Temporal and spatial variation of extreme precipitation in the Longchuan River Basin in 1978-2015 years

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Abstract. Based on the daily precipitation data of 26 meteorological stations in the Longchuan River Basin from 1978 to 2015, the spatial distribution and trend of extreme precipitation events in the Longchuan River Basin were analyzed by trend analysis and Kriging interpolation method. The results showed that the spatial distribution of the annual mean values of each extreme precipitation index in the basin has obvious regional characteristics. The total extreme precipitation, annual precipitation, extreme precipitation days and rainy days in the southwest were higher than those in other regions, however, the extreme precipitation thresholds and daily precipitation intensity were lower than those in other areas, and the opposite occurred in the northeast. In addition to, the interannual variation of the extreme precipitation and daily precipitation intensity showed a trend of growth while the remaining indicators showed a downward trend from 1978 to 2015, indicating that both the precipitation intensity and extreme precipitation in the region increased.

1. Introduction

Under the background of global warming, extreme precipitation events are happening more frequently, which attracts more and more people’s attention. The increase in extreme precipitation events has had a serious negative impact on China's economic development, grain production, people's lives and property, as well as the ecological environment. In particular, floods caused by extreme precipitation events have caused nearly RMB 100 billion direct economic losses annually, and this loss has an upward trend year by year [1, 2]. At present, Chinese scholars have carried out a large number of studies on the tendency of extreme precipitation based on different spatial and temporal scales, and have achieved rich research results. From a national perspective, most studies believed that the intensity of extreme precipitation events in China has generally increased, and extreme precipitation in most regions has increased [3-6]. From different regions, the extreme precipitation intensity in the north of the Northeastern, central North China, South China, western and southwestern of China showed an upward trend [7-13]. Because of the complex terrain and changeable climate in China, the variation of extreme precipitation has obvious regional and local characteristics. To explore the variation trend of extreme precipitation from the regional scale can help us better understand the characteristics and laws of climate change and formulate policies and measures adapted to mitigate the impact of abnormal climate change [14-15]. The Longchuan River Basin is an important economic zone in the central Yunnan Province [16]. It is of great importance to study extreme precipitation in Longchuan River Basin, however there are not many studies on this basin. Based on the daily precipitation data of Longchuan River Basin from 1978 to 2015, the spatial distribution and variation trend of extreme precipitation were studied in this paper, in order to provide theoretical basis and reference for local agricultural production, ecological protection and restoration, efficient allocation and utilization of water resources, disaster prevention and reduction in Longchuan River Basin.

2. Data and methods

2.1. Description of the study area

Longchuan River is a first-class tributary of the right bank of Jinsha River in the middle and upper reaches of the Yangtze River, which is located in Chuxiong Prefecture of Yunnan Province (24°45′-26°15′ N, 100°56′-102°02′ E). Longchuan River Basin is situated in the dry and hot valley of Hengduan Mountains and the terrain tilts from the northwest to the southeast. Longchuan River originated in Tianzimiao, Nanhua County, flowing through Nanhua, Chuxiong, Mouding, Lufeng and Yuanmou, and joined Jinsha River in Jiangbian Township, north of Yuanmou. The total length of the river was 257 km, with an average specific drop of 6.1‰, and the basin area was about 9187 km^2. It was a subtropical monsoon climate with distinct dry and wet seasons. The rainfall was mainly concentrated in the July to September.

2.2. Data selection

The precipitation data used in this paper are measured data of the Longchuan River Basin in 1978-2015. In order to ensure the consistency and continuity of data, 26 meteorological stations with continuous precipitation data were selected after eliminating the meteorological stations established after 1978. All data were subjected to strict quality control and error correction. The location map of the Longchuan River Basin and the distribution map of the 26 meteorological stations are shown in Figure 1.

