Examination of Traffic Pollution Distribution in a Street Canyon Using the Nantes'99 Experimental Data and Comparison with Model Results

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1. Introduction

Traffic pollution in a street canyon is characterised by large temporal, horizontal and vertical variability, which is not only related to the diurnal variation in the traffic amount but is also influenced by the meteorological conditions. This has a great importance for e.g. evaluation of the urban population's exposure to the traffic pollution and therefore requires special attention. Very little is still known about the vertical distribution of the pollution in street canyons. Only a few experimental data exists and most of the data are from wind tunnel experiments (Pavageau et al., 1997). Recently a new unique data set became available based on results from the Nantes'99 experiment. During this experiment, pollution concentrations, flow and turbulence conditions were measured at several locations in the street Rue de Strasbourg, Nantes, France. A detailed description of the experimental set-up is given in Vachon et al. (1999). Analyses of the turbulence measurements in the street, with special emphasis on the dependence on traffic flow and thermal effects, are presented in two accompanying papers (Louka et al., 2001; Vachon et al., 2001). In this presentation we focus on examination of the spatial distribution of traffic pollution and the effect the meteorology has on this variation.

The experimental data are compared with results from two models: the Operational Street Pollution Model (OSPM) (Berkowicz, 2000) and a 3-D CFD model MISKAM (Eichhorn, 1995). Results presented here are still preliminary and some modifications of the modelling procedures based on conclusions from this study are expected.

2. The Site and the Data

Rue de Strasbourg is a 3-lane, one-way, highly trafficked street. The mean height of the buildings along the street is ca. 21m and the width of the street is 15m, resembling a street canyon of the W/H ratio of ca. 0.7. The street orientation is 28^{O} to West with respect to North.

The components of flow and turbulence were measured by 3D sonic and propeller anemometers at three levels on each side of the street. Meteorological parameters were also measured on a 7m high roof mast, on the westerly side of the street.

Concentrations of CO were measured on both sides of the street at 1.5m, 4m and 12m on the East side, and 1.5m, 4m and 16m on the West side. Measurements were also available from an upper level location in the middle of the street, but they are not used in this study. Background concentrations were monitored at the roof location, the same place as the meteorological mast.

Traffic was measured by vehicle counters at different places within the street. Traffic speed was monitored as well.

The measuring campaign was conducted in the period June - July 1999 but only data from a selected intensive observation period are used in this study. This period was selected to suite conditions required for study of the traffic produced turbulence and the thermal effects (Louka et al., 2001; Vachon et al., 2001) and is characterised by quite low wind speeds. The frequency distribution of wind speed measured on the roof mast and the frequency distribution of wind directions are shown in Figure 2.1.

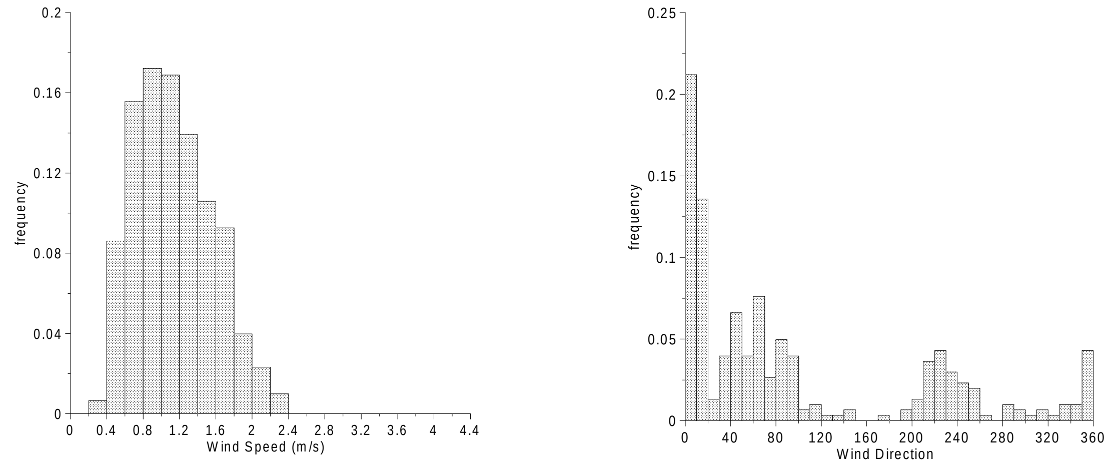

Figure 2.1 Frequency distribution of wind speed and wind direction as measured during the selected intensive observation period.

3. Model Results and Discussion

Hourly averaged CO concentrations were calculated with OSPM for all the measuring points in the street. OSPM is a highly simplified model but previous model tests have proven its reasonable good performance. This study is however the first intensive test of the model using data from different heights in the street. Results of model comparison with measurements from the 1.5m level at both sides of the street are shown in Figure 3.1.

