Yale 耶鲁大学-南京信息工程大学大气环境中心

Yale-NUIST Center on Atmospheric Environment

A Simulation Analysis of the Effect of Building on Air Temperature Observation Environment

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Outline

- Backgroud
- Model & Cases
- Rusults & Discussions
- Conclusions
- Next work

Backgroud

- Reliable meteorological observation data is the basis of weather forecast, meteorological service and meteorological research work(Mahmood 2006).
- Observing surface air temperature has been important because air temperature is a meteorological variable that is related to life, agriculture and other industries. The surface air temperature is the most mentioned variable in discussions of global warming. Thus, the importance of air temperature observation is increasing more and more in recent years(Vincent 1999).
- Environmental conditions of a site, such as building, tree, water, road, may generate measurement errors exceeding the tolerances envisaged for instruments (Leroy 2010).

- With the accelerating urbanization, the buildings around the sites are increasing, minimizing errors arising from the surroundings of the sites is required. It is essential to know quantitatively the influence of observation environment on the measured temperature for scientific application of the observing surface air temperature data and meteorological sites selection.
- Academics have studied the effect of roads, water and trees on air temperature observation environment with experiment and numerical simulation method (Avissar 2000; Kumamoto 2013; YouYuan 2015; Qiu Yangyang 2013), but the quantitative research for the influence of building is few.
- 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 barrier height respectively.

Model

- The city sub-domain scale model (CSSM1.0) has been established by the Department of Atmospheric Sciences, Nanjing University in 2001, which is a three-dimensional non-hydrostatic model with k-ε closure.
- In this model the screening of short wave radiation by buildings and underlying surface type of urban are considered, the ground temperature is simulated using force-restored method.
- We use the 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).

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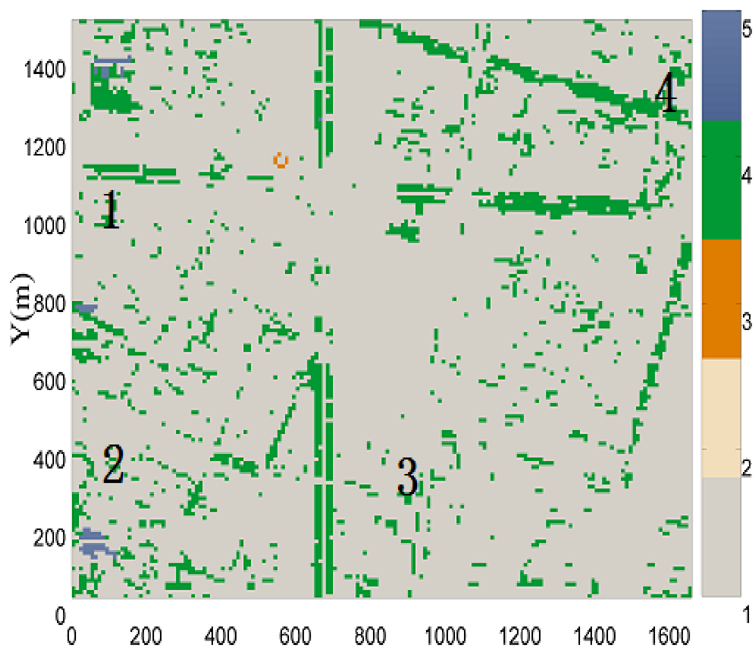

Fig.1 Land use of the NanJing CBD
(1:concrete, 2:water, 3:grass, 4:tree, 5:bare soil; number 1-4 are fixed observation sites)

