An investigation of the dynamic and thermodynamic impacts of urbanization via WRF-LES

Xiaoliang Zhu[1]; Dan Li[2]; Ting Sun[1]; Guangheng Ni[1]

[1]Tsinghua University
[2]Princeton University

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http://www.urbanhydromet.org

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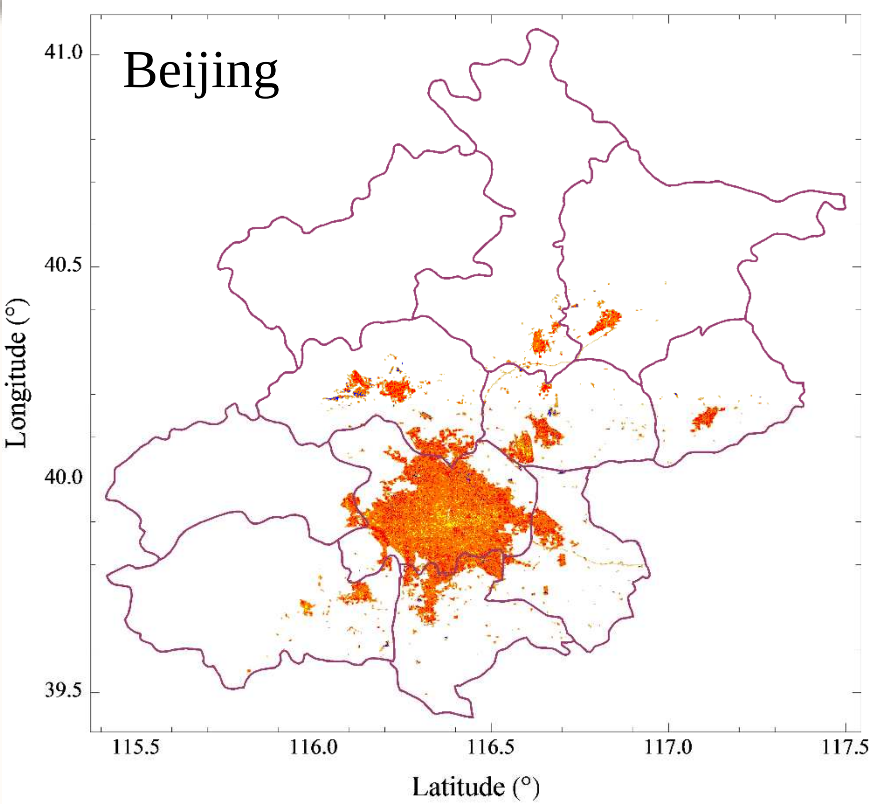
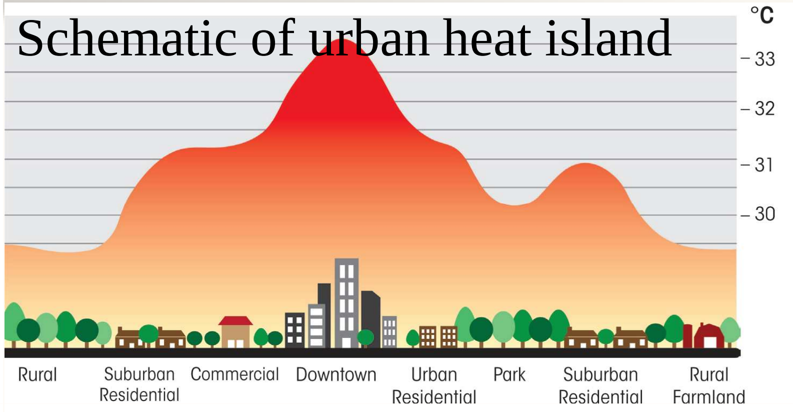
1. Introduction





- ✓ Momentum roughness length (dynamic)
- ✓ Surface temperature (thermodynamic)

Source: c3headlines.com

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1. Introduction

- Previous studies show that surface heterogeneity has an important impact on the atmospheric flow, temperature profile and so on. (Letzel and Raasch 2003; Liu et al. 2011; Kang and Lenschow 2014)

- Most of these studies focusing on urban area use fixed sensible heat flux (HFX) as lower boundary conditions.

- In this study, we want to separate the influence of momentum roughness length (z_0) and surface temperature (TSK) and to investigate the effect of urban heterogeneity scale on urban climate.

2. Numerical model
- Model description

- WRF-LES
  - ✓ An ideal case in WRF model
  - ✓ A good tool to investigate PBL

    (Moeng et al. 2007; Talbot et al. 2012; Zhang et al. 2014)

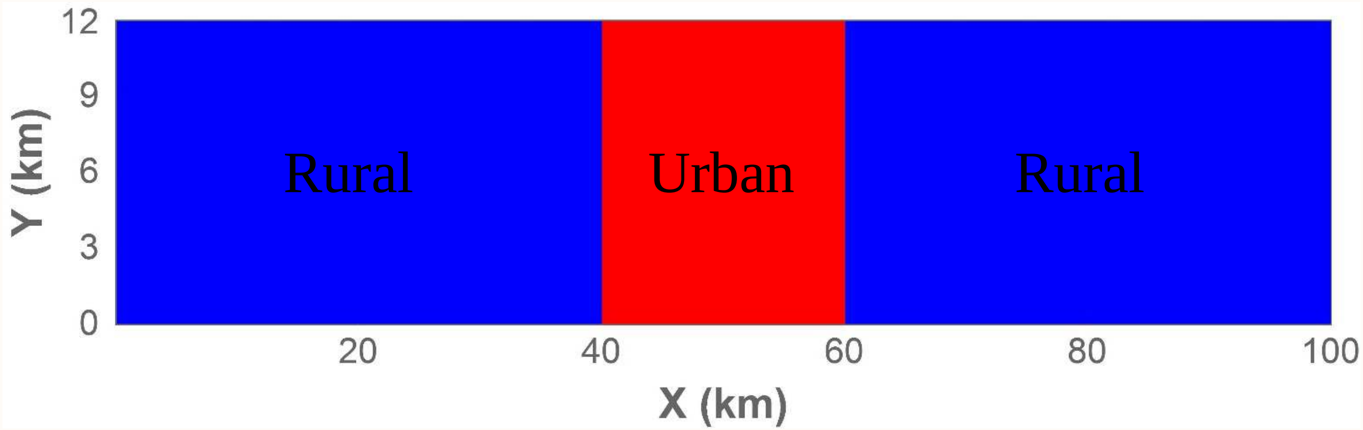
Boundary condition

HFX	⇨	TSK and z_0
Original codes		**Modified codes**

The original code only allows fixed sensible heat flux as boundary conditions. We modified the code so that it is capable to apply surface temperature and momentum roughness length as boundary conditions.

