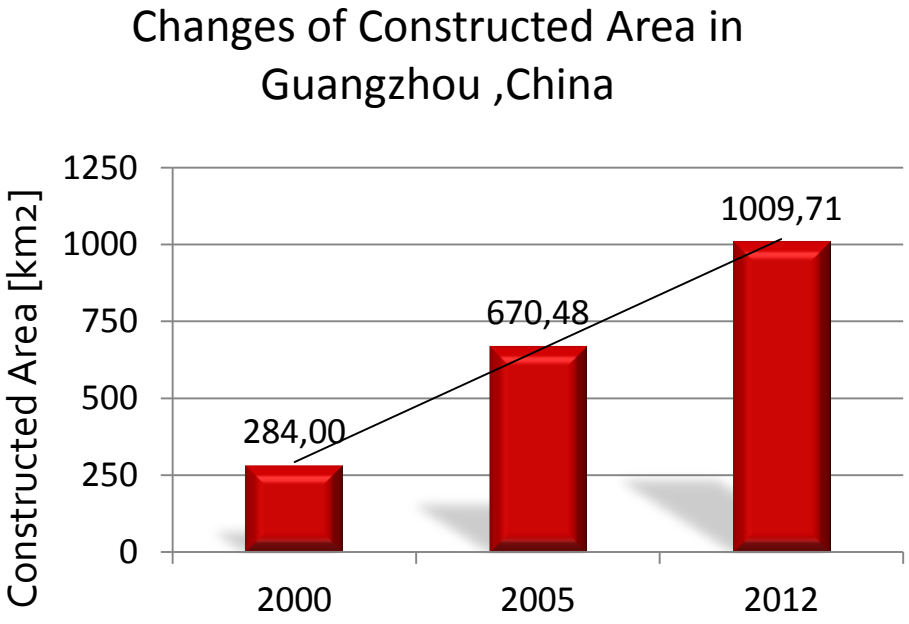
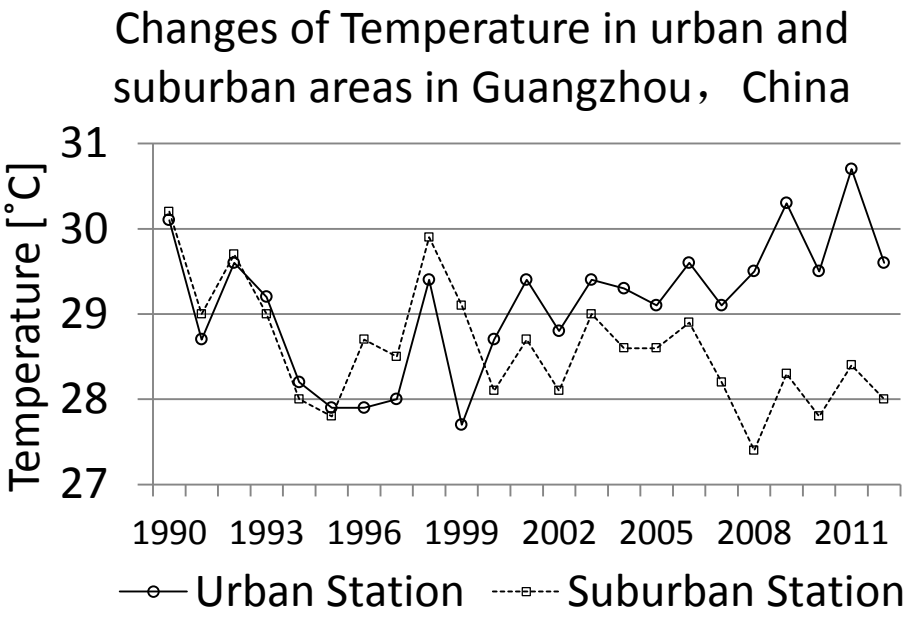
Simulation of the urban heat island under the background of urbanization around Guangzhou

Guang Chen
South China University of Technology, China & Tohoku University, Japan
Lihua Zhao
South China University of Technology, China
Akashi Mochida
Tohoku University, Jpan

Background

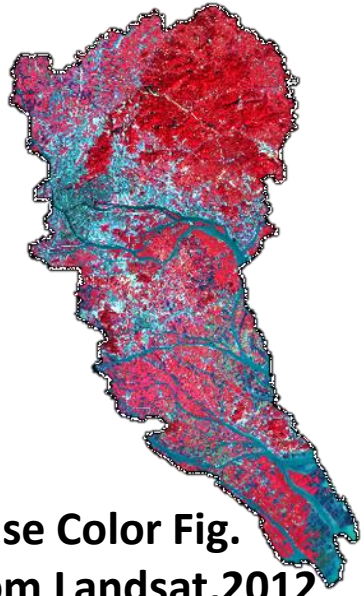




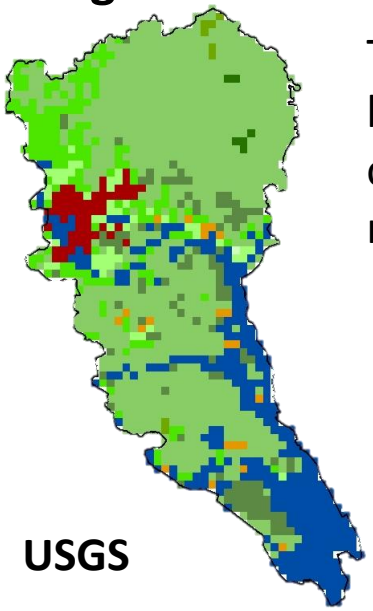
- China has been undergoing a period of fast urban expansion since the late 1970s, making the urban heat island *(UHI)* more serious.
- WRF coupled UCM model are widely used in urban environment simulation.

Background

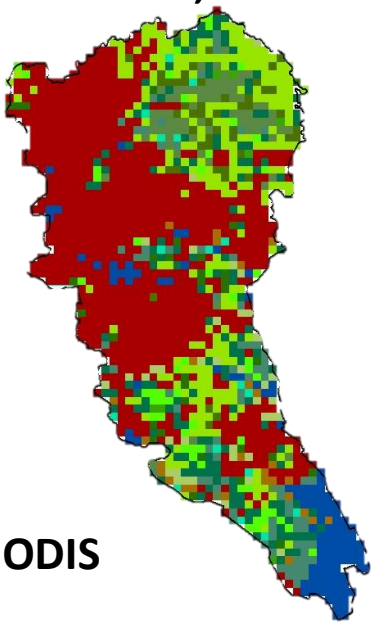
Land-Use Data extracting



False Color Fig. from Landsat,2012



USGS



MODIS

The geo data used in WRF is generally defaulted to be the USGS data, which can hardly fit the situation of the City in Year 2012. Modis is more likely to reflect the city area so large.

