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Temporal and Spatial Variation of Summer Extreme High Temperature in Guizhou Province from 1970 to 2020

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Abstract

Based on the daily maximum temperature data of 31 meteorological observation stations and some statistical methods, the temporal and spatial characteristics of summer extreme high temperature in Guizhou province from 1970 to 2020 are analyzed. The results indicate that: 1) The threshold of extreme high temperature (EHT) in summer in Guizhou province had a large spatial difference, with decreasing characteristics from the northeast to the southwest, it was negatively correlated with the altitude. 2) In most parts of Guizhou province, the extreme high temperature days (EHTD) in summer can reach about 4.2 d, the lowest EHTD occurred in the southernmost part. From June to August, the EHTD gradually increased, especially in Central and eastern parts of Guizhou province. However, the extreme high temperature intensity (EHTI) displayed similar distribution characteristics in summer, June, July and August, with larger value in the northeast part and lower value in the southwest part of Guizhou. 3) EHTD had a rising trend in almost stations, except for the PZ station, the increased range and intensity gradually increased from June to August. But the EHTI had a larger spatial difference, especially in June, it declined in most parts of Guizhou, the declined scope and intensity gradually decreased in July, and completely increased in August, this made EHTI show an increasing trend in summer in most parts the Guizhou province. 4) The averaged EHTD increased by 0.62 d/10a ($p < 0.1$), the significant increase also occurred in August, but it increased insignificantly in June and July. The averaged EHTI had insignificant increase in summer and the three months. In general, the EHTD and EHTI increased in most parts of Guizhou province during the period of 1970-2020, this may be related to the changes of them in August.

Keywords

Guizhou, Extreme High Temperature, Temporal and Spatial Variation

1. Introduction

According to the Fifth Assessment Report of the United Nations Intergovernmental Panel on Climate Change, global surface temperature and the rate of warming have continued to increase since the 1880s. The frequency and intensity of extreme weather and climate events have continued to increase, including extreme heat, heavy precipitation events, droughts and so on (Wang et al., 2022), this had significant negative impacts on the natural environment and human. Therefore, extreme weather and climate events have been one of the hotspot science studies.

In recent decades, extreme high temperature (EHT) in summer has occurred in many regions worldwide (Cao et al., 2023; Liu et al., 2018; Barriopedro et al., 2011; Sun et al., 2016). Occurrences of EHT have enormous socio-economic damage and human health issues. For instance, in 2003, Europe suffered recording-breaking heat in summer and killed more than 4000 (Barriopedro et al., 2011). China has been frequently struck by heat waves in recent years. In August 2011, a wide range of continuous hot weather occurred in southern China, in some parts of Sichuan province and Guizhou province daily maximum temperatures exceeded 40˚C for 9 consecutive days, breaking historical records for many times (Si et al., 2012). Sun et al. (2014) indicated that the strongest heat waves during the past several decades mostly occurred after 2000 in eastern China.

Against the background of global warming, it was reported that the EHT had significantly increased (Mishra et al., 2016; Christidis et al., 2015; Manton et al., 2001; Kothawale et al., 2010). Han et al. (2019) pointed that the annual extreme high temperature and the number of extreme high temperature days also showed a significant upward trend in arid Northwest China. Xu et al. (2009) also suggested that the EHT in North China showed an increasing trend. Guizhou province is located in the southwest inland region. Under the background of global warming and frequent extreme weather and climate events, it is prone to extreme weather and climate events due to the influence of circulation situation and geographical location.

Guizhou is located in the east region of the southwest of China, it belongs to the karst mountainous area, the elevation gradually increases from east to west. Due to the impact of topography and geology, the agriculture in Guizhou province is more sensitive to the change of extreme climate (Chen et al., 2015). In recent years, the extreme events occurred frequently in Guizhou, which has threatened the industry distribution, urban development and people's life safety (Huang et al., 2017). However, the current studies are still lacking in EHT in Guizhou. Therefore, this paper mainly analyzes the spatial-temporal variation characteristics of EHT in Guizhou province, which provides important scientific significance and practical application value for meteorological disaster prevention and reduction in Guizhou province.

2. Data and Method

2.1. Data

The data is from National Meteorological Information Center of China (http://www.nmic.cn). Since the establishment time of meteorological stations and the start time of recording meteorological data are different, the integrity, continuity, time consistency and other principles of meteorological data were taken into account, and strict quality control and inspection was carried out. In this paper, the daily maximum temperature data of 31 meteorological observation stations in Guizhou province from June to August during the period of 1970 to 2020 were selected, and the distribution of meteorological stations were displayed in Figure 1, the information of stations can be seen in Table 1.

