Analysis of Changes in the Maximum and Minimum Temperatures and Regional Temperature Ranges in Western Anhui during the Past 50 Years

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Analysis of Changes in the Maximum and Minimum Temperatures and Regional Temperature Ranges in Western Anhui during the Past 50 Years

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Abstract: Using the observation data from 1960 to 2013 of the prefectural meteorological stations in Western Anhui, this paper analyzes the maximum and minimum temperature changes and regional temperature ranges among the counties with the linear method. The results show that the maximum temperature had a fluctuation within a narrow range; the minimum temperature continuously rose, but the diurnal temperature range decreased. The monthly, seasonal and annual average daily temperature as well as the monthly, seasonal and annual temperature ranges showed a decreasing trend in most areas, and the trend was obvious in winter and summer but weak in spring and autumn. The changes in the maximum and minimum temperatures in Western Anhui are associated with the moisture content in the whole atmospheric layer. The inter-area difference of the changes in the diurnal temperature range decreased from the southwest to the northeast, which is well consistent with the local topography. The author considers that it is the result of the influence of topographic factors.

1. Introduction

The global average temperature has increased by 0.3-0.6℃ since the 19th century, and warmed by 0. 2-0. 3℃ [1] in the last 40 years. The annual average temperature across China increased by 0.3°C in the period from 1951 to 1990[2]. Karl et al. consider that the increase of the minimum temperature is significantly larger than the increase of the maximum temperature in most regions during the increasing of the global land surface temperature, thus showing an asymmetry in the day and night warming, which narrows the diurnal temperature range[3]. The chief scientist of the IPCC Working Group I specifically called on all the countries to conduct research on the changes of maximum and minimum temperatures [4], as it is of great significance for understanding the law of climate changes and exploring the causes of the same. Chinese scholars have also done relevant research on this aspect. Zhai Panmao studied the changes of maximum and minimum temperatures across China in the past 40 years [5], and Hua Lijuan analyzed regional temperature ranges across China from 1961 to 2000 [6]. However, there are few studies on relatively small regions.

Western Anhui is located between the Yangtze River and the Huaihe River, covering the area from

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115.20^{0}E to 117.14^{0}E and from 31.05^{0}N to 32.40^{0}N, with the terrain featured as high in the southwest and low in the northeast. Few studies on the characteristics of temperature changes in Western Anhui have been carried out, except that Xu Wenhua et al believe that the summer temperature has decreased and the winter temperature increased, but the annual average temperature remains basically stable therein[7]. This paper analyzes the changes in the maximum and minimum temperatures and inter-area temperature ranges based on the 50-year measured data of five meteorological stations, to explore the law of climate changes in Western Anhui.

2. Data and Methods

The data used in this study is the records of the maximum and minimum temperatures, the percentage of sunshine and the atmospheric moisture content of the five meteorological stations in Western Anhui from 1960 to 2013. Since the region has a single climate type, it was divided into six areas in the study, namely, Liu'an, Huoqiu, Jinzhai, Shucheng and Huoshan (see Fig.1).

