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Climate change in Urumqi City during 1960–2013

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ABSTRACT

Based on the long-term trends analysis of five meteorological parameters (temperature, precipitation, wind speed, sunshine duration and relative humidity) in the four chosen stations of different settings, this paper attempts to reveal the characteristics of climate change in Urumqi City during 1960–2013. Our analytical results showed that both the temperature and precipitation in the Urumqi City have increased significantly since the middle 1980s. Autumn was the season when the temperature increased most drastically, and winter was the season when the precipitation increased most drastically. The average minimum temperature increased faster than the average maximum temperature, thus resulting in greatly reduced diurnal and annual temperature ranges. The wind speed was weakening significantly since the middle 1980s. The sunshine duration did not display any geographic coherence or consistency among different stations. The relative humidity has maintained more or less a constant, meaning that the absolute amount of water vapor has been increased under warming conditions. Comparatively, the Urumqi station (i.e., the urbanized area) had the most pronounced changes in temperature, precipitation and sunshine duration and the most pronounced changes were possibly due to the combined effects of natural and anthropogenic factors. Climate change in the mountainous area was synchronous with that in the plain area and the underlying surfaces and topographies, together with degrees of human activities, distinguished the regional climatic responses to global warming.

1. Introduction

The global temperature increased about 0.89 C° over the period 1901–2012 (IPCC, 2013). The adverse effects of the observed warming and the expected future warming can be exacerbated in cities where human population is dense and human activities are intense. Karl and Diaz (1988) analyzed the data of 1219 stations from the U.S. Historical Climatology Network and pointed out that the annual mean temperature affected by urbanization was about 0.06 C° over the period 1901–1984 in the United States. Hansen and Lebedeff (1987) eliminated the data from the stations associated with population centers which had more than 100,000 people in 1970 and found that the global average temperature decreased from 0.7 C° to 0.6 C° during 1880–1985. A similar finding was reported that the surface air temperature over the eastern United States increased only by 0.02 C° during the period 1920–1984 despite the impact of urbanization (Balling and Idso, 1989). It is apparent that scientific communities were not yet confident in claiming that all of the observed warming resulted from human addition of CO_2 to the atmosphere and that the urban effect is one such uncertainty. It is thus critical to assess the effect of urbanization on the observed global warming contribution in different climatic settings.

Urumqi City is located on the northern slope of Tianshan Mountains of Xinjiang in northwest China, where the westerly circulation is the dominant climate system. With global warming, the heat and water status of the westerly circulation changed and the change consequently affected the areas influenced by the westerly circulation. During the past ~50 years, Central Asia has witnessed a significant increase of temperature (Wang et al., 2008a; Huang et al., 2013), and a much small area including Xinjiang and the adjacent areas within the Central Asia unexpectedly experienced a notable increase in precipitation (Ren and Yang, 2007; Chen et al., 2011). Was the temperature and precipitation increasing related to urbanization? Urumqi City lies in Xinjiang. The previous study on the climate change in Urumqi City paid more

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attention to the urban heat island issues (Li et al., 2007; Gong and Lv, 2009; Wang et al., 2009; Li et al., 2010) and other factors, such as precipitation, humidity, wind speed and sunshine, were less focused on (Pu et al., 2005; Wu et al., 2008; Li et al., 2009; Cheng, 2010; Liu et al., 2010). This paper selected four meteorological stations under the different settings and different degrees of urbanization to investigate the temporal patters of climate change and the possible mechanisms in Urumqi City during 1960–2013.

2. Study area

Urumqi City (42°45′~45°00′N; 86°37′~88°58′E), the capital of Xinjiang Uygur Autonomous Region, is located on the northern slope of Tianshan Mountains and in the southern margin of Junggar Basin. There are seven districts (Tianshan, Shayibake, Shuimogou, Gaoxin-Xinshi, Kaifa-Toutun, Midong and Dabancheng) and one county (Urumqi County) under the administration of Urumqi City. It covers an area of 1.4×10^4 km^2 with about 50% of the total area being mountainous. Thus, the urbanized area only refers to the several core districts with relatively small areas, and the other large area is suburban and rural. Its elevations range from 490 to 5445 m, with an average of 800 m. Urumqi City is far from any sea and the climate here belongs to the semi-arid temperate continental zone. The diurnal temperature difference is large and the four seasons are rather distinct. Precipitation is scarce and normally increases with elevation. Affected by high pressure and topography, Urumqi City is often controlled by orographic temperature inversions in winter.

