The Distribution of Precipitation and Rain Days over the Tianshan Mountains in Northwest of China

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Abstract. Analysis of precipitation is important to hydrologists and forecasters over mountain, especially in the arid and semi-arid regions of the world. The distribution of precipitation and rain days are analyzed based on 31 stations during the period from 1960 to 2018 in Tianshan Mountains. The results is show that the precipitation and precipitation days is significantly affected by topography in Tianshan mountains. The pattern of precipitation is increased from southern to northern, from eastern to western. High precipitation and precipitation days are located in the Ili Valley. The precipitation and precipitation days are increase with elevation increase decrease with longitude increase. But, the relationship is different between precipitation and rain days with latitude in south and north slope over Tianshan mountains.

1. Introduction
Precipitation is an important components of the hydrological cycle that transferred the mass and energy from the land surface to atmosphere [1-2]. With the climate change, the process of hydrological cycle has significant change that directly affected the change of precipitation both in global and regional [3-5]. At present, the data of precipitation is mainly gained by ways of rain gauge, precipitation radar, remote sensing precipitation inversion and model simulation [6]. Among them, rain gauge measurement is the only way to directly obtain precipitation data. The data of precipitation obtained by precipitation radar, inversion by remote sensing or model simulation is indirect, and need to be calibrated or corrected by the measurement data of rain gauge for applying [7-8]. As the main input to the ecological and hydrological models, the accuracy of precipitation data directly affects the accuracy of the simulation [9]. Owing to affect by many factors (wind, topography), precipitation has become one of most difficult to accurately observe meteorological elements. Simultaneously, the spatial-temporal variation of precipitation is significant both in local and global scale, analysing the spatial and temporal variation of precipitation has become the focus and hotspot content for water resources. Furthermore, due to the influence by the
factors, such as topography, airflow and wind direction, the reliable and accurate precipitation data is difficult to obtain [13-15].

The variation of precipitation in spatial-temporal is a key characteristic over mountain regions in the arid and semi-arid regions [16]. The aims of this study are to investigate the variation and distribution of precipitation over Tianshan Mountains using the data from 31 meteorological stations during the period of 1960-2017. Through the analysis of variation of precipitation, it better to understanding the impact of climate change on precipitation in mountain regions, and the distribution and variation for use in the management and policymakers related to water resources [16-17].

2. Study Area and Data

2.1. Study Area

The Tianshan Mountains are located in the arid and semi-arid regions of northwestern China (Fig 1). It stretches 1700 km from western to eastern, divided Xinjiang Uygur Autonomic District into two different climate zones [18]. The altitude of the Tianshan Mountains is between 1500 and 7455 m a.s.l. (e.g. Tuomuer Peak, 7,455 m a.s.l.), most of the peaks are higher than 4000 m a.s.l.. There are many glaciers, with more than 9,000 glaciers in the Tianshan Mountains. Due to lie in the hinterland of Eurasia, and far away from the ocean, the precipitation is rare in the plains and lower portion. Owing to the huge altitude and the blocking of water vapor, precipitation is more abundant in high mountains of the Tianshan Mountains where are the sources of several important inland rivers (e.g. Tarim River, Ili River, Kaidu River) in northwest of China and central Asia. The major water resource in Tianshan Mountains is mainly brought by the westerly circulation, and small portion is brought by the dry and cold water vapour from the Arctic Ocean [12]. Due to the huge uplift of the Qinghai-Tibet Plateau, and the blocking of the Qilian Mountains, the East Asian monsoon from Pacific Ocean influenced the eastern China, and the South Asian monsoon influenced the southwest China are hard reached. The distribution of precipitation is very heterogeneous in mountains regions. The mean annual precipitation is 180 mm in whole study regions. But, the mean annual precipitation of northern slope, with average of 220 mm is higher than that of southern slope with average of 70 mm. The dry and wet seasons are very obvious, and precipitation is concentrated in Tianshan Mountains. The studies have shown that about 80% of precipitation occurs from May to September [19].

