Abstract. Based on the daily pan evaporation and air temperature data of 28 meteorological stations in Huaihe River Basin from 1951 to 2015, the variation characteristics of pan evaporation and air temperature series in the same period are analysed, the evolution law of pan evaporation with climate change is discussed, and the existence of evaporation paradox is tested. The results show that: (1) the average annual evaporation changed significantly both in 1978 and 1998, dividing the evaporation series into high value fluctuating period, significant decreasing period and weak rising period. (2) the pan evaporation decreased obviously after the first mutation with air temperature increasing significantly, which indicates that there existed evaporation paradox in the basin from 1978 to 1998, and the spatial distribution of pan evaporation tendency was different obviously, gradually increased from southeast to northwest, from coast to inland, and from humid area to sub-humid area. The change of air temperature tendency was in contrast with evaporation at the same time. (3) after the second mutation, the decreasing trend of pan evaporation was stopped, and increased again insignificantly with the air temperature having a weak downward trend, which indicates that the evaporation paradox in the basin no longer exists after 1998.

1. Introduction
Evaporation is an important factor both in the surface heat balance equation and water balance equation, which is directly affected by land use, climate change and human activities in the water cycle. Different from visible terms such as rainfall and runoff, the physical mechanism of actual evapotranspiration is too complex to be measured accurately by means of instruments. It is often calculated by pan evaporation indirectly. Therefore, it is of great significance to explore the variation of the pan evaporation because it can help people have a deeper understanding of climate change and learn more about the law of water circulation.

In the last century, global warming has become an indisputable fact. The fifth IPCC report [1] pointed out that the global temperature rose by 0.89 °C between 1901 and 2012 and increased by 0.72 °C between 1951 and 2012, 1983-2012 was likely to be the warmest 30 years for the Northern Hemisphere. It was widely believed that global warming would dry up the atmosphere and led to an increase in evaporation in terrestrial waters, but Peterson et al. [2] found the opposite in 1995. The pan evaporation in most parts of the United States and the former Soviet Union began to decline obviously in the 1950s, which led to a hot spot on the "evaporation paradox [3]". Soon, the existence of evaporation paradox has been verified...
in various major basins and regions of China [4-7] (Yangtze River Basin [8], Yellow River Basin [9], Haihe River Basin [10], Three-River Source region [11], Tibetan Plateau [12], Guangdong Province [13], arid region [14-17], etc.).

However, there were a lot of controversies in the scientific community for the global climate change after the strong El Nino event happened during 1997-1998 [18, 19]. Knight et al. [20] first pointed out that global warming had stagnated in 1999-2008, which was called "global warming breaking period [21]". The IPCC's fifth assessment report [1] pointed out that the global surface warming rate was 0.05 °C / 10a from 1998 to 2012, smaller than 0.12 °C / 10a during 1951-2012. A 2013 report by the British Meteorological Bureau [22-24] showed that global temperature had increased by about zero over the past 15 years, or even had a weak downward trend. In this context, the variation of temperature in China has also attracted the attention of Chinese scholars. The research by Fan et al. [25] showed that the total temperature in China had the characteristics of fluctuating and decreasing in this period, but the decreasing trend was not significant.

In view of this, we selects the most representative Huaihe River Basin in our country to study on the spatial and temporal variation of pan evaporation of it under the background of climate change, judge the actual time of interdecadal turning, and analyse the tendency before and after the turning points in order to understand the response of pan evaporation to climate change and better understand the law of water cycle change.

2. Material and methods

2.1. Study area

The Huaihe River Basin is located at 111°55′-121°25′E, 30°55′~36°36′N, with an area of 270,000 km². The west, southwest and northeast of the basin are mountains and hills, accounting for about 1/3 of the total area, and the rest are plains. The regional overview is shown in Figure 1.