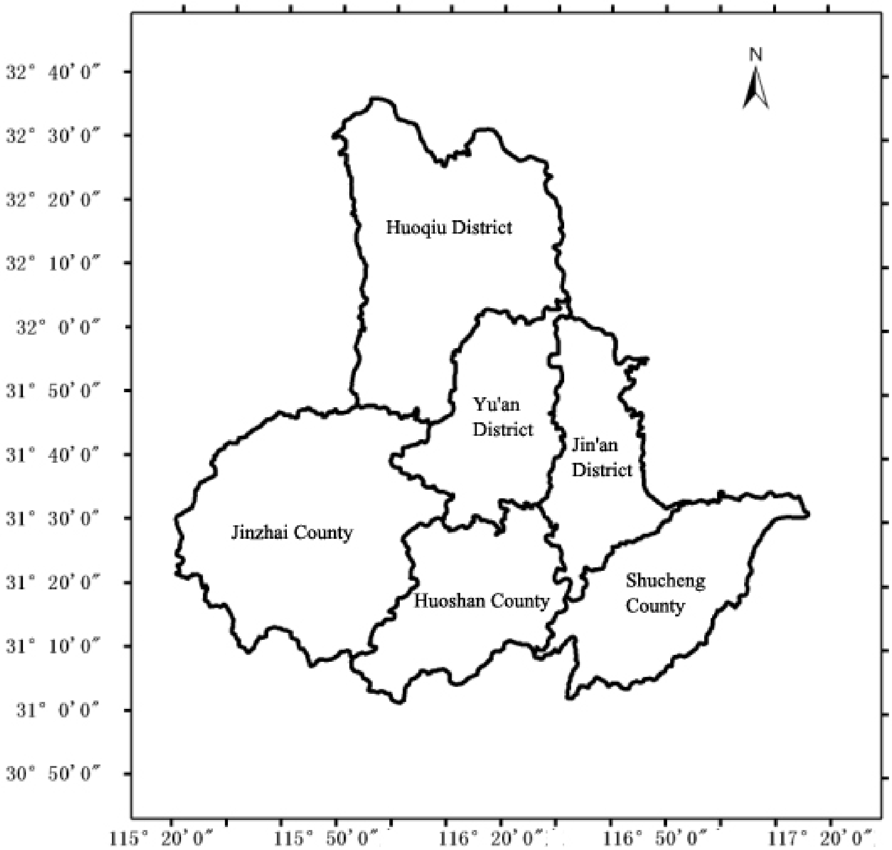


Fig. 1 Division of Climate Regions and Distribution of the Stations

The maximum and minimum temperatures of all the stations were formed into a sequence and the sequence was linearized by with Formula (1). Then, the linearized result was used to fit the original sequence T, and the trend of extreme temperatures was solved with the least squares method.

$$T'(t) = a + bt \tag{1}$$

$$a = \frac{\sum t^2 \sum T - \sum t \sum T}{n \sum t^2 - (\sum t)^2} \tag{2}$$

$$b = \frac{n\sum t \sum tT - \sum t \sum T}{n\sum t^2 - (\sum t)^2} \tag{3}$$

The diurnal temperature range is the difference between the diurnal maximum temperature and the diurnal minimum temperature; the monthly temperature range is the difference between the monthly maximum temperature and the monthly minimum temperature; the seasonal Temperature range is the difference between the seasonal maximum temperature and the seasonal minimum temperature; and similarly, the annual Temperature range is the difference between the annual maximum temperature and the annual minimum temperature.

The specific calculation method is as follows: the diurnal, monthly, seasonal and annual temperature ranges of individual stations were obtained first. Then, the values obtained in the first step were averaged by the five stations, to obtain the diurnal, monthly, seasonal and annual temperature ranges of the region. And finally, the changes in the diurnal, monthly, seasonal and annual temperature ranges of individual stations and the whole region for the past 54 years were calculated with the above-mentioned linear method.

3. Analysis of Results

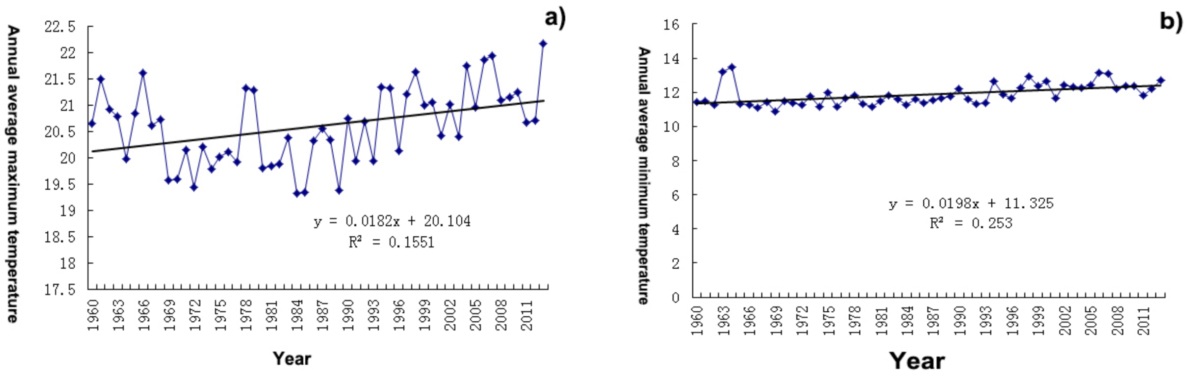
3.1 Change Trends of the Maximum and Minimum Temperatures as well as Diurnal Temperature Range of the Whole Region

