Impact of Climate Change on Water Resources at Local Area in Anhui Province

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Abstract

As an important component of the natural cycle, climatic change can exert a great impact on water resources which play an important role in both the natural ecosystem and people’s life and production. To understand the interdependence of climatic change and water resources, this paper analyzed the recent 50 years’ climatic and hydrologic data at three sites in Anhui province, using statistics, linear trend variation, accumulated anomaly, coefficient of variability and coefficient of association methods. The results show that the temperatures and precipitations at these three sites have been increasing at different levels, and may keep increasing in the future. Affected by temperature, precipitation, evaporation and complex landform conditions, total water resources at Ningguo and Chaohu are increasing While which at Chuzhou is decreasing slightly. In general, there is an obvious and positive correlation between precipitation and total water resources. In the past 25 years, the inter-annual heterogeneous distribution of climatic and hydrologic elements is more conspicuous than the whole period, through which extreme climate events occur more frequently

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1. Introduction

Climate is an indispensable component of the natural ecosystem, the change of which can produce a profound effect on human beings’ living environment. In the past 40 myriad years, global climate had a
periodic variation. The third IPCC global climate appraisal report [1] said that in the recent 100 years’ period, temperature was keeping an obvious increasing trend, approximately 0.5°C in total. And Zhenchun HAO et al [2], found the temperature changed conspicuously in recent 100 years in China, with a lower amplitude than the global average level. Tao TAO [3] and Jianyun Zhang et al. [4], all believed that temperature change inevitably caused the alternations of other climate factors and natural conditions, namely, glacial melting, evaporation, precipitation and so on. Climate change will alter the hydrologic cycle, and then cause the temporal and spatial redistribution of water resources, for example, the redistribution of precipitation, evaporation, runoff, soil moisture etc. And all these changes will affect the whole ecosystem and social economic development. It is essential to understand the influence of climate change on regional water circulation, so that we can make positive countermeasures in water resources management. This paper studied the climate changes at three stations in Anhui provinces.

2. Field site

Anhui province is in hinterland of East China. The Yangzi river and Huai river run over the terrene of Anhui province, and divide the province into two catchments and three areas. Anhui province has a special geographical position. It is at transition of middle latitude, transition of South—North, transition of Sea—Land, and climate condition is very sophisticated. It is north subtropical monsoon climate, temperate, humid. But the temporal and spatial distribution of precipitation is quite non-uniform. The average precipitation of long-term ranges from 800 to 1800mm. This paper analyzed the temperatures and precipitations (1955-2007) of three stations (Ningguo, Chaohu, and Chuzhou), with different latitudes and different land configurations, estimated the influence of climate change on water resources.

Ningguo site is at the south of Anhui. It is the combining site of mountain areas and lower Yangzi river basin. And the area of mountains and hills is more than 83.5% of the total. The average temperature is about 16.3°C. The average precipitation is about 1447.0mm.

Chaohu site is at the middle of Anhui province. It is north to the Yangzi river. It has an obvious surface relief, with hills and valley floodplains interlaced. The main land forms are hills, earth slopes and river basins. There lies the fifth biggest fresh lake of China—Chao lake. The average temperature is about 15.8°C. The average precipitation is approximately 1144.5mm.

Chuzhou site is at the north of Anhui province, between Yangzi and Huai River. It is separated to Yangzi river basin and Huai river basin by the hills in middle. The main land configurations are hills, earth slopes, flatlands, and water areas. The average temperature and precipitation are 15.4 °C and 955.2 mm respectively.

3. Method and analysis

This paper analyzed the temperature and precipitation of months, seasons and years of three sites from 1957 to 2007. The evaporation was calculated by Takahashi Koichiro Lang Equation [5]. It is a simple method to estimate evaporation and has a relatively widespread availability.

Takahashi Koichiro Lang Equation

\[
E = \frac{3100P}{3100 + 1.8P^2 \exp \left( \frac{-34.4T}{235.0 + P} \right)}
\]

(1)

Where, E (mm) is month evaporation, P (mm) is month precipitation, and T (°C) is month average temperature of ground surface.
Total year average water resources (mm) is

\[ W = P - E \]  

(2)

The paper calculated anomalies of annual average of every climatic and hydrologic element, like the method Meihua HUANG [6] and Jie LI et al [7] used in their studies. Combined with the latitude variations and land configurations, the influence on water resources was evaluated.

