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Climate variations in northern Xinjiang of China over the past 50 years under global warming

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ABSTRACT

Based on the data of five observed meteorological elements (temperature, precipitation, wind speed, sunshine duration, and relative humidity) from 22 stations, the paper investigated the climate variations in northern Xinjiang over the past 50 years. The analytical results showed that both the temperature and the precipitation have increased significantly (0.35 °C/10 y, 11.2 mm/10 y) during the period of 1960–2011. An abrupt change was detected to have occurred in 1986 for temperature and in 1987 for precipitation. Autumn was the season when the temperature increased most dramatically, and winter and autumn were the seasons when the precipitation increased most dramatically. The twenty years after 1990 were the warmest and wettest two decades of the past ~50 years, but the warming and wetting paces have slowed down during the same period. The results also showed that the mean annual minimum temperature increased more dramatically than the mean annual maximum temperature, resulting in a greatly reduced diurnal range. The reasons or mechanisms for rising trend of temperature during the past 50 years and also for the faster rising rate of the temperature in northern Xinjiang and the adjacent areas have been reasonably explored in published literature. However, the reasons or mechanisms for the rising trend of the past 50-year precipitation in northern Xinjiang and the adjacent areas have not been reasonably explored. This wetting trend has not extended further to the surrounding areas including Republic of Mongolia, major part of North China, and five republics of the former Soviet Union, and the need is thus pressing to explore the reasons or mechanisms behind this relatively "localized" wetting trend.

1. Introduction

The latest climate change assessment report AR5 (IPCC, 2013) shows a global temperature increase of about 0.89 °C over the past ~110 years (from 1901 to 2012). However, regional differences in the increase were well documented. For example, during the warm period of the 1920s–1940s, temperature increased much more dramatically in North America, Africa and Arctic than in Europe, Asia, and Australia (Jones and Moberg, 2003). Over the past ~50 years (from 1960 to 2012), temperature was observed to have increased in most parts of the world (Easterling et al., 2000; Klein Tank et al., 2006; Kysely and Romana, 2009; Hu et al., 2014). The precipitation was also observed to have increased, but to a lesser extent. The precipitation increased significantly mainly in the middle and high latitudes of northern hemisphere (Zhai and Pan, 2003; Qian et al., 2007; Ren et al., 2010; Chen et al., 2011; Shen et al., 2013; Wang et al., 2013a, 2013b; Chen et al., 2014). This paper focuses on Northern Xinjiang to explore the geographic characteristics of climate change during the past ~50 years, in the hope that the IPCC-delineated patterns of climate change can be spatially refined.

Northern Xinjiang lies in the northwestern corner of China (Fig. 1) and is also a part of Central Asia. The climate in northern Xinjiang has its unique characteristics compared with those in other parts of China and also with those in other parts of Central Asia because of its unique topographies and underlying surfaces (Shi et al., 2003; Wang et al., 2004; Chen et al., 2010a; Li et al., 2012; Huang et al., 2013). There have been some studies concerned with climate change in northern Xinjiang (Mao et al., 2006; Xin et al., 2008; Zhao et al., 2011a; Zhang et al., 2013a). Two issues are calling for further attention. First, much attention was paid to the changes in temperature and precipitation and little attention was directed to the changes in other meteorological elements. Second, although most of published works agreed that both precipitation