Table 1 Change Trends of the Maximum and Minimum Temperatures as well as Diurnal Temperature Range of Western Anhui from 1960 to 2013 (°C/10a)

	Trend of Maximum Temperature	Trend of Minimum Temperature	Trend of Diurnal Temperature Range
Spring	**0.0422****	**0.0206****	**0.0165***
Summer	-0.003	0.0126	**-0.0228****
Autumn	**0.0222****	**0.0201***	-0.0036
Winter	0.0145	**0.0269****	0.0182
Annual	0.0182	**0.0198****	-0.0073

*Passing the significance test of α=0.05(95%); ** Passing the significance test of α=0.01(99%)

According to Table 1, there was a slight fluctuation in the maximum temperature during the past 54 years in Western Anhui, while the minimum temperature during the same period showed a significant increase trend in all seasons. The diurnal temperature ranges of all seasons and the annual average diurnal temperature range showed a decreasing trend (see Fig.2 and Table 2).



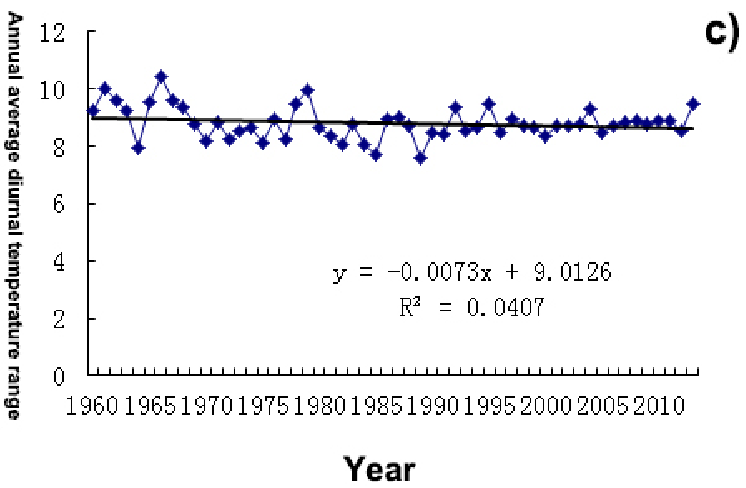


Fig. 2 Change Trends of the Annual Average Maximum and Minimum Temperatures as well as Diurnal temperature range of the Whole Region (a: Maximum Temperature; b: Minimum Temperature; c: Diurnal Temperature Range)

Table 2 Change Trends of the Maximum and Minimum Temperatures as well as Diurnal Temperature Range of the Stations in Western Anhui from 1960 to 2013 (°C/10a)

		Trend of Maximum Temperature	Trend of Minimum Temperature	Trend of Diurnal temperature range
Huoqiu	Spring	**0.042****	**0.323****	0.092
	Summer	-0.002	**0.181****	**-0.323****
	Autumn	**0.0224****	**0.282****	-0.056
	Winter	0.162	**0.377****	**-0.228***
Huoshan	Spring	**0.349****	**0.168****	**0.179***
	Summer	-0.051	**0.165****	**-0.216***
	Autumn	0.104	**0.206****	-0.102
	Winter	0.072	**0.208****	-0.134
Jinzhai	Spring	0.204	**0.329****	0.018
	Summer	0.069	**0.298****	**- 0.48****
	Autumn	**0.305****	**0.411****	**- 0.259****
	Winter	-0.116	**0.424****	**- 0.297****
Liu'an	Spring	**0.459****	**0.36****	0.097
	Summer	**-0.101****	**0.159****	**- 0.257****
	Autumn	**0.244****	**0.354****	-0.011
	Winter	0.178	**0.396****	**- 0.199***
Shucheng	Spring	**0.432****	**0.14***	**0.295****
	Summer	0.002	0.052	-0.052
	Autumn	**0.243****	**0.146***	0.098
	Winter	0.159	**0.188***	-0.026

