# Annual Precipitation Series Multiple Time Scale Analysis of Major Grain Production Regions in Sanjiang Plain

**Hong Ding [1], Liguo Jiao [2], [*]Dong Liu [1,3,]**

[1]School of Water Conservancy & Civil Engineering, Northeast Agricultural University, Harbin, 150030,China
[2]Flood Control engineering in daqing area office, Daqing Heilongjiang ,163000, China
[3]Postdoctoral Student Work Station of Agriculture and Forestry Economic Management, Northeast Agricultural University, Harbin Heilongjiang 150030, China
*Correspondence author: Email: dinghong428@126.com, liu72dong@126.com

**Abstract:** In order to research the drought phenomenon of Sanjiang Plain that has appeared in the unconventional drought region frequently in recent years, the authors took the annual average precipitation of Hongxinglong Branch Bureau and its ten farms as the basic data, analyzed the multi-time scales variation characteristics with the application of a complex Morlet wavelet. The alternate variation process of drought and flood are also shown in the different time scales. The results showed annual average precipitation series had two main periods which were 3 years and 11 years; the changes of the two main periods played a major role in variant characteristics of annual average precipitation; and the major variant trend of the annual average precipitation has been in the low flow since 2008.

[World Rural Observations 2009;1(1):63-67]. ISSN: 1944-6543 (print); ISSN: 1944-6551 (online).

**Key words**: Sanjiang Plain; precipitation series; wavelet transformation; multi-time scales analysis

## 1. Introduction

Sanjiang Plain lies in the northeast of Heilongjiang province, which is surrounded by Heilong river, Xingkai lake, Wusuli river and Xiaoxinganling region, and contains 21 cities (countries) such as Jiamusi and 50 state farms in administrative region. This site has a temperate humid, semi humid continental monsoon climate. The distribution of precipitation is odds in a year, in which approximately 75%～85% takes place from June to October. Even though the water conservancy facilities were improved constantly since the 1990s, the occurrence of flood and drought had an increasing tendency, especially drought, even in the wet year. Sanjiang Plain, as one of nine major commodity grain production regions in China, plays a decisive role in the food security. Therefore, in order to ensure the sustainable agriculture development, it is important to research the drought of this site.

It has been known for some time that there are some relationships between precipitation and drought. Conventional analysis methods were mainly functional analysis, Fourier analysis, numerical analysis and so on. However, these methods had some disadvantages including single-level time scale, lock of localized character and precision in multi-time scale analysis of precipitation. Therefore, wavelet analysis method is introduced and applied in this research to analyses drought occurring characteristics and regularity of Sanjiang Plain. The study can provide a new theoretical basis for exploring drought complexity deeply, forecasting the future drought quantitatively and revealing the drought occurring regularity and mechanism in a fully new angle, and also provide a reference for drought prediction scientific.

## 2. Study Method

### 2.1 Wavelet Function

The core of wavelet analysis is wavelet transform that determines the localized variation between time and frequency domain. It is in complete contrast to the Fourier analysis that can solve many difficult issues. Because of better localization properties in both time and frequency domain, the Morlet wavelet is chosen for analyzing the multiple time scale of precipitation series and is defined as:

$$\phi(t) = e^{ict} e^{-t^2/2} \quad (1)$$

Where $c$ is the constant, $i$ is the imaginary number.

Morlet wavelet is a single frequency complex sine modulation Gaussian wavelet, and is a common complex wavelet. There is a one-to-one correspondence between scale factor $a$ of Morlet wavelet and cycle of

Fourier transform, that is $T=[4\pi/(c+\sqrt{2+c^2})]\cdot a$ . And there is an expression as $T=1.00057a\approx a$ when the constant $c$ is 6.2. Therefore, Morlet wavelet can be applied to cycle analysis [2].

Because the precipitation series has a discrete features in practical applications, it is necessary to disperse factors to $f(k\Delta t)$ . In this research, the discrete form of wavelet transform is chosen as the analysis method and its function expression as follows [3]:

$$W_f(a,b)=|a|^{-\frac{1}{2}}\Delta t\sum_{k=1}^{n}f(k\Delta t)\bar{\phi}(\frac{k\Delta t-b}{a}) \qquad (2)$$

Where $W_f(a,b)$ is the wavelet transform coefficient, $a$ is scale factor reflecting the length of wavelet cycle, $b$ is the time factor reflecting the translation in the time domain, $f(k\Delta t)$ is the precipitation anomaly ( $k=1,2,\Lambda,n$ , $\Delta t$ is the time interval of samples).