- How can we get land use data to satisfy the fast urbanization?

Color	Signature Name
	Urban and Built-Up
	Croplands
	Grassland
	Evergreen Needleleaf Forest
	Evergreen Broadleaf Forest
	Deciduous Broadleaf Forest
	Mixed Forests
	Open Shrublands
	Permanent wetlands
	Barren or Sparsely Vegetated
	Water

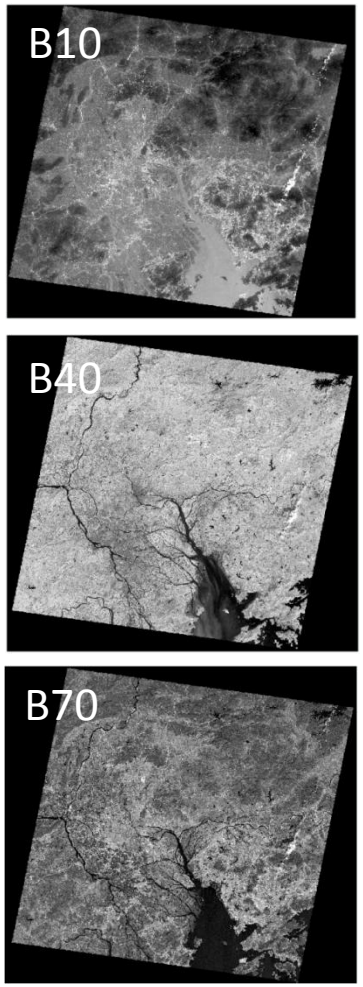
content

Data resource and Processing

Remote sensing Data Main Remote-sensing Data Source: Landsat7 (Resolution 30m)

In order to extract the land use data in year 2012 for further research and simulation, 6 of the 9 bands of Remote-sensing data from Landsat 7 are used.

Imaging Device	Band No.	Type	Wavelength (microns)	Main Effect
ETM+	B10	Blue-green band	0.45-0.52	For water penetration and resolution of soil vegetation
	B20	Green Band	0.52-0.60	To distinguish vegetation
	B30	Red Band	0.63-0.69	For observations of road / bare soil / vegetation types
	B40	NIR	0.76-0.90	Used to estimate bio-Quantity
	B50	Mid-infrared	1.55-1.75	Used to distinguish between road / bare soil / water
	B61,62	Thermal infrared	10.40-12.50	For the Induction of emit thermal radiation targets.
	B70	Mid-infrared	2.09-2.35	Used to distinguish rocks / minerals
	B80	Micron panchromatic	0.52-0.90	For enhanced resolution



Data resource and Processing

Land-use Data extracting

Study of the RS data & Select Training Sites Manually

↓

Spectral signature files

↓

Supervised classification

↓

Comparison and Correction of the Land-use Data

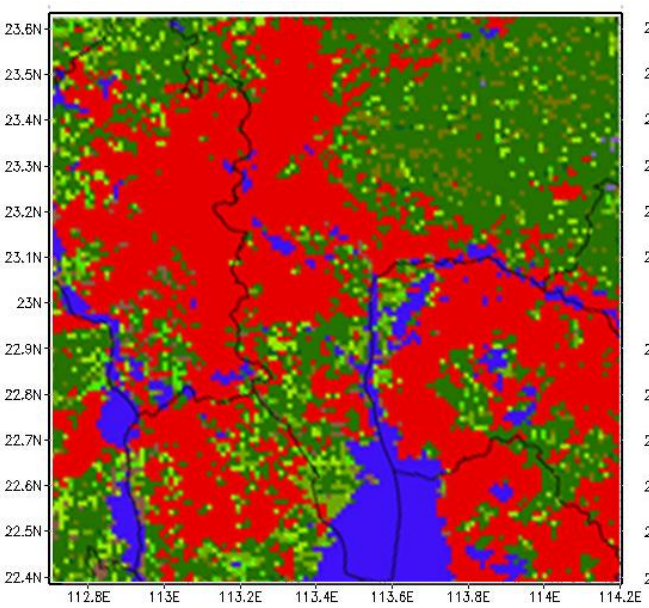
ID	Signature Name
1	Evergreen Needleleaf Forest
2	Evergreen Broadleaf Forest
4	Deciduous Broadleaf Forest
5	Mixed Forests
7	Open Shrublands
10	Grassland
11	Permanent wetlands
12	Croplands
13	Urban and Built-Up
16	Barren or Sparsely Vegetated
17	Water

IDRISI is developed by the Clark lab, which includes tools for segment-based classification, providing nearly 300 modules for the analysis and display of digital spatial information.

Pixel number for each kind of Land-Use should be no less than 10 times of the band Number. In this way, the pixel number of each type should be at least 60.

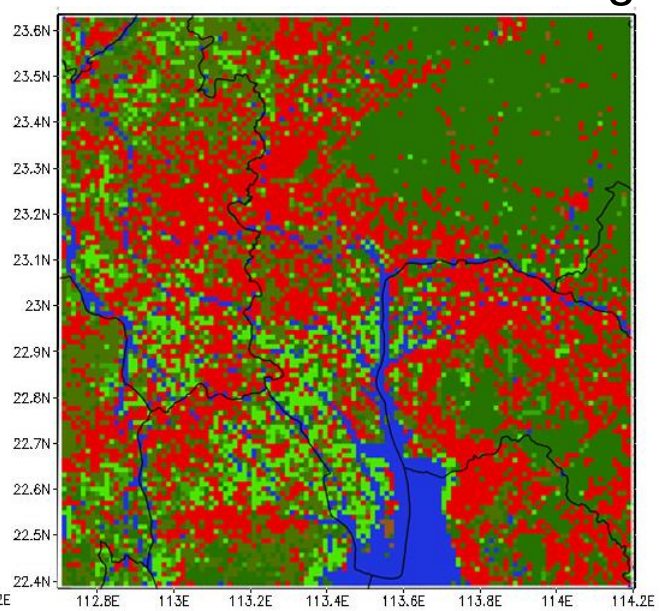
Data resource and Processing

Extracted urban land use data from Remote sensing



Modis

Defaulted WRF land-use after version 3.1



Lu2012

Extracted land-use data from 2012 RS datasets

Evergreen Needleleaf Forest | Evergreen Broadleaf Forest | Mixed Forests | Shrub land

Permanent wetlands | Croplands | Urban and built-up | Barren/ Sparsely vegetated | Water

- It is very obvious that there is a difference between the defaulted land-use data and the extracted land-use.