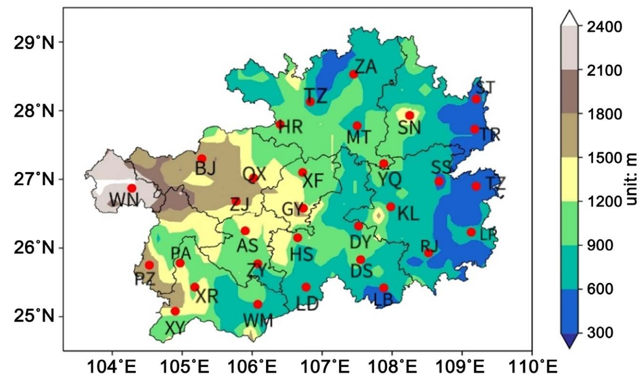

Figure 1. Distribution of meteorological stations in Guizhou province.

Table 1. The detailed information of stations.

Station	abbreviation	Lat	Lon	Altitude	Station	abbreviation	Lat	Lon	Altitude
Weining	WN	26.5	104.2	2238.6	Guiyang	GY	26.4	106.4	1227.3
Puan	PA	25.5	104.6	1449.4	Kaili	KL	26.4	107.6	720.3
Panzhou	PZ	25.5	104.4	2025.9	Sansui	SS	26.6	108.4	626.9
Tongzi	TZ	28.1	106.5	972.0	Liping	LP	26.1	109.1	568.8
Zhengan	ZA	28.3	107.3	816.4	Tianzhu	TZ	26.5	109.1	401.4
Songtao	ST	28.1	109.1	406.1	Xingren	XR	25.3	105.1	1378.5
Bijie	BJ	27.1	105.1	1510.6	Wangmo	WM	25.1	106.1	616.8
Renhuai	RH	27.5	106.2	890.3	Xingyi	XY	25.1	104.6	1299.6
Xifeng	XF	27.1	106.4	1112.3	Ziyun	ZY	25.5	106.1	1197.6
Meitan	MT	27.5	107.3	807.6	Huishui	HS	26.1	106.4	991.6
Yuqing	YQ	27.1	107.5	903.2	Luodian	LD	25.3	106.5	450.3
Sinan	SN	27.6	108.2	574.9	Dushan	DS	25.5	107.3	1013.8
Tongren	TR	27.4	109.1	353.2	Libo	LB	25.3	107.5	429.9
Qianxi	QX	27.0	106.0	1322.0	Rongjiang	RJ	25.6	108.3	285.7
Zhijin	ZJ	26.4	105.5	1319.3	Duyun	DY	26.2	107.3	967.7
Anshun	AS	26.1	105.6	1431.1					

2.2. Regression Analysis

$$y = b_0 + bx \tag{1}$$

Equation (1) shows the relation between the prediction y and variable x. Where b_0 and b presents the intercept and slope of the regression equation, respectively, which can be calculated by the following equations:

$$b_0 = \overline{y} - b\overline{x} \tag{2}$$

$$b = \frac{\sum_{i=1}^{n} x_i y_i - \frac{1}{n}\left(\sum_{i=1}^{n} x_i\right)\left(\sum_{i=1}^{n} y_i\right)}{\sum_{i=1}^{n} x_i^2 - \frac{1}{n}\left(\sum_{i=1}^{n} x_i\right)^2} \tag{3}$$

where $\overline{y}$ and $\overline{x}$ denote the average of variable y and x, y_i and x_i are the ith component of variable y and x, respectively.

2.3. Correlation Analysis

Correlation coefficient r represents the degree of linear correlation between climate variable x and variable y, which is expressed as follows:

$$r = \frac{\sum_{i=1}^{n}(x_i - \overline{x})(y_i - \overline{y})}{\sqrt{\sum_{i=1}^{n}(x_i - \overline{x})^2 \sum_{i=1}^{n}(y_i - \overline{y})^2}}$$

The absolute value of the correlation coefficient r is between 0 and 1, and its absolute value can reflect the strength of the linear correlation between climate variable x and variable y. When the absolute value of r is larger, the correlation between climate variable x and variable y is stronger; otherwise, the correlation between them is weaker.

3. Spatial Distribution of Extreme High Temperature Thresholds in Summer in Guizhou Province

Figure 2 shows the spatial distribution of thresholds of EHT in Guizhou province in summer (June-July-August) from 1970 to 2020. It can be seen that the thresholds of EHT in eastern Guizhou were all above 34.5˚C, and about 33˚C in central Guizhou, and lower than 30˚C in western Guizhou. The minimum value appeared in WN station, where the threshold was below 27˚C. The maximum value occurred in the northeast of Guizhou province, mainly distributed in TR, ST and SN. On the whole, the threshold presented a decreasing distribution characteristic from northeast to southwest, and the difference value between the maximum and maximum threshold was more than 10˚C. The threshold showed an opposite spatial distribution characteristics with altitude (Figure is omitted), the correlation coefficient between them was −0.9575.