3.1. Temperature change

![Figure 1](image1.png)

Throughout the whole time-interval, temperatures of three stations had an obvious rising trend. The trend ratios of Ningguo and Chaohu were similar, rising by 0.14°C/10a in average. From middle of 1960s to middle of 1990s, they were below average. Contrarily, they were higher than average from middle of 1990s to 2007 (Fig.1). The temperature of Chuzhou station was increasing by 0.23°C every ten years in average. The average of fifty years was 15.4°C, the same with long term. At Chaohu station, the average was 16.1°C, higher than long term (15.8°C), and it was 15.56°C at Ningguo station, lower than long term (16.3°C). The change of temperature had an obvious periodic property.

3.2. Precipitation change

![Figure 2](image2.png)

With the infection of monsoon circulation flow and land configuration, precipitation had a strong
randomness. During the study time-interval, they was rising by 2.5 mm/a and 4.9 mm/a separately at Ningguo and Chaohu in average. Ningguo was slightly arid from middle of 1960s to early of 1980s and slightly humid from early of 1980s to middle of 2000s. Similarly, Chaohu was arid from middle of 1960s to late of 1970s, and humid from late of 1970s to 2007 (Fig.2). But the final trends were different. It was rising at Chaohu while it was decreasing at Ningguo station. There was an extraordinary year (1991) at Chaohu station, in which precipitation (1988.4 mm) was more than average of long term (1144.5mm) by 90.8%. If removed it from the sequence, the precipitation would have been rising and falling around the average from late of 1970s to 2007. The rising trend was obscure at Chuzhou, merely 0.5mm/a. From 1960s to 2007, it was waving at the average all the time. Compared with Ningguo and Chaohu, the anomaly of annual precipitation absolute value at Chuzhou was much bigger, and the difference was more noticeable. In the past 50 years, the average precipitation at Chuzhou was 1045.4 mm, higher than long term (955.2mm). And it was 1041.9mm at Chaohu (lower than long term —1144.5 mm ) and 1429.6mm at Ningguo station (slightly lower than long term —1447.0 mm).

3.3 Evaporation change

![Figure 3 Anomaly of annual evaporation and its 10-year running mean over in Anhui province. (a) at Ningguo station, (b) at Chaohu station, (c) at Chuzhou station](image)

The evaporation at Ningguo and Chuzhou kept rising in the past 50 years, separately by 2.0mm/10a and 8.9mm/10a. But it kept decreasing slightly at Chaohu, by 0.7mm/10a. Neglecting the contribution of 1991 flood, the trend would be rising, by 0.53mm/10a. From 1960s to early of 1980s, evaporation at Ningguo and Chaohu were higher than average, then fell down till middle of 1990s, finally, it rose up sharply and higher than average by 2007. The evaporation at Chuzhou was lower than average from 1960s to middle of 1970s, then waved at the average till late of 1990s. From 2000, it had a noticeable rising trend (Fig.3).

3.4. Water resources change

The total volume of water resources at Ningguo and Chaohu had been increasing during the study period, with speed rates of 2.3mm/a and 5.0mm/a. At Chaohu station, it had a slightly decreasing trend, with speed rate of 0.4mm/a. At Ningguo station, it was below the average from 1960s to early of 1980s, then higher than average from early of 1980s to early of 2000s, finally decreased to below average in 2007. At Chaohu station, it was up and down all the time. But on the whole, it was below the average from 1960s to early of 1970s, and above the average from early of 1970s to middle of 1990s, then below the average again until 2007. At Chuzhou site, it fluctuated around average with even variations (Fig.4).
Figure 4. Anomaly of annual water resources and its 10-year running mean over in Anhui province. (a) at Ningguo station, (b) at Chaohu station, (c) at Chuzhou station

3.5. Coefficient of inter-annual distribution heterogeneity and correlation

Table 1. Average of each factor and $C_v$ at three stations

| Factor       | Ningguo | Chaohu | Chuzhou |
|--------------|---------|--------|---------|
| Temperature  |         |        |         |
| average of long term/°C | 16.3    | 15.8   | 15.4    |
| average of 50 years/°C | 15.56   | 16.1   | 15.4    |
| $C_v$ of 50 years | 0.0296  | 0.0338 | 0.0406  |
| $C_v$ of 25 years | 0.0332  | 0.0381 | 0.0471  |
| Precipitation |         |        |         |
| average of long term/mm | 1447.0  | 1144.5 | 955.2   |
| average of 50 years/mm | 1429.6  | 1041.9 | 1045.4  |
| $C_v$ of 50 years | 0.185   | 0.238  | 0.249   |
| $C_v$ of 25 years | 0.196   | 0.238  | 0.264   |
| Evaporation   |         |        |         |
| average of 50 years/mm | 439.5   | 449.4  | 423.7   |
| $C_v$ of 50 years | 0.1124  | 0.1016 | 0.1055  |
| $C_v$ of 25 years | 0.1287  | 0.1121 | 0.1000  |
| Water resources |         |        |         |
| average of 50 years/mm | 990.1   | 592.5  | 621.7   |
| $C_v$ of 50 years | 0.298   | 0.4441 | 0.437   |
| $C_v$ of 50 years | 0.3413  | 0.5099 | 0.470   |

