### Introduction

- Urban Heat Island Circulation (UHIC), also referred to as urban dome, influences the transport of heat and moisture, and air motion in both urban and rural areas.
- Detailed simulation of the urban dome is very limited by either mesoscale or microscale models due to their own limitations. A modified City-Scale CFD approach (csCFD) is proposed to simulate it in fine grid (e.g. 20 m).
- Ideal 2D cases with or without building clusters’ effect were simulated by csCFD to find out the influence of urban clusters on the urban dome.
- The wind environment around a building during the evolution of urban dome is also shown.

### Methodology

Compared with traditional CFD, csCFD

1) Use KRB coordinate

- Basic principle: the pressure gradient in the reference state in a layer of original and the transformed height should be the same.

\[ h = \frac{1}{\zeta} \left( 1 - e^{-\frac{z}{\zeta}} \right) \]

\[ \zeta = \left( RT \right)^{-1} \ln \left( 1 + \frac{T_e - T_i}{T_i} \right) \]

- Other relations between transformed variables (κ) and the original variables (θ) are 1)

\[ u_\infty = u_\infty \]

\[ w = e^{-\frac{z}{\zeta}} w_\infty \]

\[ v_\infty = v_\infty \]

\[ \rho_\infty = e^\theta \rho_\infty \]

\[ \rho_\infty = \rho + \rho_\infty \left( 1 - e^{-\frac{z}{\zeta}} \right) \]

2) Add mesoscale terms

3) Improve numerical stability by adding absorbing layers

4) Model city scale effect by adding porous turbulence model

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### Results

1. The simulated vertical profiles agree reasonably well with other data in literature.

![Graph showing simulated and empirical data comparison](image)

2. City’s effect lead to wider neck of the plume, smaller velocity in the city and multi-upward flows.

![Graph showing potential temperature](image)

3. When the porosity of the city decreases, the relative reverse height increases.

![Graph showing relative reverse height](image)

<table>
<thead>
<tr>
<th>Case</th>
<th>ϕ</th>
<th>RRH (%)</th>
<th>Flow reversal height (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flat city (Theory)</td>
<td>30</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Flat city (ϕ=0.5)</td>
<td>30</td>
<td>2</td>
<td>0.5</td>
</tr>
<tr>
<td>Porous city (ϕ=0.75)</td>
<td>30</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Porous city (ϕ=0.5)</td>
<td>30</td>
<td>2</td>
<td>0.5</td>
</tr>
</tbody>
</table>

4. Wind environment around a building in the city was first dominated by the plume generated by itself, but finally was dominated by the urban dome during the evolution of urban dome.

![Graph showing hourly mean velocity vectors](image)

### Conclusion

- The simulated results by csCFD agrees well with other data in literature.
- When the city is introduced by porous media, the velocity in the city decreases, the neck of the plume increases, and multi-upward flows are observed.
- Dense city also increases the relative reverse height at the edge of the city.
- The wind environment around a building in the city was simulated simultaneously with the evolution of urban dome.