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Climatic change and urbanization effect in China

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Abstract — Climatic change and urbanization effect in China during the last 39 years were investigated. It is found that a warming of about 0.23 ℃ for the annual temperature has been noticed from 1951 to 1989. The warmings of about 0.78 ℃ in winter and 0.34 ℃ in spring have been shown. It is also presented that a cooling of about −0.27 ℃ in summer has been indicated. The bigger cities are warmer than smaller cities in China. The dried trends in the annual precipitation during the last 39 years were presented. The precipitation decreased obviously in summer all over China. The bigger cities were drier than smaller cities.

Keywords: climatic change; urbanization effect; global warming.

INTRODUCTION

According to the results of the Working Group I, IPCC (1990), the global warming of about 0.3–0.6 ℃ for the last 100 years has been found. Some areas were getting drier and some wetter.

Chinese scientists are interested in the climatic change on the globe. Several researches have presented the warming in north China in winter and the cooling in south China in summer (Chen, 1990; Liao, 1990; Lin, 1990).

In this paper, the changes of the annual and seasonal temperature and precipitation in China during the last 39 years will be given. The trends of temperature and precipitation in several types of cities in China are also analyzed.

DATA AND ANALYTICAL METHOD

The data of temperature and precipitation in China (160 observation stations) during 1951 to 1989 for January – December were obtained from National Meteorological Center. The reasons to choose these data are because they were used by most meteorological institutes and universities in China. Secondly, there were the long time series from 1951 to 1989 in those 160 stations. The statistic data of population in China (1988) were from the Ministry of Public Security in China.

At first, the seasonal and annual mean temperatures and the seasonal and annual total precipitations for 160 stations were calculated respectively. Then, the decadal means and anomalies from 1951 to 1989 of temperature and precipitation were computed respectively.

According to the work (Karl, 1988; Zhao, 1990), the population in a city is able to indicate its situation. Therefore, 160 stations were separated into five types by means of the populations in cities. Table 1 shows the definitions and numbers of stations of five types. The locations and types of 160 stations are given in Fig.1. It is noticed from Table 1 and Fig. 1 that type 1, 3 and 4 distributed well in China and the most stations of type 2 located in north China. The stations of type 5 are far less than other types.

Table 1 Definitions and numbers of five type stations

Type	1	2	3	4	5
Population, $\times 10^4$	>100	50−100	10−50	1−10	<1
Numbers	24	15	64	52	5
Percentage, %	15	9	40	33	3

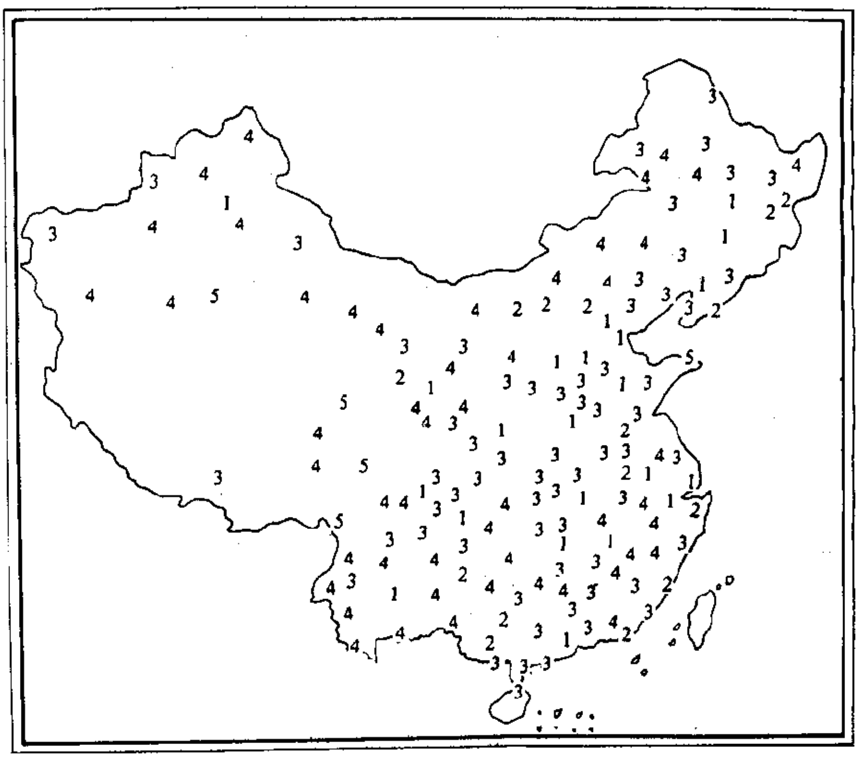

Fig. 1 Locations of five types of stations in China

For a simple and direct analysis, the regional mean temperature and precipitation over China and for five types were calculated by using the mathematical means for the annual and seasonal values, respectively.

