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ANALYSIS OF THE IMPACT OF URBAN GROWTH ON THE TEMPERATURE FIELD IN GUANGZHOU

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ABSTRACT: Based on the 1973 – 2003 temperature data of Guangzhou meteorological station and 1980 – 2000 temperature data of Foshan airport, the variations of urbanization effect on temperature of Pearl River Delta (PRD) and Guangzhou city were analyzed. It was found that the temperature has increased significantly due to the PRD's urbanization. During the last 20 years, Foshan airport's temperature has increased by 0.7°C, and the Guangzhou city's temperature increased by about 1.1°C during last 30 years. The heat island of Guangzhou city is obvious but has some differences from other big Chinese cities.

Key words: urbanization; heat island effect; Guangzhou city

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1 INTRODUCTION

Impact of urbanization on urban climate is receiving more and more attention in China. Large cities like Beijing and Shanghai have conducted more studies on the issue of urban climate changes induced by urbanization, and so does smaller cities such as Shenyang, Zhengzhou, Hangzhou, Lanzhou, Huhehaote, Xining, Kunming, Jinghong and Chuxiong. However, in Pearl River Delta (PRD), where urbanization develops rather rapidly, there is relatively little research on this issue[1-13].

By using temperature data observed in Guangzhou surface station from 1973 to 2003 and that from 1980 to 2000 observed in Shadi airport station in Foshan city, which is adjacent to Guangzhou and relatively less affected by urban growth, this paper is devoted to an analysis of the trend of temperature change in PRD and the influence of urban growth of Guangzhou on the temperature field.

2 URBAN GROWTH OF GUANGZHOU AND DATA FOR RESEARCH

Guangzhou is located at the north end of PRD that belongs to the monsoonal and oceanic climate in the southern subtropics. It has two towns and ten districts with a total area of 3718.5 km2 and population of 5.8389 millions by the end of 2003[14]. In 1978 the urban area of Guangzhou covered only 89 km^2, while it had been enlarged to 297.5 km2 by 2000 at a mean growth rate of 9.5 km2/a. The population of the city proper in 1978 was 2.831millions, and it increased to 4.259 millions by the end of 2003. The mean growth rate was 57.0 thousand persons per year.

Guangzhou surface weather station (hereafter referred to as Guangzhou station) was originally located in Tianhe district of Guangzhou. As the population density in Tianhe district increased from 2433 to 5525 person/ km2 during 1985-2002, it turns from suburbs into an urban area. So Guangzhou station was moved to Wushan of Guangzhou in 1996. Shadi airport of Foshan (hereafter referred as Foshan airport), which is a small airport to the northwest of Guicheng district of Foshan city and has the same latitude with Guangzhou, is about 8 and 20 km apart from Guicheng and Guangzhou, respectively. The airport is surrounded by farmland

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without big buildings or houses. Since the environment around Foshan airport has not changed greatly as compared with other weather stations in PRD cities, it can stand for the natural climate change of this region. By taking Foshan airport as the reference point, Chen et al. (2003)[12] studied the temperature change in the past half century.

Datasets used in this research are 4-times-daily temperature of 1973 – 2003 observed in Guangzhou station and hourly temperature of 1980 – 2000 observed at Foshan airport. A comparison study is made between city and suburb by using data of the two stations. Since the location of Guangzhou station was changed in 1996, in our comparison the time series of Guangzhou station is divided into two segments, i.e. data before (1980 – 1995) and after the move of the station (1996 – 2000).

3 RESULTS AND ANALYSIS

3.1 Trend in temperature change

Fig.1 shows the trends of annual mean temperature in Guangzhou and Foshan airport. It is clear that the trends of annual mean temperature in these two places are consistent with each other. Temperature changed slowly in the 1980's while in the 1990's there was an significant upward trend. So the situation in the PRD is consistent with the conclusion that the warming of the whole country began in the 1980's and got intensified in the mid-1990's[6, 12-13].

