

Climate Change Characteristics and Runoff Response in the Yarkant River Basin, 1957-2015: Postprint

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Abstract

Based on long-term observational data from meteorological and hydrological stations within the basin, methods such as linear trend, correlation coefficient, cumulative anomaly, and Mann-Kendall (M-K) mutation test were employed to analyze climate change characteristics during dry and wet seasons in different regions, and assuming different climate scenario combinations, the response degree of runoff to climate change was analyzed. The results show that: From 1957 to 2015, temperature and precipitation in the four units showed an increasing trend; except for the upper reaches, relative humidity, average wind speed, and number of strong wind days showed a decreasing trend, while basin runoff showed an increasing trend. Temperature experienced an abrupt change in 1996; precipitation did not show an obvious mutation point; relative humidity underwent an abrupt change around 2005; except for the lower reaches, average wind speed experienced an abrupt change in 1983; runoff experienced an abrupt change in 1993, after which runoff increased by $9.08 \times 10^8 \text{ m}^3$. Correlation analysis shows that basin runoff is extremely significantly positively correlated with wet-season average temperature, average minimum (maximum) temperature, and negatively correlated with wet-season average wind speed, number of strong wind days, and relative humidity; except for runoff in the upper reaches which is positively correlated with dry-season precipitation, other regions are negatively correlated with precipitation. Sensitivity analysis shows that when precipitation remains unchanged and temperature increases by 1°C , runoff increases by 9.06%; when temperature remains unchanged and precipitation increases by 10%, runoff decreases by 1.67%, which is mainly related to runoff composition. 77.4% of the basin's runoff comes from snow-ice meltwater supply; when precipitation increases, temperature decreases, reducing the melting of glaciers and snow, thus basin runoff is positively correlated with temperature and negatively correlated with precipitation, and is more sensitive to temperature changes.

Full Text

Response of Runoff Volume to Climate Change in the Yarkant River Basin during the Period of 1957-2015

Abstract: The characteristics of dry and wet climate changes in different regions were analyzed using linear trend, correlation analysis, cumulative anomaly, and the Mann-Kendall (M-K) mutation test based on long-term observation data from meteorological and hydrological stations in the Yarkant River Basin. Moreover, different climate scenario combinations were assumed to analyze the response degree of runoff volume to climate change. The results showed that:

Both temperature and precipitation in the four units showed an increasing trend; in addition to the upper reaches, relative humidity, average wind speed, and wind days in the drainage basin showed a decreasing trend, but runoff volume showed an increasing trend; The mutations of temperature and relative humidity occurred in 1996 and 2005 respectively, but there was no obvious mutation of precipitation; the mutation of mean wind speed in the drainage basin occurred in 1983 except in the lower reaches, and the runoff volume was sharply increased by $9.08 \times 10^3 \text{ m}^3$ in 1993; Correlation analysis showed that runoff volume was positively correlated with mean air temperature and minimum (maximum) air temperature in the wet season, and negatively correlated with average wind speed, gale days, and relative humidity in the wet season. In addition, runoff volume was positively correlated with dry season precipitation in the upper reaches, but negatively correlated with precipitation in other areas; Sensitivity analysis showed that when precipitation remained constant and temperature increased by 1°C , runoff volume increased by 9.06%; when temperature remained unchanged and precipitation increased by 10%, runoff volume decreased by 1.67%, which was mainly related to runoff composition. The 77.4% of runoff was recharged by ice-snow meltwater. With the increase of precipitation, temperature decreased, and the melting of glacier and snow was reduced. At this time, the increase of precipitation could not make up for the recharge decrease of ice-snow meltwater, so runoff volume was positively correlated with temperature but negatively correlated with precipitation, and it was more sensitive to temperature change.

Keywords: climate change; air temperature; precipitation; runoff volume; sensitivity; Yarkant River Basin

3. Results and Analysis

3.1 Climate Factor Variations

3.1.1 Temperature The M-K test revealed that temperature at all four stations showed a significant increasing trend over the 60-year period. The mutation years for temperature at each station are shown in . The cumulative anomaly curve indicated that temperature remained relatively stable from 1957 to 1996, then exhibited a significant warming trend after 1996 (Figure 1). Sta-

tistical analysis showed that the average temperature during 1997–2015 was 0.57% higher than during 1957–1996 ($P < 0.01$), indicating a significant upward shift. On a decadal scale, the 10-year moving average temperature increased by 0.25%–1.24% ($P < 0.01$). Notably, an abrupt temperature increase occurred around 1986, consistent with previous studies [?].

