UNIVERSITY OF SURREY

Effect of tall buildings on the urban environment

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UKRI Engineering and Physical Sciences Research Council
Scenario Doctoral Training Partnership
Institution of Mechanical Engineers
UKRI Natural Environment Research Council

Outline of the talk

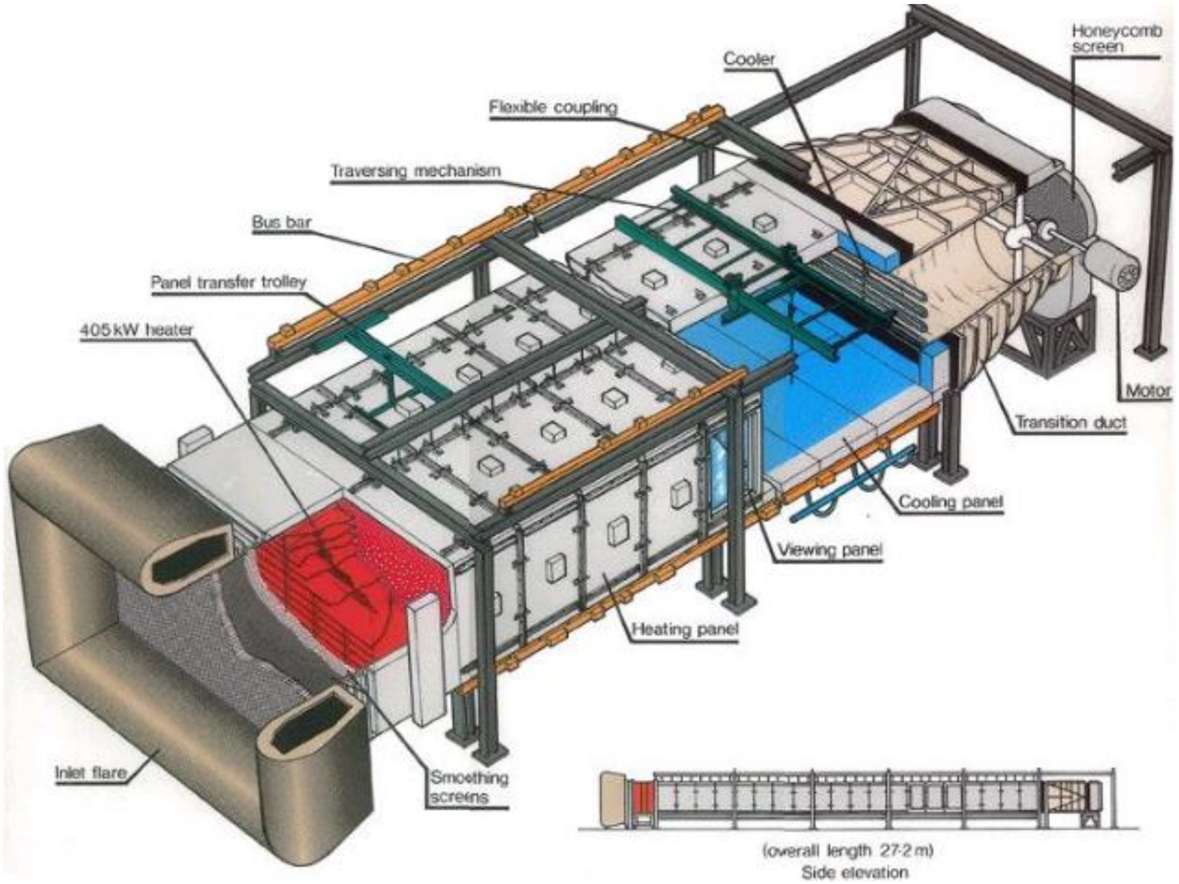
- The EnFlo Lab

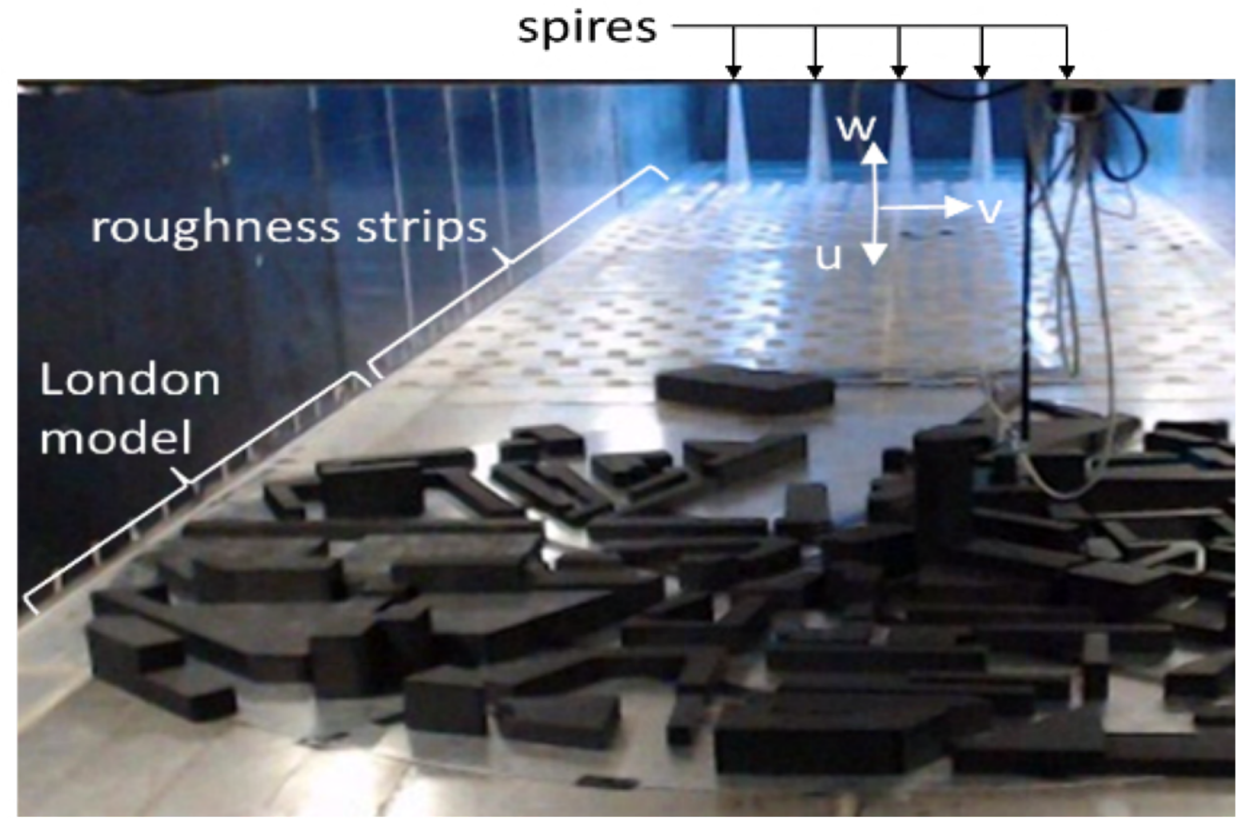
  - Facilities and equipment

- Previous/current work on tall buildings in the EnFlo Lab

  - Wakes of cylinders in ABL
  - Tall building in complex terrain
