Comparative Analysis of Precipitation Variation Characteristics between Subtropical Monsoon Climate and Temperate Monsoon Climate—Take Changsha and Chengde for Example

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Using the methods of literature review, regression analysis and moving average, this paper selects the daily precipitation of Changsha and Chengde from 1951 to 1986 as samples, and analyzes the average precipitation, precipitation frequency, precipitation intensity, extreme precipitation time and other indicators of Changsha and Chengde from the perspective of interannual and seasonal changes Trends. The researches show that: the average precipitation of Changsha in the 36 years is 1151.2mm, spring is the wet season, autumn and winter are the dry seasons, and the maximum average precipitation is in spring; the average annual precipitation, precipitation frequency in spring, summer and winter, annual precipitation frequency, annual precipitation intensity and extreme precipitation events show a decreasing trend. The average annual precipitation of Chengde city is 454.1 mm, wet season in summer and dry season in spring, autumn and winter; the average annual precipitation, precipitation in four seasons, annual precipitation frequency, precipitation frequency in spring, autumn and winter, annual precipitation intensity and extreme precipitation events show a decreasing trend, while the precipitation frequency in summer shows an increasing trend. The study of regional climate change based on the time series data of this stage is of great significance to comprehensively understand the law of regional climate change and predict the future trend of climate change.

Keyword:Precipitation; Precipitation frequency; Precipitation intensity; Extreme precipitation events
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BACKGROUND

Ecosystem is the material basis and condition for human survival and development. With the increase of global climate change events, climate issues have become the focus of the international community. The change of ecological environment presents a certain regularity in time series. The impact of global climate change on different regions is different. The production activities of human society also have a certain impact on the ecological environment.

Historical Background

From 1950s to 1980s, the rapid development of global industrialization and urbanization brought serious harm to the natural environment and human health. Environmental degradation has developed to a global scale, and the pollution problem in developing countries is particularly serious. This stage is from the first "Five Year Plan" to the sixth "Five Year Plan", which is a tortuous exploration stage and a recovery development stage of China's people's livelihood construction.

"Five Year Plan" refers to the planning of the distribution of productivity of major construction projects in China and the important proportion of

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the national economy, and the setting of goals and directions for the long-term development of the national economy[1]. Since then, the Chinese government has paid more and more attention to people's livelihood, breaking through the thinking mode and construction mode of "production before life", and paying more attention to the harmonious coexistence between human society and the natural environment.

Sample Site Background

The sample data are from the meteorological data of Changsha meteorological station (station number 57687) in Hunan Province and Chengde meteorological station (station number 54423) in Hebei Province from 1951 to 1986.

As the capital of Hunan Province, Changsha is not only the political, economic, cultural and transportation center of the province, the national historical and cultural city, but also one of the famous tourist cities in China. Combined with the 12th National "Five Year Plan" and even the medium and long-term development, the state approved the Changsha Zhuzhou Xiangtan Urban Agglomeration to become a resource-saving and environment-friendly comprehensive reform pilot area in 2007. Changsha is cold in winter and hot in summer, short in spring and autumn, and long in winter and summer, which is typical features of subtropical continental monsoon climate [2]. The annual average temperature is 17.2 ℃, the coldest in January, with an average of 4.7 ℃, and the hottest in July, with an average of 29.4 ℃. The frost free period is 275 days and the snow covered day is 6 days. The annual precipitation is 1360 mm, and the annual average rainy days are 152 days, but the rainfall is more from March to May. Changsha is located in the northern center of "Changsha Zhuzhou Xiangtan Urban Agglomeration" and the economic and traffic node of central China. The environmental and ecological requirements of Changsha are significantly higher than other cities.

Chengde, located in the northeast of Hebei Province, is the largest central city in Hebei Province. Chengde is not only a national historical and cultural city, a national key scenic spot, but also the back garden of Beijing Tianjin Hebei metropolitan area, with the unique location advantage of "one city connecting five provinces". Chengde city belongs to temperate continental monsoon mountain climate. The annual average temperature of Chengde city is 5.0 ℃ - 9.0 ℃, and the annual precipitation is 300 mm-850 mm. The distribution difference is large, and it basically decreases from southeast to northwest. Due to the influence of monsoon circulation, the seasonal distribution of precipitation in the whole city is uneven. The precipitation is mainly concentrated in summer, and there is little rain and snow in winter and spring. The evaporation of the whole city is 1500mm, which is more than twice of the annual precipitation. The dominant ecological functions of Chengde city are water conservation functional area and windbreak and sand fixation functional area, and their ecological functions are very obvious. There are more than 30 forest parks and wetland parks above the provincial level in Chengde City, which can not only adjust the surrounding climate, but also be an important ecological barrier in Beijing Tianjin Hebei region. The annual precipitation in this region is more than 500mm. As Chengde city is located in the economic center of northern China, its ecological environment requirements are more prominent.