Temperature change rate of Guangzhou is 0.08°C/a for the 1980's. For the period of 1996-2003 it becomes 0.15°C/a. Temperature change rate of Foshan airport is 0.02°C/a and 0.10°C/a for the 1980's and 1990's, respectively. Annual mean temperature change rate is greater in Guangzhou than in Foshan airport. According to the annual mean temperature data in Foshan airport, temperature in PRD increased by 0.82°C over 20 years. In order to remove the influence of global warming, we subtract averaged temperature over the 5 years of 1980 – 1984 from that of 1996 – 2000 and get 0.72°C, which is the increment of temperature over 20 years in PRD. This is consistent with the result (0.6°C – 0.8°C) given by Zeng, Sha and other researchers[6, 13] and greater than the increment in inland cities at similar latitudes (0.47°C in Kunming and 0.50°C in Jinghong).

The observed temperature in Guangzhou station after its move in 1996 is near to or even lower than that in Foshan airport, which indicates this observed temperature represents the temperature in suburb of Guangzhou with better vegetation rather than that in the city. It also means that Foshan airport can be viewed as the suburb of Guangzhou. The 1995 annual mean temperature of Guangzhou station is 0.71°C higher than that of Foshan airport, on the contrary, it becomes 0.21°C lower after the station was moved to the new location in 1996. So the annual mean temperature observed at the new Guangzhou station is at least 0.92°C lower than that observed at the old one. Guangzhou has many big buildings in its urban area where commerce and trade develop rapidly, so the warming rate in the urban area should be greater than

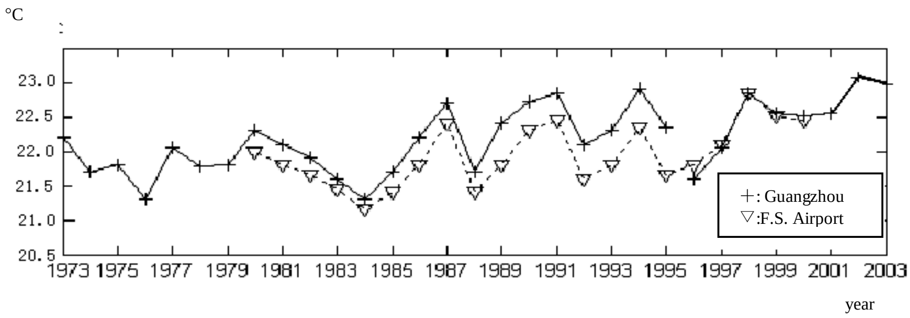

Fig. 1. Comparison between trends of annual mean temperature in Guangzhou and Foshan airport.

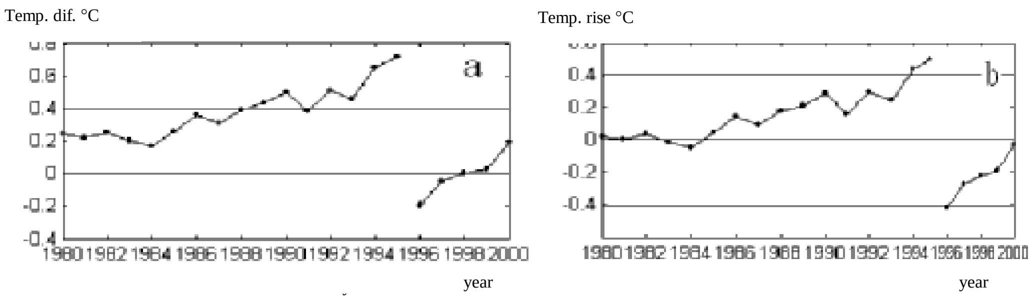

Fig.2 Interannual variation of urban heat island effect in Guangzhou. (a) Difference of annual mean temperature between Guangzhou and Foshan airport. (b) Temperature rise induced by urban growth of Guangzhou.

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the value of 0.15°C/a observed in Guangzhou station and needs further study.

3.2 Urban heat island effect

In order to remove the influence of global warming, using temperature data of the same period of 1980-2000, the annual mean temperature in Guangzhou station is subtracted from that in Foshan airport and get the deference in annual mean temperature between the two stations (see Fig.2a). Then a mean over 4 years of 1980-1983 is taken as reference to determine the difference between the reference and individual annual averages. The result obtained is regarded as the impact of urban growth of Guangzhou on temperature, that is, the urban heat island effect (see Fig.2b).

