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Identification and Determination of Inconsistent Rainfall in Water Source Areas of Cixi City based on K-S Test

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Abstract

Cixi City is located on the south bank of Hangzhou Bay in eastern Zhejiang Province. It is a severely water scarce area with a per capita water resource share of only 445 cubic meters, which is only one-third, quarter, and one-fifth of the per capita share of Ningbo City, Zhejiang Province, and the whole country. With the continuous growth of population and rapid economic and social development, the supply-demand contradiction of water resources in Cixi City will become increasingly prominent. Precipitation forecast is a prerequisite for water resource planning and management in Cixi City. Currently, water resource planning and management are based on historical hydrological data. Therefore, the accuracy of hydrological data is of great significance for water resource planning. In order to determine whether the rainfall data sequence is stable and whether its development pattern is consistent, K-S test was introduced to test the rainfall sequence in this study. By testing, it was found whether there was inconsistency in rainfall and when it occurred, in order to provide better reference for future water resource management. The rainfall in the water source area of Cixi City has undergone inconsistent changes, with the change occurring in 1965.

Keywords

Cixi City; Rainfall; Inconsistency; Water Resources; K-S Test.

1. Introduction

Cixi City is located on the south bank of Hangzhou Bay, with obvious location and transportation advantages. It is the center of the economic golden triangle of Shanghai, Hangzhou, and Ningbo. The Hangzhou Bay Cross Sea Bridge has brought a once-in-a-lifetime historic opportunity to Cixi, making it a golden node connecting the two major cities of Shanghai and Ningbo. However, Cixi City is a severely water scarce area, with a per capita water resource share of only 445 cubic meters, which is only 1/3, 1/4, and 1/5 of the per capita share of Ningbo City, Zhejiang Province, and the whole country. With the continuous growth of population and rapid economic and social development, the supply-demand contradiction of water resources in Cixi City will become increasingly prominent. Precipitation forecast is a prerequisite for water resource planning and management in Cixi City. Currently, water resource planning and management are based on historical hydrological data. Therefore, the accuracy of hydrological data is of great significance for water resource planning. In order to determine whether the rainfall data sequence is stable and whether its development pattern is consistent, K-S test was introduced to test the rainfall sequence in this study.

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2. Basin Water System

The Cixi River system is well-developed, with dense waterways interwoven into a network. According to the "Cixi City Water Survey Report" compiled by the Cixi Water Resources Bureau in 2007, there are a total of 21 backbone Class I rivers (sections) in the city, 15 general Class I rivers, 434 Class II rivers, and 1404 Class III and below rivers. Under normal water levels, the water area of the river network in Cixi City is over 50 square kilometers. Calculated based on the total land area of 1361 square kilometers at that time, the water surface rate of the river network in Cixi City is 3.75%. The plain area is 987.2 square kilometers, and the water surface ratio of the plain river network is 4.39%. Although the Cixi River system belongs to the Yaojiang River system, the drainage area into the Yaojiang River is less than 19%, and most of it flows into Hangzhou Bay from the north of the water system. Based on the terrain of high in the west and low in the east, the area is divided into four river areas from east to west, namely Donghe, Zhonghe (including the downstream area of the Henghe People's Sluice), Xihe, and Northwest River areas. The Donghe and Zhonghe areas are bounded by Yangpu, while the Zhonghe and Xihe areas are bounded by Yangshan Lujiang to Luzhong Bay, Liutang River, and Sizaopu. After the completion of the drainage project in the west, Xihe and Northwest River areas are generally subject to joint scheduling, with the downstream area of the Henghe People's Sluice. The area is still draining into the Yao River. The Municipal Flood and Drought Prevention Command Headquarters implements unified control and scheduling of water levels and volumes in various river areas, and is responsible for supervising their implementation. The characteristic water level values of each river area are shown in Table 1.

Table 1. Table of Water Level Characteristics of Cixi River Network

water level / river system	Warning water level (m)	Normal water level (m)	Dry water level (m)
Donghe	1.90	1.45-1.65	0.60
Zhonghe	2.10	1.75-1.95	0.90
Xihe	2.80	2.25-2.45	1.20
Northwest River	3.10	2.25-2.80	1.90

Note: The elevation system is the 85 national elevation benchmark, the same below.

