

Analysis of Climate and Water Resources Characteristics in Chongqing

Rong Chen, Jinglan Wang and Weihua Zhang*

College of Resources and Environment, Southwest University, Chongqing, China.

*Email: swuwater@126.com

Abstract: Due to the impact of climate change, the spatial and temporal distribution of water resources has also changed accordingly. We want to know the response of Chongqing's water resources to climate change. By using the methods of linear regression and cumulative anomaly, this paper analyses the meteorological data of Chongqing from 1951 to 2018 and the climatic and hydrological conditions in recent years. It is found that Chongqing is in a period of high temperature and rainy weather under the influence of global warming, and is very prone to drought and flood disasters. This study can show the climate and water resources changes in Chongqing in the future to some extent and help the local authority for designing and operating the hydrological sensitive facilities.

1. Introduction

Climate change will inevitably cause temporal and spatial changes in water resources, and then affect the ecological environment and socio-economic development. To study the response of hydrology and water resources to climate change is of great significance in the long-term development and utilization of water resources, alleviating the contradiction between supply and demand of water resources and promoting regional economic development [1]. In the past hundred years, the earth's climate is experiencing a significant change characterized by global warming. The IPCC Fourth Climate Change Assessment Report pointed out that in the past 100 years (1906-2005), the global average surface temperature has increased by 0.74 °C. This global warming is caused by natural climate fluctuations and the enhanced greenhouse effect of human activities[2].

Under the background of global warming, climate change also has obvious regional differences [3]. Chongqing is located in the sensitive area of climate change, with complex topographic conditions, high incidence of local abnormal climate and frequent disasters. Especially in September 2004, the catastrophic rainstorm in Kai County, Chongqing, the high temperature and drought in summer 2004, and the once-in-a-century floods in some parts of Chongqing in July 2007, has already affected the region. Regional economy and people's lives have a serious impact. Previous studies have shown that Chongqing's climate change trend is unique compared with global and national climate change, and its warming lags behind. After 1990s, Chongqing showed a more significant warming trend [3].

Chongqing is located in the southwest of China, between 28 10'N to 32 13'N, 105 17'E to 110 11'E, with a total area of 824,000 km². Chongqing is situated in the southeastern part of Sichuan Basin in the upper reaches of the Yangtze River, surrounded by mountains and spanning the transition zone between the plain of the middle and lower reaches of the Yangtze River and the Qinghai-Tibet Plateau. The landform is complex and changeable. Chongqing is in low latitude and affected by the subtropical monsoon and topography. It belongs to the subtropical monsoon humid climate. There are many rivers in Chongqing, which belong to the Yangtze River system. Precipitation plays a decisive role in the seasonal variation of river runoff[4]. The scope of the study area and the meteorological stations are



shown in figure 1.



Figure 1. Scope of study area and distribution of meteorological stations

2. Data and Methods

2.1. Data

The precipitation and temperature data selected in this paper are from the climate data provided by the China Meteorological Data Network from the China Surface International Exchange Station, Shapingba and Youyang Meteorological Station in Chongqing (As shown in figure 1). The time span is 68 years (1951-2018).

2.2. Methods

(1) The linear trend of precipitation and temperature is estimated according to time series, and a linear regression equation is established: $y = bx + c$. In the formula, y is the precipitation, b is the trend of precipitation, x is the time and c is the constant. When $b > 0$, the precipitation shows an increasing trend; when $b < 0$, the precipitation shows a decreasing trend.

(2) At the same time, draw the cumulative anomaly curve of precipitation and temperature series. The cumulative anomaly at a given time is expressed as: $X = \sum_{i=1}^t (x_i - \bar{x})$, $t = 1, 2, 3, \dots, n$. The cumulative anomaly curve [4] can be drawn by calculating all the anomaly values of the series.

(3) Because there are some missing or missing data of precipitation and temperature in the two stations, linear interpolation of adjacent data is used to complete them.

3. Results and Analysis

3.1. Characteristics of Precipitation Variation

From 1951 to 2019, the annual precipitation in Chongqing fluctuated greatly. The annual average precipitation was 1224.8 mm and the annual standard deviation was 165.7 mm. Figure 2 shows that in the 68 years from 1951 to 2018, the annual precipitation was stable between 850 mm and 1600 mm, but the linear trend was not obvious because R^2 is too small ($R^2 = 0.0026$). The maximum value was 1539.3 mm in 2016 and the minimum value was 896.1 mm in 2011.