The Qinling Mountains-Huaihe River Line [26, 27] is an important geographical boundary (geomorphology, climate, soil) in China. Geographically, China is divided into two regions, north of the dividing line is the warm temperate sub-humid monsoon climate region, and south of it is the subtropical humid monsoon climate area. Therefore, the Huaihe River Basin has obvious characteristics of north-
to-south climate transition, and is a better basin to study the hydrological cycle process and the evolution law of hydrological elements.

2.2. Data
In this paper, the daily pan evaporation and temperature data of 28 meteorological stations with uniform distribution in the Huaihe River Basin are selected. The data are downloaded from the China Meteorological Data Network (http://data.cma.cn/site/index.html), and all of them have been subjected to strict homogenization quality control. The inverse distance weight interpolation (IDW) method is used to interpolate the missing data or to replace the missing data by the average of several days before and after the missing day. The data series are shown in Table 1.

| No. | Station | Longitude E° | Latitude N° | Elevation/m | Period D20 pans | E601 pans | T/° |
|-----|---------|--------------|-------------|-------------|----------------|------------|-----|
| 1   | Yi'yuan | 118.15       | 36.18       | 304.5       | 1958-2001     | 1998-2015  | 1958-2015 |
| 2   | Yanzhou | 116.92       | 35.58       | 51.0        | 1952-2001     | 1998-2015  | 1951-2015 |
| 3   | Feixian | 117.93       | 35.27       | 109.8       | 1959-2001     | 1998-2015  | 1998-2015 |
| 4   | Juxian | 118.87       | 35.60       | 86.4        | 1952-2001     | 1988-2015  | 1951-2015 |
| 5   | Rizhao | 119.53       | 35.38       | 13.8        | 1955-2001     | 1999-2015  | 1955-2015 |
| 6   | Zhengzhou | 113.58     | 34.75       | 80.6        | 1951-2001     | 1985-2015  | 1951-2015 |
| 7   | Xuchang | 113.82       | 34.02       | 68.0        | 1952-2001     | 1998-2015  | 1953-2105 |
| 8   | Kaifeng | 114.33       | 34.83       | 75.0        | 1951-2001     | 1998-2015  | 1951-2015 |
| 9   | Baofeng | 113.05       | 33.88       | 135.1       | 1957-2001     | 1998-2015  | 1957-2015 |
| 10  | Xihua | 114.50       | 33.75       | 51.3        | 1953-2001     | 1999-2015  | 1954-2015 |
| 11  | Zhumadian | 114.05     | 32.97       | 78.8        | 1958-2001     | 1998-2015  | 1958-2015 |
| 12  | Xinyang | 114.08       | 32.17       | 74.0        | 1951-2001     | 1985-2015  | 1951-2015 |
| 13  | Shangqiu | 115.82       | 34.45       | 50.1        | 1953-2001     | 1985-2015  | 1955-2015 |
| 14  | Dangshan | 116.35       | 34.42       | 43.3        | 1954-2001     | 1998-2015  | 1955-2015 |
| 15  | Xuzhou | 117.30       | 34.28       | 43.0        | 1960-2001     | 1984-2015  | 1960-2015 |
| 16  | Ganju | 119.13       | 34.83       | 2.1         | 1957-2001     | 1998-2015  | 1957-2015 |
| 17  | Bozhou | 115.78       | 33.88       | 37.6        | 1953-2001     | 1998-2015  | 1953-2015 |
| 18  | Suxian | 117.05       | 33.65       | 28.0        | 1952-2001     | 1987-2015  | 1953-2015 |
| 19  | Xuyi | 118.62       | 33.05       | 13.4        | 1957-2001     | 1999-2015  | 1957-2015 |
| 20  | Sheyang | 120.25       | 34.08       | 1.6         | 1954-2001     | 1998-2015  | 1954-2015 |
| 21  | Fuyang | 115.83       | 32.93       | 33.3        | 1953-2001     | 1998-2015  | 1954-2015 |
| 22  | Gushi | 115.70       | 32.20       | 40.4        | 1952-2001     | 1998-2015  | 1953-2015 |
| 23  | Shouxian | 116.58      | 32.53       | 23.3        | 1955-2001     | 1993-2015  | 1955-2015 |
| 24  | Bengbu | 117.37       | 32.93       | 20.6        | 1952-2001     | 1998-2015  | 1952-2015 |
| 25  | Gaoyou | 119.50       | 32.75       | 6.4         | 1958-2001     | 1998-2015  | 1954-2015 |
| 26  | Dongtai | 120.32       | 32.85       | 5.8         | 1953-2001     | 1998-2015  | 1953-2015 |
| 27  | Lu'an | 116.48       | 31.77       | 39.5        | 1955-2001     | 1998-2015  | 1956-2015 |
| 28  | Huoshan | 116.37       | 31.32       | 91.9        | 1954-2001     | 1998-2015  | 1954-2015 |

