

## Analysis of Rainfall Runoff in the Dian Lake Based on Wavelet Analysis

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**Abstract.** Influenced by global warming and other factors, the climatic characteristics of the Dianchi Lake (in Yunnan Province) are obviously different from those in northern China. Based on the data of rainfall and runoff from 1956 to 2012, this paper analyzed the variation characteristics of precipitation and runoff in Dianchi Lake Basin. The results showed that the precipitation and runoff showed a decreasing trend. There are several time scales in the runoff variation, which has the first main cycle of 15a.

### Introduction

Affected by many factors such as global warming, great changes have taken place in the Yunnan Province area climate. But because Yunnan Province is located in the Yunnan-Guizhou plateau and Qinghai-Tibet plateau low latitudes, and affected by plateau mountain tridimensional climate, climate change is very different from northern China [1], Such as Zaixiang Chi etc. Based on the meteorological data of 18 meteorological stations in Qiandongnan area during 1996-2000, it was found that the precipitation increased and the temperature decreased in Qiandongnan in recent 40 years[2]; Similarly, in 2015, heavy snow in Kunming caused many street plants to die. The Dian Lake basin belongs to the central economic region of Yunnan Province, and its water resources play an important role in the economy. This paper uses wavelet analysis of The Dian Lake hydrological station in 1956-2012 runoff study, to analyze its changes in different time scales of the wavelet frequency distribution and the change of clustering and alternate cycles, to predict long-term hydrologic forecasting and water resources evolution to provide important basis.

The Dian Lake is located in the southwest of Kunming City, the lake is the largest area of Yunnan Province, also known as Kunming lake, Kunming Lake Basin, shape slightly arched, back to the east. North and south about 40km, the maximum width of about 12.5km, the lake line about 130km. When the water level is 1887.4m, the lake area is 310 km<sup>2</sup>, the lake is 1.56 billion m<sup>3</sup>, with an average depth of 5 meters, the deepest depth of 8 meters. The Dian Lake river basin is the seat of Kunming city, the area of 2920km<sup>2</sup>, the trunk stream Panlong river is 87.5km, flows through the urban area, originated from Songming County Liangwang mountain north, from north to south through Songming County, after the left side tributary Dianwei river join it in Guandu district near enters the Songhuaba Reservoir, a reservoir after entering the Kunming basin, runs through the city after the injection of The Dian Lake district. Lake water in the southwest of Haikou, said the mantis, the source of the Jinsha River River tributaries.

The Dian Lake basin terrain north high south low, large terrain gap, the river flows from north to south, located in the Yunnan Province Guizhou Plateau, elevation is high, the highest elevation of 4344m, generally rising at an altitude of 100 m, average drop in temperature 0.7 °C, with the characteristics of the "plateau mountain three-dimensional climate". the Dian Lake basin is a subtropical monsoon climate zone, which is affected by the southwest monsoon, and has the characteristics of dry and wet season clear, summer without heat, no cold winter, summer and autumn rain, winter and spring drought, "four seasons without winter and heat, the case of rain into winter" belongs to the semi humid region of Yunnan province[3]. The wet season is from May to October, mainly from the South Pacific North southeast the influence of warm air, precipitation

increased significantly, precipitation accounted for 87% of the year, especially the most rainfall in July, accounted for 21.1% of the year, easy to produce the characteristics of high temperature, precipitation, rainfall, evaporation, humidity and so on; for the year November to the dry season the following year in April, mainly affected by continental westerlies and the northern cold air southward, precipitation accounted for only 13% of the year, especially least precipitation in February, only 1.4% of the year, easy to produce cold wave weather, with a large wind speed, more sunny, less cloud cover, less precipitation, evaporation, humidity and other characteristics.

## Method

The basic idea of wavelet analysis is to use a set of wavelet function to represent or approximate a signal or function. Therefore, the key of wavelet analysis is the choice of wavelet function, and the wavelet function is a kind of function which has the property of shock and can be quickly reduced to zero. Morlet wavelet is one of the most commonly used complex wavelet, the scale function does not exist, and does not have the orthogonality, but the time and frequency two domain has the very good localization characteristic.