  - Tall and dense canopies
  - Wakes of building clusters in ABL

Facility and equipment – EnFlo WT





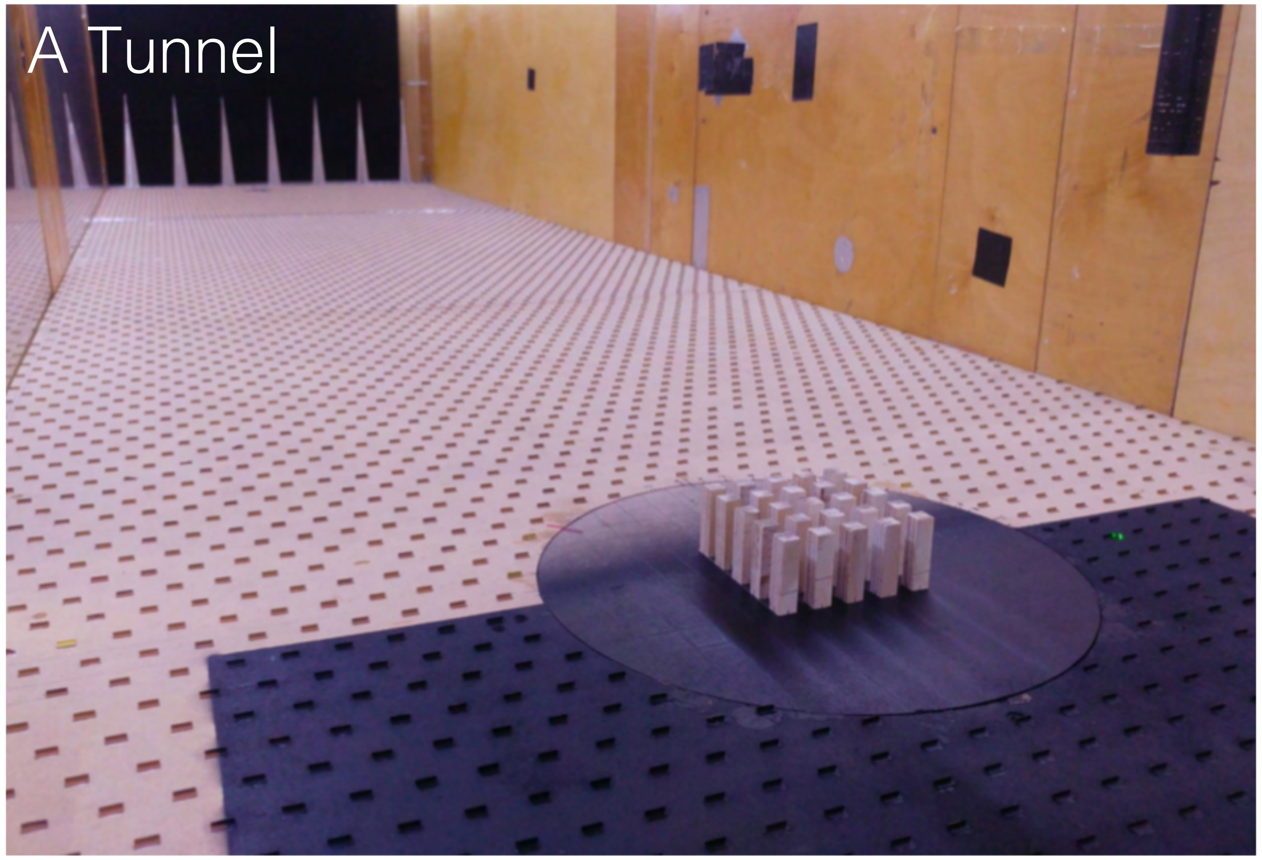
<u>Facility</u>

- Working section: 20 m x 3.5 m x 1.5 m
- Velocity: 1.5 m/s ($P \propto V^3$)
- Inlet heating: 15 layers, 405kW
  $(dT/dz)_{max}$=80C/m
- Floor heating/cooling: 1 kW/m^2 / 10 ˚C
- 2 overhead 3-axis traverses

<u>Equipment</u>

- Dantec - 3D LDA (NCAS)
- Dantec - 1D LDA
- Cambustion – FFID (NCAS S&F Grant)
  2 x 2 channel
- Cold probe anemometry for T'
- Volumetric positioning system 6 cameras