*Passing the significance test of α=0.05(95%); ** Passing the significance test of α=0.01(99%)

3.2 Analysis of Changes in Monthly, Seasonal, and Annual Average Diurnal Temperature Ranges

3.2.1 Characteristics of Changes in Monthly Average Diurnal Temperature Ranges

Table 3 The Total Percentage of the Stations with Deceasing Monthly Average Diurnal Temperature Range as well as the Percentage of the Stations Passing the 95% Reliability Test from 1960 to 2013

Month	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Total percentage	100%	100%	0%	0%	20%	80%	100%	100%	100%	80%	40%	80%
Test percentage	60%	0%	0%	0%	0%	80%	20%	80%	0%	0%	0%	0%

The monthly average diurnal temperature ranges of the stations in Western Yunnan showed a significant decreasing trend in most months, and the months when the total percentage of the stations with a decreasing trend reached 100% include January, February, July, August and September, of which, in January, July and August, 60%, 20% and 80% of the stations passed the 95% reliability test respectively; the total percentage of the stations with a decreasing trend in June reached 80%, and all of them passed the 95% reliability test; the total percentage of the stations with a decreasing trend in February, October, November and December ranged from 40% to 100%, but none of them passed the test. Therefore, the monthly average diurnal temperature range of Western Anhui generally showed a decreasing trend, which was featured as strong in winter and summer but weak in spring and autumn. Jinzhai, Huoshan, and Liu'an showed a significant decreasing trend, Huoqiu was at medium level and Shucheng was weak.

3.2.2 Change Characteristics of Seasonal Average Diurnal Temperature Range

The changes in the seasonal average diurnal temperature range of the stations across the region are as follows: ① In summer, Jinzhai, Liu'an, Huoshan and Huoqiu had the change by -0.48 °C/10a, -0.257 °C/10a and -0.216 °C/10a, respectively and all of them passed the 95% reliability test, while Shucheng showed a decreasing trend and failed to pass the reliability test. ② In winter, Jinzhai had the change by -0.297 °C/10a, and passed the 99% reliability test; Huoqiu had the change by -0.028 °C/10a and passed the 95% reliability test; Huoshan, Liu'an and Shucheng showed a decreasing trend, but failed to pass the reliability test. ③In autumn, Jinzhai had a change by -0.259 °C/10a, and passed the 99% reliability test. Huoshan, Liu'an and Huoqiu showed a decreasing trend, but failed to pass the reliability test. Shucheng showed an increasing trend. ④ In spring, all the stations showed an increasing trend, and furthermore, Huoshan and Shucheng passed the 95% reliability test (see Table 4). This indicates that the changes in the seasonal average diurnal temperature range in Western Anhui were also featured as strong in winter and summer, and weak in spring and autumn. Jinzhai, Huoshan and Liu'an showed a significant decreasing trend, Huoqiu was at medium level and Shucheng was weak.

Table 4 Change Trends of Seasonal Average Diurnal temperature Ranges from 1960 to 2013（℃/10a）

Station	Spring	Summer	Autumn	Winter
Huoqiu	0. 092	**-0.189****	-0.059	**-0.028***
Huoshan	**0.179***	**-0.216***	-0. 102	-0. 134
Jinzhai	0. 018	**-0.48****	**-0.259****	**-0. 297****
Liu’an	0. 097	**-0. 257****	-0. 102	-0. 199
Shucheng	**0.295****	-0. 052	0. 098	-0.026

*Passing the significance test of α=0.05(95%); ** Passing the significance test of α=0.01(99%)

3.2.3 Characteristics of Changes in Annual Average Diurnal Temperature Range

Regarding the changes in the annual average diurnal temperature range, all the areas showed a decreasing trend except Shucheng which showed an increasing trend (0.085 °C/10a). The decrease ranges were as the following in sequence from the largest to the smallest: Jinzhai (-0.262 °C/10a), Liu'an (-0.124 °C/10a), Huoqiu (-0.099 °C/10a) and Huoshan (-0.064 °C /10a), of which, Liu’an passed the 99% reliability test, and Jinzhai passed the 95% reliability test (see Table 5), which indicates that Liu'an and Jinzhai had a significant decreasing trend and Shucheng had a weak decreasing trend.