Update of land use data

In addition, both USGS 24-category ,MODIS 20-category land use data and Extracted land-use data from 2012 RS datasets consider only one urban land category and thus cannot reproduce urban effects on local climate caused by the inhomogeneity in an urban area.

WRF+UCM, It is preferable to use urban land-use maps of the region of interest with the following three urban categories:

WRF

Urban

WRF+UCM

31: ***Low Intensity residential(LIS):***
32: ***High Intensity residential(HIR)***
33: ***Commercial/Industrial/Transportation(CIT)***

How classify urban land into three subcategories?

Update of land use data

HSI(Human settlement Index)（(Lu et al., 2008）was used for deriving up-to-date urban land use data and specifying detailed urban land use categories in the UCM .
HSI data were obtained from a combination of nighttime light imagery{Defense Meteorological Satellite Program（DMSP）Operational Line scan System（OLS）} and the normalized difference vegetation index (NDVI), as expressed by Eq. (1).

$$HSI = \frac{(1-NDVImax)+\mathrm{OLSnor}}{(1-\mathrm{OLSnor})+\mathrm{NDVImax}+\mathrm{OLSnor}\times\mathrm{NDVImax}} \quad (1)$$

$$OLS_{nor} = \frac{OLS-OLSmin}{OLS_{max}-OLSmin} \quad (2)$$

$$NDVImax = MAX(\mathrm{NDVI}_1, \mathrm{NDVI}_2, \ldots, \mathrm{NDVI}_{23}) \quad (3)$$

HSI values were used to classify urban land in Guangzhou into the following subcategories:

(1) pixels with HSI values ≥ 80th percentile represented CIT areas;

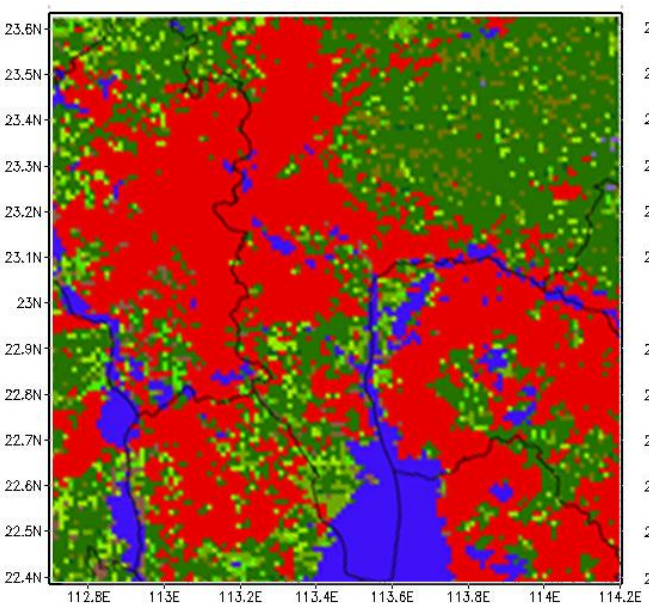
(2) pixels with HSI values between the 30th and the 80th percentile represented HIR areas;

(3) pixels with HSI values ≤ 30th represented LIR areas

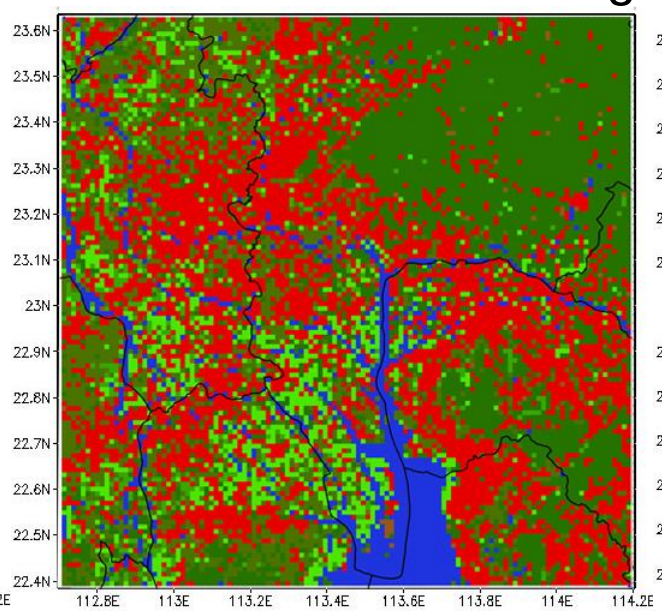
Lu D, Tian H, Zhou G, et al. (2008) Regional mapping of human settlements in southeastern China with multisensor remotely sensed data. *Remote Sensing of Environment* 112(9): 3668-3679.

