5.28 PARAMETRIC STUDY OF THE DISPERSION ASPECTS IN A STREET-CANYON AREA

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INTRODUCTION

Continuously increasing vehicles' fleet is still considered to be the main emission factor in urban environments, despite the enormous progress of modern catalytic technology. Under that perspective, calculation of transportation induced pollutant dispersion is of augmented importance, especially within street canyons, where poor ventilation can result in awkward concentration levels.

Computational Fluid Dynamics (CFD) studies have been conducted in the past by *Neofytou, P. et al*, (2003) so as to define appropriate locations for measuring-instrument placement by numerically simulating the flow and pollution dispersion fields in the vicinity of the measuring site taking into account the wind rose of the area and selecting locations of high pollution concentrations so that non-zero indications are assured. *Vardoulakis, S. et al*, (2003) provides a general overview of the street-canyon studies concerning both modelling and experimental investigations and offers plenty of references on air quality within street canyons. Besides air-quality, street canyon CFD studies have also been performed to evaluate accident consequences and hydrogen safety, *Venetsanos A. et al*, (2003). The current study examines a real street canyon in Thessaloniki, Greece. It was performed in order to examine dispersion patterns for different parameters' scenarios and help deciding where to place actual pollutant measurement instruments to better capture traffic pollution data. Various wind directions and speeds are examined and height influence on concentration levels is investigated. Complex area geometry is a key factor of the whole study.

MODELLING SYSTEM

The Computational Fluid Dynamics (CFD) model ADREA-HF (*Bartzis, J.G.*, 1991) was used for the simulation of wind flow and pollutant dispersion. This is a 3-D unsteady Reynolds Averaged Navier-Stokes (RANS) code especially developed for dispersion of buoyant or passive gases over complex terrain in local scale. The code solves the transient, Reynolds averaged, mass and momentum 3D conservation equations for the mean flow and the mass fraction conservation equation for the pollutant dispersion. An original, anisotropic one-equation model is used for the turbulence closure (*Bartzis, J.G.*, 1989, *Bartzis, J.G. et al*, 1991). The code has been validated in the past against various environmental 3-D flows, including street canyons (*Vlachogiannis, M. et al*, 2002).

Geometry and grid

Mitropoleos street, at the Aristotelous square of Thessaloniki (Figure 1) was the area of interest. Computation domain covered a 736x763x180m area discretised as a 41x48x30 grid, refined near the location where the experimental measurements were to take place. The geometry was simulated using the DELTA-B pre-processor (*Venetsanos, A. G. et al*, 1995). All buildings close to the measurement location were taken into account with the aid of aerial photographs and maps.

Cases examined

Calculations were performed for five different incident-wind directions, namely South-east (SE), North-east (NE), North-west (NW), South-west (SW) and North (N). The last case was examined for two wind velocities: 8m/s on top of the domain, resulting in 5m/s over buildings and less favourable 5m/s on top of the calculation domain, resulting in 3m/s over the buildings, the latter being chosen for all other wind directions. Vehicles passing along Mitropoleos street were modelled as an area source, emitting homogeneously and with a constant rate. Results are presented non-dimensionalised with the total amount of emission mass flow, thus making the modelling independent of the vehicle fleet density and composition. Buoyant effects are neglected and the pollutant is considered to be passive as a first approximation, making results suitable for concentration estimations of any pollutant, as far as the emission rate is known.

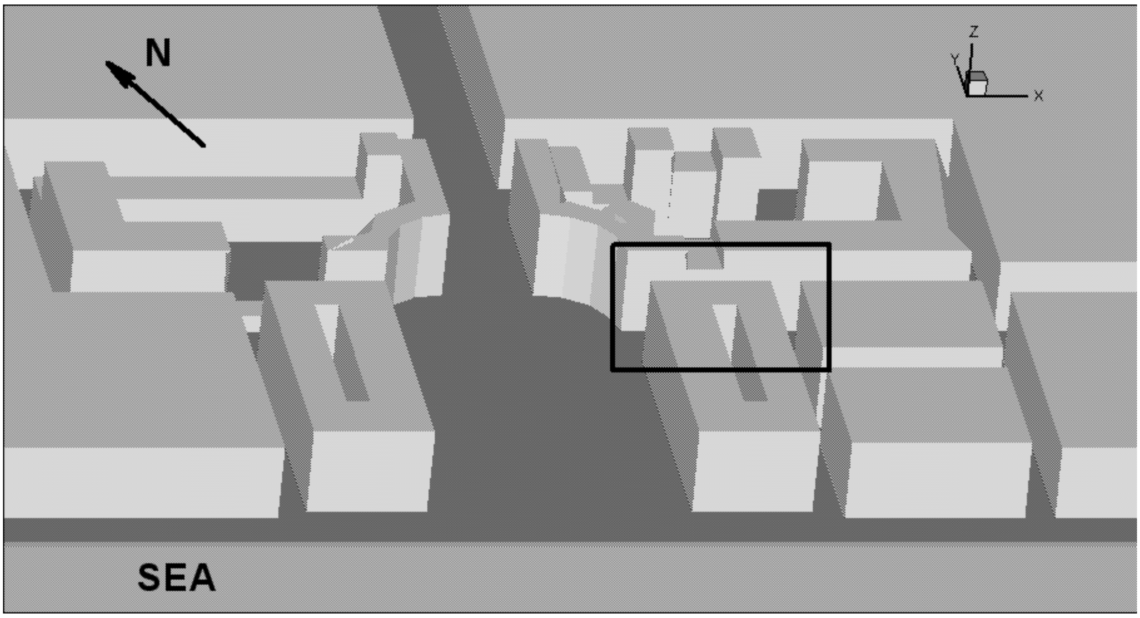


Figure 1. Part of the modelled city and the Mitropoleos street canyon.

