# AIR TEMPERATURE AND PRECIPITATION VARIATION TRENDS OF THE LANCANG RIVER UPSTREAM FROM 1957 TO 2011

by

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*Air temperature and precipitation variation trends of the upstream of Lancang river using the time series from 1957 to 2011 are evaluated. The Mann-Kendall method is applied to study the trend and climatic jump of the air temperature and precipitation time series. It shows that the temperature has an obvious uptrend with an increase of 0.023 °C per year. The annual precipitation of the upstream of Lancang river is 954.96 mm without any change, however, the precipitation is gradually increased from upstream to downstream. This paper is significant for understanding the climate change over the years, and it has practical significance for water resources allocation and management in the future.*

Key words: *Mann-Kendall test method, Lancang river, temperature, precipitation, climatic jump points*

## Introduction

The climate change plays a more important role in the water resource management over time [1, 2]. More climate factors can indicate the climate change, for example, temperature, precipitation, wind, solar radiation, and others. However, many studies have proven that the main climate factors for water resources management are temperature and precipitation, which affect the present situation of the hydrologic cycle and spatial-temporal redistribution of water resources [3-6]. The analysis of the spatial and temporal distribution of temperature and precipitation is very significant to understand the climate change, and the climatic jump of the time series is very important to analyze the change of the climate factors. There are already many studies to research the trend of climate factors; however, a few works are to analyze the climatic jump of the time series. The Mann-Kendall test method is widely used in the trends and climatic jump of precipitation and temperature time series [7-10]. The method is effective to calculate and widely used in the time series of climate factors.

Lancang river basin is a sensitive area to climate change. Based on the time series of temperature and precipitation in the Lancang river basin in period 1971-2000 are studied in the previous study [11], but the data is short and old. In order to further analyze the change trend and climatic jump of the temperature and precipitation of the upper reaches of the Lancang river basin using the newest long time series in period 1957-2011, the paper applies the Mann-Kendall test method to study the spatial and temporal distribution of temperature and precipitation.

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## Mann-Kendall test method

The Mann-Kendall test method is first proposed by Kendall [12] and Mann [13] which is widely used in the trends test of precipitation, temperature and runoff. The time series used in the Mann-Kendall test method do not ask for following a certain distribution and some abnormal value will not influence the results of the method. Thus, the Mann-Kendall method is an effective method to analyze the non-normal distribution data, such as hydrology and meteorological data. The detailed steps to analyze the trend and the climatic jump points of the Mann-Kendall test method are described in the paper written by Kendall and Mann [12, 13]

## Application and results

Six meteorological stations in the upstream of Lancang river are selected to analyze the spatial-temporal distribution of temperature and precipitation including the change trends and climatic jump years. They are Deqin, Weixi, Lijiang, Baoshan, Dali, and Jingdong. The data series of temperature and precipitation are from 1957 to 2011 years, total 55 years. The using method is the Mann-Kendall test method. The confidence level is 95%, with the $Z$ is 1.962. If the value of $Z$ calculated by Mann-Kendall test method is greater than the 1.962, the change trend is significant, otherwise is not significant.