Facility and equipment – EnFlo Lab



Facilities

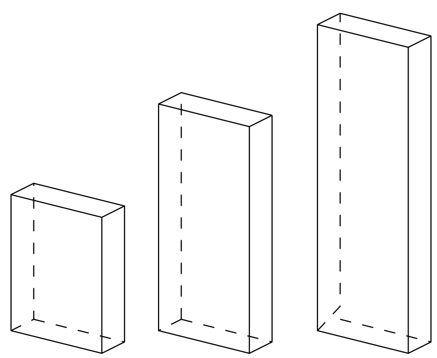
A Tunnel
- Working section: 4.5 m x 0.9 m x 0.6 m
- Velocity: 25 m/s

Aero Tunnel
- Working section: 9 m x 1.05 m x 1.27 m
- Velocity: 40 m/s

Equipment

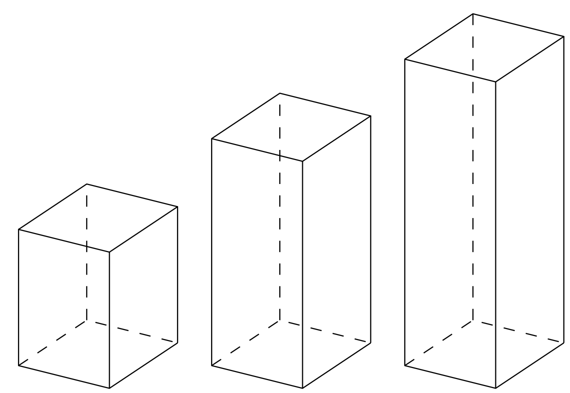
- Dantec – 2 x 2D LDA + mirrors (mean/fluctuating velocities)
- LaVision - Tomographic PIV (NERC Grant) 3 x 5.5 Mpixel sCMOS cameras
- SurreySensors – *P, T, U*

Wake of a cylinder in ABL



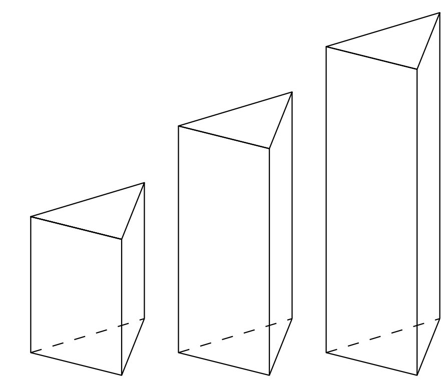
Flat Plate

- AR = 4, 6, 8
- δ/H_B = 0.3-0.5



Square Cylinder

- AR = 4, 6, 8
- δ/H_B = 0.3-0.5



Triangular Cylinder

- AR = 4, 6, 8
- δ/H_B = 0.3-0.5

Building dimensions

(width x height x depth)

Flat Plate:

- 10 x 40-60-80 x 2 mm^3

Square Cylinder:

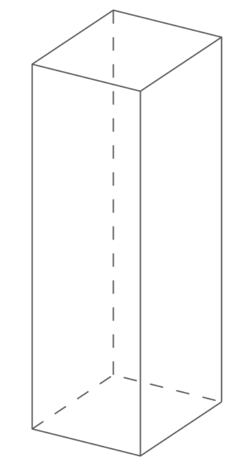
- 10 x 40-60-80 x 10 mm^3
- 17 x 40-60-80 x 17 mm^3

Triangular Cylinder:

