The characteristics of climate changes over Nantong during the period 1951-2018

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Abstract. Climate change is a hot issue concerned by governments, society and scientists all over the world. Some measures will be developed by the governments after studying district climate change. Based on climate data such as average temperature, average maximum temperature, average minimum temperature, and precipitation at the monthly scale obtained from eight meteorological stations over the Nantong region in Jiangsu province during the Period 1951-2018 in this paper. Climate change law was studied. This research methods include accumulative anomaly method, linear trend estimation, Mann-Kendall trend test and Morlet wavelet analysis. Results showed as following: (1) temperature has an obviously upward trend, but the differences between annual average temperature, annual average maximum temperature, and annual average minimum temperature are at little level. The trend in precipitation is not prominent in the period. The average values for the first 10 years of this century and the last 30 years are the chronological and period maximum. (2) The increase rate of temperature in spring is greatest during four seasons, and the significant is also the biggest. The increase rate of temperature in winter is greater than autumn, but the significant is reverse. Precipitation increases in summer and winter, but decrease in spring. (3) Mutation years of temperature and precipitation change were mainly in 1996-1998 and 2002-2004. (4) For period change, temperature and precipitation showed stable changes at a shorter time scale, such as 10 years or 2-3 years, and some longer scale period change for 30 years for mean average temperature. Overall, climate change over Nantong was consistent with other regions in China, and it also had its own unique features in some aspects.

1. Introduction
Climate change is a hot issue concerned by governments, society and scientists all over the world. Various observation data of the earth system showed that temperature of the surface and troposphere has increased significantly, and the global climate has been warming significantly in the last hundred years. Global warming is expected to continue in the 21st century, and the frequency, duration and range of extreme weather events are also increasing [1]. In the past century (1909-2011), the average temperature of land area in China increased by 0.9-1.5°C. In the recent 50 or 60 years, the warming rate of the surface temperature was about 0.21-0.25°C per ten years, which was higher than the global level. However, there was no significant trend change in average annual precipitation, but it showed significant inter-decadal change and regional distribution difference [2].

In recent 10 years, many scholars have studied the characteristics of climate change at the national and regional scales in China, and achieved a series of results. Such as change characteristics of air
temperature and precipitation in different regions of China from 1951 to 2009[3], the climate variations of temperature extremes in the eastern of China[4], temporal and spatial characteristics of temperature and precipitation in China's coastal areas from 1951 to 2016[5], in some provinces such as Zhejiang, Shandong and Jiangxi[6-8], in some cities such as Jilin of Jilin province, Fuxin in Liaoning province, Hangzhou and Yanqing of Beijing[9-12]. The research methods included linear regression, cumulative anomaly, MK test and wavelet transform. The research contents mainly included decadal variation, mutation characteristics, periodic analysis and spatial distribution characteristics and so on.

Located on the north wing of the Yangtze River Delta, and on the south side of the Yangtze River, Suzhou and Shanghai, Nantong is the intersection of coastal development of Jiangsu province and the Yangtze River Economic belt. In 2019, the city's GDP was close to 1 trillion yuan, playing an important role in Jiangsu Province and even the Yangtze River Delta region. The contents related to the climate change research of Nantong are temperature and precipitation of decadal and seasonal variation characteristics[13] the summer temperature and precipitation[14], local microclimate[15], etc. Compared to other areas of research on climate change, there are still some shortcomings, for example, the quantity is less, the time sequence is not more than 60 years, and some years are lack since 2010, which is very important because the five years (2014-2018) are the hottest in the past thirty years, and without full and system analysis on temperature and precipitation, to a certain extent, this article can make up for a lack of the above parts. To sum up, the analysis of climate change characteristics from the measurement records of meteorological stations can provide some scientific references for tackling climate change and ecological civilization construction in this region, and also provide certain early warning for the climate change to Shanghai's agricultural products supply.

