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Article

Spatial and temporal patterns of temperature and Precipitation changes in the surrounding areas of Hongze Lake from 1951 to 2014

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Abstract: Under global warming, in order to comprehensively explore the change characteristics of the lake's water and heat budget in time and space and its influence on lake-gas interaction, the multi-factor study was carried out. Based on the meteorological data of precipitation and temperature of 16 meteorological stations in the surrounding area of Hongze Lake in recent 64 years (1951-2014), the temperature and precipitation of 16 meteorological stations are analyzed from the characteristics of time and space by using the methods of climate tendency rate, anomaly and inverse distance weight in ArcGIS. The results show that : (1) In the past 64 years, the precipitation around Hongze Lake has changed greatly, with a decrease of $-7.0837 mm \cdot (10a)^{-1}$;the temperature increased by 0.316 $°C \cdot (10a)^{-1}$, and the change trend of average temperature and average precipitation was opposite. The average temperature of many years showed an upward trend, and the temperature change from 1951 to 1961 was particularly obvious. After 1962, the temperature fluctuated around the average temperature. The temperature and precipitation in summer showed a downward trend. (2) On the whole, the temperature and precipitation showed an increasing trend from the west to east, roughly taking Hongze Lake as the dividing line. The warming and humidification in the west of Hongze Lake were slower, and the warming and humidification in the east was faster. The temperature was warming and the precipitation decreased, so the climate was warm and dry. The research results provide a reference for the establishment of a comprehensive early warning system for agricultural meteorological disasters and the local government 's response to agricultural meteorological disaster prevention and mitigation.

Keywords: Temperature, Precipitation, Spatial and temporal pattern, Surrounding areas of Hongze Lake

The increasing risk of climate change, which endangers human survival, has aroused widespread concern [1–2]. Climate change is one of the greatest environmental challenges facing mankind today [3]. The frequency and intensity of extreme events such as rainstorms, floods, droughts and high temperatures caused by climate change have increased [4–5], which has seriously affected people 's production and life and the sustainable development of social economy [6].

Temperature and precipitation are important indicators of climate change [7–8]. Although domestic and foreign scholars have done a lot of research on the characteristics of regional temperature and precipitation changes [9–11], there are few studies on the characteristics of climate change in the area around the lake. Lake is an important forcing factor affecting the local climate and has a strong influence on the hydrothermal cycle in the surrounding area. In order to explore the temporal and spatial variation characteristics of the lake's water-heat budget and its influence on the lake-air interaction [12], the lake has a certain regulating effect on the climate. Xiao Tingting et al. [13] used the climate tendency rate and anomaly analysis method to analyze the interannual and interdecadal variation characteristics of the annual average temperature in the Balkhash Lake Basin by using the four representative stations from 1936 to 2005. Liu et al. [14] systematically analyzed the distribution characteristics of temperature in Dongting Lake area and its influence on the temperature distribution of the whole province by using the 30-year climate data of 95 meteorological stations in Hunan from 1971 to 2000. Ding et al. [15] analyzed the variation characteristics of temperature series around Poyang Lake from 1961 to 2007 based on the observation data of daily average temperature, daily maximum temperature and daily minimum temperature at 10 meteorological stations around Poyang Lake. Based on the average temperature data of 24 meteorological stations in Dongting Lake area from 1952 to 2010, Huang et al. [16] analyzed the characteristics of temperature change in Dongting Lake area by using climate tendency rate and other methods. He et al. [17] used the daily temperature data of

10 meteorological stations in the Taihu Lake Basin to study the long-term variation characteristics of temperature fluctuations in the Taihu Lake Basin.

In summary, at present, there are many studies on the influence of lakes on the surrounding temperature in terms of time, and there are few studies in terms of space. There are many studies on one factor of temperature, and there are few reports on the comprehensive study of two factors of temperature and precipitation. In addition, there are few studies on the temperature and precipitation in the surrounding area of Hongze Lake. Based on the meteorological data, this paper analyzes the temporal and spatial variation characteristics of temperature and precipitation in the surrounding areas of Hongze Lake in the recent 64 years. The research results provide a reference for the establishment of a comprehensive early warning system for agricultural meteorological disasters and the local government 's response to agricultural meteorological disaster prevention and mitigation.

1. Overview Of The Study Area And Research Methods

1.1. Overview Of The Study Area

Hongze Lake is located between (32° 39′ –33° 38′ N, 118° 13′ –118° 45′ E, which is a freshwater lake in the northwest of Huai 'an City, Jiangsu Province. The average annual temperature of Hongze Lake is 15.3 °C, and the average annual precipitation is 925.5 mm. The maximum precipitation from June to September is 605.9 mm, accounting for 65.5 % of the annual precipitation. Due to the influence of the lake surface and monsoon region, the precipitation is more than other regions at the same latitude. The surrounding areas of Hongze Lake in this paper refer to Wuhe County, Lai 'an County, Sixian County, Mingguang City and Tianchang City in Anhui Province, and Baoying County, Lianshui County, Siyang County, Shuyang County, Xuyi County, Sihong County, Chuzhou County, Jinhu County, Hongze District, Huai 'an District and Suqian City in Jiangsu Province. Among them, the northeastern region of Hongze Lake has Siyang County (14.6 °C), Shuyang County (14.1 °C), Lianshui County (14.3 °C), Chuzhou County (14.4 °C), Huai 'an District (15.1 °C). The southeast area of Hongze Lake includes Hongze District (15 °C), Tianchang City (15.1 °C), Baoying County (15.2 °C) and Jinhu County (15 °C). The southwest region of Hongze Lake includes Xuyi County (15.1 °C), Lai 'an County (15.2 °C), Wuhe County (15 °C) and Mingguang City (15.4 °C). There are Sixian County (14.7 °C), Sihong County (14.8 °C) and Suqian City (14.4 °C) in the northwest of Hongze Lake.

1.2. Research Method

1.2.1. Data Sources And Data Processing

(1) **Data sources**

As shown in Figure 1, the meteorological stations around Hongze Lake include Sihong, Siyang, Huai 'an, Chuzhou, Hongze, Jinhu, Xuyi, Suqian, Shuyang, Lianshui, Baoying, Tianchang, Lai 'an, Mingguang, Wuhe, Sixian, a total of 16 meteorological stations (Figure 1). The temperature and precipitation monitoring data of 16 meteorological stations in the area around Hongze Lake from January 1,1951 to December 31, 2014 were selected. The data were retrieved from the China Meteorological Data Network[18] .

