The Distribution of Precipitation in the Qilian Mountains

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Abstract: Precipitation in the mountains plays a significant role in providing water for the sustainable development of oasis cities downstream. The precipitation data of 49 national meteorological stations that surround the Qilian Mountains were analysed during the period from 1980 to 2013. The results show that the precipitation is affected not only by the source of water vapour, but also by the topography. The distribution of mean annual precipitation decreased from southeast to northwest. The value of precipitation is high around Qinghai Lake. Considering the seasonal distribution, the summer precipitation accounts for above half of annual precipitation, whereas the winter precipitation accounts for below 10% of annual precipitation.

1 INTRODUCTION

Precipitation is a critical component of the global water cycle frequently influencing the availability of water resoureces (Ngongondo C S 2006; Michaelides S et al., 2009). Understanding its spatiotemporal distribution at various scales is an important step toward a better recognizing the hydrological cycle and associated phenomena such as drought and flood. Such information may be finally used to address current climate variations and future climate change to dryland agriculturalists and policymakers (Crochet et al., 2007, Batisani et al., 2010; Westerberg et al., 2010). Generally, the precipitation data has been obtained by in situ observation, remote sensing and numerical modelling (Michaelides S et al., 2009). Although remote sensing and numerical modelling have proved the spatially complete coverage resolution, such approaches are subjected to different types of errors such as inherent measurement, retrieval errors, and sampling uncertainty. Meanwhile, the accuracy of remote sensing and numerical modelling need to be calibrated or verified using the ground measurement (New et al., 2001; Xie et al., 2003). The precipitation data from rain gauge measurement is considered to be the most accurate even though they suffered from different types of errors such as sampling, inherent measurement, and uncertainty in sub-catchment (Chen et al., 1997).

Mountains exert a major role in maintaining the water supply for ecological environment and the sustainable development of oasis cities downstream, as they are the main contributor to runoff (De et al., 2009; López-Moreno et al., 2011). Due to the complex terrain, the distribution pattern of precipitation is frequently linked to the morphological parameters such as altitude and airflow direction in mountain regions (Daly et al., 2002; Sinclair 2010). Furthermore, used meteorological stations are sparsely distributed and most of them are located in foothill regions. Therefore, the precipitation pattern is hardly discernible in the summit area. Investigation of spatiotemporal distribution of precipitation makes it very challenging for hydrological cycle and climate change in mountains regions.

The aim of this study is to clarify the spatiotemporal distribution of precipitation in the Qilian Mountains during the period 1980-2013 using the data from 49 meteorological stations. We analyze (i) the annual and seasonal distribution of precipitation and (ii) the relationship between precipitation and topography in mountain regions.

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2 STUDY AREA AND DATA

2.1 Study Area

The Qilian Mountains (36°30'–39°30'N, 93°30'–103°00'E), are located in the arid and semi-arid region of northwestern China, at the northern margin of the Tibetan Plateau (Figure 1) (Qiang et al., 2016; Tian et al., 2017). It borders the Hexi Corridor in the northeast and the Qaidam Basin in the southwest, stretches approximately 850 km from the east to the west, and approximately 250-400 km from the south to the north (Zhang et al., 2015). The altitude of the Qilian Mountains is between 2000 and 6000 m a.s.l. (e.g. Tuanjie Peak, 5,826 m a.s.l.), most of the peaks are higher than 4000 m a.s.l.. There is a great number of modern glaciers in the summit parts of the Qilian Mountains, and many inland rivers (including Shiyang River, Heihe River and Shule River) in the arid northwestern China originate from the alpine regions (Zhang et al., 2007). Due to position of the Qilian Mountains in the interior of Euro-Asia continent, the moisture comes from the East Asian monsoon, westerly circulation and circulation above the Tibetan Plateau (Tian et al.,2009). The mean annual precipitation varies between 150–410 mm and is unevenly distributed in both space and time. The mean annual temperature ranges from -0.3 ℃ to 8.1 ℃ (Wang et al., 2009). Winter is quite cold and dry, while summer is relatively hot. The precipitation is mainly concentrated in May to September.

2.2 Data

We acquired the precipitation data from the National Climate Centre of China (China Meteorological Administration - CMA). The meteorological stations measure the precipitation with resolution of 0.1 mm. In total, 58 meteorological stations surrounding the study area are available for the period of 1980–2013 while most of them are located in the foothills (below 3000 m a.s.l.; Figure 1). There are five meteorological stations with more than 1 year of missing data, and four meteorological stations with too short records. In order to ensure the reliability of results, these meteorological stations were excluded from the analysis.