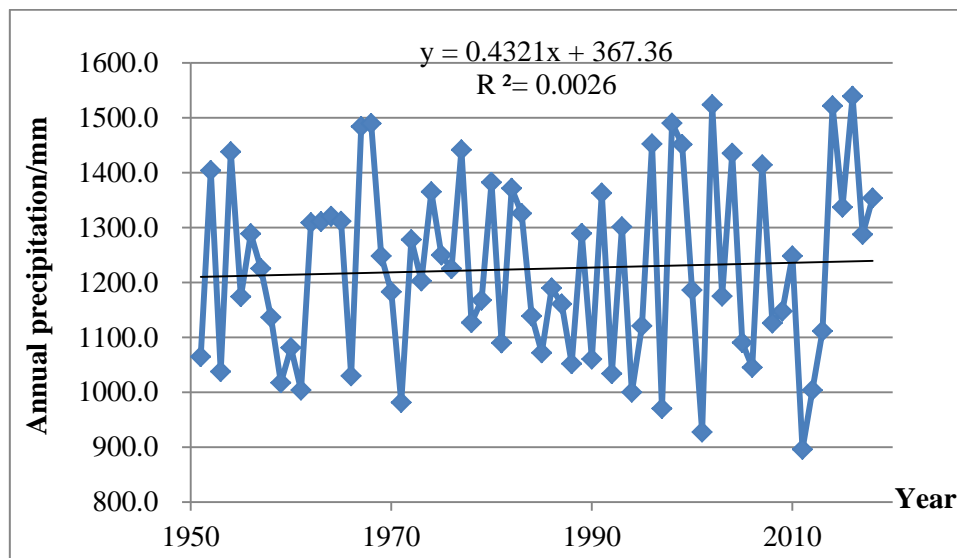


Figure 2. Annual precipitation change of Chongqing from 1951 to 2018

As shown in figure 3, from the annual precipitation cumulative anomaly curve, it can be found that there are several distinct high and low water years in these 68 years from 1951 to 2018. The low-water year group is from the mid-1950s to the early 1960s, the early 1980s to the late 1990s, and the beginning of the decade to the beginning of the decade; the high-water year group is from the early 1960s to the early 1980s, the middle and late 1990s to the beginning of the century and the beginning of the decade to the present.

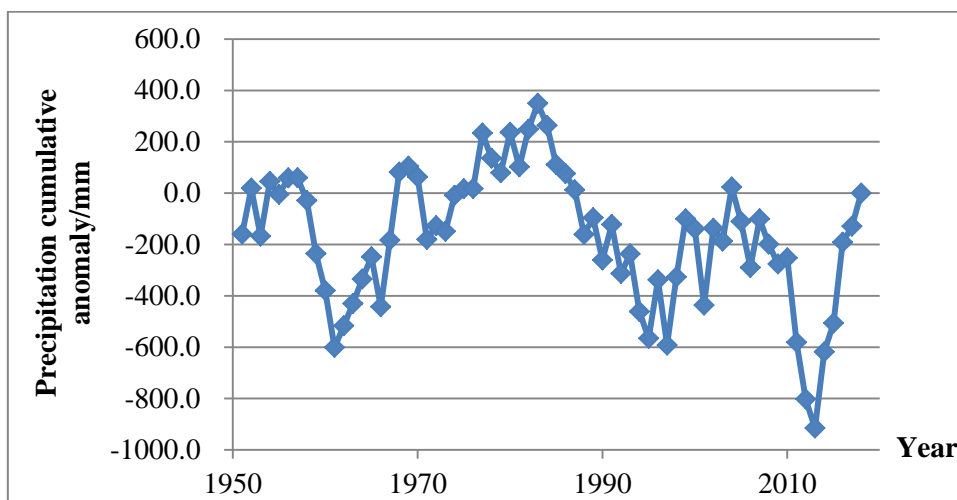


Figure 3. Precipitation cumulative anomaly curve

3.2. Characteristics of Temperature Variation

From figure 4, it can be seen that the annual average temperature in Chongqing has increased steadily and slightly in the past 68 years (the variation rate is 0.0093 °C per a), the annual average temperature is 16.7 °C, and the annual standard deviation is 0.4 °C. The highest temperature in history appeared in 2006, which was 17.6 °C. The lowest temperature of 16.1 °C appeared in 1989, 1984, 1982, 1976 and 1954. The difference between the highest temperature and the lowest temperature was 1.5 °C.

