# The effect of building on the observation of surrounding air temperature

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# Outline

- Background
- Method
- Results
- Conclusion & Discussion

# Background

- Reliable meteorological observation data is the basis of weather forecast, meteorological service and meteorological research work(Mahmood 2006).
- Environmental conditions of a site, such as building, tree, water, road, may generate measurement errors (Leroy 2010).
- According to the regulation, the national meteorological station, the basic station and the general weather station on the evasion of the monomer obstacle distance shall not be less than 10 times, 10 times, 8 times of building height respectively.

# Background

- With the accelerating urbanization, the buildings around the sites are increasing. Building is becoming the one of the most important factors that influence the temperature observation of meteorological stations.

- It is essential to study quantitatively the influence of observation environment on the measured temperature for scientific application of the observing surface air temperature data and meteorological sites selection.

# Method

- The city sub-domain scale model has been established by the Department of Atmospheric Sciences, Nanjing University in 2001.

- We use this model to study the meteorological problem in the urban sub-domain, it’s horizontal scale is 1~2 km.

- The model has good application in the simulation of the meteorological field and pollution diffusion in actual area(Miao 2002) ,the assessment of urban district planning (Wang 2006) and the forecasting atmospheric environment after planning(Wang 2007).

# Method

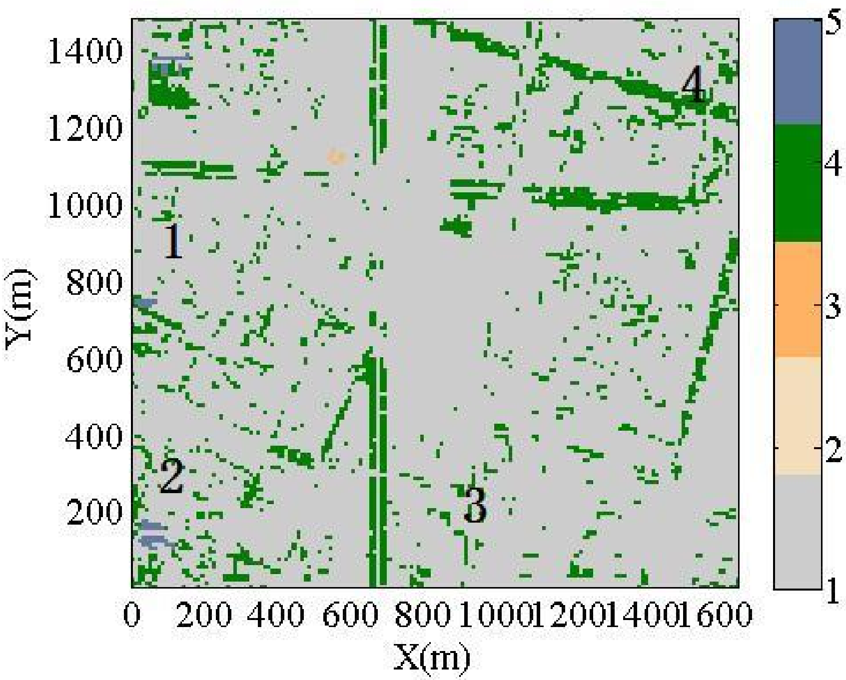



Fig.1 Land use of the NanJing CBD
(1:concrete, 2:water, 3:grass, 4:tree, 5:bare soil;
number 1-4 are fixed observation sites)

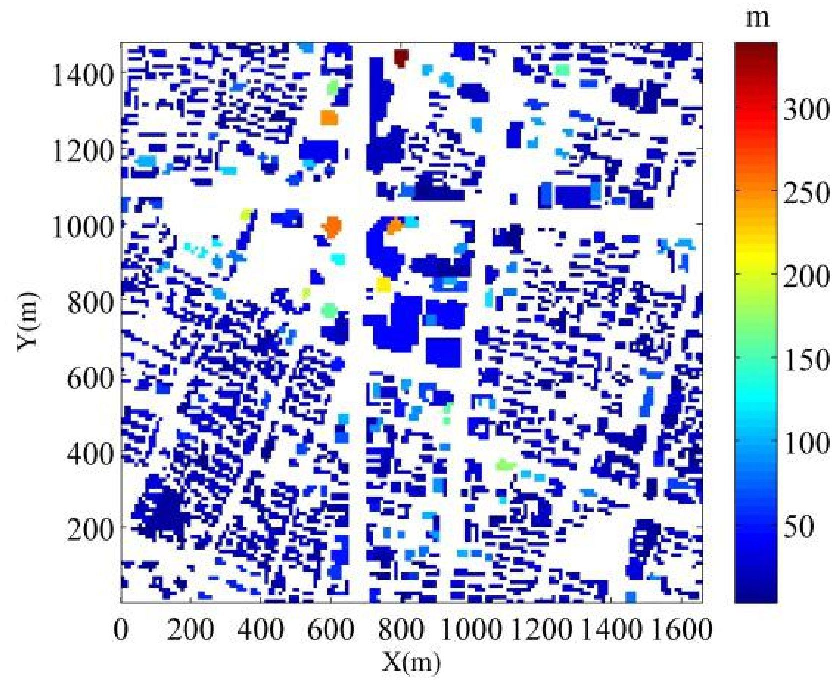



Fig.2 The building height of the NanJing CBD

# Method

Table 1  Introduction of the cases

| 算例 | 层结条件 | 模拟时间 | 初始风向风速 | 建筑物高度 |
|---|---|---|---|---|
| 验证算例 | WRF模拟结果 | 2015年8月3日 0:00-23:00 | WRF模拟结果 | 中央商务区建筑物高度 |
| case1—case72 | WRF模拟结果 | 2015年8月3日 0:00-23:00 | WRF模拟结果 | 单体建筑物 H= 6,18,30 m |

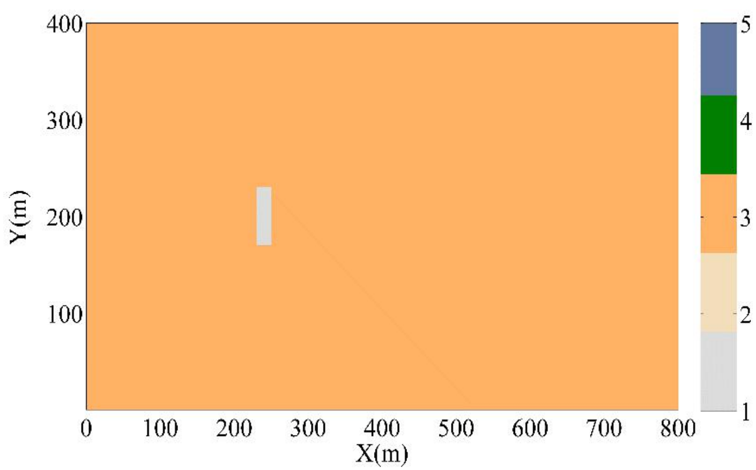



Fig.3 Land use of the simulated area
(1:concrete, 2:water, 3:grass, 4:tree, 5:bare soil)

