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Analysis of Maximum and Minimum Temperature in Qilian Mountainous, Northwest China

Chuancheng Zhao[1], Hongkai Gao [2], Shuxia Yao[3*] and Jiaxin Zhou[1]

[1] College of Geography and Environmental Engineering, Lanzhou City University, Lanzhou, 730000, China
[2] School of Geographic Sciences, East China Normal University, Shanghai, 200241, China
[3] College of Mathematics, Lanzhou City University, Lanzhou, 730000, China
Emial:yaosx@lzcu.edu.cn

Abstract. As one of the key elements of climate change, the temperature changes can affects the energy balance and hydrological cycle. The variations and trend of mean annual maximum temperature (T_{max}) and minimum temperature (T_{min}) were analyzed by using linear regress for 44 stations inside and surrounding the Qilian Mountains for period of 1960-2017. The results have shown that the variations of mean annual T_{max} and T_{min} have significant increasing in whole study regions. The warming trend of mean annual T_{mix} is higher than that of T_{max}. Both the trend of mean annual T_{max} and T_{min} in the southern slope is warmer than those in the northern slope of Qilian Mountains. In spring, the warming trend of T_{max} is significantly weaker inside than that outside the Qilian Mountains. For all seasons, the trend of T_{max} and T_{min} is the highest in winter, and is weakest in spring.

1. Introduction

Climate change has become the focus in recent years because it has a significant effect on the ecological environment and social development [1-2]. The change of temperature has serious impact on the energy balance, hydrological cycle and human activities on local, regional, and global scale [3-4]. A large number of observations indicate that the mean temperature has increased by 0.85°C during the period of 1880 to 2012 in global [5]. Due to the influence of location and topography, the change of temperature is far from uniform in different regions [6]. A rise in temperature of China is higher than global change that has been largely demonstrated by many studies in different regions [7-9]. In China, some studies show that the trend of temperature is higher in southeast with a rate of 0.26°C/decade than that in northwest with a rate of 0.18°C/decade [7,10]. The warming trend is significantly in spring and winter in the eastern part of China, but significantly in summer and autumn in the western part of China [11-12].

Mountains, plateaus, and desert Gobi are widely distributed in northwestern China. Due to the influence of complex terrain on atmospheric circulation, there are certain differences in temperature changes. Deng and Zhang (2018) reported increasing trends of mean temperature with a rate of 0.37°C/decade in Qinghai-Tibet Plateau, and mean temperature increases with altitude rising in spring, summer, and winter[13]. The warming trend of mean temperature is rapid with a rate of 0.32 °C/ decade in Tianshan mountains [14]. The change of temperature in Taklimakan Desert experienced obvious climbing trends with a rate of 0.30°C / decade over the past 50 years [15]. With the warming temperature, it is caused the glaciers to retreat in the high mountainous that lead to increase runoff, which contributes to the stability and development of oasis in arid and semi-arid regions [16]. Because of fragile and sensitive to changing climate in mountains regions, analyzing observational data is one of best ways to understand the impact of climate change [17].

In this study, the aim is to explore the warming trend in mean annual and seasonal T_{min} and T_{max} using the linear regression during 1960 to 2017 over the Qilian Mountains. There are 44 stations with monthly temperatures were selected from the National Climate Centre of China. The stations with missing data in more than 3 months are excluded from the analysis. Thence, comprehensively understand of temperature changes can be helpful to provide scientific knowledge for water resource management in the Qilian mountains.

2. Study Area and Data

2.1. Study Area

The Qilian Mountains are the important mountain system and the boundary between semi-arid and arid regions in northwest of China[18]. It is located on the northeastern margin of the Qinghai-Tibet Plateau, south of the Hexi Corridor (Fig 1). It rises to altitudes from 2000 m and 5800 m and spans about 850 km from east to west, 250-400 km from south to north. Due to the wide distribution of modern glaciers, it is the main source of water supply to maintain agricultural irrigation and societal development for downstream oasis [19]. Owing to complex orography and fragile ecosystem, the Qilian Mountains are expected to be sensitive to climate change, and the change of temperature is not homogenous. The mean annual precipitation ranges from 150 to 410 mm, and mainly occurs in wet season (May to September). The mean annual temperature ranges from -0.3 ℃ to 8.1 ℃due to the altitude change greatly [20].

