Atmospheric Research 203 (2018) 141–163

Contents lists available at ScienceDirect

Atmospheric Research

journal homepage: www.elsevier.com/locate/atmosres

Detection of spatio-temporal variability of air temperature and precipitation based on long-term meteorological station observations over Tianshan Mountains, Central Asia

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ARTICLE INFO

Keywords:
Tianshan Mountains
Air temperature and precipitation
Mann-Kendall test
Mutations
Periodicity
Elevation dependency

ABSTRACT

As abundant distribution of glaciers and snow, the Tianshan Mountains are highly vulnerable to changes in climate. Based on meteorological station records during 1960–2016, we detected the variations of air temperature and precipitation by using non-parametric method in the different sub-regions and different elevations of the Tianshan Mountains. The mutations of climate were investigated by Mann-Kendall abrupt change test in the sub-regions. The periodicity is examined by wavelet analysis employing a chi-square test and detecting significant time sections. The results show that the Tianshan Mountains experienced an overall rapid warming and wetting during study period, with average warming rate of 0.32 °C/10a and wet rate of 5.82 mm/10a, respectively. The annual and seasonal spatial variation of temperature showed different scales in different regions. The annual precipitation showed non-significant upward trend in 20 stations, and 6 stations showed a significant upward trend. The temperatures in the East Tianshan increased most rapidly at rates of 0.41 °C/10a. The increasing magnitudes of annual precipitation were highest in the Boertala Vally (8.07 mm/10a) and lowest in the East Tianshan (2.64 mm/10a). The greatest and weakest warming was below 500 m (0.42 °C/10a) and elevation of 1000–1500 m (0.23 °C/10a), respectively. The increasing magnitudes of annual precipitation were highest in the elevation of 1500 m–2000 m (9.22 mm/10a) and lowest in the elevation of below 500 m (3.45 mm/10a). The mutations of annual air temperature and precipitation occurred in 1995 and 1990, respectively. The large atmospheric circulation influenced on the mutations of climate. The significant periods of air temperature were 2.4–4.1 years, and annual precipitation was 2.5–7.4 years. Elevation dependency of temperature trend magnitude was not evidently in the Tianshan Mountains. The annual precipitation wetting trend was amplified with elevation in summer and autumn. The strong elevation dependence of precipitation increasing trend appeared in summer.

1. Introduction

Global warming trend is obviously during the past century and has been the topic of climate change (Alexander et al., 2006; Hansen et al., 2006; Gay-Garcia et al., 2009; Wen et al., 2017). The Intergovernmental Panel on Climate Change (IPCC) indicated that the global warming has caused changes of precipitation, contrasted in precipitation between wet and dry regions and between wet and dry seasons increased (IPCC AR5, 2013). Global land precipitation increased by approximately 2% over the 20th century (New et al., 2001). Previous studies suggested that changes of air temperature and precipitation are considerably diverse patterns from the tempo-spatial trends at the regional and global scales due to regional disparities of natural resources (Easterling et al., 1997; Crowley, 2000; Blandford et al., 2008; Li et al., 2016; Ozturk et al., 2017). Besides, regional climatic variations can increase the occurrence of droughts and floods due to the uneven availability of water (Yang and Lau, 2004). Therefore, there is a growing demand for detecting regional oscillations of past trend, change, and variability in air temperature and precipitation resulting from global warming, this information is important for understanding the causes and the regional impacts of climate change on natural environment and ecosystems.

Researchers found that the warming at high-elevation sites was

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https://doi.org/10.1016/j.atmosres.2017.12.007
Received 2 November 2017; Received in revised form 19 December 2017; Accepted 20 December 2017
Available online 22 December 2017
0169-8095/