Update of land use data

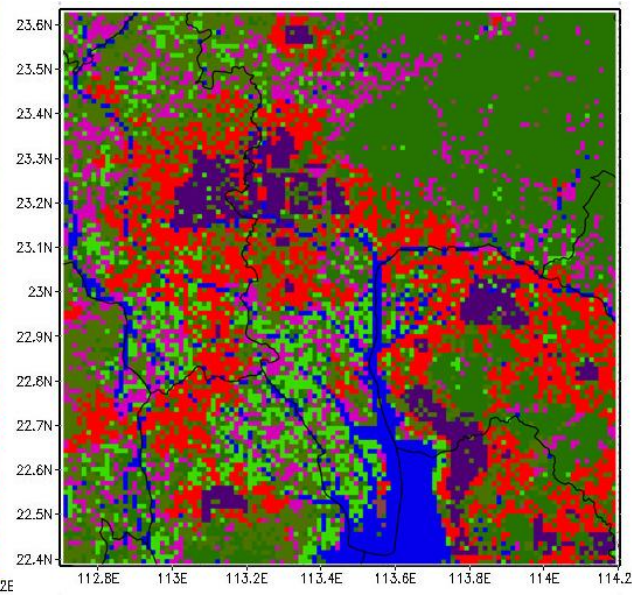
Extracted urban land use data from Remote sensing



Modis
Defaulted WRF land-use after version 3.1



RS2012
Extracted land-use data from 2012 RS datasets



UCM2012
Classify urban land to three urban categories

Evergreen Needleleaf Forest
Evergreen Broadleaf Forest
Mixed Forests
Shrub land
Permanent wetlands
Croplands
Urban and built-up
Barren/ Sparsely vegetated
Water
Commercial(CIT)
Hi-den Res(HIR)
Low-den Res(LIR)

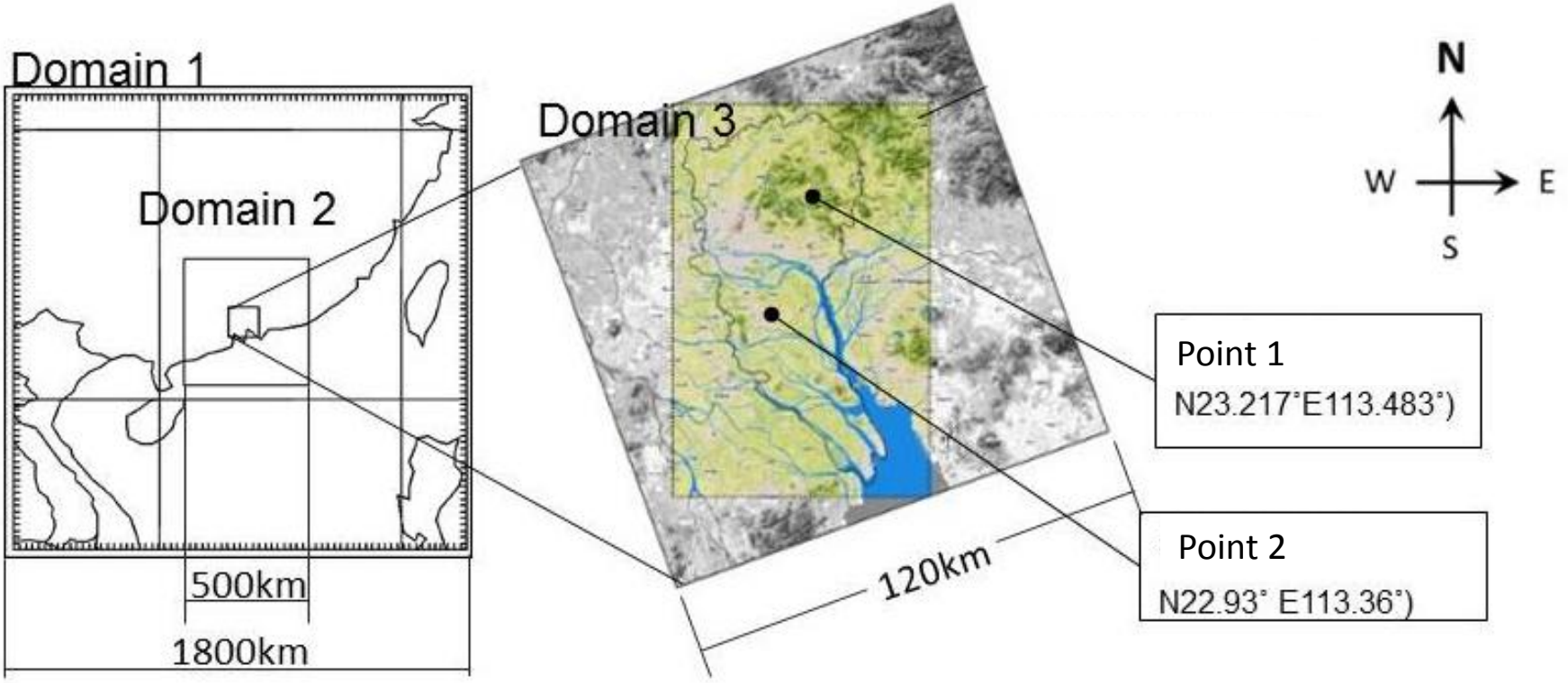
- The urban land-use was classified into three subcategories

Number experiments design

Experiments	Urban canopy	Land use categories	Anthropogenic heat release (w/㎡)
Modis	No	20(Modis)	No
Lu2012	No	20(Modis) **(RS2012)**	No
Lu2012-A	yes	33(Modis+CIT+HIR+LIR) **(UCM2012)**	Yes (90 50 20)
Lu2012-B	yes	33(Modis+CIT+HIR+LIR) **(UCM2012)**	No

- **Modis:** an experiment run with used MODIS land use data default in WRF.
- **Lu2012:** an experiment based on updated urban land use data in 2012 without three additional subcategories and without corresponding anthropogenic heat release;
- **Lu2012-A:** an experiment based on the updated urban land use data in 2012 with three subcategories and corresponding anthropogenic heat release;
- **Lu2012-B:** an experiment on the updated urban land use data in 2012 with three subcategories, but without anthropogenic heat release.

