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Model analysis of human activities impacts on the local thermal environment under hot weather conditions

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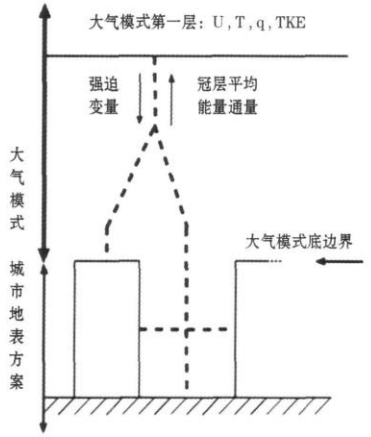
2016.5.13

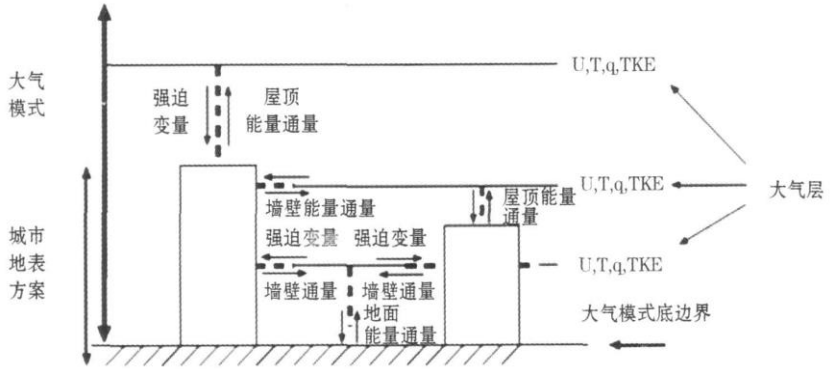
Background

- The World Health Organization reported that the urban population in 2014 accounted for 54 % of the total global population, up from 34 % in 1960 (Martine and Marshall 2007). Therefore, estimation of the impacts of human activities on the local and regional boundary layer and human comfort and health, especially in extreme weather conditions (such as heat wave events), is an important research topic.
- In metropolitan areas, anthropogenic heat (AH) emission is very important energy. AH emission result from sources including air conditioning, household electric appliance, and human metabolism, however, this part of the energy exchange is more complicated. Results show that AH increased the air temperature up to 2℃ during the night in some region of the city of Houston(Salamanca et al,2011). At present few studies in China urban area in this respect.
- Urbanization, an extreme example of land use land cover(LULC) change caused by human activities, is rapidly increasing globally. It increases surface roughness by forming urban canopy layers, decreases evapotranspiration by changing land cover from vegetated or natural surfaces to impervious surfaces, influences the surface energy balance by absorbing and reflecting solar radiation.
- Due to the limitations of observation, therefore, a nested high–resolution mesoscale numerical model, WRF model, coupled with urban canopy model, was employed in this work to discuss the influence of urbanization.

Model configuration

- WRFV3.4.1
- UCM: a single-layer urban model
- BEP: multilayer urban canopy model
- BEM: multilayer urban models with a building energy model including anthropogenic heat due to air conditioning





Model and date

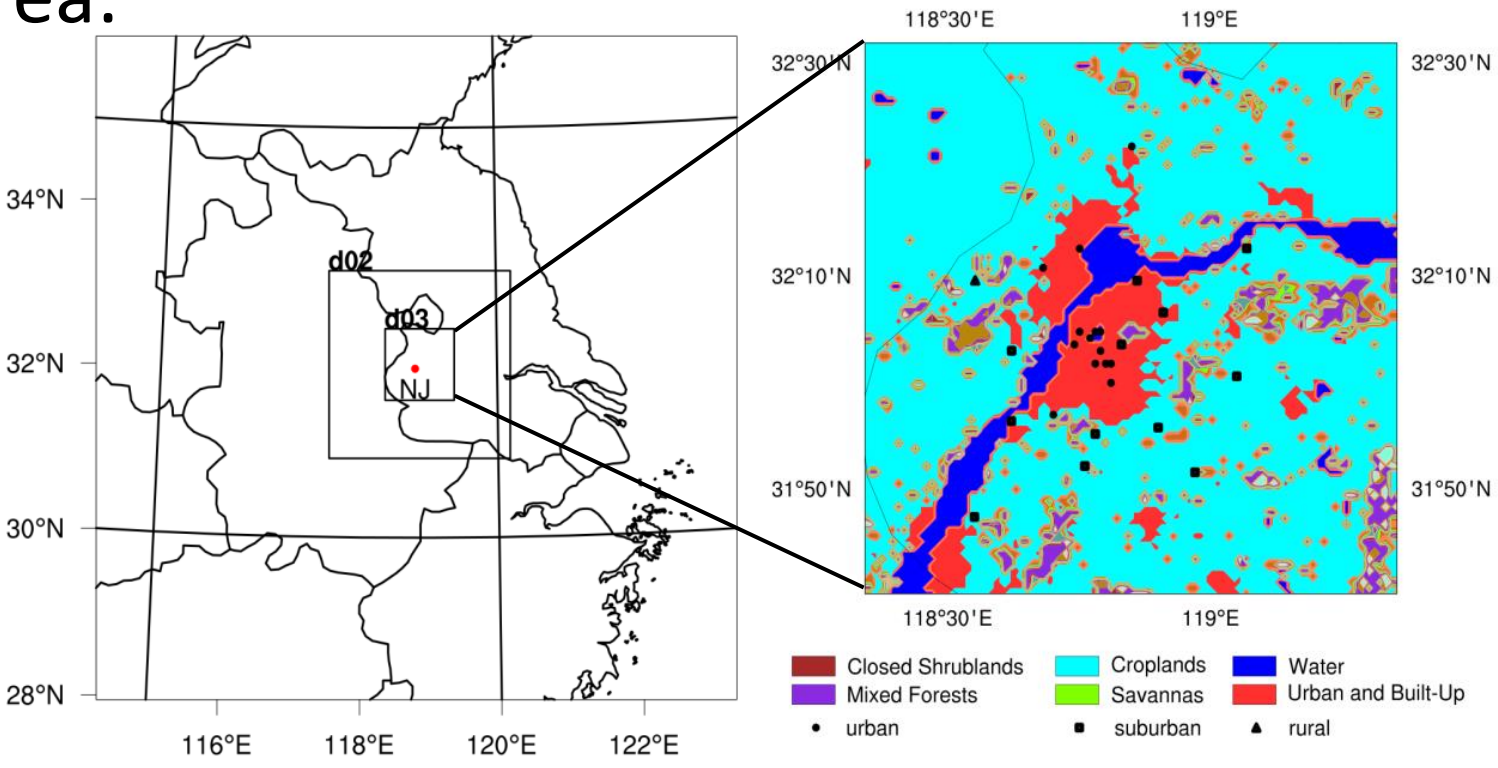
- Synoptic background:2010.8.1 08:00 - 8.3 08:00