The linear trends of the annual and seasonal temperatures and precipitations for the last 39 years in China and five types were indicated the climatic changes. The trends (*Lxt*) were calculated as

$$Lxt = \frac{\sum_{i=1}^{n} (t_i - \bar{t})(x_i - \bar{x})}{\sum_{i=1}^{n} (t_i - \bar{t})^2} \qquad i = 1,\ 2,\ \cdots\cdots,\ n$$

where, t is time (year) ; x is temperature or precipitation; the number of total sample (n) equals 39 (years) ; i is the variable of time; x and t are averaged means, respectively. The units of the trends *Lxt* for temperature and precipitation are ℃/a or mm/a respectively. Thirty-nine times *Lxt* expresses the trends of the changes of temperature and precipitation for 39 years.

The correlation coefficients *Rxy* between the annual and seasonal temperatures and precipitations for 160 stations were calculated as

$$Rxy = \frac{\sum_{i=1}^{n} x_i y_i - n\bar{x}\bar{y}}{\sqrt{\sum_{i=1}^{n} x_i^2 - n\bar{x}^2}\ \sqrt{\sum_{i=1}^{n} y_i^2 - n\bar{y}^2}} \qquad i = 1,\ 2,\ \cdots\cdots,\ n$$

where x is temperature and y is precipitation. The number of total sample n equals 39 (years), $\bar{x}$, $\bar{y}$ are the averaged means of temperature and precipitation respectively, and i is the variable of time. The significant levels of 5% and 1% for 39 years are 0.32 and 0.41, respectively.

CHANGE OF TEMPERATURE

As the methods mentioned above, the trends of the annual and seasonal temperature over China and for five types of cities have been obtained. Table 2 shows the results. The anomalies of the annual mean temperatures over China and for five types of cities during 1951 to 1989 are shown in Fig. 2 as an example.

It is interesting to notice that there is a warming of about +0. 23 ℃ for the annual mean temperature during the last 39 years of China was observed (Table 2). A significant warming of about +0.78 ℃ during the last 39 years has been presented in winter. In spring, a warming of about +0.34 ℃ during the last 39 years has occurred. A cooling of about −0.27 ℃ in summer during the last 39 years has been indicated. But the warming in autumn over China was not obvious in this period.

Table 2 The linear trends of the annual and seasonal temperature for China and type 1, 2, 3, 4 and 5 (unit: ℃) during 1951 to 1989 (39 years)

Type	China	1	2	3	4	5
Annual mean	+0.23	+0.27	+0.45	+0.20	+0.12	+0.04
Spring	+0.34	+0.43	+0.54	+0.25	+0.02	+0.03
Summer	−0.27	−0.39	+0.12	−0.27	−0.22	−0.18
Autumn	+0.06	+0.11	+0.17	+0.04	+0.05	−0.13
Winter	+0.78	+0.89	+0.94	+0.77	+0.75	+0.44

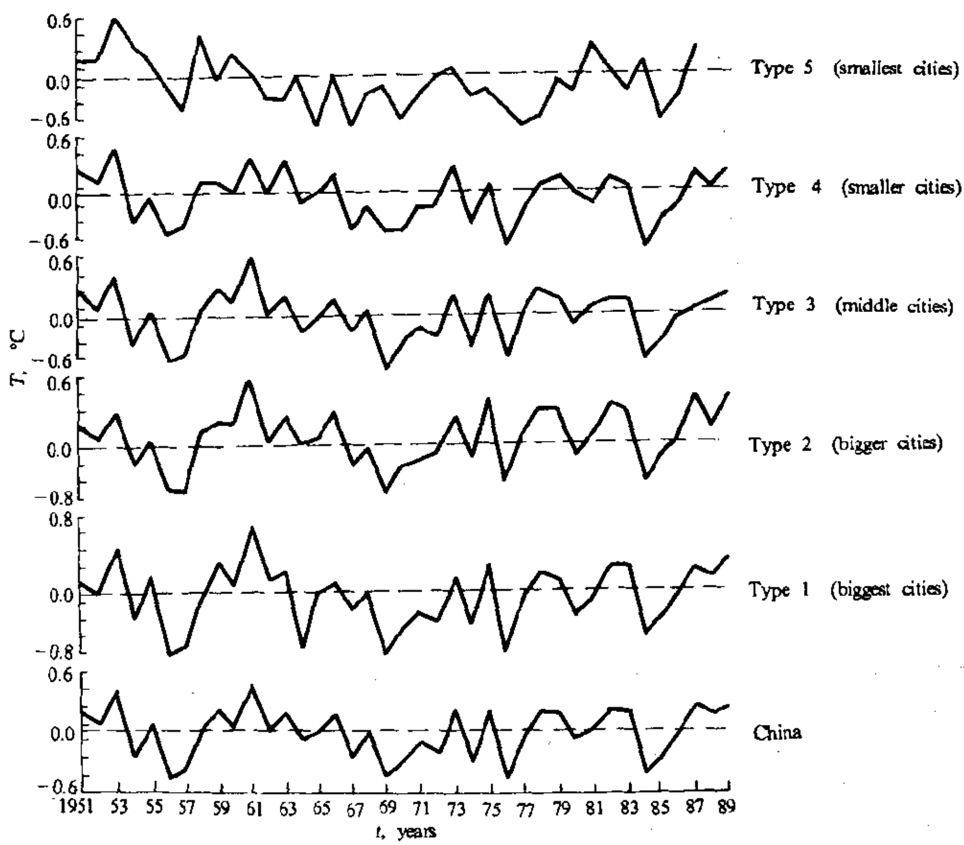

Fig. 2 Anomalies of the annual mean temperatures in China and for five types of cities during 1951 to 1989 (unit: ℃). The solid lines express the anomalies of the annual temperature and the dashed lines express the linear trends of the temperature.

