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Brief communication
"Assessment of change in temperature and precipitation over Xinjiang, China"

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Abstract. Climate changes seriously affect people's daily life. Temperature and precipitation have been the focus of many studies dealing with regional climate changes in recent decades. In this study, the climatic trends in Xinjiang, northwest of China during 1961–2008 are analysed in detail on the basis of several parameters: annual and seasonal mean precipitation, and annual mean, minimum, and maximum temperatures. The results show a significant increasing trend of 7.40 mm decade^{-1} in the annual mean precipitation and a relatively minimal upward trend of 1.45 mm decade^{-1} in winter in Xinjiang. The annual mean temperature increases significantly in Xinjiang with an increasing trend of 0.30 °C decade^{-1}. There is an increasing trend of 0.25 °C decade^{-1} in the annual maximum temperature and an increasing trend of 0.52 °C decade^{-1} in the annual minimum temperature.

1 Introduction

One focus of study in recent years has been the investigation of the observed trends/changes in both the long-term climatic mean state and the intensity (Easterling et al., 2000; Manton et al., 2001). Obviously these studies are important for understanding the projection of future climate change. Especially, temperature and precipitation have been the focus dealing with climate change on both a regional and global scale, since they play an important role in the global water and energy cycle. On the other hand, there is also a general perception that the number, intensity and frequency of extreme events have increased worldwide in the past decade. For example, since 1880s, the temperature in 2008 is ranked as the 9th warmest year on record, at the same time the warmest years were recorded from 1997 to 2008 (Xu et al., 2009). Europe has experienced several extreme events, such as the Central European flood in the summer of 2002, and the heat wave in the summer of 2003 (STARDEX, 2007). Analysing the annual precipitation, Karl et al. (1996) reported that an increasing trend of highly intense precipitation spreaded across the United States in the period of 1910 to 1996. Since the 1990s, the frequency of floods on the seven big rivers in China was of high frequency, and both floods and geological disasters have increased due to the increase of intense precipitation (e.g. Zhang et al., 2008). The extreme hot day index increased greatly, while the frost day index decreased significantly in northern China, especially in northeastern China and Xinjiang (Zhai et al., 2003). Yang (2003) found no significant trends in annual precipitation but a significant increase in above normal mean intensity of precipitation in Xinjiang during 1961–2000.

In this study, we extend the previous analyses of precipitation and temperature trends over Xinjiang, and study the inter-relation between circulation trends and trends in both seasonal precipitation in summer and winter based on the

daily observed data of temperature and precipitation, which include 50 meteorological stations from 1961 to 2008.

2 Study region and data

Xinjiang Uygur Autonomous Region (Xinjiang) is located far away from oceans and is well known for an arid climate pattern. As one of the largest provinces in China, Xinjiang has an area of 1.6 million square kilometres. Two deserts, Taklimakan and Gurbantunggut, are at the foot of three mountains (Atay Mts, Tianshan Mts, and Kunlun Mts) (Chen, 2010). All these make complex topography and different climatic sub-regions in this area. Located in the middle latitude, this region is considered as a sensitive area to global change.

The observed daily precipitation data from 54 stations were obtained from the Chinese National Meteorological Centre for 1 January 1951–31 December 2008. The density of stations is not homogeneous; it is particularly low in the sparsely populated high mountainous and desert/semi-desert areas of west and south Xinjiang. To avoid bias in the trend analysis due to the missing data, we restrict our analysis to the period from 1961–2008. For this period, four stations have missing data. In total, the missing data accounts for 0.1 % of the data series. The missing data were interpolated by using a simple linear correlation method between its neighboring stations. Finally, 50 stations, whose locations are shown in Fig. 1, are chosen in this study.