Research Background

In recent years, many scholars have done a lot of research on this aspect in different regions: Zhan Yunjian et al. calculated the linear change trend of precipitation index in East Asia by using the longitude and latitude grid area weighted average method and the calculation method of each station separately. Li Hongmei et al. analyzed the change of precipitation characteristics in summer in eastern China by using trend analysis, composite analysis and Mann Kendall climate catastrophe monitoring method[3]. Chen Yonglin analyzed the variation characteristics and trend of precipitation in Ganzhou City in the past 60 years by selecting the average precipitation, precipitation frequency, precipitation intensity, extreme precipitation events and maximum daily precipitation and other indicators [4]. Meng Xiujing et al. studied the temperature and precipitation in Hexi Corridor from 1995 to 2011 by using running average, linear regression and other trend analysis methods as well as Mann Kendall, Pettitt and cumulative anomaly test methods[5]. Li Miao et al. used wavelet analysis to analyze the interannual variation time series of precipitation in Beijing in recent 300 years, revealed the periodic law of precipitation change in this area, and predicted the future precipitation change[6]. Zhang Jianming et al. analyzed the spatiotemporal distribution characteristics of precipitation in Hunan Province using monthly precipitation data[7]. Liao Hongling et al. used linear regression, precipitation accumulation anomaly, wavelet analysis and other methods to analyze the precipitation variation characteristics of 17 county meteorological stations in Ganzhou City from 1959 to 2007 [8]. In recent years, most of the related researches focus on the monthly mean value change and mutation analysis of precipitation, while the daily change data of precipitation are few. The main research methods are mutation test, trend prediction, wavelet analysis and other statistical methods.

Based on the daily precipitation data of Changsha and Chengde from 1951 to 1986, this paper analyzed the variation characteristics and trends of the average precipitation, precipitation frequency, precipitation intensity, extreme

precipitation events and other indicators, which provided the reference resources for the study of water resources utilization and ecological environment evolution of Changsha Zhuzhou Xiangtan Urban Agglomeration, Dongting Lake region and the middle and lower reaches of the Yangtze River. It also provides a reference for the study of ecological problems in the north of Beijing Tianjin Hebei metropolitan area, water resources crisis, spatial distribution contradiction of water resources, waterlogging in the South and drought.

DATA PROCESSING AND RESEARCH METHODS

Data Sources and Processing

The research data are from the National Meteorological Information Center. Changsha (District Station No. 57696) and Chengde (District Station No. 54423) are selected by the meteorological stations. The data are from January 1, 1951 to December 31, 1986. Each station has 13140 daily precipitation data. A total of 26280 daily precipitation data of the two stations are sorted out, and the blank and missing data are interpolated according to the regression method The pure fog, dew, frost, snow and sleet are converted into equivalent precipitation. The calculation time of annual average value is from January 1 to December 31 of the current year, and the calculation time of seasonal average value is spring from March to may, summer from June to August, autumn from September to November, and winter from December to February. This paper analyzes the variation of precipitation characteristics of sample cities in North and South China from the perspective of trend change and decadal seasonal change. Research indicators include precipitation, precipitation frequency, precipitation intensity and extreme precipitation events [9]. Precipitation frequency is the percentage of days with precipitation in total days [10]; annual precipitation intensity is the average value of daily precipitation of days with precipitation; extreme precipitation event is the precipitation event when the daily precipitation of a station exceeds the threshold of extreme precipitation. Due to the regional differences of precipitation in different regions, the thresholds of extreme precipitation in the two places are determined by the local precipitation.

Research Methods

Regression analysis

Regression analysis is a method used to find the statistical relationship between several variables, using the statistical relationship to estimate the future time of a variable. Linear regression method is used to estimate the long-term trend of precipitation. In the study of precipitation, one variable linear regression is often used.The regression function can be expressed as:

$$P = \alpha_0 + kt \quad (1)$$

P is precipitation; α_0 is constant, K is precipitation trend rate, t is time. The unit of annual precipitation is millimeter(mm). When k > 0, it means that the precipitation increases with time. When k < 0, the precipitation decreases with time.