3. Inconsistent Testing of Rainfall in Water Source Areas of Cixi City

The assumption of consistency is a fundamental prerequisite for water resource planning and management, hydrological analysis and calculation, water conservancy engineering design, construction, and operation. By using consistent hydrological sequences for analysis, future predictions can be made based on historical hydrological patterns and statistical characteristics. However, when the consistency of hydrology changes, using historical hydrological data for analysis can mislead subsequent water resource planning. However, under the influence of climate change, current rainfall sequences often exhibit non consistency. In order to better plan future water resources, it is necessary to distinguish the consistency of rainfall data, discover historical patterns, and identify the time of abrupt changes. The discrimination of consistency can provide reference for subsequent hydrological data restoration, water resource planning and management.

3.1 Non Consistency Diagnostic Methods

The Kolmogorov Smirnov (K-S) test is a commonly used inconsistency test method, which detects the existence of inconsistency by distinguishing whether two variables are of the same distribution. Therefore, we usually set the step size and judgment time for the occurrence of inconsistency changes,

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and conduct sliding window tests to determine the time and degree of inconsistency occurrence.The steps for K-S hypothesis testing are as follows:

Step1:Assuming that the two sets of sample data $X(x_l, x_2, x_3, \ldots, x_{n-l}, x_n)$ and $Y(y_l, y_2, y_3, \ldots, y_{m-l}, y_m)$ are respectively, and their distributions are $F(x)$ and $G(x)$;

Step 2: Establish the null hypothesis and the chosen hypothesis:

$$H_0: F(x) = G(x), \quad \forall x \in (-\infty, +\infty)$$
$$H_I: F(x) \neq G(x), \quad \exists x \in (-\infty, +\infty)$$

Step3: Construct statistical test variables. Record $Sx(x)$ and $Sr(x)$ are the empirical distribution functions of the population X and Y separately. If the null hypothesis holds, for x, $|S_X(x) - S_Y(x)|$ becomes small or approaching zero value. Therefore, construct the K-S test statistic D:

$$D = \max|S_X(x) - S_Y(x)|$$

Step 4: Calculate the statistical test quantity QKS and significance p:

$$Q_{KS}(\lambda) = 2\sum_{j=1}^{\infty}(-1)^{j-1} e^{-2j^2\lambda^2}$$
$$p = Q_{KS}\left(\left|\sqrt{N_e} + 0.12 + 0.11\right|\sqrt{N_e}\right|D)$$

In the formula:$N_e = \lambda\sqrt{(m+n)/mn}$, λ Is it related to α The correlation coefficient, when α When taking 0.05 or 0.01, λ They are 1.32 or 1.63, respectively.

Step 5: Calculate the value of the statistic and determine whether the null hypothesis holds. Calculate the value of significance p and associate it with the level of significance α Compare if p< α, Reject the null hypothesis and prove that two sequences do not follow the same distribution, or that they have significant differences. Anyway, there is no significant difference in clothing and it follows the same distribution.

3.2 Analysis of Inconsistent Diagnosis Results

Use the K-S test method mentioned above to diagnose the inconsistency of rainfall sequences at representative stations in the water source area of Cixi City, in order to determine whether there has been a non-uniform change in rainfall. If the test result follows the null hypothesis, it is considered that there has been no inconsistent change in the hydrological series, and there has been no inconsistent change in the hydrological process (hydrological) within the control basin of the station; If the test results reject the null hypothesis, it is considered that the station has undergone a hydrological series inconsistency change. The monthly rainfall process of this representative station is shown in the following figure1.

In order to determine whether there has been a non-uniform change in the rainfall sequence, two methods, fixed period and non fixed period, were used in this study to determine whether there has been a non-uniform change. Take 1955-1964 as a sample, with a sample size of 120 data points, and slide for one month each time to see if the inconsistency changes after the test time is extended. In the second case, with a fixed length of 120 months and a sliding step size of 1, we tested whether

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there was any inconsistency between these testing cycles and the 1955-1964 testing cycles for every 120 months of sliding after 1964-2019.