3 The Climate during 1961–2008

3.1 The temperature during 1961–2008

The annual mean temperature for the period of 1961–2008 in Xinjiang was 7.8 °C. The mean daily minimum temperature was 1.5 °C. The daily maximum temperature for the region was 14.8 °C. Examination of a plot of annual temperatures reveals one distinguished feature: temperature varied gently with a slight decrease before 1984, and then climbed markedly after 1984. The linear least square regression analysis of mean, minimum, and maximum temperatures in 48 yr shows that Xinjiang has a warming trend (Fig. 2). The general 48-yr trends reveal that mean, minimum, and maximum temperatures increased by 0.30 °C decade^{-1}, 0.25 °C decade^{-1}, and 0.52 °C decade^{-1}, respectively. Importantly, the minimum temperature trend was more pronounced than that of mean and maximum temperature over 48 yr (Table 1).

Recently, many studies have reported that global mean temperatures decreased for about 25 yr between the late 1940s and 1970s. Aerosols of anthropogenic origin perhaps lead to this temperature variation, but most climate scientists now believe that it was in fact an expression of natural variability (Johannessen et al., 2004; Tourpali, 2005). At the time this decrease was widely attributed to the so-called "human volcano". But during the period 1980–2008, temperatures trended to increase to higher-average annual, average minima and average maxima. Many scientists come to different conclusions, e.g. Shi et al. (2003) showed that under global warming, the climate in the northwest China was basically characterized by the warm-dry climate pattern since the end of the little ice age until 1980s. However, an obvious climate pattern shift from warm-dry to warm-wet with a roughly decadal fluctuation has occurred in the middle of 1980s in northwest China.

3.2 Precipitation during 1961–2008

The mean multi-year precipitation for the period of 1961–2008 in Xinjiang region was 130.1 mm (Fig. 3 and Table 2). The linear least square regression analysis reveals that the precipitation has increased at the rate of 0.74 mm yr^{-1} over the last 48 yr (Fig .3a). As reported earlier, the inter-annual pattern, which is one dominated by variability, with many "wet" years/periods and at least as many "dry" ones. Particularly noteworthy among the latter was the infamous drought of 1961–1965, Xinjiang is well known for an arid climate and drought is a serious natural disaster (Jiang et al., 2004). During the drought stage in the 1961–1965, the mean annual precipitation region-wide fell to 112.8 mm (and only 103 mm in 1962), an event which caused widespread hardship still bitterly recalled throughout Xinjiang.

The majority of annual precipitation recorded in Xinjiang comes during the Summer, although, as earlier noticed, this is somewhat deceiving because it is so hot, the mean potential evaporation or moisture loss values of these months far exceeds the moisture "income" in the form of rains. In other words, the rainy season is actually the dry season, i.e. the period of the year experiencing the largest average moisture deficiencies. The median of average annual summer (April–September) rainfall for the region is 60.3 mm and temperature is over 25 °C.

Examination of the half century-long plot (Fig. 3) reveals that the general increase trend (Fig. 3b) at the rate of 0.33 mm yr^{-1} can be found for the summer precipitation, and the summer rainfall was if anything more prone to exaggerated variability than was annual precipitation. This is not particularly surprising, as the six-month "summer" includes the month of September, during which the region sometimes experiences heavy rains.

The winter climate in Xinjiang is relatively dry. The median of average winter (January) precipitation for the period 1961–2008 was 12.5 mm, less than 10 % of the yearly mean. Compared to that of mean total precipitation and summer precipitation, the winter precipitation has a relatively less increase tendency of 0.17 mm yr^{-1} (Fig. 3c). The linear trends, their determination coefficients and the result of the statistical test for the regression coefficient are listed in Table 3. It can be found from Table 3 that temperature and precipitation increase during 1961–2008 at 95 % confidence level.

Table 1. Mean annual temperature, mean annual minimum temperature and mean annual maximum temperature of Xinjiang during 1961–2008.

