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Reference Evapotranspiration Changes in the Haihe River Basin during Past 50 Years

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Abstract

In this paper, temporal trend of annual reference evapotranspiration (ET_0) calculated using the FAO Penman-Monteith equation with the observed daily meteorological data at six stations (i.e. Datong, Weichang, Qinhuangdao, Tianjin, Beijing and Huimin) of Haihe River Basin, China, were detected with the help of parametric t-test and Mann-Kendall (MK) analysis. The six stations were divided in three different classes representing mountain (Datong and Weichang), continental (Beijing and Huimin) and coastal areas (Qinhuangdao and Tianjin), respectively. The result shows that there was a significant upward trend in ET_0 at mountain area of the Haihe River Basin. On the contrary, a significant downward trend in ET_0 can be found at coastal area. Moreover, the analyses of ET_0 at continental area indicate that after 1960, ET_0 of Beijing showed a sharp significant increase, while a moderate variation was presented for ET_0 at Huimin.

Keywords: The Haihe River Basin; trend analysis; reference evapotranspiration

1. Introduction

In recent years, the consciousness about modifications into the atmospheric composition caused by both human activity and natural processes which may led to lager global-scale changes into the earth climate is getting stronger in the scientific community as well as in unscientific field. The global surface temperature in the 20th century exceeded the average of period 1961-1990 with 0.6±0.2℃ according to the third report of IPCC prepared in January 2001.

One of the most important necessities of research into climate change and the water cycle is to analyze

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and detect historical changes in the climatic system. Therefore, the historical observation of climatic variables is receiving a more and more considerable attention, as many scientists are attempting to verify whether or not there is a detectable climate and hydrological signal change subsequent to the greenhouse effect [1].The purpose of this study is to quantify the trends in reference series in the Haihe River basin (HRB). This paper presents the first results of ongoing research with the main objective of studying the impact of climate change on hydrological variables in the HRB in China. All the tests are based on the reference evapotranspiration series calculated by weather data collected from 6 meteorological stations in the HRB during past 50 years.

2. Study area and data processing

2.1. Description of the HRB

The HRB is located in the eastern part of North China, between 35°-43°N and 112°-120°E. The mean annual precipitation in the HRB is 520.4 mm with notable interannual variations, reaching 800mm in flood years and less than 270 mm in the drought years. In general, the amount of rainfall during summer accounts for 70% to 85% of the annual total amount, and is mostly concentrated in one or two heavy rainstorms in July and August.

The HRB is a region with a tremendous conflict in the water supply and demand. The lack of water resources in the HRB resulted in such severe environmental problems as the serious reduction of the water supply from mountainous areas, subsidence of the land surface due to over-exploitation of groundwater, degradation of rivers and lakes and water pollution [2].

2.2. Data processing

Table 1. Detailed weather data record of stations in the Haihe River Basin

Station	Latitude	Longitude	Elevation(m)	CL	Time interval
Datong	40.100°N	113.333°E	1067.2	M	1955-2006
Weichang	41.933°N	117.75°E	842.8	M	1956-2006
Qinhuangdao	39.850°N	119.517°E	2.4	C	1954-2006
Tianjin	39.083°N	117.067°E	2.5	C	1957-2006
Beijing	39.800°N	116.467°E	31.3	L	1952-2006
Huimin	37.483°N	117.533°E	11.7	L	1951-2006

Legend: M=mountain station, L=continental station, C=coastal station

The reference evapotranspiration data was calculated using the FAO Penman-Monteith equation, which is the sole method recommended by FAO to calculate reference evapotranspiration. The P-M method for calculating daily reference evapotranspiration can be written as [3]:

$$ET_0 = \frac{0.408\Delta(R_n - G) + \gamma(900/T + 273))u_2(e_s - e_a)}{\Delta + \gamma(1 + 0.34u_2)} \quad (1)$$

Where R_n is the net radiation at the crop surface ($MJm^{-2}day^{-1}$), G the soil heat flux density ($MJm^{-2}day^{-1}$), T the mean daily air temperature at 2m height (℃), u_2 the wind speed at 2m height (ms^{-1}), e_s

the saturation vapor pressure (kPa), e_a the actual vapor pressure (kPa), $e_s - e_a$ the saturation vapor pressure deficit (kPa), Δ the slope of the vapor pressure (kPa℃$^{-1}$), and γ the psychrometric constant (kPa℃$^{-1}$).

Data used in this study from six National Meteorological observatory stations was provided by the National climatic Centre of CMA (the China Meteorological Administration), including daily observations of maximum, minimum and mean air temperature, wind speed, relative humidity and sunshine duration. The weather data used in this paper were collected on a daily basis, and the locations, the classes and the data periods of the stations are present in Table 1.