As is shown in Fig.2, temperature in Guangzhou is affected more and more by the urban growth, the urban heat island effect is getting stronger and stronger and the 1990's saw a more significant urban heat island effect than 1980s. The negatives in Fig. 2 are resulted from the move of Guangzhou station in 1996. Actually, at lest 0.92°C should be added to annual mean temperature difference after 1996 (according to the estimation in subsection 2.1, the annually mean temperature observed at the new Guangzhou station is at least 0.92°C lower than that observed at the old one), although the exact value of the increment is still needed to study.

In order to evaluate the impact of urban growth of Guangzhou, using temperature data observed at Guangzhou station from 1973 to 2003, the mean value averaged over the 5 years of 1973 – 1977 is subtracted from that of 1999 – 2003 to estimate the increment of annual mean temperature, about 1.1°C over the 30 years, in which 0.4°C (after removing 0.7°C, the rise in the whole PRD) is induced by urban growth. Compared with the results of the researches for other domestic cities, urban heat island effect of Guangzhou is weaker and the warming effect of urban growth is not as strong

Tab.1 Monthly mean temperature and heat island intensity (℃) in Guangzhou station and Foshan airport

Month	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual mean
GZ station	13.8	14.4	17.6	22.0	25.6	27.7	28.7	28.7	27.4	24.4	19.9	15.2	22.1
FS airport	13.3	13.8	17.2	21.8	25.4	27.6	28.6	27.6	27.0	23.7	19.2	14.9	21.7
Heat-island intensity	0.5	0.6	0.4	0.2	0.2	0.1	0.1	0.1	0.4	0.7	0.7	0.3	0.4

Tab.2 Diurnal variation of Guangzhou heat island intensity (℃) in summer and autumn

month	July					November				
time	02	08	14	20	mean	02	08	14	20	Mean
1994	0.48	0.27	0.13	0.49	0.34	2.19	1.91	0.45	1.91	1.61
1995	0.49	0.21	0.38	0.35	0.36	2.25	1.55	0.23	2.28	1.58
mean	0.485	0.24	0.255	0.42	0.35	2.22	1.73	0.34	2.095	1.595

Tab.3 Frequency (%) and intensity (℃) of Guangzhou heat island effect in summer and autumn under different conditions of wind speed

	Time	02		08		14		20		diurnal	
month	Wind speed/ (m•s^{-1})	f. / %	Heat island f. / ℃	f. / %	Heat island f. / ℃	f. / %	Heat island f. / ℃	f. / %	Heat island f. / ℃	f. / %	Heat island f. / ℃
Jul.	<1	5.7	0.55	0.4	0.6	0.9	0.8	2.6	0.82	9.6	0.69
	1～2	3.9	0.54	4.4	0.98	1.3	0.93	2.2	1.0	11.8	0.86
	2～3	7.9	0.83	7.0	0.39	7.0	1.74	10.0	0.81	31.9	0.94
	3～4	2.2	0.44	4.4	0.65	4.4	0.68	3.5	0.71	14.4	0.62
	≥4	1.7	0.46	0.9	0.35	2.6	0.7	0	0	5.2	0.38
Nov.	<1	8.6	2.17	4.3	2.17	1.3	0.53	11.2	2.03	25.3	1.72
	1～2	4.7	2.31	5.6	2.22	6.9	0.74	4.7	2.46	21.9	1.93
	2～3	9.9	2.43	10.3	1.58	5.6	0.81	6.4	2.11	32.2	1.73
	3～4	2.1	1.76	2.6	1.28	2.6	1.1	2.6	1.8	9.9	1.48
	≥4	0	0	0.9	1.1	0.9	0.8	0.4	0.9	2.2	0.95

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as that of inner-land cities and cities with high latitudes, because the move of Guangzhou observation station from city area to suburb in 1996 caused a reduction to the rise of the temperature in Guangzhou. Tab.1 gives the results of comparison analysis between monthly mean data of the 16 years from 1980 to 1995 for Guangzhou station and those for Foshan airport. The difference of temperatures between the Guangzhou station and Foshan airport is defined as the heat island intensity of Guangzhou.

