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Long Time Series Rainfall Analysis in Ganze Prefecture, Sichuan Province

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Abstract

Ganzi Prefecture of Sichuan Province is located in the sub-temperate and sub-humid monsoon climate zone of the plateau, and flood disasters occur frequently. In order to more comprehensively understand the variation pattern and temporal and spatial distribution characteristics of rainfall in Ganzi Prefecture of Sichuan Province, wavelet analysis and anomaly analysis were carried out on the annual rainfall data of Ganzi Prefecture from 1980 to 2020 using MatLab platform. The annual rainfall variation in Ganzi Prefecture was analyzed by monthly data. The results show that: In the past 40 years, the annual rainfall in Ganzi Prefecture has been increasing, and the annual rainfall in 2019 reached a record high in the past 40 years. The precipitation has significant interdecadal fluctuation, which can be divided into four stages: the dry period from 1980 to 1989, the frequent fluctuation period from 1990 to 1999, the continuous dry period from 2000 to 2009, and the wet period after 2010.

Keywords

Ganzi Prefecture; MatLab; Wavelet Analysis; Anomaly Analysis.

1. Introduction

In recent years, global warming has intensified, and extreme precipitation events have increased, which has expanded the occurrence area of drought and flood disasters and intensified the frequency and intensity of drought and flood disasters [1]. Under the background of climate change, the study of regional precipitation fluctuation and its temporal and spatial distribution will reveal the characteristics of regional rainfall more accurately.

The climate of Ganzi Tibetan Autonomous Prefecture mainly belongs to the climate of the Qinghai-Tibet Plateau, with an obvious vertical distribution with the height difference. It is characterized by low temperature, long winter, little precipitation and full sunshine. The geographical latitude of Ganzi Prefecture belongs to the subtropical climate zone, but due to the strong uplift of the terrain, complex terrain, deeply inland, most of the region of Ganzi Prefecture has lost the subtropical climate characteristics, formed a continental plateau mountain monsoon climate, complex and diverse, significant regional differences. The annual total precipitation is 417.8~935.8 mm.

Ganzi Prefecture is located in the northwest of Sichuan Province and the southeast of Qinghai-Tibet Plateau. It is in the transition zone from the first step of Qinghai-Tibet Plateau to the second step of Yunnan-Guizhou Plateau and Sichuan Basin. The basic geomorphic features are high terrain, protruding in the middle, high in the north and low in the south, deep in the southeast, great difference in height, parallel mountains and rivers, modern glaciers developed in the high mountains, and significant regional differences [2]. Its latitude and longitude range is 97.347493°~102.489586° east, 27.966517°~34.211642° north. Affected by topography and rainfall, Ganzi is prone to landslides, collapses, debris flows and other geological disasters in the rainy season. The development of geological disasters in the area has seriously restricted the economic development of the whole prefecture, which has aroused the high attention of governments at all levels in the prefecture. However, there are few relevant studies on the analysis of the characteristics of precipitation change in Ganzi Prefecture, Sichuan province. In view of this, we analyzed the rainfall characteristics of Ganzi Prefecture by using anomaly analysis, wavelet analysis and other methods on the basis of collecting the rainfall data of Ganzi Prefecture [3].

2. Data sources and research methods

2.1 Data sources

The research data in this paper came from the National Meteorological Information Center. The monthly and annual rainfall data from 1980 to 2020 were selected to analyze the spatial and temporal variation of rainfall in the past 40 years. The seasons are divided as follows: Spring is from March to May, summer is from June to August, autumn is from September to November, and winter is from December to February of the next year.

2.2 Research methods

Time Series is frequently encountered issues in geological research. In the study of time series, time domain and frequency domain are two basic forms commonly used. Time domain analysis has the ability of time localization, but it cannot get more information about the change of time series. Frequency domain analysis can accurately locate frequencies, but it is only suitable for stationary time series analysis. However, many geographic phenomena, such as runoff, seismic waves, storms, flood, etc.) along with the change of time is often affected by many comprehensive factors, which mostly belong to the non-stationary sequence. They not only have features such as trend, cyclical, but also have randomness, mutability, and "multiple time scales" structure, the law of multi-level evolution. The study of this kind of non-stationary time series usually requires time information corresponding to a certain frequency band, or the frequency domain information of a certain period of time. Obviously, neither time domain analysis nor frequency domain analysis can do anything about this.