2.2. Data

Owing to the complex terrain, the measurement stations are very scarcely and distribution unreasonable in Tianshan Mountains. There are 42 stations surrounding the study regions available during the period of 1960–2018, whereas most of them are located in the lower portion(<1500 m). The daily precipitation data for each station are collected from the National Climate Centre of China (China Meteorological Administration - CMA). The released data were checked by the double-mass method. Since 11 stations were missed data for more than one month that were rejected from the analysis in order to ensure the reliability of results. From the distribution of station's elevation, there are 14 stations below 1000 m, 14 stations are located at 1000-2000 m, 2 stations are located at 2000-3000 m, and only 1 station is higher than 3000 m.
3. Results

3.1. The Distribution of Precipitation

The mean annual precipitation was calculated for each meteorological station during the period of 1960-2018 in the Tianshan Mountains. The distribution of mean annual precipitation is spatially interpolated using inverse distance weighted (IDW) interpolation method (Fig 2). The mean annual precipitation ranges from 44 to 471 mm. It is obvious that precipitation is most abundant around the Ili Valley where enjoys a place with south-China-type scenery beyond the frontier. The Zhaosu on the southern side of Ili Valley is the most precipitation in whole Tianshan Mountains. The precipitation is most rare in Turpan where mean annual precipitation is less than 20 mm. The distribution is show that precipitation is more in western parts than in eastern parts and more in northern slope than in southern slope in Tianshan Mountains. The precipitation is mainly brought by the westerly circulation in Tianshan Mountains. The vapor come in from Ili Valley (the trumpet of the Tianshan Mountains), it forms abundant precipitation as the terrain risen. After over the ridge, the vapor sinks which is not conducive to form the precipitation in the southern slope of the Tianshan Mountains.

The precipitation is usually closely related to the topography in mountain regions. The longitude, latitude and elevation of topography factor are selected. The results is shows in figure 3(southern slope) and in figure 4(northern slope). The distribution of precipitation is significant difference between the
northern and southern slope of the Tianshan Mountains. So, the relationship between precipitation and terrain factor is separate in northern and southern slope. The relationship is best between precipitation and elevation in Tianshan Mountains. The precipitation increases with the increase of elevation, with the correlation coefficient 0.86, 0.76 respectively. But, the relationship is negative between precipitation with longitude and latitude. In the southern slope, the precipitation is decrease with longitude or latitude, with the correlation coefficient 0.55, 0.49 respectively. In the northern slope, there is a significant relationship between precipitation and latitude with the correlation coefficient 0.72, but is un-significant with longitude.

**Figure 3.** Relationships between Precipitation and (a) Longitude, (b) Altitude, and (c) Elevation in Southern Slope of Tianshan

**Figure 4.** Relationships between Precipitation and (a) Longitude, (b) Altitude, and (c) Elevation in Northern Slope of Tianshan

### 3.2. The Distribution of Rain Days

The distribution of rain days is consistent with the distribution of precipitation (figure 5). The mean annual rain days range from 20 to 124. The rain days are the most lied in Yili Valley, with more than 120 days per year. The rain days are least lied in eastern parts, with less than 50 days per year. Similarly, the rain days are more in northern slope than in southern slope.
**Figure 5.** The Distribution of Rain Days in Tianshan Mountains

Figure 6 and figure 7 are illustrated the relationship between rain days and terrain factor (longitude, altitude and elevation). The relationship between rain days and elevation is significant, with correlation coefficient of 0.95 in southern slope, but un-significant in northern slope of Tianshan Mountains. The rain days are decreased with the longitude increase both in southern and northern slope of Tianshan Mountains. The rain days are decreased with the latitude increase in southern slope, while increased with the latitude increase in northern slope of Tianshan Mountains.

**Figure 6.** Relationships between Rain Days and (a) Longitude, (b) Altitude, and (c) Elevation in Southern Slope of Tianshan
Figure 7. Relationships between Rain Days and (a) Longitude, (b) Altitude, and (c) Elevation in Northern Slope of Tianshan

4. Conclusions
In Tianshan Mountains, the distribution of precipitation increased from the southern slope to the northern slope, from eastern parts to western parts. The precipitation is most abundant in Ili Valley. The distribution of rain days is consistent with the distribution of precipitation. The relationship is significant between precipitation and terrain such as longitude, latitude and elevation of meteorological stations. The relationship is most significant between precipitation and elevation both in southern slope and northern slope. The precipitation is increased with the decrease of elevation, but decreased with the increase of longitude or latitude. The relationship between rain days and terrain is inconsistent, and is different in southern and northern slope. The rain days are decreased with latitude increase in southern slope, but increased with latitude increase in northern slope.

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