2. Numerical model
- Model setup

- **Size**: 100 km × 12 km
- **Resolution**: 0.1 km
- **Time step**: 1 s
- **Grid number (x,y,z):** 1000, 120, 100



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3. Design of Experiment 1

Case Name	**Surface Temperature (K)** Urban VS Rural	**Surface Roughness** Urban VS Rural
W（control）	**304**	**0.1**
A	**306 vs 304**	**0.1**
B	**304**	**0.5 vs 0.1**
AB	**306 vs 304**	**0.5 vs 0.1**

We also investigate the influence with different background wind speed in these cases.(0m/s,1m/s,5m/s)

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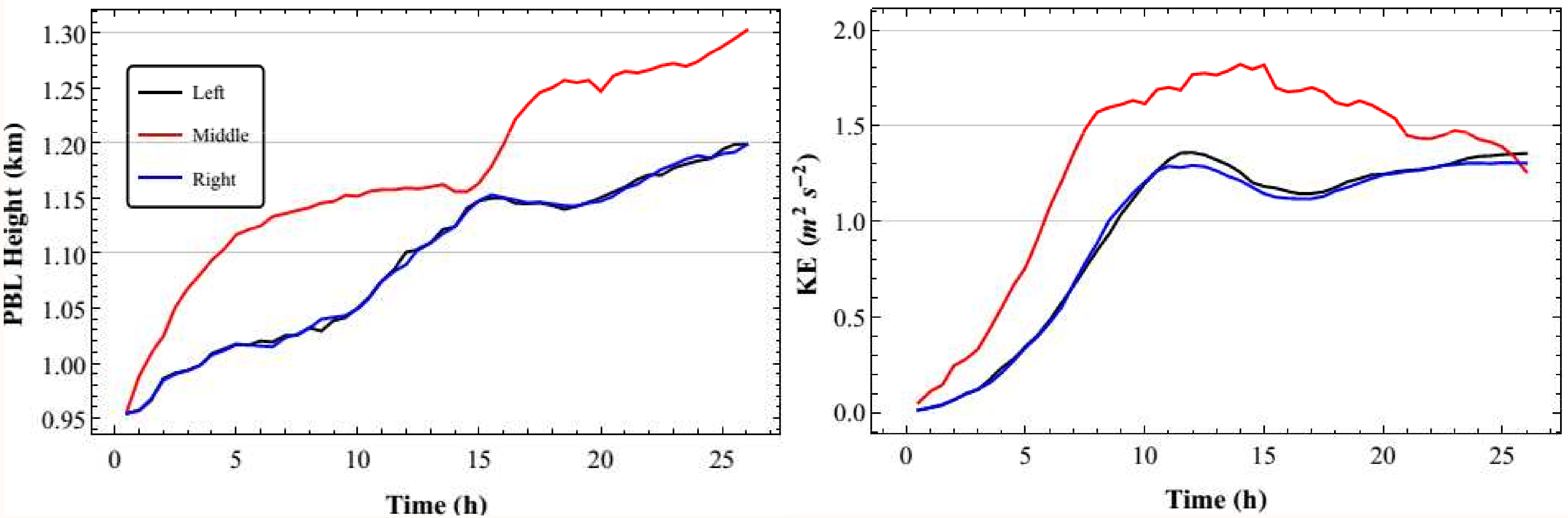
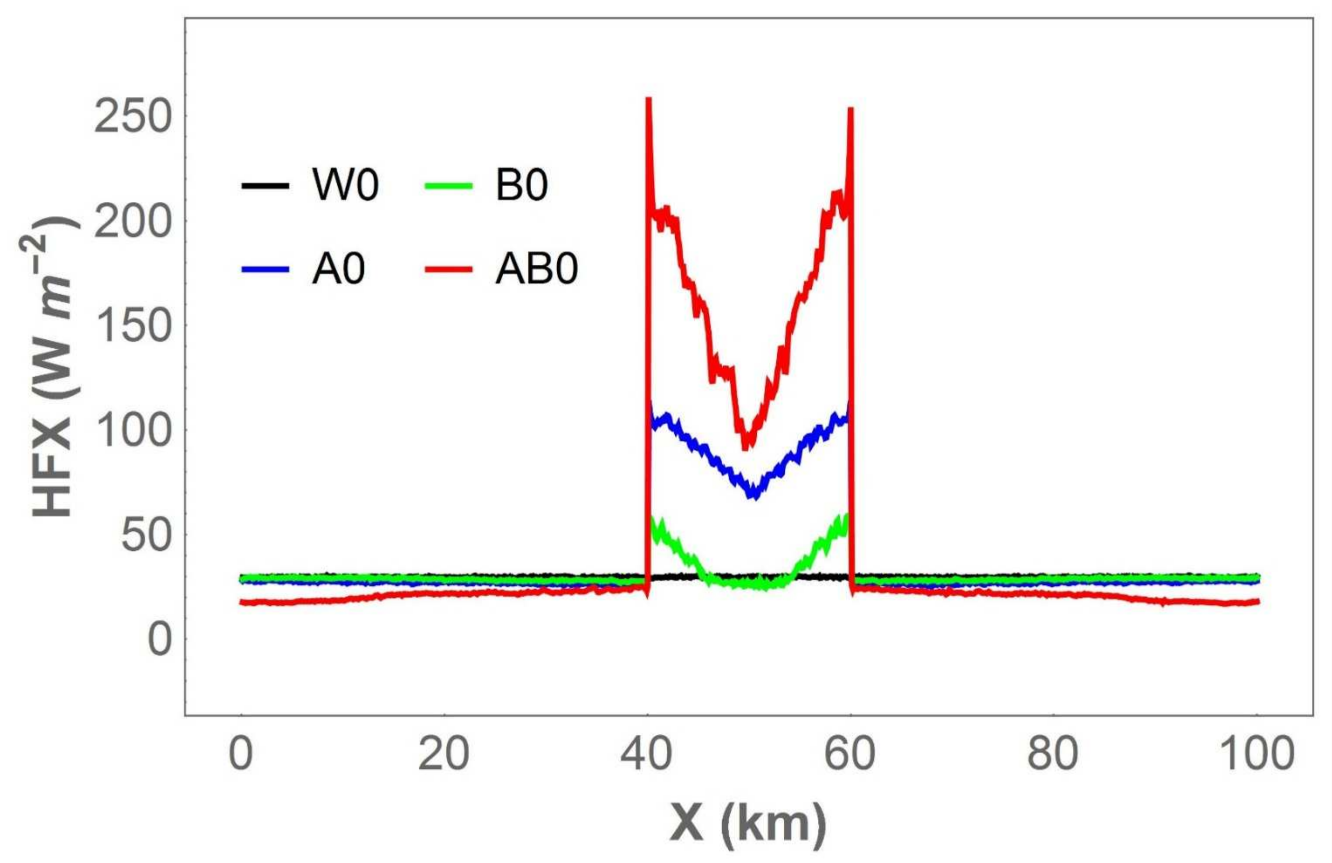
3. Results of Experiment 1
- Temporal evolution



