Analysis on Temperature Variation over the Past 55 Years in Guyuan City, China

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Abstract: ***Global climate change has far-reaching effects on natural ecosystem and socio-economic system, and it is a hot issue that the governments and the scientific community as well as the general public pay attention to today. Meanwhile, climate change has strong regional characteristics. In the global context of climate warming, the climate change trends and intensity is not entirely consistent. Therefore, strengthening small regional climate change research plays an extremely important role on local agricultural production, livelihood and disaster prevention. On the basis of the monthly average temperature series in Guyuan meteorological station from 1957 to 2011, the temperature trends were analyzed with Mann-Kendall test and Pettitt jump test. The result with linear regression analysis showed that the annual average temperature in Guyuan City is in an increasing trend, and the average increase rate is 0.3071℃/10a. The annual highest temperature, the annual lowest temperature, and the annual average temperature in Guyuan City showed an upward trend with Mann-Kendall test. The biggest change is the annual lowest temperature, and the change rate is 0.60 ℃/10a, and then is the annual average temperature and annual highest temperature. Pettitt jump test results showed that the annual lowest temperature in Guyuan City changed in the earliest year before 1984. The annual average temperature and annual highest temperature changed nearly the year of 1993. Multiple regression analysis showed that changes of temperature in Guyuan City mainly occurred after the 1980s, and there is a significant upward trend into the 21st, which is in accordance with Pettitt jump test results.***

Keywords: Guyuan city; Temperature change; Linear regression analysis; Mann-Kendall test; Pettitt jump test.

1. Introduction

It is not doubt that the climate was warming over the past century in China, and its climate tendency rate is 0.19 ~ 0.72 ℃ /100a. The past 50 years climate warming are more pronounced, and it increased 0.64 ~ 0.92 ℃ about every hundred year [1]. Local temperature trend researching can provide a theoretical basis for the local governments' decisions. In recent years, the analysis of the temperature variations has caused a lot of attention of scholars. X.M. WANG et al analyzed Shi Liuyang river basin highest and lowest temperatures for nearly five decades [2], M.J. DING et al used Mann-Kendall test and Pettitt-Mann-Whitney jump test to analyze highest and lowest temperature around the Poyang Lake region and its highest and lowest temperature trend was in a significant upward trend [3].

Guyuan City is located in southern of Ningxia Hui Autonomous Region and it is far from the sea. The temperature variations throughout the region have big effects on the ecological, economic and social development. The variations of temperature in Guyuan City were analyzed with the Mann-Kendall test and Pettitt-Mann-Whitney jump test. Through the research on the long-term temperature data, the trend of temperature variation over the years in Guyuan City was analyzed, and the purpose is to provide basic information in aspects of the ecology, agriculture, meteorology in this region.

2. Study area and data sources

Guyuan city is located in the south of Ningxia Hui Autonomous Region. Qingyang City, Pingliang City, Baiyin City and Zhongwei City are respective on the east, south, west and north of Guyuan City. From the geomorphic units, Guyuan city is located in the northwest edge of Loess Plateau in China, and Liupan Mountain is the north-south spine in the territory, and the city are divided into east and west side by the Liupan Mountain, and the north is high and south is low. There are high temperature, low rainfall, and abundant sunshine in Guyuan City. The annual average temperature is between 6.8 ℃ and 8.8 ℃. Guyuan city administrative divisions are shown as Figure 1.

Figure 1: The study area administrative region diagram

The Guyuan City meteorological station monthly average temperature data from 1957 to 2011 is selected as the research object, the length of sequence is 660 months.

3. Methods

3.1 Regression analysis

Regression analysis is a method used commonly in statistical hydrology, which can be mainly divided into linear regression and multivariate linear regression. In this study, linear regression and multivariate linear regression method are used to analyze the trends of temperature changes in Guyuan City for many years.