2.2.2 Sliding t-test

In order to discuss the possible periodic changes between years, this study uses the sliding t-test to check the significance.The formula is as follows:

$$t=\frac{\bar{x}_1-\bar{x}_2}{s\sqrt{1/n_1+1/n_2}} \quad (2)$$

$$s=\sqrt{\frac{(n_1-1)s_1^2+(n_2-1)s_2^2}{n_1+n_2-2}} \quad (3)$$

t is the deviation statistic between the sample mean and the population mean; s is the variance; $\bar{x}$ is the mean; n_1、n_2 is the year. After many calculations and verification, here the value of n_1、n_2 is 5; $\bar{x}_1$、$\bar{x}_2$ and s_1^2、s_2^2 are the mean and variance of the five years before and after.

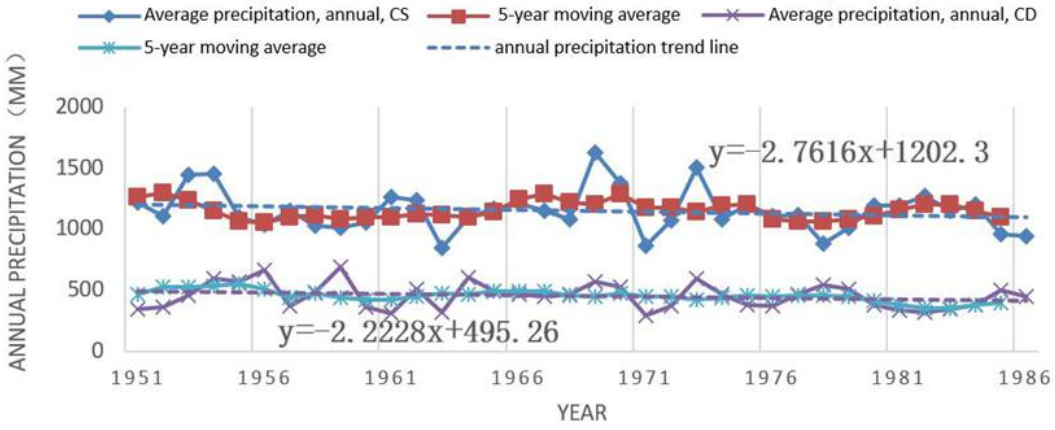
RESULT ANALYSIS

Time Variation and Trend Analysis of Precipitation

From the analysis of the annual average precipitation change trend of Changsha and Chengde in Figure 1, it can be seen that the precipitation in Changsha basically presents a gentle downward trend in the past 36 years, and the precipitation change trend line is gentle, with the annual average precipitation of 1151.2 mm. According to the 5-year moving average, the average precipitation has 4 peaks (1951-1953, 1964-1971, 1973-1976, 1980-1985) and 2 troughs (1953-1964, 1976-1980). The maximum average precipitation occurred in 1969 and the minimum in 1963. In the past 36 years, the precipitation of Chengde city also showed a gentle downward trend, the trend line of precipitation change was gentle, and the average annual precipitation was 454.1 mm. According to the 5-year moving average, the average precipitation has 4 peaks (1952-1957, 1965-1968, 1969-1971, 1975-1979) and 3 troughs (1957-1963, 1973-1974, 1980-1985). The maximum average precipitation occurred in 1959

and the minimum in 1971.

Fig. 1. Variation trend of annual precipitation in Changsha and Chengde from 1951 to 1986.



From the perspective of seasonal variation (Fig. 2a, 2b, 2C, 2D), Changsha has wet season in spring, dry season in autumn and winter, and summer precipitation is flat every year; the maximum average precipitation is in spring, with an average of 1865.5mm in 36 years; the minimum average precipitation is in winter, with 648.4mm, 728.8mm in autumn and 1362.4mm in summer. From the change trend of 36 years, the precipitation decreased the fastest in spring, increased slowly in summer and winter, and decreased slowly in autumn. Chengde city has wet season in summer and dry season in spring and autumn and winter; the maximum average precipitation is in summer, with an average of 1268mm in 36 years; the minimum average precipitation is 29.7mm in winter, 247.4mm in spring and 267.5mm in autumn. From the change trend of 36 years, the precipitation in four seasons decreased, and the precipitation in summer decreased most obviously.