RESULTS AND DISCUSSION

The area of interest is the street canyon marked in Figure 1, having a height of 30 meters and a length of about 44 meters. The emitting area source is considered to be 44 meters long at the centre of the street. Sensitivity analysis revealed that longer source does not have major influence in pollutant concentration *inside* the canyon.

Figures 2a to 2d present the flow and concentration field results at a height of 0.5m for the four wind directions parallel to the street plan.

Complex geometry results in strong recirculation effects within the flow field all over the calculation domain. In SW wind case, the recirculation loop coming from top of the building interferes with that coming from its side, resulting in strong diagonal (north) flow at street level, transferring the pollutant towards the secondary street. In NE wind case, a flow splitting in the middle of the canyon can be observed, dispersing the pollutant in both directions of the street and keeping concentration values at the middle of the canyon low. In NW wind case, a recirculation in the secondary street downwind of the building makes the pollutant stagnate there. In the SE case, reverse flow in the Aristotelous square area does not allow the pollutant to be easily carried out of the canyon, as happens with the NW case.

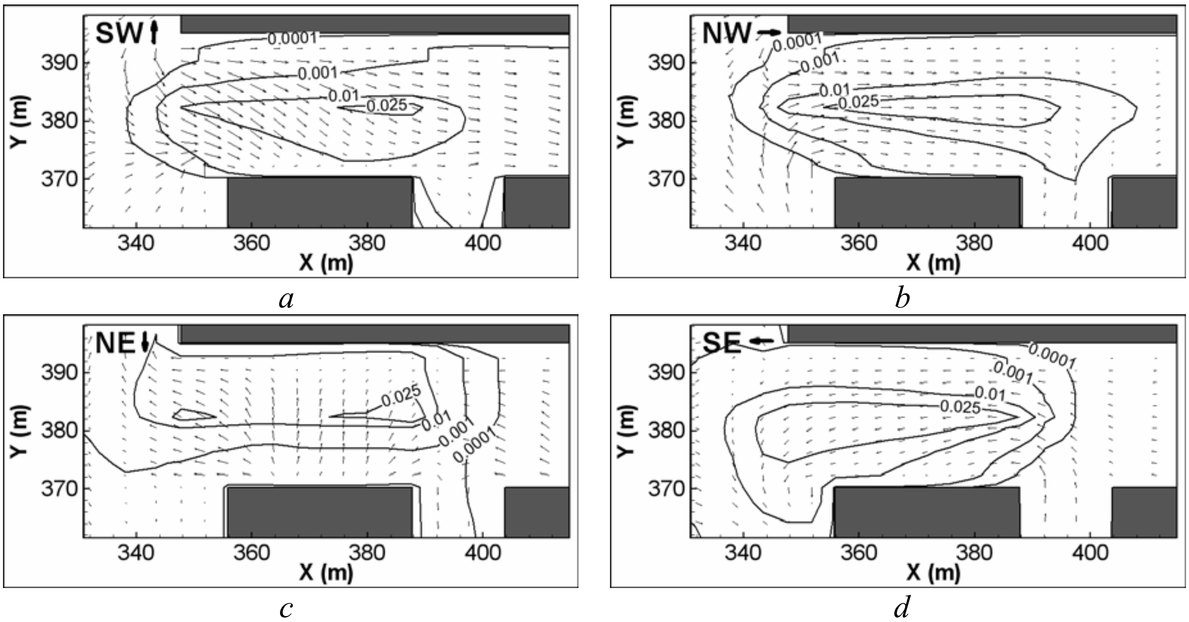


Figure 2. Concentration and flow field for SW (a), NW (b), NE (c) and SE (d) free wind stream directions. Contours for 10^6 ppm per kg/s of emission are presented at z=0.5m.

Figures 3a to 3d present the concentration per emission flow rate along a path vertical to the street in the middle of the canyon, at z=0.5m.

