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Spatial analysis of climate change in Inner Mongolia during 1961–2012, China

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ABSTRACT

Global warming has changed the distribution of climate resources with previous studies indicating that the arid and semi-arid areas have become drier because of decreasing precipitation. Based on daily meteorological data collected at 46 meteorological stations in Inner Mongolia, we analyzed the spatial distribution and trends of major climate variables (precipitation, daily mean, minimum and maximum temperatures) at monthly and annual scales over the past 52 years. Variation of humid index was also analyzed.

An increasing trend was identified for the daily mean temperature in the study area, and the trend (0.37 °C/decade) is higher than the global warming rate (0.14 °C/decade). Compared to daily mean temperature and daily maximum temperature, daily minimum temperature showed a greater increasing trend (0.51 °C/decade). As for most stations, the largest trends for daily mean, minimum and maximum temperatures occurred in the last ten days of February. Through a series of regression analyses, it was found that the change of vapor pressure had a high correlation coefficient with temperature trends and both temperature and vapor pressure showed the strongest increasing trend in February. Annual precipitation showed a slightly decreasing trend, mainly because of a decrease of precipitation in July and August. Forty-three out of 46 stations exhibited negative slopes in the time series of humid index, which indicates that Inner Mongolia has become drier in the past 52 years.

In summary, Inner Mongolia has become warmer and drier with increasing temperature and decreasing precipitation during the past several decades.

Introduction

The earth's climate has warmed globally by approximately 0.72 °C [0.49–0.89] during 1951–2012, and the decade of the 2000s has been the warmest period compared to any other decades since the late 19th century (IPCC, 2013). The intensity and spatial distribution of precipitation also changed as global warming is expected to cause increases in the atmospheric water vapor content (O'Gorman & Schneider, 2009; Trenberth, 2011), but the changes in the precipitation regime are neither spatially nor temporally uniform (Frich et al., 2002; Walther et al., 2002). Previous studies have suggested that wet regions would become wetter and dry regions would become drier (Wentz, Ricciardulli, Hilburn, & Mears, 2007). Dore (2005) found that precipitation increased in high latitudes in the Northern Hemisphere, and decreased in China, Australia, and the Small Island States in the Pacific Ocean.

Inner Mongolia owns the most important grassland resources of China (Fan et al., 2009). The grassland area is about 792,000 km^2 (Zhang, 1990), accounting for 22 percent of China total grassland. However, the grassland in Inner Mongolia has severely degraded over the past several decades because of human activity and climate change (Zhou, Zhao, Zhang, Zhou, & Tan, 2002) with about 106,600 km^2 of grassland degradation during 1970–2000 (Zhao & Xu, 2000), which led to negative impacts on the biological diversity, husbandry industry, and social economics (Yin, H, & Yun, 2011). Climate change in the future would likely accelerate the degradation of semi-arid grasslands on large scales in North America and Asia (Manabe & Wetherald, 1986). Niu (2001) studied the response of Inner Mongolia grassland to the scenario of climate change, and found that the grassland area and grassland production would both

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decrease remarkably in the future. Many studies have shown that the grassland ecosystem is affected by climate change (Hall & Scurlock, 1991; Melillo et al., 1993; Parton, Scurlock, Ojima, Schimel, & Hall, 1995; Suttle, Thomsen, & Power, 2007), because the net primary productivity (NPP) correlates positively with precipitation (Deshmukh, 1984; Li & Ji, 2004; Zavaleta et al., 2003) as well as daily mean air temperature (Chapin, Shaver, Giblin, Nadelhoffer, & Laundre, 1995) and minimum temperature (Abu-Asab, Peterson, Shetler, & Orli, 2001; Alward, Detling, & Milchunas, 1999). Although many studies on the climate change and its impacts in different regions and in a wide-range of spatial and temporal scales have been carried out, there has been insufficient study on climate change in the last 52 years for Inner Mongolia, particularly related to the climate change characteristics of daily minimum and maximum temperatures. Therefore, a systematic study of primary climate variables such as precipitation, and daily mean, maximum and minimum temperatures in Inner Mongolia is needed. This study aims to improve our understanding of the spatial and temporal characteristics of climate change in Inner Mongolia and the cause of climate change, and thus could help decision-makers develop better strategy and measures for adaptation to and mitigation of climate change. The objectives of this study are: 1) to analyze the changes of precipitation, daily mean, maximum and minimum temperatures at monthly and annual scale in Inner Mongolia over the past 52 years, and 2) to explore the probable reasons for the climate change in Inner Mongolia.

