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Flow structure and near-field dispersion in arrays of building-like obstacles ☆

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ABSTRACT

Dispersion in the near-field region of localised releases in urban areas is difficult to predict because of the strong influence of individual buildings. Effects include upstream dispersion, trapping of material into building wakes and enhanced concentration fluctuations. As a result, concentration patterns are highly variable in time and mean profiles in the near field are strongly non-Gaussian. These aspects of near-field dispersion are documented by analysing data from direct numerical simulations in arrays of building-like obstacles and are related to the underlying flow structure. The mean flow structure around the buildings is found to exert a strong influence over the dispersion of material in the near field. Diverging streamlines around buildings enhance lateral dispersion. Entrainment of material into building wakes in the very near field gives rise to secondary sources, which then affect the subsequent dispersion pattern. High levels of concentration fluctuations are also found in this very near field; the fluctuation intensity is of order 2 to 5.

1. Introduction

Understanding dispersion processes in urban areas is important for modelling air quality as well as pollution from accidental or terrorist releases. The chaotic nature of turbulent flow and the complexity of the building geometry both contribute to making such modelling non-trivial. Urban geometry affects the mean flow and turbulence significantly (Barlow and Coceal, 2009) and thereby exerts a strong control on dispersion processes (Belcher, 2005). For localised releases, such effects are particularly important in the near-field region (here defined as within a few building blocks of the release), where conventional models such as Gaussian plume models fail (Belcher et al., 2013). In this region, certain characteristics of the dispersion become significant, although they are usually justifiably neglected further downstream. Recently, Wood et al. (2009) reported above-background dosages within 6–8 times the building height in all directions around the source in field experiments in central London. But comprehensive data and understanding on these near-field dispersion aspects are currently lacking. The present paper is an attempt to document such near-field aspects for simple urban-like geometries, where their effects can be more easily isolated and therefore better understood.

Specifically, the main questions investigated here are the following:

- What are the main characteristics of near-field dispersion from localised sources in urban areas?
- How are they related to the underlying flow structure around the buildings?
- How do the mean concentration and concentration fluctuations vary in the near field?

These questions are explored by analysing data from the recent direct numerical simulations (DNS) reported in Branford et al. (2011) and new simulations presented here. These simulations involve the continuous release of a passive scalar from localised ground-level sources within a regular array of cubes. The effect of different flow directions, obstacle layout and source location is investigated. The paper is structured as follows. In Section 2, we elaborate on the methodology and the cases studied. Results are presented in Section 3, which first looks at the instantaneous and mean flow field; the scalar field is then explored by looking at the instantaneous and mean concentration patterns, concentration profiles and time series. Conclusions are presented in Section 4.

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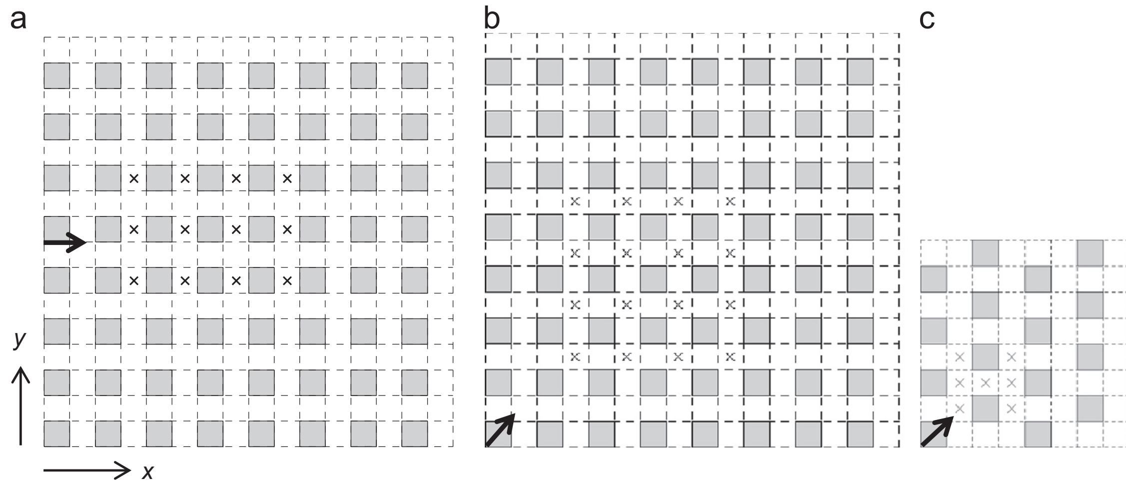

Fig. 1. Plan view of computational domain in the DNS. Crosses denote the locations of an ensemble of ground-level sources. (a) Regular array: 0° forcing direction (b) regular array: 45° forcing direction and (c) staggered array: 45° forcing direction. Arrows denote forcing directions.