3. Results of Experiment 1

- Y-averaged Heat Flux(HFX) distribution

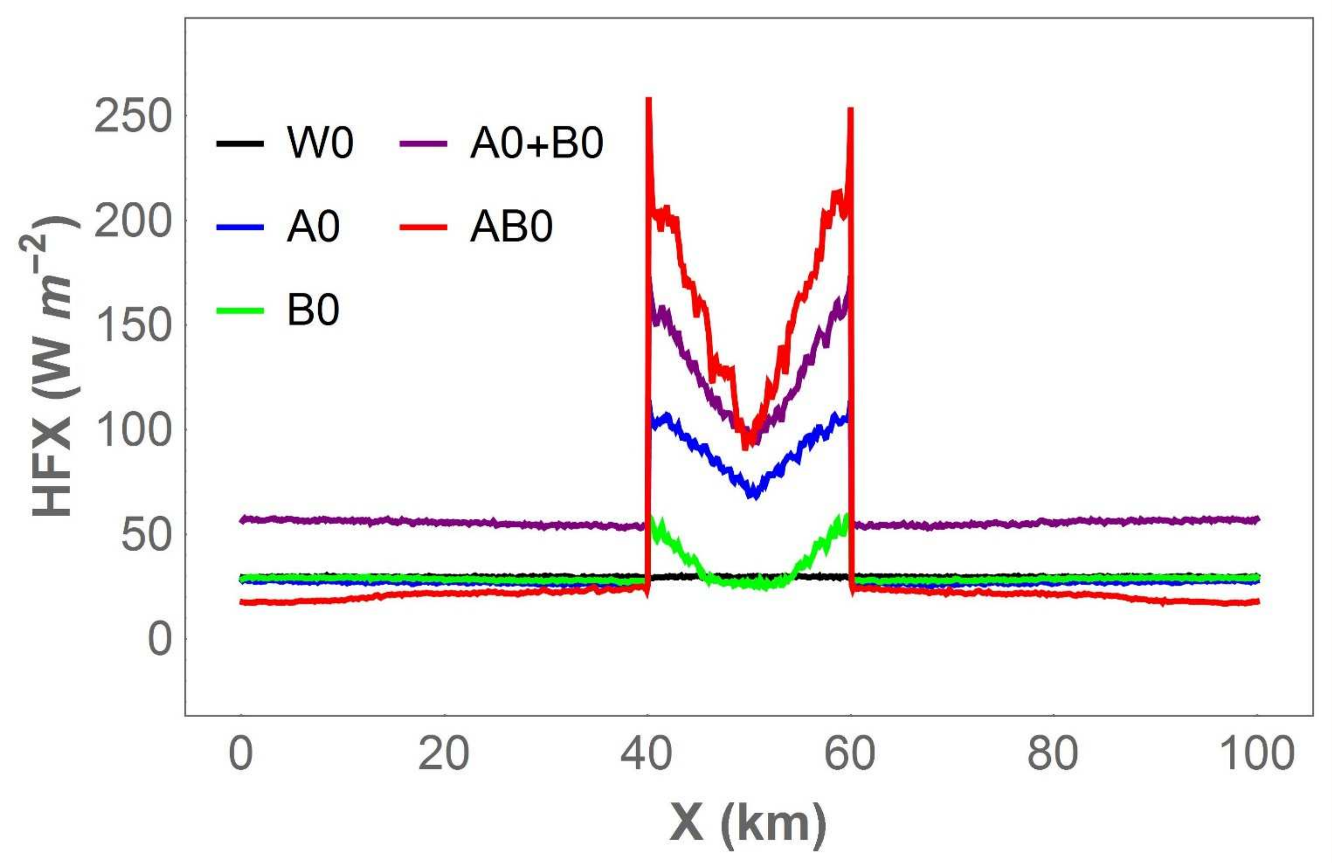
Case W : control case　　Case B : effects of z_0
Case A : effects of TSK　　Case AB: the combined effect
0 stand for Wind speed 0m/s.