  A strong heat-wave swept across Nanjing city

  Calm, cloudless, and hot weather

  South dominant wind direction

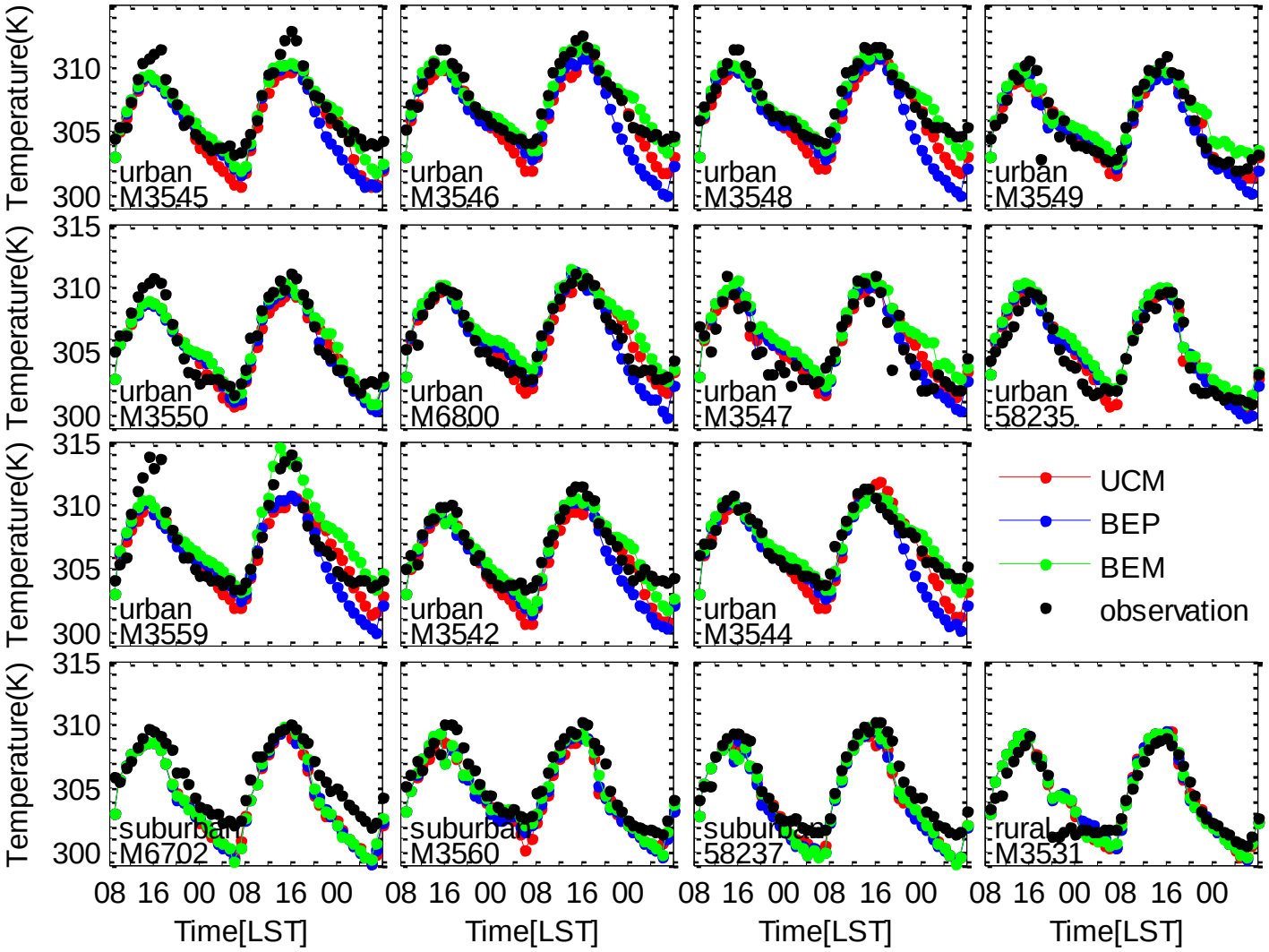
- Study area:



Case desigh

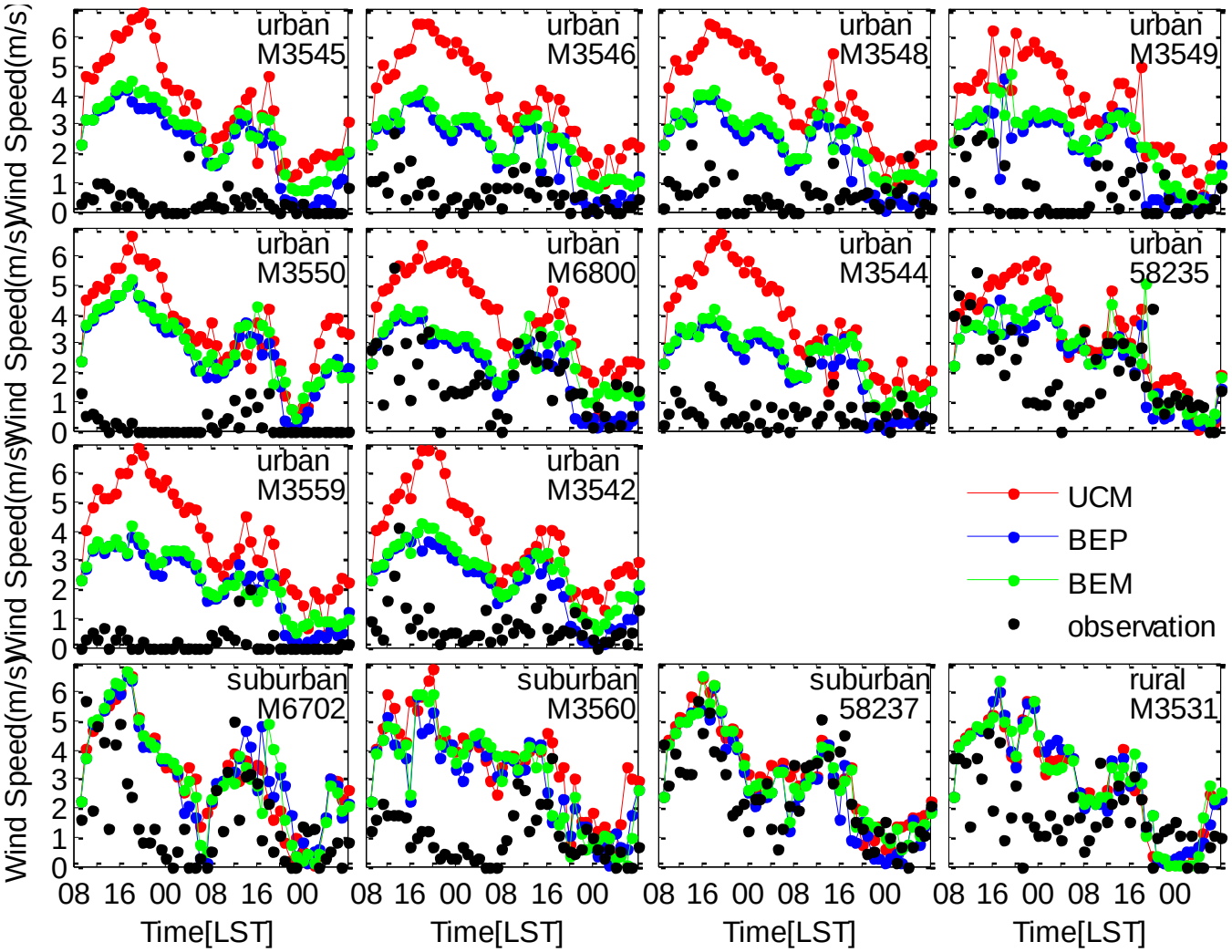
		Group 1			Group 3	
Case name		UCM	BEP	BEM	BEM (1993)	BEM (2010)
Urban canopy scheme		UCM	BEP	BEM	BEM	
Land use		2010			1993	2010
natural ventilation		-		Disable	Disable	
A/C	Functioning			Work	Work	
	Running time			24H	24H	
	Target temperature			298±0.5K	298±0.5K	
	Cooling coefficient			3.5	3.5	

Model Validation



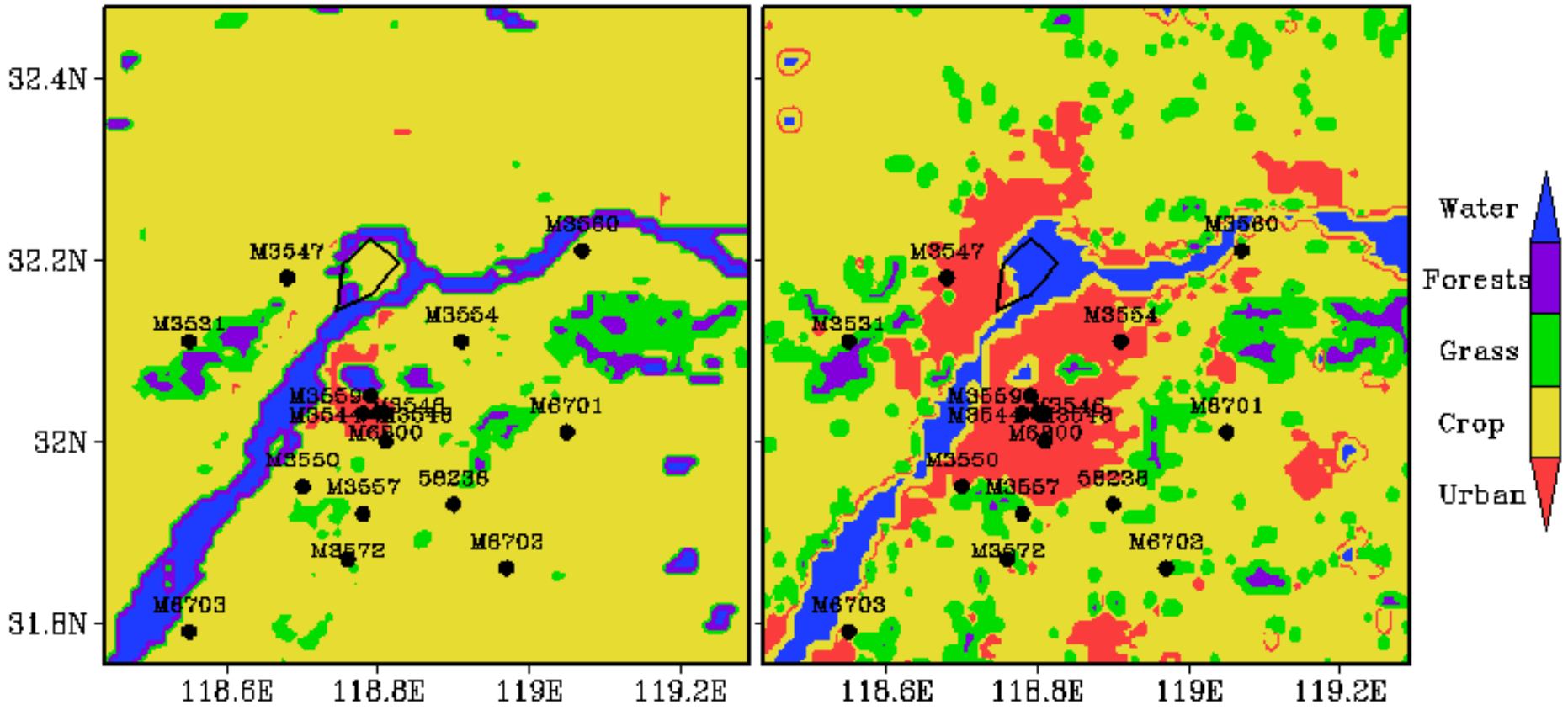
The Comparision between Simulations and Obserbations of 2m Temperature