It can be seen from the table that the length of the D20 pan evaporation data series of each station is longer than the series length of the E601 pan evaporation, while there also exists synchronous observations of the two types of pans. In order to reduce the influence of the data conversion on the analysis result, we establishes the correlation according to the synchronous observation data of the two types of pans. Figure 2 are the correlation graphs of Bozhou station (4 years synchronous observation.
data), Shouxian station (9 years synchronous observation data) and Suxian station (15 years of synchronous observation data). It can be seen from the graphs that the data of different synchronous observation periods have good linear correlations and the correlation coefficients exceed 0.9.

![Scatter plots between pan evaporation observed by two pans in three representative stations.](image)

Figure 2. Scatter plots between pan evaporation observed by two pans in three representative stations.

| No. | Station | Conversion functions | Relative error% | No. | Station | Conversion functions | Relative error% |
|-----|---------|----------------------|-----------------|-----|---------|----------------------|-----------------|
| 1   | Yiyuan  | \( y = 0.49x + 1097.4 \) | 0.44            | 15  | Xuzhou  | \( y = 1.08x + 563.9 \) | 3.64            |
| 2   | Yanzhou | \( y = 1.86x + 35.4 \)  | 3.60            | 16  | Ganyu   | \( y = 1.21x + 254.4 \) | 1.55            |
| 3   | Feixian | \( y = 2.17x - 525.4 \) | 0.32            | 17  | Bozhou  | \( y = 1.05x + 615.8 \) | 1.72            |
| 4   | Juxian  | \( y = 1.16x + 191.7 \) | 2.38            | 18  | Suxian  | \( y = 1.17x + 335.3 \) | 2.68            |
| 5   | Rizhao  | \( y = 0.38x + 101.7 \) | 2.20            | 19  | Xuyi    | \( y = 1.76x - 206.6 \) | 0.79            |
| 6   | Zhengzhou | \( y = 0.29x + 1416.5 \) | 2.18            | 20  | Sheyang | \( y = 1.69x - 57.3 \)  | 0.92            |

Table 2. Error analyses and conversion functions of the two types of pan evaporation.
Xuchang: $y = 0.56x + 987.3$  
Fuyang: $y = 1.33x + 319.6$

Kaifeng: $y = 0.90x + 719.9$  
Gushi: $y = 1.44x - 84.3$

Baoji: $y = 1.46x - 49.9$  
Shouxian: $y = 1.37x + 265.5$

Xi: $y = 0.56x + 796.1$  
Bengbu: $y = 1.66x + 64.7$

Zhumadian: $y = 0.45x + 1025.7$  
Gaoyou: $y = 1.24x + 334.9$

Xinyang: $y = 1.46x - 49.9$  
Dongtai: $y = 1.39x + 175.6$

Shangqiu: $y = 0.47x + 954.8$  
Lu’an: $y = 0.98x + 580.5$

Dangshan: $y = 0.66x + 203.5$  
Huoshan: $y = 0.98x + 580.5$

Note: relative error is calculated by equation (2).

$$y_i = \alpha x_0 + b$$  \hspace{1cm} (1)

$$\delta = \frac{|y_i - y_0|}{y_0} \times 100\%$$  \hspace{1cm} (2)

Where $x_0$ is E601 pan evaporation, $y_0$ is D20 pan evaporation, $y_i$ is converted D20 pan evaporation and $\delta$ is relative error.

