High Resolution Flow Measurements in an Idealised Urban Street Canyon

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1. Introduction

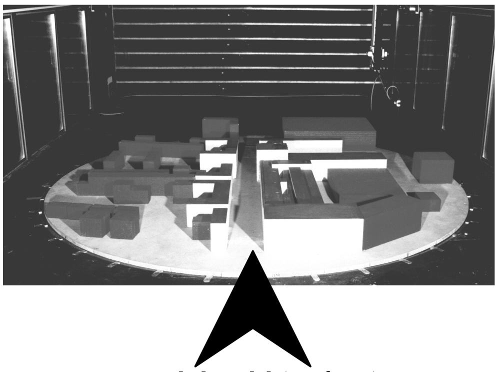
Numerical models are frequently used for the simulation of pollutant dispersion within the urban canopy layer. Complex numerical tools for urban dispersion modelling have been developed during the last decade, and most of them prove themselves as a more or less perfect representation of reality in terms of the quality of physical modelling of scalar transport phenomena as well as of the quality and accuracy of the model results. On the other hand, comparisons of models results with independent field data or results of physical dispersion modelling in boundary layer wind tunnels still show significant discrepancies in the results of a numerical simulation and physical reality. Searching for what is causing those differences one has to subdivide the problem into two major categories of error sources. One group is represented by differences due to the simplified physics implemented in numerical models. There is a lack of information on urban scale turbulence, wind fluctuations in complex urban areas as well as a gap in knowledge on how to model turbulent dispersion within the urban canopy layer. The second group of differences obviously is caused by differences in the geometrical representation of the physical reality due to discretization.

The presented study gives the results of the laboratory investigations performed in the boundary layer wind tunnel of the Meteorological Institute, University of Hamburg (Germany). Based on high-resolution flow measurements close to the ground, we measured the flow pattern in an idealise urban street canyon and compared results with the numerical simulation.

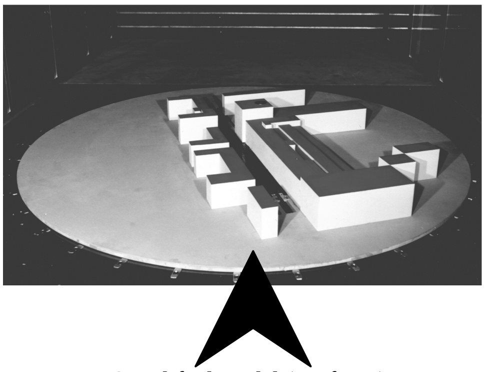
The study presented quantifies also the effects of geometrical simplification. Based on the results of wind tunnel measurements from several physical models with different complexity and geometrical abstraction.

2. Experimental set-up

Several models directly adapted from numerical grids which were used for flow and dispersion simulations have been tested in the multi-layer wind tunnel at the University of Hamburg. For example, Fig. 2.1 shows a simplified as well as a more detailed model representation of the "Goettinger Strasse" field site in Hanover. Using a modified spires/roughness configuration, a neutrally boundary layer was generated at a scale of 1:200. The models built at exactly the same scale were mounted on a turntable with a diameter of 1.83 meters. Fig. 2.2 shows the approaching flow profile measured. All the measurements were performed with a 2-Component-LDA with a focal distance lens of 80 mm. High acquisition and validation rates were assured and sufficient averaging time were allowed in order to achieve reliable and accurate measurements. In critical areas with highly unsteady signals measurements were repeated several times. The reference speed was measured independently by a Prandtl-tube located upstream of the model 100 meter above ground (full scale).



Extended model (config. 2)



Simplified model (config. 1)