Two-dimensional contour map is plotted based on the wavelet transform coefficients $W_f(a,b)$ changes with the time parameter $a$ and $b$ , in which the abscissa is $a$ and ordinate is $b$ .The wavelet map represents the change wavelet features of precipitation series.

### 2.2 Wavelet Variance

The wavelet variance is obtained by integrating all the square of wavelet coefficients that belong to different scales after demeaning the precipitation series, which is expressed as follows [4~6]:

$$Var(a)=\int_{-\infty}^{+\infty}|W_f(a,b)|^2\,\mathrm{d}b \qquad (3)$$

The change process of wavelet variance following with the scale $a$ is called wavelet variance change chart, in which reflects the fluctuations and strength variation characters of various scales (cycles) of the hydrological time series. Therefore, the main time scale (cycle) of one time series is obtained easily from this map.

## 3. Case Study

### 3.1 Data sources and anomaly analysis

In this research, the annual precipitation within the period 1971-2008 at the Hongxinglong branch bureau and its ten farms (853、852、597、291、youyi、raohe、shuangyashan、jiangchuan、beixing and hongqiling) will be applied for wavelet analysis as the basic data, which is from Hongxinglong meteorological observatory. It is necessary to demean (centralize) the annual average precipitation of 11 stations. And the anomaly variation of the annual average precipitation is shown in Fig.1.

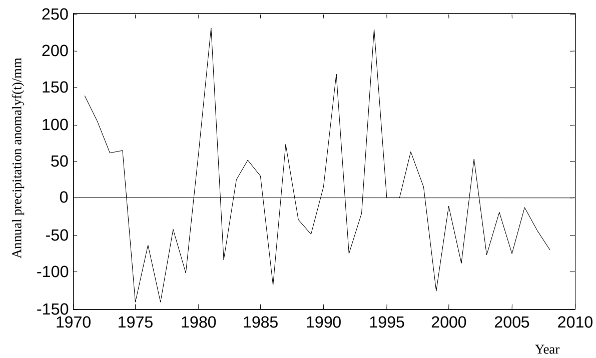


Fig.1 The anomaly variation curve of annual average precipitation in Hongxinglong branch bureau and its ten farms from 1971 to 2008

### 3.2 Time-frequency analysis of annual average precipitation anomaly series

The wavelet transform coefficients modulus square distribution (fig.2) and real part time-frequency distribution map (fig.3) of annual average precipitation anomaly series is plotted to analyze the time-frequency variation based on above methods.

#### 3.2.1 Time-frequency analysis of wavelet transform coefficients modulus square

From Fig.2, the strength of signal energy distribution in various time scales can be seen clearly, in which the greater the gray scale, the smaller the signal energy, and vice versa. There are 9 energy gathering centers of annual average precipitation in fluctuation energy curved surface of wave variation domain, which represents the energy variation features. However, 2 energy gathering centers are obtained from the magnitude of modulus square peak value. They are A (11, 1997) and B (3, 1993).

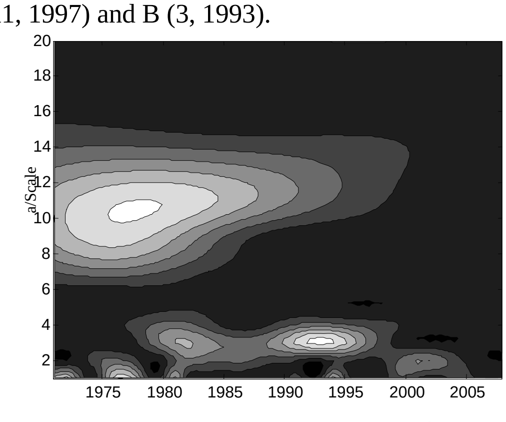


Fig.2 The wavelet transform coefficients modulus square distribution map of annual average precipitation anomaly series of Hongxinglong branch bureau and its ten farms

On center A, the greater fluctuation energy of annual average precipitation in fluctuation variation domain run through the most part of time domain, which the effect range is about 1975-1979. There is a gentle fluctuation energy gradient variation except the spectrum, which effect scale spectrum is about 6-15 years, the scale center is about 11years, and the oscillation center is about 1997; On center B, there is also a greater fluctuation energy that the effect spectrum is about 1993-1994. But the greater gradient variation gathering area and periphery are very small, in which the effect scale spectrum is about 2-5 years, the scale center is about 11 years, and the oscillation center is about 1993. Meanwhile, it is faintish that the fluctuation energy of center B affects the period of 1971-1977.And the spectrum affected by a low fluctuation energy that the center is (1, 1976).Therefore, the fluctuation of annual average precipitation affect the most part of time domain on a 3-year scale. The strength of fluctuation changes with various fluctuation centers energy at different times.