3.2 Mann-Kendall test

Mann-Kendall test (MK) [4] - [7] is a non-parametric statistical test, which is described as follows. Assumed X_1, X_2 … X_n is the time series variable, n is the length of time series. Then the MK statistic, S, is defined as follows:

$$S = \sum_{k=1}^{n-1} \sum_{j=k+1}^{n} \mathrm{sgn}(X_j - X_k) \quad (1)$$

Where,

$$\mathrm{sgn}(X_j - X_k) = \begin{cases} 1, & X_j - X_k > 0, \\ 0, & X_j - X_k = 0, \\ -1, & X_j - X_k < 0, \end{cases} \quad (2)$$

When n value is bigger than 10, the standard normal statistical variables, Z can be described in the following equation.

$$Z = \begin{cases} \frac{S-1}{\sqrt{Var(S)}}, & S > 0, \\ 0, & S = 0, \\ \frac{S+1}{\sqrt{Var(S)}}, & S < 0, \end{cases} \quad (3)$$

Where,

$$Var(S) = \frac{\left[n(n-1)(2n+5) - \sum_{p=1}^{g} t_p(t_p-1)(2t_p+5)\right]}{18} \quad (4)$$

Where g is the number of groups in same value, t_p is the number of the same value in every group. For example: a particular series: $\{3,4,4,4,3,3\}$ n = 6, g = 2, t_1 = 3, t_2 = 3.

Z is a normal statistical distribution volume; α is a given confidence level of α, if $|Z| > Z_{\alpha/2}$, it means that there is an obvious upward or downward trend within the time series data at a given confidence level of α .

If it is determined there are obvious trends, use Sen slope estimation method to calculate the size of the trend, the trend function is:

$$f(t) = Qt + B \quad (5)$$

Where Q refers to the trend degree, The more greater the Q is, the tendency is more obvious. B is a constant, t refers to the years.

$$Q_i = \frac{x_j - x_k}{j-k} \quad (6)$$

Where, j> k. if the length of time series is n, N = N (N - 1) / 2 Q_i can be obtained, and the value of the Q refers to the mid-value of Qi.

3.3 Pettitt Jump Test

Pettitt jump test [8]-[11] is a non-parametric statistical test. Given n samples of time series: x_i, i=1, 2, 3…n. Then the Pettitt statistic, U_t, is defined as following:

$$U_{t,n} = U_{t-1,n} + V_{t,n} \quad (7)$$

Where,

$$V_{t,n} = \sum_{j=1}^{n} sgn(x_t - x_j) \quad (8)$$

If the t_0 time meets:

$$k_{t0} = \underset{1 \le t \le n}{Max} |U_t| \quad (9)$$

Then, t_0 is the mutation points. Its confidence level can be calculated by the equation.

$$p(t) = 2\exp\left[\frac{-6K_{t0}^2}{n^3 + n^2}\right] \quad (10)$$

4. Analysis on characteristics of temperature change within the year

Through analyzing secular of Guyuan City monthly average temperature, the results show that, the temperature distribution of Guyuan City during the year shows a significant regularity. The lowest temperature appeared in January, and it is minus 7.99 ℃, then the temperature rise from month by month, reaching the peak in July, 19.54 ℃. Then the temperature gradually gets lower. Until December the temperature drops to nearly minus 5.99 ℃. Temperature changing with time curve is single-peak type (Figure 2).

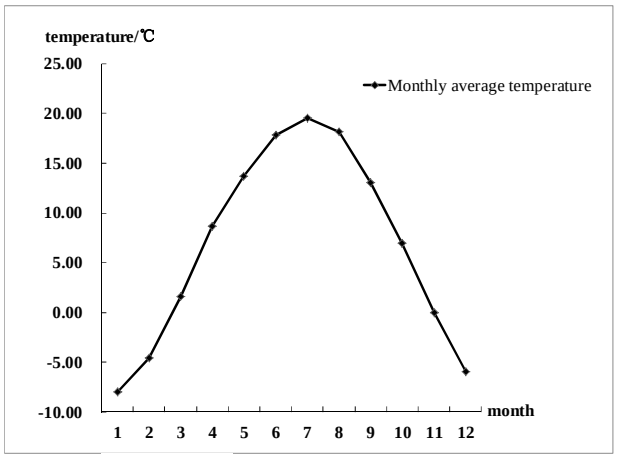

Figure 2: Secular monthly average temperature change curve

5. The features of inter annual temperature

5.1 Analysis on the characteristics of yearly temperature time series in Guyuan city

According to the linear fitting results, Guyuan City average temperature for many years is a rising trend, which increase by an average rate of 0.3071 ℃ / 10a (Figure 3). Annual average

temperature is slowly increasing, and the temperature increasing trend can be represented with the linear equation y = 0.03071x +57.572.

