Study on noise reduction of rainfall at Shizhu Station and protection of villages along Nanxi River

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Abstract. Nanxi River is one of the largest tributaries in the lower reaches of Oujiang River. There are many traditional villages along the river. When there are more rainy seasons or typhoon storms, floods will occur in the basin. There is Shizhu hydrological station on the main stream of Dananxi in the lower reaches of the basin. Shizhu station is the flood control station in the middle and lower reaches of Nanxi River, which plays an important reference role in flood prevention of Nanxi River. Due to the influence of many factors, rainfall data contains system noise and measurement noise. The analysis and calculation of the model parameters from the rainfall series with noise can not truly reflect the nature of the rainfall system. The reliability of data and the accuracy of data analysis results can be improved by denoising rainfall series. In this paper, the wavelet denoising method is used to denoise the annual rainfall series of Shizhu station, and its useful rainfall data is obtained. The amount of rainfall has a direct impact on the socio-economic development along the line, the health of the ecological environment and the people's living and working in peace and contentment on both sides of the Nanxi River. The research results can provide basic data for flood control and water resources utilization of Nanxi River, and enable relevant departments to take measures in advance to ensure the safety of people's living environment and sustainable development of ecological environment, and provide technical support for Rural Revitalization in Nanxi River.

1. Introduction

Nanxi River Basin is located in 120°19′~120°59′ E and 28°00′~28°34′ N. It is the largest tributary on the left bank of the lower reaches of Oujiang River. It belongs to Yongjia County, Jinyun County, Huangyan District, Yueqing City and Qingtian County. With its natural form, the Nanxi River conveys the spatial information and content of ancient landscape painting and natural landscape [1], which is an indispensable natural landscape resource. Nanxi River is the largest tributary of the lower reaches of Oujiang River, with the drainage area of 2436km², the main stream of 142km long and the average gradient of 6.0‰. The basin is located in the subtropical monsoon climate zone, with an average annual precipitation of 1811.2mm, an average annual runoff depth of 1139.2mm, and a total annual runoff of 2.775 billion m³. The spatial and temporal distribution of precipitation is significantly different, decreasing from north to south and concentrated in April to September. Typhoon rainstorms with large amounts and high intensity often cause flooding on both sides of Nanxi River; when Ranin
season or typhoon has less wind and rain, it will lead to basin drought. There are a large number of national and provincial traditional villages along the Nanxi River Basin, which have high value of human resources and rich spatial form [2]. But they are greatly affected by floods. There is Shizhu hydrological station on the main stream of Dananxi in the lower reaches of the basin (the catchment area is 1273km²). Shizhu station is the flood control station in the middle and lower reaches of the Nanxi River, which plays an important reference role in flood prevention of the Nanxi River.

Due to the influence of multiple factors, rainfall data contains system noise and measurement noise [3]. System noise is the feedback of the system in each time step when it is subject to small random interference, which directly affects the evolution of the system in time. Measurement noise is the error caused by measurement. The existence of noise drowns the real changing characteristics of rainfall series [4]. The analysis and calculation of the model parameters from the rainfall series with noise can not truly reflect the nature of the rainfall system [5]. It can improve the reliability of the data and the accuracy of the data analysis results [6].

2. Noise reduction method of rainfall

Wavelet analysis is a good multi-scale analysis method [7-8], which can effectively separate high-frequency components from low-frequency components. Based on this, according to different characteristics of different signals (such as useful signal, white noise) after wavelet transform, the wavelet decomposition sequence is processed and the processed sequence is reconstructed to realize signal-to-noise separation [9]. The steps of wavelet denoising are as follow [10]:

2.1. Wavelet decomposition of one dimensional signal

The appropriate wavelet function is selected and the level N of wavelet decomposition is determined. Then, the N-level wavelet decomposition is carried out for the annual rainfall data of Shizhu station.