Table 5 Change Trends of Average Diurnal Temperature Ranges from 1960 to 2013（℃/10a）

Huoqiu	Huoshan	Jinzhai	Liu’an	Shucheng
-0.099	-0.064	**-0.262***	**-0.124****	0.085

*Passing the significance test of α=0.05(95%); ** Passing the significance test of α=0.01(99%)

3.3 Analysis of Changes in Monthly, Seasonal and Annual Temperature Range

3.3.1 Characteristics of Changes in Monthly Temperature Range

The decrease trend of the monthly temperature range in Western Anhui was significant in January, February, April, July, August and December; and weak in March, September, October and November (Table 6).

The changes in the monthly temperature range of the stations were as follows: Jinzhai and Liu'an had a decreasing trend throughout the year, of which, Jinzhai passed the 95% reliability test in January and December; Huoshan and Huoqiu showed a decreasing trend throughout the year except individual months; and Shucheng showed an increasing trend throughout the year.

Table 6 The Total Percentage of the Stations with Deceasing Monthly temperature range as well as the Percentage of the Stations Passing the Reliability test of 95% from 1960 to 2013

Month	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Total percentage	100%	80%	40%	80%	60%	60%	80%	60%	60%	80%	60%	100%
Test percentage	40%	0%	0	0%	0%	0%	0%	0%	0%	0%	0%	40%

3.3.2 Characteristics of Changes in Seasonal Temperature Range

① In summer, Jinzhai, Huoshan and Liu'an had an decrease by -0.037℃/10a，-0.0187℃/10a，and -0.0136℃/10a, respectively; Huoqiu and Shucheng showed an increasing trend; and all the stations failed passed the test. ② In winter, all the stations other than Huoqiu showed a decreasing trend, and Jinzhai had the largest decrease, i.e. **-0. 833**℃/10a, and passed the 99% significance test, while Liu'an, Huoshan and Shucheng failed to pass the test.③ In spring, only Liu'an showed the decrease trend. ④ In autumn, Jinzhai, Qiuhuo and Liu'an showed a decreasing trend and failed the test (see Table 7).

Table 7 Change Trends of Seasonal Temperature ranges from 1960 to 2013（℃/10a）

Station	Spring	Summer	Autumn	Winter
Huoqiu	0.0005	0.0103	-0.0648	0.96
Huoshan	0. 0153	-0.0136	0.004	-0.0679
Jinzhai	0.0026	-0.037	-0. 0398	**-0. 833***
Liu'an	-0.0222	-0.0187	-0. 0122	-0. 0584
Shucheng	0.0224	0.0075	0. 0593	-0.0216

*Passing the significance test of α=0.05(95%); ** Passing the significance test of α=0.01(99%)

3.3.3Change Characteristics of the Annual Temperature Range

The annual temperature range of the stations in Western Anhui showed a decreasing trend. The areas passing the tests only include Huoqiu and Huoshan, and the one with the smallest decrease is Shucheng (see Table 8).

Table 8 Change Trends of Annual Temperature Ranges from 1960 to 2013（℃/10a）

Station	Huoqiu	Huoshan	Jinzhai	Liu'an	Shucheng
Annual	**-0.0888****	**-0.0798****	-0.0611	-0.11	-0.0397

*Passing the significance test of α=0.05(95%); ** Passing the significance test of α=0.01(99%)

From the above analysis, the decrease of the monthly, seasonal and annual average diurnal temperature ranges as well as the monthly, seasonal and annual temperature ranges had the features as strong in winter and summer, and weak in spring and autumn. As for the inter-area difference, it was significant in Jinzhai, Liu'an and Huoshan, medium in Huoqiu and weak in Shucheng.