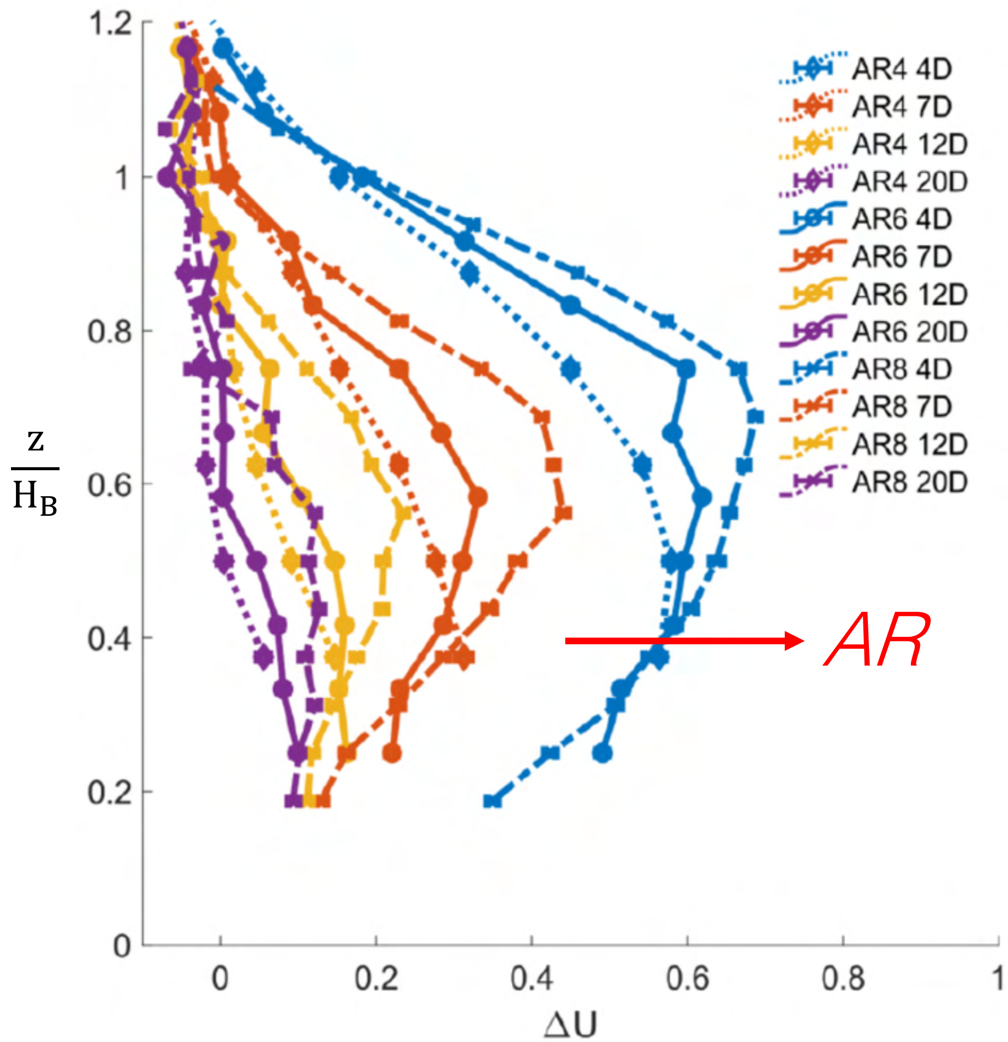
- 10 x 40-60-80 x 10 mm^3

Effect of AR & H_B/δ

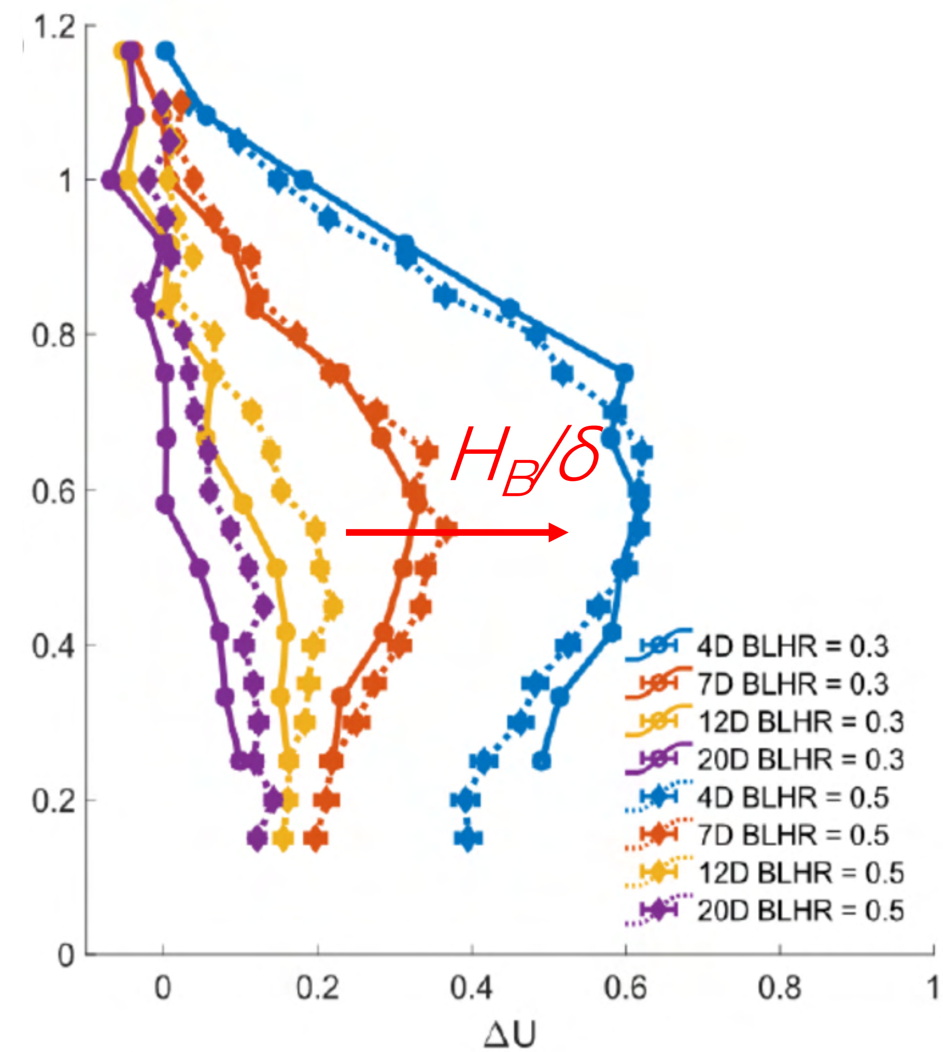
Samuel Shone



Aspect ratio



Relative height



U: mean axial velocity

U_e: edge velocity