In the early 1980s, a Wavelet Analysis with time-frequency multi-resolution function proposed by Morlet provided a possibility for better study of time series. It can clearly reveal a variety of changing cycles hidden in time series, and fully reflect the changing trend of the system on different time scales. And the future development trend of the system can be qualitatively estimated.

Therefore, this paper selects the wavelet analysis to analyze the spatial and temporal variation of rainfall data in Ganzi Prefecture of Sichuan province in the past 40 years from 1980 to 2020, and uses the anomaly analysis to analyze the annual fluctuation of rainfall in the past 40 years.

2.2.1 Wavelet analysis

Wavelet analysis technology is developed on the basis of Fourier transform, which overcomes the shortcomings of traditional spectrum analysis method. It adopts a variable window with variable size and movable position to analyze spectrum, thus meeting the requirements of time and frequency localization of signal. It is widely used in signal processing, image compression, pattern recognition, numerical analysis, atmospheric science and many other nonlinear scientific fields [4]. Wavelet analysis takes time and frequency as independent variables and expands one-dimensional signal in both directions of time and frequency, so as to clearly understand the frequency characteristics of time series in different time domains and understand the time distribution characteristics of different frequencies. Wavelet transform can be divided into continuous wavelet transform and discrete wavelet transform, in which continuous wavelet transform is more suitable for discrete signal feature extraction. Morlet continuous wavelet transform is used in this study.

The time domain form of Morlet wavelet function is as follows:

$$\phi(t) = e^{-t^2 2} e^{i\omega_0 t} \quad (1)$$

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Where: ω0 - constant, take 6.2, i represents an imaginary number.

For the time series F (t) ∈L2 (R), its continuous wavelet variation is:

$$W_f(a,b) = |a|^{-\frac{1}{2}} \int_{-\infty}^{+\infty} f(t)\,\overline{\phi}\left(\frac{t-b}{a}\right) dt \tag{2}$$

Where: a - scale factor, b - time factor, $\overline{\varphi}(t)$ - complex conjugate function of φ(t), Wf (a, b) -wavelet coefficient. In this paper, the wavelet transform is carried out by using the wavelet toolkit of Matlab software.

2.2.2 Anomaly analysis

Anomaly is the most common expression for the deviation of climate variables from normal conditions. The difference between a certain number of a set of data and the mean is anomaly. In climate diagnosis and analysis, anomaly series are often used to replace the observed data of climate variables themselves. After anomaly processing, any series of climate variables can be converted into a series with an average value of 0. This paper mainly analyzes the interannual anomaly and cumulative interannual anomaly of relevant data.

3. Result analysis

3.1 Annual variation analysis

The column chart of monthly average precipitation in Ganzi Prefecture from 1980 to 2020 is shown in Fig. 1. According to this figure, the intra-annual distribution of precipitation in Ganzi Prefecture is extremely uneven, mainly concentrated in summer, accounting for 54% of the annual precipitation. The average precipitation in June is the largest, accounting for 20.55% of the annual average precipitation, which is 137.75mm. The rainfall in December is at least 3.18mm, accounting for only 0.47% of the annual precipitation. It can be seen from Figure 1 that the seasonal distribution of annual precipitation in Ganzi Prefecture is uneven, and the precipitation in summer determines the amount of annual precipitation.

