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Analysis on Characteristics of Rainfall Change in Dali Prefecture in Recent 54 Years

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Abstract

Through the method of Linear trend, Cumulative anomaly and Morlet wavelet, the interdecadal variation, annual, seasonal, monthly variation, abrupt change of climate and cycle of rainfall in Dali Prefecture from 1962 to 2015 were analyzed. The start date of rainy season occurred on May 8th, 2001 is the earliest; The start date of rainy season occurred on July 1st, 2015 is the latest; The average value of the start date of rainy season from 1962 to 2015 is May 31st. During the past 54 years, the annual, seasonal and monthly rainfall showed the different degrees of reduction. Linear trend analysis showed that the trend of annual rainfall was decreasing with linear trend rate of −14.02 mm/10a, the annual rainfall decreases with the number of years is not significant. Seasonal rainfall decrease with the year number is not significant. The rainfall in summer and autumn decreased with the year number. The decreasing trend of rainfall in summer is greater than that in autumn. The rainfall in Winter and Spring increased with the year number. The increasing trend of rainfall in summer is greater than that in autumn. By using the method of cumulative anomaly and Morlet wavelet, the abrupt change of annual rainfall was analyzed, and the change of annual rainfall were found in 1974, 2002 and 2008. The annual rainfall was mainly in the period of 6 and 30. On the 6a and 10a period scales, the annual rainfall from 2015 to 2019 is increasing, which predicts that Dali Prefecture is in the wet period from 2015 to 2019.

Keywords

Rainfall, Trend, Cycle, Abrupt Change of Climate

1. Introduction

In recent years, in the context of global warming, various types of extreme weather and climate events, meteorological disasters caused by the loss and the impact of increasing, climate change caused by the community and all levels of government's general concern and attention [1]. At present, there are more and more researches on the meteorological elements, such as temperature, air pressure, humidity, rainfall, wind and so on [2]. Numerous studies have been done from different time and space scales. Due to the limited meteorological data year by year, it is not enough to study the interdecadal variation of meteorological elements. We study the change trend and mutation of rainfall from the time; reveal the distribution of rainfall in the space from the space, in order to understand the variation of rainfall in Yunnan Province, to analyze the influencing factors of drought and flood disasters, but also provide reference for the study of hydrological model in Yunnan province [3]. Large rainfall is closely related to national defense and social economic construction, timely and appropriate rainfall can provide favorable conditions for agricultural production, and abnormal rainfall may bring disaster [4]. Dali Prefecture is located in the northwest of Yunnan Province. It is a subtropical monsoon climate in the north subtropical plateau, with many years of meteorological drought and uneven distribution of rainfall. It is characterized by less rainfall and less water resources. The drought is severe in winter and spring. There are many kinds of meteorological disasters in Dali Prefecture, which have brought adverse effects on people's production and life. Meteorological drought occurred frequently before flood season. Flood and Rainstorm occurred frequently in flood season. Based on the linear Regression analysis, Cumulative anomaly method and Morlet wavelet method, the annual, seasonal and monthly rainfall characteristics of Dali prefecture are analyzed to reveal the regularity of periodic variation and abrupt change of rainfall in multi-period scales, to provide scientific basis for flood control and drought relief.

2. Materials and Methods

2.1. Data Sources

The annual rainfall data of Dali Prefecture from 1962 to 2015 were analyzed by using the meteorological station of Dali Prefecture. The seasonal and monthly rainfall of meteorological station in Weishan County was used to analyze the correlation coefficient of seasonal and monthly rainfall.

2.2. Research Methods

Spring is from March to May, spring rainfall accounts for 5% - 17% of annual rainfall; Summer is from June to August, summer rainfall accounts for 50% - 66% of annual rainfall; Autumn is from September to November, autumn rainfall accounts for 25% - 30% of annual rainfall; Winter is from December to February, winter rainfall accounts for 1% - 6% of annual rainfall [5]. The mean value method was used to study the change of annual rainfall in 10 years and the regression analysis was performed by using the linear fitting method [6]. The cumulative anomaly method was used to analyze the abrupt change year of rainfall and the signal to noise ratio [7] was calculated in order to check whether the turning year could reach the standard of abrupt climate change. Morlet wavelet method [8] [9] was used to analyze the variation of rainfall cycle in the past 54 years.

