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Temporal and spatial variations of precipitation in Northwest China during 1960–2013

Peng Yang [a,b], Jun Xia [a,c,*], Yongyong Zhang [a], Si Hong [c]

[a] Key Laboratory of Water Cycle & Related Land Surface Processes, Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences, Beijing 100101, China
[b] University of Chinese Academy of Sciences, Beijing 100049, China
[c] State Key Laboratory of Water Resources & Hydropower Engineering Sciences, Wuhan University, Wuhan 430000, China

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ABSTRACT

Based on the precipitation data from 96 weather stations in Northwest China (NWC) during 1960–2013, the Continuous Wavelet Transform (CWT) and the Mann-Kendall (MK) test were applied to analyze the precipitation spatiotemporal variations at different time scales. The relationships between the original precipitation and different periodic components were investigated. The results indicated that the annual precipitation was significantly increasing ($P < 0.01$) at the rate of 0.55 mm/a in the NWC. In terms of seasonal precipitation, the summer original precipitation significantly increased ($P < 0.05$) in the Southern Altay Mountain Basin (SAMB), Qaidam Basin (QB), Qiang Tang Plateau Basin (QTPB), Turpan-Hami Basin (THB), Tarim Desert Basin (TDB), Northern Tianshan Mountain Basin (NTMB) and NWC. For the winter original precipitation, except the Inner Mongolia Inland Rivers Basin and Northern Kunlun Mountain Basin, the significant increases ($P < 0.05$) were detected in the other subbasins. In terms of monthly precipitation, significant increases were detected in January in the SAMB, NTMB and NWC, and July in the QB, Headstreams of Tarim River Basin (HTRB) and N. Additionally, most of the increasing and decreasing trends began in the mid-1980s or mid-1990s. Moreover, the periodic components were not always similar to the original data with the significant trends. The dominant scale of the original data from the periodic components was different in spatiotemporal distribution. Meanwhile, the relationship between the precipitation and El Niño-Southern Oscillation (ENSO) was different from period to period and from time scale to time scale. This study will help to develop better management measures to account for climate change and the supply/demand of water.

1. Introduction

Precipitation is one of the most important factors for the hydrological cycle and human life for the reason that the natural disasters, loss of biodiversity and agricultural productivity may be influenced by the changes of precipitation (Sayemuzzaman and Jha, 2014). Thus, the spatiotemporal characteristics of precipitation have received increasing attention in the studies related to the changes of regional water cycles (Xing et al., 2015).

Precipitation exhibited significant changes in many regions of the world during the 20th century (New et al., 2001). For instance, while it showed an increasing trend at a rate of 0.5–1% per decade in most areas at high latitudes in the Northern Hemisphere, the trend showed an increase of 2% in the low and middle latitudes of the Southern Hemisphere (Houghton et al., 2001; Xu et al., 2005). Recently, the precipitation trends were studied and analyzed in a number of regions in Asia. For example, Naidu et al. (1999) observed the precipitation trends in certain months during 1871–1994 and found decreasing trends during 1880–1905 and 1945–1965 and increasing trends during other periods in the Indian subcontinent. Significant changes of long-term precipitation in January, February, and September were observed in Turkey (Partal and Kahya, 2006). Three out of the five stations observed significant decreasing trends in precipitation in northwestern Iran (Tabari and Talaee, 2011). She et al. (2013) found that the mean maximum length of dry spells showed a negative trend in most stations in the Yellow River Basin, China. Based on the concept of extreme precipitation events, She et al. (2015) investigated the variation and non-stationary traits in precipitation extremes at Dan Jiangkou in China during 1956–2013. They found that event-based extreme precipitation (EEP) analysis was more appropriate than the traditional method for the extreme precipitation (EP) analysis.

The arid and semi-arid region of the NWC is one of the most sensitive areas for global climate change in the world (Ding et al., 2007; Shi et al., 2007), with a diversity of climatic characteristics appearing in this region. While arid and humid climates are observed, monsoon and non-monsoon zones also exist (Shi et al., 1994). In addition, complex physical geographical features and vulnerable eco-environments

* Corresponding author at: State Key Laboratory of Water Resources & Hydropower Engineering Sciences, Wuhan University, Wuhan 430000, China.
E-mail address: xiaj@igsnrr.ac.cn (J. Xia).

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are found in the NWC (Liu et al., 2015). In the past decades, while the spatial and temporal distribution of precipitation has changed significantly, droughts have become a serious natural hazard with the increasing need for water in the NWC (Liu et al., 2015). Therefore, it is important to study the variations of precipitation over long periods, especially in the northwest semi-arid and arid areas. Wang et al. (2013) studied the spatial distribution and temporal trends of the mean precipitation and extremes in the NWC, including the Xinjiang and Hexi corridor area, during 1960–2010. Li et al. (2016) identified the possible cause of the significant increasing trend of precipitation in the NWC during 1960–2010. Liu et al. (2013) investigated the spatiotemporal characteristics of the dryness/wetness conditions across Qinghai Province by using the rotated empirical orthogonal function (REOF) and Continuous Wavelet Transform (CWT). Liu et al. (2015) also analyzed the relationship between the spatiotemporal patterns of drought and ENSO in the NWC.