Figure 3 shows the spatial distribution of the annual average extreme high temperature days (EHTD) in summer, June, July and August in Guizhou province. It can be seen from Figure 3(a) that the largest EHTD in summer was

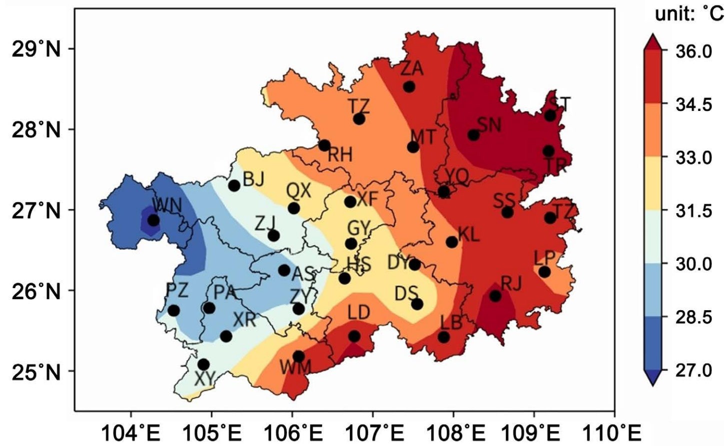

Figure 2. Spatial distribution of summer extreme high temperature threshold in Guizhou province from 1970 to 2020.

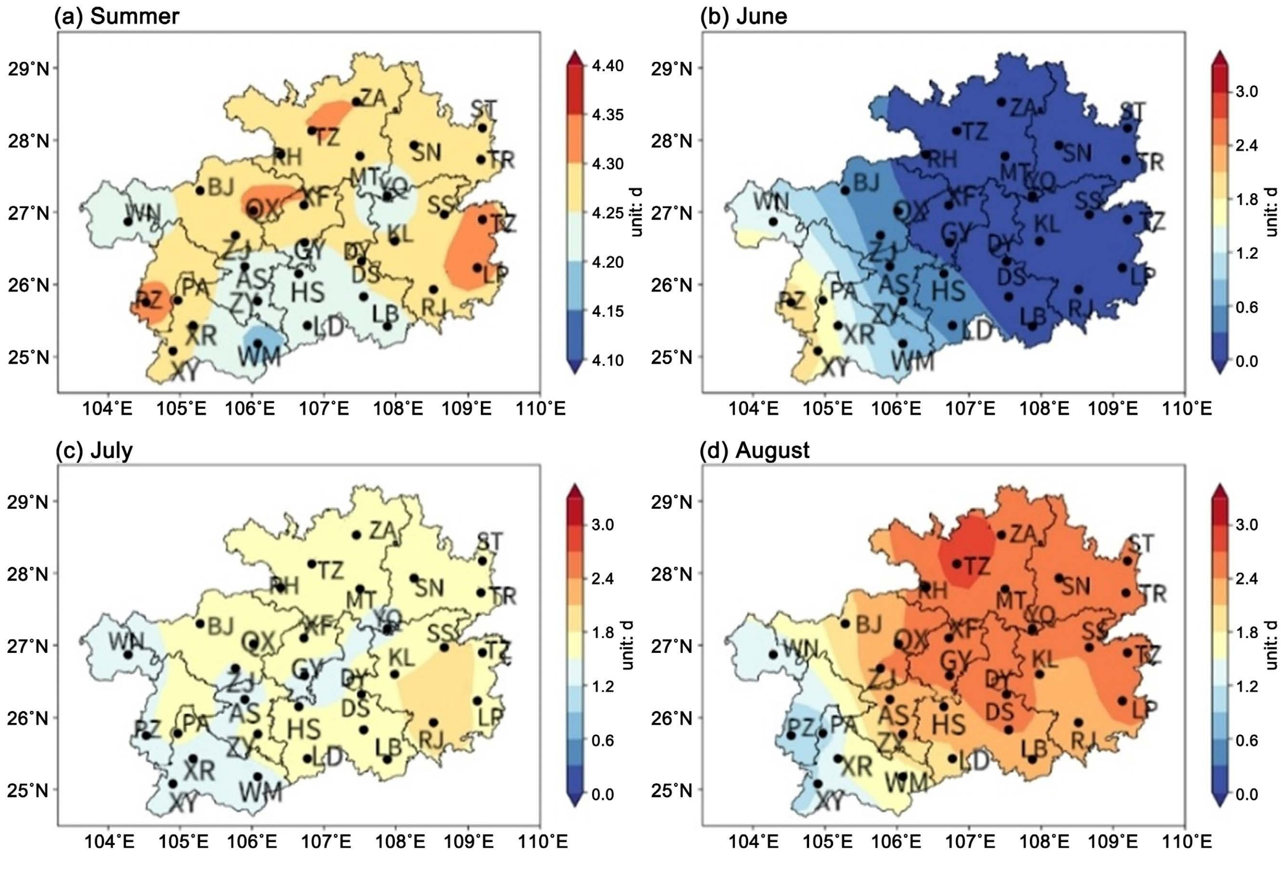

Figure 3. Spatial distribution of extreme high temperature days in summer, June, July and August in Guizhou province.