Wavelet transform is a new analysis method, it inherited and developed the short-time Fourier transform the idea of localization, but also overcomes the disadvantages of window size does not change with frequency, can provide a time - frequency with the frequency change of the window, is an ideal tool for time-frequency analysis and processing of signals[4]. It's mathematical expression is showed as formula 1, in which  $a$  represents the scale of expansion, which reflects the cycle length of the wavelet;and  $b$  translation parameter, which reflects the translation of the time.

$$W_f(a, b) = |a|^{-\frac{1}{2}} \int_{\mathbb{R}} f(t) \bar{\psi}\left(\frac{t-b}{a}\right) dt \quad (1)$$

By integrating the square value of wavelet coefficients in the  $b$  range, the wavelet variance can be obtained, It's mathematical expression is showed as formula 2.

$$\text{Var}(a) = \int_{-\infty}^{\infty} |W_f(a, b)|^2 db \quad (2)$$

In order to determine the periodic change of the The Dian Lake river basin, it is necessary to analyze the rainfall runoff with multiple time scales. In the multi time scale analysis based on the Morlet wavelet analysis, the wavelet transform frequency distribution characteristics of the The Dian Lake river basin at different time scales are analyzed.

## Decadal Variability of Rainfall Runoff

Figure 1 is the process of runoff and the 5 year moving average curve of rainfall in The Dian Lake. As is showed in Figure 1, the Dian Lake rainfall 1959-1966 years rainfall is abundant, larger than the average annual rainfall, annual rainfall in the wet period; 1966-1972 in average rainfall years, and there is a Slight fluctuations, low rainfall in dry season; 1973-1981 rainfall abundant, but not obvious; 1982-2001 years in the dry season, there is a Slight fluctuations, with obvious 1966-1972 years of rainfall less than 2002-2011; the annual rainfall slightly rebounded in the wet period. It can be seen that the annual rainfall process generally experienced a rainy - less rain - rainy - less rain - rainy alternate circulation, but the rainfall showed a downward trend in general.

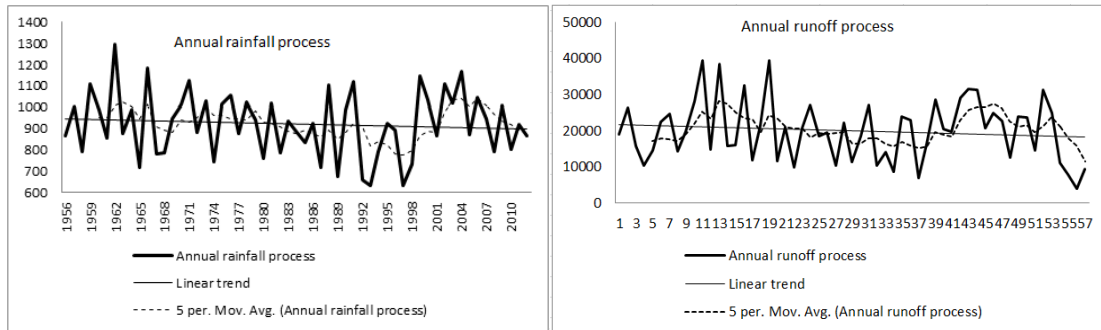


Figure 1. Rainfall runoff process (left Songhuaba station, right Baoxianghe station).

The rainfall is the main influencing factors of runoff, The annual runoff process is the process of runoff in the upper reaches of the The Dian Lake River in the trunk stream panlong river. It can be seen from the figure that 1958-1965 annual runoff and average annual runoff is relatively small, it is in the dry season; 1966-1976 annual runoff was significantly increased, in the wet period; 1980-1993 runoff is relatively stable, in the annual runoff below the low water period; 1994-2008 runoff has picked up, in the wet period. The change of runoff and rainfall showed a general trend in consistency, showing a downward trend in general.

Below is the main stream of The Dian Lake Songhuaba Reservoir and tributaries of The Dian Lake Baoxianghe Reservoir like river reservoir runoff series Morlet wavelet coefficients real part contour map[5], It can reflect the annual cycle and the strength of the basin, Figure 2 wavelet coefficients of the real part is positive, on behalf of the wet season, shown with solid lines; the real part of the wavelet coefficient is negative, that the dry season, the dashed line; the real part of the wavelet coefficient is 0, representing the average water period, represented by thick lines. It can be seen from the following chart that the flow of the river is the most obvious on the scale 15a scale, and there are 12 alternate cycles of drought and flood. Between 1956-1958, 1964-1969, 1974-1979, 1984-1990, 1996-2001, and 2006-2010, the runoff was very large; 1958-1964, 1969-1974, 1979-1984, 1990-1996, 2001-2006 ,2010-2012 runoff in dry season. There are some fluctuations in runoff process, but in general, the annual runoff of 1956-2012 is dominated by 15a cycle.