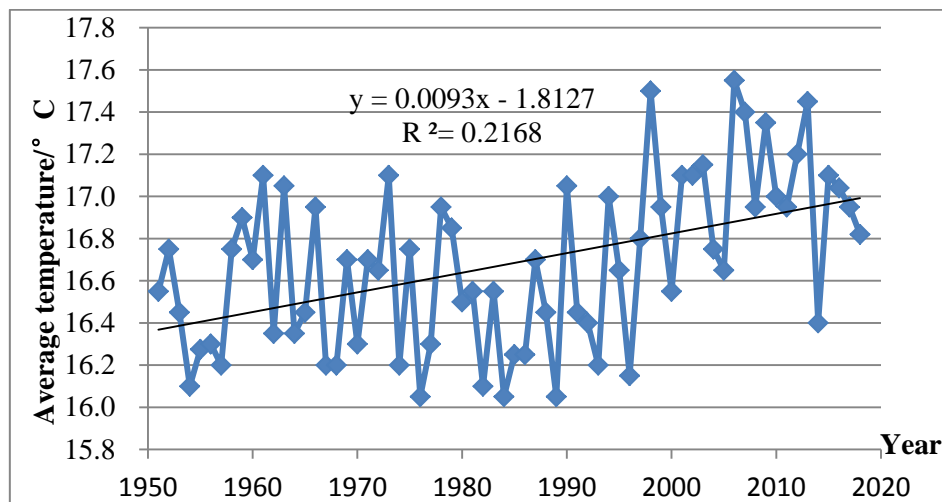


Figure 4. Annual average temperature change of Chongqing from 1951 to 2018

As can be seen from figure 5, the cumulative anomaly curve of average temperature presents a "V" shape on the whole, with only one inflection point in the mid-1950s. From the early 1950s to the mid-1950s, there was a very short period of low temperature, and from the mid-1950s to the early 1960s, it was also a very short period of high temperature. Then from the early 1960s to the mid-1990s, it was a long period of low temperature, and from the mid-1990s to now, it has been in a high temperature period, indicating that Chongqing is currently in a relatively warm period, the warming trend is very obvious, which also responds to the global warming situation in recent years.

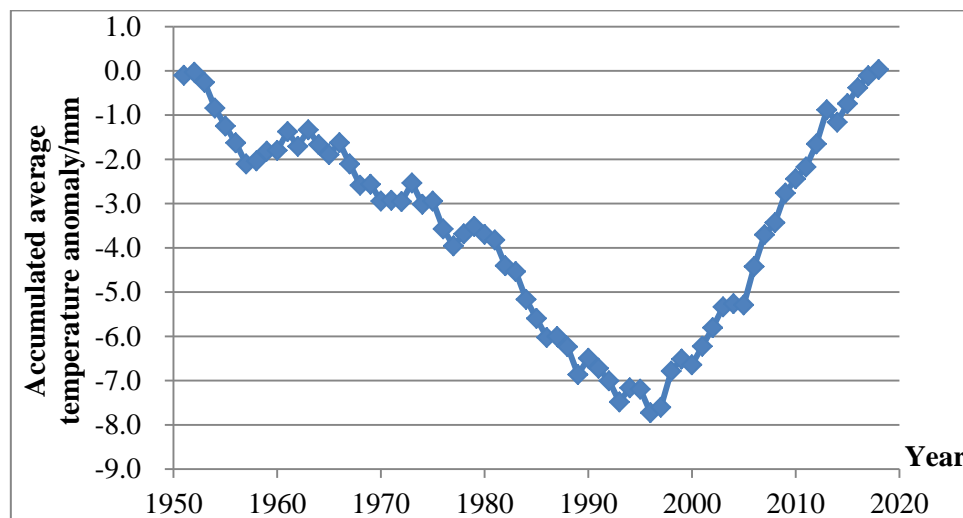


Figure 5. Accumulated anomaly curve of average temperature

3.3. Effects of Precipitation and Temperature on Drought and Flood Disasters

As can be seen from figure 6, although the annual precipitation in Chongqing is very large, the annual distribution is extremely uneven. The precipitation is mainly concentrated in May-September, and the high temperature weather also occurs in July-August. When the precipitation reaches its peak in June, the temperature reaches its peak in July, which well reflects the characteristics of the same period of rain and heat in Chongqing.

