COMPARISON OF PREDICTIONS FROM THE BASELINE URBAN DISPERSION MODEL WITH DAPPLE TRACER FIELD EXPERIMENTS

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1. Introduction

In this note the measurements from the first DAPPLE tracer field experiment are interpreted in the context of a comparison with predictions from the Baseline Urban Dispersion model developed in [1].

2. The baseline urban dispersion model

The baseline urban dispersion model is a Gaussian-plume based model for simulating the concentration field resulting from near-surface releases in urban canopies [1], accounting for low wind speeds and large initial mixing in the urban area. For the ground-level concentration on the plume centre-line, the model prediction is of the form:

$$CU/Q = 1/(\pi\sigma_y\sigma_z)$$

where σ_y and σ_z are given for two scenarios:

(a) for all conditions except a sunny summer day

$$\sigma_z = \sigma_{z0} + 0.14x/(1+0.0003x)^{1/2}$$

$$\sigma_y = \sigma_{y0} + max(0.16, 0.25/U)x/(1+0.0004x)^{1/2}$$

(b) for sunny summer days

$$\sigma_z = \sigma_{z0} + 0.24x(1+0.001x)^{1/2}$$

$$\sigma_y = \sigma_{y0} + max(0.32, 0.25/U)x/(1+0.0004x)^{1/2}$$

where $\sigma_{z0} = \sigma_{y0} = H_r/2$ and C (kg/m^3) is the maximum concentration that would be measured at a ground-level receptor located on an arc a distance x (m) from the source. This is for a continuous emission with release rate Q (kg/s) at or near ground level and for a representative

wind speed *U (m/s)*. It is not clear what prescription of wind speed (U) is most appropriate to use to represent the plume growth in the urban topography. Though the baseline urban dispersion model is presented here in terms of the maximum concentration downwind of the source, the result could be restated that the concentrations at any receptor a distance R from the source in any direction should be smaller than that provided by the model, with R replacing x. This observation may be particularly useful for operational modelling.

3. The experimental data

The experiment provided a time series of sequential 3 minute averaged data over a 30 minute time period at 9 receptor sites (one of the 10 receptors failed, and one was at elevation and the remaining 8 were close to ground level). The release was for 15 minutes and at the short distances between source and receptor in the experiments it was anticipated that the release would appear as a continuous one. However, a clear "constant" concentration was never apparent in the concentration records.

We have chosen the maximum of the 3-minute averaged data from each receptor for comparison. The receptor positions, along with the concentration data, are tabulated below and are also shown on the area map in Figure 1. The average building height (H_r) was estimated to be 22m [2]; the mean wind speed (U) and direction (θ) were taken from the meteorological measurements (at the reference station atop the Westminster City Council building) to be 3m/s and 200°; the source release rate (Q) was taken from the tracer experiment data set and was 1.27×10^{-7}kg/s. These values were used for both the model predictions and for the normalization and non-dimensionalisation of the field experiment results. Essentially we are using meteorological data near the top of the "urban canopy".

Box Number #	**Distance from the source - *Direct, R (m)***	**Distance from the source *By the road (m)***	**Angle with wind direction, φ (°)**	**Concentration $C(kg/m^3)$**	**Non-dimensional concentration $CUHr^2/Q$**
1	200	200	67 (to the right)	1.14E-12	0.0131
2	200	250	38 (to the right)	-----	-----
3	120	160	28 (to the right)	9.58E-12	0.109
4	115	150	2 (to the left)	1.38E-11	0.158
5	115	150	2 (to the left)	1.20E-11	0.138
6	200	280	14 (to the right)	6.38E-12	0.0731
7	275	350	26 (to the right)	2.03E-12	0.0233
8	430	540	36 (to the right)	3.81E-13	0.00437
9	200	250	13 (to the left)	5.41E-12	0.0620
10	75	90	21 (to the left)	2.13E-11	0.244

4. Comparison and Interpretation

A comparison between model predictions and experimental measurements is shown in Figure 2 and 3 in dimensional and non-dimensional forms. The model does provide an upper bound for all the field measurement for conditions excluding summer days (the one closer to the DAPPLE experiment).