(2)**Data processing**

Data processing includes data quality control, statistical analysis and numerical prediction. Quality control is used to identify outliers in data and determine data reliability. Statistical analysis is the use of statistics-based methods to analyze a large number of meteorological data, including some trend analyses, regression analyses, correlation analyses, etc. Numerical prediction is mainly based on a model calculation, selecting different levels and accuracy.

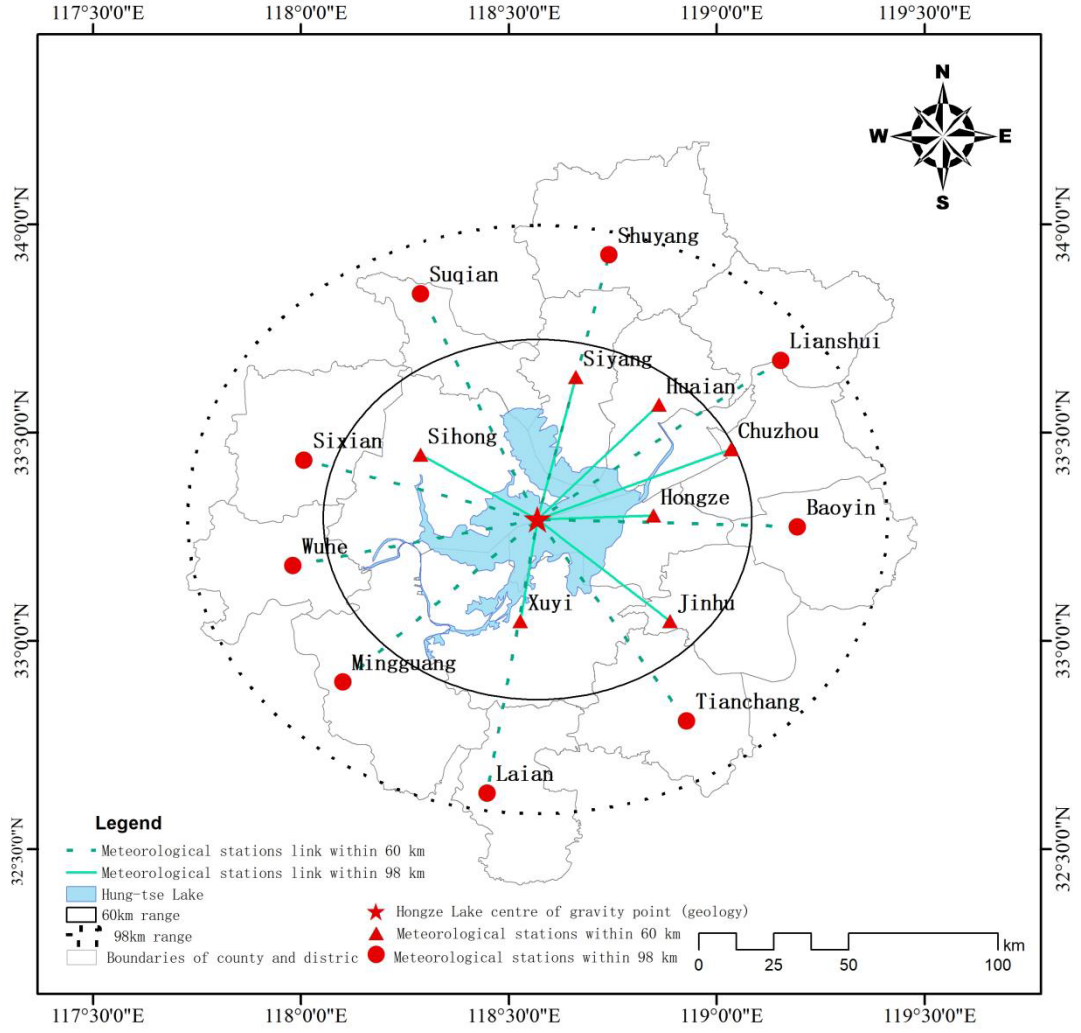


Fig.1. Distribution diagram of meteorological stations around Hongze Lake.

Table 1. Geographical location table of meteorological stations around Hongze Lake.

Geographic element	Su Qian	Shu Yang	Lian Shui	Bao Ying	Tian Chang	Lai An	Ming Guang	Wu He	Si Xian	Si Hong	Si Yang	Huai An	Chu Zhou	Hong Ze	Jin Hu	Xu Yu
Longitude/°E	118.13	118.45	119.14	119.18	119.01	118.25	117.58	117.5	117.52	118.13	118.41	118.56	119.09	118.45	118.58	118.3
Latitude /°N	33.56	34.05	33.46	33.1	32.41	32.27	32.39	33.08	33.28	33.25	33.41	33.38	33.30	33.06	32.59	32.57

1.2.2 Analysis Method

In order to explore the spatio-temporal variation of temperature and precipitation in the surrounding area of Hongze Lake, the temporal variation of temperature and precipitation is analyzed from three aspects: interannual variation, seasonal variation and interdecadal variation. The spatial variation is analyzed from two aspects: the spatial superposition of temperature and precipitation and the seasonal spatial variation. Climate tendency rate analysis is used to explore the interannual and seasonal variation trends of temperature and precipitation, inverse distance weight analysis is used to explore the spatial variation trends of temperature and precipitation, and anomaly analysis is used to explore the interdecadal variation characteristics of temperature and precipitation. Although the methods of climate tendency rate, inverse distance weight and anomaly analysis are mature, there are still some limitations. The main factors are uncertainty, complexity of flow field and lack of data. Many physical processes of temperature and precipitation change are non-linear and affected by many factors, such as terrain, land and ocean. These factors lead to great uncertainty in the study. The complexity of the flow field makes it difficult to solve the model and increases the error of the forecast.

The temperature and precipitation data mainly come from observation equipment, and the lack of equipment leads to the lack of data in spatial distribution, which reduces the accuracy of the study.

（1）Climate tendency rate analysis method

The temperature and precipitation data in the surrounding area of Hongze Lake were analyzed by a linear regression equation. The formula for linear trend analysis of climate factors is y = at + b, where y is the climate factor, t is the time, b is the regression constant, a is the linear trend term, and a × 10 is called the climate tendency rate, indicating the rate of change of climate factors every 10 years [19]. The positive climate tendency rate indicates that the climate factors are on the rise, mainly warm, and the negative climate tendency rate indicates that the climate factors are on the decline, mainly cold [20].

