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Multi-timescale analysis of rainfall in Karst in Guizhou, China

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Abstract. The rainfall data are evaluated by performing multi-timescale analysis. Weixin station was considered as a representative location for collecting rainfall data in Karst area of Guizhou Province in China. The results are as follows: (1) there is an increasing trend in annual precipitation, whereas the spring, summer, and winter seasons exhibit a positive contribution to the growth of annual rainfall; however, autumn shows a negative contribution; (2) the annual precipitation series is strongly volatile in the period extending from 2005–2016; summer and autumn show the highest volatility in recorded rainfall, whereas the change in rainfall is not that significant in spring and winter; (3) the main factor contributing to a change in rainfall is not the frequency of rainfalls, but the condition of a single rainfall in a certain time.

1. Introduction

Guizhou mountainous area has numerous sources of water. As a result, water resources per capita value of this region is higher than the national average in China. However, the region has karst topography, so there are very scarce sources of surface water. On the other hand, surface water readily transforms into groundwater; therefore, it is difficult to harvest water resources in this region. Thus, a paradoxical situation created in that the region faces the problem of drought frequently [1-3]. In recent years, soil erosion has increased massively, and flood disasters have occurred frequently. Consequently, there has been an adverse impact on social development. Furthermore, there is significant ecological imbalance in this region, which is accentuated with climate change and special geological conditions inherent in karst topography [4-6]. In the 12th five-year plan drafted by policy makers of Guizhou province, there were strategies proposed to tackle ecological imbalance and to improve social development in the region. In the 13th five-year plan drafted by the government of Guizhou province, the objectives addressed were as follows: healthcare, big data, ecology, and tourism. To address these objectives, a common minimum program for development was presented in the 13th five-year plan in Guizhou province, China. In accordance with this plan, policy makers felt it is necessary to conduct a multi-timescale analysis of rainfall in Guizhou province having Karst

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topography. The results of the analysis can be used for optimum development of water resources, ecological management and protection, and sustainable social structure in Guizhou province, China.

In the Weixin rainfall station, a key water-control project was developed by Bijie city in Guizhou province, China. Under this project, the study example was the rainfall data: this was evaluated to analyze the climate changes according to the rules presented in multi-timescale method. Based on the analysis, we deciphered the trends in climate change. In addition, we also elucidated the relationship between different times and rainfall in a region with typical karst topography. The methodology is an analytic method with which we evaluate rainfall data on a multi-timescale level (annual, monthly, and four seasons), and we further determine rainfall frequency in every timescale. After obtaining the results of the study, we would like to reiterate that it is a preliminary study based on multi-timescale analysis; so the results not only explain the relationship of various rainfall times at a single station but they also provide an investigative account of how the intensity of water problem varies with seasonal climatic changes in the mountainous region with karst topography.

2. Study area and data

Weixin station is located in the Weixin township of Nayong County, Guizhou Province, China. The geographical (latitude and longitude) coordinates of this station are 105°11′ E, 27°01′ N. The station is located in a subtropical region with a typical monsoon climate. Because it is located in the middle of Guizhou plateau, it has distinctly cold mountainous areas with the following geographical characteristics: high altitude and low temperature. The location at which Weixin station is situated has four distinct seasons: i) monsoon with abundant rainfall, ii) a long winter season, and iii) a short summer season. The temperature difference is distinct between day and night; the temperatures vary appreciably in wet and dry seasons. Meanwhile, there are widespread rivers and complex geological conditions in this region with karst topography.

The rainfall data were collected on a daily basis from 2005 to 2016. The data collection was done by Guizhou Bureau of Hydrology and Water Resources in China.