Fig.2a. Variation characteristics of spring average precipitation in Changsha and Chengde from 1951 to 1986

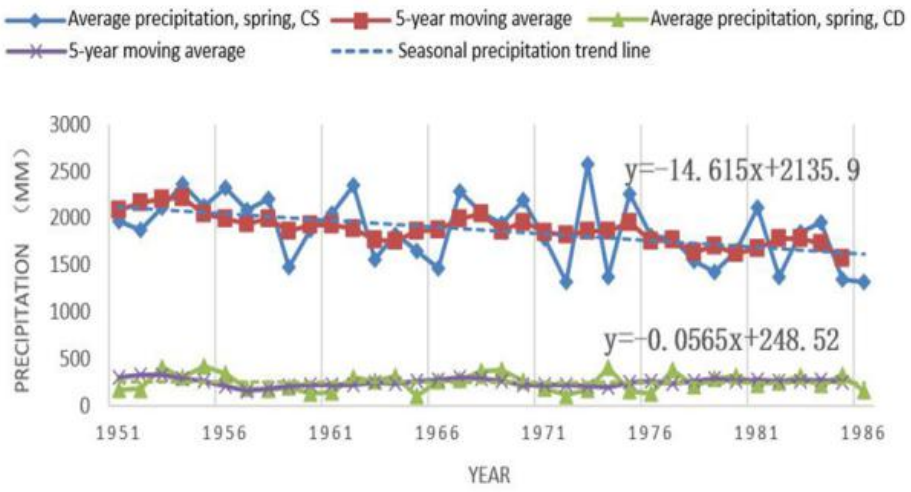


Fig.2b. Variation characteristics of summer average precipitation in Changsha and Chengde from 1951 to 1986.

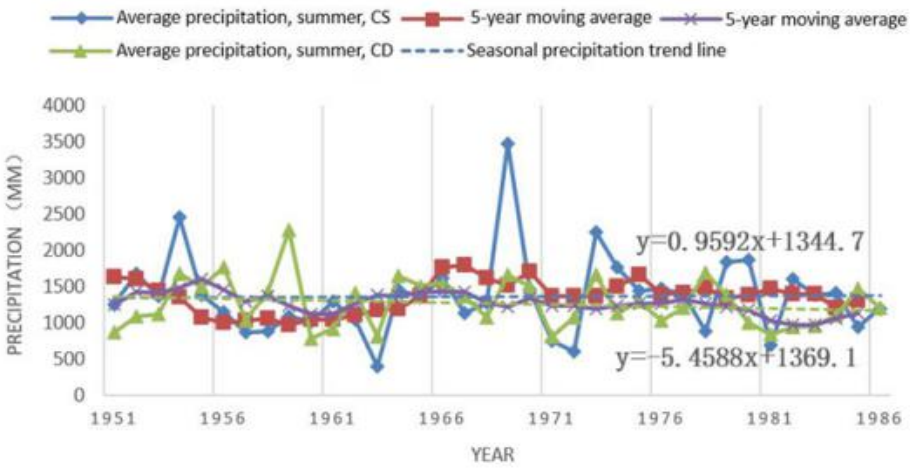


Fig.2c. Variation characteristics of autumn average precipitation in Changsha and Chengde from 1951 to 1986.

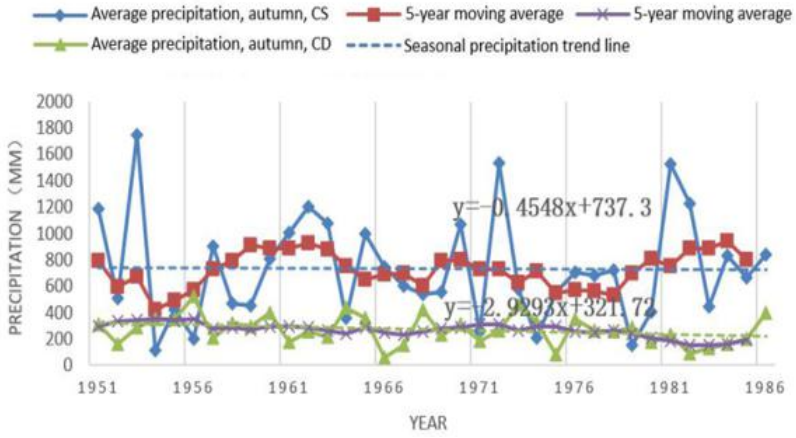
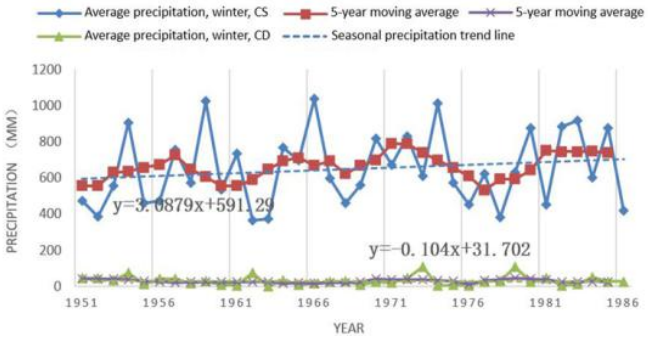


Fig.2d. Variation characteristics of winter average precipitation in Changsha and Chengde from 1951 to 1986.

