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

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# 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

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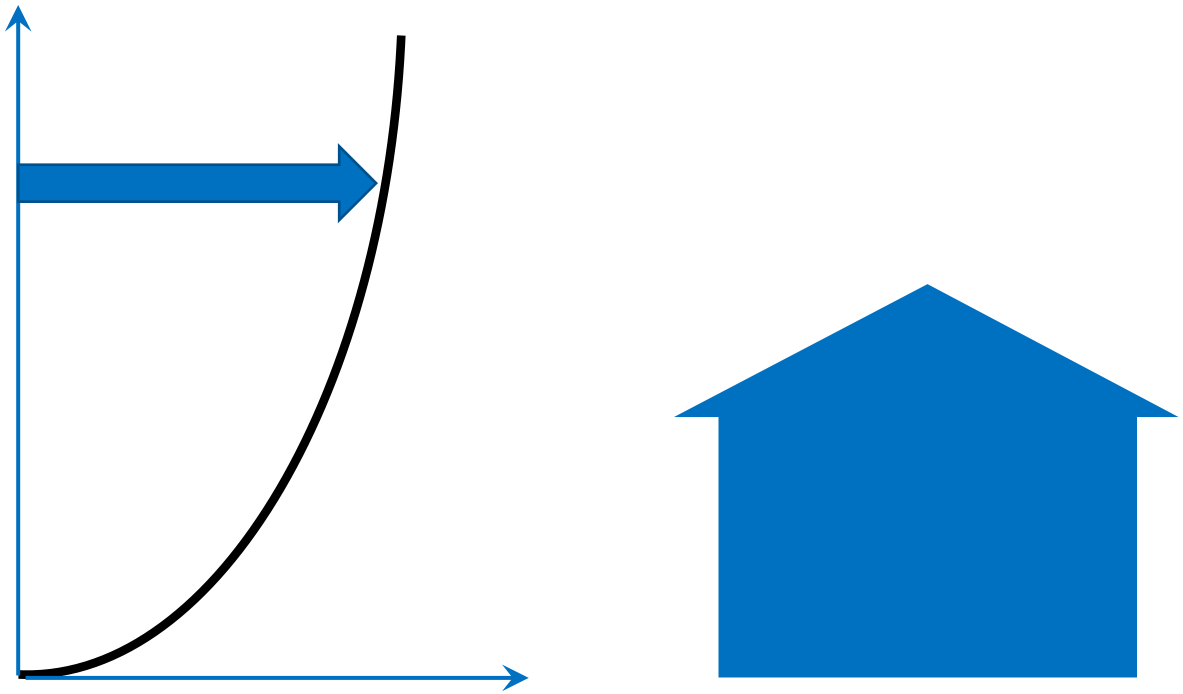