Although many researchers have conducted comprehensive analyses regarding precipitation trends, the information on the trends in various periodic components and their influence on the original observed precipitation trend in the NWC still need to be strengthened. Additionally, assessing the trends and the correlations of trends between decomposed time scales and the original time series in the NWC will provide information for managing water resources effectively and improving the efficiency for the restoration and reconstruction of ecology. Therefore, the objectives of this study are: (1) to reveal the temporal and spatial variations of precipitation at 96 weather stations and in 13 areas, (2) to identify and decompose the periodicities in the precipitation series, (3) to check the correlations between the periodic components and original series, (4) to detect the dominant periodic component of the annual and seasonal precipitation, and (5) to analyze the relationship between the precipitation and the ENSO.

2. Study area

The NWC (73° E-120° E, 30° N-50° N) includes the provinces of Xinjiang, Gansu, and some parts of Inner Mongolia, Hebei, Qinghai, and Tibet provinces with an area of 3,362,260 km^2 (Fig. 1). It is difficult for marine vapor to reach the study area due to the long distance from the ocean and the obstacles posed by the mountains (i.e., Altay Mountain, Kunlun Mountain, Qilian Mountain, and Helan Mountain). As a result, the climate in the NWC is a typical continental climate, which has little precipitation (below 250 mm) and a wide range of temperature (from −2 to 19 °C) (Deng et al., 2014; Liu et al., 2010). Because the cold and dry weather prevails, there is some precipitation in the form of snow and ice in the winter. However, in the summer, the land surface warms up quickly over the widespread desert (Deng et al., 2014; Wang et al., 2013). Under the influence of the climate, topography, and geomorphology, there are many inland drainage basins and deserts, including the Tarim Basin, Tsaidam Basin, Badanjilin Desert, Tengger Desert, Taklimakan Desert, and Kubuqi Desert.

The study area is divided into 14 parts according to the partitioning of water resources by the Ministry of Water Resources of the People's Republic of China (Fig. 1 and Table 1). Table 1 provides the names of the areas in the second column, while the third column is the shorthand name of the area. There is no meteorological station in the Mainstream of the Tarim River basin (MRTB) (or the area of K120 000). Therefore, the MRTB was excluded from the study.

3. Data and methods

3.1. Data

The daily meteorological data from 108 meteorological stations in the NWC during 1960–2013 were collected from National Climate Center of China Meteorological Administration (CMA) http://www.cams.cma.gov.cn. The stations installed after 1960 and those with data gaps were excluded. From these, we selected 96 stations to obtain the monthly meteorological data, seasonal meteorological data, and annual meteorological data from the daily meteorological data. Meanwhile, we obtained the regional average precipitation by taking the average precipitation value for all stations in the 13 specific areas. Additionally, the sea surface temperature (SST)-monthly Niño 3.4 indexes during 1950–2002 were obtained from the Climate Prediction Centre (CPC) (http://www.cpc.ncep.noaa.gov). We calculated the annual SST by taking the 12 month average SST value in a specific year.

3.2. Method

In this study, the annual, seasonal, and monthly precipitation was analyzed in the NWC to detect trends during 1960–2013. First, we applied CWT to decompose the precipitation data into different periodic components because the existence of significant autocorrelations in some series would impact the Mann-Kendall (MK) trend test (Hamed and Rao, 1998). The significant autocorrelation in the original and

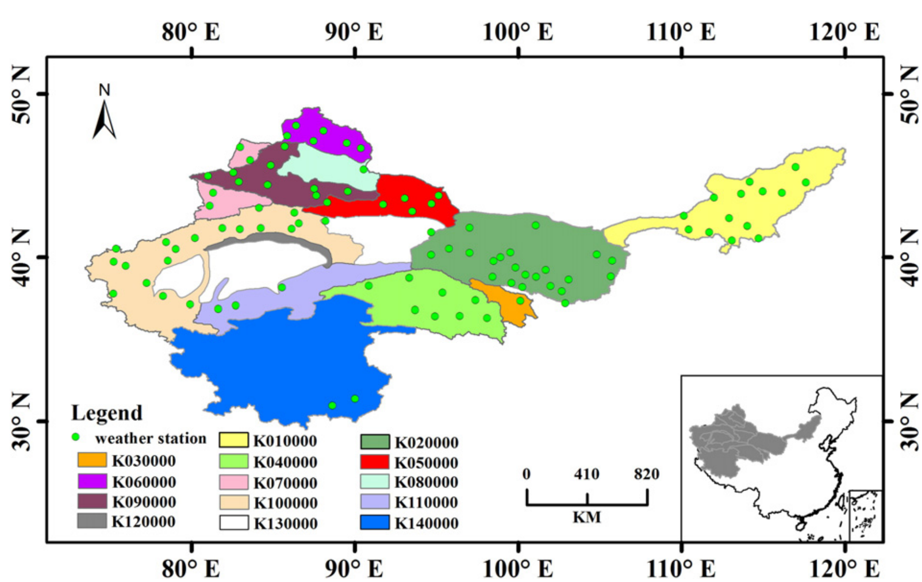

Fig. 1. The study area. The right below small figure located in the whole figure represents the location of study area. The green points stand for the weather stations.