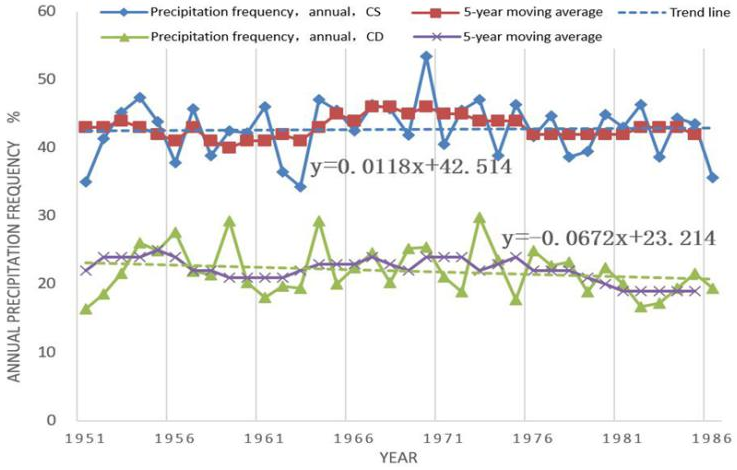


Time Variation and Trend Analysis of Precipitation Frequency

From the perspective of annual precipitation

frequency (Fig 3): in recent 36 years, the annual precipitation frequency of Changsha City shows an overall flat trend, with an average annual precipitation frequency of 43%, the maximum precipitation frequency of 53% in 1970 and the minimum of 34% in 1963. The 5-year moving average shows that the periods with high precipitation frequency are 1952-1953 and 1965-1975. The annual precipitation frequency of Chengde city presents a slow downward trend, the average precipitation frequency is 22%, the maximum precipitation frequency is 30% in 1973, and the minimum is 16% in 1951. The 5-year moving average shows that the periods with high precipitation frequency are 1952-1956 and 1964-1975.

Fig. 3. Variation trend of annual average precipitation frequency in Changsha and Chengde from 1951 to 1986.



From the seasonal precipitation frequency of the two cities (Fig. 4a, 4b, 4c, 4d), it can be seen that the precipitation frequency of spring, summer and winter in Changsha shows a slow downward trend, in which the precipitation frequency in spring is the largest, with an average of 59% for many years, and that in autumn is the smallest, with an average of 34% for many years. The precipitation frequency in spring, autumn and winter of Chengde city shows a slow downward trend, in which the precipitation frequency in summer is the largest and shows an upward trend, with an average of 46% for many years; the precipitation frequency in winter is the smallest, with an average of 6% for many years.

Fig. 4a. Variation trend of spring average precipitation frequency in Changsha and Chengde from 1951 to 1986.

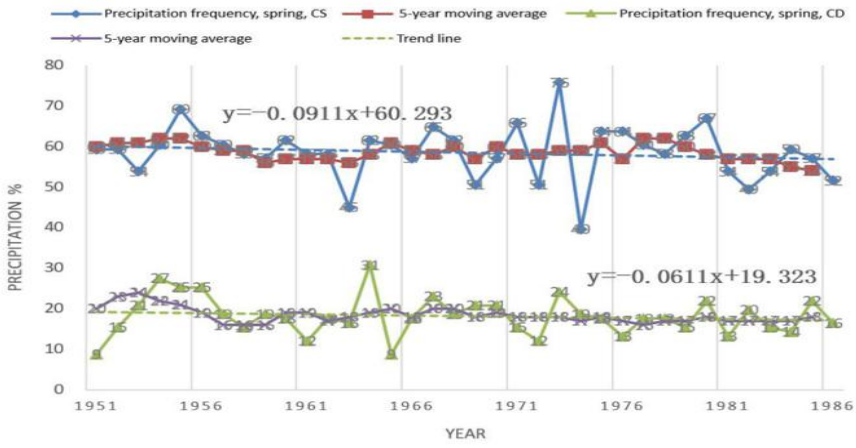


Fig. 4b. Variation trend of summer average precipitation frequency in Changsha and Chengde from 1951 to 1986.