z: wall-normal location

H_B: building height

$$\Delta U = \frac{U_e - U}{U_e}$$

<u>Effect of Aspect Ratio (AR)</u>

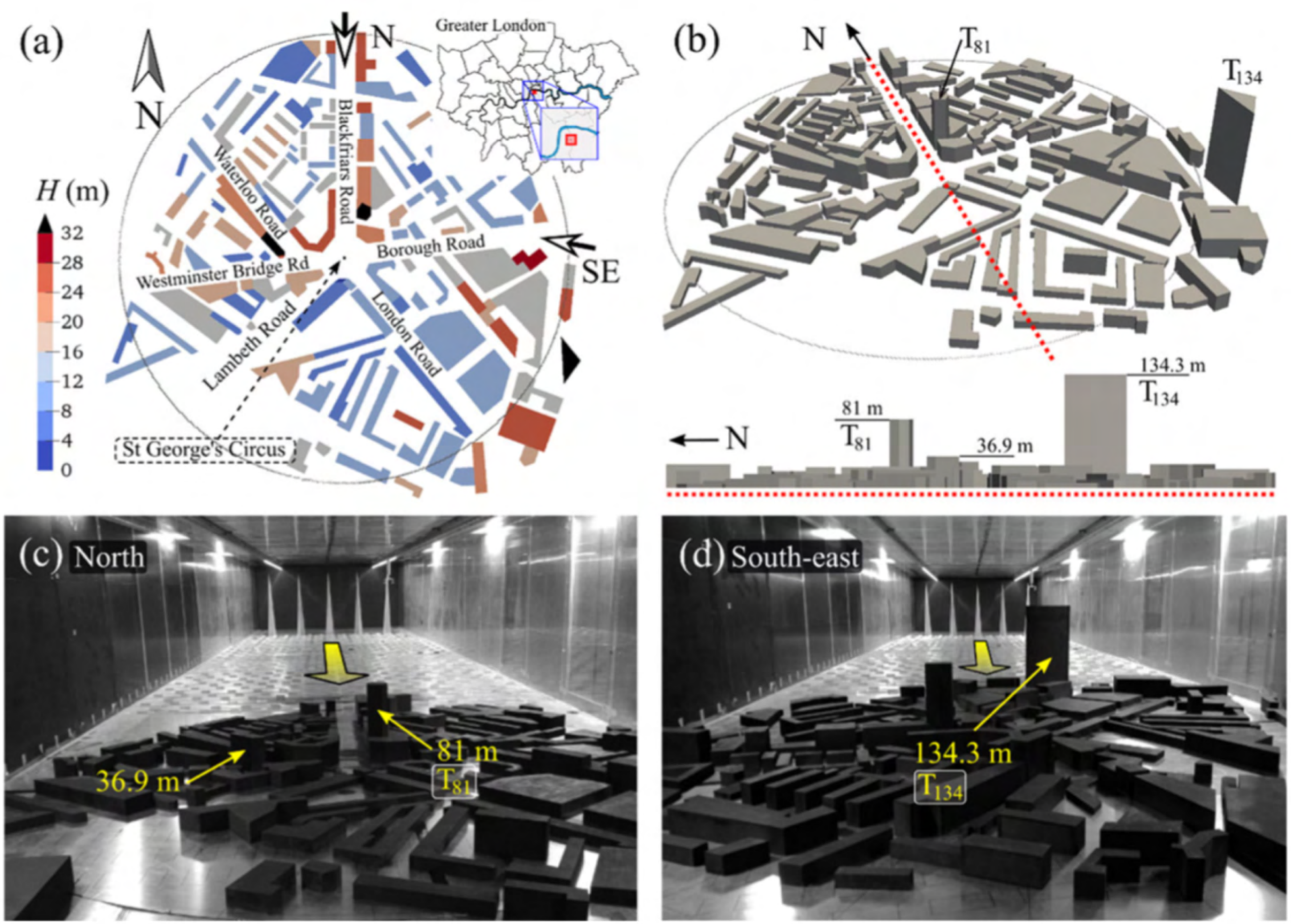
- Increasing the aspect ratio of a building increases the axial velocity deficit

