

# Spatio-temporal Analysis of Precipitation data in the Poyang Lake Basin, China

Liyang Xiao<sup>1\*</sup>

<sup>1</sup>School of Hydraulic and Ecological Engineering, Nanchang Institute of Technology, Nanchang, 330099, Jiangxi, China

**Abstract.** The monthly precipitation data from 14 stations were used to research the precipitation variation in Poyang lake basin during 1957–2012. The Mann–Kendall method was applied to analysis precipitation trends. There are two main periods of 1964~1975 and 1986~1999 with increasing annual precipitations for this basin. There is a highest coefficient of variation of the annual precipitation in the north mountain area of the basin. There are significant increasing trends in annual precipitation for Lushan station and Zhangshu station which located in the north. Six stations in the north had the significant upward trend in summer and eleven stations had the significant upward trend in winter. It can be determined that the Poyang lake basin has become wetter in winter over the period 1957-2012.

## 1 Introduction

Extreme hydrological disaster events such as droughts and floods are very common for the Poyang Lake Basin. It was recorded that droughts occurred mainly in 1963,1978, 1986,2003, 2006, 2007 and 2011, especially more severe during the last decade and floods occurred in 1954,1955,1967,1982,1992, 1995, 1996 and 1998 in this basin. In recent years, frequent occurrences of droughts hit this basin, and the long-term drought influences the water crisis of this basin. Precipitation is an important variable which influences greatly the occurrence of extreme hydrological events. Therefore, fully understanding precipitation characteristics which is the basis of drought and flood analysis is very important.

There have been many studies on precipitation trends (Liu et al., 2008; Tabari et al., 2012). Long-term or short-term precipitation trends (Gemmer et al., 2011; Wu et al.,2017) are often detected by using methods such as the Mann Kendall test and Sen's slope method. Moreover, some papers (Zhang et al., 2015) have been published on precipitation and drought analysis on this basin. However, few studies have focused on both long-term and short-term precipitation analysis for this basin. Thus, it is necessary to have a comprehensive precipitation analysis and variability for the Poyang Lake Basin. In this paper, we aim to look at the spatiotemporal change of the precipitation series. The purpose of this research is to: (1) gain the basis precipitation characteristics at different time scale;

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\* Corresponding author: [liyang-xiao@163.com](mailto:liyang-xiao@163.com)

and (2) gain the trend and variability in precipitation and investigate the extreme precipitation events over the period of 1957 ~ 2012.

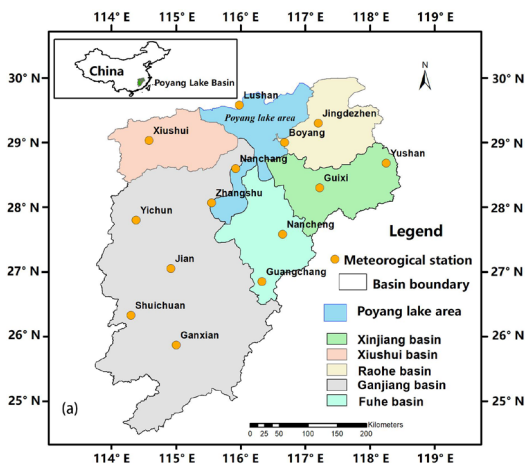
## 2 Study Area and data

The Poyang Lake Basin (Fig. 1) extends from 115° 49'E to 116° 46'E Longitude and 28° 24'N to 29° 46'N latitude with a total drainage area of 16.22×104 km<sup>2</sup>, about 97 % of Jiangxi province (Wang et al. 2012). The climate for this basin is a humid subtropical climate, with 1,680 mm annual mean precipitation during 1960–2007(Liu et al. 2013). The average annual rainfall is 1570 mm in 1951-1984, and it is 1655 mm in 1991-2005. There is an obviously wet and a dry season for annual precipitation. About 54% of annual precipitation is in the wet season, but only 16% is in the dry season.