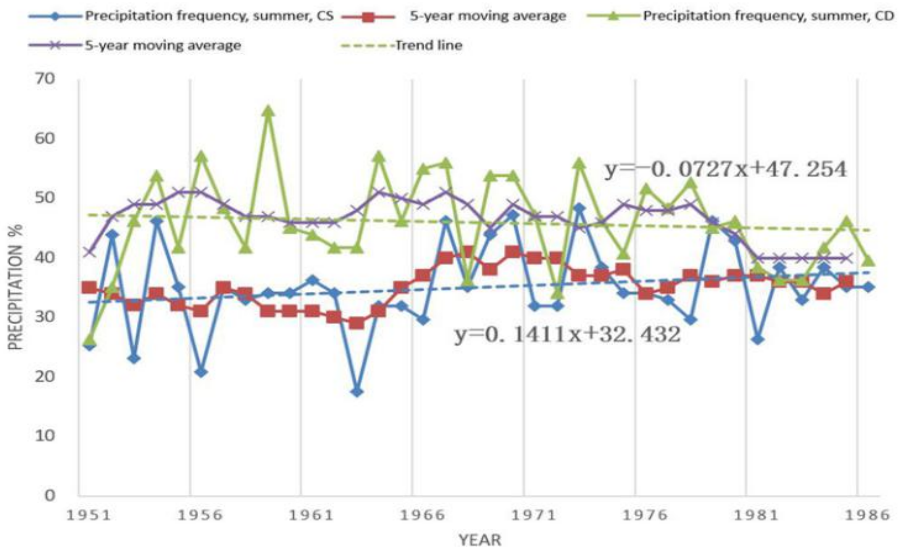


Fig. 4c. Variation trend of autumn average precipitation frequency in Changsha and Chengde from 1951 to 1986.

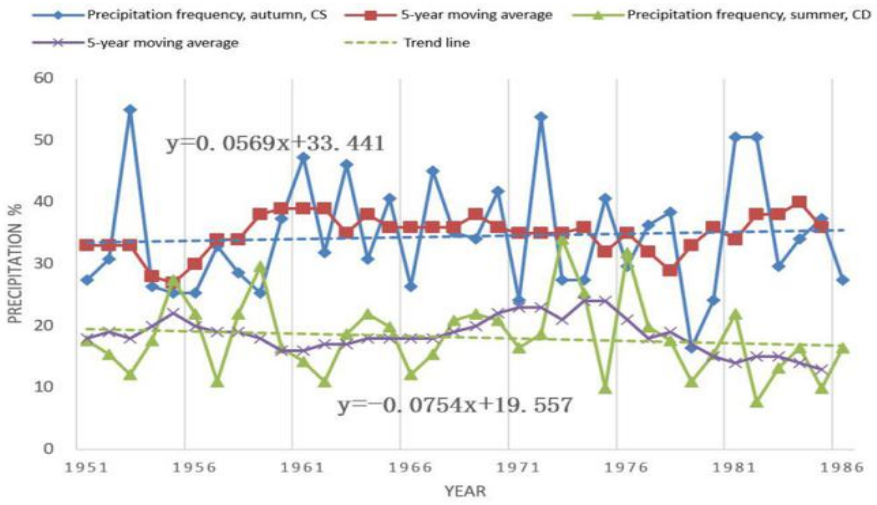
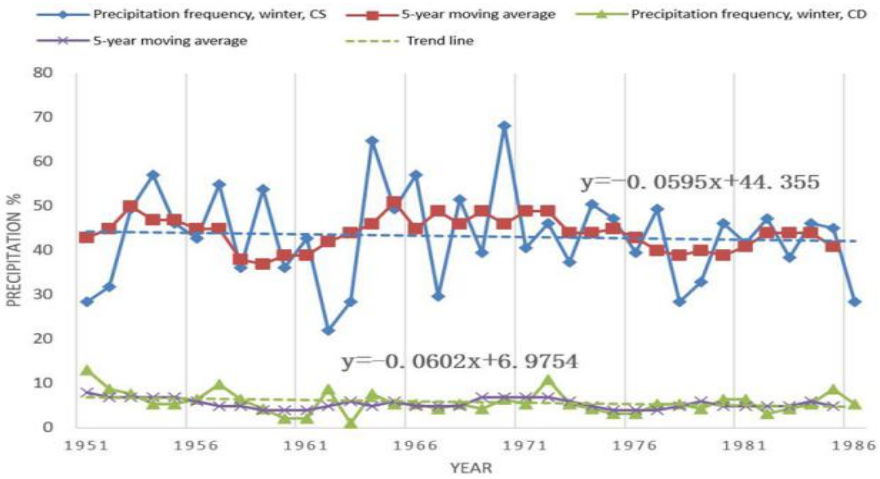