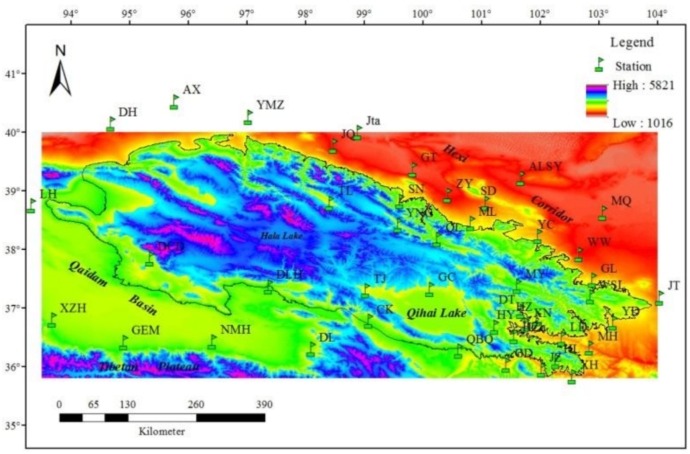

Figure 1. The distribution of the stations in the Qilian Mountains

2.2. Data

Daily T_{min} and T_{max} of local meteorological recorded at 44 stations inside and surrounding the Qilian Mountains as shown in figure 1, was obtained from the National Climate Centre of China (China Meteorological Administration - CMA). The records were of varying length with the longest record being 1960–2017. The selected stations are located at altitudes between 1140 and 3418 m. The stations with 34% are located in lower part of Qilian Mountains below 2000 m. A total of 48 % of all stations are placed at altitudes between 2000 and 3000 m. Only 18 % of the stations are at altitudes higher than 3000 m. The seasonal and annual of maximum and minimum temperature were calculated by daily maximum and minimum temperature respectively.

2.3. Linear Regression

As a conventional approach, simple linear regression was applied to analyze trends in temperature. It ignores the distribution though linear regression is a simple method. It is enough to analyze the trend or variability if the sample size is larger than 35. The slope is main parameter that can be drawn from the regression which indicates the trend of the studied variables. The value of slope is positive showed increasing trends, while negative indicated decreasing trends. The trend can be calculated as the following formula [17]:

$$T_{rend} = bX + a \quad (1)$$

where T_{rend} is the dependent variable, b is the slope of the line, and a is the T_{rend} intercept.

3. Results

To investigate whether the characteristic of variation temperature over the Qilian mountains resembles regional trend, the mean annual and seasonal T_{min} and T_{max} for all the stations were computed and analyzed during the period of 1960–2017. The long-term variation of T_{max} and T_{min} for 44 stations over Qilian mountains as a whole are shown in Fig. 2. The results have been show that both mean annual T_{max} and T_{min} have significant increasing trend, and the trend of T_{min} with 0.54°C/decade is higher than T_{max} with 0.4°C/decade. The maximum of mean annual T_{max} above 34.7°C is occurred in 2010, and minimum of mean annual T_{max} below 28.8°C is occurred in 1968. The maximum of mean annual T_{min} above -20.3°C is occurred in 2015, and minimum of mean annual T_{max} below -27.7°C is occurred in 1991.