3. Results and Analysis

3.1. Decadal Variation of Rainfall and Start Date of Rainy Season

As can be seen from Table 1, the interdecadal mean rainfall shows that the interdecadal average rainfall is the largest in the 1990s and the smallest in the 2010s. From the 1960s to the 1980s, the rainfall decreased. From the 1990s to the 2010s the rainfall decreased.

Figure 1 shows the start date of rainy season occurred on May 8th, 2001 is the earliest; The start date of rainy season occurred on July 1st, 2015 is the latest; The average value of the start date of rainy season from 1962 to 2015 is May 31st.

3.2. Annual Variation of Rainfall

The study of the annual variation of rainfall in Dali Prefecture is helpful to the drought resistance in the dry weather. Based on the linear regression analysis of annual rainfall from 1962 to 2015, the curve of annual rainfall change with time was obtained (Figure 2).

It is concluded that the trend of annual rainfall tends to decrease, and the decreasing trend is very obvious. The trend of annual rainfall was decreasing with linear trend rate of −14.02 mm/10a. The average rainfall of 1962~2015 is 809.9

Table 1. 1962~2015 average interdecadal rainfall in Dali Prefecture (mm). “Difference” means the difference between the average decadal rainfall and the average annual rainfall.

Decade	1960s	1970s	1980s	1990s	2000s	2010s
Precipitation	882	817	780	882	831	708
Difference	56	−9	−46	56	5	−118

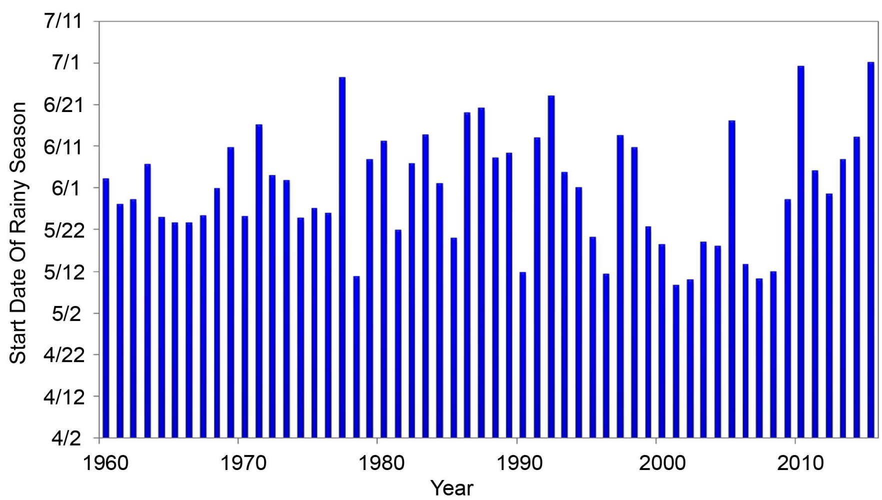

Figure 1. Start date of rainy season.

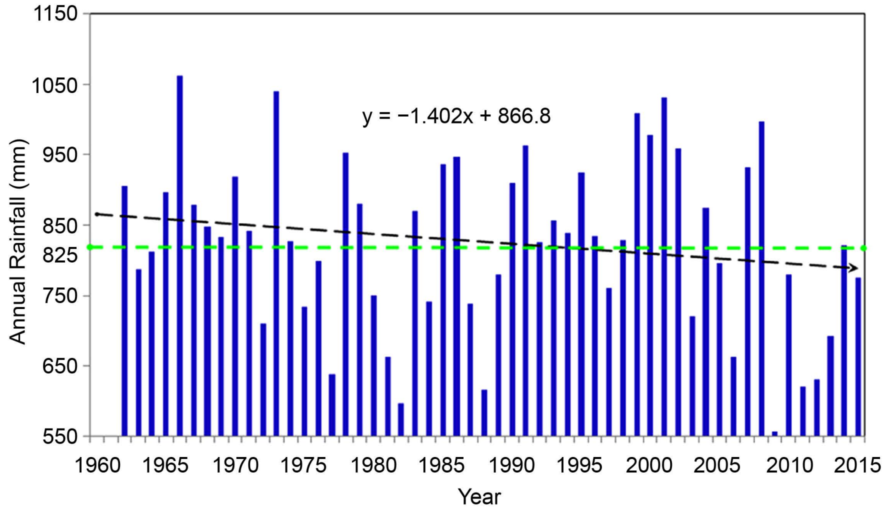

Figure 2. Annual rainfall in dali prefecture from 1962 to 2015 (mm).

mm. The annual rainfall was the largest in 1966 and the smallest in 2009. The correlation coefficient between annual rainfall and year number from 1962 to 2015 was 0.18, that has passed the significance test of the confidence level of 0.05. The annual rainfall trend decreases with the year number is significant.