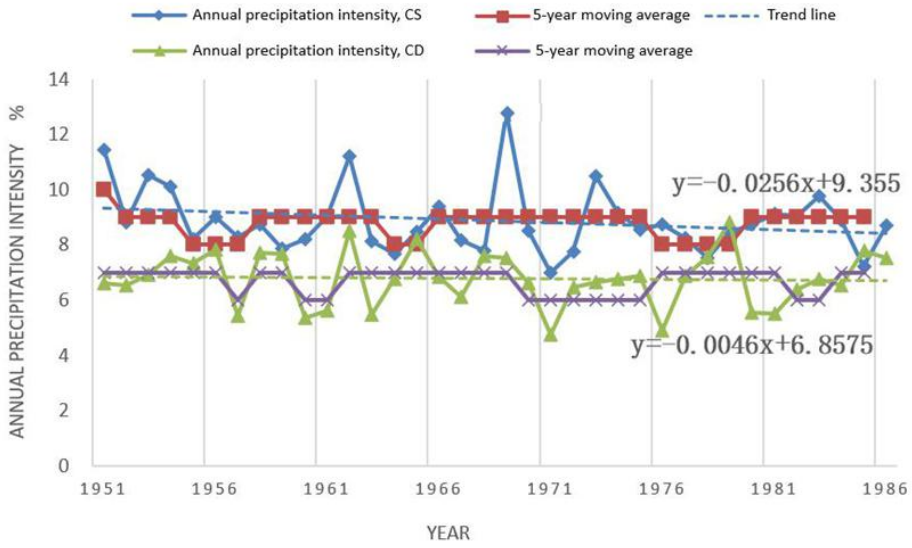
Fig. 4d. Variation trend of winter average precipitation frequency in Changsha and Chengde from 1951 to 1986



Variation and Trend Analysis of Annual Precipitation Intensity

The annual precipitation intensity is the average of the daily precipitation of the days with precipitation. From the perspective of annual precipitation intensity (Fig. 5), the annual precipitation intensity in Changsha showed a slow decreasing trend in the past 36 years, with the annual anomalous percentage of 9%, and the maximum precipitation intensity of 13% in 1969. From the five-year moving average, the precipitation intensity in 1951-1954 is higher than that in 1958-1963, 1966-1975 and 1980-1985. During the 36 years, the annual precipitation intensity in Chengde city also showed a slow decreasing trend, with the annual anomalous percentage of 7%, and the maximum precipitation intensity of 9% in 1979. According to the five-year moving average, the precipitation intensity in 1951-1956, 1962-1969 and 1976-1981 is higher than that in 1970-1975.

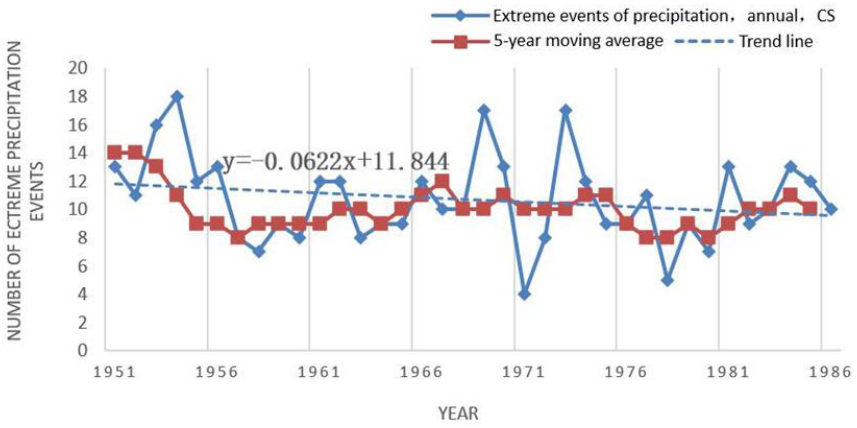
Fig. 5. Variation trend of annual precipitation intensity in Changsha and Chengde from 1951 to 1986.



Change and Trend Analysis of Extreme Precipitation Events

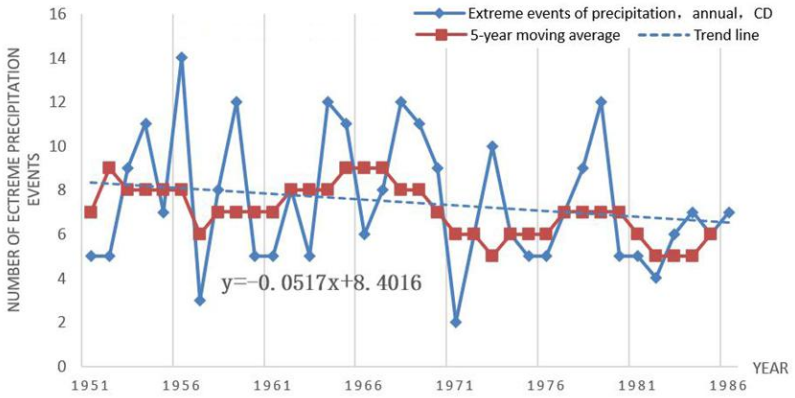
It can be seen from Figure 6 that the number of annual extreme precipitation events in Changsha shows a decreasing trend, with an average of 10 times for many years; the maximum number of extreme precipitation events occurred in 1954, 18 times, and the minimum number occurred in 1971, 4 times; in the past 36 years, there were 4 peaks (1951-1954, 1966-1967, 1974-1975, 1984-1985) and 3 troughs (1955-1961) , 1964-1965, 1976-1981).