# Results

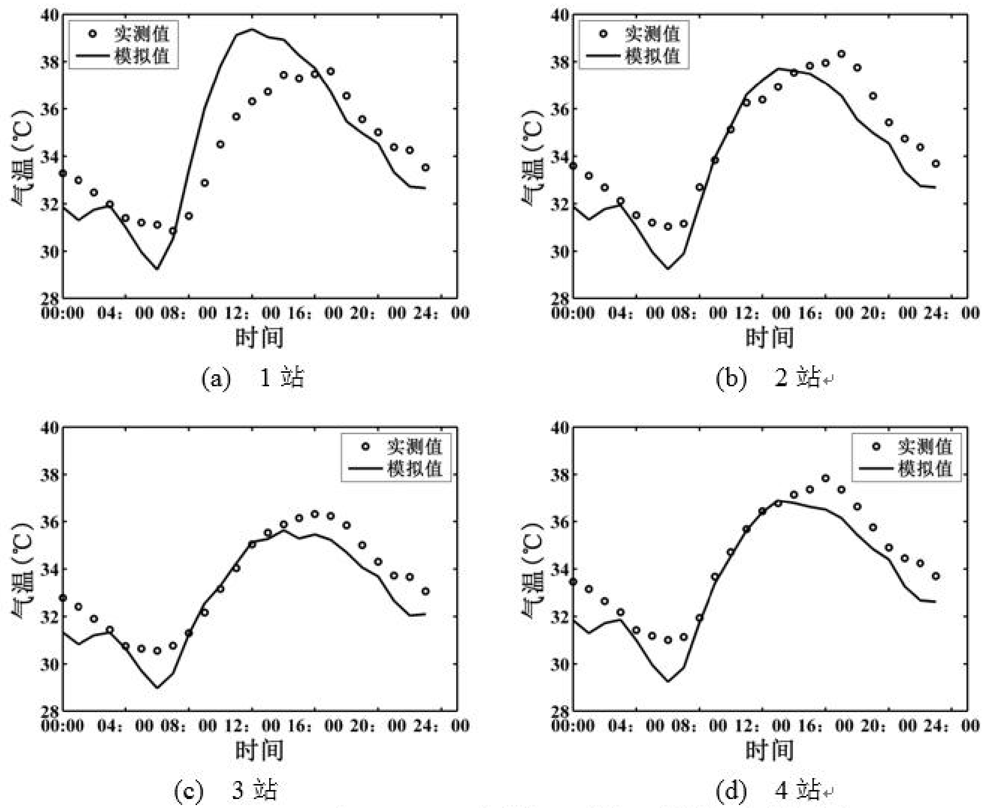



Fig.4 The comparison of simulated and observed air temperature at the height of 2m with the actual underlying surface of four stations

Table 2 Model performance statistics for the cases

| 站号 | 1 | 2 | 3 | 4 | 平均值 |
|---|---|---|---|---|---|
| 相关系数 | 0.86 | 0.95 | 0.96 | 0.97 | 0.94 |
| 均方根误差（℃） | 1.73 | 1.18 | 0.91 | 1.03 | 1.21 |

- Air temperature comparisons are made at the height of 2m between the experiments with the building and those without the building, The temperature difference $\triangle T$ is defined as

$$\triangle T = T_{building} - T_{ref}$$

- The influence distance is calculated by the standard which $|\triangle T| \geq 0.1℃$.

# Results

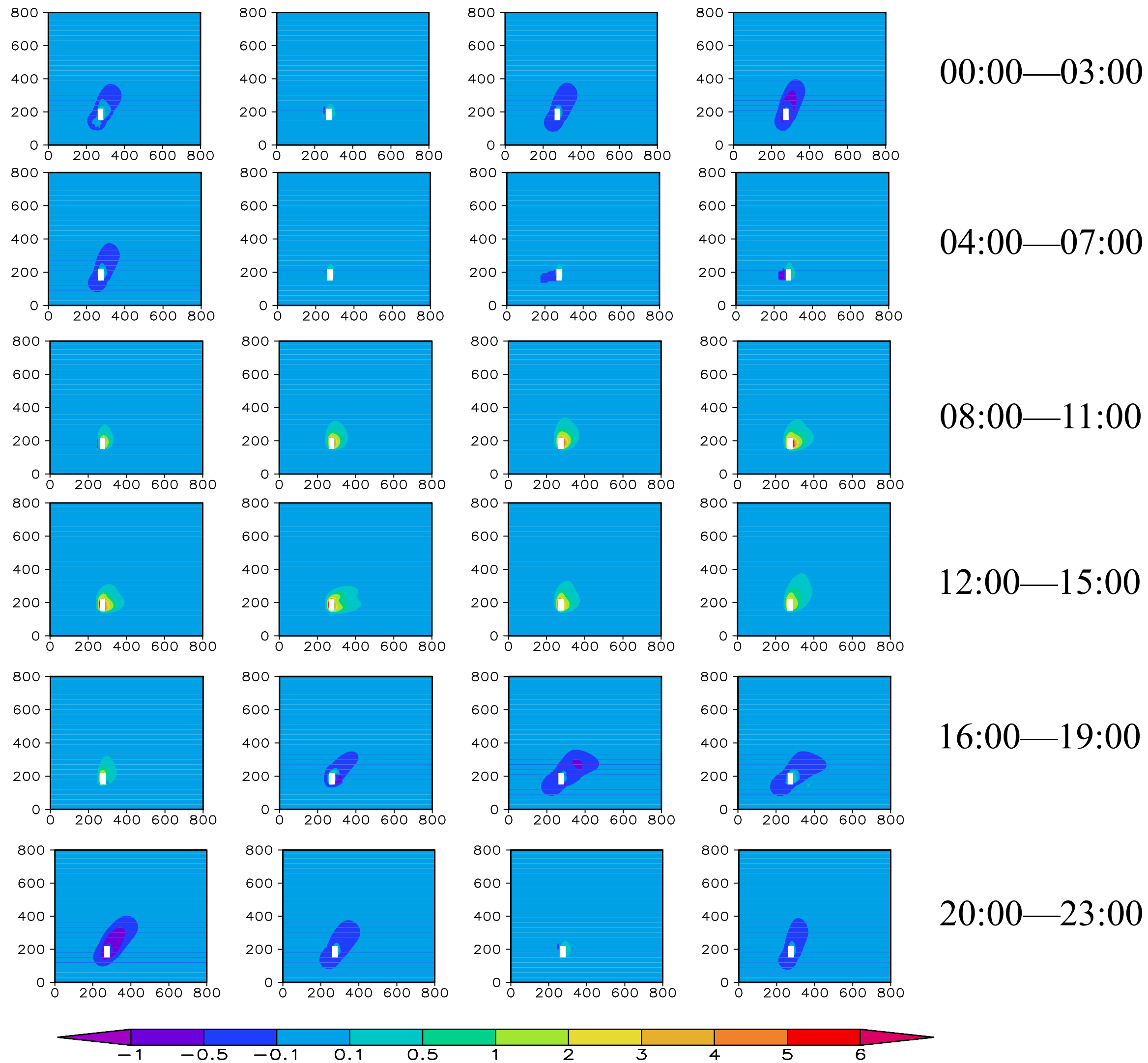



Fig.5 Effect of building on air temperature when the height of the building is 18m in August 3,2015

