Turbulent flow over groups of urban-like obstacles

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The ability to compute complex turbulent flows around bluff bodies is important for many applications, particularly with regard to flow control in engineering. More recently, stringent demands for urban air quality control and increased concern about the release of hazardous materials in cities have heightened the need to accurately model flow and dispersion in urban areas.

Understanding the dynamics of mixing and transport in urban areas also enables parameterisations of urban areas to be developed for incorporation into numerical weather prediction models, and thereby increases the accuracy of weather forecasts.

The present work is a collaboration between the Department of Meteorology, University of Reading, and the School of Engineering Sciences, University of Southampton. Highly resolved Large Eddy Simulations (LES) and Direct Numerical Simulations (DNS) are performed to simulate turbulent flow around arrays of cubical, urban-like, obstacles. The arrays are arranged in different configurations and at different packing densities to investigate the effects of building proximity and layout on the flow. Initial aims are to compute time and spatial averages of flow quantities, from which parameterisations of drag and turbulence can be extracted. Another important aim is to identify organised structures in the flow and to understand their dynamics. Future work will model dispersion of tracers placed in the flow.

The model used is the Multiblock LES code, which has been developed by Glyn Thomas at Southampton University. The code is parallelised using MPI, and until recently has been run on a Linux cluster at Southampton as well as on the CSAR Cray T3E (Turing). In October 2003, Neil Stringfellow at CSAR ported and optimised the code for the new SGI Altix (Newton). The performance of the code on the Altix has been astounding, giving speed-ups of up to an order of magnitude as compared to the T3E, and of two orders of magnitude as compared to the Linux cluster at Southampton! This has compressed run times from weeks to days, and has enabled research possibilities that could not be envisaged before.

The substantial computational resources make it possible to compute highly resolved turbulent flows at sufficiently high Reynolds number and for sufficiently long to allow the calculation of converged and stable statistics. This is important to establish the credibility of the simulations. Results from the simulations are in very good agreement with published wind tunnel data. These results indicate the potential of the present modelling approach for these important problems in urban meteorology.

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http://www.met.rdg.ac.uk/Research/urb_met

Snapshot of velocity vector field over a staggered array of cubes: (a) vertical slice through middle of cube, (b) horizontal slice at half cube height.

Each cube is resolved with 32 x 32 x 32 gridpoints.

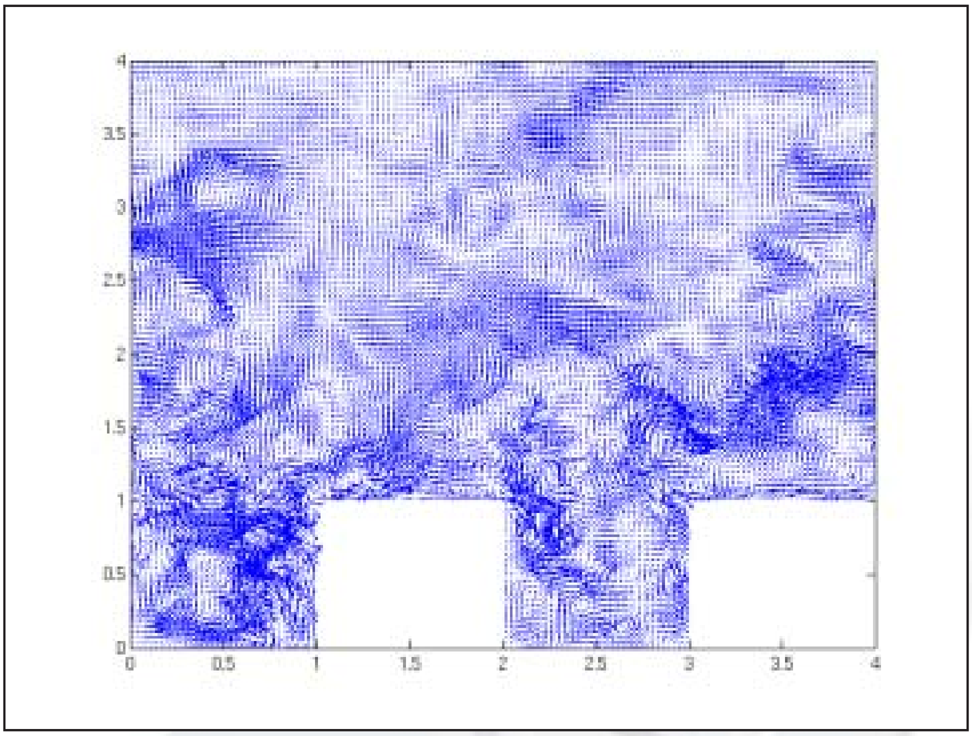

Figure 1: vertical slice through middle of cube.

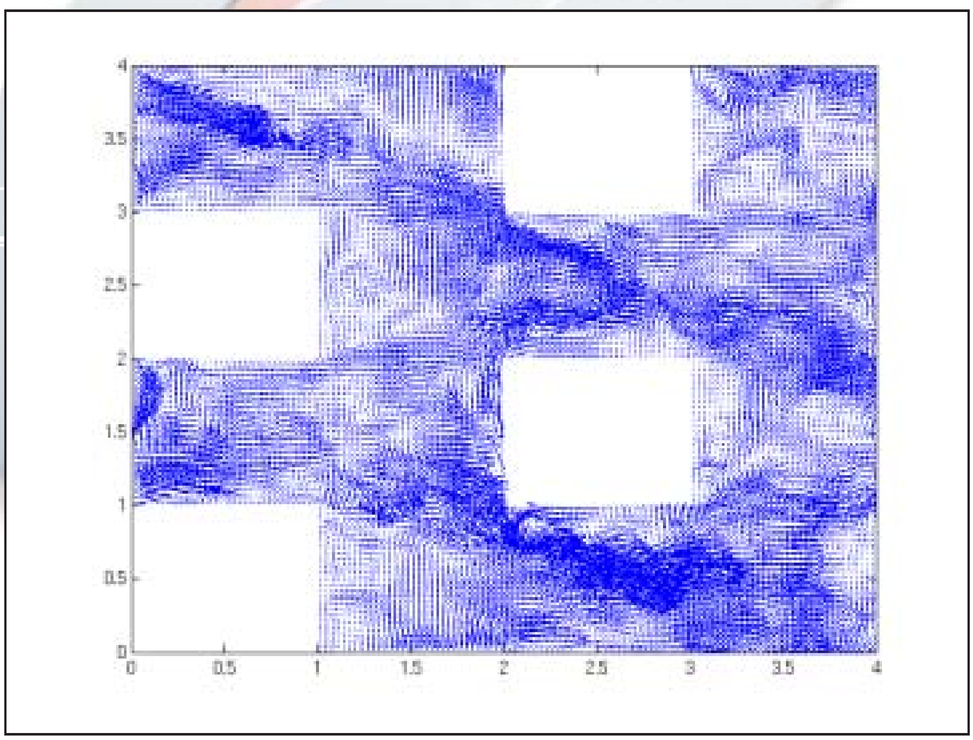

Figure 2 horizontal slice at half cube height.