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Streamflow variability for the Aksu River on the southern slopes of the Tien Shan inferred from tree ring records

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ABSTRACT

Gauged river flow records from China generally span only a few decades, which hampers the detection of long-term, decadal- to centennial-scale cycles and trends in streamflow variability. New and updated tree-ring chronologies help reconstructed the water-year (October–September) streamflow for the Aksu River, which is an important river at the edge of the Taklimakan Desert that drains into the Tarim Basin. The reconstruction dates back to 1692 and has an adjusted r^2 of 0.61 (1957–2006). Based on frequency, intensity and duration of droughts and pluvial events, the lowest streamflows occurred in the 1920s. Since then streamflow has continuously increased, and was exceptionally rapidly after the 1960s, until today. The start and end of the 20th century to the present were the highest streamflow periods. The mid-20th century was the longest and driest period over the past 300 yr. The reconstructed streamflow series has a strong positive correlation with the North Atlantic Oscillation Index. Changes in mid-latitude circulation patterns influencing precipitation may have indirectly resulted in streamflow variations along the Aksu River over the past 300 yr. The rapid increase and the exceptional streamflows of the 1960s are likely linked with global warming and mid-latitude atmospheric circulation changes.

Introduction

The climate in northwestern China has been changing, most notably in Xinjiang, since the 1980s responding to human-induced global climate change. Precipitation, glacial meltwater, river runoff, and air temperature have all increased continuously over the past few decades (Shi et al., 2007). Increased river streamflow is beneficial to economic and societal development; however, it can also have disastrous consequences such as flooding. The Aksu River (40° 20′–41° 15′N, 80° 00′–81° 00′E) located on the southern slopes of the Tien Shan and the northwest edge of the Taklimakan Desert and is one of the main rivers in southern Xinjiang and an important tributary of the Tarim River, the largest inland river in China (Fig. 1). In terms of streamflow, the Aksu River is the largest of the three major tributaries (Aksu, Hotan, and Yarkant Rivers), providing up to 75% of the water for the Tarim River (Deng, 2011). Variations in the Aksu River's streamflow have an important impact on oasis agriculture, and the ecosystem and social stability of southern Xinjiang. Streamflow records in China are, in most cases, limited to the past few decades. Such relatively short records are conventionally used as a basis for planning and engineering design, but they are too short to properly determine true streamflow frequency, severity, and duration of dry and wet events. Tao et al. (2009) showed that the temperature, precipitation, and river streamflow in the Aksu River Basin have increased distinctly over the past 45 yr, but remarkably little is known about its possible driving mechanisms. Furthermore, it is not clear how the Aksu River's flow has changed over the past 300 yr as a consequence of human-induced global climate change. We must, therefore, use other proxy data to understand the long-term natural variability of streamflow for the Aksu River.