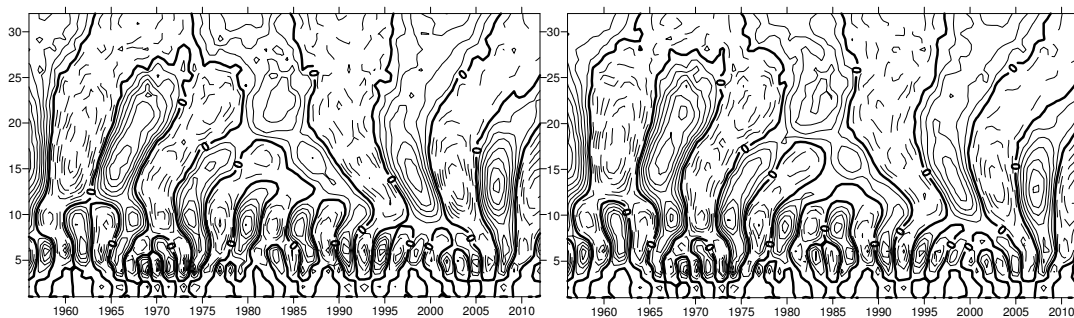


Figure 2. Real contour map of wavelet coefficients (left Songhuaba station, right Baoxianghe station).

The above analysis shows that the changes of The Dian Lake river runoff stations are basically the same, all with periodic changes of about 15a, the cycle time scales are similar, which can reflect the Dianchi basin during the heavenly stems and Earthly Branches runoff change characteristics and its evolution trend[6].

The wavelet variance reflects the distribution of the fluctuation energy of the runoff time series with the period[7]. In order to determine the main period of each station, that is to say, the main function of the runoff sequence, the formula (2) is used to calculate the variance of each station, as shown in Figure 3.

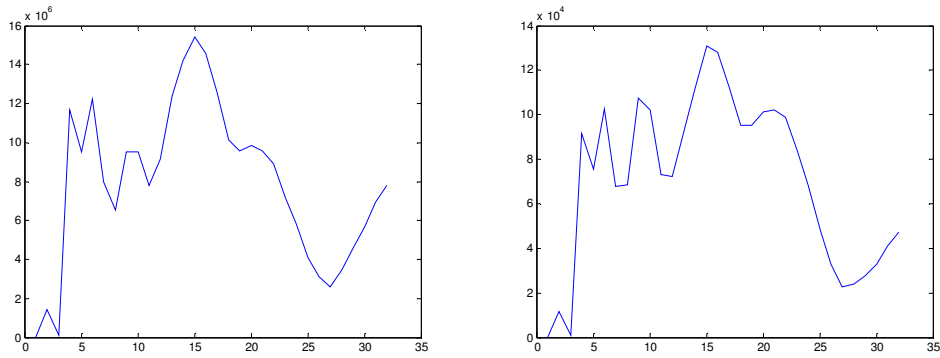


Figure 3. Wavelet variance map (left Songhuaba station, right Baoxianghe station).

It can be seen from the figure of each station has multiple time scale characteristics, and there are 5 peaks value in the Songhuaba station and the Baoxianghe station, Songhuaba station corresponding to 15a, 6a, 4a, 10a and 20a oscillation cycle, Baoxianghe station corresponding to 15a, 10a, 20a, 6a and 4a oscillation cycle, of which 15A time scale wavelet variance is most obvious, It shows that the first main period of the two stations is 15a, there are some differences in the 2-5 cycle, corresponding to the real contour map of Morlet wavelet coefficients, the change characteristics of natural runoff in The Dian Lake basin are determined in the whole time domain, It can be seen that there is a certain similarity between the change trend of The Dian Lake dry tributaries. But there are certain differences in the 2-5 cycle, indicate that in the Yunnan Province plateau mountain three-dimensional climate under the basin on different rivers there will be some changes in the evolution process of runoff, should pay attention to prediction of water resources evolution.

### Discuss

The Morlet wavelet analysis method was used to analyze the runoff data of the Songhuaba station and Baoxianghe station from 1956 to 2012. The results showed that:

1. The interannual variation of rainfall in the Dianchi Lake Basin was mostly rainy - less rainy - rainy - less rain - rainy alternation from 1956 to 2012, and the rainfall was decreasing on the whole. The runoff variation was consistent with rainfall, showing a decreasing trend.
2. There are several time scales in the periodic variation of the runoff in the Dianchi Lake basin, with 15, 6, 4, 10 and 20a oscillatory cycles, and 15a is the first major period. The runoff was in the dry years after 2010.

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