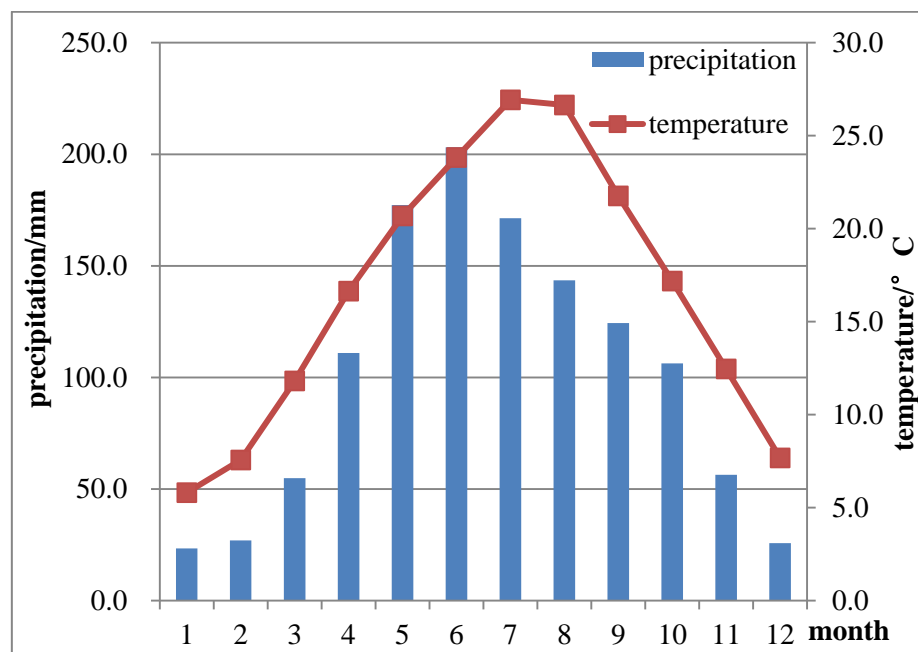


Figure 6. Monthly variation of precipitation and temperature in Chongqing from 1951 to 2018

Because of the concentration of precipitation, the instantaneous rainstorm is easy to cause disasters, so the rainstorm is the most important factor for the formation of urban floods in Chongqing. From the records of Shapingba Meteorological Station in 1951-2018, the extreme precipitation in the main urban area of Chongqing has changed remarkably in the last ten years from the end of the 20th century to the beginning of the 21st century. On July 21, 1996, the rainfall was 206.1 mm, which was the historical maximum since Shapingba Meteorological Station was built in the main urban area. Although the rainfall of 190.1 mm on June 14, 2002 failed to break the record of 1996, it was still destructive and caused great losses. The rainfall on July 17, 2007 was 266.6 mm, which was the highest record recorded by meteorological data in the main urban area of Chongqing in the past 115 years. It broke the record of one-day precipitation set in 1996, causing mountain torrents and urban waterlogging, resulting in serious economic losses and casualties[5, 6]. And these floods almost occurred in May to September when precipitation was concentrated.

Because the precipitation in the year is mainly concentrated in May-September, and the precipitation from November to March is very little, Chongqing will suffer a large area of drought in these months in a year. It also shows that winter drought and spring drought are more common in Chongqing. At the same time, Chongqing is in a high temperature period from June to August. Although the precipitation during this period is relatively rich, there will also be severe summer drought in some area. Due to the change of precipitation, there are floods in some areas every year, and the drought with the greatest impact is spring drought, summer drought and autumn drought, and the duration of drought and flood is long. In the past 40 years, drought is more serious than flood in Chongqing[7-10].

4. Conclusion

(1)The annual precipitation in Chongqing has fluctuated much in the past 68 years, but there are several distinct groups of high and low water years, which span about 10 years. In the past 10 years, Chongqing has been in a high water year group. I think in the next few years, Chongqing may enter a low water years period.

(2)The annual average temperature in Chongqing has a slight upward trend in the fluctuation of 68 years. It is a long low temperature period from 1960 to 1996 and a long high temperature period since 1996 to now, which also corresponds to global warming. And I think the temperature in Chongqing will keep going up in the future.

(3) Although the annual precipitation in Chongqing is very large, the annual distribution of precipitation is extremely uneven, and the precipitation is concentrated in May to September, which is very prone to flood disasters. While in November and March of the following year, winter drought and spring drought are prone to occur because of the low precipitation.

(4) In the future, the temperature in Chongqing is likely to continue to rise, and the precipitation is likely to continue to be low, which will lead to frequent droughts, so we should make preparations in advance.

5. Acknowledgement

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