The precipitation data (monthly) from 14 meteorological stations in the Poyang lake basin (Table.1) are collected over the period from 1957 to 2012. These monthly ground-based meteorological observation data are from the National Climate Center (NCC) (<http://cdc.cma.gov.cn>). All the observation sites are illustrated in Figure 1.

**Table 1.** Information of 14 meteorological stations

Stations	Longitude	Latitude	Altitude	Temperature	Annual Mean Precipitation
	(E)	(N)	(m)	(°C)	(mm)
Boyang	116.68°	29.00°	40.1	17.87	1598
Ganxian	115.00°	25.87°	137.5	19.52	1424
Guangchang	116.33°	26.85°	143.8	18.42	1719
Guixi	117.22°	28.30°	51.2	18.61	1842
Jian	114.92°	27.05°	71.2	18.60	1491
Jingdezhen	117.20°	29.30°	61.5	17.75	1740
Lushan	115.98°	29.58°	1164.5	11.84	1909
Nanchang	115.92°	28.60°	46.9	17.92	1572
Nancheng	116.65°	27.58°	80.8	17.96	1672
Shuichuan	114.30°	26.33°	126.1	18.70	1438
Xiushui	114.58°	29.03°	146.8	16.71	1558
Yichun	114.38°	27.80°	131.3	17.46	1586
Yushan	118.25°	28.68°	116.3	17.67	1787
Zhangshu	115.55°	28.07°	30.4	18.06	1623



**Fig. 1.** Spatial distribution of 14 rainfall stations

## 2 Method

### 2.1 Mann–Kendall test

The Mann-Kendall test (MK test) can detect trends for precipitation series. The test statistic is calculated as:

$$S = \sum_{i=2}^n \sum_{j=1}^{i-1} \text{sgn}(x_i - x_j) \tag{1}$$

where

$$\text{sgn}(x_i - x_j) = \begin{cases} -1 & \text{for}(x_i - x_j) < 0 \\ 0 & \text{for}(x_i - x_j) = 0 \\ 1 & \text{for}(x_i - x_j) > 0 \end{cases}$$

Where  $x_i$  or  $x_j$  means precipitation value at time  $i$  or  $j$ . For  $n \geq 10$ , the statistic  $S$  can be considered as a normal distribution, and its statistic  $Z$  is calculated as:

$$Z = \begin{cases} (S - 1) / \sqrt{n(n-1)(2n+5) / 18} & S > 0 \\ 0 & S = 0 \\ (S + 1) / \sqrt{n(n-1)(2n+5) / 18} & S < 0 \end{cases} \tag{2}$$

When  $|Z| > Z_{\alpha/2}$ , the trend is rejected at the significance level  $\alpha$  of 0.05. If  $|Z| > 1.96$ , this means precipitation trends are significant. When  $Z > 1.96$ , there is a significant rising trend, while when  $Z < -1.96$ , there is a significant downward trend. When  $|Z| < 1.96$ , statistically insignificant trends are detected for precipitation.

## 3 Results and discussion

### 3.1 Characteristics of average annual precipitation for all stations

The average annual precipitation is 1424 ~1909 mm for 14 meteorological stations during 1957~2012(Table 1).The coefficient of variation value ( $C_v$ ) of the average annual precipitation were found highest at Lushan station (which located in the north mountain area of the basin), and the lowest  $C_v$  with the value of 0.17 was at Yichun station (in the west of the basin). Fig. 2 shows the annual precipitation series for 14 meteorological stations.

As Fig. 2 shows that, great variations for the annual precipitation are found during 1957~2012. The maximum precipitation with the value of 2997 mm was found in 1975 at the Lushan station and the minimum precipitation with the value of 766 mm was found in 1971 at Shuichuan station. Stations with annual precipitation over 2500mm are Guixi station (in 1975,1998,2010 and 2012, respectively), Lushan station (in 1975,1990, 1998, 1999,2005 and 2012, respectively), Guanchang station (in 2002), Jingdezhen station (in 1998, 1999 and 2010, respectively).Two main periods of 1964~1975 and 1986~1999 can be also found, during which the annual precipitations are mainly increasing for most of stations.