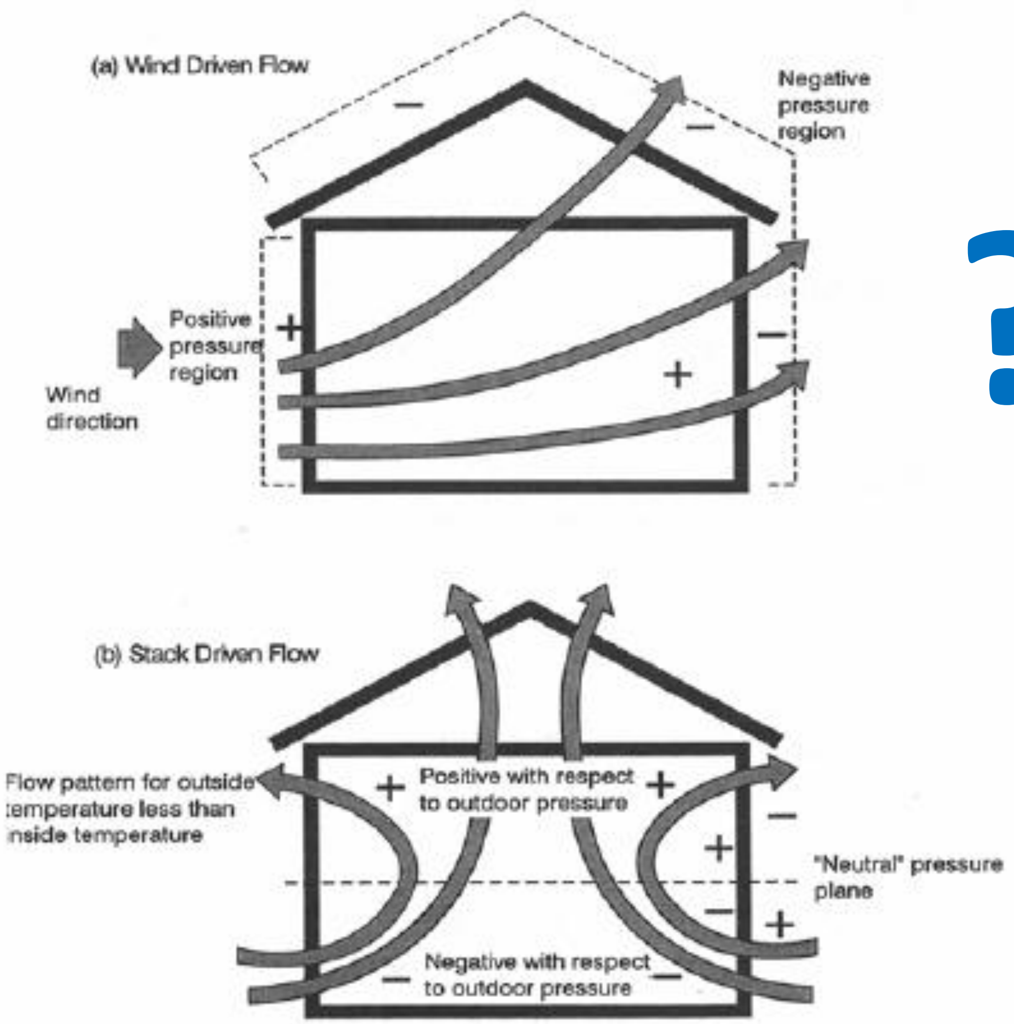


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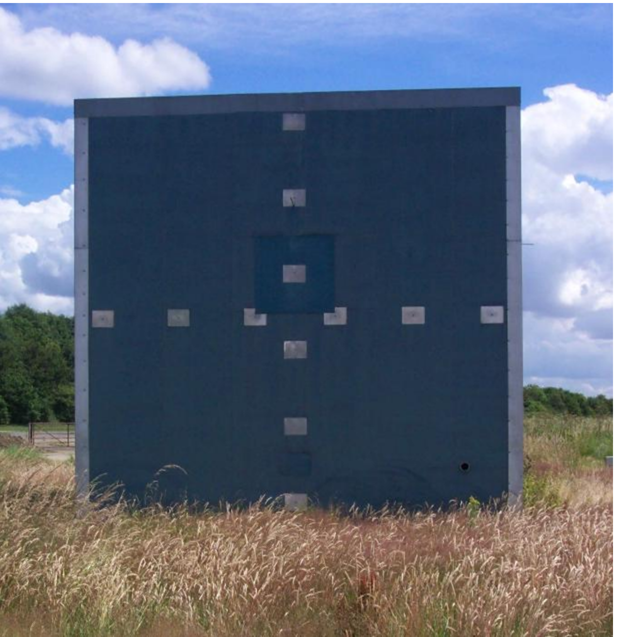
- How is ventilation of a building changed by presence of other buildings?