To consider this further, and assuming a Gaussian plume structure for the measured plume, estimates of the maximum concentrations on an hypothesised plume center-line (given the recorded mean wind direction and a model estimate for σ_y and σ_z) can be made and be compared with the corresponding predictions by the Baseline Urban Dispersion Model [1]. These calculations produced results in somewhat better agreement with the model, particularly closer to the source. However further from the source the estimated concentrations turned out to be much larger than the model predictions. This suggests that (a) the width of the measured plume may be larger than that assumed from [3] and/or (b) there is a preferred flow direction along the Marylebone Road with part of the plume not diffusing/dispersing but rather being advected along long, large roads and thereby establishing a preferred direction so that the center-line of the plume does not correspond to the reference mean wind direction.

It also has to be noted that the DAPPLE measurements are 3-minute averages. In the Baseline Model there is no particular mention about the averaging time to which the predictions correspond. Nonetheless the expressions for σ_z and σ_y of the model which are based on those given by the curves in [3] represent an averaging time of 10 minutes.

5. Conclusions

In this note, the DAPPLE field measurements were interpreted in the context of a comparison with predictions from the Baseline Urban Dispersion Model [1]. The model can be interpreted as providing an upper bound for any measured concentration downwind the source. The DAPPLE measurements fell well below the upper bound, supporting the arguments of the model.

References:

[1] Hanna S, Britter R and Franzese P (2003). A baseline urban dispersion model evaluated with Salt Lake City and Los Angeles tracer data. *Atmospheric Environment*, 37, 5069-96.
[2] Neophytou MK and Britter RE.(2004). A simple correlation for pollution dispersion prediction in urban areas. *DAPPLE Note / Cambridge 1*, January 2004.
[3] Hanna SR, Briggs GA and Hosker RPJr. (1982). Handbook on Atmospheric Diffusion, Editor: JS Smith, US Department of Energy