For temperature, compared with the whole study period, it changed more fiercely in the last 25 years at three stations, the $C_v$ was larger. Of the three, $C_v$ of Chuzhou was the largest, Chaohu in second spot, Ningguo at last. It increased with the creasing of latitude. For precipitation, the $C_v$ value changed more fiercely in the last 25 years at Ningguo and Chuzhou stations, while it stayed the same at Chaohu. This indicated that more water areas could counterweigh the influence of temperature change compared with
hilly and plain areas. The $C_v$ of precipitation increased with the creasing of latitude too. Evaporation was mainly affected by temperature, precipitation and wind speed. At Ningguo and Chaohu stations, the $C_v$ of last 25 years was larger than the whole period. But at Chuzhou station, it was contrast. The differences of the three stations were minimal.

Water resources were the difference of precipitation and evaporation. At three stations, the inter-annual inhomogeneous distribution was more obvious in last 25 years than whole period. Similarly as precipitation, the $C_v$ value grew with the creasing of latitude. There was an exception. At Chaohu station, the $C_v$ of water resources became larger while the $C_v$ of precipitation remained stable. This might be because that the noticeable rising of temperature made evaporation larger, and that the precipitation was at the lower level of history. All of these resulted that the water resources inter-annual inhomogeneous distribution was noticeable.

By analyzing the correlations of annual water resources and temperature and precipitation of corresponding period, we knew that the correlation of water resources and temperature was poor. And there was an obvious positive correlation between precipitation and water resources. The coefficients of association were separately 0.981, 0.971, 0.974 at Ningguo, Chaohu, and Chuzhou station. (Fig.5)

4. Discussion

Compared with Chaohu station, the average temperature of long term at Ningguo station was higher, but in 50 years recently, it was contrast. Why? For one thing, in long term, Ningguo was at the lower temperature period and Chaohu was at the warmer period. For the other thing, change of hydrology condition had feedback on climate, they had interrelationship with each other. Rising of temperature could cause the rising of evaporation, and make total water resources grow down. Decreasing of water areas in Chao Lake would reduce its natural regulating action on the climate, and the temperature would rise more obviously.

Although the temperatures of three stations all had a rising trend, there were still differences. Chaohu was at warmer period, Chuzhou was at average period, and Ningguo was at lower temperature period. And all these would brought different contributions to water resources. For Chaohu station, warmer weather would lead to more evaporation. As the data of 50 years shown, the evaporation of Chaohu station was the most of three. More evaporation would lead to less water resources, but in the other hand, it would bring more precipitation, and might lead to more obviously uneven inter-annual distribution.
Contribution of climate change to water resources was integrated, complicated and reciprocal. According to the general trend, in future, water resources at Ningguo station would reduce, and water resources at Chaohu and Chuzhou would rise.

5. Conclusion

As has been discussed, we can make some conclusions.

(1) Along with the global warming, 50 years recently, the temperatures of three stations in Anhui province raised at different degrees, meanly about 0.141-0.278℃ every ten years. Annual precipitations were keeping raising, amplifying Ningguo and Chaohu larger than Chuzhou. Due to the rising of temperature, there was an upward trend in evaporation at Ningguo and Chuzhou stations, but, at Chaohu, there was a slightly decreasing trend.

(2) The total water resources had a noticeable rising trend at Ningguo and Chaohu stations, by the rates of 2.3mm/a and 5.0mm/a separately, while which at Chuzhou decreased weakly with rate of 0.4mm/a. Over the last 25 years, inter-annual inhomogeneous distributions were more noticeable. The $C_v$ values were increasing with the rising of degree of latitude.

(3) Water resources was mainly contributed by precipitation. There was an obvious linear correlation between water resources and precipitation.

(4) Compared with long term, extreme climate events occurred more frequently in the past several decades. Main representations were increasing frequency of extreme storms, longer arid periods, and inter-annual inhomogeneous distribution of water resources.

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