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Analysis of Temporal and Spatial Characteristics of Precipitation in a Certain Basin

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Abstract: In order to investigate the spatiotemporal distribution characteristics of precipitation in the midstream region of a basin over recent years, this study collected precipitation data from 2013 to 2024. After rationality analysis of the data, mathematical methods were employed to analyze the temporal distribution, interannual variability, and spatial pattern of precipitation, as well as regional rainfall amounts. The results show that precipitation in the central basin is concentrated in June–September, with sharp seasonal contrasts and marked interannual differences. It alternates between wet and dry years, with a slow upward trend, though this trend is not statistically significant. Rainfall generally increases from the northeast to the southwest of the study area, with the highest annual rainfall exceeding 600 mm.

1 Introduction

Systematically analyzing the patterns of regional rainfall variation is not only of great significance for optimizing regional water resource allocation and improving the operational efficiency of reservoirs within the area, but also crucial for safeguarding the security of residents in downstream towns and enhancing the region's flood prevention and disaster mitigation capabilities. Through the analysis of the evolution and driving forces of ecological zoning in the middle and lower reaches of the Han River Basin, Liang and Li [1] found that changes in rainfall have a greater impact on ecosystem services and zoning changes than land use changes, providing a scientific basis for the sustainable development of regional water ecological environment. Zhong WeiB [2] used methods such as the coefficient of variation, extreme value ratio, and difference-accumulation curve to analyze the spatiotemporal changes in precipitation and the variation patterns of annual precipitation days in the upper reaches of the Xin'anjiang River; Zhong et al. [3] proposed a hybrid model for rainfall prediction in eastern Hubei, which significantly improved the accuracy of prediction (R^2 up to 0.96) by decomposing noise reduction combined with particle swarm optimization and support vector machine. This is of great significance for flood control and disaster reduction, as well as understanding and responding to climate change.; Xuan DangW et al. [4] adopted the multi-scale wavelet analysis method to analyze the flood season precipitation sequence in the Yellow River source area. The Certain basin is a second-order tributary of the Yangtze River. Due to the complexity of its topography and climate, abnormal weather events have occurred frequently in recent years. It’s bringing various uncertainties and risks to the operation of reservoirs in the basin and the safe economic development of the region. In this study, we collected rainfall data from basin midstream over the past decade and analyzed the changes in rainfall amounts in recent years using statistical analysis, wavelet analysis, and spatiotemporal analysis methods. The results provide references for flood control and drought resistance efforts in the basin.

2 Basin overview and selection of meteorological data

2.1 Basin overview

The basin is a second-order tributary of the Yangtze River. It originates from Langmusi, located at the border between Gansu Province and Sichuan Province, and flows through both Gansu and Sichuan provinces before joining the first-order tributary of the Yangtze River within the territory of Guangyuan City, Sichuan Province. The overall drainage pattern of the basin is irregular and dendritic, with most tributaries converging on the right bank, and the main channel and major branches extending toward the northwest. The total length of the basin's main stream is 576 km, with an average river gradient of 4.83%, a natural drop of 2783 m, and an average annual flow of 389 m^3/s.

2.2 Selection of meteorological data

This paper primarily focuses on analyzing the precipitation regularity in this basin midstream. The purpose of the analysis is to provide scientific references

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for flood prevention, drought resistance, and reservoir flood control scheduling within the Region. Therefore, the selection of meteorological stations is mainly based on those that can reflect the major industrial and agricultural areas in the basin and the inflow to the reservoirs. Based on this criterion, we have selected precipitation data from 10 meteorological stations, namely Wenxian, Shangde, Jianshan, Linjiang, Koubadam, Wuku, Sancang, Yulei, Fanba, and Bikou, to draw isohyet maps and analyze the spatial and temporal distribution, as well as the intra-annual and inter-annual variation patterns.