2. Data, method and regional overview

![Figure 1. A map of the study area and climate stations (The small image on the upper right shows the location of the study area in China).](image)

Based on eight weather stations (Figure 1) in Nantong region (Hai’an, Rugao, Rudong, Nantong, Tongzhou, Haimen, Qidong and Lusi) across 68 years (1951-2018), monthly mean temperature, monthly mean maximum temperature, monthly mean minimum temperature, and monthly total rainfall dates were collected, in whose station the first year is different. Nantong station originated from 1951, which is the earliest, several other sites for 1956-1960 respectively. Due to the flat terrain in Nantong region, and meteorological site distribution more uniform, the correlations of temperature between eight sites are all above 0.9, and the correlations of precipitation are also more than 0.7. The correlation between Nantong station and other sites is relatively high; therefore, the arithmetic mean value of temperature and precipitation of eight stations is adopted. On the other hand, for the climatic data of a few missing months, the mean value of the same month for many years is used for interpolation correction or time series linear regression fitting. In terms of seasonal distribution, spring, summer, autumn and winter correspond to March-May, June-August, September-November and December-the following February respectively.
Firstly, the inter-annual, inter-decadal and seasonal variation characteristics of temperature and precipitation are analyzed. Secondly, the abrupt transition characteristics of temperature and precipitation are analyzed. Thirdly, time frequency characteristic analysis is carried out. Finally, it is discussed by pointing out the potential implication of climate feature and comparing with relevant researches. Data processing methods include anomaly analysis, linear trend method, moving average method, Mann-Kendall (MK) non-parametric method, and Morlet wavelet analysis method. Please refer to relevant literature [16-18] for specific methods, and no details will be repeated.

Located on the north wing of the Yangtze River estuary, Nantong is in the southeastern part of Jiangsu province, adjacent to Taizhou to the west, and bordering on Yancheng to the north. Nantong is surrounded by water on three sides, and thus is shaped as a peninsula, with its northern to the northeastern parts adjacent to the Huanghai Sea, and its southern part facing the Yangtze River. Nantong is connected to Suzhou and Shanghai via two cross-river bridges, the Su-Tong Yangtze River Highway Bridge and the Chongqi Bridge. The terrain is low and flat, most of which belong to the flat Yangtze River Delta plain. Except for the bedrock less than 1km² exposed in The Wolf Mountain area, they are all covered by quaternary sediments and waters. Nantong region belongs to the north subtropical monsoon climate zone, with mild climate, distinct four seasons, abundant rain, and obvious maritime climate.

3. Results
3.1. Inter-annual and inter-decadal variation features
The Inter-annual temperature changes all showed a significant upward trend, with the average annual temperature(T), minimum temperature(Tmin) and maximum temperature(Tmax) increasing rates of 0.26°C/10a, 0.24°C/10a and 0.21°C/10a respectively, and the significance degree also decreased in turn. The statistical test P and F values of the three variables were P=1.78E-12 F=74.93, P=6.38E-10 F=52.23 and P=1.04E-07 F=35.66, respectively, while the change trend of annual total precipitation (P) was not obvious (P=0.2692, F=1.24). From the perspective of anomaly changes, no matter T, Tmin, or Tmax, before 1997, negative anomaly dominated, and after that, positive anomaly (except Tmax in 2012), and P has a staggered distribution of positive and negative anomaly. According to the 5-year moving average (Figure 2), the temperature was expected to be in fluctuation in the mid-1980s, and then it was in rising state, reached the maximum around 2007, and then dropped rapidly to the trough around 2012. At present, the temperature is on the rise with different degrees. From the time mean, the change from 1950s to 1980s was small, and it began to increase in 1990s. In the first decade of this century, the mean value was the largest, and the mean value of both temperature and precipitation in the last 30 years was the maximum in this period. See Table 1 for detailed information.

![Figure 2](image-url). The annual changes of temperature and precipitation over Nantong during the Period 1951-2018.