3. Methodology

Two methods, namely, simple linear regression and Mann–Kendall test [4] are used in the study to detect trend from reference evapotranspiration (ET_0) series. The simple linear regression method is a parametric t-test method, which consists of two steps, fitting a linear simple regression equation with the time t as independent variable and the hydrological variable, Y as dependent variable, and testing the statistical significance of the slope of the regression equation. The parametric t-test requires the data to be tested is normally distributed. The normality of the data series is first tested in the study by applying the Kolmogorov–Smirnov test.

The rank-based Mann–Kendall method is a nonparametric and commonly used method to assess the significance of monotonic trends in hydro-meteorological time series. This test has the advantage of not assuming any distribution form for the data and has the similar power as its parametric competitors. Therefore, it is highly recommended for general use by the World Meteorological Organization [5].

4. Results

The results are first presented for individual stations in three different area of the HRB and then the common and unique features are discussed thereafter.

4.1. Stations in the mountain area: Datong station and Weichang station

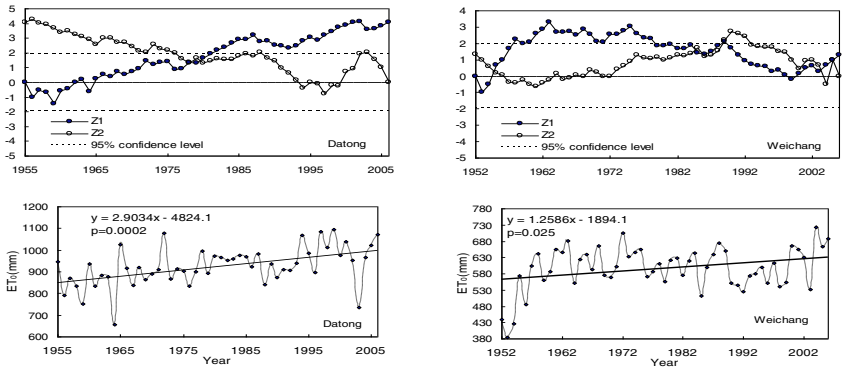

Fig.1. Mann-Kendall and parametric t-test (simple regression analysis) trends of ET_0 of Datong station and Weichang station

The result of MK trends of ET_0 variation of Datong station and Weichang station are shown in Fig.2.It can be seen that during 1955-1965 the ET_0 of Datong station is decreasing trend (but not significant

at >95% confidence level); after 1965 the ET_0 is in increasing trend and after 1975 this increasing trend is significant at >95% confidence level. The result of simple linear regression (with the ET_0 as the dependent variable and the time as the independent variable) indicates a significant upward trend (at >95% confidence level) for the ET_0 series (the slope of simple linear regression line is 2.9034) in Datong station. At the same time, the MK test shows an increasing trend during 1955-2006, and this increasing trend is significant at >95% confidence level during 1960-1980. The result of simple linear regression also indicates a significant upward trend (at >95% confidence level) for the ET_0 series (the slope of simple linear regression line is 1.2586) in Weichang station. The intersection point of Z_1 and Z_2 curves of ET_0 of Datong station and Weichang station occurred during 1980, 1955 and 1985, respectively.

4.2. Stations in the coastal area: Qinhuangdao station and Tianjin station

As for Qinghuangdao station, fig.2 (left) displays the upward MK trend of annual ET_0 before 1972, and after that the downward MK trend of annual ET_0 except 1993-1996. However, neither upward trend nor downward trend becomes significant at 95% confidence level. The MK trends of annual ET_0 of Tianjin station present a intense downward trends after 1985, and this downward trend become significant after 1995 at 95% confidence level. Simple linear regression analysis shows a stronger downward trend of Qinhuangdao station and Tianjin station (the slope of linear regression line is -1.4953 and -2.3571, respectively). At the same time parametric *t*-test show that comparing Qinhuangdao station, the MK downward trend of ET_0 Tianjin station is stronger. The intersection point of point of Z_1 and Z_2 curves of ET_0 of Qinhuangdao station and Tianjin station occurred between 2000 and 2003 and during 1982, respectively.

