# Model Analysis of Urban Hydrological Process Impacts on Urban Thermal Environment

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# Outline

- Introduction
- Problems and Ideas
- Material and Method
- Result and Discussion
- Conclusion

# Introduction

- During the process of urbanization, human activities seriously affected the regional climate and environment, resulting in urban heat island effect. High-temperature heat waves continue to impact the urban areas and the daily life of urban residents.
- At present, the WRF/SLUCM scheme lacks a reasonable parameterized model of the urban hydrological process, so it is difficult to accurately describe the dynamic changes of the sensible heat and latent heat flux in the city.
- Some researchers implemented physically-based parametrizations of the hydrological processes into the single layer urban canopy model in the WRF model, such as (1) artificial latent heat, (2) green irrigation, (3) oasis effect, and (4) green roofs (Yang et al.,2014).
- In this study, the Enhanced hydrologic modelling above was used to improve the simulation results of urban sensible and latent heat flux, and the influence of various urban hydrological processes on the urban thermal environment in Beijing is discussed.

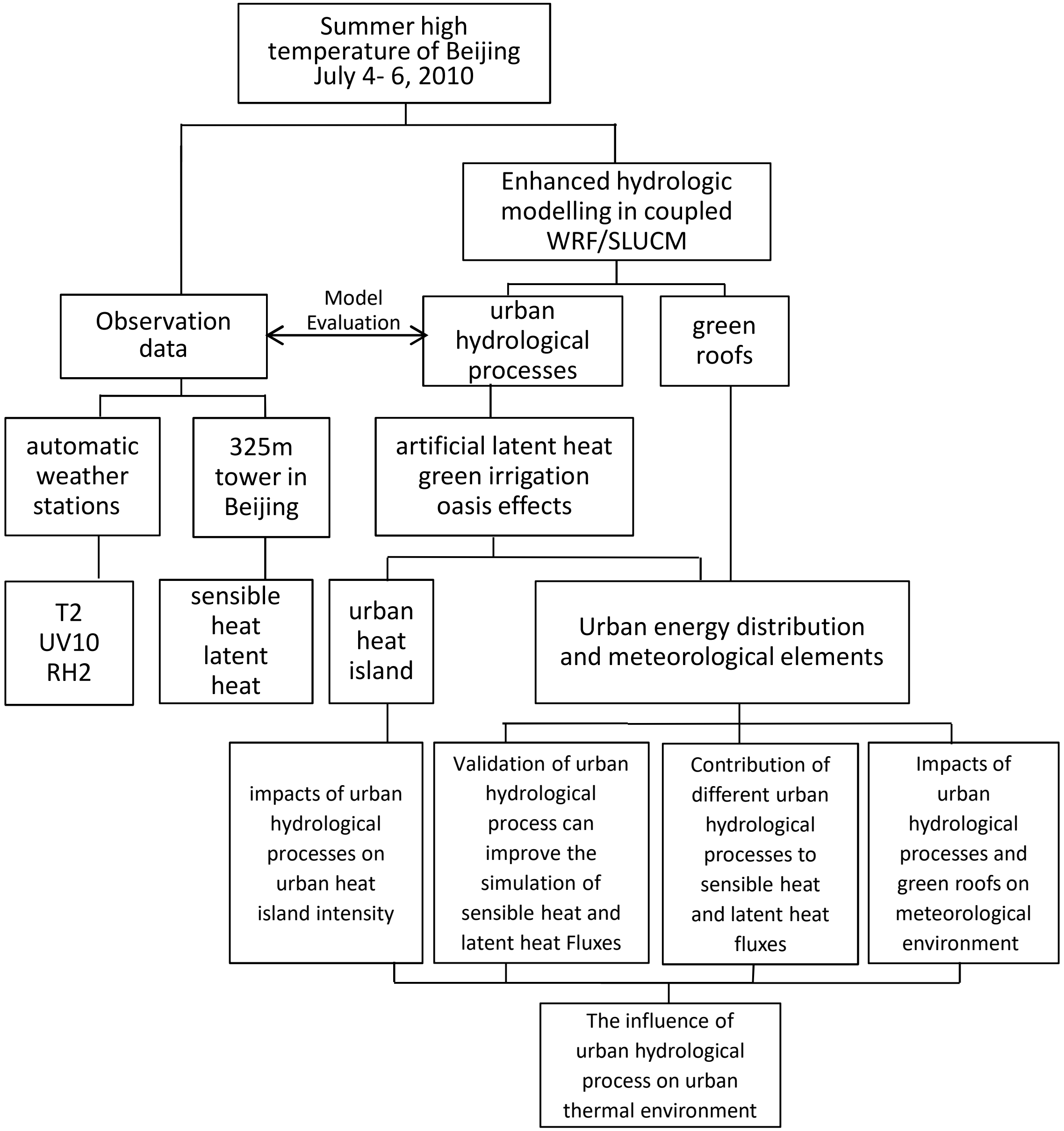
# Problems and Ideas

**Problems?**

- To analyze the influence of enhanced hydrologic modelling on sensible heat and latent heat fluxes, and the contribution of different hydrological processes to the sensible heat and latent heat flux.
- Under the background of summer high temperature in Beijing, to analyze the impact of urban hydrological processes on urban meteorological environment.
- to analyze the impact of urban hydrological processes on urban heat island intensity.

# Problems and Ideas

## Research ideas



# Material and Method

## 1 Observation data

The meteorological data are from 45 urban and 108 suburban automatic weather stations in Beijing, including 2-m temperature, 2-m relative humidity, 10-m wind speed. Flux data is from the observation data of sensible heat and latent heat flux at 140m height of 325m tower in Beijing.