Figure 2. The annual changes of temperature and precipitation over Nantong during the Period 1951-2018.
Table 1. Average value of temperature and precipitation in Nantong during different periods.

| Year | T /℃ | Tmax /℃ | Tmin /℃ | P /mm | Period   | T /℃ | Tmax /℃ | Tmin /℃ | P /mm |
|------|------|---------|---------|-------|----------|------|---------|---------|-------|
| 1950s| 14.65| 19.22   | 11.49   | 1147.92| 1951-1980| 14.79| 19.29   | 11.33   | 1060.44|
| 1960s| 14.91| 19.57   | 11.24   | 1025.90| 1961-1990| 14.84| 19.22   | 11.33   | 1031.99|
| 1970s| 14.86| 19.16   | 11.34   | 1018.3 | 1971-2000| 15.04| 19.34   | 11.56   | 1057.24|
| 1980s| 14.69| 18.96   | 11.25   | 1071   | 1981-2010| 15.45| 19.76   | 12.00   | 1077.7 |
| 1990s| 15.45| 19.78   | 11.95   | 1084.7 | 1990-2018| 15.84| 20.16   | 12.38   | 1132.31|
| 2000s| 16.06| 20.36   | 12.62   | 1064.3 |          |      |         |         |       |
| 2010s| 16.03| 20.35   | 12.60   | 1260.7 | 1951-2018| 15.23| 19.62   | 11.78   | 1092.94|

3.2. Seasonal variation

Spring: The temperature is on the rise during the period 1951-2018 in Nantong, and precipitation is on the decline (Figure 3). The increasing rate of T, Tmax and Tmin is respectively 0.38℃/10a, 0.32℃/10a and 0.42℃/10a, and temperature increased obviously by the statistical tests (P value is 4.63E-12, 5.97E-10 and 6.73E-07 respectively; F value is 80.73, 60.89 and 60.43 respectively), and T rise significantly greater than Tmin and Tmax, but precipitation was not significant (P=0.2461, F=1.37). Before 1997, T in spring was mainly negative anomaly, followed by all positive anomalies (except 2010). Both Tmin and Tmax are the same as T. However, the positive anomaly for Tmax and Tmin before 1997 was 3 years more than T, and the negative anomaly after that was 1 year more. It can be seen from the 5-year sliding average curve that T in the period of 1976-1984 and 2002-2007, Tmax in the period of 1975-1984, and Tmin in the period of 1961-1967 were relatively flat, and the changes in other years were relatively obvious, that is, either rising or falling. In addition, T and Tmin from the mid-1990s to the beginning of this century, and in the last 10 years, have been rising sharply.

Figure 3. The annual anomaly of temperature and precipitation in spring over Nantong from 1951 to 2018.

Summer: From 1951 to 2018, T, Tmax, Tmin and P in Nantong area all showed an upward trend (Figure 4). The increasing rate of linear fitting was 0.15℃/10a, 0.17℃/10a, 0.09℃/10a and 9.2mm/10a, respectively. In summer, the test statistic P value is larger than that in other seasons, while F value is smaller, which is contrary to the degree of significance. From 5-year moving average curve, we can see that the change on temperature is as follows: after the mid-1950’s it began to rise, reached the peak in the early 60’s(1962 year), and then began to decline, until the end of the 1960’s, followed...
by growing volatility in the 1990’s began to rise, achieved peak around 2007, then under falling volatility, and this is obviously contrary to the spring. P varies from temperature: there are two distinct peaks (1957 and 2001) and troughs (1968 and 2006). P increased in 1958-1968 and 2001-2005, and decreased from 1968 to 1983, but has been in an increasing trend since 2006 with smaller amplitude.