3. Results of Experiment 1

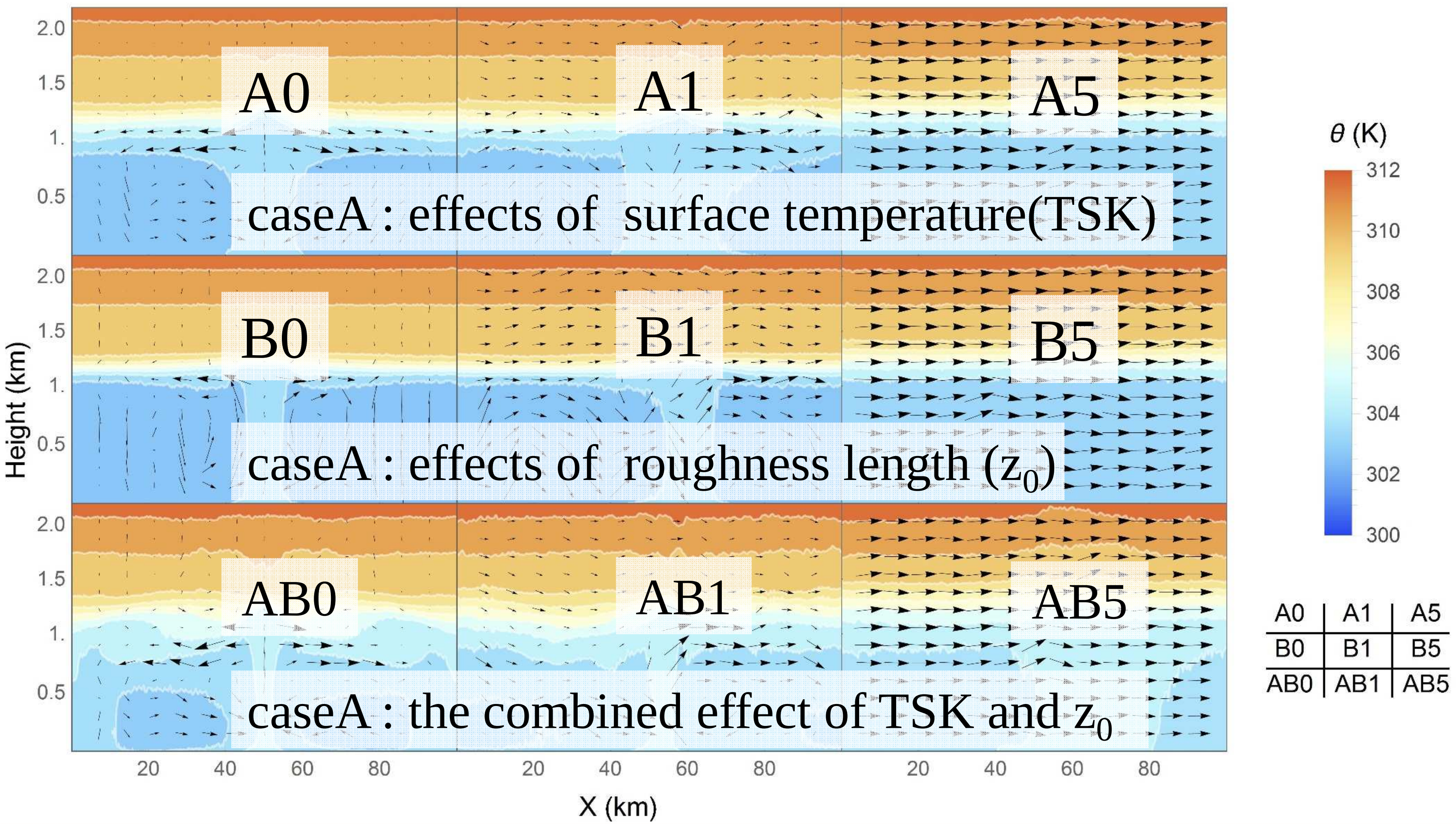
- The synergistic effect of TSK and z_0

Case W : control case   Case B : effects of z_0
Case A : effects of TSK   Case AB: the combined effect
0 stand for Wind speed 0m/s.