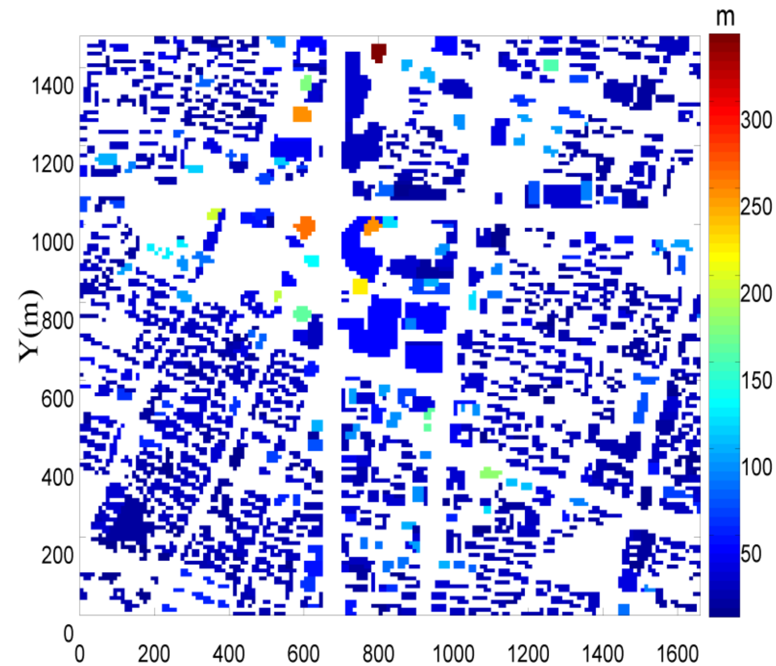

Fig.2 The building height of the NanJing CBD

Cases

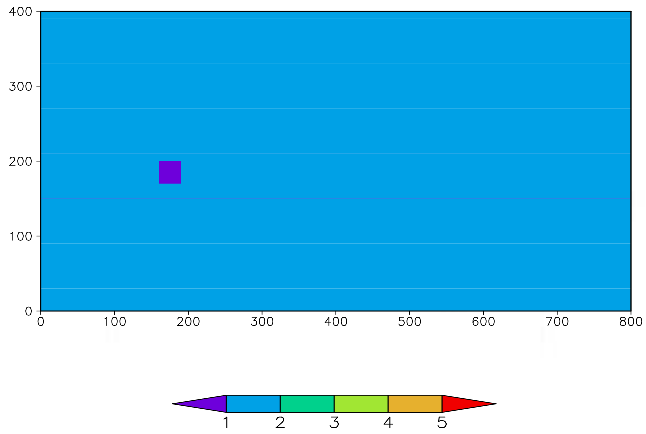

Fig.3 Land use of the simulated area
(1:concrete, 2: grass, 3:water, 4:tree, 5:bare soil)

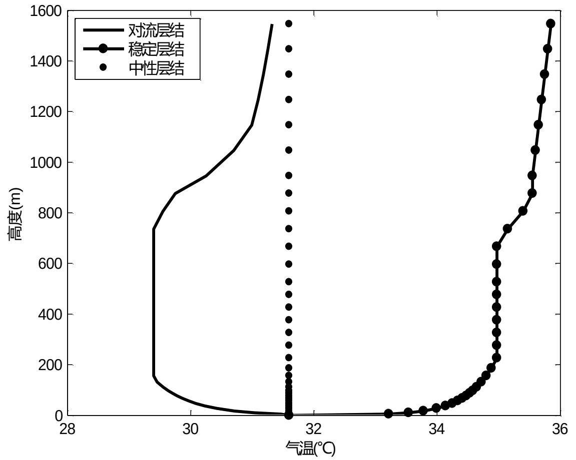

Fig.4 Initial air temperature profile under three stratifications

Table 1 Introduction of the cases

Case	stratification	initial wind	Building height
Validation case	WRF simulation result	WRF simulation result	building heights of an actual district
Group1	unstable stratification (14:00)	west direction U10=2,4,6,8,10m/s	H=6,12,18m
Group2	neutral stratification (20:00)	west direction U10=2,4,6,8,10m/s	H=6,12,18m
Group3	stable stratification (02:00)	west direction U10=2,4,6,8,10m/s	H=6,12,18m