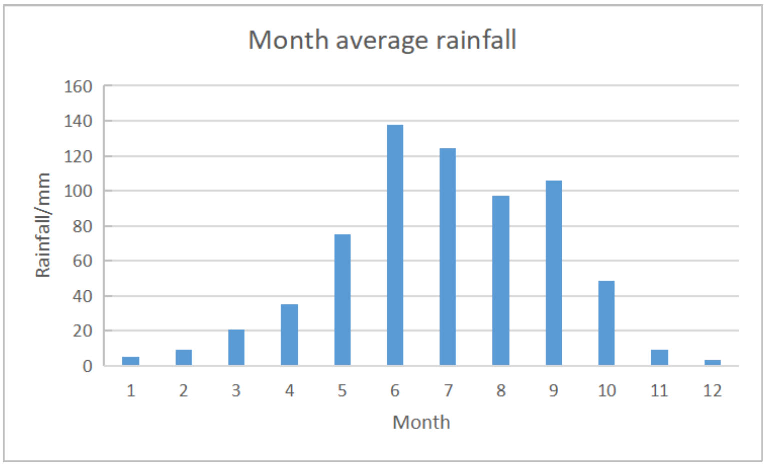

Fig. 1 Average monthly rainfall from 1980 to 2020

3.2 Trend law analysis

In this paper, linear analysis method is adopted to analyze the variation trend of annual rainfall in Ganzi Prefecture, Sichuan Province from 1980 to 2020. The analysis results are shown in Fig. 2 [5]. According to statistics, the annual average rainfall of Ganzi Prefecture in Sichuan province in the past 40 years is 670.7341mm, and the annual rainfall is generally increasing, and the linear trend of Ganzi Prefecture is 18.31mm/10a. The annual rainfall in 2019 was the highest at 859.4mm, and the annual rainfall in 2012 was the second highest at 830.3mm. The annual rainfall was the lowest in 2007 with 472mm, and the second lowest in 1997 with 511.8mm.

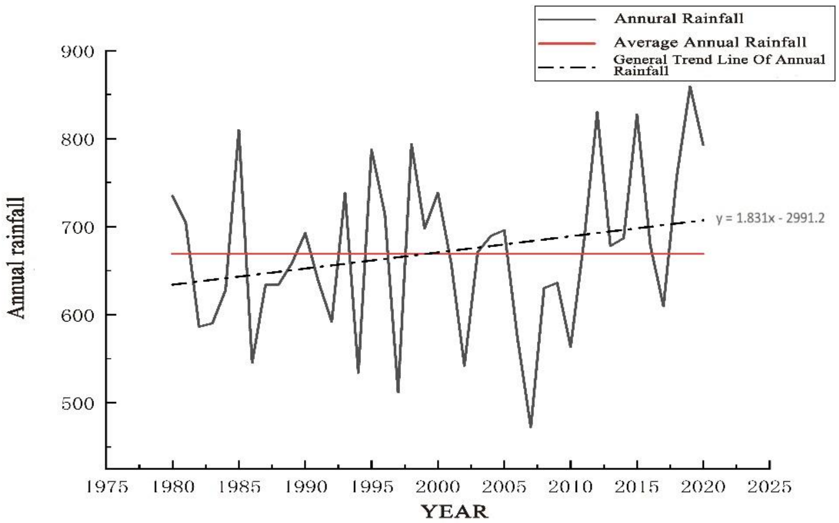

Fig. 2 Annual rainfall variation from 1980 to 2020

3.3 The wavelet analysis results discussed

The variation process of wavelet variance with time scale can reflect the distribution of wave energy of rainfall time series with different time scale. At the same scale, the wavelet variance represents the strength of periodic fluctuations of this scale in the time series. Therefore, the wavelet variance diagram can determine the main time scale of the existence of the series and can be used to determine the main period in the evolution process of rainfall [6].

Figure 3 is the wavelet variance chart of annual rainfall in Ganzi Prefecture, Sichuan province from 1980 to 2020. As can be seen from Fig. 3, in recent 40 years, there have been 4 more obvious rainfall change cycle scale centers in Ganzi Prefecture, which are the 5a, 7a, 13a and 22a respectively.

The strongest periodic oscillation occurred in the 22a, which is the first major period of annual rainfall variation. The time scale of 7a corresponds to the second peak, which is the second main period. The time scale of the 13a corresponds to the third peak, which is the third main period. The time scale of 5a corresponds to the fourth peak, which is the fourth main period. The fluctuation of these four cycles controlled the variation characteristics of rainfall in Ganzi Prefecture of Sichuan province during 1980-2020.

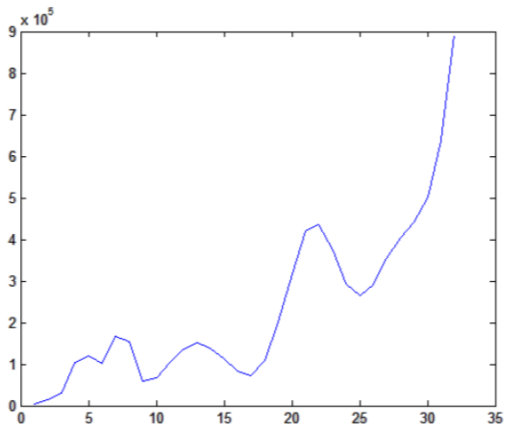

Fig. 3 Wavelet variance diagram

Morlet wavelets are complex wavelets, and the real part reflects the distribution and phase information of signals with different characteristic time scales at different times [7]. Matlab and

