

# Distribution and Variation Law of Drought and Flood in Multi-scale in Poyang Lake Basin Based on SPI

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**Abstract.** The Poyang lake basin has been affected seriously by drought and flood. The monthly precipitation data from 1951 to 2013 were used to analyze the variation law of drought and flood in Poyang lake basin based on standardized precipitation index in different time scales. Results indicated that the Poyang lake basin is suffered with frequent droughts and floods and the standardized precipitation index is suitable to analyze the law of drought and flood for the Poyang lake basin.

## 1 Introduction

Droughts and waterlog have strong social, economic and environmental impacts. This study focuses on the drought and waterlog over the Poyang lake basin by using the Standardized Precipitation Index (SPI) technique. The SPI (McKee et al. 1993<sup>[1]</sup>; Hayes et al. 1999<sup>[2]</sup>) is widely used to reveal droughts. It has been proven to be a useful and convenient tool just because the computation of SPI value is based on precipitation data only. Wu et al. (2001<sup>[3]</sup>) indicated that the SPI was developed to detect droughts and flood periods at different time scales. Morid et al. (2006<sup>[4]</sup>) showed by a case study that SPI was able to detect the onset of a drought, its spatial and temporal variation consistently. In this case, the SPI method is accepted in this study to analyze drought and waterlog variations.

## 2 Study region and data

Poyang Lake Basin is situated between 28° 24' – 29° 46' N longitude and 115° 49' – 116° 46' E latitude. The total drainage area of the water systems is 16.22×104 km<sup>2</sup>. The basin is located on the south shore of the Yangtze River, in the northern part of Jiangxi Province. Poyang Lake basin has a subtropical flood climate characterized with a mean annual precipitation of 1,680 mm for the period of 1960–2007. Daily precipitation data from 14 rain gauging stations in Poyang lake basin were analyzed, and the data were obtained from the National Climate Center (NCC) of the China Meteorological Administration (CMA). Locations of the meteorological stations are shown in Fig. 1.

Table.1 The details of 14 meteorological stations in Poyang Lake Basin

	Meteorological station	Location		Annual Mean Rainfall ( <i>mm</i> )	Length (year)	Period
		Latitude (E)	Longitude (N)			
1	Boyang	116.41°	29.00°	1613	59	1955~2013
2	Ganxian	115.00°	25.52°	1437	63	1951~2013
3	Guangchang	116.20°	26.51°	1728	60	1954~2013



4	Guixi	117.13°	28.18°	1858	61	1953~2013
5	Jian	114.55°	27.03°	1487	62	1952~2013
6	Jingdezhen	117.12°	29.18°	1786	61	1953~2013
7	Lushan	115.59°	29.35°	1938	59	1954~2013
8	Nanchang	115.55°	28.36°	1604	62	1951~2013
9	Nancheng	116.39°	27.35°	1679	61	1953~2013
10	Shuichuan	114.30°	26.20°	1448	63	1951~2013
11	Xiushui	114.35°	29.02°	1586	61	1953~2013
12	Yichun	114.23°	27.48°	1602	61	1953~2013
13	Yushan	118.15°	28.41°	1828	63	1951~2013
14	Zhangshu	115.33°	28.04°	1642	57	1957~2013

### 3 Methodology

SPI allows an analyst to determine the rarity of a drought at a given time scale of interest for any rainfall station with historic data. The gamma distribution is defined by its frequency or probability density function<sup>[5]</sup>:

$$g(x) = \frac{1}{\beta^\alpha \Gamma(\alpha)} x^{\alpha-1} e^{-x/\beta} \quad (1)$$

$$\Gamma(x) = \int_0^\infty x^{\alpha-1} e^{-x} dx \quad (2)$$

where:  $\alpha > 0$   $\alpha$  is a shape parameter,  $\beta > 0$   $\beta$  is a scale parameter;  $x > 0$   $x$  is the precipitation amount,  $\Gamma(\alpha)$  is the gamma function. The maximum likelihood solutions are used to optimally estimate  $\alpha$  and  $\beta$ :