Model Validation



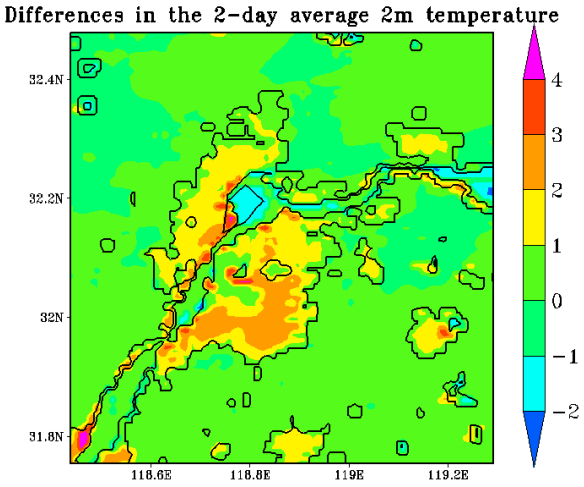
The Comparision between Simulations and Obserbations of 10m Wind Speed

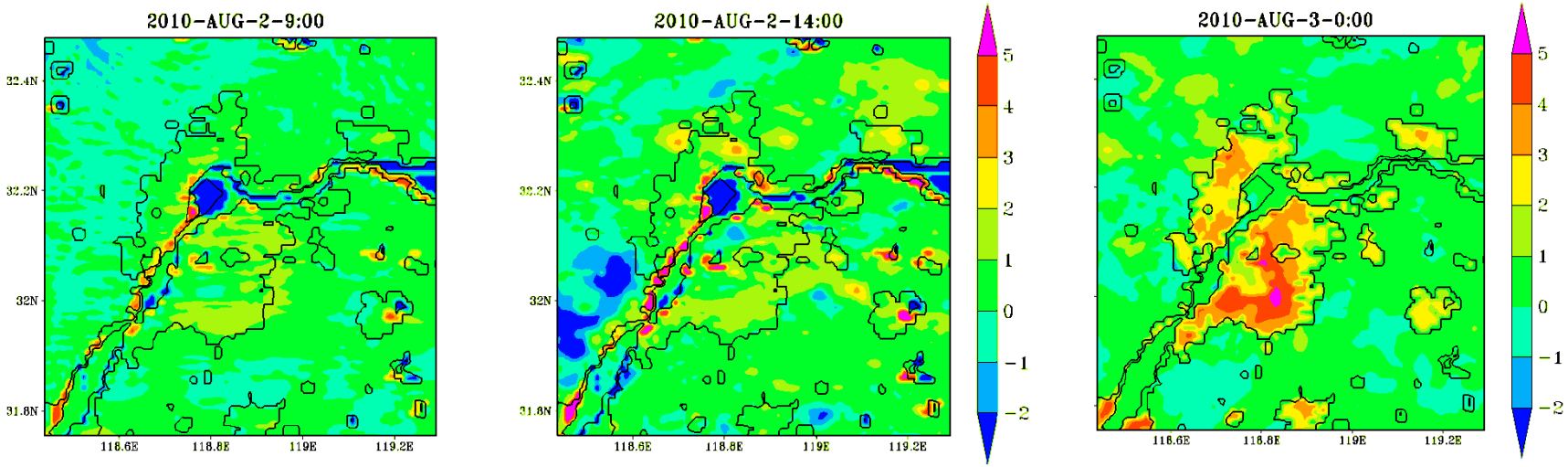
Effect of the Land-use Change on Urban Local Thermodynamic Circulation



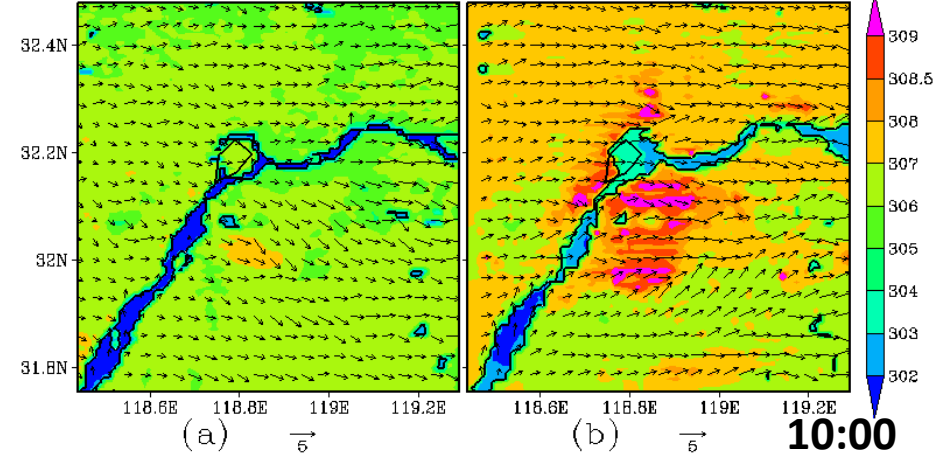
Landuse of The Third Layer Simulation Area

