Baomin WANG

Study on the Urban Heat Islands and the Meteorological Elements over the Pearl River Delta

Baomin Wang, Shuoyi Ding, Guanjin Qiao, Yuanyuan Guo and Yuxuan Wu
Department of atmospheric sciences, Sun Yat-sen University, Guangzhou, China, wangbm@mail.sysu.edu.cn

Dated: 12 June 2015

Abstract

The scientific evaluation of urban heat islands (UHI) over city clusters is important for the study of the urbanization effects of regional climate and environment. In this paper, UHI and meteorological elements over the Pearl River Delta (PRD) are investigated using data measured at 20 meteorological observatories during the period of 1999-2008. A standard deviation method is adopted to choose the suburb meteorological observatories for calculating UHI intensities over three zones in PRD. The average UHI intensity is 0.71℃ and the linear trend is 0.29℃/10a. The spatial distribution of UHI presents a tri-pole pattern, in which the UHI intensities in the middle zone of PRD are higher than those in the east and the west zone. The average UHI shows clearly seasonal and diurnal changes, is weakest in spring (0.39℃), strongest in autumn (1.06℃), higher in nighttime (0.91℃) than in daytime (0.53℃). The UHI intensity decreases with increasing low cloud cover, relative humidity, wind speed and precipitation. The results may contribute to city planning and risk zoning of meteorology and environment in PRD

1. Introduction

As the continuous strengthening of the global urbanization process, UHI effect has become an interdisciplinary important scientific problem, which gains increasing attentions of scholars in the fields of climate, environment, hydrology, ecology and energy. Although the heat island effect is not in itself as extreme weather such as typhoons and torrential rain caused such direct major natural disasters, but often by changing the local energy balance, water cycle process, the atmospheric boundary layer structure, pollutant transport and diffusion process, thus on human production and life caused indirect harm. On the one hand, the urbanization is speeding up, while the other is the growing demand for the living environment, the contradiction between the two is a problem to be solved urgently.

UHI effect of individual city or mega city has been a lot of research results, such as UHI intensity characteristics and seasonal changes of mega cities of Beijing, Shanghai, and Mexico City. However, the study of UHI effect over urban cluster is still to be strengthened. The concept of urban cluster is proposed in recent years, such as the three major urban clusters of Bo Hai Coastal Region, Yangtze River Delta and Pearl River Delta, China. The urban heat island is no longer a local phenomenon. Under certain weather conditions in urban clusters, urban heat islands may interact and strengthen heat island phenomenon or downstream effects. Heat island may also be associated with the local circulation and the afternoon storms.

In the researches of UHI over the Pearl River Delta area, the main focus was on a single city such as Guangzhou and Shenzhen, while in this paper, we regard the Pearl River Delta as a whole research and analyze the characteristics of UHI and the meteorological elements.

2. Data and methods

2.1 Research area

PRD is located in the east coast of Guangdong Province, China, including the Huizhou, Shenzhen, Dongguan, Guangzhou, Foshan, Jiangmen, Zhuhai, Zhongshan, etc. (Fig.1).

2.2 Weather stations

Based on meteorological data of 20 weather stations from 1999 to 2008, we analyzed temperature, low cloud cover, precipitation, relative humidity and wind speed which were observed at 02, 08, 14, 20 (Beijing Time). The altitudes of weather stations range from 2.4 to 2.4m, avoiding the effects of altitude difference on the analysis of UHI intensity.

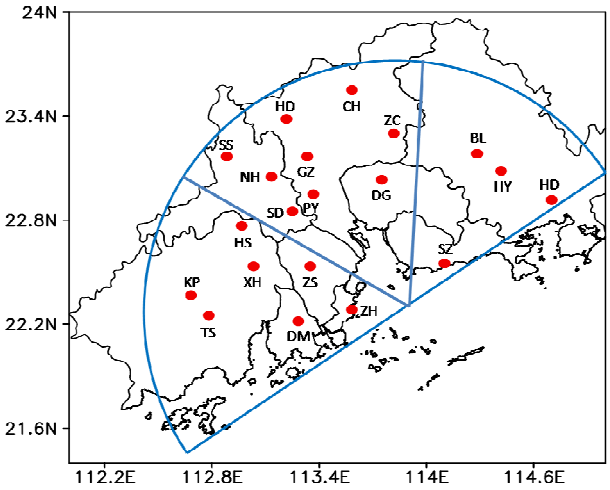

Fig. 1 Weather stations over Pearl River Delta area, China

2.3 Selecting the suburb sites

A normalized standard deviation of temperature is adopted to choose the suburb meteorological observatories for calculating UHI intensities over three sub zones (East, Center and West) in PRD (Fig.2). Huidong (HD) stands for the suburb site of East area, Conghua (CH) and Zengcheng (ZC) stands for the suburb sites of Center area and Taishan (TS) stands for the suburb site of West area.