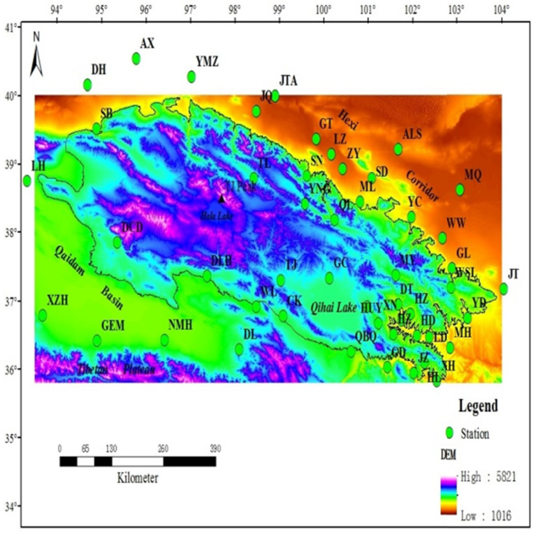

Figure 1: The distribution of the meteorological stations in the Qilian Mountains

3 RESULTS

3.1 The Distribution of Annual Precipitation

The mean annual precipitation was calculated for each meteorological station during the period of 1980–2013 in the Qilian Mountains. The distribution of mean annual precipitation is spatially interpolated using inverse distance weighted (IDW) interpolation method (Figure 2). The mean annual precipitation ranges between 24 to 538 mm. The distribution of mean annual precipitation increased from northwest to southeast. The precipitation is obviously lower in north of Qaidam Basin and south of the west part of Hexi Corridor. After long distance, the westerly circulation has brought little moisture, and difficult to form precipitation in the west part of the Qilian Mountains. Because of the effect of Qaidam Basin, the circulation above the Tibetan Plateau is hardly formed the precipitation in the southwest part of the Qilian Mountains. However, the precipitation is high in the east part of Qilian Mountains which is influenced by East Asian monsoon circulation. Obviously, high values of mean annual precipitation occurred around the Qinghai Lake. It clearly indicates that the large water body influences the spatial distribution of precipitation around.

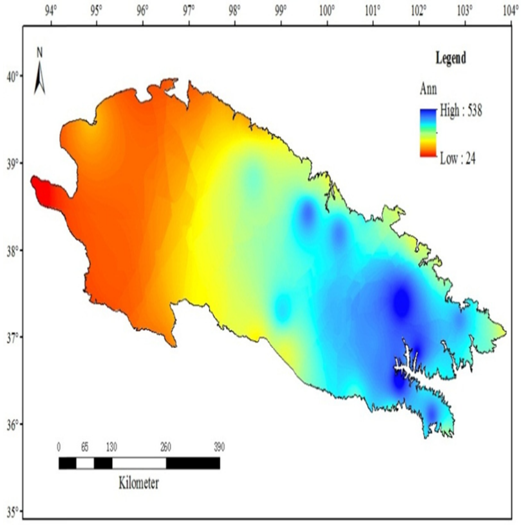

Figure 2: The distribution of mean annual precipitation in the Qilian Mountains

Figure 3 illustrates the relationship between the mean annual precipitation and the geographical characteristics of the analyzed stations (altitude, longitude and latitude). The correlation between mean annual precipitation and altitude and latitude is significant, with correlation coefficient of 0.71 and 0.69, respectively. The correlation is positive between mean annual precipitation and altitude; the value of mean annual precipitation gradient is 15mm/100m (Figure 3a). At high altitude (>3000 m a.s.l.), the relationship between precipitation and altitude is ambiguous due to complex type of precipitation. Generally, the meteorological stations observe the rainfall in lower altitudes, whereas stations at higher altitudes observe the snowfall. The catch ratio of snowfall is lower than that of rainfall because the snowfall can be more easily affected by wind. The correlation is negative between mean annual precipitation and latitude, the mean precipitation decreased by 70.4 mm with latitude increased one degree (Figure 3c). There is a weak positive correlation between mean annual precipitation and longitude (Figure 3b). It could by caused by uneven distribution of meteorological stations (the most of the meteorological stations is located in the eastern part of the Qilian Mountains).