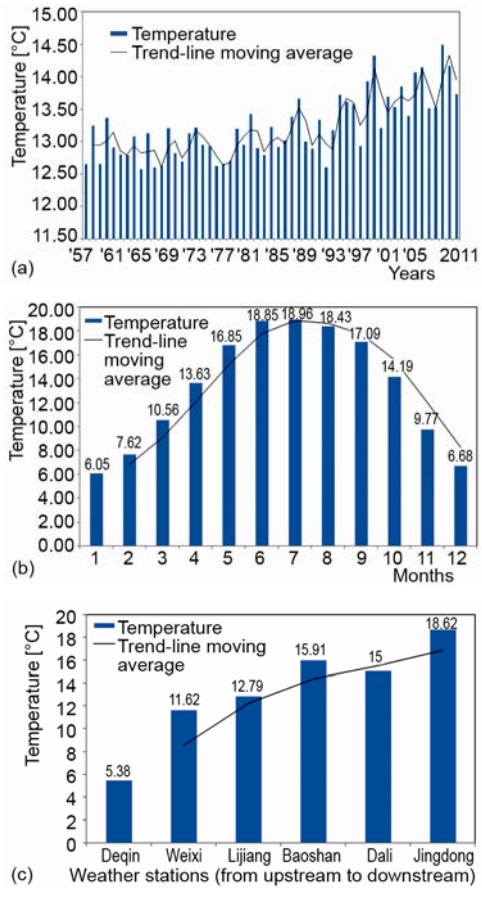


**Figure 1. Temperature variation trends of the upstream of Lancang River from 1957 to 2011; (a) inter-annual variation; (b) intra-annual variation; (c) spatial variation**

### *Trends of temperature*

#### *The temporal and spatial distribution of temperature*

According to the 1957-2011 total 55 years meteorological temperature data, the temperature trends are analyzed as in fig. 1(a). The trend of the temperature is uptrend. From fig. 1(b) we can also see the temperature presents a certain regularity from January to December. From January to July, the temperature is gradually increased and from July to December, it is gradually decreased. The maximum month temperature is 15.8 °C which occurs on July and the minimum month temperature is 6.05 °C which occurs on January. In terms of the spatial change, the temperature also presents a certain regularity. The temperature is gradually increased from upstream to downstream just as in fig. 1(c).

According to the Mann-Kendall test method, the annual temperature of the upstream of Lancang river is 13.22 °C and the Z statistic value is 5.41, which is greater than 1.64 (the $Z$ of the 95% confidence). Thus, the temperature has an obvious change trend and is significant uptrend with 0.023 °C per year increasing rate. In January, $Z$ = 3.56, with 0.0226 °C per year increasing

rate; in February, $Z$ = 3.88, with 0.0361 °C per year increasing rate; in March, $Z$ = 3.09, with 0.0245 °C per year increasing rate; in April, $Z$ = 3.01, with 0.0209 °C per year increasing rate; in May, $Z$ = 2.61, with 0.0154 °C per year increasing rate; in June, $Z$ = 3.85, with 0.0223 °C per year increasing rate; in July, $Z$ = 3.30, with 0.0150 °C per year increasing rate; in August, $Z$ = 4.20, with 0.0200 °C per year increasing rate; in September, $Z$ = 2.45, with 0.0157 °C per year increasing rate; in October, $Z$ = 2.93, with 0.0258 °C per year increasing rate; in November, $Z$ = 2.95, with 0.0211 °C per year increasing rate; in December, $Z$ = 2.67, with 0.0162 °C per year increasing rate. Thus, from January to December, all of the temperature is significantly uptrend.

The temperature of each weather station per month is also analyzed by Mann-Kendall test method. Through calculation, the statistic values of $Z$ of each weather station are given. In Deqin station, $Z$ = 6.89 and the increasing rate is 0.04 °C per year; in Weixi station, $Z$ = 4.38 and the increasing rate is 0.02 °C per year; in Lijiang station, $Z$ = 3.53 and the increasing rate is 0.01 °C per year; in Baoshan station, $Z$ = 4.99 and the increasing rate is 0.02 °C per year; in Dali station, $Z$ = 2.25 and the increasing rate is 0.01 °C per year; in Jingdong station $Z$ = 5.09 and the increasing rate is 0.02 °C per year. Therefore, all of the stations present significantly uptrend, but the increasing rates are different from each other.

### *The climatic jump years of temperature*

The climatic jump years are also studied by Mann-Kendall test method. The climatic jump years of annual average temperature and each month are analyzed. Figure 2 shows the climatic jump years of the annual average temperature from 1957 to 2011 years of upstream Lancang river.