（2）Inverse distance weight analysis method

The data of annual and seasonal temperature tends and precipitation tends around Hongze Lake are imported into ArcGIS. Secondly, it is necessary to open the environment and set the processing range, which is the same as the layers around Hongze Lake. Otherwise, the results may not fully cover the required layers, through the above operation, the final required graph is obtained.

（3）Anomaly analysis method

In 1951–2014, the difference between the average of every 10 years and the average of 64 years is an era. According to this division, the interdecadal can be divided into seven stages: 1951–1959, 1960–1969, 1970–1979, 1980–1989, 1990–1999, 2000–2009, 2010–2014. The temperature and precipitation changes in the surrounding areas of Hongze Lake were studied in depth to explore the laws and causes of their changes, so as to better grasp the climate change law. Where the difference is greater than 0 is a positive anomaly, and the difference is less than 0 is a negative anomaly.

2. Results And Analysis

2.1 Time Variation Of Temperature And Precipitation

2.1.1 Interannual Variation Of Temperature And Precipitation

As shown in Figure 2, the temperature in the surrounding area of Hongze Lake showed an upward trend from 1951 to 2014, while the precipitation showed a downward trend. In the past 64 years, the average temperature in the surrounding area of Hongze Lake was 15.5 °C, with the highest temperature in 1959 (25.5 °C) and the lowest in 1952 (13.1 °C), with a difference of 12.4 °C (see Figure 2). The annual average temperature of 1952–1954, 1961–1965, 1967–1993, 1995–1997 and 1999–2001 is lower than the 64-year average temperature, while the annual average temperature of 1955-1960, 2004-2008 and 2012–2014 is higher than the 64-year average temperature. Due to the global warming, the climate has changed abruptly. In 1951–1961, due to the influence of natural disasters, the temperature changed greatly compared with other years. Among them, the temperature increased significantly in 1959, which was 8.9 °C higher than that in 1958. The temperature tendency rate was 0.316 °C $(10a)^{-1}$, indicating that the temperature in the surrounding area of Hongze Lake showed a rising trend in the past 64 years.

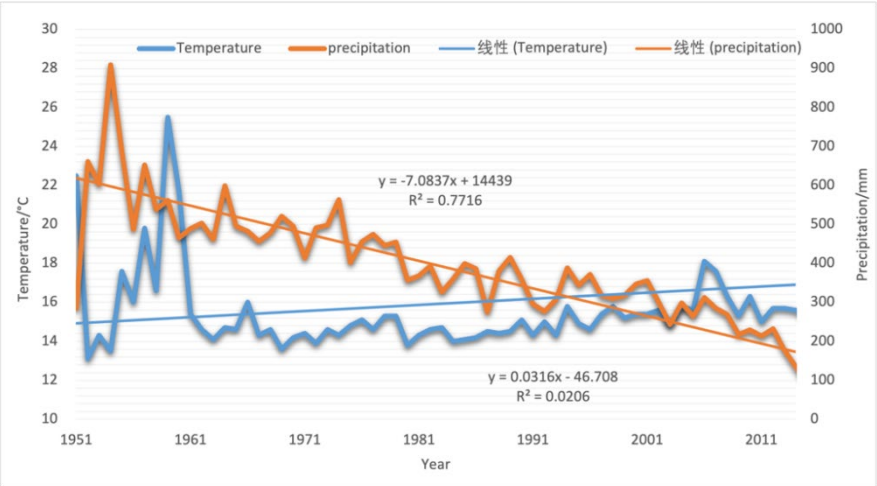


Fig. 2. Interannual variations of temperature and precipitation in the area around Hongze Lake during 1951–2014

The average precipitation in the surrounding area of Hongze Lake is 384.4 mm, and the precipitation tendency rate is -7.0837 mm $(10a)^{-1}$, indicating that the precipitation in the surrounding area of Hongze Lake has been declining in the past 64 years. This is likely to be due to the topography of the region and other reasons. In these higher altitude areas, the temperature may be relatively low, and the precipitation will be reduced accordingly. Hongze Lake station is located in the central plain area with less cold and warm airflow in summer, so the precipitation is relatively low [21].

In addition, the meteorological conditions around Hongze Lake are also important factors affecting local precipitation, such as temperature, humidity and wind direction, which will affect precipitation. The precipitation exhibits a downward trend, and the temperature exhibits an upward trend. The temperature tendency rate was 0.316 °C $(10a)^{-1}$, which was higher than the national average of 0.22 °C $(10a)^{-1}$ [22].

2.1.2 Seasonal Variation Of Temperature And Precipitation

Figure 3 shows the change trend of temperature and precipitation in the surrounding area of Hongze Lake in four seasons. The temperature tendency rates of spring, summer, autumn and winter in the surrounding areas of Hongze Lake from 1951 to 2014 were 0.084 °C $(10a)^{-1}$, -0.024 °C $(10a)^{-1}$, 0.119 °C $(10a)^{-1}$ and 0.142 °C $(10a)^{-1}$, respectively. The temperature tendency rates of spring, autumn and winter are all positive, and the temperature shows an obvious upward trend. Among them, the winter rise is the most significant and the temperature increase is the largest. The autumn is second only to the winter, and the spring temperature increase is the smallest.

It shows that the relatively cold winter is more sensitive to global warming, indicating that the winter temperature rises fastest under global warming [23]. The temperature tendency rate in summer is negative, and the temperature shows a downward trend. In the surrounding areas of Hongze Lake from 1951 to 2014, the highest temperatures in spring, summer, autumn and winter were 30.4 °C (1955), 35.8 °C (1960), 27.9 °C (1960) and 7.4 °C (1954), respectively. The highest temperature in summer was the highest, followed by spring and the lowest in winter. The lowest temperatures in spring, summer, autumn and winter were 11.8 °C (1952), 24.3 °C (1954), 14.3 °C (1955) and -0.3 °C (1969), respectively. The lowest temperature in winter was the lowest, followed by spring. The lowest temperature is the highest in summer.