a. Landuse type of 1993 b. Landuse type of 2010

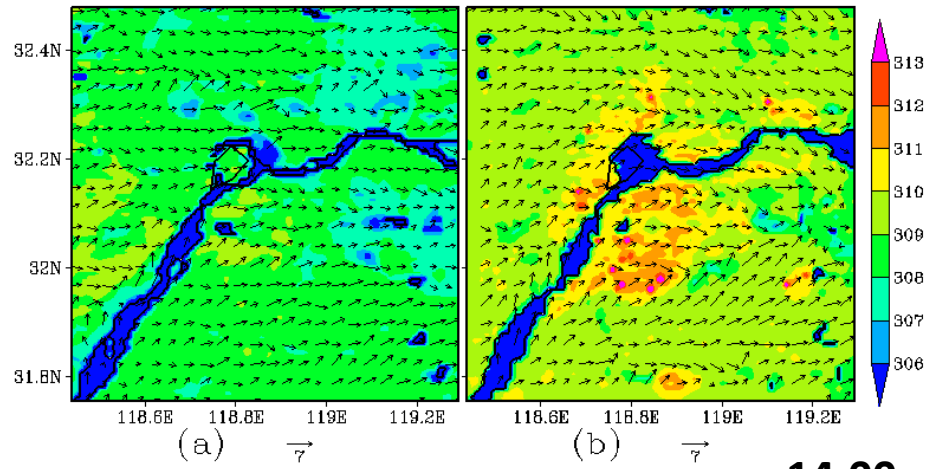




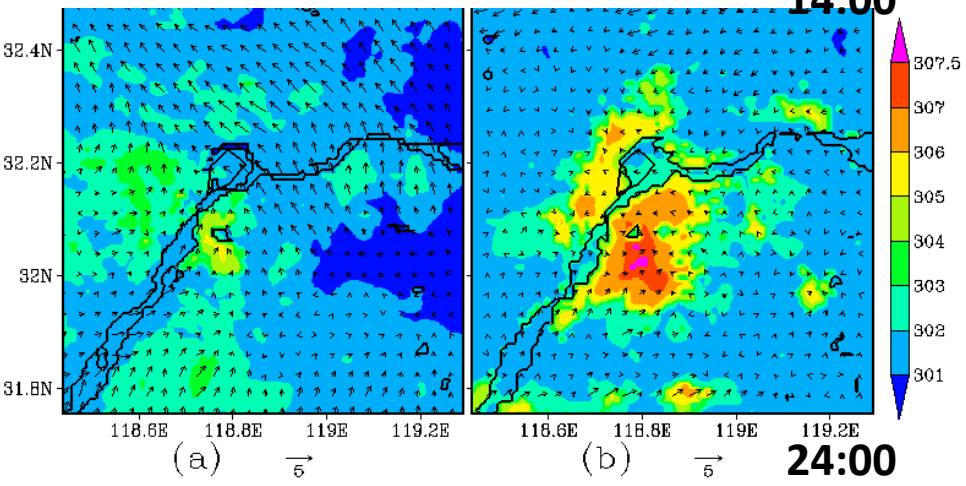
a)Differences in the 2-day average 2-m temperature between BEM(1993) and BEM(2010)
b)Differences of 2-m temperature between BEM(1993) and BEM(2010) at 9:00 on August 2
c)Differences of 2-m temperature between BEM(1993) and BEM(2010) at 14:00 on August 2
d)Differences of 2-m temperature between BEM(1993) and BEM(2010) at 00:00 on August 3