3. Material and methods

3.1. Data and observation stations

Five meteorological parameters (temperature, precipitation, relative humidity, wind speed and sunshine duration) were investigated in this paper. Considering the complex of underlying surfaces and topography of Urumqi City, four stations (Urumqi, Dabancheng, Caijiahu and Daxigou) were chosen for the representativeness (Fig. 1; Table 1). The Urumqi station represents the urban setting that is intensively affected by the human activities. Dabancheng and Caijiahu stations lying on the southern and northern slopes of the Tianshan Mountains, respectively, represent the distant suburban settings that are minimally affected by human activities. These three stations (Urumqi, Dabancheng and Caijiahu) represent the plain area with low elevations. The fourth station, Daxigou, represents the mountainous area with high elevations. Data from the plain stations (Urumqi, Dabancheng and Caijiahu) covers the period of 1960–2013 and data from the mountainous station (Daxigou) covers the period of 1961–2011. For the three plain stations, the annual and seasonal variations of all the five parameters together with the maximum and minimum temperatures were analyzed. For the mountainous station (Daxigou) where observed data are limited, only the annual and seasonal temperatures and precipitations were analyzed.

3.2. Homogeneity test and correction of data sequence

The instrument replacement, the station relocation and the variation of observation methods often result in the inhomogeneity of data sequences and thus distort the observable patterns of climate change. In this study, the three plain stations all had site relocation histories (Table 1). For example, the Urumqi station has been relocated twice in 1958 and 1975, and the elevation difference between those two relocations is as high as 280 m, resulting in relatively large differences in many climate-related factors. To eliminate those differences, homogeneity tests and correction should be applied to the data sequence. The standard normal homogeneity test (SNHT) is a popular method for the homogeneity test based on the maximum likelihood method (Alexanderson, 1986; Liu, 2000; Jiang et al., 2008; Li et al., 2008). It aims at finding the differences of mutation or linear trend between the candidate sequence and the reference sequence. Firstly, it uses the adjacent stations to construct a reference sequence, and reconstruct a new tested sequence combining both the candidate sequence and the reference sequence using the difference method or the ratio method. Secondly, it applies the statistical hypothesis testing to the tested sequence to find the discontinuous point in it. The final step corrects the candidate sequence and makes the means of the two subsequences before and after the discontinuous point homogenous. In SNHT the candidate sequence and the reference sequence could be the different climatic factors and the reference sequence could be constructed based on the stations that were not necessarily close to the candidate station (Tuomenvirta and Alexanderson, 1992). Thus, the SNHT is especially suitable for Western China where the stations are distributed sparsely.

In this study, the five meteorological factors all had been pretreated by the SNHT to reduce the errors induced by the station relocation, and other factors. At least three stations with good correlation coefficients (more than 0.6) with the candidate station were chosen to construct the reference sequence. For the different parameters, different reference stations could be chosen. For the parameters with good spatial continuity, e.g., temperature and sunshine duration, the difference method was applied in the construction of the tested sequence; otherwise, the ratio method was used. The SNHT test results showed that there were some discontinuous points in the data sequences of the stations, e.g., two points (1958 and 1976) in the temperature and one point (1976) in the precipitation of the Urumqi station were detected. These discontinuous points affected the homogeneity of data series, and thus the data correction should be applied.

3.3. Long-term trend detection

The Mann–Kendall method is a nonparametric test to detect the long-term change in time series (Burn and Hag, 2002). It is simple in computation and there is no the requirement of normal distribution of data, so it has been widely used in many disciplinary

Table 1
Information of the meteorological stations used.

Station	Station no.	Latitude/N	Longitude/E	Elevation/m	Affiliated administrative district	Station relocation[a,b]
Urumqi	51463	43°47′	87°37′	935.0	Tianshan district	1958.3, 1960.1, 1975.12, 2000.1
Dabancheng	51477	43°21′	88°19′	1103.5	Dabancheng district	1957.10, 1958.10
Caijiahu	51365	44°12′	87°32′	440.5	Midong district	1966.11
Daxigou	51468	43°06′	86°50′	3543.8	Urumqi county	/

Note: there were two long-distance site relocations (over 10 km) for the Urumqi station in 1958 (from 43°47′N, 87°37′E to 43°49′N, 87°33′E) and 1975 (from 43°54′N, 87°28′E to 43°47′N, 87°37′E).
[a] Zhang and Zhang (2006).
[b] Wang et al. (2010).