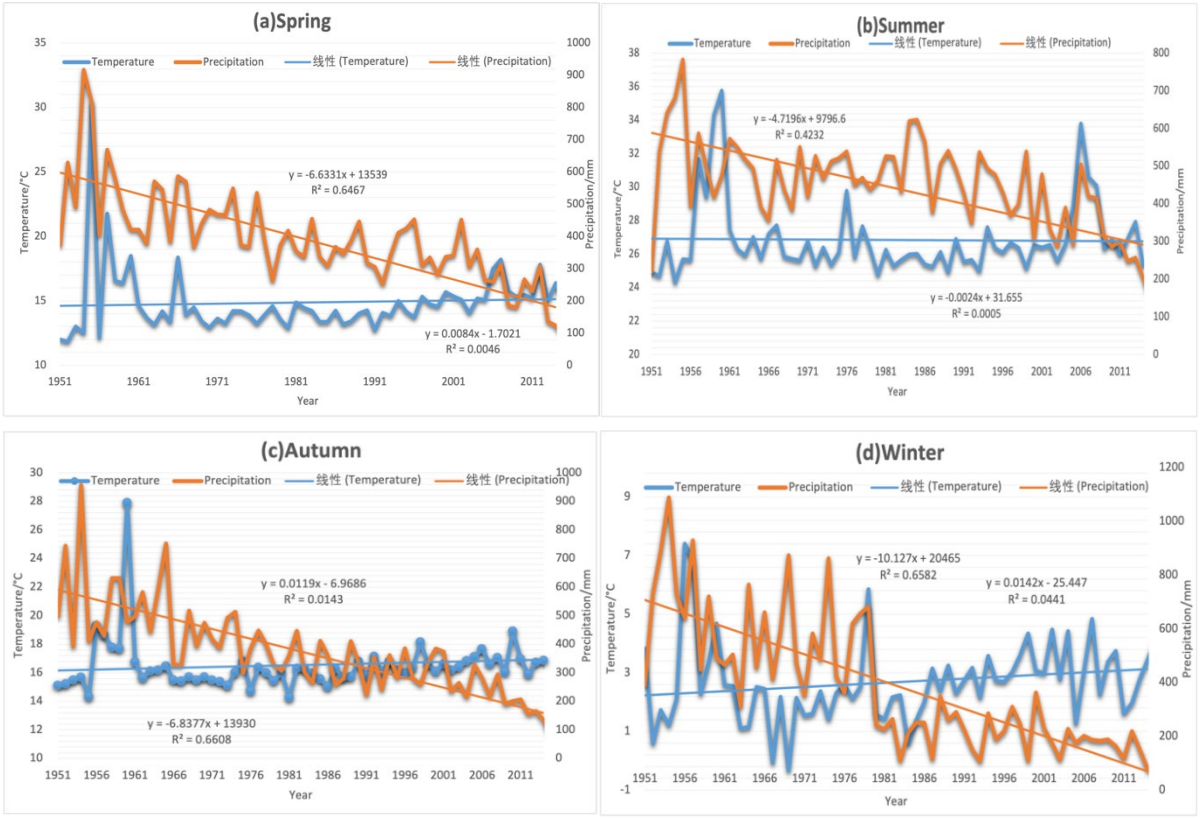


Fig. 3. Seasonal variation trends of temperature and precipitation in Hongze Lake during 1951–2014

The precipitation tendency rates of spring, summer, autumn and winter in the surrounding area of Hongze Lake from 1951 to 2014 were -6.6331 mm·$(10a)^{-1}$, -4.7196 mm·$(10a)^{-1}$, -6.8377 mm·$(10a)^{-1}$ and-10.127 mm·$(10a)^{-1}$, respectively. On the whole, the

precipitation tendency rate shows a downward trend, and the precipitation around Hongze Lake is constantly decreasing. However, from the perspective of seasonal precipitation, the reduction of winter precipitation is the largest, especially in 1979-1980. The largest reduction was followed by autumn. In the past 64 years, the maximum precipitation in spring around Hongze Lake was 916.6mm (1954), and the minimum was 122.2mm (2014). The maximum precipitation in summer was 783mm (1955), and the minimum was 203.4mm (2014). The maximum precipitation in autumn was 956.5mm (1954), and the minimum was 133.1mm (2014). The maximum precipitation in winter was 1088.8mm (1954), and the minimum was 75.8mm (2014).

The results of Fig.2 and Fig.3 show that the precipitation is less and less in recent years, which is mainly caused by global warming. There are many factors causing climate warming, such as a large number of burning fossil fuels, greenhouse effect, and climate warming contributes to global climate change anomalies, leading to the northward shift of the temperature zone, and will also aggravate the occurrence of meteorological disasters such as high temperature, drought and flood. The northward movement of the temperature zone will have a certain impact, such as affecting atmospheric movement, so that global precipitation will also change accordingly. It can be seen from Fig.3 that the precipitation tendency rate in summer is negative, the precipitation shows a downward trend, and the precipitation decreases. In general, the summer precipitation in the mid-latitude region (30 °- 60 °) will decrease. According to Table 1, it can be seen that the latitude of the surrounding area of Hongze Lake ranges approximately from 32°N to 35°N, which belongs to the mid-latitude region, so the summer precipitation will decrease.

2.1.3 Interdecadal Variation Of Temperature And Precipitation

According to Table 2, the temperature in the surrounding area of Hongze Lake is positive anomaly in 1951-1959, 2000–2009 and 2010–2014, and the whole is in the warm period, the values are 2.14 °C, 0.49 °C and 0.56 °C respectively. The temperature in 1960–1969, 1970–1979,1980–1989 and 1990–1999 was negative anomaly, and the whole was in the colder era, with values of -0.14 °C, -0.85 °C, -1.18 °C and -0.45 °C, respectively. The precipitation in 1951–1959,1960–1969,1970–1979 and 2010–2014 was positive anomaly, with values of 214.04 mm, 110.77 mm, 85.08 mm and 139.96 mm, respectively. The precipitation in 1980–1989,1990–1999 and 2000–2009 was negative anomaly, with values of -18.48 mm, -55.6 mm and -95.38 mm, respectively. From 1951 to 2014, the average annual temperature in the surrounding area of Hongze Lake showed a significant increase in 25 years, and there was a clear boundary between cold and hot periods. However, due to the influence of climate change in different years, the annual average temperature change trend is not the same, and the specific pattern of this change varies.