10:00



14:00

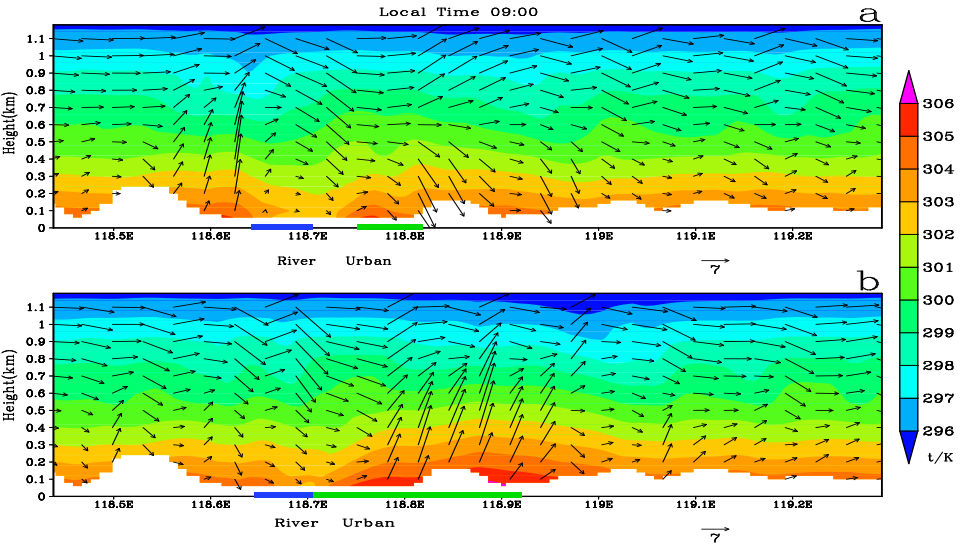


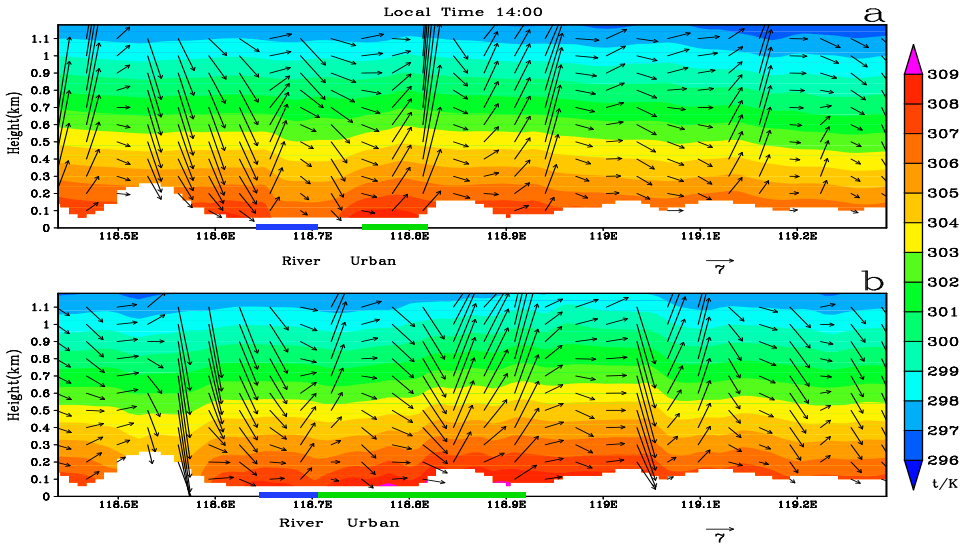
24:00

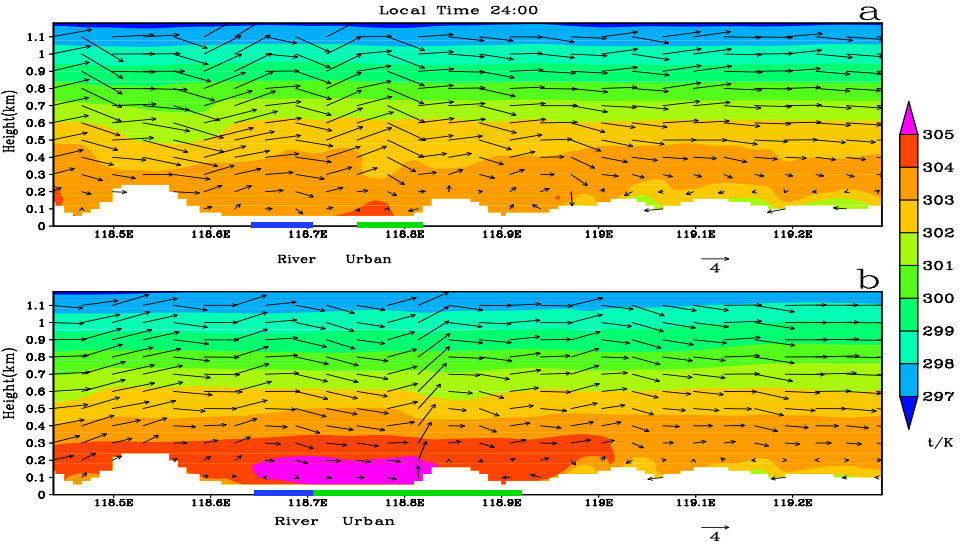
Horizontal Distribution of 2m Temperature and 10m Wind Vector on August 2

