

3 Results and discussion

3.1 Changes in the precipitation, PET and annual runoff

For the past 55 yr, the NRB showed an annual average precipitation of 441 mm yr^{-1} ranging from 156 mm yr^{-1} to 1111 mm yr^{-1} . Annual average temperature, however, had a higher variability, ranging from $-0.7^{\circ}\text{Cyr}^{-1}$ to $3.6^{\circ}\text{Cyr}^{-1}$ with a mean of $1.5^{\circ}\text{Cyr}^{-1}$. The estimated PET in the NRB averaged 885 mm yr^{-1} per year, varying from 807 mm yr^{-1} to 937 mm yr^{-1} . Annual surface runoff from the entire basin averaged 138 mm yr^{-1} , fluctuating from 53 mm yr^{-1} to 245 mm yr^{-1} (Fig. 2). The precipitation had a significant change from 1956 to 2010, with a decreasing trend of $5.0\text{ mm}(10\text{ yr})^{-1}$, while the PET did not show obvious change (Table 1, Fig. 4). The runoff, however, showed a considerable decrease at a rate of 8.6 mm per 10 yr (with a positive significance of 0.99). The *N* statistic of the Kendall test was -2.31 , indicating a clear decreasing trend.

The decline in the runoff is most likely due to the additional water demand from the increasing population, economic growth and agricultural development that have occurred since the 1950s. Apparently, the decline is spatially variable within the basin. To further understand the trends and change point of the annual runoff, the Pettitt test was applied to the entire NRB, while the DCC test was applied to detect the change points in the annual runoff individually for each of the upstream, midstream and downstream basins.

The results showed two change-points in the runoff series: the year of 1975 and the year of 1981 (Table 2). In addition, the DCC test demonstrated that in the upstream basin of the Nenjiang River, the precipitation and runoff were relatively consistent prior to 1975 and changed thereafter. In the midstream and downstream basins, however, the change-point occurred in 1974 (Fig. 3). The combined Pettitt and DCC test results indicate that 1975 could be the change-point reflecting the effect of human activities on runoff.

Effects of climate change and human activities in the Nenjiang River

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