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Climate change in Kazakhstan during the past 70 years

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ABSTRACT

The changes of the air temperature and the precipitation in the whole territory of Kazakhstan were studied for the period from 1941 to 2011. The mean annual air temperature and the mean annual precipitation were used as the main indicators of the regional climate and the seasonal changes were analyzed for further characterizing the variation in the air temperature and precipitation. The abnormality index *K* was adopted for assessing the changing trends of the climate extremes. Our results sufficiently demonstrated increasing trends of the air temperature during the studied period (1941–2011) in Kazakhstan for all seasons. A weak decreasing trend of the annual precipitation was also detected. Accompanying the observed warming were: a dramatic increase in the daily temperature maximum, a significant increase in the number of days with the air temperature higher than 35 C, and a decreasing trend of days with the minimum daily temperature below 0 C.

1. Introduction

Earth's climate has been sufficiently documented to have changed both on global scale and on regional scales (Folland et al., 2001; Bengtsson et al., 2004; Gruza and Ran'kova, 2004; Shkolnik et al., 2006; Klimenko, 2011; Perevedentsev et al., 2012). Most relevant to this research is the Asian Arid Zone (35–55°N; 60–120°E) within which Kazakhstan is situated. The Asian Arid Zone is a geographic region that has been documented to be extremely sensitive to climate change during the last 100 years and is expected to be severely impacted by projected future warming (IPCC, 2007). The close association between the observed drying trend and the observed warming trend during the past 100 years further affirms the sensitivity of the Asian Arid Zone to natural and human-induced environmental changes and illustrates that this region is at high risk in the future for water resource availability and ecological security.

Climatologically, Kazakhstan is protected by the W–E striking Tianshan Mountains approximately along the 40th parallel, blocking the climatic influence of the Arabian Sea from the south and allowing the climatic dominance of the westerlies from the west (Bridgman and Oliver, 2006). The warm-season precipitation is primarily from the North Atlantic via the northward-shifted westerlies, whereas the cold-season precipitation is primarily from the Mediterranean Sea via the southward-shifted westerlies (Bothe et al., 2011). Frequent southward invasions of the polar front are the most important precipitation-promoting mechanism (Aizen et al., 2001). The cold-season climate in the study area is modulated by the interactions between the North Atlantic Oscillations (NAO) and the Siberian High. The warm-season climate is controlled by the interactions between the Asian Low occupying the interiors of Asia and the Azores High (Meeker and Mayewski, 2002).

2. Regional setting

Kazakhstan, situated near the center of vast Eurasian continent, is an inaccessible area for the Pacific and Indian air masses. It is on the path of westerlies that bring water vapor from the North Atlantic. However, the water influx in the air is normally extremely low after a long-distance travel. The frequent invasions of the Siberian air masses during winters make the area extremely cold. The climate in Kazakhstan is characterized by two major features: high continentality and frequent droughts.

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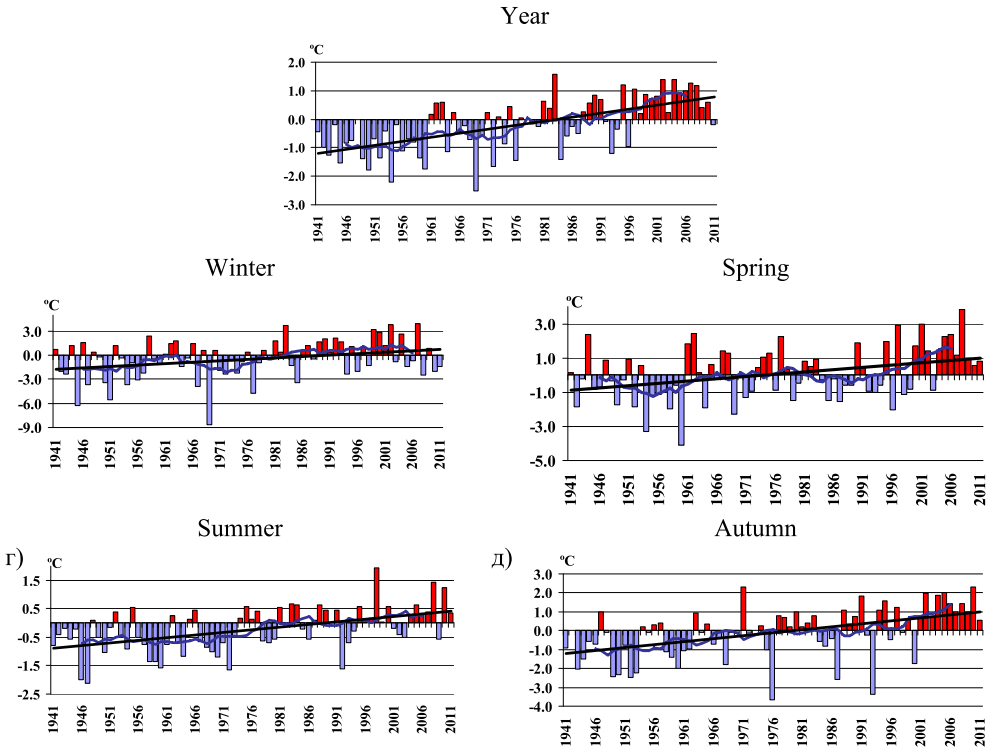