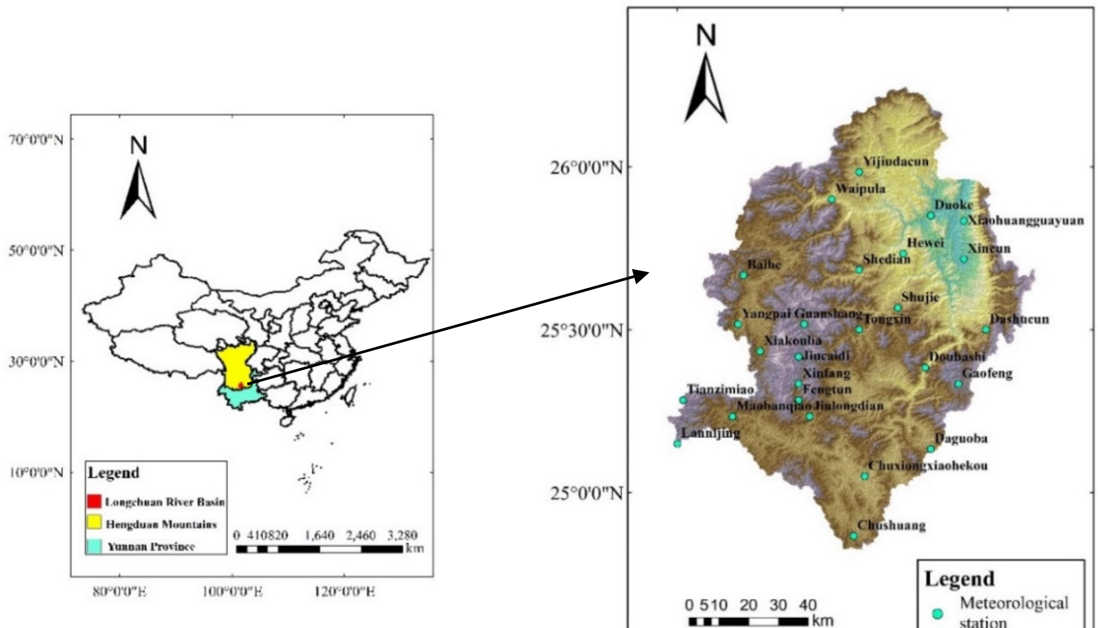

Figure 1. Location and stations distribution of the Longchuan River Basin.

2.3. Research methods

2.3.1. Determination of extreme precipitation indices. At present, the most widely used method of defining extreme precipitation events is percentile. The absolute threshold method is generally used by China Meteorological Bureau to classify precipitation into light rain(less than 10 mm/d), moderate rain (10-25 mm/d), heavy rain (25-50 mm/d), rainstorm (50-100 mm/d), large rainstorm (100-200 mm/d) and extraordinary rainstorm (more than 200 mm/d). However, due to the extremely complex topographic and climatic conditions in China, precipitation events have obvious regional characteristics. Therefore, it is not reasonable to define the precipitation level by using uniform daily precipitation [10]. The percentile method overcomes the fact that the absolute threshold method cannot be different from place to place, and this paper also uses this method to define extreme precipitation events that is, the precipitation of each station from 1978 to 2015 is arranged in ascending order of all the daily precipitation (>0.1 mm) and its 95 percentile is taken as the threshold of extreme precipitation. When daily precipitation of a station exceeds the threshold, extreme precipitation events occur. In 2003, the Expert Team on Climate Change Detection and Indices (ETCCDMI) [17] defined 27 proxy climate indices, mainly focusing on describing extreme events, including 11 extreme precipitation indices, which were most widely used. On this basis, six extreme precipitation indices are selected (Table 1). These extreme precipitation indices can show different aspects of extreme precipitation.

Table 1. Definitions of extreme precipitation indices.

Number	Index	Descriptive name	Definition	Unit
1	R95	Extreme precipitation	The 95^{th} percentile precipitation of all rainy days (> 0.1 mm) during the study period is in ascending order.	mm
2	R95P	Total extreme precipitation	Annual total precipitation with daily precipitation $\geq 95^{th}$ percentile	mm
3	R95D	Extreme precipitation days	Annual number of days with daily precipitation $\geq 95^{th}$ percentile	d
4	RA	Annual precipitation	Annual total precipitation from rainy days(> 0.1 mm)	mm
5	RD	Rainy days	Annual number of days with daily precipitation ≥0.1 mm	d
6	SDII	Simple daily intensity index	Average precipitation on rainy days(> 0.1 mm)	mm/d

2.3.2. Analysis method. Based on the determination of extreme precipitation indices, the extreme precipitation indices of each station in Longchuan River Basin from 1978 to 2012 were calculated year by year, and the average values of each indices for 38a were calculated station by station, which represented the mean values of extreme precipitation indices for the 38 years of the station. Each index generates 26 spatial points, and then the Kriging interpolation method of ArcGIS 10.3 was used to interpolate and plot the contour map to form the continuous spatial distribution of the extreme precipitation indices in the region. At the same time, the long-term trend of extreme precipitation indices was analyzed by linear trend analysis. The least squares method was used to estimate the interannual variation trend of a certain index. If the trend rate is positive, it shows that the extreme precipitation index shows an increasing trend in 1978-2015. On the contrary, the extreme precipitation index shows a decreasing trend.