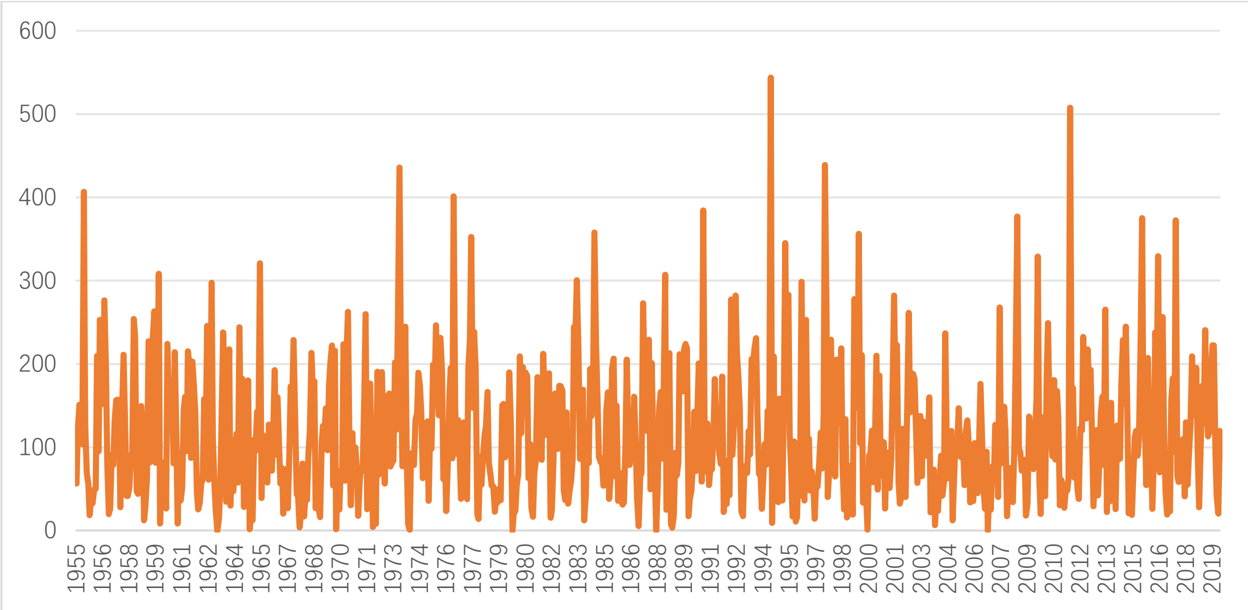

Figure 1. Monthly Rainfall Changes at Representative Stations

3.2.1 Analysis of Inconsistent Diagnosis Results

Using the monthly water level from 1955 to 1964 as a comparison sample, with a step size of 1 and a sliding window for K-S sliding window test, the significance p-values are shown in the figure.