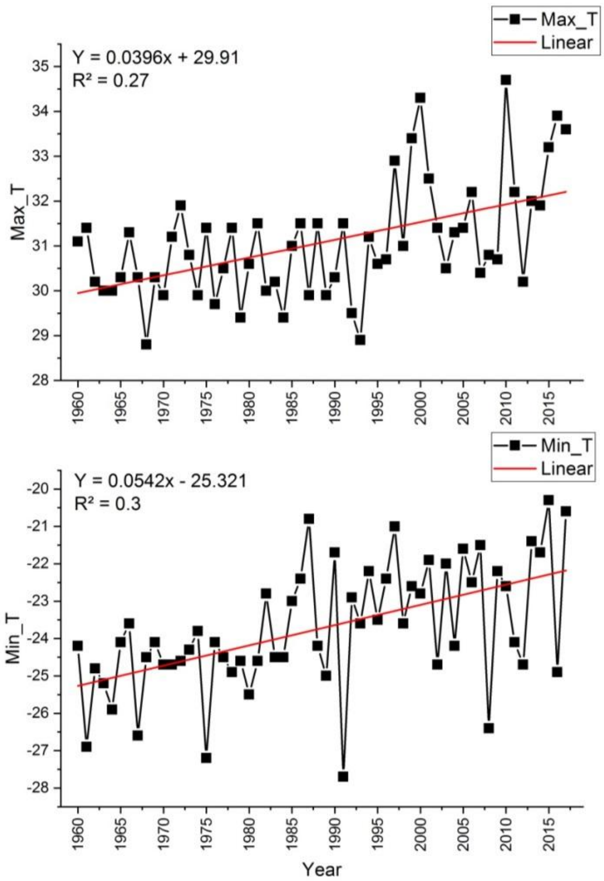

Figure 2. The variation of mean annual T_{max} and T_{min} in Qilian Mountains

3.1. *The Trend of Annual T_{max} and T_{min}*

The trend of mean annual T_{max} and T_{min} values were calculated for all of stations in the study area during the period of 1960–2017 (Fig 3). Except for YD, the value of T_{max} trend for all other stations is positive. This shows that mean annual T_{max} is on the rise in the whole Qilian Mountains. The trend of mean annual T_{max} is range from 0.16 °C/decade to 1.03 °C/decade, with mean trend 0.33 °C/decade. It can be seen from the figure 3a that the trend in the southern slope is warmer than those in the northern slope, and in south-eastern part were warmer than those in north-western part of Qilian Mountains. The trend of mean annual T_{max} is significant in the middle mountain, while the change is weak in the high mountain area and the low mountain area. However, the very small increase of temperature has a very obvious impact on the surrounding ecosystem such as glaciers and permafrost.

The mean annual T_{min} trend change is slightly different from the mean annual T_{max}. The trend of mean annual T_{min} is range from 0.34 °C/decade to 0.94 °C/decade, with mean trend 0.71 °C/decade. Thus, the warming trend of mean annual T_{min} is two time higher than that of mean annual T_{max}. The warming trend of mean annual T_{min} shown in figure 3b is more significant on the southwestern part of Qilian Mountains. Among them, the trend of mean annual T_{min} is most obvious in GEM and DLH. The warming trend in the southern slope is more obvious than those in the northern slope. But, the trend of mean annual T_{min} in southeast is same as in northwest. The warming trend of mean annual T_{min} is weak in the low mountain, the trend is significant in the middle mountain. The warming trend of mean annual T_{min} is higher than that of mean annual T_{max} in the high mountain.