3. Results and analysis

3.1. Spatial distribution of the multi-year average of extreme precipitation indices

By calculating the average value of each extreme precipitation index for 38a station by station, the spatial distribution of the annual mean value of each extreme precipitation index in Longchuan River Basin from 1978 to 2015 can be obtained by Kriging interpolation method.

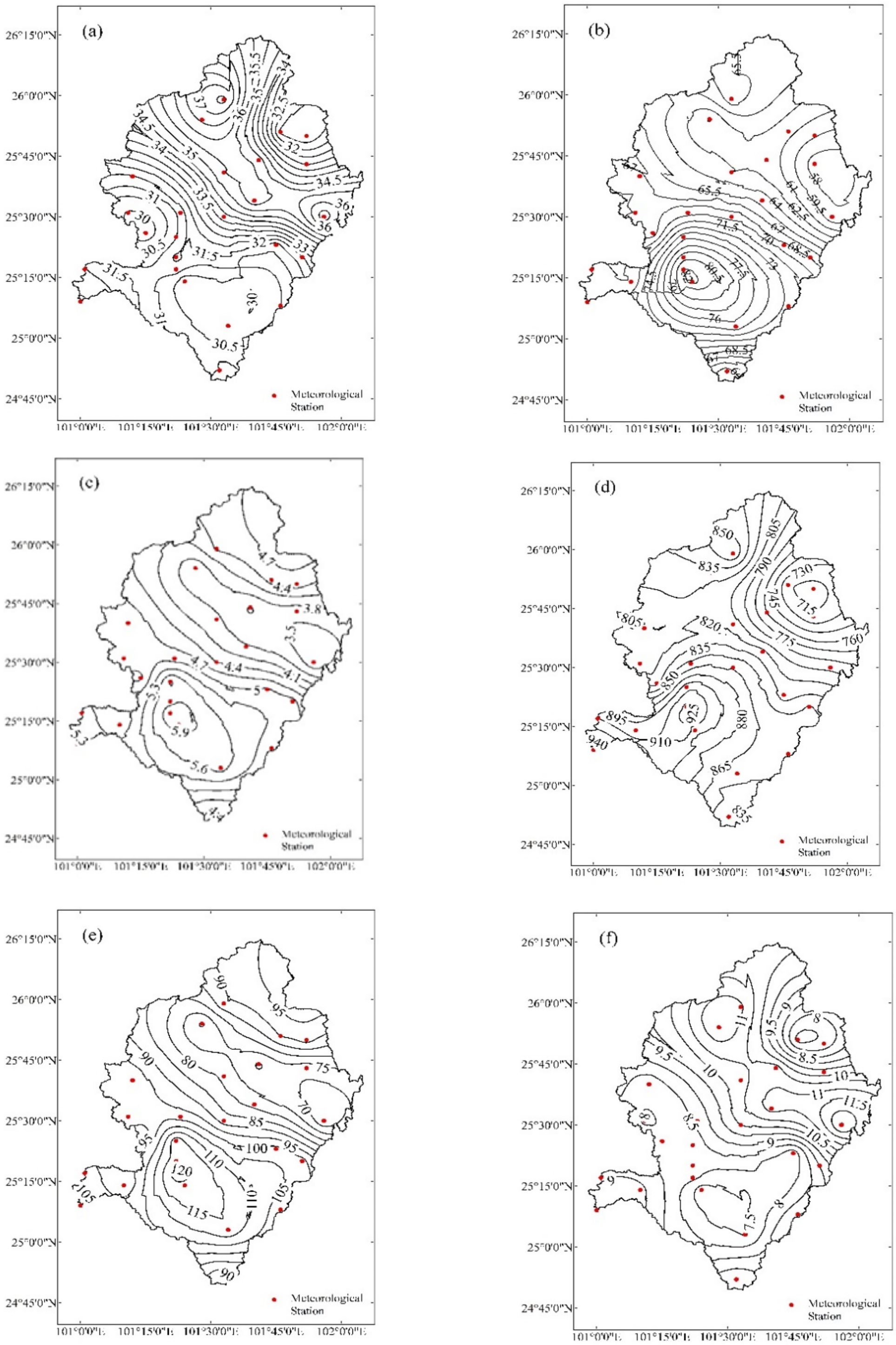

Figure 2. Spatial distribution of extreme precipitation indices over the Longchuan River Basin.