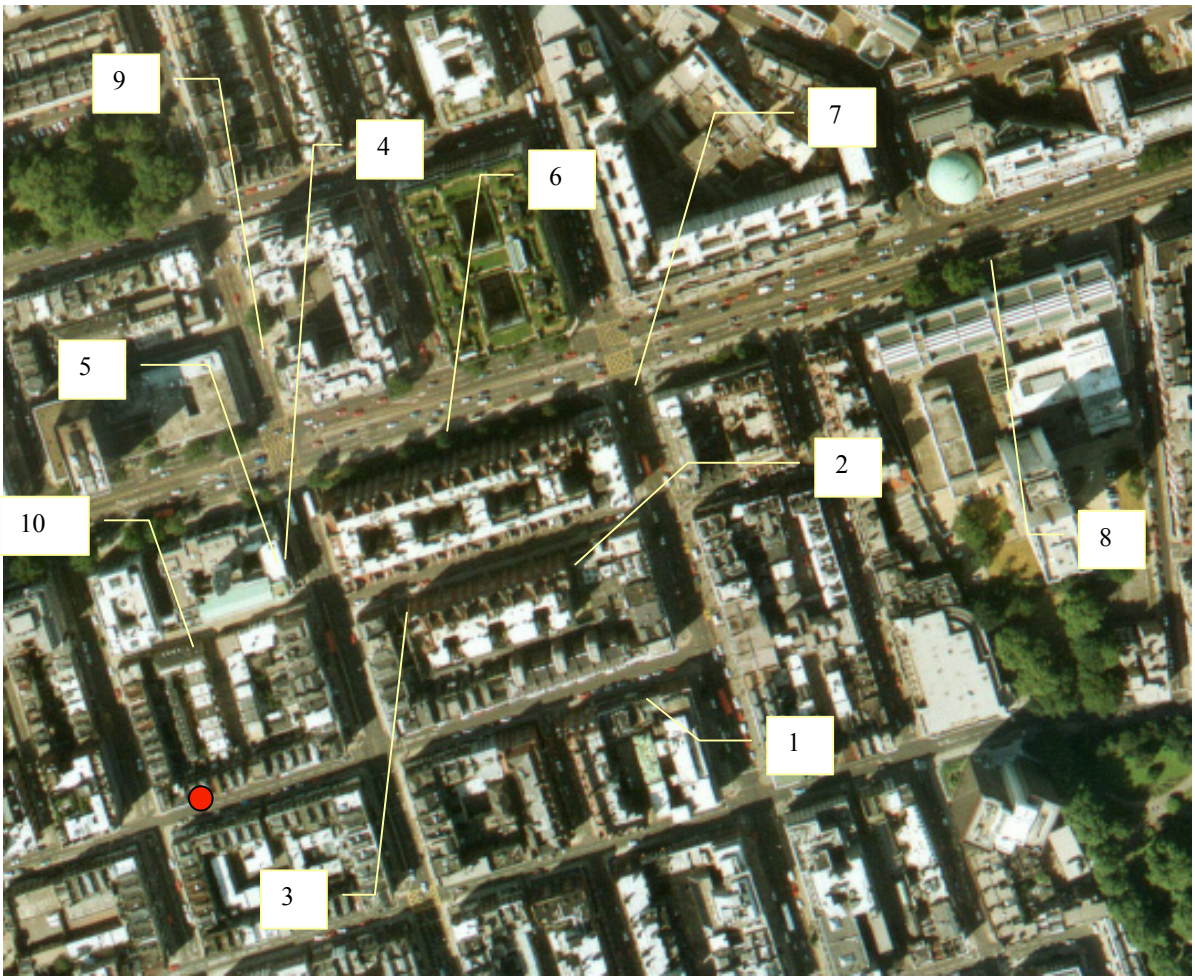

Figure 1: Area map of the tracer field study (Marylebone area) depicting source-receptor positions; source indicated by red the spot, and receptors are numbered and indicated by the yellow lines.