The 38 years of annual average precipitation of Hongxinglong branch bureau and its ten farms has a main fluctuation variation that the scale center is about 11 years and the oscillation center is about 1997; The scale center of strength fluctuation variation is about 3 years auxiliary (the oscillation center is about 1993) in the late 1970s. The fluctuation of the two scales (cycles) play an important role in multiple time analysis of annual average precipitation series.

### 3.2.2 Time-frequency analysis of wavelet transform coefficients real part

The Fig.3 shows the variability in time scale, and it represents the droughts-floods alternation features of the annual average precipitation that change with time at different scales, which characterized by wavelet coefficients, and the location of catastrophe point. The time scale of 2-5 years and 6-15 years behave significantly, and the positive-negative phase appears alternate, which the time scale centers are about 3 years and 11 years. In order to further research above features, the hydrograph is plotted that the time scale value $a$ is fixed and the cutting lines is drawn parallel to $b$ axis, which represents the real part of wavelet transform coefficients $W_f(a,b)$ (expressed as $R[W_f(a,b)]$ ) changes with the time shift $b$, as shown in Fig.3.

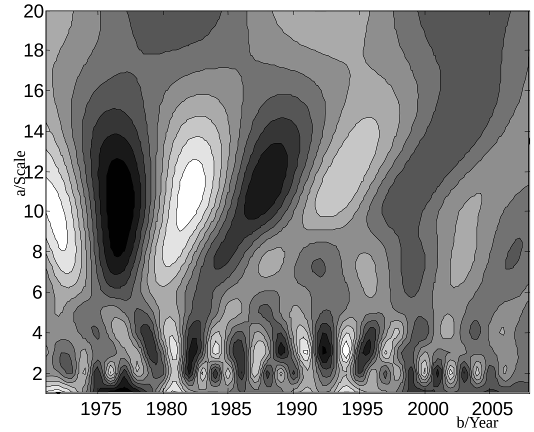


Fig.3 The wavelet transform coefficients real part time-frequency distribution of annual average precipitation anomaly series of Hongxinglong branch bureau and its ten farms

The fluctuation variation of annual average precipitation characterized by wavelet coefficient can be seen from Fig.4. On a 3-year scale, the periods of1971-1972, 1974-1975, 1976-1977, 1980-1982, 1984-1985, 1986-1988, 1990-1991, 1994-1995, 1996-1997, 2000-2001 and 2005-2007 are the high-water periods, while1972-1974, 1975-1976, 1977-1980, 1982-1984, 1985-1986, 1988-1990, 1991-1994, 1995-1996, 1997-2000 and 2007-2008 are the low-water periods since 1970s. And the annual average precipitation would enter into a low-water period after 2008.

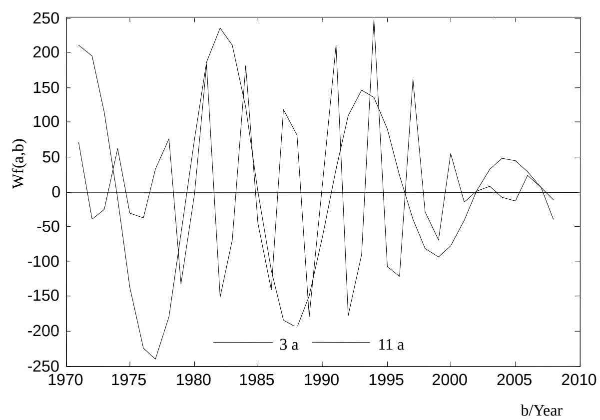


Fig.4 The Morlet wavelet transform real part variation course of annual average precipitation anomaly series with different scales

On an 11-year scale, the periods of 1971-1974, 1980-1985, 1991-1996 and 2003-2007 are the high-water periods, while 1974-1980, 1985-1991, 1996-2003 and 2007-2008 are the low-water periods since 1970s. And the annual average precipitation would enter into a low-water period after 2008.