mainly located in TZ, TZ, LP, QX and PZ, and the average EHTD in summer was all above 4.3 d, while the lowest value was located in WM Station. The spatial distribution of EHTD in June, July and August had great differences. As can be seen from **Figure 3(b)**, the larger EHTD in June was mainly distributed in PZ and XY in southwest Guizhou, while in other regions the EHTD were relatively smaller, even equal to zero. Compared with June, **Figure 3(c)** shows that the

EHTD was about 1.8 d in July in most parts of Guizhou, this implies that the EHTD gradually increased from June to July. Figure 3(d) shows that the EHTD in August had larger regional difference, gradually increasing from southwest to northeast. The largest EHTD was close to 3 day, which appeared in TZ station, the minimum occurred in PZ and PA stations, and the EHTD was less than 1.2 days. In general, the larger EHTD mainly appeared in the northeast Guizhou, and there were larger EHTD in august than that in June and July.

Figure 4 reflects the spatial distribution of extreme high temperature intensity (EHTI) in Guizhou province in summer, June, July and August. It can be seen that the EHTI gradually increased from southwest to northeast, the higher EHTI was above 38˚C, mainly appeared in SN, TR and ST stations in northeast Guizhou. The lower EHTI was about 27˚C, occurred in WN Station (Figure 4(a)). The EHTI had the same spatial distribution in June, July and August, but the magnitude and range of the EHTI gradually increase from June to August.

Figure 5 displays the spatial trend distribution of EHTD in summer, June, July and August. It can be seen from Figure 5(a) that the EHTD showed an increasing trend in almost all the stations, except for PZ station. However, there were only 14 stations (45%) with significant increasing trend ($p < 0.1$). Compared with the summer, the spatial trend distribution of EHTD had a large difference in June, July and August. Figure 5(b) indicates that EHTD displayed a