year/month	1	2	3	4	5	6	7	8	9	10	11	12
2005	20.1	24.1	17.6	48.1	141.6	124.3	140.5	192.8	83.1	40.6	34.5	37.5
2006	12.6	24.7	36.7	24.1	141.6	142.5	99.8	81.4	135.3	98.8	30.8	15.0
2007	6.0	21.5	31.1	50.1	159.1	187.0	236.0	181.6	110.4	62.7	16.5	30.5
2008	29.0	28.2	33.8	57.5	126.6	278.8	170.3	188.9	255.4	134.2	96.2	22.3
2009	22.3	14.3	39.5	88.5	101.5	101.9	95.6	179.6	19.6	93.9	14.4	35.3
2010	1.6	17.6	8.3	48.9	62.2	159.3	196.5	72.1	148.4	101.8	33.2	19.8
2011	11.0	19.5	22.5	55.5	45.5	127.5	83.0	90.5	84.5	52.5	35.5	36.5
2012	26.0	21.0	21.5	46.0	134.0	190.5	399.0	107.5	153.0	55.0	26.5	22.5
2013	16.5	12.5	55.0	50.0	73.0	155.0	61.5	160.0	99.0	45.5	26.5	29.0
2014	17.5	33.0	93.0	54.5	105.5	142.5	217.0	122.5	152.0	64.5	52.5	22.0
2015	43.0	23.5	43.0	98.5	189.0	140.5	125.0	190.5	154.5	120.0	9.5	29.5
2016	24.5	18.0	50.5	127.5	118.5	384.5	105.5	118.0	104.5	66.5	40.5	16.0
Mean value	19.2	21.5	37.7	62.4	116.5	177.9	160.8	140.4	125.0	78.0	34.7	26.3
Slope γ_i	1.26	-0.19	3.21	4.95	-1.36	7.51	-0.136	-2.09	0.89	-0.42	-0.64	-0.54
η_i /%	10.1	-1.5	25.8	39.8	-11.0	60.4	-1.1	-16.8	7.1	-3.4	-5.2	-4.3

Table 1.	Monthly	rainfall in	study station.
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3. Monthly rainfall analysis

The slope of the series representing rainfall data illustrates the trends of decrease or increase in rainfall at different points of time; negative and positive values indicate trends of decrease and increase in rainfall, respectively. In the months of February, May, July, August, October, November, and

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December, the slope of the rainfall data series is negative; therefore, we infer that the monthly rainfall decreases in these months. The month of August has the least value of negative slope at -2.09. In the remaining months, we were able to obtain series with positive slope; the positive slope had a maximum value of 7.51 in the month of June. The rate of contribution represents the contribution degree of monthly rainfall in a year; positive value represents positive contribution, while negative value represents negative contribution. Please see formula 1. As shown in table 1, the rates of contribution are 10.1%, -1.5%, 25.8%, 39.8%, -11.0%, 60.4%, -1.1%, -16.8%, 7.1%, -3.4%, -5.2%, and -4.3% for the months ranging from January to December, respectively. This indicates that August was the month that witnessed maximum negative contribution at -16.8%, whereas June is the month that witnessed maximum positive contribution at 60.4%.

$$\eta_i = \gamma_i / \sum \gamma_i \times 100 \tag{1}$$

Where η_i is the rate of contribution in time i, γ_i is the slope of time i.

4. Rainfall analysis for annual and seasonal periods

As shown in table 2 and figure 1, the mean values of rainfall are 216.6 mm, 479.1 mm, 237.7 mm, and 67.0 mm in spring, summer, autumn and winter; the annual rainfall in the region is 1000.5 mm. This indicates that rainfall mostly occurs in summer; the amount of rainfall decreases gradually as seasons change from spring and autumn; the minimum rainfall is recorded in winter season. In autumn, the slope of rainfall series has a negative value, indicating a decreasing trend in rainfall. In contrast, the slopes of rainfall series have positive values in the remaining seasons, with spring season having a maximum positive slope value of 6.8. The slope of annual rainfall series is 12.44; the rainfall shows an increasing trend in Weixin station. Meanwhile, the rates of contribution are 54.6%, 42.5%, -1.4%, and 4.3% in the period progressing from spring to winter; the rate of contribution is negative in autumn, whereas the rate of contribution is positive in spring, summer, and winter seasons.