Table 2 is the conversion result of the two types of pan evaporation. The table shows that the average relative error of all stations is 2.2%, and the relative error of single site is no more than 5.4%. In general, the correlation of the two types of evaporation is good.

### 2.3. Methods

In this paper, the variation characteristics of pan evaporation and air temperature are described in terms of mutation and trend. The method of Pettitt test [28, 29] is used to detect mutation, which is not limited by whether the population is normal distribution or not, and can better identify the mutation point of sequence distribution. The trends of pan evaporation and air temperature are analysed by using linear tendency estimation method [30, 31].

### 3. Results

#### 3.1. Variation of D20 pan evaporation

What is commonly referred to as climate mutation is mean mutation. i.e., a sharp change of climate from one average to another. Since the evaporation from 1951 to 2015 was measured by two different types of pans, there were no complete unified 65-year series when the mutation analysis was carried out, so we first carried out the mutation detection of the two series, then qualitative and quantitative analysis of the trends were also carried out and at last we further identified the turning points in combination with the trends (the reliability of this approach is verified in Section 2.2 of this paper).

Before 2001, the evaporation was measured by D20 pans, so the data of this period were used for the first mutation detection of pan evaporation in 28 meteorological stations in the basin. 22 stations have passed the significance test at the level of 0.05, and the results are shown in Table 3. There were no obvious turning points of 6 stations, namely Xuchang, Xinyang, Huoshan, Xuyi, Gaoyou and Rizhao.

Table 3. Pettitt test results of pan evaporation during 1951-2001.

| No. | Station  | Turning points | $P$  | $K$  | Average before mutation | Average after mutation | Ratio of average after and before mutation |
|-----|----------|----------------|-----|-----|-------------------------|-----------------------|------------------------------------------|
| 1   | Yiyou    | 1972           | 0.011 | 276 | 1930                    | 1747                  | 0.91                                     |
| 2   | Yanzhou  | 1978           | 0.000 | 588 | 1825                    | 1410                  | 0.77                                     |
| 3   | Feixian  | 1983           | 0.040 | 230 | 1865                    | 1681                  | 0.90                                     |
| 4   | Juxian   | 1978           | 0.000 | 530 | 1712                    | 1468                  | 0.86                                     |
| 5   | Zhengzhou| 1972           | 0.002 | 398 | 2086                    | 1810                  | 0.87                                     |


Table 4 is a summary of the turning points. As can be seen from the table, most of the site's turning points are concentrated in 1978. Therefore, it is considered that the average pan evaporation changed significantly in 1978 during 1951 to 2001, which coincides with the conclusions of Guo et al. [32] and Rong et al. [33].

Table 4. Summary of turning points in Huaihe River Basin.

| Turning points | Number of sites | Site number |
|----------------|----------------|-------------|
| 1971           | 3              | 16, 21, 26  |
| 1972           | 2              | 1, 6        |
| 1974           | 1              | 17          |
| 1978           | 7              | 2, 4, 9, 10, 11, 13, 24 |
| 1979           | 4              | 18, 22, 23, 27 |
| 1981           | 2              | 14, 20      |
| 1982           | 1              | 8           |
| 1983           | 2              | 3, 15       |

Table 3 shows that the mean value of pan evaporation after mutation reduced by about 13.2% than before, so it can be seen that the variation law of pan evaporation was different before and after mutation. The linear trend analysis is then carried out for all stations with significant mutations in the basin.

