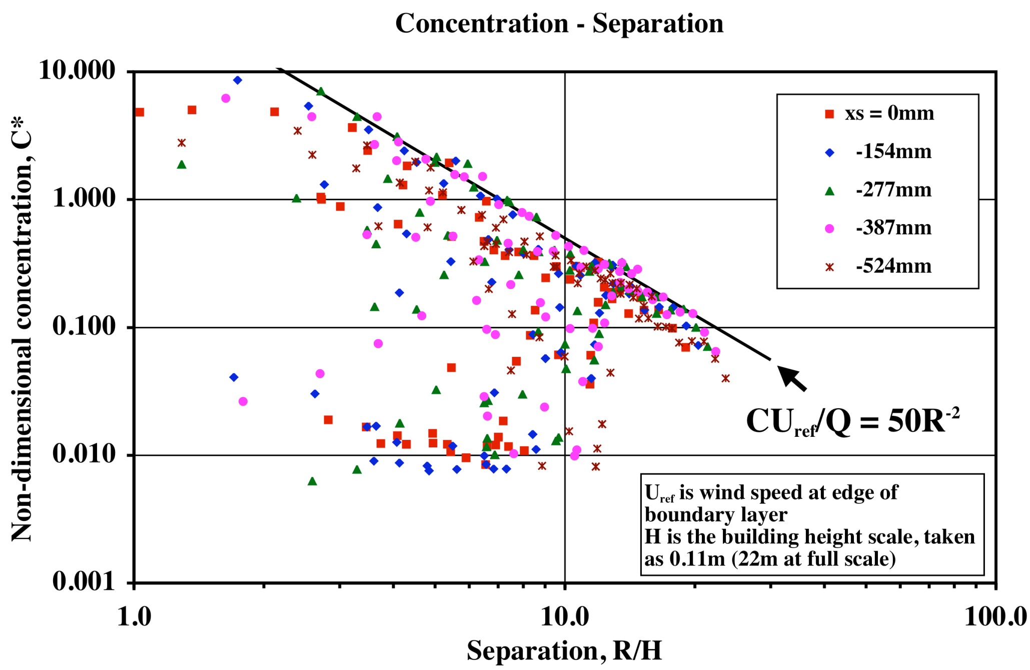

Figure 1. Non-dimensional concentration, $C^*=CU_{ref}H^2/Q$, as a function of separation, R/H for DAPPLE experiments; Robins and Cheng (2003).

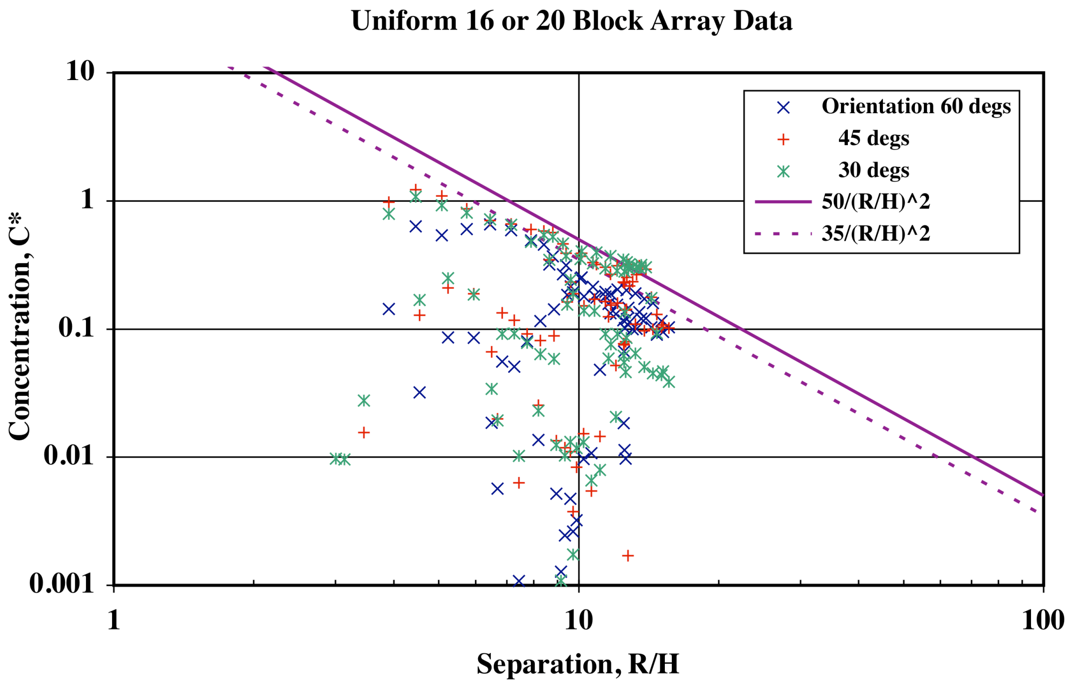

Figure 2. Non-dimensional concentration, $C^*=CU_{ref}H^2/Q$, as a function of separation, R/H from uniform array experiments; Martinie (private communication).

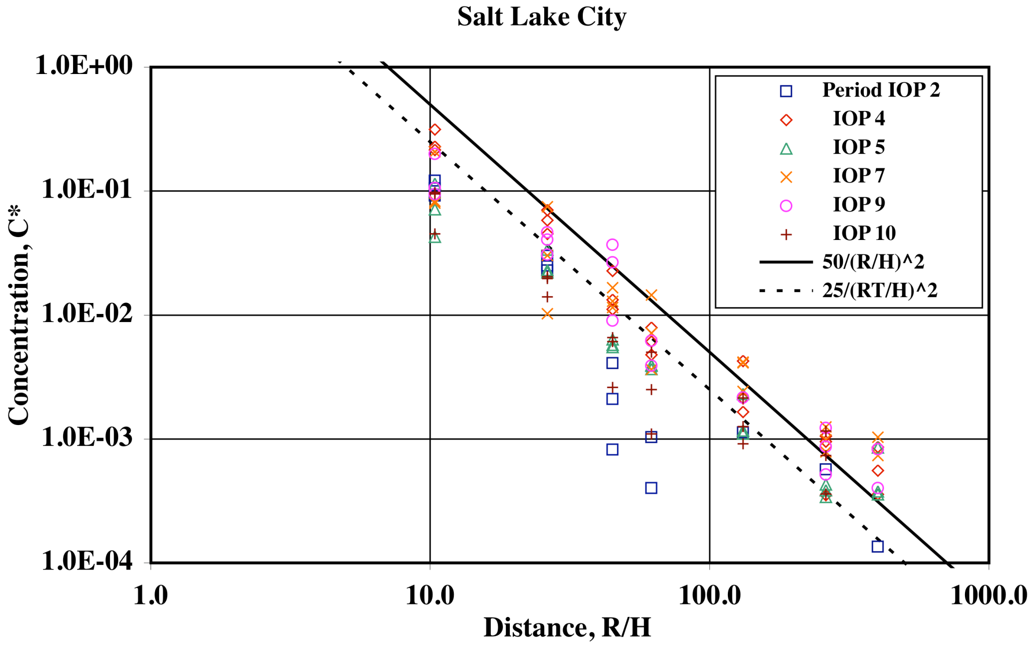

Figure 3. Non-dimensional concentration, $C^*=CU_H H^2/Q$, as a function of separation, R/H from Salt Lake City data; Hanna et al (2003).