Figure 2.1: Two of the three models investigated

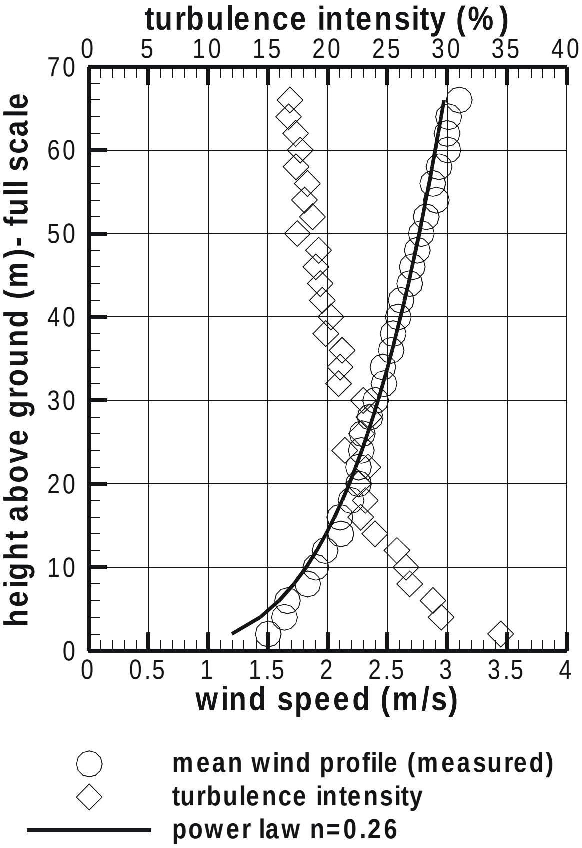
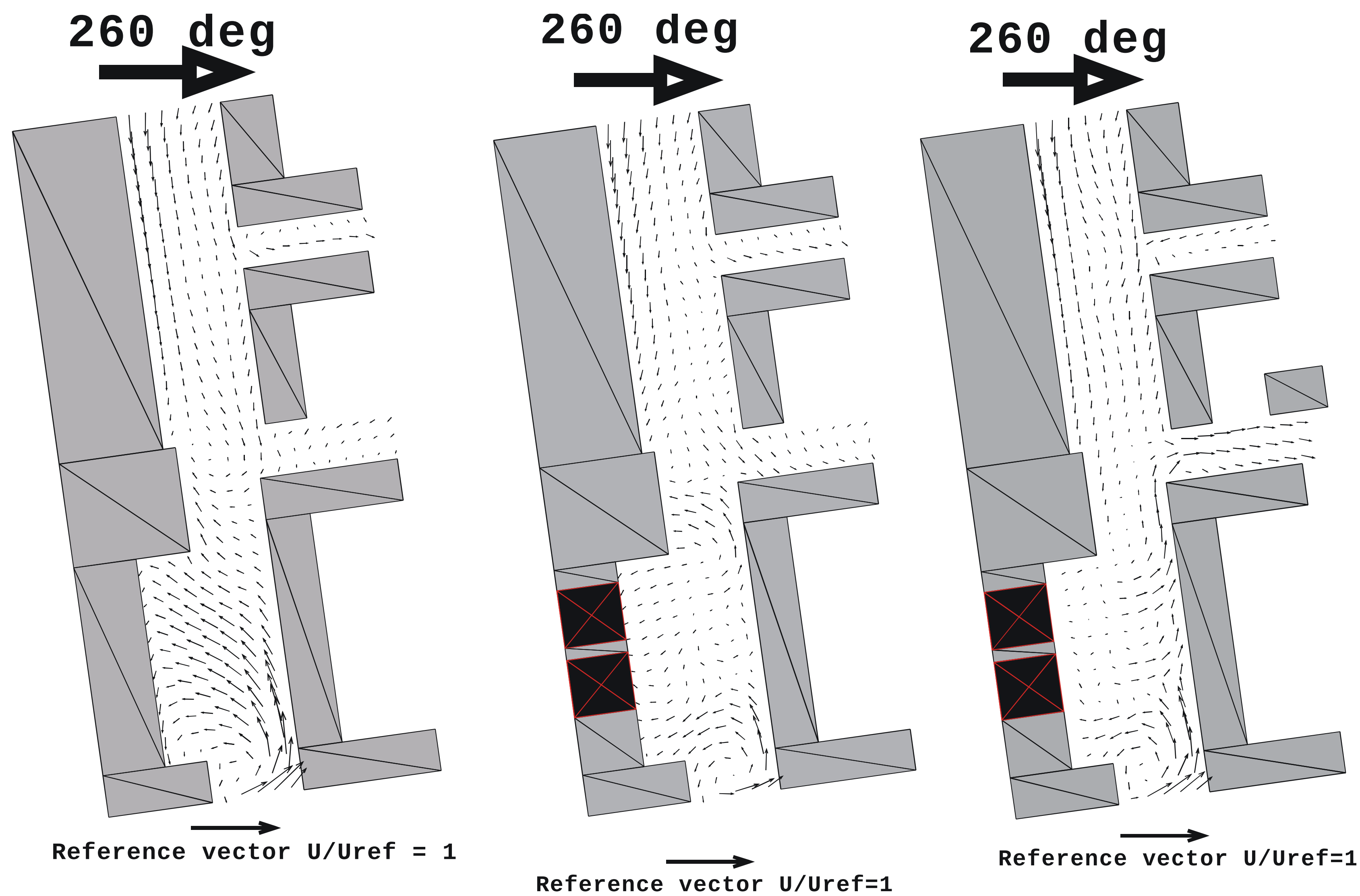


Figure 2.2: Approaching flow profiles.