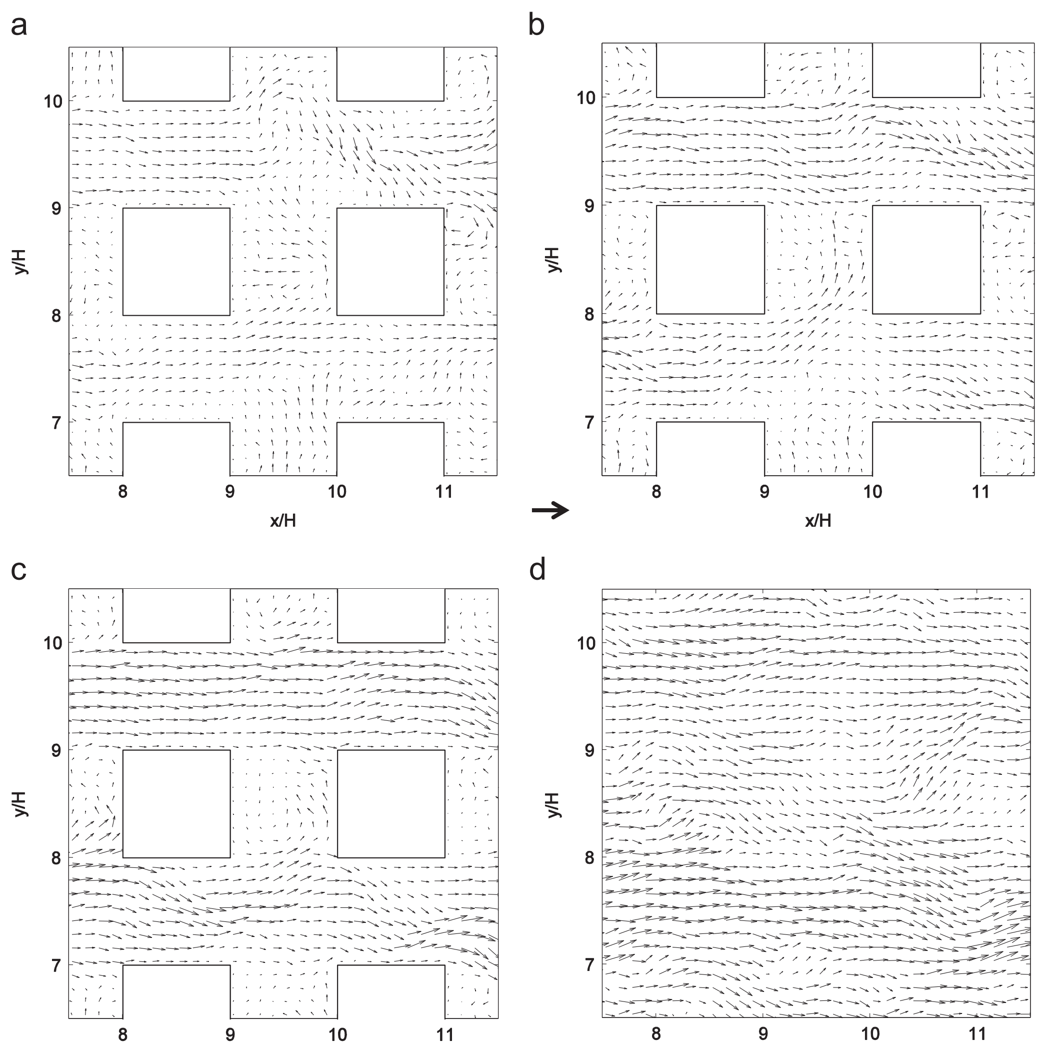

Fig. 2. Snapshots of (u, v) wind vectors for a forcing direction of 0° in horizontal planes at values of z/H of (a) 0.23 (b) 0.52 (c) 0.80 and (d) 1.08. Arrow denotes forcing direction.