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Effect of Urbanization on Climate Change in Nanjing

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Abstract: This paper chose urbanization and climate change of Nanjing city as the research object, by using trend analysis, correlation analysis, multivariate linear regression analysis and other methods, using the climate data and social statistical data of 1951~2011 observation stations in Nanjing City, analyzing the trend of city climate change and the correlation between different parameters and main climate factors. Results show that, the warming trend in Nanjing is very weak, the mainly temperature change is a rising temperature in winter, while it was not obvious in summer, reduce the heat wave phenomenon, the average year temperature has increased slightly; over the years precipitation showed increasing trend, the sunlight hours was decreasing, in addition to the city dark island effect. Through the analysis of the relationships between urbanization and climatic factors found that close relations between urbanization and annual mean temperature, and its impact is significant, and the impact of extreme minimum temperature is not very obvious, but the but the influence of extreme maximum temperature is obvious. In addition, in the analysis of Nanjing found that years of reform and opening up has become theories of demarcation point climate change trends and impacts of urbanization on climate change, before and after the cut-off point on climate change and the effects of urbanization on climate change have has the remarkable differences, the reason and mechanism still need further analysis and discussion.

Keywords: Nanjing City, urbanization, climate change

1 Introduction

Nanjing is located in the middle of the lower reaches of the Yangtze River, the east of China, a national and regional center city in china at 118°22′~ 119°14′E， 31°14′~ 32°37′N, belongs to the northern subtropics monsoon climate zone, four seasons, mild climate, moderate rainfall. In recent years, urbanization has been developing rapidly in Nanjing, the population surged from 1.56 million in the period of reform and opening up to 8 million in 2011. And In economic terms, the GDP of Nanjing developed from 17.7 billion RMB in the 90s last century to 614.6 billion RMB in 2011, got great development of urban economy. But at the same time, climate

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change and environmental quality of Nanjing urbanization cause for worry.

2 Research materials and methods

The climate data of observation stations in Nanjing during 1951~2011 is used in this article. Select extreme maximum temperature and extreme minimum temperature, average temperature, annual precipitation and sunshine time in each year as analysis object. The data of economic index from the Nanjing Statistical Bureau in 1951 ~2011, selection of related parameters of population, GDP, and municipal construction as the research object. Research methods mainly use the trend analysis, correlation analysis and multiple linear regression analysis, etc.

3 Climate change of Nanjing in recent decades

3.1 The tendency of temperature in Nanjing in recent 60 years

Trend analysis method is used to discuss the change of extreme high temperature, extreme minimum temperature, average temperature in 1951~2011. The result is shown in Fig. 1 and Fig. 2. As can be seen from the Fig. 1, over the past 60 years, the years of highest temperature in Nanjing were mainly in the sixties and seventies of the 20th century and the early 21st century. Although in recent years, Nanjing's highest temperature dropped slightly, but still kept above 35℃; The minimum temperature rose to - 10 ℃ or higher, shown a tendency of warming. As can be seen from the Fig. 2, the tendency of warming is weak, the highest temperature was 17.4℃ in 2007, but in recent years also has a tendency to fall, dropped by 1.3℃ to 2011.

Judging from the comprehensive analysis of Fig. 1 and Fig. 2, in the context of global warming, The temperature in Nanjing in the past 60 years rose very weak, the temperature change was mainly seem a rising temperature in winter and it was not very obvious in summer, but the heat wave phenomenon became less, the year average temperature had increased slightly.

