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The effect of sampling time on concentration fluctuations measured over the Dapple site model

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1. Introduction

This brief note has been produced to assist the interpretation of tracer measurements made during the field campaign, in particular to illustrate the likely level of concentration fluctuations appropriate to the sampling time used in the field.

2. Analysis

The relation between time at full and model scale is expressed through equality of UT/H, where U is the wind speed, T time and H a characteristic building height, so:

$$T_M = T(H_M/H)(U/U_M)$$

where the suffix 'm' denotes the wind tunnel model. The geometrical scale is 1:200 and U/U_M typically lies in the from range 2 to 5, say, so that T/T_M lies between 40 and 100 – we can use 60 as a convenient, yet typical value; i.e. 1s in the tunnel is 1min in the field. In reaching this conclusion, we take the near roof level wind speed in the tunnel to be about a half of the reference wind speed measured at the boundary layer edge.

The example is based on measurements at street level in Gloucester Place for a continuous source in York Street. The concentration field was sampled at 200Hz for a period of 300s. Block averaging was then applied to the signal to produce statistics of the fluctuations observed by instruments sampling the concentration signal over the period equivalent to the block length. Results are summarised below, for a building height, H = 0.11m, and a reference wind speed, Uref = 2.5m/s..

Block size	Block duration, T (s)	$U_H T/H$	$\sigma_C/\langle C\rangle$	$C_{99.9}/\langle C\rangle$
1	0.005	0.057	0.546	3.77
20	0.1	1.1	0.472	3.02
100	0.5	5.7	0.379	2.30
200	1	11	0.320	2.03
500	2.5	28	0.234	1.68
600	3	34	0.218	1.56
1000	5	57	0.184	1.44
2000	10	110	0.126	1.24

Some statistics of block-averaged concentration data (assuming U_H/U_{ref} = 0.5)

The table shows the intensity of fluctuations, σ_C/<C>, and the 99.9 percentile, $C_{99.9}$, scaled by the mean, <C>, as a function of the block duration expressed both in seconds and non-dimensionally. This indicates a 22% intensity of concentration fluctuations for the equivalent of a 3 minute sampling period in the field. The figure below shows the record resulting from 3s averaging of the tunnel data.

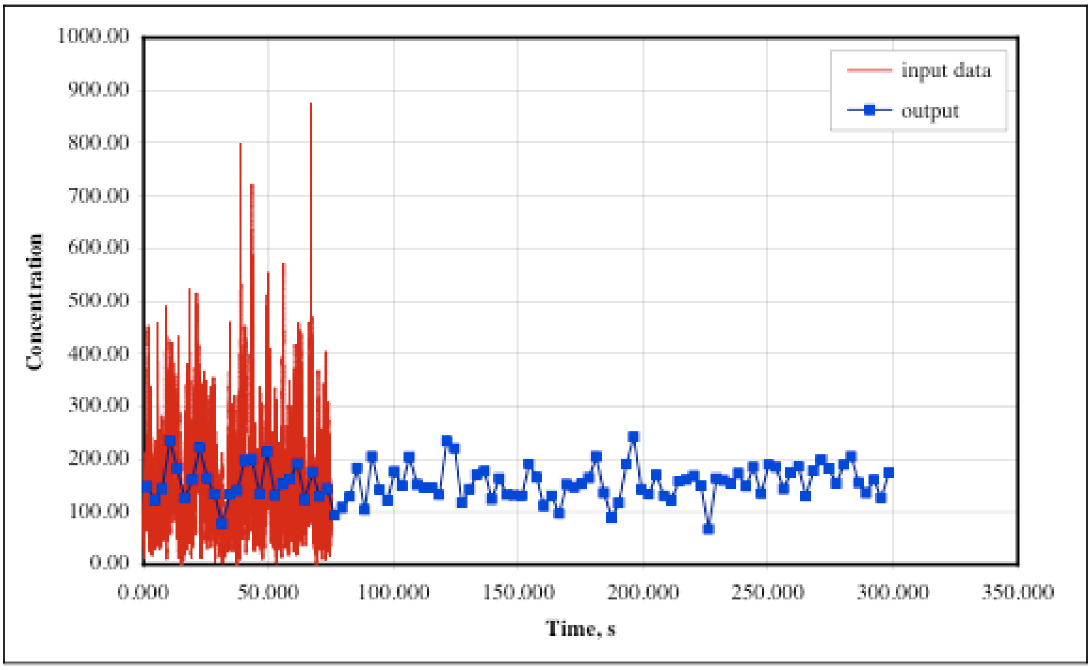

Figure. 3sec block averaged concentrations from the wind tunnel (blue) and section of original data (red).

3. Discussion

The table shows that the non-dimensional block duration lies between about 11 and 110 for block lengths between 1 and 10s. That significant fluctuations are observed on these time scales is not surprising as H/U_H is a time scale of the canyon circulation. The time scale of the external flow is H_B/Uref, where H_B is the boundary layer depth (1m in this case) and U_{ref} the reference speed at the boundary layer edge. This is about 0.4s and in these terms the non-dimensional block durations, TU_{ref}/H_B, lie between about and 2.5 and 25, implying that significant fluctuations are also to be expected due to unsteadiness in the flow conditions above the street canyon.

The level of fluctuations derived from the wind tunnel data lies in the range from 32% to 13% for block durations from 1s to 10s, approximating 1 to 10 minutes at full scale. Somewhat larger values should be anticipated in the field because the boundary layer depth, expressed as H_B/H, would be greater at full scale. Additionally, wind tunnel simulations are always limited to some degree in the range of lateral scales of turbulence that they simulate. The variations in the three minutes samples seen in the tracer studies seem entirely consistent with the deductions from the wind tunnel experiments and can probably be regarded as ‘normal’.