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(a) Station 1

(b) Station 2

(c) Station 3

(d) Station 4

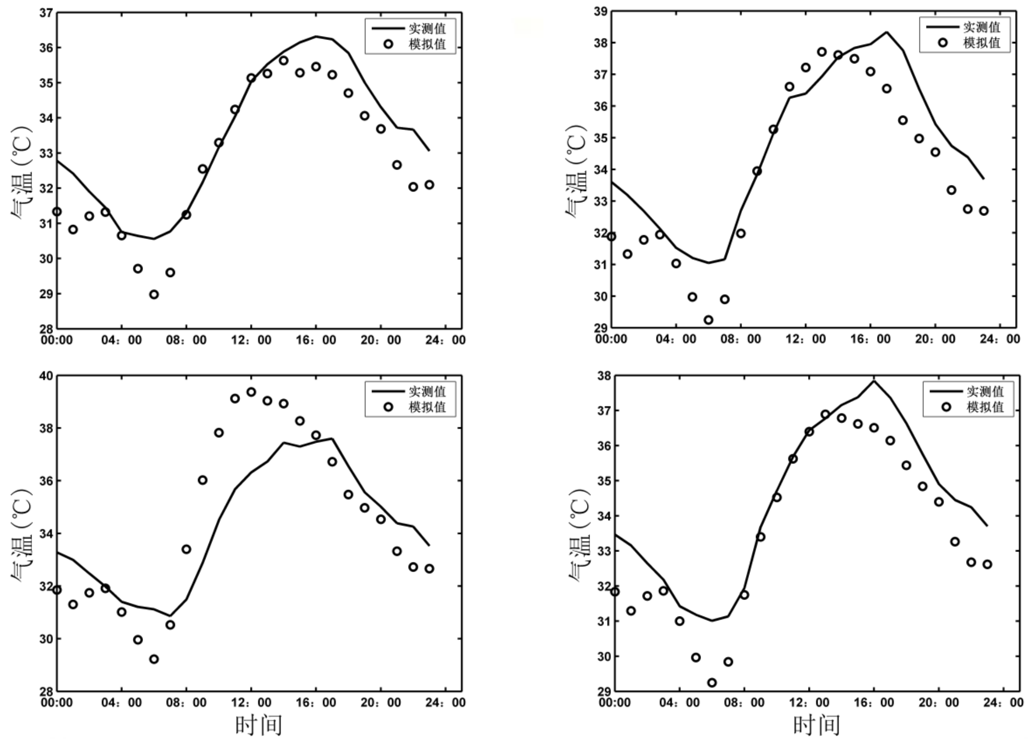

Fig.5 The comparison of simulated and observed air temperature at the height of 2m with the actual underlying surface of four stations

Table 2 Model performance statistics for the cases

station	1	2	3	4	Average
R^2	0.96	0.95	0.86	0.97	0.94
Rmsd（℃）	0.91	1.18	1.73	1.03	1.21

Rusults & Discussions

- 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

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

where $T_{building}$ and T_{ref} are the air temperature of the experiment with the building and that without the building, respectively.