3 Analysis result

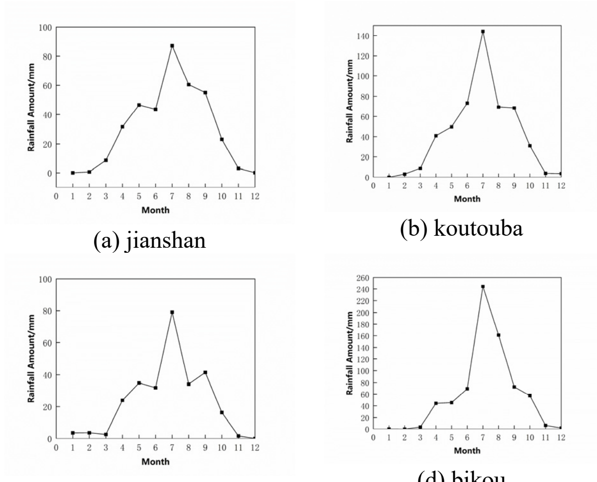
3.1 Annual distribution of precipitation

The annual variation of regional precipitation is affected by many factors, including climate type, landform, seasonal variation, atmospheric circulation, temperature, humidity, etc [5]~[6]. As a result, the variation of rainfall in the year is very different and the distribution is not uniform. In this basin midstream, four meteorological stations, Jianshan, Kouba, Yulei and Bikou, were selected from top to bottom to analyze the variation of annual rainfall in the region. As shown in Table 1, the average annual precipitation in the region ranges from 273.6 to 496.5mm, and the rainfall from May to September in flood season ranges from 221.6 to 592.8mm, accounting for 80.99% to 83.89% of the annual rainfall. The precipitation in this basin midstream is mainly concentrated within 5 months of the flood season, and the precipitation is not evenly distributed within the year, which is greatly affected by the continental climate [7].

Table 1. Annual Distribution Characteristics of Precipitation at Representative Stations

Serial number	Represent-tive station	flood season average precipitation /mm	Average annual precipitati-on /mm	flood season rainfall Proporti-on /%
1	jianshan	292.9	360.0	81.36
2	koutouba	405.1	496.5	81.59
3	yulei	221.6	273.6	80.99
4	bikou	592.8	706.6	83.89

Figure 1 shows the annual process line of annual average monthly precipitation of representative stations in this basin midstream from 2013 to 2024. As can be seen from the figure, the annual variation in precipitation at each station is basically the same, and the maximum precipitation basically occurs in July, and the total rainfall in July accounts for 24%-35% of the total annual rainfall. The dry season rainfall from November to March of following year accounted for 1.7% to 4.2% of the total rainfall. The annual variation of rainfall at all stations is basically the same. The distribution of rainfall in the basin midstream is extremely uneven in flood season and dry season, and the precipitation in dry season is less.



(a) jianshan (b) koutouba (c) yulei (d) bikou

Figure 1. Annual Average Monthly Rainfall at Representative Stations

3.2 Interannual and trend changes of precipitation

3.2.1 Interannual variation of precipitation

In this paper, the characteristics of annual variation of precipitation are analyzed based on the variation rule of statistical indexes such as C_v and extreme value ratio [8]~[9]. Table 2 statistics the annual mean precipitation variation coefficient C_v and extreme value ratio of the four representative stations in 12 years. It shows that the coefficient C_v of precipitation varies greatly, ranging from 0.31 to 0.74, and the extreme value ratio ranges from 3.1 to 23.9. Both the coefficient C_v and the extreme value ratio of Yulei Station are larger. The overall inter-annual variation of precipitation in the central region of basin is quite different, which is related to the topography and landform. The landform type in this region belongs to the medium and high terrain of structural erosion. The elevation is generally 880-1500m, and the relative elevation difference is about 700m. The different locations of the stations have a great influence on the results of rainfall monitoring.