Table 1 shows the Mann-Kendall test results of Guyuan city average temperature, highest temperature, and lowest temperature for many years. As can be seen, the annual average temperature, highest temperature, lowest temperature showed a rising trend. But there are significant differences in confidence level and trend coefficient. Change trend of annual lowest temperature is the most obvious, and the changing rate is 0.60 ℃ /10a. The change trend of annual average temperature is followed, and the annual highest temperature change trend is the most indistinctive. Mann-Kendall analysis results show that: the annual average temperature increased, and it is in accordance with linear fitting analysis result.

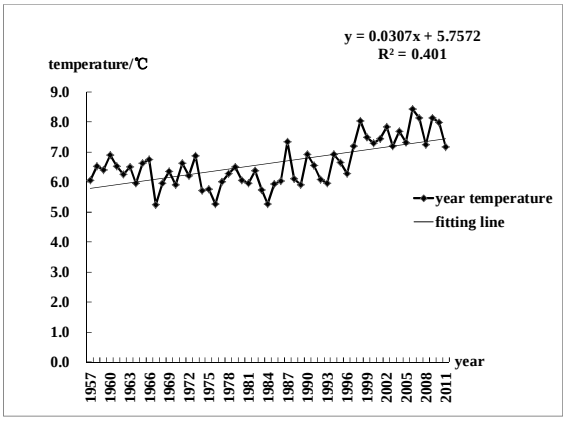

Figure 3: The average temperature changes of Guyuan city for many years

Table 1: Mann-Kendall test results of annual temperature variation in Guyuan City

Time Series	*Z Statistic Value*	*Trend Coefficient Q (℃/10a)*
Average Temperature	4.27	0.55
Maximum Temperature	1.54	0.1
Minimum Temperature	2.32	0.6

Figure 4 shows the Pettitt jump test results of temperature series in Guyuan city. Form Figure 4 it can be known that the annual lowest temperature changed the year of the earliest, nearly 1984, and the highest temperature changed nearly the year of 1993. But both of confidence levels were low. Mutation of annual average temperature occurred in 1993 with a higher confidence level. Therefore, changes in annual average temperature mainly occurred after the year of 1993.

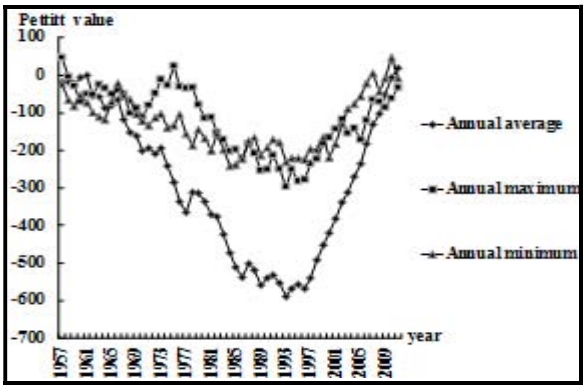

Figure 4: Pettitt jump test results of annual temperature sequence in Guyuan City

5.2 Trend analysis on time series of seasons temperature

Besides the trend of annual temperature change, change trend of temperature with the seasons is more important. Master the temperature change with seasons can provide a basis of decisions for agriculture, economic and so on.

Mann-Kendall trend test and Pettitt jump test show that the changes of temperature in each season were different. This study analyze four seasons, spring is from March to May; the summer is from June to August; the autumn is from September to November; the winter is from December to February. According to the analysis results (Table 2), the temperature in different seasons has shown a significant upward trend, but the confidence level and trend coefficient are different. Winter change trend is maximum 0.67 ℃ / 10a, and then is spring and autumn, and summer is minimum.

Table 2: MK test results of seasonal temperatures changes in Guyuan City

Time Series	*Z Statastic Value*	*Trend Coefficient Q (℃/10a)*
Spring	3.27	0.5
Summer	3.41	0.37
Autumn	4.25	0.53
Winter	3.59	0.67

The Pettitt jump test results of temperature changes with seasons in Guyuan city can be seen in Figure 5. The figure shows that change of temperature in winter is the earliest, nearly 1985, but the confidence level is not high. Changes occurred in spring and summer are similar, respectively in 1993 and 1995, and confidence level is basically same. The abrupt change year of autumn is in 1986, and the confidence level is highest. In general, all changes occurred after the 1980s.