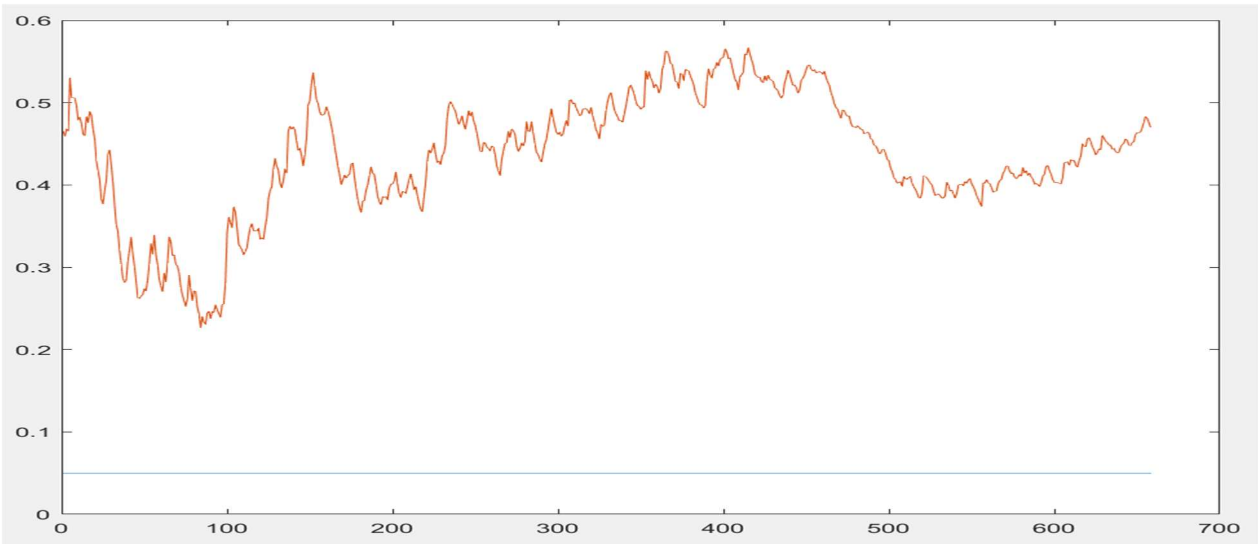

Figure 2. represents the significance value of monthly rainfall sliding test

Using the monthly water level from 1955 to 1964 as the comparison sample, with a step size of 1 and a fixed length sliding window of 120, K-S sliding window test was conducted. The significance p-value and the comparison of the non fixed length p-value are shown in the figure.

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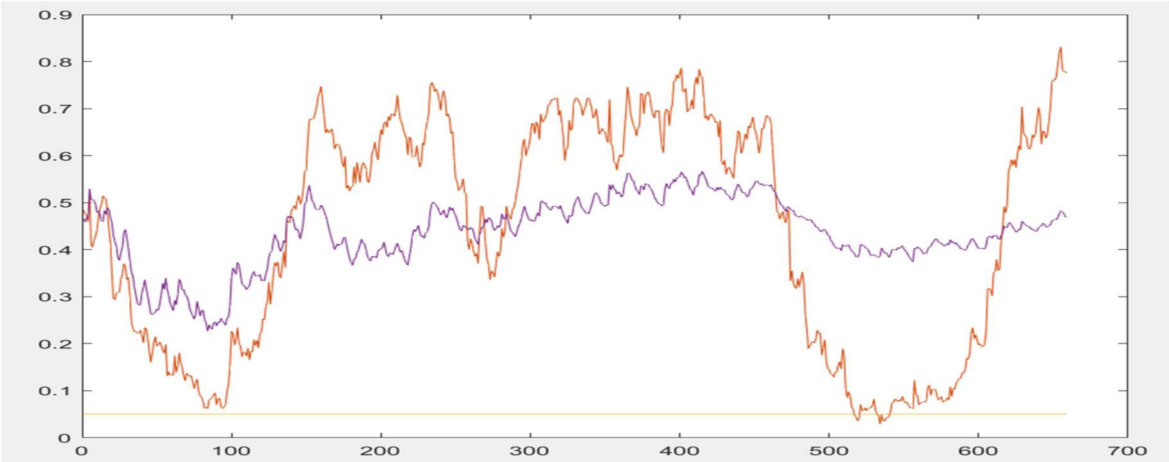

Figure 3. Comparison of significance values of fixed and non fixed length sliding at water level

From the above figure2-3, it can be seen that the representative station of Cixi water source area, with a fixed length, began to approach 0.05 significantly in 1963 and underwent non-uniform changes in 1999. As the sequence length gradually increased, there was a significant downward trend in 1963, but there was no overall non consistent change.

4. Conclusion

Cixi City is a severely water scarce area, with a per capita water resource share of only 445 cubic meters, which is only 1/3, 1/4, and 1/5 of the per capita share of Ningbo City, Zhejiang Province, and the whole country. With the continuous growth of population and rapid economic and social development, the supply-demand contradiction of water resources in Cixi City will become increasingly prominent. Precipitation forecast is a prerequisite for water resource planning and management in Cixi City. Currently, water resource planning and management are based on historical hydrological data. Therefore, the accuracy of hydrological data is of great significance for water resource planning. This article introduces the K-S test method to test the consistency of rainfall in the water source area of Cixi City. Through inspection, it was found that there was a non-uniform change in rainfall, which occurred in 1963.

Acknowledgments

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