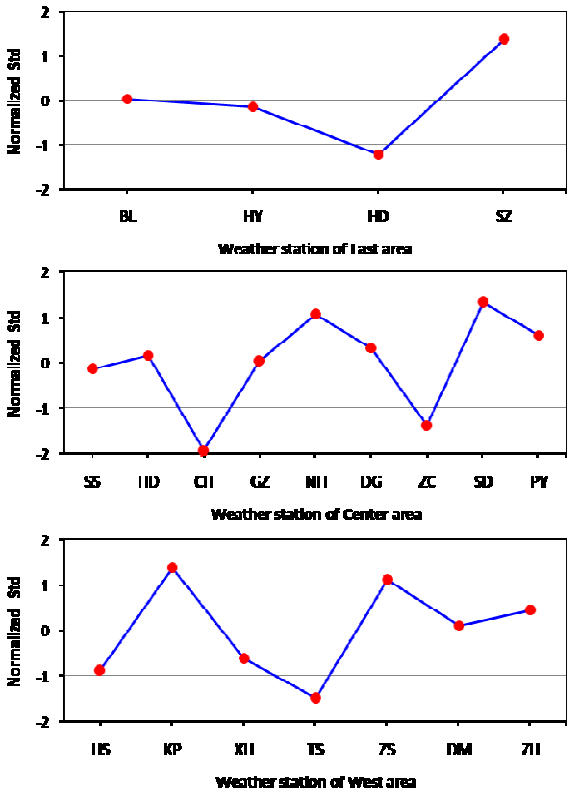

Fig. 2 The method of selecting suburb sites over PRD by normalized standard deviation of temperature

2.4 Frequency of UHI (UHIF)

UHI intensity is defined as the difference of temperature in urban sites and suburb sites. UHIF is defined as the frequency of UHI when UHI intensity is greater than 0.5 ℃. UHIF is the function of meteorological elements, namely low cloud cover, relative humidity, wind speed and precipitation.

3. Temporal evolution of UHI

Annual change (Fig.3): In general, from 1999 to 2008 in PRD, the annual average intensity of heat island is on the rise, linear increasing trend is 0.29 ℃ / 10 a, 10 years average heat island intensity was 0.71 ℃. The three

sub zones have different forms, the intensity of heat island in the central region is the largest, the second is the east and the west is the weakest.

Seasonal change (Fig.4): regardless of the Pearl River Delta, or eastern, central and western areas, the average intensity of heat island trends has the same pattern. UHI intensity in April is the lowest and the peak occurs in October or November. On average, the strongest heat island is 1.06℃ in October, the weakest is 0.39℃ in April.

Diurnal change (Fig.5): the urban heat island intensity has obvious diurnal variation. During the day, the Pearl River Delta average heat island intensity is 0.53℃ and 0.91℃ during the night. Heat island intensity difference between day and night is the largest in central region, a difference of 0.61℃ and the western region difference is small, 0.14℃.

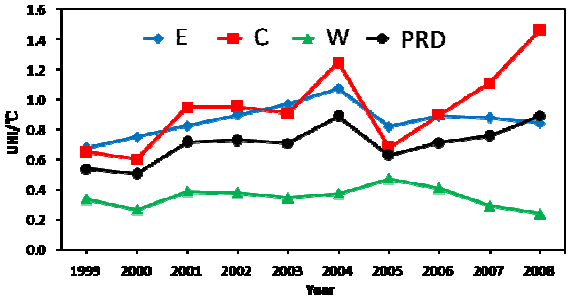

Fig. 3 UHI intensity from 1999 to 2008 over PRD, East area (E), Center area (C) and West area (W)

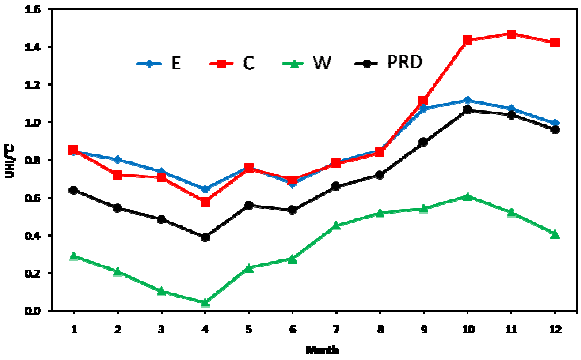

Fig. 4 Seasonal change of UHI intensity over PRD, East area (E), Center area (C) and West area (W)

