



# Spatiotemporal variability of temperature and precipitation in Gansu Province (Northwest China) during 1951–2015



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## ABSTRACT

Climate change is potentially challenging the sustainable development in many parts of the world, especially the semi-arid and arid regions on the earth. Northwest China (NWC) is one of the most arid areas in East Asia, and Gansu Province is located at the important climate transition zone in NWC. Spatiotemporal variability of both temperature and precipitation were analyzed based on the daily observation dataset at 29 meteorological stations over Gansu during 1951–2015. The Mann–Kendall trend test was utilized to detect monotonic trends in extreme climate indices, mean temperature, and total precipitation. The results revealed that the warming trends were statistically significant at most stations in Gansu, especially at the high altitude stations; however, the change trends in annual and seasonal precipitation over Gansu were not significant as expected. Furthermore, the 29 stations were spatially grouped using hierarchical clustering method. The regional-averaged temperature anomalies also showed a significant warming trend beginning at the end of 1970s. Spatial variations were also observed in the annual and seasonal precipitation over Gansu. In general, precipitation increased in the western part of Gansu while decreased in the eastern part. Additionally, the wavelet analyses revealed that the teleconnection between large scale circulation and summer precipitation varied not only from region to region, but also was different at different time scale and different time periods. Analysis of large-scale atmospheric circulation changes showed that a strengthening anticyclonic circulation, increasing geopotential height and rapid warming over the Eurasian continent were considered to be attributable to climate change in Gansu and even in NWC.

## 1. Introduction

Recent studies have revealed a significant global warming trend during the past century (Easterling et al., 2000; Yan et al., 2002; Brohan et al., 2006; Gay-Garcia et al., 2009; IPCC, 2014). Global warming in turn leads to a higher moisture content in the atmosphere and then potentially affects the global hydrological cycle (Trenberth, 2011). It was estimated that global land precipitation increased by approximately 2% over the 20th century (New et al., 2001), resulting a slight overall increase in global river runoff and in average soil moisture (Huntington, 2006). For decades, global changes in temperature and precipitation have been extensively investigated using long-term observational data (Klein Tank et al., 2002; Alexander et al., 2006). Evident regional differences in the temperature and precipitation change on global scale were also observed (Houghton et al., 2001; Alexander et al., 2006). The Intergovernmental Panel on Climate Change (IPCC) suggested that it was necessary to study climate change on regional and local scales, which was of particular importance to nations and

economic groups to response climate change (IPCC, 2007).

Semi-arid and arid regions of the world are often considered as being particularly vulnerable to climate change due to warming and drying (Sarr, 2012; Revi et al., 2015). Gansu Province (32°31′–42°57′ N and 92°13′–108°46′ E) is located in Northwest China (NWC), one of the most arid areas in East Asia. Regarding the area (0.45 million km<sup>2</sup>) across the province level in China, Gansu is merely a moderate-sized administrative province, but stretches over 1400 km from southeast to northwest (Fig. 1). Gansu Province covers multiple climate types from humid (in southwest) to semi-humid, and then to semi-arid and arid. Generally, the summer is warm and hot while the winter is cool and cold. Some high altitude areas of Gansu also exhibit a subarctic climate, and the snow line can be as high as 5500 m above sea level. The annual total precipitation ranges from 40 mm to 800 mm with a drying gradient from southeast to northwest (H.X. Wang et al., 2013; H.J. Wang et al., 2013). The spatial variabilities in precipitation are attributable to the combing effects of monsoon system and topography. Besides spatial variabilities, there are significant temporal variabilities in the