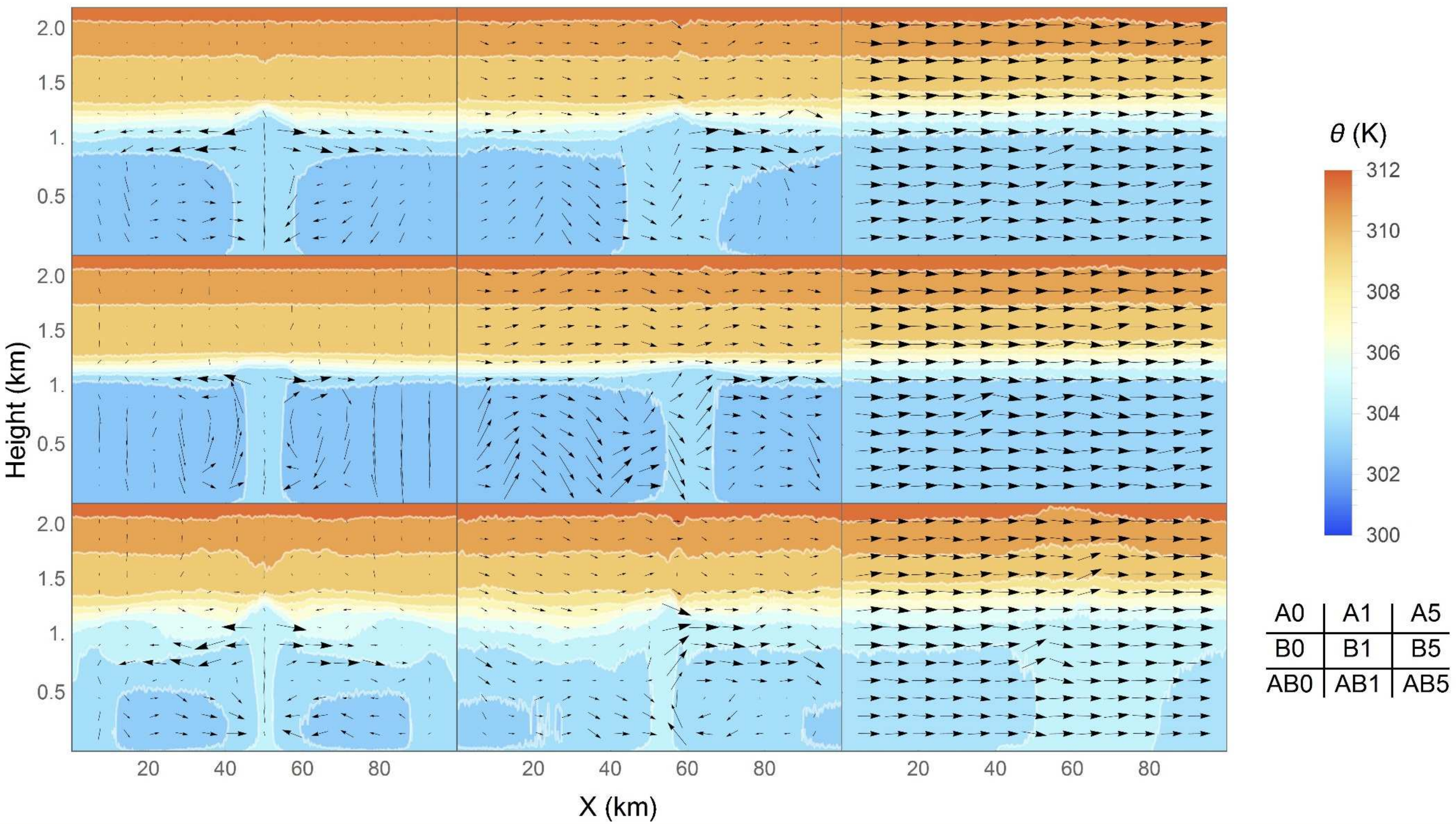


3. Results of Experiment 1

- The effect of heterogeneity and winds



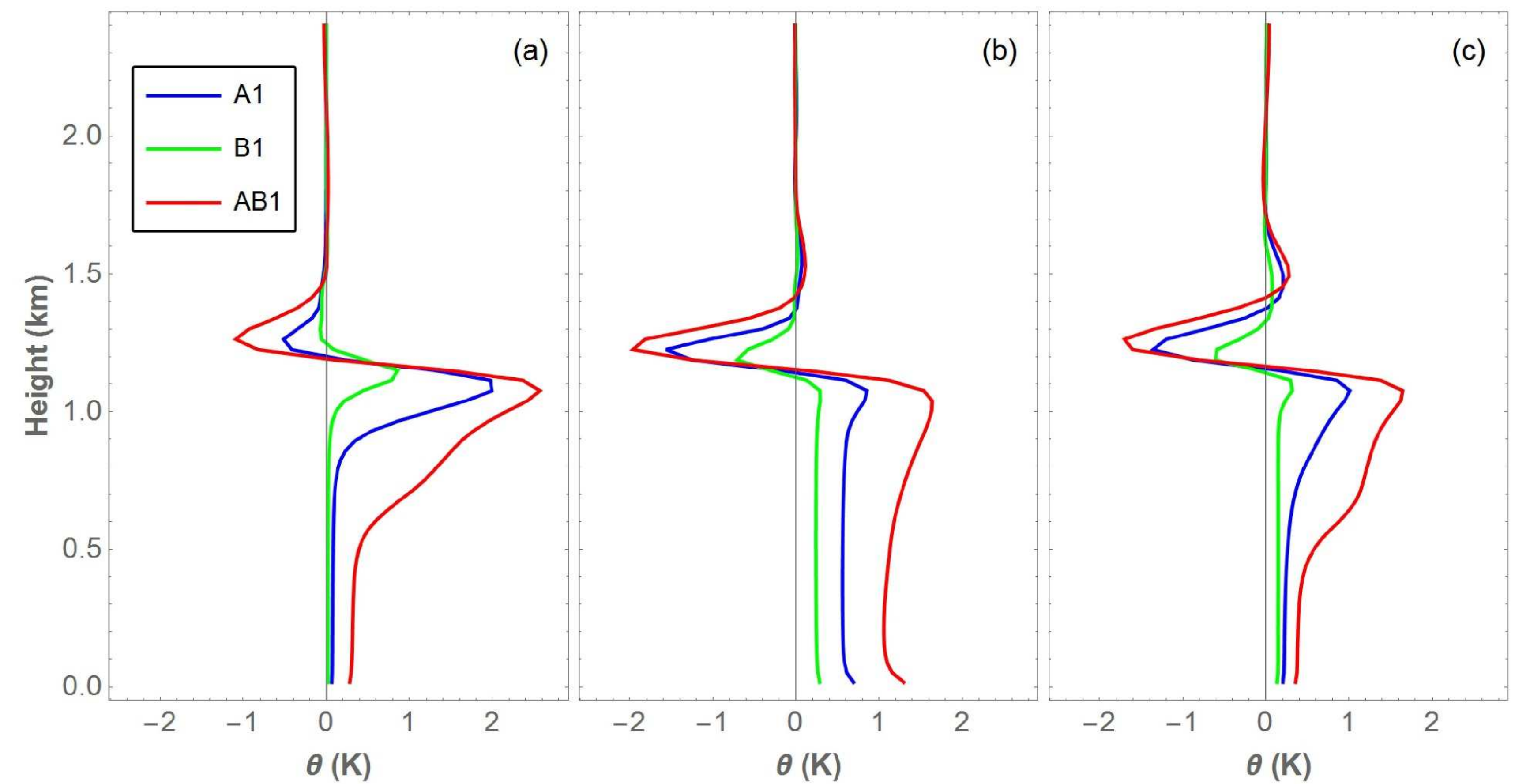
3. Results of Experiment 1
- The effect of heterogeneity and winds



3. Results of Experiment 1

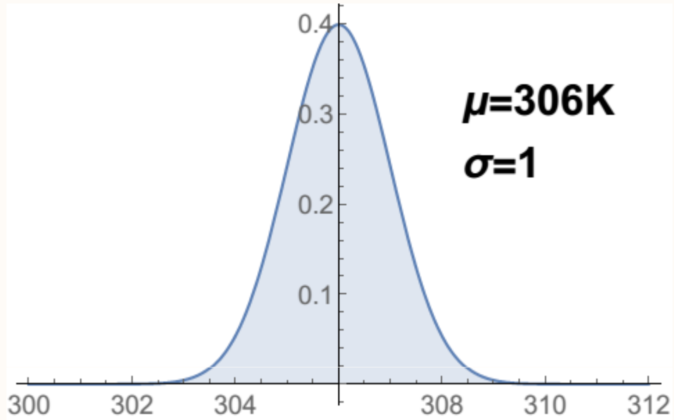
- The difference with the control case

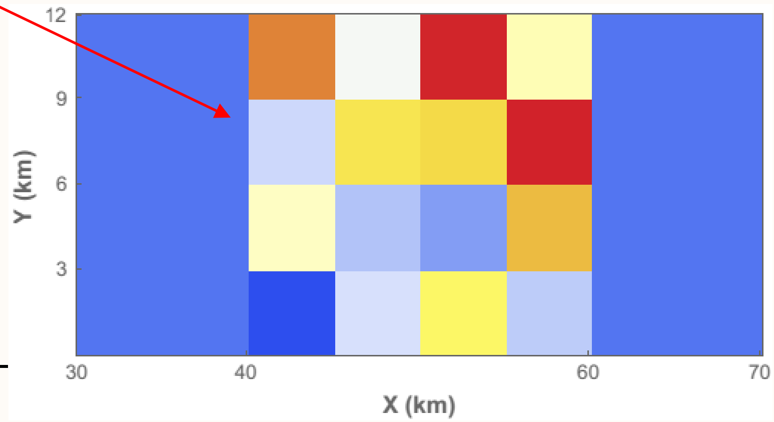
left (rural) **middle (urban (** **right (rural)**



4. Design of Experiment 2

Case Name	urban patch number
A	1
C4	2 × 2
C16	4 × 4
C64	8 × 8
C100	10 × 10
C300	15 × 20
C1200	30 × 40
C6000	60 × 100
C24000	120 × 200