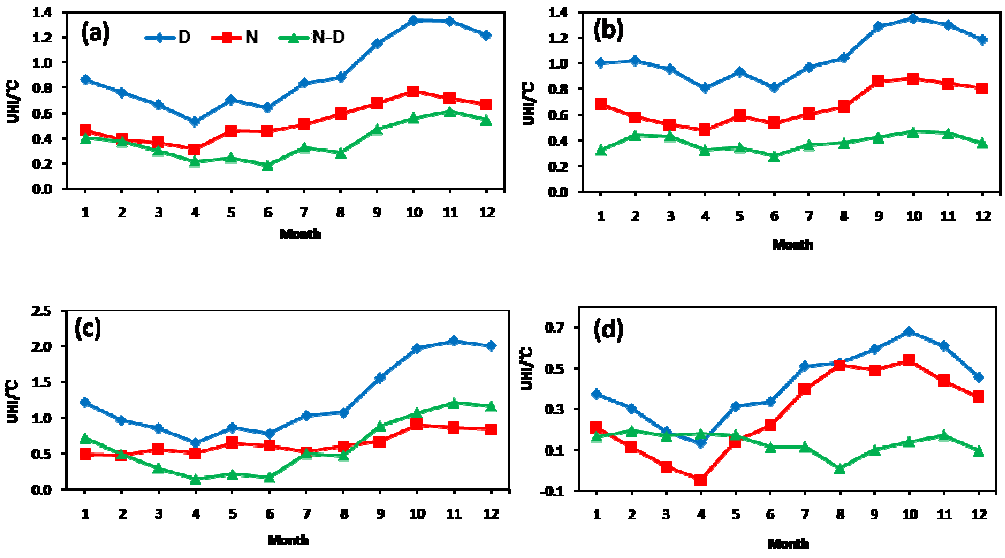

Fig. 5 Diurnal change of UHI intensity over PRD (a), East area (b), Center area (c) and West area (d)
D represents Day, N Night and N-D the difference of Night and Day UHI intensity.

4. Spatial distribution of UHIs

The average heat island intensity over PRD (Fig.6) shows that there are two high value centers, located in Shenzhen and Panyu and the intensity is greater than 1.00℃. On both sides of the heat island intensity is abate, the west side of weaker strength, has a low center, 0.20℃.

EOF analysis for the UHI intensity over PRD shows that variance contribution ratios of the first two modes are 71.2% and 8.9% respectively, so the first mode is the main one. From the characteristics of the modal vector field, we can see that the spatial distribution of heat island intensity in Pearl River Delta -, +, -, middle intensity is stronger, on both sides of the weak. The positive of time series coefficients suggests that the spatial distribution of the heat island intensity has no obvious change.

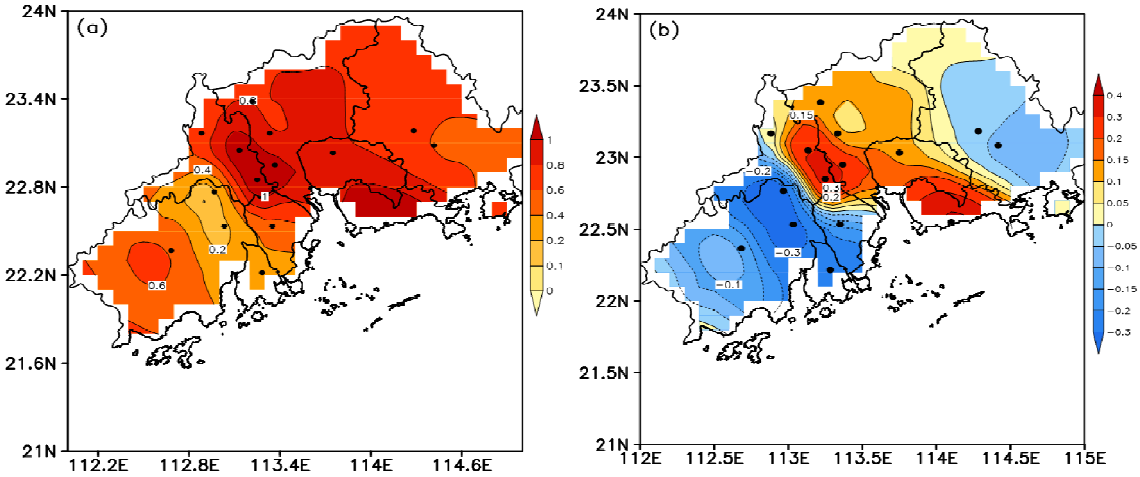

Fig. 6 Spatial distribution of UHI intensity over PRD (a) and the first mode of EOF (b)

5. Impact of meteorological elements on UHIF

The UHI intensity decreases with increasing low cloud cover, relative humidity, wind speed and precipitation. Details are shown in Figure 7 and table 1 and table 2.