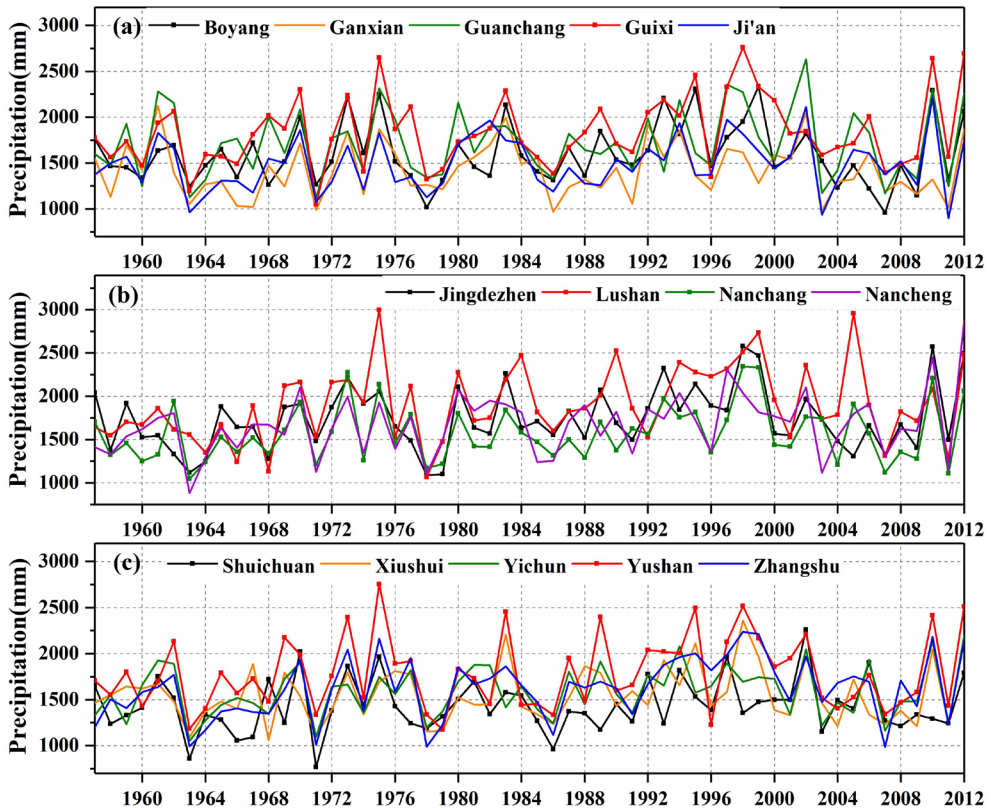


Fig. 2. Annual precipitation series for 14 meteorological stations

### 3.2 Some statistical parameters of monthly precipitation for all stations

Table 2 summarized some statistical characteristics of monthly precipitation series at 14 meteorological stations. The value of average monthly precipitation is 119~159 mm. The station located in the north (Lushan station) had the maximum value of mean monthly precipitation and three stations located in the south (Ganxian, Ji'an and Shuichuan station) had the minimum value. The maximum monthly precipitation for 14 stations is 509~1100 mm. The station in the north (Lushan station) had the maximum monthly precipitation and the Ganxian station which located in the south had the lowest. The maximum  $C_V$  of the monthly precipitation was found at Boyang station and Guangchang at the rate of 87%, while the minimum  $C_V$  with the value of 73% was detected at Shuichuan station and Yichun station located in the west.

Table 3 shows the statistical data of average monthly precipitation for each station over the period 1957–2012. It is evident that the station in the north (Lushan station) had the highest average monthly precipitation from July to November, and the minimum average monthly precipitation is found in February. The station in the north (Guixi station) had also the highest maximum monthly precipitation in January, February, April and June, respectively. On the contrary, the station in the south (Shuichuan station) had the lowest average monthly precipitation in January, from March to May, December, respectively.