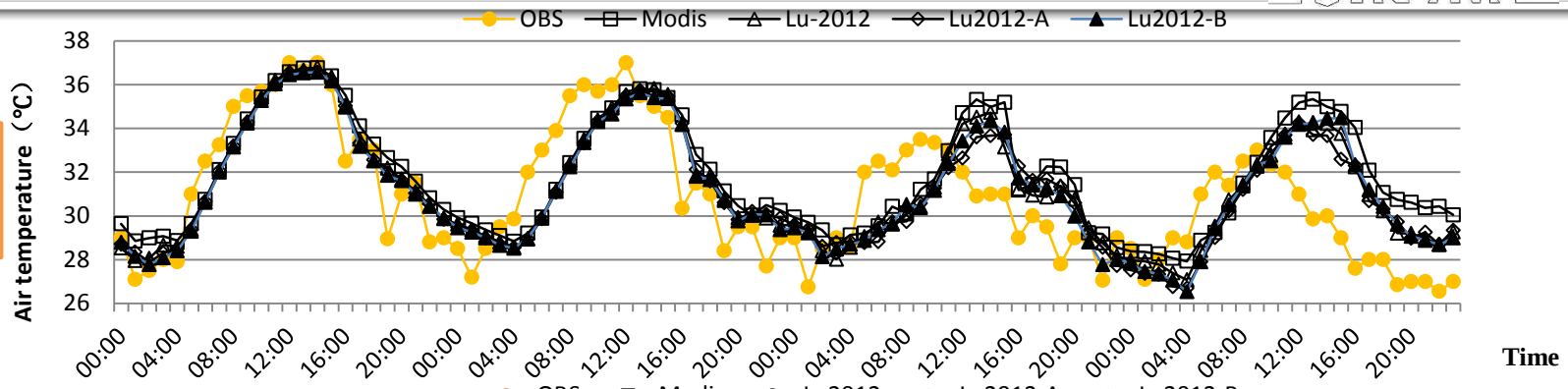
Number experiments design----Domain



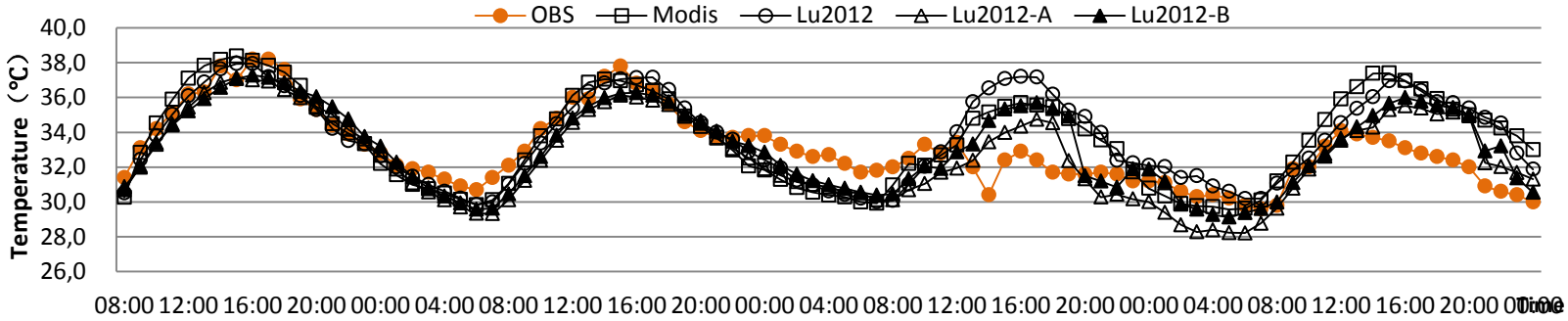
- This study is operated in Guangzhou city, the capital of Guangdong province which is located in south China.
- 2 comparison points were selected in suburban and urban area separately for validation.
- **Time:** 2012/8/01 0:00----8/04 24:00 total 96hours

Result-validation-temperature

Point1 suburban



Point2 urban



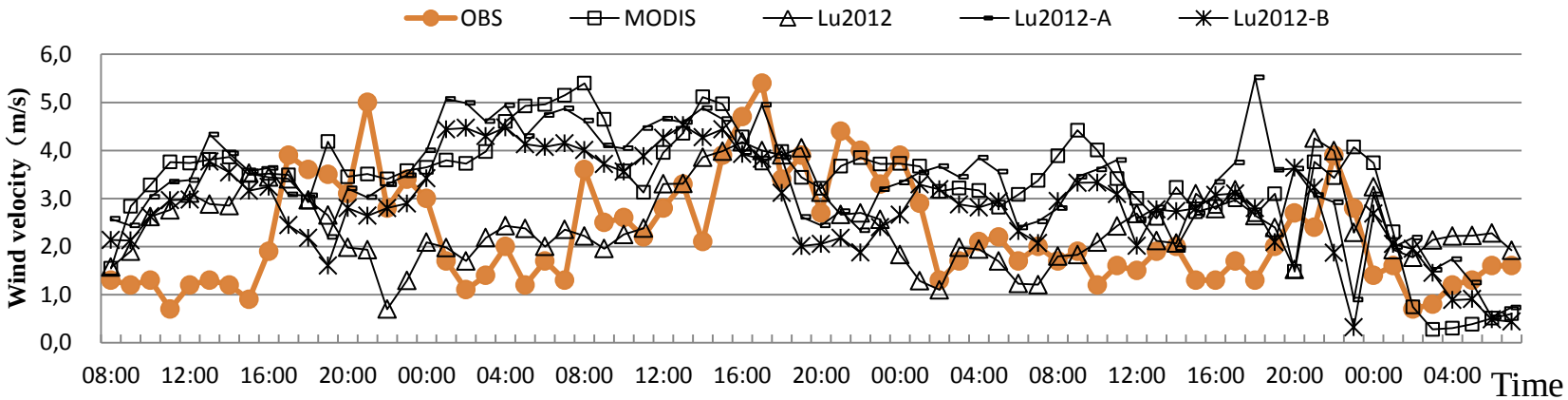
- All of the experimental schemes have better reproduction of the diurnal variation of temperature, though with varying magnitudes.
- **Lu2012-A** experiment is the best in reproducing the variation of urban temperature

