Determining the impact of urban canopy flow on building ventilation rates: an experimental study

Hannah L. Gough, Christos H. Halios, Janet F. Barlow, Zhiwen W. Luo
University of Reading
Adam P. Robertson, Andrew D. Quinn
University of Birmingham
Motivation

• Up to 90% of our time spent indoors (Leech et al. 2002)
• UK building stock relies heavily on natural ventilation (Meijer et al., 2009)
• Work hours will be lost due to overheating of cities under climate change (Greater London Authority, 2006)
• How well can we predict natural ventilation of buildings in a city?
Building ventilation

- How is ventilation of a building changed by presence of other buildings?
  - flow pattern, turbulence, temperature, inside and out
Ventilation measurements using the Silsoe cube

• Site and building behaviours are well known in wind engineering (Richards 2012; Straw 2000; Yang 2004) – rural site in UK
• Previous experiments only undertaken during certain conditions
• Complete control of instrument positions and ventilation set-up
• Aiming to gain an understanding of how an urban canopy may affect natural ventilation rates in building
Measuring:
- Rainfall
- Radiation
- Wind speed
- Wind direction
- Temperature
- Pressure
- CO$_2$ concentration

Ref wind at 10, 6 m

WSW 247°
- Strongly fluctuating ventilation
- Opening area = 0.4 x 1.0 m²
- Opening type: Single-sided
  Cross ventilation
Pressure taps (10 Hz)

Thermocouples (10 Hz)

Sonic anemometer (10 Hz)

CO₂ sensor (2 Hz)
Overview of experiment

- Wind, met and pressure data September 2014 to July 2015
- 156 CO$_2$ tracer gas decay releases undertaken (Sherman, 1990):

$$ C_i(t) = (C_0 - C_a) \exp(-\lambda_T t_i) + C_a $$

$$\lambda_T = 5.76 \text{ ACH} \pm 0.01$$
Impact of wind speed on ventilation rate (ACH)
Wind rose for ventilation experiments

Wind rose of Sept-March 10m mast data
Impact of wind direction on ventilation rate (ACH)
Impact of wind direction on normalised ventilation

- Ventilation rate in SI units
  \[ Q (\text{m}^3 \text{s}^{-1}) = \lambda T V / 3600 \]
- Normalised ventilation
  \[ Q' = Q / UA \]
Preliminary conclusions

• A limited array of buildings reduces
  cross ventilation rate by c. 28%
  single sided ventilation rate by c. 64%

• Relatively small shifts in wind direction can reduce ventilation rate by 30 to 35%

• Single sided ventilation in a building at the edge of an array appears to be the same as an isolated building
Future Work

• Compare ventilation rate from pressure data with tracer gas
• Relate pressure data to flow patterns (average, unsteady)
• Wind tunnel model – pressure data for all wind angles; extend array; vary density
• Compare with CFD simulations by the University of Leeds
• Real office buildings in London...
  ... with human beings!

www.refresh-project.org.uk

j.f.barlow@reading.ac.uk