![Figure 4](image1.png)

**Figure 4.** The annual anomaly of temperature and precipitation in summer over Nantong from 1951 to 2018.

**Figure 5.** The annual anomaly of temperature and precipitation in autumn over Nantong from 1951 to 2018.

**Autumn:** T, Tmin and Tmax have an obvious rising trend, linear fitting increasing rate was 0.25°C/10a, 0.27°C/10a, 0.15°C/10a respectively, which statistical significance is in turn reduce (F value was 39.63, 26.10 and 13.59 respectively). Although P also has the rising trend (increasing rate is 1.36 mm/10a) (Figure 5), the correlation is not significant (P=0.8393, F=0.041) . From 5-year moving average curve, the temperature change is as follows: it began to decline from 1954, reaching trough in the late 1950’s, then began to rise, reaching the peak in the mid-1960, next start declining until the early 1970’s, arriving in the trough. Then it was in a slow fluctuation, rising once again at the beginning of 1990’s, achieving peak around 2006, and then in the decline stage. It is on the rise in recent years, and the time of duration in every stage is just slightly different. The procession of P change can be divided into four stages: in the first stage, from the mid-1950’s to the mid-1960’s, it firstly increased and decreased following; then fluctuated around the mean value till the early 1990’s; in the third stage, P moved ahead in wave below the mean from the beginning of the 21st century to the early of the 10th century. At present, it is in the fourth stage, and the P is on the rise.
Winter: In recent 68 years, the temperature in the study area showed an increasing trend. The linear fitting rate of T, Tmin and Tmax was 0.26°C/10a, 0.32°C/10a and 0.22°C/10a respectively, with statistical value (F value was 22.24, 20.71 and 12.96 respectively), and the P showed a slight increasing trend (gradient rate was 4.1mm/10a) (Figure 6) \((P=0.1902\text{, } F=1.75)\). From 5-year moving average curve, the climate change features in winter can be seen: temperature has three obvious warming period (around the mid-1970’s, from mid-1980’s to around the turn of the century, and recent 5 years or so), three cooling period (in the 1960’s, in the early and mid-1980’s, and the first decade of this century or so); In the 20th century, the precipitation experienced three downward-rising processes, and the duration became shorter and the amplitude became smaller. Since this century, the precipitation showed a fluctuating downward trend.

3.3. Mutation analysis

Note: The blue broken line represents the positive sequence; the red broken line represents the negative sequence. Two straight line show confidence level of 95%.

Years of mutation in temperature and precipitation over Nantong was carried out by using the MK method. The results showed that the positive and negative sequences of T intersected in 1996 and were within the 95% confidence level, indicating that T might change suddenly in 1996. In terms of T in different seasons, the two sequences of T in spring, summer, autumn and winter intersected in 1996, 2002-2003, 1996-1997 and 1988-1989 respectively, and the intersection point is also within the
confidence interval, so these years may be the abrupt transition time of T in four seasons. The mutation years for Tmax and Tmin may be 2000, 1997-1998. Tmax in spring occurred in 1998-1999, Tmin in 1994-1995, in summer occurred in 2004, Tmax and Tmin in autumn occurred in 1996 and 2001 respectively, and Tmax and Tmin in winter occurred in 1991 and 1998.

Compared with the temperature, the value of positive and negative sequences for precipitation changes is a little confusion, there are 3 points for inter-annual change after 2014, and some points before the 1980s for precipitation in spring, but no intersection since that. In summer, P in the positive and negative sequence was fellowship in 2008, which was in the scope of the confidence interval. The positive and negative sequences in autumn occurred three times before 1963 and two times after 2014. In winter, there was an apparent intersection in 1996-1997, occurring twice again after 2014. Considering the beginning and end of the data time, and combined with anomaly analysis diagram, summer precipitation in 2008 and winter precipitation in 1996-1997 may be abrupt. A representative feature mutation chart (Figure 7) is selected here and other graphs are omitted.