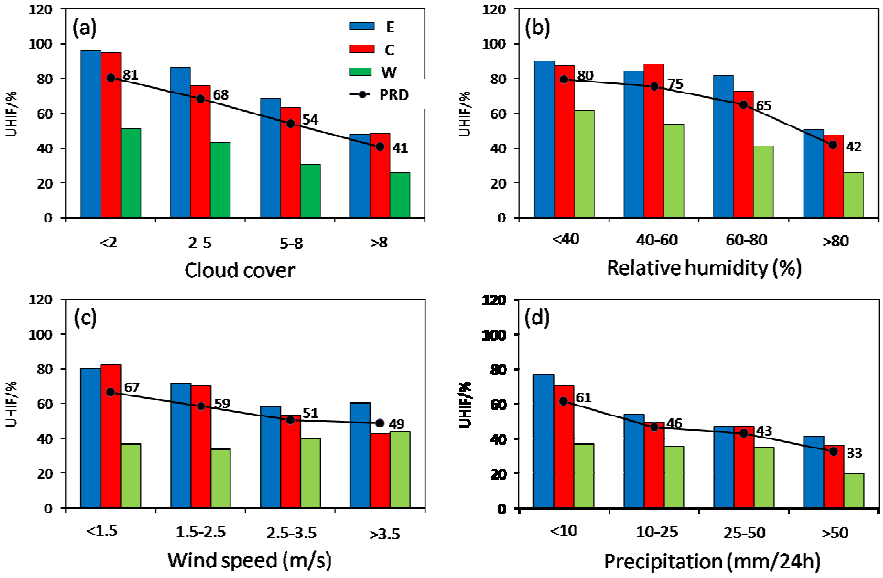

Fig. 7 Impact of meteorological elements on UHIF. Cloud cover (a), Relative humidity (b), wind speed (c) and precipitation (d). E represents East area, C Center area and W West area.

Table 1 Average UHI intensity under the different meteorological conditions（℃）

Cloud cover	PRD	East	Center	West	RH (%)	PRD	East	Center	West
≤ 2	1.39	1.42	2.03	0.73	≤40	1.26	1.29	1.76	0.72
2~5	1.06	1.14	1.25	0.78	40~60	1.33	1.33	1.89	0.76
5~8	0.99	1.01	1.14	0.82	60~80	1.08	1.16	1.32	0.75
> 8	0.88	0.90	0.99	0.76	>80	0.93	0.95	1.02	0.82
Wind speed (m/s)	PRD	East	Center	West	Precipitation (mm/24h)	PRD	East	Center	West
<1.5	1.25	1.22	1.75	0.77	<10	1.10	1.16	1.39	0.76
1.5~2.5	1.08	1.13	1.34	0.77	10~24.9	0.97	0.99	1.07	0.84
2.5~3.5	0.91	0.92	1.04	0.78	25~49.9	0.93	0.91	1.05	0.83
>3.5	0.86	0.95	0.87	0.77	>50	0.83	0.85	0.84	0.79

Table 2 The correlation coefficient of UHI and meteorological elements

	Low cloud cover	Relative humidity	Wind speed	Precipitation
PRD	-0.45	-0.38	-0.18	-0.18
East area	-0.54	-0.38	-0.22	-0.24
Center area	-0.56	-0.48	-0.38	-0.22
West area	-0.26	-0.26	0.05*	-0.07*

* Failed to pass the test of significance 99%

Acknowledgment

This research was supported by the National Basic Research Program of China (973 Program, 2010CB428500), China Special Fund for Meteorological Research in the Public Interest (GYHY201406031 and GYHY201306042).

References

Arnfield A. J., 2003: Two decades of urban climate research: a review of turbulence, exchanges of energy and water and the urban heat island, *Int. J. Climatol*. **23**, 1-26.

Ernesto J., 1997: Heat island development in Mexico City. *Atmospheric Environment*, **31(22)**, 3821-3831.

Kim Y. H., Baik J. J., 2002: Maximum urban heat island intensity in Seoul, *J. Appl. Meteor. Climatol.* **41**, 651-659.

Stewart I.D., 2011: A systematic review and scientific critique of methodology in modern urban heat island literature. *Int. J. Climatol*. **31**, 200-217.

Zhang D. L., Shou Y. X., Dickerson R. R., 2009: Upstream urbanization exacerbates urban heat island effects. *Geophys. Res. Lett*. **36(24):** L24401, doi: 10.1029/2009GL041082

Zhang D. L., Shou Y. X., Dickerson R. R., 2011: Impact of up-stream urbanization on the urban heat island effects over the Washington-Baltimore metropolitan region. *J. Appl. Meteor. Climatol.*, **50(10)**, 2012-2029.

Zhou K., Ye Y., Peng S., 2008: Variations of urban heat island and its relationships with total suspended particulates in Guangzhou, China. *Ecology and Environment,* **17(5),** 1861-1867.