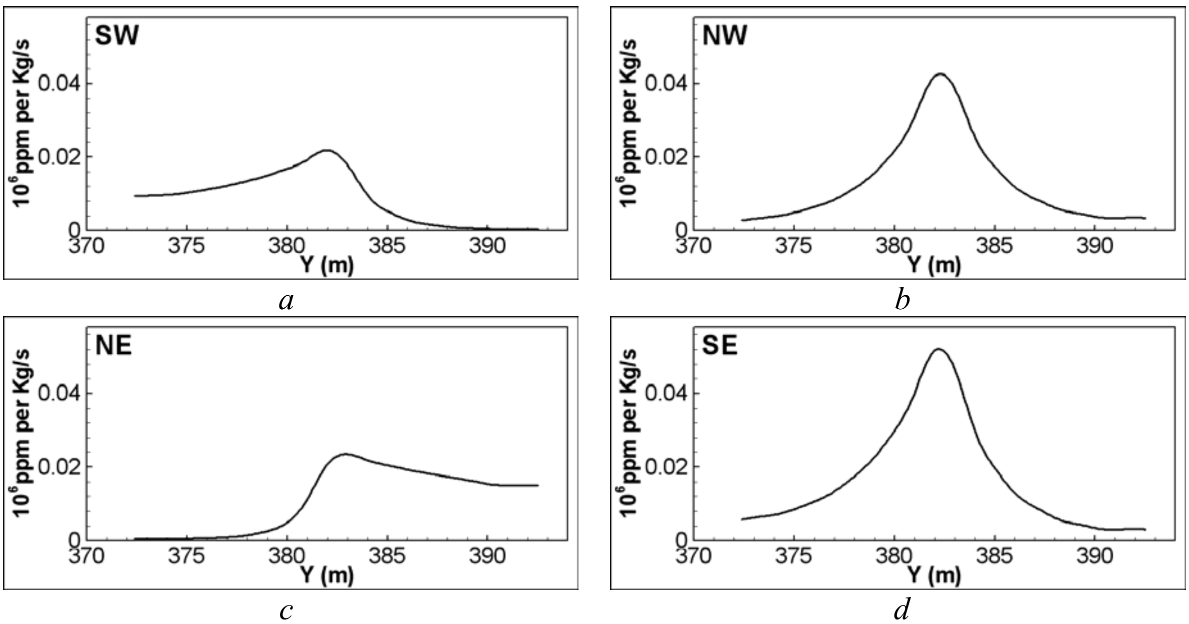
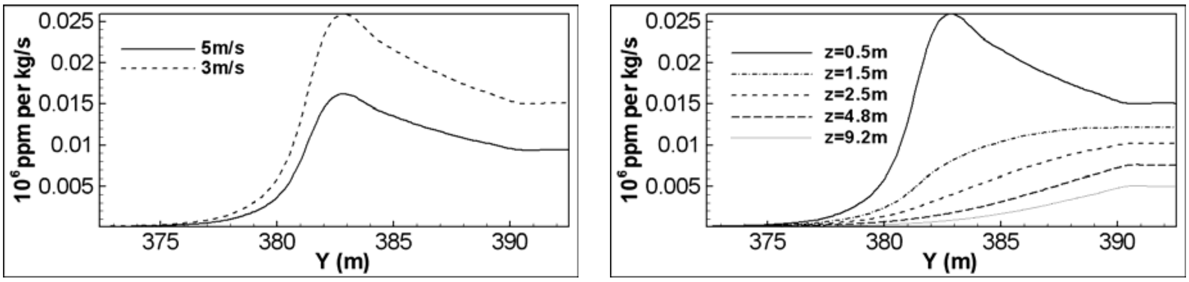


Figure 3. Concentration across the street for four wind directions.

Winds parallel to the street direction result in higher concentration levels; the accumulation of pollutant along the canyon axis dominates over the wind's sweeping away the emissions. Winds vertical to the street-axis result in high concentration at the leeward side. These results cross-check issues already known from the literature (*Vardoulakis, S. et al*, 2003). In all cases the distribution exhibits a peak in the middle of the street showing that the pollution is still localised near the source. Note that for the two parallel-to-the-street-direction wind cases results are very similar; when the wind is south-east concentration is higher due to the reverse flow above the Aristotelous square as explained earlier.

Figure 4a presents the influence of wind strength for the case of the north wind. As expected, the 3m/s above the buildings case is the less favourable. Concentration levels are inversely proportional to the wind speed.

In Figure 4b the influence of the height for the north case can be seen. Close to the street concentration levels reduce very rapidly, while at bigger heights pollutant reduction rate is weaker. A good height for pollution measurement is considered to be z=0.5m. Above z=1.5m, the peak value is no longer at the centre of the canyon, but close to the leeward side building (for non-parallel to the street-axis winds).



a *b*

Figure 4. North wind concentration results. (a) Comparison of pollution levels for two different wind speeds at z=0.5m across the centre of the street canyon. (b) Different heights' concentration for the 3m/s wind speed case.

CONCLUSIONS

As expected, concentration levels are generally high at low heights, close to the emission source. Regarding the different wind directions, top concentration values are reached for parallel to the street winds, at street axis. Non-parallel winds result in high concentration at the leeward side, which surprisingly does not drop drastically with height, see Figure 4b.

Complex geometry is the governing parameter that influences the flow field and consequently the concentration levels within the canyon. The flow is very complicated near solid surfaces. Recirculation and stagnation points, as well as flow passages have to be seriously taken into account before deciding where to place any pollutant measuring instrument. For exact positioning a more detailed and localised geometry input would be desirable.

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