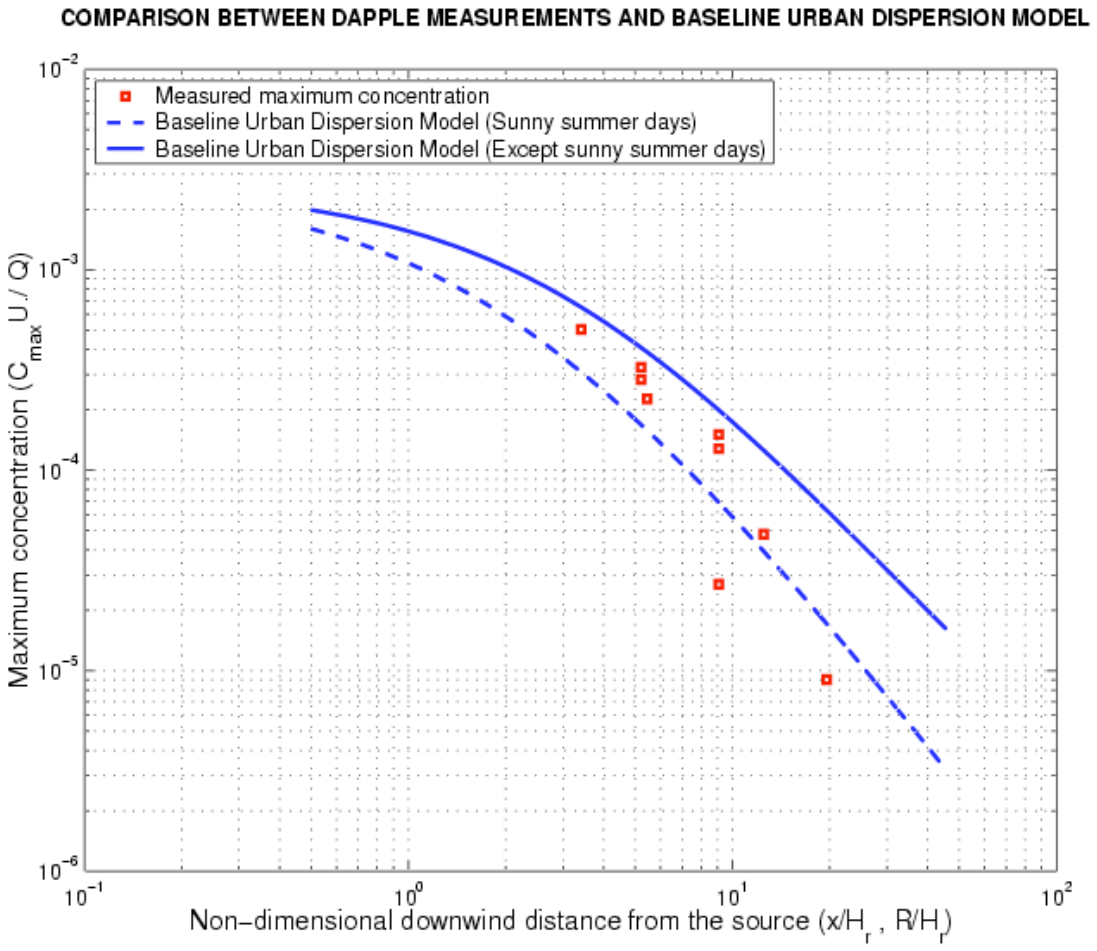

Figure 2: Comparison between DAPPLE field measurements and the Baseline Urban Dispersion Model developed in [1].

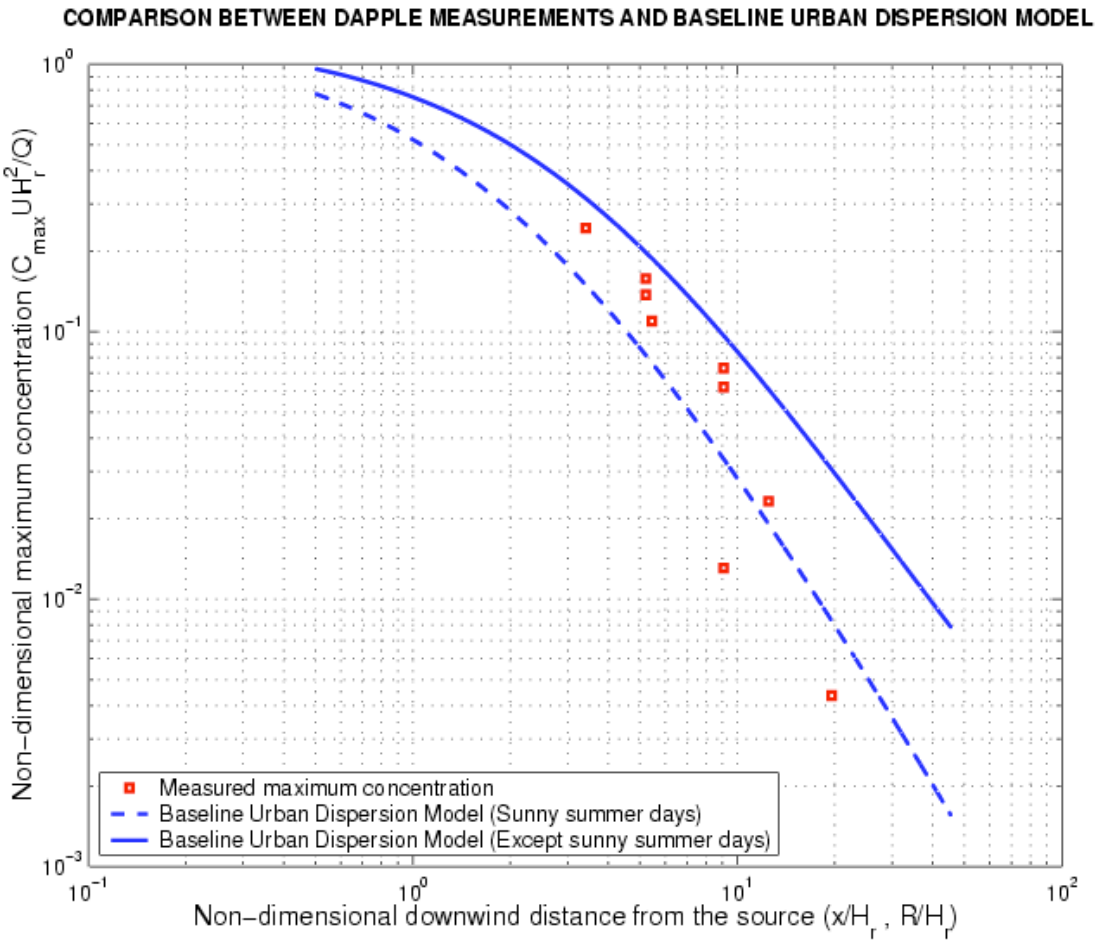

Figure 3: Comparison between DAPPLE field measurements and the Baseline Urban Dispersion Model developed in [1].