### 3.3 Main period analysis of annual average precipitation variation

The wavelet variogram is applied in this research to analyses the main period that the time-dependent variation process of annual average precipitation of Hongxinglong branch bureau and its ten farms. The wavelet transform variation of annual average precipitation anomaly series is computed based on formula (3) and is plotted as shown in Fig.5.

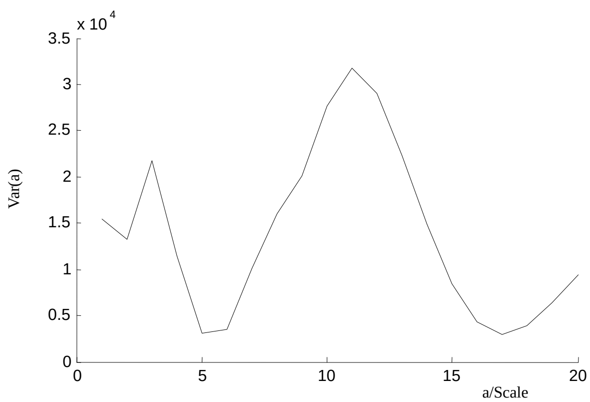


Fig.5 The wavelet variation of annual precipitation anomaly series in Hongxinglong branch bureau and its ten farms

The wavelet variation peak value is significantly obvious within 3-year and 11-year scale from Fig.5. It also shows that the most powerful cycle are 3-year and 11-year scale. As is known, above two scales have an obvious periodic oscillation, and the fluctuation represents the features of annual average precipitation of Hongxinglong branch bureau and its ten farms in the whole time domain.

## 4 Conclusions

Based on the 38 years of annual average precipitation data (1971-2008) from Hongxinglong branch bureau and its ten farms, the multiple time scale analysis have been accomplished using a complex Morlet wavelet. The results showed that:

The annual average precipitation of Hongxinglong branch bureau and its ten farms has an obvious periodic variation on the 3-year and 11-year scale that determines the variation features of annual precipitation in this site.

According to the droughts-floods alternation features analysis of annual average precipitation of Hongxinglong branch bureau and its ten farms within two main periods, the annual average precipitation would enter into a low-water period after 2008. Therefore, it is of great importance to research the drought in Sanjiang Plain.

**Acknowledgement:**

Foundation item: Natural Science Foundation of China (No.30400275), Postdoctoral Science Foundation of China (No.20080440832), Scientific and Technology Foundation of Education Department of Heilongjiang Province (No.11541024) ,Scientific Research Foundation of Northeast Agricultural University, Agricultural Technology Cooperative Construction Sub-project of Northeast Agricultural University and Fangzheng county: Water Saving Irrigation Application Technology and Demonstration of Paddy Field in Fangzheng county.

**Correspondence to:**
Dong Liu, Hong Ding
School of Water Conservancy & Civil Engineering, Northeast Agricultural University,
Harbin, 150030,China
Telephone: 86-451-55191501
Emails: dinghong428@126.com, liu72dong@126.com

## References

[1] Liu Dong, Fu Qiang, Ma Yong-sheng, ect.System analysis and sustainable utilization of water resources in Sanjiang Plain well-irrigation area [M].Water resources and hydropower publishing of China, 2008.

[2] Liu Dong, Fu Qiang. Multi-Time Scales Analysis of Main Flood Season Precipitation Series Based on Wavelet Transform in Area of Well-Irrigation in Sanjiang Plain [J]. Soil and water conservation research, 2008, (6): 43-45.

[3] Wu Dong-jie, Wang Jin-sheng, Teng Yan-guo. Application of wavelet decomposition and wavelet transform method to forecasting of groundwater regime [J]. Journal of hydraulic engineering, 2004(5):39-45.

[4] Wang Wen-sheng,Yuan Peng,Ding Jing. Wavelet analysis and its application to stochastic simulation of daily flow [J]. Journal of hydraulic engineering, 2002,(11):43-48.

[5] Heng Tong, Wang Wen-sheng, Ding Jing. Wavelet cgaracteristics of the change in precipitation time series [J]. Resources and Environment in the Yangtze Basin, 2002, 11(5):466-470.

[6] Anthony T. Cahill determination of changes in streamflow variance by means of a wavelet-based test[J]. Water Resource Research, 2002, 38(6): 1-14.