Year	Mean annual maximum temperature (°C)		Mean annual temperature (°C)		Mean annual minimum temperature (°C)	
	Yearly average	5-yr running average	Yearly average	5-yr running average	Yearly average	5-yr running average
1961	15.0	14.9	7.7	7.6	1.4	1.2
1966	15.0	15.0	7.7	7.6	1.4	1.2
1971	14.1	15.4	7.2	8.4	0.8	1.1
1976	14.9	14.7	7.5	7.6	1.1	0.9
1981	14.1	14.6	6.7	7.3	0.2	1.1
1986	14.1	14.2	7.2	7.3	1.0	0.9
1991	14.4	14.5	7.4	7.7	1.1	1.4
1996	14.9	14.5	7.9	7.6	1.6	1.4
2001	14.0	15.1	7.3	8.2	1.0	1.9
2006	15.3	15.0	8.4	8.3	2.2	2.3
48 yr mean	14.8	14.9	7.8	7.9	1.5	1.6

Table 2. Mean annual total precipitation, mean annual summer precipitation and mean annual winter precipitation.

Year	Mean annual total precipitation (mm)		Mean annual summer precipitation (mm)		Mean annual winter precipitation (mm)	
	Yearly average	5-yr running average	Yearly average	5-yr running average	Yearly average	5-yr running average
1961	109.0	131.5	56.1	61.2	7.0	12.5
1966	142.4	132.9	61.1	59.4	17.2	13.6
1971	134.2	129.1	57.8	61.2	14.6	13.4
1976	125.4	133.7	53.8	64.6	13.3	13.7
1981	146.6	136.2	77.3	67.1	10.2	13.7
1986	115.8	131.1	47.2	60.7	12.6	16.1
1991	123.3	134.9	69.9	64.1	16.3	17.0
1996	157.5	138.8	74.8	62.2	16.2	17.2
2001	137.6	129.4	66.5	55.9	13.4	17.7
2006	121.3	121.3	45.3	45.3	22.0	22.0
48 yr mean	130.1	130.8	60.3	60.5	12.5	12.7

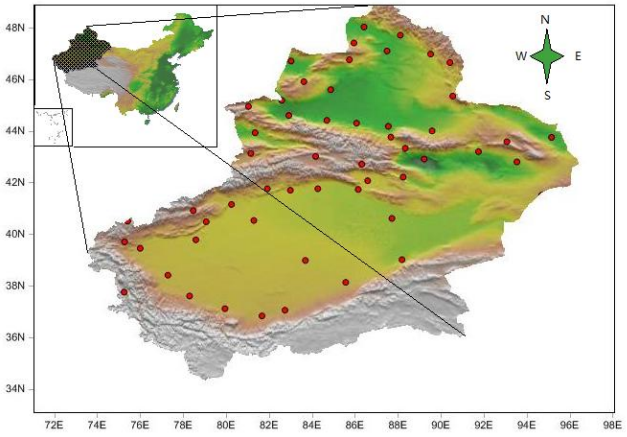

Fig. 1. Location map of Xinjiang.

Table 3. Linear trends of the 6 series.

		Line trend
Temperature (°C yr^{-1})	Annual mean	0.03*
	Maximum	0.05*
	Minimum	0.02*
Prepicitation (mm yr^{-1})	Annual mean	0.74*
	Summer mean	0.33*
	Winter mean	0.17*

* Means significant at the 95 % level assessed by a t-test.