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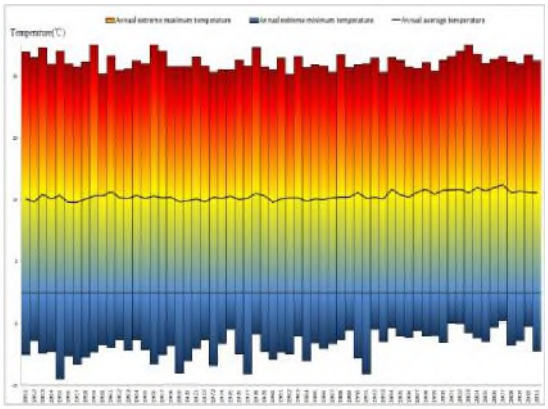

Fig. 1 Nanjing 1951~2011 annual extreme maximum temperature, minimum temperature, average temperature

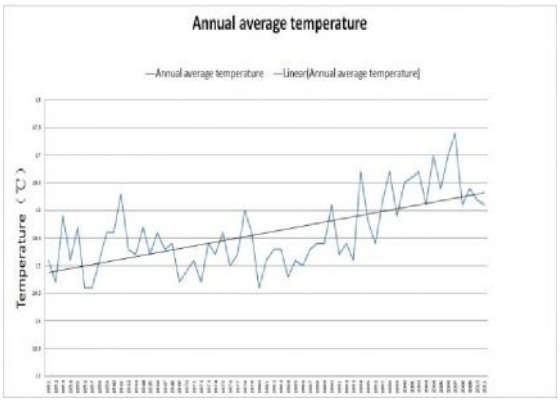

Fig. 2 the change for the trend of Nanjing 1951~2011annual average temperature

3.2 The change of precipitation and sunlight hours in Nanjing

Trend analysis method is used to analyze the change of precipitation and sunlight hours, results are shown in Fig. 3. It shows an increasing trend of precipitation in recent decades in Nanjing, precipitation increase 17.43mm every 10 years. Precipitation reached the maximum in 1991, to 1825.8 mm, while the minimum precipitation year appeared in 1978, to 534.0 mm. We take 1978 as a division point, before 1978, the trend of precipitation changed for -9.11mm/10a, and after 1978, it was changed for 36.17mm/10a, and 1978 was the year of the reform and opening up in China, so the conclusion needs further research and analysis, if the change of

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precipitation is related to development of urbanization after reform and opening up.

Inter-annual variability of sunlight hours in Nanjing is decreasing, as we can see in Fig. 3, sunlight hours decreased 66.28h every 10 years. We take 1978 as a division point, before 1978, the trend of sunlight hours changed for -43.88h/10a, and after 1978, it was changed for -17.13h/10a, since the reform and opening up, the sunlight hours reduced more slowly, this situation may be related to the progress of society and the human awareness of environmental protection, but the exact reason needs further study. But overall, the number of sunlight hours in Nanjing continues decreasing, reflecting the effect of city dark island, which may be caused by the process of urbanization and other environmental pollution that are inseparable.

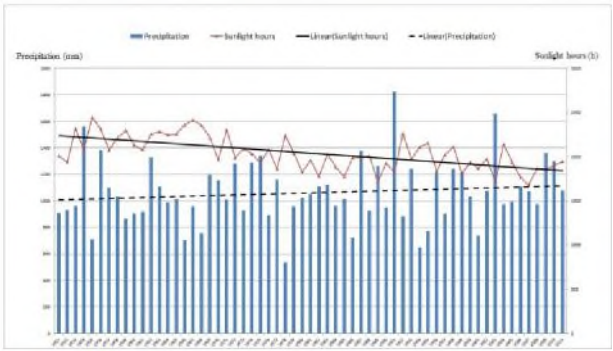

Fig. 3 the interannual change and linear trend of Nanjing precipitation and sunlight hours in recent years