3.3. Seasonal Variation of Rainfall

The study of the seasonal variation of rainfall in Dali Prefecture is helpful to guide agricultural production, especially for the local agricultural production. The linear regression and correlation of the monthly rainfall from 1962 to 2015 show the average seasonal rainfall values, linear trend and correlation coefficient. F-test analysis of double sample variance was performed to confirm whether the significance P of the rainfall group and the year number group reached the significance level α, $\alpha = 0.05$. α is used to test the reliability of their correlation coefficients. The unit of rainfall is mm. The unit of linear propensity is mm/a.r is the correlation coefficient.

Figure 3 shows the average seasonal rainfall in Dali Prefecture from 1962 to 2015. The rainfall in winter is 46.44 mm. The rainfall in spring is 103.29 mm. The rainfall in summer is 426.21 mm. The rainfall in autumn is 215.02 mm. Using the quadratic polynomial trend analysis, the seasonal mean rainfall increased gradually from winter to summer, and the seasonal mean rainfall in summer reached the maximum. From the summer to the autumn, the average rainfall gradually decreased.

Figure 4 shows the linear tendency rates and correlation coefficient of seasonal rainfall. The linear trend of summer and autumn rainfall is negative, indicating that the rainfall in summer and autumn decreases with the year number, and the trend of decreasing rainfall is summer > autumn. The correlation coefficient of rainfall in summer and autumn did not pass F-test with significance level of 0.05, indicating that the rainfall in summer and autumn decreased with the year number is not significant.

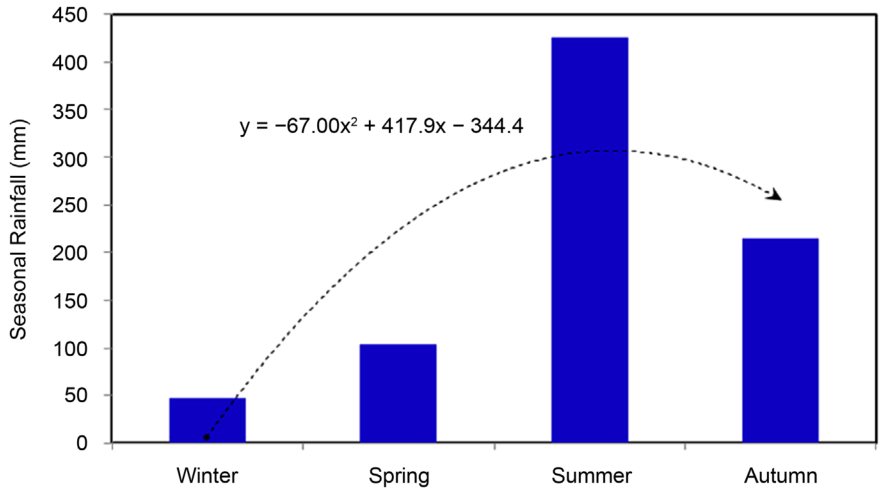

Figure 3. Average seasonal rainfall in Dali Prefecture from 1962 to 2015 (mm).