Interdecadal variation of temperature. In the 1950s, the temperature around Hongze Lake increased, and began to decline in the 1960s. The largest decline was 2.28 °C. The cumulative anomaly of temperature decreased significantly, and the temperature anomaly began to become negative. From 1970 to 1979, the temperature anomaly continued to decline, which was 0.71 °C lower than that of the previous era. From 1980 to 1989, the temperature anomaly continued to decline, which was 0.33 °C lower than that of the previous era. In the 1980s, the temperature anomaly was the smallest. In the 1990s, the temperature anomaly began to rise, which was 0.73 °C higher than that of the previous era, but it was still negative, and the whole was in the cold era. In the 21st century, the temperature anomaly began to be positive, which was 0.94 °C higher than that of the previous generation, and the temperature rise was the largest. The temperature anomaly remained positive from 2010 to 2014, with an increase of 0.07 °C compared to the previous generation, indicating that the overall period was within a warmer era.

Interdecadal variation of precipitation. The precipitation anomaly was the largest in the 1950s, and the precipitation showed an upward trend. The precipitation anomaly began to decrease in the 1960s and 1970s, but it was still positive. From 1980 to 1989, the precipitation anomaly began to be negative. At the beginning of the 21st century, the precipitation anomaly decreased to the lowest point, and then the precipitation anomaly increased significantly. From 2010 to 2014, the precipitation anomaly increased by 235.34 mm compared with the previous generation, and the precipitation increased the most.

Table 2. Interdecadal anomalies of temperature and precipitation around Hongze Lake

Period/Year	1951–1959	1960–1969	1970–1979	1980–1989	1990–1999	2000–2009	2010–2014
Temperature anomaly/°C	2.14	-0.14	-0.85	-1.18	-0.45	0.49	0.56
Precipitation anomaly/mm	214.04	110.77	85.08	-18.48	-55.6	-95.38	139.96

According to Table 3, the spring temperature in the surrounding area of Hongze Lake is positive anomaly in 1951–1959, 2000–2009, 2010–2014, and the whole is in the warmer era. In 1960–1969, 1970–1979, 1980–1989, 1990–1999, it is negative anomaly, and the whole is in the colder era. Among them, the temperature anomaly in spring began to be negative after 1959, which was 2.27 °C lower than that in the previous era, and the temperature drop was the largest. The interdecadal average temperature of summer and autumn is higher than the average temperature over the past 64 years. The temperature difference between summer and autumn

from 1951 to 2014 was positive, indicating a warmer period. By contrast, the winter temperature anomalies were negative from 1951 to 2014, suggesting that this period was generally a colder period.

During the period of 1951–1999, the average precipitation anomaly in spring was positive, and there was a significant decreasing trend. Between 2000 and 2009, the precipitation anomaly in spring turned negative, and during 2010–2014, it reached its most negative value. Compared with the previous era, the change in precipitation during 2010–2014 was the most significant, with a decrease of 154.65 mm. In summer, except for the negative precipitation anomaly in 2010–2014, the precipitation anomaly in other periods was positive, while the precipitation anomaly in autumn and winter changed greatly and decreased greatly.

Table 3. Temperature and precipitation anomalies around Hongze Lake during 1951–2014

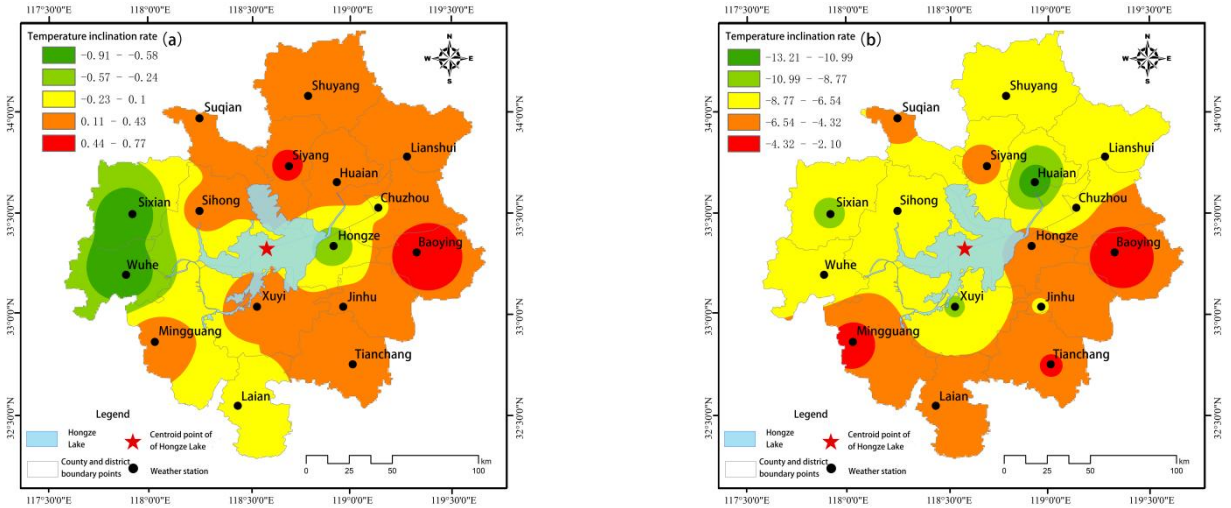
Period	Spring/ Temperature	Summer/ Temperature	Autumn/ Temperature	Winter/ Temperature	Spring/ Precipitation	Summer / Precipitation	Autumn / Precipitation	Winter / Precipitation
1951-1959	1.53	11.9	1.08	-12.24	258.13	191.81	237.17	392.06
1960-1969	-0.74	11.96	1.62	-13.63	130.51	132.47	153.88	215.48
1970-1979	-1.76	11	0.21	-13.06	88.73	152.17	77.06	211.91
1980-1989	-1.18	10.05	0.21	-13.49	37.64	180.46	2.87	-109.47
1990-1999	-1.26	10.63	1.09	-12.47	5.62	114.2	-31.87	-124.42
2000-2009	0.23	12.62	1.16	-12.26	-38.14	35.96	-59.09	-133.65
2010-2014	0.36	11.1	0.79	-12.8	-184.81	-78.24	-82.6	192.46

2.2 Spatial Variation Of Temperature And Precipitation

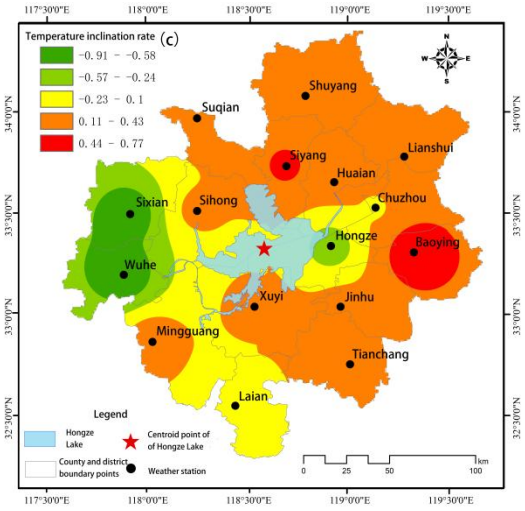
2.2.1 Spatial Overlay Analysis Of Temperature And Precipitation