# Results

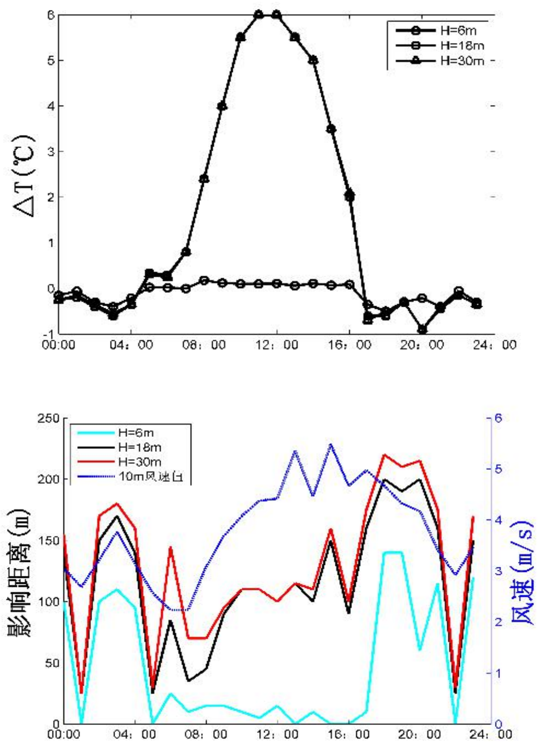



Fig.6 Effect of building on air temperature under different heights (a) △T (℃) and (b) distance (m)

Table 3 Effect of building on air temperature under different heights in August 3,2015

| 时间 | 影响数值 (℃) | | | 影响距离 (m) [建筑物高度倍数] | | |
|---|---|---|---|---|---|---|
| | H=6m | H=18 m | H=30 m | H=6 m | H=18 m | H=30 m |
| 00:00 | -0.15 | -0.25 | -0.25 | 100[16.7H] | 140[7.8H] | 155[5.2H] |
| 01:00 | -0.06 | -0.2 | -0.15 | 0 | 25[1.4H] | 25[0.8H] |
| 02:00 | -0.3 | -0.4 | -0.35 | 100[16.7H] | 150[8.3H] | 170[5.7H] |
| 03:00 | -0.4 | -0.6 | -0.55 | 110[18.3H] | 170[9.4H] | 180[6H] |
| 04:00 | -0.21 | -0.35 | -0.35 | 95[15.8H] | 140[7.8H] | 160[5.3H] |
| 05:00 | 0.025 | 0.35 | 0.3 | 0 | 25[1.4H] | 30[1H] |
| 06:00 | 0.02 | 0.3 | 0.25 | 25[4.2H] | 85[4.7H] | 145[4.8H] |
| 07:00 | 0 | 0.8 | 0.8 | 10[1.7H] | 35[1.9H] | 70[2.3H] |
| 08:00 | 0.18 | 2.4 | 2.4 | 15[2.5H] | 45[2.5H] | 70[2.3H] |
| 09:00 | 0.12 | 4 | 4 | 15[2.5H] | 90[5H] | 95[3.2H] |
| 10:00 | 0.1 | 5.5 | 5.5 | 10[1.7H] | 110[6.1H] | 110[3.7H] |
| 11:00 | 0.1 | 6 | 6 | 5[0.8H] | 110[6.1H] | 110[3.7H] |
| 12:00 | 0.11 | 6 | 6 | 15[2.5H] | 100[5.6H] | 100[3.3H] |
| 13:00 | 0.06 | 5.5 | 5.5 | 0 | 115[6.4H] | 115[3.8H] |
| 14:00 | 0.11 | 5 | 5 | 10[1.7H] | 100[5.6H] | 110[36.7H] |
| 15:00 | 0.07 | 3.5 | 3.5 | 0 | 150[8.3H] | 160[5.3H] |
| 16:00 | 0.09 | 2 | 2 | 0 | 90[5H] | 100[3.7H] |
| 17:00 | -0.35 | -0.6 | -0.7 | 10[1.7H] | 160[8.9H] | 175[5.8H] |
| 18:00 | -0.5 | -0.6 | -0.5 | 140[23.3H] | 200[11.1H] | 220[7.3H] |
| 19:00 | -0.3 | -0.3 | -0.3 | 140[23.3H] | 190[10.6H] | 210[7H] |
| 20:00 | -0.21 | -0.9 | -0.9 | 60[10H] | 200[11.1H] | 215[7.2H] |
| 21:00 | -0.4 | -0.45 | -0.4 | 115[19.2H] | 160[8.9H] | 175[5.8H] |
| 22:00 | -0.05 | -0.15 | -0.15 | 0 | 25[1.4H] | 30[1H] |
| 23:00 | -0.3 | -0.35 | -0.35 | 120[20H] | 150[8.3H] | 170[9.4H] |

