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ON TEMPERATURE CHANGES OF SHANGHAI AND URBANIZATION IMPACTS

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Abstract: To understand how temperature varies in urban Shanghai under the background of global climate change and how it is affected by urbanization, the Shanghai temperature responses to global warming were analyzed, and then the temperature trends of urban and suburb stations under different climatic backgrounds were obtained. The urbanization effects on temperature were studied by comparing urban stations to suburb stations, the relationship between urbanization variables and temperature components were obtained, and observation data of surface and high level were combined to assess the contribution of urbanization effect. In the last part of the paper, the cause of urbanization effects on temperature was discussed. The results indicated: The long term change trend of Shanghai annual mean temperature is 1.31/100a from 1873 to 2004, the periods of 1921 – 1948 and 1979 – 2004 are warmer, and the 1979 – 2004 period is the warmest; compared to suburb stations, the representative urban station has slower decreases in the cool period and faster increases in the warm one; the urban and suburb temperatures have distinct differences resulting from urbanization and the differences are increasing by the year, with the difference of mean temperature and minimum temperature being the greatest in fall and that of maximum temperature being the largest in summer between the urban and suburban areas. The urbanization process accelerates the warming speed, with the minimum temperature being the most obvious; the urbanization effect contributes a 0.4°C increase in 1980s and 1.1°C in 1990s to the annual mean temperature.

Key words: climatology; shanghai air temperature; climate change; urbanization effect

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1 INTRODUCTION

The global surface mean air temperature has increased by 0.6±0.2°C in 20th century. The 1990s might be the warmest decade since the beginning of instrumental records, and the warming amplitude of over the Northern Hemisphere was most likely the highest in the 20th century in the past millennium. Characterized by warming [1], the global climate change has various patterns in different regions [2]. As an indicator station for climate change in the East China coastal regions, Shanghai observatory has the most complete temperature records of all the stations in China, being very important in the investigation into the temperature variation in Shanghai under the global warming background. Some related research achievements [3 – 5] have been obtained. Meanwhile, as a mega city, its urban climate effect is very typical, on which some works [6 - 8] also have been done.

The urban construction of shanghai is stepping up fast in recent years, making its climate change exposed to not only the variation of regional climatic background but also the urbanization effect on local scales. As a result, the study on the variation pattern of temperature in Shanghai should take into account the regional climate change and urbanization effect comprehensively, on which few works have focused and little quantitative assessment has been made of the urbanization effect. Based on the responses of the temperature in Shanghai to the global change and an analysis of climate effect due to urbanization, influences of the urbanization process on the temperature change, one of the climate elements in Shanghai, are investigated, and the contribution of urbanization effect to the

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urban temperature variation in Shanghai is also quantitatively evaluated in this article.

2 CHANGES IN SHANGHAI TEMPERATURE

From 10a-moving-tendency rates determined for the weather station at Xujiahui (Fig.1), the periods of 1921 – 1948 and 1979 – 2004 are much warmer than the other two in the annual series of mean temperature (Fig.1). The warming rates in the second phase for global [9], the Northern Hemisphere and Shanghai (represented by Xujiahui Station, same below) are all higher than the first, particularly obvious for Shanghai, with a difference of 0.53℃/(10a). The significant differences in Shanghai between the two phases indicate that the warming of the second phase may be a combined result of both the feedback to global climate change, to which local climate change, particularly the impact of urbanization, may have attributed. For 1961 – 1978, all of the 11 stations in the Shanghai region show a cooling trend, among which the cooling rate of Xujiahui Station is the slowest with the trend coefficient being only -0.13 [10 - 11]. In the period from 1979 to 2004, stations in Shanghai all show a remarkable warming trend, most obviously for the Minhang and Xujiahui stations with a trend coefficient of 0.88 for the former. From the above we can see a consistent trend of temperature response of Shanghai stations to global change and the Xujiahui station had the slowest drops in the cooling period and fastest increases in the warming period, which is significantly different from other stations, especially those in the outskirt, indicating that the process of urbanization in Shanghai may have had an impact on long-term changes of temperature [12].