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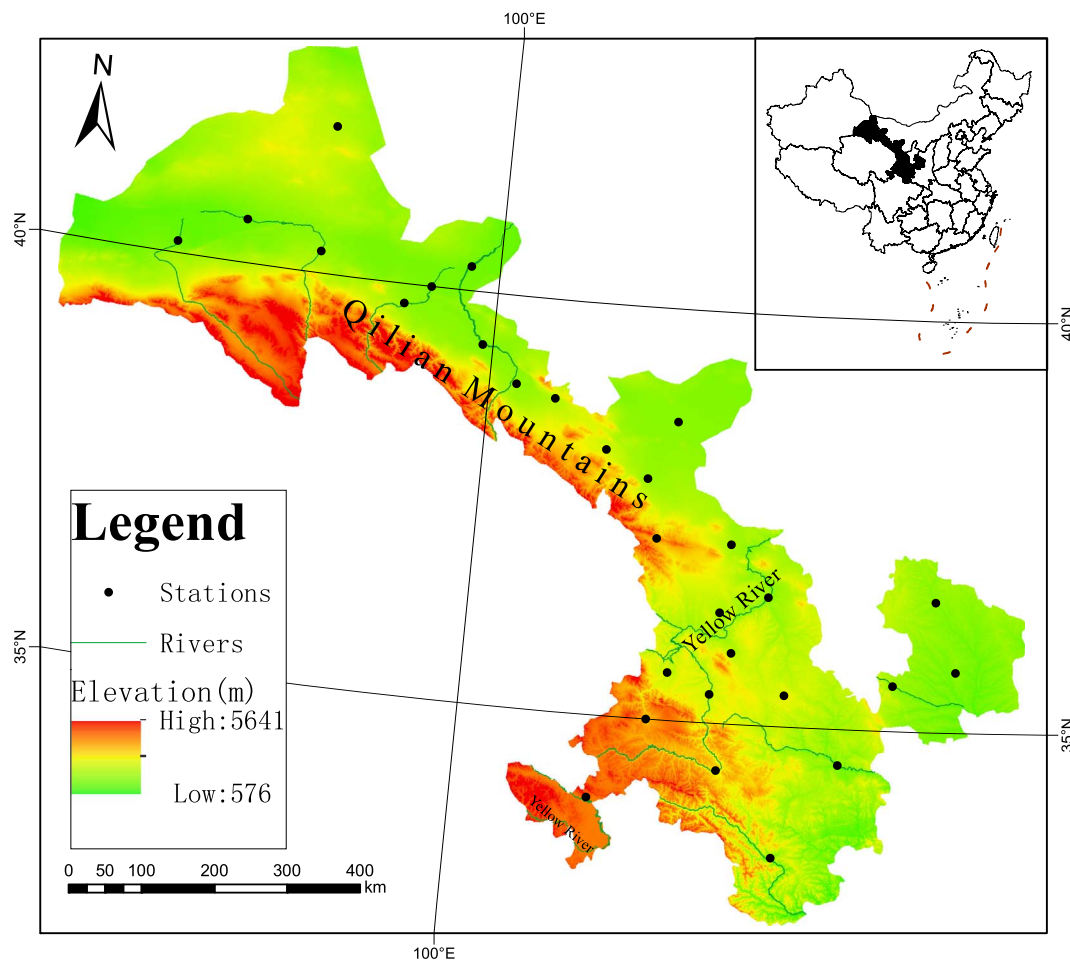


Fig. 1. Map of Gansu Province showing the topography and locations of the selected 29 meteorological stations.

precipitations in Gansu. Within each year, most of the precipitation is delivered in summer, and there are also significant inter-annual and inter-decadal variability in the precipitation. The limited precipitation is extremely critical to the irrigated agriculture and oasis eco-environment in Gansu. However, spatiotemporal variability in precipitation negatively affects the human use of water resources and limits the socio-economic development in Gansu, especially in the central and western parts of Gansu. Additionally, Gansu lies among the Tibetan Plateau, the Mongolian Plateau, and the Loess Plateau. The vast majority of its land is higher than 1000 m above the sea level with a mountainous landscape (Fig.1). Mountainous and highland regions are especially sensitive and vulnerable to extreme climate change (Beniston et al., 1997; Diaz et al., 2003). Due to climate change, the frequency and intensity of climate extremes, such as floods, droughts and heat waves, have significantly increased (IPCC, 2012). Because of low level of vegetation cover, heavy rainfalls easily cause natural hazards such as floods and mudslides in mountainous areas in Gansu. On August 8th 2010, a severe mudslide caused by heavy rainfall and flooding occurred in Zhugqu county, southern Gansu. It left 1557 people dead and 208

missed, and the estimated economic loss reached 13.3 billion CNY (about 1.94 billion USD) (Xinhua News, 2015). Therefore, it is worthy to study the changes in climate extremes in Gansu under the background of global climate change.

In an administrative division, the Gansu Province belongs to NWC; however, in a traditional natural division, the Gansu Province is a region covering all three zones (Arid Northwest China, Monsoon East China and Tibetan Plateau) or four zones (Arid Northwest China, Monsoon North China, Monsoon South China and Tibetan Plateau). Great efforts have been made to characterize the spatiotemporal variability of temperature and precipitation, especially the change of climate extremes in NWC. H.X. Wang et al. (2013) and H.J. Wang et al. (2013) studied the spatial distribution and temporal trends of the mean precipitation and extremes in the NWC including the Xinjiang and the western part of Gansu, during 1960–2010. Li et al. (2013) compared the temperature and precipitation changes in three different landscapes, mountain, oasis, and the desert areas, in NWC. Li et al. (2016) identified the possible causes of the significant increasing trend of precipitation in the NWC during 1960–2010. Yang et al. (2017) analyzed the

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