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Dispersion of a point-source release of a passive scalar through an array of cubes

Elisa Goulart (1), Simon Branford (1), T Glyn Thomas (2), Omduth Coceal (3), and Stephen Belcher (1)

(1) Department of Meteorology, University of Reading, P.O. Box 243, Reading, RG6 6BB, UK, (2) School of Engineering Sciences, University of Southampton, Southampton, SO17 1BJ, UK, (3) National Centre for Atmospheric Science (NCAS), Department of Meteorology, University of Reading, P.O. Box 243, Reading, RG6 6BB,UK

Understanding dispersion from localized sources in urban areas is important due to its relevance for modelling releases from accidents or terrorist attacks. Whilst there is a vast literature on urban dispersion in relation to air quality, there is relatively little work on dispersion from localised sources, especially in the short range, where releases can be most dangerous and where the local buildings strongly affect the dispersion. In this work we investigate the dispersion of a point-source release of a passive scalar in a regular array of urban-like cubical obstacles by means of direct numerical simulations (DNS).

We focus on dispersion through regular arrays of buildings, and several characteristics can be identified in the flow structure. Firstly, the wake regions behind the buildings are dominated by recirculation, which cause material to be trapped and re-released more slowly. This process gives rise to so-called secondary sources in the near-field region. Secondly, updrafts behind the buildings also transport material towards the building top and out of the array. Thirdly an aisle of fast flow across the domain channels material. For example, for a wind direction of 45 degrees, there are regions along the streets and intersections where the flow is faster. Higher up, those regions connect, creating a corridor of fast flow. Fourthly, dividing streamlines enhance lateral dispersion of material around the buildings.

Despite the complexity of the flow and dispersion patterns across the domain, temporal fluctuations in the concentration field within the array are smaller than in open terrain. The temporal fluctuation of the concentration along the core of the plume is comparable in magnitude with the mean value of concentration. This is because of efficient mixing of the scalar due to small-scale turbulent fluctuations in the flow within the array. Meanwhile, along the border of the plume this value tends to increase due to a large concentration gradient.

Similar behaviour is observed for spatial fluctuations in concentration within intersections. Except close to the source, spatial fluctuations in concentration are generally small. Moreover, within an intersection, the vertical profile of mean concentration varies little with location. Therefore, the scalar within an intersection can be considered well mixed and a single measurement can represent well the concentration within the intersection. This is not necessarily true within a street, where larger concentration gradients may occur.

The comprehensive dataset from the DNS is further analysed within the framework of simple formulations such as a box-averaged street network model and the Gaussian plume model. Further results will be presented comparing the concentration plume within the array with that above.