3 ANALYSIS ON URBANIZATION EFFECT

3.1 *Temperature difference between urban and outskirt regions*

Matching *t* tests were made on the average, maximum and minimum temperature of Xujiahui and suburb stations, with the latter determined by averaging those of Nanhui, Jinshan, Qingpu and Chongming stations and the results pass a α=0.01 significance test, suggesting that with the same background of climate change, there was a significant difference between the temperature of the urban (Xujihui) and suburb with obvious local effect [13 - 15]. Long-term linear trends suggest that during 1960 – 2004 the Xujiahui Station shows a clearly upward trend for the average, maximum and minimum temperatures, which were higher than those stations in suburban areas, and the minimum temperature increased the fastest, with an average of 0.58℃ / (10 a) comparing to 0.29℃ / (10 a) in the outskirts.

3.2 *Assessment of urbanization effect*

Linear regression coefficients were determined by using the 850hPa temperatures of Baoshan station as dependent variables and the annual average surface temperatures of Xujiahui Station as independent variables in the period of 1961 – 1970. Utilizing the regression equation, urban annual temperatures in the period of 1971 – 2000 were estimated by using 850 hPa mean temperature of Baoshan station as input to remove heat island effects. The differences between estimation and observation were considered as the result of

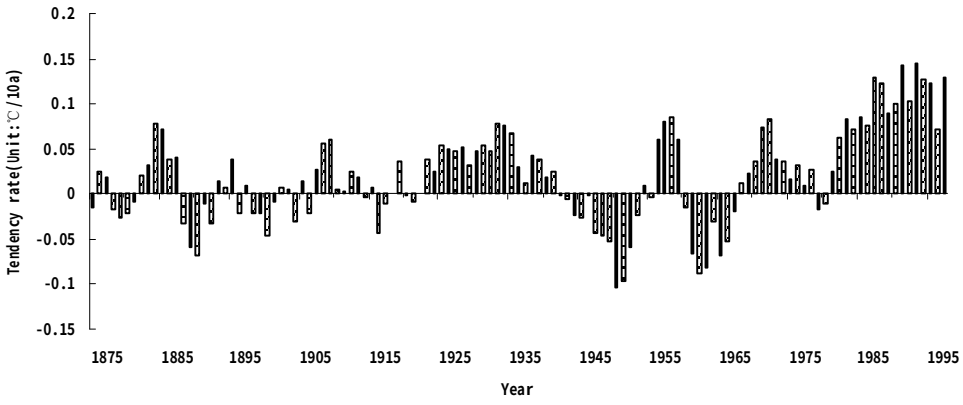

Fig.1 10-year moving trend rate of annual average temperature for urban Shanghai.

urbanization effect [16, 17]. The urbanization effect of Xujiahui station was becoming obvious, increasing from 0.4°C in 1980 to 1.1°C in 1990s; as for Chongming Station, a difference of 0.2°C in 1990s indicates that the urbanization effect is beginning to appear, and the urbanization impact on Minhang was getting obvious in 1990s with a difference of 0.6°C (See Table 1).

Table 1 Surface temperature differences between the observed and estimated temperature at 850hPa.

Period	Urban (Xujiahui)	Outer Suburb (Chongming)	Suburb (Minghang)
1961 – 1970	0.0	0.0	0.0
1971 – 1980	0.1	-0.1	0.0
1981 – 1990	0.4	0.0	0.0
1991 – 2000	1.1	0.2	0.6

For analyses of other aspects, refer to the Chinese edition of the journal.