  flow pattern, turbulence

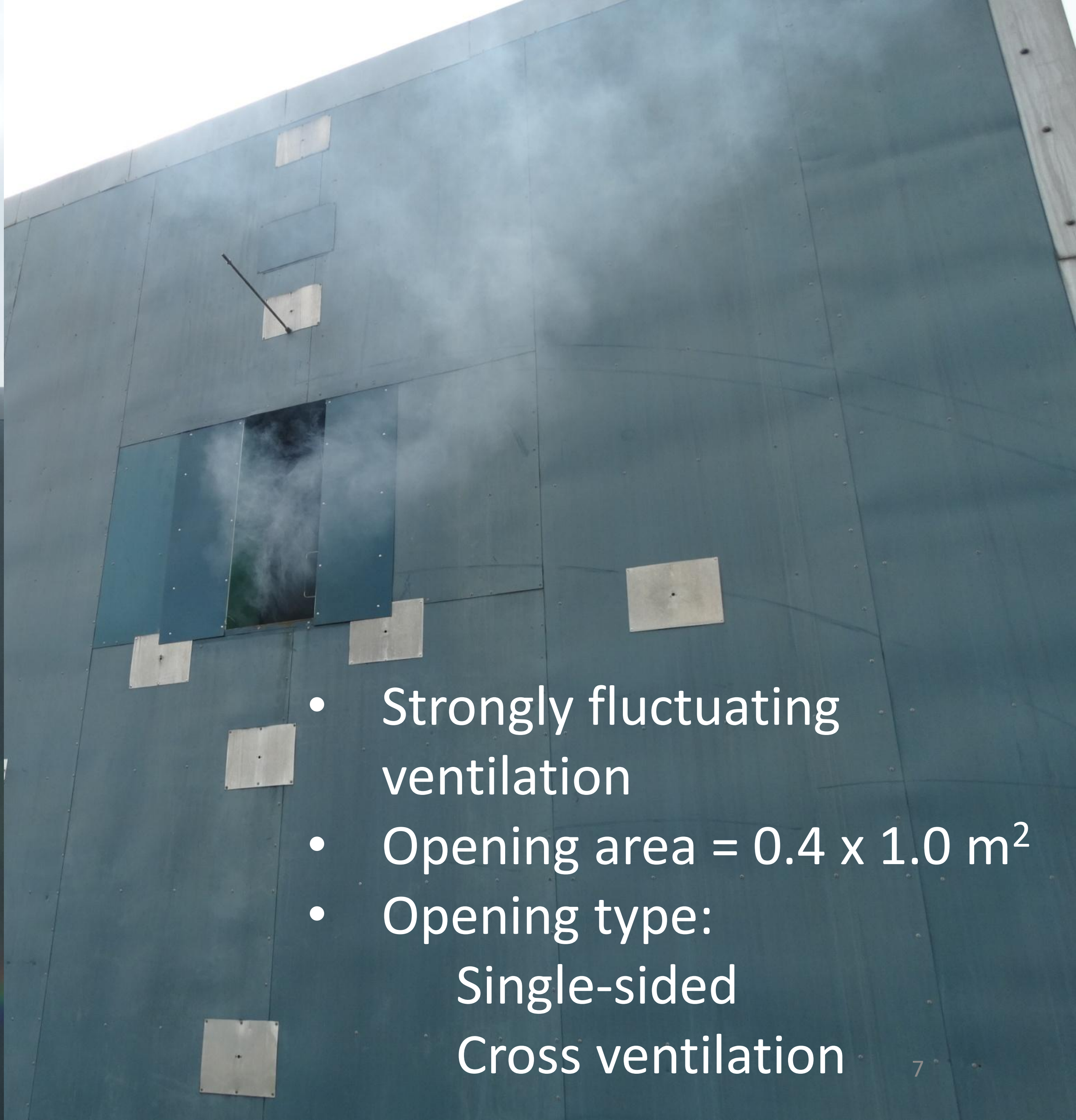
  temperature, inside and out

# Ventilation measurements using the Silsoe cube

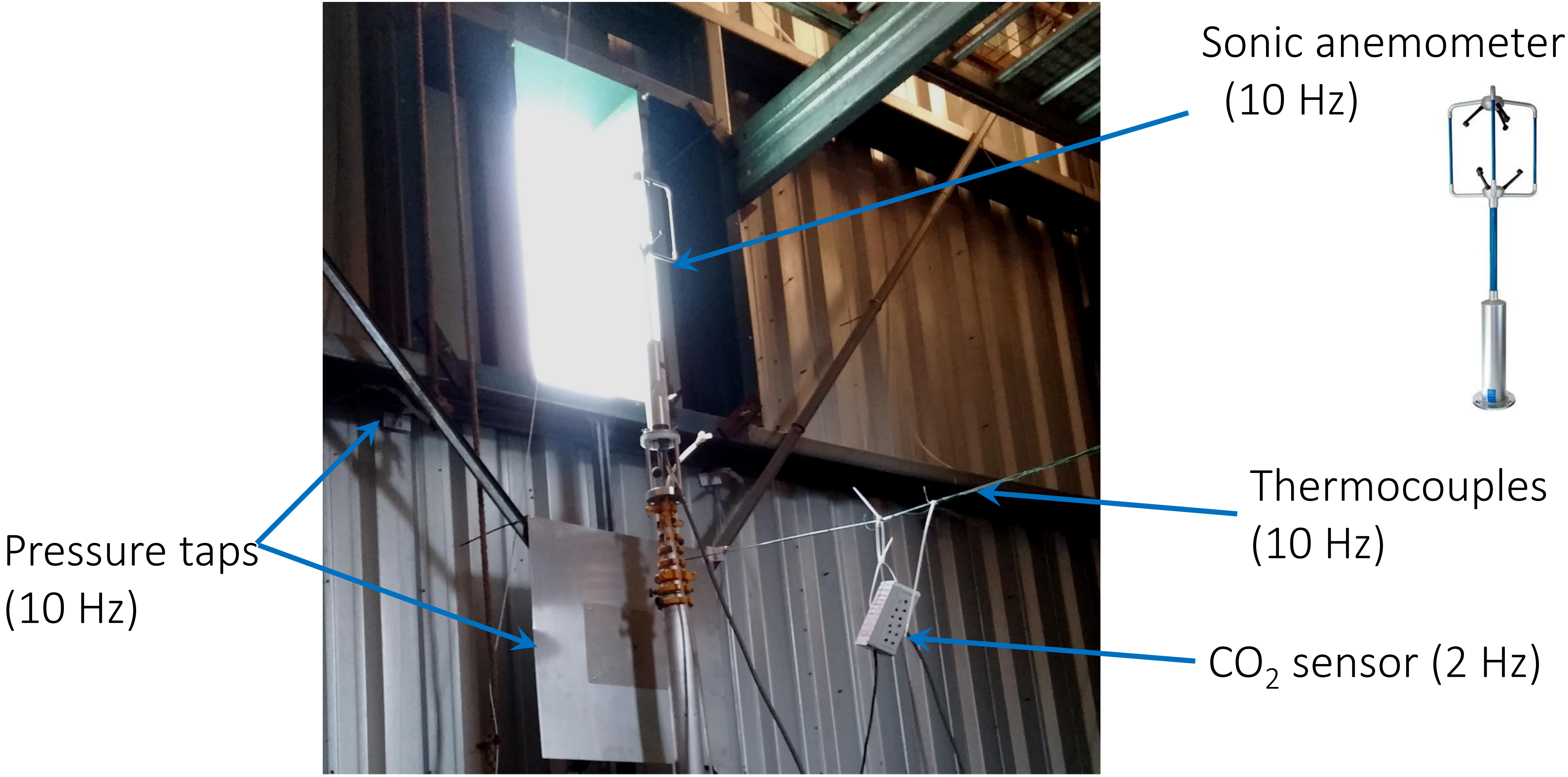
- Site and building behaviours are well known in wind engineering (Richards 2012; Straw 2000; Yang 2004) – rural site in UK
- Previous experiments only undertaken during certain conditions
- Complete control of instrument positions and ventilation set-up
- Aiming to gain an understanding of how an urban canopy may affect natural ventilation rates in building




Ref wind at 10, 6 m
WSW 247°
Measuring:
Rainfall
Radiation
Wind speed
Wind direction
Temperature
Pressure
CO2 concentration
6 m
6 m
6 m
N



- Strongly fluctuating ventilation
- Opening area = 0.4 x 1.0 $m^2$
- Opening type:
  - Single-sided
  - Cross ventilation