# Results

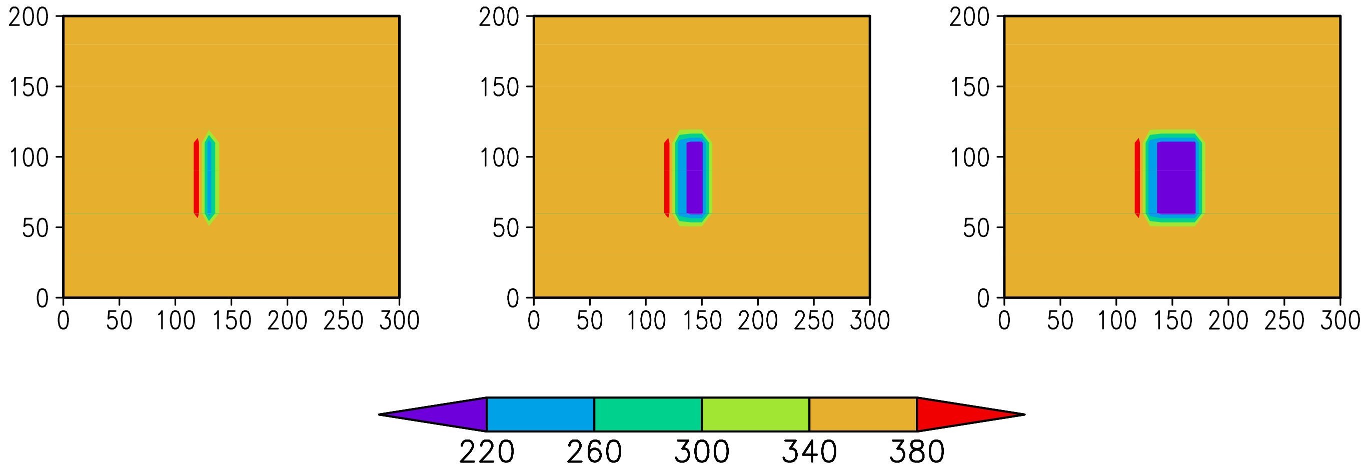



Fig.7 The surface shortwave radiation distribution of building under different heights (W/m$^2$)

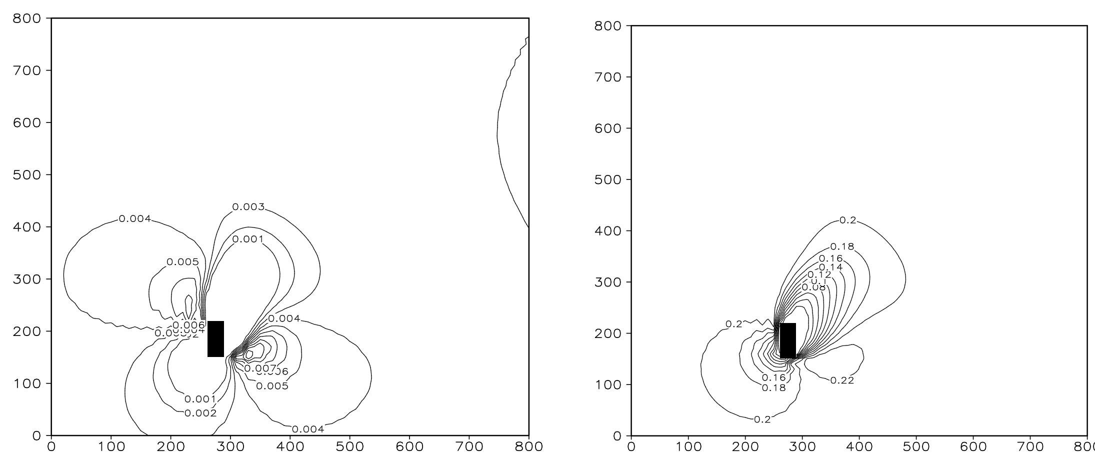



Fig.8 The turbulence intensity distribution of building when the height of the building is 30m（m$^2$/s$^2$）

（a）02:00 and（b）14:00

# Results

Table 4 Introduction of the sensitivity cases

| 试验组 | 层结条件 | 初始风向风速 | 建筑物高度(m) | 建筑物长度(m) | 建筑物厚度(m) |
|---|---|---|---|---|---|
| 1 | 理想稳定层结（02时）<br>理想不稳定层结（14时）<br>理想中性层结（20时） | 西风<br>2,4,6,8,10m/s | 18 | 60 | 20 |
| 2 | 理想稳定层结（02时）<br>理想不稳定层结（14时）<br>理想中性层结（20时） | 西风<br>6 m/s | 6,18,30 | 60 | 20 |
| 3 | 理想稳定层结（02时）<br>理想不稳定层结（14时）<br>理想中性层结（20时） | 西风<br>6 m/s | 18 | 60 | 20,40,60 |
| 4 | 理想稳定层结（02时）<br>理想稳定层结（14时） | 西风<br>6 m/s | 18 | 20,40,60 | 20 |
| 5 | 理想弱稳定层结（02时）<br>理想弱不稳定层结（14时） | 西风<br>6 m/s | 18 | 60 | 20 |