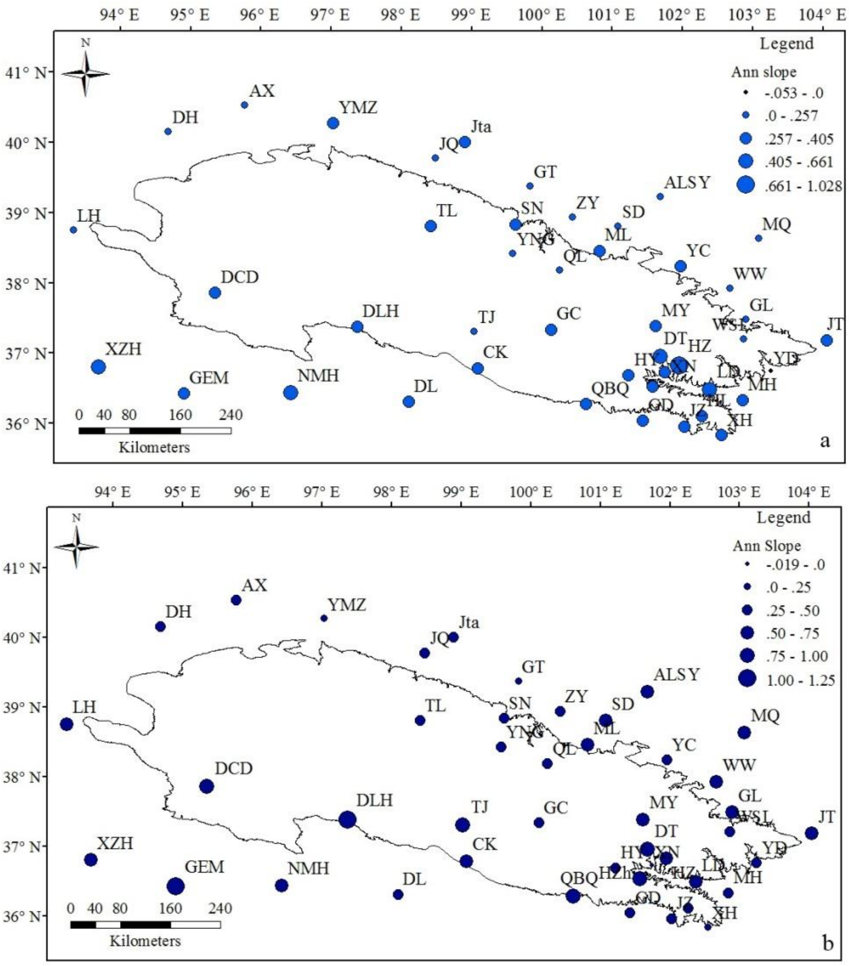

Figure 3. The trend of mean annual T_{max} and T_{min} in Qilian Mountains

3.2. The Trend of Seasonal T_{max} and T_{min}

The distribution of trend for seasonal T_{max} has shown in figure 4. In spring, except YD station, the value of T_{max} trend is above zero for all stations with range of 0.01 °C/decade to 0.91 °C/decade, mean trend is 0.21 °C/decade. The warming trend of T_{max} is significant in southeast and southwestern of Qilian Mountain. In north slope of Qilian Mountain, the warming trend of T_{max} is obvious west of ZY. The warming trend of T_{max} is weak inside the Qilian Mountains. In summer, except YD and DH station, the value of T_{max} trend is above zero for all stations with range of 0.01 °C/decade to

1.08 °C/decade, mean trend is 0.29 °C/decade. The warming trend of T_{max} in the southern slope is more obvious than those in the northern slope, and is more obvious in southeast than those in northwest of Qilian Mountain. In autumn and winter, the value of T_{max} trend for all stations is above zero with 0.01 °C/decade to 1.01 °C/decade, 0.08°C/decade to 1.09 °C/decade, and mean tread is 0.32°C/decade, 0.44 °C/decade respectively. Due to the influence of the warming of the Qinghai-Tibet Plateau, the southern slope has a more significant warming trend of T_{max} than the northern slope of the Qilian Mountains. For all seasons, the trend of T_{max} is the highest in winter, and is weakest in spring.

