Variation characteristics of meteorological and hydrological factors and Attribution analysis of runoff variation in Qinhuai River Basin

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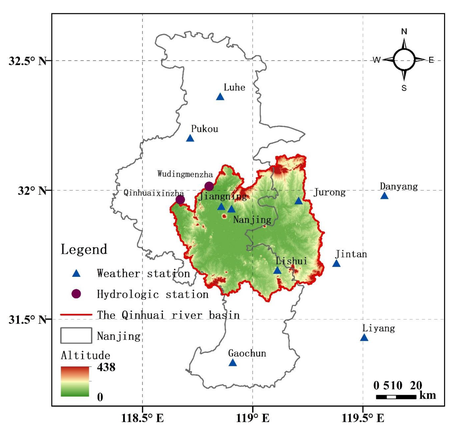
Objectives

In recent years, under the background of climate change, water and drought disasters have become more frequent in the Qinhuai River Basin. The increase in human activities, such as urban construction, has led to enhanced hydrological effects. However, there have been few studies on trend analysis and abrupt change detection of meteorological and hydrological elements in the basin. In this study, meteorological and hydrological data in the Qinhuai River Basin, along with remote sensing data, were used to conduct trend analysis and abrupt change detection of meteorological and hydrological sequences.

The elasticity coefficient of runoff change to various factors was calculated, and the quantitative contribution of climate change and human activities to runoff variation was assessed. The research clarified the changing patterns of meteorological and hydrological elements in the Qinhuai River Basin, distinguished the impacts of climate change and human activities on runoff variation, and provided decision-making references for flood and drought disaster prevention and water resources management in the basin.



Methods

●The β-z-h three-parameter comprehensive indicator method: This method utilizes the Mann-Kendall (M-K) trend test to obtain the upward or downward trend β and the significance z of the sequence. Then, the Rescaled Range Analysis (R/S) method is used to determine whether the historical development trend of the sequence shows positive persistence or negative persistence in the future, represented by the Hurst index h.

●Joint change detection method: This method prevents false change points from being detected. It combines multiple change point detection techniques, including the M-K test, Pettitt method, sliding t-test, and Yamamoto method. The year with the highest weight is selected as the change point.

●Elasticity coefficient method based on the Budyko hypothesis: This method evaluates the sensitivity of runoff to climate change and human activities, quantitatively calculating the contribution rates of climate change and human activities to runoff variation.

$$\mathrm{d}Rx_i = \varepsilon x_i \frac{R}{x_i} dx_i \qquad Cx_i = \frac{dRx_i}{dR'} \times 100\%$$

Results

(1) The annual average temperature and runoff depth in the Qinhuai River Basin show a significant increasing trend, while the annual precipitation and reference crop evapotranspiration exhibit a non-significant increasing trend. On the other hand, the annual average relative humidity shows a significant decreasing trend, and these trends are expected to continue into the future.

Tab.1 Computation result of β-z-h

Element	β	z	h-0.5	Characteristics of Element Evolution
Annual Mean Temperature	0.03	5.70	0.42	Increased in the past, with a significant trend, and will continue to increase in the future.
Annual Precipitation	2.77	1.74	0.08	Increased in the past, with a non-significant trend, and will continue to increase in the future.
Annual Reference Crop Evapotranspiration	0.50	1.16	0.26	Increased in the past, with a non-significant trend, and will continue to increase in the future.
Annual Average Relative Humidity	-0.11	-5.46	0.45	Decreased in the past, with a significant trend, and will continue to decrease in the future.
Annual runoff depth	14.25	4.09	0.20	Increased in the past, with a significant trend, and will continue to increase in the future.

Results

(2) The annual precipitation has not experienced significant variation. However, the annual average temperature showed a strong variation from low to high in 1994, the annual reference crop evapotranspiration exhibited a moderate variation from low to high in 2003, the annual average relative humidity experienced a huge variation from high to low in 2004, and the annual runoff depth demonstrated a weak variation from low to high in 2002.

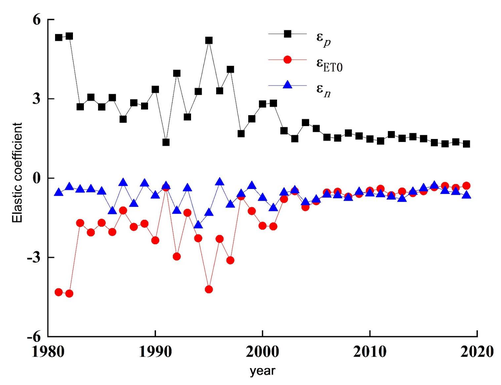
(3) During the baseline period (1981-2002) and the changing period (2003-2019), runoff showed a significant positive correlation with precipitation and a negative correlation with reference crop evapotranspiration and underlying surface index. In the changing period, the elasticity coefficient of precipitation decreased, while the elasticity coefficients of reference crop evapotranspiration and underlying surface index increased. The contribution rates of various factors to the increase in runoff during the changing period are as follows: underlying surface index (91.20%), precipitation (10.78%), and reference crop evapotranspiration (-1.99%).

Tab.2 Change points of Hydro-meteorological factors in Qinhuaihe River Basin

Element	MK	Pettitt	Sliding T	Yamamoto	Change Point	Hurst Exponent	Degree of Variation
Annual Mean Temperature	1999	1994	1994	1994	1994	0.92	Strong Variation
Annual Precipitation	—	—	—	—	No Variation	0.58	No Variation
Annual Reference Crop Evapotranspiration	2004	2000	2003	2003	2003	0.76	Moderate Variation
Annual Average Relative Humidity	1999,2000	1992	2004	2004	2004	0.95	Significant Variation
Annual Runoff Depth	2005	2002	2002	2002	2002	0.70	Weak Variation

Conclusions

●The response of meteorological and hydrological elements to human activities is quite significant. The period of most drastic changes in land use, particularly in construction and cultivated land areas, coincides with the occurrence of runoff abrupt change points. Over the past 40 years, the Qinhuai River Basin has experienced rapid changes in land use, with natural surfaces being replaced by impermeable surfaces.



●During the process of urban expansion in the Qinhuai River Basin, it is essential to fully consider the hydrological effects of land use and land cover changes. On one hand, it is crucial to protect farmland and forests with strong surface storage capacity. On the other hand, attention should be paid to the potential flood control pressure brought by climate change in the basin.