Effect of tall buildings on the urban environment

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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

**Facility**

- 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 \( (dT/dz)_{\text{max}}=80\degree \text{C/m} \)
- Floor heating/cooling: 1 kW/m\(^2\) / 10 °C
- 2 overhead 3-axis traverses

**Equipment**

- 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

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
  - $AR = 4, 6, 8$
  - $\delta/H_B = 0.3-0.5$
  - Building dimensions
    - $10 \times 40-60-80 \times 2 \text{ mm}^3$

- Square Cylinder
  - $AR = 4, 6, 8$
  - $\delta/H_B = 0.3-0.5$
  - Building dimensions
    - $10 \times 40-60-80 \times 10 \text{ mm}^3$
    - $17 \times 40-60-80 \times 17 \text{ mm}^3$

- Triangular Cylinder
  - $AR = 4, 6, 8$
  - $\delta/H_B = 0.3-0.5$
  - Building dimensions
    - $10 \times 40-60-80 \times 10 \text{ mm}^3$
Effect of AR & $H_B/\delta$

**Effect of Aspect Ratio (AR)**
- Increasing the aspect ratio of a building increases the axial velocity deficit

**Effect of relative roughness height (BLHR)**
- The wake has a weaker dependency on relative roughness height
Tall building in complex terrain

William Lin

- Collaborative work within MAGIC (Reading-Surrey)

Tall and dense canopies
Alexandros Makedonas

Uniform height
- $h_{\text{avg}} = 80$ mm
- $\lambda_p = 0.44$
- $\sigma_h = 0$
- $h_{\text{max}} = h_{\text{avg}}$
- Staggered and aligned

Varied height
- $h_{\text{avg}} = 80$ mm
- $\lambda_p = 0.44$
- $\sigma_h = 49$ mm
- $h_{\text{max}} = 2.5 \times h_{\text{avg}}$
- 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 et al. BLM (2021)
Wake of tall building clusters in ABL

So far we have investigated:

1. Number of buildings $3 \times 3$, $4 \times 4$, $5 \times 5$

2. Aspect ratio of buildings $\text{AR} = 4$, $6$, $8$ ($\delta/H_B \approx 6$, $4$, $3$ )

3. Spacing of buildings

4. Heterogeneity in height ($\sigma_{HB}$)
Effect of Aspect Ratio (AR)
• small effect on the wake of 5 x 5 cluster, as the wakes are similar at different downstream locations regardless of AR

Effect of cluster size
• 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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