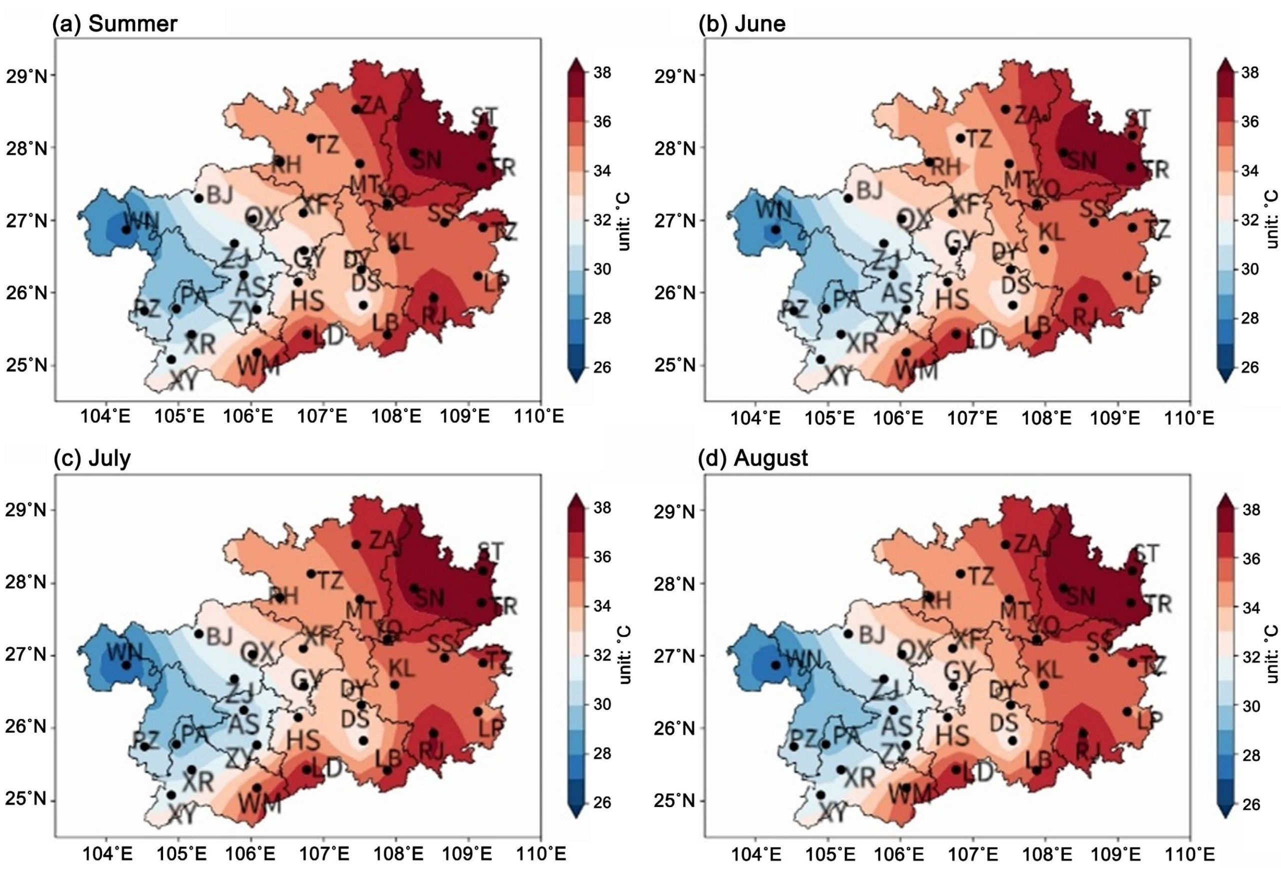

Figure 4. Spatial distribution of extreme high temperature intensity in summer, June, July and August in Guizhou province.

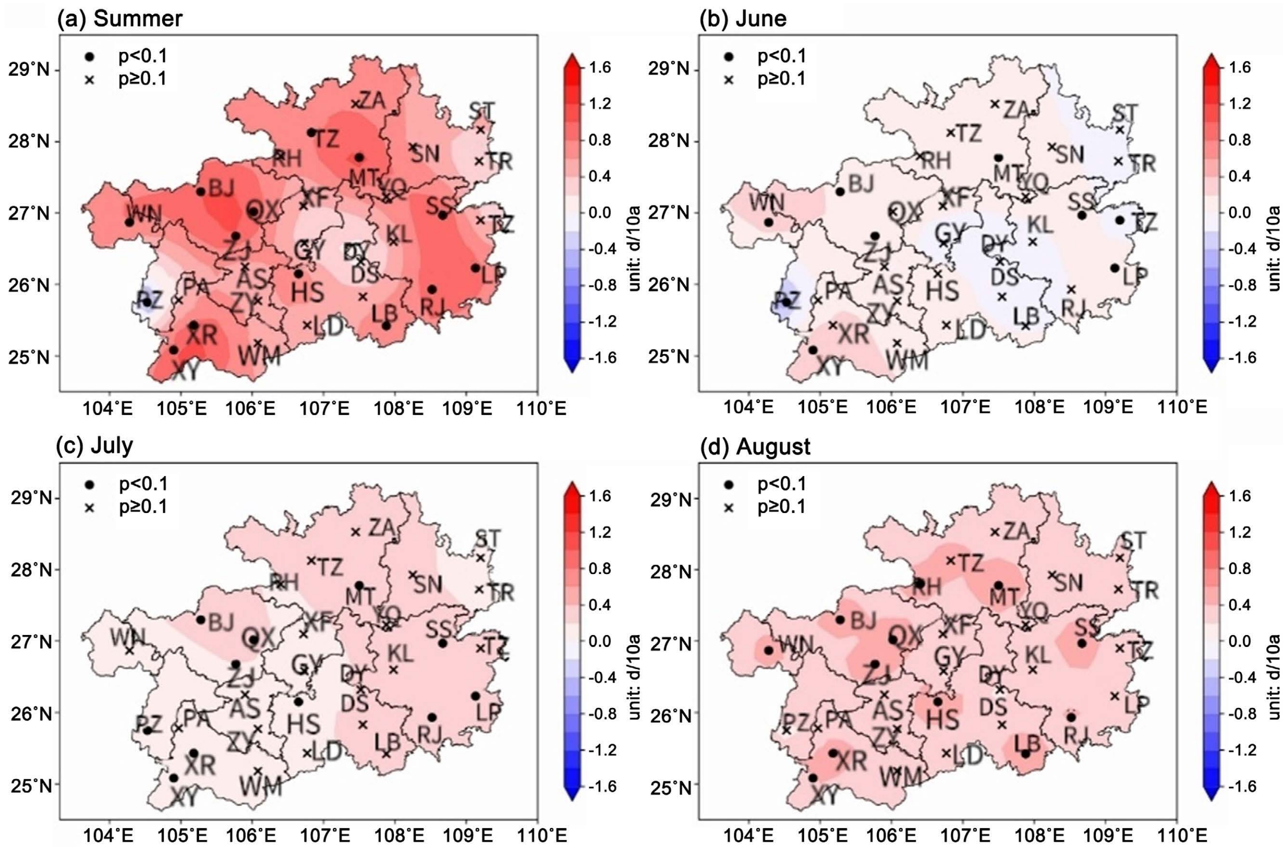

Figure 5. Spatial distribution of the trend of extreme high temperature days in summer (a), June (b), July (c) and August (d) in Guizhou province.

decreasing trend on 9 stations, the most significant decreases occurred at the PZ station, the decreasing rate reached 0.4 d/10a ($p < 0.1$), while on the other stations EHTD had an increasing trend, the most significant increase occurred on the XY station. Figure 5(c) illustrates that the EHTD showed an increasing trend, ranging from 0.2 to 0.4 d/10a, the change of EHTD in the eastern part of Guizhou was more obvious than that in the western Guizhou. Figure 5(d) shows that EHTD had an increasing trend in all the part of Guizhou, especially there were 12 stations with significant increase in EHTD ($p < 0.1$). This implies that the increase of EHTD mainly occurred in August.