<u>Effect of relative roughness height (BLHR)</u>

- The wake has a weaker dependency on relative roughness height

Tall building in complex terrain

William Lin

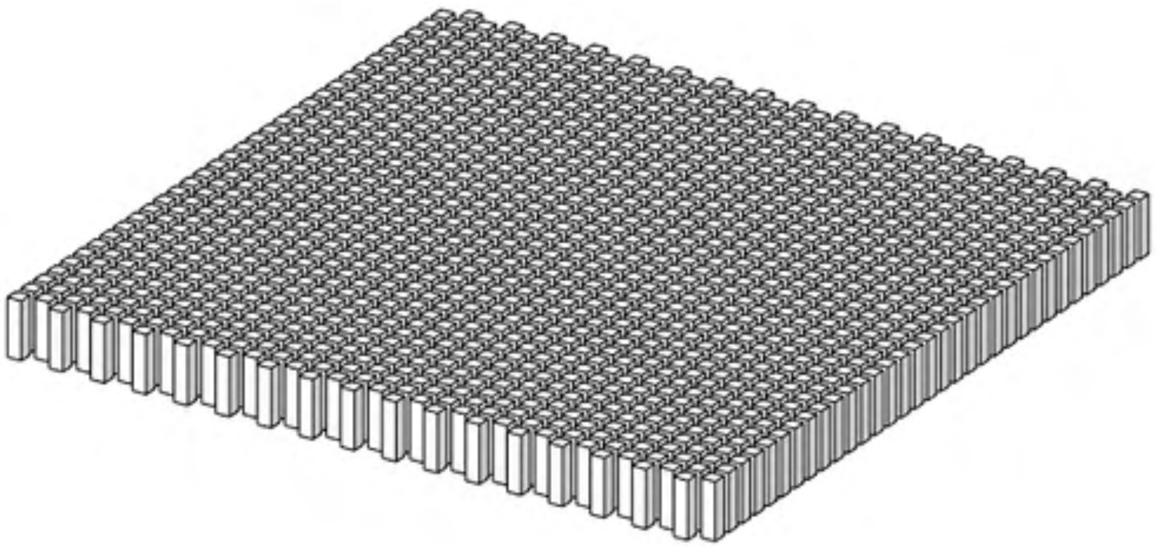


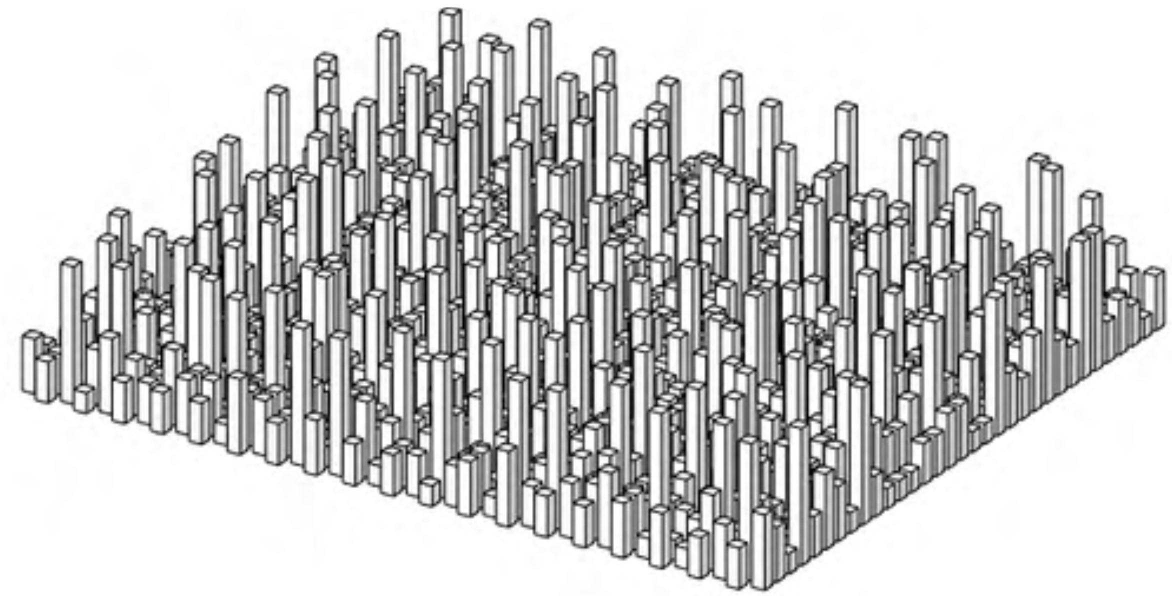
- Collaborative work within MAGIC (Reading-Surrey)

Hertwig at al. BLM 172:239–270 (2019)

Tall and dense canopies

Alexandros Makedonas





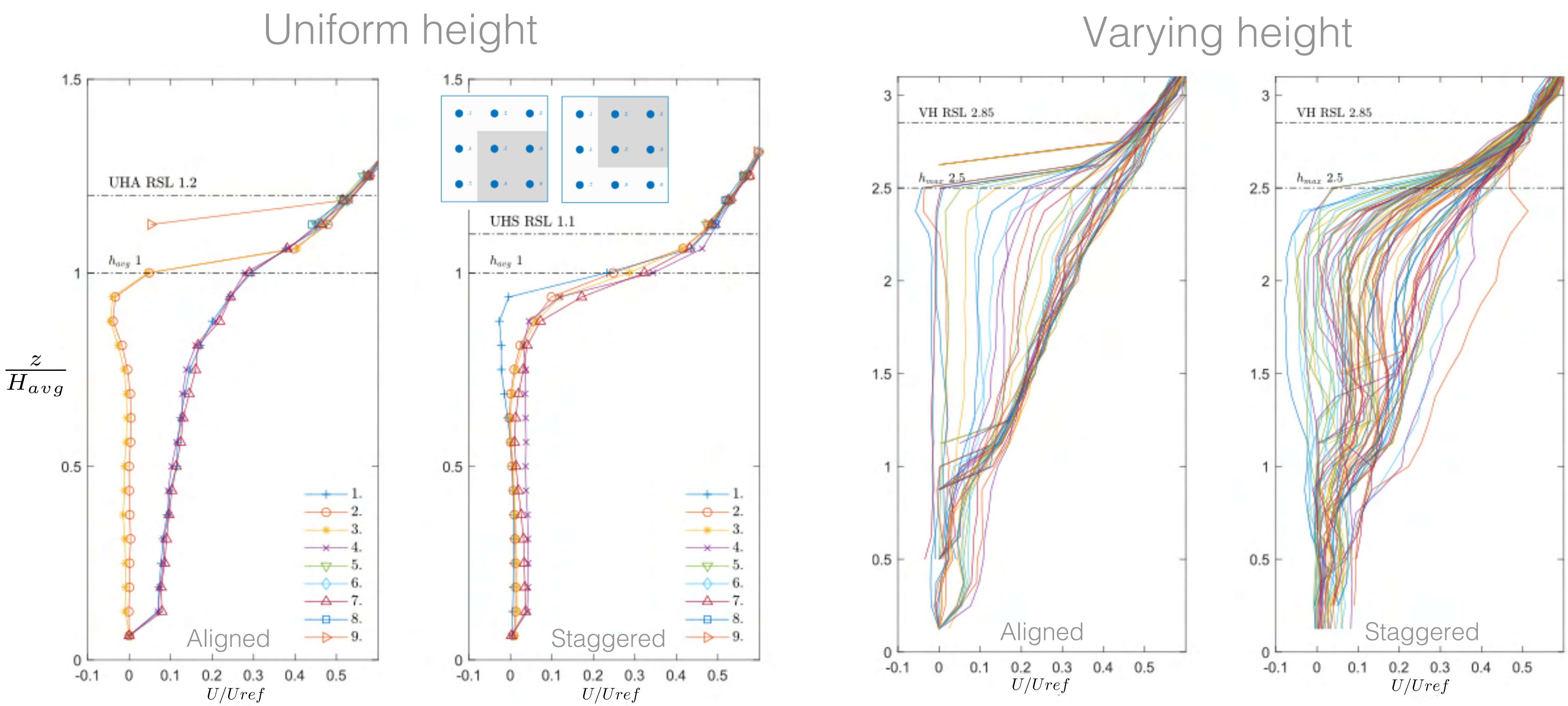
Uniform height

- h_{avg} = 80 mm
- λ_P = 0.44
- σ_h = 0
- $h_{max} = h_{avg}$
- Staggered and aligned

Varied height

- h_{avg} = 80 mm
- λ_P = 0.44
- σ_h = 49 mm
- $h_{max} = 2.5\ h_{avg}$
- Staggered and aligned

