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AVERAGE CONCENTRATION PROFILES IN AN IDEALIZED URBAN CANOPY BASED ON HIGH RESOLUTION NUMERICAL SIMULATIONS

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1 INTRODUCTION

The urban canopy formed by the buildings and the surrounding space has a profound impact on the processes in the atmospheric surface layer. For example, if we consider the low level dispersion of pollutants, we have competing mechanisms that increase or decrease the concentrations in the canopy as compared with flat terrain. The decreased average flow in the canopy leads to a decreased dilution and therefore to an increase of the concentrations. On the other hand, the increased turbulence intensity tend to decrease the concentrations. Depending on the situation, as reported by several authors, the concentrations in the canopy can either be lower or greater than the flat terrain value.

To investigate this and other issues, we have performed detailed, high resolution, numerical simulations of the flow in and above an idealized urban canopy, using a E-ε turbulence closure model. The idealized canopy is formed by a regular array of obstacles, either cubes or billboards, with different geometrical layout (square and staggered). Different source position relative to the obstacles and different source heights have been investigated but only one example is discussed here. The simulations are performed at full scale, not laboratory scale.

The analysis of the flow field and its average properties has been reported in Carissimo and Macdonald (2001) and Carissimo and Tehranian (2001).

In this paper we focus on the analysis of the dispersion calculations.

2 DESCRIPTION OF THE NUMERICAL SIMULATIONS

2.1 *Summary model description*

• developed by Electricite de France for local scale atmospheric flow and dispersion simulations

• atmospheric version based on CFD core code (ESTET)

• relies on complex geometry capabilities of core code to handle obstacles

• use a E-ε turbulence closure, modified for the atmosphere and which is well suited to flow around obstacles

• atmospheric logarithmic wall law (stability dependent), taking roughness into account.

Recent results of mesoscale simulations, together with a more detailed model description can be found in Troude et al. (2001) and in the references therein.

2.2 *Simulation domain*

Five different geometrical layouts have been simulated, following closely the layout used in the water flume experiments of Macdonald et al. (2000).

In addition to the flat ground case, four types of arrays of obstacles were studied, including square and staggered arrays consisting of cubes and billboard with the same frontal packing densities of λ_f = 0.16. The frontal packing density λ_f is a dimensionless ratio, where the numerator is the frontal area (facing the wind) of an individual obstacle, and the denominator is the "lot area" occupied by a single obstacle (Macdonald et al., 2000)

In order to simulate a large number of row in the downstream direction, the geometry has deliberately been chosen to be limited in the cross stream direction but still sufficient to be able to check the influence of the lateral wall conditions. The simulation domain has a total height of five times the obstacle height.

The grid size is 1 m in both horizontal and vertical directions. Each cubic obstacle is 10 m high. The total number of grid element is over 2 million.

2.3 *Upstream meteorological conditions*

For the upstream condition, we have used a neutral logarithmic profile with a roughness of zo=0.12m. In

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this equilibrium profile, the production of turbulence is balanced by the dissipation. We have verified that these upstream profiles, mean flow and turbulence, are maintained in the computational domain in the absence of obstacles.

Other boundary conditions :

lateral sides of the domain : symmetry conditions,
downstream : outflow conditions
top : rigid lid with free slip conditions

The source is located behind the third row and the release rate is 0.001 kg/s.

3 RESULTS AND DISCUSSION

In Figure 1 we can see, on the horizontal cross section of the concentration field in the canopy, that the global effect of the obstacle is to increase the lateral dispersion. This effect is much more pronounced for the staggered billboard.

In Figure 2, we have a much more detailed comparison, both in the cross stream direction (a) and in the vertical direction (b). First we can see, as expected, that the global lateral mixing is always increased compared to the no obstacle case. However we also see that, near the centerline, we can have both higher (square-obstacle) and lower concentrations (staggered-billboard).

If we now turn to the vertical profile on figure 2.b, we again see, as expected, a global increase of the vertical mixing by all obstacles. This effect is felt up to approximately 3 obstacle height. Above, that height, concentrations for all obstacle configurations are systematically lower.than for the no obstacle case.

Below that height, the situation is more complex. Around 1.5 to 2 H, the concentrations are systematically higher in all obstacle cases. Finally, near the ground, we have higher concentration in the square cube case and lower for the other cases.

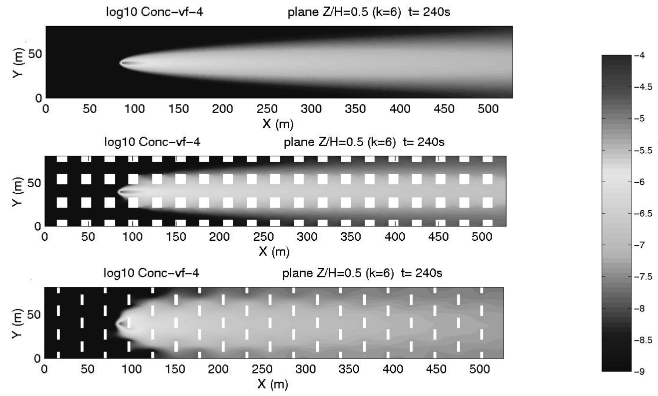

Figure 1 : Horizontal cross section of concentration field (kg/kg) in the middle of the canopy (Z/H=0.5) for the following geometrical layout : a) no obstacle; b) square cube; c) staggered billboard.

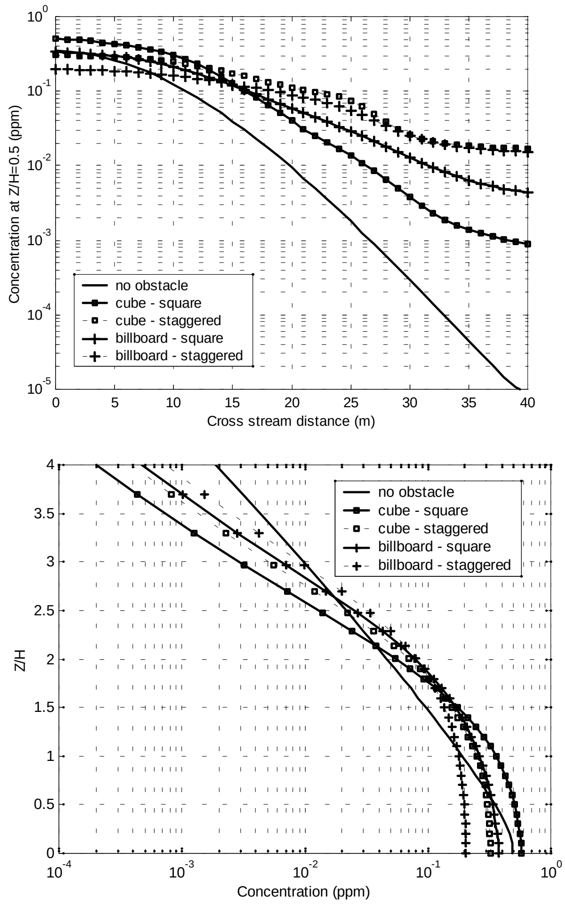

Figure 2 : a) Horizontal cross stream profile of concentration (ppm) behind row 8 in the middle of the canopy (Z/H=0.5); b) Vertical profiles of centerline concentration (ppm) behind row 8.

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