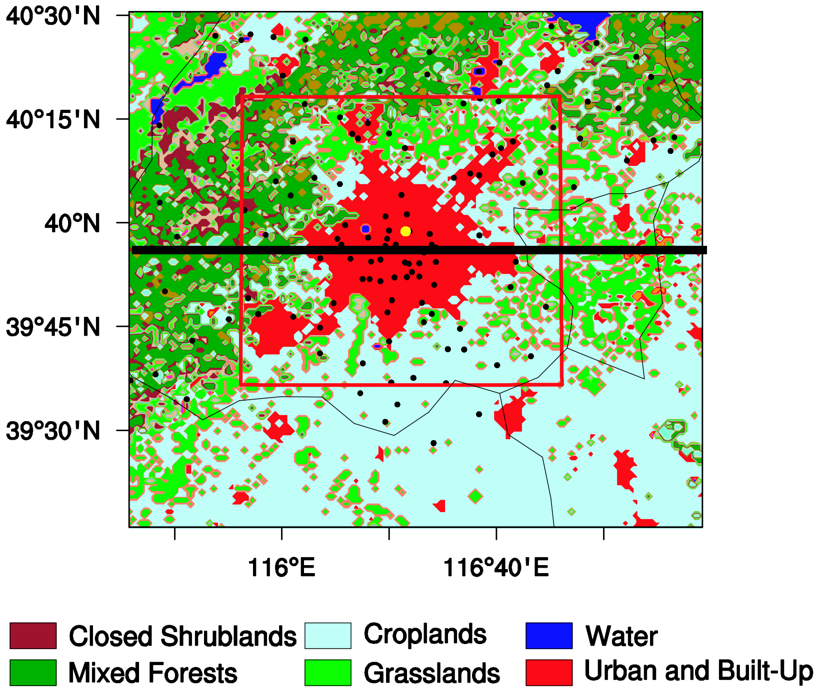



**Fig.1 The distribution of observation site.**

# 2 Enhanced Hydrologic Model

**Table 1. Parameterization scheme**

| | | | |
|---|---|---|---|
| **WRF version** | WRF3.8 | | |
| **Time** | 2010.07.04—2010.07.06 | | |
| **Centerpoint lon/lat** | 40.405$^{o}$N, 116.326$^{o}$E | | |
| **Nest** | 100x95; 136x121; 151x136 | | |
| **Grid length** | 9km; 3km; 1km | | |
| **Eta levels** | 53 vertical levels (upper 50hpa) | | |
| **Geog** | Modis_30s | Modis_30s | Modis_30s |
| **Initial boundary condition** | The NCEP FNL (Final) Operational Global Analysis data (1° x1° and 6h) | | |
| **Land-surface option** | Noah | | |
| **Urban canopy model** | Single-layer, UCM | | |
| **Microphysics option** | WRF Single-Moment 3-class (WSM 3-class) simple ice | | |
| **Longwave radiation** | rapid radiative transfer model（rrtm） | | |
| **Shortwave radiation** | Dudhia | | |
| **Boundary-layer option** | MYJ | | |
| **Surface-layer option** | Eta Similarity | | |
| **Cumulus option** | off (Grid length<10km) | | |
| **FRC_URB** | 0.783 | | |

# 2 Enhanced Hydrologic Model

**Table 2. List of cases**

| | The first group | | | | | The second group | | |
|---|---|---|---|---|---|---|---|---|
| **Case name** | case1 | case2 | case3 | case4 | case5 | case1 | case4 | case6 |
| **Artificial latent heat** | — | + | — | + | — | — | + | — |
| **Green irrigation** | — | — | + | + | — | — | + | — |
| **Oasis effects** | — | — | + | + | — | — | + | — |
| **Green roofs** | — | — | — | — | + | — | — | — |

Note: "+" means opening the option. "—" means closing the option.

# 2 Enhanced Hydrologic Model

**Surface energy balance equation of Enhanced hydrologic modelling as follows :**

$$R_n + Q_{ALH} = LE + H + G \quad (1)$$

$$Q_{ALH} = Q_{ALHmax} \times f_{ALH} \quad (2)$$

**The grid of urban underlying surface in WRF is divided into urban impervious surface and vegetation surface, and latent heat flux is calculated separately.**

$$LE = \left(LE_{veg} \times \alpha_{oasis}\right) \times (1 - f_{urb}) + LE_{urb} \times f_{urb} \quad (3)$$

$$LE_{urb} = r f_{\mathrm{gr}} LE_{gr} + r\left(1 - f_{\mathrm{gr}}\right) LE_r + (1 - r)\, LE_g + 2hLE_w \quad (4)$$

$$\mathrm{L}E_{gr} = \mathrm{L}E_{dir} + \mathrm{L}E_c + \mathrm{L}E_t \quad (5)$$