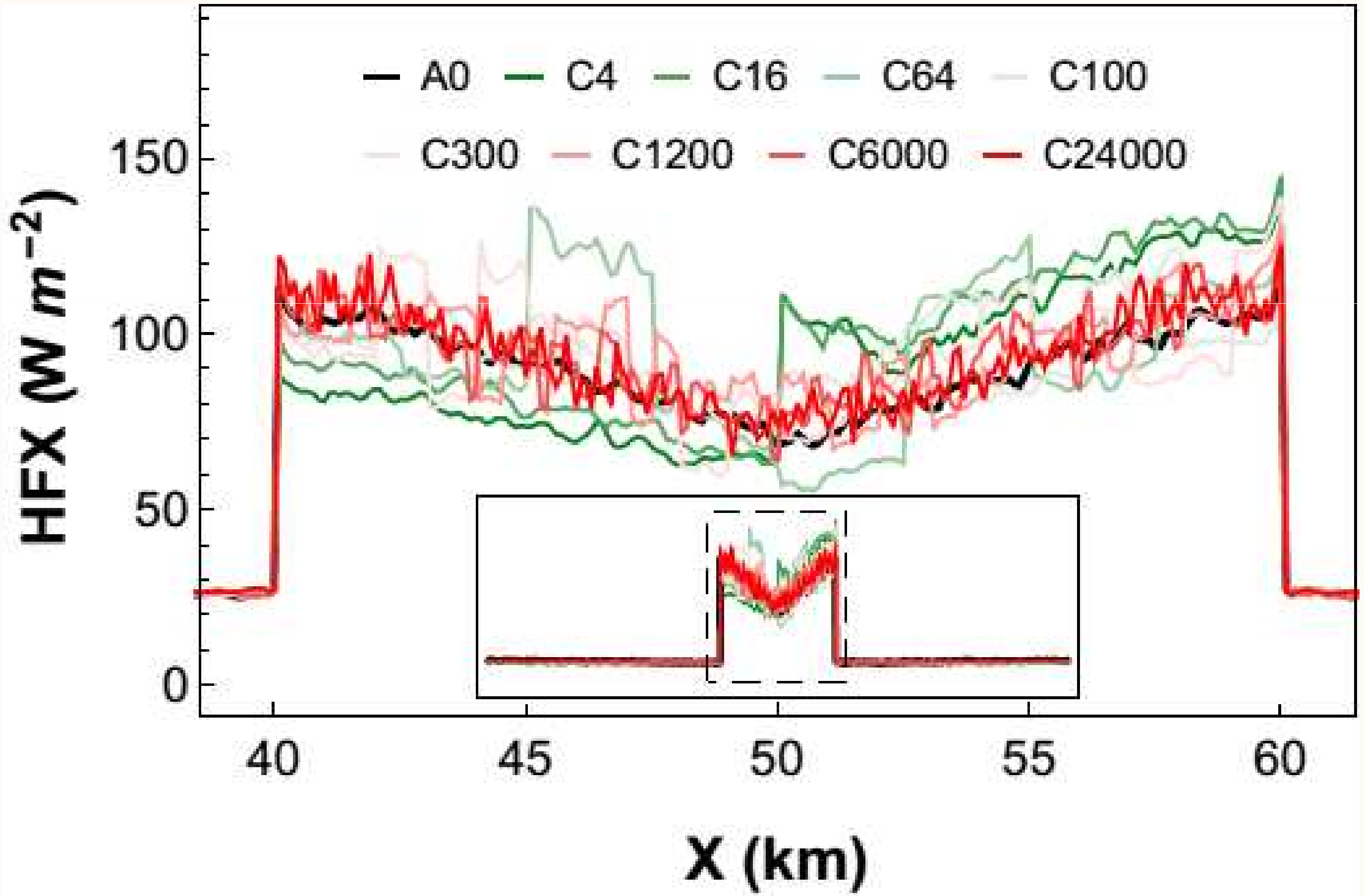




The roughness length is 0.1 and the background wind is 0 in all the cases in this experiment.

4. Results of Experiment 2

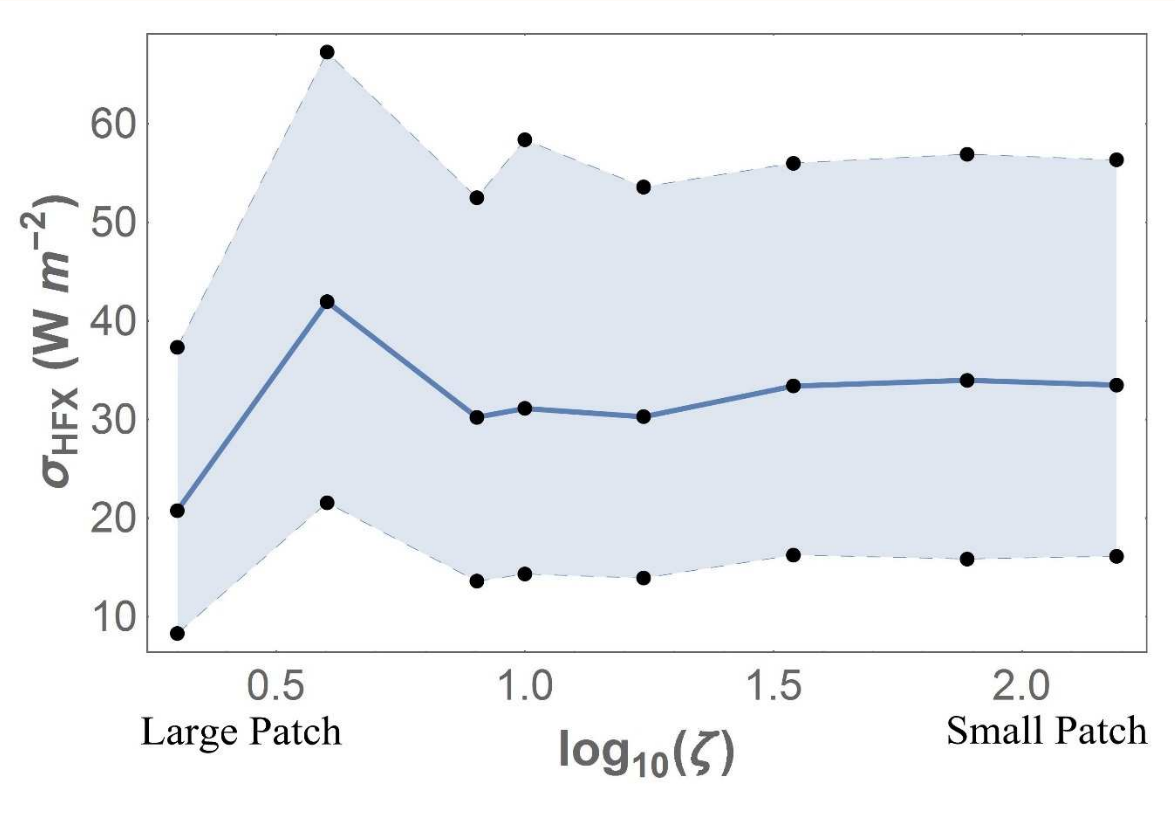
- The comparison with the default case A0