Fig. 1. Time series and the abnormalities of the annual and seasonal air temperatures for the period from 1941 to 2011 across Kazakhstan. The abnormalities are calculated as the deviations from the norms that are defined as the average values for period from 1971 to 2000. The fitted curve was derived using an 11-year moving averaging method.

The mean January temperature is −15 C with the minimum mean January temperature reaching −40 C. Strong snowstorms, blizzards and freezing drizzle during winters are common. The summers are fairly hot, with the maximum mean July temperature up to 40 C in the low-lying steppes and desert steppes. The mean annual precipitation is 250–350 mm in the northern regions of the country and is only 100–120 mm in the southern regions. Correspondingly, the atmospheric humidity at 1:00 pm during the hottest month (July) is about 39% in the northern regions and is only 17% in the southern regions. The climates in the Tianshan Mountains along the southeastern margin of Kazakhstan are complicated by such topographic factors as elevation, aspect, relief, and others.

3. Materials and methods

First, mean monthly air temperature and mean monthly precipitation from 190+ meteorological stations were obtained for the period from 1941 to 2011 to assess the monthly trends. Second, minimum and maximum daily air temperatures and mean daily precipitation from 80+ meteorological stations were obtained for the period from 1941 to 2011 to assess the daily trends. Third, the long-term mean annual values (monthly and daily) for the period from 1971 to 2000 were taken as the "norms". The air temperature abnormalities were then calculated as the deviations of the observed values from the norms and the precipitation abnormalities were considered as the deviations from the corresponding norms. Fourth, the assessment of air temperature and precipitation tendencies was conducted for the 14 administrative regions of Kazakhstan according to the station-observed data within each one of the 14 regions. Fifth, the climate change indices introduced by the World Meteorological Organization (2013) were used for assessing the tendencies in the extremes of air temperature and precipitation.

4. Results and discussion

4.1. Temperature

The assessment of the seasonal variations in the air temperature was carried out for the whole territory of Kazakhstan (Fig. 1) and the average rate of the temperature change (C°/10-year) was calculated for each of the 14 administrative regions (Fig. 2). Fig. 1 shows that the surface air temperature has been generally rising for the studied period (1941–2011) during all seasons. The mean annual air temperature has increased by a rate of 0.28 C°/10-year in Kazakhstan. The greatest warming occurred during the winters with an average rate of 0.35 C°/10-year and the least warming happened in summers with the average rate of 0.18 C°/10-year. The rate was 0.32 C°/10-year in autumns and 0.27 C°/10-year in springs. The trends observed in the total variance of the mean annual temperatures are statistically significant at 95% confidence level in most cases.

When the trends were examined for each one of the 14 administrative regions, a spatial pattern emerged. The mean annual air temperatures increased at a fastest rate in West Kazakhstan Province, 0.37 C°/10-year. The slowest increasing rates were found in South Kazakhstan Province, West Kazakhstan Province, Almaty Province, and Mangystau Province, ranging from 0.24 to 0.26 C°/10-year. The increasing rates were in the range of 0.28–0.31 C°/10-year in the rest of provinces. The winter-warming maximum also exhibited spatial variation. Winter warming was fastest in northern Kazakhstan and also in the Tianshan Mountains along the southeastern margin (Fig. 2). The spatial variations of the warming were not well displayed for other seasons (Salnikov, 2013).