Quaternary International xxx (2015) 1–10

Contents lists available at ScienceDirect

Quaternary International

journal homepage: www.elsevier.com/locate/quaint

Detecting changes in extreme streamflow in the Tarim River, Northwest China

Huaijun Wang [a, b], Yaning Chen [a, *], Haijun Deng [a, b], Yingping Pan [a, b]

[a] State Key Laboratory of Desert and Oasis Ecology, Xinjiang Institute of Ecology and Geography, Chinese Academy of Sciences, 818 South Beijing Road, Urumqi, Xinjiang, 830011, China
[b] University of Chinese Academy of Sciences, No.19A Yuquan Road, Beijing 100049, China

ARTICLE INFO

Article history:
Available online xxx

Keywords:
IHA model
Hydrological extremes
Human activities
Tarim River

ABSTRACT

We analyzed the characteristics of streamflow changes in the Tarim River Basin using daily data collected at 7 hydrological stations. We ran the nonparametric Mann–Kendall test to detect trends in hydrological extremes. We also applied the Indicators of Hydrological Alteration (IHA), to assess flow regime variations. The results indicate that: (1) the hydrological extremes in headwater experienced increases in magnitude, duration, and high flow frequency; the mainstream exhibited increases in low flow duration and low flow frequency, and a decrease in high percentile flow and high flow frequency; (2) The trends of extremes related to minimum flow is greater than maximum flow; the date of maximum flow in both the headwater and mainstream has advanced; the most drastic changes in extreme streamflow occurred during winter; (3) Climate change has considerably altered flow regime in the headwater. Although climate change has profoundly affected the water supply upstream, human activities are dominant in determining flow regime.

1. Introduction

In recent years, hydrological extremes, such as floods and droughts, frequently occur due to climate change (Wang et al., 2008; Mishra and Singh, 2011). It is very likely that the number of cold days (nights) has decreased and the number of warm days (nights) has increased on the global scale between 1951 and 2010. The number of heavy precipitation events over land has increased in more regions than it has decreased (Seneviratne, 2012). Changes in precipitation extremes are consistent with a wetter climate, although with a less spatially coherent pattern of change than temperature (Donat et al., 2013a, 2013b). Floods larger than recorded since the 20th century occurred during the past five centuries in northern and central Europe, the western Mediterranean region and eastern Asia. There is also medium confidence that in the Near East, India and central North America, modern large floods are comparable or surpass historical floods in magnitude and/or frequency (IPCC, 2013). Other studies for Europe (Petrow and Merz, 2009; Stahl et al., 2012; Forzieri et al., 2014) and Asia (Jiang, 2008; Delgado et al., 2010) show evidence for upward, downward or no trend in the magnitude and frequency of floods, so that there is currently no clear and widespread evidence for observed changes in flooding (IPCC, 2013).

Historical data also indicate the increased concentration of greenhouse gases in the atmosphere is likely to produce more hydrological extremes (Cunderlik and Simonovic, 2005; Zhang et al., 2011). Climate models and hydrological studies suggest that global warming may lead to change of characteristics of hydrological extreme events (Cunderlik and Simonovic, 2005; Burn et al., 2010; Taye et al., 2011). Hydrological extremes can cause major damages and losses, especially in densely populated and/or ecologically vulnerable areas (Biggs and Atkinson, 2011; Huttenlau and Stotter, 2011). For example, extreme droughts may cause crop failures, water supplies deficiency, and power production reduction at hydroelectric plants (Zelenhasic, 2002). Floods increase risks of diseases, cause social and economic disruptions, and place continuing stresses on public services (Alderman et al., 2012). In addition, hydrological extremes may lead to alteration of the flow regime (Yang et al., 2012). Such alterations may affect the composition, structure, and function of the local aquatic, wetland, and riparian ecosystems by modifying physical habitat characteristics, including water temperature, oxygen content, water chemistry, and substrate particle sizes (Richter et al., 1996, 1997).

* Corresponding author.
E-mail address: chenyn@ms.xjb.ac.cn (Y. Chen).

http://dx.doi.org/10.1016/j.quaint.2014.12.048
1040-6182/

The Tarim River is the largest inland river of China and a vital water resource in a vast arid area. It supports 40% of the population of Xinjiang, the largest provincial administration unit (in terms of area) and a strategic base of natural resources. Numerous studies have shown that this area is sensitive to climate change and regional responses to such changes are phenomenal (Chen et al., 2007, 2009). Particularly, several studies found significant trends in hydroclimatic variables, including annual precipitation, air temperature, and runoff (Chen et al., 2007; Xu et al., 2010; Zhang et al., 2010). They revealed that: 1) both temperature and precipitation have been increasing; and 2) the streamflow in the mountainous region has been increasing, whereas the mainstream has been decreasing.

