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SPECIAL TOPIC ON REGIONAL CLIMATE CHANGE

Changes in Climatic Factors and Extreme Climate Events in Northeast China during 1961–2010

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Abstract

This study focuses on examining the characteristics of climate factors and extreme climate events in Northeast China during 1961–2010 by using daily data from 104 stations, including surface air temperature, precipitation, wind speed, sunshine duration, and snow depth. Results show that annual mean temperature increased at a significant rate of 0.35°C per decade, most notably in the Lesser Khingan Mountains and in winter. Annual rainfall had no obvious linear trend, while rainy days had a significant decreasing trend. So, the rain intensity increased. High-temperature days had a weak increasing trend, and low-temperature days and cold wave showed significant decreasing trends with rates of –3.9 d per decade and –0.64 times per decade, respectively. Frequency and spatial scope of low-temperature hazard reduced significantly. Warm days and warm nights significantly increased at 1.0 and 2.4 d per decade, while cold days and cold nights decreased significantly at –1.8 and –4.1 d per decade, respectively. The nighttime warming rate was much higher than that for daytime, indicating that nighttime warming had a greater contribution to the overall warming trend than daytime warming. The annual mean wind speed, gale days, and sunshine duration had significant decreasing trends at rates of –0.21 m s^{-1} per decade, –4.0 d per decade and –43.3 h per decade, respectively. The snow cover onset dates postponed at a rate of 1.2 d per decade, and the snow cover end date advanced at 1.5 d per decade, which leads to shorter snow cover duration by –2.7 d per decade. Meanwhile, the maximum snow depth decreased at –0.52 cm per decade. In addition, the snow cover duration shows a higher correlation with precipitation than with temperature, which suggests that precipitation plays a more important role in maintaining snow cover duration than temperature.

Keywords: climatic factors; extreme climate events; climate change; Northeast China

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1 Introduction

The IPCC Fourth Assessment Report (AR4) [*IPCC*, 2007] showed that global climate had undergone a significant warming change; observations also demonstrated that global mean surface air temperature increased 0.74°C during 1906–2005, and the warming has even accelerated by 0.13°C per decade during the most recent 50 years. In China, the mean temperature increased 1.38°C during 1951–2009 [*ECSCNARCC*, 2011]; precipitation did not show any significant change trend, but there was a 20–30 years

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oscillation. Northeast China, which includes Liaoning, Jilin and Heilongjiang provinces, is an important grain production base of China. Along with global climate change and increasing urbanization in recent years, the regional economic and social development in Northeast China faces multiple challenges. Regional economy has demonstrated high sensitivity to global and regional climate changes. As a result, the increase of extreme weather/climate events has brought great pressure on disaster prevention and mitigation. In order to provide better decision-making services for regional economic development, it is critical to perform detailed analyses on climate variations in Northeast China during the past half century.

2 Data and methodology

The *in situ* data used in this study include temperature, precipitation, wind speed, sunshine duration, snow and other climatic factors during 1961–2010 at 104 stations selected from 162 stations in Northeast China based on homogeneity test (Fig. 1). The definitions of terminologies used in the text are listed in Table 1 below.

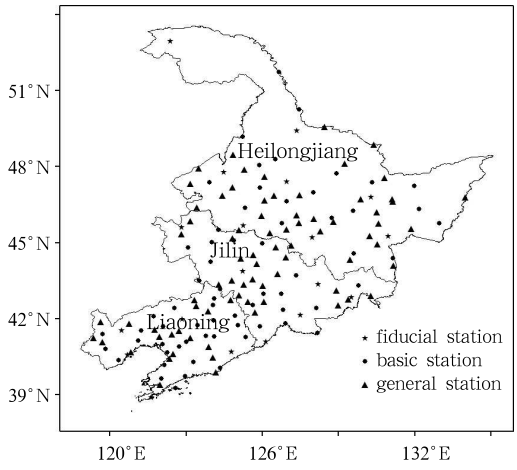

Figure 1 Spatial distribution of meteorological stations in Northeast China

Homogeneity test is used to eliminate the impacts of site migration [*Alexanderson*, 1996]. The method of t-test is used to examine the significance of the linear trend at 95% confidence level [*Wei*, 2007]. Hereafter, all statistical significance will be referred to this confidence level unless a higher level is specifically noted.

3 Results

3.1 *Temperature*

3.1.1 *Mean temperature*

Annual mean temperature had a significant increasing trend at 0.35°C per decade in Northeast China during 1961–2010. The increase rate is higher than the global (0.13°C per decade) [*IPCC*, 2007] and national rate (0.23°C per decade) [*ECSCNARCC*, 2011] during the same period. From 1960s to 1980s, temperature was below normal, but it has shown an upward trend since the late 1980s. Mean temperature in the four seasons all showed significant increasing trends, being largest in winter at 0.55°C per decade, followed by spring, autumn and summer. The diurnal temperature range had a significant decreasing trend at –0.29°C per decade. Geographically, the warming rate showed an increase pattern from south to north, being largest at 0.61–0.64°C per decade on the northern Lesser Khingan Mountains (Fig. 2).

3.1.2 *Extreme temperature*

High-temperature days with daily maximum temperature $\geqslant$35°C had a weak increasing trend in Northeast China during 1961–2010, which is consistent with the results for the great North China during a similar period [*Zhai and Pai*, 2003]. Low-temperature days with daily minimum temperature $\leqslant$–25°C had a significant decreasing trend of –3.9 d per decade. Areas with annual low-temperature days more than 40 d were located in the north of 45°N in the 1960s (Fig. 3), and the boundary had gradually moved northward since the 1970s. In the 1990s, the boundary was near 47°N, but it moved southward slightly in the 2000s.

3.1.3 *Warm days, warm nights, cold days, and cold nights*

The regional mean annual warm days had a weak increasing trend (1.0 d per decade) during 1961–2010. Most regions had an increasing trend except for central Liaoning and central and western Jilin, with strong increase of 2.1–4.0 d per decade in northern Heilongjiang and southern Liaoning (Fig. 4a). Warm nights had a significant increasing trend of 2.4 d per decade, and the highest (4.1–5.7 d per decade) was found in