Roughness and inertial SL



Uniform height

- Shallow roughness sublayer is found to extend to $1.2h_{avg}$
- Inertial sublayer is present for $1.1 < z/h_{avg} < 1.85$

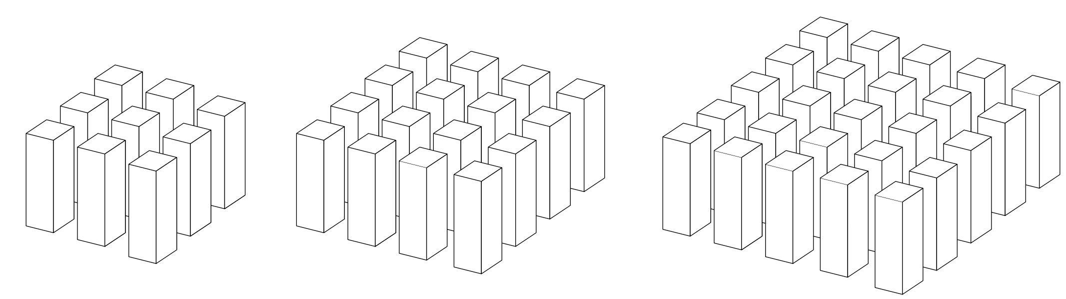
Varying height

- Deep roughness sublayer is found to extend to $2.85h_{avg}$ – just over h_{max}
- “Inertial sublayer” is present for $2.85 < z/h_{avg} < 4.4$

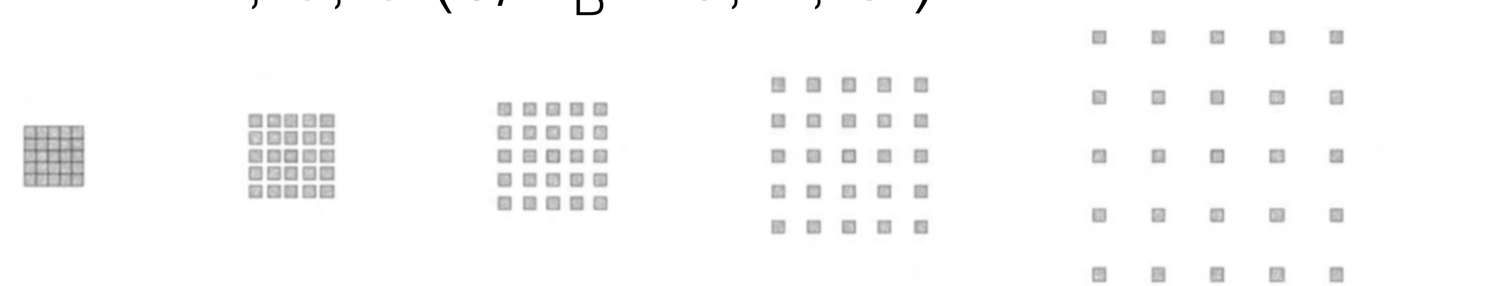
Makedonas at al. BLM (2021)

Wake of tall building clusters in ABL

So far we have investigated:



1. Number of buildings 3 x 3, 4 x 4, 5 x 5
2. Aspect ratio of buildings AR = 4, 6, 8 ($\delta/H_B \approx$ 6, 4, 3)
3. Spacing of buildings