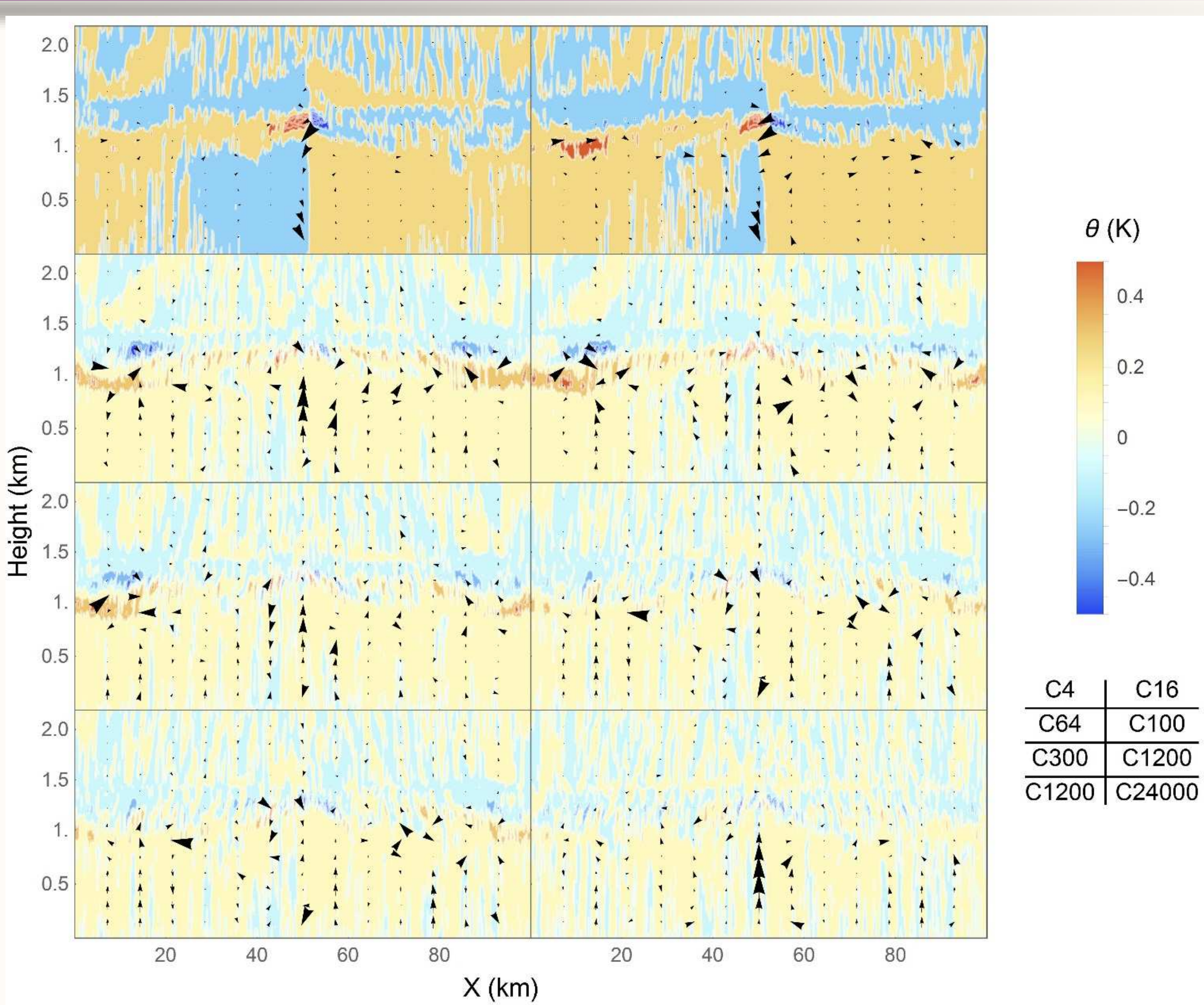
4. Results of Experiment 2

- The standard deviation of difference

$\zeta = \dfrac{1}{\sqrt{S_{patch}/S_{urban}}}$, S_{patch} and S_{urban} is the area of patch size and urban size



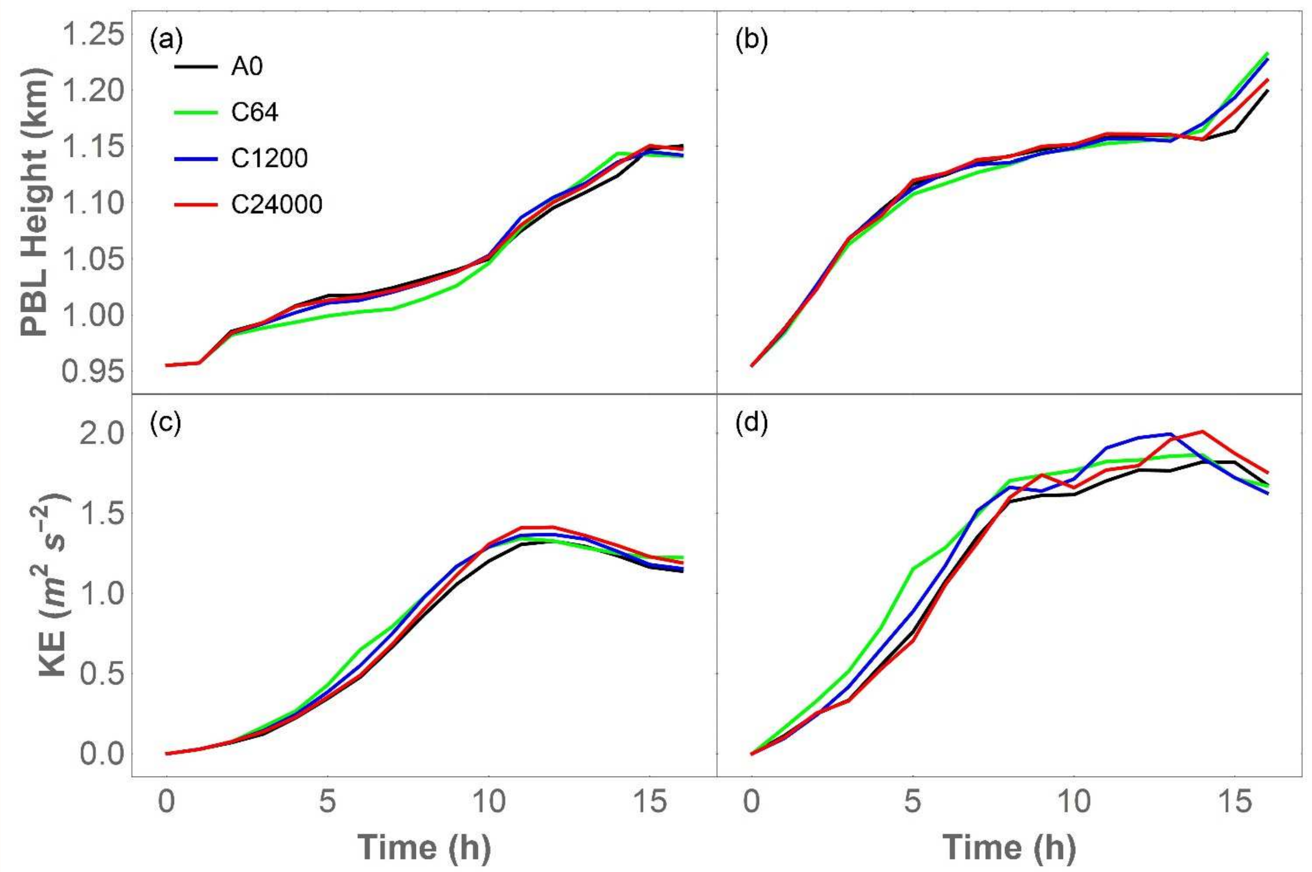
4. Results of Experiment 2
- The effect of heterogeneity scale