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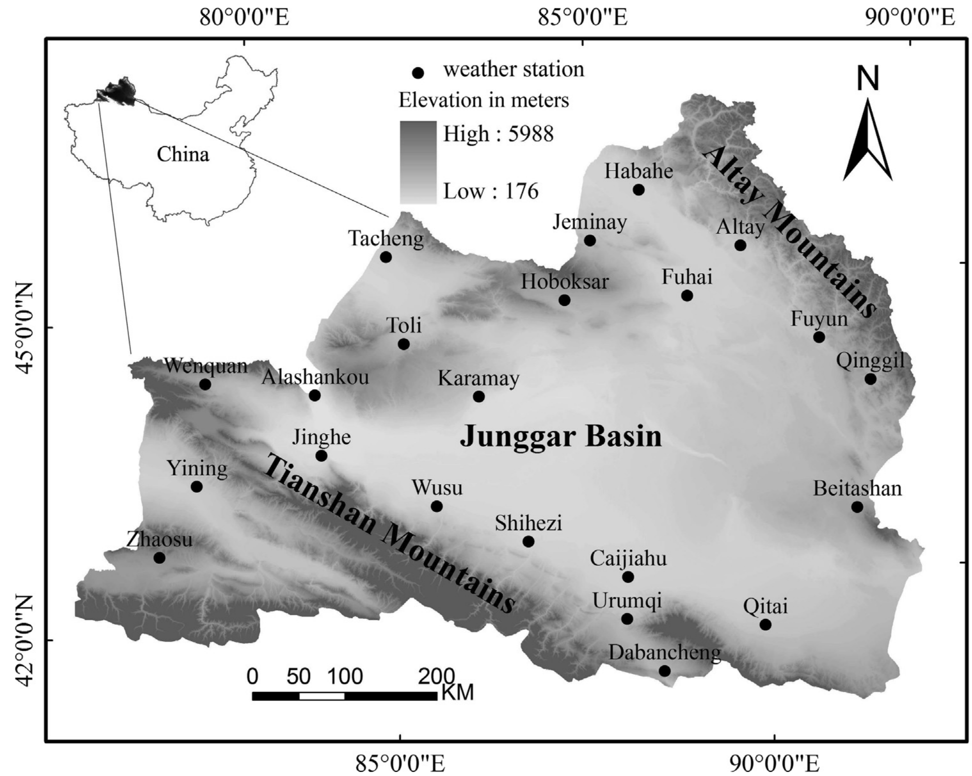

Fig. 1. Sketch map of the northern Xinjiang and the locations of meteorological stations.

and temperature in northern Xinjiang have increased over the past ~50 years, inconsistencies in delineated temporal trends and spatial patterns are readily visible among the published works, primarily resulting from such factors as the observed data-covering time length, selected data-covering time span for delineating the temporal trends, and selected stations participating for delineating the spatial patterns. This paper used the data covering the period 1960–2011 from 22 stations that have acceptable data-quality controls to investigate the temporal trends and the spatial patterns of the changes in temperature and precipitation. At the same time, the changes in wind speed, sunshine duration, and relative humidity were also analyzed to refine our understanding of regional response to the global climate change.

2. Data and methods

2.1. Data

Data analyzed in this paper include five observed daily meteorological elements (i.e. temperature, precipitation, wind speed, sunshine duration and humid relativity) and were downloaded from China Meteorological Data Sharing Service System (http://cdc.cma.gov.cn). The data have been pre-disposed through the strict quality control and homogenized by China Meteorological Administration. Stations with >%5 data missing were rejected in this study. Totally, 22 meteorological stations were selected (Fig. 1) and minor data gaps (i.e., data missing of <5%) were filled by averaging the data from the immediate preceding period and the data from the immediate following period.

2.2. Methods

The Mann–Kendall non-parametric test is widely applied to detect the significance of trend change and determine the occurrence of abrupt change points in meteorological and hydrologic series (Wei, 1999; Yue et al., 2002). Advantages of the method are that the normal distribution of data is not expected; the result is seldom influenced by the fewer abnormal values; and the calculation is simple.

(a) Mann–Kendall test for monotonic trend

The trend test has two hypotheses, null hypothesis H_0 and alternative hypothesis H_1. H_0 is that the data ($X_1, X_2, \ldots, X_n$) are a sample of n independent and identically distributed random variables. H_1 of a two-tailed test is that the distribution of X_i and X_j are not identical for all i, j. The test statistic S is given by

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} \operatorname{sgn}(x_j - x_i) \tag{1}$$

in which X_i and X_j are the sequential data values, n is the length of the data set, and

$$\operatorname{sgn}(\theta) = \begin{cases} +1 & \theta > 0 \\ 0 & \theta = 0 \\ -1 & \theta < 0 \end{cases} \tag{2}$$

Particularly, if the sample size is larger than ten, the statistic S is nearly normally distributed, i.e., the statistic

$$Z_c = \begin{cases} \dfrac{S-1}{\sqrt{\operatorname{var}(S)}} & S > 0 \\ 0 & S = 0 \\ \dfrac{S+1}{\sqrt{\operatorname{var}(S)}} & S < 0 \end{cases} \tag{3}$$