3.4 Analysis of Possible Causes for Decrease of Diurnal Temperature Range

The decrease of the diurnal temperature range was associated with the increase of the minimum temperature, which obviously links to the greenhouse effect. Then, how does the greenhouse effect interprets the asymmetric change of the maximum and minimum temperatures? The increase of CO_2 in the atmosphere or the increase of atmospheric moisture can produce obvious greenhouses effect. Here we carry out the preliminary discussion using the observation data about the percentage of sunshine and the moisture content as well as the maximum and minimum temperatures in Western Anhui during the past 50 years.

Table 9 Correlation between the Percentage of Sunshine and the Maximum Temperature Tmax from 1960 to 2013

Station	Jan.	Apr.	Jul.	Oct.
Huoqiu	**0.1981****	**19.413****	**19.038****	**16.418****
Huoshan	**8.2517****	**14.611****	**18.916****	**12.872****
Jinzhai	**9.843****	**13.38****	**22.501****	**17.143****
Liu'an	**8.7841****	**17.037****	**15.878****	8.7055
Shucheng	-0.4489	**13.2229****	6.4969	5.7784

*Passing the significance test of α=0.05(95%); ** Passing the significance test of α=0.01(99%)

Table 9 shows the correlation between the percentage of sunshine and the maximum temperature Tmax in Western Anhui. The positive correlation between the two is clearly presented in the table, and it nearly completely passed the 95% and 99% significance tests. A few correlations were not significant, which is most likely because of the influence of the adjustment of circulation.

Table 10 shows the positive correlation between the moisture of the whole atmospheric layer and the minimum temperature Tmin from 1960 to 2013, and this correlation mostly passed the 95% and 99% tests in all seasons.

Table 10 Correlation between the Moisture Content in the Whole Atmospheric Layer and the Minimum Temperature Tmin from 1960 to 2013

Station	Jan.	Apr.	Jul.	Oct.
Huoqiu	0.0779	**0.317****	**0.2576***	**0.2125****
Huoshan	**0.4344****	**0.7884****	**2.5026****	**0.7759****
Jinzhai	0.3982	1.52	0.1895	0.4507
Liu'an	**0.1869****	-0.0846	-0.1711	0.0504
Shucheng	**0.4508****	**0.735****	**0.8345****	**0.6131****

*Passing the significance test of α=0.05(95%); ** Passing the significance test of α=0.01(99%)

From Table 11, we can see the inverse correlation between the moisture content of the whole atmospheric layer and the percentage of sunshine, which was significant in winter and summer and partially passed the significance test. From this, it can be inferred that the increase of atmospheric moisture content can affect the sunshine conditions, reduce the solar radiation reaching the ground, and make the maximum temperature decrease. In addition, the increase of atmospheric moisture content can affect the minimum temperature through the increase of the greenhouse effect, thereby reducing the diurnal temperature range. In spring and autumn, however, the decrease of the maximum temperature is relatively weak due to the influence of the adjustment of circulation, therefore, the decreasing trend of the monthly and seasonal average diurnal temperature range as well as the decreasing trend of the monthly and seasonal temperature ranges were significant in winter and summer, and weak in spring and autumn.

In Western Anhui, the southwestern part is mountainous, and the northeast part is low and flat, so the terrain leans from the southwest to the northeast. Prominent uplifting area sits in the southwestern part, forming the hinterland of the Dabie Mountain. The central part is undulating hills and lands, and the eastern and northern parts are flat and open plains. The inter-area difference of the changes in the diurnal temperature range was well consistent with the topographical fluctuations, indicating the influence of topographic factors.

Table 11 Correlation between Water Vapor Content in the Whole Atmospheric Layer and Percentage of Sunshine

Station	Jan.	Apr.	Jul.	Oct.
Huoqiu	**-0.137****	-0.0029	0.003	-0.0169
Huoshan	**-0.0116****	-0.0081	0.0424	0.0194
Jinzhai	-0.1056	-0.1356	-1.09	-0.1275
Liu'an	-0.0048	-0.0101	-0.0042	-0.0061
Shucheng	-0.0068	0.0094	**-0.0111****	-0.0015

*Passing the significance test of α=0.05(95%); ** Passing the significance test of α=0.01(99%)

4. Conclusion

1. From 1960 to 2013, the maximum temperature in Western Anhui fluctuated slightly, and the minimum temperature increased a lot, which resulted in a decrease of the diurnal temperature range.