experiments	Modis	Lu2012	Lu2012-A	Lu2012-B
RMSE	2.41	2.00	1.46	1.58

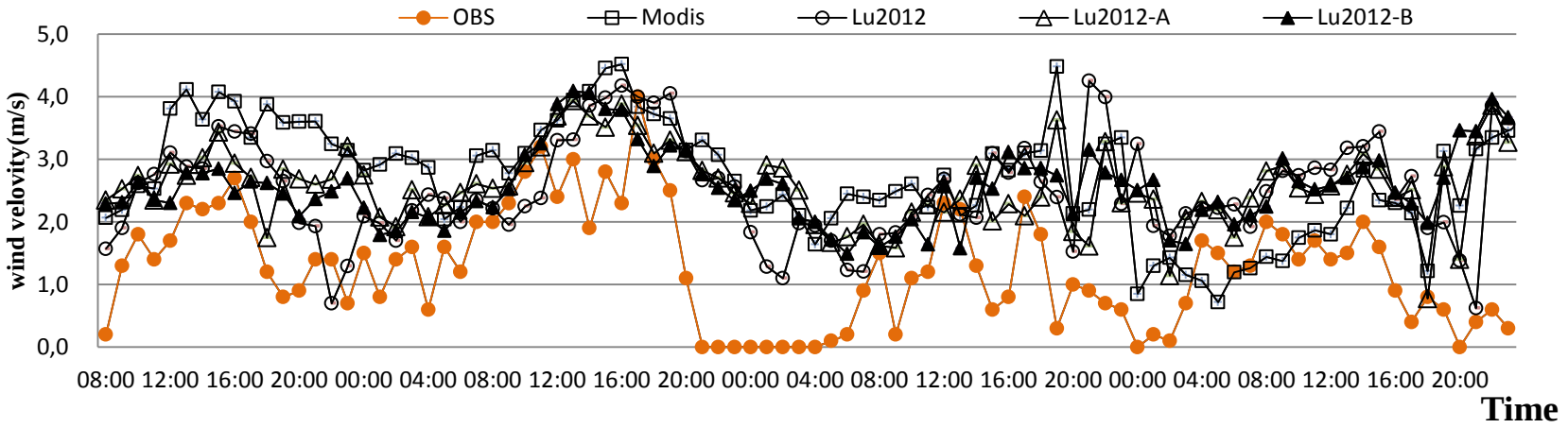
- WRF simulation enjoys a bad performance on rainy and cloudy day, such as August 3rd and 4th, but a better performance on sunny and hot day.

Result-validation-wind velocity

Point1

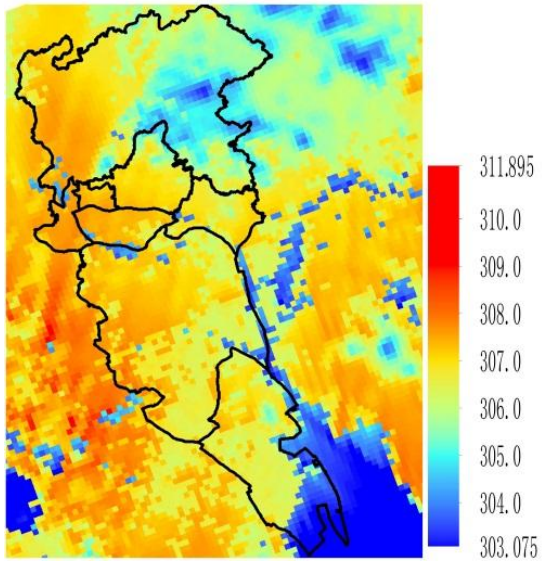


Point2

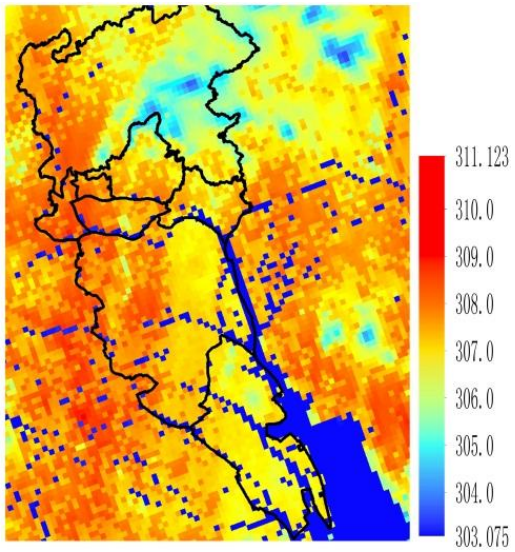


- WRF simulation results cannot accurately reflect the observation, especially in urban area.
- Although couple with UCM model，still can not reflect the reality of the building influence on the wind environment

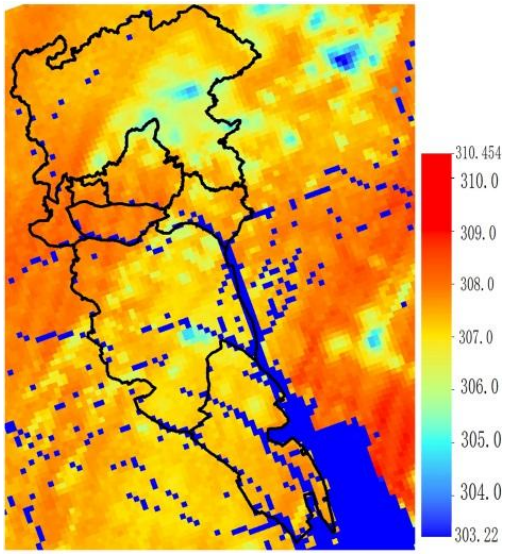
Result-validation-temperature distribution