3.4. Period analyses

Based on the wavelet analysis of climate data in Nantong, the results were shown in Figure 8. For T, inter-annual variation was the main factor. In recent 68 years, 1-11 years period passed 95% significance test, among which 1-2 years and 10-11 years were more obvious. In terms of the wavelet analysis of T of each season, the four seasons (spring, summer, autumn and winter) were still dominated by the inter-annual cycle. Among them, the characteristics of the spring wavelet transform were most similar to the inter-annual change. The 3-year cycle in summer, 1-7 years period in autumn and 2-5 years period in winter had passed the 95% significance test in the study period. The characteristics of the wavelet transform of Tmax and Tmin were similar to that of T, and mainly varied from year to year. The 1-10 years and 1-11 years period for Tmax and Tmin passed 95% significance test. The period of Tmax in four seasons was 1-10 years, 3 years, 1-6 years and 2-4 years respectively.

Figure 8. The wavelet analysis of annual and four seasons’ average temperature in Nantong.

Note: Black dots are on behalf of confidence level in 95%. Red represents the positive value of the wavelet coefficient, while blue the negative value, and the darker the color, the greater the absolute value of the coefficient.
and was 1-9 years, 2-5 years, 1-7 years and 2-5 years for Tmin. Compared with temperature, the characteristics of the wavelet transform of precipitation was mainly within 5 years, and the inter-annual P 2-4 years cycle, spring precipitation 2-5 years cycle, summer P 3-year cycle, autumn P 2-5 years cycle and winter P 3-year cycle passed the significance test.

The wavelet coefficient can reflect the change characteristics of temperature and precipitation. For T, the value of wavelet coefficients in short time scale (annual change) was small, and the fluctuation was not obvious. The wavelet coefficients of medium time length (about 10-20 years) became larger, but the fluctuation was still not obvious. In the long time scale (over 20 years), the wavelet coefficient value was larger more, with the more obvious fluctuation. As shown in Figure 9, on the 20-year and 22-year timescale, T was 2.5 cycles, with 3 warm periods and 2 cold periods. It had 1.5 cycles, 2 warming phases and 1 cooling phase on a 30-year. It is currently in warm phase regardless of either scale, but the degree of warming is decreasing. On the other hand, after debugging and monitoring, it was found that temperature and precipitation of seasonal change was given priority to with 10 to 16 years of medium time scales, such as 16 years scales for T in spring and around 15 years scales for Tm. An average of wavelet coefficients showed the obvious features of volatility. In summer, it was obvious with the average temperature of 10 years scale and precipitation with 28 years scale. In autumn, average temperature of 14 years and 11 years precipitation, and the winter 10-year average temperature and precipitation, cycle characteristics of wavelet coefficients were relatively obvious.

![Figure 9. The wavelet coefficient of climate change at different scales in Nantong.](image-url)

4. Discussion
All above research about the climate change characteristics over Nantong were basically consistent with that what others had already done [13, 14, 19], which explained the commonness of climate change in Nantong to some extent. The inconsistencies were shown in the following aspects: firstly, the range and correlation of the changes. In this paper, the inter-annual temperature increase rate did not differ much, and was relatively significant in spring, autumn and winter. Compared with the literature [13], the inter-annual increase trend of precipitation was slightly larger, but the correlation was reduced. Secondly, in terms of the seasonal variation characteristics, the increasing rate of temperature in spring was the biggest, with the most obvious test value, and the increasing rate of precipitation in summer is greater than that of precipitation in winter. Third, in terms of the abrupt transition and periodic characteristics, except that the abrupt transition year of Tmin in spring was earlier than T, other seasonal and inter-annual changes were all earlier than the Tmin. And the inter-annual cycle was relatively obvious regardless of temperature or precipitation.