The annual temperature increased by 0.316 °C $(10a)^{-1}$, and the temperature in the surrounding areas of Hongze Lake showed an upward trend in the past 64 years. As shown in figure 4 (a), there are 5 areas (Baoying County, Siyang County, Suqian City, Tianchang City, Mingguang City) in the surrounding area of Hongze Lake have a significant warming trend. There were significant warming in the northeastern and southeastern regions of Hongze Lake. The maximum warming in Baoying County in the southeastern region was 0.77 °C·$(10a)^{-1}$, while the temperature tendency rate in the northwestern and southwestern regions of Hongze Lake was small, and the temperature had a significant downward trend. The smallest was Wuhe County in the southwestern region [-0.91 °C·$(10a)^{-1}$]. The temperature in the surrounding area of Hongze Lake shows a decreasing trend from east to the west and from north to the south.

The annual precipitation generally showed a downward trend, with a decrease of -7.0837 mm $(10\ a)^{-1}$. As shown in Fig.4 (b), the decrease of precipitation in the south is smaller than that in the north. Among them, Huai 'an District in the northeast of Hongze Lake is the area with the largest decrease of annual precipitation [-13.21mm $(10a)^{-1}$], while Baoying County in the southeast is the area with the smallest decrease of annual precipitation [-2.11mm·$(10a\ )^{-1}$]. In the spatial distribution of precipitation, the overall trend is gradually decreasing from southeast to northwest.



（a）Annual mean temperature　　（b）annual rainfall



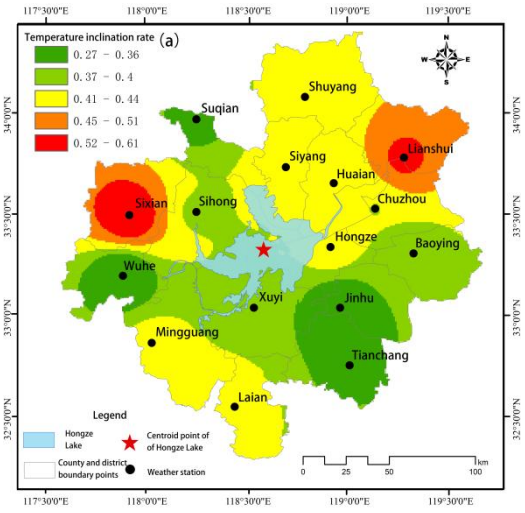
（c）superposed graph

Fig. 4. Distribution of annual temperature and precipitation trend rates around Hongze Lake during 1951–2014

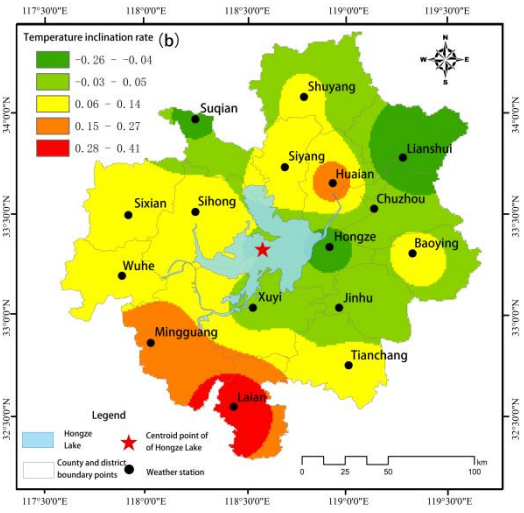
Combining the tendency rate of temperature and precipitation [Fig.4 (c)], the surrounding areas of Hongze Lake showed a trend of warming and drying, and decreased from east to the west. Taking Hongze Lake as the dividing line, it is divided into two regions. The warm and humid trend in the east of the lake is more obvious than that in the west of the lake. Among them, Baoying County has the largest warm and humid rate, followed by Tianchang City, but individual regions do not show a warm and humid trend. Huai 'an District has a small increase in temperature and precipitation, but a warm and dry trend. There was a cold-dry trend in the west of the lake. Among them, the increase of temperature in Sixian County was small, the decrease of precipitation was large, and the cold-dry trend was obvious.

2.2.2 Seasonal Variation Of Air Temperature On Spatial Scale

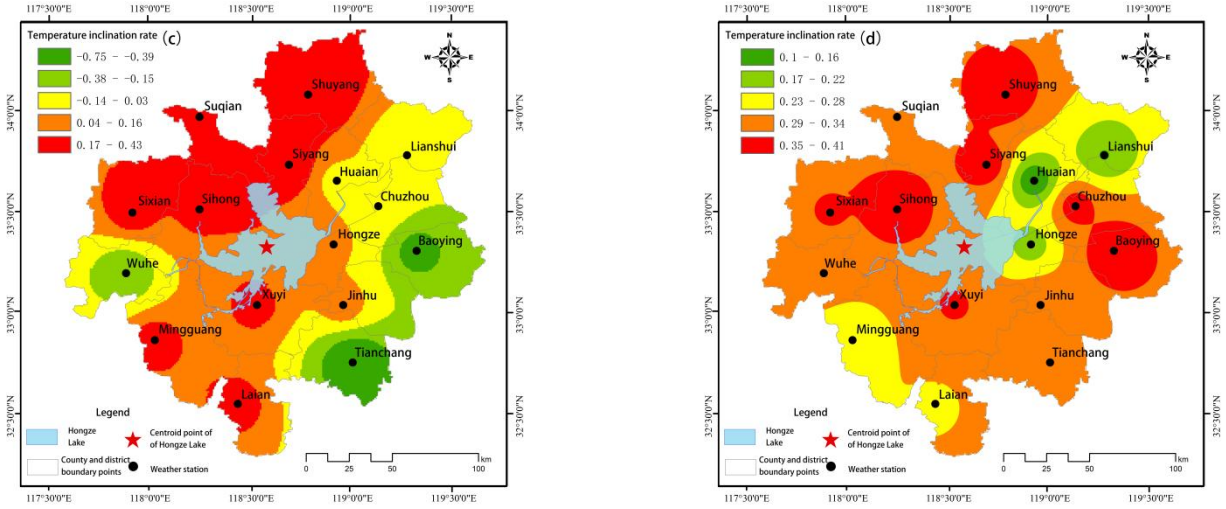
From the perspective of spatial scale, the temperature in spring, autumn, and winter around Hongze Lake showed an upward trend, unlike the temperature in summer, which showed a downward trend. The spatial distribution of warming rates have different distribution characteristics in different seasons. (Fig.5).