Figure 6 shows the spatial trend distribution of EHTI in summer, June, July and August in Guizhou province. As can be seen from Figure 6(a), the EHTI showed an increasing trend at the most of stations in summer, but only the HS and DS stations where the increasing was significant ($p < 0.1$). Furthermore, the EHTI had a declined trend in the northeastern and southwestern part of Guizhou province, but the trend was not obvious except for the PZ station. Figure 6(b) illustrates that the EHTI showed an increasing trend in the centre of Guizhou province, while in the other regions EHTI had declined trend, but the increasing and decreasing trend in most parts of Guizhou were insignificant. Compared with the June, the reduced range and intensity of EHTI got smaller

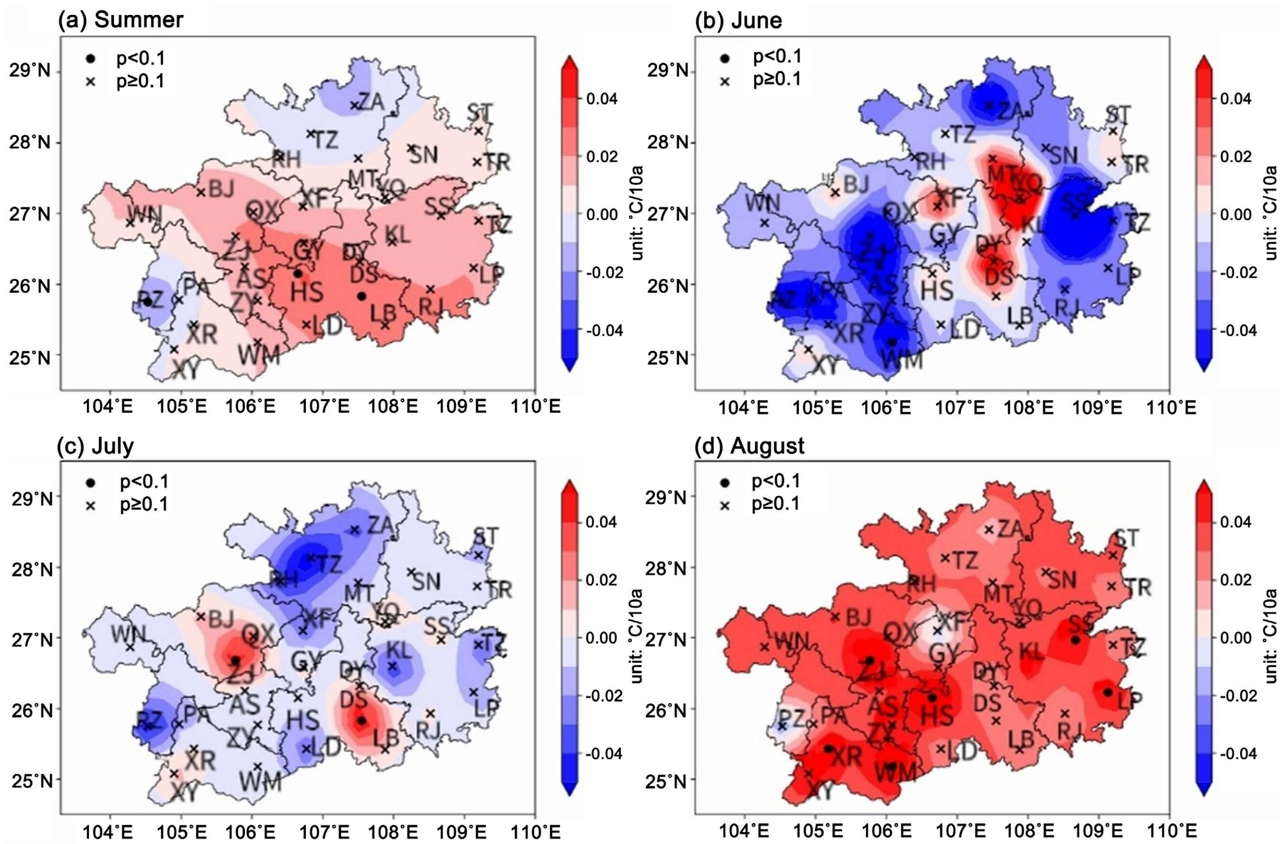

Figure 6. Spatial distribution of the trend of extreme high temperature intensity in summer (a), June (b), July (c) and August (d) in Guizhou province.

and weaker in July (Figure 6(c)). However, the EHTI showed an increasing trend in all the parts of Guizhou province, except the PZ stations, and the number of the station with increasing trend was more that that in June and July. Generally, the EHTI had increasing and decreasing trend in June and July, and the reduced range was larger than that of the increased range, while it showed an increasing trend in August, so the increasing of EHTI in August made more contribution to that in summer.