2. The monthly, seasonal and annual average diurnal temperature ranges in different areas of Western Anhui showed a decreasing trend significant in winter and summer but weak in spring and autumn. The trend was medium in Liu'an, Huoshan and Jinzhai, and weak in Shencheng (see Figure 3). The inter-area difference in changes of diurnal temperature range may be related to the terrain in the region.

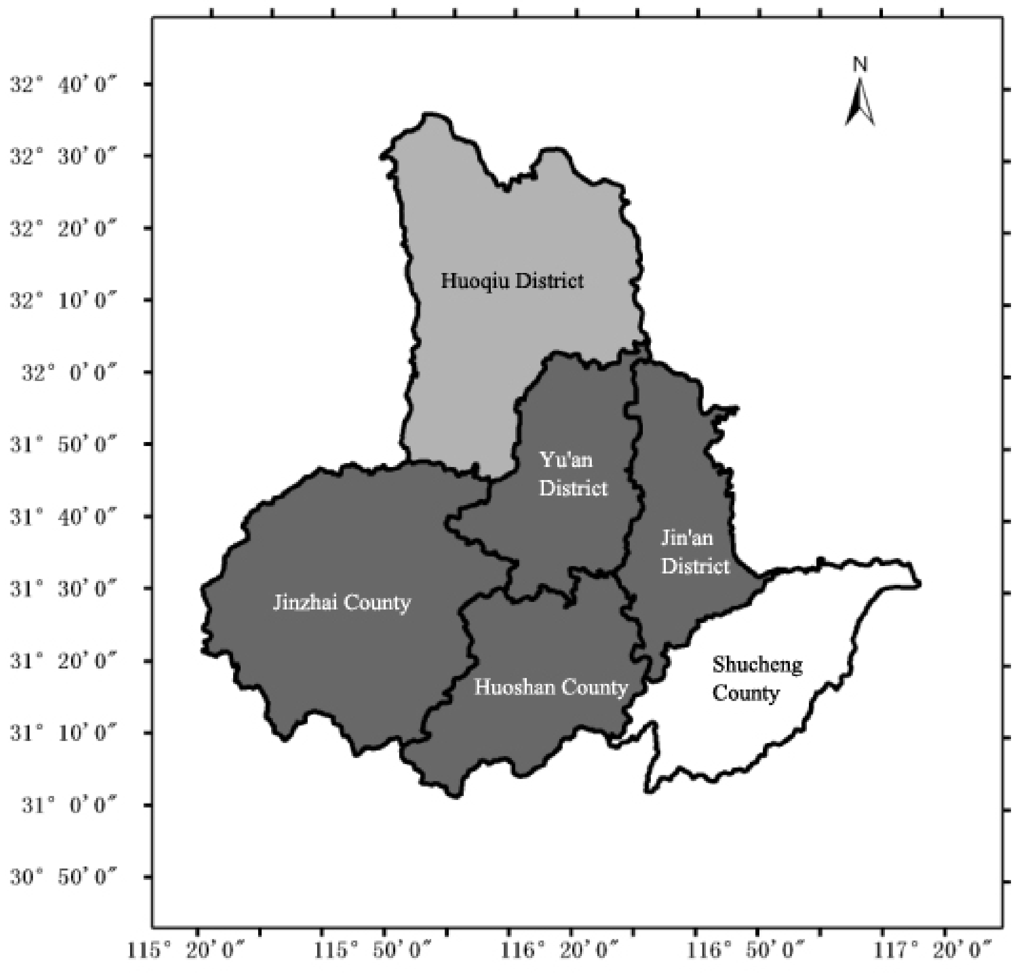


Fig. 3 The dark area in the figure refers to the area where there was a significant change of diurnal temperature range, the dark gray is the area with medium change of the same and the light area is the area with weak change.

3. The moisture content in the atmosphere increased, which resulted in the decrease of the percentage of sunshine and the maximum temperature in the daytime; and in the increase of the

minimum temperature at night due to the greenhouse effect, thus the diurnal temperature range decreased. In the spring and autumn, however, the decrease of the maximum was relatively weak due to the influence of the adjustment of circulation.

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