However, most of those previous works on the hydrological changes in the Tarim River are limited to the average state of streamflow. Studies on changing characteristics of streamflow extremes in the Tarim River have been limited. We are not aware of works on the dynamics of hydrologic extremes and flow regime alteration caused by contemporary climate change and human activities. In this study, we used long-term discharge gauges to assess hydrological extremes and flow regime alterations in the Tarim River Basin during the last 50 years. The objectives of this study include: (1) to identify hydrologic extreme changes in magnitudes, intensity, frequency, timing and durations at annual, seasonal, and monthly scale; (2) to analyze flow variability using the IHA/RVA analysis.

2. Study area, data and methods

2.1. Study area

The Tarim River Basin, located between 34 and 45°N, 73 and 97°E, is the largest inland river basin in China (Fig. 1), with an area of 1.02 million km^2. The mean annual natural runoff of surface water is 3.98×10^{10} m^3, supplied by ice, snow, and precipitation in the mountains (Chen et al., 2011a). There used to be 114 rivers, belonging to nine water systems, flowing into the mainstream of the Tarim River, but only three water systems currently still have natural hydraulic relationships with the mainstream, including the Aksu River, Hotan River, and Yarkand River. Among the three, the Aksu River is the main contributor, supplying 73.2% of the total. The Hotan River and Yerkand River contribute 23.2% and 3.6%, respectively (Chen et al., 2007). The Tarim River Basin has an extreme drought desert climate with an average annual air temperature of 10.6–11.5 °C, and annual precipitation of 17.4–42.0 mm. Monthly mean air temperature ranges from 20 °C to 30 °C in July and from −10 °C to −20 °C in January (Chen et al., 2009). The annual precipitation ranges from 200 to 500 mm in the mountainous areas, 50–80 mm in the edge areas of the basin, and only 10 mm in the middle of the basin. The annual precipitation of the study area is 116.8 mm, and is unevenly distributed throughout the year, with more than 80% between May and October (Chen et al., 2009). During the past 50 years, the total precipitation and air temperature have increased significantly at the rate of 7.644 mm/decade ($P < 0.05$) and 0.286 C°/decade ($P < 0.01$), respectively, which implied that the climate in the Tarim River has become warmer and wetter.

2.2. Data

The daily hydrological data for 1960–2007 used in this study were collected at eight hydrological stations; we obtained the data from the Xinjiang Water Bureau, China (Fig. 1). Xehera and Sharikilank stations are on the Aksu River; the Kaqung station is on the Yarkand River; and the Tonguzluok and Wruwat stations are on the Hotan River. We sum up the streamflows from those five stations to approximate the runoff generated in the headwater area. The data obtained from Wruwat hydrological station was not taken into consideration, as its missing data exceed 1%. Because all the stations are located in the source areas of their rivers, the human-consumed water before the station point is minimal, compared to the total discharge of the river. Therefore, we assumed that the hydrological records at the station reflect the natural conditions at that point. The discharge from the three headwaters into the

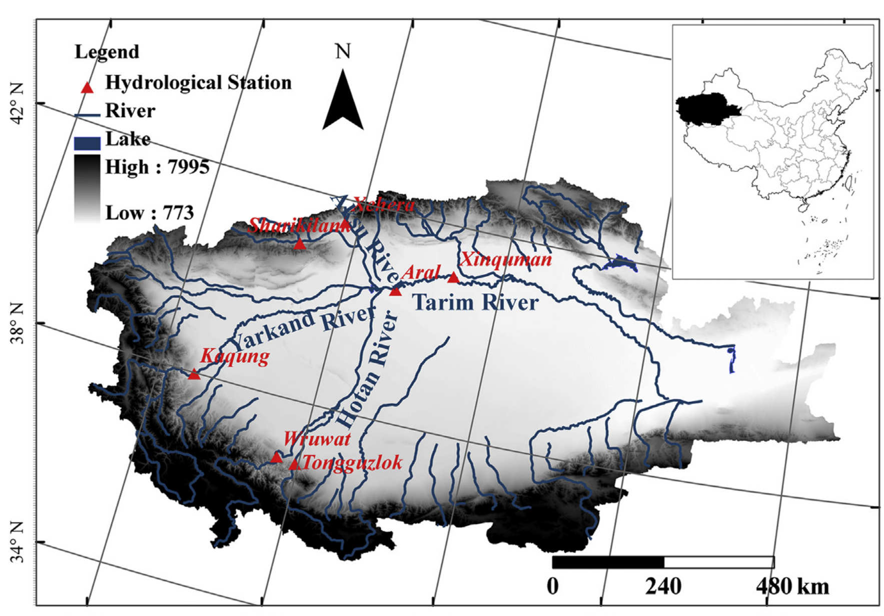

Fig. 1. Distribution of the river system in the Tarim River Basin.

Please cite this article in press as: Wang, H., et al., Detecting changes in extreme streamflow in the Tarim River, Northwest China, Quaternary International (2015), http://dx.doi.org/10.1016/j.quaint.2014.12.048