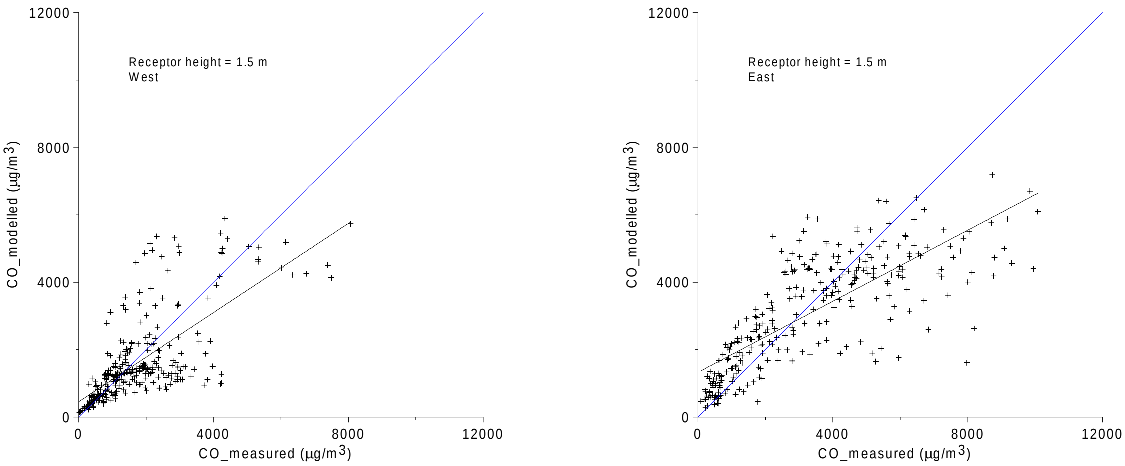

Figure 3.1 Comparison of OSPM results with CO measurements from the 1.5m level at both sides of the street.

A similar comparison, but with results obtained with the 3-D numerical model MISKAM is shown in Figure 3.2. MISKAM is a very CPU time-demanding model and calculations are usually done for selected wind directions only (in this case for 12 directions with 30^{O} interval) and results are presented in terms of the non-dimensional concentration c*,

$$c^* = c \cdot u \cdot S / Q \qquad (1)$$

where u is a reference wind speed, Q is the emission and S is a length scale related to the street dimensions (here we use the height of the buildings).

Using Eq. (1) for calculation of concentrations for any value of wind speed implies the assumption that the ambient wind is the only mechanism responsible for dispersion of pollution in the street. This is a reasonable approximation for higher wind speeds, but fails totally for lower wind speeds. It is believed that at low wind speed conditions, the main mechanism governing dilution of the car exhaust gases is the turbulence created by the traffic itself (Kastner-Klein et al., 2001; Vachon et al., 2001).

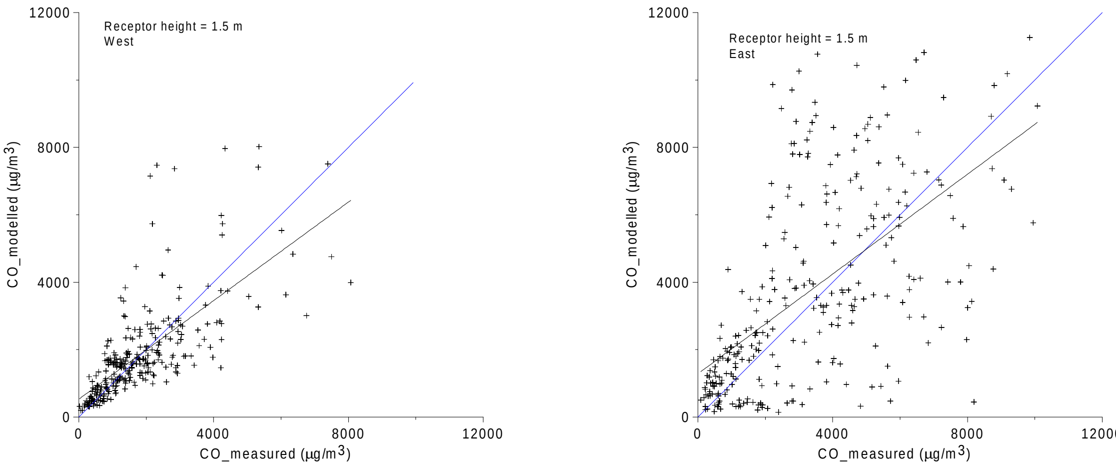

Figure 3.2 Comparison of MISKAM results with CO measurements from the 1.5m level at both sides of the street.

The traffic produced turbulence is not directly included in the present version of MISKAM. The dimensionless concentrations (c*) calculated by the model are therefore scaled using a velocity scale which depends on the traffic produced turbulence. This replaces the traditional wind speed scaling, which for low wind speed conditions results in totally unrealistic concentrations. The traffic contribution to the turbulence in the street is calculated in the same way as in OSPM (Berkowicz, 2000). The principles of the traffic produced turbulence scaling are discussed in Kastner-Klein et al. (2001) but the details of the method applied for "correction" of the MISKAM results will be presented elsewhere (Ketzel et al, 2001).