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

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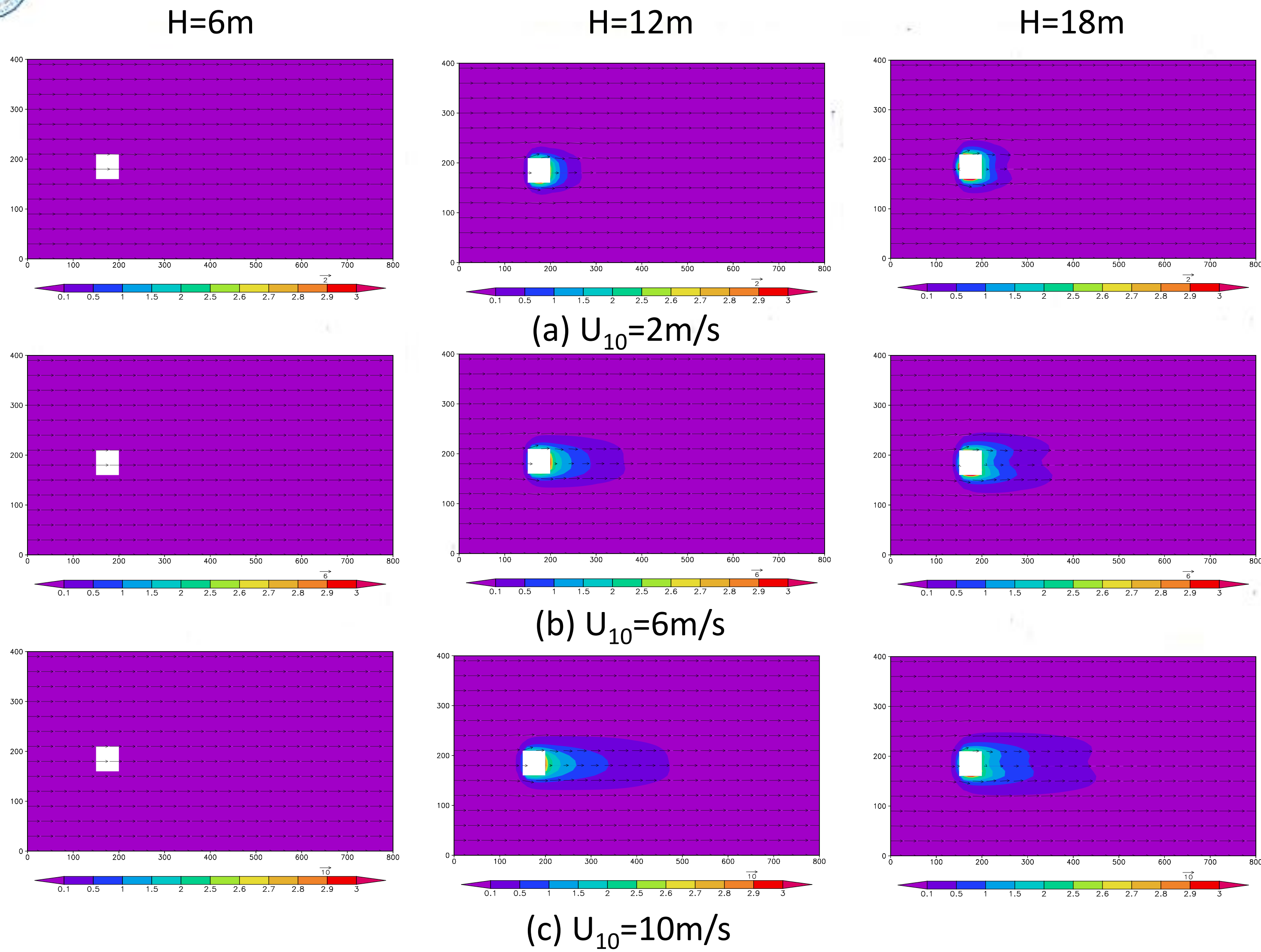
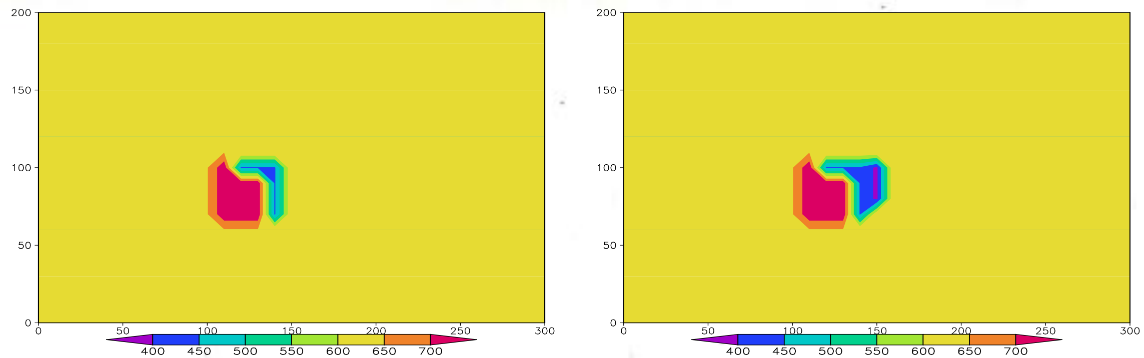


Fig.6 Effect of building on air temperature in case group1



(a) (b)

Fig.7 The surface shortwave radiation distribution of different height of building(W/m^2)
(a) H=12m (b) H=18m

Table 3 Effect of building on air temperature and wind speed in case group1

H(m) / U10(m/s)	6		12		18	
	△T & distance (℃) (m)	u (m/s)	△T & distance (℃) (m)	u (m/s)	△T & distance (℃) (m)	u (m/s)
2	0 0	-0.09	+2.5 70(5.8H)	-2	+2.4 60(3.3H)	-2
4	0 0	-0.05	+2.8 120(10H)	-4	+2.4 110(6.1H)	-4
6	0 0	+0.03	+2.9 160(13.3H)	-5.5	+2.4 150(8.3H)	-6
8	0 0	+0.12	+2.9 210(17.5H)	-7	+2.4 200(11.1H)	-7
10	0 0	+0.24	+2.9 270(22.5H)	-8	+2.4 250(13.9H)	-9