Methodology

Study area

Inner Mongolia Autonomous Region, the third largest province in China, is located within 97° 12′~126° 04′E, 37° 24′ ~53° 23′N in the northern China. Inner Mongolia is a narrow and long strip of land extending from northeast to southwest, with a length about 2400 km from east to west, and 1700 km from south to north, and the total land area is 1.18 million km^2. The Inner Mongolia plateau has elevations ranging from 82 m to 3430 m above sea level (Wang et al., 2013). There are twelve major cities in Inner Mongolia, i.e., Hulun Buir, Hinggan League, Tongliao, Chifeng, Xilin Gol League, Ulaqab, Hohhot, Baotou, Ordos, Bayan Nur, Alxa League, Wuhai (Fig. 1).

Inner Mongolia is a transition zone between the arid and semi-arid northwest inland region and the humid and semi-humid southeast coastal region affected by Asian monsoon (Sun, Guo, Yan, & Zhao, 2010). The climate in Inner Mongolia is cold and dry in winter, and warm and wet in summer (Xiao, Ojima, Parton, Chen, & Chen, 1995). Liu, Zhao, and Zhao (1997) summarized the mean meteorological conditions in Inner Mongolia as follows: mean annual solar radiation is 5200 MJ m^{-2}, total annual sunshine duration is about 2946 h, and mean annual accumulated air temperature above 10 °C ranges from 3000 to 3400 (°C day). Nearly 70 percent of annual precipitation falls from June through August, decreasing from east to west. According to the spatial distribution of precipitation, Inner Mongolia usually is divided into five climatic zones from east to west, i.e., humid, semi-humid, semi-arid, arid and hyper-arid. As water and heat energy are two critical factors controlling the mid-latitude temperate grasslands, the dominant grassland vegetation types in Inner Mongolia are meadow steppe, typical steppe and desert steppe from east to west, respectively (Wu, 1980).

Technique description

Meteorological data

In this study, 46 meteorological stations each with 52-year data record (from 1961 to 2012) were selected among more than 50 stations in Inner Mongolia (Fig. 1). The data were downloaded from the China Meteorological Data Sharing Service Network (http://cdc.cma.gov.cn/home.do), including daily precipitation, daily mean, maximum, and minimum temperatures. The quality of datasets was tested and controlled, e.g., there were no error data, and the missing data counts for no more than 0.1% for the precipitation and temperature datasets. All the missing data were filled by using the following methods: 1) if the time gap of the missing data was less

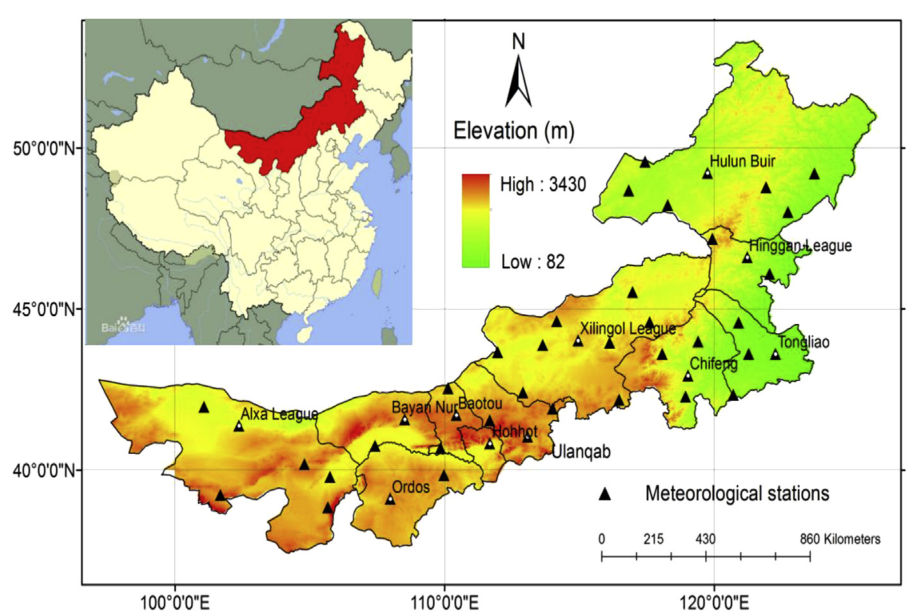

Fig. 1. Boundary and meteorological stations in Inner Mongolia.

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