Fig. 6. Variation trend of annual precipitation extreme events in Changsha from 1951 to 1986.



It can be seen from Fig 7 that the number of annual extreme precipitation events in Chengde city generally shows a decreasing trend, with an average of 7 times for many years; the maximum number of extreme precipitation events occurred in 1956, with 14 times, and the minimum number occurred in 1971, with 2 times; in the past 36 years, there were 2 peaks (1952-1956, 1962-1969) and 3 troughs (1957-1958, 1971-1976, 1981-1986) .

Fig. 7. Variation trend of annual precipitation extreme events in Chengde from 1951 to 1986.



CONCLUSION AND DISCUSSION

Comparison of Precipitation Between the Two Places

During the 36 years from 1951 to 1986, the characteristics of precipitation in Changsha City are as follows: the average annual precipitation is 1151.2 mm, the wet season is in spring, and the dry season is in autumn and winter. The maximum average precipitation is in spring. The annual precipitation frequency showed a general flat trend. The average annual precipitation frequency is 43%. The larger periods are 1952-1953 and 1965-1975. The precipitation frequency is the highest in spring and the lowest in autumn. The average number of extreme precipitation events is 10 times for many years.The maximum number of extreme precipitation events occurred in 1954, 18 times, and the minimum occurred in 1971, 4 times. The annual precipitation intensity anomalous percentage is 9%, and the maximum precipitation intensity is 13% of 1969.

During the 36 years, the precipitation characteristics of Chengde city are as follows: the average annual precipitation is 454.1 mm, the wet season in summer, the dry season in spring and autumn and winter, and the maximum average precipitation is in summer. The annual precipitation frequency of Chengde city presents a slow downward trend, with an average annual precipitation frequency of 22%, and the larger periods are 1952-1956 and 1964-1975; the summer precipitation frequency is the largest and shows an upward trend, and the winter precipitation frequency is the smallest. The annual precipitation intensity anomalous percentage is 7%, and the maximum precipitation intensity is 9% in 1979. The annual average number of extreme precipitation events is 7; the maximum number of extreme precipitation events occurred in 1956 with

14 times, and the minimum number occurred in 1971 with 2 times.

Comparison of Precipitation Trends Between the Two Places

During the 36 years from 1951 to 1986, the precipitation trend of Changsha City: the annual average precipitation showed a slow decreasing trend; the precipitation in spring decreased the fastest, the precipitation in autumn decreased slowly, and the precipitation in summer and winter increased slowly. The annual precipitation frequency showed a trend of overall flat, and the precipitation frequency in spring, summer and winter showed a slow downward trend, with the largest precipitation frequency in spring and the smallest in autumn. The annual precipitation intensity and precipitation extreme events showed a decreasing trend.

In these 36 years, the precipitation trend of Chengde City: the annual average precipitation showed a gentle downward trend. The precipitation in four seasons decreased, and the precipitation in summer decreased most obviously. The precipitation frequency of the whole year and spring and autumn and winter showed a slow downward trend. The precipitation frequency in summer was the highest, with an average of 46% for many years; the precipitation frequency in winter was the lowest, with an average of 6% for many years. The annual precipitation intensity and the frequency of annual extreme precipitation events showed a decreasing trend.

Based on the background of the first to the sixth "Five-Year Plan" in China, this study analyzes the 36 year daily precipitation changes in Changsha and Chengde, the core cities of two typical climate zones in southern and Northern China, and reveals the trend of daily precipitation changes in the period. The purpose of regional climate research is to provide wisdom and methods of scientific and political guidance for the construction of regional people's livelihood. Due to the limited number of years of research data, it can only provide reference for revealing the long-term trend of daily and hourly precipitation in sample cities. In addition, the natural environment of different climate zones is complex. Whether the conclusions of the analysis of the daily precipitation characteristics of these two sample cities are also applicable to other regions in these two climate zones needs to be verified in the follow-up research.

DECLARATION OF CONFLICTING INTERESTS

The author(s) declared no potential conflicts of interest with respect to the research, author- ship, and/or publication of this article.

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