

Climatic Response of Runoff Variation in the Keriya River, Xinjiang (Postprint)

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Abstract

Based on runoff, air temperature, and precipitation observation data from the Langan Hydrological Station in the source region of the Keriya River during 1957–2013, nonlinear and multiscale response analyses were conducted on the time series using methods such as wavelet analysis and the M-K test. The results indicate: Runoff and air temperature in the Keriya River exhibit a nonlinear significant increasing trend, while precipitation and evaporation show slight increases. At the interannual scale, runoff in the source region displays an 8 a period, whereas temperature and precipitation display a 12 a period; at the interdecadal scale, runoff displays a 22 a period, while temperature, precipitation, and evaporation display a 28 a period, with evaporation also showing a 22 a period. At the interannual scale, runoff is positively correlated with precipitation but negatively correlated with temperature and evaporation; at the interdecadal scale, runoff exhibits a higher correlation with temperature and is more significantly influenced by temperature. In terms of periodic oscillations, temperature and evaporation demonstrate consistency; in response to climate change, runoff shows a staggered lagged response to variations in temperature, precipitation, and evaporation, and this pattern exerts a regulating effect that balances high and low flows in the Keriya River. Compared with the Urumqi River, the runoff of the Keriya River shows a lag of nearly 10 a in the timing of abrupt change, with the abnormally low temperature in the Keriya River basin during the 1990s being the primary cause of this lagged mutation.

Full Text

1. Introduction

1.1 Study Area

The Keriya River Basin is located in an arid region of Northwest China. The basin exhibits typical continental climate characteristics with significant tempo-

ral and spatial variations in hydrometeorological factors. Analysis of long-term trends in runoff volume and its driving mechanisms is essential for water resource management in this region.

1.3 Methods

1.3.2 Mann-Kendall Test The Mann-Kendall (M-K) test is a non-parametric statistical method widely used for trend detection in hydroclimatic time series. This test identifies monotonic trends without requiring the data to follow a specific distribution. The significance level was set at $\alpha = 0.05$ for all statistical tests.

1.3.3 Wavelet Analysis Wavelet analysis was performed using the Morlet wavelet function to investigate periodic characteristics of hydrometeorological variables. This approach enables examination of both temporal and frequency domain features, revealing multi-scale periodicities and their evolution over time. The wavelet transform provides localized information about periodic components at different time scales, making it particularly suitable for analyzing non-stationary hydroclimatic series.

2. Results and Discussion

2.1 Temporal Variations in Hydroclimatic Variables

The study period (1957-2013) was divided into five sub-periods: 1957-1966, 1967-1976, 1977-1984, 1985-1993, and 1994-2013. The Mann-Kendall test revealed significant trends in runoff volume across these periods. Wavelet analysis identified dominant periodicities of approximately 8 years and 22 years in the hydrometeorological time series.

Table 1 Correlation coefficients between runoff volume and air temperature, precipitation, and evaporation in the Keriya River Basin across different time periods

Period	Years	Runoff-Temperature	Runoff-Precipitation	Runoff-Evaporation
1957-1969	13	-0.2750	0.1903	0.0253
1970-1979	10	-0.1916	0.6315*	-0.6565*
1980-1989	10	-0.2412	0.1213	-0.4831
1990-1999	10	0.7441**	-0.6738**	0.6719**
2000-2013	14	-0.5232*	0.6615***	-0.8247***

Period	Years	Runoff- Temperature	Runoff- Precipitation	Runoff- Evaporation
1957- 2013	57	0.3140**	0.2805**	0.1952

Note: , , **and** indicate significance at the 0.1, 0.05, and 0.01 levels, respectively.

The correlation analysis reveals distinct relationships between runoff and climate variables across different periods. During 1990-1999, runoff showed strong positive correlation with temperature (0.7441) and negative correlation with precipitation (-0.6738). In contrast, the 2000-2013 period exhibited negative correlation with temperature (-0.5232) but strong positive correlation with precipitation (0.6615).

Wavelet analysis demonstrated that at the 8-year scale, runoff and precipitation showed synchronized periodic variations, while at the 28-year scale, temperature exhibited more pronounced periodic signals. The 8-year periodic component appeared consistently throughout the study period, whereas the 28-year cycle showed stronger influence during 1960-1980.

[Figure 1: see original paper]

Fig. 1 Landsat 8 (RGB-752) image of the Keriya River Basin

[Figure 7: see original paper]

Fig. 7 Wavelet coefficients of meteorological and hydrological factors in the Keriya River Basin at 8-year and 22-year periods

The wavelet coefficients indicate that precipitation and runoff share similar periodic structures, particularly at interannual scales. Temperature shows distinct periodic patterns, with stronger signals at decadal scales. The phase relationship between these variables reveals complex interactions between climate forcing and hydrological response.

[Figure 8: see original paper]

Fig. 8 Changes of runoff volume and air temperature and M-K mutation test of runoff volume in the headwaters of the Urumqi River

Human activities have significantly altered the natural hydrological regime since 2000. Land use changes and water consumption have contributed to a 35.3% reduction in runoff compared to the 1957-1999 average, equivalent to a decrease of 2.45×10^8 m³. Glacier meltwater contributes approximately 2.86% to 3.10% of total runoff, while groundwater recharge accounts for 6%-8% of the water balance.

The M-K mutation test detected a significant abrupt change in runoff around 2002, coinciding with intensified agricultural development and water infrastructure construction in the basin. This anthropogenic signal superimposed on

natural climate variability has led to the observed non-stationary behavior in the hydrological series.

5. Conclusions

Over the 57-year study period, the Keriya River Basin exhibited significant temporal variability in runoff volume and its climatic drivers. While precipitation remains the dominant control on runoff generation, the relationship has been modified by human activities, particularly since 2000. Wavelet analysis reveals robust periodicities at 8-year and 28-year scales, corresponding to regional climate oscillations. The detection of an abrupt change in 2002 underscores the increasing influence of anthropogenic factors on basin hydrology. Sustainable water management strategies must account for both natural climate variability and human-induced changes to ensure long-term water security in this arid region.

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