4 DISCUSSIONS ON REASONS OF URBANIZATION EFFECT

With the increase of floor space in urban housing [18], the difference of annual average temperature between Xujiahui and Chongming stations is rising with similar trend of variations (See Fig.2). Corresponding to the slow growth of urban housing floor space before 1980, the differences between urban and outskirts changed stably; when the area of urban housing entered a rapid growth period after the mid-1980s, the differences are rapidly increasing on the whole despite some fluctuations, which shows that temperature differences between urban and outskirts have a clear relationship with Shanghai's urbanization process. As the pressure gradient in the autumn of Shanghai is smaller in the hours of early mornings and the weather is relatively stable, it is contributing to the formation and development of urban heat island effect, making autumn the season with the strongest urbanization effect on minimum temperature. The strongest effect of urbanization on maximum temperature occurring in the summer season may be related to substantial amount emissions of man-made heat from air conditioning and little consumption of heat from evaporation in urban areas [19].

5 CONCLUSIONS AND DISCUSSION

(1) The long-term tendency for annual mean temperature in urban Shanghai is 1.31°C/(100 a) from 1873 to 2004, which is higher than that of the Northern Hemisphere and the globe. There are two obvious warming periods, 1921 – 1948 and 1979 – 2004, for the urban mean temperature in Shanghai, and the second period is higher than the first one in terms of the warming rate. Comparisons with Shanghai suburban stations show that the temperature of the urban stations decreased more slowly in the cooling period (1961 – 1978) and increases faster in the warming period (1979 – 2004).

(2) The development of Shanghai urban construction results in obvious temperature differences between urban and suburban areas, which increase by the year with the largest difference of mean and minimum temperature appearing in fall and that of maximum temperature in summer. The urbanization progress affects the

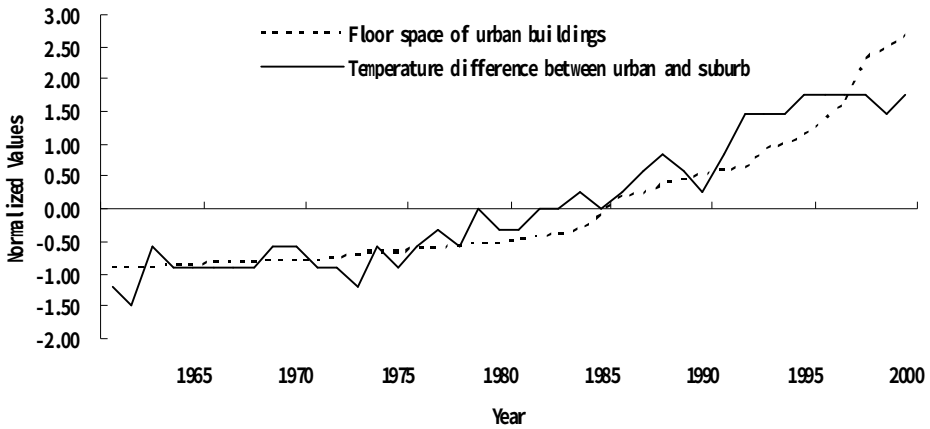

Fig.2 Shanghai urban building floor space and surface temperature difference between urban and suburb.

long-term tendency of the mean, minimum and maximum temperature by accelerating the rise of the urban surface air temperature, among which the minimum temperature is the most obvious.

(3) The urbanization effect has caused the annual mean temperature in urban Shanghai areas to increase by 0.4℃ in 1980s and 1.1℃ in 1990s, according to an estimation utilizing both the upper-air and surface observation data, which took the 1960s as a reference decade.

From the above, our analysis shows that under the global warming background the influence of the urbanization progress on the temperature change in urban Shanghai is significant, which is shown not only through the temperature difference between urban and suburb areas, but also the long-term changing tendency of temperature. The urbanization impact on local climate is stronger and more directly than that of global warming in certain aspects. Therefore we should not merely pay attention to the influence of global warming; research on the influence of the urbanization progress on the urban climate needs to be strengthened too. In addition, in order to mitigate the impacts of city development on urban local climate, proper measures should be taken in the progress of urban planning and construction, so as to improve the urban climate condition, benefit the production activities and living conditions of urban residents.

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