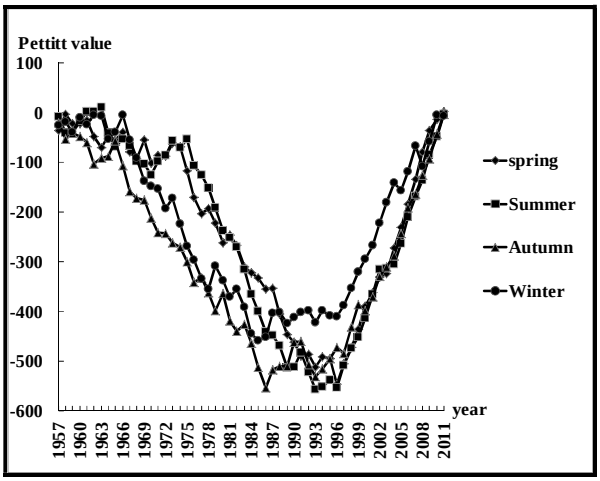

Figure 5: Pettitt jump test results of seasonal temperatures changes in Guyuan City

5. The inter decadal variation of temperature

Guyuan City temperature inter decadal changes show a certain characteristics. The analyze results of inter decadal temperature changes with polynomial fitting were shown in Figure 6. The figure shows: temperature change from the 1960s to the 1980s was a smooth process, and the temperature changed little. The temperature began to rise after the 1980s, into the 21st century it was a significant upward trend in temperature. This is also in accordance with Pettitt jump test results. Guyuan City's temperature changes can be characterized by the following polynomial: y=-0.0253x4+0.3594x3-1.4524x2+2.0326x+5.3932

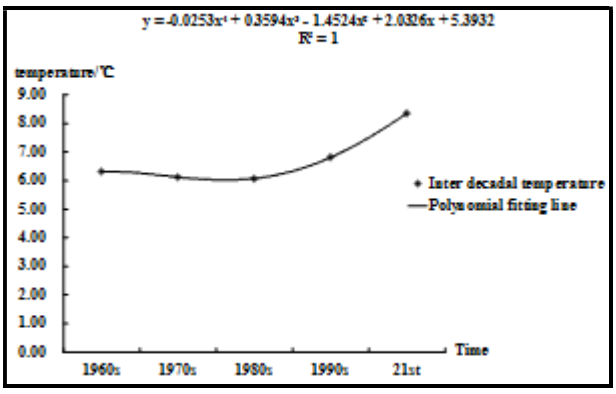

Figure 6: Inter-decadal temperature change in Guyuan City

6. Conclusion

In this study, Guyuan temperature variation within the year, inter annual variation, seasonal variation and inter decadal variability were analyzed with means of regression analysis, trend analysis, Mann-Kendall test, Pettitt jump test and other statistical methods. The results show that:

(1) Through analysis the monthly average temperature of Guyuan city, Guyuan temperature variation within the year show a clear rules. Lowest temperature appeared in January, 7.99 ℃, then the temperature increase month by month, reaching to peak in July, 19.54 ℃, then the temperature reduced month by month. Temperature changing with time curve is the single-peak type.

(2) Linear regression analysis shows that the average annual temperature of Guyuan city show a upward trend, and the rising rate is 0.3071 ℃/10a.

(3) Through the Mann-Kendall test analysis in Guyuan City, the annual average temperature, annual highest temperature and lowest temperature showed an increasing trend. The annual lowest temperature increases most obviously, and the change rate is 0.60 ℃/10a, then it is the annual average temperature, and the annual highest temperature increase most indistinctively. This is consistent with the linear regression analysis on results. At the same time, through the analysis of temperature series of Guyuan in different seasons, the temperature in different seasons also show an increasing trend, and the largest increase of temperature in winter is 0.67 ℃/10a, then they are autumn and spring, and the summer is minimum.

(4) From the Pettitt jump test analysis results, Guyuan City in lowest temperature change earliest, probably in 1984 or thereabouts, while the highest temperature and the annual average temperature change are in similar time, and both are in 1993. At the same time, Pettitt jump test results of different seasons showed that mutations in the winter is the earliest, in 1985, then they are the autumn, spring and summer.

(5)With multivariate regression analysis, inter decadal temperature trend showed that the temperature before 1980s maintained a steady state. After1980s, the temperature began to rise. Into the 21st, the temperature increasing trend is more significant, which is consistent with Pettitt jump test results.

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