a. The Case of 1993

b. The Case of 2010



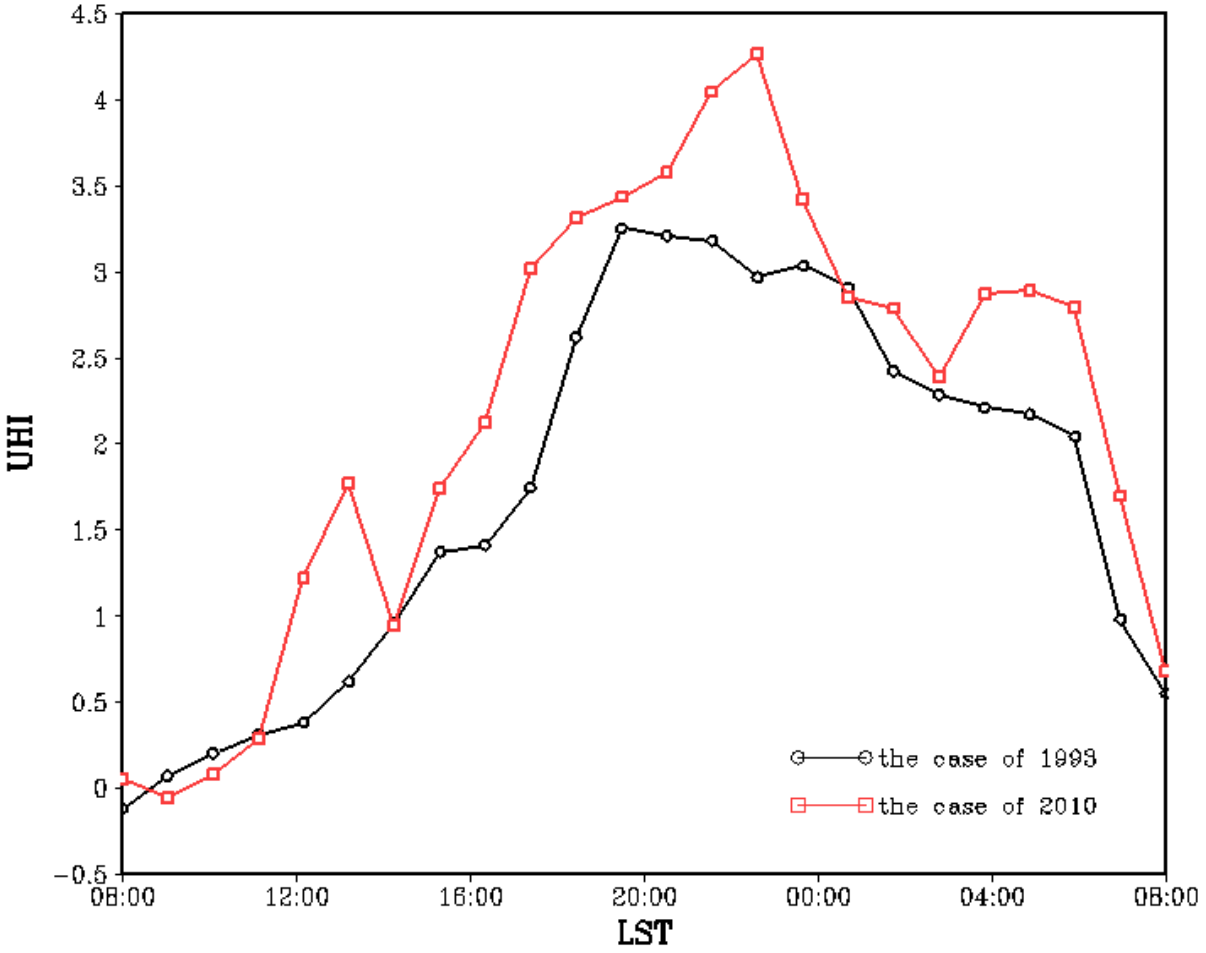




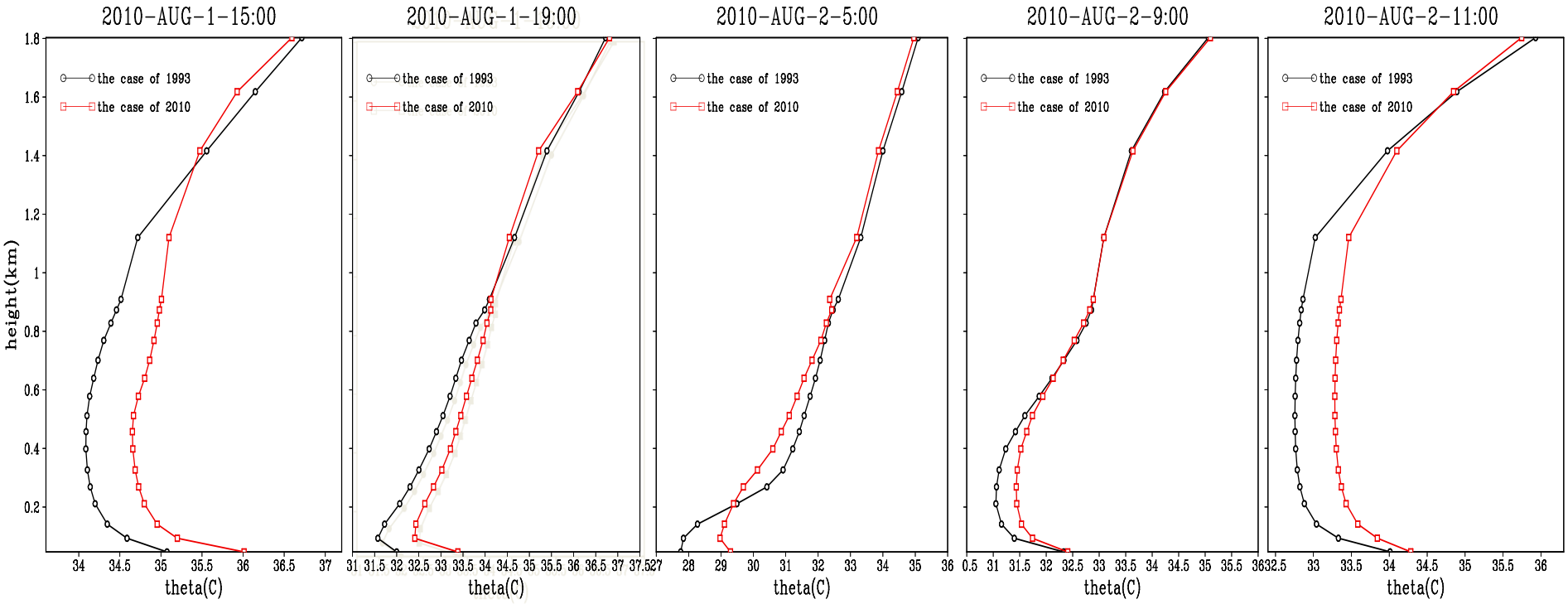
The Vertical Profile Distribution of Temperature and Wind Situated 32.05° N at 9am on August 2