H=6m H=12m H=18m

(a) U_{10}=2m/s

(b) U_{10}=4m/s

(c) U_{10}=6m/s

(d) U_{10}=10m/s

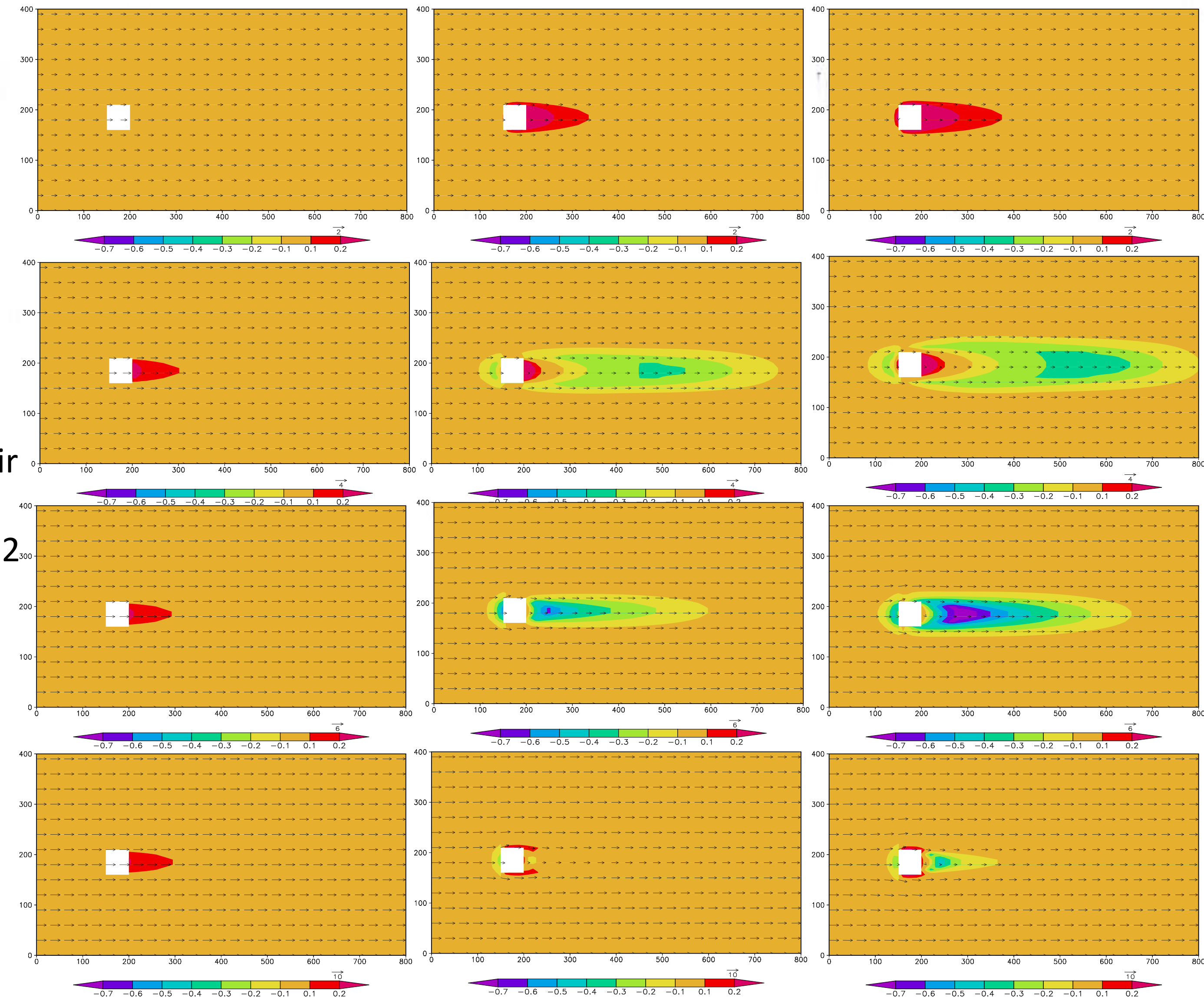


Fig.8
Effect of building on air temperature in case group2

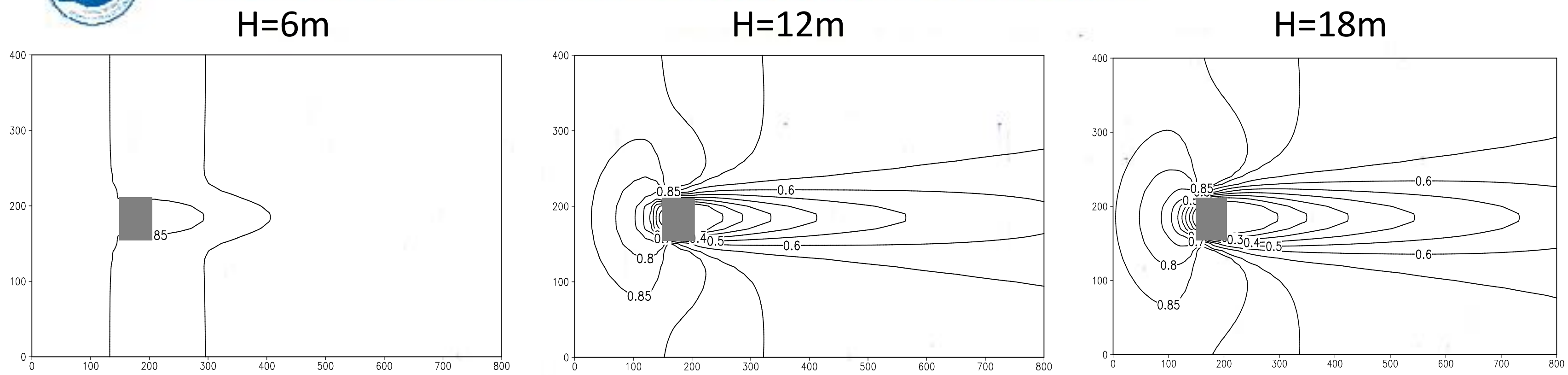


Fig.9 The distribution of turbulence kinetic energy when U_{10}=10m/s at 20:00

Table 4 Effect of building on air temperature and wind speed in case group2

H(m)	6		12		18	
U10(m/s)	△T & distance (℃) (m)	u (m/s)	△T & distance (℃) (m)	u (m/s)	△T & distance (℃) (m)	u (m/s)
2	0 0	+0.16	+0.2130(10.8H)	-0.7	+0.2 180(10H)	-0.9
4	+0.25 100(16.7H)	+0.4	+0.2 -0.4 550(45.8H)	-2	+0.2 -0.4 600(33.3H)	-2
6	+0.2 90(15H)	+0.35	-0.6 400(33.3H)	-4	-0.7 450(25H)	-4.5
8	+0.2 90(15H)	+0.4	-0.4 220(18.4H)	-6	-0.6 450(25H)	-6
10	+0.2 90(15H)	+0.4	-0.1 30(2.5H)	-7	-0.5 170(9.4H)	-8