Fig 3 shows the temporal distribution of the mean precipitation for each month (averaged by the Thiessen Polygon approach) of this basin. A lot of precipitation is found

in April ~June and less precipitation in October ~January, which is concentrated in spring and summer.

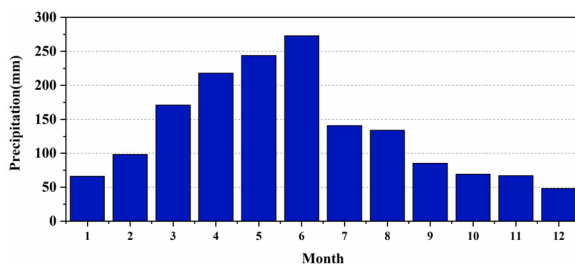
**Table 2.** Characteristics of monthly precipitation for 14 meteorological stations

Stations	Maximum (mm)	Minimum (mm)	Average (mm)	Standard deviation (mm)	Cv
Boyang	874	0	133	115	<b>0.87</b>
Ganxian	<b>509</b>	0	<b>119</b>	<b>93</b>	0.78
Guangchang	815	0	143	125	<b>0.87</b>
Guixi	1025	0	154	129	0.84
Ji'an	574	0	124	98	0.79
Jingdezhen	749	0	145	124	0.86
Lushan	<b>1100</b>	0	<b>159</b>	<b>130</b>	0.81
Nanchang	735	0	131	112	0.86
Nancheng	636	0	139	114	0.82
Shuichuan	519	0	<b>120</b>	88	<b>0.73</b>
Xiushui	629	0	130	106	0.82
Yichun	519	0	132	96	<b>0.73</b>
Yushan	867	0	149	125	0.84
Zhangshu	638	0	135	111	0.82

**Table 3.** Averaged monthly precipitation for each station(mm)

Stations	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Boyang	69	106	173	234	240	277	144	123	<b>62</b>	63	61	47
Ganxian	61	99	169	180	224	<b>202</b>	<b>111</b>	140	80	66	<b>53</b>	41
Guangchang	66	102	196	238	<b>283</b>	316	120	125	83	74	69	48
Guixi	<b>79</b>	<b>111</b>	196	<b>256</b>	276	<b>349</b>	158	134	88	58	77	<b>60</b>
Ji'an	61	91	158	217	228	234	118	122	81	70	67	46
Jingdezhen	72	109	178	240	251	302	195	136	71	71	64	51
Lushan	56	<b>80</b>	143	214	257	291	<b>231</b>	<b>258</b>	<b>149</b>	<b>101</b>	<b>82</b>	47
Nanchang	69	99	164	220	248	296	125	116	68	<b>55</b>	66	47
Nancheng	67	100	187	238	253	306	134	123	84	64	66	52
Shuichuan	<b>54</b>	84	<b>133</b>	<b>167</b>	<b>195</b>	223	121	153	123	86	60	<b>39</b>
Xiushui	62	82	147	212	231	277	165	119	79	69	72	44
Yichun	69	97	168	217	231	239	146	127	81	79	78	54
Yushan	<b>79</b>	110	<b>198</b>	248	272	335	151	<b>107</b>	89	64	75	60
Zhangshu	72	101	174	225	258	286	134	113	75	59	76	51
Max	79	111	198	256	283	349	231	258	149	101	82	60
Min	54	80	133	167	195	202	111	107	62	55	53	39

The maximum of monthly precipitation is italic and in bold; the minimum of monthly precipitation is in bold.