The reasons for different climate change may be as follows: First of all, the time may be inconsistent, in this paper, the time period of 1951-2018, is currently the longest measurement data in Nantong, T in 1950s’ was relatively lower, and it had been since 2000 in warm condition, especially peaked in 2016 and 2017. Of course, in this paper, the new Lvis site is located in the coastal towns, may have an effect, in addition to Nantong site has the characteristics of urban climate, other sites may be even more has the characteristics of rural climate, especially before 2000, and the climate of Nantong region belongs to the north subtropical humid climate. Compared to the temperature, the precipitation has a significant regional nature. Secondly, it plays an important role that global warming and urbanization on climate (20). After 2000, especially after Sutong Bridge in 2008 opened to the
southern in traffic, the economic development of Nantong area was not only concentrated in the urban area, but also the economy of the counties and cities under its jurisdiction entered the fast lane, the level of urbanization is rising with more and more urban size and changed land use structure, which affected local climate to some extent. The regional population slowly increased and the urban scale kept expanding. In addition, the natural background of global warming may lead to seasonal differences in the climate in Nantong. Finally, the difference between mutation and cycle may lie in the following two aspects: on the one hand, it was related to the seasonal variation characteristics of temperature and precipitation. Some conclusions were drawn from the previous analysis, such as the greatest increase rate of temperature in spring, the lowest increase rate of temperature in autumn and winter. It was in turn Tmin, T and Tmax. On the other hand, the morlet wavelet method was used to analyze time-frequency characteristics, which may also cause differences with other wavelet functions or spectral analysis methods.

At the same time, the potential significance of climate change characteristics in Nantong area is further analyzed: Firstly, this findings can help us better predict future climate change in Nantong, seasonal and decadal changes in predicting the future climate projections should focus on the primary problem, at the same time the interaction between different time scales climate change is directly related to the content of science and technology of time scale climate prediction and forecast level of ascension[20-21], so comprehensive analysis systematically the seasonal and inter-annual and inter-decadal variations of climate change and mutation and cycle characteristics, can be as the research area of different time scales climate forecast model to improve the relatively comprehensive and reliable basic data, and improve the level of prediction. Secondly, the trend, amplitude and cycle characteristics of temperature and precipitation change can provide scientific reference for the region to formulate climate change plans, thus contributing to the construction of beautiful Jiangsu province. Finally, these would also help broaden the scope of interest of the paper, which is currently focused on one specific region, to be of interest to readers elsewhere in the world; for example, it provides a demonstration of an analytical approach that could be used elsewhere.

5. Conclusion

In this paper, monthly temperature and precipitation data from 1951 to 2018 of 8 weather stations in Nantong area were used to comprehensively and systematically analyze the regional climate change characteristics in recent 68 years. The main conclusions are as follows:

(1) The inter-annual temperature variation in Nantong area had a significant upward trend, but there was little difference between the increment rate and the precipitation variation trend. From the perspective of the time mean, the change from 1950s to 1980s was small, and it began to increase in 1990s. In the first decade of this century, the mean value was the largest, and the mean value of both temperature and precipitation in the last 30 years was the maximum. From the perspective of seasonal changes, the temperature increasing rate in spring had the greatest correlation and was the most significant, while the temperature increasing rate in autumn had a higher significance. The temperature increasing rate in autumn and winter was the lowest temperature > the average temperature > and the highest temperature. For precipitation, spring precipitation had a downward trend, while other seasonal precipitation had an increasing trend.

(2) The timing of the abrupt changes was concentrated in the 1990s and 2000s, especially 1996-1998 and 2003-2004. The characteristics of periodic change were obvious in short time scales, especially in 10-year and 2-3 year periods, and relatively obvious in other longer time scales, such as in 30-year average annual temperature. Except that the abrupt transition year of the lowest temperature in spring was earlier than the average temperature, the other three seasons and inter-annual changes were all that the average temperature was earlier than the lowest temperature. No matter the temperature or precipitation, the inter-annual cycle was relatively obvious.