$$\hat{\alpha} = \frac{1 + \sqrt{1 + 4A/3}}{4A} \quad \hat{\beta} = \frac{\bar{x}}{\alpha} \quad A = \ln \bar{x} - \frac{1}{n} \sum_{i=1}^n \ln \bar{x}_i$$

where:  $n$  = number of precipitation observations. The cumulative probability is given by:

$$G(x) = \int_0^x g(x) dx \quad (3)$$

$$G(x) = \frac{1}{\beta^\alpha \Gamma(\alpha)} \int_0^x x^{\alpha-1} e^{-x/\beta} dx \quad (4)$$

Letting  $t = x / \beta$ , the above equation becomes the incomplete gamma function:

$$G(x) = \frac{1}{\Gamma(\alpha)} \int_0^x t^{\alpha-1} e^{-t} dt \quad (5)$$

Since a precipitation distribution may contain zeros, the cumulative probability becomes:

$$H(x) = q + (1-q)G(x) \quad (6)$$

where  $q$  is the probability of no rainfall on specified time scale. If  $m$  is the number of zeros in a precipitation time series,  $q$  can be estimated by  $m/n$ . The cumulative probability,  $H(x)$ , is then transformed to the standard normal random variable  $Z$  with mean zero, which is the value of the SPI.

$$\text{For } 0 < H(x) \leq 0.5, \text{ Where } t = \sqrt{\ln \left\{ \frac{1}{[H(x)]^2} \right\}}, \text{ then } Z = SPI = - \left( t - \frac{c_0 + c_1 + c_2 t^2}{1 + d_1 t + d_2 t^2 + d_3 t^3} \right) \quad (7)$$

$$\text{For } 0.5 < H(x) < 1, \text{ Where } t = \sqrt{\ln \left\{ \frac{1}{[1 - H(x)]^2} \right\}}, \text{ then } Z = SPI = \left( t - \frac{c_0 + c_1 + c_2 t^2}{1 + d_1 t + d_2 t^2 + d_3 t^3} \right) \quad (8)$$

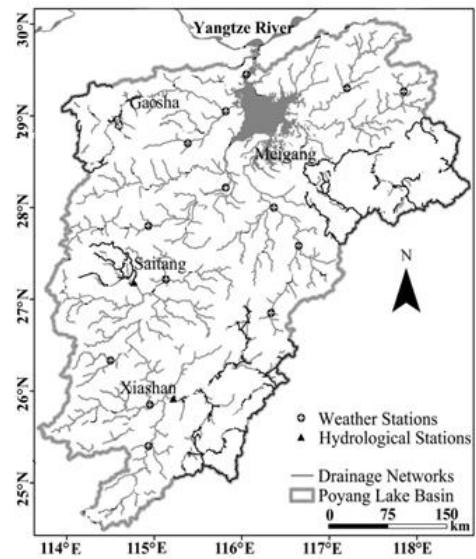


Fig. 1 Location of the study area

Where:  $c_0 = 2.515517$ ,  $c_1 = 0.802853$ ,  $c_2 = 0.010328$ ,

Where:  $d_1 = 1.432788$ ,  $d_2 = 0.189269$ ,  $d_3 = 0.001308$ .

The drought classification<sup>[6]</sup> adopted in this study is defined in Table. 2.