# 2 Enhanced Hydrologic Model

## Experimental Design

The simulation time is July 4- 6, 2010. The simulation area as shown below：

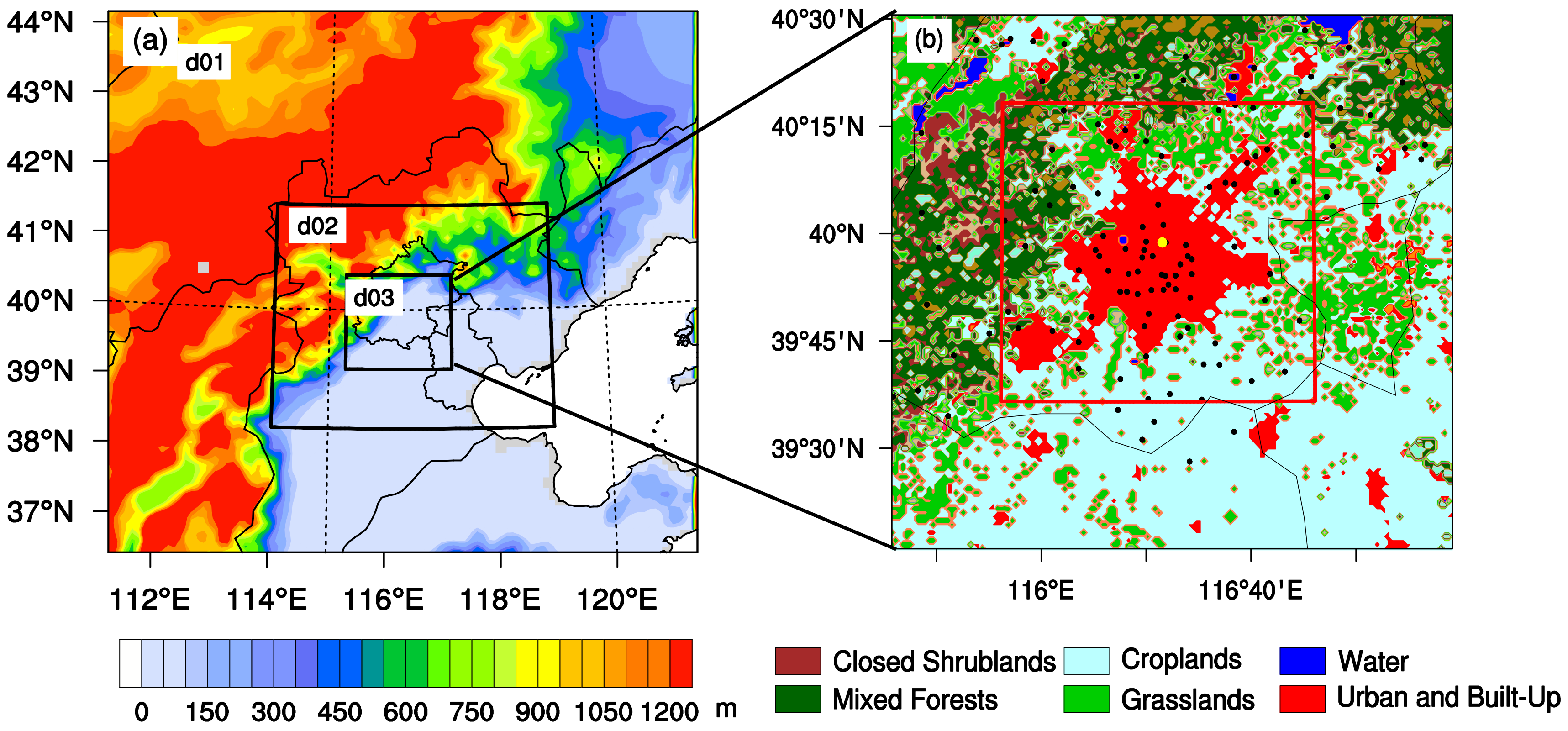



**Fig.2 WRF simulation area and the innermost landuse.**

# Result and Discussion

## 1 Model Evaluation

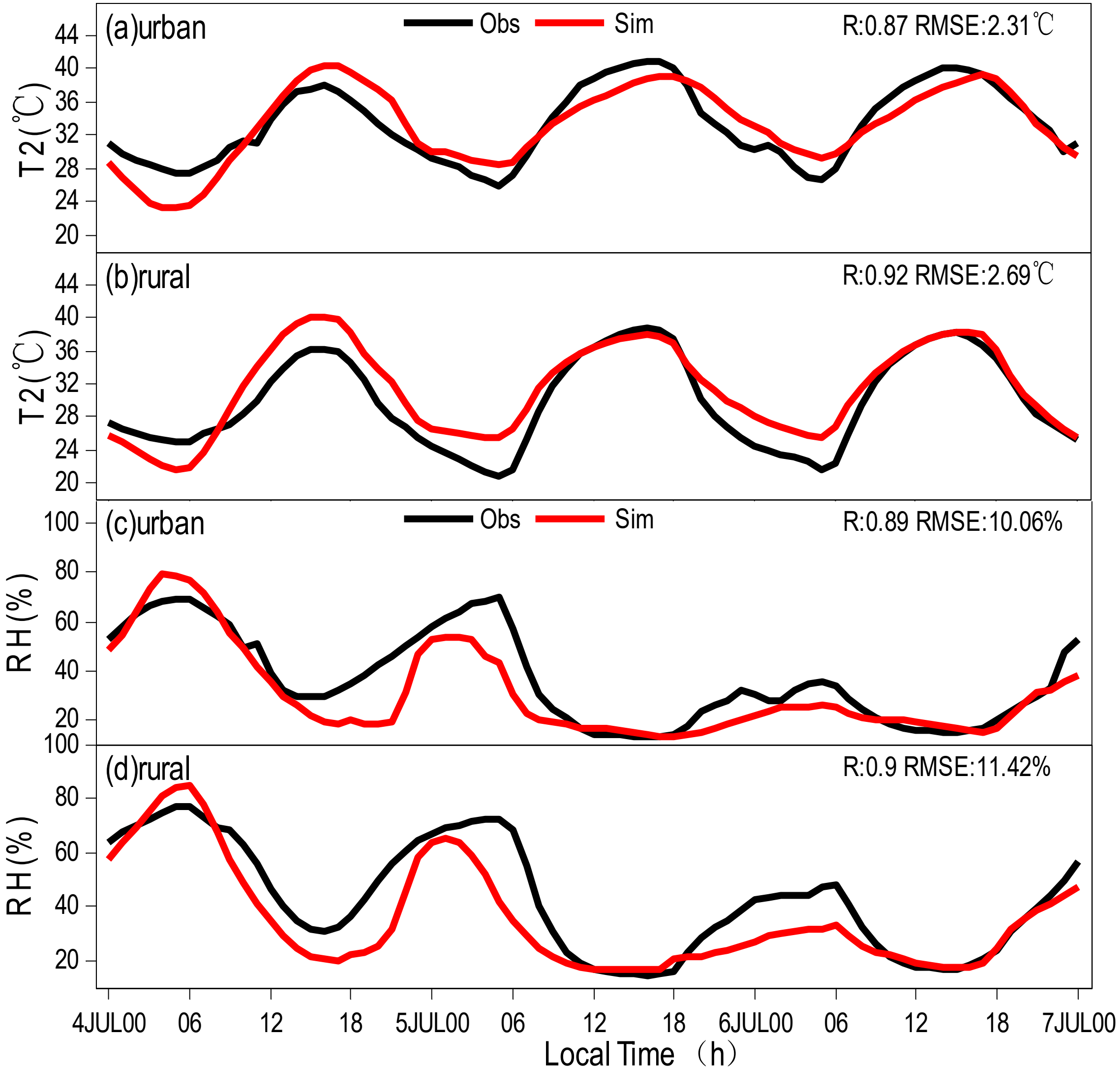



**Fig.3 The comparison between simulated values and observed values on 4-6 July , (a) (b) 2m air temperature; (c) (d) relative humidity.**

# Result and Discussion

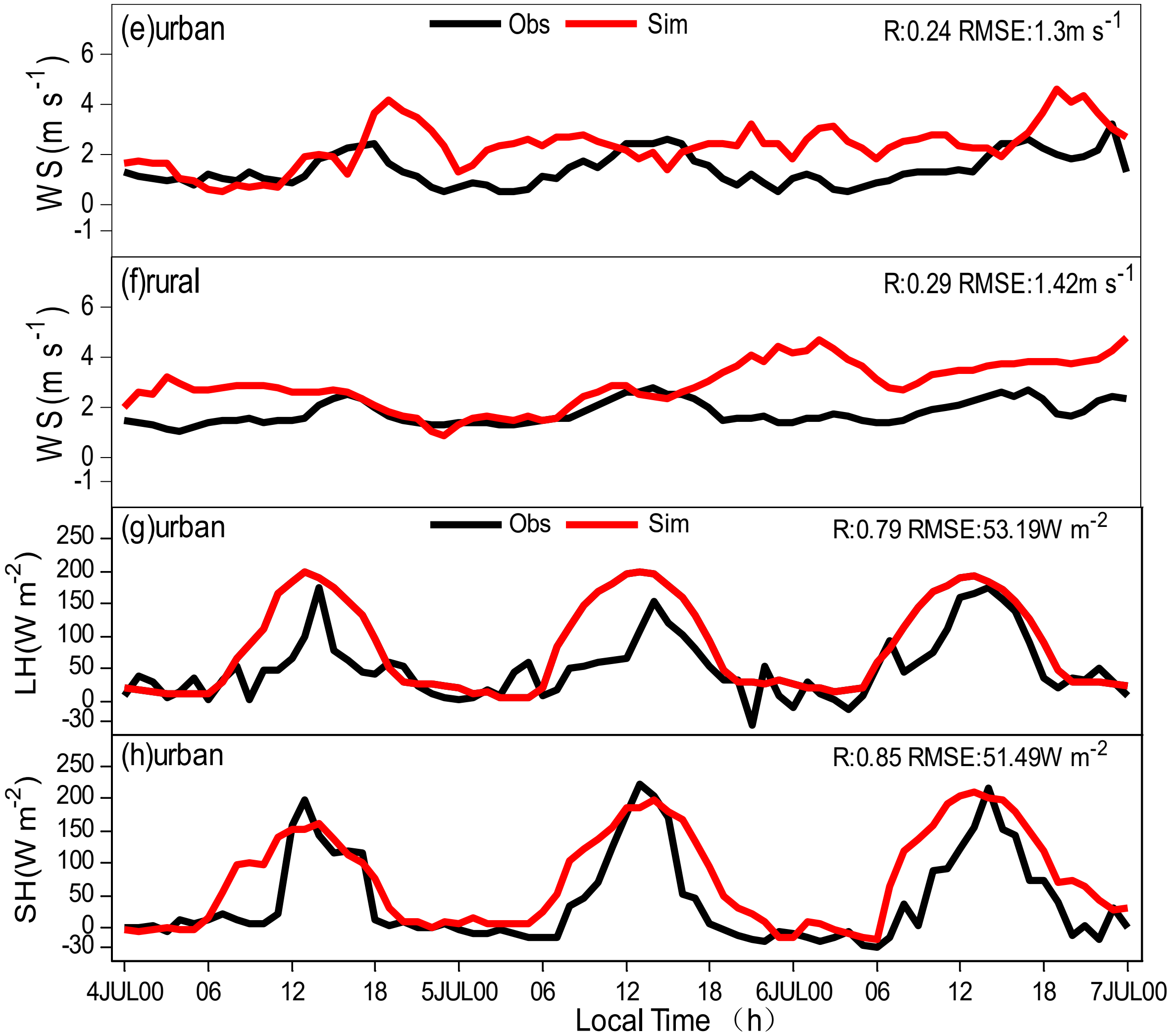



**Fig.4 The comparison between simulated values and observed values on 4-6 July ,**
**(e) (f) 10m wind speed; (g) Latent heat flux; (h) Sensible heat flux.**