4. Results of Experiment 2
- Temporal evolution

- **The temporal evolution of the PBL height and kinetic energy for the different urban heterogeneous scale**

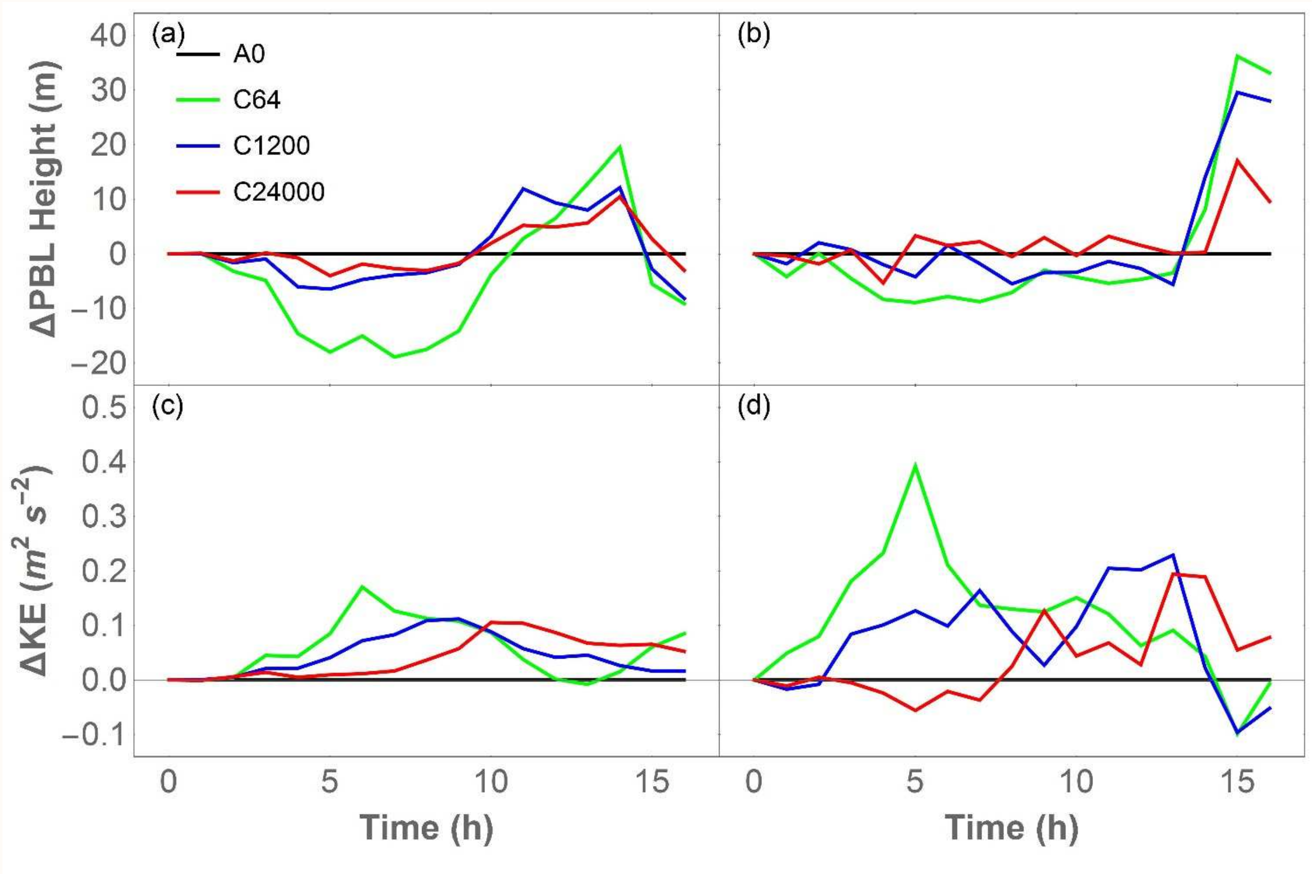
rural area **urban area**



4. Results of Experiment 2
- Temporal evolution

- **The temporal evolution of the difference of PBL height and kinetic energy**

rural area **urban area**



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5. Concluding Remarks

- **TSK** and $\mathbf{z_0}$ have significant but different effects on the heat flux and the vertical distribution of potential temperature
- When setting TSK and z_0 at the same time, they have an **synergistic effect** on the urban boundary layer, rather than a simple summing up effect.
- These cases with a heterogeneity scale has a obvious. And when scale decreases, the difference is smaller and smaller.
- The urban heterogeneity scale heating will generate a enhanced kinetic energy, but we do not see a reasonable trend.

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Thanks for your attention