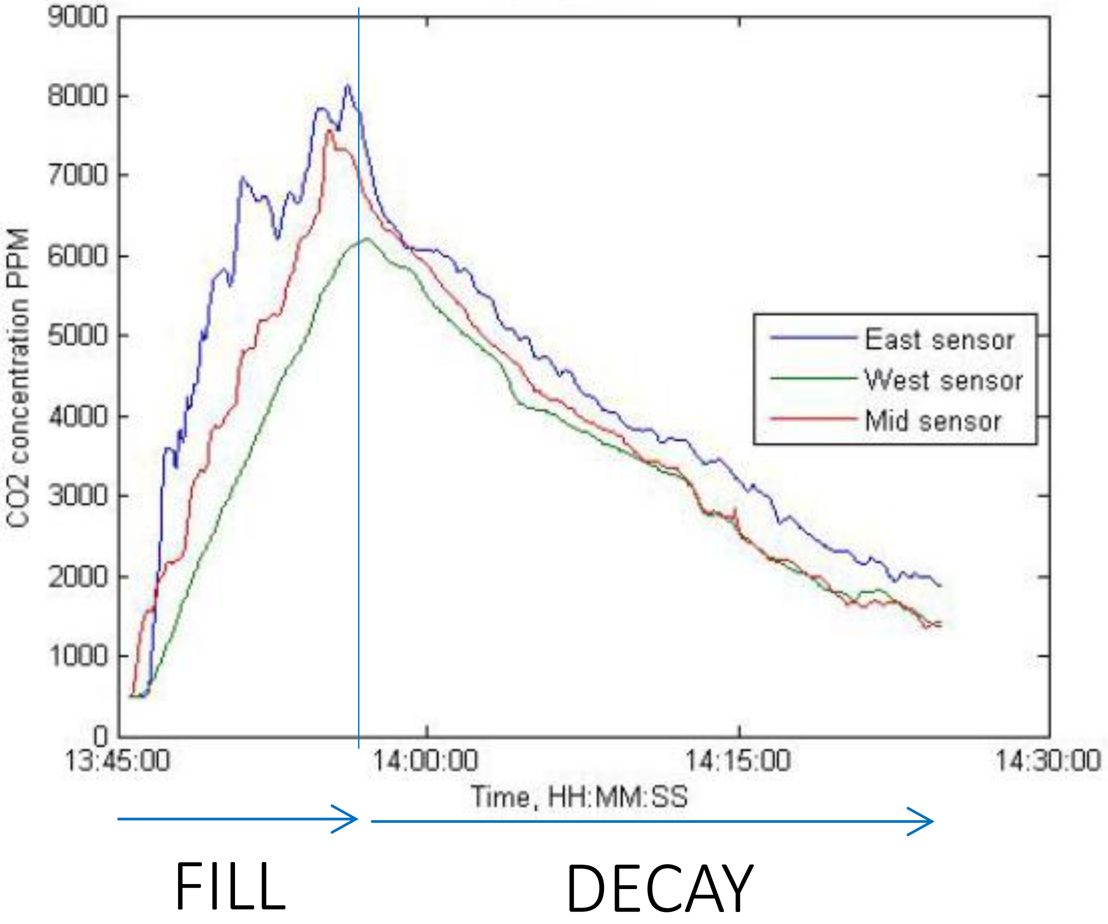


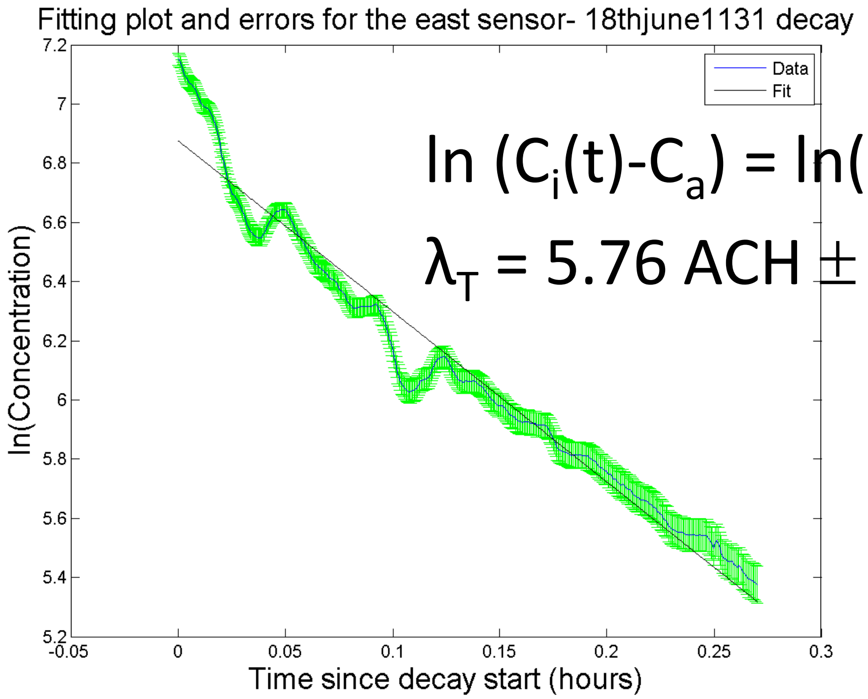
Sonic anemometer
(10 Hz)
Pressure taps
(10 Hz)
Thermocouples
(10 Hz)
$CO_2$ sensor (2 Hz)

# Overview of experiment

- Wind, met and pressure data September 2014 to July 2015
- 156 $CO_2$ tracer gas decay releases  undertaken (Sherman, 1990):