# Result and Discussion

## 2 Influence of urban hydrological process on urban surface energy distribution

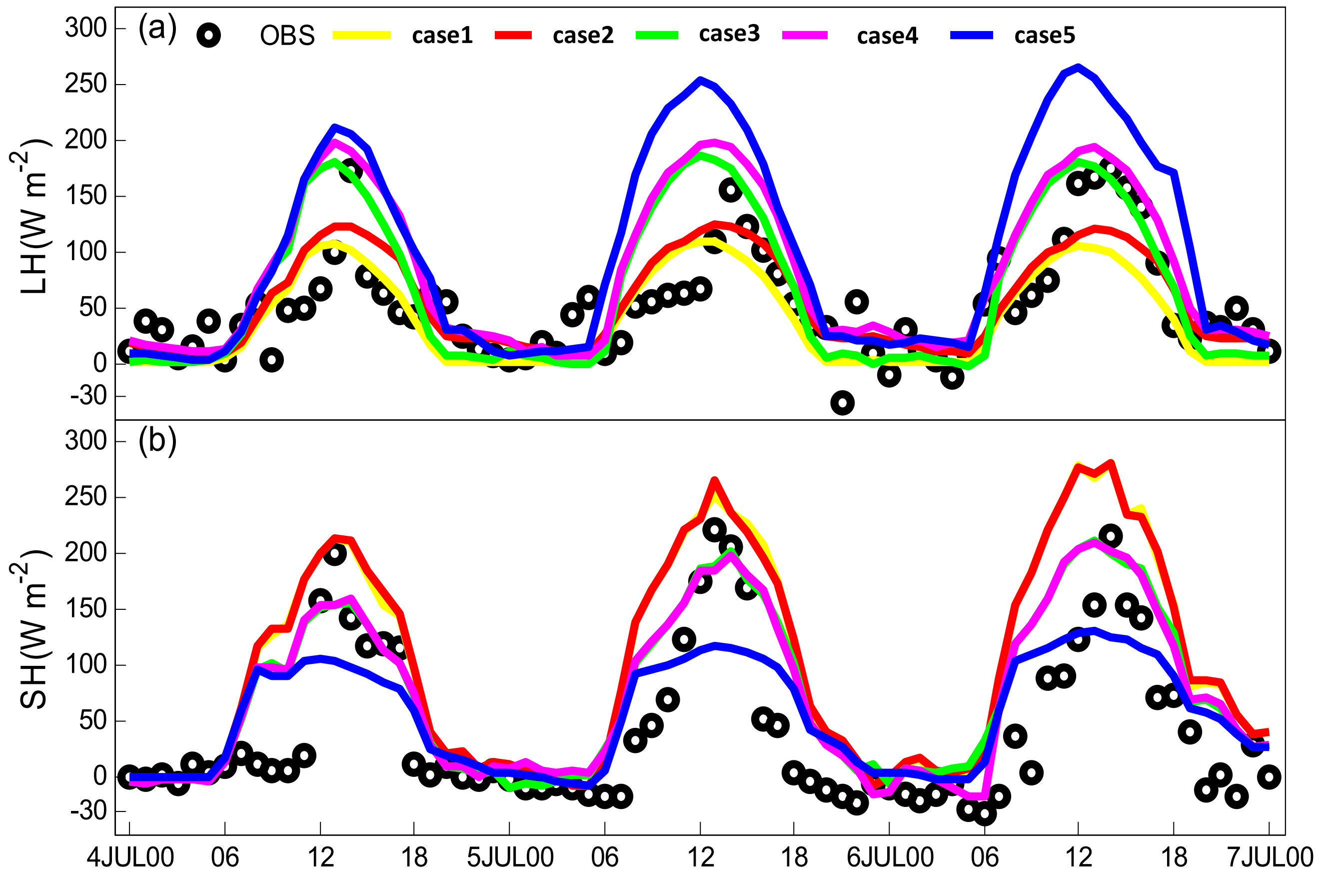



**Fig.5 Comparison of OBS, case1 to case5 on July 4-6,**
**(a) Latent heat flux; (b) Sensible heat flux.**

## 3 Influence of urban hydrological process on surface meteorological field

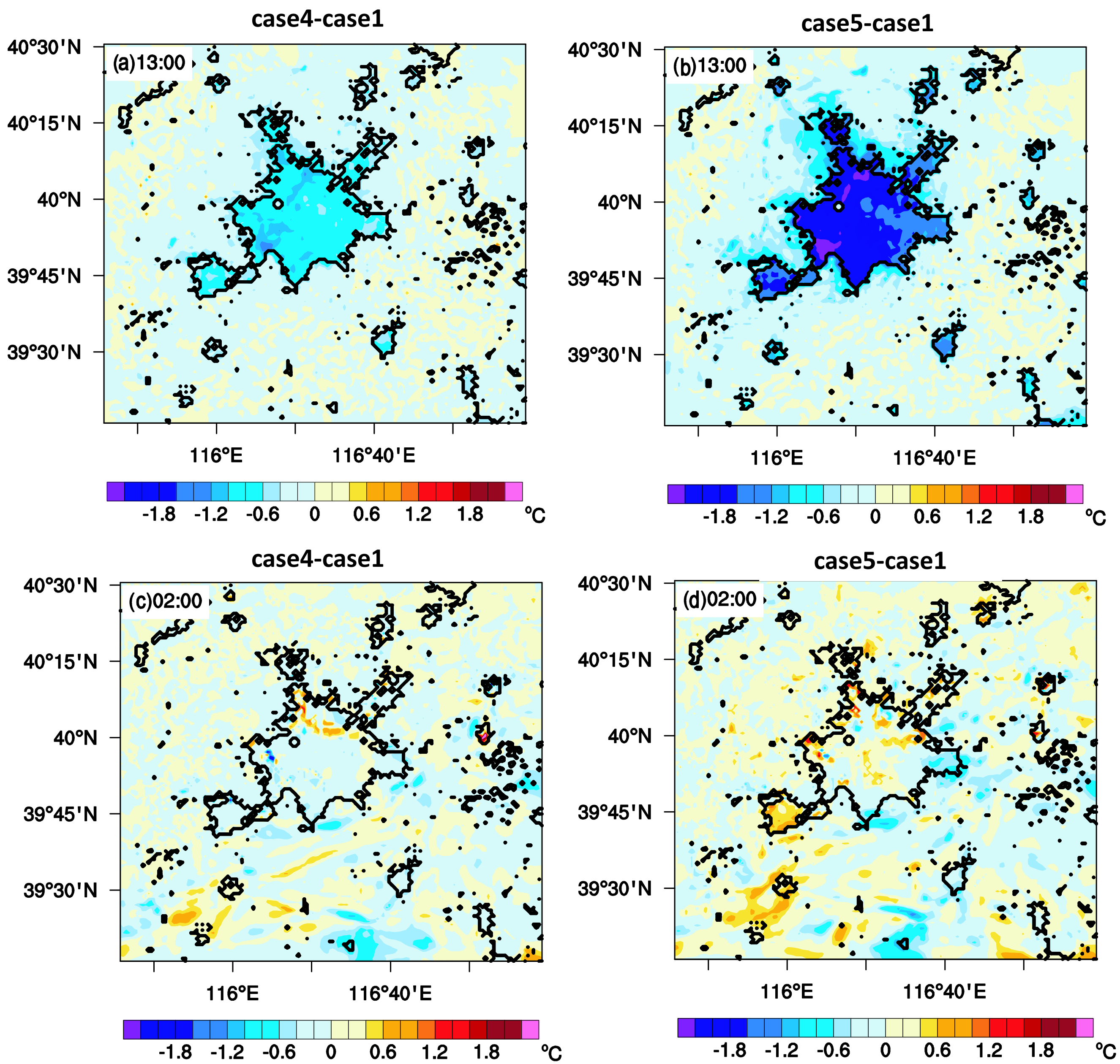