Surfer software were used to draw the real part contour map of the wavelet coefficient of the rainfall data in Ganzi Prefecture (Fig. 4), which could reflect the periodic change and distribution of the time series of precipitation at different time scales, so as to analyze the change characteristics of the precipitation series at different time scales [8]. The abscissa is the year and the ordinate is the time scale year. In the figure, the solid line part indicates that the value of the real part of the wavelet coefficient is greater than 0, that is, positive phase, indicating the wet season with more precipitation; the dotted line indicates that the value of the real part of the wavelet coefficient is less than 0, that is, negative phase, indicating that the station is in the dry season with less precipitation.

Through the time-frequency variation map of the real part of Morlet wavelet transform of the annual precipitation series, the time-scale variation, mutation point distribution and phase structure characteristics of the precipitation series can be clearly seen [9]. As shown in Fig. 4, the annual precipitation series in Ganzi Prefecture has two obvious time-scale periodic change rules, which are 13-25 years and 5-10 years respectively. Among them, quasi-2 and 9 oscillations with alternating positive and negative phases appear on the scales of 13-25a and 5-10a respectively, and the process is stable and global [10].

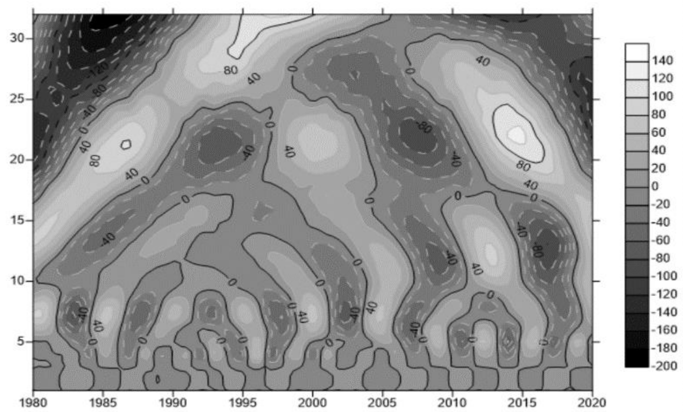

Fig. 4 Contour map of real part of wavelet coefficients

3.4 The anomaly analysis results discussed

3.4.1 Interannual anomaly

The average precipitation of Ganzi Prefecture from 1980 to 2020 is 670.7341mm. The calculated annual precipitation anomaly is shown in Fig. 5. The results show that during the 41 years from 1980 to 2020, the positive anomaly is 22 years, accounting for half of the total, and the positive anomaly mainly occurs between the negative anomaly, with fewer consecutive years. The other half were negative anomaly, and the negative anomaly occurred continuously from 2006 to 2010, during which the precipitation had a decreasing trend.

The annual rainfall change since 1980 can be roughly divided into four periods: the first stage is the dry season from 1980 to 1989. In the 10 years of this period, except 1980, 1981 and 1985, the rainfall anomaly in the other 7 years is all negative, and the average rainfall in this period is 652.57mm, which is slightly less than the 40-year series average. The maximum rainfall in this period was 809.8 mm in 1985 and the minimum was 545.3 mm in 1983. The second stage was the frequent fluctuation period from 1990 to 1999, during which the alternating periods of high and low rainfall were frequent, in which 1991, 1992, 1994 and 1997 were the dry seasons. The average rainfall of this period was 670.03mm, which was lower than the average rainfall of 40 years. The third stage is the continuous dry season from 2000 to 2009, the average rainfall in this period is only 630.77 mm, 39.96 mm less than the average rainfall in 40 years. The fourth stage is the wet period after 2010, with an average rainfall of 724.22 mm.