Table 5. Trend analysis of pan evaporation in Huaihe River Basin during 1951-1978.

| No. | Station | r  | Tendency | Significance | No. | Station | r  | Tendency | Significance |
|-----|---------|----|----------|--------------|-----|---------|----|----------|--------------|
| 1   | Yiyuan  | -0.34 | -13.84 | /            | 15  | Xuzhou  | 0.34 | 86.63    | /            |
| 2   | Yanzhou | -0.24 | -47.60 | /            | 16  | Ganyu   | 0.18 | 36.70    | /            |
| 3   | Feixian | 0.52  | 118.71  | 0.01         | 17  | Bozhou  | 0.13 | 38.15    | /            |
| 4   | Juxian  | 0.01  | 3.38    | /            | 18  | Suxian  | -0.16 | -32.35   | /            |
| 6   | Zhengzhou | 0.64 | 160.02  | 0.01         | 20  | Sheyang | 0.56 | 71.18    | 0.01         |
| 8   | Kaifeng | 0.36  | 89.18   | /            | 21  | Fuyang  | 0.29 | 65.41    | /            |
| 9   | Baofeng | -0.48 | -142.65 | 0.01         | 22  | Guasi   | -0.02 | -6.67    | /            |
Table 5 presents trend analysis of pan evaporation in the Huaihe River Basin from 1951 to 1978. The spatial distribution of evaporation tendency during the same period is shown in Figure 3(a). It can be seen that the trend of average evaporation before 1978 was not significant, among which 4 stations showed significant upward trends, 8 stations showed insignificant upward trends, 10 stations had insignificant downward trends, except Baofeng station. The stations with upward and downward trends were interlaced with each other, and there was no obvious regularity in their arrangement. Therefore, in general, the pan evaporation in the Huaihe River Basin from 1951 to 1978 fluctuated around the mean value with insignificant rising trend, and the trend line was approximately the mean value line.

Table 6. Trend analysis of pan evaporation in Huaihe River Basin during 1979-2001.

| No. | Station | r   | Tendancy | Significance | No. | Station | r   | Tendancy | Significance |
|-----|---------|-----|----------|-------------|-----|---------|-----|----------|-------------|
| 1   | Yiyuan  | 0.07| 25.618   | /           | 15  | Xuzhou  | -0.63| -196.94  | 0.01         |
| 2   | Yanzhou | -0.72| -147.73  | 0.01        | 16  | Ganyu   | 0.04 | 6.712    | /           |
| 3   | Feixian | -0.64| -202.93  | 0.01        | 17  | Bozhou  | -0.39| -72.422  | 0.05         |
| 4   | Juxian  | -0.44| -89.495  | 0.05        | 18  | Suxian  | -0.43| -83.294  | 0.05         |
| 6   | Zhengzhou | -0.17| -18.39   | /           | 20  | Sheyang | -0.20| -46.69   | /           |
| 8   | Kaifeng | -0.49| -157.81  | 0.05        | 21  | Fuyang  | 0.02 | 5.12     | /           |
| 9   | Baofeng | -0.46| -124.48  | 0.05        | 22  | Gushi    | -0.41| -70.584  | 0.05         |
| 10  | Xihua   | -0.50| -115.20  | 0.05        | 23  | Shouxian| 0.10 |          |              |
| 11  | Zhumadian | -0.04| -20.969  | /           | 24  | Bengbu   | -0.21|          |              |
| 13  | Shangqiu | -0.40| -74.629  | 0.05        | 26  | Dongtai  | -0.13| -23.051  | /           |
| 14  | Dangshan | -0.67| -121.98  | 0.01        | 27  | Lu'an    | -0.05| -12.157  | /           |