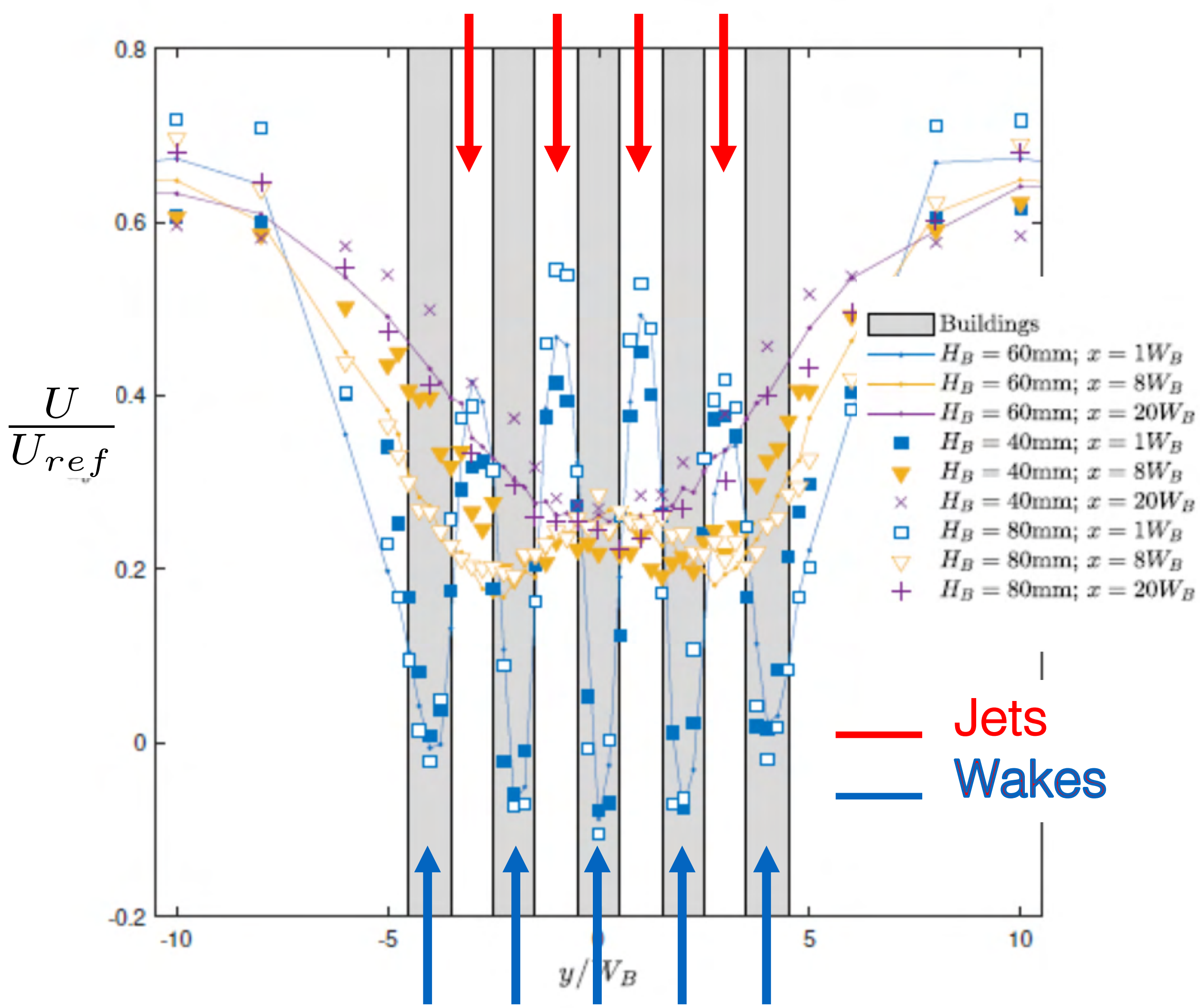


4. Heterogeneity in height (σ_{HB})

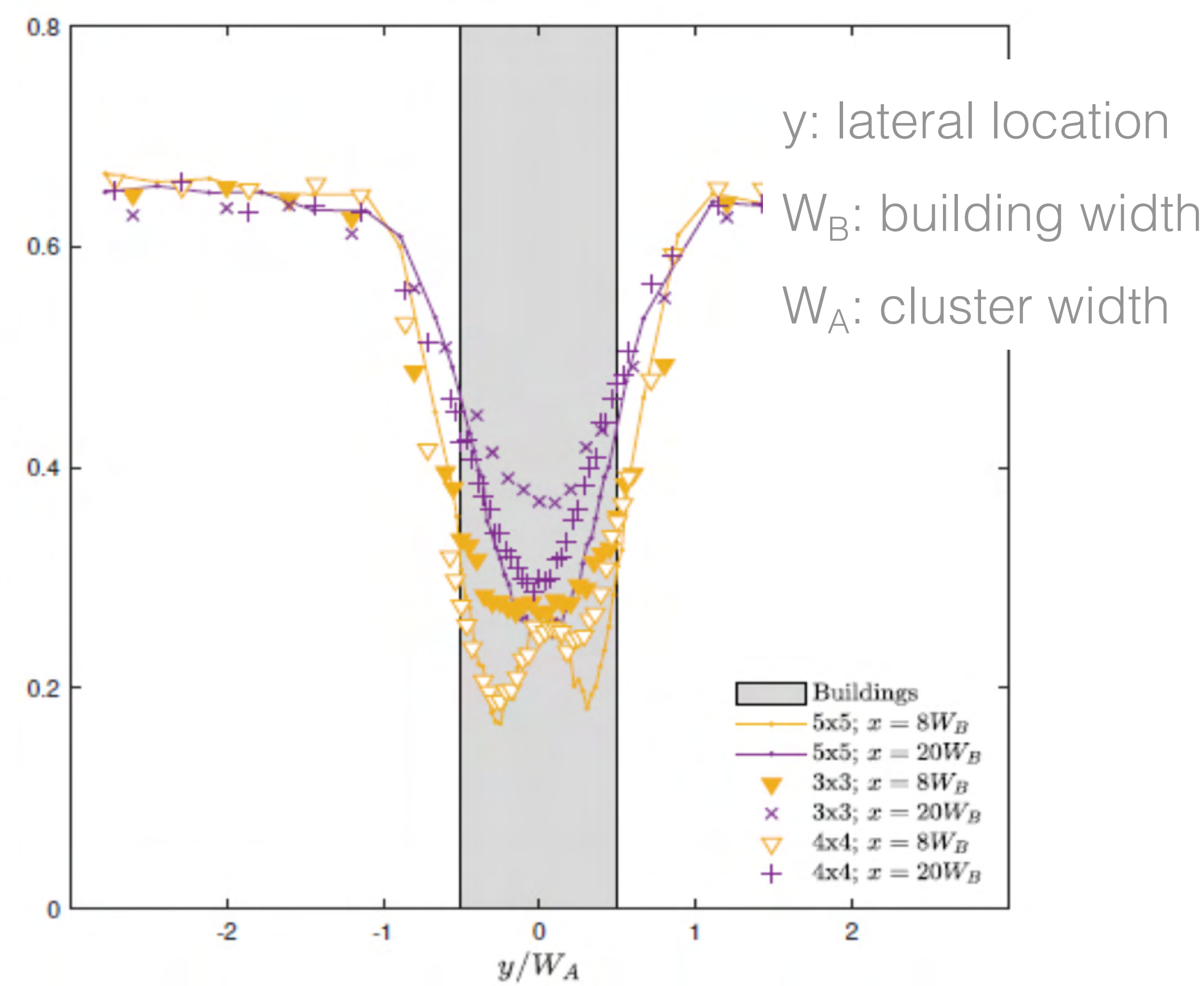
Cluster height and size

Paul McDonald

Aspect Ratio



Cluster size



<u>Effect of Aspect Ratio (AR)</u>

- small effect on the wake of 5 x 5 cluster, as the wakes are similar at different downstream locations regardless of AR

<u>Effect of cluster size</u>

- little influence of the cluster size once in the far field, wake is similar to that of an isolated tall building

Questions?

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