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

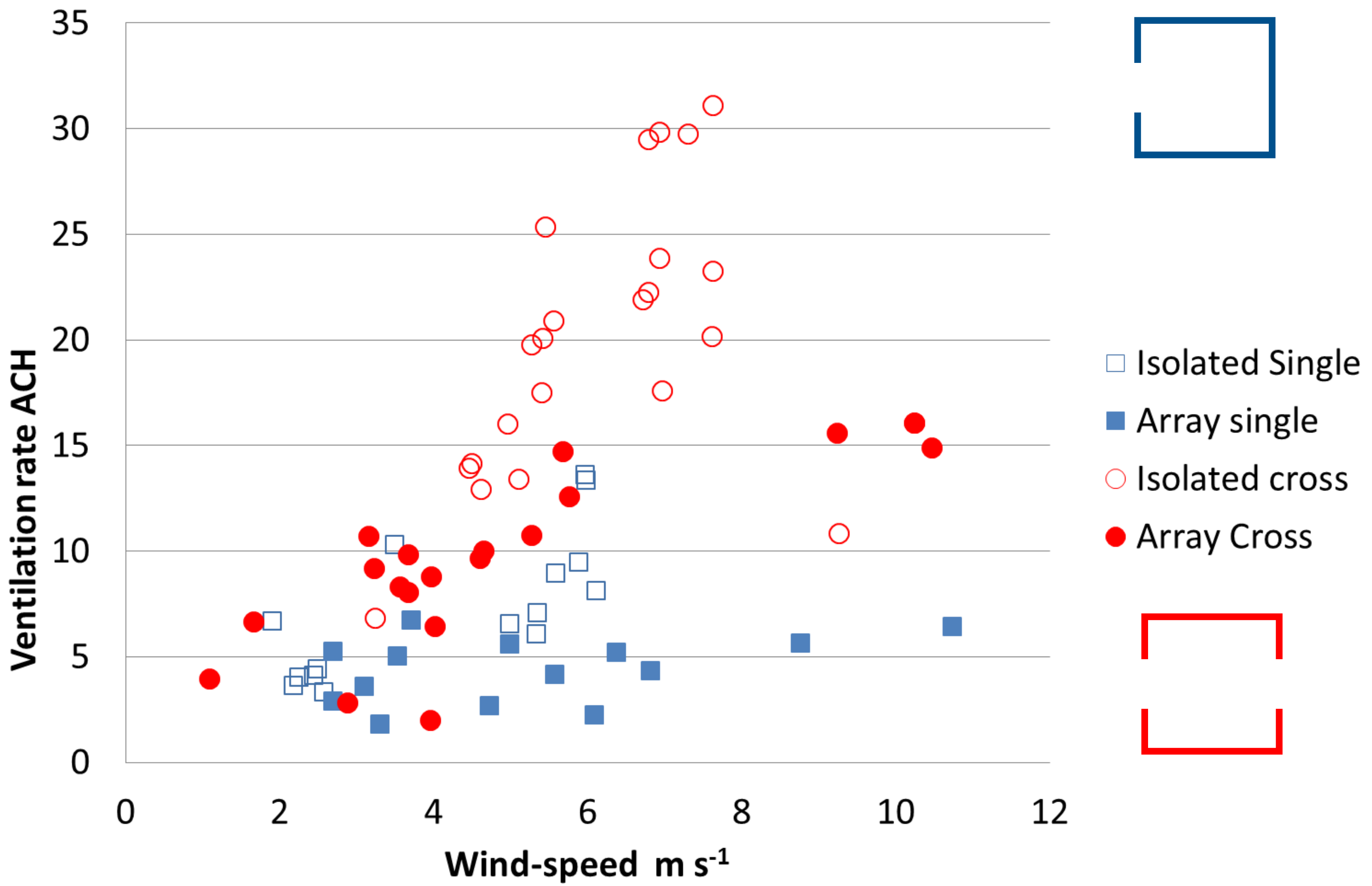


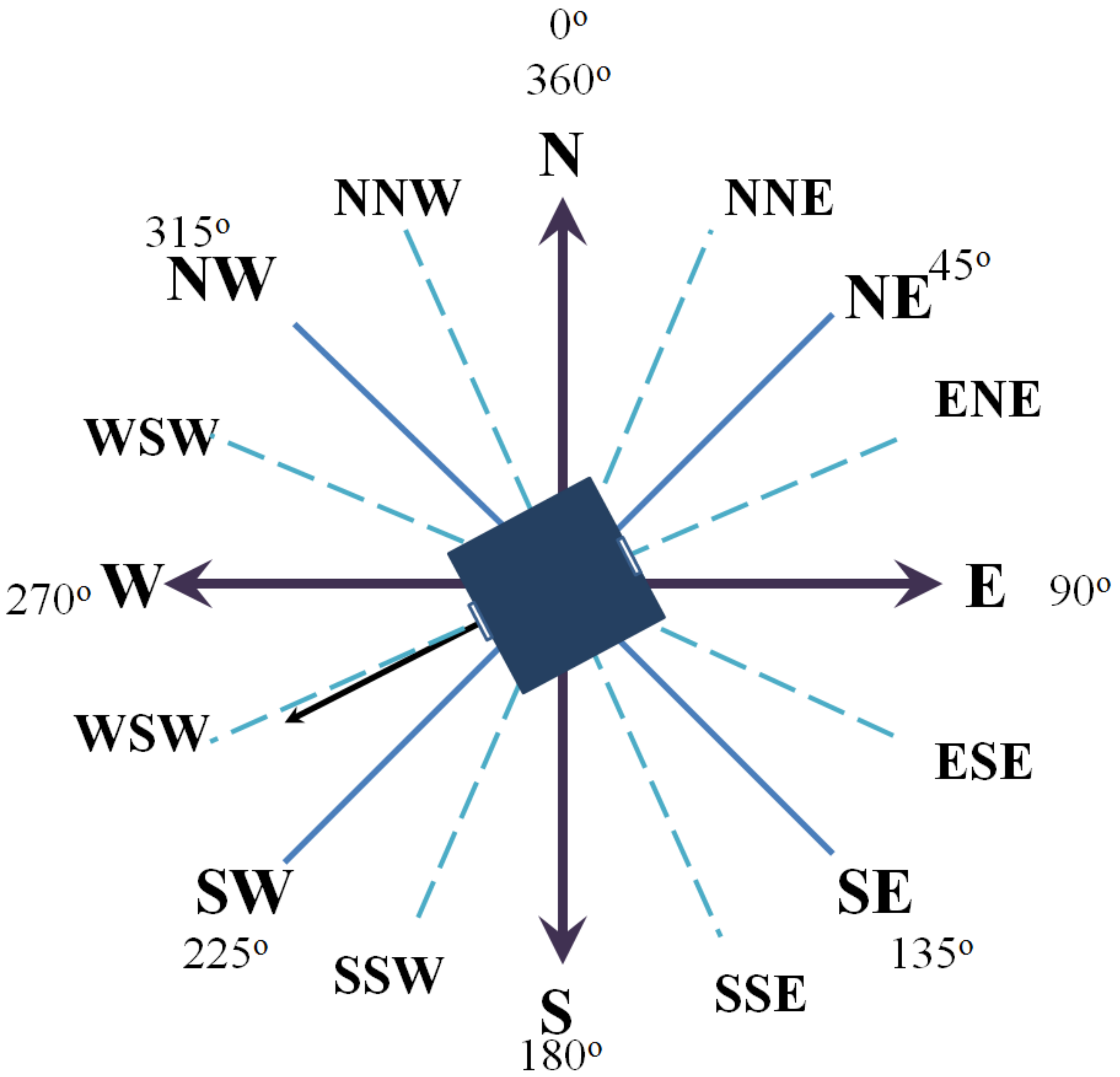

$$\ln(C_i(t) - C_a) = \ln(C_0 - C_a) - \lambda_T t$$

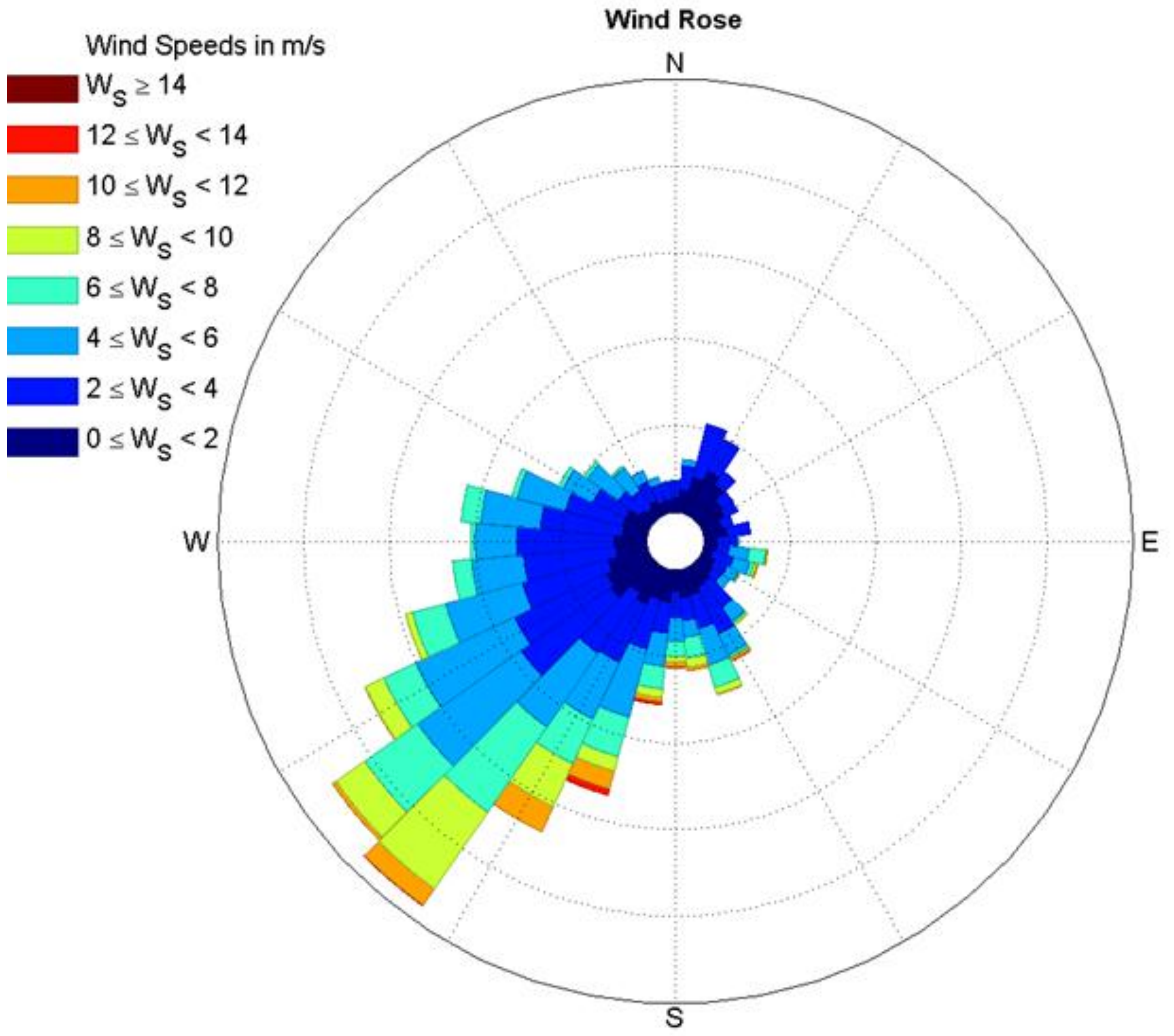
$\lambda_T$ = 5.76 ACH $\pm$ 0.01