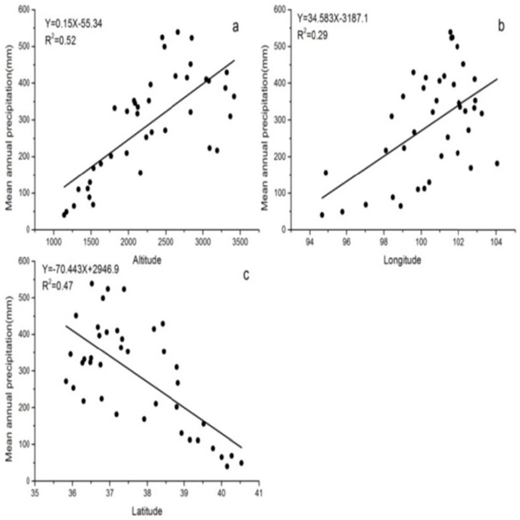

Figure 3: Relationships between mean annual precipitation and (a) altitude, (b) longitude, and (c) latitude

3.2 The Distribution of Seasonal Precipitation

The mean seasonal precipitation was calculated for each station during the period of 1980–2013 in the Qilian Mountains. In winter, the mean precipitation is very low; the value is less than 10 mm except individual regions (Figure 4d). There is no relationship between precipitation and topography. With the rising temperature, the mean seasonal precipitation increases rapidly in eastern part of the Qilian Mountains affected by East Asian monsoon. The mean seasonal precipitation of spring is between 3 mm to 120 mm (Figure 4a), while the maximum is located around the Qinghai Lake. The maximum of mean summer precipitation is up to 300 mm. Precipitation higher than 200 mm covers the area from the east to the mid-west of the Qilian Mountains (Figure 4b). With the weakening of East Asia monsoon, the mean fall precipitation decreases rapidly to the same level as during spring (Figure 4c). Therefore, the variability of seasonal precipitation is mainly influenced by the East Asian monsoon.

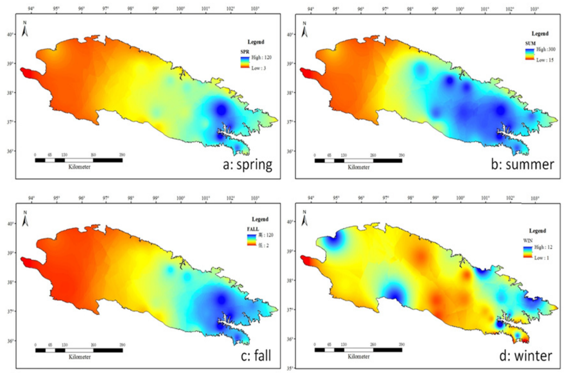

Figure 4: The distribution of mean seasonal precipitation in the Qilian Mountains

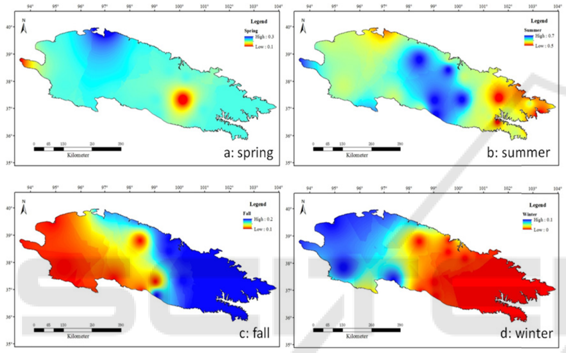

Figure 5: The percentage distribution of seasonal mean precipitation in the Qilian Mountains

The seasonal contribution to the annual precipitation totals is also an important variable for the precipitation distribution (Figure 5). Ratio between seasonal and annual precipitation was calculated for each meteorological station during the period of 1980–2013 in the Qilian Mountains. In winter, the ratio is less than 10%, and the characteristic is decreased from northwest to southeast. In spring, the ratio is between 10% and 30%. Except individual regions, the distribution of ratio is more consistent across the Qilian Mountains. In summer, the ratio ranges between 50% and 70% while the highest values are distributed in the most elevated parts of the central mountains. In fall, the ratio ranges between 10% and 20%. In contrast to winter, there is an increase from the northwest to the southeast. Overall, the precipitation mainly occurs in summer, which account for more than a half of annual precipitation.

4 CONCLUSIONS

In the Qilian Mountains, the distribution of mean annual precipitation decreased from the southeast (530 mm) to the northwest (20 mm). The relationship is significant between amount of precipitation and topography such as altitude, latitude and longitude of meteorological stations. The precipitation mostly occurs in summer with a half of annual precipitation, while the lowest totals occur during winter. In summary, the precipitation is significantly affected by East Asian monsoon in the eastern part, while the influence is not significant by the westerly circulation in the western part due to the circulation above the Tibetan Plateau in the edge of Qaidam basin.

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