**Fig.6 The difference between 2m temperature simulated by case4 and case5.**

# 3 Influence of urban hydrological process on surface meteorological field

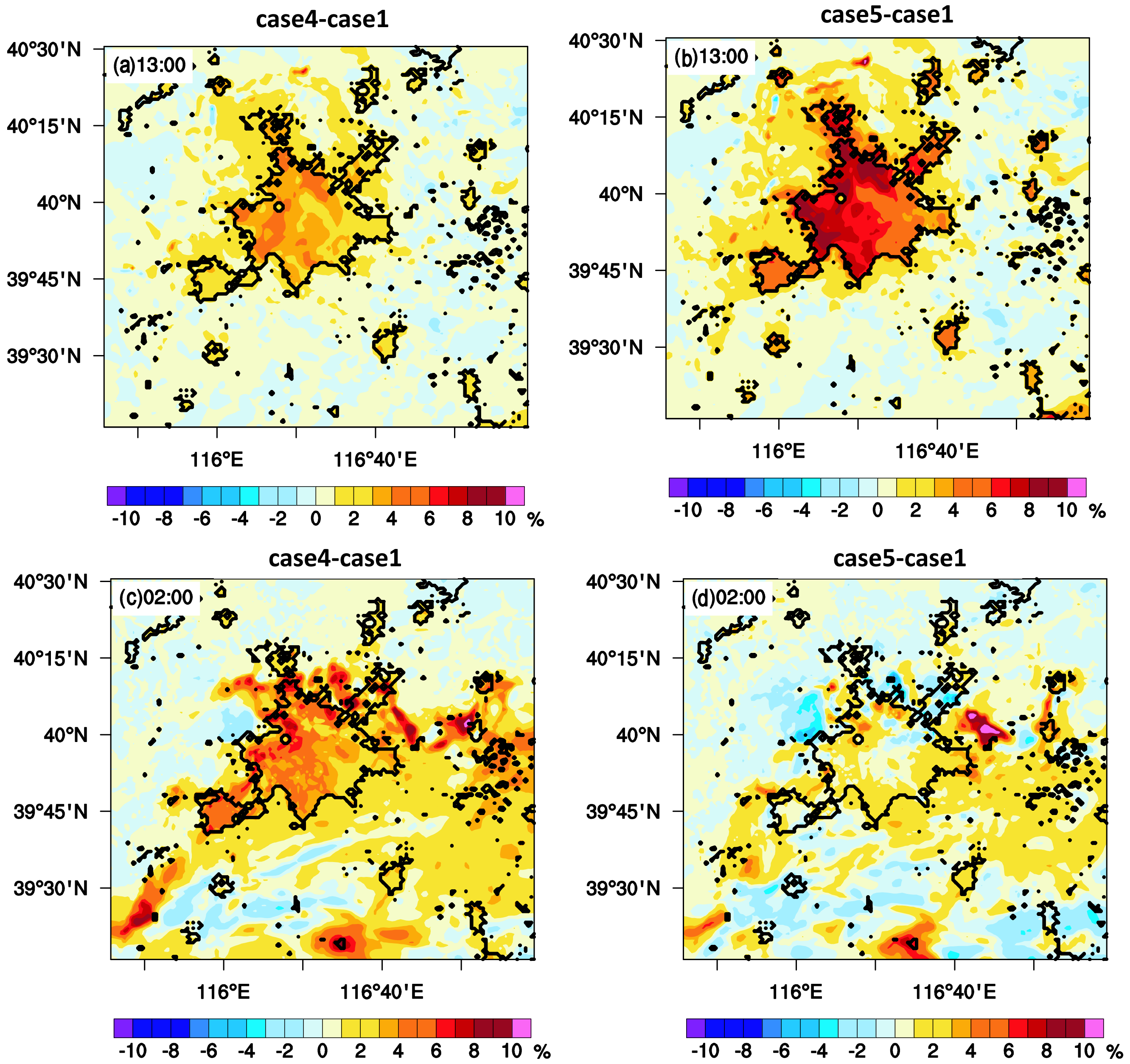



**Fig.7 The difference between relative humidity simulated by case4 and case5.**

## 3 Influence of urban hydrological process on surface meteorological field

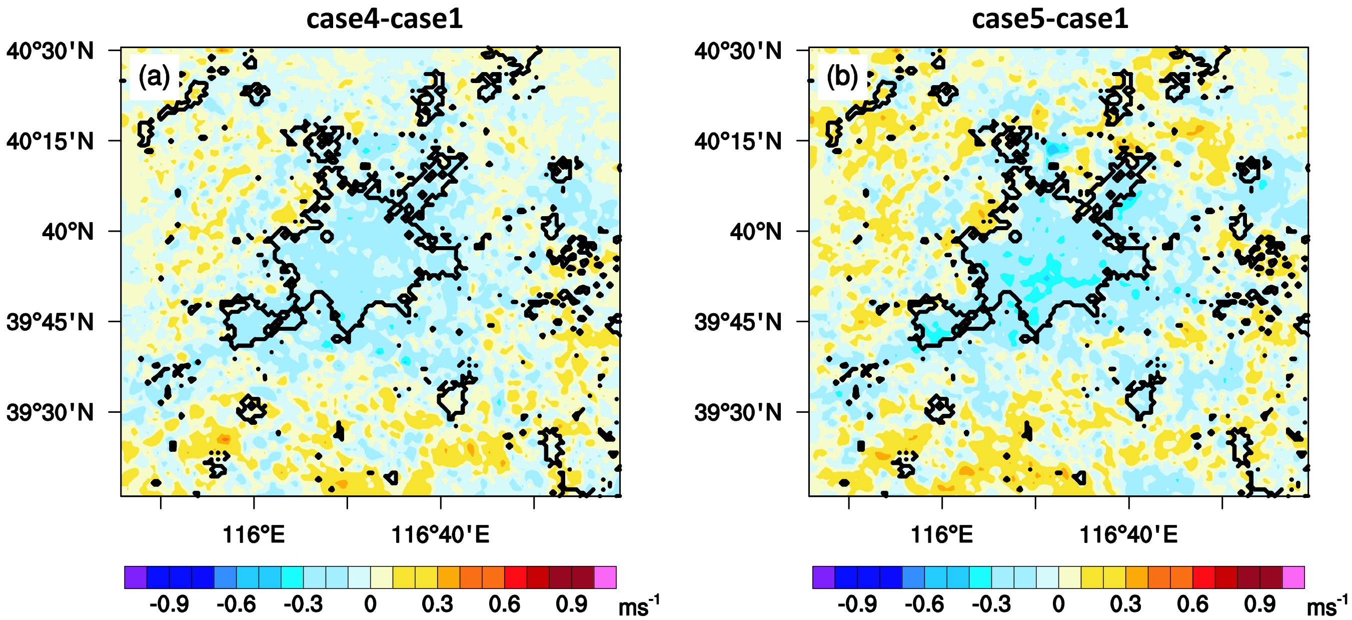



Fig.8 The difference between 10m wind speed simulated by case4 and case5.