# Impact of wind speed on ventilation rate (ACH)



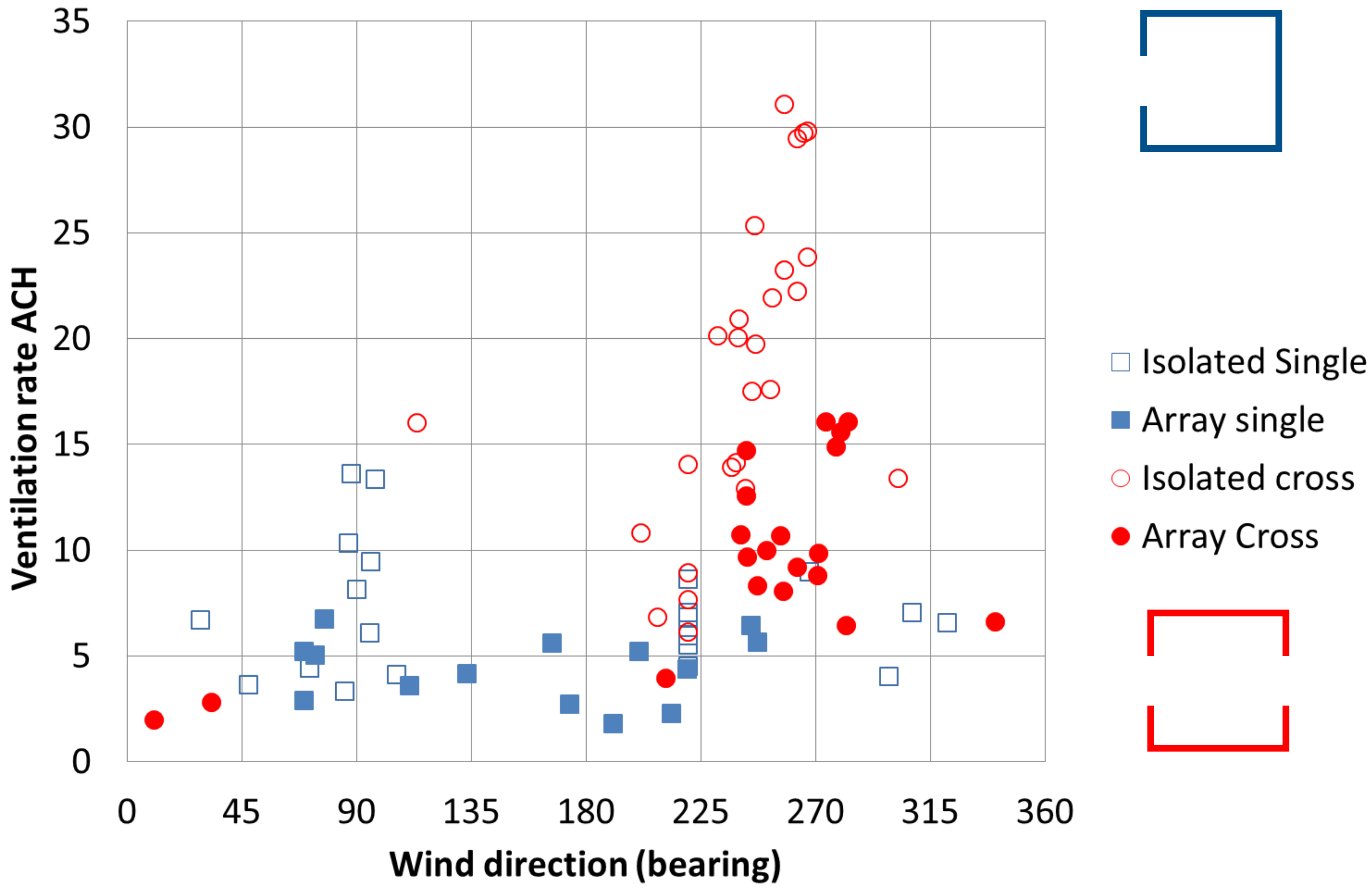
# Wind rose for ventilation experiments



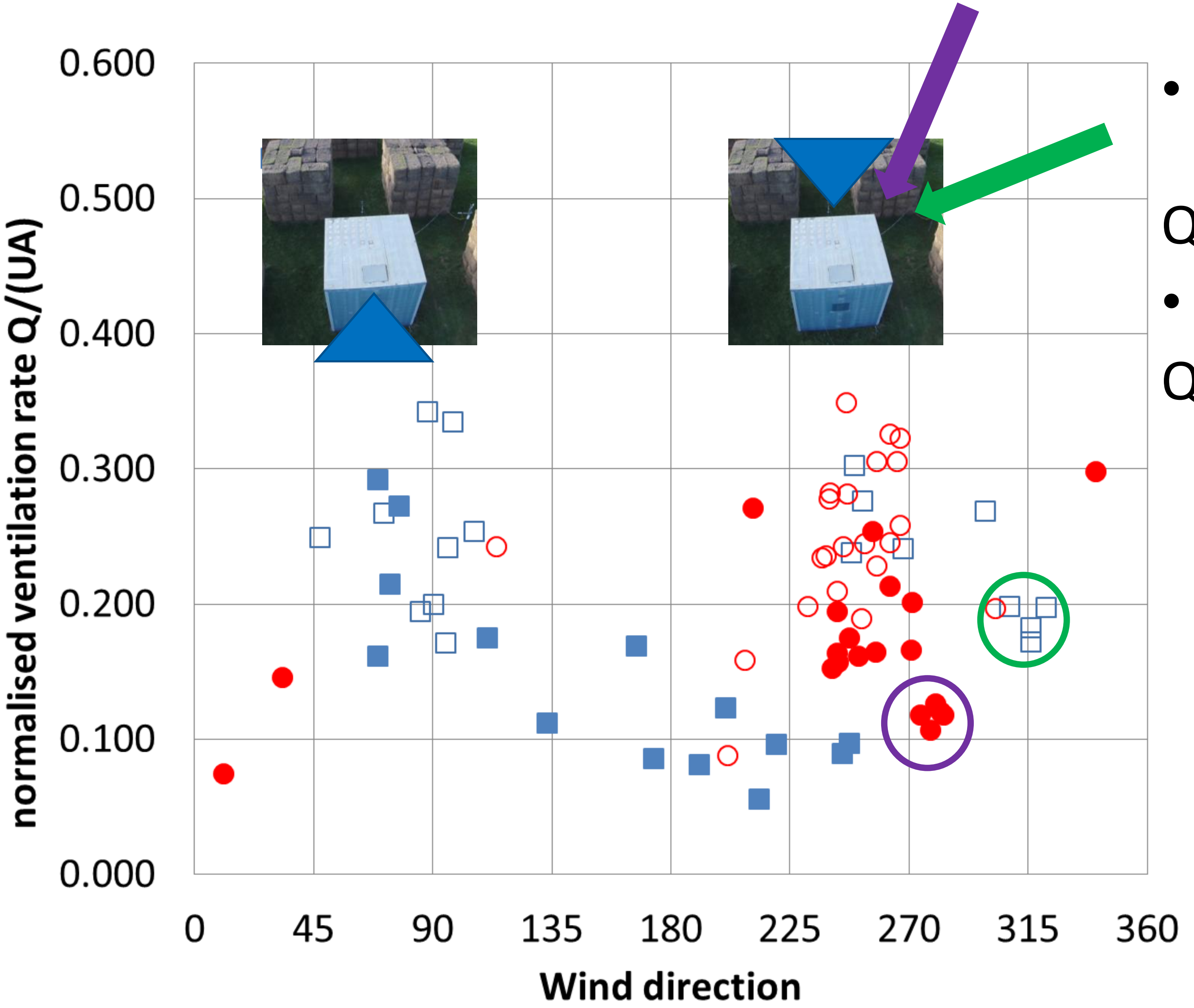




Wind rose of Sept-March 10m mast data

# Impact of wind direction on ventilation rate (ACH)



# Impact of wind direction