2.2. Threshold quantization of wavelet decomposition function

For each layer of high frequency coefficients (J 1, 2, ..., N) in 1 ~ N layers, a threshold T is selected for threshold quantization to obtain the high-frequency components after denoising. Soft threshold method is used to process, that is, to compare the absolute value of the signal with the threshold value, the point less than or equal to the threshold value becomes 0. And the point greater than the threshold value becomes the difference between the value of the point and the threshold value. The mathematical formula is expressed as follows:

$$
\hat{d}_j(t) = \begin{cases} 
\text{sgn}(d_j(t))(|d_j(t)| - T) & |d_j(t)| > T \\
0 & |d_j(t)| \leq T
\end{cases}
$$

(1)

The soft threshold method is used to process, and the signal is continuous at T.

2.3. Wavelet reconstruction of signals

According to the low-frequency coefficients of the N-level wavelet decomposition and the high-frequency coefficients from the first to the N-level after quantization, the real signal is obtained, that is, the de-noising signal.

3. Noise reduction of rainfall in Shizhu station of Nanxi River

The annual rainfall data of Shizhu station of Nanxi River from 1956 to 2019 are used for analysis. And the trend is shown in Figure 1.
Wavelet analysis is applied to denoise the annual rainfall at Shizhu station of Nanxi River. In the process of wavelet decomposition, DB4 function is selected for wavelet transform. It is found that the Layer two of wavelet decomposition is appropriate. Next, the unbiased risk threshold method of Stein, which is commonly used in hydrological treatment is used. That is, the square of the wavelet coefficients of a certain layer is arranged from small to large to get a vector $W = [w_1, w_2, \cdots, w_n]$ , where $w_1 \leq w_2 \leq \cdots \leq w_n$. Thus, the risk vector $R = [r_1, r_2, \cdots, r_n]$ is calculated, where

$$ r_i = \frac{n - 2i + (n - i)w_i + \sum_{k=1}^{i} w_k}{n} \quad (2) $$

Take the minimum element $r_b$ in $R$ as the risk value, and find the corresponding value $w_b$ from the subscript $b$ of $w_b$, then the threshold $T$ turns out to be $T = \sigma \sqrt{w_b}$, where $\sigma$ is the noise intensity. The denoising results are shown in Figure 2.
From Figure 2, we can see that the general trends of the low-frequency series and the original rainfall series are the same after two-level wavelet decomposition. Therefore, it is appropriate to decompose into Layer two. The decomposed noise sequence is a high frequency fluctuation sequence, which accords with the characteristics of noise signal. It can be seen that the denoising results are in line with the expectation. The comparison between the decomposed effective annual rainfall series and the original series is shown in Fig. 3.

Figure 3. Comparison of denoised signal and original signal

4. Discussion and conclusion
Shizhu station is the flood control station in the middle and lower reaches of Nanxi River, which plays an important reference role in flood prevention of Nanxi River. Due to the influence of many factors, rainfall data contains system noise and measurement noise. This paper used the different characteristics of useful signal and noise signal in wavelet analysis coefficient. And it used wavelet denoising technology to denoise the annual rainfall series of Shizhu station and obtained the denoised data of annual rainfall series at Shizhu station. The data series can show the effective trend of annual rainfall series of Shizhu station, and can provide basic supports for improving the rainfall forecast effects of Shizhu station. It also provides data support for the protection of traditional villages along the Nanxi River Basin. Although there are more researches on traditional villages [11], the research on spatial morphology optimization and protection is less [12]. However, this study can provide more accurate data to support for the relevant departments to formulate development measures in this area, so as to more effectively guarantee the sustainable development of ecological environment on both sides of Nanxi River and protect the life and property safety of people along the river. Especially, it provides hydrological technical support for the protection and the utilization of traditional villages along the Nanxi River Basin. And it provides more accurate data requirements for scientific flood control.

Acknowledgments
This work was financially supported by Ministry of Education Humanities and Social Sciences Research Youth Fund Project (19YJC850005): Research on Spatial Form and Protection of Landscape Resources of Traditional Villages in the Nanxi River Basin.

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