# Results

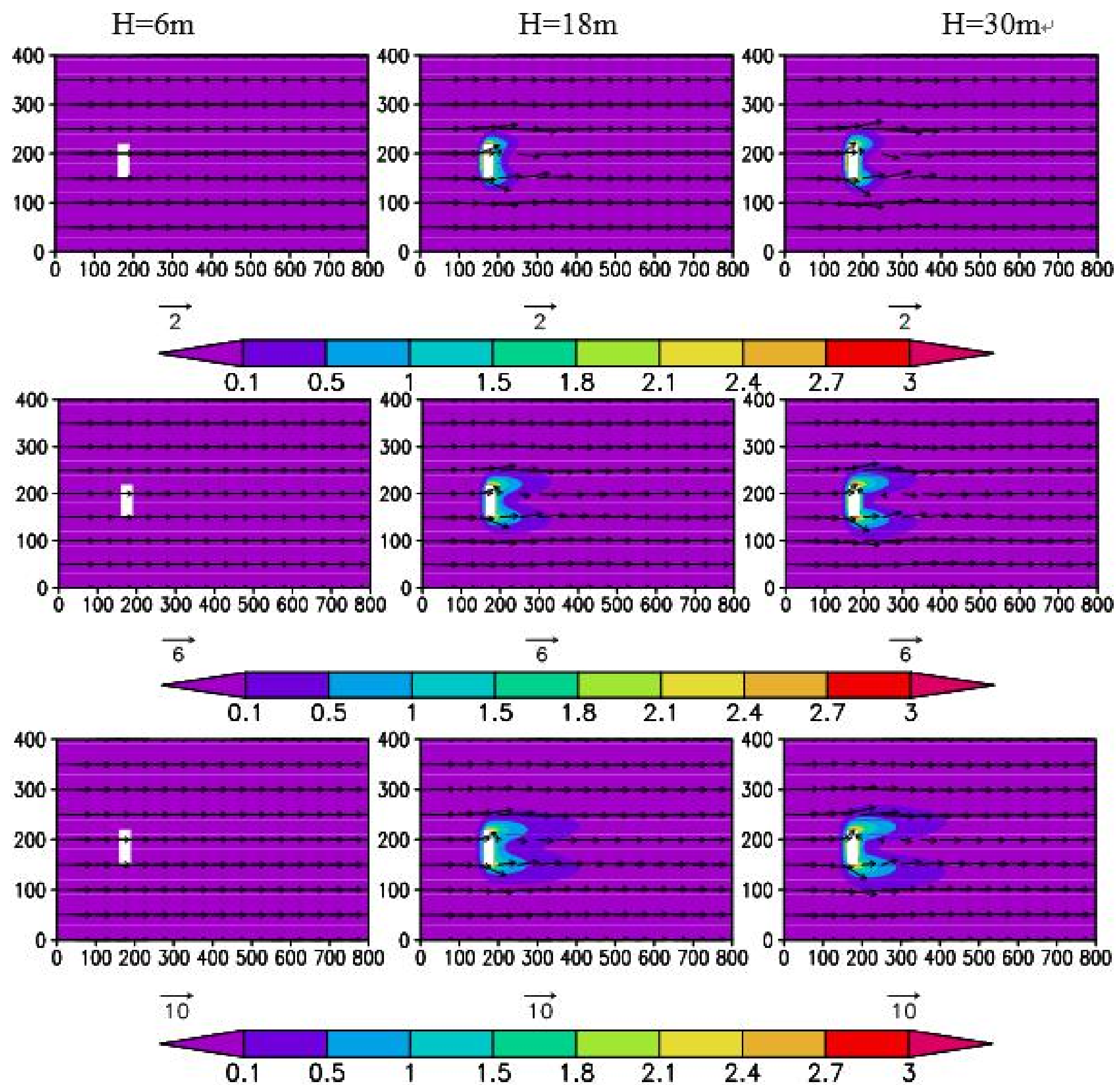



Fig.9 Effect of building on air temperature under different heights under strong unstable stratification at 14:00

# Results

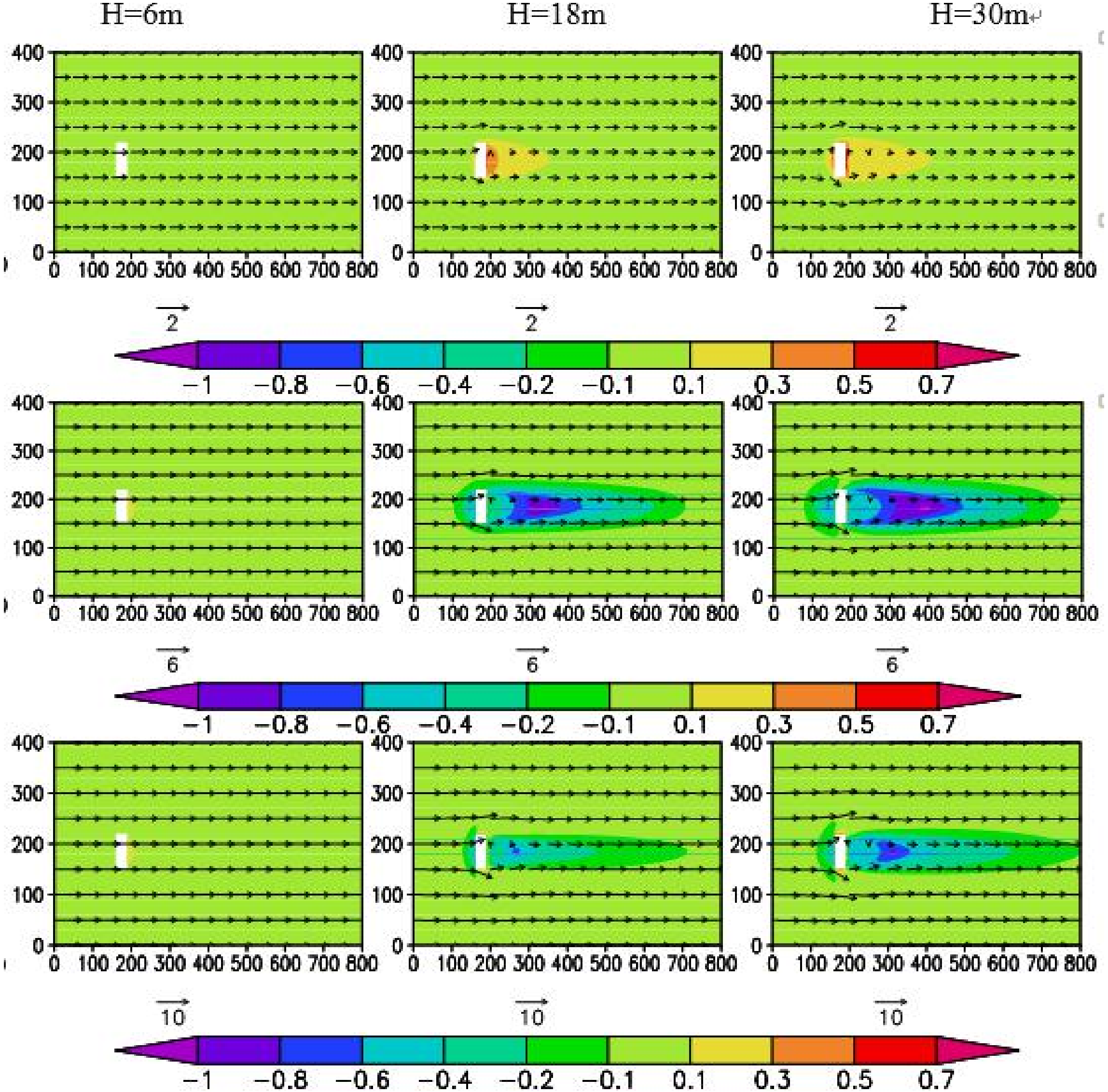



Fig.10 Effect of building on air temperature under different heights under neutral stratification at 20:00