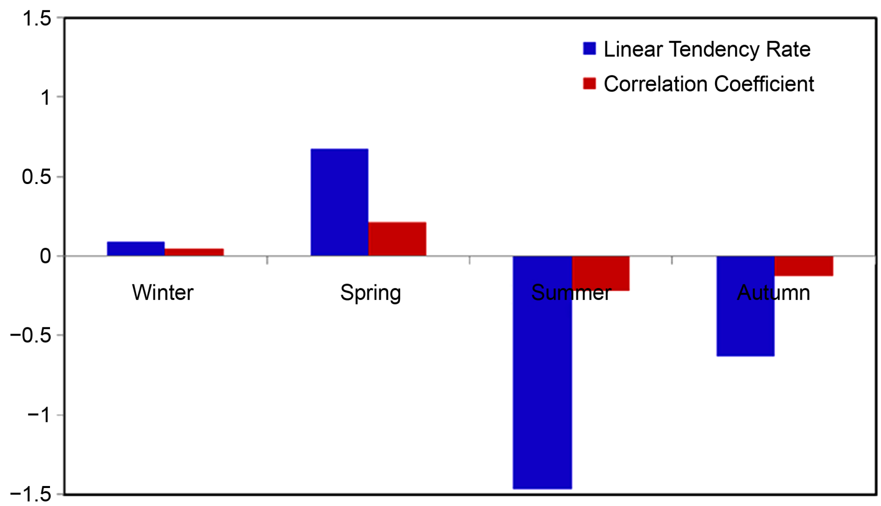

Figure 4. Linear tendency rates and correlation coefficient of seasonal rainfall.

The linear tendency of rainfall in winter and spring is positive, that indicates that the rainfall in winter and spring increases with the year number. The increasing trend of rainfall is spring > winter. The correlation coefficient of winter and spring between rainfall and the year number did not pass the F-test with significance level of 0.05, indicates that the increase of rainfall in winter and spring was not significant.

3.4. Monthly Variation of Rainfall

The study of monthly precipitation variation in Dali Prefecture is helpful for the relevant departments to provide meteorological decision service. As can be seen from Figure 5, the monthly rainfall is the largest in July and the smallest in December. The monthly rainfall increases gradually from January to July, that decreases gradually from August to December.

Figure 6 shows the linear tendency rates and correlation coefficient of monthly rainfall. The linear trend of the monthly rainfall was negative in February, June,

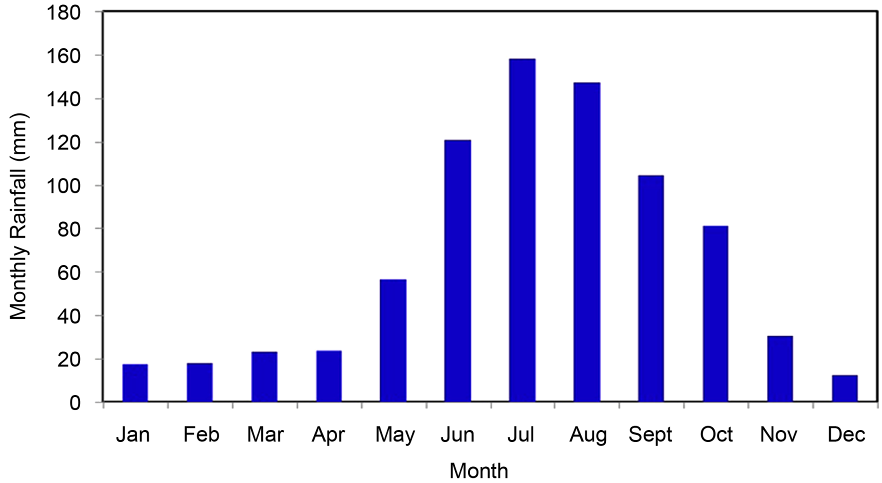

Figure 5. Monthly rainfall in Dali prefecture from 1962 to 2015 (mm).

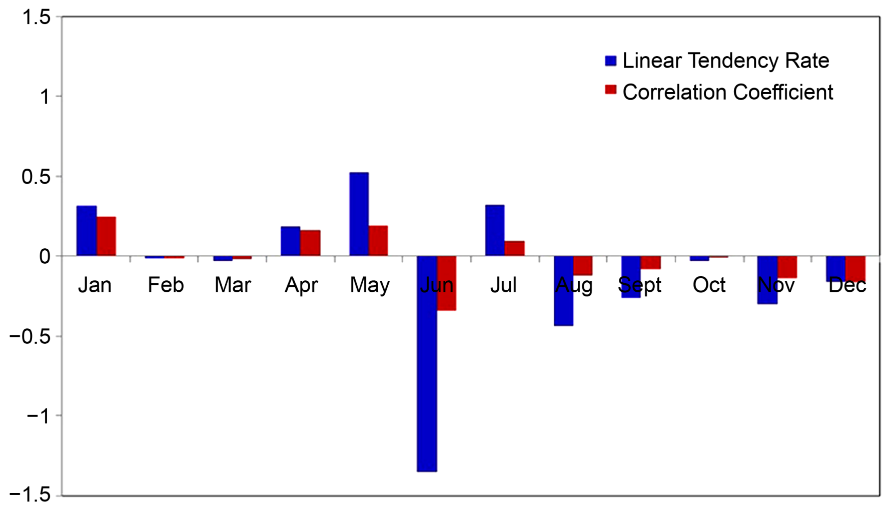

Figure 6. Linear tendency rates and correlation coefficient of monthly rainfall.