on normalised ventilation




- Ventilation rate in SI units

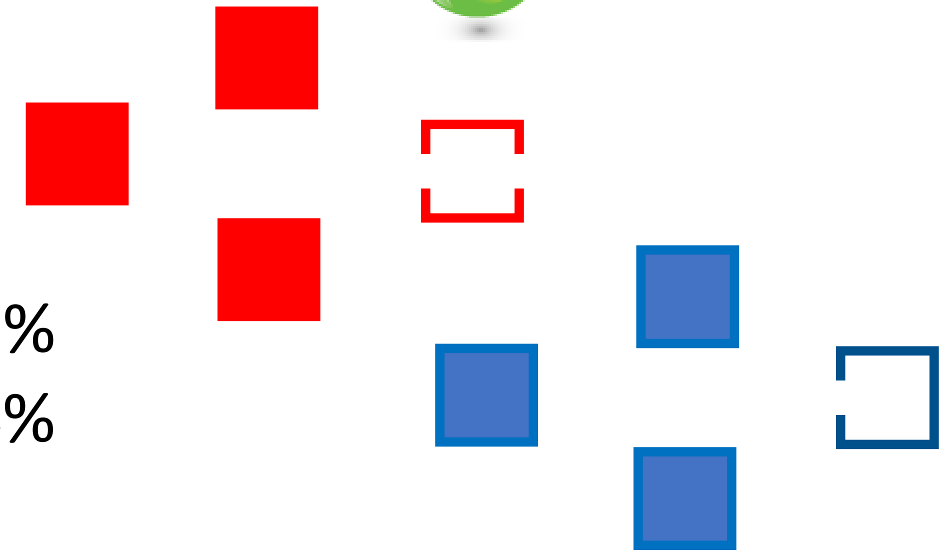
$Q\ (m^3\ s^{-1}) = \lambda_T V / 3600$

- Normalised ventilation

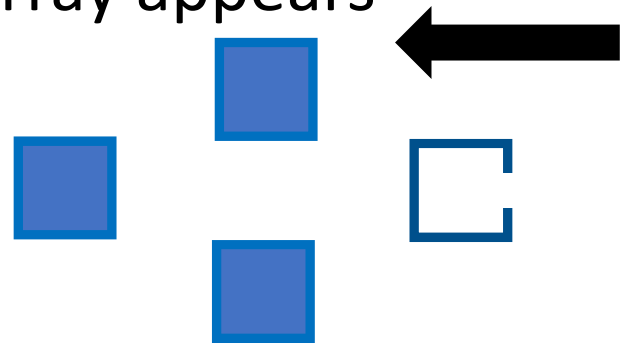
$Q' = Q/UA$

□ Isolated Single
■ Array single
○ Isolated cross
● Array Cross

# 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



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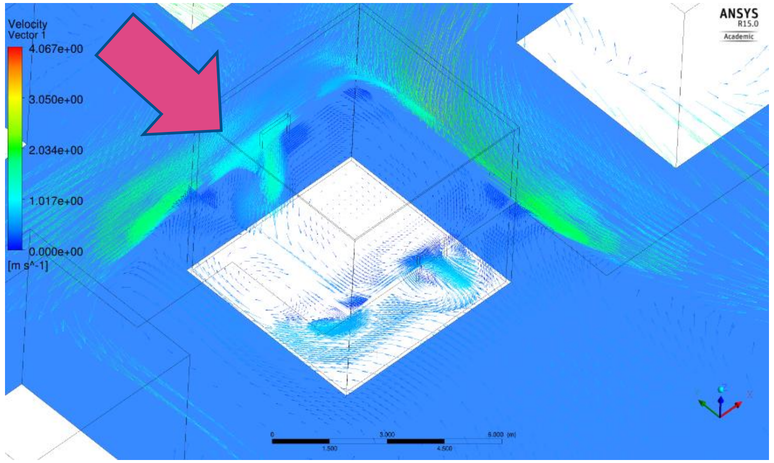
# Future Work

- 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!

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