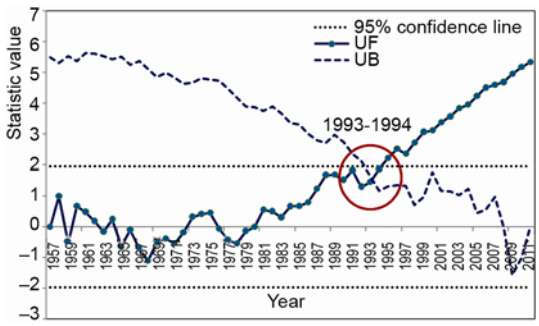


**Figure 2. Climatic jump years of the annual average temperature in period 1957-2011 of upstream Lancang river based on Mann-Kendall test method**

There is only one intersection point (1993-1994) between line UF and line UB as shown on fig. 2. The point is in the 95% confidence lines and the statistic value is bigger than zero, so the intersection point is the climatic jump year. The temperature is significantly increased after the climatic jump year. Besides, the climatic jump years of each month are different from each other. Apart May without obvious climatic jump years, the others have climatic jump years. And most of the months, the climatic jump years occurs on 1990s, except September and December which occur on 2000s. The analysis results are in accordance with the average temperature.

The analysis results of the climatic jump years of each weather station are also analyzed. In terms of most of the weather stations, the climatic jump years appear on 1990s except Dali station which is in accordance with the above results. Form the upstream to downstream, there is no obvious regularity.

## *Trends of precipitation*

The precipitation trends are also analyzed based on the 1957-2011 years weather data, just as shown in fig. 3. Figure 3(a) shows the trend of the precipitation has non-signifi-

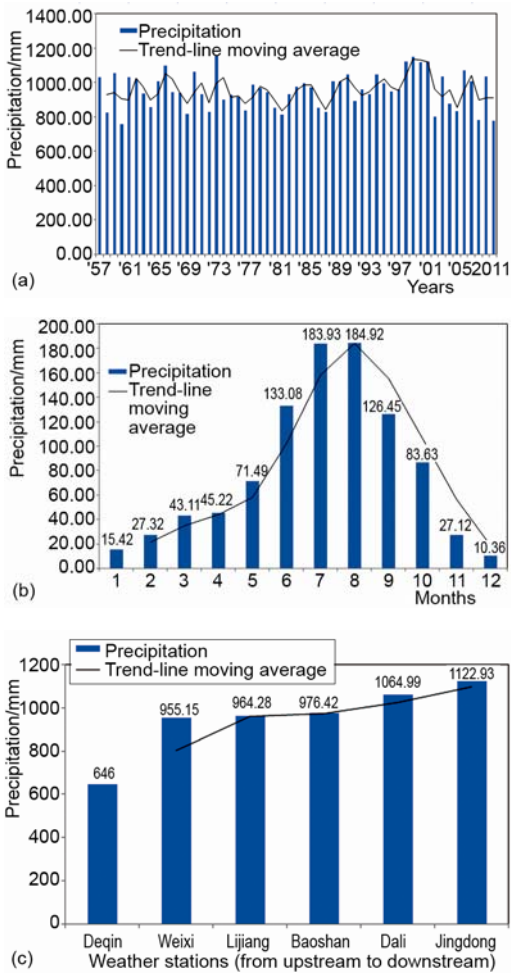


**Figure 3. Precipitation variation trends of the upstream of Lancang river from 1957 to 2011; (a) inter-annual variation; (b) intra-annual variation; (c) spatial variation**

cantly changed. From fig. 3(b) we can see the precipitation also presents a certain regularity from January to December. From January to July, the precipitation is gradually increased and from July to December, it is gradually decreased. The maximum month precipitation is 184.92 mm which occurs in August and the minimum month precipitation is 10.36 mm which occurs in December. Besides, wet-season of Lancang river is from May to October and the precipitation of the phase occupies 82% of the whole year. In terms of the spatial change, the precipitation also presents a certain regularity. The precipitation is gradually increased from upstream to downstream just as shown in fig. 3(c).

