Multi scale analysis of rainfall in Anhua reservoir

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Abstract. Anhua reservoir is located in Zhuji City on the upper reaches of Puyang River (the upstream of reservoir area involves Baima town of Pujiang County), which is an important medium-sized reservoir mainly for flood control. In this paper, the continuous wavelet transform of wavelet analysis is used to analyze the rainfall of Anhua reservoir in multi-scale. The results show that the main period of rainfall in Anhua reservoir is 6-33 years. In the 33 year scale, the rainfall from 2020 to 2030 is relatively dry, while in the 6-year scale, the rainfall from 2020 to 2023 is relatively dry. It can be seen that the rainfall in Anhua reservoir will be less in the next few years, so the reservoir management department should take measures in advance.

1. Brief introduction to Anhua reservoir

Anhua reservoir is located in Zhuji City on the upper reaches of Puyang River (the upstream of reservoir area involves Baima town of Pujiang County), which is an important medium-sized reservoir mainly for flood control. The reservoir controls a drainage area of 640 km² (including 104.5 km² of Anhua reservoir on the Pujiang River) with a total storage capacity of 58.8 million m³. The project was started in October 1957 and completed in June 1958. In 1978, dam protection and reinforcement were carried out and an extra spillway was opened. At the end of 2000, the flood gate was reconstructed and strengthened, and completed in 2001. The main works of the reservoir include dam, flood gate, water gate and extraordinary spillway.

The dam is a sand shell dam with clay inclined wall (the inclined wall reaches the bedrock), with the maximum dam height of 16.3m, the corresponding crest elevation of 36.3m and the crest length of 301m. The flood gate is located at the right end of the dam. It is connected with the dam on the left and the emergency spillway on the right. There are four holes in total. Each hole is 5.3 × 3.75m (width × height), and the net width is 21.2m. It is a flat steel gate. The gate bottom elevation is 20.0m, and the downstream is connected with the secondary stilling basin for energy dissipation, and the maximum discharge is 960m³/s. The extraordinary spillway is located on the right bank and built by splitting mountains. It is a channel type on one side. The top elevation of the inlet weir is 32.0m, and the weir length is 169m. The length of the side weir is 140m and the length of the main weir is 29m. The maximum flood discharge is 2545m³ / s. The water conveyance tunnel is located on the left bank of the dam. The inlet bottom elevation is 23.5m. The inlet is an arch section lined with 2m. The design flow is 5m³ / s, which is used for irrigation of downstream farmland.
2. Multi scale analysis method

Wavelet analysis is a good signal analysis tool. Multi-scale analysis function of wavelet analysis is mainly through continuous transformation trend of the evolution of the wavelet coefficient [1-3], which can determine the transformation process of rainfall. Sequence $f(t)$'s Continue Wavelet Transform—CWT [4-5] is:

$$W_f(a,b) = |a|^{-1/2} \int_{-\infty}^{\infty} f(t) \Psi \left( \frac{t-b}{a} \right) dt$$  \hspace{1cm} (1)

Type: $W_f(a,b)$ is wavelet transform coefficient. When $a$ decreases, the time-domain waveform of $\Psi_{a,b}(t)$ contraction in the time axis direction, it analysis the signal's details, then we can get the signal's contained high frequency information; when $a$ increases, the time domain waveform of $\Psi_{a,b}(t)$ extension in the direction of time axis, it analyzes the signal’s profile, then we can receive the signal's containend information of low frequency signal. That is, by adjusting the size of $a$ and change the time frequency window of time and wide bandwidth, it can analyze the frequency of different local scale implementation of series $f(t)$.

3. Multi scale analysis of rainfall in Anhua reservoir

Step 1: continuous wavelet transform of rainfall series

For rainfall series, Morlet wavelet function is selected for continuous wavelet transform, and the variance, modulus square and real part of continuous wavelet transform coefficients are obtained.

Step 2: find out the main scale of rainfall series

The distribution maps of modulus square, real part and variance of continuous wavelet transform of rainfall series with time are drawn, and the main scales of rainfall series are analyzed.

Step 3: analyze the trend of the main scale of rainfall

The real part of continuous wavelet transform coefficients of each main scale descending rainfall series with time is drawn. From the change of real part of continuous wavelet transform from positive to negative, the trend of wet and dry change of each main scale descending rainfall series is determined. Based on the comprehensive analysis of the wet and dry conditions of a certain time at various scales, the trend of the rich and low at that time is determined.

4. Multi scale analysis of rainfall in Anhua reservoir

Morlet wavelet function is selected to carry out continuous wavelet transform on the rainfall in Anhua. The modulus square, real part and variance of wavelet transform coefficients are calculated, and their distribution map with scale variation is drawn, as shown in Fig. 1.

![Figure 1. Modulus square, real part and square error of wavelet transform](image_url)
According to Fig. 1, we can see that the rainfall of Anhua reservoir has a cycle of 6 and 33 years. By analyzing the real part change process of wavelet transform in main scale, we can find the change process of rainfall in various scales.

![Figure 2. Real part change process of wavelet transform in 6 years scale](image)

At the 6-year scale, the abrupt change points of the maximum daily rainfall are 1957 (from wet to dry), 1962 (from dry to wet), 1964 (from wet to dry), 1969 (from dry to wet), 1972 (from wet to dry), 1975 (from dry to wet), 1978 (from wet to dry), 1981 (from dry to wet), 1984 (from wet to dry), 1987 (from dry to wet), 1991 (from wet to dry) and 1994 (From dry to wet), 1998 (from wet to dry), 2001 (from dry to wet), 2004 (from wet to dry), 2008 (from dry to wet). From the change trend, it can be seen that the maximum daily rainfall in 2020-2023 is relatively dry under the 6-year scale.

![Figure 3. Real part change process of wavelet transform in 11 years scale](image)

In the 33 year scale, the mutation point of the maximum daily rainfall is in 1971 (from wet to dry), 1990 (from dry to wet) and 2010 (from wet to dry). From the change trend, it can be seen that the maximum daily rainfall of the year from 2020 to 2030 is relatively dry under the 33 year scale.
5. Conclusion
In this paper, the continuous wavelet transform of wavelet analysis is used to analyze the rainfall of Anhua reservoir in multi-scale. The results show that the main period of rainfall in Anhua reservoir is 6-33 years. In the 33 year scale, the rainfall from 2020 to 2030 is relatively dry, while in the 6-year scale, the rainfall from 2020 to 2023 is relatively dry. It can be seen that the rainfall in Anhua reservoir will be less in the next few years, so the reservoir management department should take measures in advance.

References
[1] Wang Wensheng, Ding Jing, Xiang Honglian. Application and Prospect of wavelet analysis in hydrology [J]. Progress in water science, 2002, 13 (4): 515-520
[2] Cui Jintai. Introduction to wavelet analysis [M]. Xi'an: Xi'an Jiaotong University Press, 1995:1-20.
[3] Ma Xixia, Chen Xin, Guo Huifang, reservoir annual runoff combined forecast model based on wavelet ANFIS [J]. China Rural Water Conservancy and hydropower, 2008 (7): 12-14
[4] Wang Wensheng, Ding Jing, Xiang Honglian. Application and Prospect of wavelet analysis in hydrology [J]. Progress in water science, 2002, 13 (4)
[5] Guo Huifang. Study on medium and long term runoff prediction model based on wavelet analysis [D]. Zhengzhou: Zhengzhou University, 2007:20-22.