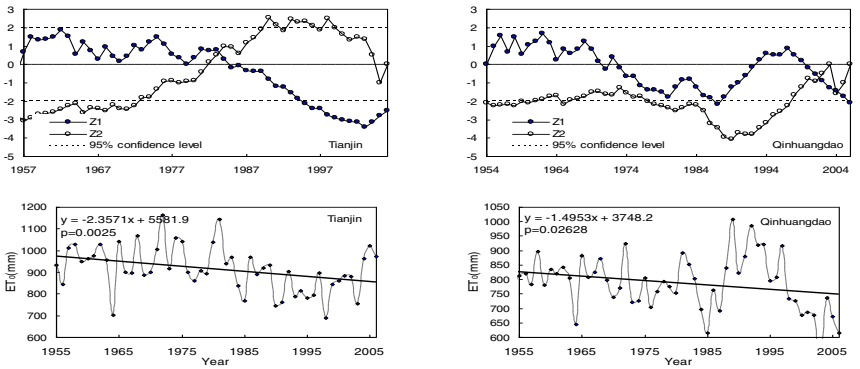

Fig.2. Mann-Kendall and parametric t-test (simple regression analysis) trends of ET_0 of Qinhuangdao station and Tianjin station

4.3. Stations in the continental area: Beijing station and Huimin station

Fig.3 shows the MK trends of annual ET_0 of Beijing station and Huimin station. it is seen that annual ET_0 of Beijing station shows a intense upward trend except during 1952-1962, and this upward trend becomes significant after 1988 at 95% confidence level. The MK trends of annual ET_0 of Huimin station present an upward trend during1953-1984 and a downward trend, and these trends hardly become significant at 95% confidence level. The results of the simple linear regression analysis of annual ET_0 of Beijing station also reveal the whole strong upward trend. However, the results of the simple linear regression analysis of annual ET_0 of Huimin station reveal the trend of the whole research time is downward. Furthermore, the intersection point of point of Z_1 and Z_2 curves of ET_0 of Qinhuangdao

station and Tianjin station reveal that the abrupt change of annual ET_0 of Beijing station and Huimin station occurred in 1988 and 1982, respectively.

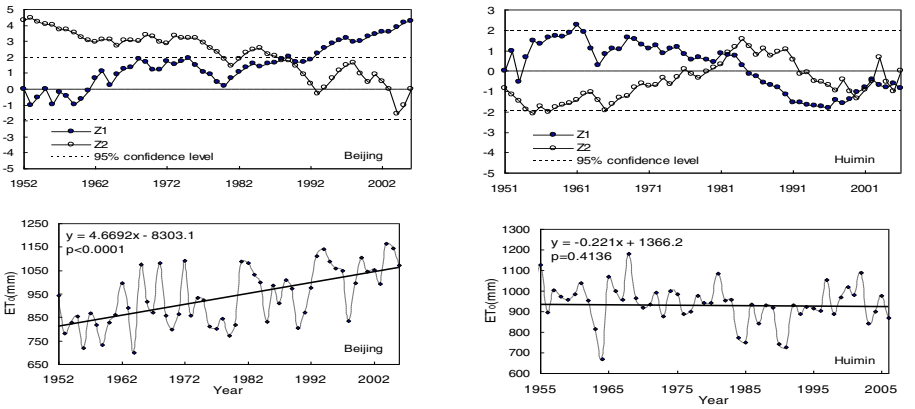

Fig.3. Mann-Kendall and parametric *t*-test (simple regression analysis) trends of ET_0 of Beijing station and Huimin station

5. Discussion

The result of parametric t-test and MK test indicate that the annual reference evapotranspiration in the mountain area of Haihe River is increasing trend while the opposite is true in the coastal area of Haihe River. In continental area, the results of ET_0 trend of Beijing and Huimin are not consistent. Annual ET_0 of the mountain area, has strong and most significant upward trend. This result indicates that the mountain area of Haihe Rive have the possibility of becoming drought during the past 50 years. Annual ET_0 in the coastal area, has sharp significant downward trend (significant at >95% confidence level). This result may show that the changes of ET_0 mainly impacted by the climate change in the coastal area of Haihe River. As for the continental area, ET_0 of Beijing has a sharp significant upward. ET_0 of another station, Huimin, have no obvious whole change during the past 50 years. This result indicates that ET_0 change degree of this region may be influenced by multiple factors like the degree of human activities. For example, the intense human activity in Beijing may strength the degree of climate change in that region. The detailed evidence possibly existing will be explored and the correspond research work are under way, and will be addressed in forthcoming papers

6. Conclusion

In this paper, the temporal trend of annual reference evapotranspiration (ET_0) at six representative stations (i.e. Datong, Weichang, Qinhuangdao, Tianjin, Beijing and Huimin) of the HRB, China, was investigated using the parametric t-test and MK analysis. It's found that the mountain area of the HRB presented a significant upward trend in ET_0.While the coastal area in this basin was dominated by the significant downward trend in ET_0. The inconsistent changing patterns of ET_0 in Beijiang (sharp increase) and Huimin (moderate variation) imply ET_0 change degree may be extensively influenced by human activities.

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