July, August, October, November and December, indicating that their monthly rainfall decreased with the year number. The correlation coefficients between rainfall and year number in February, June, August, October, November and December were tested by the significance level with confidence level of 0.05, indicating that their monthly rainfall was significantly reduced with the year number. The correlation coefficient of rainfall in July did not pass the significance test of 0.05 confidence level, indicating that its monthly rainfall is not significant decrease with the year number. The Linear tendency of the monthly rainfall in January, March, April, May and September were positive, indicating that their monthly rainfall increased with the year number. The correlation coefficient between rainfall and year number in January, April and May has been tested by the significance level of 0.05 confidence level, indicating that their monthly rainfall increase with the year number is significant. The correlation coefficient between the rainfall and the year number in March and September did not pass the test with the confidence level of 0.05, that indicates that their monthly rainfall is not significant with the year number.

3.5. Analysis of Abrupt Climate Change in Rainfall

The analysis method for the year periodic variation of rainfall from 1962 to 2015 by using Morlet wavelet analysis. It is found that the annual rainfall change exists long period that contains short cycle. The annual rainfall is formed by different periodic shocks superimposed. The climate change is a reflection of the nonlinear climate system. In recent years, it has attracted more and more attention, which has become an important topic. Abrupt climate change exists in the climate change process, which is not a continuous phenomenon. The cumulative curve of climatic factors was used to determine it. Using the following Equation (1):

Equation (1) is $c(t)=\sum_{i=1}^{t}\left(Z_i-\bar{Z}\right)$

If the absolute value of the Equation (1) is the largest, the corresponding t is the mutation year. In order to test whether the climate transition year is up to the standard of abrupt climate change, the corresponding signal to noise ratio is calculated in the turning year. Using the following Equation (2):

Equation (2) is $S/N=\frac{\left|\bar{X}_a-\bar{X}_b\right|}{S_a+S_b}$

In Equation (2), $\bar{X}_a$ and $\bar{X}_b$ are the average values before and after the climate transition year respectively. S_a and S_b are the standard deviation before and after the climate transition year respectively. When $S/N>1$ is specified, it can be considered that the climatic factors have abrupt climate change in the turning year, otherwise the climate transition year is not significant.

Figure 7 shows the cumulative rainfall anomaly curve. According to the above method, the rainfall from 1962 to 2015 is substituted into Equation (1), the cumulative anomalous value of each year is calculated, and the cumulative rainfall anomaly from 1962 to 2015 is plotted. As can be seen from Figure 7, the

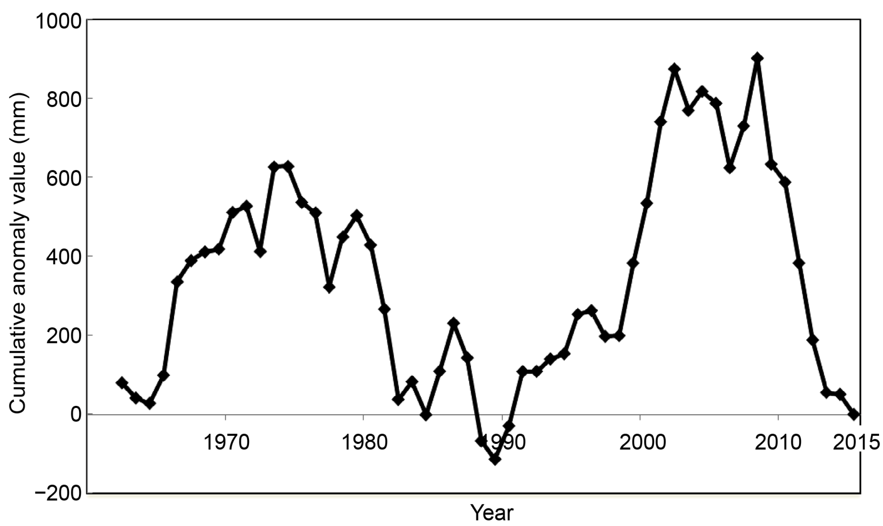

Figure 7. The cumulative anomaly curve of annual rainfall in Dali prefecture.

cumulative peak of annual rainfall anomalies occurred in 1974, 2002 and 2008, and the annual rainfall changed from the multiple stage to the minor phase. In order to test whether the above transition years have reached the standard of abrupt climate change, according to Equation (2), the signal-to-noise ratio corresponding to the transition years were calculated. By studying the annual rainfall of 10 years before and after the climate turning year, we found that the corresponding SNRS of rainfall in 1974, 2002 and 2008 were 0.16, 0.83 and 0.78. The abrupt climate change was not significant. The turning years could only be used as the climatic transition years.