Table 2. Characteristic Values of Interannual Precipitation Changes at Representative Stations

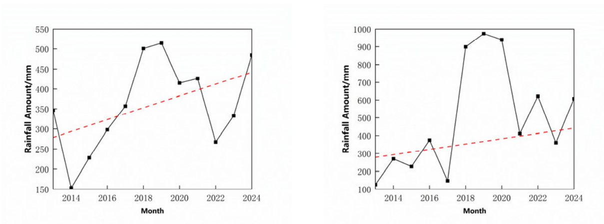
Representative station	C_v	Max value/mm	Min value/mm	Extreme Value Ratio
jianshan	0.31	514.7	153.1	3.4
koutouba	0.62	974.1	126	7.7
yulei	0.74	690.4	28.9	23.9
bikou	0.45	1178.2	376.9	3.1

3.2.2 Trend change of Precipitation

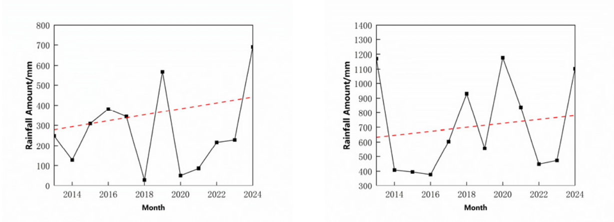
Figure 2 and Table 3 show the interannual trend changes in precipitation estimated by linear function fitting. As can be seen from the charts, the slopes of the linear equations for precipitation at 4 representative stations along the basin from upstream to downstream—Jianshan, Kou Tou Ba, Yulei, and Bi Kou—are 0.148, 0.402, 0.115, and 0.133, respectively, all of which are greater than zero. This indicates that over the 12-year period, the precipitation in the basin midstream has shown an increasing trend to varying degrees. Non-parametric statistical method Kendall rank correlation test was used to test the monotone variation trend, and the confidence level α=0.05 was taken. The increase trend of rainfall at 4 representative stations was not obvious.

Table 3. Multi-year Change Trend at Representative Stations

Representative station	Linear equation	Trend	Kendall's Rank Correlation Test	
			Tau	significance
jianshan	y=0.148x-29.59	increase	0.33	non-significant
koutouba	y=0.402x+2.34	increase	0.36	non-significant
yulei	y=0.115x+1.98	increase	0.12	non-significant
bikou	y=0.133x+6.19	increase	0.15	non-significant



(a) jianshan (b) koutouba

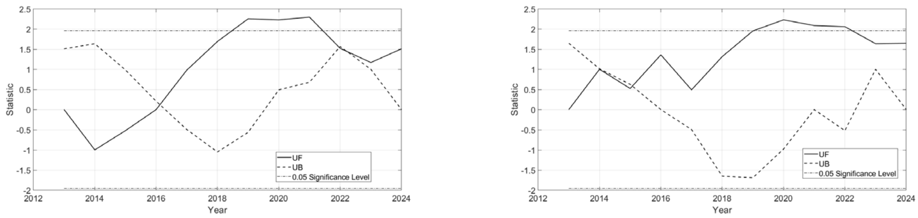


(c) yulei (d) bikou

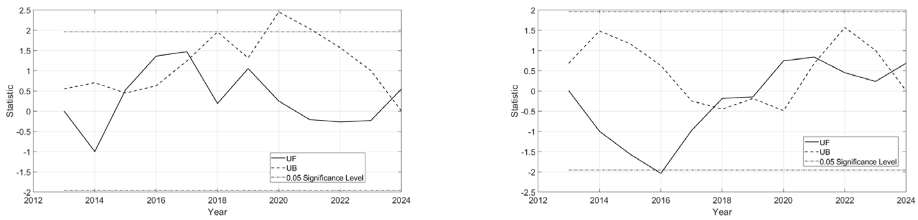
Figure 2. Linear Trend of Precipitation of Typical Station

