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Analysis of extreme temperature events in the Qinling Mountains and surrounding area during 1960–2012

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ABSTRACT

In this study, 16 indices of extreme temperature were calculated on the basis of daily maximum and minimum temperature data in the northern and southern regions of the Qinling Mountains (NSQ) using linear trend and correlation analysis and other methods to investigate the temporal variation trend, spatial distribution pattern and correlation of extreme temperature events. The results are as follows. (1) The extreme cold and warm indices exhibited contrasting variation trends over the entire region: the cold indices (TX10, TN10, ID, FD and CSDI) decreased; the warm indices (TX90, TN90, SU, TR and WSDI) increased; the extremal indices (TXn, TNn, TXx and TXn) increased; and the diurnal temperature range (DTR) decreased. (2) The absolute indices, extremal indices and other indices showed a certain latitudinal zonality: ice days (ID) and frost days (FD) decreased from north to south, while summer days (SU), tropical nights (TR), extremal indices (TXn, TNn, TXx and TXn), the cold and warm spell duration indicators (CSDI and WSDI, respectively) and growing season length (GSL) increased from north to south. (3) The correlation analysis results showed that, except for the extremal indices and individual indices, the extreme temperature indices correlated well. (4) The altitude has a large impact on spatial distribution of extreme temperature indices, and the ubiquity of the heat island effect in urban constructed regions also had an impact on amplitude of variation in extreme temperature.

1. Introduction

In the last 100 years, the severe changes of the global climate have attracted attention, and the number of studies on climate change, especially extreme weather events, is increasing. At present, the focuses are on forecasting spatial and temporal variations, the possible causes and the future trends of one or more climatic factors of the climate system and the effects on natural and socioeconomic systems (McMichael et al., 2006; Giorgi et al., 2006). Climate change intensifies the instability of the climate system, and the frequency of extreme weather events continues to increase (Katz and Brown, 1992). Historical observational data indicate that, in the past 100 years, the frequency of floods, droughts, heat waves and cold waves has exhibited an increasing trend, and the range of these impacts has increased. In the future climate scenario simulated by a global current model (GCM), the frequency of extreme events in some areas will be higher and cause more catastrophes (IPCC, 2007, 2012). The statistical report of the Emergency Events Database showed that 72.6% of natural disasters globally were meteorological disasters. A research report by the Swiss Reinsurance Company also indicated that extreme weather events were responsible for as many as 91% of the natural disasters in 2010 (SwissRe, 2010). However, among the various extreme weather types, heat waves and cold waves receive the most attention because they have most obvious and direct impact on politics, the social economy, the environment, ecosystems and human health (Koch and Vögele, 2009; Hay and Mimura, 2010). For example, a large-scale European heat wave event in 2003 killed approximately 40,000 people (Garcia et al., 2010). In eastern Europe in 2010, the impact range, intensity and duration of summer heat wave events were greater than in the 2003 event (Barriopedro et al., 2011). In addition, sudden cryogenic freezing rain and snow disasters impacted most regions in southern China in the winter of 2008 and

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caused large losses of life and property. These severe meteorological disasters have attracted the attention of a growing number of researchers (Hong and Li, 2009). Relative to the global scale, extreme weather events at the regional scale also received attention, especially in certain geographical locations, topographies and climatic regions that are more vulnerable to meteorological disasters and suffered heavier losses. International scholars conducted studies in different areas, including France (Pantavou et al., 2011), Italy (Grize et al., 2005), and Switzerland (Pirard et al., 2005). The above studies assessed not only the frequency, intensity, impact range and other detailed features of extreme weather events but also the fatality rate, economic loss, and social impacts of the disasters.

In China, cold waves break out over North China in winter frequently, while hot days and heat waves are commonly seen in South China in summer, and arid and semiarid regions in Northwest China often suffer from drought (Zhai et al., 1999; Wang et al., 2011, 2013a,b). Moreover, other scholars conducted systematic and thorough studies in the Qilian Mountains (Jia, 2012), the Yangtze River Basin (Wang et al., 2013a,b), the Yellow River Basin (Chen et al., 2011), the Tibetan Plateau (Du et al., 2013), the Loess Plateau (Li et al., 2013), the Wei River (Liu and Xu, 2009), and the Han River Basin (Chen et al., 2006). Furthermore, changes in extremes can be strong indicators of climate change, as it has been hypothesized that in a warming world where the atmosphere can hold more water vapor, the hydrological cycle could become more active (Aguilar et al., 2005). However, knowledge of changes in extremes compared with mean temperature is usually sparse, especially in the climate transition zones of China which has the most fragile ecological environments in the world. Recent studies on the changes of temperature extremes over China suggested decreasing trends in cold extremes but increasing trends in warm extremes (Wang et al., 2011; You et al., 2011). Water is the foundation of composition, development, and stability of grassland and oasis ecosystems in semiarid areas and determines the evolution of the ecological environment (Chen et al., 2007). Temperature, especially in arid and semiarid areas, directly impacts the spatial and temporal distribution of water resources, because increasing temperature will severely influence the mountain glacier and then affect water supplies to rivers (Zhang et al., 2009). Therefore, exploring changing characteristics of extreme temperature in the climate transition zones of China is a prerequisite for the assessment of impacts of climatic changes on regional ecological environment and agricultural development.