3.6. Periodicity Analysis of Rainfall

The analysis method for the year periodic variation of rainfall from 1962 to 2015 by using Morlet wavelet analysis. It found that the annual rainfall change exists long period that contains short cycle.

Figure 8 shows the time-frequency distribution of the Morlet wavelet transform modulo square. It is found that the signal intensity is different at different period scales. The signal intensity of 6 ~ 10 years is strong, that mainly occurred in 1976~1996, 2000~2010; The signal intensity of 32 ~ 44 years is weak, that distributed in the entire period scale.

Figure 9 shows the time-frequency distribution of the real part of Morlet wavelet transform. The annual rainfall change has two aspects: signal intensity and phase. The annual rainfall change was distributed in multi-time scales. The time-frequency distribution of the real part of Morlet wavelet transform is obvious at the period scale of 3 ~ 9 and 20 ~ 40, that is weak on the period scale of 5 ~ 15 and 16 ~ 20. It appears the alternation of positive and negative terms. The period scales are 6, 10 and 30. On the period scale of 6a, there are nine dry and wet alternating periods with an average change period of 3a. On the period scale of 10a, there are six dry and wet alternating periods with an average change period of 7a. On the period scale of 30a, there are two dry and wet alternating

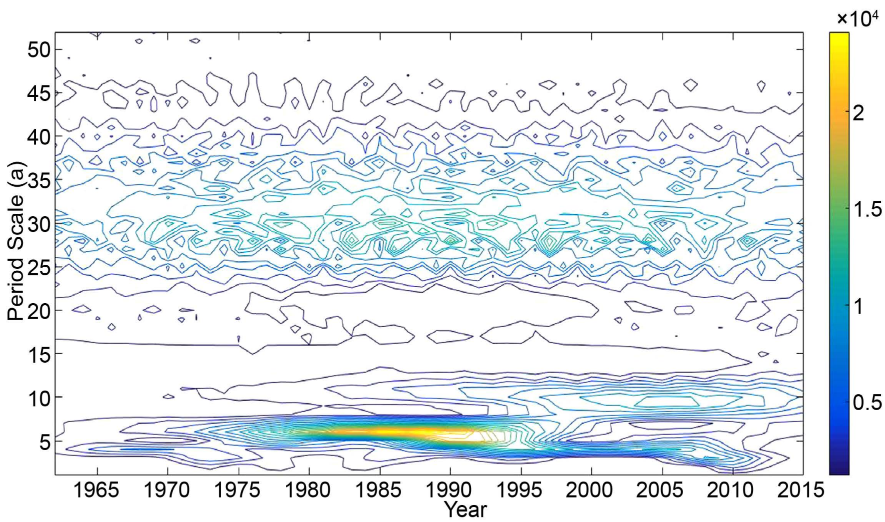

Figure 8. Time-frequency transformation of modulus square of wavelet transform.

periods with an average change period of 16a. On the 6a and 10a period scales, the annual rainfall from 2015 to 2019 is increasing, which predicts that Dali Prefecture is in the wet period from 2015 to 2019.

Wavelet variance gets changed with the period scale. Figure 10 can reflect the annual rainfall in the period series that contains a variety of cycle fluctuations and its energy intensity with the period scale of the characteristics of change. Each peak corresponds to a significant period. It is possible to determine the main period exists in period series. The peak of the wavelet variance appears in the period scales of 6, 10, 18 and 30. The periodic oscillations of 6 and 30 years are intense that makes more sense on the study of wavelet transform process.