# Results

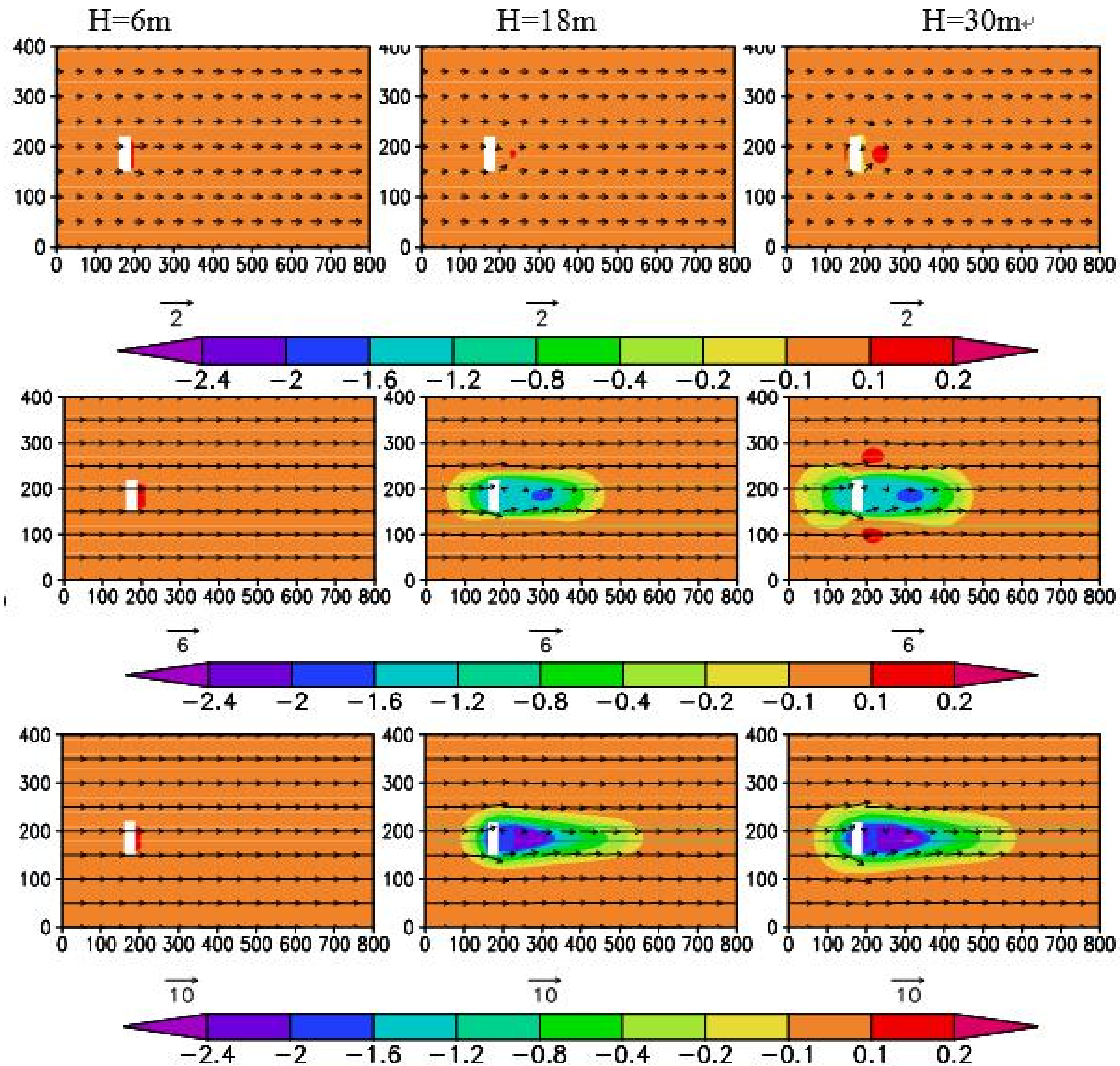



Fig.11 Effect of building on air temperature under different heights under strong stable stratification at 02:00