Figure 7 displays the inter-annual variation of EHTD in summer, June, July and August during the period of 1970-2020. The EHTD had a larger fluctuation amplitude during 1970-1980 and 2010-2020, it showed an increasing trend from 1970 to 2020, and the increasing rate was about 0.62 d/10a ($p < 0.1$). The EHTD also increased in June and July, and the rates were about 0.06/10a and 0.20/10a, but they were insignificant. While in August the EHTD significantly increased at the rate of 0.37 d every ten years ($p < 0.1$).

Figure 8 indicates the inter-annual variation of EHTI in summer, June, July and August during the period of 1970-2020. It can be seen from Figure 8(a) that the EHTI had a larger amplitude, the maximum EHTI was 34.4˚C, it occurred in 1971, and the minimum EHTI was only 30.7˚C, it appeared in 1993. It increased at the rate of 0.05˚C every ten years from 1970 to 2020, but it was not significant. However, the EHTI in June showed a slight reduction, both in July and August

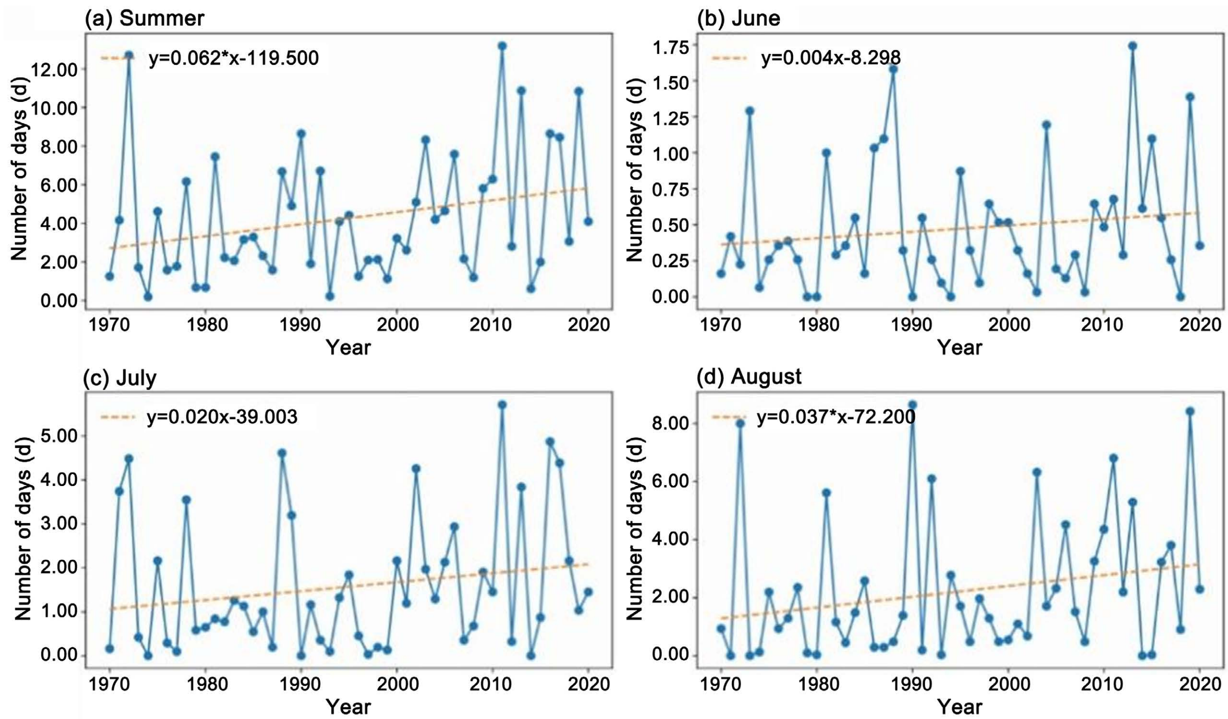

Figure 7. Interannual variation of extreme high temperature days in summer (a), June (b), July (c) and August (d) in Guizhou province from 1970 to 2020.

