Variation Trends of Precipitation and Runoff in the Jinsha River Basin, China: 1961-2015

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Abstract. Data analysis and mathematical statistics are used to analyze the Interannual variation of runoff and precipitation in the Jinsha River basin from 1961 to 2015. The area average annual precipitation showed no significant upward trend, and the annual runoff showed no significant downward trend. The results of cumulative anomaly test, MK mutation test and sliding t test are consistent, there were three mutation years of 1984, 1997 and 2005 in the time series of annual precipitation and runoff in the Jinsha River basin. This study also provides necessary hydrometeorological basic information for quantitative assessment of the contribution rate of climate change and human activities to runoff change.

1. Introduction
The Jinsha River basin, located at the source and upper reaches of the Yangtze River basin, is one of the largest hydropower energy bases in China, and also the most vulnerable area of ecological environment. Due to the particularity of geographical location and the rapid development of social economy, the water system of the Jinsha River basin is constantly experiencing the interference from human activities and climate change [1, 2]. In particular, runoff reduction in recent years has attracted great attention [3]. It is of great scientific significance and practical value to comprehensively analyze the evolution of hydrometeorological elements and influencing factors in the Jinsha River basin. Therefore, this paper studies the variation trends of precipitation and runoff in the Jinsha River basin during 1961-2015.

2. Overview of the study area
The Jinsha River originates from Tanggula Mountain range in Qinghai Province, and runs through Sichuan, Tibet and Yunnan provinces. There is the Yalong River, the largest tributary, joins the Jinsha River in Panzhihua. Furtherly, the Jinsha River is named as the Yangtze River when it converges the Mingjiang River in Yibin, Sichuan Province. The Jinsha River basin is located between 90°0'14"E-104°56'38"E and 24°28'12"N-35°53'49"N. The main river from the source of Qinghai Province to
Yibin City, Sichuan Province, is approximately 3400km long, accounting for 77% of the total river length of the upper reaches of the Yangtze River. The drainage area is about 500000km², accounting for 55% of the area of the upper reaches of the Yangtze River. The runoff is mainly supplied by precipitation, supplemented by groundwater and ice snow melt water. The Jinsha River basin has a large river channel drop, rich technical exploitable hydropower resources, and the level of cascade hydropower development is the highest in the world. The spatial distribution of watershed system, meteorological observation station and hydrological control station in Jinsha River basin is shown in Figure 1.

![Figure 1. The spatial distribution of watershed system, meteorological observation stations and hydrometric stations in the Jinsha River basin.](image)

3. Data and methods

3.1. Data materials

The research data used in this paper include the monthly precipitation data of 32 meteorological stations in the Jinsha River basin and its surrounding areas from January 1961 to December 2015, and the monthly river discharge of the Xiangjiaba station, the downstream control hydrological station of the Jinsha River. All data are provided by the Hydrological Bureau of the Yangtze River Water Conservancy Commission.

The area average precipitation of the basin is calculated by the method of Taisen polygon weighting, which is based on the measured meteorological station in the basin and the precipitation data of neighboring stations around the basin. The runoff of the Jinsha River basin is expressed by river discharge of Xiangjiaba station. It should be noted that the Xiangjiaba station is very close to the Yibin section, that is, the outlet of the Jinsha River basin.

3.2. Methods

The Mann-Kendall test [4-6] (abbreviated as MK), Sen's slope estimation method and linear regression test are used to estimate the precipitation and runoff trend of the Jinsha River basin from 1961 to 2015. The F-test of linear regression test is generally used to test whether the regression relationship between independent variables and dependent variables is significant [7].

The results of cumulative anomaly test, MK mutation test and sliding t test are sometimes inconsistent in evaluating the year of hydrological regime mutation. In order to ensure the reliability of
the results, MK mutation test, sliding t test and cumulative anomaly test are selected together to determine the year of mutation.

4. Results and discussion

4.1. Variation trend of precipitation and runoff
The trend of precipitation and runoff can be obtained by different trend analysis methods, but different methods have different inspection capabilities, and the trend change range calculated by different methods is also different. Table 1 shows that the area average annual precipitation of the whole basin is increasing and the annual runoff is decreasing, but the trend is not significant. The test results of the three methods are consistent. Figure 2 is the precipitation and runoff scatter map of the Jinsha River basin during 1961-2015.

| Statistics                  | MK  | Sen’s Slope | Linear  | Tend           | Significance |
|-----------------------------|-----|-------------|---------|----------------|--------------|
| Area average annual         | 1.1760 | 0.5713 | 0.2816 | increasing     | No           |
| precipitation               |     |            | 0.5601 |                |              |
| Annual runoff               | -0.2250 | -2.5794 | -4.2659 | decreasing     | No           |

Figure 2. Precipitation and runoff scatter points of Jinsha River basin during 1961-2015: (a) area average annual precipitation; (b) annual runoff.

4.2. Analysis of precipitation and runoff mutation
The MK mutation test method was used to analyze the area average annual precipitation and the annual runoff of the Jinsha River basin, and the UF curve and UB curve were drawn. In order to ensure the reliability of the results, sliding t test and cumulative anomaly test are selected to determine the mutation year together, as shown in Figure 3.
Since the late 1960s, the cumulative precipitation anomaly has continued to decrease, with the minimum value in 1984 and then basically stable. After 1997, the cumulative precipitation anomaly has continued to increase significantly, with the maximum value in 2005 (Figure 3(a)).

The area average annual precipitation of the whole basin fluctuated and decreased before 1970, and then increased. After 2000, the UF value exceeded 0.05 significant level, indicating that the average annual precipitation of the whole basin increased significantly. The UF and UB curves intersected in 1984 (Figure 3(c)).

In 1984, 1997 and 2005, t value exceeded 0.05 significance level, even exceeded 0.01 significance level in 2005 (Figure 3(e)).

Combined with the results of MK mutation test, sliding t test and cumulative anomaly test, it can be concluded that the average annual precipitation of the whole basin in 1984, 1997 and 2005 have mutation.

As shown in Figure 3(b) (d) (f), from the results of cumulative anomaly test, MK mutation test and sliding t test, the runoff mutation years are the same as the precipitation mutation years of the basin, which are also 1984, 1997 and 2005.
Before the 1980s, human activities in the Jinsha River basin were relatively weak. The inflection point 1984 reflected that the change of runoff before was mainly affected by climate, especially precipitation, which can be regarded as the base period. After 1984, the influence of human activities gradually appeared. Besides the influence of natural factors such as precipitation, runoff also superimposed the influence of human activities. The mutation points 1997 and 2005 reflect the influence of human activity intensity on runoff variation in different periods.

5. Conclusion
In this paper, data analysis and mathematical statistics are used to comprehensively analyze the interannual evolution of runoff and precipitation in the Jinsha River basin from 1961 to 2015. The main conclusions are summarized as follows:

(1) From 1961 to 2015, the annual precipitation of Jinsha River basin showed no significant upward trend, and the annual runoff showed no significant downward trend.

(2) Multiple methods are needed to complement each other to determine a reasonable year of mutation. From 1961 to 2015, there were three abrupt years of 1984, 1997 and 2005 in the time series of annual precipitation and runoff in the Jinsha River basin.

(3) The ascertain of mutation points also provides necessary hydrometeorological basic information for quantitative assessment of the contribution rate of climate change and human activities to runoff change.

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