Tab.1 shows the heat island effect of Guangzhou has an significant seasonal change. The heat island intensity of Guangzhou in dry season (October – March) is greater than that in wet season (April-September), which demonstrates a correspondence between the change in heat island intensity of Guangzhou and dry/wet seasons. Maximum peak value of heat island intensity in Guangzhou appears in October and November of the autumn, while secondary peak value appears in January and February of the winter. It has the minimum value in June, July and August of the summer. Guangzhou is governed by high pressure system in autumn when the atmosphere is stable with clear sky and daily radiation reaches the climax of the whole year, so heat island intensity in autumn is the strongest in all seasons. Heat sources due to antropogenic activities and stable weather systems are the main reason for the strong urban heat island effect in winter. In summer, unstable weather with cloudy, windy conditions and more rainfall makes it easy for pollutants and heat released by human activities to disperse into surrounding region, unfavorable for the formation and development of heat island effect. Heat island intensity depends on factors such as the size of city and population density. Terrain condition, ambient atmospheric circulation and regional climate are important factors affecting the heat island effect as well. In order to study the diurnal variation of urban heat island, we compare 4-times-daily temperature of Guangzhou station before its move in 1994 – 1995, when heat island intensity has its largest value, with that of Foshan airport. Regarding July and November, the weakest and strongest months of heat island intensity, as the representing months of the summer and the winter, Tab.2 gives the diurnal variation of heat island intensity of Guangzhou in summer and winter.

Tab.2 shows the averaged heat island intensity of November in the mid-1990’s has reached 1.6°C and exceeds 2°C in night. Warming effect is more significant in autumn. The difference between heat island intensity of November and July reaches 1.2°C. The peak values always appear in night and bottom values in afternoon, which is consistent with the research results for most domestic cities.

Tab.3 gives the frequency and intensity of Guangzhou heat island effect in summer and autumn under different conditions of wind speed. From this table, one can find that urban heat island of Guangzhou usually appear in nights with breeze, and both its frequency and intensity are greater in autumn than in summer. When wind speed exceeds 4 m/s, whether in summer or in autumn, frequency of heat island becomes very low with small intensity.

Some further analysis shows that strong heat island intensity ($\Delta T \geqslant 3$°C) of Guangzhou in autumn appears after sunset. It has a probability of 13% and a maximum of 4.7°C. Probability of moderate heat island (1.5°C$\leqslant \Delta T \leqslant$2.9°C) after sunset reaches 65%.

4 SUMMARY AND DISCUSSIONS

(1) Annual mean temperature of Guangzhou city increased by 1.1°C within 30 years, while that of PRD increased by 0.7°C. About 0.4°C in the increment of annual mean temperature is induced by the urban growth of Guangzhou, which is less than those of other inland cities and cities at high latitudes in China, because the move of Guangzhou station from urban are to the suburb in 1996 has caused a reduction to the rise of the temperature in Guangzhou.

(2) The intensity of heat island of Guangzhou increases year after year and is greater in dry season (October-March) than in wet season (April-September). It has large value in autumn and small value in summer. In the middle 1990’s the averaged heat island intensity in November reaches 1.6°C and exceeds 2°C in night. The averaged value of the difference between heat island intensity in November and in July reaches 1.2°C, indicating a significant warming effect in autumn.

3) Urban heat island of Guangzhou usually appears in nights with breeze, and its frequency is greater in autumn than in summer. When wind speed exceeds 4 m/s, whether in summer or in autumn, the frequency of heat island becomes very low and with small intensity. The occurrence of strong heat island (ΔT$\geqslant$3°C) of Guangzhou in autumn has a probability of 13%, while that of moderate heat island (1.5°C$\leqslant \Delta$T$\leqslant$2.9°C) is 65%.

4) The heat island effect of Guangzhou has significant interannual, seasonal and diurnal variation that is different from those of other cities in China.

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