a. The Case of 1993

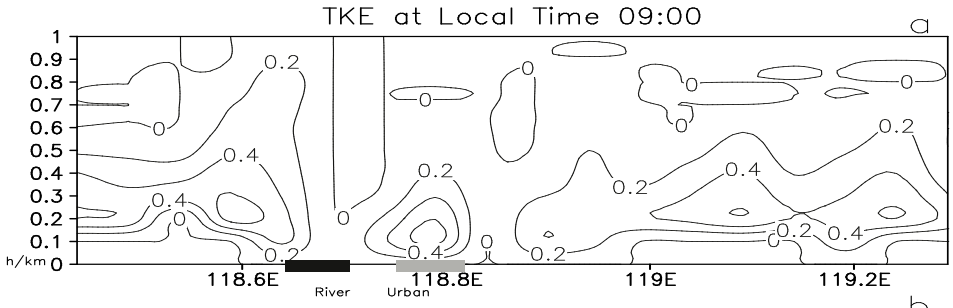
b. The Case of 2010

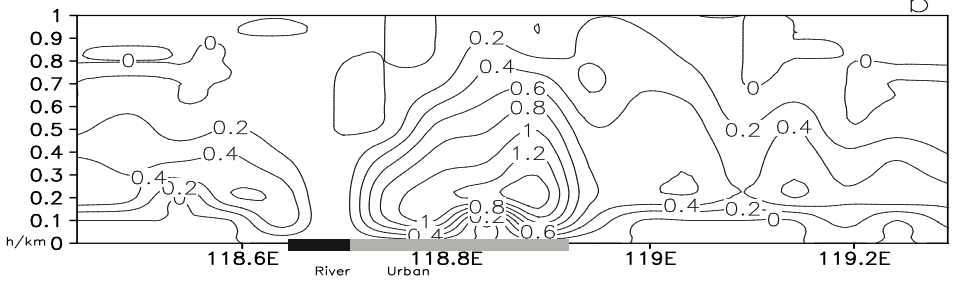


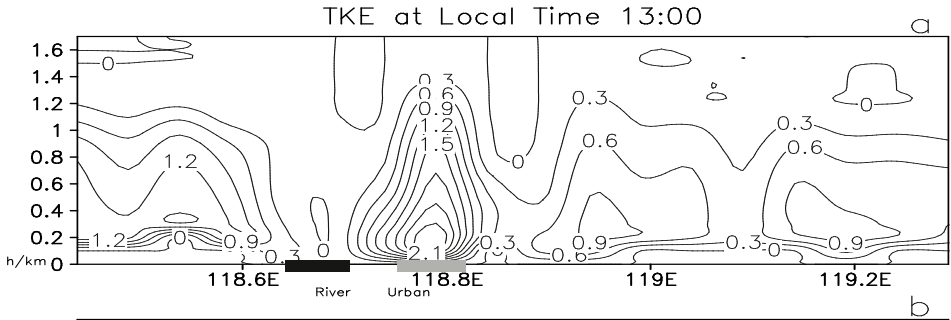
Diurnal variation of the 2-day average UHI intensity

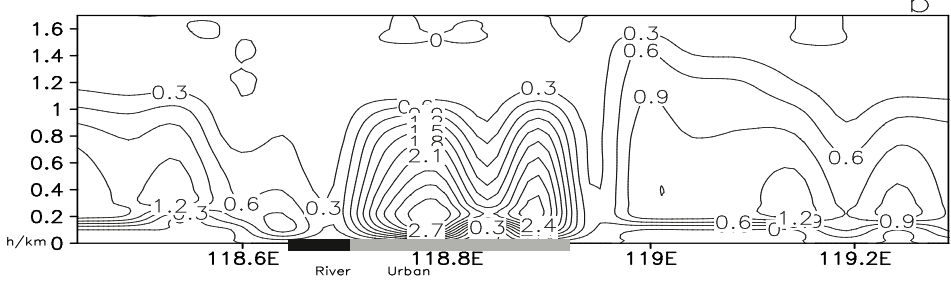


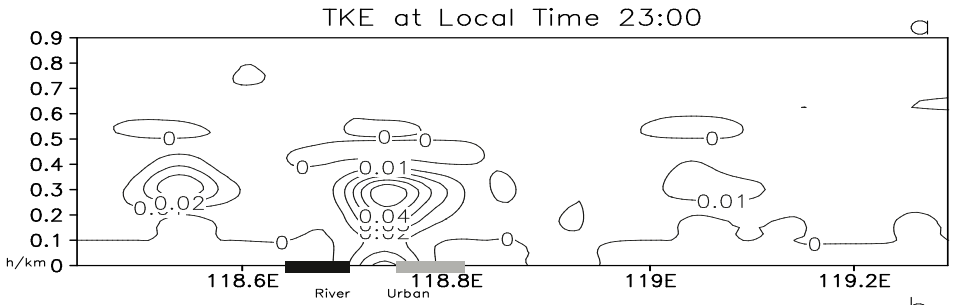
Potential temperature profiles averaged over urban areas at 1500 , 1900 on 2 August 2010 and 0500, 0900, 1100 on 3 August 2010

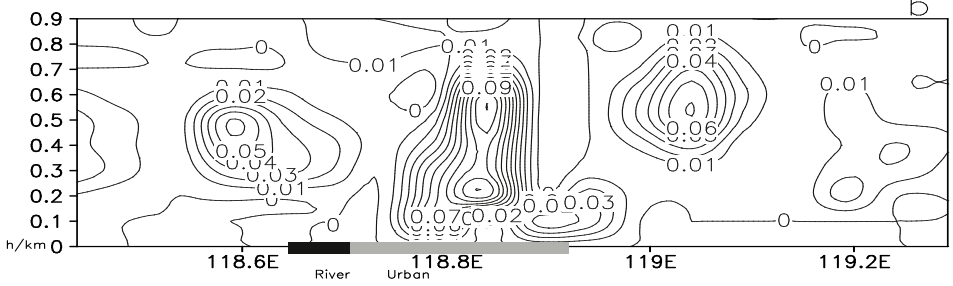












The Vertical Distribution of TKE Situated 32.05° N on August 2

a. The Case of 1993

b. The Case of 2010

Summary and conclusions

- The first three cases with different urban canopy scheme were designed to compare the simulation performance of WRF model coupled with urban canopy schemes. The RMSE between observation and simulation of UCM, BEP and BEM scheme were 1.37℃, 1.55℃, 1.27℃, respectively.
- The simulation results show that 2m temperature in urban region increases from 1993 to 2010, and the addition of temperature can reach 5K at 24:00. Urban heat island leads to the convergence of airflow in the lower layer of atmosphere, With more urbanized region, stronger turbulent kinetic energy(TKE), for example the maximum of TKE at noon increased from 2.1 $m^2 \cdot s^2$ to 2.7 $m^2 \cdot s^2$.

THANK YOU!