3.1.2 Precipitation The M-K test indicated that precipitation showed an increasing trend across the basin, though the trend was not statistically significant at the 95% confidence level. The coefficient of variation for precipitation ranged from 0.85 to 1.09. While precipitation exhibited considerable interannual variability, no obvious mutation point was detected in the time series.

3.1.3 Wind Speed Analysis of the 60-year record revealed that average wind speed at the four stations was 1.60, 1.92, 1.32, and 1.57 $\text{m} \cdot \text{s}^{-1}$, respectively. The overall trend showed a significant decrease, with decadal averages declining by 0.05–0.14 $\text{m} \cdot \text{s}^{-1}$ per decade. The decreasing trend was particularly pronounced after 1983, with the mutation occurring in that year across all stations except the lower reaches. For the upper, middle, and lower reaches, wind speed decreased by 0.20–0.26 $\text{m} \cdot \text{s}^{-1}$ during the 10-year period following the mutation. The abrupt decline in wind speed after 1983 aligns with findings from regional climate studies [?]. A secondary mutation in wind speed occurred in 1999 for the upper and lower reaches.

3.1.4 Relative Humidity Relative humidity demonstrated a decreasing trend over the study period, with the mutation occurring in 1993. The declining humidity, combined with increasing temperatures, indicates a trend toward drier conditions despite increased precipitation.

3.2 Runoff Characteristics

3.2.1 Runoff Trends Runoff at the Kaqung Hydrological Station showed a significant increasing trend from 1957 to 2015. Decadal average runoff volumes are presented in . The most dramatic change occurred in 1993, when runoff volume sharply increased by $9.08 \times 10^3 \text{ m}^3$. The year 2006 recorded the highest runoff volume in the entire time series, exceeding the long-term average by 6.61%. The mutation test identified 1993 as a significant turning point in the runoff series.

3.2.2 Correlation Analysis Correlation analysis revealed that runoff volume was positively correlated with mean air temperature and both minimum and maximum air temperatures during the wet season ($P < 0.05$). Conversely, runoff showed significant negative correlations with average wind speed, gale days, and relative humidity during the wet season. Interestingly, while runoff was positively correlated with dry season precipitation in the upper reaches, it exhibited negative correlations with precipitation in other areas of the basin.

This contrasting pattern reflects the dominant role of ice-snow meltwater (accounting for 77.4% of total runoff) in the basin's hydrological regime.

3.2.3 Sensitivity Analysis Sensitivity analysis demonstrated that runoff volume in the Yarkant River Basin is more responsive to temperature changes than precipitation changes. When precipitation remained constant and temperature increased by 1°C, runoff volume increased by 9.06%. However, when temperature remained unchanged and precipitation increased by 10%, runoff volume decreased by 1.67%. This inverse relationship occurs because increased precipitation is often associated with decreased temperature, which reduces glacier and snow melt. The resulting decrease in ice-snow meltwater recharge cannot be compensated by the increased precipitation, leading to an overall reduction in runoff. These findings confirm that runoff in the Yarkant River Basin is positively correlated with temperature but negatively correlated with precipitation, exhibiting greater sensitivity to temperature variations.

TABLE:2 The mutated years of climatic factors

Station	Temperature	Precipitation	Wind Speed	Relative Humidity
Upper Reach	1995	1996*	1992, 2000	1966, 1977, 1982
Middle Reach	2006*	1986	1973, 1977, 1989, 2002	1989
Lower Reach	1989	1966, 1972, 1983, 1996	2008	1982*
Basin Average	1985*	1985*	1981*	1987*

Note: Asterisks denote mutations significant at the 95% confidence level.

TABLE:3 Runoff volumes at Kaqung Hydrological Station in different decades

Period	Runoff Volume (10 ⁶ m ³)	Anomaly (10 ⁶ m ³)
1957-1960	63.97	-3.21
1961-1970	62.80	-4.38
1971-1980	66.02	-1.16
1981-1990	65.24	-1.94
1991-2000	68.04	0.86
2001-2015	72.44	5.26
1957-2015	67.18	—

Note: Figure translations are in progress. See original paper for figures.

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