Investigation of the impact of urban wind-flow on unsteady wind-driven natural ventilation.

Christos H. Halios[1,*], Hannah L. Gough[1], Janet F. Barlow[1], Marco-Felipe King[2], Catherine Noakes[2]

[1] Department of Meteorology, University of Reading, Reading, UK
[2] School of Engineering, University of Leeds, Leeds, UK

[*]*Corresponding email: c.halios@reading.ac.uk*

SUMMARY
Ventilation is one of the key factors controlling indoor thermal comfort and air quality. Ventilation assuming steady flows has been extensively assessed by several studies, but unsteady ventilation which is also likely to be important has attracted significantly less attention. In addition, it is well known that wind-flow around arrays of buildings is highly unsteady. The aim of this study will be to examine the effect of urban wind-flow on ventilation using field measurements taken during a period of 10 months in the framework of the Refresh project.
During a case study under high wind speeds when the background flow was perpendicular to the front of a test building, preliminary results showed that flow in front of the building was reversed by the presence of an idealised urban array. Next steps will test the array's impact on the steadiness of the flow through the building's openings.

PRACTICAL IMPLICATIONS
Basic understanding of unsteady ventilation in a highly turbulent urban environment will contribute to improved modelling of building ventilation and building design.

KEYWORDS
Turbulence, fluctuating ventilation, unsteady flow, urban canopy,Refresh.

1 INTRODUCTION
Ventilation is one of the key mechanisms that control indoor air quality, thermal comfort, and energy consumption in the built environment. The importance of ventilation has long been recognized by both the scientific community and policy makers. In principal, ventilation can be natural, mechanical or hybrid. Because mechanical ventilation and air conditioning of buildings consume large amounts of energy, natural ventilation has recently re-emerged as an energy efficient alternative for reducing energy consumption. Models have been developed to predict natural ventilation under various external conditions, building types and usages. Yet most models do not account for urban flows, which are highly turbulent and unsteady (Coceal et al., 2006). Fundamentally, the effect of fluctuating urban flows on natural ventilation is not well understood.

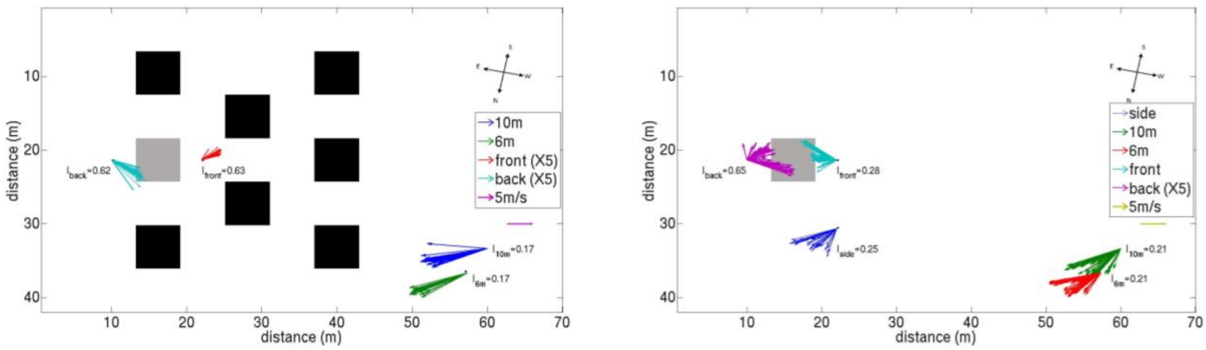
The main aim of this study is to examine the effect of urban wind-flow on ventilation using field measurements taken during a period of 10 months in the framework of the Refresh project (www.refresh-project.org.uk). Here we report preliminary results demonstrating typical flow patterns in an idealised urban canopy. In paper ID 300 at this conference (Gough et al., 2016) full details of the experiment are given, and the dependence of ventilation rate on wind direction is tested.

2 MATERIALS AND METHODS

A staggered array of 6 m high cubes, representing idealised buildings, was set up at a rural experimental facility used in wind engineering studies (Silsoe, UK), with one metal, internally instrumented cube representing a ventilated building. The cube was equipped with 30 external and 2 internal pressure taps and two Gill R3 sonic anemometers. “Total” ventilation rates were measured using the tracer gas decay method. The upstream flow was measured by two sonic anemometers at heights of 6 m and 10 m above ground level. The flow around the metal cube was measured by three sonic anemometers placed at the back, front and side of the metal cube at 3.5 m. The positions of the instruments can be seen in Figure 1. For the period September 2014 - April 2015 the full array was present; during May - July 2015 the array was removed. Different ventilation scenarios were examined (sealed, single-sided and cross-ventilated cases), using openings of area 0.4 m^2 at the front and back faces of the cube.

3 PRELIMINARY RESULTS

Before assessing unsteady effects, spatial flow patterns in the urban array should be established. In Figure 1a) the flow field for the array under high winds is presented (mean wind speed at 6 m, U_{6m} = 10 m s^{-1}). For comparison, the flow field during a case when the cube was isolated is presented in Figure 1b), U_{6m} = 8 m s^{-1}. As evident from turbulence intensities (also shown in figures) the flow is highly turbulent in front and at the back of the test cube in the presence of the array. Flow in front of the test cube is reversed in the presence of the array due to interacting wakes from upstream cubes.



(a) (b)

Figure 1. Flow patterns around a building when (a) surrounded by an array (10-1-2015, 00:00-10:00 UTC) and (b) isolated (2-6-2015, 00:00-23:00 UTC). Sonic anemometer data are shown as 30-minute mean wind vectors. Measurements at 10 m and 6 m are displaced laterally for clarity, but were co-located on the same mast. In a) vectors at both front and back locations have been magnified 5 times; in b) vectors only from the back location have been magnified 5 times. Turbulence intensities are also shown for every anemometer.

4 CONCLUDING REMARKS

Preliminary results demonstrate significant changes in the spatial pattern of the mean flow around a building in the presence of an array. The study will continue by examining the effect of the urban canopy on unsteady flow and ventilation rates.

5 REFERENCES

Gough H., Barlow J.F., Luo Z., Halios C.H., King M-F. 2016. The effect of urban micro-climate on indoor-outdoor air exchange. *The 14th International Conference on Indoor Air Quality and Climate – Indoor Air 2016*, Ghent, Belgium, July 3-8 2016.

Coceal O., Thomas T.G., Castro I.P., Belcher S.E. 2006. Mean flow and turbulence statistics over groups of urban-like cubical obstacles. *Boundary-Layer Meteorology*, 121(3), 491-519.