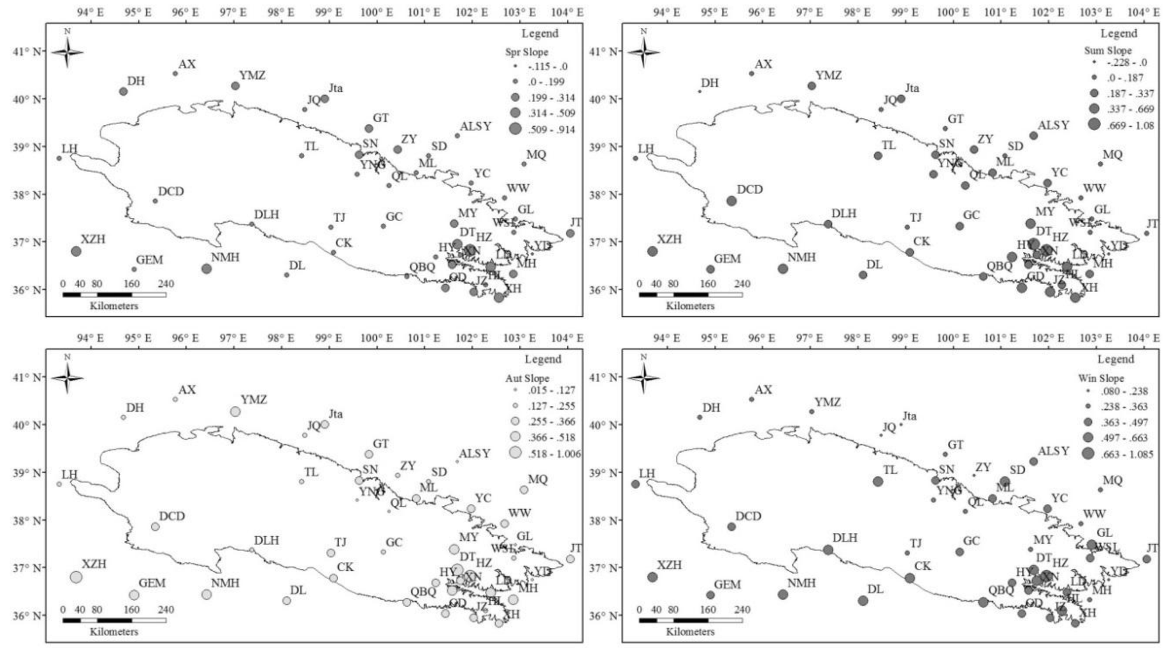

Figure 4. The trend of seasonal T_{max} in Qilian Mountains

Figure 5 is described the trend of seasonal T_{mix} in Qilian Mountains. Obviously, the value of T_{mix} trend is above zero for all stations, and the warming trend of seasonal T_{mix} is higher than those of seasonal T_{mix} for all seasons except for individual regions. The warming trend of T_{mix} is the most significant in GEM on the edge of the Qinghai-Tibet Plateau. In winter, the warming trend of T_{mix} is significant in southwest of Qilian Mountain, and is weak in the low and high mountains. In summer, the warming trend of T_{mix} in the southern slope is obviously higher than that of the northern slope of Qilian Mountains. In autumn and winter, the warming trend of T_{mix} is aggravated. The warming trend of T_{mix} is weakest in winter in the midwest of Hexi corridor. The mean trend of each season of T_{mix} is 0.44 °C/decade, 0.47 °C/decade, 0.59 °C/decade, 0.64 °C/decade respectively. Obviously, the warming trend of T_{mix} is highest in winter for all seasons.

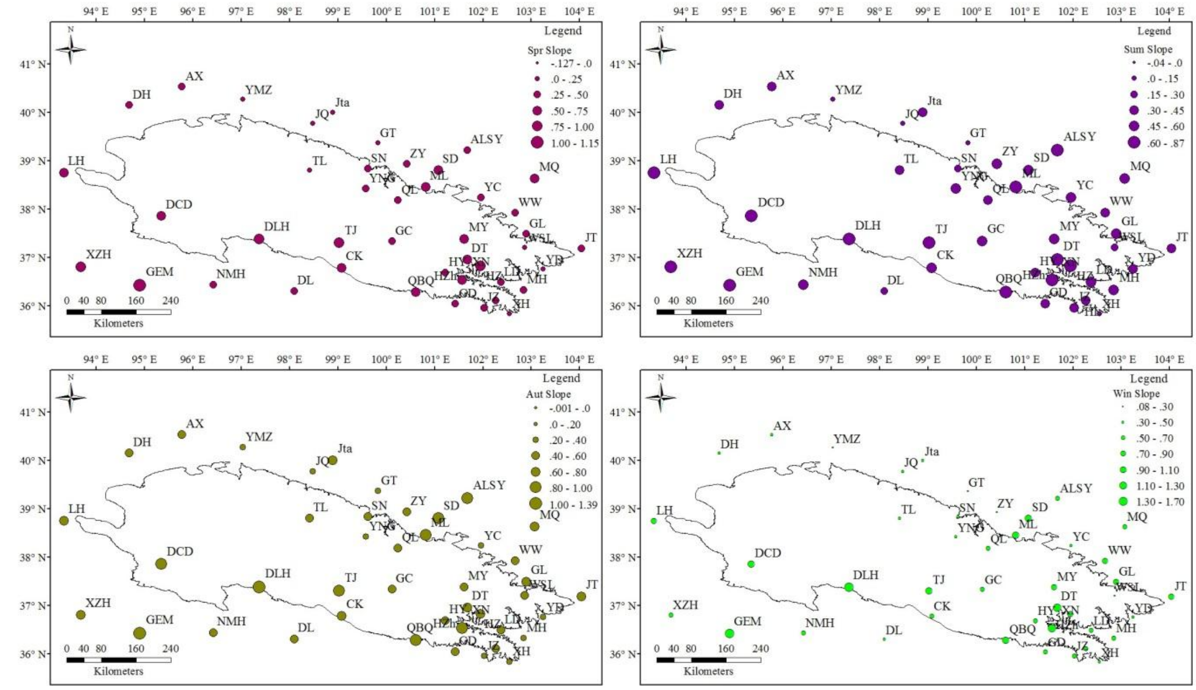

Figure 5. The trend of seasonal T_{mix} in Qilian Mountains

4. Conclusions

In order to investigate the trend of annual and seasonal temperature changes in Qilian Mountains, the data from mean maximum and minimum temperature of 44 stations were analyzed during the period of 1960 to 2017. Due to the complex topography, the maximum and minimum temperature change is far from uniform. Both mean annual T_{max} and T_{min} have significant increasing, and the variation of mean annual T_{mix} is higher than that of T_{max}. The trend of mean annual T_{max} and T_{min} is significant in the middle mountain, while the change is weak in the low mountain regions. For all seasons, the trend of T_{max} and T_{min} is the highest in winter, and is weakest in spring.

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