CFD MODELLING OF POLLUTANT DISPERSION IN URBAN ENVIRONMENTS

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Numerous studies have demonstrated the existence of a strong link between air pollution and the prevalence and severity of cardio-respiratory diseases, especially when considering fine particulate matter (PM2.5). With an increasing potential for industrial applications of even smaller particles (diameter 1 to 100 nm), additional questions regarding possible adverse health effects are being raised. In order to establish a meaningful relationship between a particular pollutant source and the resulting health impact, two distinct questions have to be considered: what is the exposure to the pollutant and what is the resulting toxicological effect of this exposure. The present research addresses the first question, i.e. the exposure modelling, and focusses more specifically on the dispersion of small particles in urban environment.

The particle dispersion is investigated for inert particles in a neutral boundary layer without temperature effects. Under these conditions, the dispersion is governed by the local wind climate, which is highly turbulent within urban environments. Turbulent dispersion consequently has a significant influence on the particle concentration field. The purpose of the present thesis is to improve the understanding of different turbulent dispersion modelling methods available and to contribute to the establishment of a validated methodology to model the dispersion of small, inert particles in urban areas using CFD. Wind tunnel data sets of flow and dispersion are available for the configurations studied and have been used for validation of the CFD results.

In the first part the focus is on the correct modeling of the velocity and turbulence kinetic energy of the atmospheric boundary layer using RANS simulations and on the influence of the turbulence kinetic energy on the dispersion of small particles using a particle tracking method. Secondly, this ABL modeling methodology is used to simulate the dispersion behind a single rectangular building, both by using a particle tracking method and by solving the transport equation for a passive scalar. The results indicate the importance of correctly predicting the velocity and turbulence field, while also defining appropriate values for the additional paramaters that govern the turbulent dispersion. These parameters are the Lagrangian time scale for the particle tracking algorithm and the turbulent diffusion coefficient when solving the transport equation for a scalar. To obtain a more accurate estimate of their values, LES simulations are performed. The results will be used as input for a final set of RANS simulations to investigate if the prediction of the concentration field can be improved.
In addition to modelling the dispersion in the wake of a single building, simulations for the dispersion through a model of Oklahoma City were performed. This test case demonstrates the complexity of modelling the dispersion in real urban areas and indicatea that the standard model settings and the numerical models used should be improved to obtain accurate predictions of the flow and concentration field.

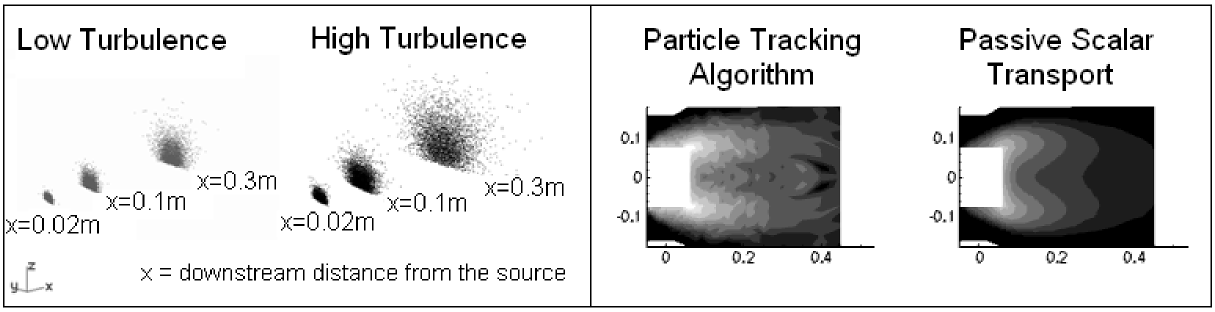

Figure 1: Left: The influence of turbulence on the dispersion of particles (d=1μm) over flat terrain; Right: Contours of concentration in the wake of a building on a horizontal plane (z = 0.28H)