In short, under the background of global warming, the climate change in Nantong area has great consistency with other regions in China, and has its own unique feature.
References

[1] Ding Y H, Wang H J 2016 Newly acquired knowledge on the scientific issues related to climate change over the recent 100 years in China (in Chinese) Chin Sci Bull 61

[2] The Third National Assessment Report on Climate Change Editorial Committee 2015 The third national assessment report on climate change (in Chinese) Science Press 9,976

[3] Yu H Y, Liu S H, Zhao N, et al 2011 Characteristics of air temperature and precipitation in different regions of China from 1951 to 2009 (in Chinese) Journal of Meteorology and Environment 27

[4] Qi Q H, Cai R S, Guo H X 2019 The climatic variations of temperature extremes in the Eastern of China (in Chinese) Scientia Geographica Sinica 39

[5] Gao Y B, Lu C Y, Zhong L X, et al 2018 Temporal and spatial characteristics of temperature and precipitation in China's coastal areas from 1951 to 2016 (in Chinese) Journal of Forest and Environment 39

[6] Xiao JJ, Li ZQ, Guo FF, et al 2018 Construction and analysis of annual precipitation serious from 1901 to 2017 in Zhejiang province (in Chinese) Climate Change Research 14

[7] Ma Z C, Yu H B, Zhang Q F, et al 2019 Characteristics of climate and abrupt change of temperature and precipitation in Inner Mongolia Area over the period 1960-2016 (in Chinese) Research of Soil and Water Conservation 26

[8] Lu Q, Yan B, Zhan D S. 2019 The temporal-spatial characteristics of climate change in Jiangxi province over the period 1961-2016 (in Chinese) Research of Soil and Water Conservation 26

[9] Wu L Q, Li N 2011 Climate change characteristics from 1951 to 2009 in Quzhou, Zhejiang province (in Chinese) Journal of Meteorology and Environment 27

[10] Sun B L, Sun F H, Sun K, et al 2017 Characteristics of climate change in Fuxin during 1961-2015 (in Chinese) Journal of Meteorology and Environment 33

[11] Li J, Chen Y M 2019 Analysis of climate change characteristics in Hangzhou in recent 66 years (in Chinese) Bulletin of Science and Technology 35

[12] Cheng T T, Ma S S, Zhang S S, et al 2019 Characteristics of climate change in Beijing Yanqing over the period 1960-2018 (in Chinese) Modern Agricultural Science and Technology 18

[13] Wang T, Tao H, Yang Q 2011 Characteristics of inter-annual and seasonal changes in temperature and precipitation over the Nantong region during the period 1960-2007 (in Chinese) Resources Science 33

[14] Huang L, Shen Y P, Peng X Y et al 2010 Characteristics of summer temperature and precipitation in Nantong in recent 60 years (in Chinese) The 27th Annual Meeting of The Chinese Meteorological Society 10

[15] Xu C Y, Chen Y, Zhu H X, et al 2010 The influence of urban development on local microclimate change in Nantong (in Chinese) The 27th Annual Meeting of The Chinese Meteorological Society 10

[16] Daubechies I 2004 Ten lectures on Wavelets National Defense Industry Press 2004 5

[17] Yang H, Song Z S 1999 Multi-time-scale analysis of water resources in north China (in Chinese) Plateau Meteorological 18

[18] Shao X M, Xu Y Q, Yan C R 2006 Wavelet analysis of rainfall variation in the Yellow River Basin (in Chinese) Acta Scientiarum Naturalium Universitatis Pekinensis 42

[19] Xia L, Zhang Q, Sun N, et al 2015 Climate change characteristics in Jiangsu Province, 1960-2012 (in Chinese) Journal of Glaciology and Geocryology 37

[20] Ji Z H, Guo Y F, Zha L S 2011 Comparison about impact of urbanization on urban temperature in the downstream of the Yangtze River: A case study of Anqing, Wuhu and Nanjing (in Chinese) Resources and Environment in the Yangtze Basin 2011

[21] Wang H J, Ren H L, Chen H B, et al 2020 Highlights of climate prediction study and operation in China over the past decades Acta Meteorologica Sinica 78