Table 6 is the trend analysis of pan evaporation in Huaihe River Basin from 1979 to 2001. The spatial distribution of evaporation tendency in the same period is shown in Figure 3(b). We can see that there were downward trends in 18 stations, among which 12 stations had significant downward trends, distributed in the northern and western parts of the basin, the remaining 4 stations (Yiyuan, Ganyu, Fuyang and Shouxian) rose slightly. From 1979 to 2001, the pan evaporation in Huaihe River Basin decreased significantly, and the evaporation tendency increased gradually from southeast to northwest, which was contrary to the trend of precipitation [34]. It was due to the fact that the water vapor in the semi-humid region was in an unsaturated state so the evaporation was more likely to occur with the evaporation rate faster than the humid zone.
Therefore, the process lines of 18 stations (about 70%) in the basin are roughly "\", i.e., the pan evaporation in Huaihe River Basin has changed from steady fluctuation to significant decline since 1950s. In order to understand the existence and exact time of evaporation paradox in Huaihe River Basin, we then analyse the trends of air temperature in Huaihe River Basin before and after 1978.

Table 7. Trend analysis of temperature in Huaihe River Basin during 1951-1978.

| No. | Station | r     | Tendency | Significance | No. | Station | r     | Tendency | Significance |
|-----|---------|-------|----------|-------------|-----|---------|-------|----------|-------------|
| 1   | Yiyuan  | -0.04 | -0.028   | /           | 15  | Xuzhou  | -0.04 | -0.037   | /           |
| 2   | Yanzhou | 0.23  | 0.0135   | /           | 16  | Ganyu   | 0.03  | 0.025    | /           |
| 3   | Feixian | /     | /        | /           | 17  | Bozhou  | 0.18  | 0.013    | /           |
| 4   | Juxian  | 0.21  | 0.0125   | /           | 18  | Suzian  | 0.22  | 0.0161   | /           |
| 5   | Rizhao  | 0.14  | 0.0104   | /           | 19  | Xuyi    | 0.03  | 0.020    | /           |
| 6   | Zhengzhou| 0.3   | 0.170    | /           | 20  | Shanyang| 0.18  | 0.013    | /           |
| 7   | Xuchang | 0.36  | 0.1265   | /           | 21  | Fuyang  | 0.39  | 0.0267   | /           |
| 8   | Kaifeng | 0.29  | 0.176    | /           | 22  | Gushi   | -0.01 | -0.009   | /           |
| 9   | Baofeng | -0.07 | -0.050   | /           | 23  | Shouxian| 0.2   | 0.0190   | /           |
| 10  | Xihua  | 0.25  | 0.187    | /           | 24  | Bengbu  | 0.18  | 0.0125   | /           |
| 11  | Zhumadian| -0.02 | -0.0005  | /           | 25  | Gaoyou  | 0.08  | 0.0052   | /           |
| 12  | Xinyang | 0.33  | 0.195    | /           | 26  | Dongtai | 0.09  | 0.0063   | /           |
| 13  | Shangqiu| 0.22  | 0.171    | /           | 27  | Lu'an   | 0.16  | 0.0115   | /           |
| 14  | Dangshan| 0.19  | 0.134    | /           | 28  | Huoshan | 0.12  | 0.080    | /           |

Table 7 shows the trend analysis of temperature in Huaihe River Basin from 1951 to 1978. The distribution of temperature tendency in the same period is shown in Figure 4(a). 22 stations (excluding Feixian Station) had upward trends from 1951 to 1978, and 5 stations had downward trends. None of them were significant. The stations with upward and downward trends were disordered in spatial distribution and had no obvious geographical boundary. This indicates that the temperature of Huaihe River Basin from 1951 to 1978 was fluctuating around the mean value, the rising trend was weak and the overall trend was relatively stable. This is consistent with the conclusions of Cong et al. [6] and the British Meteorological Bureau report [22].

Table 8. Trend analysis of temperature in Huaihe River Basin during 1979-2001.
Table 8 shows the trend analysis of temperature in Huaihe River Basin from 1979 to 2001, and Figure 4 (b) shows the distribution of temperature tendency in the same period. All the 27 stations in the basin (except Feixian Station) had upward trends, among which 15 stations with significant upward trends were concentrated in the southern part of the basin and the coastal zone, so the temperature of the entire basin had increased significantly during this period. The temperature rate gradually decreased from southeast to northwest, coast to inland and subtropical humid zone to warm temperate semi-humid zone.

