Effect of urban morphology on scalar transport in the roughness sublayer

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Scalars such as heat and moisture in an urban canopy tend to be released from area sources on the ground or from each building surface. Similarly, pollution released from traffic sources can be modelled as an area source near the ground. Buildings are bluff bodies which each occupy relatively large volumes of the canopy space and induce recirculations in their wakes which scale with the urban canopy depth. Such flow patterns can dominate roughness sublayer turbulence and thus determine the rate of transfer of scalars from the surface to the air above. Hence, it is hypothesised that exchange of scalars between sources within the urban canopy and the air above is strongly influenced by building shape and layout. Results are presented here from wind-tunnel simulations of scalar transport around idealised building morphologies.

The naphthalene sublimation technique was used in conjunction with wind-tunnel models of idealised building configurations. A neutral urban-type boundary layer was simulated upstream of each model and incident flow direction was perpendicular to the street canyons or cubes used. Naphthalene was applied to the street surface within each model to simulate an area scalar source at ground level. The technique yields an area averaged bulk transfer coefficient (equivalent to a Stanton number), which tends to a constant value for higher Reynolds numbers. The effect of changing building morphology was observed thus:

1) For a 2D street canyon, the transfer coefficient reached a peak for intermediate values of aspect ratio height (H) to width (W), H/W~0.6 to 0.7.
2) For aspect ratio H/W=0.75, the transfer coefficient peaked in the first street canyon in a row, but rapidly decreased to equilibrium value within 2-3 streets. The peak in the first street increased with a decrease in upstream roughness.
3) When changing source location within the street, transfer coefficient for each surface decreased in the order: roof, downstream wall, street surface, upstream wall. This was shown to be reasonably consistent with a simple model of street canyon exchange which parameterized the recirculation region behind the upstream building.
4) Changing roof shape to pitched roofs resulted in reduced transfer across a range of aspect ratios compared to the flat roof case, with a maximum reduction of 40%. Flow visualisation and measurements revealed a change in the recirculation pattern within the street canyon due to changing roofshape.
5) A street source was simulated for a staggered array of uniform height cubes with aspect ratio H/W=0.25. For an array with randomized roof height distribution, the transfer from street level was slightly decreased although the value of Reynolds stress was slightly increased.
6) Concentration measurements made within the randomized height cube array revealed rapid vertical dispersion in the lee of taller buildings, and significant lateral spreading compared to the uniform height cube array. Comparison with LES data showed consistency between scalar concentrations and flow structures induced by the buildings.