Figure 11 shows the real part of the 6a-period scale wavelet transform changes periodically with the year number. The amplitude from 1979 to 1999 is larger than that from 1962 to 1978 and from 2000 to 2015. The real part of the wavelet transform with the end of year number is 9 and 5, that is the positive peak. The real part of the wavelet transform with the end of year number is 2,

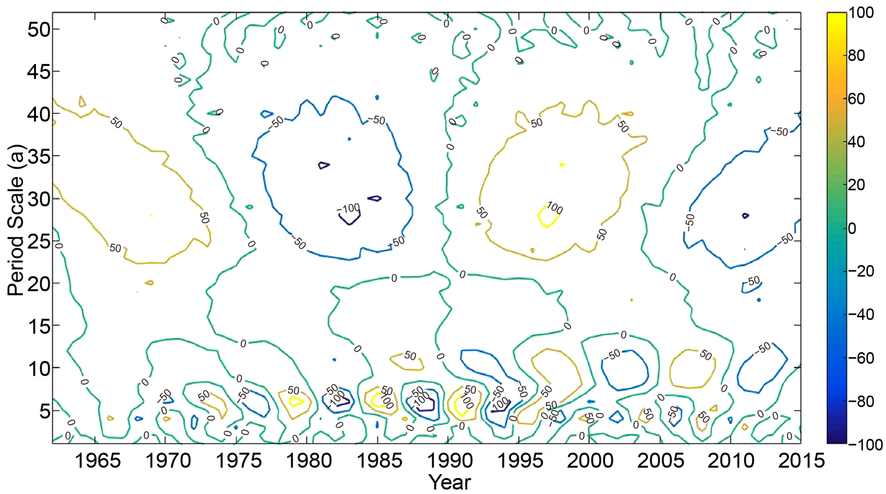

Figure 9. The time-frequency distribution of wavelet real part.

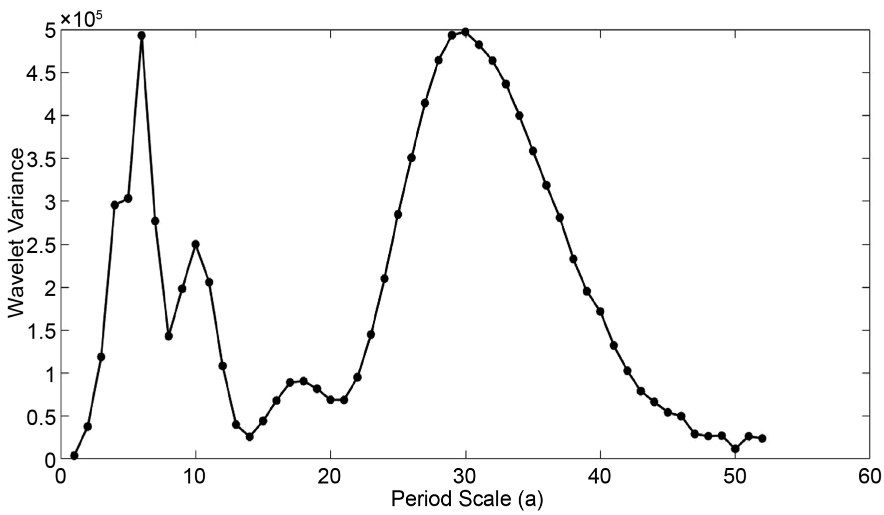

Figure 10. Wavelet transform variance.

that is the negative peak. The real part of the wavelet transform of the end of year number is 9 and 5 with the following three years, that is a decreasing function. The real part of the wavelet transform of the end of year number is 2 with the following three years, that is an increasing function.

Figure 12 shows the real part of the 30a-period scale wavelet transform changes periodically with the year number. 1962~1990 is the first cycle, 1990~2015 is the second cycle. It is found that the wavelet real part of 1962~1974 and 1990~1998 increased with the year number, the wavelet real part of 1974~1985 and 1998~2010 decreased with the year number, the wavelet real part of 1985~1990 and 2010~2015 increased with the year number.