Table 2 also shows the urbanization effects in China. Several facts are shown in Table 2. At first, the warming in the bigger cities (type 1 and 2) were more obvious than in the middle (type 3) and smaller cities (type. 4 and 5) in the annual means and winter, spring, autumn by about +0.1 ℃ to +0.5 ℃ . Secondly, the cooling in the biggest cities (type 1) were more obvious than in the middle (type 3) and smaller cities (type 4 and 5) in summer by about −0.1 ℃ to −0.2 ℃ . It is noticed in Table 2 that the bigger cities (type 2) were warming more obviously than the biggest cities (type 1) for four seasons and the annual mean. This fact might be the most cities of type 2 locate in north China and the warming in north China was significant in four seasons during the last 39 years. Another reason might be the different rates of population growth between type 1 and 2 from 1951 to 1988. Section 6 will give some analyses.

The meteorological data showed that an obvious warming about 1−2 ℃ in the north China and cooling of about −0. 1 to −0.5 ℃ in the south China from 1951 to 1989. Oppositely, a cooling pattern in the most part of China in summer and autumn from 1951 to 1980 occurred.

CHANGE OF PRECIPITATION

Similar to the analyses of temperature, the linear trends of the annual and seasonal total precipitation over China and for five types during the last 39 years have also been analyzed. Table 3 shows those results.

Table 3 The linear trends of the annual and seasonal total precipitation in China and for five types from 1951 to 1989 (39 years, mm)

Type	China	1	2	3	4	5
Annual values	−50	−84	−65	−32	−41	−57
Spring	−7	−17	1	3	−17	0
Summer	−38	−52	−49	−34	−21	−46
Autumn	1	−11	−10	6	5	−7
Winter	−7	−5	−7	−6	−9	−4

Table 3 shows that over China, the dry trends have been noticed for the annual and most seasonal precipitation during 1951 to 1989, especially in summer decreased by 38 mm. The precipitation in autumn increased by 1 mm.

It is also found in Table 3 that the precipitation for five types during 1951 to 1989 decreased, especially in summer. China is a monsoon country. Therefore, the precipitations in summer are important for China. The dry trends in summer over China and for five types of cities during 1951 to 1989 should be paid attention to those situations. It is emphasized that the dry trends in the bigger cities (type 1 and 2) in annual precipitation and summer were more significant than those in the middle (type 3) and smaller cities (type 4 and 5) .

The meteorological data showed that the anomalies of the annual and seasonal precipitation of China from 1951 to 1989. It was getting drought by about −100mm along the Yellow River Valley and south China from 1951−1989 in the annual mean and summer. At the same time, the wet areas by about +100 mm located in the Yangtze River Valley.

RELATIONSHIPS BETWEEN SEASONAL-ANNUAL TEMPERATURE AND PRECIPITATION

The relationships between seasonal-annual temperature and precipitation during the last 39 years were investigated. The correlation coefficients between seasonal-annual temperature and precipitation were calculated. The meteorological data showed that the negative correlations occurred in the annual and most seasonal patterns, especially in the annual and summer patterns in the Yangtze River Valley, northeastern and northwestern China. It means that in those areas the warmer climates corresponded to the drier climates during the last 39 years in annual and summer time.

ANALYSES OF POSSIBLE URBANIZATION EFFECT

The climatic change in different types of cities in China might relate to the development of population in cities. As mentioned above, 160 stations have been separated into five types. Table 4 presents the numbers of cities for five types in 1949 and 1988. It is found that both type 1 and 2 in 1949 only had 12 cities, 7.5% of the total cities; but 39 cities in 1988, 24.4% of the total cities. Type 3 had also increased from 21 cities in 1949 to 64 cities in 1988. It was noticed that type 5 in 1949 had 73 cities, 45.6% of the total cities; but 5 cities in 1988, 3.1% of the total cities.

Table 4 The numbers of cities for five types in China

Type of city	1	2	3	4	5	Total
1949	5	7	21	54	73	160
1988	24	15	64	52	5	160

It should be pointed out that all of 15 cities for type 2 in 1988 were from type 5(6% of 15 cities), type 4 (47% of 15 cities) and type 3 (47% of 15 cities) in 1949, respectively. Therefore, the warming was more obvious in some cities (Type 2) than that in the others (Type 1).

CONCLUSION AND DISCUSSION

As mentioned above, it was getting warmer and drier over China during the last 39 years, especially in the north China. The research also indicated that the warming and drying characteristics were more obvious in the bigger cities than that in smaller cities.

The reasons of warming and drying during the last 39 years of China were not investigated in this study. The further studies will be focused on this field.

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