As noted by IPCC (Intergovernmental Panel on Climate Change) (IPCC, 2007, 2012), the vulnerability to extreme weather events depends not only on the number of people affected by the disaster but also on the disaster area's response capacity to extreme weather; these factors are related to the area's latitude, altitude, habitat suitability, climate zone, topography, other natural conditions, economic development level, traffic accessibility, irrigation, water conservancy facilities and other socio-economic conditions. Previous studies of extreme temperature events mostly concerned the different west-east or north-south climate zones or used watersheds and provinces as the research units. Insufficient research has been conducted on climate transition zones, ecological environment conservation, middle and low-latitude mountains in high altitude and plains areas. However, these regions are vulnerable to extreme weather disasters, and the losses caused by disasters were often much greater. As a result, these regions need to be more thoroughly studied.

The Qinling Mountains are located in the central region of China; the huge mountain range is oriented from east to west and is an important geographical and ecological boundary that is significant for the environment and development. However, the knowledge of the region is currently lacking, and research data are too sporadic and incomplete for research and decision making. The past studies of the region are mostly confined to biodiversity protection, hydrology and water resources protection, soil conservation and other similar aspects, whereas studies of climate change are few. The studies on climate change that have been conducted mainly focused on the temporal and spatial variations of heat sources (Zhu, 1958; Ren and Yang, 1961; Physical Geography in China Editorial Board of Chinese Academy of Sciences, 1985; Yang et al., 2006; Zhou et al., 2011) and precipitation sources (Jiang et al., 2012, 2013) in NSQ, Shaanxi Province (southern Shaanxi and Guanzhong area). Even fewer studies have been conducted on extreme weather events. The selected indicators from previous studies of extreme events in surrounding areas are relatively simple (Chen et al., 2006, 2011; Liu and Xu, 2009; Li et al., 2013; Wang et al., 2013a,b) and are mostly based on various percentile thresholds. Single-sided indicators are often not sufficient to fully reveal the detailed characteristics of extreme events; the actual significance is also more limited.

Based on the above findings, we used historical observation data of 47 meteorological stations in NSQ in the period of 1960–2012. The study adopted 16 extreme temperature indices of climate change detection and indices (Aguilar et al., 2005) identified by the Expert Team on Climate Change Detection and Indices (ETCCDMI), which is widely recognized and adopted at present. We offer a comprehensive and detailed study of spatial distribution patterns and spatio-temporal variations of extreme temperature events over the past 53 years to provide a basis for mitigation and adaptation to climate change, disaster prevention and mitigation, the water resources planning and national decision making.

2. Overview of study area

The study area, generalized as the Qinling Mountains, comprises the Qinling Mountains and the surrounding contiguous areas of rolling mountains, hills, intervening basins and valleys, and large plateaus and local plains. The Qinling Mountain area is approximately 1500 km from east to west; it is west of the Kunlun Mountains and is bounded by Min Mountain to the north. The area extends eastward through the Gansu territory to southern Shaanxi, then to Funiu Mountain of the Henan territory. There, the mountains trend change to a northwest-southeast direction and extend to areas near the north shore of the Yangtze River, including the Dabie Mountains, Hong Mountains, and Zhangba Mountains (Zhu, 1958; Ren and Yang, 1961; Physical Geography in China Editorial Board of Chinese Academy of Sciences, 1985; Yang et al., 2006; Zhou et al., 2011; Jiang et al., 2012, 2013). To investigate the regional characteristics of temperature and extreme temperatures events, the study references the results of Zhou et al. (2011) by dividing the research area into four sub-regions: the northern slope of the Qinling Mountains and the northern warm temperate regions (hereafter referred to as "NSQ"); Funiu Mountains and its eastern plains (hereafter referred to as "SSQ" because much of the area is located on the southern slope of the Qinling Mountains); the Han River valley, Ba Mountains, Yunshui valley and the northern subtropical regions of the Huaihe River valley upstream (hereafter referred to as "HRB" because most of these regions belong to the Han River basin); Ba Mountains southern mountains, Wu Mountains valley and the Jianghan Plain northwest regions (hereafter referred to as "BWV"). The spatial distribution of the study area and meteorological stations are shown in Fig. 1; detailed information is listed in Table 1 (Zhou et al., 2011).