Figure 1. The scatter diagram of seasons and annual rainfall.

year/seasons	Spring	Summer	Autumn	Winter	annual
2005	207.3	457.6	158.2	81.7	904.8
2006	202.4	323.7	264.9	52.3	843.3
2007	240.3	604.6	189.6	58.0	1092.5
2008	217.9	638.0	485.8	79.5	1421.2
2009	229.5	377.1	127.9	71.9	806.4
2010	119.4	427.9	283.4	39.0	869.7
2011	123.5	301.0	172.5	67.0	664.0
2012	201.5	697.0	234.5	69.5	1202.5
2013	178.0	376.5	171.0	58.0	783.5
2014	253.0	482.0	269.0	72.5	1076.5
2015	330.5	456.0	284.0	96.0	1166.5
2016	296.5	608.0	211.5	58.5	1174.5
Mean value	216.6	479.1	237.7	67.0	1000.5
Slope γ_i	6.80	5.29	-0.18	0.53	12.44
η_i /%	54.6	42.5	-1.4	4.3	/

Table 2. Seasons and annual rainfall.

As shown in figure 1, the scatter diagram presents the trends in rainfall series. The annual rainfall series changed dramatically from 2005 to 2016; the year 2008 received maximum rainfall of 1421.2 mm, while lowest rainfall of 664.0 mm was recorded in 2011. The changes in summer rainfall series was a consistent trend that complied with that witnessed in annual rainfall series. There was a drastic change in rainfall series in autumn; however, the change in rainfall series was almost steady in spring and winter.

5. Analysis of rainfall times

As shown in figure 2, the monthly rainfall frequency is similar from January to December. The month of June had the maximum rainfall frequency of 18.6 times, while the minimum rainfall frequency of 12.3 times was recorded in February. As shown in figure 3, the annual rainfall frequency is 178.8 times. The rainfall frequency in spring, summer, autumn, and winter seasons are 46.1 times, 46.1 times, 45.7 times, and 41.3 times, respectively. However, rainfall times are similar in all the four seasons. Therefore, rainfall frequency is not the main factor that influences the distribution of rainfall.



Figure 2. Times of monthly rainfall per year.

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Figure 3. The times of seasons and annual rainfall.

6. Results and discussion

The trend analysis approach is a simple and useful way to investigate the rainfall series in a multi-timescale parameter. Therefore, we analyzed the trend in rainfall distribution in this paper.

The annual rainfall has an increasing trend, with the slope of its trend line being 12.44. The series of spring, summer, and winter witness an increasing trend; the slopes of trend lines for the series of spring, summer, and winter are 6.80, 5.29, and 0.53, respectively. The main contribution of rainfall mainly occurred from spring and summer, whereas the contribution of rainfall is negative in autumn.

Based on the changes witnessed in the rainfall series recorded from 2005–2016, we infer that the change in rainfall series is a steady state in spring and winter, with the slopes of rainfall series in spring and winter being 6.8 and 0.53. The main factor responsible for the growth in annual rainfall is the growth of rainfall in spring. Meanwhile, the mean value of summer rainfall is maximum: the mean value of summer rainfall is 485.8mm, whereas the slope of summer rainfall series is 5.29. The rate of contribution of summer rainfall is 42.5%. All these results indicate that the main factor responsible for the growth in annual rainfall is also summer rainfall.

Because the rainfall frequency is similar in most months, the four seasons also do not show any drastic change in rainfall frequency. Hence, "rainfall times" is not the main factor influencing the annual rainfall; however, the single rainfall precipitation is one of the main factors influencing annual rainfall growth.

7. Conclusions

The meteorological condition is very unique in karst mountainous area; it adversely affects the development and utilization of water resources. It also sharply influences the regional climatic conditions.

Rainfall is one of the main factors governing the meteorological condition in karst area, so it is important to know the development of different climatic conditions and their impact in karst area.

Due to the availability of limited rainfall data and a significant rise in water conservancy in Guizhou region, both the climatic conditions and human activities equally influence the region. This article is a preliminary study conducted by performing multiple time-scale analysis; its objective was to analyze recent climatic conditions, so only the recent daily rainfall data was selected for research.

Weixin station is a representative karst area in Guizhou Province, China. The results explain the relationship between rainfall and times at a single station. The results of this study can serve as

reference standards for future research studies intending to investigate the changes in climatic conditions in karst mountainous area.

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