Periodicity Variation Analysis and Trend Prediction of Temperature in Yaoba Oasis

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Abstract. In order to study the periodicity variation and trend prediction of temperature in Yaoba Oasis, based on the temperature data from 1955 to 2012 of Barunbieli weather station, linear trend method, Mann-Kendall test and wavelet analysis were used to analyze the trend, mutation point and periodicity. The results showed that the temperature had a significantly warming trend nearly 60 years in Yaoba Oasis while there was one mutation point at 1986. The temperature had short periodicities of 4 and 9 years, so it would increase from 2016 to 2020 that it was closely related to the background of the global climate warming trend. This paper not only provided a scientific basis of the future short-term temperature change for Yaoba Oasis but also provided a theoretical reference for the local agricultural production.

1.General instructions

Yaoba Oasis is located in Alxa Left Banner of Inner Mongolia Autonomous Region that it is the largest and earliest oasis. The climate problem has always been a common and serious problem Yaoba Oasis facing to. The periodicity characteristics of the temperature series and the development trend in the future can be roughly inferred from the climate of the rich and dry alternating regular pattern, this analysis for the local production and life has an important guiding significance. The temperature change is a non-stationary stochastic hydrological phenomenon and the series has many characteristics such as trend and periodicity[1]. Tao Jianhong et al[2] analyzed the temperature data nearly 40 years of 114 meteorological stations in the northwest of China by using wavelet method. The results showed that the temperature in the northwest of China generally increased except Shaanxi. You Li et al[3] obtained that there was a significantly increasing temperature and the mutation occurred in 1986 by analyzing the temperature data nearly 46 years of 70 weather stations in Inner Mongolia using mutation test. Yan Jun et al[4] analyzed the characteristics of temperature change nearly 53 years in Alxa League, they found that the trend of temperature in this area was +0.393mm/10 years and the mutation time was between 1987 to 1988.

Previous studies had focused on the basic characteristic analysis of the local temperature data but rarely studied its periodicity and trend. Therefore, based on the temperature data from 1955 to 2012 of Barunbieli Weather Station in Yaoba Oasis, linear trend method, Mann-Kendall test and wavelet analysis were used to analyze the mutation point, periodic evolution process and trend. It not only provided a scientific basis of the future short-term temperature change for Yaoba Oasis but also provided a theoretical reference for the local agricultural production.

2.Data sources and research methods

2.1 Data sources

Yaoba Oasis is located in the west of Helan Mountain bordering the Tengger Desert on the west side, covering an area of 81.2km^2 and belonging to Barunbieli Town of Alxa Left Banner. The climate is characterized by: winter cold and summer hot, little rain and more drought. In this paper, according to the complete daily meteorological data from 1955 to 2012 of Barunbieli Weather Station (E:105° 36'12.12"; N:38°30'25.74"; elevation:1295m) in Yaoba Oasis, the average annual precipitation is 198.0mm while the average annual evaporation is 2394mm and the average annual temperature is 8.21℃, so it belongs to the typical arid climate.

2.2 Research methods

2.2.1 Mann-Kendall test

Non-parametric Mann-Kendall test method usually were used to test the mutation year and the long-term trend of the temperature[5]. The test statistic S_k:

$$S_k = \sum_{i=1}^{k}\sum_{j}^{i-1}\alpha_{ij} \quad (k=1,2,\ldots,n;1\le j\le i) \tag{1}$$

$$\alpha_{ij} = \begin{cases} 1 & X_i > X_j \\ 0 & X_i < X_j \end{cases} \quad 1\le j\le i \tag{2}$$

Where, X_1, …, X_j=the time series.

Define statistical variables UF and UB：

$$UF = \frac{[S_k - E(S_k)]}{\sqrt{V_{\alpha r}(S_k)}} \quad (k=1,2,\ldots,n) \tag{3}$$

$$E(S_k) = k(k+1)/4 \tag{4}$$

$$V_{\alpha r} = k(k-1)(2k+5)/72 \tag{5}$$

$$\begin{cases} UB = -UF \\ k = n+1-k \end{cases} \quad (k=1,2,\ldots,n) \tag{6}$$

Setting up the significance level, if UF exceeds the critical line，then the time series has a significant trend. Using two curves of UF and UB can test the mutation year and trend of the temperature.