# Results

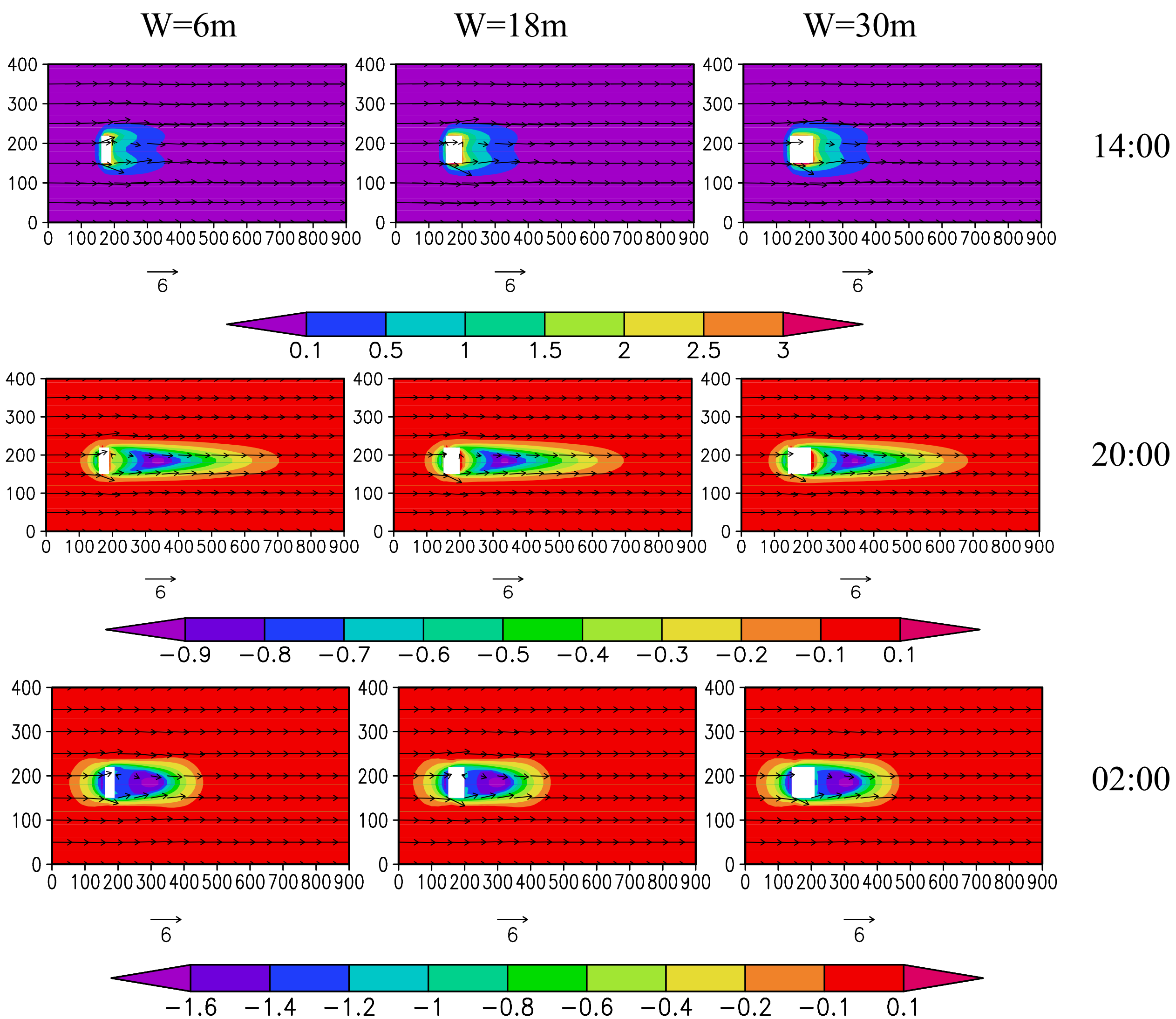



Fig.12 Effect of building on air temperature under different thickness

# Results

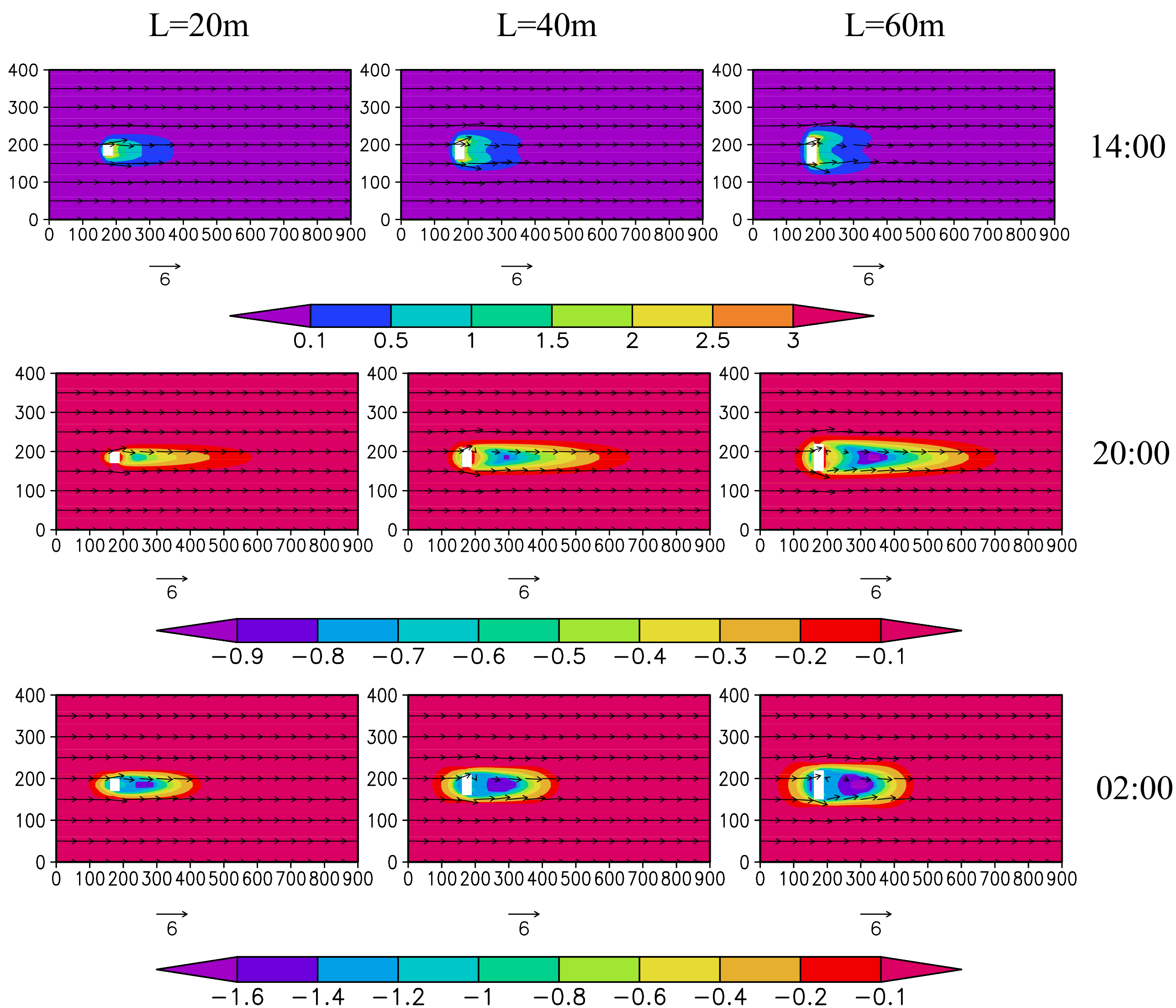



Fig.13 Effect of building on air temperature under different lengths

# Results

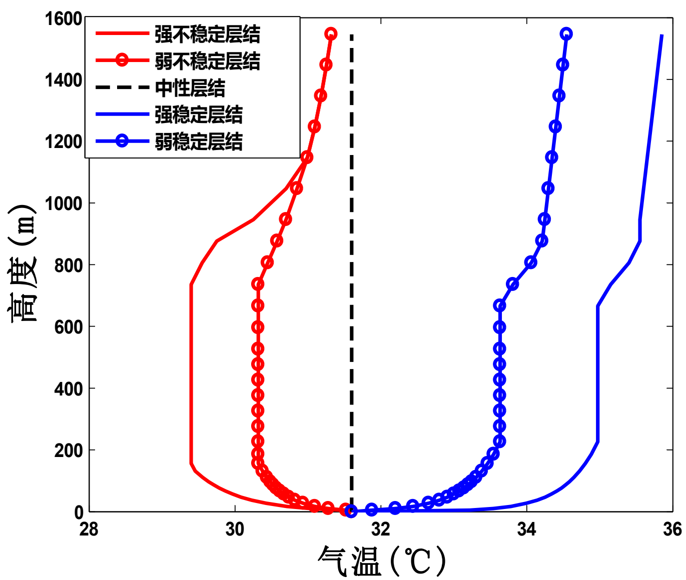



Fig.14 Initial air temperature profile under five stratifications

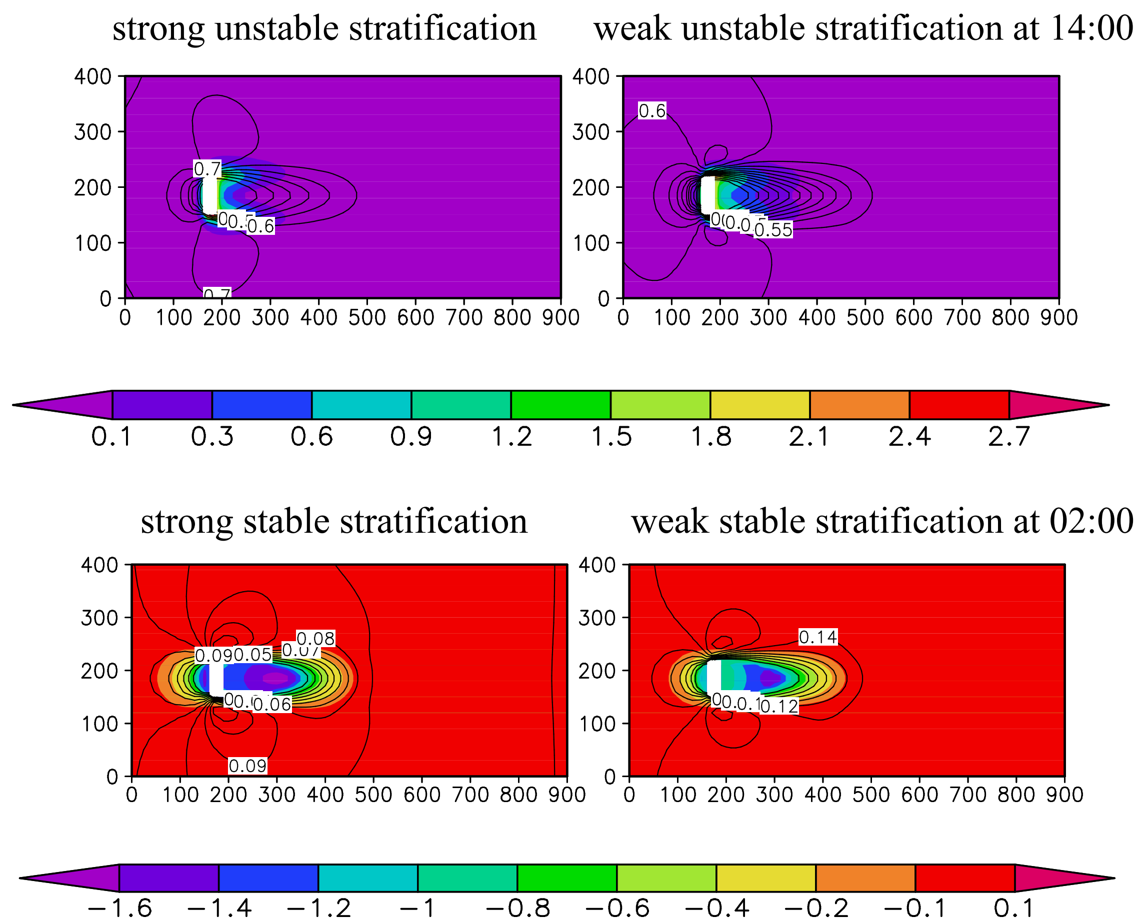
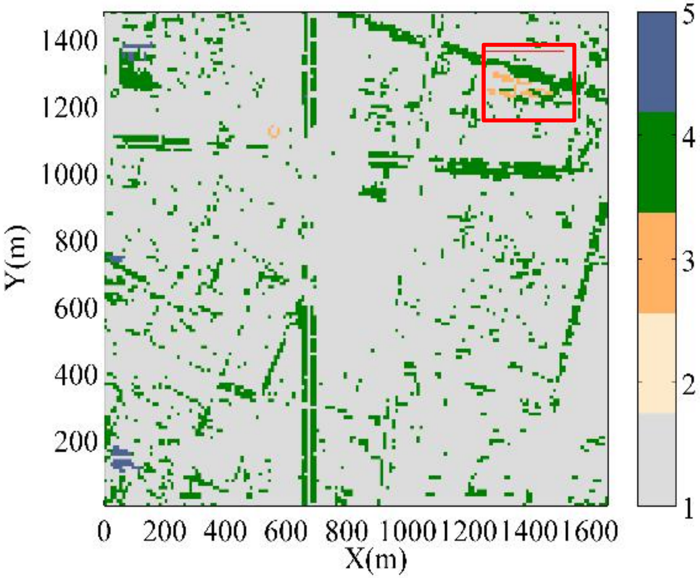



Fig.15 Effect of building on air temperature

# Results

Fig.16 The observation environment surrounding the jiuzhong automatic weather station



# Results

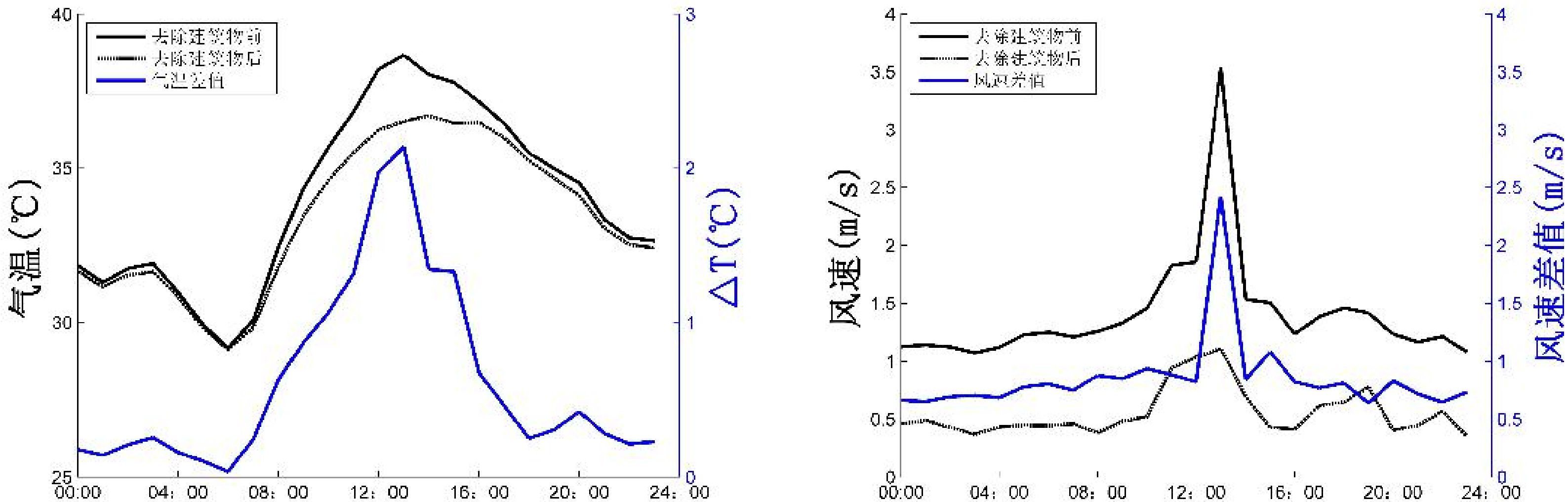



Fig.17 The diurnal variation of the air temperature at the height of 2m (a) and the wind speed at the height of 10m (b) before and after the removal of the building

# Conclusion

- During the summer daytime, the building has a warming effect on the surrounding atmosphere, and during the night, building has a weak cooling effect on the surrounding atmosphere.

- Compared with the night, the influence distance of building on the temperature is small during the daytime, because the atmospheric stratification is mainly convective stratification, and the turbulence is stronger, so that the heat generated by the building more likely transported vertically to the upper atmosphere, thus the impact of building on the leeward atmosphere is small.

# Conclusion

- The results of the sensitivity simulation analysis show that the temperature change of the surrounding of the building is more sensitive to the height, length of the building, initial wind speed and the stratification condition, and the sensitivity to the building's thickness is small.
- The influence on temperature is greater than 0.1 degrees as the criterion, under the summer sunny day, the influence distance of building on the leeward air temperature is basically beyong the value of avoidance distance due to the regulation: 8-10 times the height of the building, so the avoidance distance should be increased appropriately in the real work.
- After replacing the buildings around the automatic weather station, it has obvious cooling effect on the surrounding atmosphere.

# Discussion

- The effect of a single building on the air temperature is analyzed on a typical sunny day in summer, lacking of study of buildings group. In the future work, the study of building on the surrounding air temperature under different types and layouts in the different seasons should be carried out.

# THANKS