Table. 2 Classification of droughts and floods by SPI

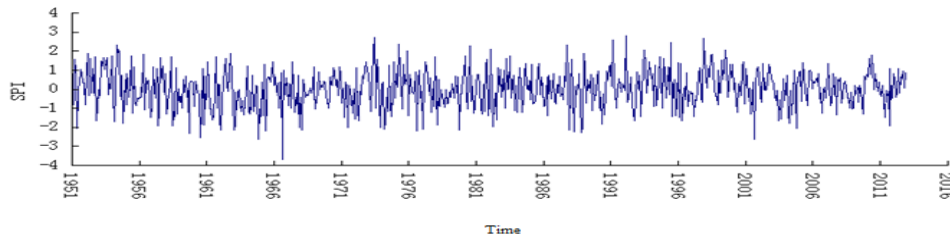
Classification	SPI	Classification	SPI
Extremely drought	$\leq -2.0$	Slightly wet	$[0.5, 1.0)$
Severe drought	$(-2.0, -1.5]$	Moderately wet	$[1.0, 1.5)$
Moderately drought	$(-1.5, -1.0]$	Very wet	$[1.5, 2.0)$
Mild drought	$(-1.0, -0.5]$	Extremely wet	$\geq 2.0$
Near normal	$(-0.5, -0.5)$		

## 4 Results and discussion

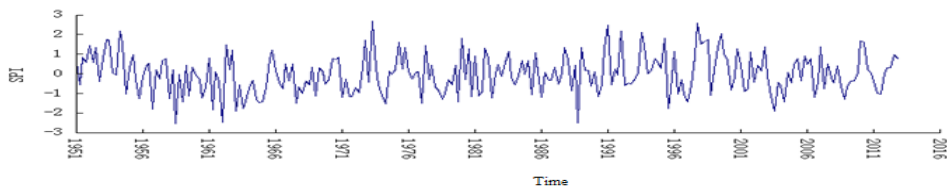
### 4.1 Applicability of SPI method in the study of droughts in the Poyang Lake River Basin

The precipitation data from 14 stations were used to calculate the SPI value of each station. And then the mean SPI value of the basin can be calculated. Therefore, the distribution and variation law of drought and flood can be analyzed by SPI in different time scales (1,3,6,12 months). The SPI evolution in different time scales in Poyang Lake Basin during 1951-2013 is shown in Fig. 2.

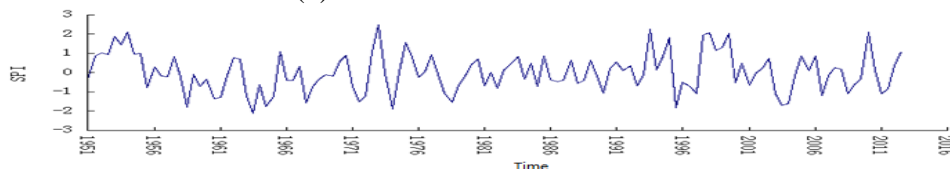
The SPI in short time scales has been affected more by short time precipitation. With the growth of the time scale, SPI value is less affected by rainfall. Waterlog occurred four times, respectively in 1953, 1954, 1998; while heavy flood happened three times, in 1973, 1975 and 2010, respectively. The SPI value which is highest in 1954 reached by 2.12. The most serious drought is in 1963. Overall, the drought and flood appear alternately in the Poyang lake basin with a rising trend.



(a) SPI evolution in 1 month scales



(b) SPI evolution in 3 months scales



(b) SPI evolution in 6 months scales

(c) SPI evolution in 12 months scales

Fig.2 SPI evolution in different time scales in Poyang Lake Basin during 1951-2013

#### 4.2 Change law of drought and flood in multi-scales in Poyang lake basin

Studies have shown that [6]: In season drought analysis, the SPI index in 3 months scale can better represent the agricultural drought conditions. One year can be divided into: January to March for the first quarter, April to June for the second quarter, and so on. The SPI along the temporal variation characteristics of each period can explore the change trend of drought and flood situation along the time sequence.

In Fig. 3, the SPI value within the first season and fourth season is a rising trend, and it is not a significant decline in the second quarter. The trend is not obvious in the third season, but there has an overall rise during 1951-2013. Related studies have shown that [7] the SPI is on a rise trend during nearly 50 years in the Poyang lake basin. The result is consistent with Fig. 3.