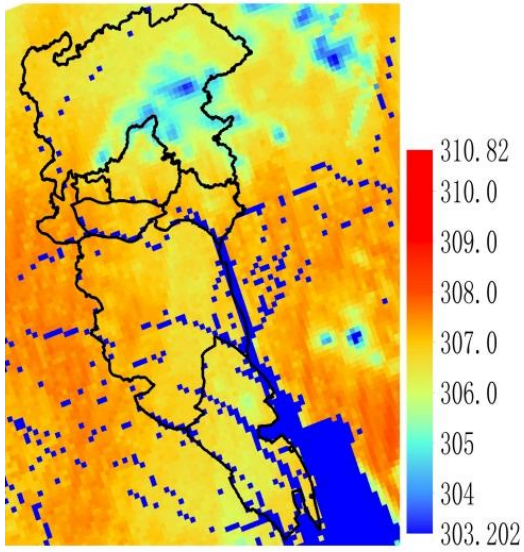
Modis



Lu2012



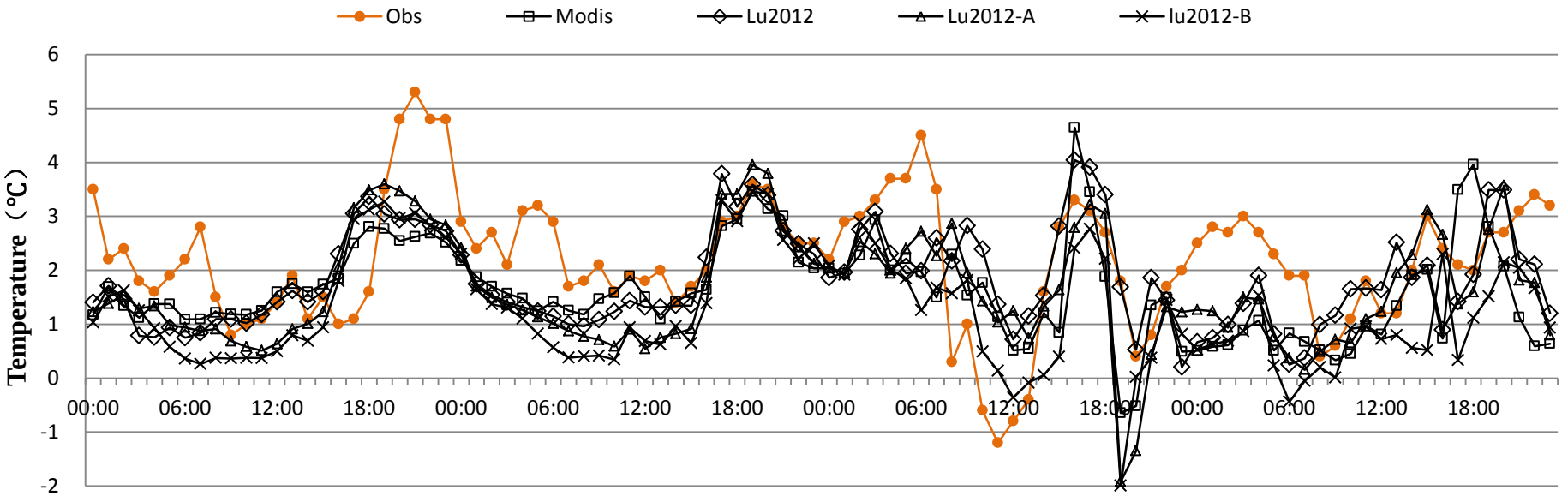
Lu2012-A



Lu2012-B

- Four experiments simulation result of Aug 1st 14:00 2m temperature distribution were showed .
- Urban heat island effect of Guangzhou is mainly distributed its west and southwest in Foshan with the core shaped like a stripe orienting northeast-southwest.
- All experiments reproduces the character of 2m temperature distribution.

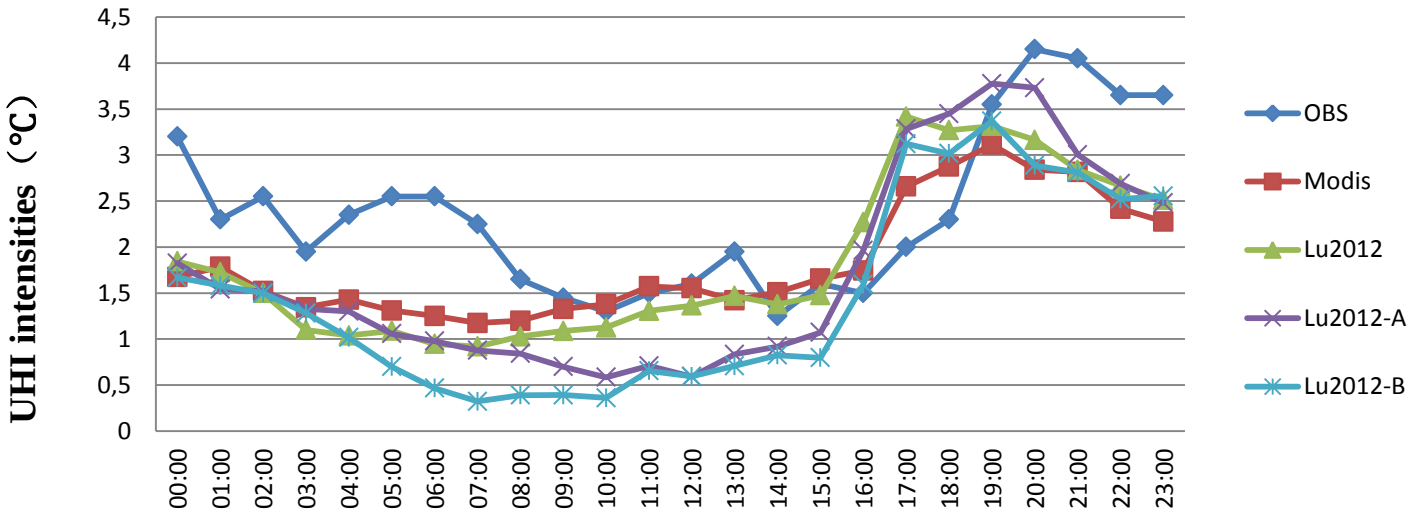
Result-UHI intensities



The intensity of the heat island is calculated by the difference in temperature at the 2-m height between comparison poin1(suburban area) and comparison poin2(in urban area).

- Urban heat island intensity gradually increasing after midday and become strongest at night, while it gradually decreases in the morning and even gets negative at noon.
- All the cases reproduce these characteristics of the UHI evolution except failure to depict the negative UHI on Aug.3rd and most time the modeled underestimate UHI intensity.
- All experiments underestimate the maximum UHI intensity. Although Lu2012-A enjoys the maximum UHI intensity in four experiments, but lower than observation.
- The experiments with UCM model reveal a better performance at night but disappointed at daytime.