# 4 Influence of urban hydrological process on vertical meteorological field

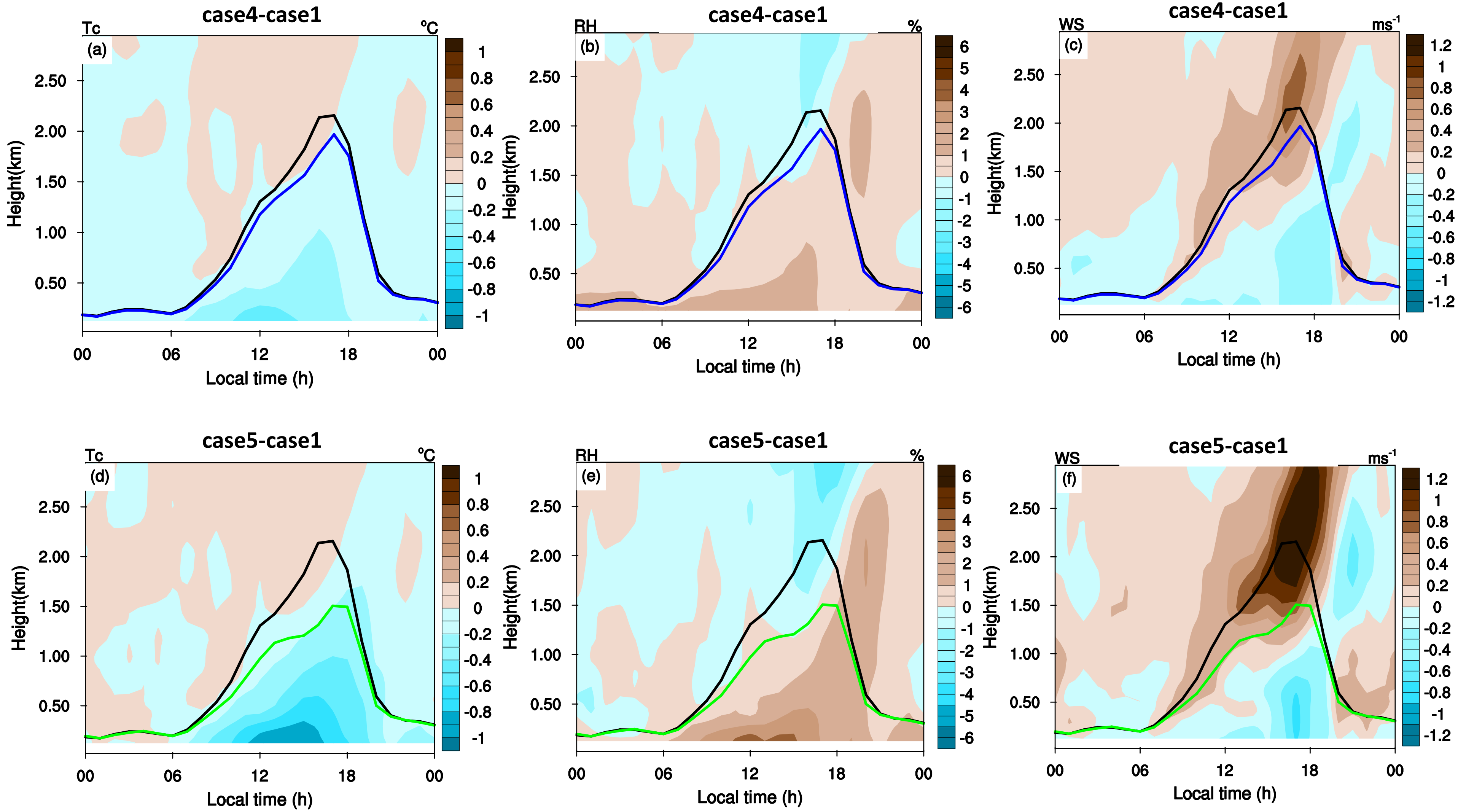



**Fig.9 Daily variation of vertical meteorological field simulated by case4 and case5 in urban area.**

# 4 Influence of urban hydrological process on vertical meteorological field

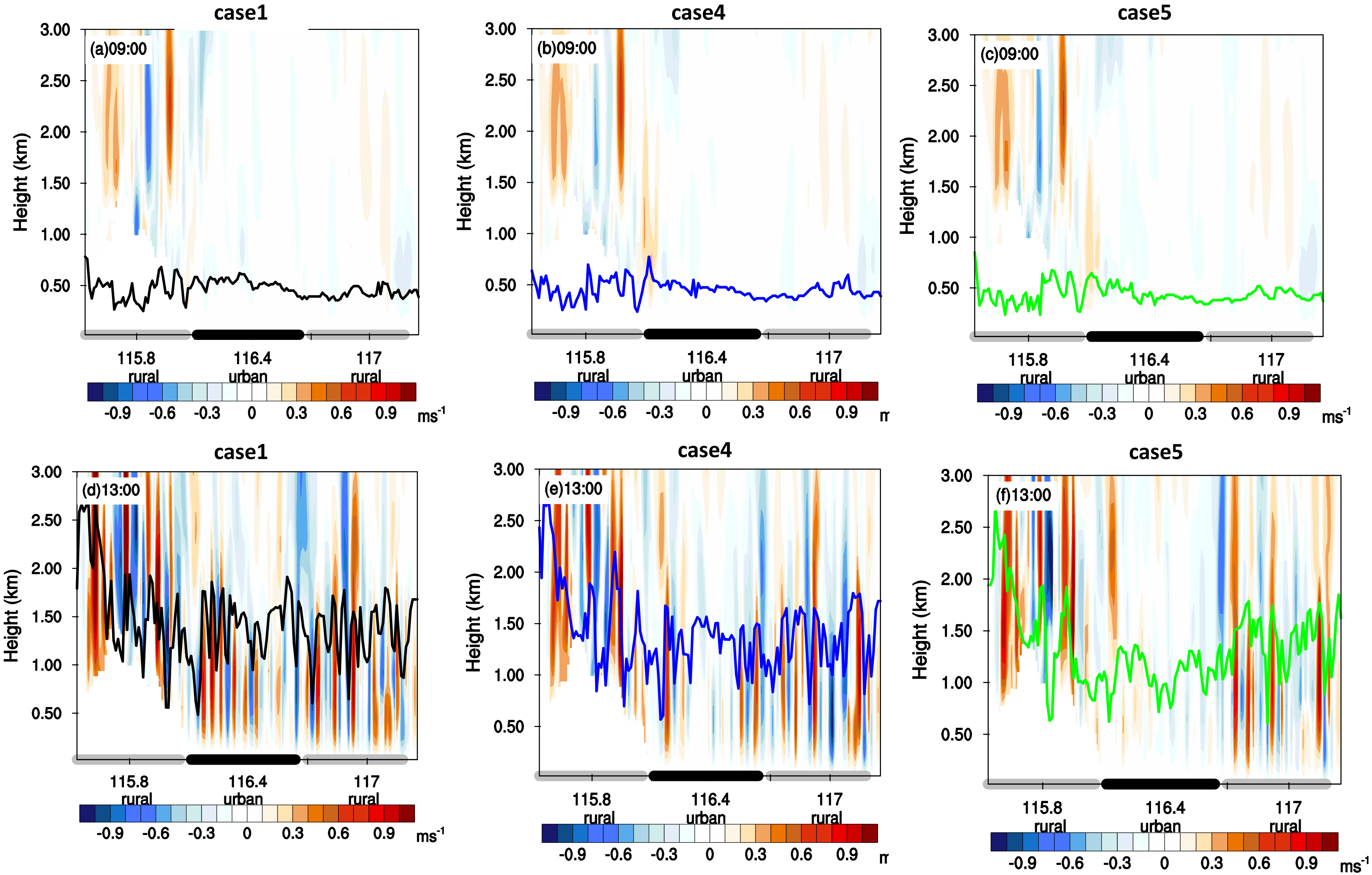



Fig.10 Vertical wind velocity distribution of case1 , case4, case5.