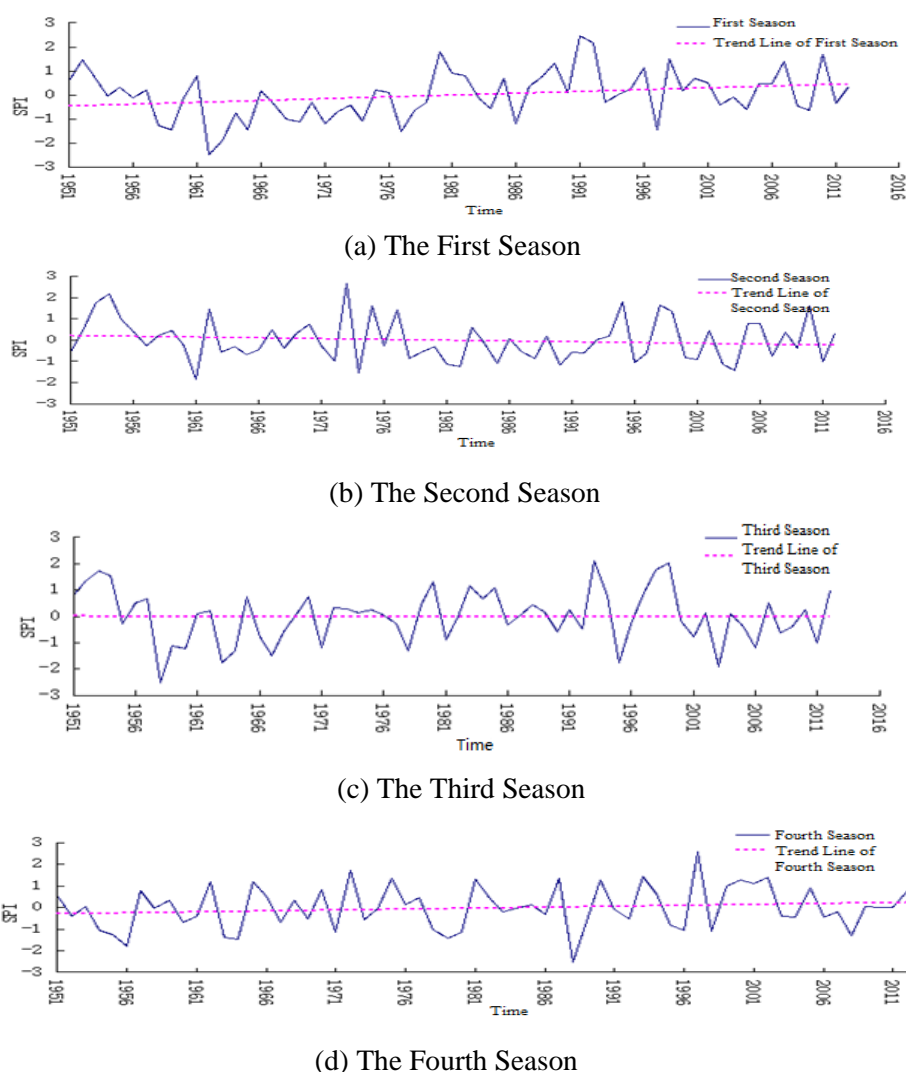


Fig.3 SPI changes in time series in Poyang Lake Basin during 1951-2013

#### 5 Conclusions

The change law of drought and flood in the Poyang lake basin is analyzed based on SPI. Results show that the conversion between drought and flood, with regional change trend. Drought increased from south to north, from east to west within the basin. Flood is intensified from south to north and from the

east to west. The results are consistent with the actual basic, and are similar to some research achievements<sup>[7]</sup>. All these show that the method is practical and effective.

The major objectives of this study are to investigate changing drought and flood properties by SPI. Results indicated that the SPI is suitable to analyze the law of drought and wet for this basin. The generation of drought and flood are inseparable with hydrological factors, therefore, it is the research direction to analysis the relationship between the drought and flood and the hydrological elements for the Poyang lake basin in the future.

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