Fig.2a shows that R95 is between 30 and 37.5 mm in Longchuan River Basin. The distribution of R95 generally shows a decreasing trend from east to west and north to south, and the contours of central and northern regions are dense, indicating that the regional character of R95 is more obvious. The isoline of the southern area is sparse, and R95 is not significantly changed.

Fig.2b shows the spatial distribution of R95P in the Longchuan River Basin over the past 38 years. It can be seen that R95P in the basin is between 190 and 260 mm. R95P is increasing from east to west, and north to south, which reveals a trend of decreasing-increasing-decreasing. The high value center appears near the station of Jiucaidi, with a maximum value of more than 255 mm/a.

Fig.2c shows the spatial distribution of R95D in Longchuan River Basin for 38 years. It can be seen that R95D in the basin are 3-6 d/a. Except for a small part of the eastern and central part of the basin which is less than 4 d/a, the other areas are all more than 4 d/a. The high value center appears around the station of Jiucaidi station and Chuxiongxiaohekou station, and the number of days reached 5 d/a or more.

Fig.2d shows the spatial distribution of RA in Longchuan River Basin over the past 38 years. RA is in the range of 700-950 mm. The maximum precipitation is near the Lannijing station in the southwestern corner of the basin and the annual precipitation is over 940 mm. The minimum precipitation is near the Xiaohuangguayuan station in the northeast of the basin and the annual precipitation is about 715 mm. On the whole, RA presents an increasing trend from east to west and north to south.

Fig.2e shows the spatial distribution of RD in the Longchuan River Basin during the past 38 years. RD in the basin are 70-120 d/a. The spatial distribution of RD is basically the same as that of R95D. The maximum value appears near Jiucaidi site, reaching 120 d/a, and the minimum value appears near the Dashucun station in the eastern part of the basin, with only 70 d/a.

Fig.2f shows the spatial distribution of SDII in the Longchuan River Basin over the past 38 years, which is similar to the spatial distribution of R95. SDII in the basin is 7-13 mm/d, and the high value center appears near Dashucun station in the east of the basin, reaching 12 mm/d. In addition, SDII at Waipula station and Yijiudacun station in the northwest is also higher, reaching 11 mm/d, while the low value center is located near Duoke station in the northeast and Chuxiongxiaohekou station in the southeast, reaching 7.5 mm/d. SDII in the middle part of the basin is also large, about 9-11 mm/d.

3.2. Interannual variability of extreme precipitation

The interannual variation characteristics of extreme precipitation indices were analyzed by calculating the mean value of extreme precipitation indices (regional average) of 26 meteorological stations in the Longchuan River Basin and establishing time series of extreme precipitation indices. The overall trend of R95P in the past 38a is increasing, and the interannual propensity rate is 2.99 mm/10a (Fig.3a). The annual average of R95P in the basin is 221.3 mm. Among them, R95P in 15 years is higher than the annual average in multi-year, while R95P in 11 years is lower than 221.3 mm. The maximum value is 409.2 mm in 1986, and the minimum value is 78.9 mm in 1984.

The R95D in the Longchuan River Basin shows a slight downward trend in the past 38a, and the interannual propensity rate is -0.021d/10a (Fig.3b). The annual average of R95D is 5 d, of which the R95D in 21 years is higher than or equal to the multi-year average, and the R95D of 5 years is lower than the multi-year average.The maximum and minimum R95D appears in the same year as R95P, which are 9 days in 1986 and 2.5 days in 1984, respectively.

The overall change of RA shows a downward trend with an interannual propensity rate of -8.7mm/10a (Fig.3c). The multi-year average of RA is 835.1 mm,. Among them, RA in 18 years is higher than that in the multi-year average, while RA in 8 years is lower than that in the multi-year average.The maximum value of RA is 1114.3 mm in 2001, and the minimum value is 577.5 mm in 1988.

The RD shows a more obvious downward trend in 1978-2015, and the interannual propensity rate was -4.2d/10a (Fig.3d). The average annual value of RD is 99.7 d. RD in 20 years was higher than that in 99.7d, and in 6 years, it was lower than 99.7d. The largest RD is 126 d in 1990, and the smallest RD is 70 d in 2009.