4. Conclusions

Based on the above analysis, the following conclusions can be drawn:

(1) The annual rainfall decreases with the linear tendency of −14.02 mm/10a, the annual rainfall decreases with the year number is not significant. The rainfall

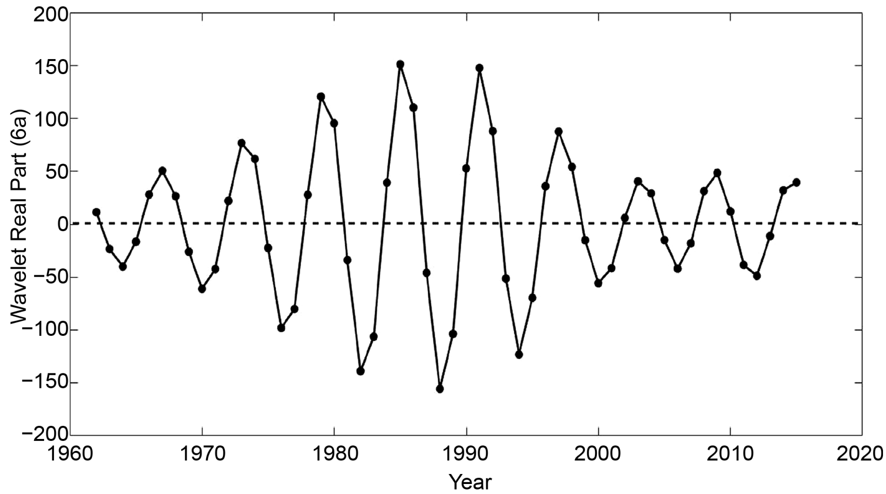

Figure 11. The process of 6a-period scale wavelet transform.

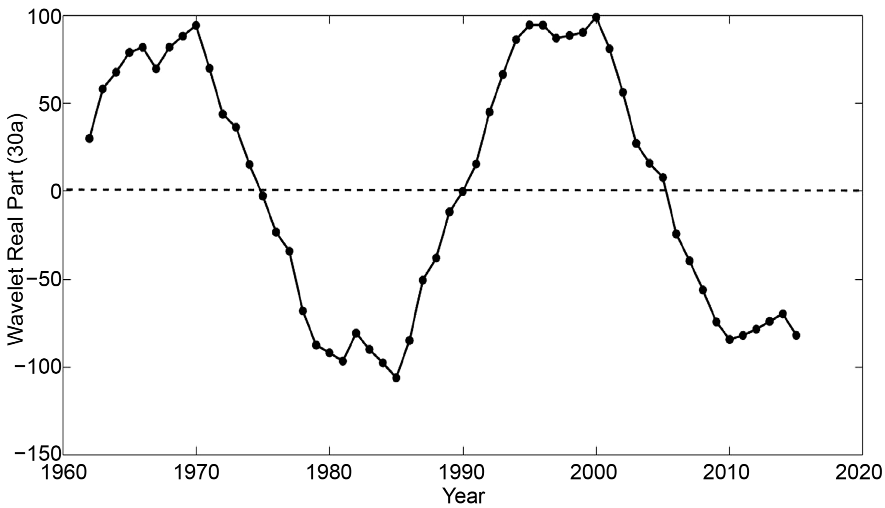

Figure 12. The process of 30a-period scale wavelet transform.

of the seasons decrease with the year number is not significant. The rainfall in summer and autumn decreased with the year number, and the decreasing trend between them was summer > autumn. The rainfall in winter and spring increased with the year number, and the increasing trend between them was spring > winter.

(2) The monthly rainfall in February, June, July, August, October, November, and December decreases with the year number, that is significant. The monthly rainfall in July decrease with the year number is not significant. The monthly rainfall in January, March, May and September increases with the year number is significant.

(3) The summer rainfall decrease with the year number, that is significant. The rainfall in January, March, May and September increase with the year number, that is significant. The rainfall in January increase significantly, that could lead to the chilling injury of crops. The increase of rainfall in March is favorable for the growth of spring crops. The increase of rainfall in May will lead to rainy season ahead of schedule. The increase of rainfall in September will lead to that autumn rainy weather lasted longer. The rainfall in February, October, November and December decrease with the year number, but the decreasing trend is not significant. It indicates that their monthly rainfall is almost the same as the average monthly rainfall.

(4) It is found that the corresponding SNRS of rainfall in 1974, 2002 and 2008 were 0.16, 0.83 and 0.78. The abrupt climate change was not significant.

(5) On the 6a and 10a period scales, the annual rainfall from 2015 to 2019 is increasing, which predicts that Dali Prefecture is in the wet period from 2015 to 2019.

(6) The real part of the 6a and 30a period scales wavelet transform changes periodically with the year number. The amplitude from 1979 to 1999 is larger than that from 1962 to 1978 and from 2000 to 2015. 1962~1990 is the first cycle, 1990~2015 is the second cycle.

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