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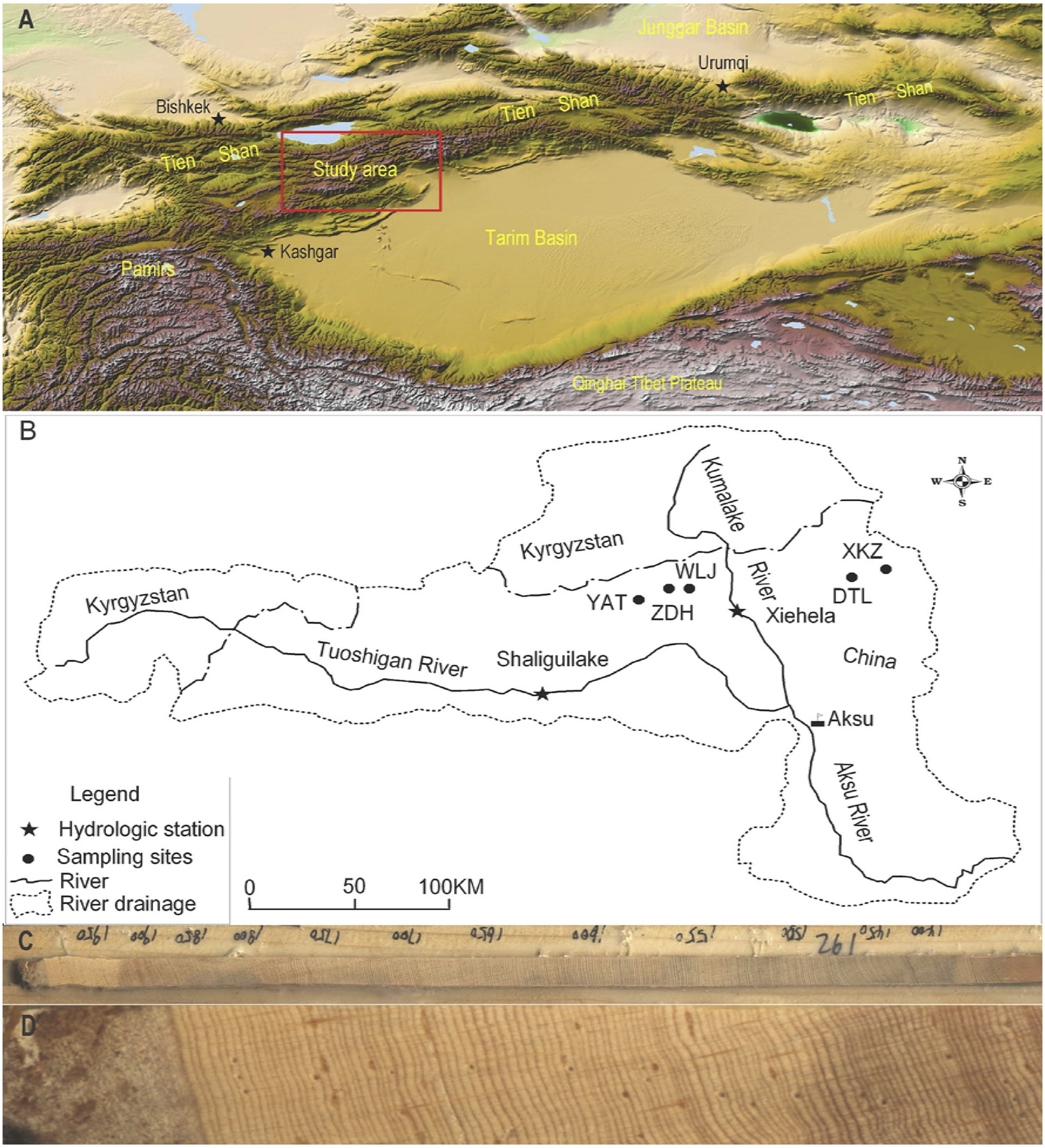

Figure 1. A) and B). Locations of tree-ring sampling sites and hydrologic stations. C). 600-year-old tree-ring in Wulijielike (WLJ) site. D). Tree-ring width changes of the previous 100 yr.

Tree-ring data are widely used as reliable proxies for streamflow, and they can be used to assess the long-term discharge behavior of a river and its management in various water resource sectors from the different regions of the world (e.g., Pederson et al., 2001, 2013; Davi et al., 2006, 2013; Akkemik et al., 2008; D'Arrigo et al., 2011; Margolis et al., 2011; Meko and Woodhouse, 2011; Leland et al., 2013; Cook et al., 2013; Shah et al., 2013, 2014). Dendroclimatology studies in China have mainly focused on the arid northwestern region and on the Tibetan Plateau (Zhang et al., 2015a,b). The field has also developed in the northeastern and subtropical regions in recent years (Duan et al., 2012; Chen et al., 2012). In terms of long-term climate reconstruction, Shao et al. (2010) developed the longest (3585 yr) tree-ring-width chronology for China. Yang et al. (2014) reconstructed a 3500-yr annual precipitation record for the northeastern Tibetan Plateau. Liu et al. (2011) analyzed amplitudes, rates, periodicities, causes, and future trends of the temperature variations for the past 2485 yr for the central-eastern Tibetan Plateau. Tree-ring based hydrometeorological reconstruction has been developed for many areas of China, such as the upper Yellow (Gou et al., 2007, 2010) and Heihe (Liu et al., 2010; Yang et al., 2011) rivers. The tree-ring response to climate is more sensitive in Xinjiang because it is located in central arid Asia, and precipitation and temperature series spanning more centuries have been reconstructed using dendroclimatological methods. Previous studies have shown the tree-ring width response to precipitation (Yuan et al., 2000, 2001, 2003; Wei et al., 2008; Zhang et al., 2009,