3.2.3 Temporal mutation analysis

The non-parametric statistical M-K mutation test method was used to analyze the mean annual precipitation data of representative stations in Basin midstream [10]. The results are shown in Figure 3. The abrupt changes in annual rainfall of Jianshan and Koutouba occurred in 2016, 2018 and 2020, and both stations were located on the middle stream of main stem and arranged from top to bottom. Therefore, the abrupt changes in precipitation of the two stations were consistent. Yulei is located on Baishui River, a tributary of Basin. The abrupt rainfall years are 2014, 2018 and 2022, which are different from the main stem. Bikou is located in the downstream of the confluence of the main stem and the tributary Baishui River. The abrupt rainfall years are 2016 and 2020, and the abrupt rainfall years are related to both the main stem and the tributary.



(a) jianshan (b) koutouba



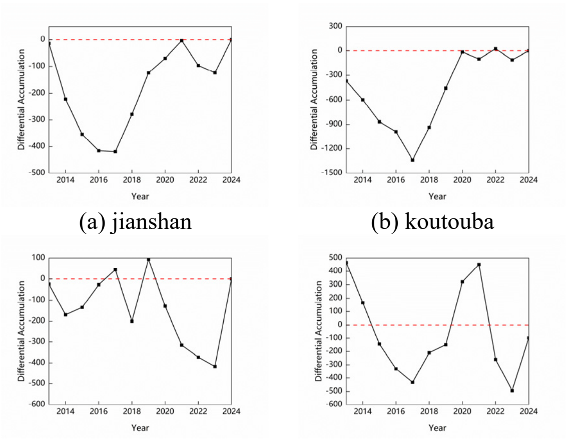
(c) yulei (d) bikou

Figure 3. M-K Test Results of Precipitation at Representative Stations

3.2.4 Precipitation abundance and variability

Figure 4 shows the precipitation process difference product curve of each representative station. The slope of the cumulative precipitation curve rising indicates the wet season, the slope falling indicates the dry season, and a horizontal slope indicates flat season.From 2013 to 2016, the difference product curve of Jianshan Station fluctuated, and there was a 4-year dry period. The fluctuation of the difference product curve increased from 2017 to 2020, and there was a 4-year flood period. From 2021 to 2022, the difference product curve fluctuated and decreased, and there was a 2-year dry period. From 2023 to 2024, the difference product curve fluctuated, and there was a 2-year flood period. The difference product curve of the Koutouba station fluctuated and decreased from 2013 to 2016, and there was a 4-year dry period. The fluctuation of the difference product curve increased from 2017 to 2020, and there was a 4-year flood period. The fluctuation level of the difference product curve from 2021 to 2024 shows a 3-year flat period. From 2013 to 2014, the difference product curve of Yulei Station fluctuated, and there was a 2-year dry period. The fluctuation of the difference product curve increased from 2015 to 2017, and there was a 3-year flood period. From

2019 to 2022, the difference product curve fluctuated and decreased, and there was a 4-year dry period. From 2023 to 2024, the difference product curve fluctuated, and there was a 2-year wet period. The difference product curve of Bikou Station fluctuated from 2013 to 2017, and there was a 5-year dry period. From 2018 to 2020, the difference product curve fluctuated, and there was a 3-year flood period. From 2021 to 2022, the difference product curve fluctuated and decreased, and there was a 2-year dry period. From 2023 to 2024, the difference product curve fluctuated, and there was a 2-year flood period.

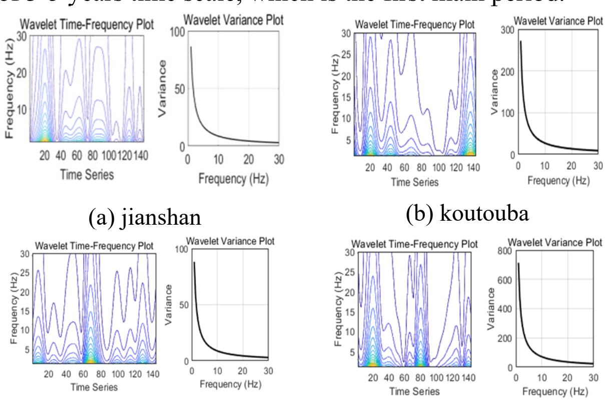


(a) jianshan (b) koutouba
(c) yulei (d) bikou

Figure 4. Precipitation Process Differential Accumulation Curve at Representative Stations