2.2.2 Wavelet analysis

Wavelet analysis had been widely used in testing temperature series in recent years[6]. In this paper, the Morlet wavelet transform was used to analyze the periodic evolution process of temperature. The discrete wavelet coefficient is：

$$W_f(a,b) = |a|^{-1/2}\Delta t\sum_{k-1}^{N} f(k\Delta t)\overline{\psi}\left(\frac{k\Delta t - b}{a}\right) \tag{7}$$

Where, a=the scale factor; b=for the time factor.

The wavelet variance function is the time integral of the square of the wavelet coefficients[7]. Wavelet variance can reflect the main periodicity and different oscillation time scales of the temperature. Discrete wavelet variance function is:

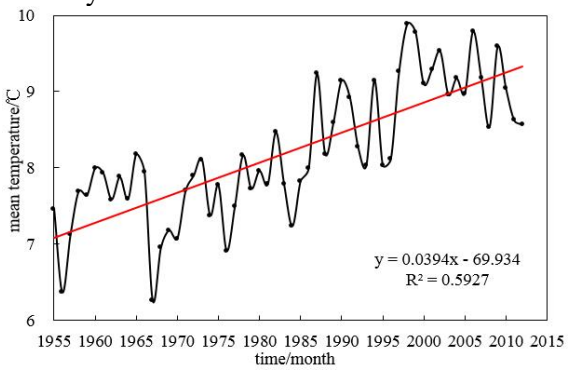
$$Var(a) = \int_{-\infty}^{\infty}\left|W_f(a,b)\right|^2 db \tag{8}$$

3.Results and analysis

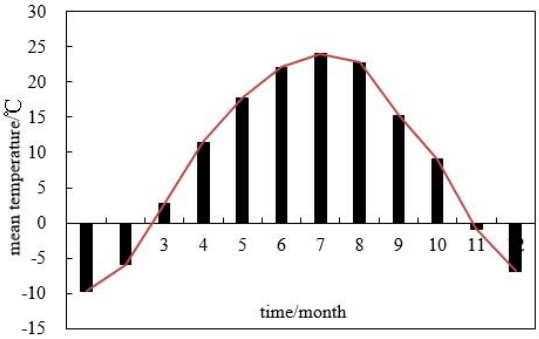
3.1 Linear trend analysis of temperature

According to the meteorological data from 1955 to 2012 of Barunbieli weather station[8], the average annual temperature was 8.21℃ while the lowest annual temperature was -31.4℃ in 1955 and the highest temperature was 38.4℃ in 2010. From figure 1(a), the temperature trend equation was y=0.0394x-69.934 and the tendency rate was +0.394mm/10years. In the past 60 years, the temperature had undulating increasing tendency and the average temperature increased about 1.11℃ in Yaoba Oasis.

By statistical analysis of monthly average temperature data from 1955 to 2012, the result showed below in figure 1(b). Yaoba Oasis had four distinct seasons. The average spring temperature was 10.63℃ from March to May, the average summer temperature was 22.95℃ from June to August, the average autumn temperature was 7.83℃ from September to November and the average winter temperature was -7.49℃ from December to February. The highest average temperature was in July and the lowest average temperature was in January.



(a) Curves of average annual temperature from 1955 to 2012



(b) Curves of monthly average temperature from 1955 to 2012

Figure 1. Curves of average annual temperature and monthly average temperature from 1955 to 2012 in Yaoba Oasis

3.2 Mann-Kendall test of temperature

Mann-Kendall test was used to check the temperature series from 1955 to 2012 of Yaoba Oasis by using 0.05 significance level. It can be seen from figure 2 that there was a node between curve UF and UB, so the mutation occurred in 1986. The curve UF was more than 0 but not exceed the critical line, so the temperature increased non-significantly before 1989. The curve UF exceeding the critical line after 1990 indicated that the temperature significantly increased in Yaoba Oasis.

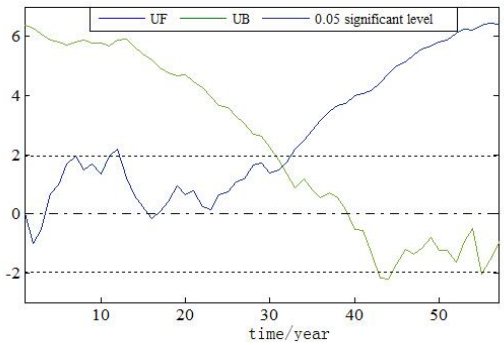


Figure 2. Curves of Mann-Kendall test of temperature

3.3 Periodic evolution process of temperature

The wavelet coefficient contour of temperature was shown in figure 3. As known from this table, there were three time scales of 17 to 30, 7 to 15 and 2 to 6 years of periodic evolution. It appeared one non-global alternation of rich and dry in 17 to 30 time scale. The periodicity was chaotic before 1985 and the performance was more stable after 1985. The temperature decreased between1985 to 1995 and the oscillation center was 1990. The temperature increased between 2000 and 2010 and the oscillation center was 2005. It appeared six global alternation of rich and dry in 7 to 15 time scale. The negative phase contour was not completely closed after 2012, so the temperature would be continuously increasing in the next few years in this scale. There were fourteen global alternation of rich and dry in 2 to 6 time scale. The periodicity was chaotic before 1975 and the performance was more stable after 1975.

