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IMPACT OF BUILDING SEPARATION ON NATURAL VENTILATION BEHAVIOUR AND PERFORMANCE FOR LOW-RISE STRUCTURES

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Introduction

Substantial airflow modifications by buildings make natural ventilation behaviour in urban areas hard to be determined. The cross-ventilation through an indoor space is expected to respond differently to the outdoor environment. Research effort dedicated to this area is surprisingly small. Therefore, large-eddy simulation (LES) was employed in this study to address the natural ventilation performance of low-rise buildings within street canyons of various aspect ratios.

Mathematical Model

LES with the one-equation SGS model for k_{sgs}

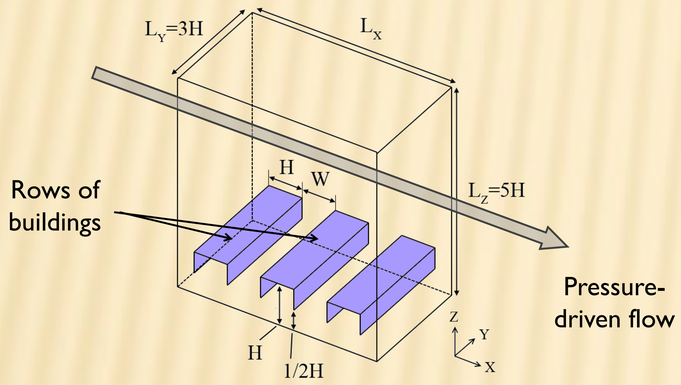
$$\frac{\partial k_{sgs}}{\partial t}+\frac{\partial}{\partial x_j}(\overline{u}_i k_{sgs})=2\nu_t \overline{S}^2-\frac{C_\varepsilon (k_{sgs})^{3/2}}{\Delta}+\frac{\partial}{\partial x_j}\left(\frac{1}{\mathrm{Re}}+\frac{1}{\mathrm{Re}_t}\right)\left(\frac{\partial k_{sgs}}{\partial x_j}\right)$$

Simulations were performed by OpenFOAM 1.5.

Model Validation

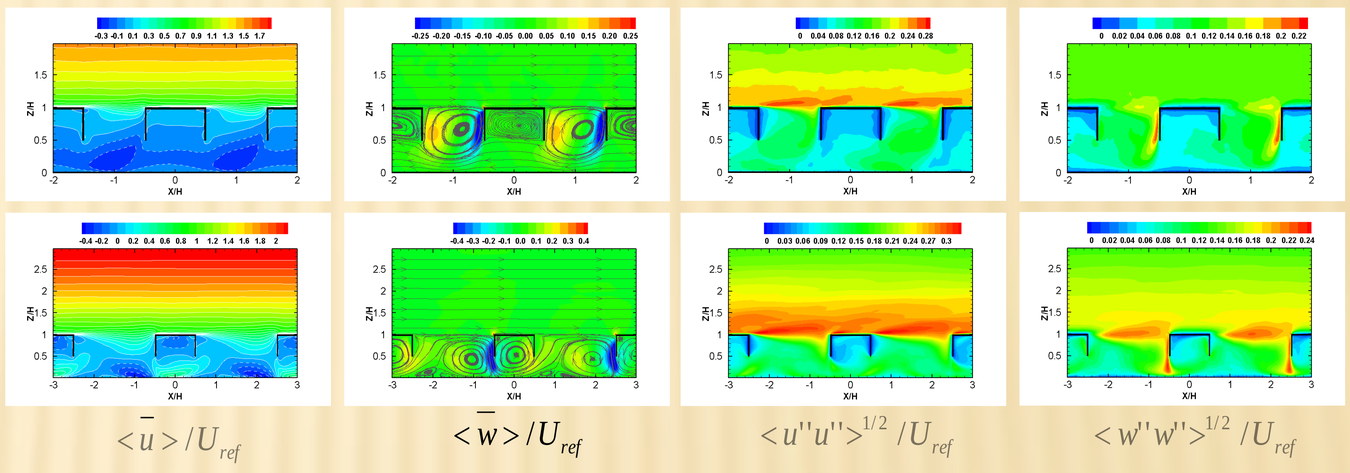
Good agreement was observed in the comparison of the mean velocities and the fluctuations to the experimental data obtained by Jiang et al. (2003[1]) on a cubic cross-ventilated building. Moreover, the one-equation SGS model performed slightly better than the standard Smagorinsky SGS model.

Results & Major Findings



Geometry of the computational domain

- Three two-dimensional buildings ($H\times H$) at equal separation W.
- Periodic in the x- and y-directions.
- Four aspect ratios, H/W = 1, 0.67, 0.5 and 0.25, were simulated.



Mean streamwise and vertical velocities and the fluctuations at 2 aspect ratios

- Flow mechanisms are different; The mean flow through the openings are reversed for the buildings of H/W=1.
- At H/W = 0.5, a portion of the shear-layer flow reaches the ground level and penetrates the building; Higher $\langle w''w''\rangle^{1/2}/U_{ref}$ also suggests stronger fresh air entrainment.
- Average indoor flow speeds are higher at smaller H/W; Turbulence then contributes less to the natural ventilation.

Conclusion

The LES revealed a number of dissimilarities of the mean airflow and the relative importance of turbulent ventilation across the rows of hypothetical buildings at different separations (densities). Further studies could help facilitate ventilation by refining the design of windows and separations.

[1] Jiang, Y., Alexander, D., Jenkins, H., Arthur, R. and Chen, Q., 2003: Natural ventilation in buildings: measurement in a wind tunnel and numerical simulation with large-eddy simulation, *J. Wind Eng. Ind. Aerodyn.*, **91**, 331–353.

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