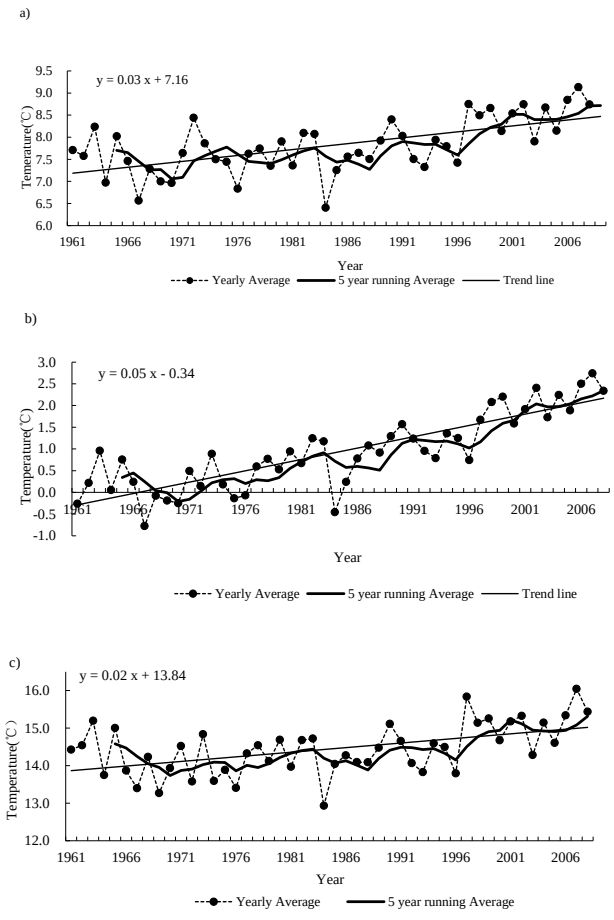

Fig. 2. Mean annual temperature **(a)**, mean annual minimum temperature **(b)**, and mean annual maximum temperature **(c)** of Xinjiang during 1961–2008.

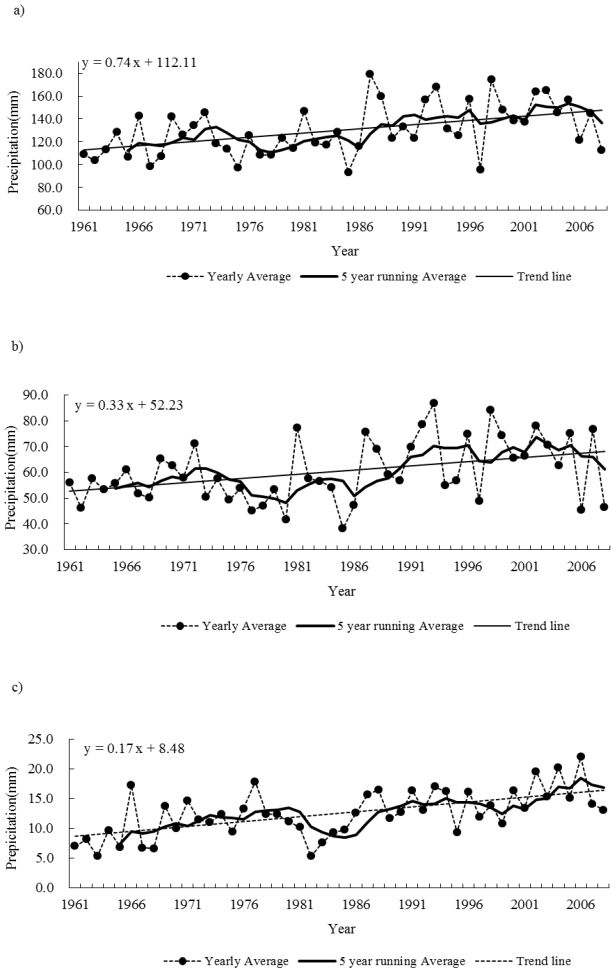

Fig. 3. Mean annual total precipitation **(a)**, mean annual summer precipitation **(b)**, and mean annual winter precipitation **(c)** of Xinjiang during 1961–2008.

4 Conclusions

Based on high quality daily observed data from 50 meteorological stations in Xinjiang during 1961–2008, the trends of annual and seasonal mean precipitation and temperature were analyzed. The results show that the annual mean precipitation increases significantly in Xinjiang. The increasing trend in the summer season is significant, while not significant in other seasons. Increasing trends in both minimum and maximum temperature are also found. The annual maximum, minimum, and mean trends are 0.30 °C decade^{-1}, 0.25 °C decade^{-1} and 0.52 °C decade^{-1}, respectively. The relationship between temperature and precipitation trends discussed in this study will help to understand the physical processes underlying the observed precipitation and temperature trends, and can be used to study the climate variability and climate change in coupled model simulations in future projects.

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