(a) Spring



（b）Summer



（c）Autumn　　（d）Winter

Fig. 5. Seasonal spatial distribution of temperature tendency rate in the area around Hongze Lake during 1951–2014

In spring, the warming rate decreased from northwest to southeast, and there were two regions with large temperature changes, namely Lianshui County and Sixian County. Among them, Lianshui County had the largest increase in temperature, and the maximum increase occurred in Sixian County, northwest of Hongze Lake, at [0.61 °C·(10a)$^{-1}$]. The area with small increase is Jinhu County in the southeast of Hongze Lake, and the minimum increase appears in Wuhe County in the southwest [0.27°C (10a)$^{-1}$]. In summer, the area with the largest increase in temperature is Huai 'an District in the northeast of Hongze Lake [0.41 °C·(10a)$^{-1}$], followed by Mingguang City in the southwest ; in Lianshui County, Chuzhou County, Xuyi County, Jinhu County, Suqian City and Hongze District, these areas are temperature reduction areas. Among them, the areas with large temperature reduction are Suqian City in the northwest area of Hongze Lake and Hongze District in the southeast area. The area with the largest temperature reduction is Lianshui County in Northeast China [-0.26 °C·(10a)$^{-1}$].

In autumn, the warming rate is divided into two regions with Hongze Lake as the critical line. Most of the east of the lake is a temperature reduction area. The area with a large temperature reduction is Baoying County in the southeast of Hongze Lake. The area with the largest temperature reduction is Tianchang City in the southeast, with a value of [-0.75 °C·(10a)$^{-1}$]. In contrast, except for Wuhe County in the west of the lake, all other regions are warming. Among these, Sixian County in the northwest of Hongze Lake experiences a significant temperature increase, while Shuyang County in the northwest (presumably a completed region description should follow here) exhibits the largest temperature increase.In winter, the areas with a large increase in temperature are Siyang County and Shuyang County in the northeast of Hongze Lake and Sihong County in the northwest, and the maximum temperature increase occurs in Baoying County in the southeast [0.41 °C·(10a)$^{-1}$] ; the area with less warming is Lianshui County in Northeast China, and the minimum increase appears in Huai 'an District of Northeast China [0.1 °C·(10a)$^{-1}$].

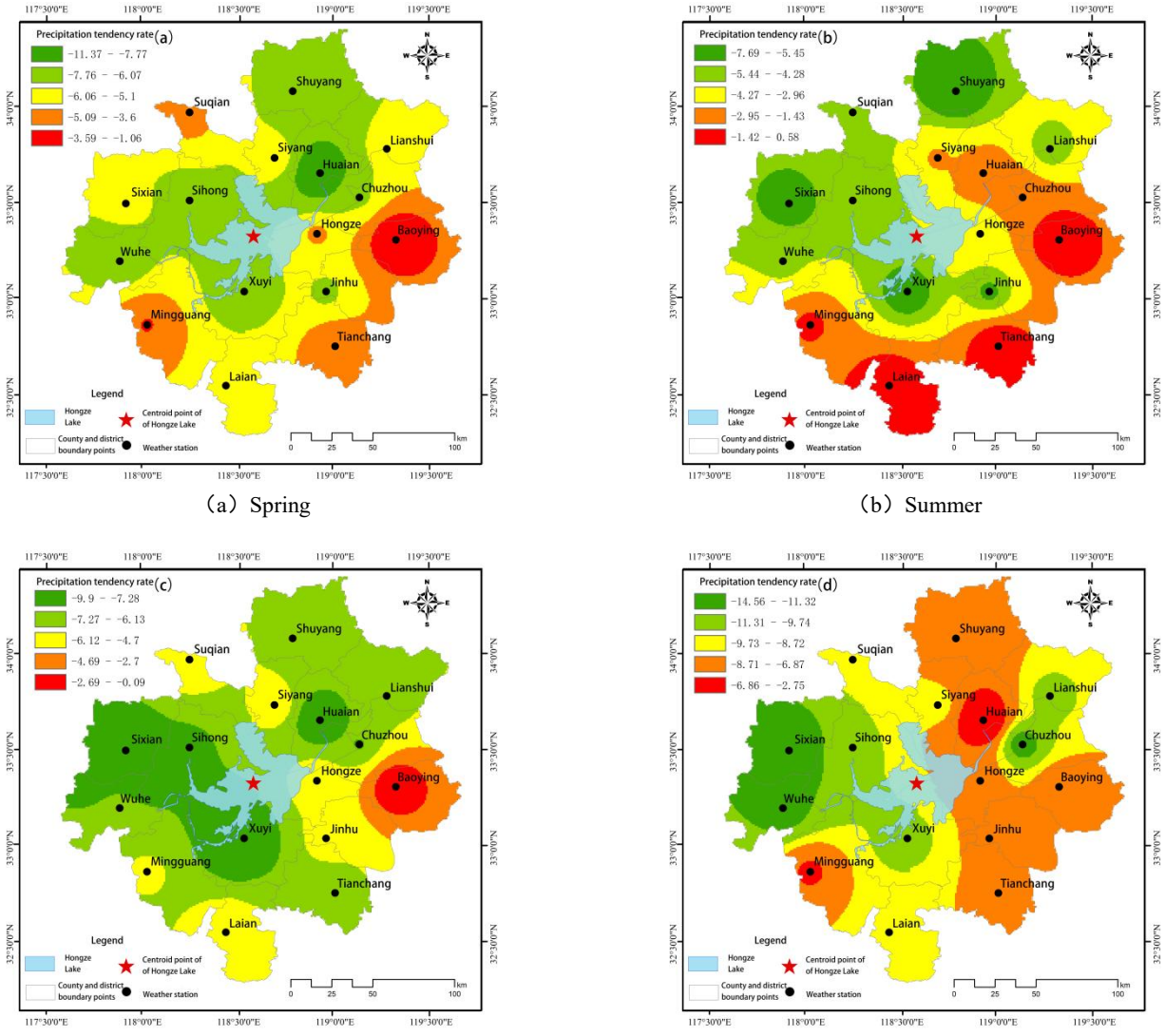
2.2.3 Seasonal Variation Of Precipitation On Spatial Scale

The precipitation in the four seasons around Hongze Lake exhibited a decreasing trend, and the spatial distribution of this reduction exhibited varying characteristics across different seasons (Fig.6).