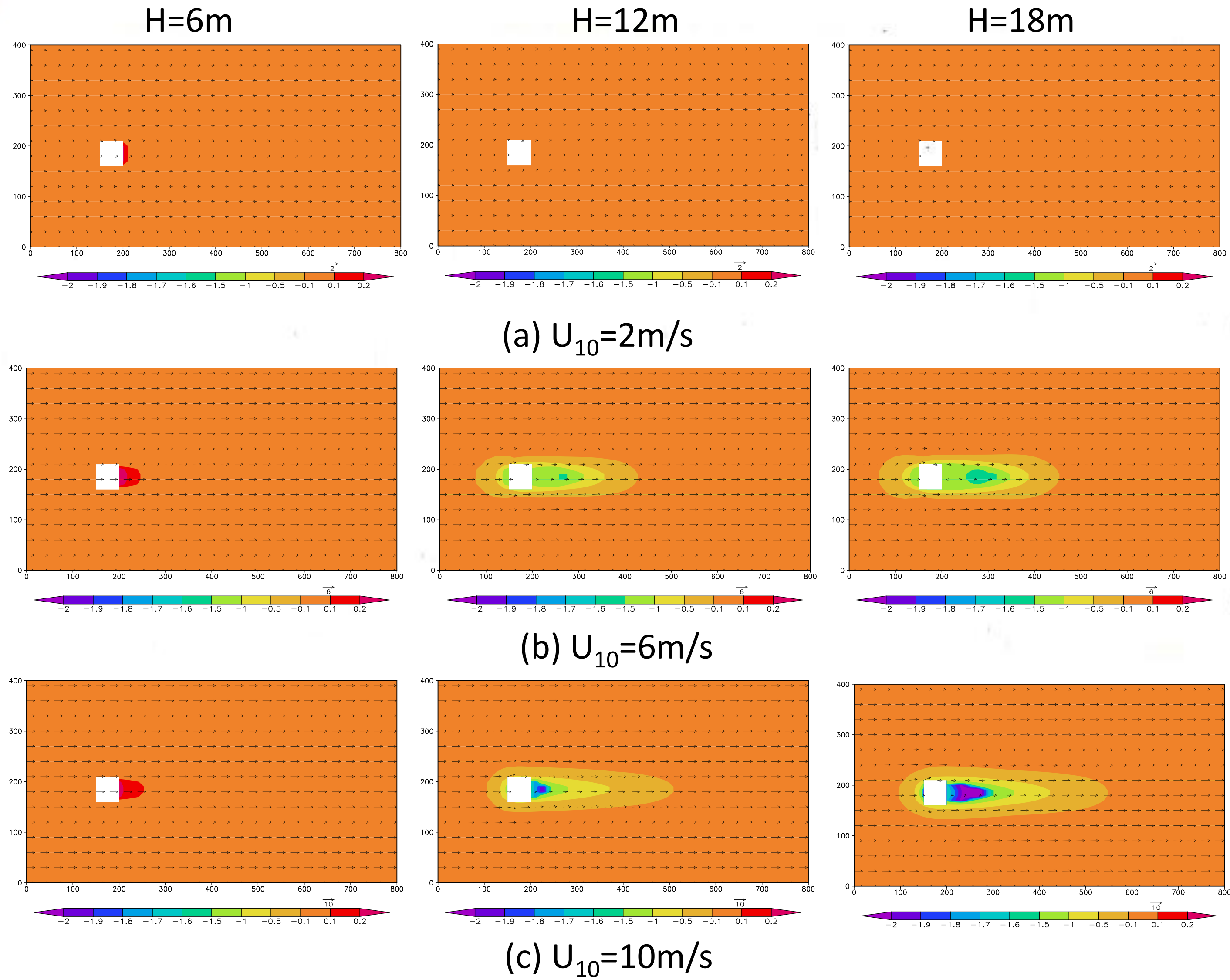


Fig.10 Effect of building on air temperature in case group3

Table 5 Effect of building on air temperature and wind speed in case group3

H(m) U10(m/s)	6		12		18	
	△T & distance（℃）（m）	u（m/s）	△T & distance（℃）（m）	u（m/s）	△T & distance（℃）（m）	u（m/s）
2	+0.2 10(1.7H)	+0.3	0 0	-0.3	0 0	-0.3
4	+0.2 30(5H)	+0.35	-0.1 110(9.2H)	-2	-0.1 130(7.2H)	-2
6	+0.2 40(6.7H)	+0.1	-1.5 230(19.2H)	-3.5	-1.5 250(13.9H)	-4
8	+0.2 40(6.7H)	-0.18	-1.8 270(22.5H)	-5.5	-2 300(16.7H)	-5.5
10	+0.2 50(8.3H)	-0.32	-1.9 300(25H)	-7	-2 350(19.4H)	-7

Conclusions

- Because of the building, the air temperature increased by 2.9 ℃ at 14:00 and reduced by 0.7 ℃,2 ℃ at 20:00 and 02:00,respectively.
- On the basis of 0.1 ℃, the building had obvious effect on a distance of 270m at 14:00,600m at 20:00 and 350m at 02:00 from the building leeward, these distances are 22.5 times,45.8 times and 25 times the height of the building, which beyond the value of regulation: 8-10 times.
- The wind speed attenuation caused by the building is the most important reason which influence the heat exchange between the ground and atmosphere. The stronger the wind speed attenuation, the great the heat exchange.

Next work

- The different initial directions of the wind and a whole day in four seasons should be taken into consideration when simulate and analyse the effect of building on air temperature observation environment in the next work.

Thank you