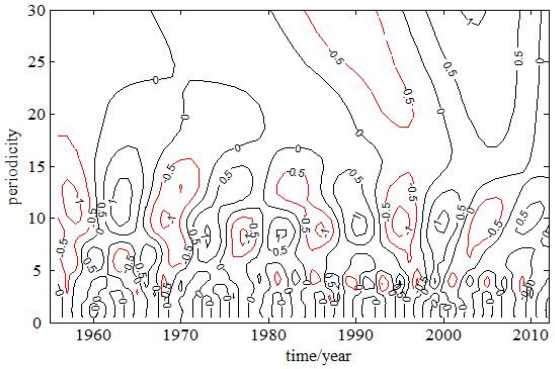


Figure 3. Wavelet coefficients of temperature

It can be seen from figure 4 that 9 years was the first main periodicity of the temperature series and the second main periodicity was 4 years while the oscillation intensity of the first main periodicity was much stronger than that of the second main periodicity. Two main periodicities controlled variation characteristics of the temperature from 1954 to 2012 in Yaoba Oasis.

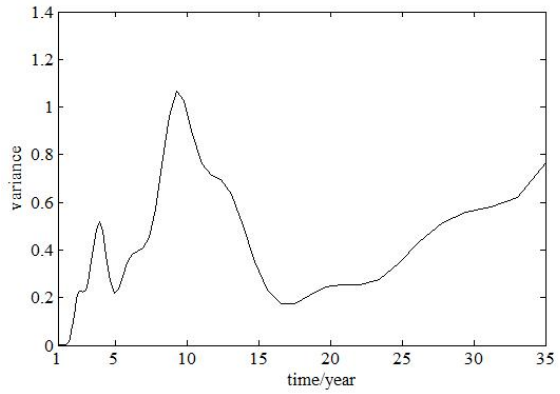


Figure 4. Wavelet variance spectrum of temperature

The first and second principal trends of the temperature series were plotted by wavelet variance test. From figure 5, it was shown that the temperature had experienced 6 alternation in the first main periodicity, so it was predicted that Yaoba Oasis would be in the temperature warming period from 2016 to 2020. The temperature had experienced 14 alternation in the second main periodicity, the temperature was predicted to be in increasing period from 2017 to 2018 and in decreasing period from 2019 to 2020. The oscillation intensity of the first main periodicity was much stronger than that of the second main periodicity, so Yaoba Oasis was more likely in the temperature warming period from 2016 to 2020.

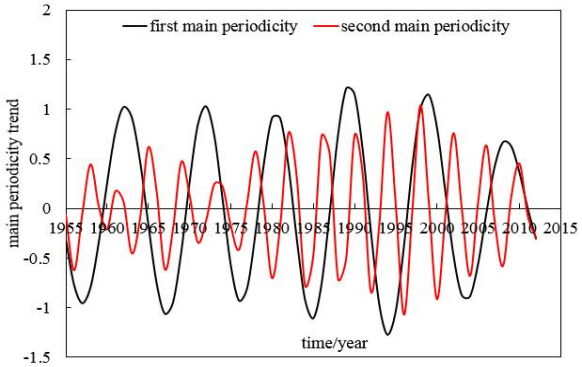


Figure 5. The main periodicity trend of temperature

4.Conclusions

1. In the past 60 years, the average annual temperature was 8.21 ℃and increased about 1.11℃.The temperature had a undulating increasing trend and the tendency rate was +0.394mm/10years in Yaoba Oasis.

2. The temperature had significantly increasing trend nearly 60 years in Yaoba Oasis while there was one mutation point at 1986.

3. The temperature had short periodicities of 4 and 9 years, it would increase from 2016 to 2020 that it was closely related to the background of the global climate warming trend. The shortcoming of this paper was that it could only predict the future short-term trend not predict long-term climate change by using wavelet analysis as a qualitative point of view.

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