4 Effects of urbanization on climate change in Nanjing

4.1 Data preprocessing

Through visiting, investigation, reference the existing research results, we choose GDP (X_1)(one hundred million RMB), the first industry (X_2) (one hundred million RMB), the second industry (X_3) (one hundred million RMB), industrial (X_4) (one hundred million RMB), the tertiary industry (X_5) (one hundred million RMB), per capita GDP (X_6) (one hundred million RMB), total population (X_7)(million people), non-agricultural population (X_8) (million people), the agricultural population (X_9) (million people), road length (X_{10})(km), road area (X_{11})(Million square meters), green coverage area (X_{12})(hectare), land area (X_{13})(Thousands of hectares), the whole society passenger traffic $_{(X14)}$ and the urban consumer price index $_{(X15)}$ as the target of urbanization. And select the annual average temperature (Y_1)(0.1'C), extreme minimum temperature (Y_2) (0.1'C), extreme maximum temperature (Y_3) (0.1 'C), precipitation (Y_4) (0.1mm) and sunshine hours (Y_5)(0.1h) as the meteorological

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factors to reflect climate change.

4.2 Influence of urbanization on climate change

We use SPSS software to analyze the correlation coefficients between each urbanization index and meteorological elements in Nanjing, and we found that the total population (X_7) is the index which affects the annual average temperature greatest, and the urban consumer price index $_{(X15)}$ is the weakest one, according to the absolute value of the correlation coefficient, influence the level of the order from largest to smallest is as follows: $X_7 > X10 > X_8 > X12 > X11 > X_2 > X_6 > X_4 > X_3 > X_{13} > X_1 > X_9 > X_{14} > X_5 > X_{15}$, the agricultural population (X_9) and the urban consumer price index $_{(X15)}$ were found to be negatively correlated with the annual mean temperature (Y_1), and the correlation coefficient pass through 0.01 significant test, except the urban consumer price index (X_{15}). There is a certain effect on urban temperature from the population growth; the same regional change in land surface also had a very important influence on urban temperature.

As the same to annual average temperature, the total population (X_7) is the index which affects the extreme minimum temperature greatest, and the urban consumer price index $_{(X15)}$ is the weakest one, according to the absolute value of the correlation coefficient, influence the level of the order from largest to smallest is as follows: $X_7 > X_{13} > X_{10} > X_{12} > X_8 > X_2 > X_{11} > X_6 > X_4 X_3 > X_{14} > X_1 > X_5 > X_9 > X_{15}$, only the correlation of the total population (X_7), road length (X_{10}), green coverage area (X_{12}), land area $_{(X13)}$ and extreme minimum temperature (Y_2) pass through 0.05 significant test, but its correlation coefficient was not large, which explain the effect of urbanization on extreme minimum temperature is not significant.

The extreme maximum temperature is most affected by the road length (X_{10}), followed by green coverage area (X_{12}), the correlation coefficients were 0.435 and 0.425, both pass through the 0.05 significant test, which explain that it is significant for the influence of the regional change in land surface due to urbanization on extreme maximum temperature.

The effect of urbanization on precipitation and sunlight hours is not obvious.

5 Conclusions

In the context of climate warming, urbanization affects local climate change, which causes a series of urban environmental quality problems. With the analysis in this article, we found that the warming trend in Nanjing is very weak, the mainly temperature change is a rising temperature in winter, while it was not obvious in summer, reduce the heat wave phenomenon, the average year temperature has increased slightly; over the years, precipitation increased by 17.43mm every 10 years, but it was volatile during different periods; With the trend continues, the sunlight hours was decreasing by 66.28h every 10 years, which reflects the effect of city dark island, and this may be related inseparable to fog haze caused by environmental pollution in the course of urbanization. Also through the analysis of the relationship between urbanization and climate factors, we found that the total population, agricultural population and urban green area are close to annual average temperature, and it is significant; and the effect of urbanization on the extreme minimum

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temperature in Nanjing is not very significant, but affects extreme maximum temperature obviously, the correlation coefficients of the road length and green coverage area were 0.435 and 0.425, both pass through the 0.05 significant test, which explain that it is significant for the influence of the regional change in land surface due to urbanization on extreme maximum temperature. At last, we found that years of reform and opening-up become the theory cut-off point of the trend of climate change and the effect of urbanization on climate change, before and after the cut-off point, climate change and urbanization effect on climate change have significant differences, the reasons and related mechanism still need further analysis and discussion.

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