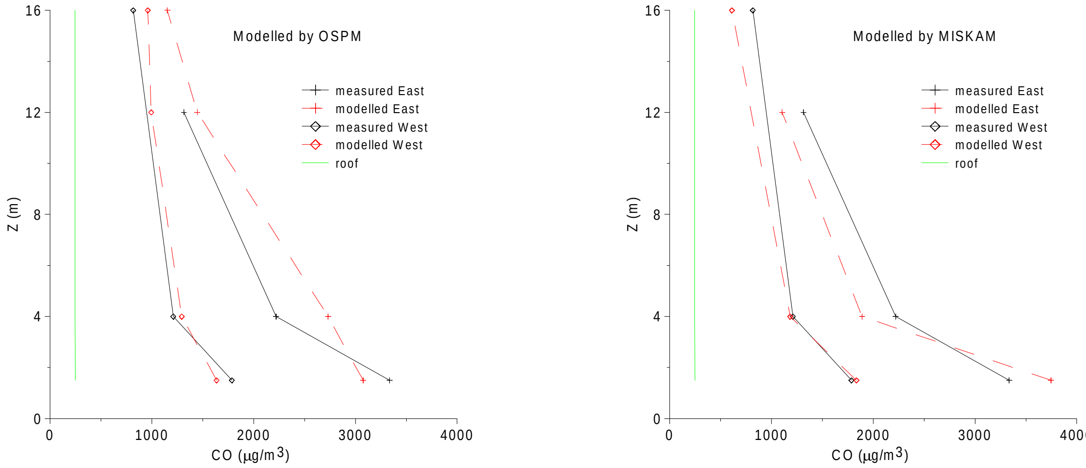

Figure 3.3 The vertical distribution of the measured and modelled concentrations. Results are shown both for OSPM and for MISKAM.

The vertical distribution of CO is shown in Figure 3.3. Both the measured and the modelled concentrations are averaged over all the available data. Background concentrations (roof monitor) are shown as well. Concentrations on the East side of the street are significantly higher than on the West side. This is the result of prevailing Easterly winds during the campaign (see Figure 2.1). For Easterly winds the East side of the street is leeward and receives higher concentrations than the windward West side. The variation with height is somewhat smaller on the West side (predominantly windward) than on the East side. This variation is quite well reproduced by MISKAM. OSPM underestimates the vertical gradient on the East side. The main reason for the underestimation of the vertical gradient by OSPM is the assumption on the initial vertical dispersion of vehicle exhausts. In OSPM this value is assumed to be 3m. In MISKAM, the initial mixing is set to 2m, which is the height of the first numerical grid. Smaller initial mixing height results in larger vertical gradients in the lowest level of the street.

The difference in the behaviour of pollutants on the leeward and the windward sides of the street is illustrated in Figure 3.4. Here, the dependence of concentrations (street contribution only) normalised by emissions is shown as function of wind speed. The wind directions are selected so, that the East side is always leeward and the night time hours with small emissions are excluded. The dependence on wind speed is less pronounced on the leeward side (the East side). This is again believed to be due to larger contribution of the traffic produced turbulence to the dispersion conditions on the leeward side. The scatter in the experimental data is, however, very large and the results must be taken with some caution.

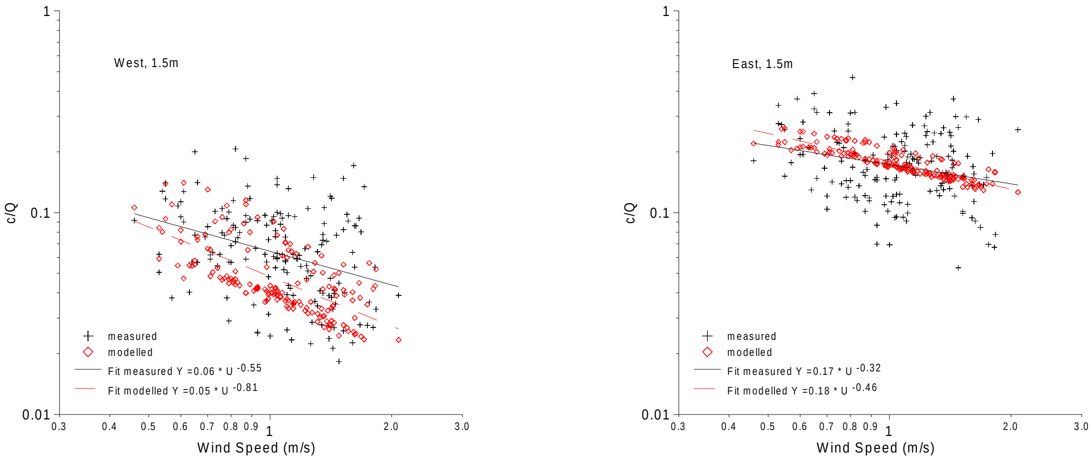

Figure 3.4 The dependence of the windward (West) and the leeward (East) concentrations on wind speed. Both model results (OSPM) and measurements are shown.

Acknowledgements

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