Result-UHI intensities

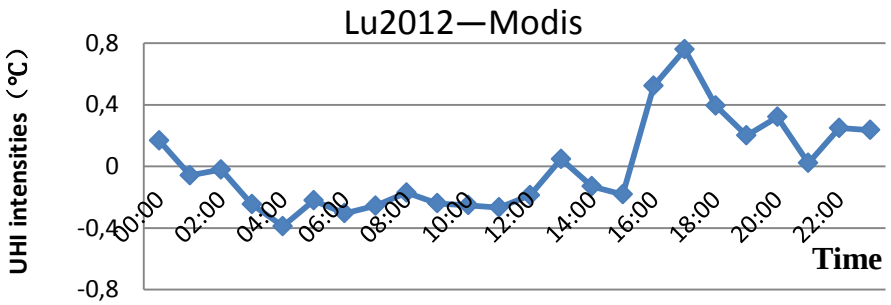


Diurnal cycles of the UHI intensities averaged over the four days

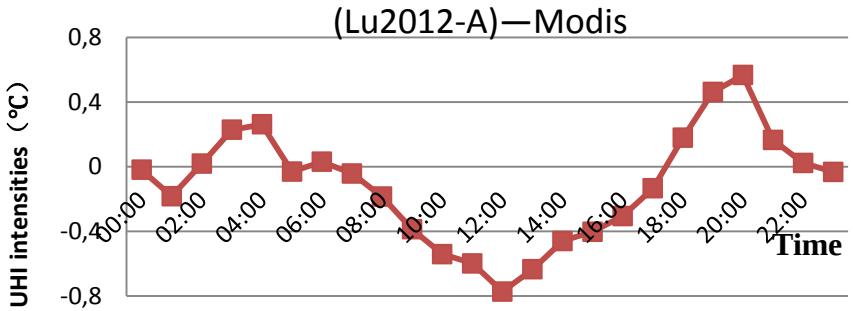
- All cases have a better UHI intensity characteristics reproduction from 9:00 to 21:00, but a big gap in other time.
- The WRF model have a good performance on daytime but poor before sunrise.

- The WRF model with the extracted land use data can have a better performance than default geographic model though it not perfect to depict the observation.

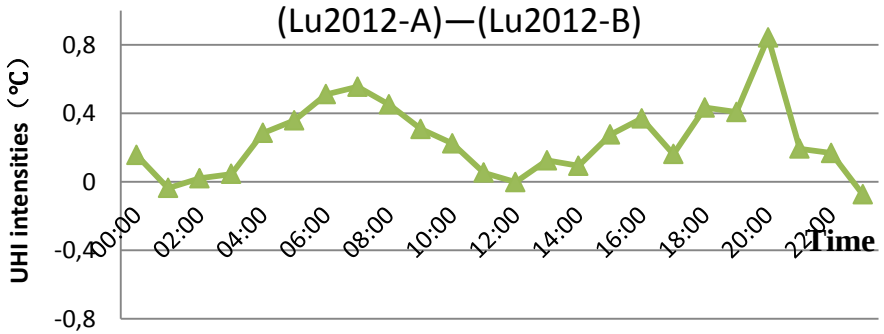
Result-UHI intensities



Daily range of 2m height UHI **intensities** of different experiments



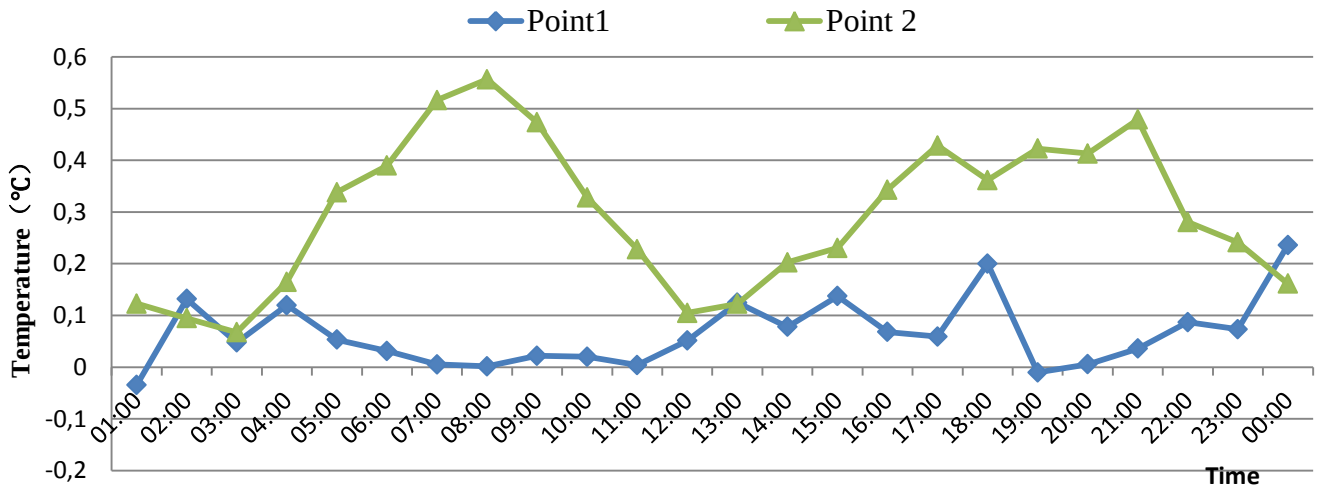
Daily range of 2m height UHI **intensities** of different experiments



Daily range of 2m height UHI **intensities** of different experiments

- Land use data effect on UHI intensity, and great differences are shown when using different land use data.
- Differences between the **Lu2012-A** and **Lu2012** indicate the total effects of coupled UCM model on UHI intensity, and coupled UCM model can enhance the UHI intensity almost night time.
- Differences between the **Lu2012-A** and **Lu2012-B** identified a positive significant relationship between the anthropogenic heat release (AHR) and UHI intensity all day, and the maximum about 0.89℃ at 20:00.

Result-Temperature-AHR



Averaged diurnal range of 2-m temperature between **Lu2012-A** and **Lu2012-B**

- AHR regularly affects the 2-m temperature can be up to 0.5℃ at urban area at 8:00 and 19:00. The AHR used in this study and its diurnal variation are based on default values in the UCM and may differ from actual AHR in Guangzhou.

Conclusions

- The experiments with different land use data have a significant impact on the WRF simulation result.
- The land use data extracted from the RS data of year 2012 can have a encouraging agreement with observations. By this method, we can research the Urban heat island under the background of urbanization in China.
- The experiment Lu2012-A which with new land use data and coupled with the UCM model has a lowest mean-root-square-error, which reveals a positive role of coupled UCM model on reproducing the variation of temperature.
- Comparisons among the results of four sensitivity runs showed that coupled the UCM model with classification of three urban land subcategories, and consideration of anthropogenic heat release respectively contributed 0.58℃ and maximum 0.89 ° C to the simulated UHI effects.

Future

- Based on the extracted land use data from the RS data . The urban expansion model will be established, which can predict the urban thermal climate in future.

Thanks for your attention !