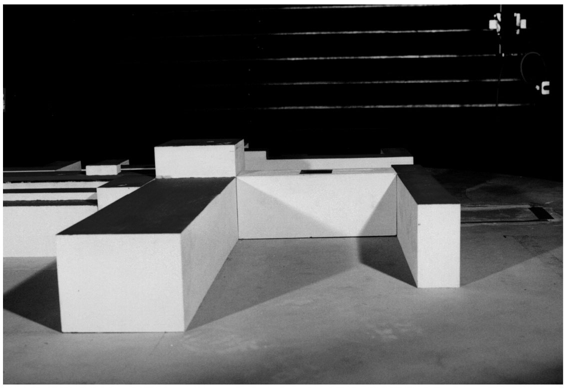
3. Results

Flow measurements within the canopy layer were carried out under constant ambient conditions with 3 different model realisations of the same real site. The 3 models differed with respect to geometrical detail. Two of the configurations were adjusted to the numerical grid of a 3-d-micro-scale model, see Fig.2.1. The difference between configurations 1 and 2 was mainly that additional buildings in the neighbourhood of the street canyon were taken into account and that the extended configuration (2) considered also a large gateway (height 5 m) in one of the buildings alongside the street canyon (see Fig. 3.2). In configuration 3, finally(not shown here), all geometrical details of the site and its surroundings were replicated in the physical model. The measurements were carried out at about half of the building height 10m above ground (full scale).

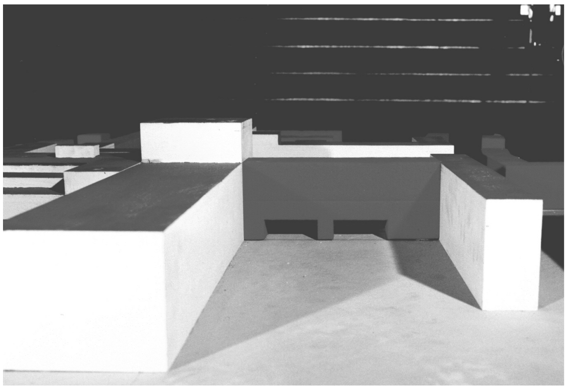


Configuration 1 Configuration 2 Configuration 3

Figure 3.1: Mean velocity fields within a street canyon measured for tree different realisations of the same site under otherwise identical conditions.



Original configuration (Configuration 1)



Configuration with gateway modified (Configuration 2)

Figure 3.2: Model modifications

As the results presented in Fig 3.1 clearly show, model simplifications fundamentally change the flow behaviour within street canyons. Adding geometrical detail and further buildings to the wind tunnel model modifies not only the flow inside the street canyon but also in the adjacent streets. The flow in the streets perpendicular to the canyon can even change direction, which results in a completely different ventilation pattern and thus large differences in local pollutant concentrations within the canyon. Although the measurements presented here were performed at twice the height of the gate way, the effects are still very obvious.

4. Conclusions

Comparisons between high-resolution velocity fields measured in models with different degrees of simplification show significant differences. The flow within the street canyon depends on both, geometrical detail and the number of surrounding buildings. Consequently, the ventilation pattern changes and quite distinct concentration fields are to be expected. This (not at all surprising) result should be carefully taken into account when decisions for the selection of positions for urban monitoring stations have to be made. The results show furthermore that the agreement or disagreement found in comparisons of field data sampled usually at only one position within a street canyon with numerical model results is not necessarily a quality indicator for the model. Due to the large variations in local concentrations, agreement and disagreement is likely to be highly influenced by random. A proper validation of micro-scale numerical models developed for the simulation of dispersion processes within the urban canopy layer will not be possible without data collected under carefully controlled conditions in boundary layer wind tunnels.

Acknowledgement

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