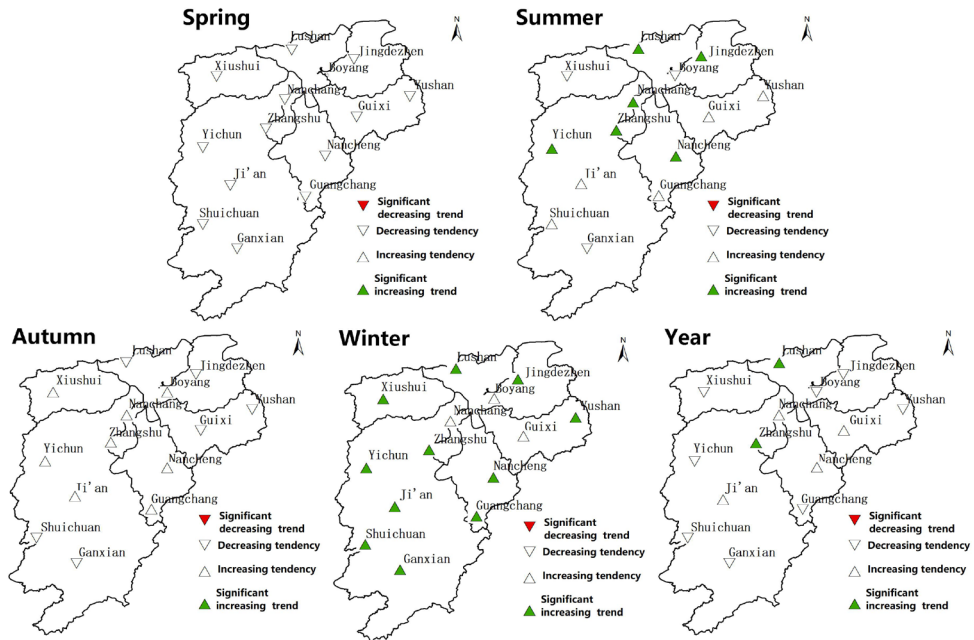


**Fig. 3.** Temporal distribution of the precipitation in a year

### 3.3 Trend analysis of seasonal and annual precipitation for all stations

For four seasons and the whole year, precipitation trend tests are shown in Fig. 5 over the period 1951–2012, where the significance level  $\alpha$  is 0.05. If  $|Z| > 1.96$ , this means the trend of the precipitation series is significant. When  $Z > 1.96$ , it is a significant increase trend (significant wet); when  $Z < -1.96$ , it is a significant decrease trend (significant dry). The value of  $Z$  below the 95% confidence level is defined as wet tendency or dry tendency. Also, Fig. 4 shows the spatial distribution of the results of trend tests ( $Z$ ) for four seasons and a whole year.

There is an upward tendency in winter precipitation and a downward tendency in spring precipitation for most of stations. As shown in Fig. 4, six stations in the north had the significant upward trend in summer and eleven stations had the significant upward trend in winter. No statistically significant trends were found both in spring and autumn. On the annual scale, there are significant upward trends for two stations (Lushan station and Zhangshu station) which located in the north.



**Fig. 4.** Spatial distribution of precipitation trends for four seasons and a whole year

## 4 Conclusions

In this study, the changes of precipitation both in short term and long-term time scale for the Poyang lake basin between 1957 and 2012 were analyzed. The following conclusions may be made:

(1) The annual precipitation decreased from north to south basically for the basin. The stations with annual precipitation often over 2500 mm are Guixi station, Lushan station, Jingdezhen station (in the north). There are two main periods of 1964–1975 and 1986–1999 with increasing annual precipitations for most of the basin. A maximum value of  $C_v$  for annual precipitation is found in the north mountain area of the basin, while the inter-annual precipitation changed slightly in the west area of the basin.

(2) The average monthly precipitation also decreases from north to south. There is a

highest coefficient of variation for monthly precipitation in the north of the basin, while the lowest value in the west of the basin. Monthly precipitation concentrates in April to June and less distributes in October to January.

(3) On the seasonal scale, the precipitation concentrated in spring and summer. Meanwhile, precipitation shows an upward tendency in winter and a downward tendency in spring. In summer, six stations in the north had the significant upward trend; and in winter, eleven stations had the significant upward trend. On the annual scale, significant upward trends in precipitation are found at Lushan station and Zhangshu station which located in the north.

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