The SDII of the Longchuan River Basin showed a weak growth trend among 38a, and the interannual propensity rate was 0.3 mm·d^{-1}/10a (Fig.3e). The multi-year average of SDII is 8.4 mm·d^{-1}, of which SDII in 15 years is higher than that in the multi-year average, and SDII in 11 years is lower than that in the multi-year average. The largest SDII is 11.3 mm·d^{-1} in 1986, and the smallest SDII is 6.1 mm·d^{-1} in 1988.

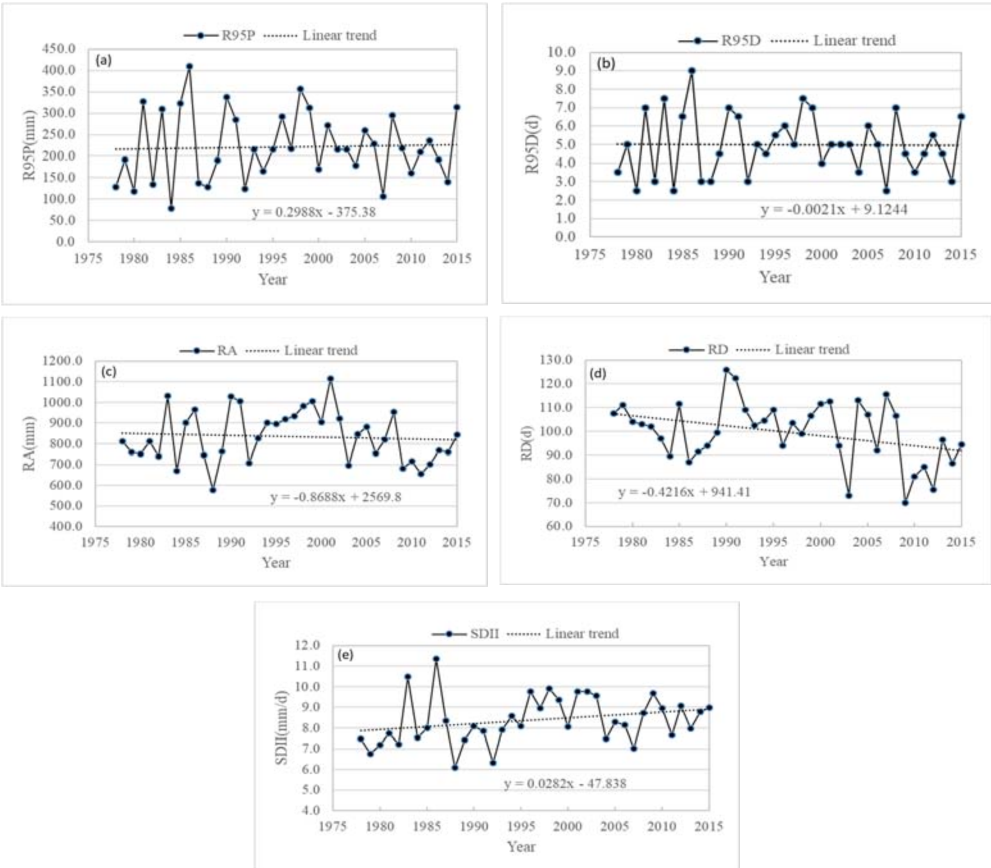

Figure 3. Interannual variability of extreme precipitation in Longchuan River Basin.

4. Conclusion

In this paper, the trend analysis method and Kriging interpolation methods are used to study the temporal and spatial variation characteristics of the extreme precipitation indices in the Longchuan River Basin. The conclusions are as follows:

(1) From the spatial distribution of the multi-year average of extreme precipitation indices, there are obvious regional characteristics of extreme precipitation indices in the Longchuan River Basin. On the whole, the total extreme precipitation, annual precipitation, extreme precipitation days and rainy days in the southwestern part of the basin were higher than those in other regions, while the extreme precipitation threshold and daily precipitation intensity were lower than those in other regions. The conclusions drawn from the northeastern part of the basin were contrary to those in the southwest.

(2) In terms of interannual variation, the total amount of extreme precipitation and the intensity of daily precipitation increased in 1978-2015, and the interannual propensity rate were 2.99 mm/10a and 0.3 mm·d^{-1}/10a respectively. However, the number of extreme precipitation days, annual precipitation and rainy days showed a downward trend, and the interannual propensity rate were -0.021d/10a, -8.7mm/10a and -4.2d/10a respectively, indicating that the total precipitation and the number of precipitation days in the Longchuan River Basin decreased, but the intensity of precipitation increased, and the extreme precipitation tended to increase.

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