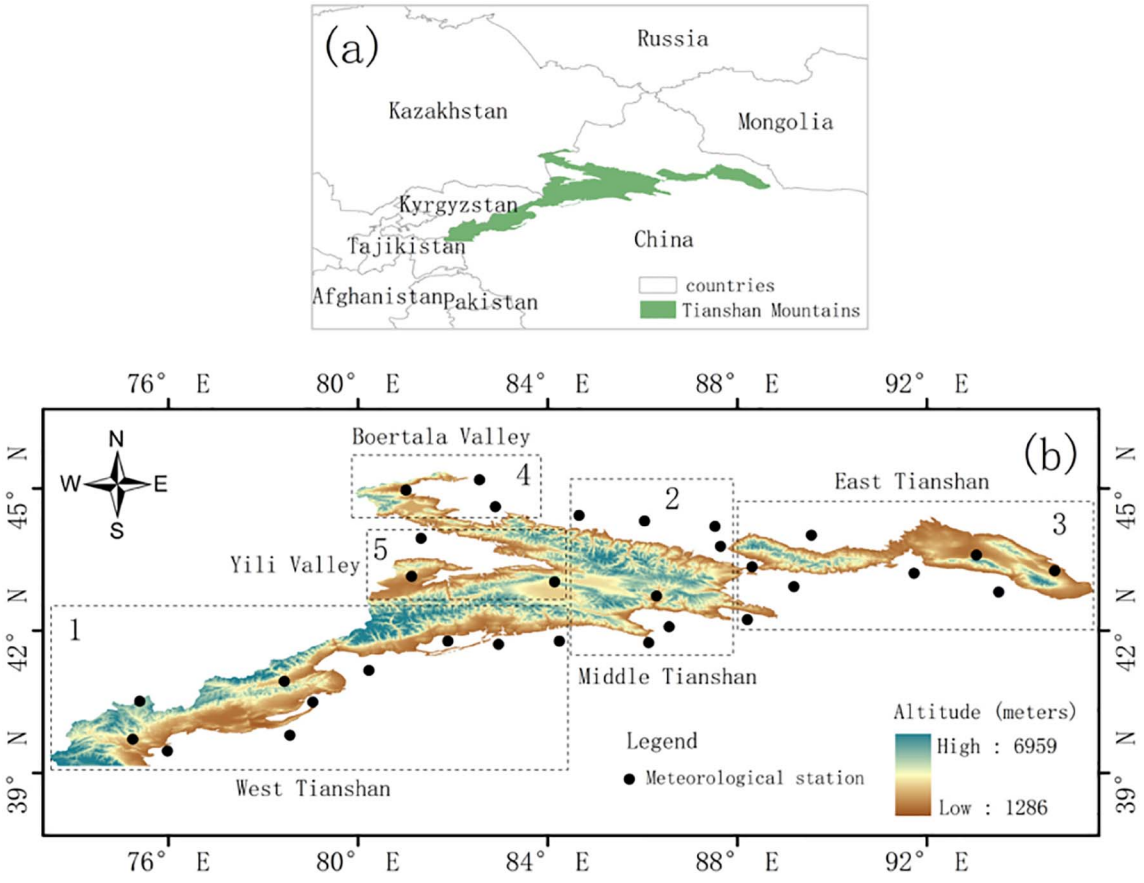

Fig. 1. Locations of Tian Shan Mountains and selected meteorological stations.

more pronounced than at low-elevations, recent concern about regional changes of temperature and precipitation have focused attention on high-elevation areas and mountains (Blandford et al., 2008; You et al., 2010; Holden and Rose, 2011; Wang et al., 2013; Deng et al., 2015; Guo and Li, 2015; Guo et al., 2016). The Tianshan Mountains are the largest mountain systems in Central Asia which is a semi-arid and arid region (Chen et al., 2016). As great northern peripheral mountains, the Tianshan Mountains play an important role of determining the climatic processes in the global and regional climate systems of Central Asia (Aizen et al., 1995; Aizen, 1997). Due to the long distance to the surrounding oceans causes lower precipitation and a dry climate in Central Asia, glaciers and snow of the Tianshan Mountains are important water resources in Central Asia, and are affected by various effects in changes of temperature and precipitation (Ye et al., 2005; Sorg et al., 2012; Chen et al., 2015; Deng et al., 2015; Xu et al., 2017a, 2017b). Global warming has accelerated the hydrological cycle (Brutsaert and Parlange, 1998; Gao et al., 2007; Yang et al., 2011). The changes of air temperature and precipitation in the Tianshan Mountains not only affected the changes of glaciers, but also influenced on hydrological systems which provide supplies for approximately 50 million people in Kyrgyzstan, Kazakhstan, Uzbekistan, northern Tajikistan, and the Xinjiang Province of China and support lowland agriculture, urban areas, and industries within those regions (Chen et al., 2008; Sorg et al., 2012; Ling et al., 2013a, 2013b; Xu, 2017). The Tianshan Mountains is highly vulnerable to changes in climate. The changes in temperature and precipitation of the mountain significantly affect the surrounding lowlands.

Meteorological station observations is an important and reliable data source for exploring climate change in alpine regions, these data can not only reveal climatic conditions, but also facilitate for the validation of climate models and accurate simulation of future climate change. Based on observation data, previous studies indicated that air temperature has exhibited a rising trend, and precipitation has increased in Central Asia (Lioubimtseva et al., 2005; Li et al., 2015). Inner Asia and northern China have experienced simultaneously a warming trend and decreasing precipitation over the past 40 years (Piao et al., 2010). As a main area of Central Asia, the air temperature in the arid region of northwest China demonstrated a significant rising trend by a rate of 0.33–0.34 °C/10a since 1960s, and the precipitation had a significantly increasing trend, at a rate of 0.61 mm/a (Sun and Yin, 2010; Li et al., 2016). Some studies also showed that both the temperature and precipitation display increasing tendency during past several decades in the Tianshan Mountains (Xi et al., 2005; Wang et al., 2011). In previous studies, the Tianshan Mountains were included or results were only reported roughly on whole mountain. However, the Tianshan Mountains are a huge region, the air temperature and precipitation has typical characteristics of multi-scale in space and nonlinearity. The air temperature and precipitation in different sub-regions and elevations of the Tianshan Mountains were not investigated systematically.

In this study, the objective is to understand the tempo-spatial characteristics of air temperature and precipitation during 1961–2016 over the Tianshan Mountains, its sub-division and different elevations using non-parametric methods. The mutations, significant periodic changes, large scale atmospheric circulation and elevation dependence of trends in air temperature and precipitation were discussed. The results will provide useful information for assessment of the impacts of