In spring, the areas with a large decrease in precipitation are Shuyang County, Chuzhou County, Siyang County, Wuhe County, Xuyi County and Jinhu County in the northeast of Hongze Lake, and the maximum decrease occurs in Huai'an District [-11.37mm·(10a)$^{-1}$]. The areas with less precipitation reduction are Suqian City in the northwest of Hongze Lake and Mingguang City in the southwest, and the minimum reduction occurs in Baoying County in the southeast [-1.06mm·(10a)$^{-1}$]. In summer, the area with the largest decrease in precipitation is Lianshui County in the northeast of Hongze Lake and Si County in the northwest of Hongze Lake, and the area with the largest decrease is Shuyang County in the northeast of Hongze Lake [-7.69mm·(10a)$^{-1}$]; the area with the smallest decrease is Mingguang City in the southeast of Hongze Lake. The precipitation in Baoying County, Tianchang

City, and Lai'an County in the southeast of Hongze Lake showed an increasing trend. Specifically, the largest increase was observed in Baoying County in the southeast of Hongze Lake, with a rate of [0.58 mm·(10a)$^{-1}$].

In autumn, the areas with the largest decrease in precipitation are Wuhe County in the southwest of Hongze Lake, Sihong County in the northwest, Tianchang City in the southeast, Chuzhou County and Lianshui County in the northeast, and Xuyi County in the southwest of Hongze Lake [-9.9mm·(10a)$^{-1}$]. The areas with smaller reductions are Suqian City in the northwest of Hongze Lake, Siyang County in the northeast and Lai 'an County in the southwest. The minimum reduction occurs in Baoying County in the southeast [-0.09mm·(10a)$^{-1}$]. In winter, the areas with a large decrease in precipitation are mainly distributed in the northwest and southwest of Hongze Lake. The areas with the largest decrease were Sixian County in the northwest region, Wuhe County in the southwest region, Xuyi County in the southwest region and Lianshui County in the northeast region. The area with the largest decrease was Chuzhou County in the northeast region of Hongze Lake [-14.56mm·(10a)$^{-1}$]. The area with a small decrease in precipitation is mainly distributed in the northeast of Hongze Lake, and the area with the smallest decrease is Huai 'an District in Northeast China [-2.75mm·(10a)$^{-1}$].



（a）Spring　　（b）Summer

（c）Autumn　　（d）Winter

Fig. 6. Seasonal spatial distribution of precipitation tendency rate in Hongze Lake during 1951–2014

3. Conclusion And Suggestions

3.1. Conclusion

Based on the monitoring data of temperature and precipitation from 16 meteorological stations in the surrounding area of Hongze Lake in 64 years (1951–2014), the variation patterns of temperature and precipitation were analyzed from the temporal and spatial scales, and the following conclusions were obtained :

1. The temperature in the surrounding area of Hongze Lake showed an upward trend, and the temperature tended to be warmer. The average temperature in the past 64 years was 15.5 °C, and the temperature tendency rate was 0.316 °C $(10a)^{-1}$.
2. The precipitation in the surrounding area of Hongze Lake showed a downward trend, and the precipitation tended to be dry. The average precipitation in the past 64 years was 384.4 mm, and the precipitation tendency rate was -7.0837 mm $(10a)^{-1}$.
3. The temperature in summer showed a downward trend, indicating that the temperature decreased, while the temperature in autumn, winter and spring showed an upward trend, indicating that the temperature increased. Among them, the temperature rise in winter was the most significant, with the largest increase in temperature, followed by autumn, and the smallest increase in spring.
4. The precipitation tendency rates of spring, summer, autumn and winter were-6.6331 mm $(10a)^{-1}$, -4.7196 mm $(10a)^{-1}$, -6.8377 mm $(10a)^{-1}$ and -10.127 mm $(10a)^{-1}$, respectively. The precipitation in the four seasons showed a downward trend, and the precipitation was less and less, indicating that global warming had a great impact on precipitation. Among them, winter precipitation decreased the most, followed by autumn and spring.
5. The climate around Hongze Lake is generally warm and dry. The temperature in the northeast and southeast of Hongze Lake increased significantly, and the temperature change showed obvious spatial variation characteristics, decreasing from east to the west. From the perspective of evolution trend, the annual temperature and precipitation is significantly different from east to the west, the warming rate decreases from east to the west, and the precipitation decreases from southeast to northwest. Taking Hongze Lake as the dividing line, it is divided into two regions. The east of the lake shows a warm and humid trend, and the west of the lake shows a cold and dry spatial characteristics. Therefore, Hongze Lake has a certain regulating effect on the climate. The main reason for the formation of this temperature pattern is that the large area of Hongze Lake can absorb and store a lot of heat, making the temperature of the surrounding area relatively stable. Lakes can also evaporate water, creating lake winds and waves that change the distribution of air currents and precipitation in the surrounding area, and precipitation evaporation increases the intensity and frequency of local precipitation.

In summary, the temperature and precipitation of 16 meteorological stations are analyzed from the characteristics of time and space, and the temperature and precipitation in the surrounding areas of Hongze Lake changed significantly from 1951 to 2014. By studying the temperature and precipitation, the characteristics of climate change in the surrounding area of Hongze Lake are revealed, so as to provide reference for the local government to deal with disaster prevention and mitigation, and to take active measures to deal with the impact of climate change in the face of climate change.

3.2. Suggestions

1. Integrate scientific and technological forces, strengthen lake research, and establish a sound scientific and technological support system.
2. Set up science and technology lake chiefs in important lakes in China to provide scientific and technological support for the administrative lake chief system.
3. Establish and improve the comprehensive evaluation and assessment system for lake protection, establish a cross-regional joint prevention and control mechanism for lake basins, build a value realization mechanism for lake basin ecological products, and form a government-led and society-involved lake basin protection model.
4. Adopt the "ecological bank" model to improve the compensation system for lake ecological benefits.
5. Explore the establishment of green development funds for key lake basins, and strengthen support for the research and development, the demonstration application, and industrialization of lake ecological environment treatment technologies.

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