## 5 Temporal distribution characteristics of Urban Heat Island Intensity

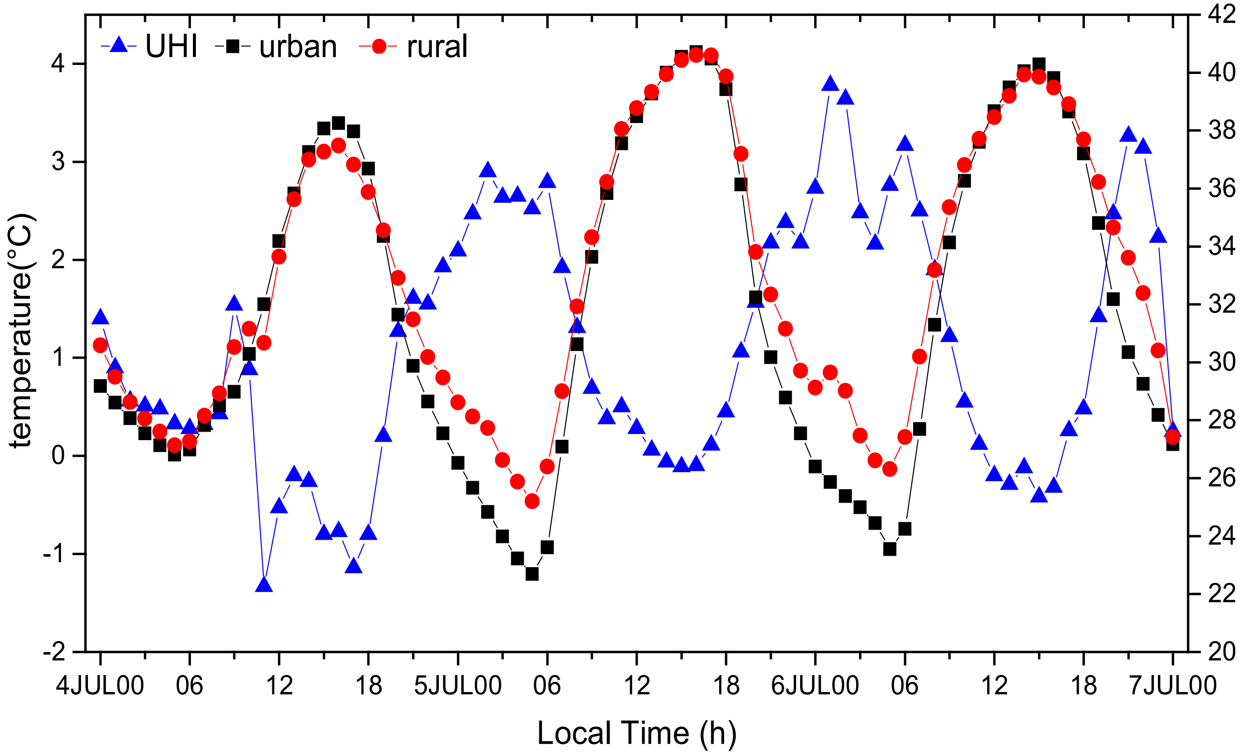



**Fig.11 Average temperature and heat island intensity in urban and suburban areas.**

## 5 Temporal distribution characteristics of Urban Heat Island Intensity

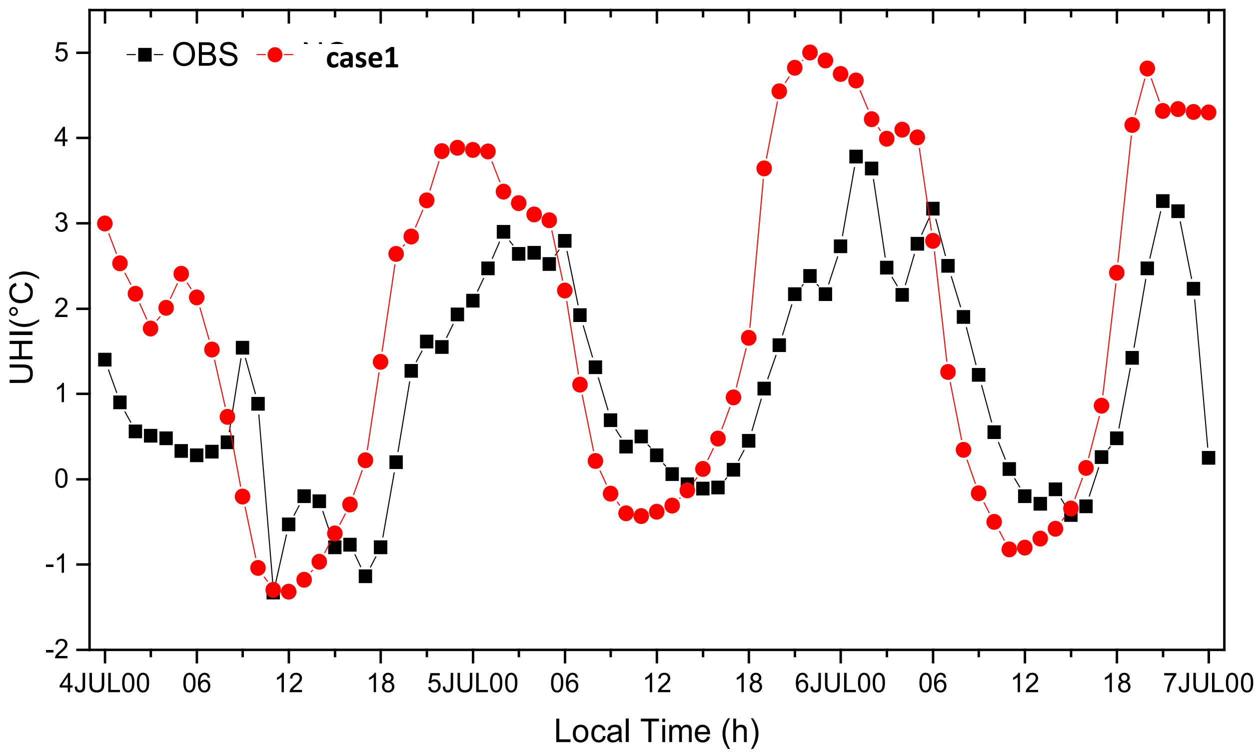



**Fig.12 Comparison between the simulated and observed values of the intensity of the heat island.**

# 6 Influence of Urban Hydrological Process on Surface Heat Island Intensity

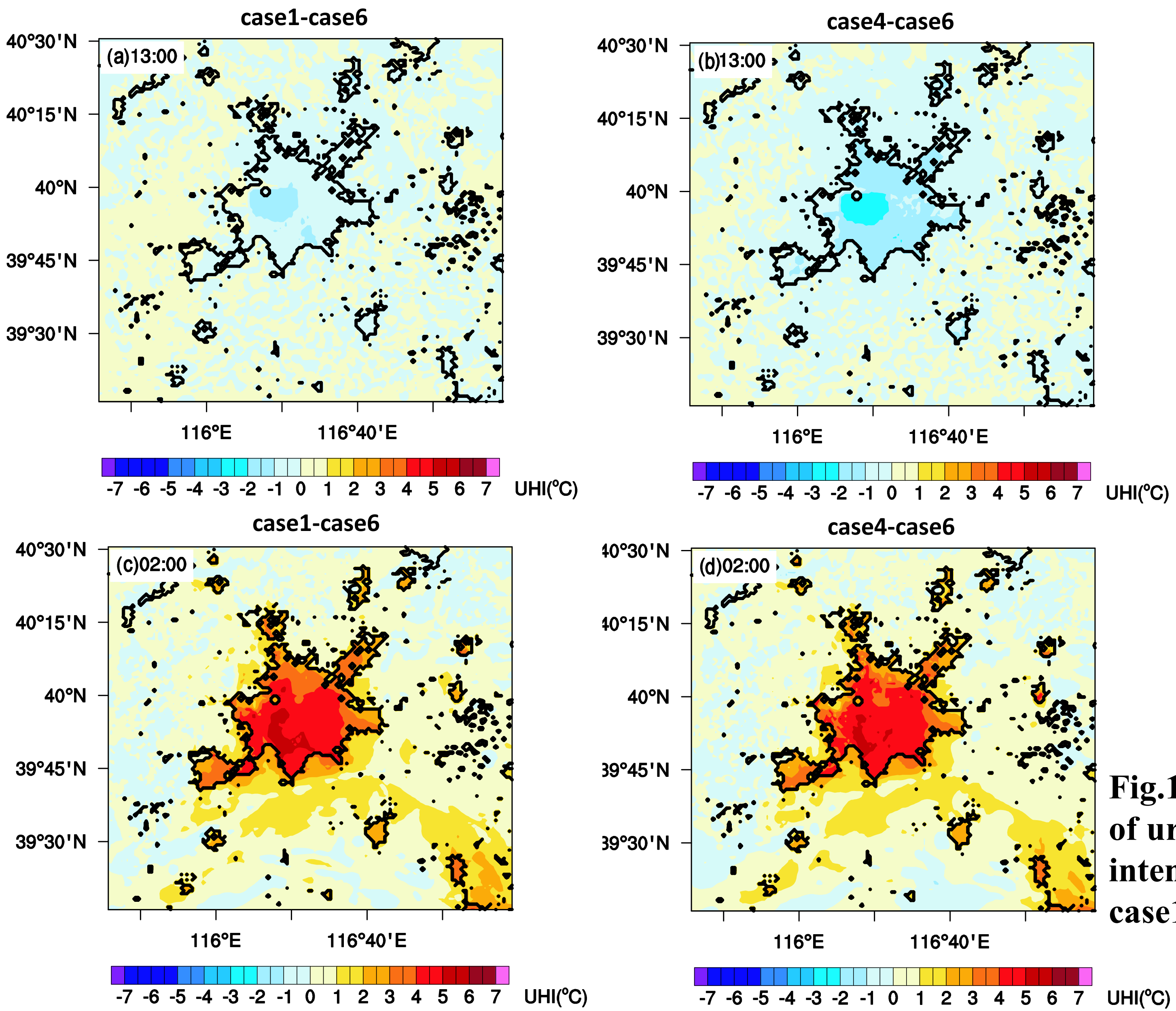



**Fig.13 Spatial distribution of urban heat island intensity simulated by case1 and Case4.**

# 7 Influence of urban hydrological process on the vertical distribution of heat island

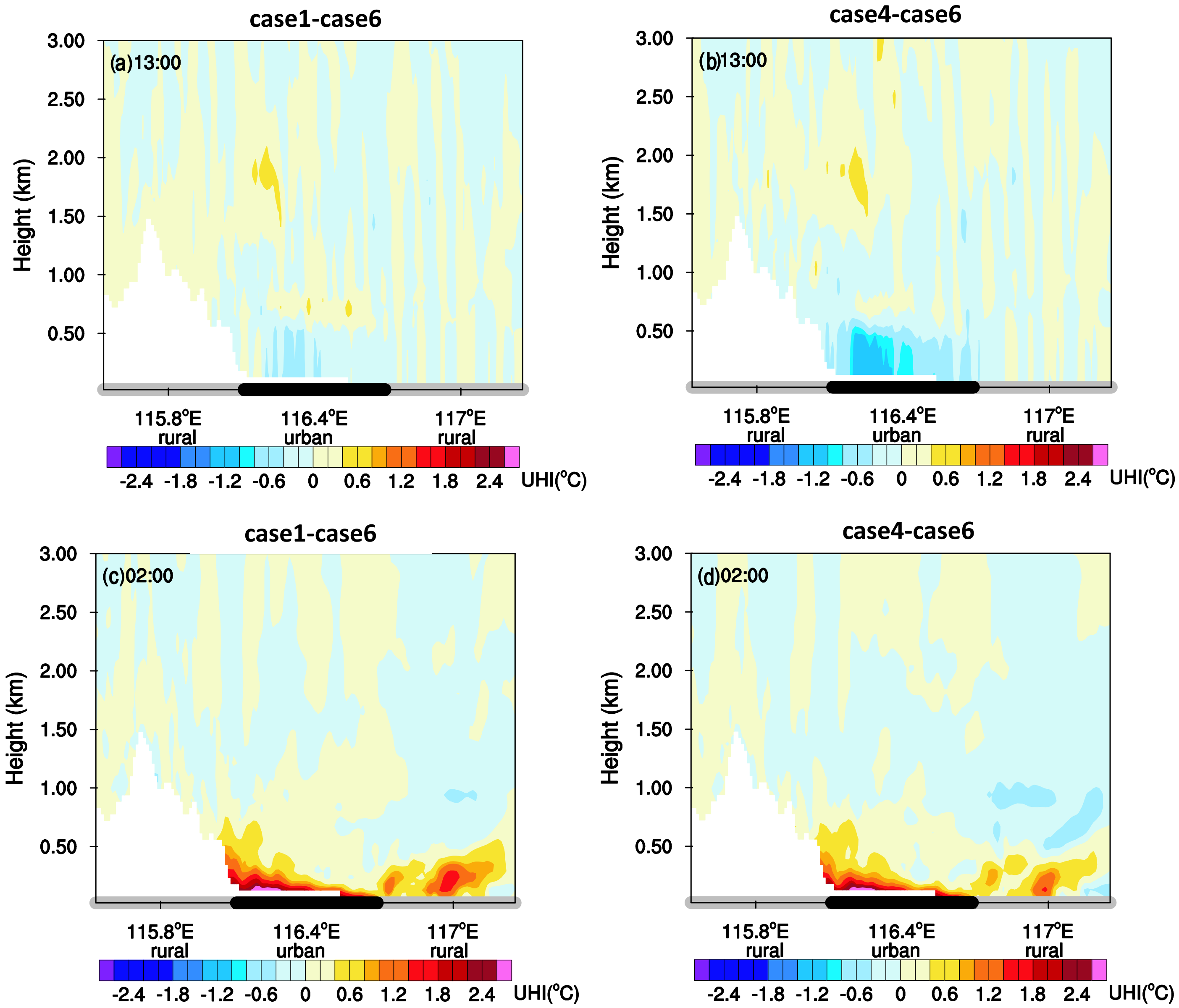



**Fig.14 Vertical distribution of urban heat island intensity simulated by case1 and Case4.**

# Conclusion

- **After joining the urban hydrological process, the simulation effect of the model on energy was improved. Compared with the control example, latent heat flux simulated by artificial latent heat, green irrigation, oasis effect and green roof were increased. The sensible heat flux simulated by artificial latent heat changed little, while simulated by the green irrigation, oasis effect and green roof were decreased.**
- **2 m temperature simulated by the urban hydrologic process and green roof was reduced in the urban surface area. 2 m relative humidity were increased and the change of 10 m wind speed were not obvious.**

# Conclusion

- **Below the boundary layer height, the temperature of the urban hydrological process and the green roof  were reduced, The relative humidity of two case were increased. The wind speed were decreased near surface, while  increased at the higher level. It seen that the urban hydrological process could reduce the temperature of urban area, but the decrease of vertical wind speed was not conducive to the diffusion of pollutants.**
- **The intensity of the urban heat island at night is greater than that in the daytime, and the "cold island effect" appeared from 12:00 to 16:00. Urban hydrological processes had an inhibitory effect on the formation of urban heat island.**

# Thank you