3.2.5 Periodic variation of precipitation

Wavelet variance plots reflect the distribution of the wave energy of precipitation time series with different time scales, and the time scale corresponding to the peak wave energy is the main period in the evolution of precipitation [11]. As can be seen from Figure 5, for Representative Stations, the variation regularity of 10-year rainfall anomaly series from 2013 to 2024 is affected by a period of 3-5 years time scale, which is the first main period.



(a) jianshan (b) koutouba
(c) yulei (d) bikou

Figure 5. Wavelet Transform Analysis at Representative Stations

3.2.6 Spatial distribution of precipitation

Combined with the data of 10 rain gauge stations, the temporal and spatial distribution map of precipitation in the central region of the basin is drawn in Figure 6. the precipitation in Basin midstream gradually increased from northeast to southwest, that is, the fluctuation increased from upstream to downstream. The precipitation is concentrated near Bikou Town. In the study area, the annual precipitation between Kououba Town, Sancang Town and Yulei Town is less than 300mm, the annual precipitation in some areas is less than 200mm, and the rainfall near Bikou town can reach more than 600mm. The spatial distribution of precipitation in the study area is very different, resulting in a large inter-annual and intra-year distribution difference. Using the Thiessen Polygon Method, the annual average surface precipitation of the Basin midstream is 374.7mm, which is equivalent to the annual average rainfall of Gansu Province.

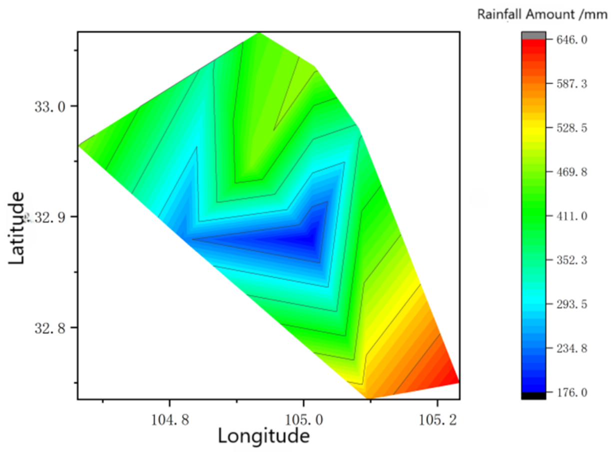


Figure 6. Spatial and Temporal Distribution of Precipitation at Representative Stations

4 Conclusion

(1) The annual variation process of precipitation of representative stations in the Basin midstream is basically the same. The maximum precipitation occurs in July and August, and the annual average precipitation in the region ranges from 273.6 to 496.5mm. The rainfall from May to September in flood season ranges from 221.6 to 592.8mm, accounting for 80.99% to 83.89% of the annual rainfall. The interannual variation of precipitation in the basin midstream is quite different, showing the regularity of alternating between flood and dry years. The annual variation of precipitation is unstable and shows an increasing trend, but the increasing trend is not obvious. The precipitation anomaly series from 2013 to 2024 has the strongest change in the corresponding period of 3-5 years, which is the first main period.

(2) The average precipitation in the basin midstream is 374.7mm, and the precipitation gradually fluctuates from northeast to southwest. The maximum precipitation area is concentrated near Bikou Town and is above 600.0mm. The precipitation in the central area of the study area is relatively small, and the minimum precipitation is below 200.0mm.

(3) In the operation of watershed reservoirs, it is necessary to make preparations for reservoir filling and fall reduction in advance according to the rainfall variation law of the basin, and optimize the utilization of water resources under the premise of ensuring safety.

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