The precipitation of each weather station per month is also analyzed by Mann-Kendall test method. The annual precipitation of the upstream of Lancang river is 954.96 mm and the $Z$ statistic value is 0.60, which is less than 1.64 (the $Z$ of the 95% confidence). Thus, the precipitation has non-significantly change trend and is with 0.542 mm per year increasing rate. Most of the weather stations also have non-significant change expect the Jingdong station in April, Lijiang station in May and September and Dali station in June. In the paper, the precipitation trends of each month are also analyzed by Mann-Kendall test method. In January, $Z$ = 0.073, with 0.008 mm per year increasing rate; in February, $Z$ = 0.48, with 0.0857 mm per year decreasing rate; in March, $Z$ = 1.18, with 0.225 mm per year increasing rate; in April, $Z$ = 0.42, with 0.047 mm per year increasing rate; in May, $Z$ = 1.77, with 0.519 mm per year increasing rate; in June, $Z$ = –1.01, with 0.500 mm per year decreasing rate; in July, $Z$ = –0.51, with 0.173 mm per year decreasing rate; in August, $Z$ = –0.89, with 0.315 mm per year increasing rate; in September, $Z$ = 1.16, with 0.407 mm per year increasing rate; in October, $Z$ = –0.64, with 0.189 mm per year increasing rate; in November, $Z$ = 0.74, with 0.109 mm per year increasing rate; in December, $Z$ = –0.65, with 0.03 mm per year decreasing rate. Thus, the precipitation on January, March to June, September and November are non-significant uptrend; the other months are non-significant downtrend.

The precipitation variation trends from 1957 to 2011 of each month and weather station are also evaluated. Through calculation by Mann-Kendall test method, the statistic values of $Z$ of each weather station precipitation are given. In Deqin station, $Z$ = –0.42 and the decreasing rate is 0.67 mm per year; in Weixi station, $Z$ = –0.47 and the decreasing rate is

0.54 mm per year; in Lijiang station, $Z = 0.63$ and the increasing rate is 0.94 mm per year; in Baoshan station, $Z = 0.91$ and the increasing rate is 1.29 mm per year; in Dali station, $Z = -0.52$ and the decreasing rate is 1.39 mm per year; in Jingdong station, $Z = 0.45$ and the increasing rate is 0.81 mm per year. So, some stations present non-significant uptrend and the others are present non-significant downtrend, and the change rates are different from each other. There is no certain regularity from upstream to downstream.

Because of the precipitation in the upstream of Lancang river is non-significantly changed, the climatic jump year is unnecessary to be studied.

## Conclusions

Based on 1957 to 2011 year data, total 55 years, of six weather stations in the upstream of Lancang river basin, the spatial and temporal distribution of temperature and precipitation are analyzed by the Mann-Kendall test method. The main conclusions can be drawn as follows:

- The temperature has an obvious change trend and is significant uptrend with 0.023 °C per year increasing rate. All of the months and weather stations are significantly uptrend. The temperature presents a certain regularity in temporal and spatial. From January to July, the temperature is gradually increased and from July to December, it is gradually decreased. Besides, the temperature is gradually increased from upstream to downstream.
- The climatic jump years of each month and six weather stations are studied by Mann-Kendall test method. Apart May without obvious climatic jump years, the others have climatic jump years. Most of the months, the climatic jump years occurs on 1990s, except September and December which occur on 2000s. The analysis results are in accordance with the average temperature. In terms of most of the weather stations, the climatic jump years appear on 1990s except Dali station which is in accordance with the above results. Form the upstream to downstream, there is no obvious regular.
- The annual precipitation of the upstream of Lancang river is 954.96 mm, and the trend of the precipitation has non-significantly changed. From January to December, precipitation presents a certain regularity. From January to July, the precipitation is gradually increased and from July to December, it is gradually decreased. The precipitation in January, March to June, September, and November are non-significant uptrend; the other months are non-significant downtrend. In terms of the spatial change, the precipitation also presents a certain regularity. The precipitation is gradually increased from upstream to downstream. Besides, some stations present non-significant uptrend and the others present non-significant downtrend, and the change rates are different from each other.

The study of the spatial and temporal distribution of temperature and precipitation of Lancang river basin in period 1957-2011 is significant for understanding the climate change over the years. It has practical significance for water resources allocation and management in the future.

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