Figure 4. Distribution of temperature tendency in Huaihe River Basin during 1951-2001.

In summary, combined with the trends and tendency distribution of pan evaporation in the same period, there was no evaporation paradox in Huaihe River Basin because of the insignificant change of pan evaporation and air temperature for the period of 1951-1978. For 1979-2001, the temperature increased significantly with the pan evaporation decreased significantly, so there was a paradox of pan evaporation in the basin during this period.

3.2. Variation of E601 pan evaporation
Since the 1990s, extreme weather events have occurred frequently, and the variation law of pan evaporation in climate change environment is worthy of further analysis and study. There is a great controversy in the field of hydrometeorology about the temperature change after 1998. Therefore, the
temperature trends of 28 meteorological stations in Huaihe River Basin are analysed taking 1998 as the node.

Table 9. Trend analysis of temperature in Huaihe River Basin during 1998-2015.

| No. | Station | r   | Tendency | Significance | No. | Station | r   | Tendency | Significance |
|-----|---------|-----|----------|--------------|-----|---------|-----|----------|--------------|
| 1   | Yi yuan | 0.10 | 0.082    | /            | 15  | Xuzhou  | -0.02| -0.014  | /            |
| 2   | Yanzhou | -0.17| -0.128   | /            | 16  | Ganyu   | -0.42| -0.417  | /            |
| 3   | Feixian | 0.02 | 0.017    | /            | 17  | Bozhou  | -0.10| -0.086  | /            |
| 4   | Juxian  | 0.18 | 0.133    | /            | 18  | Suxian  | -0.08| -0.049  | /            |
| 5   | Rizhao  | 0.14 | 0.108    | /            | 19  | Xuyi    | 0.13 | 0.084   | /            |
| 6   | Zhengzhou | 0.55 | 0.464   | 0.05         | 20  | Shexian | -0.32| -0.216  | /            |
| 7   | Xuchang | -0.18| -0.133   | /            | 21  | Fuyang  | -0.32| -0.262  | /            |
| 8   | Kaifeng | 0.56 | 0.491    | 0.05         | 22  | Guishu  | -0.45| -0.368  | /            |
| 9   | Baofeng | 0.14 | 0.124    | /            | 23  | Shouxiang | -0.07| -0.042  | /            |
| 10  | Xihua   | 0.45 | 0.337    | /            | 24  | Bengbu  | -0.63| -0.592  | 0.01         |
| 11  | Zhumadian | -0.11| -0.09   | /            | 25  | Gaoyou  | 0.22 | 0.144   | /            |
| 12  | Xinyang | 0.10 | 0.081    | /            | 26  | Dongtai | -0.31| -0.194  | /            |
| 13  | Shangqiu | -0.08| -0.064  | /            | 27  | Lu’an   | -0.35| -0.31   | /            |
| 14  | Dangshan| -0.55| -0.592   | 0.05         | 28  | Huoshan | -0.49| -0.442  | 0.05         |

Table 9 shows the trend analysis of temperature in the Huaihe River Basin from 1998 to 2015. The distribution of temperature tendency is shown in Figure 5 (a). There were 11 stations with upward trends after 1998, 9 of which were not significant, and 17 had downward trends, 14 of which were not significant. For the whole river basin, the distribution of stations with upward and downward trends was disordered with no obvious zonation phenomenon, and 82% of the stations were not significant. Because the number of stations with downward trend were more than that with upward trend and the decreasing trends were larger than that of rising, the air temperature in the whole basin showed an unremarkable downward trend, which was consistent with the research results of Fan et al. [25]. Combined with the obvious increasing trend of air temperature after 1978, it is considered that 1998 was the turning point of temperature, i.e., the significant increasing state of temperature in the basin stopped after 1998, and changed from a remarkable rise to a more stable state, with a weak decrease tendency.