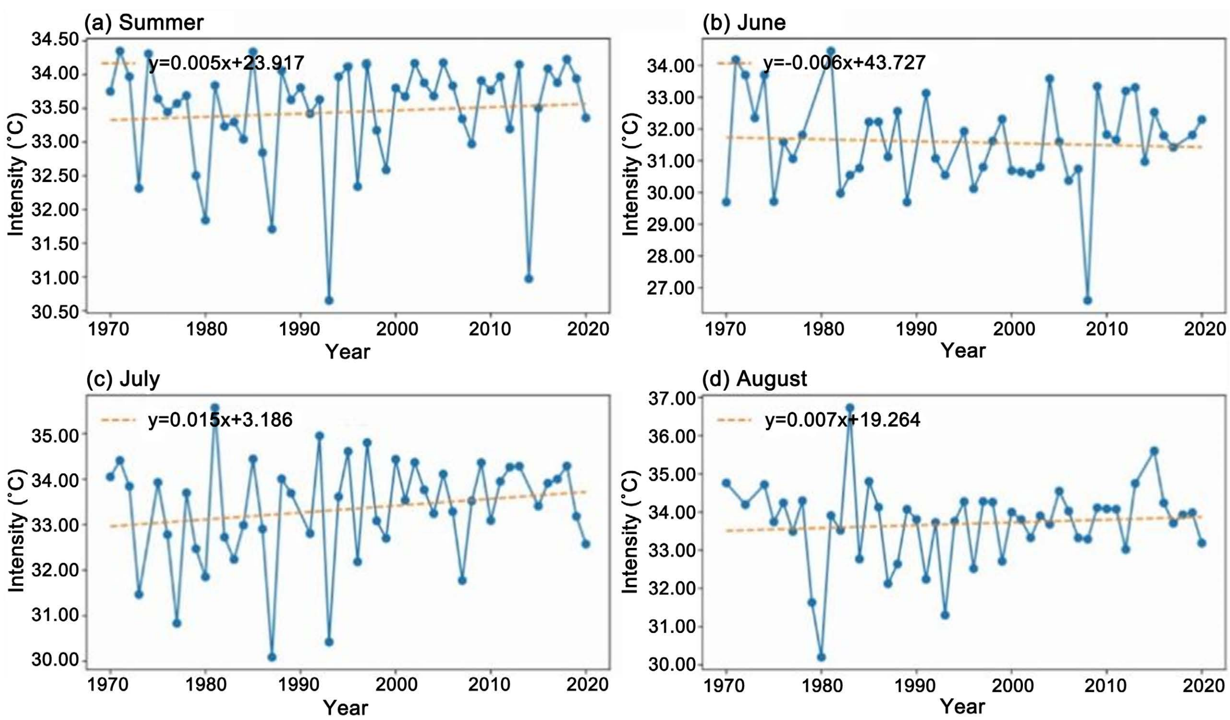

Figure 8. Interannual changes of extreme high temperature intensity in summer (a), June (b), July (c) and August (d) in Guizhou province from 1970 to 2020.

the EHTI had an increasing trend, the increasing rate was 015˚C/10a and 0.07˚C/10a, they were also insignificant.

4. Conclusion

Daily maximum temperature of 33 meteorological stations is used to investigate the spatial and temporal characteristics of EHT in Guizhou province in summer during the period of 1970-2020, this can help to understand the changes in EHT responding to the global warming. The results show that threshold of EHT had larger value in the northeast and lower value in the southwest, which was strongly inversely associated with the altitude, the correlation was about −0.96.

The EHTD basically exceeded 4 d in entire region of Guizhou province, the largest value was about 4.3 d in summer, and mainly located in TZ, TZ, LP, QX and PZ, and the lowest value appeared in the southernmost regions, the EHTD was about 4.1 d, this implies that EHTD had little spatial difference in summer. However, EHTD was smaller in June in most part of northeast Guizhou, even it was close to zero, which means the possibility of EHT occurring in June was mostly smaller. Compared with the distribution of EHTD in June, EHTD gradually increased from July to August, the largest value in August can reach about 3 d. However, EHTI showed an almost universal distribution in summer and in June, July and August, EHTI basically ranged from 27˚C to 38˚C, it was obviously higher in the northeast Guizhou and lower in the southwest Guizhou.

The EHTD showed an increasing trend in almost all the stations in summer, but there were only 14 stations with a significant increase ($p < 0.1$). while it increased insignificantly, even it showed slight decline in June. The increased range and intensity gradually increased from July to August. However, the EHTI had a larger difference in summer and June, July and August, especially in June, EHTI declined in most parts of Guizhou province, while EHTI showed inversely characteristics in August, this made EHTI vary in summer, it increased in the central Guizhou, and decreased in the northeast and the southwest Guizhou.

The EHTD demonstrated a significantly increasing trend in summer during the period of 1970-2020, the increased rate was about 0.62 d/10a ($p < 0.1$). Although EHTD also showed an increasing trend in June, July and August, they were insignificant. EHTI had a slight increase in summer, July and August, and declined in June. This implies that the EHT had an increasing trend during the period of 1970-2020, however, it increased slightly.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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