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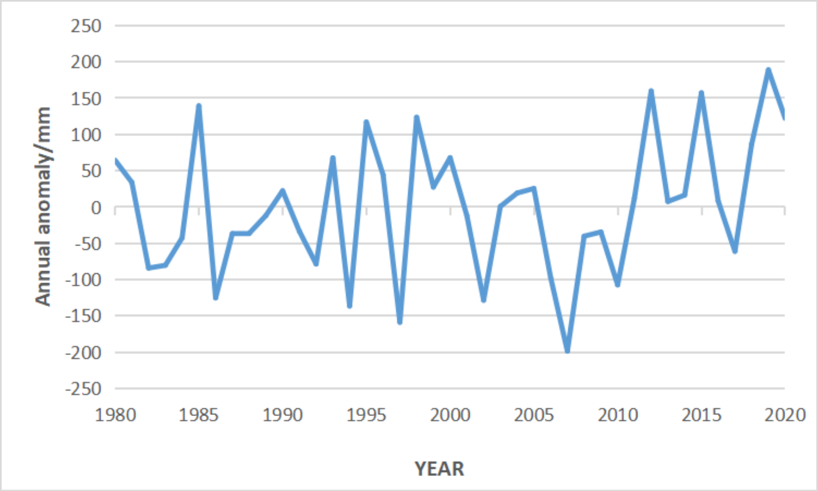

Fig. 5 Interannual anomaly

3.4.2 The accumulative anomaly

As shown in Fig. 6, the cumulative annual anomaly of precipitation during 1980-2020 showed a sharp decline and fluctuated within the range of negative anomaly. The cumulative anomaly was basically positive before 1982, which increased first and then decreased, indicating that the precipitation gradually changed from relatively high to relatively low during this period. The cumulative anomaly continued to decrease during 1985-1994, indicating that the precipitation in this period was constantly decreasing. After 1985, the cumulative anomaly basically fluctuated within the range of negative anomaly, and on the whole, the precipitation during this period was still relatively small.

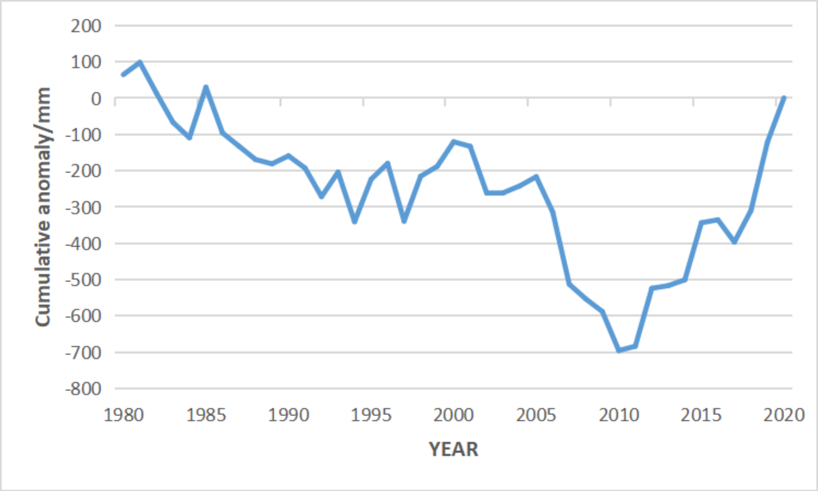

Fig. 6 Cumulative anomaly diagram

4. Conclusion

Based on the analysis of the rainfall variation of annual scale, the interannual scale and scale change for many years in Ganzi Prefecture, Sichuan province in recent 40 years, the following conclusions are drawn:

(1) The annual precipitation distribution in Ganzi Prefecture is extremely uneven, mainly concentrated in summer, accounting for 54% of the annual precipitation. The average precipitation in June is the largest, accounting for 20.55% of the annual precipitation, which is 137.75mm. The rainfall in December was at least 3.18mm, accounting for only 0.47% of the annual precipitation. It can be seen from Figure 1 that the seasonal distribution of annual precipitation in Ganzi Prefecture is uneven, and the precipitation in summer determines the amount of annual precipitation.

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(2) The annual rainfall in Ganzi Prefecture increased significantly from 1980 to 2020, and the trend was 18.31mm/10a. The cumulative anomaly method and wavelet analysis method were used to analyze the variability and periodicity of rainfall. The results show that the catastrophe points of rainfall mainly appeared in 1985, 1987, 1993 and 2002.

(3) In recent 40 years, rainfall has significant interdecadal fluctuation, which can be generally divided into four stages. The first stage is the dry season from 1980 to 1989, the second stage is the frequent fluctuation period from 1990 to 1999, and the third stage is the continuous dry season from 2000 to 2009. The fourth stage is the wet period after 2010, with an average rainfall of 724.22 mm.

(4) Through cycle analysis, the precipitation series in Ganzi Prefecture in recent 40 years has two kinds of obvious scale cycle change rules, and has obvious alternating characteristics of abundance and drought.

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