Table 10 shows the trend analysis of pan evaporation in Huaihe River Basin from 1998 to 2015. Fig. 5 (b) is the spatial distribution of evaporation tendency in the basin during the same period. There were 16 stations with upward trends, 13 of which were insignificant. There were 12 sites with downward trends, 9 of which were insignificant. Similar to the temperature, the distribution of pan evaporation was not regular and 79% of the stations showed insignificant trends. As stations showing upward trends were more than those with downward trends, the whole basin showed a weak upward trend. The results showed that the decreasing trend of pan evaporation in Huaihe River Basin has been stopped since 1998.

Therefore, 1998 is the second turning point of pan evaporation sequence, and the two turning points (1978 and 1998) divided the whole evaporation sequence of Huaihe River Basin into three parts, namely, the high value fluctuating period, the significant descending period and the weak rising period.

Table 10. Trend analysis of pan evaporation in Huaihe River Basin during 1998-2015.

| No. | Station | r   | Tendency | Significance | No. | Station | r   | Tendency | Significance |
|-----|---------|-----|----------|--------------|-----|---------|-----|----------|--------------|
| 1   | Yi yuan | -0.17| -26.9    | /            | 15  | Xuzhou  | 0.24| 27.2    | /            |
| 2   | Yanzhou | -0.78| -156.4   | 0.01         | 16  | Ganyu   | -0.29| -40.7   | /            |
| 3   | Feixian | 0.37 | 58.2     | /            | 17  | Bozhou  | 0.23 | 27.4    | /            |
| 4   | Juxian  | -0.15| -18.6    | /            | 18  | Suxian  | 0.01 | 0.05    | /            |
The essence of the "evaporation paradox" is that the temperature rises significantly with the pan evaporation decreasing significantly. After 1998, although the pan evaporation and temperature in the Huaihe River Basin had the opposite variation, they were not obvious. It is concluded that there is no evaporation paradox in the basin after 1998, or that it is of little significance to discuss the paradox at this time. Based on the above conclusions, it is concluded that the evaporation paradox existed in the basin from 1978 to 1998.

4. Conclusions
In this paper, the variation and mutation characteristics of pan evaporation and air temperature in Huaihe River Basin from 1951 to 2015 are analysed. The main conclusions are as follows:

(1) The pan evaporation had significant mutations both in 1978 and 1998. The sequence of evaporation was divided into three stages: the high value fluctuating period, the significant decreasing period and the weak increasing period. There was evaporation paradox in the basin from 1978 to 1998. After 1998, the pan evaporation stopped declining and showed insignificant upward trend.

(2) From 1978 to 1998, there was a negative correlation between air temperature and pan evaporation, and the spatial distribution of evaporation tendency was different, gradually increased from southeast to northwest, from coastal area to inland and from humid area to semi-humid area with the temperature tendency in contrast. During 1951-1978 and 1998-2015, the trends of air temperature and pan evaporation were not obvious, and there was no phenomenon of evaporation paradox. The air temperature may be only one of the factors affecting the pan evaporation, and the attribution of the variation of pan evaporation requires further study.

(3) The results of previous studies on the existence of evaporation paradox in Huaihe River Basin may be related to the series length of the selected pan evaporation (mostly ended in 2000), and the
characteristics of the short series led to the unobvious reversal of pan evaporation variation. The conclusion of this study may have an impact on the previous achievements of the attribution analysis of pan evaporation in the Huaihe River Basin, which is also the focus of our further study.

During 2015-2016, a super El Nino event similar to that of 1998 occurred again, and the future pan evaporation and temperature change need more data to be analysed and verified. In this paper, due to the limitation of data series, only qualitative analysis has been carried out on the variation of pan evaporation in Huaihe River Basin, which is a little insufficient in quantitative calculation. Therefore, how to select an effective method to obtain a consistent evaporation series and make the research results credible needs to be further discussed.

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